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Mariana Islands–Hyperspectral Airborne Remote Environmental Sensing Experiment 2010

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14. ABSTRACT
This report describes the data collected during one of a series of Naval Research Laboratory (NRL) remote sensing and calibration and validation (Cal/Val) campaigns, providing data and information for the development of models of coast types and their associated environmental factors. Models allow rapid processing of hyperspectral imagery (HSI), generating shallow water bathymetric charts and trafficability maps. Cal/Val data collected during the Mariana Islands Hyperspectral Airborne Remote Environmental Sensing 2010 (MIHARES 2010) campaign focused on spectral and geotechnical library development, bathymetry, and location of WWII remnant hazards on Pagan, Tinian, and Guam. Ground control data collected during the remote sensing experiment will be useful in building digital elevation models and maps for remote areas such as Pagan, a volcanic island in the Commonwealth of the Northern Mariana Islands (CNMI). Surveyed calibration panels, WWII relics, and underwater panels are all useful in developing anomaly detection algorithms. The primary purpose of this memorandum report is to summarize imagery collections and all Cal/Val data and the project geodatabase, with products described in future publications.

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ABBREVIATIONS AND ACRONYMS

AERONET	Aerosol Robotic Network
ARTEMIS	Advanced Responsive Tactically Effective Military Imaging Spectrometer
ASD	Analytical Spectral Devices
Cal/Val	Calibration/Validation
CBR	California Bearing Ratio
CNMI	Commonwealth of the Northern Mariana Islands
DCP	Dynamic Cone Penetrometer
ESRI	Environmental Systems Research Institute
GB	Gigabyte
GCP	ground control point
GIS	Geographic Information System
GPS	Global Positioning System
GSD	Ground Sample Distance
HAE	height above ellipsoid
HICO	Hyperspectral Imager of the Coastal Ocean
HSI	Hyperspectral imagery
HyMap	Hyperspectral Mapper
ITRF	International Terrestrial Reference Frame
LWD	Light Weight Deflectometer
MI-HARES'10	Mariana Islands-Hyperspectral Airborne Remote Environmental Sensing experiment 2010
MCI MidPac	Marine Corps Installations Middle Pacific
MLLW	mean lower low water
MN	Meganewton
NAD	North American Datum
NASA	National Aeronautics and Space Administration
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Association
NRL-DC	Naval Research Laboratory Washington, D.C.
NWS	National Weather Service
ODIN	Observational Data Interactive Navigation
OPUS	Online Positioning User Service
RHIB	Rigid-Hulled Inflatable Boat
TacSat	Tactical Satellite
TS09	Exercise Talisman Saber 2009
USNO	United States Naval Observatory
WWII	World War II

EXECUTIVE SUMMARY

The Remote Sensing Division of the Naval Research Laboratory (NRL) has been conducting research in the coastal ocean for many years. These remote sensing campaigns require the collection of imagery and calibration and validation (Cal/Val) data. Imagery is collected from airborne and space-borne sensors. Example platforms include a Piper Navajo, NP-3D Orion, Tactical Satellite-3, and the International Space Station. Example sensors include commercial sensors such as Hyperspectral Mapper (HyMap^{TM}) and Compact Airborne Spectrographic Imager (CASI) and DOD sensors such as the AFRL Advanced Responsive Tactically Effective Military Imaging Spectrometer (ARTEMIS) aboard Tacsat-3 and the NRL Hyperspectral Imager for the Coastal Ocean (HICO) on the Japanese Exposed Module aboard the International Space Station. Cal/Val data are collected by survey teams deployed in littoral regions that include beaches, wetlands, and the coastal ocean. The collection of in-water optical data requires the use of research vessels and scuba diving. This research is providing data and information for the development of models of coast types and their associated environmental factors for use in rapidly processing hyperspectral imagery (HSI) and generating shallow water bathymetric charts and trafficability maps. These innovative mobility products have been demonstrated immediately following remote sensing campaigns conducted at the Virginia Coast Reserve in Oyster, Virginia during September 2007, at Marine Corps Base Hawaii (MCBH) during January-February, 2009 during the Hawaii Airborne Remote Environmental Sensing (HIHARES'09) campaign, at Shoalwater Bay Training Area (SWBTA) in Queensland, Australia during May 2009 in association with TALISMAN SABER'09, and on several of the Mariana Islands during February and March 2010. In conjunction with the effort at SWBTA, imagery products were also provided in support of Exercise Talisman Saber 2009 aboard the USS ESSEX, at the All-Source Fusion Center located on Camp Smith, and at the Coalition Task Force C2 located at Schofield Barracks.

There are many places associated with the littorals that have been insufficiently mapped, especially the very shallow water regions where Marines land during amphibious operations. To address this information gap, NRL has started to develop project geodatabases for barrier island, mangrove, coral, and volcanic coasts. The general information found in these geodatabases for a particular coast type is particularly useful for atmospherically correcting and interpreting HSI. The project geodatabase provides an understanding of ground properties and how they relate to the measurements actually made by the hyperspectral sensor. In our case we focus on land and shallow water factors that are also useful for military mobility studies. Most importantly the geodatabase supports the exploitation of hyperspectral imagery to support the Marine Corps Planning Process as demonstrated by 31st Marine Expeditionary Unit during Exercise Talisman Saber 2009. The resultant geodatabase (e.g., the one developed from data collected on Guam and Commonwealth of the Northern Mariana Islands as described in this report) also supports projects such as the Defense Policy Review Initiative and the Marine Corps Installations Middle Pacific Planning Group (MCI MidPAC).

Geospatial information for Guam and the CNMI is strategically very important. Naval expeditionary force operations from the Mariana archipelago enhance military force flexibility, freedom of action, prompt global action, regional engagement and crisis response. Data collected during the Mariana Islands Hyperspectral Airborne Remote Environmental Sensing 2010

(MIHARES 2010) campaign is being used to compare and contrast several of the Mariana Islands. Along the Mariana archipelago, the southern islands are associated with extensive coral reefs and limestone materials while the northern islands are mostly volcanic. Although all of the islands are of volcanic origin (andesitic), only the islands at the northern end of the chain are volcanically active. Bathymetry, spectra, and geotechnical information collected on Pagan, Tinian, and Guam, the three regions studied during MIHARES'10, will be essential in developing shallow water bathymetric retrievals, trafficability maps, and locating WWII relics and remnant hazards. On Guam, in-water optical data collected near a sewage diffuser in Tipalao Bay will have the secondary benefit of highlighting near shore plumes. Ground control data collected during the remote sensing experiment will be useful in building digital elevation maps and training maps for remote areas such as Pagan, a volcanic island in the CNMI. Surveyed calibration panels, WWII relics, and underwater panels will all be useful in developing anomaly detection algorithms.

The primary purpose of this memorandum report is to summarize imagery collections and all Cal/Val data. It describes the project geodatabase for those that may have other uses for the data. Extracts from this report have already been used to describe ground control in support of a project to build a digital elevation model for Pagan. This data report is the basis for a follow on NRL Technical Report, conference proceedings, and several refereed journal articles. The geodatabase and scientific literature support follow-on bathymetric work to produce updated maps of the coast. These serve a key role in coastal zone management and are the basis for understanding how waves behave and how coastal inundation may occur.

Introduction

This data report presents airborne hyperspectral imagery (HSI) and sea and ground truth observations made during the Mariana Islands-Hyperspectral Airborne Remote Environmental Sensing (MI-HARES) 2010 experiment. Data were collected from February through March 2010 at study sites found on Pagan, Tinian, and Guam. This report documents specific data collected in support of Marine Corps Forces Pacific and research sponsored by the Office of Naval Research. Some of this data will be used for ongoing research at the Naval Research Laboratory, the National Geospatial-Intelligence Agency (NGA), and the Naval Post Graduate School.

MI-HARES'10 builds upon several projects completed by NRL-7232 at:

- Virginia Coast Reserve Long Term Ecological Research site in September 2007 (VCR'07),
- Marine Corps Base-Hawaii during February 2009 called the Hawaii Hyperspectral Airborne Remote Environmental Sensing (HI-HARES'09) Experiment, and
- Shoalwater Bay Training Area in Queensland, Australia during March 2009 called Exercise TALISMAN SABER 2009 (TS09). The execution phase of TS09 was during July 2009.

During VCR'07, a multi-sensor airborne remote sensing suite of NRL Coastal and Ocean Remote Sensing Branch (Code 7230) instruments, including two hyperspectral cameras and a broad band mid-wave IR camera (Bachmann et al., 2008 and 2010) were flown aboard a Twin Otter aircraft. Results from VCR'07 were presented to the sponsors at a demonstration day at the conclusion of the exercise, and included the debut of a trafficability map product derived from airborne hyperspectral imagery (HSI) in a barrier island coastal environment. Other demonstrated products derived from the HSI included high precision maps of shallow water bathymetry in the coastal barrier island/lagoon system, as well as land-cover (down to species level for vegetation type), and vegetation density. The HI-HARES'09 experiment resulted in the development of a preliminary project geodatabase for a coral coast and datasets for separate anomaly detection projects being conducted by the InnoVision Directorate at NGA. During TS09, NRL scientists developed a preliminary project geodatabase for a mangrove coast. Several scientists also worked with the Coalition Task Force C2 at Schofield Barracks, Hawaii and aboard the USS ESSEX with Marines from 31st Marine Expeditionary Unit to demonstrate the use of HSI-derived planning products covering landing beaches found along the Shoalwater Bay Training Area (Hallenborg and Nichols, 2009; Bachmann, Nichols, et al 2010). Littoral data elements and parameters archived in project geodatabases can be used to support the development of a coastal classification system, which helps in the exploitation of spectral region imagery. It has the secondary benefit of supporting the planning for ship-to-objective maneuver.

NRL's past remote sensing campaigns have demonstrated the utility of HSI to support the military decision making process. The HSI directly helps the military planner to characterize the

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environment to reduce levels of uncertainty and risk that are inherent in tactical operations. For imagery analysts, by looking at coast types, advances are being made in understanding the interaction of the solar incident radiation during its downward and upward passages through the atmosphere (radiative transfer modeling and atmospheric correction), and the characterization of spectral response from the illumination of individual areas (beaches, soils, vegetation, and near shore waters) in a coastal environment. Research results from MI-HARES'10 will be used to specifically support the Marine Corps Installations Middle Pacific (MCI MidPac) Planning Group. NRL will archive environmental factors relevant to selected landing beaches located on the Mariana Islands in a project geodatabase (Bachmann et al., 2010, Fry et al., 2010, and Fusina et al., 2010). The measurement program for MI-HARES'10 was described in a science plan (Bachmann et al., 2010), which also discusses important tasks that must be accomplished to assure the collection of necessary and sufficient quality-controlled data.

The primary focus for MI-HARES'10 was the development of trafficability maps, shallow water bathymetry, and the identification and detection of anomalies (e.g., WWII relics as well as hazards to navigation, whether part of the natural landscape or remnant from WWII) from HSI in coasts that are dominated by limestone and volcanic deposits. It was a multi-agency experiment led by NRL in partnership with MIRC, NPS, USMC, and ONR, which focused on the collection of airborne HSI with concurrent littoral ground and water validation data collected at Pagan, Tinian, and Guam, three islands that are included in the Mariana archipelago. A diagram of the Mariana Islands is provided in Figure 0-1.

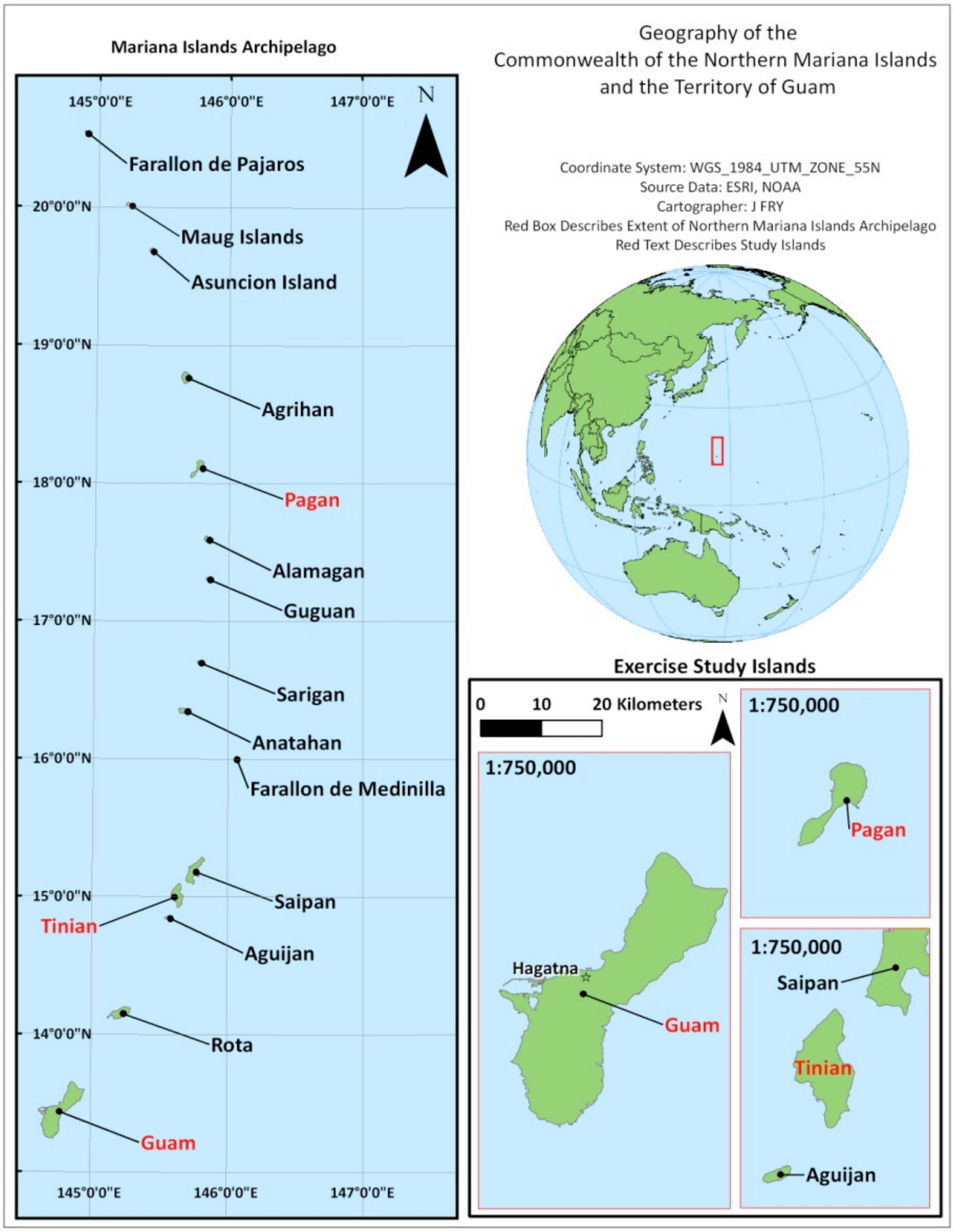

Figure 0-1. Mariana Island archipelago. Located east of the Philippines, Guam is the largest island in the group and is independent of the others, which are known formally as the Commonwealth of the Northern Mariana Islands. MI-HARES'10 included surveys on Pagan, Tinian, and Guam. This scientific project was designed to benefit the Defense Policy Review Initiative (DPRI).

1 Field Experiment

MI-HARES'10 ran from February 16, 2010 to March 12, 2010 and emphasized a rigorous validation campaign with combined *in situ* measurement of spectral reflectance of soil substrates and vegetation, geotechnical measurements, and in-water spectral sampling with coordinated over-flights by several hyperspectral cameras. Primary instruments included hyperspectral cameras, handheld spectrometers, sun photometers, lightweight deflectometers (LWDs), dynamic cone penetrometers (DCPs), soil core samplers and sieves, handheld sonar, an underwater spectrometer, and in-water optical profilers (IOPs). Study sites on the Mariana Islands, an archipelago composed of the summits of 15 volcanic mountains in the northwestern Pacific Ocean, included Pagan, Tinian, and Guam.

Pagan Island was the first site to be visited by the NRL researchers. It was a remote study site with rugged terrain and contains the largest and most active of the Mariana Islands' volcanoes. Both North and South Pagan stratovolcanoes have significant calderas, 7 and 4 km in diameter, respectively. The 570-m-high Mount Pagan at the northeast end of the island rises above the flat floor of the northern caldera. The South Pagan 548-m-high stratovolcano has an elongated summit containing four distinct craters. Most of the eruptions on Pagan, which date back to the 17th century, have originated from the North Pagan volcano. Operations on Pagan required the use of the MV MICRONESIAN (a 100 foot crew boat) and two small boats for ship to shore movement (Figure 1-1). Cloud cover and steam from the volcanoes challenged the collection of imagery. Heavy seas required researches to focus littoral surveys on the west side of Pagan. In some places along the strand, coconut palms (*Cocos nucifera*) were the dominant plant and the litter which has fallen year after year, posed a challenge to walking. In other areas, Ironwood, a native pine, was predominant. Closest to the two active volcanoes, Ironwood a pioneer species, was dominant in the relatively more fresh volcanic soil, while coconut palms tended to reside toward the middle of the island, further from the active volcanoes at either end. Coral reef development was limited, although numerous patches of extensive reef growth were found near study sites on Pagan.

The second study site was on Tinian, which lies north of Guam on the eastern edge of the Philippine Sea. Tinian is located approximately 8-km southwest of Saipan. The islands are separated by the Saipan Channel, which was extremely rough during the study period. Researchers set up operations in San Jose, Tinian's largest village, in order to survey several beaches, the limestone cliffs, and a variety of plant species. The Tinian coastline is rocky and rugged and unprotected from wave action except at a harbor located on the southwest coast, which is protected by a reef system. During MI-HARES'10, all flight operations for the airborne hypspectral data collection were aboard the twin-engine Piper PA-31 Navajo, were out of the Tinian International Airport. The airport is owned by Commonwealth Ports Authority and was a hub for the project's inter-island travel.

Guam was the last study site visited by the NRL researchers. It is the oldest, largest, and southernmost island in the Mariana Archipelago. It also contains Naval Base Guam, which provided warehouse and office space for the processing of imagery and other raw data. The northern portion of the island is relatively flat and consists primarily of uplifted limestone. The southern half of the island is primarily volcanic, with more topographic relief and soil layers rich in iron oxide and aluminum (i.e., erodable lateritic soils). Fringing reefs, patch reefs, submerged reefs, offshore banks, and barrier reefs were found at the study sites

Figure 1-1. Vessel and small boat. The 102-foot MV MICRONESIAN provided working spaces for scientists conducting surveys on Pagan. A rubber inflatable boat (RIB) was used to support in-water optical profiling, hydrographic surveying, and scientific diving. This RIB and a small skiff were used for ship to shore movement.

Electronic web resources, where complementary information for MI-HARES'10 can be found in Appendix A. This includes information provided by National Oceanic and Atmospheric Administration (NOAA) and University of Guam web sites. Example information includes wave buoy measurements, tide predictions, satellite imagery, bathymetric surveys, and numerical model output.

1.1 Airborne Survey

A twin engine Piper PA31 Navajo was used as a platform for HyMap^{TM}, the NRL MicroSHINE (a VNIR UAV-capable hyperspectral sensor), and another NRL Surface Optics SWIR hyperspectral instrument. Imagery was collected using the HyMap^{TM} spectrometer mounted aboard a twin-engine aircraft during the period from 3 to 11 March 2010. MicroSHINE data was collected over a more limited period due to instrument technical difficulties. Figure 1-2 displays the aircraft (left panel) and the sensor orientation (right panel).

Figure 1-2. Air Flight Services' Piper PA31 Navajo (left panel) and payload (right panel). Airborne instruments include HyMap^{TM}, NRL MicroSHINE, and SWIR sensors. Flight operations were out of the Tinian International Airport, a public airport located on Tinian Island in the United States Commonwealth of the Northern Mariana Islands. (see URL: http://www.cpa.gov.mp/tinapt.asp).

HyMap^{TM} provides 128 bands across the reflective solar wavelength region of 450– 2500 nm (visible, near infra-red, and short-wave infra-red) with contiguous spectral coverage (except in the atmospheric water vapor bands) and bandwidths between 15 – 20 nm. The spectral configuration of the HyMap sensor is depicted in Table 1-1. The NRL MicroSHINE sensor covers the visible and near infrared portion of the spectrum from 0.38-1.1 nm, but with better spectral resolution (3 nm native). MicroSHINE is also is well designed for coastal imaging (although not limited to these areas of application), while HyMAP is a more generic sensor designed for a large number of application domains.

Table 1-1. Spectral configuration of HyMap. Each of the spectral modules contains 32 bands for a total of 128 spectral bands.

Module	Spectral Range	Bandwidth across module	Average spectral sampling interval
VIS	450 – 890 nm	15 – 16 nm	15 nm
NIR	890 – 1350 nm	15 – 16 nm	15 nm
SWIR1	1400 – 1800 nm	15 – 16 nm	13 nm
SWIR2	1950 – 2480 nm	18 – 20 nm	17 nm
Additional details on the HyMap sensor may be accessed online at URL: http://www.hyvista.com.			

Flight lines were planned to achieve a nominal ground sample distance (GSD) of about 3m and an approximate swath of about 1.64 km for the HyMAP sensor. An overlap of approximately 25% (which is about 410 m) between adjacent flight lines was achieved in order to prevent any data gaps from small variations in the planned flight lines. To minimize glint from the water, flights were flown when solar zenith angles were between 30-60°. In addition, flights were flown into and out of the sun to further minimize glint as illustrated in the following solar azimuth heading figures. In order to achieve this, the NRL team computed optimal times of day for data acquisition, and planned flight lines to maintain flight line trajectories into and out of the sun (USNO, 2010). This has the benefit of minimizing glint and of maintaining uniform illumination across the sensor array. In order to maintain a heading into and out of the sun, flight line azimuthal bearing was defined for approximately each hour in the air because the solar azimuth changes rapidly at this time of year at this latitude. For each day, there were approximately six hourly time categories (three AM, three PM) that were chosen where sun angles were optimal for flying. The average azimuth for these time periods was calculated and this value was to be the heading in which the aircraft would fly for that time period. Each set of four days (19 February to 22 February, 23 February to 26 February, 27 February to 2 March, 3 March to 6 March, and 7 March to 10 March) was grouped and azimuths for each time category were shared among the four days. This was done to minimize the total number of flight lines. A sensitivity analysis was conducted to determine that four days would not lead to a significant deviation between the actual and optimal headings in any given window. Although flight lines were planned from the time period 19 February to 2 March, these days were not flown due to weather and resulting delays in the experiment. Flight lines were planned to cover the entire island of Pagan, the northern and central sections of Tinian, and Dadi and Tipalao beaches on Guam. Maps, azimuth and timetables, and further information regarding flight lines are explained in Appendix B.

Quicklooks are JPEG image captures of HyMap™ imagery. The quicklooks show the area covered in the flight line and are particularly useful to assess imagery quality, e.g., percent cloud cover. Appendix C displays quicklooks for HyMap™ imagery purchased from HyVista Corporation.

1.2 Calibration/Validation Data

Primary instrumentation to collect necessary and sufficient data for trafficability analysis includes spectrometers, lightweight deflectometers, dynamic cone penetrometers, and soil core samplers, drying oven, and sieves. The spectrometers were used to collect field spectra in support of remote sensing image analysis, in particular to develop relationships (models) between the observed spectral response from the ground and its associated geotechnical properties. Among the geotechnical instruments, the role of the lightweight deflectometer (LWD) was to measure the dynamic deflection modulus. The LWD instrument measures this quantity by imparting a pulse, by dropping a standardized weight from a fixed height onto an accelerometer embedded in a base plate, which simulated the response of the surface to vehicle traffic. The complementary role of the dynamic cone penetrometer (DCP) was to measure the shear strength of the soil, recorded by recording the kinetic energy required to push a probe through the soil. Soil sampling was also conducted and analyzed at a field station to determine soil moisture content as well as grain size profile. Real-time kinematic beach surveys were also conducted as described above. The use of geotechnical instruments fostered the accurate characterization of coralline and volcanic sands and rocky littoral environments. NRL found that the Mariana Islands' littoral region was very different from previously studied coasts composed of sands, plastic clays, combinations of clayey gravels and sands of lesser plasticity, and lean clays and silts. Grain sizes tended to be skewed toward larger sizes, due to the influence of relatively recent, or in some cases active, volcanic activity.

1.3 Site Characterization

The CNMI and Guam are located in the northwestern Pacific Ocean between 12 and 21 degrees north latitude and along the 145 degrees east longitude. The Marianas are located on the other side of the dateline from the rest of the United States. Volcanic rock forms the foundation of these islands and is often exposed. Topographic maps of the study area are provided in Table 1-2. The primary ocean current influencing this region is the North Equatorial Current, flowing east to west in the tropical Pacific Ocean (Nichols and Williams, 2009). Persistent trade winds (10-15 mph on average) from the east-northeast create wind driven waves that shoal and break upon the exposed shores as surf for the majority of the year. Tide predictions for the Mariana Islands are provided by NOAA's National Ocean Service (see Appendix A). The tidal reference station for MI-HARES'10 was sited at Apra Harbor, Guam (Station Id. 1630000), which serves as the basis for secondary station predictions on Tinian (Station Id. TPT625). By looking at the ratio of the main diurnal to the main semidiurnal components, the tide can be classified as mixed, mainly semidiurnal. The mean range is 0.49m. University of Guam reports that tides on the open coast occur a little earlier than predictions shown for the Apra Harbor reference station. The NOAA tide house is located on the east corner of the entrance to the Sunny Cove Marina boat harbor. Predicted tides are based on astronomical forces and do not consider the impacts of local winds and barometric conditions. Nautical charts pertinent to the study area are provided in Table 1-3.

Table 1-2. Topographic Maps pertinent to MI-HARES'10. Most USGS map series divide the United States into quadrangles bounded by two lines of latitude and two lines of longitude. The 1:24,000-scale topographic maps, also known as 7.5-minute quadrangles, are the only uniform map series covering the United States.

Map	Scale	Type	Date	Title	SE Corner
Topographic	1:63,360	15-MIN DRG	1978	Guam	13°13'00.01"N, 144°58'00.01"E
Topographic	1:24,000	7.5 x 7.5-MIN DRG	1978	Agana Harbor	13°25'00.12"N, 144°48'00.00"E
Topographic	1:25,000	DoD/NIMA	1999	Island of Tinian	14° 52' 30" N, 145° 41' 30"
Topographic	1:25,000	7.5 x 7.5-MIN DRG	2000	Agat Quadrangle	13° 17' 30" N, 144° 42' E

Topographic	Not Given	USGS	2006	Preliminary Geological Map of Pagan	CURRENT SUDOCS #: I 19.76: 2006-1386

Table 1-3. Nautical Charts pertinent to MI-HARES'10. NOAA produces charts covering the coastal waters of the U.S. and its territories. NOAA's charts are available in a variety of formats, such as paper charts, Print-on-Demand charts, Raster Navigational Charts®, and Electronic Navigational Charts®. NOAA also produces sailing publications such as the United States Coast Pilot®.

Chart	Scale	Edition	Date	Title
81004	931,650	5	2008	Commonwealth of the Northern Mariana Islands
81048	100,000	10	2006	Marianas Island of Guam Territory of Guam;Cocos Lagoon
81054	10,000	16	2008	Apra Harbor
81067	75,000	9	2009	Commonwealth of the Northern Mariana Islands Saipan and Tinian
81071	20,000	7	2004	Commonwealth of the Northern Mariana Islands Bahia Laolao, Saipan Island and Tinian Harbor, Tinian Island
81092	26,420	5	2007	Commonwealth of the Northern Mariana Islands Pagan Island;Plan: Maug Islands
Digital versions of the charts can be accessed via the URL: http://www.charts.noaa.gov/OnLineViewer/PacificCoastViewerTable.shtml				

Common habitats in the Mariana Islands include strand, grasslands, secondary forest, native forest, and wetlands (Vogt and Williams, 2004). The MI-HARES'10 exercise focused on the strand habitat, which is located near the beach and characterized by dunes, high salt content, and heavy winds. Grassland areas included the airfield on Pagan, but were not surveyed on Tinian and Guam. Secondary forests may have been caused by volcanism, agriculture, or wartime activities. They are associated with a mix of introduced, agricultural, and native species. Jungle areas in Tinian that have vines, orchids, and ferns are best classified as native forests. Wetlands, such as mangrove swamps or the marshy area near several lakes on Pagan, were not surveyed. Selected vegetation common to the Mariana Islands is listed in Table 1-4.

Table 1-4. Selected list of common flora found in the Mariana Islands.

Scientific Name	Common Name(s)	Habitat Location	Comments
Areca catechu	betel nut palm	Secondary forests	Slender palm typically reaching 10–20 m.
Artocarpus mariannensis	dukduk, seeded breadfruit	native and secondary forests	Large tree (> 10m) commonly found on limestone plateaus. Mature seeds are boiled before eaten, and are locally called "hutu" when cooked.
Casuarina equisetifolia	ironwood	secondary forest	Large (>6m) nitrogen fixing tree used for erosion control in grasslands and as a windbreak for farms. The wood is hard.
Cocos nucifera	coconut palm	Strand	Large palm (up to 30m) that thrives on sandy soils and is highly tolerant of salinity.
Cordia subcordata	niyoron	Strand	Small (1-7m) tree found along the beach and on limestone cliffs. It produces orange flowers.
Ficus prolixa	Nunu, banyon	native forests	A large tree (> 10m) with numerous prop roots.
Hibiscus tiliaceus	Pago, beach hibiscus	strand and grasslands	Thickets can be difficult to move through.
Pandanus dubius	pahong, pandanus	native and secondary forests	A medium size tree (4-6 m) with many prop roots and sharp serrated leaves.
Scaevola taccada	Nansao, half flower	Strand	A shrub (1-2m) that grows in thickets. Its ripe fruits are used as a medicine to treat eye irritation, including pink eye.
Tournefortia argentea (Heliotropium foertherianum)	velvet leaf, velvet soldierbush	Strand	Typically reaches 6 m, with similar crown diameter.

The Mariana Islands provide an ideal location for coral reefs, submerged aquatic vegetation, and macro-algae. Coral reefs may be somewhat different on the various Mariana Islands owing to varying geological, oceanographic, ecological, and anthropogenic factors. For example, they tend to be well developed throughout the region, except on the coastlines of recently active volcanoes. Wave action may also limit the development of coral growth in some surf-dominated regions. Table 1-5 lists common corals, Submerged Aquatic Vegetation (SAV) and algae found in the Mariana Islands.

Table 1-5. Selected list of common corals, SAVs, and algae found in the Mariana Islands. Seaward of the waterline, the bottom is quite complex where one may find fringing reefs, patch reefs, submerged reefs, offshore banks, barrier reefs, or patches of cobble and sand. Cover of stony corals, dead corals, soft corals and algae was highly variable among the different sites in the CNMI and Guam.

Scientific Name	Common Name	Comments
Acropora	bush, elkhorn, staghorn, or table, coral	Stony corals growing as plates or slender or broad branches.
Alveopora	flowerpot, daisy, or ball coral	Stony corals made of interconnecting rods and spines. Tubular polyps with 12 tentacles per polyp.
Cladiella	colt or finger leather coral	Soft coral with jelly-like appearance with lots of small fluffy polyps found on reefs
Enhalus acoroides	tape seagrass	Seagrass found on some fringing reefs.
Dictyosphaeria	bubble algae	Seaweed with bubble-like cells is grass green in color and can form extensive mats over rocks.
Favia	brain, knob, moon, pineapple, and star coral	Stony corals exhibiting fleshy polyps and long sweeper tentacles
Goniastrea	brain star, honeycomb, wreath, moon, or closed brain coral	Stony coral with massively round or dome-shaped honeycomb appearance.
Goniopora	daisy or flower pot coral	Reef building coral with tubular polyps having 24 tentacles (flower-like) per polyp.
Halimeda	money plant	Calcareous algae having irregular oval segments that appear as small green coins glued from end-to-end, forming a chain. When the algae die, calcium carbonate is deposited in tropical lagoons and reefs.
Heliopora coerulea	blue or blue fire coral	Reef building soft coral with a hard skeleton found on reef flats and upper reef slopes.
Halodule uninervis	needle seagrass	Seagrass with a pale rhizome, one central vein, clean black leaf scars, and trident leaf tip.
Halophila minor	paddle grass	Seagrass found on shallow/intertidal sand flats with less than 8 pairs of cross veins, small oval leaves occurring in pairs, wedge-shaped leaf sheath.
Leptoria	lesser brain and ragged brain coral	Stony coral forming massive or encrusting colonies, often with lumpy protuberances.
Lobophyton	devil’s finger, leather, or lobed leather coral	Soft corals that are extremely varied in shape, form, and color.

Scientific Name	Common Name	Comments
Lobophyllia	open brain, lobed, or bouquet flower coral	Stony coral found in a variety of textures and colors. Some are smooth, while others are pimply, and look like carpet. Colors vary from bright red, green, orange, gray, tan, or brown.
Montipora	cabbage, cup, encrusting pore, porous leaf, whorl bowl, and vase coral.	Stony coral commonly found in shallow reef environments with bright sunlight and moderate wave motion.
Padina	onion ring or mermaids fan	Brown algae with calcified fan-shaped blades several inches wide with torn margins. Abundant on quite sandy reefs.
Platygyra	brain worm, maze, closed brain, or bowl coral	Stony corals that are usually massive and either dome-shaped or flattened, with various color shades of green, brown, or gray and contrasting valleys which may be fluorescent under actinic lighting.
Pocillopora	cauliflower, bird's nest, branch, brown stem, brush, cluster, finger, and lace coral	Stony corals having branches that are either flattened and blade-like, or fine and irregular. Species situated on shallow reefs with heavy wave action are often stunted, while those in deep water are thin and open.
Porites	boulder, lobe, finger, and jeweled coral	Stony coral forming flat, branching, spherical or hemispherical structures; some hemispherical colonies are huge (> 5m across). Some are dead on the top but living around the perimeter. Have a fuzzy look. Largest of coral colonies.
Psammocora	sandpaper, Haime's lump, pillar, superficial coral	Stony encrusting corals.
Porifera	cryptic (hidden in crevices between rocks or coral rubble) and encrusting sponges	Many sponges were found. The majority of the species are siliceous (Class Demospongiae). Terpios hoshinota, a black encrusting calcareous sponge, has received much attention on Guam due to the threat it poses to coral reefs.
Sarcophyton	Fiji yellow leather, mushroom leather, toadstool, and trough coral	Soft corals that generally have a thick stalk with a leathery top. They have a fuzzy appearance when the polyps are all extended and a smooth leathery appearance when the polyps are retracted.
Sinularia	knobby or thin finger leather coral.	Soft rugged-looking encrusting coral.
Udotea	green fan, green finger, mermaid's fan	Macroscopic green algae composed of calcified blades that are funnel or fan-shaped, calcified stipe, and uncalcified mass of siphonous root-like filaments, i.e., rhizoids.

Data collected during this survey focused on the west side of Pagan, the northern portion of Tinian, and the southern extent of Guam. On Pagan ash shrouds the cliffs of layered pyroclastic rock, resulting from a time series of eruptions. Each eruption has produced a layer of ash, lapilli or bombs which eventually lithify to form tuff or volcanic breccia. Tinian and Guam are overlain by carbonate rocks. On Tinian, the maximum elevation is approximately 187m and the northern part is the lowest. Volcanic products have been extensively weathered, with only relict structures and textures remaining. Like Tinian, volcanic rock forms the foundation of Guam and is exposed over about 35 percent of the island's surface, predominantly to the south. On Guam, streams are present in the south since the volcanic rocks slow the infiltration of rainwater thereby allowing ground-water discharge to streams.

1.4 General Information

Remote sensing campaigns at NRL are of great importance since they are being conducted at various coastal sites and allow the collection of large-scale data of representative coast types. The archived datasets are crucial to generating useful relationships among California Bearing Ratio (CBR), a standard index of soil shear strength, and other fundamental material properties for soils, especially in selecting favorable littoral penetration points. CBR is derived from penetration tests that measure the pressure required to penetrate the soil. The USMC uses CBR to determine the load-bearing capacity of soils used for building roads and expeditionary airfields. Harder surfaces will have higher CBR ratings. In general, a CBR of 3 equates to tilled farmland, a CBR of 4.75 equates to turf or moist clay, while moist sand may have a CBR of 10. High quality crushed rock has a CBR over 80. Archiving this type of data from NRL's remote sensing campaigns complements existing databasing efforts such as the small scale (1:5,000,000) United Nations Food and Agriculture Organization's world soils map (see FAO-UNESCO 1974) and the medium scale (1:250,000) Soil and Terrain Database (see ISRIC 2004), and relating this and other associated geotechnical data to *in situ* spectral measurements and remote sensing data is the basis of NRL's approach to remote retrieval of soil bearing properties. It also supports the development of coastal classification systems for remote sensing and mapping (Bachmann et al., 2010).

1.5 Geodatabase

When developing a geographic database or "geodatabase" to archive the results of feature classification, it's important to include, at a minimum, the imagery from which each feature was derived, and the associated feature class or vector file. Information regarding the project geodatabase is described in Appendix D. Raster, vector, and text file information from MI-HARES'10 were organized in a file geodatabase, which resides on computer disk drives of size 500GB or greater. Memory greater than 500GB is required due to the voluminous size of HSI data cubes. For the HSI, spatial information is represented in the X-Y plane while spectral information is represented in the Z-direction. When developing these geodatabases, we include selected intermediate files. Showing all the imagery analyses involved in creating the final result is helpful to those who want to repeat the same process for similar projects. Regardless of the number of files included, metadata is provided for each feature so others can understand how a particular file was produced and the proper way it should be interpreted.

The software package used in the development of NRL CODE 7232 geodatabases is ESRI's ArcGIS desktop (ArcView license) although free Geographic Information System (GIS) viewers such as ESRI's free ArcGIS Explorer 900 and Google Earth ® can view some of the products in the geodatabase. ArcGIS explorer users can upload vector and raster files into the viewer while Google Earth® supports keyhole markup language (.kml) and keyhole markup language-zipped (.kmz) files made in the geodatabase.

Specific types of data (raster, vector, and text) included in the MI-HARES'10 geodatabase are as follows:

- **Imagery** - HyMap imagery quicklooks in georectified JPEG format. These files, which provide reflectance values at each wavelength, can be analyzed to give spectra for a variety of environmental targets over the study area (ENVI operable). Similar imagery quicklooks for the NRL microSHINE are also provided. Geotagged photographs for landing beaches are linked to GPS positions.
- **Survey data** - Each of the Trimble differential GPS locations were processed into a shapefile, depicting the point where data were captured, as well as Ashtech survey-grade post-processing kinematic GPS data captured from beaches and the water level gauge.
- **Cal/Val data** - The GPS shapefiles highlight the location on the Earth's surface where instrument data were taken. The instrument data were stored as Microsoft Excel spreadsheets, JPEG images, or Word documents with information about the data capture. These data sources are accessed by pressing on the hyperlink in the GIS viewer through the identify feature tool in ArcMap.
- **Metadata** - Digital photographs and field notes are provided that help explain the data as well as FGDC format metadata for layers.

These types of data have been analyzed by NRL to develop innovative new products such as very shallow water bathymetric retrievals and trafficability maps.

1.6 Data Files

Example files from the geodatabase are included as tables, appendices, and figures for this data report. Most of the data table files are tab-delimited text files, usable in spreadsheet and database software. The imagery and map data are in several formats for use in digital mapping software. The types of data present in the MI-HARES'10 exercise can be broken down into data archived in geographical form (which are presented through ArcMap) and data that are not archived in geographical form. Appendix D describes the access of attribute data within ArcMap. Attribute data can be accessed from the "MIHARES10_ALL_DATA.xlsx" spreadsheet on the top level of the disk drive or by selecting the identify feature tool and then selecting the geotechnical positions layer. Types of data available on the geodatabase drive but not accessed through ArcMap are listed in Table 1-6.

Table 1-6. MI-HARES'10 data files. There are numerous MI-HARES'10 data types, including data tables, GIS files, spectra, and plot files. This table summarizes data that are not rendered through ArcGIS, but do appear on the geodatabase disk. These data are rendered through alternative means such as the operating system browser tools or packages such as ITT's ENVI®.

Path	Folder	File Types/Notes
\ MIHARES10\Attribute_Data\	ASD\	Contains ASD reflectance files broken down by substrate

		subject. Also contains raw ASD data.
\ MIHARES10\Attribute_Data\	Field_notes\	Field notes in .pdf format
\ MIHARES10\Attribute_Data\	HSI\	HyMap and NRL microSHINE HSI imagery that can be opened in ENVI IDL, as well as accompanying intermediate files.
\ MIHARES10\Attribute_Data\	IOP\	In-water optical profiler data and spreadsheets.
\MIHARES10\Attribute_Data\	Photographs\	Work and background photographs. Photos of flora for ASD control as well as underwater photographs. Soil experiment photos. Miscellaneous touring photos. Photographs are separated by folder by location or type.
\MIHARES10\	Products\	Various PowerPoint™ presentations as well as JPEG map images, JPEG graphs, and text products including this data report.

2 Visualization

Various products were built from the imagery and cal/val data. They included maps of trafficability and very shallow water bathymetry. Trafficability is the ability of the terrain to support the movement of vehicles and people. Some of the important factors are vegetation density, bearing capacity, and shear strength of the soil. Analysis was conducted to classify HSI to represent trafficability for the various “littoral penetration areas” found on Pagan, Tinian, and Guam. A littoral penetration area is of sufficient size to conduct unrestricted sea, air, and land operations. Estimates of trafficability from the imagery were binned into excellent, good, fair, poor, or bad categories. The very shallow water bathymetry of the littoral environment was extracted from HSI in order to complement trafficability maps. As indicated in Section 3, all of the data and imagery are available through the MI-HARES’10 project geodatabase.

2.1 Spectra Collection

By using a spectroradiometer, such as the FieldSpec Pro® from Analytical Spectral Devices (ASD®), the researcher is able to capture radiance entering the aperture of this instrument. These ASD®-Full Range (FR) spectrometers record radiance in the 350-2500 nm range every 1nm with a 2nm spectral resolution. Results are converted to units of reflectance by comparing samples with those obtained from a white reference Spectralon® plaque. Spectralon® provides an approximately 99% reflecting surface, and is a standard used by the spectral remote sensing community. In our sampling strategy, two alternating sets of 30 samples each of white plaque and substrate were averaged to reduce noise and vulnerability to variations in solar illumination during the period of measurement. For SWIR measurements, a large number of measurements are desirable because of lower photon counts in this portion of the spectrum. A variety of configurations were used depending on conditions, but the preferred configuration consisted of two tripods, one for the spectrometer fore-optics and the other for the white Spectralon ® reference plaque. The spectrometer fiber optic cable was mounted in a pistol grip on one tripod in a nadir-looking configuration, while the Spectralon® plaque was mounted on a second tripod and rotated into and out of the field of view of the spectrometer to allow rapid collection of white plaque and specimen radiance measurements needed for the reflectance ratio. To maintain consistency in leveling and viewing geometry, alternating specimen and reference spectral samples were collected.

Spectroscopy was the most labor intensive component of the *in situ* measurement program, with the typical measurement paradigm consisting of dual use spectrometer methodology which includes one ASD®-FR spectrometer measuring the white reflectance plaque and a rover ASD®-FR spectrometer alternating measurements between substrate and white reflectance plaque. This methodology, developed by the NRL team (Bachmann et al, in prep) is used in cloudy or partial sun sky conditions, which happened to be the majority of sky conditions during MI-HARES'10. The normal method of spectroscopy would consist of a single ASD®-FR spectrometer measuring white reference plaque and then measuring substrate, then repeating.

Spectral measurements were taken of bathymetry (water column properties), calibration panels, geotechnical measurement locations, *in-situ* vegetation sources, leaf sources (leaf optics), man-made features/relics (bunkers, monuments, Japanese airplanes, anti-aircraft artillery), and terrain features (lava rocks). Spectra and comments on the spectra are viewed in Appendix E SPECTRA.

2.1.1 Bathymetry (Shallow Water) Spectra

Spectral measurements were taken of the water column on Guam, Pagan and Tinian. The methodology involves measuring the water depth with a meter-stick scale before the first spectral measurement and after the second spectral measurement. Sampling positions on each island involved taking readings at different water level heights to achieve adequate sampling from wet substrate to approximately 1m of water. The bottom type differed among the three islands. The sample beaches on Guam consisted of mainly large pieces of coral mixed with small particle sand and patches of tape seagrass (*Enhalus acoroides*) in the shallow water. On Pagan, bottom composition consisted of dark volcanic sand while the seafloor on Tinian consisted of coral, white sand, limestone rock, and volcanic rock formations. Sampling depths were either recorded as an average of the two meter-stick measurements (Guam and Pagan) or as a range from the first measurement to the second measurement (Tinian). Information regarding the location and number of samples is displayed in Table 2-1. In addition spectral reflectance from just above the water surface was recorded in conjunction with the measurement of IOP's taken from the small boats.

Table 2-1. Shallow water bathymetry sample information.

Island	Location	Date	Water Level Samples
Guam	Dadi Beach	9-March-2010	24

Pagan	Beach 1	2-March-2010	20
Tinian	Unai Lamlam	7-March-2010	12

2.1.2 Calibration Panel Spectra

Two 10 m by 10 m canvas panels were deployed in order to act as calibration surfaces for aerial images. One of the deployed panels was white, while the other panel was black. The spectral reflectance of each panel was recorded with the portable ASD spectrometers. Table 2-2 displays information regarding the measurement of calibration panel spectra.

Table 2-2. Calibration panel spectra information.

Island	Location	Date	Name/Description
Pagan	airfield	3-March-2010	White Panel
Pagan	airfield	3-March-2010	Black Panel

3.1.3 Geotechnical Site Spectra

The majority of spectra were carefully collected at the same location where geotechnical information was also collected. Geotechnical measurements where compared with spectra in order to develop mapping products from HSI. The sampling protocol involved the measurement of spectra prior to the use of geotechnical instruments that disturbed the land surface. The geotechnical instruments included a lightweight deflectometer (LWD) to measure dynamic deflection modulus, a dynamic cone penetrometer (DCP) to measure soil shear strength, and a grab sampler. The samples of soils and beach deposits were of similar volume and were used for soil moisture, grain size determination, and texture analysis. A GPS unit was used to take the exact position of each sampling site. Figure 2-1 depicts each instrument used in the sampling scheme.

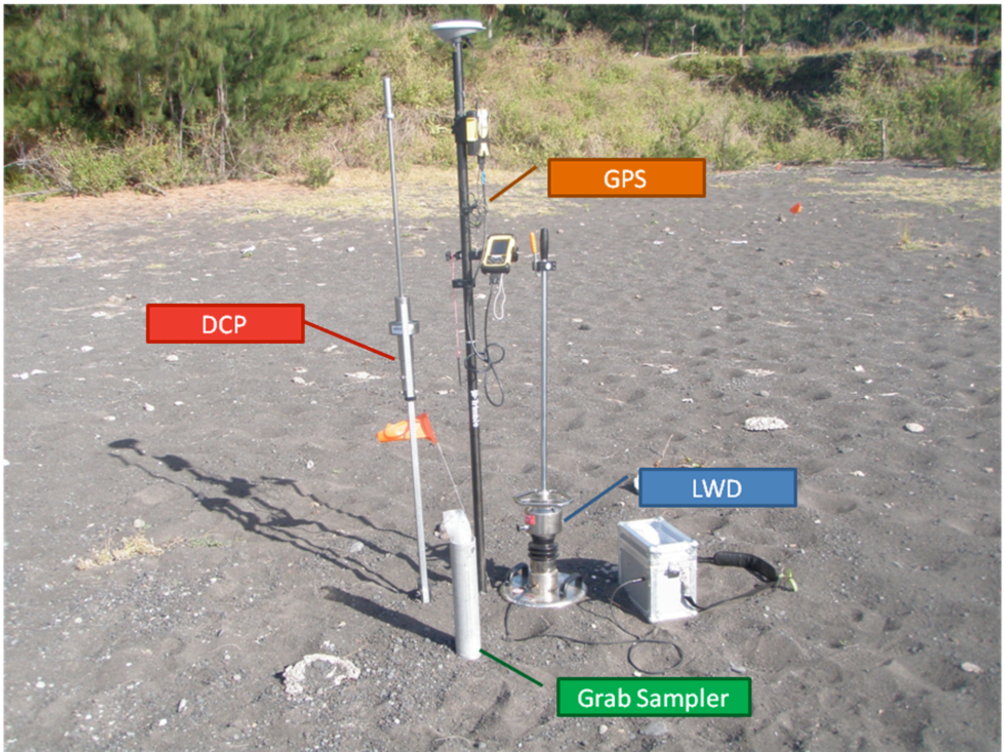

Figure 2-1. Geotechnical instruments used during MI-HARES'10. As a general note, the black sand beaches of Pagan Island get very hot during the daytime, have larger grain sizes, and have little beach vegetation in comparison to other study sites.

The same sampling protocol was completed on all three islands and included a total of 19 transects and 137 positions. Information on each transect is displayed in Table 2-3. Soil samples were saved in plastic bags and stored in a container. Moisture and grain size distributions were computed at laboratory spaces on Tinian and Guam.

Table 2-3. Geotechnical spectra type position information.

Island	Location	Date(s)	Transect Name	No. of Positions
Guam	Dadi Beach	10-March-2010	GUDT1	11
Guam	Tipalao	10-March-2010	GUTT1	7
Pagan	Beach 4	27-February-2010	PAB4T1	3
Pagan	Beach 4	27-February-2010	PAB4T2	2
Pagan	Beach 2	28-February-2010, 1-March-2010	PAB2T1	9
Pagan	Beach 2	28-February-2010, 1-March-2010	PAB2T2	10
Pagan	Beach 2	28-February-2010	PAB2T3	9
Pagan	Beach 2	28-February-2010	PAB2T4	6
Pagan	Beach 2	1-March-2010	PAB2T5	9
Pagan	Beach 2	1-March-2010	PAB2T6	9
Pagan	Beach 4	1-March-2010	PAB4T3	4
Pagan	Beach 4	1-March-2010	PAB4T4	4
Pagan	Beach 1	2-March-2010	PAB1T1	7

Pagan	Beach 1	2-March-2010	PAB1T1	6
Tinian	Unai Babui	5-March-2010	TNUBT1	15
Tinian	Unai Dangkolo	6-March-2010	TNUDT1	6
Tinian	Unai Dangkolo	6-March-2010	TNUDT2	5
Tinian	Unai Dangkolo	7-March-2010	TNUDT3	6
Tinian	Unai Lamlam	7-March-2010	TNULT1	9

2.1.5 *In-situ* Vegetation Spectra

Spectra were taken of vegetation in their natural settings and under field lighting conditions. This sampling strategy differs from leaf-optics, where vegetation sampling involved obtaining a sample in the field and analyzing this sample under laboratory conditions, i.e., using a spectrometer and a light source. Nine major coastal locations were sampled with a concentration on five particular species. Table 2-4 displays information about these positions.

Table 2-4. *In-situ* vegetation spectra descriptive information.

Island	Location	Date	Common Name/Description	Scientific Name
Guam	Dadi Beach	10-March-2010	Beach Morning Glory- GUDT1-12	*Ipomoea pes-caprae* L.
Guam	Dadi Beach	10-March-2010	Beach Hibiscus- GUDT1-14	*Hibiscus tiliaceus* L.
Guam	Dadi Beach	10-March-2010	Beach Morning Glory - GUDT1-13	*Ipomoea pes-caprae* L.
Pagan	Airfield	3-March-2010	Grass Species	
Tinian	Unai Dangkolo	7-March-2010	Velvet Soldierbush-Mature	*Heliotropium foertherianum (Tournefortia argentea* L.*)*
Tinian	Unai Dangkolo	7-March-2010	Velvet Soldierbush-Shrub	*Heliotropium foertherianum (Tournefortia argentea* L.)
Tinian	Unai Dangkolo	7-March-2010	Coconut Palm - Young	*Cocos nucifera* L.-Young
Tinian	Unai Dangkolo	7-March-2010	Coconut Palm - Dead, #1	*Cocos nucifera* L. #1
Tinian	Unai Dangkolo	7-March-2010	Coconut Palm - Dead, #2	*Cocos nucifera* L.#2

2.1.6 Leaf-Optic Vegetation Spectra

Leaf-optic sampling involved collection of leaf samples in the field and subsequent spectral analysis in the laboratory. An apparatus that attached to the ASD® spectroradiometer held the leaf sample while the ASD recorded the spectra. These spectra are different than the *in situ* spectra because they use a light source and a contact probe. The contact probe is an accessory for the FieldSpec® spectrometer, designed for sampling a small area using only internal illumination from a light source in the contact probe. The sampling involved capturing the spectra of the top and bottom of the leaf in reference to white and black reference plaques. Table 2-5 displays information regarding the collection of leaf optic spectra. The island, location of the sample, the common name, scientific name, and variant of the species are listed.

Table 2-5. Leaf optic spectra collected during MI-HARES'10.

Island	Collection Location	Common Name	Scientific Name	Variant
Guam	Dadi Beach	Tape Seagrass	*Enhalus acoroides*	#1
Guam	Dadi Beach	Tape Seagrass	*Enhalus acoroides*	#2
Guam	Dadi Beach	Tape Seagrass	*Enhalus acoroides*	#3

Guam	Dadi Beach	Beach Hibiscus	*Hibiscus tiliaceus*	
Guam	Dadi Beach	Beach Morning Glory	*Ipomoea pes-caprae*	#1
Guam	Dadi Beach	Beach Morning Glory	*Ipomoea pes-caprae*	#2
Pagan	Airfield	Ironwood	*Casuarina equisetifolia*	
Pagan	Airfield	Coconut Palm	*Cocos nucifera*	
Pagan	Airfield	Screw Pine	*Pandanus tectorius*	
Pagan	Airfield	Mango Tree	*Mangifera indica*	
Pagan	Airfield	Sayafe	*Melochia villosissima var. compacta*	
Pagan	Airfield	Unidentifiable Species # 1		
Pagan	Airfield	Unidentifiable Species # 2		
Tinian	Unai Dangkolo	Coconut Palm	*Cocos nucifera*	Dead # 1
Tinian	Unai Dangkolo	Coconut Palm	*Cocos nucifera*	Dead # 2
Tinian	Unai Dangkolo	Coconut Palm	*Cocos nucifera*	Young
Tinian	Unai Dangkolo	Screw Pine	*Pandanus tectorius*	
Tinian	Unai Dangkolo	Velvet Soldierbush	*Tournefortia argentea.*	Juvenile
Tinian	Unai Dangkolo	Velvet Soldierbush	*Tournefortia argentea*	Mature
Tinian	Unai Dangkolo	Velvet Soldierbush	*Tournefortia argentea*	

2.1.7 Man-Made Features/Relic Spectra

There are numerous cultural features that can be identified using HSI. Of particular interest are Japanese fortifications and airfields constructed by people that were conscripted by the Japanese for forced labor during WWII. Units such as the Seventh Army Air Force attacked Japanese positions on Pagan Island during World War II and some of the wreckage remains to this day. Many of the relics on Pagan seem to be Japanese, but a find during November 2005 included the wreckage of an F6-F Grumman Hellcat. The NRL team recorded spectra from various man-made features and WWII relics during MI-HARES'10. These were sampled to support the anomaly detection component of the remote sensing campaign.

Pagan's large eruption in 1981 prompted the evacuation of the island, leaving behind numerous abandoned structures. Man-made features and relics were sampled on Pagan from 2 to 3 March 2010. Five WWII relics were studied and spectra of some of the targets were collected multiple times. Information about each sample is listed in Table 2-6.

Table 2-6. Man-made feature/relic spectra.

Island	Location	Date	Name/Description
Pagan	Airfield	2-March-2010	Yokosuka P1Y Bomber
Pagan	Airfield	2-March-2010	Japanese Bunker
Pagan	Airfield	2-March-2010	Type 88 75mm Anti-Aircraft Gun
Pagan	Airfield	2-March-2010	Mitsubishi A6M Type 0 Fighter
Pagan	Beach 4 hinterland	2-March-2010	Rusted Corrugated Aluminum
Pagan	Airfield	3-March-2010	Yokosuka P1Y Bomber
Pagan	Airfield	3-March-2010	Japanese Bunker
Pagan	Airfield	3-March-2010	Type 88 75mm Anti-Aircraft Gun

2.1.8 Terrain Feature Spectra

Terrain features are substrates such as rocks, craters, Pagan lakes, outcrops, and other natural features. Most of these features do not have corresponding geotechnical measurements. Data collection involved using the normal method of sampling with white reference plaques and then sampling the terrain feature. Throughout the experiment, the dual spectrometer method described earlier (Bachmann et al, in prep) was used to mitigate the impact of the highly variable sky conditions. A key example was the lava rock that runs across the airfield on Pagan. Information about this terrain feature is displayed in Table 2-7. Trusdell (2006) describes the geology of Pagan following the 1981 eruption of Mt. Pagan.

Table 2-7. Terrain feature spectra descriptive information.

Island	Location	Date	Name/Description	Age of Rock
Pagan	Airfield	2-March-2010	Hardened Lava Rock	29 years
Pagan	Airfield	3-March-2010	Hardened Lava Rock	29 years

2.2 Underwater Spectroscopy

In addition to spectra of strand and grassland targets, bottom reflectance measurements were taken by scientific divers affiliated with the American Academy of Underwater Sciences (AAUS). The divers were deployed using small craft and used a Dive Spec® underwater spectrometer in shallow coastal areas, and just outside the surf zone. Underwater spectrometer spectra and other information pertaining to the Dive Spec® are displayed in Appendix F.

In shallow water, bottom reflectance was determined from an underwater spectrometer or DiveSpec (Mazel, 1997). A combination of blue, white, and red light-emitting diodes (LEDs) in the measurement probe head provided broadband illumination from 390 to 800 nm. The light from the LEDs passed through a holographic diffuser and provided even illumination over the measurement area. Readings of the incident light provided by the measurement probe were made by placing a Spectralon® reference surface in contact with the probe head. The probe head has a baffle seal to prevent stray light entering during the reference measurement. Specimen samples were measured in the same manner by placing the probe directly in contact with the specimen surface (e.g. coral head, submerged substrate, WWII materiel, etc.). Radiance measurements from the seafloor were then divided by the radiance measured from the reference plaque to compute reflectance. In ambient mode, the same steps are repeated except that the light source is no longer the internal light of the Divespec but rather the solar illumination in the water column. In the latter case, measurements are taken from a moderate distance from the specimen and the white plaque and the distance is determined by the requirement that the acceptance angle of the probe should only intersect the reference plaque during reference radiance measurements. New reference measurements were made at least every 15 min to guard against slow instrument drifts. A DiveSpec sand stabilizer were used to provide greater probe surface area for measurements of sediments. The underwater spectrometer used during MI-HARES'10 is shown in Figure 2-2.

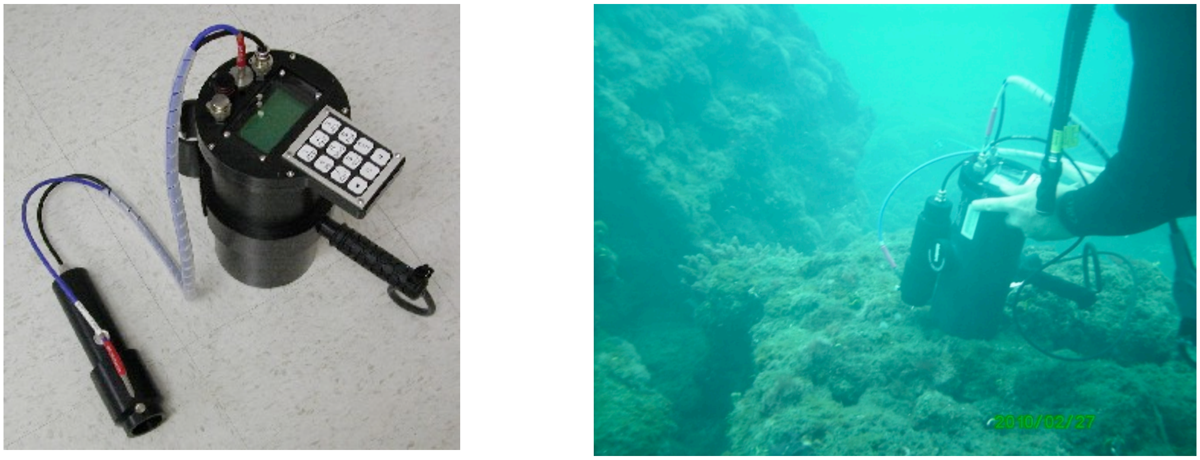

Figure 2-2. The DiveSpec is a fully self-contained, portable underwater spectrometer. The left panel highlights the LCD display, piezoelectric keypad, measurement probe, and handle with wrist lanyard. The right panel shows a scientific diver preparing to operate the instrument on Pagan.

In some locations, the bottom substrate consisted of corals, submerged aquatic vegetation, and sand patches. Resultant DiveSpec® spectral data and attribute information (depth, time, substrate type, etc.) are included in the project database in an Excel spreadsheet. The spectral data are included in their native format that contains single value peaks and noise. Smoothing of this data can be best accomplished via Savitzky and Golay filtering, which performs noise reduction while preserving higher order moments than compared with moving average techniques (Savitzky and Golay, 1964; Ruffin and King, 1999). However, due to the efficiency and ease of use of the moving average technique, the graphs presented in Appendix F are results from a 15-point moving average. The results of the two methods are not that dissimilar, and Figure 2-3 displays a comparison between the two smoothing techniques and the variance between the raw data values. In addition, values at 468.98 nm and 662.44 nm were clipped due to a systematic DiveSpec® error.

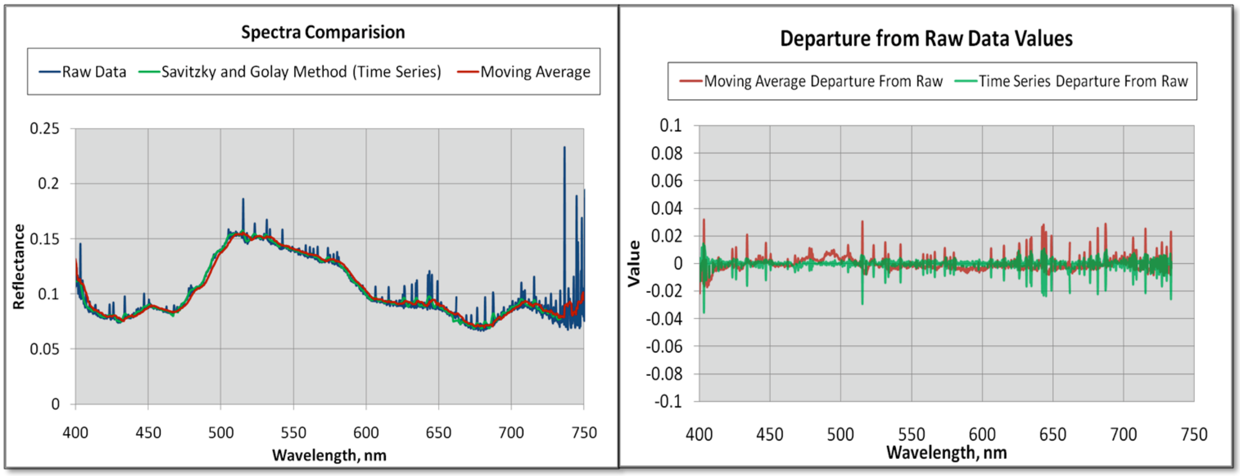

Figure 2-3. Smoothing technique analysis comparison between Savitzky and Golay method and 15-point moving average method.

The DiveSpec® was used along the approaches to selected beaches on Pagan, Tinian, and Guam to measure reflectance relative to a reference surface. In these locations, the bottom was often patchy or inhomogeneous and sloped, which affects upwelling radiances. In some locations, the bottom consisted of corals, submerged aquatic vegetation, and sand patches. Reflectance spectra are provided in Appendix F and owing to instrument noise, the reflectance values below 400 nm and greater than 750 nm were not plotted.

2.3 In-Water Optical Profiles

The boat team collected various types of data to understand optical properties of the water. Apparent optical properties used a spectroradiometer, which was lowered into the water to measure upwelling and down welling irradiance with depth. Inherent optical properties such as absorption, scattering, and beam attenuation were also measured. The key instrument was a Miniature Optical Profiler (MiniOp), which was deployed by hand from a small boat to measure these quantities, as well as the volume scattering phase function, chlorophyll fluorescence and concentration, conductivity, temperature, and depth. This instrument (Figure 2-4) measures in a wavelength range of 350-1000 nm and contains a dual head apparatus, which simultaneously measures upwelling, water radiance and down welling irradiance. MiniOP casts take approximately 15- 30 minutes per position. Casts were taken offshore Pagan on March 1, offshore Tinian on March 5 and 6, and offshore of Guam on March 9 and 10. Data and information from the MiniOP are displayed in Appendix G.

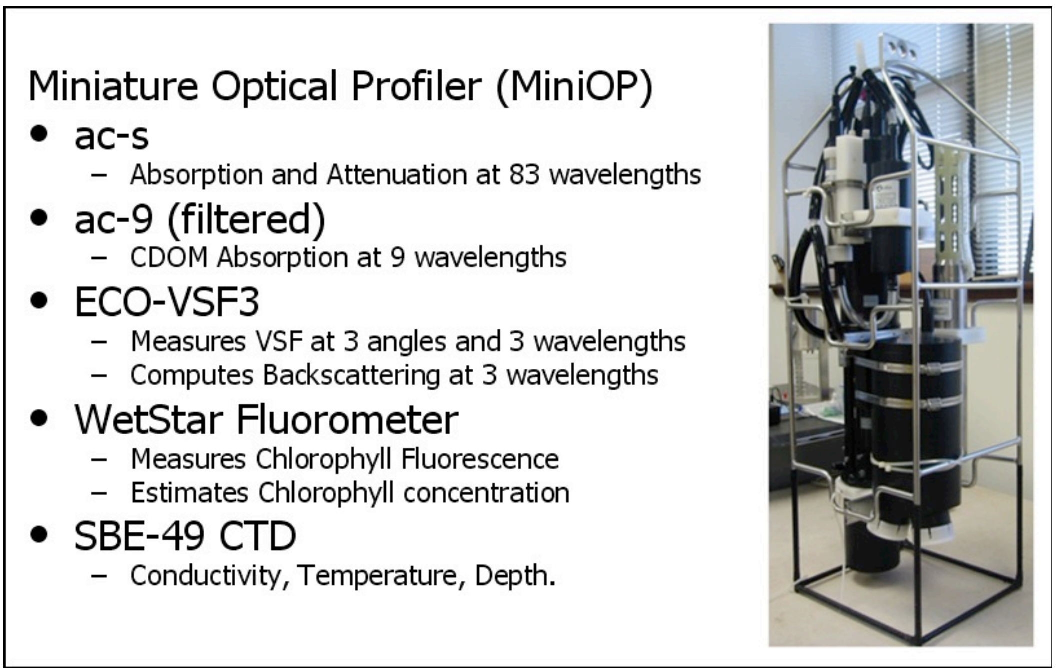

Figure 2-4. The MiniOP was deployed offshore of Guam, Pagan, and Tinian.

2.4 Light Weight Deflectometer (LWD)

The Zorn ZFG2000 Light Drop Weight Tester (Figure 2-5) is one of a class of geotechnical instruments known as a lightweight deflectometer (LWD). The Zorn LWD consists of an accelerometer attached to a steel plate of diameter 300mm, and a mountable rod with 10kg weight that is repeatedly dropped on the accelerometer. Three pulses are measured and stored on an electronic recorder and memory card, recording the deflection of the plate on the ground in response to the dropping of the 10kg weight from a known reference height.

The 10kg weight is dropped three times to achieve a stable estimate of the deflection of the plate as a function of time; these curves are used to estimate the dynamic deflection modulus (Evd), a measure of elastic response, in mega-Newtons per square meter (MN/m^2); the system also records the average deflection in time divided by its average velocity (s/v ratio). The units of this ratio are milliseconds, and the quantity gives an estimate of compression. The Zorn LWD bases the retrieval of E_{vd} on a half-space model (Zorn, 2005). LWD data and graphs are displayed in Appendix H.

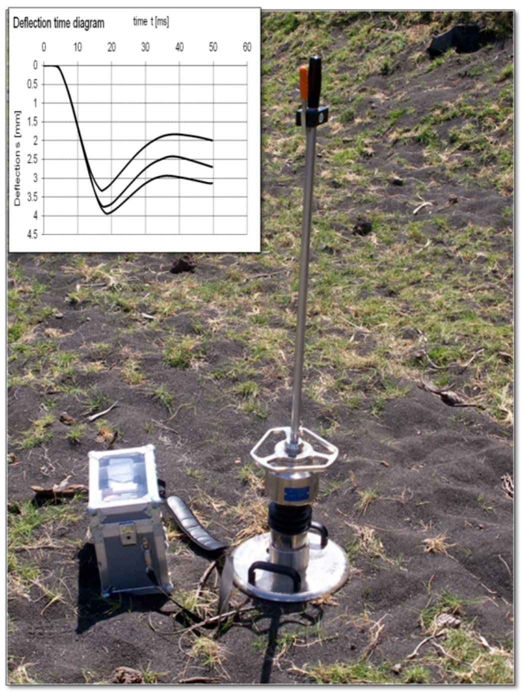

Figure 2-5. The LWD is used to measure dynamic deflection modulus. Light-weight deflectometer (LWD) used to measure dynamic deflection modulus, E_{vd}, which is estimated from three successive drops of a 10kg weight along a steel rod attached to a base plate with an embedded accelerometer. (Insert) The three pulses showing deflection (mm) as a function of time (ms) used in estimating E_{vd}.

2.5 Dynamic Cone Penetrometer (DCP)

A Kessler Dynamic Cone Penetrometer (DCP) was used in accordance with ASTM D 6951-03 in order to measure soil shear strength (ASTM, 2003). A DCP is used to estimate the California Bearing Ratio (CBR) an empirical measurement of shear strength, one of the two failure mechanisms of soil under load. The DCP is the current USMC and USAF standard for measurement of bearing strength for airfields. The dual-mass DCP consists of a 5/8-in.-diameter steel drive rod with a steel cone attached to one end, which is driven into the soil by means of a sliding 10.1 lb. dual-mass hammer. The angle of the cone is 60°, and the diameter of the base of the cone is 0.79 in. Figure 2-6 displays a DCP with its major parts marked. The DCP functions by striking a cone tipped rod with a freefalling weight, thereby driving the cone into the soil. The distance the cone penetrates is measured and the process is repeated until the desired depth is achieved. The recorded data is most commonly plotted as the number of blows divided by the penetration of the cone. DCP estimates of CBR are viewed in Appendix I.

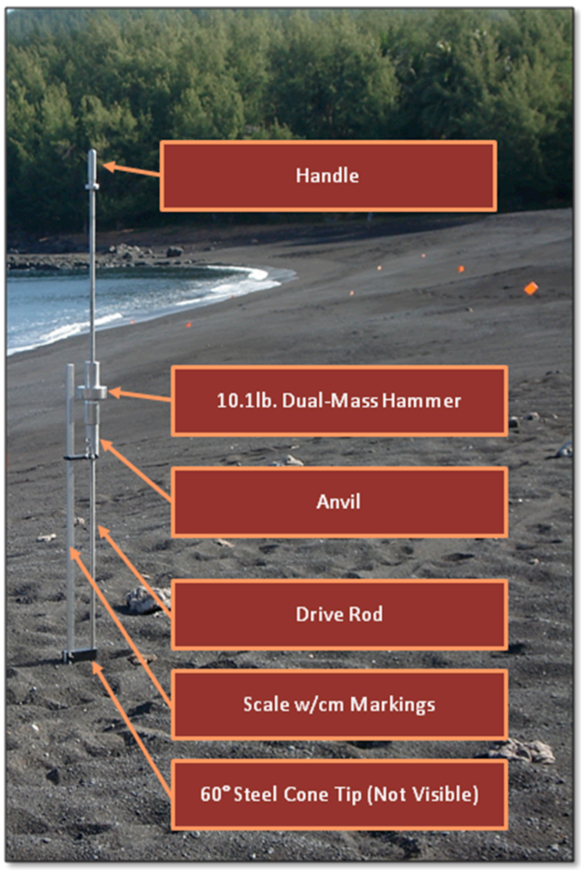

Figure 2-6. Major parts of a DCP. The operator holds the handle while lifting the 10.1 lb. dual mass hammer to the top of the handle. The hammer falls from a level of 22.6 in and strikes the anvil, thus driving the drive rod into the substrate. A second person reads the position on the vertical scale for each hammer drop.

2.6 Soil Analysis

Determining beach composition was an essential MI-HARES'10 task involving the collection of "grab samples" across the beach. A grab sampler (Figure 2-7) was used to extract a standard core from each sample position to obtain a representative sample of the first 7cm of the substrate (the approximate dimensions of the grab sampler: was 7cm diameter with a height of 7.6cm).

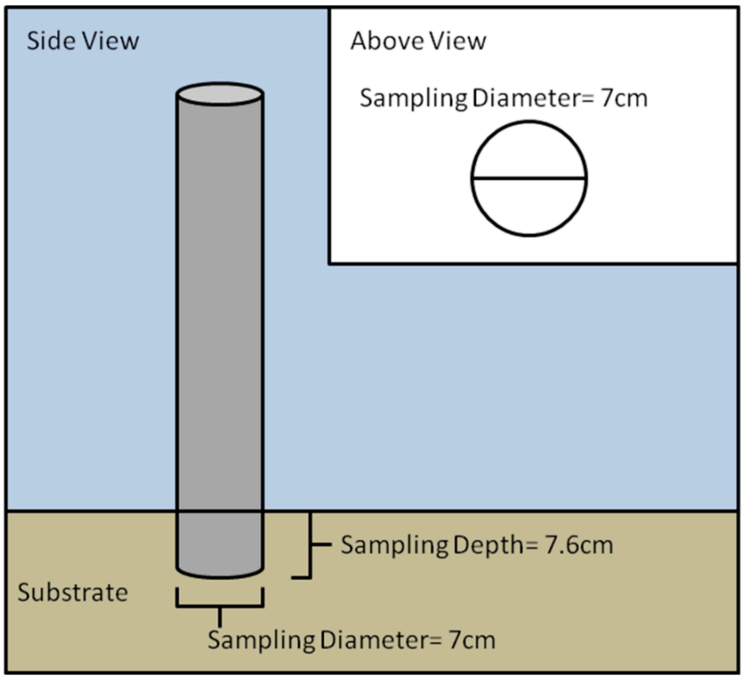

Figure 2-7. Grab sampler specifications.

After use of the sampler, beach substrate samples were placed as quickly as possible into zip-loc bags and put into a cooler to prevent loss of moisture due to evaporation. With the samples, two of four standard soil tests were accomplished; (1) moisture content determinations and (2) grading or sieve analysis. Samples were then taken to the lab and analyzed. Soil attribute data and graphs are displayed in Appendix J. Figure 2-8 displays a schematic of the process of determining soil moisture and grain size.

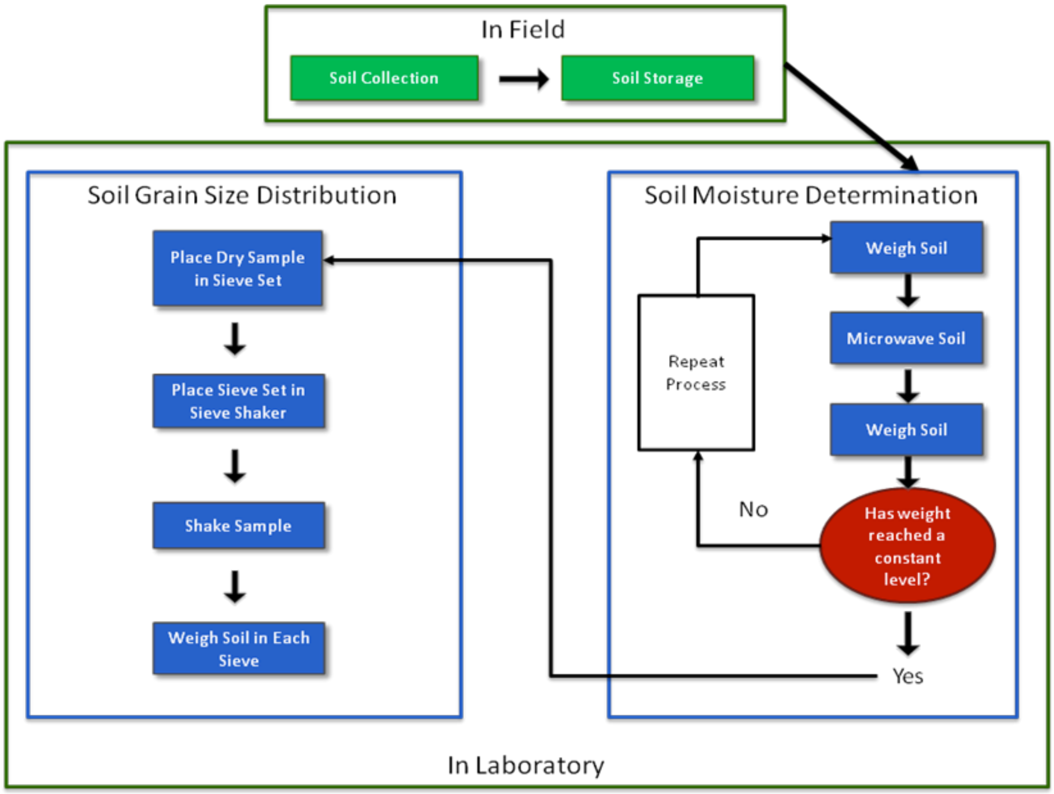

Figure 2-8. Soil processing schematic. Samples are collected in the field and then soil moisture and grain size are determined in a laboratory environment.

2.6.1 Soil Moisture Content

The soil moisture is determined by a similar protocol found in the Army Field Manual for materials testing (FM 5-472, NAVFAC MO 330,AFJMAN 32-1221(I)) which follows the microwave oven method for determining soil moisture content (ASTM D 4643-08). Soil moisture was determined by weighing a portion of the soil sample while wet and again after drying using a microwave oven. The soil's moisture content (in percent) is calculated as the ratio of the mass of the water contained in the soil to the mass of the dry soil and multiplied by 100 (Black, 1965; Schmugge, Jackson, McKim, 1980; Famiiglietti, 1998), and second measure (wet-dry/ wet) is also computed since this is the quantity observe in remote sensing. In general, if soil is placed in an oven and dried at 105°C, it is at the reference state used for expressing most soil characteristics. If the wet weight of the sample was used as the divisor, then percent moisture will change with the initial weight of the soil sample. Thus, if soluble phosphorus (in percent of the total soil) was expressed on a wet weight basis, the actual amount of phosphorus in the soil would depend on the amount of moisture in the soil; however, the caveat about what remote sensing observes is still true, which is, as just noted, the wet state. On the other hand, it should be noted that geotechnical scientists normally use the dry weight as the divisor because of issues such as were described above relating to the amount of phosphorus and its dependence on the amount of moisture present.. Figure 2-9 displays the instruments involved in determining the soil moisture of a sample.

Figure 2-9. Soil moisture determination procedure. (A) Sample is emptied from zip-loc bag onto pre-weighed microwave safe weighing dish. (B) Sample is dried in microwave for 1-minute increments until weight is constant. (C) Scale used in weighing samples.

2.6.2 Soil Grain Size

Grain-size analysis, which is among the oldest of soil tests, is used in soils classification and as part of the specifications of soil for airfields, roads, earth dams, and other soil-embankment construction. The standard grain-size analysis test (ASTM D 422-6) determines the relative proportions of different grain sizes as they are distributed among certain size ranges that are referred to as particle-size or grain-size distribution (ASTM, 1998). In order to grade the sample properly, the sieving operation used a Humboldt H4325 mechanical sieve shaker to obtain lateral, vertical, and jarring actions, which keep the sample moving continuously over the surface of the sieve. After sufficient shaking, the mass of each sieve size is determined on a scale or balance. Then, the total percentage of material passing each sieve is calculated. A photograph of the shaker and a soil sample separated into grain size distributions is displayed in Figure 2-10.

Figure 2-10. Grain size analysis was performed after drying and soil moisture calculations. (A) Soil shaker with sieves in operation. (B, C) After separation into grain size fractions, contents were weighed, and the amount for each grain size bin recorded for later correlation with spectral data and other geotechnical data. The sieve sizes are listed in each green box.

2.7 Global Positioning System (GPS) Surveying

In order to develop a relationship between attribute data at a site and HSI, each site's location was marked using a Global Positioning System (GPS) unit. Global positing data and ground control points are explained in greater detail in Appendix K.

2.7.1 Trimble ® Pathfinder® Pro-XH™ unit

Each data collection site was marked with a Trimble® Pathfinder® Pro-XH™ post-processing GPS unit (Trimble, 2007). This unit was used to mark positions in the sub foot realm, i.e., after post-processing. Post-processing GPS data involved correcting coordinates with the National Geodetic Survey's (NGS) Continuously Operating Reference Stations (CORS) in order to refine the accuracy of the field collected data (NGS (a), 2010).

Two GPS units of this type were used during the experiment. One unit was primarily used for bathymetric surveying while the other unit supported land-based operations. The team dedicated to hydrographic surveying used the GPS to mark the position of soundings, IOP casts, and underwater hazards. The land-based PRO-XH unit was used to mark the position of geotechnical sites and ground control points. Due to the absence of a geotagging camera, the land-based unit was also used to take positions of photographic observations made on the ground. Information related to geo-tagged photographs is explained in Section 2.11.

2.7.1.1 Bathymetric Soundings

A Trimble ® Pathfinder® Pro-XH™ unit was used to collect the position of bathymetric survey soundings on Guam, Pagan, and Tinian during MI-HARES'10. Soundings were made with a hand-held fathometer to mark depth in feet, and these depths were coupled with a GPS position and time of observation. The time of the fathometer reading was compared with water level data from a GPS unit (Ashtech GPS Charlie unit) mounted onboard a water level gauge. A water level corrected depth was created from the water level gauge data to mitigate the effects of tidal fluctuations. However, due to an error in the collection of water level data on 27 February, 2010, fathometer soundings could not be processed to remove effects of the tide. Information about the bathymetric soundings is found in Table 2-8.

Table 2-8. Bathymetric sounding information.

Island	Location	Date	Number Of Soundings	Comments
Guam	Tipalao Bay and Agat Bay	10-Mar-2010	909	
Pagan	Beach 4 Bay (Apaan Bay)	27-Feb-2010	87	Charlie Kinematic GPS water level gauge malfunction. Corrected depths not available
Pagan	Beach 1 Offshore (Apaan Bay)	1-Mar-2010	169	
Pagan	Beach 2 and Beach 4 Bays	1-Mar-2010	319	
Tinian	Unai Babui Offshore	5-Mar-2010	105	
Tinian	Unai Lamlam Offshore	6-Mar-2010	174	

Beach 4 on Pagan acted as the landing beach and staging area for the research team. Underwater obstacles such as coral heads, anchors, and rocks that were close to the surface posed a hazard as the scientists' Rubber Inflatable Boats (RIB) came ashore. These hazards were marked with a GPS.

2.7.1.2 Spectra collection and site marking

Sites where spectra were collected were marked with the Trimble ® Pathfinder® Pro-XH™ unit in order to develop products from HSI. The number and type of sites are described in this report in Section 2.1. Imagery derived maps that use these spectra are displayed in Appendix E as well as photographs for each site where spectra were obtained.

2.7.1.3 Ground control points

Ground control was collected at a number of locations where landmarks useful for orthorectification were found. For MI-HARES'10, airborne hyperspectral imagery was controlled using paneled control points, permanent monuments, and key terrain and remnant man-made features. Most of the Ground Control Points (GCPs) were large enough to be observed in aerial imagery. These surveyed points were used to accurately tie a remotely sensed image of the study area to its true location on the Earth's surface. This project's GCPs were collected from Global Positioning System (GPS) in the field, especially since at locations such as Pagan they could not be measured from any existing maps. This effort supports other projects that will rely on tie points, i.e., image measurements that connect the same locations in different, but overlapping images. Tie points are features (e.g., several pixels that can be clearly identified) in one image that when identified in another image may be joined together. During the orthorectification process, the real world coordinates of all other points in the imagery are calculated based on the locations of the control points.

Very few GCPs were collected over water, so the image-to-image tie point method of co-registration was important for underwater and offshore features. The GCPs were collected on peninsulas, headlands and other types of key terrain whenever possible to allow for the best spatial solution during the georegistration process. They were also collected near concrete pads, surrounding vegetative areas, around craters, around structures, at street intersections, at corners of buildings, surrounding knolls, and on geodetic control monuments, which could be associated with single pixels in digital scans. Detailed information on the GCPs is provided in Appendix K.

2.7.2 Ashtech® Z-Xtreme™

Three Ashtech® Z-Xtreme™ dual frequency Real-Time-Kinematic GPS receivers were used to obtain high-accuracy coordinates of the research areas (Thales Navigation, 2003). One unit (Alpha) was used as a base station, a second unit (Bravo) was used for beach surveying, and a third (Charlie) unit was used as part of a water level buoy (Figure 2-11).

Figure 2-11. Ashtech® Z-Xtreme RTK GPS units used for surveying. (Left) “Alpha” unit used as static base station. (Middle) “Bravo” unit used for kinematic beach surveys. (Right) “Charlie” unit used as water level gauge.

2.7.2.1 Alpha unit

One Ashtech® Z-Xtreme™ GPS unit was used to collect highly accurate base station data which was later used to post-process the data collected from the other two units. This base station unit was placed on the airfield on Pagan, on one of the WWII era airfields on Tinian, and on a NGS geodetic marker on Guam. Further details and maps detailing the position of each base station is explained in Appendix K.

2.7.2.2 Bravo unit

One Ashtech® Z-Xtreme™ GPS unit was used to collect highly accurate kinematic GPS data for beach profiles in all stages of the experiment. Beach profiling involved walking from beach headlands to approximately 1m in depth and doing this until the entire length of the beach was covered. The beach profiling kinematic unit contained a wheel that was used for easy navigation of beach terrain. Maps and details regarding GPS data are explained in Appendix K.

2.7.2.3 Charlie unit

Another Ashtech® Z-Xtreme™ GPS was used to measure highly accurate water level height fluctuations in reference to the ellipsoid (WGS 1984). This unit was attached to a PVC frame buoy and was deployed offshore of all three islands during the experiment. Maps and details are explained in the water level appendix (Appendix L).

2.8 Water level data

Water level data was also collected from sources such as the NOAA tides and currents website, NOAA’s National Data Buoy Center, and SCRIPPS Institute of Oceanography’s Costal Data Information Program (CDIP) (NOAA, a; NOAA, b; NDBC, 2010; CDIP,2010). Neither predicted nor observed tide data are presently available in the Pagan area since water level studies have not been conducted. Therefore, the NRL team deployed a highly accurate Ashtech® Z-Xtreme™ GPS water level buoy. This GPS was also deployed at locations offshore of Tinian and Guam. More information regarding the data, as well as figures and maps can be viewed in Appendix L.

2.9 Sun Photometer

A CIMEL® CE-150™ Sun Photometer (Figure 2-12) was positioned on Pagan (18°7'32" N, 145°45'26"E, 10m altitude) from 26 February until 3 March, on Tinian (15°04'29"N, 145°38'4"E, 18m altitude) on 7 March, and on Guam (13° 25' 48" N, 144° 38' 40" E, Altitude 10m) from 9 March until 11 March. No useable data was collected from the Pagan phase of the experiment due to instrument malfunction. Tinian (NASA, (a) 2010) and Guam (NASA, (b) 2010) data have been incorporated into the National Aeronautics and Space Administration's (NASA) Aerosol Robotic Network (AERONET) website and can also be viewed in Appendix M. The CIMEL® CE-150™ Sun Photometer's main purpose is to measure sun and sky radiance in order to derive total column water vapor, ozone and aerosol properties using a combination of spectral filters and azimuth/zenith viewing controlled by a microprocessor (CIMEL, (a) 2010). Information on the setup of the instrument is detailed in Appendix M. Additional setup information can be accessed via pictorial descriptions on NASA's AERONET (NASA, (c) 2010) or CIMEL®'s website (CIMEL, (b) 2010).

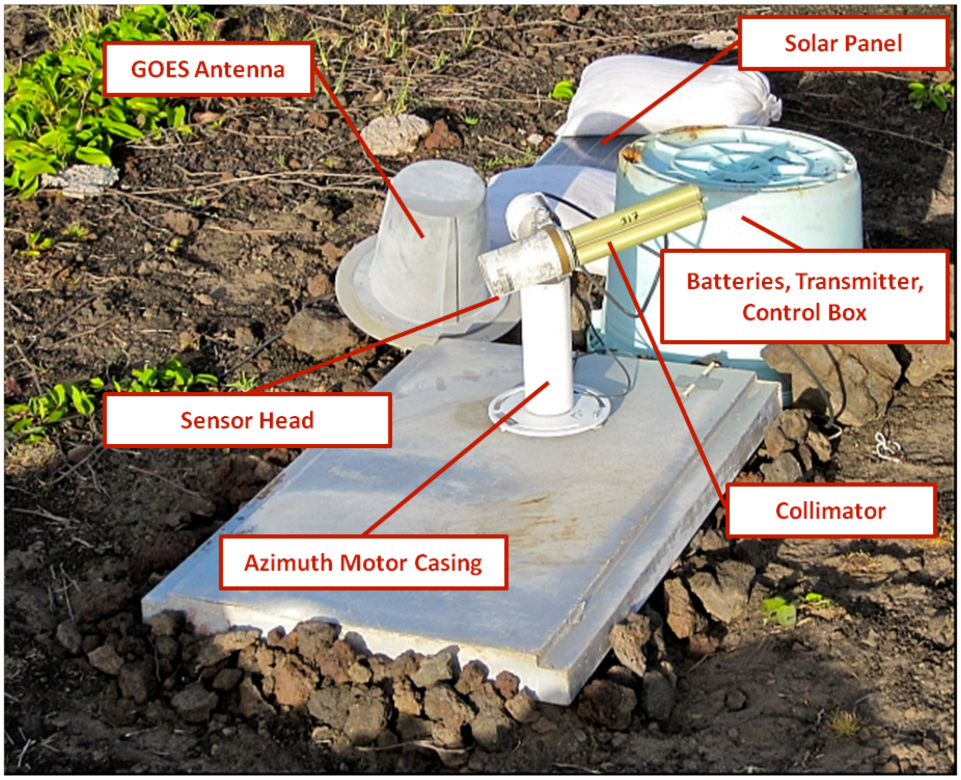

Figure 2-12. CIMEL® CE-150™ Sun Photometer. This automatic sun tracking photometer is also used by NASA's AERONET (AErosol RObotic NETwork) project, an international network composed of more than a hundred sun photometers positioned throughout the world.

2.10 Weather Record

Meteorological conditions are important to describe, especially since weather can affect field and aerial image data capture. Cloud cover and precipitation had a major impact on spectroscopy. When conditions were unfavorable, research was either conducted using a dual spectrometer mode (Bachmann et al, in prep) or halted. Other important meteorological measurements included solar radiation, temperature, relative humidity, and wind speed/direction. Weather records for the study locations can be viewed in Appendix N. The weather data were collected from the National Weather Service Forecast Office's website (NWS, 2010) and include records from stations located at the Coast Guard station in Saipan and at Guam International Airport. Records for Pagan are not available as the meteorological station located there (WMO #91222) is inoperable.

2.11 Geotagged Photographs and General Background Photographs

Geotagged photographs are photographs that have a global positioning system tag on the image, meaning when the image was taken, geocoordinates for the image are recorded. These photographs provide a capture of what the conditions were at the time the photograph was taken. Efforts were made to capture images of the beach from the perspective of what the amphibious assault personnel would see (images were taken perpendicular to the beach facing onshore). Unai Dangkolo and Unai Lamlam on Tinian as well as both beaches on Guam had geotagged photographs taken. Maps and images concerning geotagged photographs are viewed in Appendix O.

Photographs were taken during all phases of this experiment including time spent on Saipan. There were two cameras dedicated to documenting land-oriented field work (NRL-1 and NRL-2), one underwater camera dedicated to documenting DiveSpec operations, and many personal cameras which documented field work and background images. The amount of memory space used for digital photographs is approximately 10 GB. Photographs of sites where spectra were taken can be viewed in Appendix E and general background photographs including panoramic views of the study areas are provided in Appendix O.

3 Acknowledgments

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Mr. Donn Murakami, Science Advisor to Marine Corps Forces Pacific, helped develop the science plan. He highlighted specific military planning needs that could be met through the use of hyperspectral imagery.

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Ms. Krista Lee, LT Cecelia McConnon, and LTJG Jon Wende from the Naval Post Graduate School were instrumental in completing beach surveys, leaf optics, and processing soil samples.

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Captain Patrick Ulechong and Mr. Jason Reyes from Cabras Marine Corporation provided valuable assistance aboard various vessels in heavy seas to deploy in-water optical profilers and underwater spectrometers, and in taking underwater photographs.

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4 References

American Society for Testing and Materials (ASTM) (1998). ASTM D 422-63-Standard Test Method for Particle-Size Analysis of Soils. Retrieved from http://www.astm.org/Standards/D422.htm .

American Society for Testing and Materials (ASTM) (2008). ASTM D 4643-08-Standard Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method. Retrieved from http://www.astm.org/Standards/D4643.htm .

American Society for Testing and Materials (ASTM) (2003). Standard 6951-03-Standard Test Method 09 Standard Test Method for Use of the Dynamic Cone Penetrometer in Shallow Pavement Applications. ASTM International, West Conshohocken, PA, www.astm.org.

Bachmann, C. M., M. J. Montes, R. A. Fusina, C. Parrish, J. Sellars, A. Weidemann, W. Goode, V. Hill, R. Zimmerman, C. R. Nichols, P. Woodward, K. McIlhany, D. Korwan, M. Crawford, J. Monty, B. Truitt, A. Schwarzschild, (2008). Very Shallow Water Bathymetry Retrieval from Hyperspectral Imagery at the Virginia Coast Reserve (VCR'07) Multi-Sensor Campaign," Proc. IGARSS'08.

Bachmann, C.M., M.J. Montes, R.A. Fusina, C. Parrish, J. Sellars, A. Weidemann, W. Goode, C.R. Nichols, P. Woodward, K. McIlhany, V. Hill, R. Zimmerman, D. Korwan, B. Truitt, and A. Schwarzschild, Bathymetry Retrieval from Hyperspectral Imagery in the Very Shallow Water Limit: A Case Study from the 2007 Virginia Coast Reserve (VCR'07) Multi-Sensor Campaign, 2010, *Marine Geodesy*, Volume 33, Issue 1, pages 53 – 75.

Bachmann, Charles M., C. Reid Nichols, Donn Murakami, and Timothy Robert, 2010. Commonwealth of the Northern Mariana Islands Remote Sensing and Field Calibration and Validation Campaign 2010 (CNMI'10): Science Plan, Washington, D.C.: Naval Research Laboratory (unpublished).

Bachmann, Charles M.; C. Reid Nichols; Marcos J. Montes; Rong-Rong Li; Patrick Woodward; Robert A. Fusina; Wei Chen; Vimal Mishra; Wonkook Kim; James Monty; Kevin Mcilhany; Ken Kessler; Daniel Korwan; W. David Miller; Ellen Bennert; Geoff Smith; David Gillis; Jon Sellars; Christopher Parrish; Arthur Schwarzschild; Barry Truitt, 2010, Retrieval of Substrate Bearing Strength from Hyperspectral Imagery During the Virginia Coast Reserve (VCR'07) Multi-Sensor Campaign. *Marine Geodesy*. Volume 33, Issue 2-3, pp. 101-116.

Bachmann, C. M, C. R. Nichols, M. J. Montes, R. A. Fusina, R-R. Li, C.Gross, J.C. Fry, C. Parrish, J.Sellars, S.A. White, C.A. Jones, and K. Lee, Coastal Characterization from Hyperspectral Imagery: An Intercomparison of Retrieval Properties From Three Coast Types. In **Proceedings of the IEEE International Geoscience & Remote Sensing Symposium**, Honolulu, Hawaii, July 25-30, 2010.

Bachmann, C. M., M. J. Montes, R, A. Fusina, R.-R. Li, C. A. Jones, K. Lee, C. McConnon, J. Wende, C. R, Nichols, J. C. Fry, E. Hallenborg, C. Parrish, J. Sellars, S. A. White, C. Gross, W. David Miller, D. Gray, D. Korwan (in prep). "A Practical Dual-Spectrometer Approach to Measuring *In Situ* Spectral Reflectance in Adverse Sky Conditions," to be submitted to Optics Express.

Black, C.A. (1965). Methods of Soil Analysis: Part I Physical and Mineralogical Properties. *American Society of Agronomy*. Madison, Wisconsin, USA.

CIMEL, (a), (2010, April 2). Automatic Sun Tracking Photometer CE 318. Retrieved from http://www.cimel.fr/photo/pdf/ce318_us.pdf.

CIMEL, (b), (2010, April 5). User Manual- Sun Photometer. Retrieved from http://www.cimel.fr/photo/pdf/man_ce318_us.pdf.

Coastal Data Information Program (CDIP), SCRIPPS Institute of Oceanography, (2010, April 7). CDIP recent observed 121 info. Retrieved from CDIP website: http://cdip.ucsd.edu/?stn=121&stream=p1&nav=recent&sub=observed&xitem=info.

Corwin, G., Bonham, L.D., Therman, M.J. and Viele, G.W. (1957). Military geology of Pagan, Mariana Islands. Intelligence Division, Office of the Engineer Headquarters U.S. Army and U.S. Geological Survey.

Department of the Army (2001). Army Field Manual 5-472 NAVFAC MO 330 AFJMAN 32-1221(l)-Materials Testing. Retrieved April 27, 2010 from https://rdl.train.army.mil/soldierPortal/atia/adlsc/view/public/6723-1/fm/5-472/toc.htm.

Famiglietti, J.S., Rudnicki, J.W., Rodell, M. (1998). Variability in surface moisture content along a hill slope transect: Rattlesnake Hill, Texas. *J Hydrol*, 210(1-4), 259-281. DOI:10.1016/S0022-1694(98)00187-5.

FAO-UNESCO. 1974. *FAO-UNESCO Soil map of the world 1:5,000,000*. Paris: UNESCO.

Fry, J.C., C.R. Nichols, R. Fusina, C. M. Bachmann, and M. Duncan, Toward Development of a Hierarchical Coastal Classification System-An Example from the Mariana Islands, **Poster presentation at the Optical Remote Sensing of the Environment Conference**, Optical Society of America, Tucson, Arizona, June 7-8, 2010.

Fusina, R.A, J.C. Fry, C R. Nichols, C.M. Bachmann, R-R. Li, J.Sellars, C.Parrish, M.J.Montes, C. Gross, S. A. White, K. Lee, and C. A. Jones, Geodatabase Development to Support Hyperspectral Imagery Exploitation. In **Proceedings of the IEEE International Geoscience & Remote Sensing Symposium**, Honolulu, Hawaii, July 25-30, 2010.

Hallenborg, Eric and C. Reid Nichols, (2009). TACSAT-3/ARTEMIS JOINT MILITARY UTILITY ASSESSMENT: Department of the Navy Hyperspectral Technology Demonstration in Talisman Saber 09, EXERCISE TALISMAN SABER 2009, San Diego, Ca: Space and Naval Warfare Systems Command-Pacific, 22 pp. plus Appendices.

ISRIC (International Soil Reference and Information Center) (23 July, 2010). Soil and terrain database (SOTER). Wageningen, Netherlands: ISRIC. Retrieved from http://www.isric.org/isric/webdocs/Docs/soterfolder001.pdf.

Kelly, M., Hooper, J., Paul, V., Paulay, G., Van Soest, R. and De Weerdt, W., (2003). *Micronesica* 35-36:100-120.

Mazel, C. H., (1997). Diver-operated instrument for in situ measurement of spectral fluorescence and reflectance of benthic marine organisms and substrates. *Opt Eng,* 36: 2612–2617. DOI: 10.1117/12.273323.

Nichols, C.R. and Williams, R.G., (2009). *Encyclopedia of Marine Science*, New York: Facts On File.

NASA (a), Goddard Space Flight Center (2010, April 2). AERONET- Data Display Site:Tinian. Retrieved from http://aeronet.gsfc.nasa.gov/cgi-bin/type_one_station_opera_v2_new?site=Tinian&nachal=2&level=1&place_code=10.

NASA (b), Goddard Space Flight Center (2010, April 2). AERONET- Data Display Site:Apra_Harbor. Retrieved from http://aeronet.gsfc.nasa.gov/cgi-bin/type_one_station_opera_v2_new?site=Apra_Harbor&nachal=2&level=1&place_code=10.

NASA (c), Goddard Space Flight Center (2010, April 5). CIMEL Sunphotometer Set-up Manual. Retrieved from http://aeronet.gsfc.nasa.gov/Operational/pictures/set_up_frame.html.

NGS (a) (2010, March 16). National CORS. Retrieved from http://www.ngs.noaa.gov/CORS/cors-data.html.

NGS (b) (2010, March 23). OPUS: Online Positioning User Service. Retrieved from http://www.ngs.noaa.gov/OPUS/.

National Data Buoy Center (NDBC), National Oceanic Atmospheric Administration,(2010, April 7). NDBC Station 52200- Ipan, Guam. Retrieved from http://www.ndbc.noaa.gov/station_page.php?station=52200.

National Weather Service (NWS), National Oceanic and Atmospheric Administration, (2010, April 5). National Weather Service Forecast Office- Tiyan, Guam. Retrieved from, http://www.weather.gov/climate/index.php?wfo=guam.

NOAA (a) (2010, April 6). NOAA/CO-OPS ODIN. Retrieved from http://tidesandcurrents.noaa.gov/gmap3/.

NOAA (b) (2010, April 6). Data Retrieval-Station Information, Apra Harbor, Guam, Mariana Islands. Retrieved from http://tidesandcurrents.noaa.gov/station_info.shtml?stn=1630000%20Apra%20Harbor,%20Guam,%20MARIANAS%20ISLANDS.

Ruffin, C. and King, R.L., (1999). The Analysis of Hyperspectral Data Using Savitzky-Golay Filtering-Theoretical Basis, Geoscience and Remote Sensing Symposium, 1999. IGARSS '99 Proceedings. IEEE 1999 International. DOI: 10.1109/IGARSS.1999.774430. Retrieved from http://www.ece.msstate.edu/~rking/downloads/savitzky%20golay%201.pdf.

Savitzky, A. and Golay, M.J.E., (1964). Smoothing and Differentiation of Data by Simplified Least Squares Procedures, *Anal Chem,* 36 (8): 1627–1639**.** DOI: 10.1021/ac60214a047.

Schmugge, T.J., Jackson, T.J., and McKim, H.L.(1980). Survey of methods for soil moisture determination. *Water Resour Res,*16(6), 961-979.

Smithsonian National Museum of Natural History (2009, 17 December). Global Volcanism Program-Pagan. Retrieved from http://www.volcano.si.edu/world/volcano.cfm?vnum=0804-17= .

Thales Navigation (2003). Z-Xtreme Survey System-Instant RTK Technology. Retrieved from http://www.rvdi.com/cors/ZXtremeDSen.pdf.

Trimble (2007, August 17). Fully integrated Bluetooth GPS receiver with H-Star technology for sub foot accuracy. Retrieved from http://www.trimble.com/pathfinderproxh.shtml.

Trusdell, F.A., Moore, R.B. and Sako, M.K., (2006). Preliminary Geologic Map of Mount Pagan Volcano, Pagan Island, Commonwealth of the Northern Mariana Islands. USGS Open-File Report 2006-1386. Retrieved from http://pubs.usgs.gov/of/2006/1386/.

United States Naval Observatory (USNO) (2010, June 9). *Sun or Moon Altitude/Azimuth Table*. Retrieved from http://www.usno.navy.mil/USNO/astronomical-applications/data-services/alt-az-us.

Vogt, S. R. and Williams, L.L. (2004). *Common Flora and Fauna of the Mariana Islands*, Saipan, Northern Marianas: WinGuide Saipan, 158 pp.

Zorn (2005). *Operating Manual, Light Drop Weight Tester ZFG 2000*, Stendal, Germany: Gerhard Zorn Mechanische Werkstatten.

APPENDIX A

Web Resources

1 Introduction

There is considerable information relevant to MI-HARES'10 and the exploitation of hyperspectral imagery (HSI) stored on the World Wide Web. Therefore, the following list of Uniform Resource Locators (URLs) is provided since they complement this data report.

2 Web Resources

Aerosol Optical Depth, Earth Observatory, NASA (2009, December 17). Retrieved from http://neo.sci.gsfc.nasa.gov/Search.html?datasetId=MODAL2_M_AER_OD .

Global scale maps show average monthly aerosol amounts around the world based on observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite. Satellite measurements of aerosols, called *aerosol optical thickness*, are based on the fact that the particles change the way the atmosphere reflects and absorbs visible and infrared light. An optical thickness of less than 0.1 (palest yellow) indicates a crystal clear sky with maximum visibility, whereas a value of 1 (reddish brown) indicates very hazy conditions. Knowing the atmospheric condition, e.g., atmospheric aerosol information such as optical depth, is critical for processing imagery.

The CNMI Guide, (2010, May 26). Retrieved from http://www.cnmi-guide.com/.

Basic information regarding the Commonwealth of the Northern Mariana Islands is provided by the above URL. The website provides historical facts, maps, and links to other websites.

Coastal Data Information Program (CDIP), SCRIPPS Institute of Oceanography (2010, April 7). Retrieved from http://cdip.ucsd.edu/?stn=121&stream=p1&nav=recent&sub=observed&xitem=info.

The SCRIPPS Institute of Oceanography's Coastal Data Information Program website provides information on a wave buoy located on the east coast of Guam that records wave and meteorological data. Knowing environmental information such as waves can help in mitigating glint and shadowing.

Commonwealth Ports Authority (2010, May 26). Retrieved from http://www.cpa.gov.mp/default.asp.

The Commonwealth Ports Authority is charged with managing all airports and seaports in the Commonwealth of the Northern Mariana Islands (CNMI). Major airports include Saipan International Airport (SPN-Francisco C. Ada Aiport), Tinian International Airport (TIQ-West Tinian Aiport), and Rota International Airport (ROP). Saipan International accommodates wide-body aircraft travelling direct from Japan, Korea, Hong Kong, Manila, China and Guam. The airport also supports small aircraft travelling throughout the CNMI. The airports on Tinian and Rota serve inter-island travelers between the CNMI and Guam. An airstrip had been operational on Pagan (FAA=TT01) until the early 1980's when an eruption ceased function of the airstrip.

Major sea ports in the CNMI include ports on Saipan, Tinian, and Rota. The Port of Saipan acts as the main importing port accommodating medium and deep draft vessels, and having three freight forwarding and three shipping agencies.

MI-HARES'10 conducted flight operations out of Tinian International and boat operations out of the Port of Saipan.

Global Volcanism Program, Smithsonian Museum of Natural History(2009, December 17). Retrieved from http://www.volcano.si.edu/world/volcano.cfm?vnum=0804-17=.

The Smithsonian Museum of Natural History heads the Global Volcanism Program and this program maintains record of activity on Pagan Island. Volcanoes can drastically change the landscape of a coastal environment and having a record of when volcanic activity occurred can better explain the conditions of the island. Aerosols (tiny particles suspended in the air) originate naturally from active volcanoes. Clouds with high aerosol concentration reflect up to 90% of visible radiation back to space.

Museum of Underwater Archaeology (2010, May 26). Underwater Archaeology Invasion Beaches Survey Saipan, CNMI 2008. Retrieved from http://www.uri.edu/artsci/his/mua/project_journals/saipan/saipan_intro.shtml.

The Southeastern Archaeological Research, Inc. (SEARCH) with funding support from the Commonwealth of the Northern Mariana Islands Historic Preservation Office in Partnership with the National Park service, Department of the Interior conducted an underwater survey of Tanapag and Garapan lagoon in Saipan in 2008. Side scan sonar, GPS, and photographs were used to identify WWII and post-WWII sunken objects. MIRSC'10 surveyed landing beaches on Tinian.

National Aeronautics and Space Administration, Goddard Space Flight Center (2010, April 7). Aerosol Robotic Network (AERONET). Retrieved from http://aeronet.gsfc.nasa.gov/new_web/data.html.

Measurement of aerosol optical depth (AOD) is needed for post-processing of HSI and subsequent derived products. Measurements of AOD are gathered by a sun photometer, an instrument which measures direct, collimated, solar radiation. Once the value of radiation is collected, columnar water vapor can be calculated and aerosol size can be estimated. The above URL links to NASA's Aerosol Robotic Network (AERONET). A CIMEL sun photometer has been used to measure AOD over the Mariana Islands.

Sun photometer measurements of the direct (collimated) solar radiation provide information to calculate the columnar aerosol optical depth (AOD). AOD can be used to compute columnar water vapor (Precipitable Water) and estimate the aerosol size using the Angstrom parameter relationship. Two data versions (Versions 1 and 2) and three quality levels (Levels 1.0, 1.5, 2.0) exist for each product. While Levels 1.0 and 1.5 are provided in near real-time, the 12-month or longer delay (due to final calibration and manual inspection) ensures that the highest quality data can be found in Version 2, Level 2.0 data products. Version 2 AOD processing now includes fine and coarse mode AOD as well as fine mode fraction.

National Oceanic and Atmospheric Administration (NOAA)-Coral Reef Information System (2010, May 26). Retrieved from http://coris.noaa.gov/.

The Coral Reef Information System (CoRIS) is designed to be a single point of access to NOAA coral reef information and data products, especially those derived from NOAA's Coral Reef Conservation Program. Pertaining to the CNMI and Guam, maps, real-time data, and reports are available. The website contains a thorough report on reef systems and contains various types of attribute data (bathymetry, SST, typhoons, etc.) affecting reef systems.

National Oceanic and Atmospheric Administration (NOAA)-Center for Coastal Monitoring and Assessment (CCMA) (2009, December 17). Benthic Habitat Mapping of American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands. Retrieved from http://ccma.nos.noaa.gov/ecosystems/coralreef/us_pac_mapping.html.

The CCMA group of NOAA works to consistently and comprehensively map the distribution of coral reefs and other benthic habitats throughout Guam, American Samoa, and the CNMI. This group develops map, imagery, and GIS products that document benthic environments in the discussed regions. These products could be helpful in the calibration/validation (cal/val) of MI-HARES'10 developed products. In addition, by using hyperspectral imagery, features in shallow water like coral reefs can be differentiated from neighboring features.

National Oceanic and Atmospheric Administration (NOAA)-National Data Buoy Center (2010, April 7). National Data Buoy Center- Homepage. Retrieved from http://www.ndbc.noaa.gov/.

The National Data Buoy Center (NDBC) provides both real-time and historical meteorological and wave data. The center operates buoys and Coastal Marine Automated Network (C-MAN) stations in the Mariana Islands. In addition, important tsunameters are located strategically around the Mariana Islands.

Pacific Islands Ocean Observing System (2010, May 26). Retrieved from http://www.soest.hawaii.edu/pacioos/.

The Pacific Islands Ocean Observing System (PacIOOS) is one of the eleven observing programs around the country that are supporting the emergence of the U.S. Integrated Ocean Observing System (IOOS). The IOOS is a federal, regional, and private-sector partnership working to enhance our ability to collect, deliver, and use ocean information. IOOS delivers the data and information needed to increase understanding of our oceans and coasts, so decision makers can take action to improve safety, enhance the economy, and protect the environment. The PacIOOS coverage area includes the CNMI and Guam as well as other freely associated areas in the Pacific. The PacIOOS website provides links to data and documents about ocean observation.

Spalding, Mark, Ravilious, Corinna, & Green, Edmund. (2001). *World atlas of coral reefs*. Univ of California Pr. Retrieved from United Nations Environmental Programme-World Conservation Monitoring Centre website http://www.unep-wcmc.org/marine/coralatlas/index.htm.

The above website contains information on the *World atlas of coral reefs*, an atlas which illustrates reefs systems and provides detailed maps for countries to use in efforts to protect reefs. Chapter 13 of the atlas is pertinent to the CNMI and Guam.

University of Guam-College of Natural and Applied Sciences (2009, December, 18). Weather Station Data. Retrieved from http://www.uog.edu/dynamicdata/CNASweatherdata.aspx?siteid=2&p=735.

The University of Guam (UOG)-College of Natural and Applied Sciences maintain two agricultural weather stations on Guam. One weather station is located in north east portion of the island at Yigo, and another is located at Inarajan at the south east portion of the island. The UOG also provides soil and water resource management support to the Mariana Islands.

University of Hawai'i-Pacific Islands Benthic Habitat Mapping Center (PIBHMC) (2009, December 17). PIBHMC-Home page. Retrieved from http://www.soest.hawaii.edu/pibhmc/index.htm .

The PIBHMC is tasked with the delineation of the benthic habitat of coral reef ecosystems throughout the U.S. Pacific Islands. With other groups such as NOAA, PIBHMC has developed shallow-water benthic habitat maps using satellite-based techniques that are best suited for shallow-water habitats in less than 20 meters of water. PIBHMC uses acoustic and optical techniques to extend those shallow-water maps into deeper waters where satellite and diver-based techniques are not feasible. These mapping resources are important for MI-HARES'10 as these can act as cal/val datasets for developed products.

Volcano Hazards Program, United States Geological Survey (2010, May 26). Retrieved from http://volcanoes.usgs.gov/.

The Volcano Hazards Program reports volcanic activity in the United States and abroad. Recent reports for Mount Pagan have indicated trace amounts of ash present on researcher's tents the week of 21 May, 2010. Data sources for reporting of activity on Pagan are sparse due to its remote location. Reports are limited to the infrequent visual observation from research teams or from the Moderate-resolution Imaging Spectroradiometer (MODIS).

Mount Pagan is the most dangerous volcano in the Mariana Islands due to its frequent activity. Recent activity has released gas and steam into the atmosphere and an eruption in 1981 caused a lava flow which covered a village and the airfield. Gas and steam plumes add aerosols in the air which affect the processing of aerial imagery.

Water & Environmental Research Institute of the Western Pacific (WERI) and Island Research & Education Initiative (IREI) (2009, December 17). Coastal Guam Aerial Imagery Project. Retrieved from http://www.weriguam.org/v2/interface/tab1.php .

Aerial imagery is an important data resource as it captures the conditions of a study site on the date of the data capture. Data captures spanning numerous years can develop a time sequence for the study site and this can be very important for rapidly changing environments such as coastal, estuarine, and riverine environments. The above URL contains a database of oblique photographs that were taken by hand-held Nikon D70s and D40 digital cameras from a Cessna 172 Skyhawk aircraft, operated by Micronesian Aviation Systems and Freedom Air. The database contains over 4000 images collected in two weeks in February, 2007. Users of the website can access a seamless coastal view of Guam and have the choice to turn on place names, latitude/longitude, or geology for the view.

Water & Environmental Research Institute of the Western Pacific (WERI) and Island Research & Education Initiative (IREI) (2009, December 21). Natural Resource Atlas of Southern Guam. Retrieved from http://www.hydroguam.net/gis_download.php.

The above URL links to GIS datasets and digital imagery developed by WERI and IREI. These data can be used for reference and development of shapefile products.

APPENDIX B

Flight Lines

1 Introduction

Careful flight line planning is an important aspect of remote sensing exercises and entails gathering solar azimuthal data, planning logical time frames for flight, and choosing global positions which take into account swath width, and aerial survey start and stop points.

Flight lines were planned to achieve a nominal ground sample distance (GSD) of about 3m and an approximate swath of about 1.64 km. An overlap of approximately 25% (which is about 410 m) between adjacent flight lines was achieved in order to prevent any data gaps from small variations in the planned flight lines. To minimize glint from the water, flights were flown when solar zenith angles were between 30-60°. In addition, flights were flown into and out of the sun to further minimize glint as illustrated in the following solar azimuth heading figures. In order to achieve this, the NRL team computed optimal times of day for data acquisition, and planned flight lines to maintain flight line trajectories into and out of the sun (USNO, 2010) .

In order to maintain a heading into and out of the sun, flight line azimuthal bearing was defined for approximately each hour in the air because the solar azimuth changes rapidly at this time of year at this latitude. For each day, there were five or six approximate one hour-long time windows (three AM, three PM) that were chosen where sun angles were optimal for flying. The average azimuth for these time periods was calculated and this value was to be the heading in which the aircraft would fly for that time period. Each set of four days (19 February to 22 February, 23 February to 26 February, 27 February to 2 March, 3 March to 6 March, and 7 March to 10 March) were grouped and azimuths for each time category were shared among the four days. This was done to minimize the total number of flight lines. Although flight lines were planned from the time period 19 February to 2 March, these days were not flown due to weather and experiment delays. However, 3 March and 4 March (both in day set 4) flights were flown with Day Set 3 information. Flight lines were planned to cover the entire island of Pagan, the northern and central sections of Tinian, and Dadi and Tipalao beaches on Guam.

The following sections display tabular data and graphical figures of flight line information. Section 2 displays tables of average heading for time period. Table headings are Day Set (a grouping of 4 days), the date, the window (morning or afternoon), the sub-window (up to three per window), the descriptor (the azimuth (AZ) and time), and the target island. The table indicates desired azimuth and time the azimuth should be flown. These tables were used as guidance in developing flight lines.

Section 3 display tabular data and figures developed from Section 2 information. Information from Section 2 was used to develop flight line layers in ArcMap. Twenty kilometer flight lines were established (area layer in figure) in ArcMap and sectioned into 0.01 degree points to develop waypoints along the flight path (point layers in figure). This was done to shorten flight paths and create start and stop points. In the figures in Section 3, each point has a name which corresponds to latitude and longitude values. The latitude and longitude values of the start and stop points were given to the Piper Navajo pilots.

2 Average Heading and Time

	Date	Window	Sub-Window	Descriptor	Average Heading for Time Period Guam	Tinian	Pagan
DAY SET 3	Feb-27	Morning	1	AZ	113.295	114.3975	116.6875
				Time	8:55-10:05	8:55-10:05	8:55-9:55
			2	AZ	121.92	123.7825	125.8525
				Time	10:05-10:40	10:05-10:45	9:55-10:35
			3	AZ			132.7975
				Time			10:35-10:55
		Afternoon	1	AZ	239.03625	235.45875	229.0575
				Time	14:25-15:10	14:20-15:00	14:05-14:40
			2	AZ	247.89875	245.35	238.71625
				Time	15:10-16:15	15:00-16:05	14:40-15:30
			3	AZ		250.2333333	246.01625
				Time		16:05-16:15	15:30-16:05
	Feb-28	Morning	1	AZ	113.295	114.3975	116.6875
				Time	8:55-10:05	8:55-10:05	8:55-9:55
			2	AZ	121.92	123.7825	125.8525
				Time	10:05-10:40	10:05-10:45	9:55-10:35
			3	AZ			132.7975
				Time			10:35-10:55
		Afternoon	1	AZ	239.03625	235.45875	229.0575
				Time	14:25-15:10	14:20-15:00	14:05-14:40
			2	AZ	247.89875	245.35	238.71625
				Time	15:10-16:15	15:00-16:05	14:40-15:30
			3	AZ		250.2333333	246.01625
				Time		16:05-16:15	15:30-16:05
	Mar-01	Morning	1	AZ	113.295	114.3975	116.6875
				Time	8:50-10:05	8:50-10:00	8:55-9:55
			2	AZ	121.92	123.7825	125.8525
				Time	10:05-10:40	10:00-10:40	9:55-10:35
			3	AZ		128.09	132.7975
				Time		10:40-10:45	10:35-10:50
		Afternoon	1	AZ	239.03625	235.45875	229.0575
				Time	14:30-15:20	14:20-15:00	14:05-14:40
			2	AZ	247.89875	245.35	238.71625
				Time	15:20-16:15	15:00-16:05	14:40-15:30
			3	AZ		250.2333333	246.01625
				Time		16:05-16:15	15:30-16:05
	Mar-02	Morning	1	AZ	113.295	114.3975	116.6875
				Time	8:50-10:05	8:50-10:00	8:55-9:55
			2	AZ	121.92	123.7825	125.8525
				Time	10:05-10:40	10:00-10:40	9:55-10:35
			3	AZ			132.7975
				Time			10:35-10:50
		Afternoon	1	AZ	239.03625	235.45875	229.0575
				Time	14:30-15:20	14:25-15:10	14:10-14:45
			2	AZ	247.89875	245.35	238.71625
				Time	15:20-16:20	15:10-16:15	14:45-15:35
			3	AZ			246.01625
				Time			15:35-16:05

	Date	Window	Sub-Window	Descriptor	Average Heading for Time Period		
					Guam	Tinian	Pagan
DAY SET 4	Mar-03	Morning	1	AZ	111.46	112.36625	114.34625
				Time	8:50-10:05	8:50-10:00	8:50-9:50
			2	AZ	119.405	121.24625	123.75875
				Time	10:05-10:35	10:00-10:40	9:50-10:35
			3	AZ			130.22125
				Time			10:35-10:50
		Afternoon	1	AZ	242.2625	238.46625	233.01125
				Time	14:30-15:20	14:25-15:10	14:10-14:45
			2	AZ	250.5525	248.5475	242.58875
				Time	15:20-16:20	15:10-16:15	14:45-15:35
			3	AZ			249.08875
				Time			15:35-16:10
	Mar-04	Morning	1	AZ	111.46	112.36625	114.34625
				Time	8:50-10:05	8:50-10:00	8:50-9:50
			2	AZ	119.405	121.24625	123.75875
				Time	10:05-10:35	10:00-10:40	9:50-10:35
			3	AZ			130.22125
				Time			10:35-10:45
		Afternoon	1	AZ	242.2625	238.46625	233.01125
				Time	14:30-15:20	14:25-15:10	14:10-14:45
			2	AZ	250.5525	248.5475	242.58875
				Time	15:20-16:20	15:10-16:15	14:45-15:35
			3	AZ			249.08875
				Time			15:35-16:10
	Mar-05	Morning	1	AZ	111.46	112.36625	114.34625
				Time	8:50-10:05	8:50-10:00	8:50-9:50
			2	AZ	119.405	121.24625	123.75875
				Time	10:05-10:35	10:00-10:40	9:50-10:35
			3	AZ			130.22125
				Time			10:35-10:45
		Afternoon	1	AZ	242.2625	238.46625	233.01125
				Time	14:30-15:20	14:25-15:10	14:15-14:55
			2	AZ	250.5525	248.5475	242.58875
				Time	15:20-16:20	15:10-16:15	14:55-15:55
			3	AZ			249.08875
				Time			15:55-16:10
	Mar-06	Morning	1	AZ	111.46	112.36625	114.34625
				Time	8:50-10:05	8:50-10:00	8:50-9:50
			2	AZ	119.405	121.24625	123.75875
				Time	10:05-10:35	10:00-10:35	9:50-10:35
			3	AZ			130.22125
				Time			10:35-10:45
		Afternoon	1	AZ	242.2625	238.46625	233.01125
				Time	14:35-15:30	14:30-15:20	14:15-14:55
			2	AZ	250.5525	248.5475	242.58875
				Time	15:30-16:20	15:20-16:15	14:55-15:55
			3	AZ			249.08875
				Time			15:55-16:10

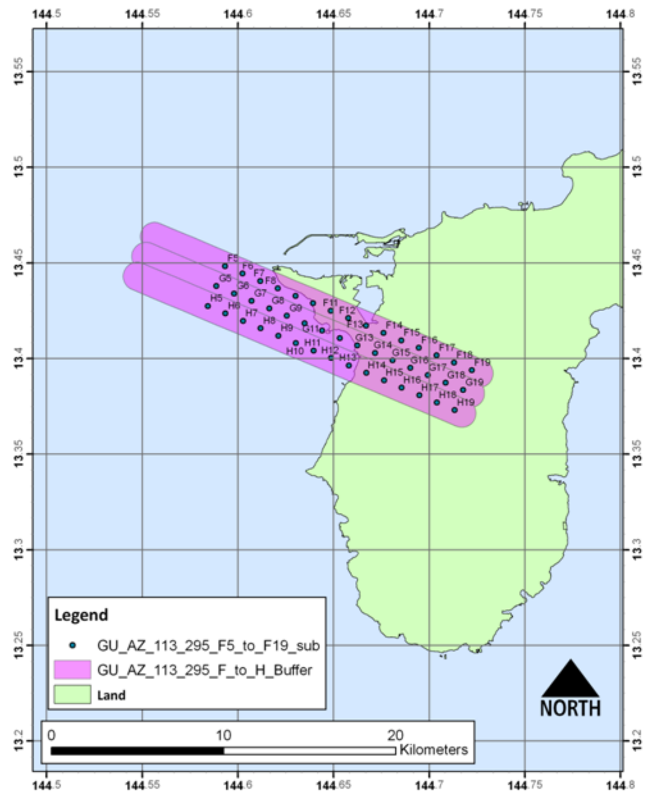
	Date	Window	Sub-Window	Descriptor	Average Heading for Time Period		
					Guam	Tinian	Pagan
DAY SET 5	Mar-07	Morning	1	AZ	109.51875	110.4025	112.8475
				Time	8:45-10:05	8:45-10:00	8:50-9:55
			2	AZ	116.8525	118.58	122.315
				Time	10:05-10:30	10:00-10:35	9:55-10:40
			3	AZ			127.8183333
				Time			10:40-10:45
		Afternoon	1	AZ	245.48375	242.82375	236.6675
				Time	14:35-15:30	14:30-15:20	14:15-14:55
			2	AZ	253	251.1425	246.3375
				Time	15:30-16:20	15:20-16:15	14:55-15:55
			3	AZ			251.89125
				Time			15:55-16:10
	Mar-08	Morning	1	AZ	109.51875	110.4025	112.8475
				Time	8:45-10:05	8:45-10:00	8:50-9:55
			2	AZ	116.8525	118.58	122.315
				Time	10:05-10:30	10:00-10:35	9:55-10:40
			3	AZ			127.8183333
				Time			10:40-10:45
		Afternoon	1	AZ	245.48375	242.82375	236.6675
				Time	14:35-15:30	14:30-15:20	14:15-14:55
			2	AZ	253	251.1425	246.3375
				Time	15:30-16:20	15:20-16:15	14:55-15:55
			3	AZ			251.89125
				Time			15:55-16:10
	Mar-09	Morning	1	AZ	109.51875	110.4025	112.8475
				Time	8:45-10:05	8:45-10:00	8:45-9:50
			2	AZ	116.8525	118.58	122.315
				Time	10:05-10:30	10:00-10:30	9:50-10:35
			3	AZ			127.8183333
				Time			10:35-10:40
		Afternoon	1	AZ	245.48375	242.82375	236.6675
				Time	14:35-15:30	14:30-15:20	14:20-15:00
			2	AZ	253	251.1425	246.3375
				Time	15:30-16:20	15:20-16:15	15:00-16:05
			3	AZ			251.89125
				Time			16:05-16:10
	Mar-10	Morning	1	AZ	109.51875	110.4025	112.8475
				Time	8:45-10:05	8:45-10:00	8:45-9:50
			2	AZ	116.8525	118.58	122.315
				Time	10:05-10:30	10:00-10:30	9:50-10:35
			3	AZ			
				Time			
		Afternoon	1	AZ	245.48375	242.82375	236.6675
				Time	14:35-15:30	14:30-15:20	14:20-15:00
			2	AZ	253	251.1425	246.3375
				Time	15:30-16:20	15:20-16:20	15:00-16:05
			3	AZ			251.89125
				Time			16:05-16:10

3 Flight line scenarios

3.1 Guam

Scenario	Location	Beach	Day Set	Window	SubWindow	Azimuth	Time	Start	Start Long	Start Lat	End	End Long	End Lat	Dates
DS3 (1)-AM	Guam	Tipalao, Dadi Beaches	3	AM	1	113.295	8:55-10:05	F5	144.59323	13.448372	F19	144.722217	13.393945	Feb 27-Mar 2
	Guam	Tipalao, Dadi Beaches	3	AM	1	113.295	8:55-10:05	G5	144.58874	13.437946	G19	144.717726	13.383517	Feb 27-Mar 2
	Guam	Tipalao, Dadi Beaches	3	AM	1	113.295	8:55-10:05	H5	144.584251	13.427518	H19	144.713236	13.373087	Feb 27-Mar 2
DS3 (2)-AM	Guam	Tipalao, Dadi Beaches	3	AM	2	121.92	10:05-10:45	F4	144.594761	13.457986	F19	144.7228	13.379845	Feb 27-Mar 2
	Guam	Tipalao, Dadi Beaches	3	AM	2	121.92	10:05-10:45	G4	144.588758	13.448349	G19	144.716796	13.370207	Feb 27-Mar 2
	Guam	Tipalao, Dadi Beaches	3	AM	2	121.92	10:05-10:45	H4	144.582756	13.438714	H19	144.710793	13.360569	Feb 27-Mar 2
DS3 (1)-PM	Guam	Tipalao, Dadi Beaches	3	PM	1	239.03625	14:25-15:10 (Feb)/ 14:30-15:20 (Mar)	I1	144.715621	13.423954	I11	144.629404	13.373291	Feb 27-Mar 2
	Guam	Tipalao, Dadi Beaches	3	PM	1	239.03625	14:25-15:10 (Feb)/ 14:30-15:20 (Mar)	J1	144.709781	13.433688	J11	144.623563	13.383026	Feb 27-Mar 2
	Guam	Tipalao, Dadi Beaches	3	PM	1	239.03625	14:25-15:10 (Feb)/ 14:30-15:20 (Mar)	K1	144.70394	13.443422	K11	144.617721	13.392762	Feb 27-Mar 2
	Guam	Tipalao, Dadi Beaches	3	PM	1	239.03625	14:25-15:10 (Feb)/ 14:30-15:20 (Mar)	L1	144.6981	13.453157	L11	144.61188	13.402498	Feb 27-Mar 2
DS3 (2)-PM	Guam	Tipalao, Dadi Beaches	3	PM	2	247.89875	15:10-16:15(Feb) /15:20-16:20 (Mar)	J1	144.716441	13.420348	J11	144.623521	13.383388	Feb 27-Mar 2
	Guam	Tipalao, Dadi Beaches	3	PM	2	247.89875	15:10-16:15(Feb) /15:20-16:20 (Mar)	K1	144.71217	13.430866	K11	144.61925	13.393907	Feb 27-Mar 2
	Guam	Tipalao, Dadi Beaches	3	PM	2	247.89875	15:10-16:15(Feb) /15:20-16:20 (Mar)	L1	144.707899	13.441384	L11	144.614978	13.404427	Feb 27-Mar 2
	Guam	Tipalao, Dadi Beaches	3	PM	2	247.89875	15:10-16:15(Feb) /15:20-16:20 (Mar)	M1	144.703628	13.451902	M11	144.610707	13.414946	Feb 27-Mar 2

Guam Day Set 3 - AM1



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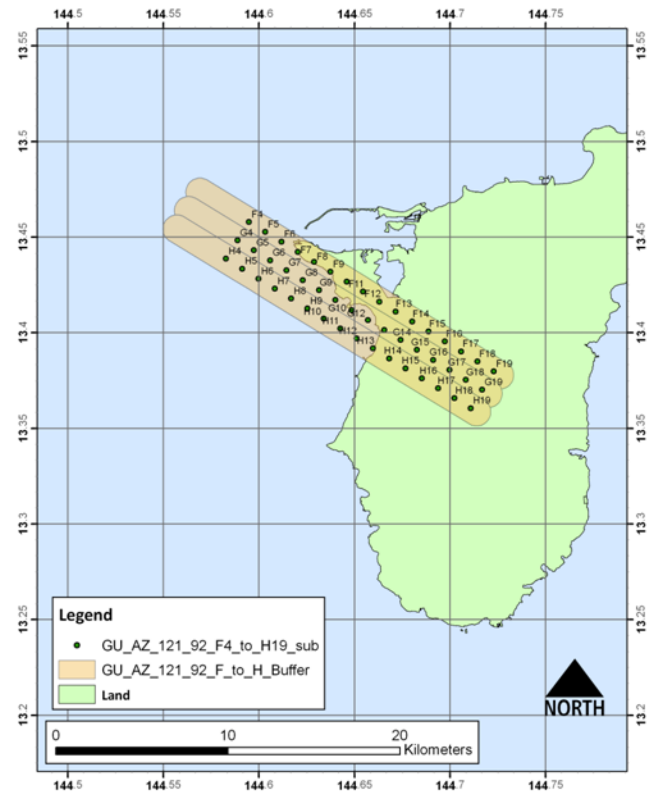

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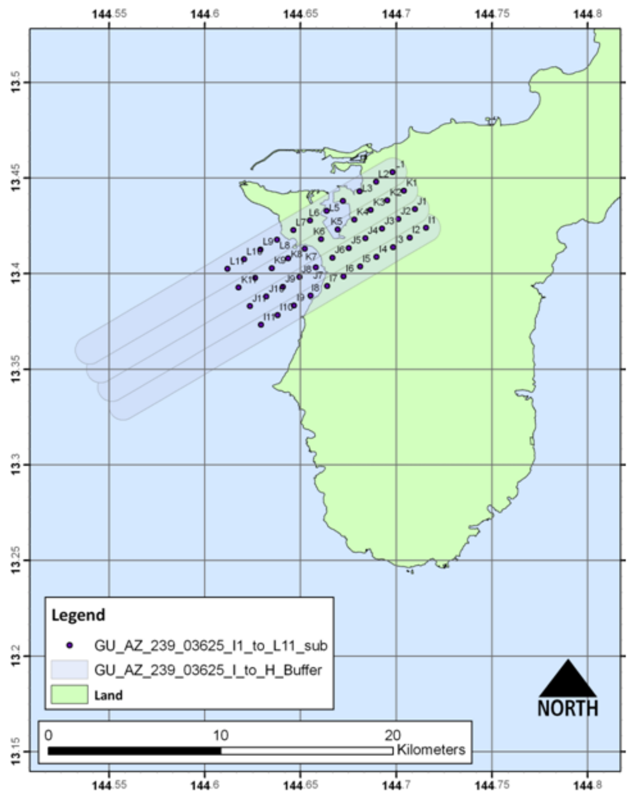

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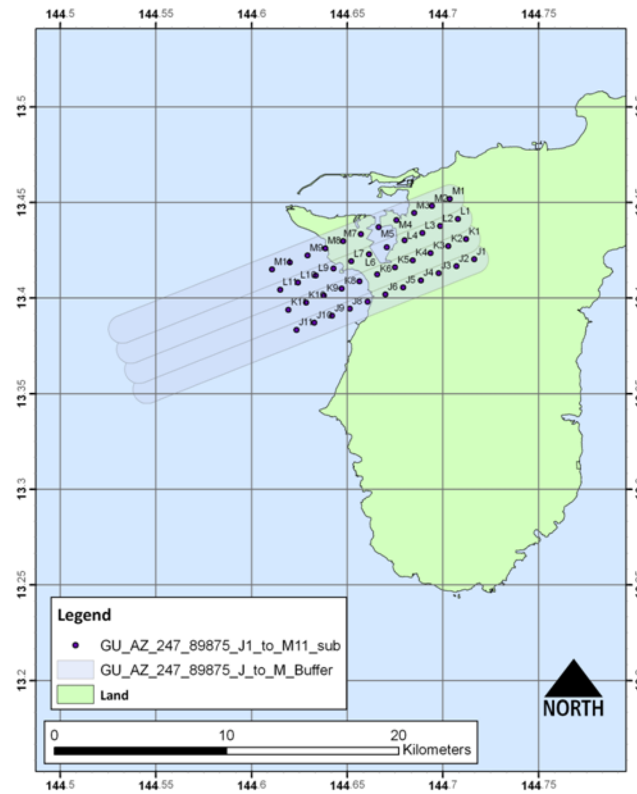

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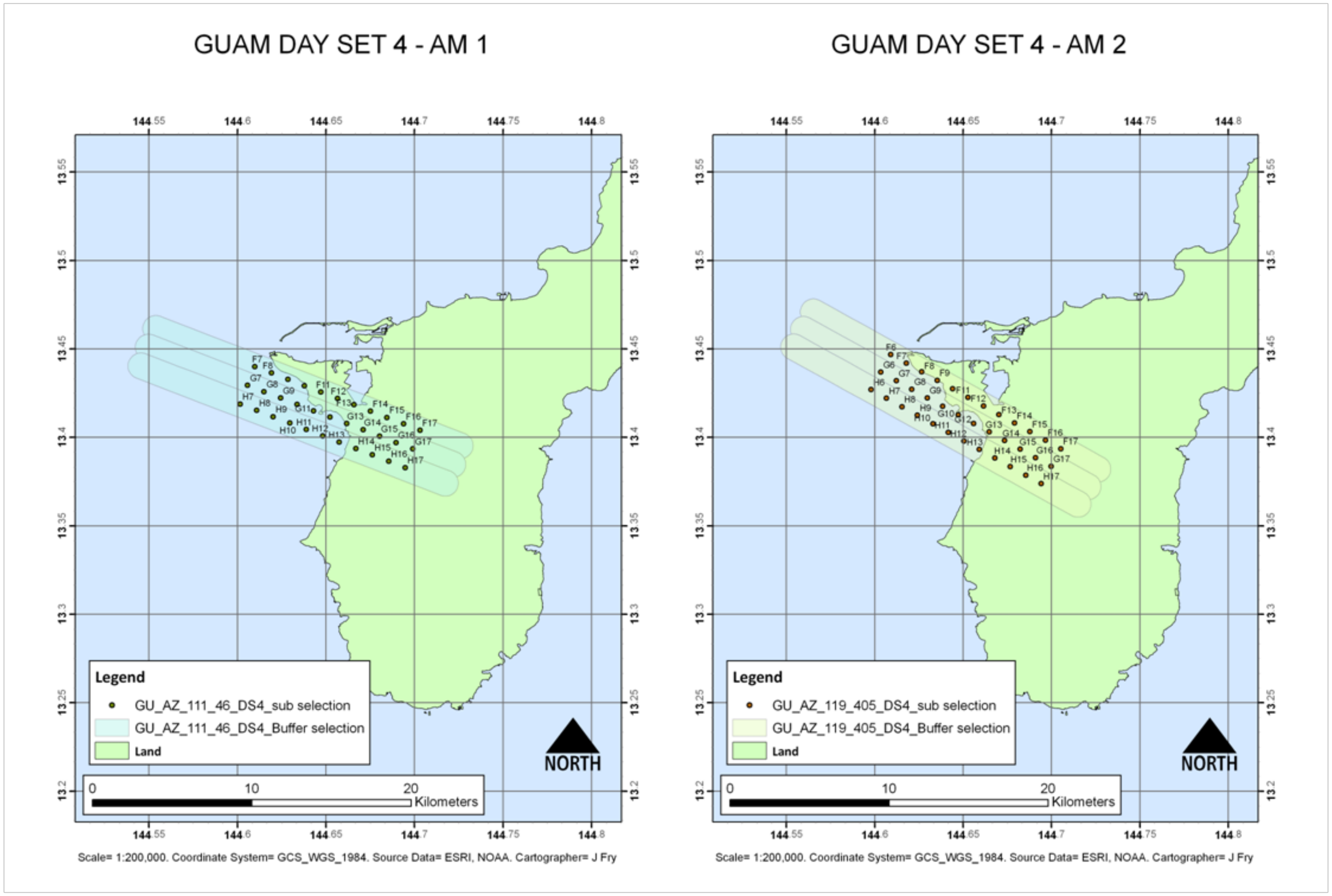
Scenario	Location	Beach	Day Set	Window	SubWindow	Azimuth	Time	Start	Start Long	Start Lat	End	End Long	End Lat	Dates
DS4 (1)-AM	Guam	Tipalao, Dadi Beaches	4	AM	1	111.46	8:50-10:05	F7	144.609845	13.440052	F17	144.703159	13.404101	3Mar-6Mar
	Guam	Tipalao, Dadi Beaches	4	AM	1	111.46	8:50-10:05	G7	144.605691	13.429487	G17	144.699004	13.393534	3Mar-6Mar
	Guam	Tipalao, Dadi Beaches	4	AM	1	111.46	8:50-10:05	H7	144.601537	13.418921	H17	144.69485	13.382966	3Mar-6Mar
DS4 (2)-AM	Guam	Tipalao, Dadi Beaches	4	AM	2	119.405	10:05-10:35	F6	144.609052	13.446823	F17	144.705347	13.393651	3Mar-6Mar
	Guam	Tipalao, Dadi Beaches	4	AM	2	119.405	10:05-10:35	G6	144.603477	13.436933	G17	144.699771	13.38376	3Mar-6Mar
	Guam	Tipalao, Dadi Beaches	4	AM	2	119.405	10:05-10:35	H6	144.597904	13.427042	H17	144.694197	13.373867	3Mar-6Mar
DS4 (1)-PM	Guam	Tipalao, Dadi Beaches	4	PM	1	242.2625	14:35-15:30	J3	144.694661	13.419798	J13	144.605763	13.374005	3Mar-6Mar
	Guam	Tipalao, Dadi Beaches	4	PM	1	242.2625	14:35-15:30	K3	144.689377	13.429846	K13	144.600478	13.384054	3Mar-6Mar
	Guam	Tipalao, Dadi Beaches	4	PM	1	242.2625	14:35-15:30	L3	144.684094	13.439894	L13	144.595194	13.394104	3Mar-6Mar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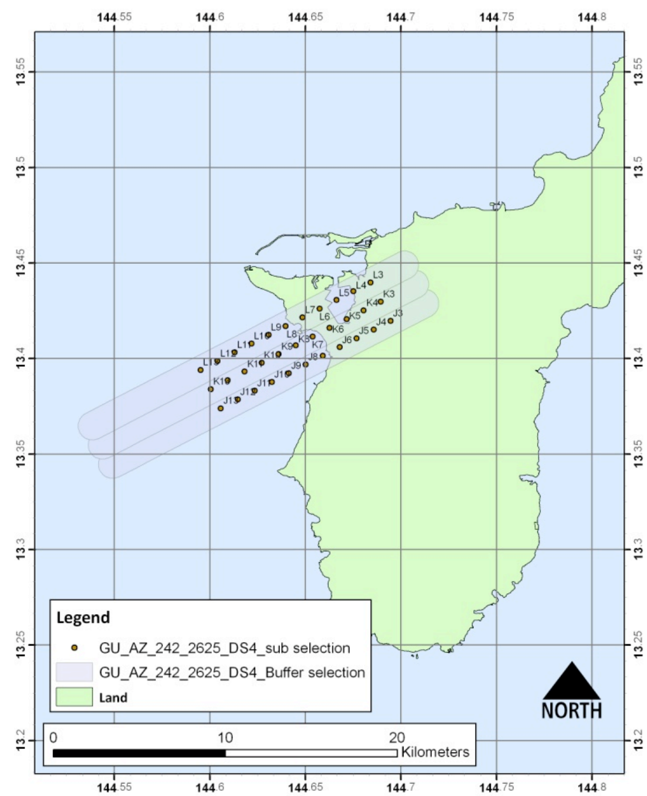
GUAM DAY SET 4 - PM 1



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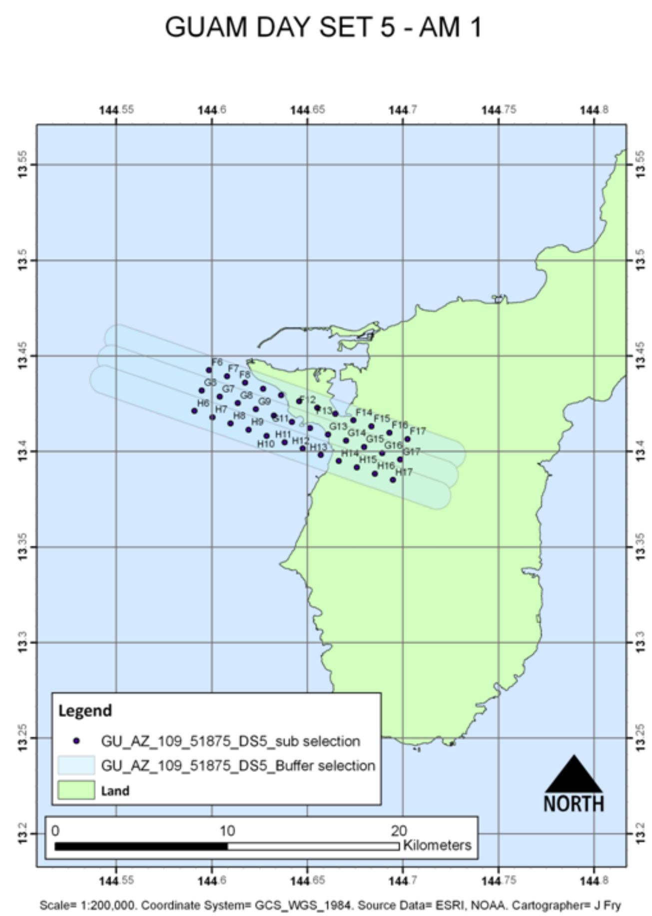
Scenario	Location	Beach	Day Set	Window	SubWindow	Azimuth	Time	Start	Start Long	Start Lat	End	End Long	End Lat	Dates
DS5 (1)-AM	Guam	Tipalao, Dadi Beaches	5	AM	1	109.51875	8:45-10:05	F6	144.598499	13.442686	F17	144.702406	13.406585	7Mar-10Mar
	Guam	Tipalao, Dadi Beaches	5	AM	1	109.51875	8:45-10:05	G6	144.594706	13.431987	G17	144.698613	13.395884	7Mar-10Mar
	Guam	Tipalao, Dadi Beaches	5	AM	1	109.51875	8:45-10:05	H6	144.590913	13.421286	H17	144.694819	13.385182	7Mar-10Mar
DS5 (2)-AM	Guam	Tipalao, Dadi Beaches	5	AM	2	116.8525	10:00-10:35	F6	144.606262	13.445935	F17	144.704803	13.397052	7Mar-10Mar
	Guam	Tipalao, Dadi Beaches	5	AM	2	116.8525	10:00-10:35	G6	144.601133	13.435807	G17	144.699674	13.386921	7Mar-10Mar
	Guam	Tipalao, Dadi Beaches	5	AM	2	116.8525	10:00-10:35	H6	144.596005	13.425678	H17	144.694545	13.376791	7Mar-10Mar
DS5 (1)-PM	Guam	Tipalao, Dadi Beaches	5	PM	1	245.48375	14:35-15:30	J3	144.696569	13.415929	J13	144.605268	13.375135	7Mar-10Mar
	Guam	Tipalao, Dadi Beaches	5	PM	1	245.48375	14:35-15:30	K3	144.691859	13.426258	K13	144.600557	13.385466	7Mar-10Mar
	Guam	Tipalao, Dadi Beaches	5	PM	1	245.48375	14:35-15:30	L3	144.687148	13.436586	L13	144.595845	13.395796	7Mar-10Mar
DS5 (2)-PM	Guam	Tipalao, Dadi Beaches	5	PM	2	253	15:30-16:20	J3	144.700154	13.406519	J13	144.604361	13.377819	7Mar-10Mar
	Guam	Tipalao, Dadi Beaches	5	PM	2	253	15:30-16:20	K3	144.696835	13.417375	K13	144.601042	13.388677	7Mar-10Mar
	Guam	Tipalao, Dadi Beaches	5	PM	2	253	15:30-16:20	L3	144.693516	13.428232	L13	144.597723	13.399534	7Mar-10Mar
	Guam	Tipalao, Dadi Beaches	5	PM	2	253	15:30-16:20	M3	144.690197	13.439088	M13	144.594403	13.410391	7Mar-10Mar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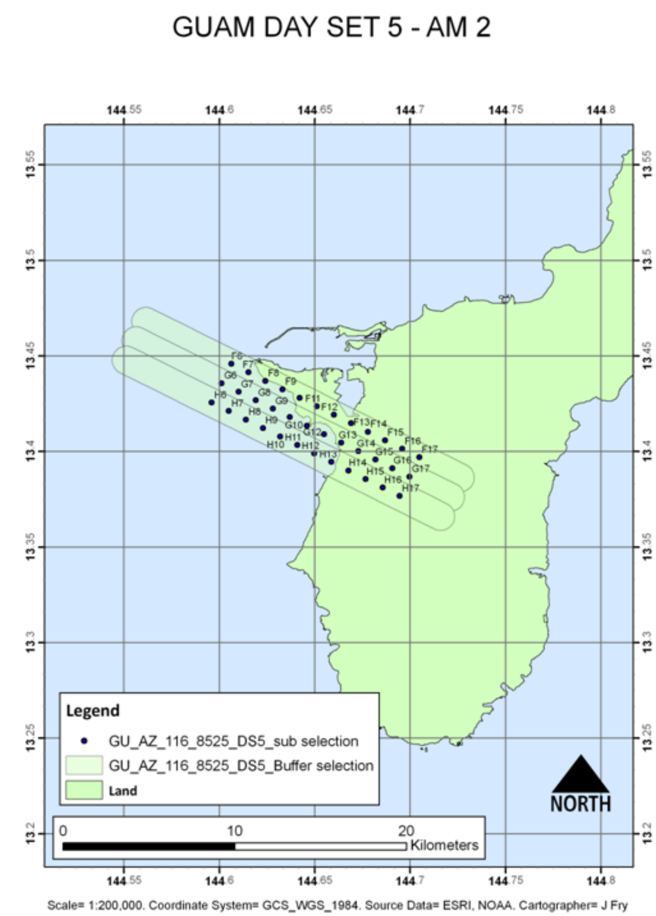
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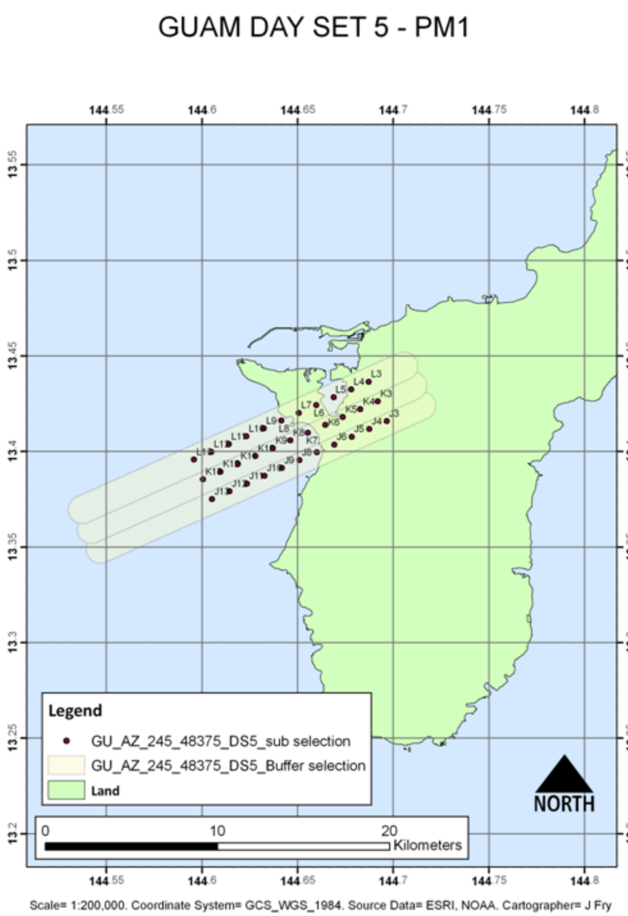
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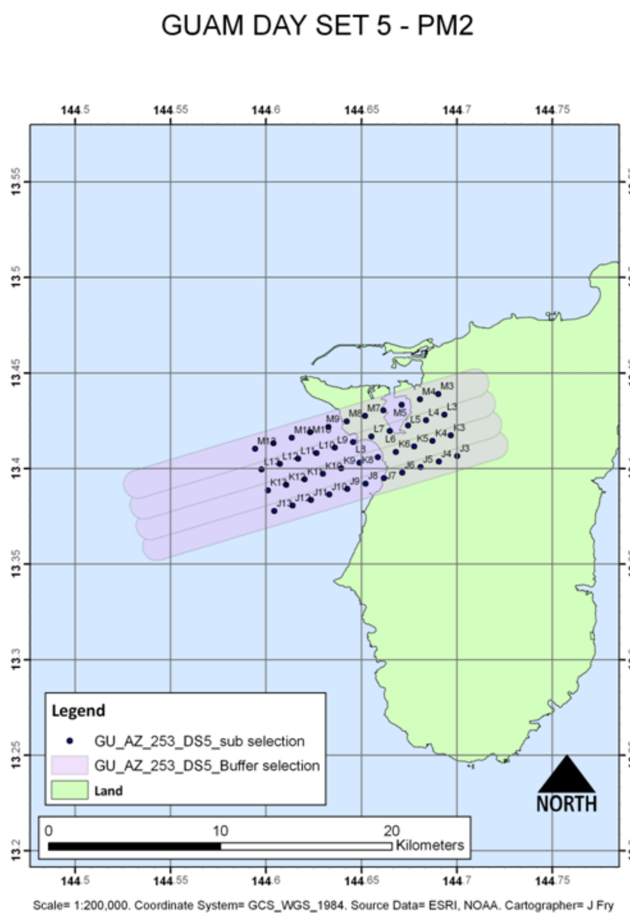
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3.2 Pagan

Scenario	Location	Beach	Day	Window	SubWind	Azimuth	Time	Start	Start Long	Start Lat	End	End Long	End Lat	Dates
DS3 (1)-AM	Pagan	Entire Island	3	AM	1	116.6875	8:55-9:55	D5	145.746598	18.19539	D16	145.845724	18.147703	27-Feb-2-Mar
	Pagan	Entire Island	3	AM	1	116.6875	8:55-9:55	E5	145.741498	18.185246	E16	145.840624	18.137557	27-Feb-2-Mar
	Pagan	Entire Island	3	AM	1	116.6875	8:55-9:55	F5	145.7364	18.175103	F16	145.835524	18.127412	27-Feb-2-Mar
	Pagan	Entire Island	3	AM	1	116.6875	8:55-9:55	G5	145.731302	18.164959	G16	145.830425	18.117266	27-Feb-2-Mar
	Pagan	Entire Island	3	AM	1	116.6875	8:55-9:55	H5	145.726202	18.154815	H16	145.825324	18.10712	27-Feb-2-Mar
	Pagan	Entire Island	3	AM	1	116.6875	8:55-9:55	I5	145.721104	18.144672	I16	145.820225	18.096975	27-Feb-2-Mar
	Pagan	Entire Island	3	AM	1	116.6875	8:55-9:55	J5	145.716004	18.134529	J16	145.815124	18.086829	27-Feb-2-Mar
	Pagan	Entire Island	3	AM	2	125.8525	9:55-10:35	K5	145.713745	18.132321	K16	145.804214	18.069748	27-Feb-2-Mar
	Pagan	Entire Island	3	AM	2	125.8525	9:55-10:35	L5	145.707096	18.123119	L16	145.797563	18.060544	27-Feb-2-Mar
	Pagan	Entire Island	3	AM	2	125.8525	9:55-10:35	M5	145.700446	18.113918	M16	145.790912	18.05134	27-Feb-2-Mar
	Pagan	Entire Island	3	AM	2	125.8525	9:55-10:35	N5	145.693797	18.104716	N16	145.784261	18.042136	27-Feb-2-Mar
	Pagan	Entire Island	3	AM	2	125.8525	9:55-10:35	O5	145.687147	18.095514	O16	145.77761	18.032932	27-Feb-2-Mar
	Pagan	Entire Island	3	AM	3	132.7975	10:35-10:55	P5	145.678127	18.096276	P16	145.760446	18.023312	27-Feb-2-Mar
	Pagan	Entire Island	3	AM	3	132.7975	10:35-10:55	Q5	145.670415	18.087945	Q16	145.752731	18.014979	27-Feb-2-Mar
	Pagan	Entire Island	3	AM	3	132.7975	10:35-10:55	R5	145.662701	18.079615	R16	145.745016	18.006648	27-Feb-2-Mar
DS3 (1)-PM	Pagan	Entire Island	3	PM	1	229.0575	14:05-14:45	K1	145.822256	18.179158	K19	145.683759	18.064185	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	1	229.0575	14:05-14:45	L1	145.814817	18.187733	L19	145.676317	18.072763	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	1	229.0575	14:05-14:45	M1	145.807378	18.196308	M19	145.668875	18.081342	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	1	229.0575	14:05-14:40	N1	145.799939	18.204883	N19	145.661433	18.08992	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	2	238.71625	14:40-15:30	G1	145.856392	18.129126	G19	145.700799	18.038621	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	2	238.71625	14:40-15:30	H1	145.850497	18.138827	H19	145.694902	18.048326	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	2	238.71625	14:40-15:30	I1	145.844602	18.148529	I19	145.689005	18.058032	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	2	238.71625	14:40-15:30	J1	145.838707	18.15823	J19	145.683108	18.067736	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	2	238.71625	14:40-15:30	K1	145.832813	18.167932	K19	145.677212	18.077442	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	3	246.01625	15:30-16:05	F1	145.862528	18.106499	F19	145.69693	18.035948	27-Feb-2-Mar
DS3 (2)-PM	Pagan	Entire Island	3	PM	2	238.71625	14:40-15:30	J1	145.838707	18.15823	J19	145.683108	18.067736	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	2	238.71625	14:40-15:30	K1	145.832813	18.167932	K19	145.677212	18.077442	27-Feb-2-Mar
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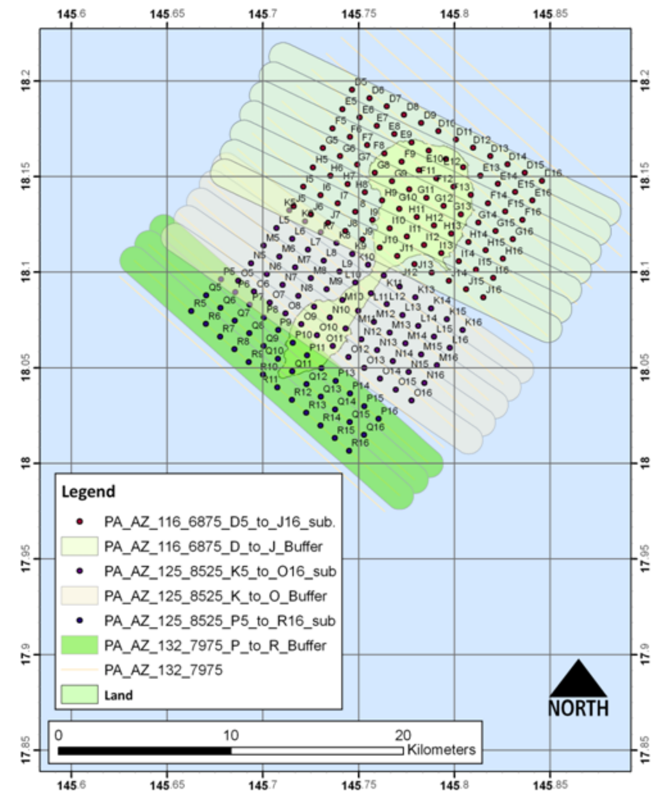
	Pagan	Entire Island	3	PM	2	238.71625	14:40-15:30	M1	145.821023	18.187335	M19	145.665417	18.096853	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	2	238.71625	14:40-15:30	N1	145.815128	18.197036	N19	145.65952	18.106557	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	3	246.01625	15:30-16:05	F1	145.862528	18.106499	F19	145.69693	18.035948	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	3	246.01625	15:30-16:05	G1	145.857914	18.116871	G19	145.692314	18.046324	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	3	246.01625	15:30-16:05	H1	145.853299	18.127242	H19	145.687698	18.056698	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	3	246.01625	15:30-16:05	I1	145.848685	18.137614	I19	145.683082	18.067074	27-Feb-2-Mar
	Pagan	Entire Island	3	PM	3	246.01625	15:30-16:05	J1	145.844071	18.147986	J19	145.678467	18.077449	27-Feb-2-Mar

Pagan Day Set 3 - AM1



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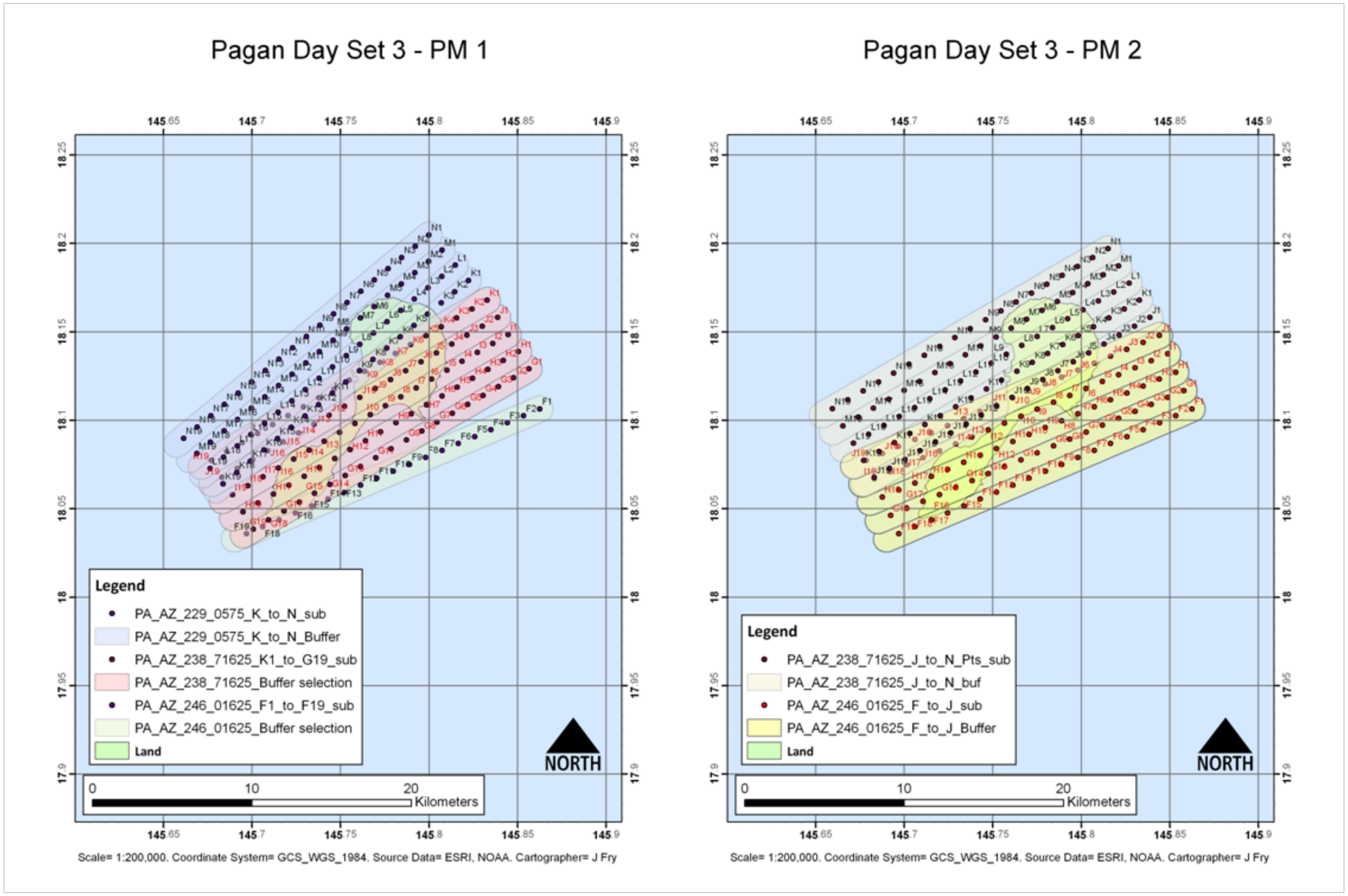

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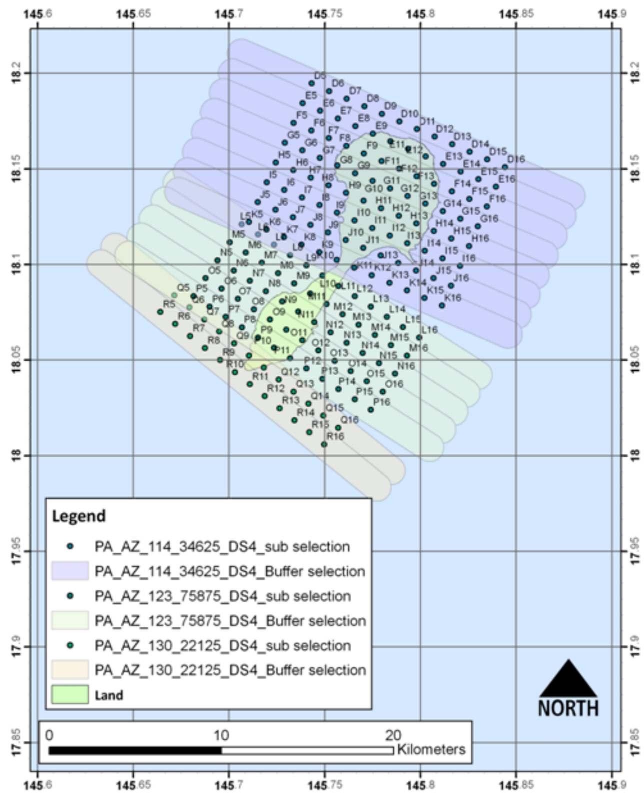
Scenario	Location	Beach	Day	Window	SubWindo	Azimuth	Time	Start	Start Long	Start Lat	End	End Long	End Lat	Dates
	Pagan	Entire Island	4	AM	1	114.34625	8:50-9:50	D5	145.743147	18.194684	D16	145.844087	18.150968	3Mar-6Mar
	Pagan	Entire Island	4	AM	1	114.34625	8:50-9:50	E5	145.738467	18.184341	E16	145.839406	18.140623	3Mar-6Mar
	Pagan	Entire Island	4	AM	1	114.34625	8:50-9:50	F5	145.733786	18.173997	F16	145.834725	18.130277	3Mar-6Mar
	Pagan	Entire Island	4	AM	1	114.34625	8:50-9:50	G5	145.729106	18.163654	G16	145.830043	18.119932	3Mar-6Mar
	Pagan	Entire Island	4	AM	1	114.34625	8:50-9:50	H5	145.724425	18.15331	H16	145.825362	18.109586	3Mar-6Mar
	Pagan	Entire Island	4	AM	1	114.34625	8:50-9:50	I5	145.719746	18.142968	I16	145.820682	18.099241	3Mar-6Mar
	Pagan	Entire Island	4	AM	1	114.34625	8:50-9:50	J5	145.715066	18.132624	J16	145.816	18.088895	3Mar-6Mar
DS4 (1)-AM	Pagan	Entire Island	4	AM	1	114.34625	8:50-9:50	K5	145.710385	18.122281	K16	145.811319	18.07855	3Mar-6Mar
	Pagan	Entire Island	4	AM	2	123.75875	9:50-10:35	L5	145.706679	18.121118	L16	145.799336	18.061834	3Mar-6Mar
	Pagan	Entire Island	4	AM	2	123.75875	9:50-10:35	M5	145.70037	18.11168	M16	145.793026	18.052393	3Mar-6Mar
	Pagan	Entire Island	4	AM	2	123.75875	9:50-10:35	N5	145.69406	18.102241	N16	145.786715	18.042952	3Mar-6Mar
	Pagan	Entire Island	4	AM	2	123.75875	9:50-10:35	O5	145.687752	18.092802	O16	145.780405	18.033511	3Mar-6Mar
	Pagan	Entire Island	4	AM	2	123.75875	9:50-10:35	P5	145.681443	18.083363	P16	145.774095	18.02407	3Mar-6Mar
	Pagan	Entire Island	4	AM	3	130.22125	10:35-10:50	Q5	145.671538	18.083883	Q16	145.75703	18.014665	3Mar-6Mar
	Pagan	Entire Island	4	AM	3	130.22125	10:35-10:50	R5	145.664207	18.075214	R16	145.749697	18.005995	3Mar-6Mar
	Pagan	Entire Island	4	PM	1	233.01125	14:15-14:55	K1	145.826805	18.174779	K19	145.680786	18.069523	3Mar-6Mar
	Pagan	Entire Island	4	PM	1	233.01125	14:15-14:55	L1	145.819975	18.183847	L12	145.730726	18.119545	3Mar-6Mar
	Pagan	Entire Island	4	PM	1	233.01125	14:15-14:55	M1	145.813145	18.192914	M12	145.723894	18.128614	3Mar-6Mar
	Pagan	Entire Island	4	PM	1	233.01125	14:15-14:55	N1	145.806315	18.201981	N12	145.717063	18.137683	3Mar-6Mar
DS4 (1)-PM	Pagan	Entire Island	4	PM	2	242.58875	14:55-15:55	F1	145.86262	18.112571	F19	145.701401	18.032518	3Mar-6Mar
	Pagan	Entire Island	4	PM	2	242.58875	14:55-15:55	G1	145.857394	18.122648	G19	145.696173	18.042598	3Mar-6Mar
	Pagan	Entire Island	4	PM	2	242.58875	14:55-15:55	H1	145.852167	18.132726	H19	145.690944	18.05268	3Mar-6Mar
	Pagan	Entire Island	4	PM	2	242.58875	14:55-15:55	I1	145.846941	18.142803	I19	145.685716	18.062761	3Mar-6Mar
	Pagan	Entire Island	4	PM	2	242.58875	14:55-15:55	J1	145.841715	18.152881	J19	145.680488	18.072842	3Mar-6Mar
	Pagan	Entire Island	4	PM	2	242.58875	14:55-15:55	K1	145.836489	18.162958	K19	145.67526	18.082923	3Mar-6Mar
	Pagan	Entire Island	4	PM	2	242.58875	14:55-15:55	F1	145.86262	18.112571	F19	145.701401	18.032518	3Mar-6Mar
	Pagan	Entire Island	4	PM	2	242.58875	14:55-15:55	G1	145.857394	18.122648	G19	145.696173	18.042598	3Mar-6Mar
	Pagan	Entire Island	4	PM	2	242.58875	14:55-15:55	H1	145.852167	18.132726	H19	145.690944	18.05268	3Mar-6Mar
	Pagan	Entire Island	4	PM	2	242.58875	14:55-15:55	I1	145.846941	18.142803	I19	145.685716	18.062761	3Mar-6Mar
DS4 (2)-PM	Pagan	Entire Island	4	PM	2	242.58875	14:55-15:55	J1	145.841715	18.152881	J19	145.680488	18.072842	3Mar-6Mar
	Pagan	Entire Island	4	PM	2	242.58875	14:55-15:55	K1	145.836489	18.162958	K19	145.67526	18.082923	3Mar-6Mar
	Pagan	Entire Island	4	PM	3	249.08875	15:55-16:10	L3	145.819164	18.157654	L11	145.744029	18.130182	3Mar-6Mar
	Pagan	Entire Island	4	PM	3	249.08875	15:55-16:10	M3	145.815137	18.168267	M11	145.740001	18.140797	3Mar-6Mar
	Pagan	Entire Island	4	PM	3	249.08875	15:55-16:10	N3	145.81111	18.178881	N11	145.735973	18.151412	3Mar-6Mar

PAGAN DAY SET 4 - AM 1



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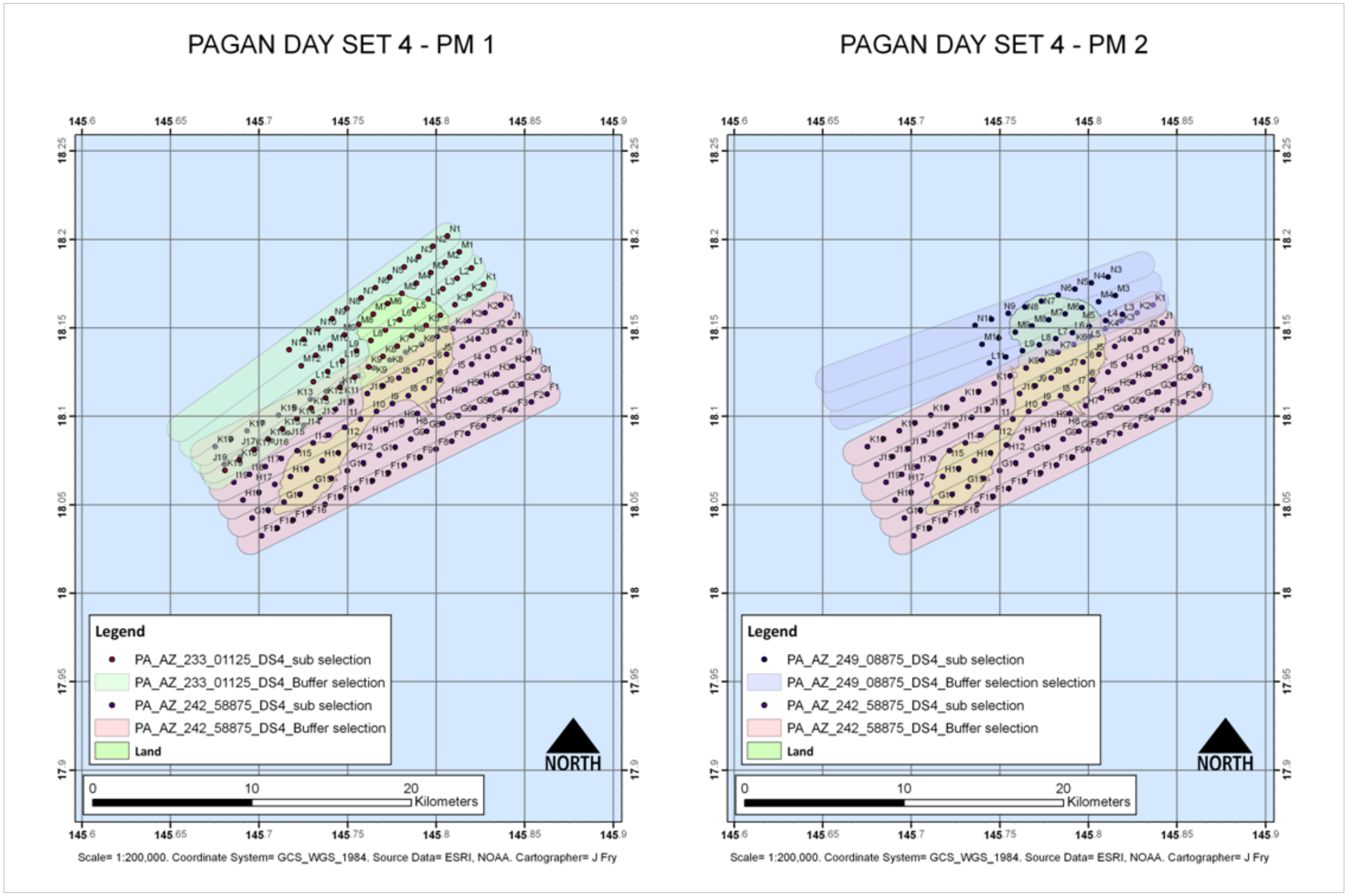
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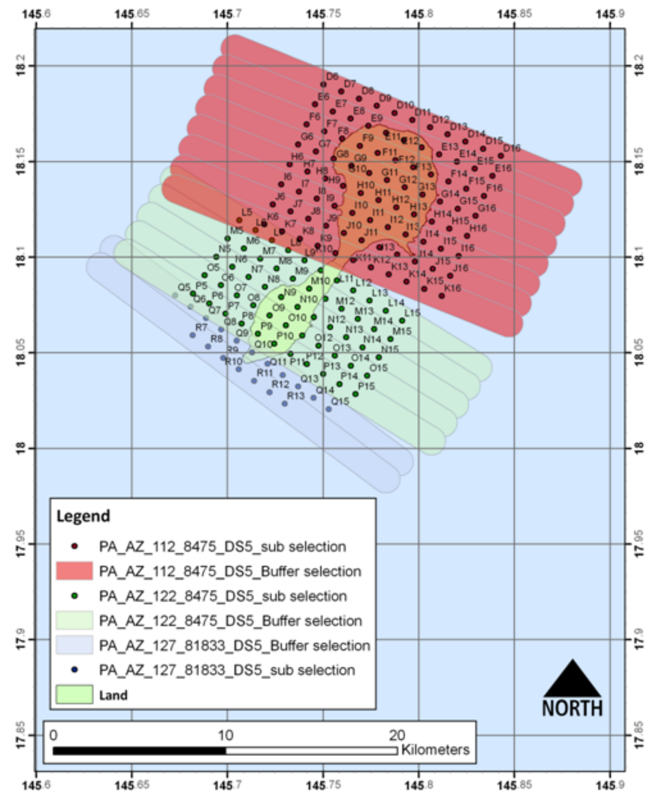
Scenario	Location	Beach	Day	Window	SubWind	Azimuth	Time	Start	Start Long	Start Lat	End	End Long	End Lat	Dates
	Pagan	Entire Island	5	AM	1	112.8475	8:50-9:55	D6	145.750229	18.190419	D16	145.84297	18.153014	7Mar-10Mar
	Pagan	Entire Island	5	AM	1	112.8475	8:50-9:55	E6	145.745821	18.179956	E16	145.838562	18.142549	7Mar-10Mar
	Pagan	Entire Island	5	AM	1	112.8475	8:50-9:55	F6	145.741413	18.169494	F16	145.834152	18.132085	7Mar-10Mar
	Pagan	Entire Island	5	AM	1	112.8475	8:50-9:55	G6	145.737005	18.159032	G16	145.829743	18.121621	7Mar-10Mar
	Pagan	Entire Island	5	AM	1	112.8475	8:50-9:55	H6	145.732596	18.148569	H16	145.825334	18.111156	7Mar-10Mar
	Pagan	Entire Island	5	AM	1	112.8475	8:50-9:55	I6	145.728189	18.138107	I16	145.820926	18.100692	7Mar-10Mar
	Pagan	Entire Island	5	AM	1	112.8475	8:50-9:55	J6	145.72378	18.127645	J16	145.816517	18.090228	7Mar-10Mar
DS5 (1)-AM	Pagan	Entire Island	5	AM	1	112.8475	8:50-9:55	K6	145.719372	18.117182	K16	145.812108	18.079763	7Mar-10Mar
	Pagan	Entire Island	5	AM	2	122.315	9:55-10:40	L5	145.706243	18.119417	L15	145.791309	18.066846	7Mar-10Mar
	Pagan	Entire Island	5	AM	2	122.315	9:55-10:40	M5	145.700173	18.109822	M15	145.785238	18.057249	7Mar-10Mar
	Pagan	Entire Island	5	AM	2	122.315	9:55-10:40	N5	145.694105	18.100227	N15	145.779168	18.047652	7Mar-10Mar
	Pagan	Entire Island	5	AM	2	122.315	9:55-10:40	O5	145.688036	18.090632	O15	145.773098	18.038055	7Mar-10Mar
	Pagan	Entire Island	5	AM	2	122.315	9:55-10:40	P5	145.681967	18.081038	P15	145.767028	18.028458	7Mar-10Mar
	Pagan	Entire Island	5	AM	3	127.818333	10:40-10:45	Q5	145.672746	18.080138	Q15	145.753011	18.020494	7Mar-10Mar
	Pagan	Entire Island	5	AM	3	127.818333	10:40-10:45	R7	145.681841	18.059244	R13	145.729999	18.023456	7Mar-10Mar
	Pagan	Entire Island	5	PM	1	236.6675	14:15-15:00	K1	145.830734	18.170459	K19	145.678398	18.074573	7Mar-10Mar
	Pagan	Entire Island	5	PM	1	236.6675	14:15-15:00	L1	145.824496	18.179944	L12	145.731388	18.121368	7Mar-10Mar
	Pagan	Entire Island	5	PM	1	236.6675	14:15-15:00	M1	145.818258	18.189428	M12	145.725149	18.130855	7Mar-10Mar
	Pagan	Entire Island	5	PM	1	236.6675	14:15-15:00	N1	145.81202	18.198913	N12	145.718909	18.140342	7Mar-10Mar
DS5 (1)-PM	Pagan	Entire Island	5	PM	2	246.3375	15:00-16:00	F1	145.862501	18.10593	F19	145.696521	18.036281	7Mar-10Mar
	Pagan	Entire Island	5	PM	2	246.3375	15:00-16:00	G1	145.857945	18.116328	G19	145.691964	18.046682	7Mar-10Mar
	Pagan	Entire Island	5	PM	2	246.3375	15:00-16:00	H1	145.853388	18.126725	H19	145.687406	18.057083	7Mar-10Mar
	Pagan	Entire Island	5	PM	2	246.3375	15:00-16:00	I1	145.848832	18.137123	I19	145.682848	18.067484	7Mar-10Mar
	Pagan	Entire Island	5	PM	2	246.3375	15:00-16:00	J1	145.844276	18.14752	J19	145.678291	18.077885	7Mar-10Mar
	Pagan	Entire Island	5	PM	2	246.3375	15:00-16:00	K1	145.83972	18.157918	K19	145.673733	18.088286	7Mar-10Mar
	Pagan	Entire Island	5	PM	2	246.3375	15:00-16:00	F1	145.862501	18.10593	F19	145.696521	18.036281	7Mar-10Mar
	Pagan	Entire Island	5	PM	2	246.3375	15:00-16:00	G1	145.857945	18.116328	G19	145.691964	18.046682	7Mar-10Mar
	Pagan	Entire Island	5	PM	2	246.3375	15:00-16:00	H1	145.853388	18.126725	H19	145.687406	18.057083	7Mar-10Mar
	Pagan	Entire Island	5	PM	2	246.3375	15:00-16:00	I1	145.848832	18.137123	I19	145.682848	18.067484	7Mar-10Mar
DS5 (2)-PM	Pagan	Entire Island	5	PM	2	246.3375	15:00-16:00	J1	145.844276	18.14752	J19	145.678291	18.077885	7Mar-10Mar
	Pagan	Entire Island	5	PM	2	246.3375	15:00-16:00	K1	145.83972	18.157918	K19	145.673733	18.088286	7Mar-10Mar
	Pagan	Entire Island	5	PM	2	246.3375	15:00-16:00	L1	145.835164	18.168316	L19	145.669176	18.098688	7Mar-10Mar
	Pagan	Entire Island	5	PM	3	251.89125	16:00-16:10	M2	145.827283	18.168684	M12	145.731848	18.138816	7Mar-10Mar
	Pagan	Entire Island	5	PM	3	251.89125	16:00-16:10	N2	145.823754	18.179474	N12	145.728318	18.149608	7Mar-10Mar

PAGAN DAY SET 5 -AM1



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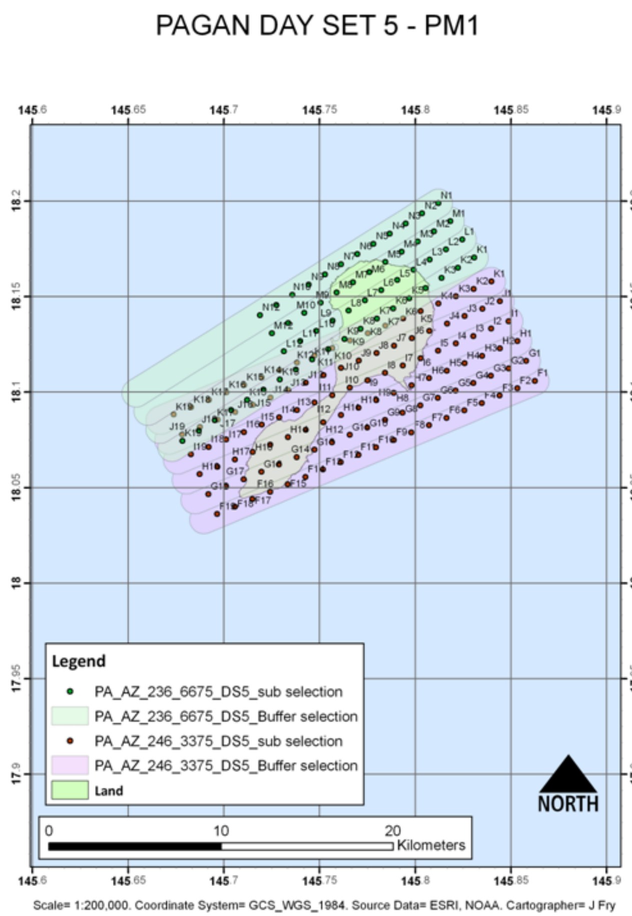
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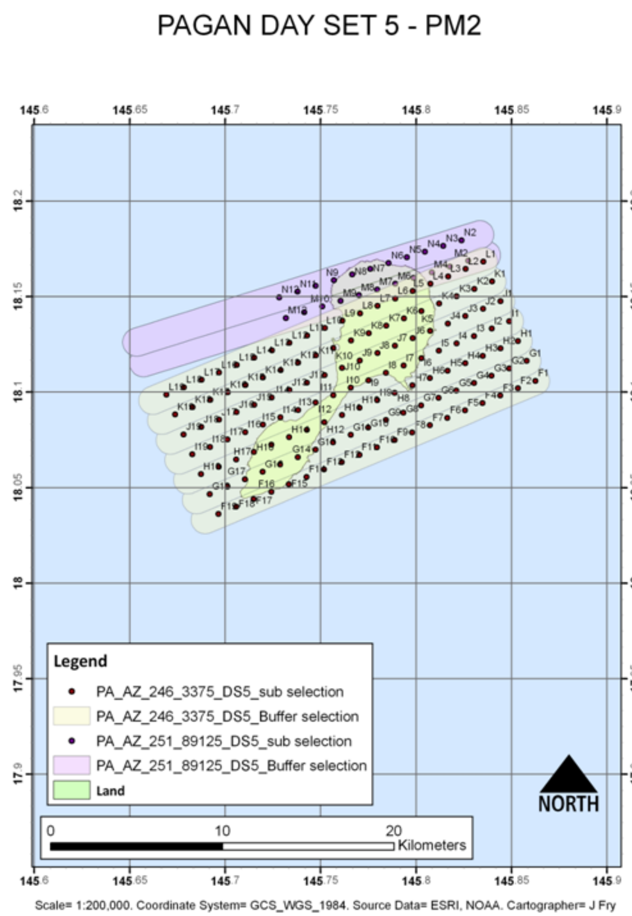
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Kilometers
NORTH
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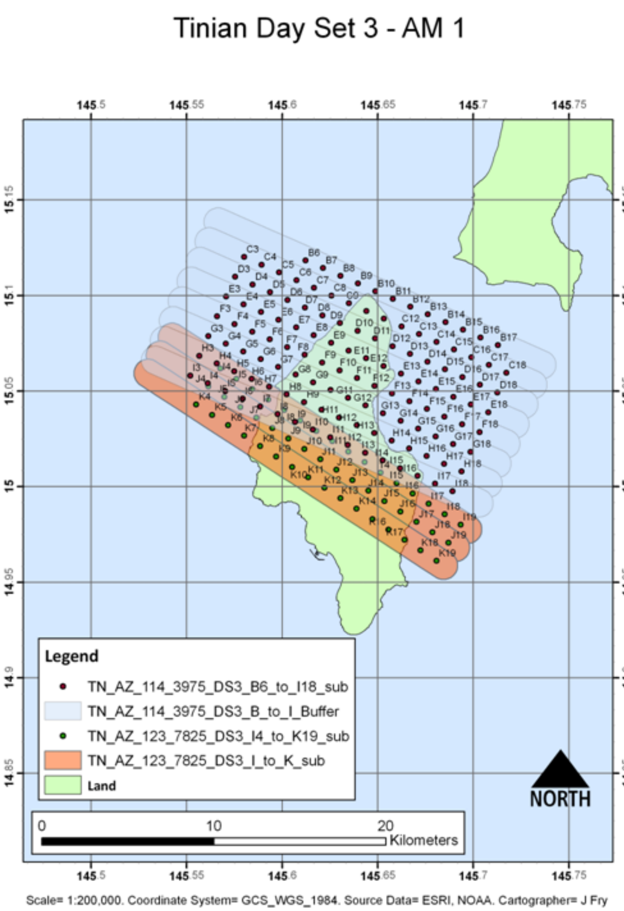
3.3 Tinian

Scenario	Location	Beach	Day Set	Window	SubWindow	Azimuth	Time	Start	Start Long	Start Lat	End	End Long	End Lat	Dates
DS3 (1)-AM	Tinian	Lam Lam, Babui, Dangkolo	3	AM	1	114.3975	8:55-10:05	B6	145.612191	15.118422	B17	145.712832	15.074021	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	1	114.3975	8:55-10:05	C3	145.58005	15.120183	C18	145.71729	15.059641	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	1	114.3975	8:55-10:05	D3	145.575361	15.109844	D18	145.7126	15.0493	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	1	114.3975	8:55-10:05	E3	145.570672	15.099506	E18	145.707909	15.038959	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	1	114.3975	8:55-10:05	F3	145.565983	15.089168	F18	145.703219	15.028618	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	1	114.3975	8:55-10:05	G3	145.561294	15.078828	G18	145.698529	15.018276	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	1	114.3975	8:55-10:05	H3	145.556604	15.06849	H18	145.693838	15.007936	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	1	114.3975	8:55-10:05	I3	145.551914	15.058152	I18	145.689147	14.997595	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	123.7825	10:05-10:45	I4	145.567613	15.061948	I19	145.693336	14.980132	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	123.7825	10:05-10:45	J4	145.5613	15.052512	J19	145.687021	14.970694	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	123.7825	10:05-10:45	K4	145.554988	15.043076	K19	145.680707	14.961256	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	123.7825	10:05-10:45	L4	145.548675	15.03364	L19	145.674393	14.951817	Feb27-Mar2
DS3 (2)-AM	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	123.7825	10:05-10:45	C4	145.605488	15.118563	C18	145.722841	15.042218	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	123.7825	10:05-10:45	D4	145.599176	15.109127	D18	145.716527	15.032781	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	123.7825	10:05-10:45	E4	145.592863	15.099691	E18	145.710212	15.023342	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	123.7825	10:05-10:45	F4	145.58655	15.090255	F18	145.703898	15.013904	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	123.7825	10:05-10:45	G4	145.580238	15.08082	G18	145.697584	15.004466	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	123.7825	10:05-10:45	H4	145.573926	15.071384	H18	145.69127	14.995028	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	123.7825	10:05-10:45	I4	145.567613	15.061948	I18	145.684956	14.985589	Feb27-Mar2
DS3 (1)-PM	Tinian	Lam Lam, Babui, Dangkolo	3	AM	1	235.45875	14:20-15:00	L1	145.673565	15.088562	L16	145.54891	15.005127	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	1	235.45875	14:20-15:00	M1	145.667129	15.097913	M16	145.542472	15.014481	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	1	235.45875	14:20-15:00	N1	145.660692	15.107264	N16	145.536034	15.023834	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	1	235.45875	14:20-15:00	O1	145.654255	15.116614	O16	145.529595	15.033187	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	245.35	15:00-16:05	H1	145.703641	15.035609	H16	145.566668	14.974465	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	245.35	15:00-16:05	I1	145.698906	15.045927	I16	145.561932	14.984785	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	245.35	15:00-16:05	J1	145.694172	15.056245	J16	145.557197	14.995105	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	245.35	15:00-16:05	K1	145.689437	15.066562	K16	145.552461	15.005425	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	245.35	15:00-16:05	L1	145.684702	15.07688	L16	145.547725	15.015745	Feb27-Mar2
	Tinian	Lam Lam, Babui, Dangkolo	3	AM	2	245.35	15:00-16:05	M1	145.679968	15.087197	M16	145.54299	15.026065	Feb27-Mar2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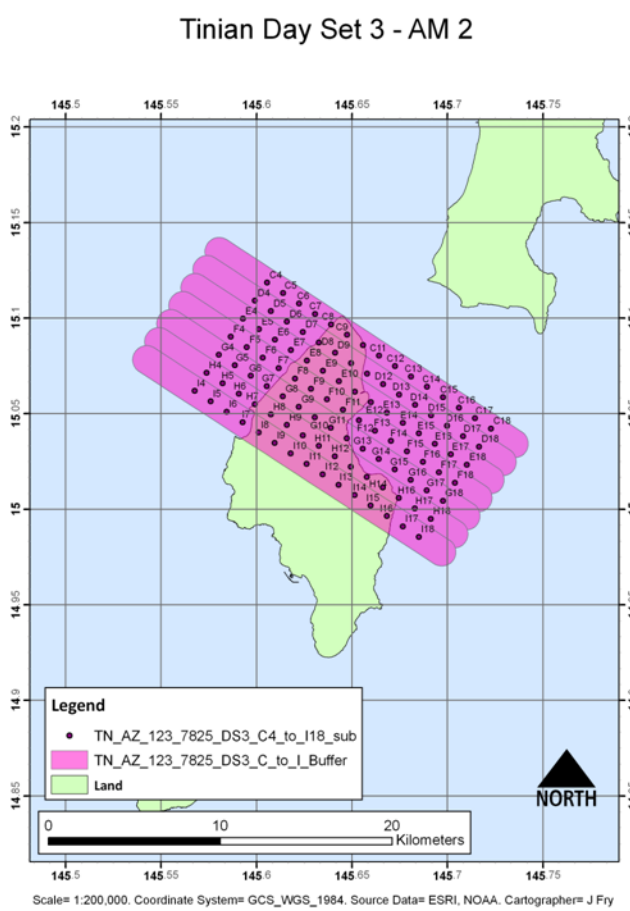
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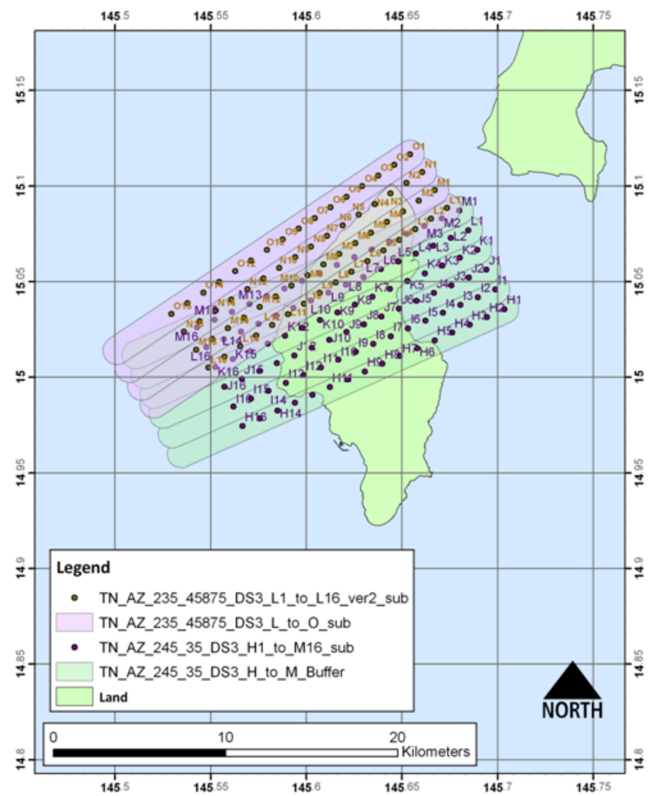
Tinian Day Set 3 - PM1



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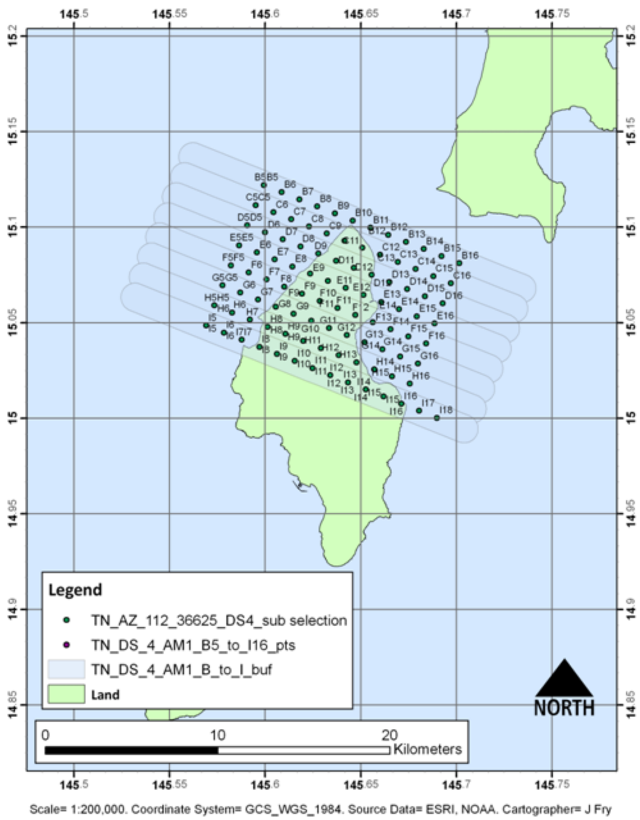
Scenario	Location	Beach	Day Set	Window	SubWindow	Azimuth	Time	Start	Start Long	Start Lat	End	End Long	End Lat	Dates
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	1	112.36625	8:50-10:05	B5	145.599346	15.122059	B16	145.701471	15.081186	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	1	112.36625	8:50-10:05	C5	145.595027	15.11156	C16	145.697151	15.070686	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	1	112.36625	8:50-10:05	D5	145.590706	15.101062	D16	145.69283	15.060186	Mar3-Mar6
DS4 (1)-AM	Tinian	Lam Lam, Babui, Dangkolo	4	AM	1	112.36625	8:50-10:05	E5	145.586386	15.090563	E16	145.688509	15.049685	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	1	112.36625	8:50-10:05	F5	145.582066	15.080064	F16	145.684188	15.039185	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	1	112.36625	8:50-10:05	G5	145.577747	15.069566	G16	145.679868	15.028684	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	1	112.36625	8:50-10:05	H5	145.573426	15.059067	H16	145.675547	15.018184	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	1	112.36625	8:50-10:05	I5	145.569106	15.048568	I18	145.689791	15.000244	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	1	112.36625	8:50-10:00	B5	145.599346	15.122059	B16	145.701471	15.081186	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	1	112.36625	8:50-10:00	C5	145.595027	15.11156	C16	145.697151	15.070686	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	1	112.36625	8:50-10:00	D5	145.590706	15.101062	D16	145.69283	15.060186	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	1	112.36625	8:50-10:00	E5	145.586386	15.090563	E16	145.688509	15.049685	Mar3-Mar6
DS4 (2)-AM	Tinian	Lam Lam, Babui, Dangkolo	4	AM	2	121.24625	10:00-10:40	E4	145.589274	15.098766	E15	145.684014	15.042871	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	2	121.24625	10:00-10:40	F4	145.583386	15.089061	F15	145.678125	15.033164	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	2	121.24625	10:00-10:40	G4	145.577496	15.079354	G15	145.672235	15.023455	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	2	121.24625	10:00-10:40	H4	145.571608	15.069649	H18	145.692177	14.998493	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	AM	2	121.24625	10:00-10:40	I4	145.565719	15.059943	I18	145.686287	14.988786	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	1	238.43325	14:25-15:10	K1	145.6831	15.07554	K16	145.554289	14.998676	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	1	238.43325	14:25-15:10	L1	145.677163	15.085216	L16	145.548351	15.008355	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	1	238.43325	14:25-15:10	M1	145.671226	15.094891	M16	145.542412	15.018033	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	1	238.43325	14:25-15:10	N1	145.665288	15.104567	N16	145.536473	15.027711	Mar3-Mar6
DS4 (1)-PM	Tinian	Lam Lam, Babui, Dangkolo	4	PM	1	238.43325	14:25-15:10	O1	145.659351	15.114243	O16	145.530534	15.03739	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	2	248.5475	15:10-16:15	G1	145.708611	15.019885	G17	145.559162	14.962744	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	2	248.5475	15:10-16:15	H1	145.704459	15.030451	H17	145.555009	14.973312	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	2	248.5475	15:10-16:15	I1	145.700308	15.041016	I17	145.550857	14.983879	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	2	248.5475	15:10-16:15	J1	145.696156	15.051582	J17	145.546704	14.994448	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	2	248.5475	15:10-16:15	K1	145.692004	15.062147	K17	145.542551	15.005015	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	2	248.5475	15:10-16:15	H1	145.704459	15.030451	H16	145.564348	14.976886	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	2	248.5475	15:10-16:15	I1	145.700308	15.041016	I16	145.560196	14.987454	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	2	248.5475	15:10-16:15	J1	145.696156	15.051582	J16	145.556043	14.998022	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	2	248.5475	15:10-16:15	K1	145.692004	15.062147	K16	145.551891	15.008589	Mar3-Mar6
DS4 (2)-PM	Tinian	Lam Lam, Babui, Dangkolo	4	PM	2	248.5475	15:10-16:15	L1	145.687852	15.072713	L16	145.547738	15.019158	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	2	248.5475	15:10-16:15	M1	145.683701	15.083278	M16	145.543586	15.029725	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	2	248.5475	15:10-16:15	N1	145.679549	15.093844	N16	145.539433	15.040293	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	2	248.5475	15:10-16:15	O1	145.675397	15.104409	O16	145.53528	15.050861	Mar3-Mar6
	Tinian	Lam Lam, Babui, Dangkolo	4	PM	2	248.5475	15:10-16:15	P1	145.671245	15.114975	P8	145.605852	15.089999	Mar3-Mar6

TINIAN DAY SET 4 - AM1



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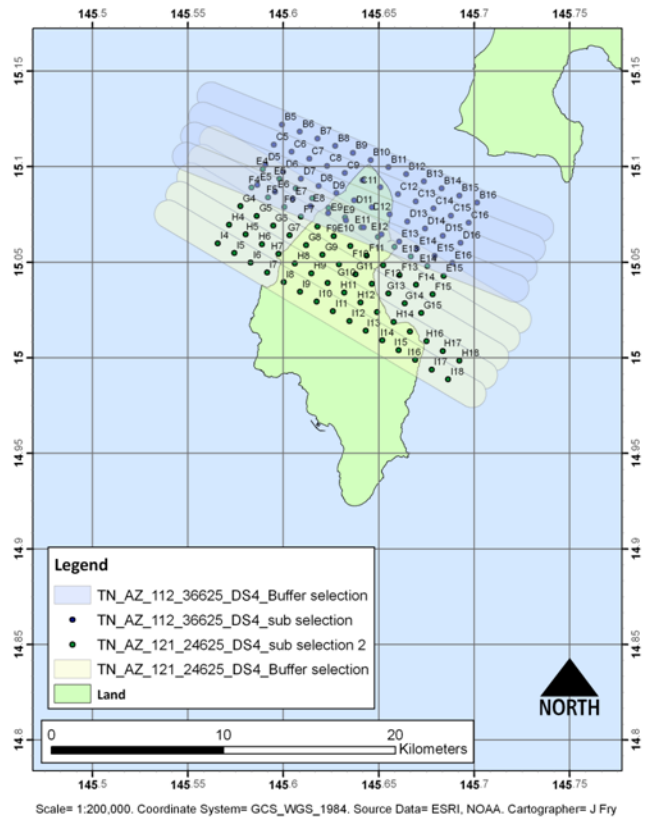

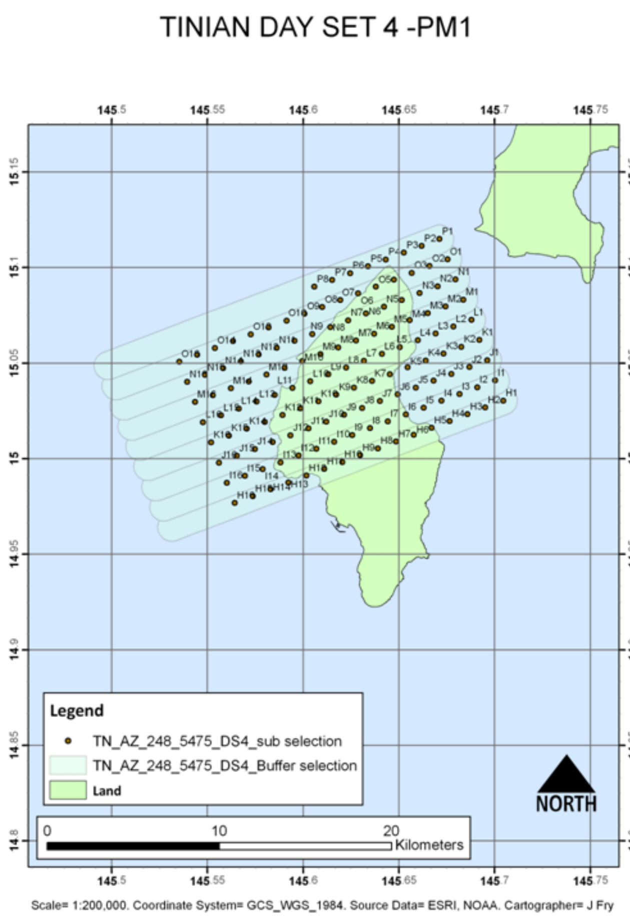
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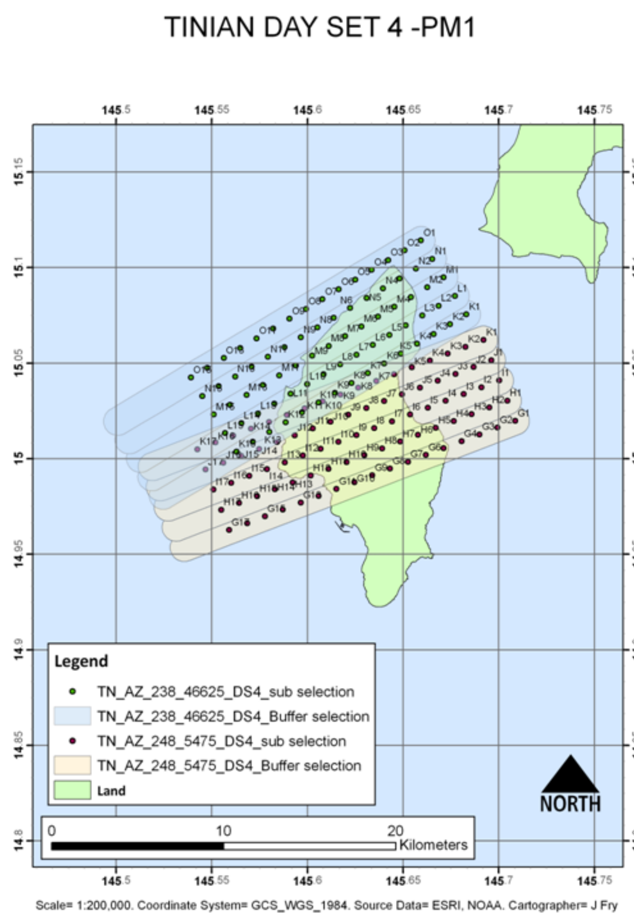
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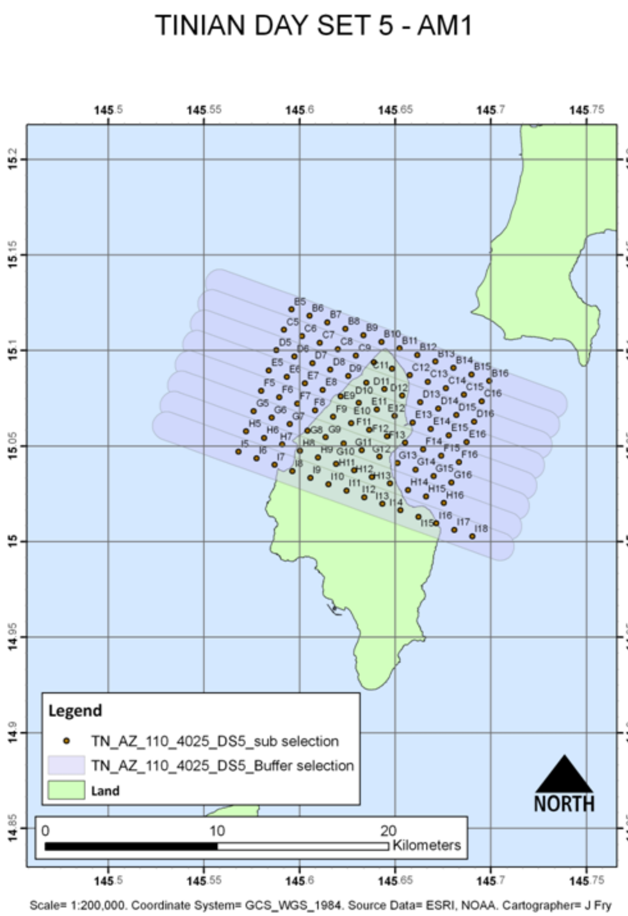
Scenario	Location	Beach	Day Set	Window	SubWindow	Azimuth	Time	Start	Start Long	Start Lat	End	End Long	End Lat	Dates
DS5 (1)-AM	Tinian	Lam Lam, Babui, Dangkolo	5	AM	1	110.4025	8:45-10:00	B5	145.59579	15.12155	B16	145.699228	15.084126	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	1	110.4025	8:45-10:00	C5	145.591833	15.110909	C16	145.69527	15.073483	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	1	110.4025	8:45-10:00	D5	145.587875	15.100269	D16	145.691311	15.062841	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	1	110.4025	8:45-10:00	E5	145.583917	15.089628	E16	145.687354	15.052199	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	1	110.4025	8:45-10:00	F5	145.579959	15.078988	F16	145.683395	15.041557	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	1	110.4025	8:45-10:00	G5	145.576002	15.068348	G16	145.679437	15.030915	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	1	110.4025	8:45-10:00	H5	145.572045	15.057707	H16	145.675479	15.020273	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	1	110.4025	8:45-10:00	I5	145.568087	15.047067	I18	145.690324	15.002818	Mar7-Mar10
DS5 (2)-AM	Tinian	Lam Lam, Babui, Dangkolo	5	AM	1	110.4025	8:45-10:00	B5	145.59579	15.12155	B16	145.699228	15.084126	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	1	110.4025	8:45-10:00	C5	145.591833	15.110909	C16	145.69527	15.073483	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	1	110.4025	8:45-10:00	D5	145.587875	15.100269	D16	145.691311	15.062841	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	1	110.4025	8:45-10:00	E5	145.583917	15.089628	E16	145.687354	15.052199	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	2	118.58	10:00-10:35	E5	145.594387	15.092942	E16	145.691587	15.041443	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	2	118.58	10:00-10:35	F5	145.588955	15.082973	F16	145.686155	15.031472	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	2	118.58	10:00-10:35	G5	145.583524	15.073003	G16	145.680722	15.0215	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	2	118.58	10:00-10:35	H5	145.578094	15.063033	H19	145.701794	14.997473	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	AM	2	118.58	10:00-10:35	I5	145.572662	15.053064	I19	145.696362	14.987501	Mar7-Mar10
DS5 (1)-PM	Tinian	Lam Lam, Babui, Dangkolo	5	PM	1	242.82375	14:30-15:20	J1	145.692422	15.059846	J16	145.558222	14.992834	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	1	242.82375	14:30-15:20	K1	145.687237	15.069945	K16	145.553036	15.002936	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	1	242.82375	14:30-15:20	L1	145.682052	15.080043	L16	145.54785	15.013036	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	1	242.82375	14:30-15:20	M1	145.676868	15.090142	M16	145.542664	15.023138	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	1	242.82375	14:30-15:20	N1	145.671683	15.100241	N16	145.537478	15.033239	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	1	242.82375	14:30-15:20	O1	145.666498	15.11034	O16	145.532292	15.043341	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	2	251.1425	15:20-16:15	H1	145.704911	15.026235	H16	145.562565	14.978929	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	2	251.1425	15:20-16:15	I1	145.701242	15.036978	I16	145.558896	14.989674	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	2	251.1425	15:20-16:15	J1	145.697573	15.047721	J16	145.555226	15.000419	Mar7-Mar10
DS5 (2)-PM	Tinian	Lam Lam, Babui, Dangkolo	5	PM	2	251.1425	15:20-16:15	I1	145.701242	15.036978	I16	145.558896	14.989674	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	2	251.1425	15:20-16:15	J1	145.697573	15.047721	J16	145.555226	15.000419	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	2	251.1425	15:20-16:15	K1	145.693904	15.058463	K16	145.551556	15.011163	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	2	251.1425	15:20-16:15	L1	145.690235	15.069206	L16	145.547886	15.021908	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	2	251.1425	15:20-16:15	M1	145.686566	15.079949	M16	145.544217	15.032654	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	2	251.1425	15:20-16:15	N1	145.682896	15.090691	N13	145.569013	15.052864	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	2	251.1425	15:20-16:15	O1	145.679227	15.101434	O12	145.574833	15.066763	Mar7-Mar10
	Tinian	Lam Lam, Babui, Dangkolo	5	PM	2	251.1425	15:20-16:15	P1	145.675558	15.112177	P8	145.609123	15.090121	Mar7-Mar10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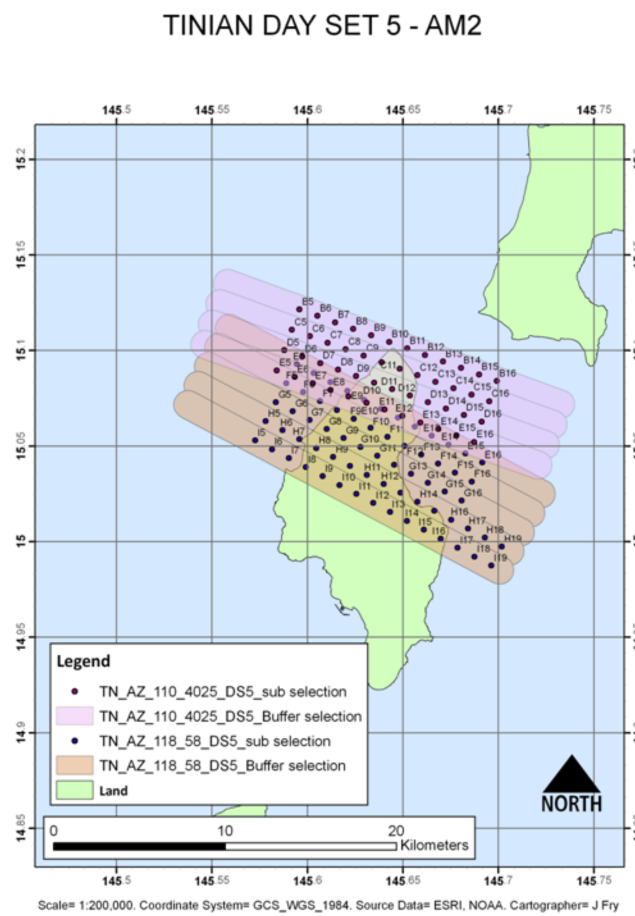
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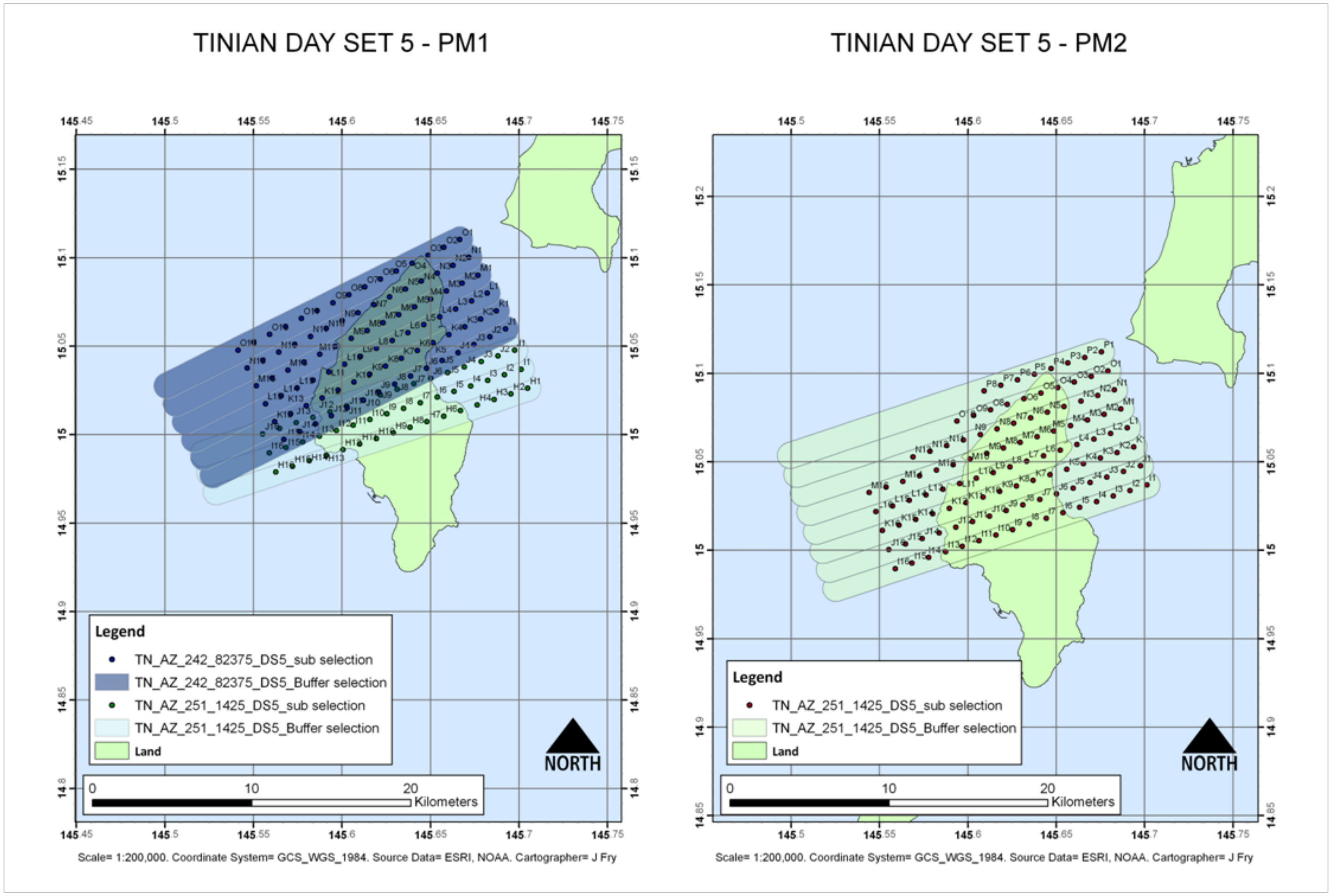
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Land
NORTH
0 10 20 Kilometers
Scale= 1:200,000. Coordinate System= GCS_WGS_1984. Source Data= ESRI, NOAA. Cartographer= J Fry

APPENDIX C

Quicklook Imagery

1 Introduction

Quicklook Imagery taken during MI-HARES'10 are georectified images that show the extent of the HSI. Programs such as ArcMap and ArcGIS Explorer cannot fully utilize the capabilities of HSI like ENVI can, so quicklook images are developed for rapid viewing of the flight line's position, image quality, and the presence of clouds. The quicklook images are RGB images (with Red, Green, and Blue components) which are easily displayed using JPEG or TIFF formats.

For the majority of the data collections, the sensor was flown into and out of the sun to ensure uniform illumination across the sensor array. Times of day were chosen to minimize glint (solar zenith angle between 35-55 degrees in most instances) from water surfaces and also to capture the study area at different tidal stages. Appendix B elaborates on the planning and development of flight line scenarios.

2 Acquired Imagery

HyMap imagery was acquired from 3 to 4 March and from 7 through 11 March, 2010. Scientists involved in the aerial survey operated out of Tinian. The land-based research team was stationed on Pagan from 25 February until 3 March, and on the morning of March 3, there was an acquisition of calibration panels sited on the grass runway of the Pagan airfield. Attempts were made to fly Pagan and other islands on earlier dates, but target areas were obscured by clouds. A total of 89 lines of HyMap imagery were acquired and this includes test lines, non-planned lines, and planned flight lines. Of the 89 lines, Guam was covered in eight, Pagan was covered in 40, and Tinian was covered in 18. The percentage of cloud coverage and overall image quality varies among the images. All collected images were provided by the HyVista Corporation. Other sensors, including the NRL microSHINE were also flown for a subset of the days. Table C - 1 lists all HyMAP flight lines with folder name (HyVista designated folder), filename, acquisition date, center line time, flight line day set (a grouping of 4- day periods (see Appendix B)), island of coverage, percent cloud coverage, cloud cover over target area, overall image quality, and any comments concerning the imagery.

Table C - 1. Acquired HyMap imagery.

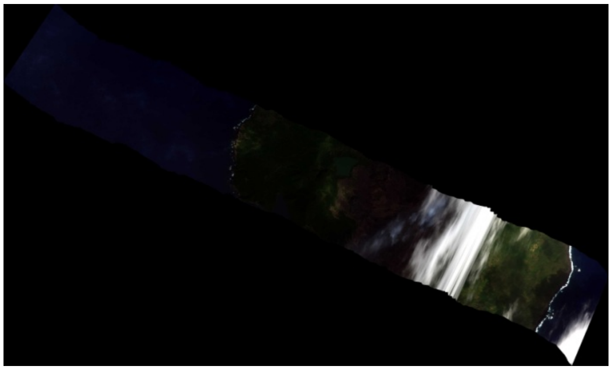
Folder Name/Subset	Filename	Date of Acquisition (Chamorro Standard Time, UTC+10)	Time of Centerline Acquisition (Chamorro Standard Time, UTC+10)	Flightline Day Set	Island	Very Approximate Cloud Coverage in Scene	Cloud Coverage of Study Area (Study Beaches/study fields)	Overall Quality
T1	pagan_04	03-Mar-10	10:13	3	Pagan	25%	Partial	Great
T1	pagan_05	03-Mar-10	10:06	3	Pagan	0%	No	Good
T1	pagan_06	03-Mar-10	9:58	3	Pagan	25%	Partial	Good
T1	pagan_07	03-Mar-10	9:50	3	Pagan	25%	N/A	Great
T1	pagan_08	03-Mar-10	9:35	3	Pagan	25%	N/A	Great
T1	pagan_09	03-Mar-10	9:41	3	Pagan	50%	N/A	Fair
T2	test	04-Mar-10	-	3	N/A	0%	N/A	Poor
T2	tinian_ds3_1_am_01	04-Mar-10	9:25	3	Tinian	25%	N/A	Poor
T2	tinian_ds3_1_am_01b	04-Mar-10	11:11	3	Tinian	25%	N/A	Poor
T2	tinian_ds3_1_am_02	04-Mar-10	11:03	3	Tinian	25%	N/A	Poor
T2	tinian_ds3_1_am_03	04-Mar-10	10:54	3	Tinian	25%	Partial	Fair
T2	tinian_ds3_1_am_04	04-Mar-10	10:45	3	Tinian	25%	Yes	Fair
T2	tinian_ds3_1_am_05	04-Mar-10	10:36	3	Tinian	0%	No	Good
T2	tinian_ds3_1_am_06	04-Mar-10	10:27	3	Tinian	50%	Yes	Fair
T2	tinian_ds3_1_am_07	04-Mar-10	10:18	3	Tinian	25%	No	Good
T2	tinian_ds3_1_am_08	04-Mar-10	10:10	3	Tinian	25%	N/A	Fair
T2	tinian_ds3_1_am_09	04-Mar-10	10:01	3	Tinian	25%	N/A	Fair
T2	tinian_ds3_1_am_10	04-Mar-10	9:52	3	Tinian	25%	N/A	Fair
T2	tinian_ds3_1_am_11	04-Mar-10	9:43	3	Tinian	0%	N/A	Good
T2	tinian_ds3_1_am_12	04-Mar-10	9:35	3	Tinian	0%	No	Good
T3	island_hvc_a	04-Mar-10	-	3	Anatahan	0%	N/A	Great
T3	island_hvc_b	04-Mar-10	-	3	Anatahan	75%	N/A	Bad

T3	pagan_ds3_2_pm_01	04-Mar-10	14:23	3	Pagan	50%	No	Fair
T3	pagan_ds3_2_pm_02	04-Mar-10	14:33	3	Pagan	50%	Partial	Fair
T3	pagan_ds3_2_pm_03	04-Mar-10	14:42	3	Pagan	75%	N/A	Bad
T3	test	04-Mar-10	-	3	N/A	50%	N/A	Bad
T4	coast_r01	07-Mar-10	11:24	5	Pagan	50%	Yes	Fair
T4	coast_r02	07-Mar-10	11:33	5	Pagan	50%	N/A	Fair
T4	pagan_ds3_1_am_03	07-Mar-10	11:03	5	Pagan	25%	N/A	Good
T4	pagan_ds3_1_am_04	07-Mar-10	10:01	5	Pagan	25%	N/A	Fair
T4	pagan_ds3_1_am_04b	07-Mar-10	10:55	5	Pagan	25%	N/A	Fair
T4	pagan_ds3_1_am_05	07-Mar-10	9:54	5	Pagan	25%	Yes	Fair
T4	pagan_ds3_1_am_05b	07-Mar-10	10:49	5	Pagan	25%	No	Good
T4	pagan_ds3_1_am_05c	07-Mar-10	11:09	5	Pagan	25%	No	Good
T4	pagan_ds3_1_am_06	07-Mar-10	9:47	5	Pagan	25%	Partial	Fair
T4	pagan_ds3_1_am_06b	07-Mar-10	10:42	5	Pagan	50%	Yes	Bad
T4	pagan_ds3_1_am_06c	07-Mar-10	11:16	5	Pagan	25%	Partial	Fair
T4	pagan_ds3_1_am_07	07-Mar-10	9:40	5	Pagan	50%	N/A	Fair
T4	pagan_ds3_1_am_07b	07-Mar-10	10:35	5	Pagan	75%	N/A	Poor
T4	pagan_ds3_1_am_08	07-Mar-10	9:33	5	Pagan	50%	N/A	Poor
T4	pagan_ds3_1_am_08b	07-Mar-10	10:23	5	Pagan	75%	N/A	Bad
T4	pagan_ds3_1_am_09	07-Mar-10	9:26	5	Pagan	25%	N/A	Bad
T4	pagan_ds3_1_am_09b	07-Mar-10	10:16	5	Pagan	25%	N/A	Fair
T4	pagan_ds3_1_am_10	07-Mar-10	10:09	5	Pagan	50%	N/A	Poor
T4	test	07-Mar-10	-	5	N/A	50%	N/A	Bad
T5	island_01	08-Mar-10	-	5	Anatahan	50%	N/A	Fair
T5	pagan_ds3_1_am_04	08-Mar-10	10:33	5	Pagan	50%	N/A	Poor
T5	pagan_ds3_1_am_04b	08-Mar-10	10:54	5	Pagan	25%	N/A	Good
T5	pagan_ds3_1_am_05	08-Mar-10	10:26	5	Pagan	50%	Partial	Fair
T5	pagan_ds3_1_am_05b	08-Mar-10	11:02	5	Pagan	50%	Yes	Bad
T5	pagan_ds3_1_am_06	08-Mar-10	10:19	5	Pagan	25%	Partial	Fair
T5	pagan_ds3_1_am_06b	08-Mar-10	11:09	5	Pagan	25%	Partial	Fair
T5	pagan_ds3_1_am_07	08-Mar-10	10:12	5	Pagan	50%	N/A	Bad
T5	pagan_ds3_1_am_07b	08-Mar-10	10:48	5	Pagan	50%	N/A	Fair

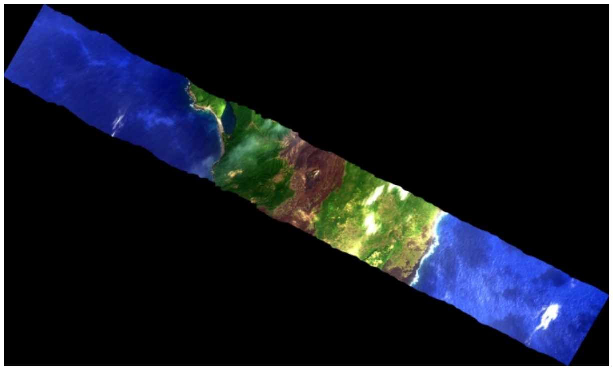
T5	pagan_ds3_1_am_08	08-Mar-10	10:05	5	Pagan	25%	N/A	Fair
T5	pagan_ds3_1_am_09	08-Mar-10	9:58	5	Pagan	25%	N/A	Fair
T5	pagan_ds3_1_am_10	08-Mar-10	10:40	5	Pagan	25%	N/A	Bad
T6	guam_ds3_1_am_01	09-Mar-10		5	Guam	25%	Partial	Good
T6	guam_ds3_1_am_02	09-Mar-10		5	Guam	50%	Yes	Poor
T6	guam_ds3_1_am_02b	09-Mar-10		5	Guam	50%	Partial	Fair
T6	guam_ds3_1_am_03	09-Mar-10		5	Guam	50%	N/A	Poor
T6	guam_ds3_1_am_03b	09-Mar-10		5	Guam	50%	N/A	Fair
T6	guam_ds3_1_am_03c	09-Mar-10		5	Guam	25%	N/A	Fair
T6	hvc_tst	09-Mar-10	-	5	N/A	25%	N/A	Good
T6	test	09-Mar-10	-	5	N/A	50%	N/A	Bad
T7	guam_ds3_2_pm_01	09-Mar-10		5	Guam	50%	Yes	Poor
T7	guam_ds3_2_pm_01b	09-Mar-10		5	Guam	25%	Partial	Good
T7	guam_ds3_2_pm_02	09-Mar-10		5	Guam	25%	Partial	Good
T7	guam_ds3_2_pm_02b	09-Mar-10		5	Guam	25%	Partial	Fair
T7	guam_ds3_2_pm_03	09-Mar-10		5	Guam	0%	No	Great
T7	guam_ds3_2_pm_04	09-Mar-10		5	Guam	50%	N/A	Fair
T7	nrl_rnd	09-Mar-10	-	5	Guam	25%	Partial	Good
T7	reef	09-Mar-10	15:34	5	Guam	25%	N/A	Good
T8	test	10-Mar-10	-	5	N/A	75%	N/A	Bad
T8	tinian_ds3_1_am_03	10-Mar-10	10:23	5	Tinian	25%	No	Good
T8	tinian_ds3_1_am_04	10-Mar-10	10:31	5	Tinian	25%	No	Good
T8	tinian_ds3_1_am_04b	10-Mar-10	11:06	5	Tinian	25%	No	Good
T8	tinian_ds3_1_am_05	10-Mar-10	10:40	5	Tinian	50%	N/A	Poor
T8	tinian_ds3_1_am_05b	10-Mar-10	10:49	5	Tinian	50%	N/A	Poor
T8	tinian_ds3_1_am_05c	10-Mar-10	10:58	5	Tinian	25%	N/A	Poor
T9	pagan_ds3_1_am_02	11-Mar-10	10:31	5	Pagan	25%	N/A	Fair
T9	pagan_ds3_1_am_06	11-Mar-10	10:00	5	Pagan	25%	Partial	Good
T9	pagan_ds3_1_am_06b	11-Mar-10	10:08	5	Pagan	25%	Partial	Fair
T9	pagan_ds3_1_am_07	11-Mar-10	9:53	5	Pagan	25%	N/A	Good
T9	pagan_ds3_1_am_11	11-Mar-10	10:21	5	Pagan	50%	N/A	Bad
T9	pagan_ds3_1_am_12	11-Mar-10	10:15	5	Pagan	50%	N/A	Bad

T9	pagan_ds3_1_am_13	11-Mar-10	9:47	5	Pagan	50%	N/A	Poor
T9	pagan_ds3_1_am_14	11-Mar-10	9:40	5	Pagan	25%	N/A	Poor
T9	pagan_ds3_1_am_15	11-Mar-10	9:33	5	Pagan	25%	N/A	Fair

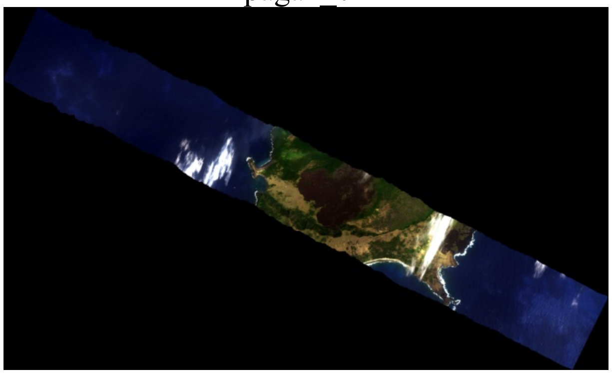
2.1 T1 Subset



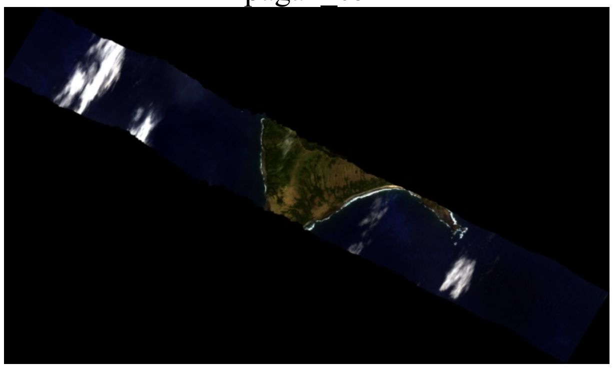
pagan_04



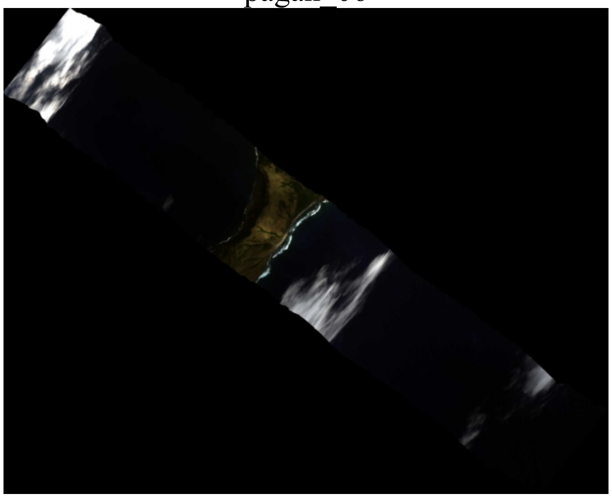
pagan_05



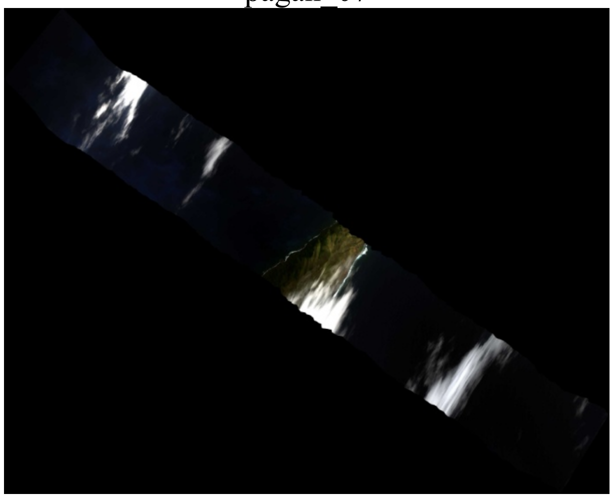
pagan_06



pagan_07

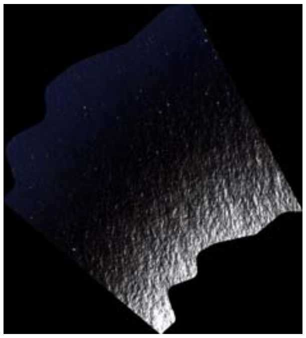


pagan_08

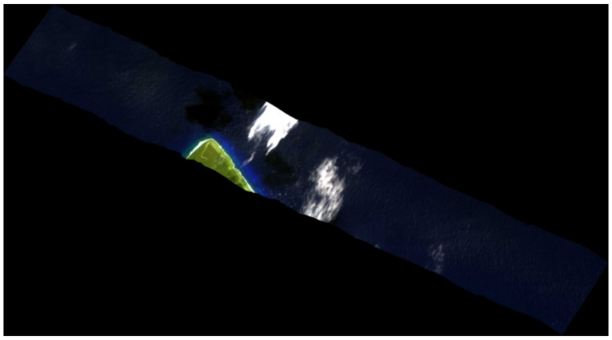


pagan_09

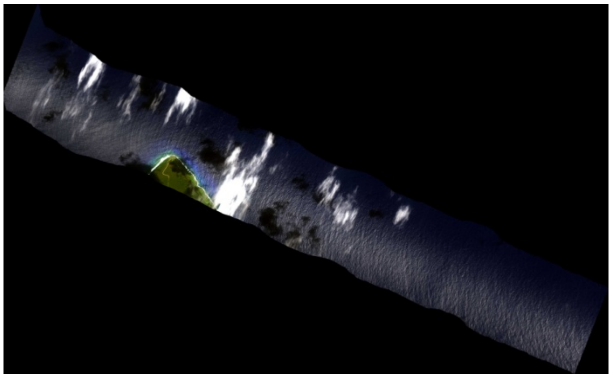
2.2 T2 Subset



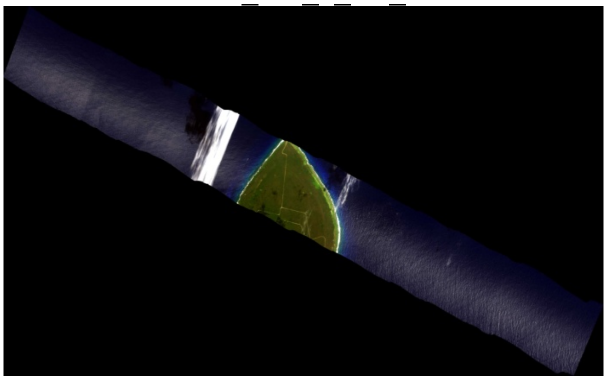
test



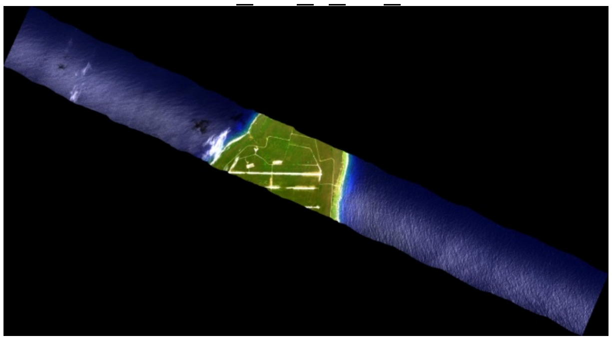
tinian_ds3_1_am_01



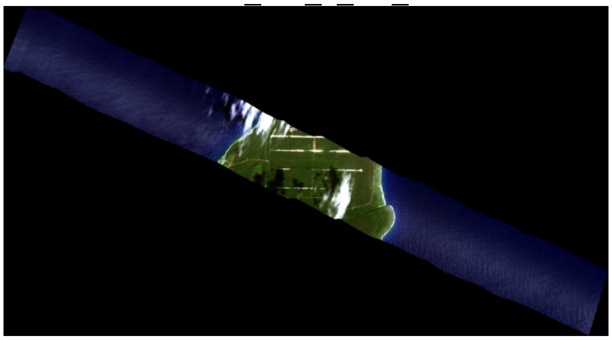
tinian_ds3_1_am_01b



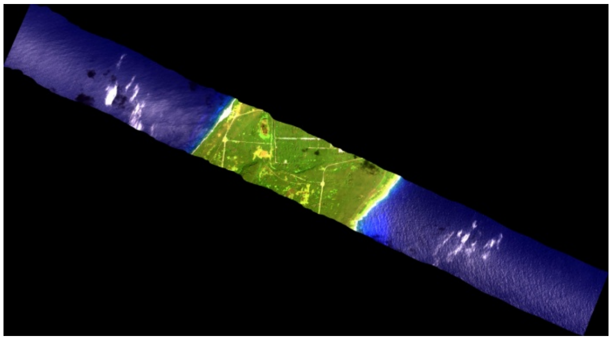
tinian_ds3_1_am_02



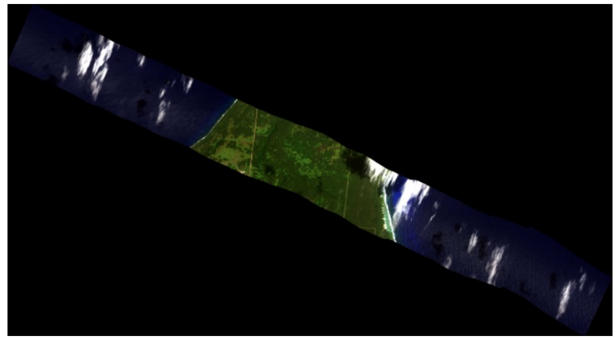
tinian_ds3_1_am_03



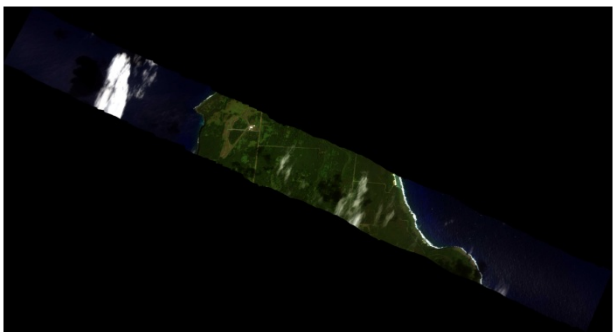
tinian_ds3_1_am_04



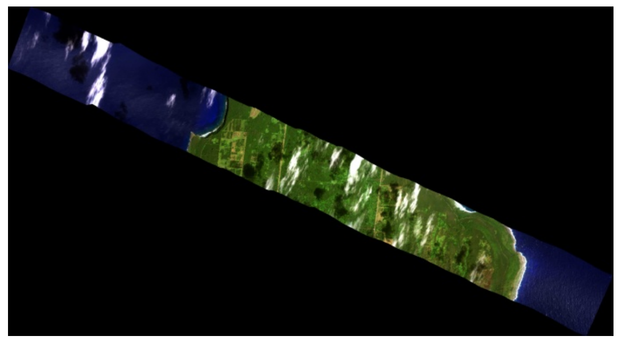
tinian_ds3_1_am_05



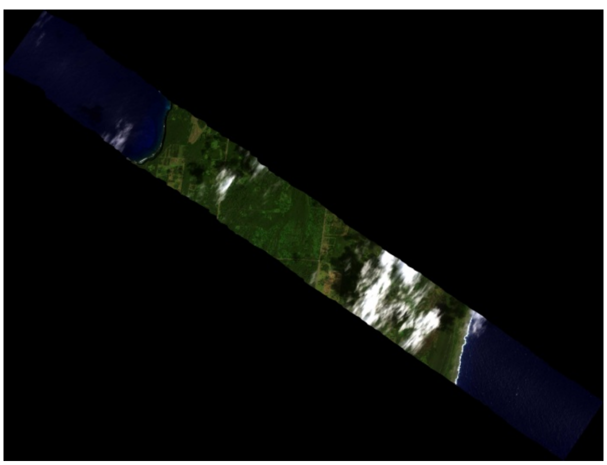
tinian_ds3_1_am_06



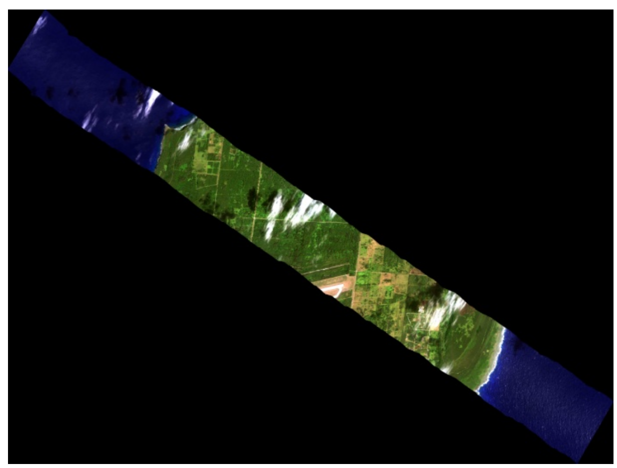
tinian_ds3_1_am_07



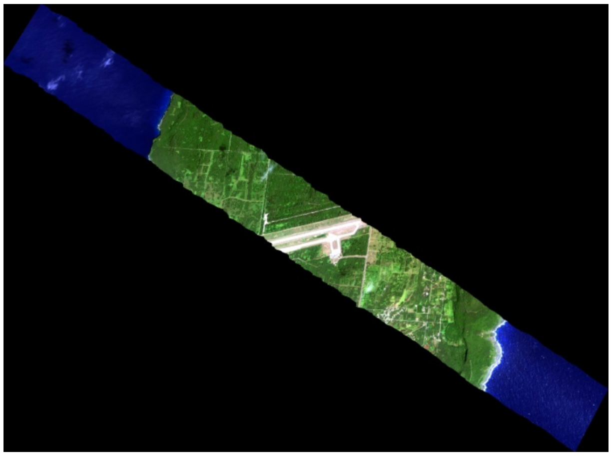
tinian_ds3_1_am_08



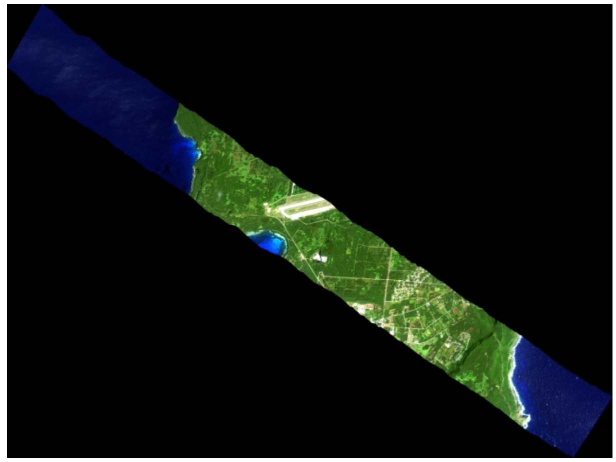
tinian_ds3_1_am_09



tinian_ds3_1_am_10



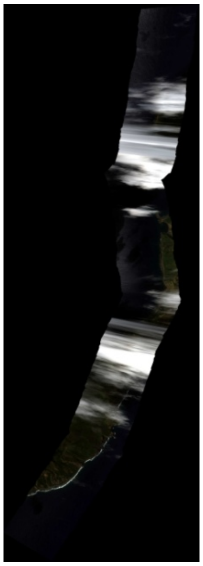
tinian_ds3_1_am_11



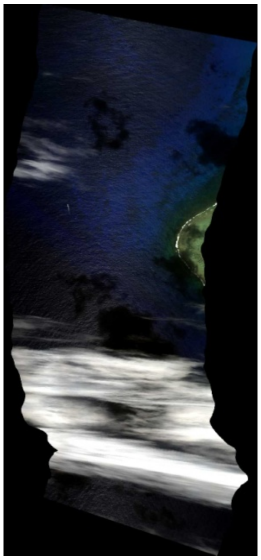
tinian_ds3_1_am_12

2.3 T3 Subset

island_hvc_a (Anatahan)

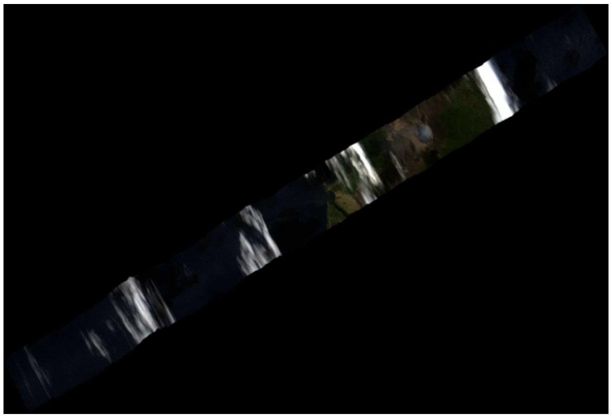


island_hvc_b (Pagan)

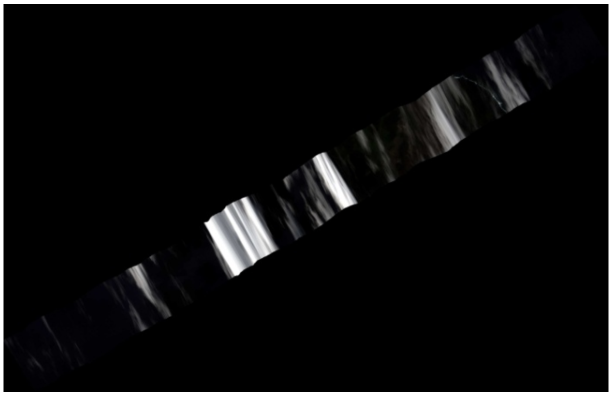


test (Saipan)

pagan_ds3_2_pm_01



pagan_ds3_2_pm_02

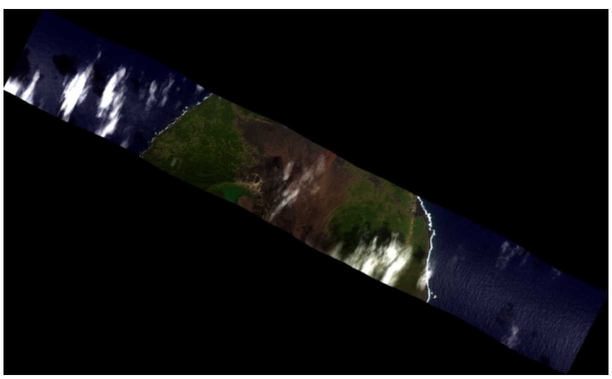


pagan_ds3_2_pm_03

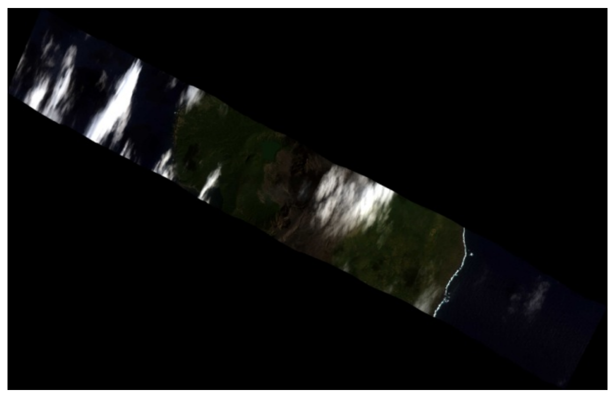
2.4 T4 Subset

coast_r01 (Pagan)

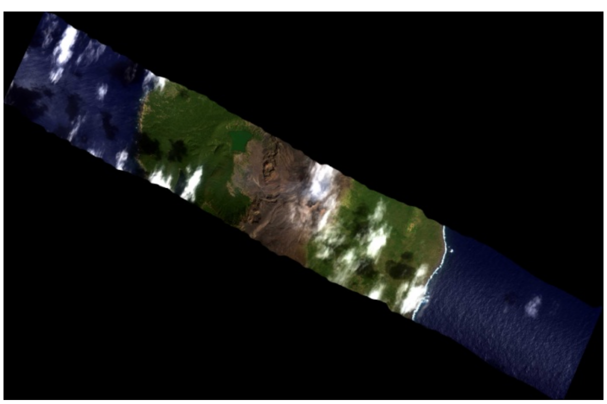
coast_r02 (Pagan)



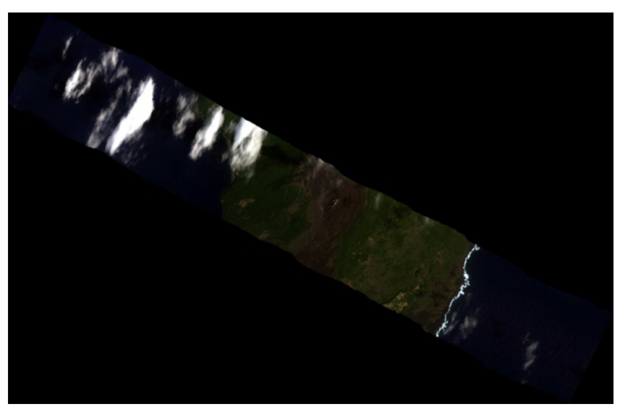
pagan_ds3_1_am_03



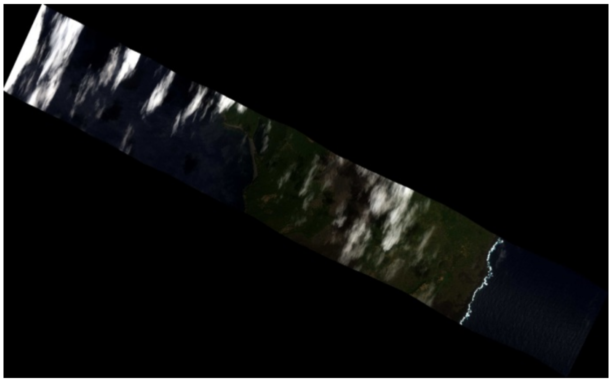
pagan_ds3_1_am_04



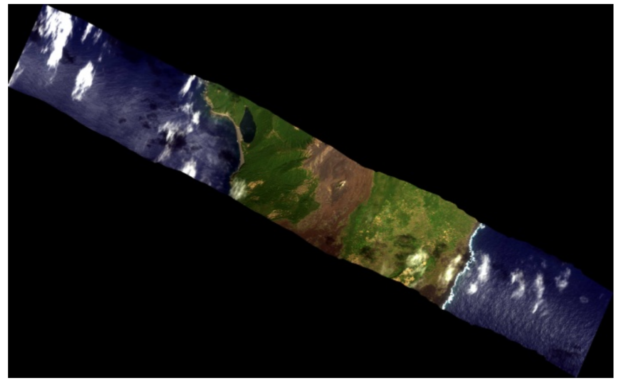
pagan_ds3_1_am_04b



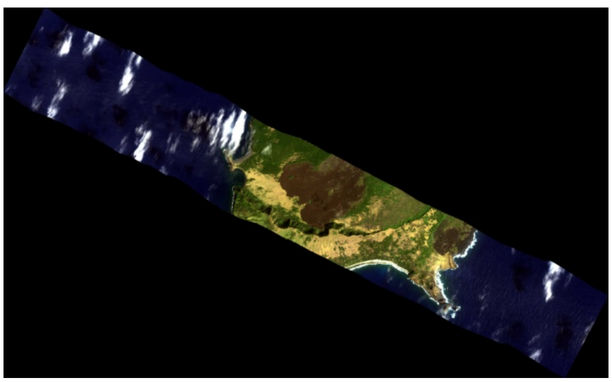
pagan_ds3_1_am_05



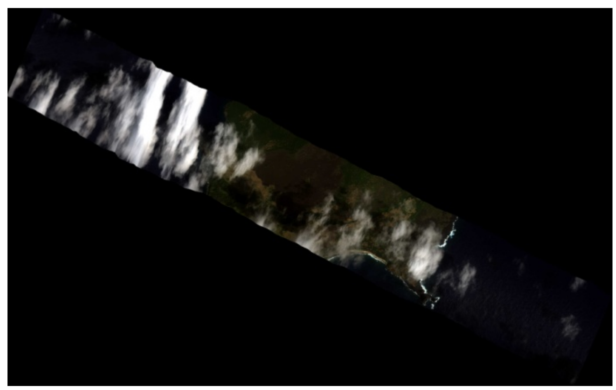
pagan_ds3_1_am_05b



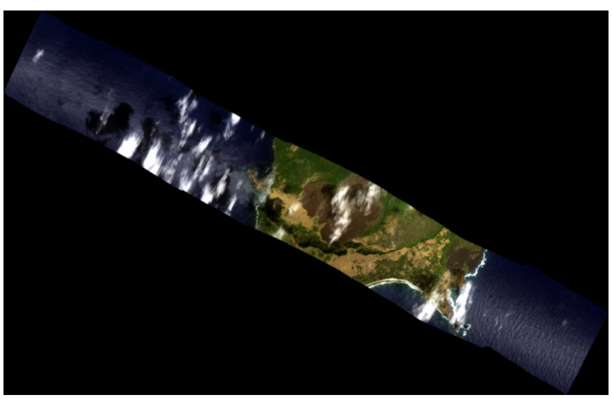
pagan_ds3_1_am_05c



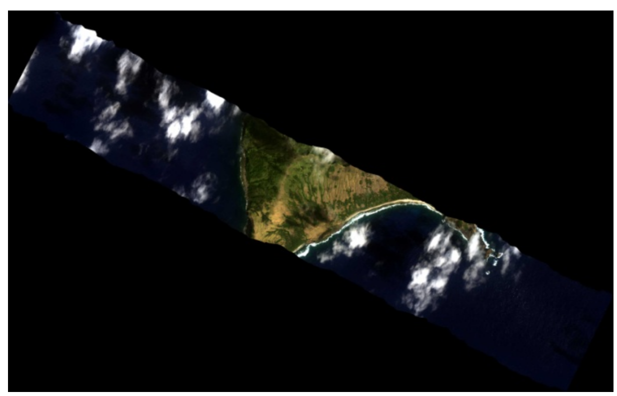
pagan_ds3_1_am_06



pagan_ds3_1_am_06b

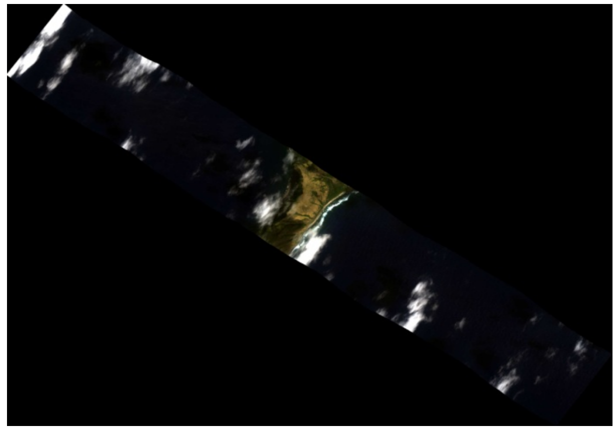


pagan_ds3_1_am_06c

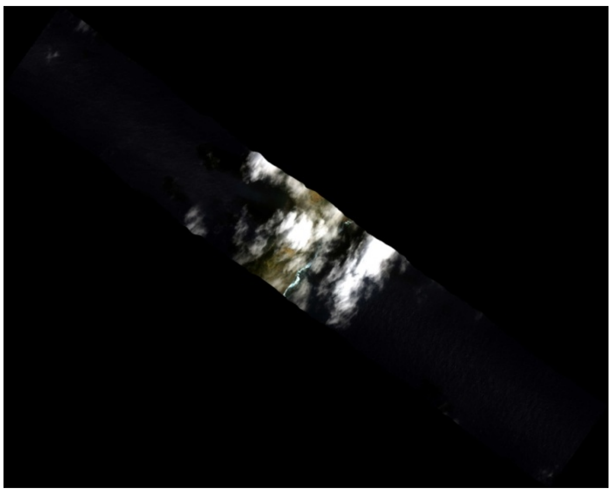


pagan_ds3_1_am_07

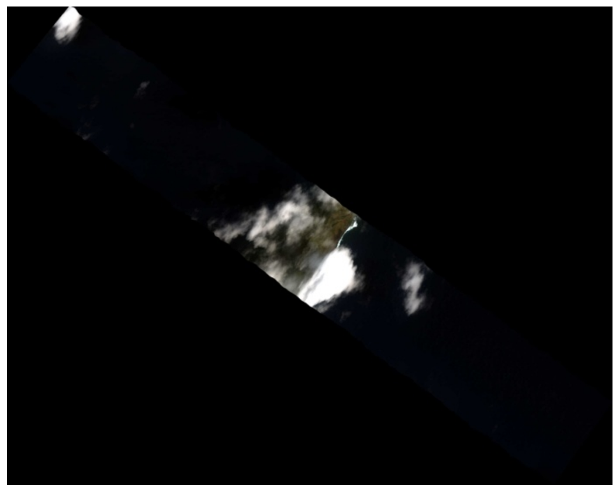
pagan_ds3_1_am_07b



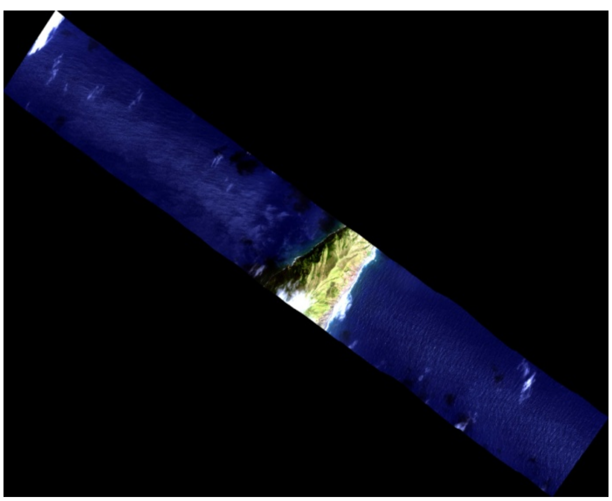
pagan_ds3_1_am_08



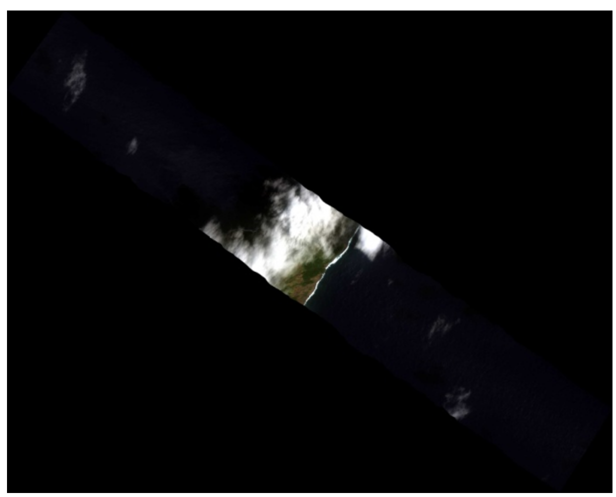
pagan_ds3_1_am_08b



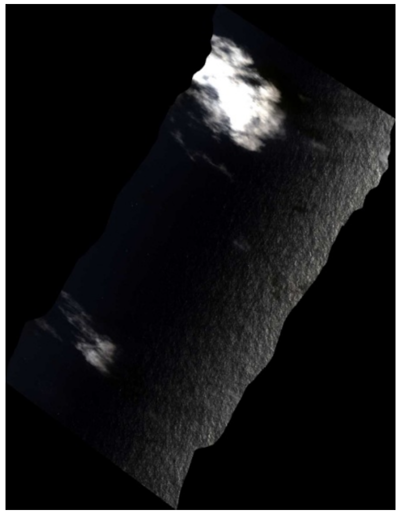
pagan_ds3_1_am_09



pagan_ds3_1_am_09b

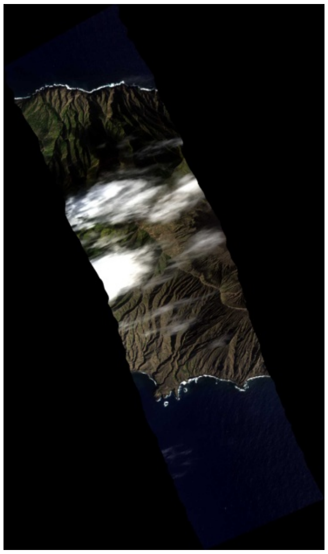


pagan_ds3_1_am_10

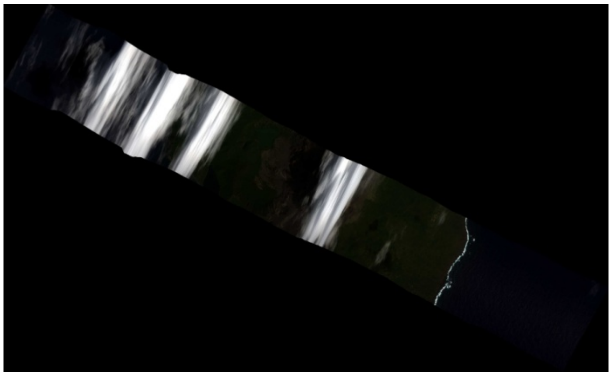


test

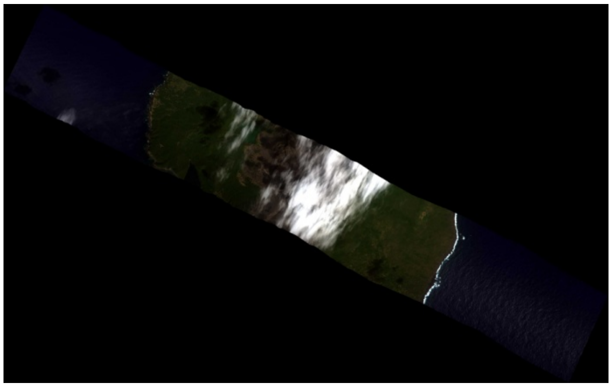
2.5 T5 Subset



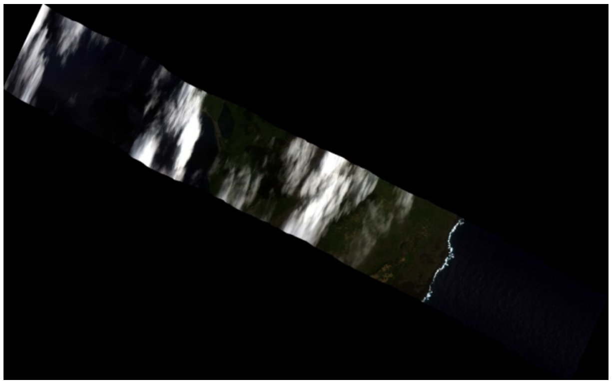
island_01 (Anatahan)



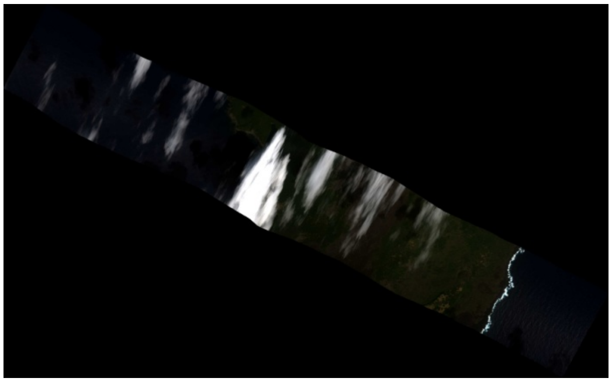
pagan_ds3_1_am_04



pagan_ds3_1_am_04b

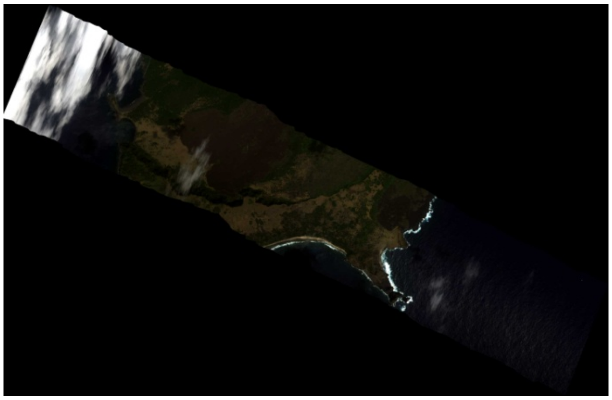


pagan_ds3_1_am_05

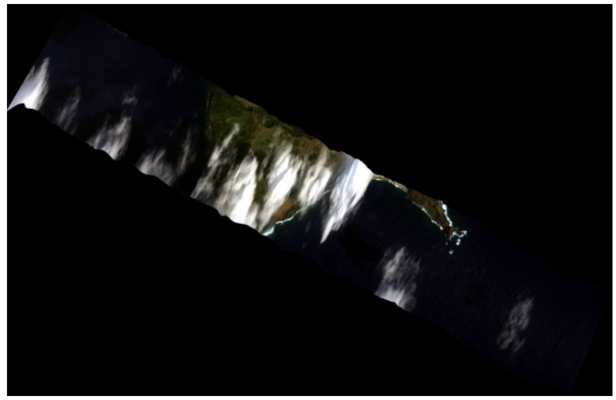


pagan_ds3_1_am_05b

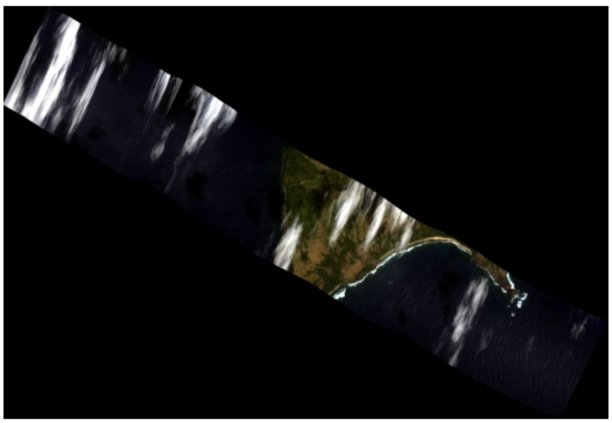
pagan_ds3_1_am_06



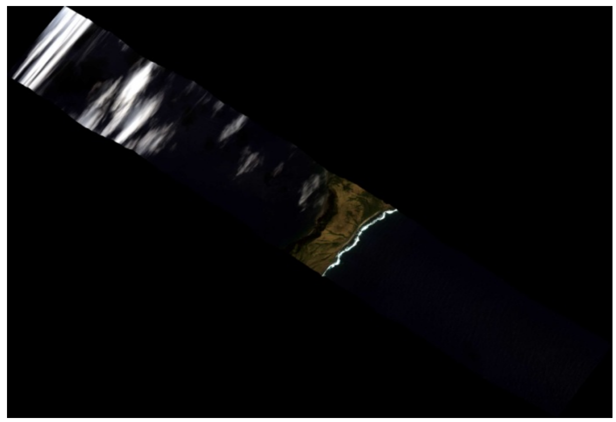
pagan_ds3_1_am_06b



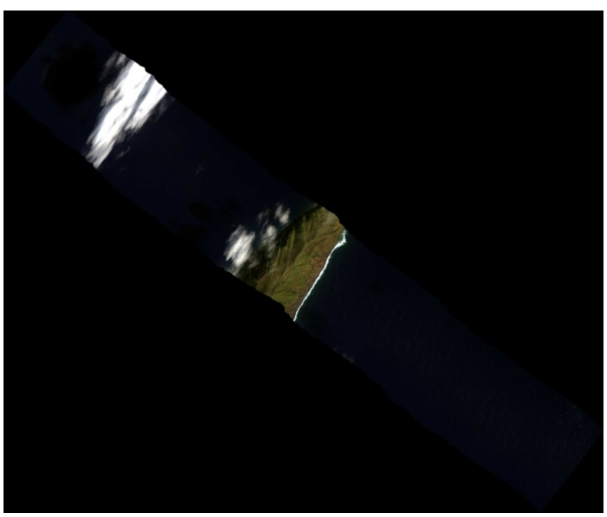
pagan_ds3_1_am_07



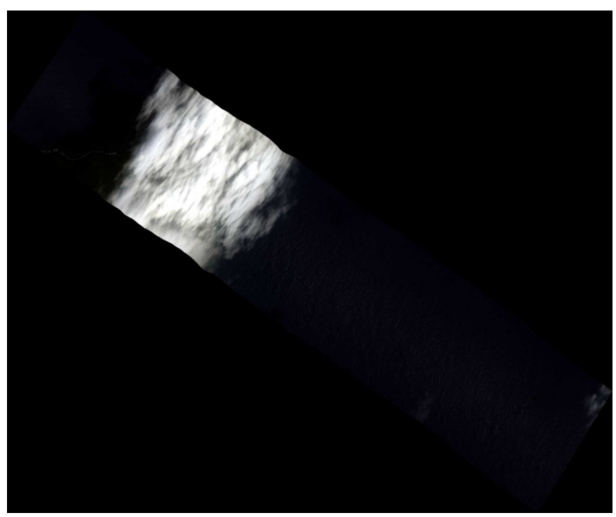
pagan_ds3_1_am_07b



pagan_ds3_1_am_08

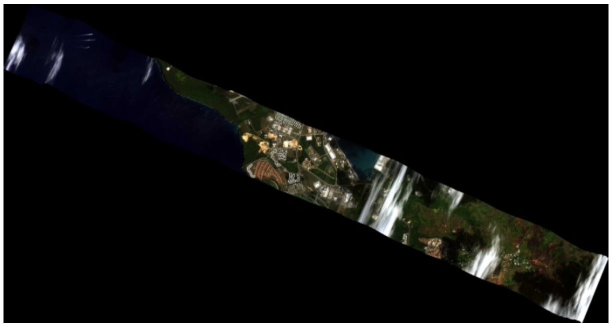


pagan_ds3_1_am_09



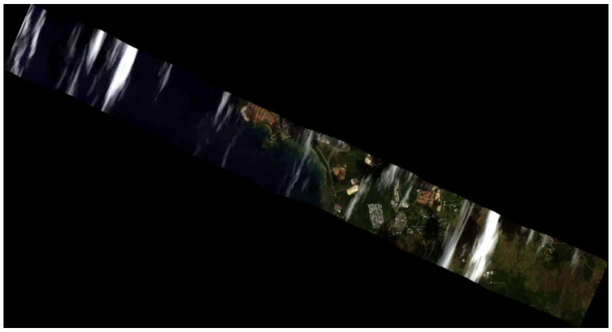
pagan_ds3_1_am_10

2.6 T6 Subset

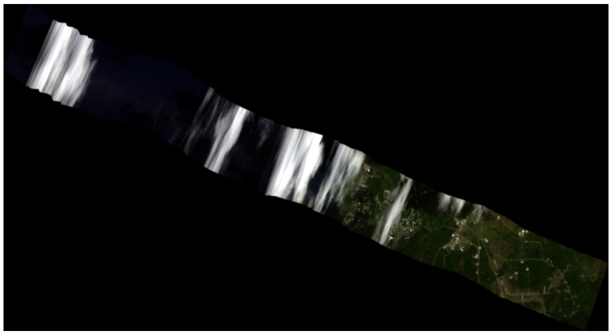


guam_ds3_1_am_01

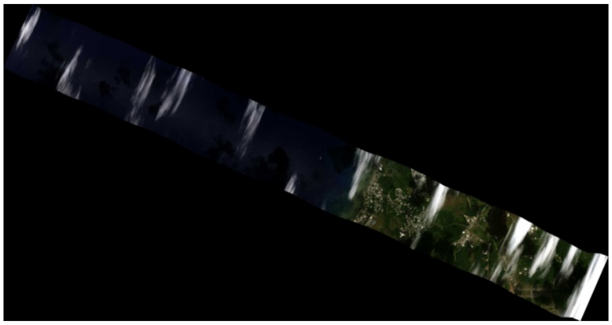
guam_ds3_1_am_02



guam_ds3_1_am_02b

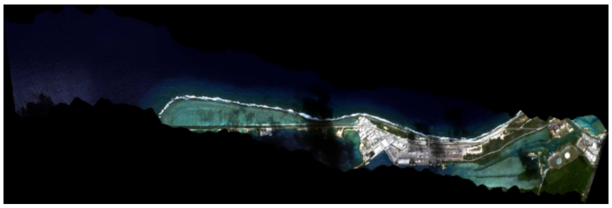


guam_ds3_1_am_03

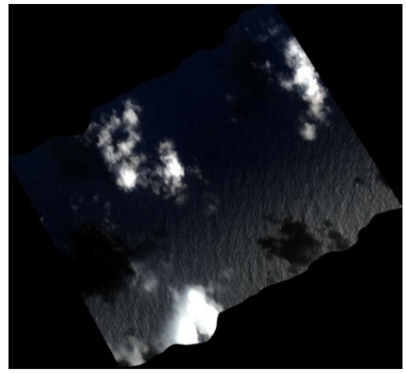


guam_ds3_1_am_03b

guam_ds3_1_am_03c

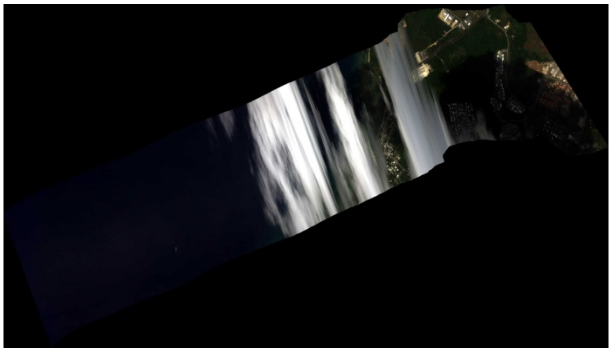


hvc_tst (Apra Harbor Guam)

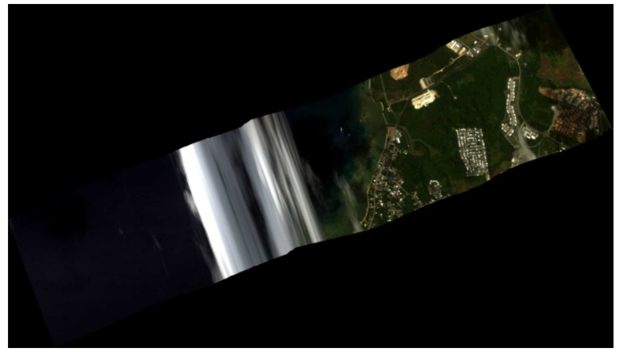


test

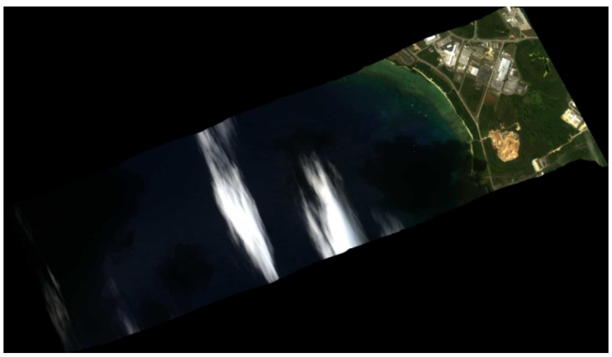
2.7 T7 Subset



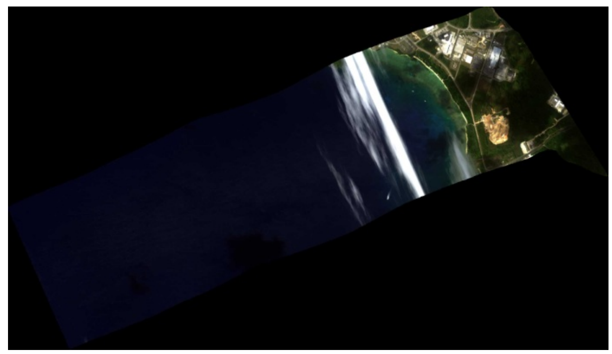
guam_ds3_2_pm_01



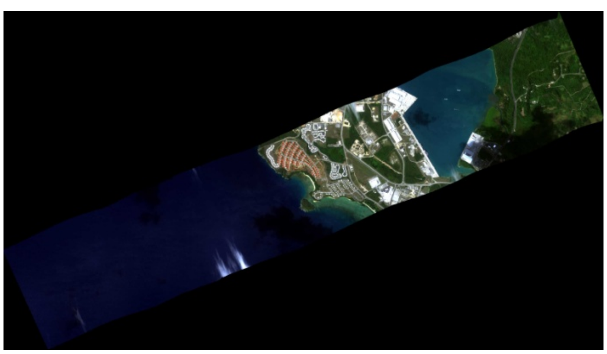
guam_ds3_2_pm_01b



guam_ds3_2_pm_02



guam_ds3_2_pm_02b



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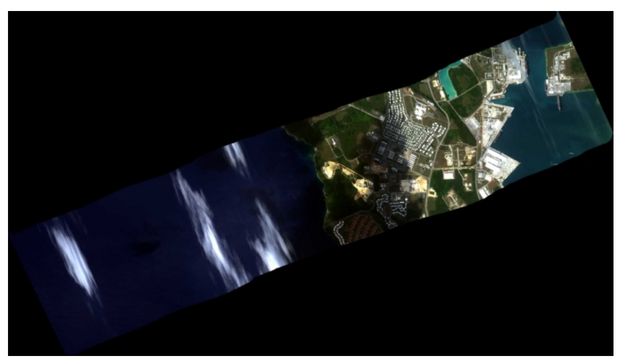


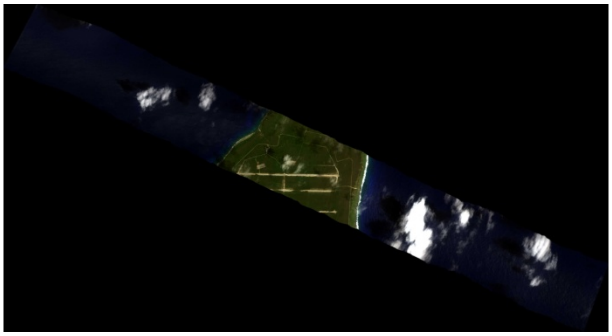
guam_ds3_2_pm_04

nrl_rnd (Guam)

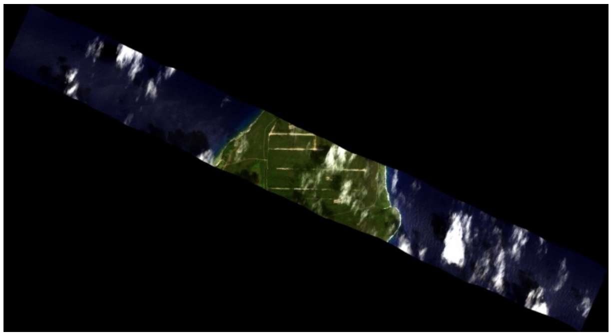
reef (Apra Harbor, Guam)

2.8 T8 Subset

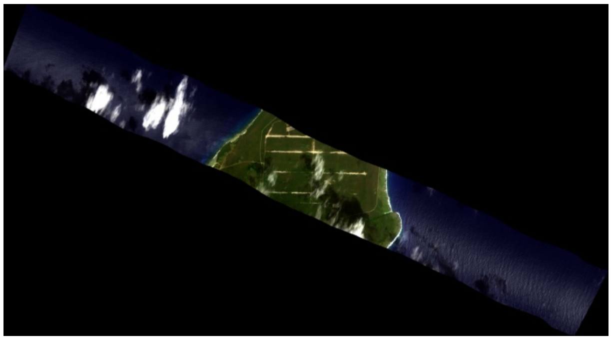
test



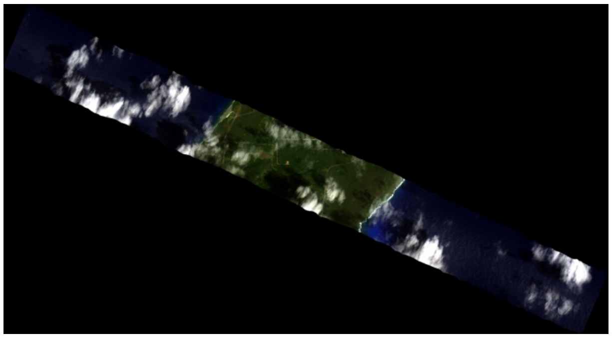
tinian_ds3_1_am_03



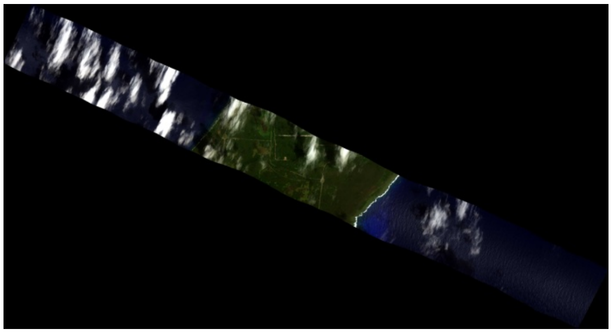
tinian_ds3_1_am_04



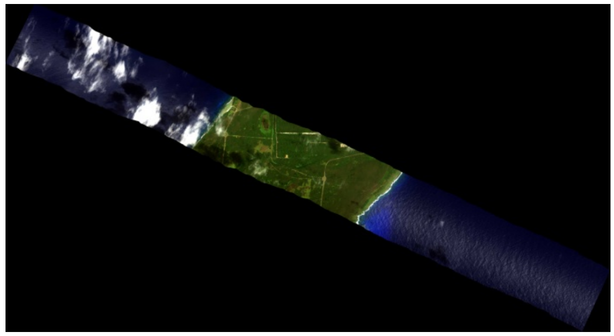
tinian_ds3_1_am_04b



tinian_ds3_1_am_05

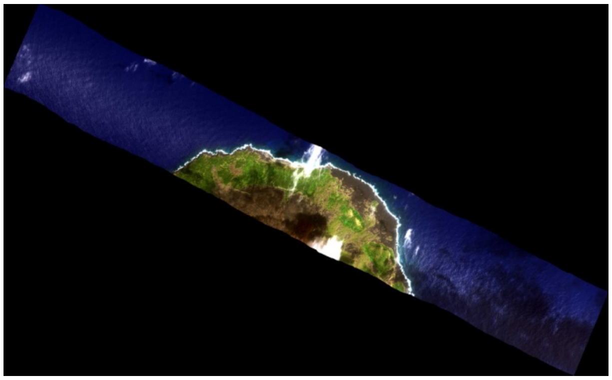


tinian_ds3_1_am_05b

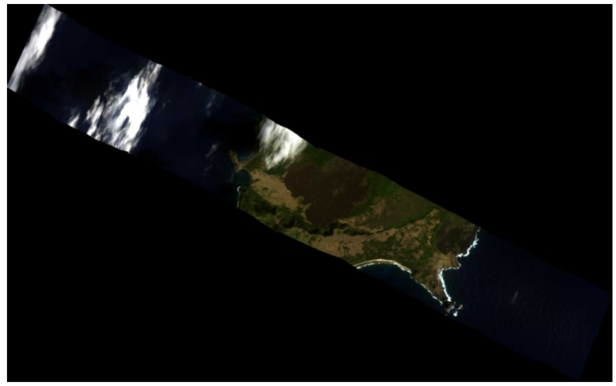


tinian_ds3_1_am_05c

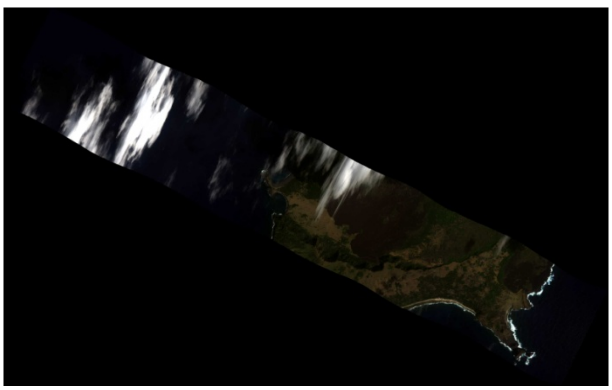
2.9 T9 Subset



pagan_ds3_1_am_02



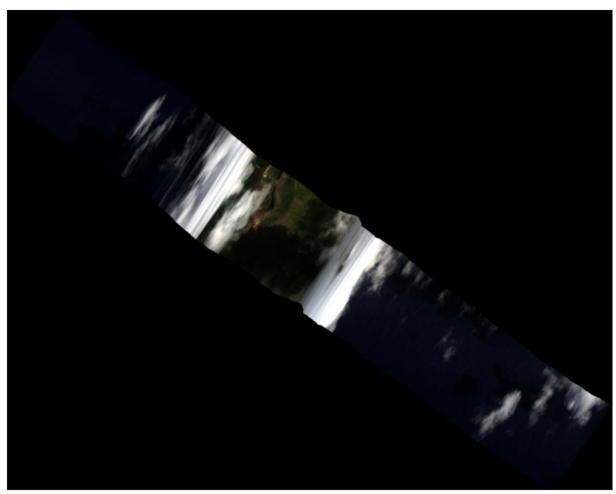
pagan_ds3_1_am_06



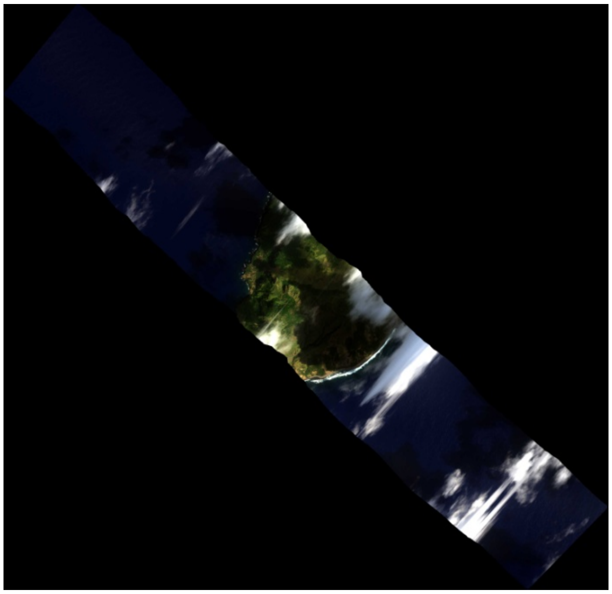
pagan_ds3_1_am_06b

pagan_ds3_1_am_07

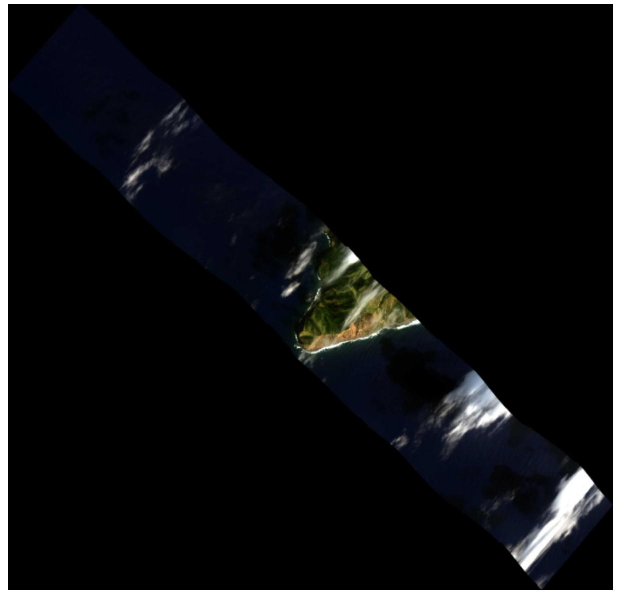
pagan_ds3_1_am_11



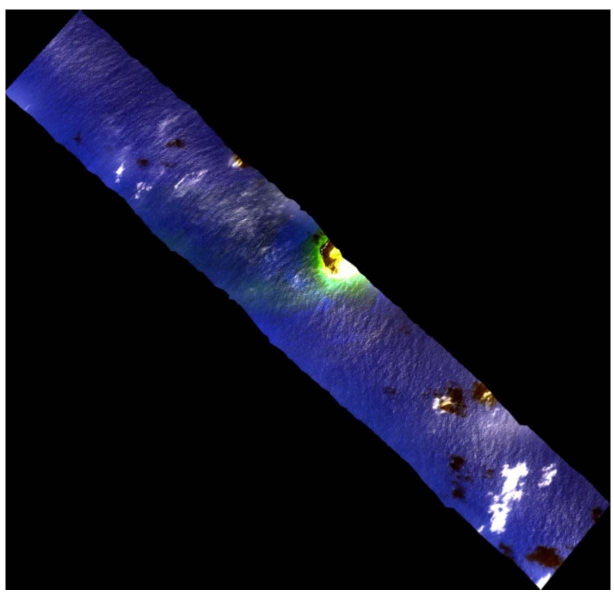
pagan_ds3_1_am_12



pagan_ds3_1_am_13



pagan_ds3_1_am_14



pagan_ds3_1_am_15

APPENDIX D

Project Geodatabase

1 Introduction

A geodatabase is an information database that contains data with a geographical component meaning that it is a collection of feature datasets for use with ArcMap or other viewers such as ArcGIS Explorer, or, Google Earth ® (kml format). ArcMap, used primarily to view, edit, create, and analyze geospatial data, is a component of ArcGIS and is a proprietary software program developed by Environmental Systems Research Institute, INC (ESRI). ArcGIS Explorer is a free software version of ArcGIS which was developed by ESRI and is used mainly for visualization and presentation purposes. The software program is similar to Google® Earth and allows for opening shapefiles and adding points and shapes to the viewer, but creating and editing shapefiles is not possible in this version. The MI-HARES'10 geodatabase was developed to be viewed in ArcMap. Users who do not have an ArcGIS license, can use ArcGIS Explorer and add features to that viewer, by navigating to the file geodatabase (.gdb) and adding in shapefiles and rasters. Those with access to ArcGIS and components such as ArcMap, ArcToolbox, and ArcCatalog will have access to the full capabilities of the geodatabase and be able to create and edit data.

The ArcGIS Explorer 900 program can be downloaded from ESRI's website at the URL: http://www.esri.com/software/arcgis/explorer/download.html. To download the program, the Microsoft .NET Framework 2.0 Service Pack 1 must be downloaded first (also included on the geodatabase drive). After installation of the Microsoft .NET update, the ArcGISExplorerDownload.exe file can be executed.

To view the geodatabase in ArcMap, navigate to the *.mxd* file in the top level folder in Windows Explorer. By opening the *.mxd* file, the ArcMap (ArcGIS) version of the geodatabase is opened. For those without an ArcGIS license, ArcGIS Explorer 900 can be used to view raster and vector files in the geodatabase. To view items developed from MI-HARES'10, navigate to the "add content" tab on the top toolbar and select "Geodatabase Data" and then navigate to the MIHARES10_GD.gdb file geodatabase. One can then add layers of interest into the ArcGIS Explorer viewer.

2 Geodatabase Drive

Data contained on the Geodatabase drive consists of all data collected from the MI-HARES'10 experiment. Navigating the geodatabase drive through Windows Explorer displays the available folders in the MI-HARES'10 geodatabase. Figure D - 1 displays the folder hierarchy that was designed for the MI-HARES'10 database. In the figure, the MI-HARES database (MIHARES10) contains six folders (Attribute Data, GIS Data, Metadata, Products, MIHARES10_GD.gdb, and User Manual Information) and two files (MIHARES10_ALL Data.xlsx, MIHARES10.mxd) at the top level. The Attribute Data folder contains sub-folders of each type of data collected during the MI-HARES'10 campaign. Most folders contain tabular data for each day that data were collected. The tabular information is combined into *MIHARES10_ALL_DATA.XLSX* with each tab containing different types of data. In the Attribute Data folder, non-tabular data are mainly contained in the folders, "HSI" and "Photographs." These two folders contain raster images that can be opened via ITT's ENVI and Microsoft® Windows Picture and Fax Viewer, respectively. The GIS Data folder contains *KML/KMZ* files used for interoperability with Google® Earth, map templates for quick map-making in ArcMap, *mxd* files (ArcMap file), *nmf* files (ArcGIS Explorer map layers) raster files, and shapefiles. The raster files and shapefiles in the GIS Data folder are files which have been gathered from multiple sources or created from the MI-HARES'10 attribute data. Files residing in these folders are the preliminary shapefiles and rasters files which have not been exported into "gdb" file format via ArcCatalog. ArcCatalog is the administration application in ArcGIS. The Metadata folder contains FGDC documentation about shapefile, raster, and geodatabase creation. The Products folder contains raster and text products created from the attribute data. The data report resides in the Text subfolder to the Products folder. The User Manual Information folder contains documentation about retrieving data and navigating the database tables and the geodatabase. When navigating via Windows® Explorer the MIHARES10.gdb (File Geodatabase) appears as a folder, but when navigating via ArcCatalog, the MIHARES10.gdb appears as a geodatabase icon. The format of the MIHARES10.gdb is a File Geodatabase.

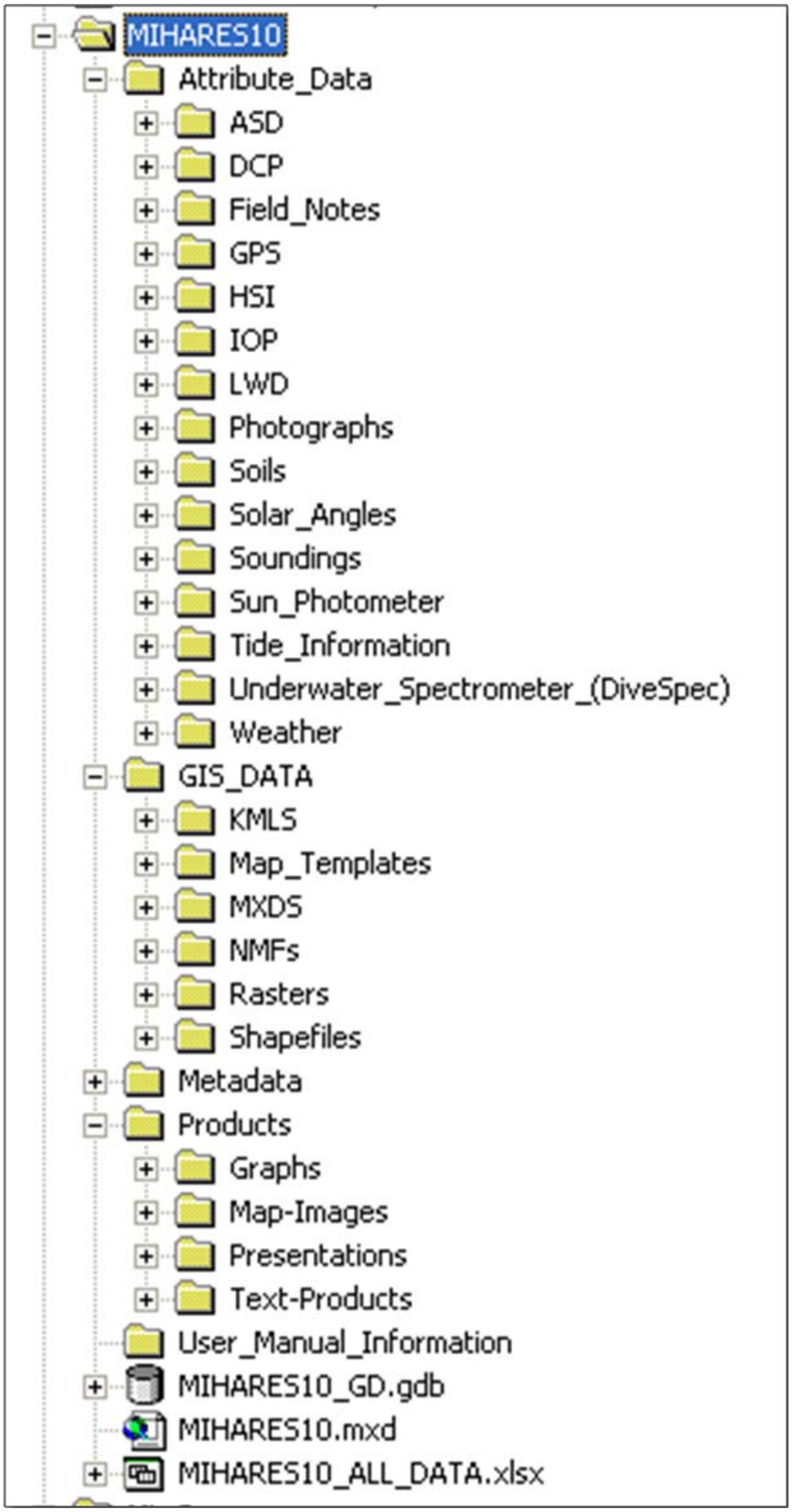


Figure D - 1. Geodatabase structure as viewed in ArcCatalog. It provides an integrated and unified view of all the data files, databases, and ArcGIS documents, integrating information that exists in many forms, including relational databases, files, and ArcGIS documents.

3 ArcGIS Desktop (ArcView) Version- Navigation and Data Access

The ArcGIS Desktop version allows for manipulating and editing datasets as well as viewing the data. Figure D - 2 displays a screen capture of the geodatabase with sections of the ArcMap interface labeled. The “Table of Contents” section displays the data available for viewing in the “Map Viewer Section.” The “Data Frame” contains all the layers that will be seen in the “Map Viewer.” “Layers” represent geographic data, usually grouped in a single theme of shapefiles or rasters. A “shapefile” is a nontopological format for storing the geometric location and attribute information of geographic features and is comprised of the individual components that describe the theme in a “Layer.” Shapefiles can represent point, line, or area (polygon) vector files and can be turned off from viewing in the “Map Viewer” by checking the box at the side of the shapefile’s name in the “Table of Contents” section. The “Menu Bar” is located at the top of ArcMap and contains drop down menus. The “Tools” toolbar contains basic navigational tools used for navigation in the “Map Viewer.” The “ArcToolbox Window” allows the more advanced user to gain access to geoprocessing functions that support editing and analyzing the data.

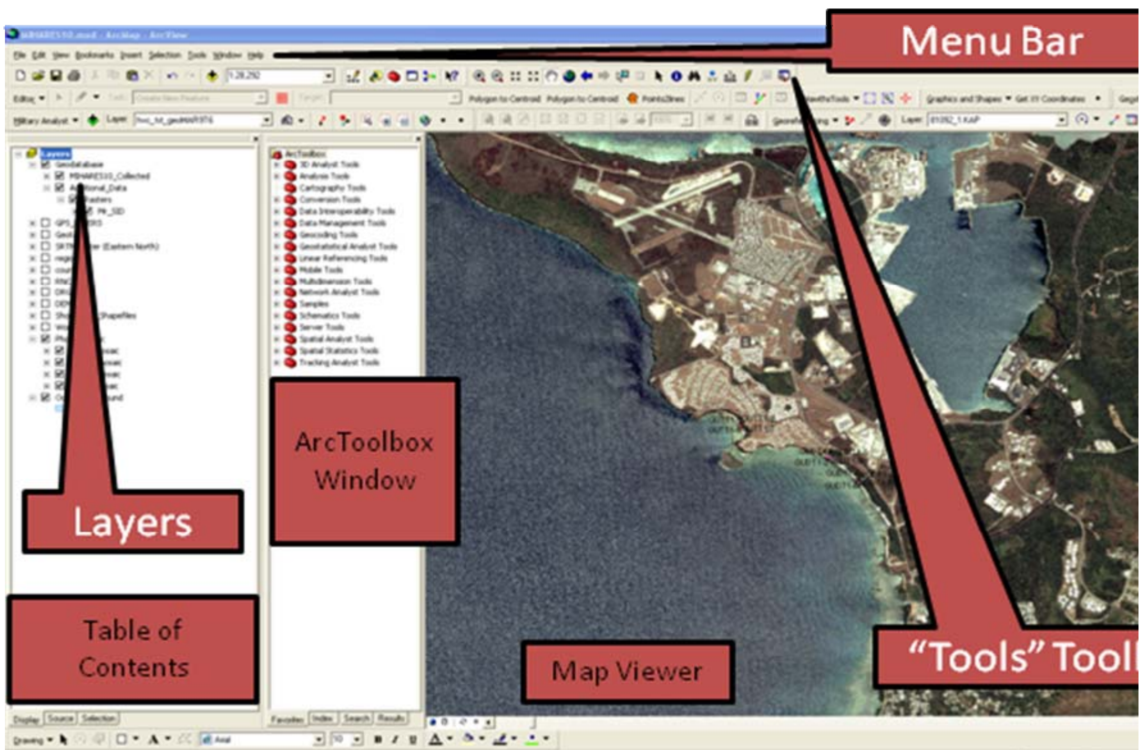


Figure D - 2. General sections of ArcMap.

By using the indentify feature tool, one can view attribute data of each shapefile that is checked in the Table of Contents. Figure D - 3 shows various data available when one clicks the MIHARES10_Trimble_Geotechnical layer. This layer represents positions where both spectral and geotechnical measurements were taken.

In the figure, pop-up windows display items that are rendered when the yellow lightning bolt hyperlink icon is clicked. The yellow lightning bolt represents a hyperlink to a URL, photograph, document, or Excel spreadsheet. In the figure, box A displays an Excel spreadsheet which contains all attribute data collected at site. Box B shows the pop-up of the main body of the MI-HARES'10 data report and Box C shows a picture of the substrate. One can also navigate through Windows ® Explorer to access the attribute data which is hyperlinked above.

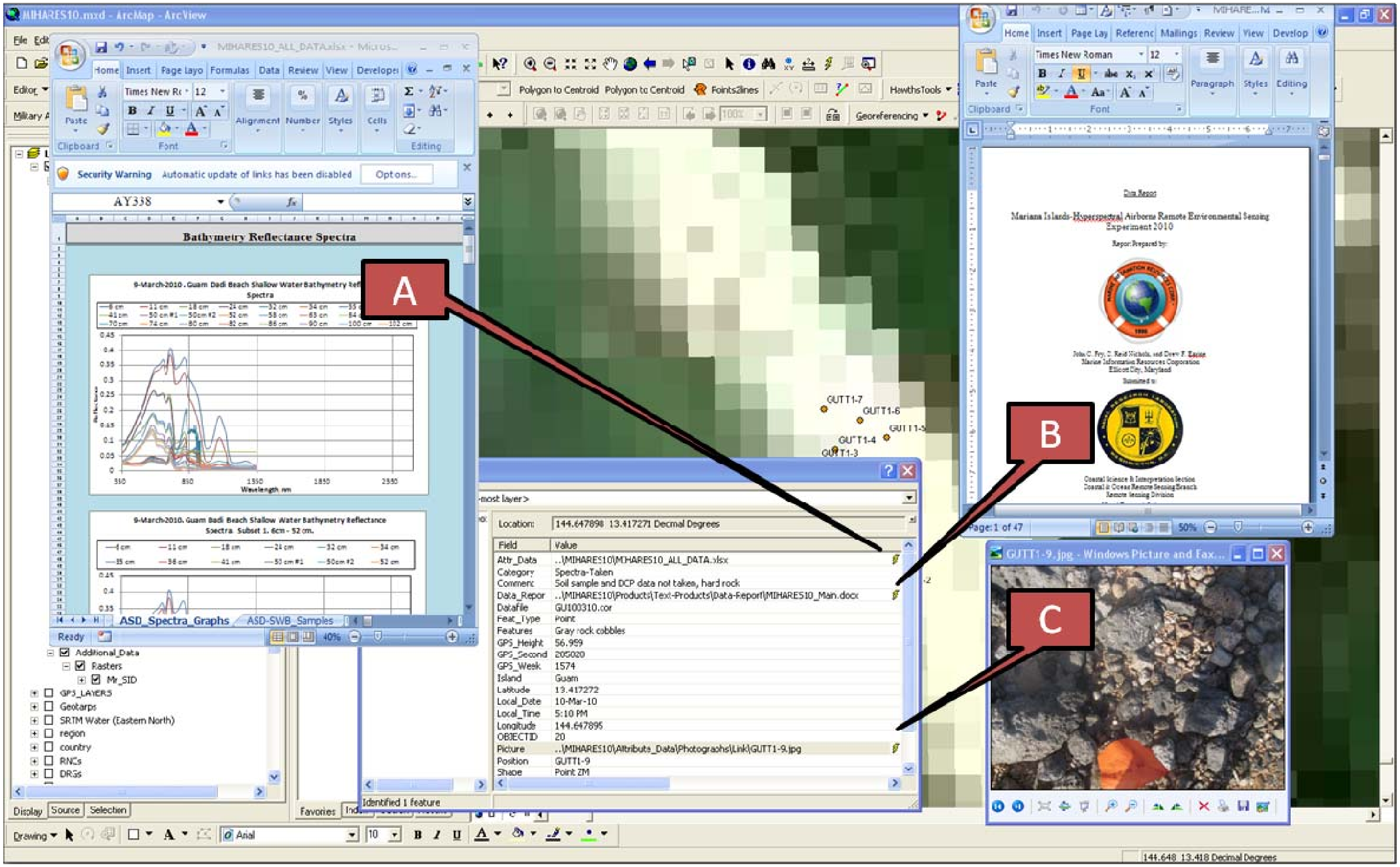


Figure D - 3. Using the identify feature tool to access attribute data. (A) The MIHARES10.xlsx spreadsheet accessed via selecting a hyper-link. (B) The MI-HARES 2010 Data Report accessed via selecting a hyper-link (C) Site photograph accessed via selection of a hyper-link.

APPENDIX E

Spectra

1 Introduction

Field spectrometers provide ground truth for comparison with measurements taken from remote sensing. Field spectrometers are therefore critical in the execution of remote sensing research. This appendix provides information on reflectance spectra that are unique, i.e., like individual fingerprints. The slopes and dips (absorption) in each spectrum, called spectral features, are determined by the atomic and molecular properties in each substance.

Spectra were measured with three Analytical Spectral Devices (ASD) portable field spectrometers covering the range from 0.35 to 2.5 µm. The ASD spectrometers used passive solar illumination and a fiber-optic probe to collect light. Solar zenith incidence angles were variable but typically ranged from 40 to 60 degrees. The ASD was used with Lambertian reflectance standards (Spectralon™), in order to convert the sample radiance to reflectance. Field spectra were collected under various sky conditions. Because of limited time for field work, some spectra were collected under partly cloudy skies and less than optimal solar zenith angles. On days with variable cloud conditions, a dual spectrometer method was employed which allowed simultaneous recording of the white reference and the specimen of interest (Bachmann et al, in prep).

Spectra were edited to eliminate spectral regions with very high atmospheric water vapor absorption; these regions have low digital number counts and ratios between the spectral response of the white plaque and the specimen are often unstable in these spectral regions. Edited bands were roughly from 1.35 µm to 1.44 µm, 1.79 µm to 1.95 µm and 2.45 µm to 2.5 µm.

Spectra measured in the lab using the leaf optic apparatus used a light source internal to a contact probe. The contact probe is an accessory for the FieldSpec® spectrometer, designed for sampling a small area using only internal illumination from a light source positioned in the contact probe. These spectra did not need to be edited for water vapor absorption features.

The digital spectral library is a component of the geodatabase. Reflectance spectra and associated comments are provided in the following sections. In Section 2 reflectance spectra are displayed in alphabetical order by category type. By categorizing the spectra, readers who did not participate in the field portion of the experiment will be better able to navigate through the appendix. Spectra are categorized as follows: bathymetric, geotechnical, *in-situ* vegetation, leaf-optics, WWII relics, structures, and terrain features.

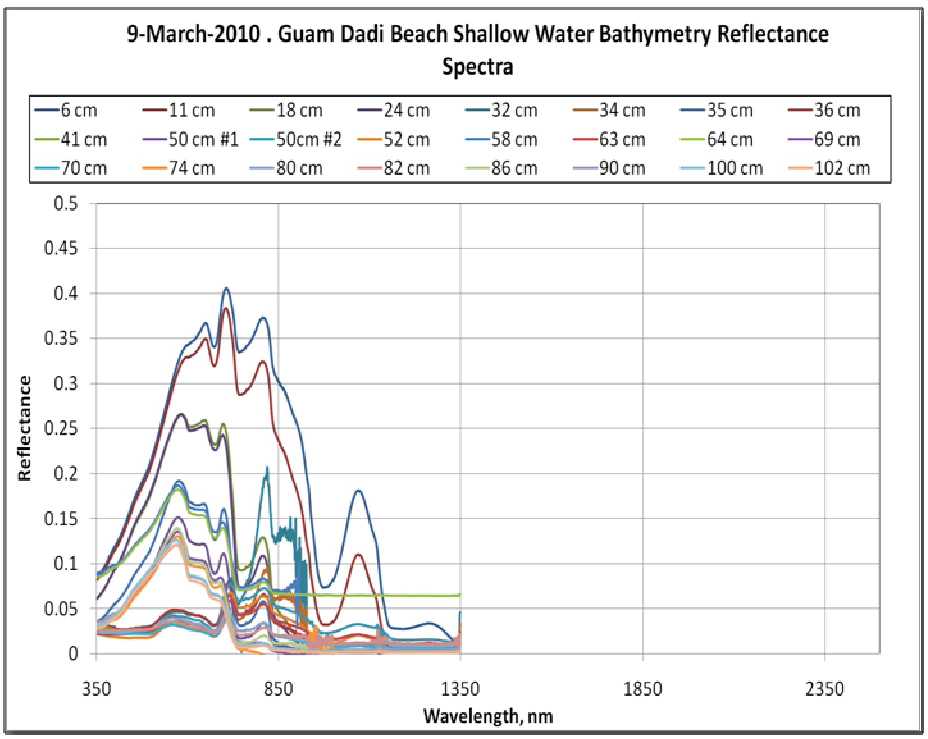
The comments section displays the time and describes general conditions when the spectra were captured.

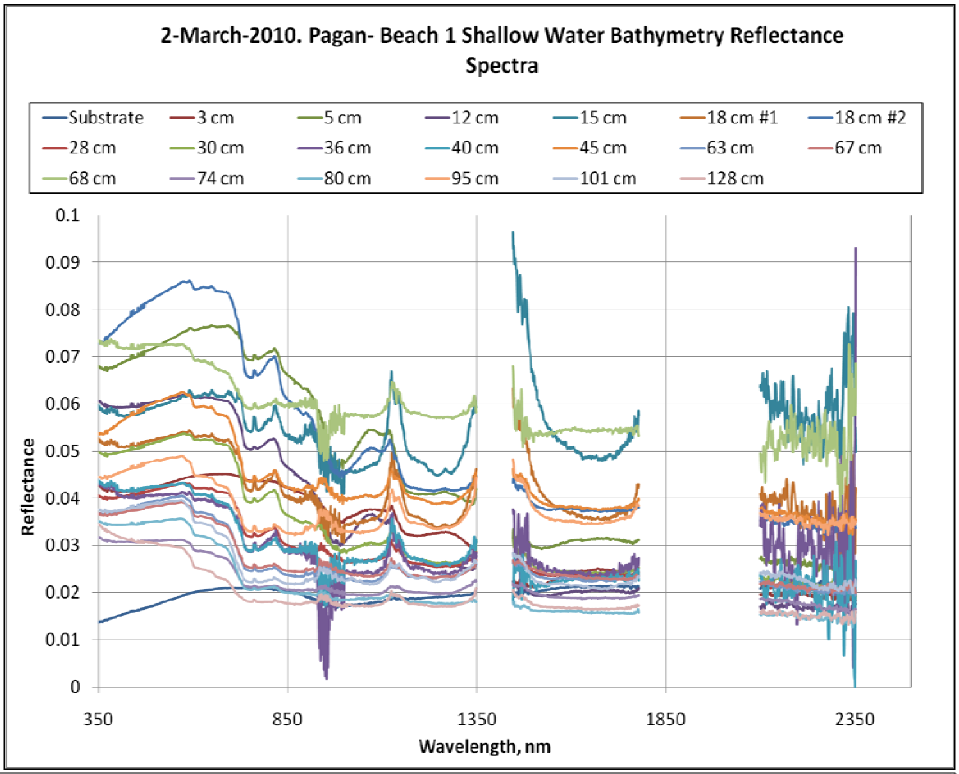
2 Spectra

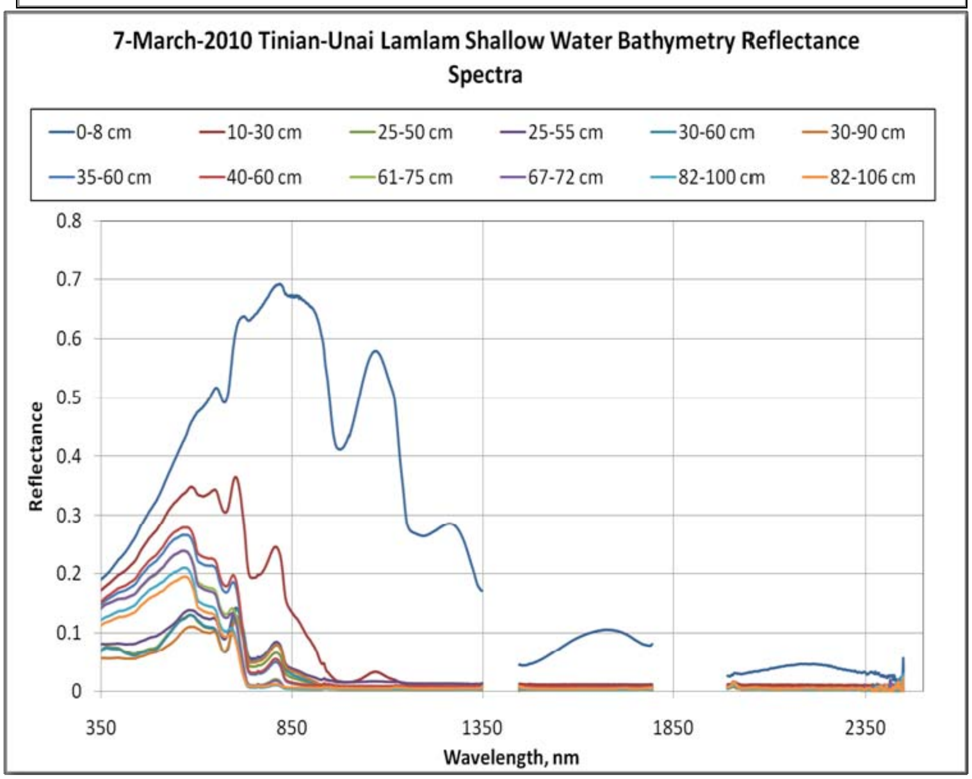
In the following sections, graphs of spectra display reflectance values versus wavelength in nanometers (nm). The scale along the *y*-axis may change among the graphs in order to highlight spectral features.

2.1 Bathymetry (Very Shallow Water)

Spectral measurements were taken in very shallow water on Guam, Pagan and Tinian. The bottom type differed among the three islands. The sample beach on Guam consisted of mainly large pieces of coral mixed with small particle sand and patches of tape seagrass (*Enhalus acoroides*) in the intertidal zone. Pagan bottom type consisted of gray volcanic sand and the bottom type of Tinian consisted of coral, white sand, limestone rock, and volcanic rock formations. Sampling depths in these foreshore regions were either recorded as an average of the two meter-stick measurements (Guam and Pagan) or as a range from the first measurement to the second measurement (Tinian).

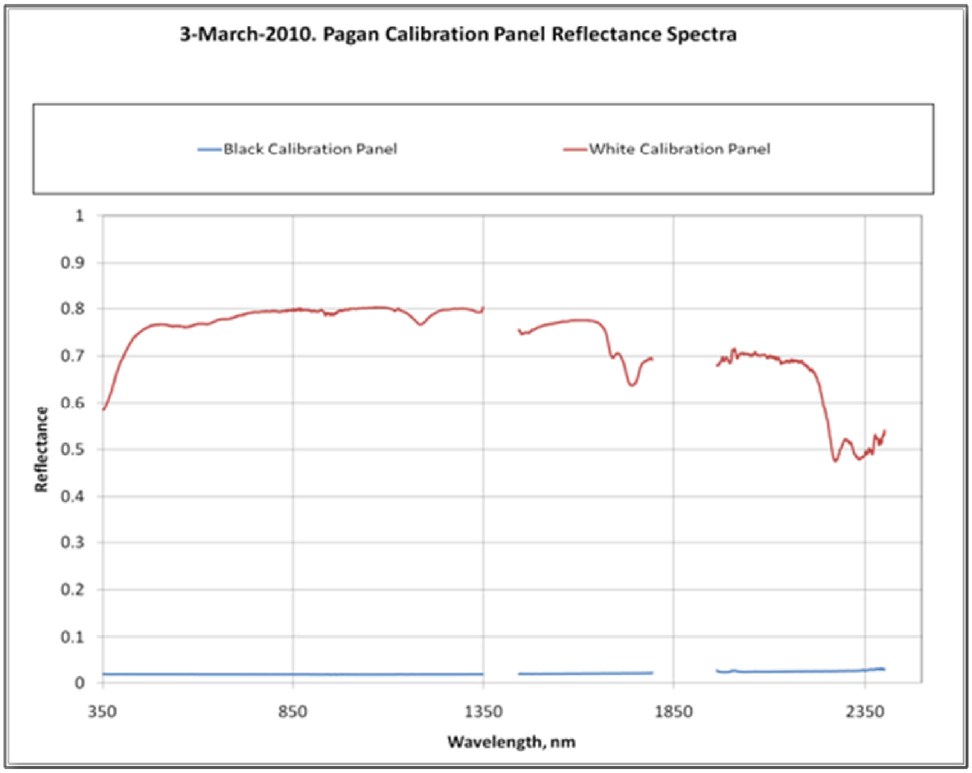



2-March-2010. Pagan- Beach 1 Shallow Water Bathymetry Reflectance Spectra
Substrate
3 cm
5 cm
12 cm
15 cm
18 cm #1
18 cm #2
28 cm
30 cm
36 cm
40 cm
45 cm
63 cm
67 cm
68 cm
74 cm
80 cm
95 cm
101 cm
128 cm
Reflectance
Wavelength, nm


7-March-2010 Tinian-Unai Lamlam Shallow Water Bathymetry Reflectance Spectra
0-8 cm
10-30 cm
25-50 cm
25-55 cm
30-60 cm
30-90 cm
35-60 cm
40-60 cm
61-75 cm
67-72 cm
82-100 cm
82-106 cm
Reflectance
Wavelength, nm

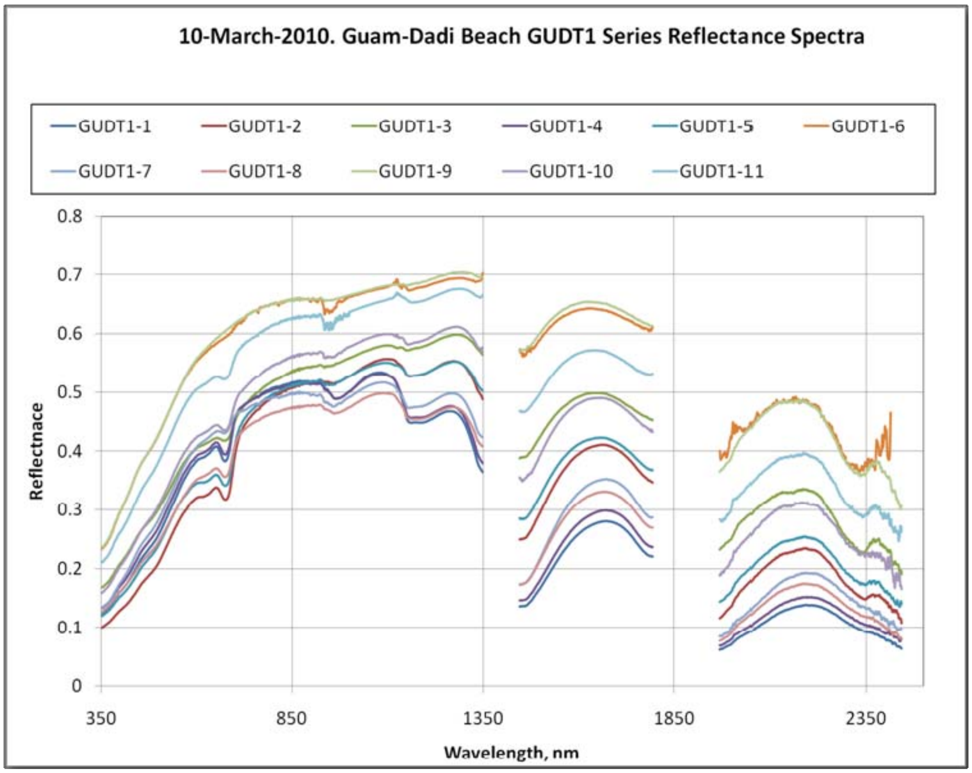
2.2 Calibration Panels

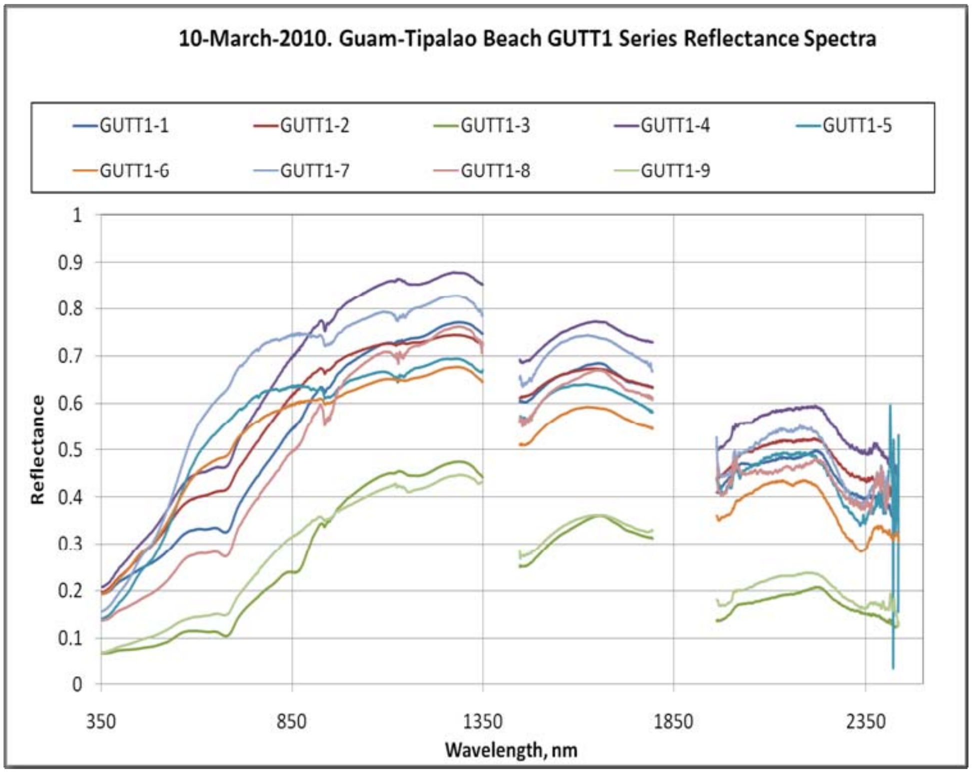
Two 10 m by 10 m canvas panels were deployed as calibration surfaces for aerial images. One of the deployed panels was white, while the other panel was black. Spectra were collected for each panel with the ASD. The graph below displays calibration panel spectra.

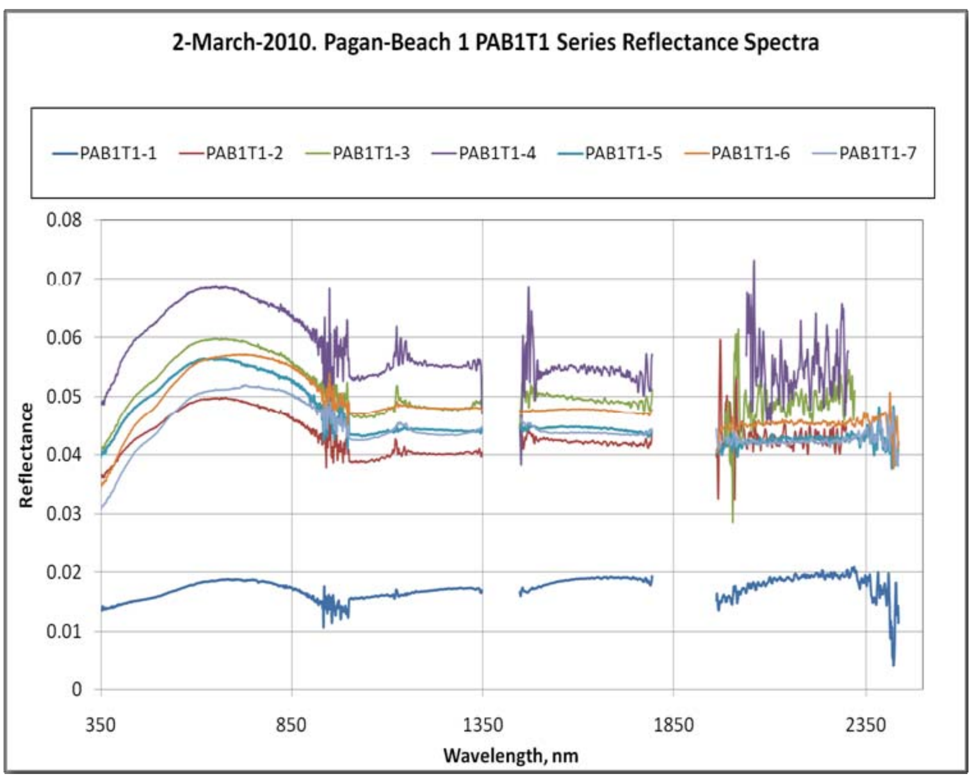


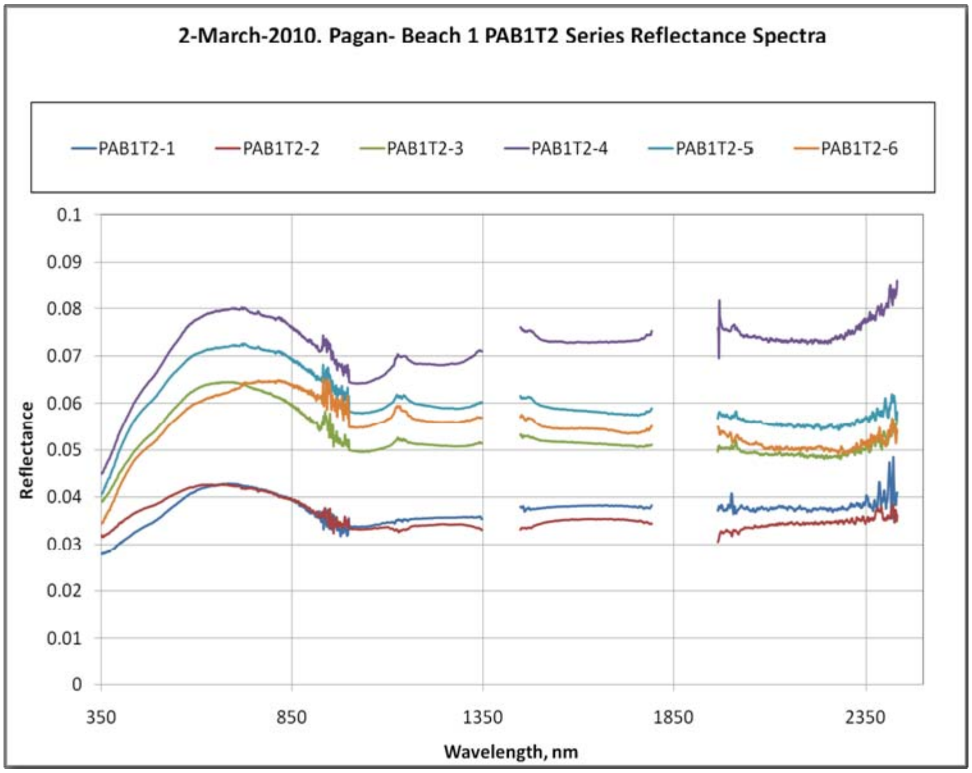
2.3 Geotechnical

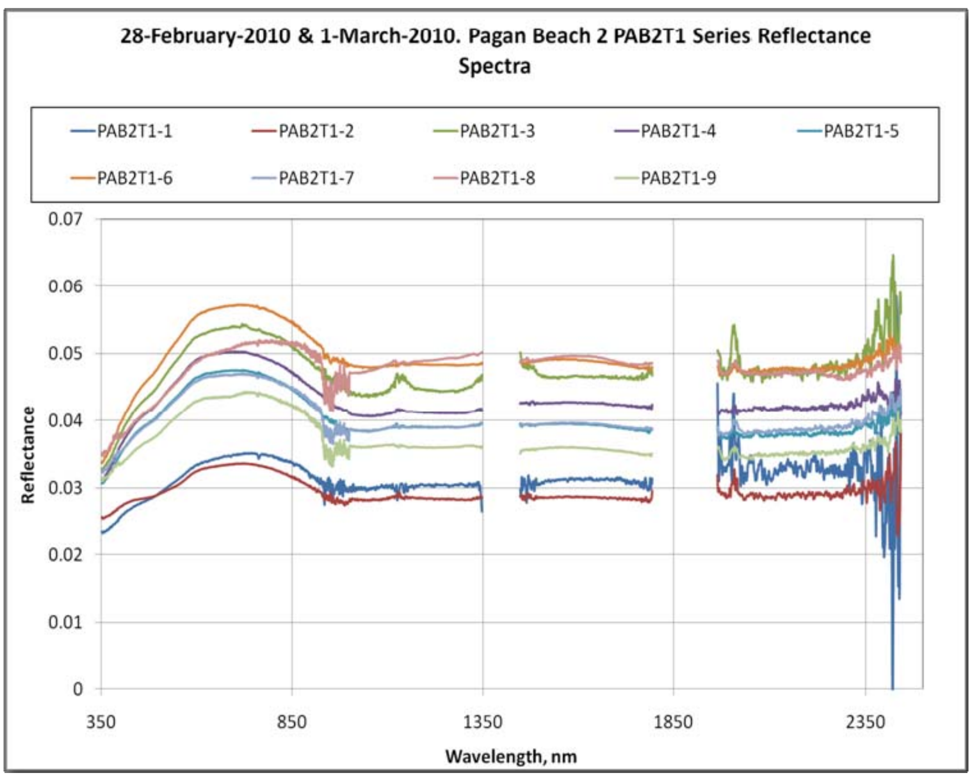
The type of spectra categorized as “geotechnical” were measured at the location where geotechnical instruments were used to collect bearing strength, grain texture, soil moisture in accordance with established protocols. Spectra were collected of the ground and then a series of geotechnical sampling was conducted that involved the use of a light weight deflectometer, dynamic cone penetrometer, and a soil “grab” sampler. Sampling of this type was done on all three islands in a total of 19 transects and 137 positions. Graphs are listed alphabetically by transect name.

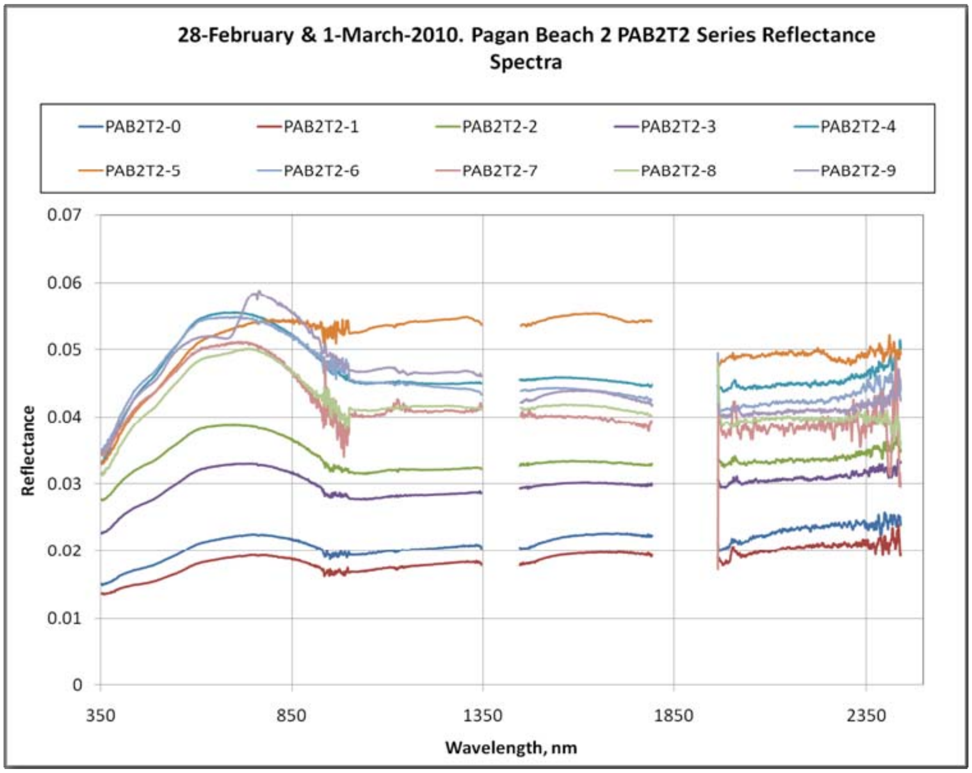



10-March-2010. Guam-Tipalao Beach GUTT1 Series Reflectance Spectra
GUTT1-1
GUTT1-2
GUTT1-3
GUTT1-4
GUTT1-5
GUTT1-6
GUTT1-7
GUTT1-8
GUTT1-9
Reflectance
Wavelength, nm

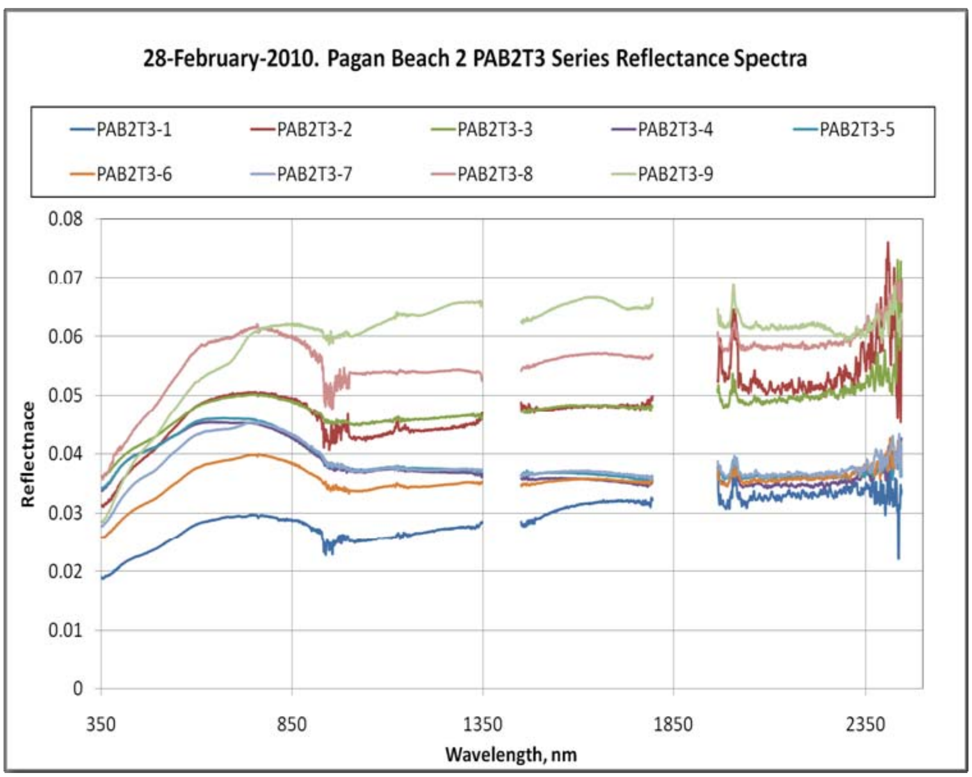

2-March-2010. Pagan-Beach 1 PAB1T1 Series Reflectance Spectra
PAB1T1-1
PAB1T1-2
PAB1T1-3
PAB1T1-4
PAB1T1-5
PAB1T1-6
PAB1T1-7
Reflectance
Wavelength, nm


2-March-2010. Pagan- Beach 1 PAB1T2 Series Reflectance Spectra
PAB1T2-1
PAB1T2-2
PAB1T2-3
PAB1T2-4
PAB1T2-5
PAB1T2-6
Reflectance
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
350
850
1350
1850
2350
Wavelength, nm

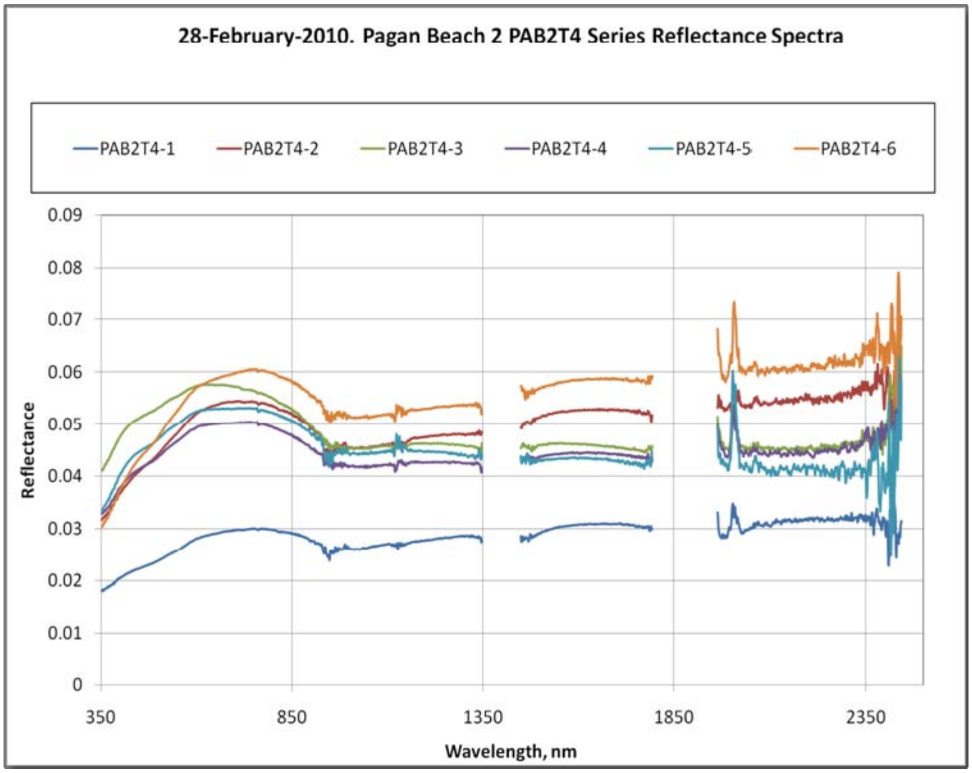

28-February-2010 & 1-March-2010. Pagan Beach 2 PAB2T1 Series Reflectance Spectra
PAB2T1-1
PAB2T1-2
PAB2T1-3
PAB2T1-4
PAB2T1-5
PAB2T1-6
PAB2T1-7
PAB2T1-8
PAB2T1-9
Reflectance
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
350
850
1350
1850
2350
Wavelength, nm

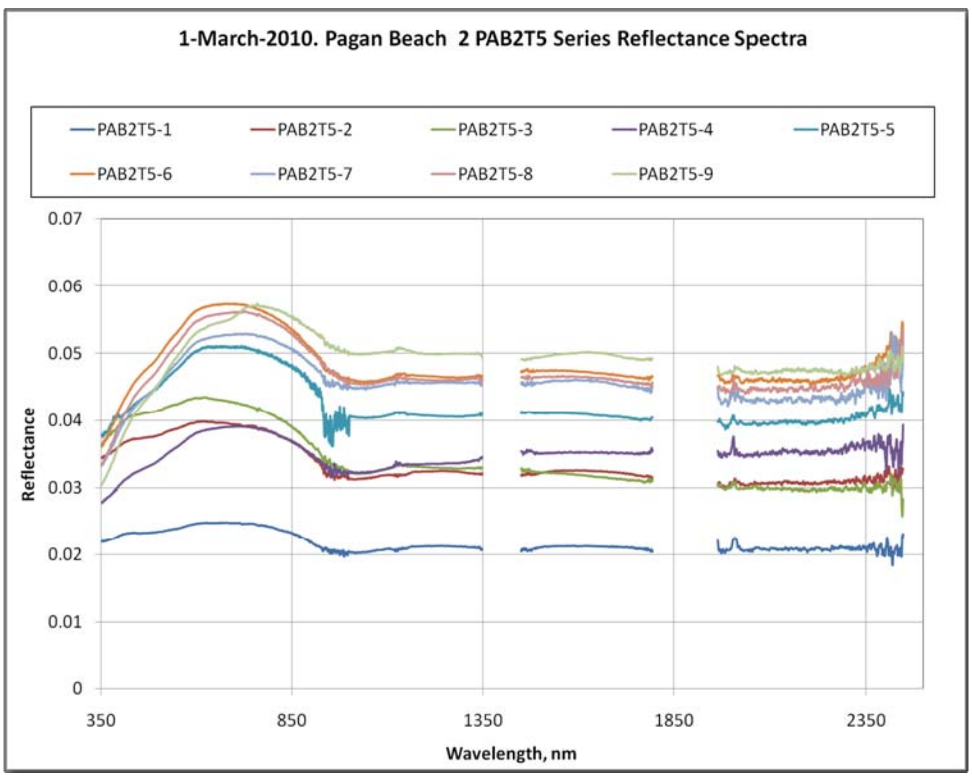


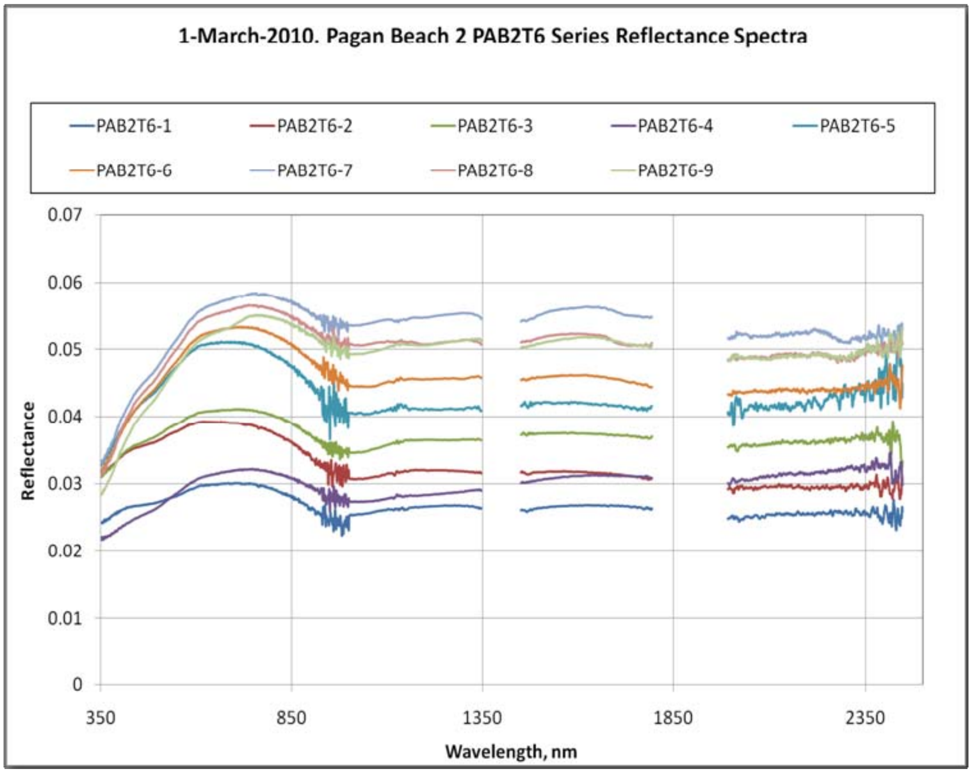
28-February & 1-March-2010. Pagan Beach 2 PAB2T2 Series Reflectance Spectra
PAB2T2-0
PAB2T2-1
PAB2T2-2
PAB2T2-3
PAB2T2-4
PAB2T2-5
PAB2T2-6
PAB2T2-7
PAB2T2-8
PAB2T2-9
Reflectance
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
350
850
1350
1850
2350
Wavelength, nm

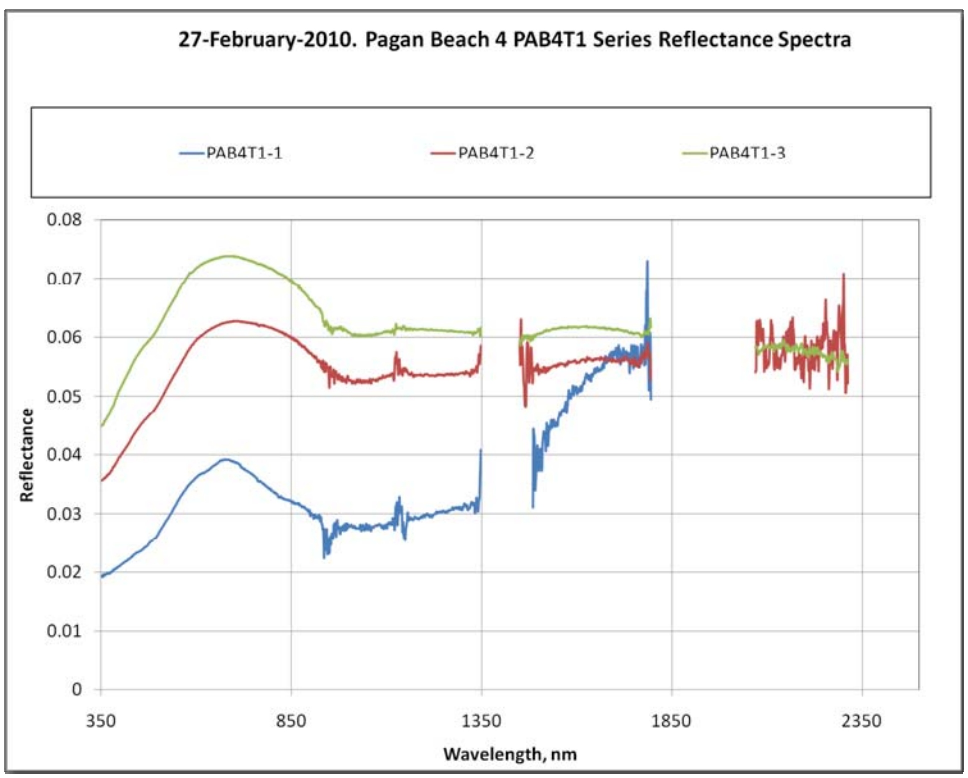


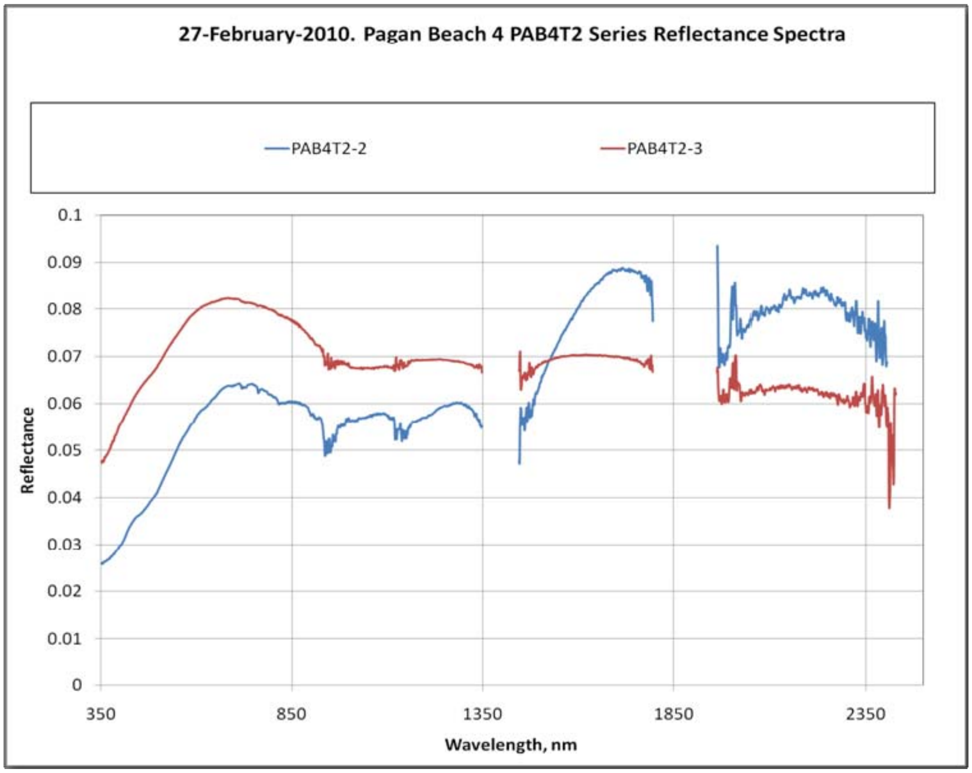
28-February-2010. Pagan Beach 2 PAB2T3 Series Reflectance Spectra
PAB2T3-1
PAB2T3-2
PAB2T3-3
PAB2T3-4
PAB2T3-5
PAB2T3-6
PAB2T3-7
PAB2T3-8
PAB2T3-9
Reflectnace
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
350
850
1350
1850
2350
Wavelength, nm

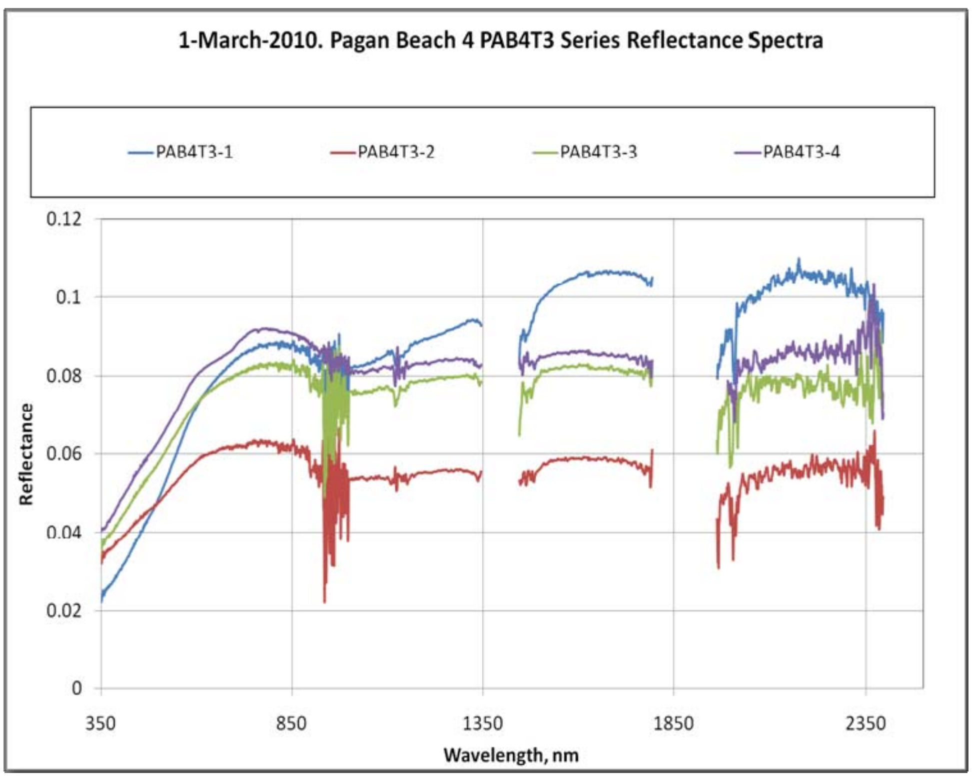

28-February-2010. Pagan Beach 2 PAB2T4 Series Reflectance Spectra
PAB2T4-1
PAB2T4-2
PAB2T4-3
PAB2T4-4
PAB2T4-5
PAB2T4-6
Reflectance
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
350
850
1350
1850
2350
Wavelength, nm

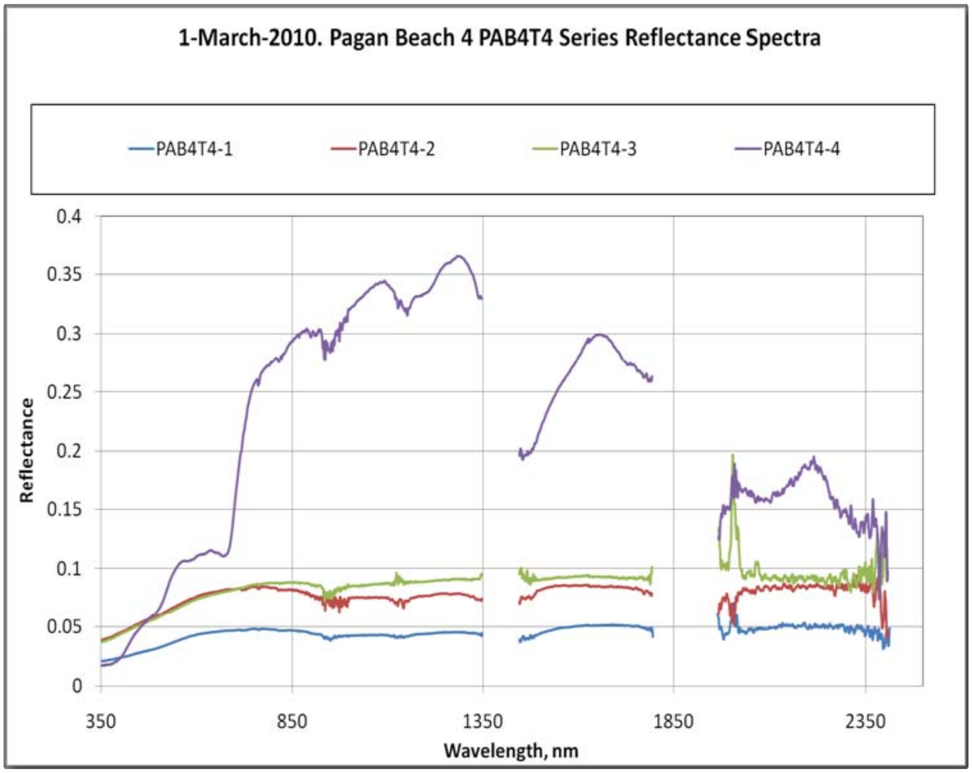

1-March-2010. Pagan Beach 2 PAB2T5 Series Reflectance Spectra
PAB2T5-1
PAB2T5-2
PAB2T5-3
PAB2T5-4
PAB2T5-5
PAB2T5-6
PAB2T5-7
PAB2T5-8
PAB2T5-9
Reflectance
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
350
850
1350
1850
2350
Wavelength, nm

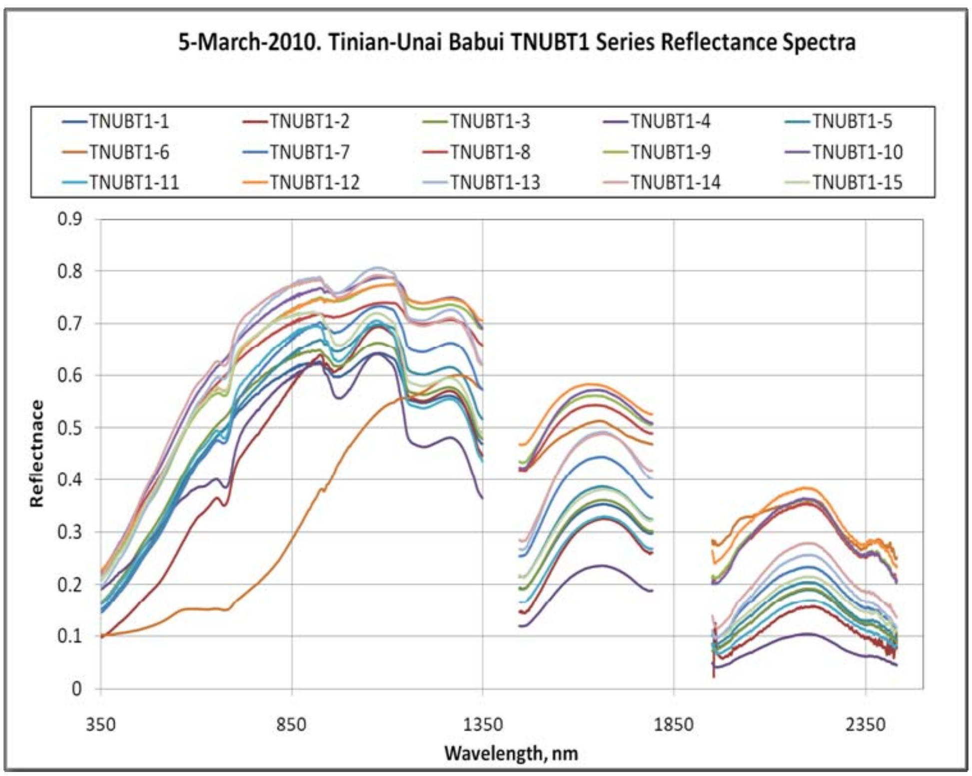

1-March-2010. Pagan Beach 2 PAB2T6 Series Reflectance Spectra
PAB2T6-1
PAB2T6-2
PAB2T6-3
PAB2T6-4
PAB2T6-5
PAB2T6-6
PAB2T6-7
PAB2T6-8
PAB2T6-9
Reflectance
Wavelength, nm
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
350
850
1350
1850
2350

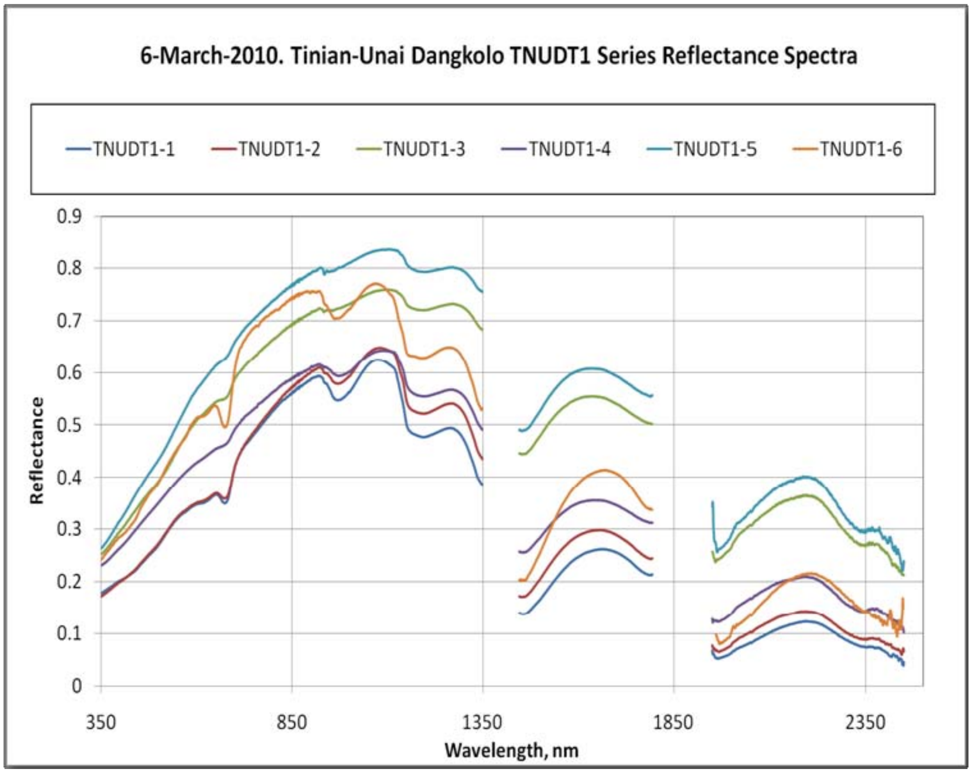

27-February-2010. Pagan Beach 4 PAB4T1 Series Reflectance Spectra
PAB4T1-1
PAB4T1-2
PAB4T1-3
Reflectance
Wavelength, nm
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
350
850
1350
1850
2350

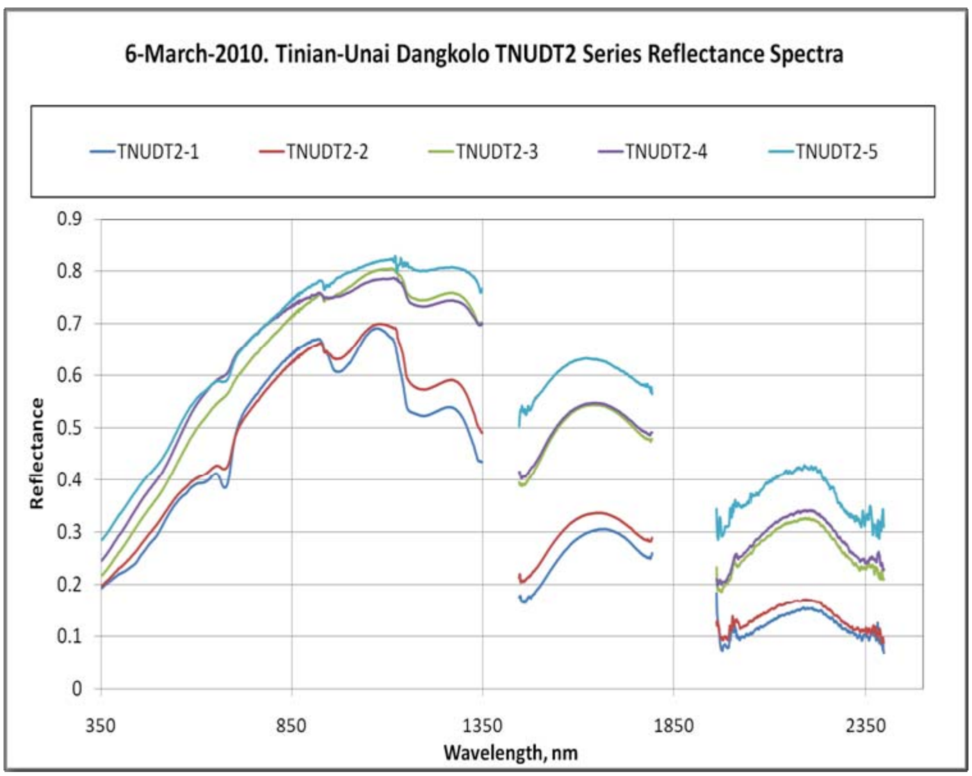

27-February-2010. Pagan Beach 4 PAB4T2 Series Reflectance Spectra
PAB4T2-2
PAB4T2-3
Reflectance
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
350
850
1350
1850
2350
Wavelength, nm

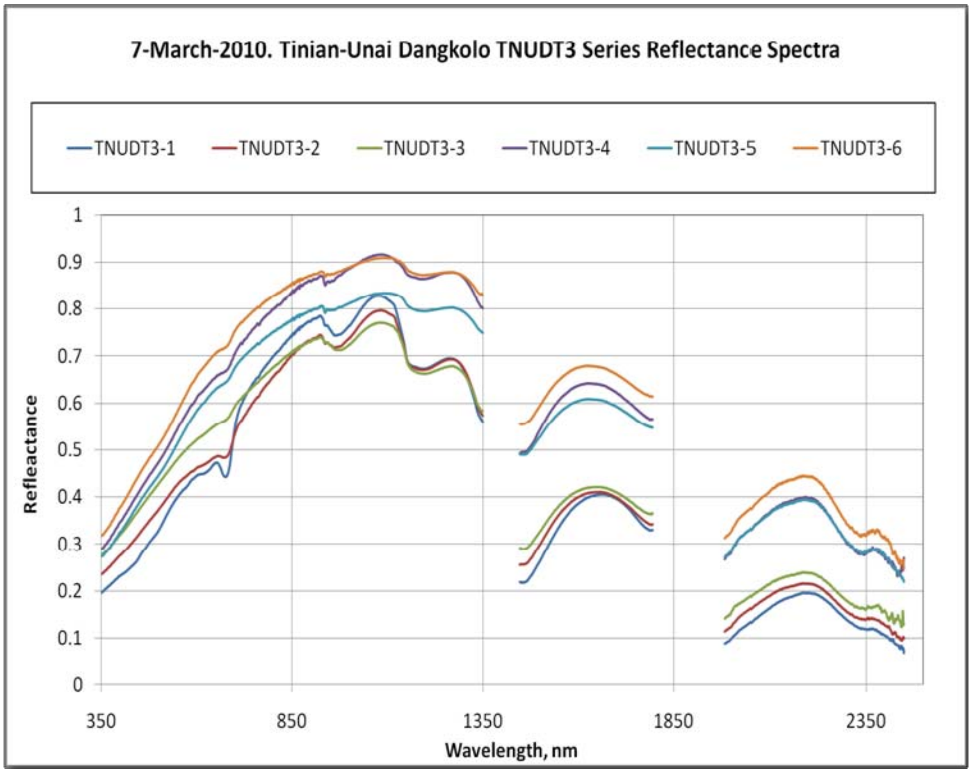

1-March-2010. Pagan Beach 4 PAB4T3 Series Reflectance Spectra
PAB4T3-1
PAB4T3-2
PAB4T3-3
PAB4T3-4
Reflectance
0.12
0.1
0.08
0.06
0.04
0.02
0
350
850
1350
1850
2350
Wavelength, nm

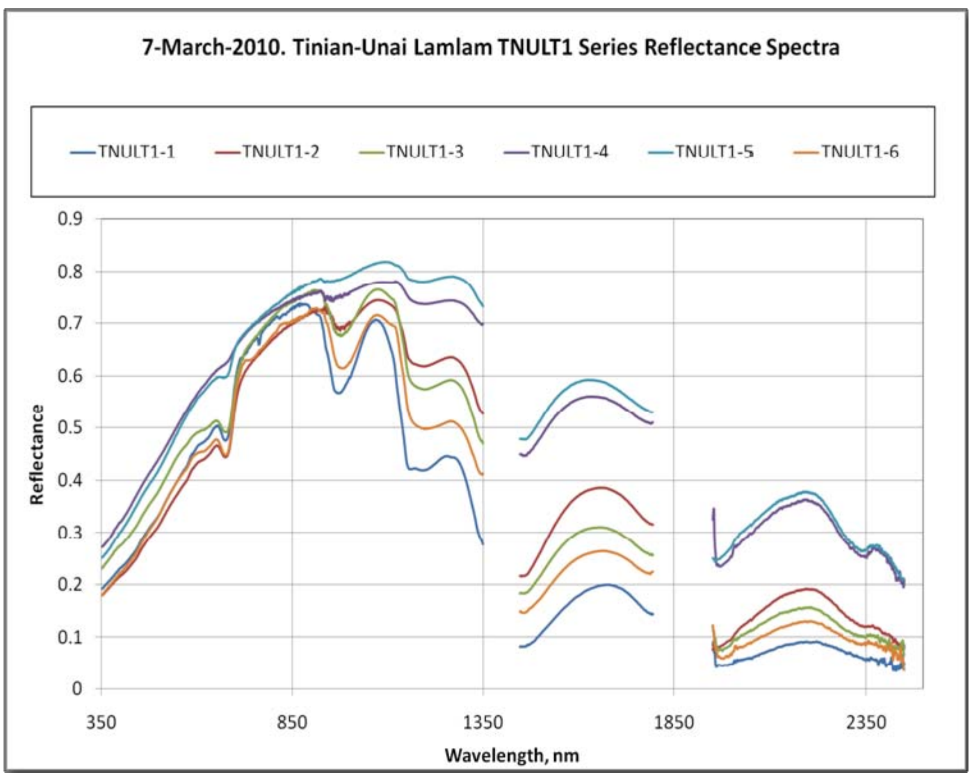

1-March-2010. Pagan Beach 4 PAB4T4 Series Reflectance Spectra
PAB4T4-1
PAB4T4-2
PAB4T4-3
PAB4T4-4
Reflectance
Wavelength, nm
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
350
850
1350
1850
2350


5-March-2010. Tinian-Unai Babui TNUBT1 Series Reflectance Spectra
TNUBT1-1
TNUBT1-2
TNUBT1-3
TNUBT1-4
TNUBT1-5
TNUBT1-6
TNUBT1-7
TNUBT1-8
TNUBT1-9
TNUBT1-10
TNUBT1-11
TNUBT1-12
TNUBT1-13
TNUBT1-14
TNUBT1-15
Reflectnace
Wavelength, nm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
350
850
1350
1850
2350


6-March-2010. Tinian-Unai Dangkolo TNUDT1 Series Reflectance Spectra
TNUDT1-1
TNUDT1-2
TNUDT1-3
TNUDT1-4
TNUDT1-5
TNUDT1-6
Reflectance
Wavelength, nm
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
350
850
1350
1850
2350

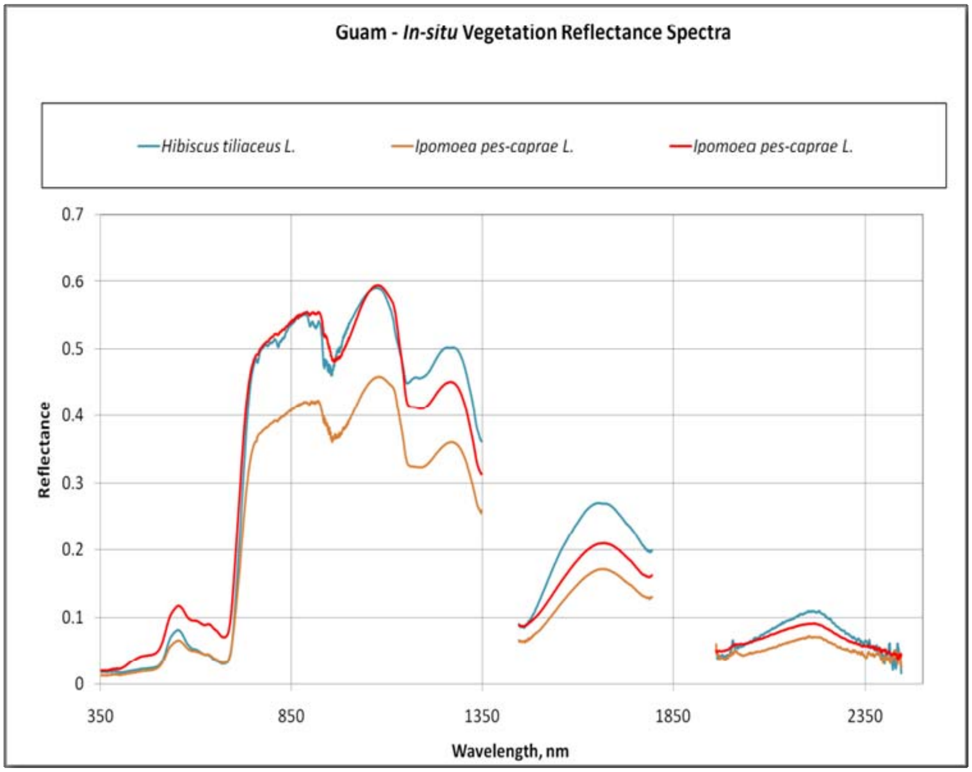

6-March-2010. Tinian-Unai Dangkolo TNUDT2 Series Reflectance Spectra
TNUDT2-1
TNUDT2-2
TNUDT2-3
TNUDT2-4
TNUDT2-5
Reflectance
Wavelength, nm
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
350
850
1350
1850
2350

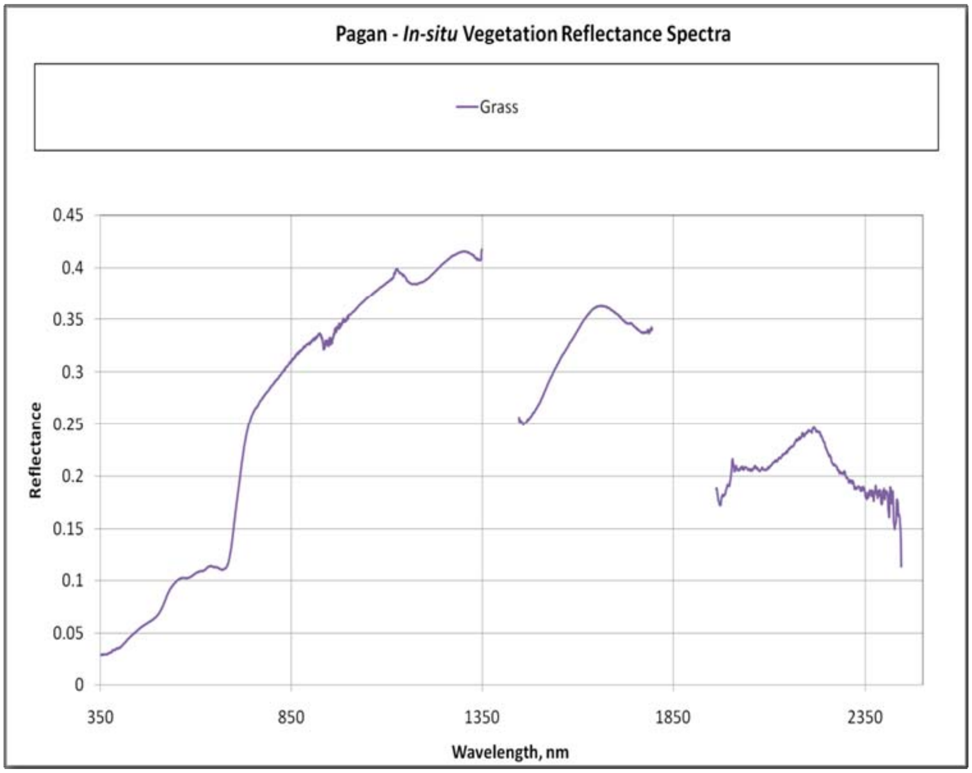

7-March-2010. Tinian-Unai Dangkolo TNUDT3 Series Reflectance Spectra
TNUDT3-1
TNUDT3-2
TNUDT3-3
TNUDT3-4
TNUDT3-5
TNUDT3-6
Refleactance
Wavelength, nm

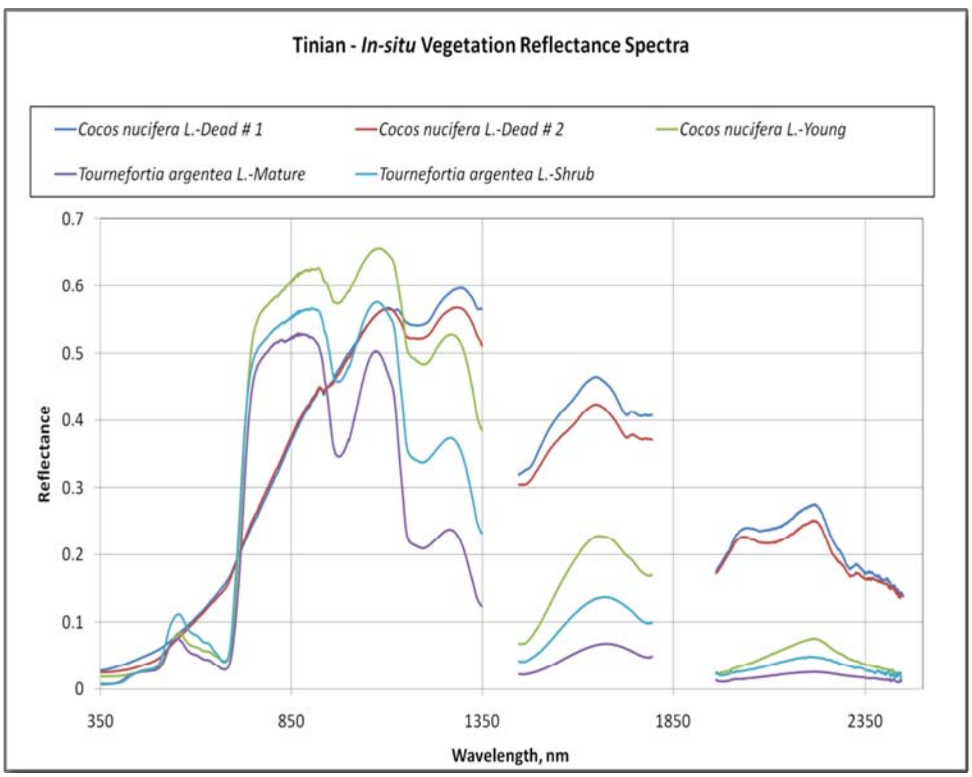

7-March-2010. Tinian-Unai Lamlam TNULT1 Series Reflectance Spectra
TNULT1-1
TNULT1-2
TNULT1-3
TNULT1-4
TNULT1-5
TNULT1-6
Reflectance
Wavelength, nm

2.4 *In-Situ* Vegetation

In-situ vegetation spectra are spectra sampled in the field with solar illumination. Graphs are listed alphabetically by species' scientific name.




Pagan - In-situ Vegetation Reflectance Spectra
Grass
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Reflectance
350
850
1350
1850
2350
Wavelength, nm

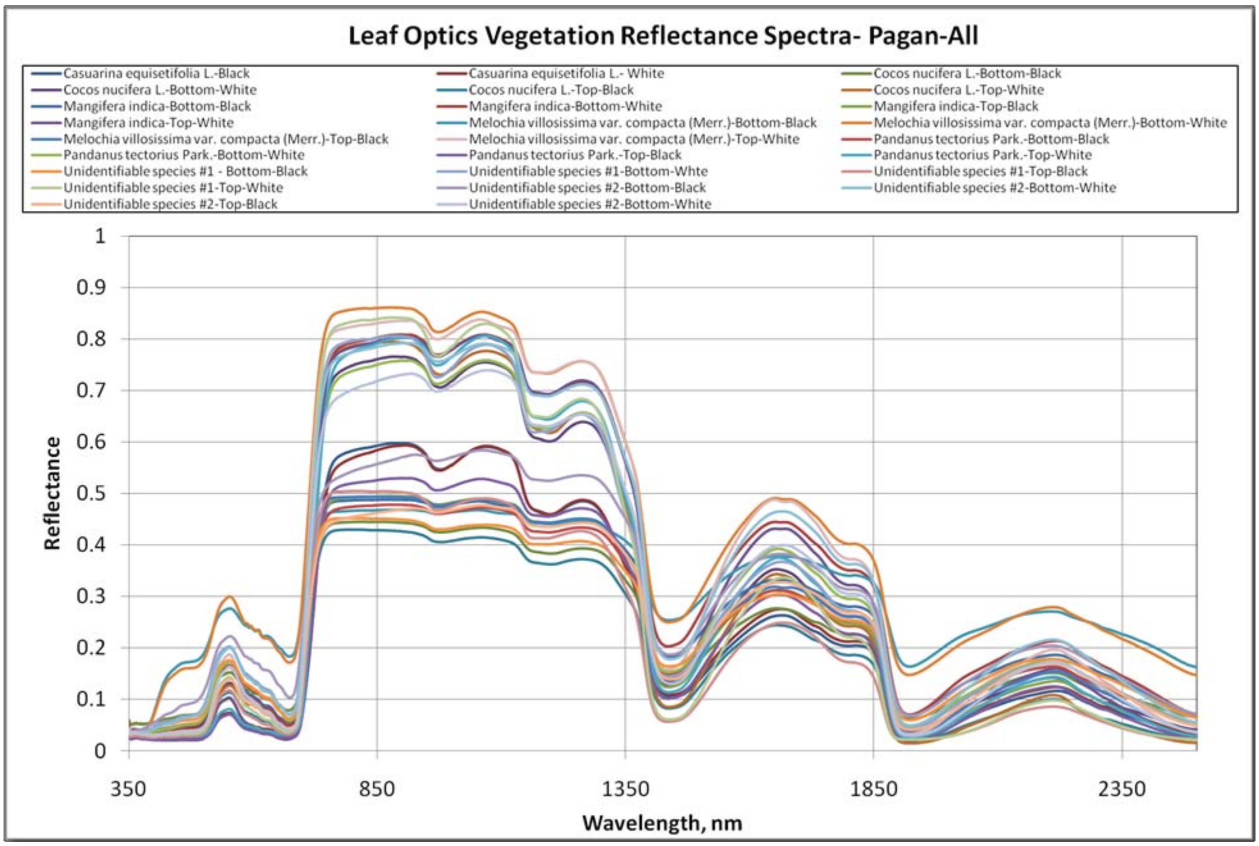

Tinian - In-situ Vegetation Reflectance Spectra
Cocos nucifera L.-Dead # 1
Cocos nucifera L.-Dead # 2
Cocos nucifera L.-Young
Tournefortia argentea L.-Mature
Tournefortia argentea L.-Shrub
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Reflectance
350
850
1350
1850
2350
Wavelength, nm

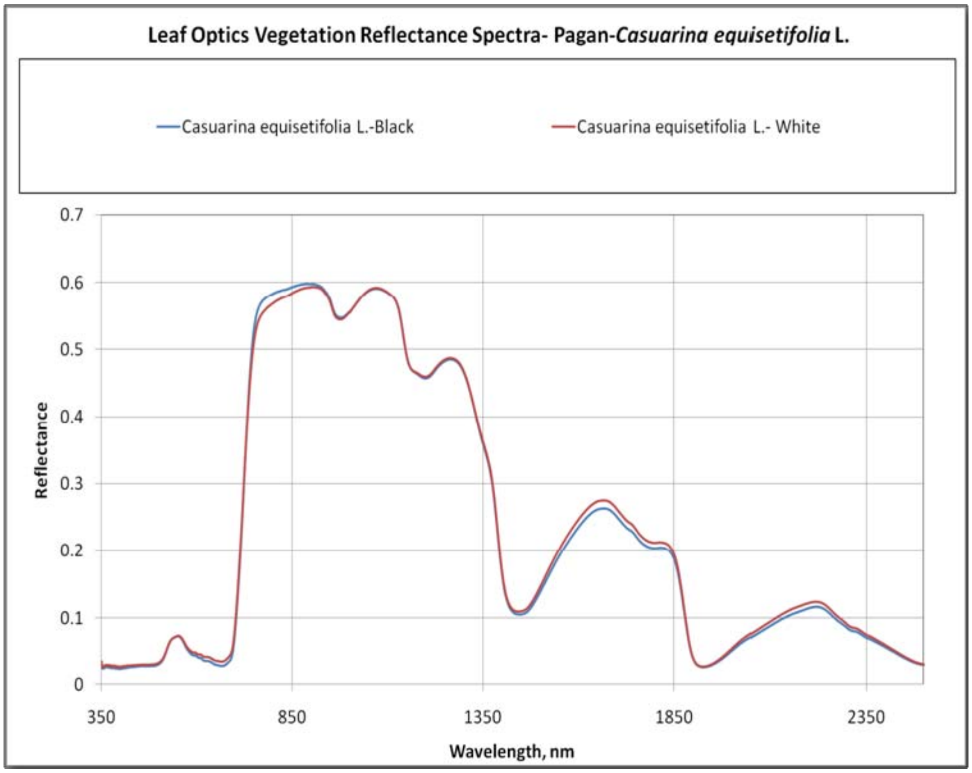
2.5 Leaf-Optics Vegetation

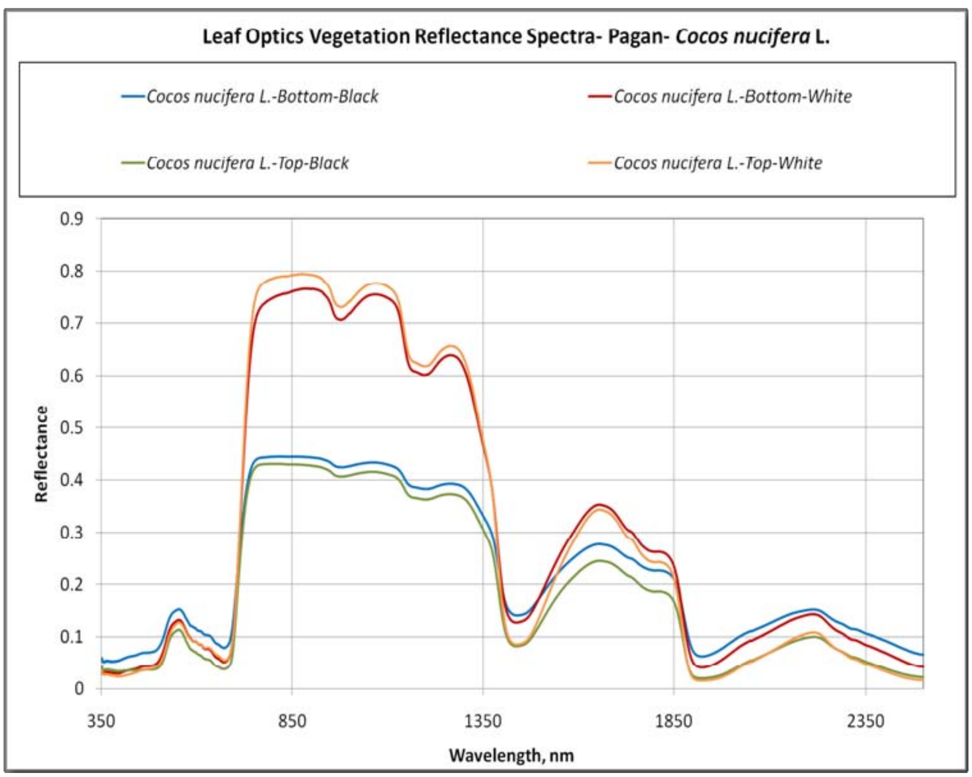
Leaf-optic sampling involved collection of leaf samples in the field and measurement of the reflectance spectra of the leaves using an apparatus that attached to the ASD® spectroradiometer. The sampling involved measuring the spectra of the top and bottom of the leaf in reference to a white and black reference plaque. Graphs are listed alphabetically by species' scientific name for each island.

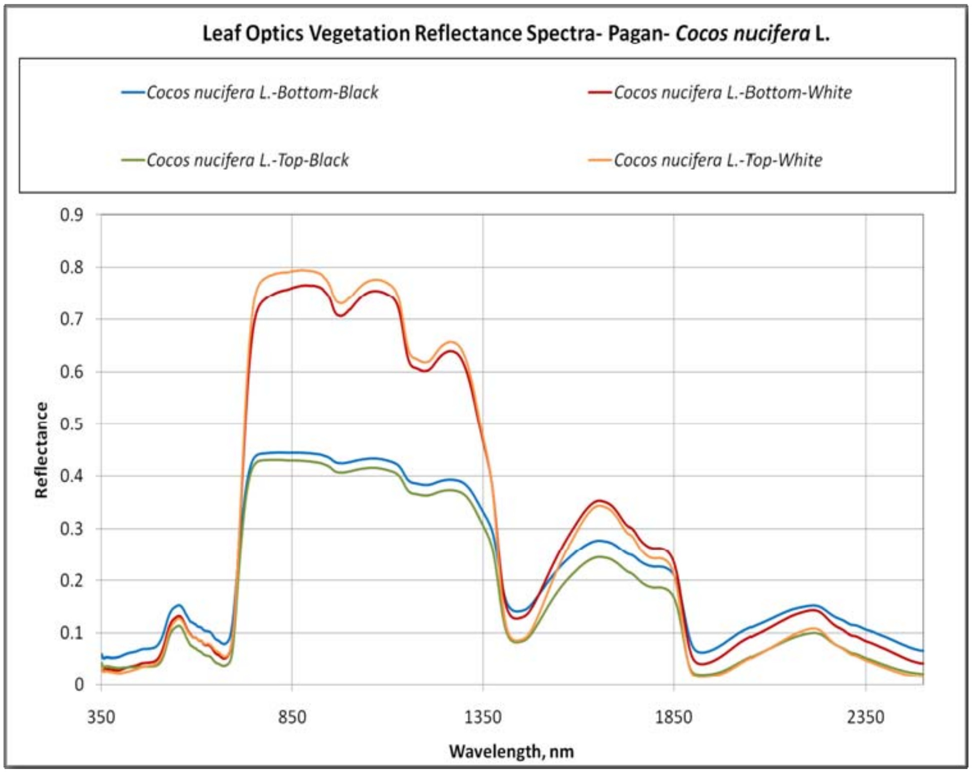
2.5.1 Pagan

The figures below present all leaf optic samples recorded at Pagan. The first is a summary graph for all samples, followed by graphs showing subsets of these spectra by species.

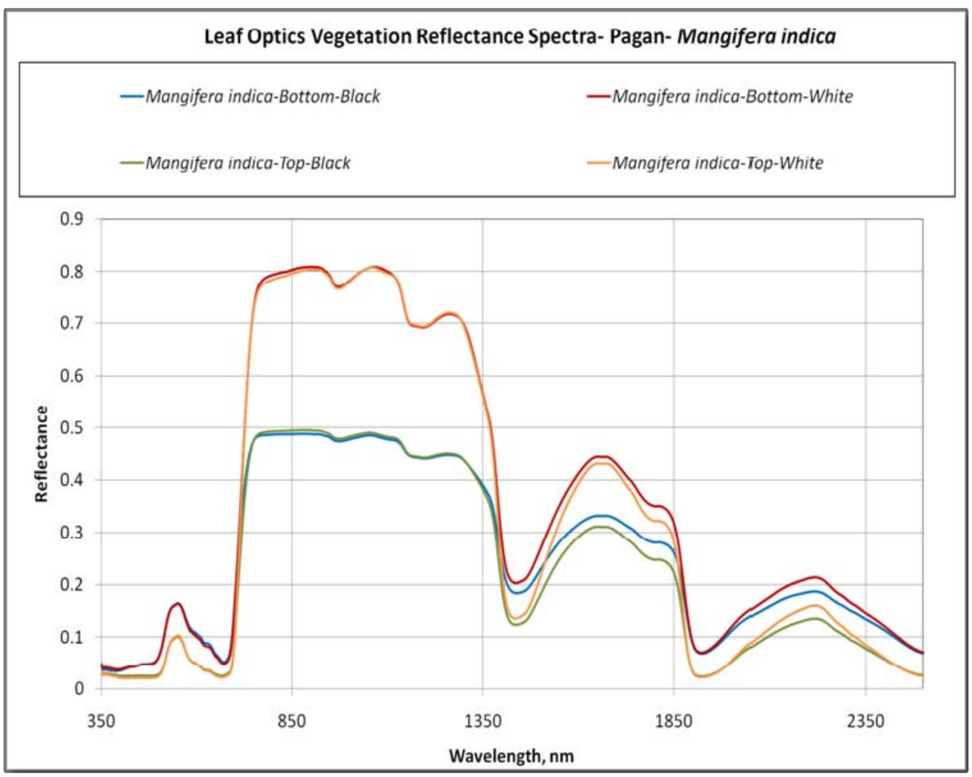



Leaf Optics Vegetation Reflectance Spectra- Pagan-Casuarina equisetifolia L.
Casuarina equisetifolia L.-Black
Casuarina equisetifolia L.- White
Reflectance
Wavelength, nm

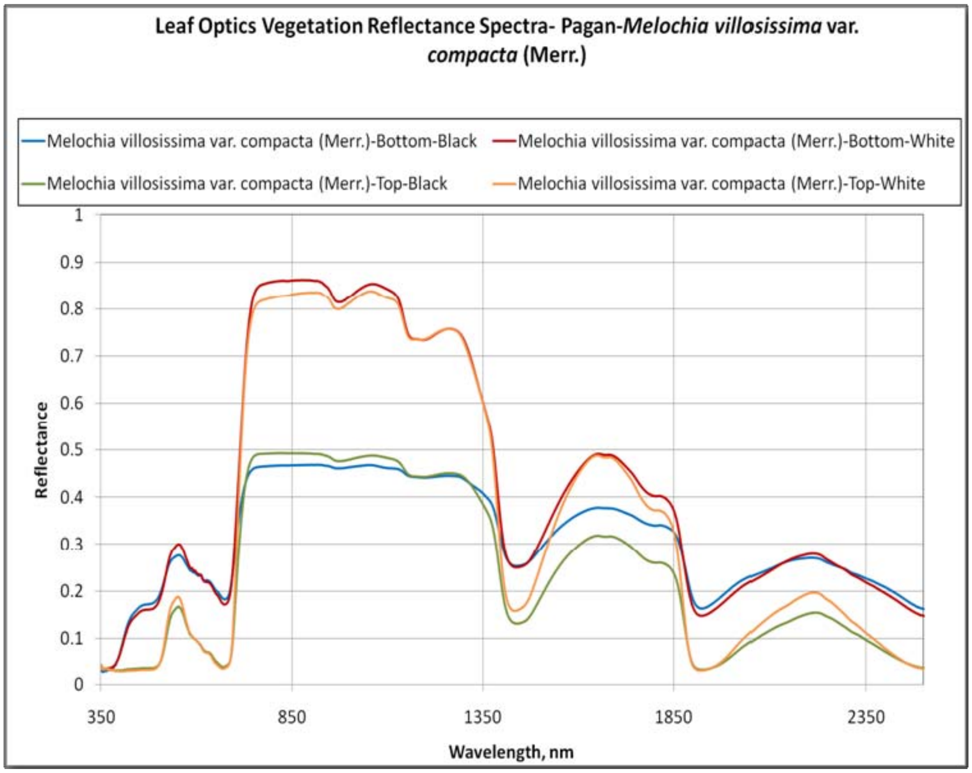

Leaf Optics Vegetation Reflectance Spectra- Pagan- Cocos nucifera L.
Cocos nucifera L.-Bottom-Black
Cocos nucifera L.-Bottom-White
Cocos nucifera L.-Top-Black
Cocos nucifera L.-Top-White
Reflectance
Wavelength, nm

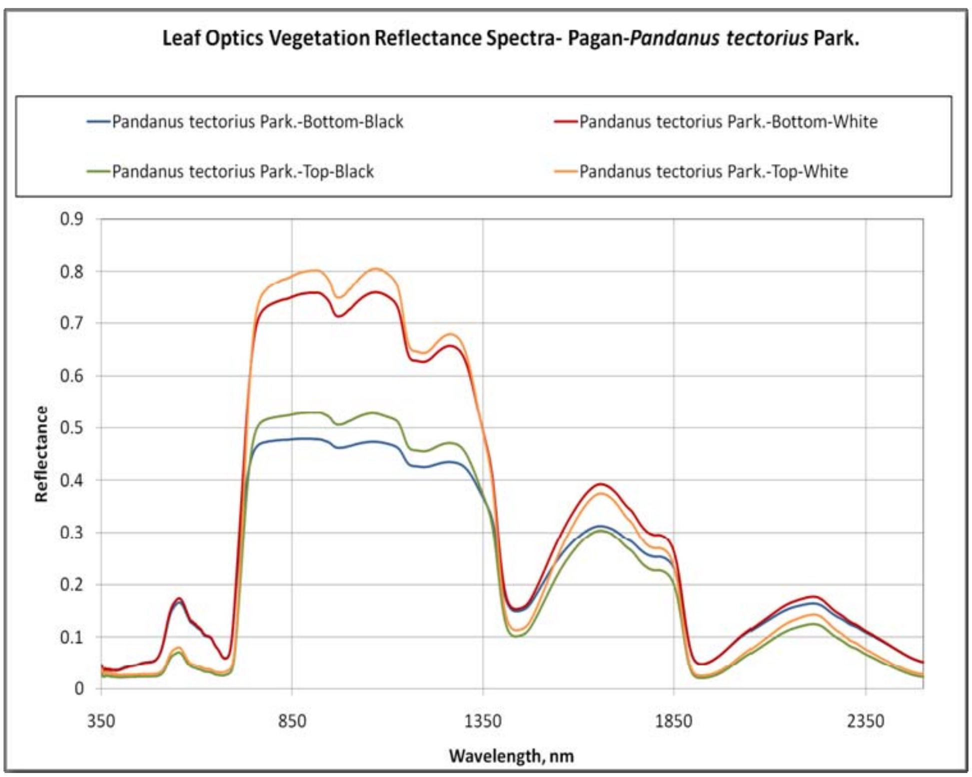


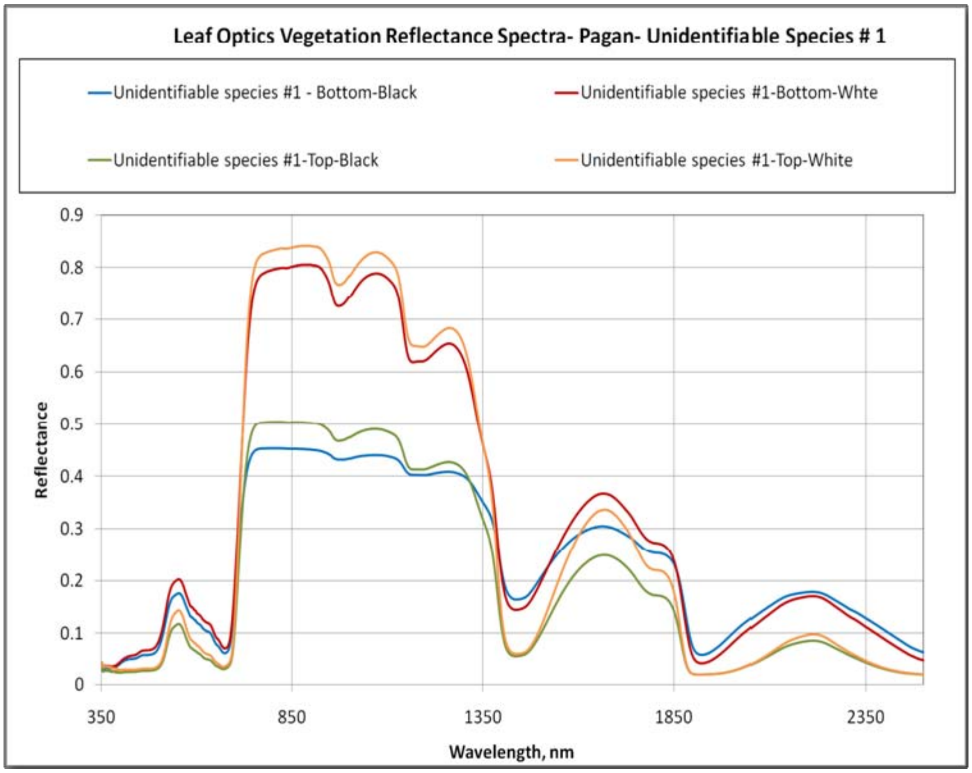
Leaf Optics Vegetation Reflectance Spectra- Pagan- *Cocos nucifera* L.
Cocos nucifera L.-Bottom-Black
Cocos nucifera L.-Bottom-White
Cocos nucifera L.-Top-Black
Cocos nucifera L.-Top-White
Reflectance
Wavelength, nm

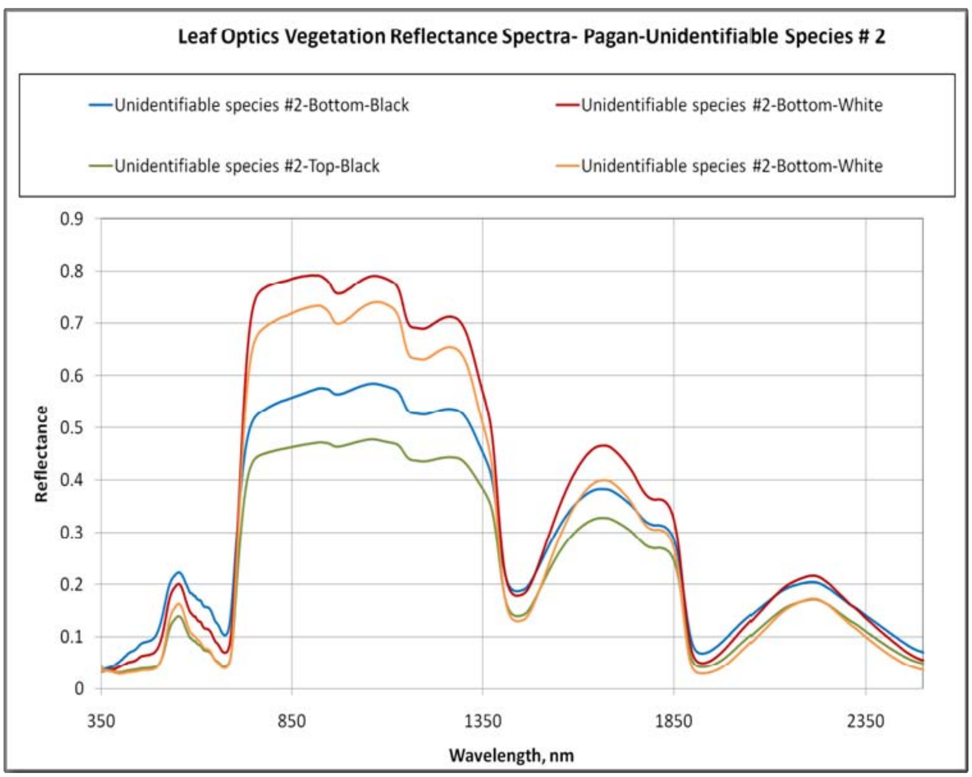


Leaf Optics Vegetation Reflectance Spectra- Pagan- *Mangifera indica*
Mangifera indica-Bottom-Black
Mangifera indica-Bottom-White
Mangifera indica-Top-Black
Mangifera indica-Top-White
Reflectance
Wavelength, nm


Leaf Optics Vegetation Reflectance Spectra- Pagan-*Melochia villosissima* var. *compacta* (Merr.)
Melochia villosissima var. compacta (Merr.)-Bottom-Black
Melochia villosissima var. compacta (Merr.)-Bottom-White
Melochia villosissima var. compacta (Merr.)-Top-Black
Melochia villosissima var. compacta (Merr.)-Top-White
Reflectance
Wavelength, nm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
350
850
1350
1850
2350

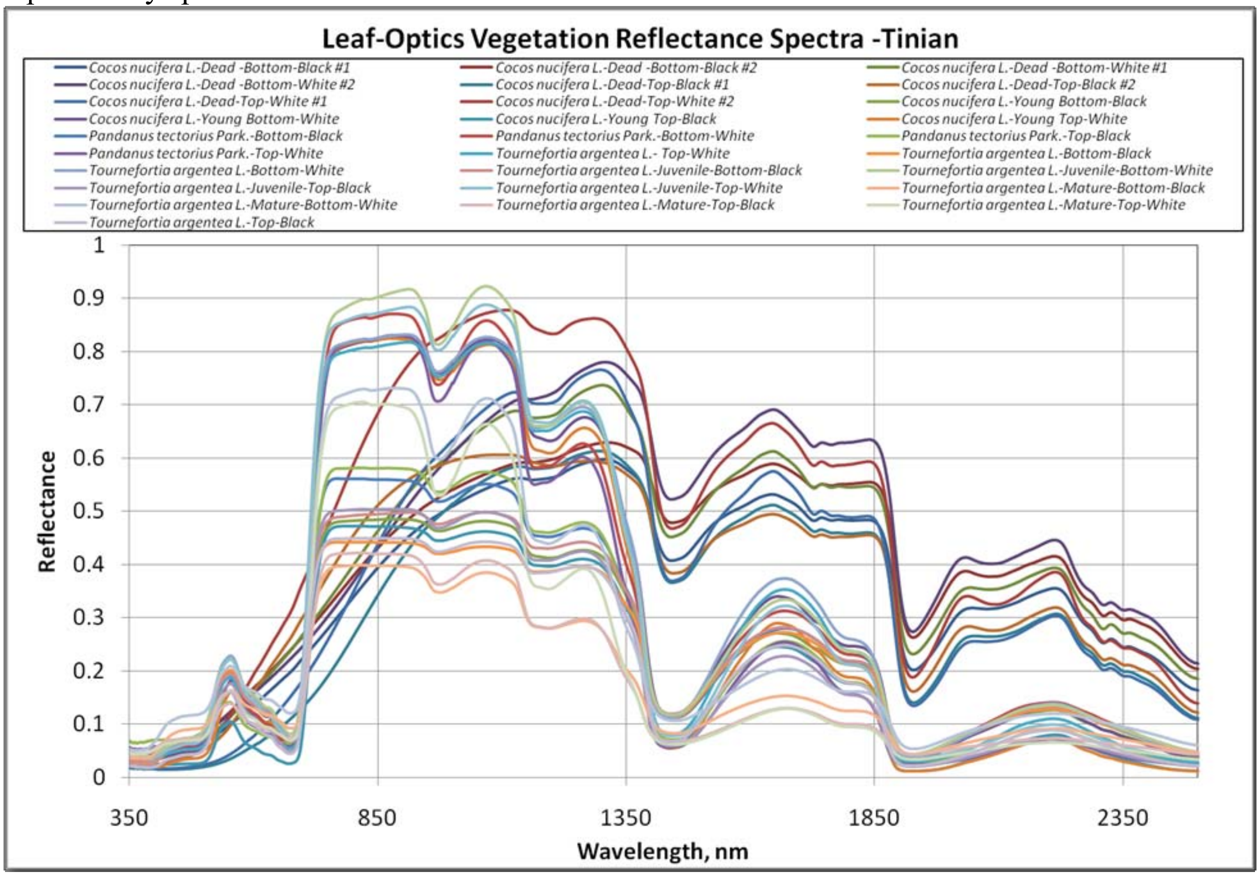

Leaf Optics Vegetation Reflectance Spectra- Pagan-*Pandanus tectorius* Park.
Pandanus tectorius Park.-Bottom-Black
Pandanus tectorius Park.-Bottom-White
Pandanus tectorius Park.-Top-Black
Pandanus tectorius Park.-Top-White
Reflectance
Wavelength, nm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
350
850
1350
1850
2350

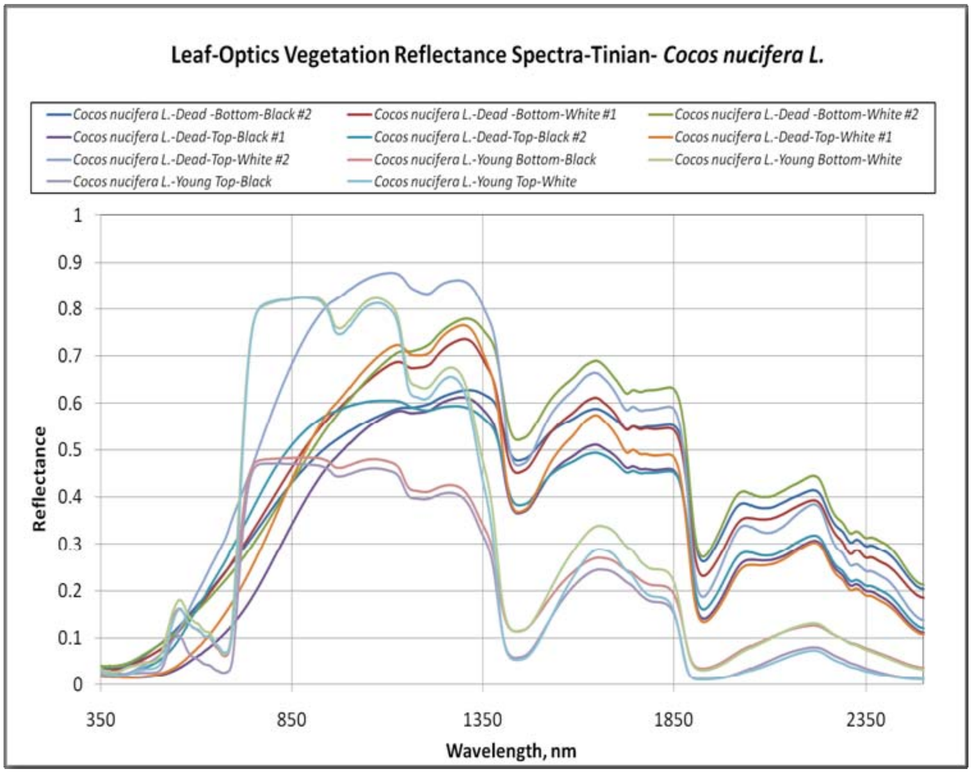

Leaf Optics Vegetation Reflectance Spectra- Pagan- Unidentifiable Species # 1
Unidentifiable species #1 - Bottom-Black
Unidentifiable species #1-Bottom-Whte
Unidentifiable species #1-Top-Black
Unidentifiable species #1-Top-White
Reflectance
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
350
850
1350
1850
2350
Wavelength, nm

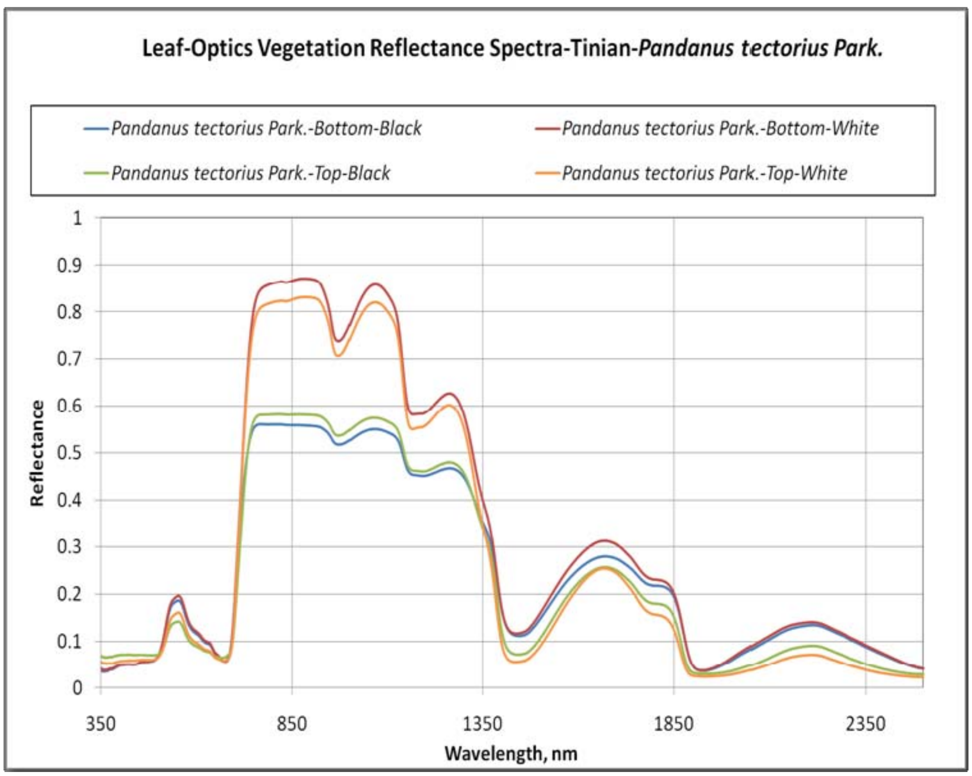

Leaf Optics Vegetation Reflectance Spectra- Pagan-Unidentifiable Species # 2
Unidentifiable species #2-Bottom-Black
Unidentifiable species #2-Bottom-White
Unidentifiable species #2-Top-Black
Unidentifiable species #2-Bottom-White
Reflectance
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
350
850
1350
1850
2350
Wavelength, nm

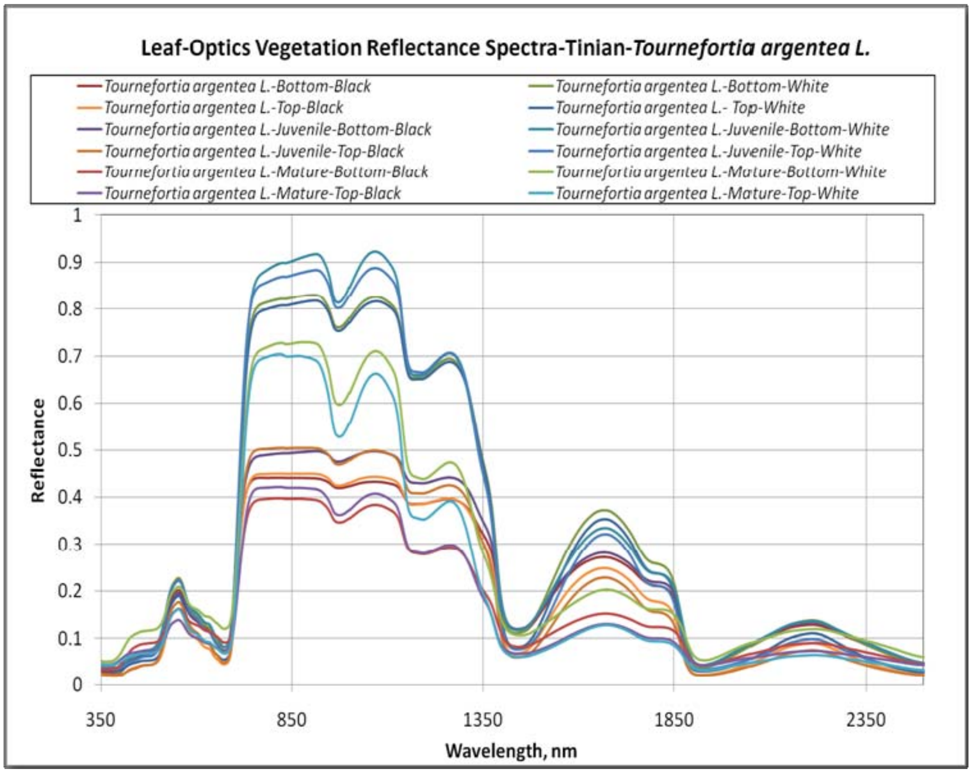
2.5.2 Tinian

The figure below presents all leaf optic samples recorded at Tinian, followed by subsets separated by species.



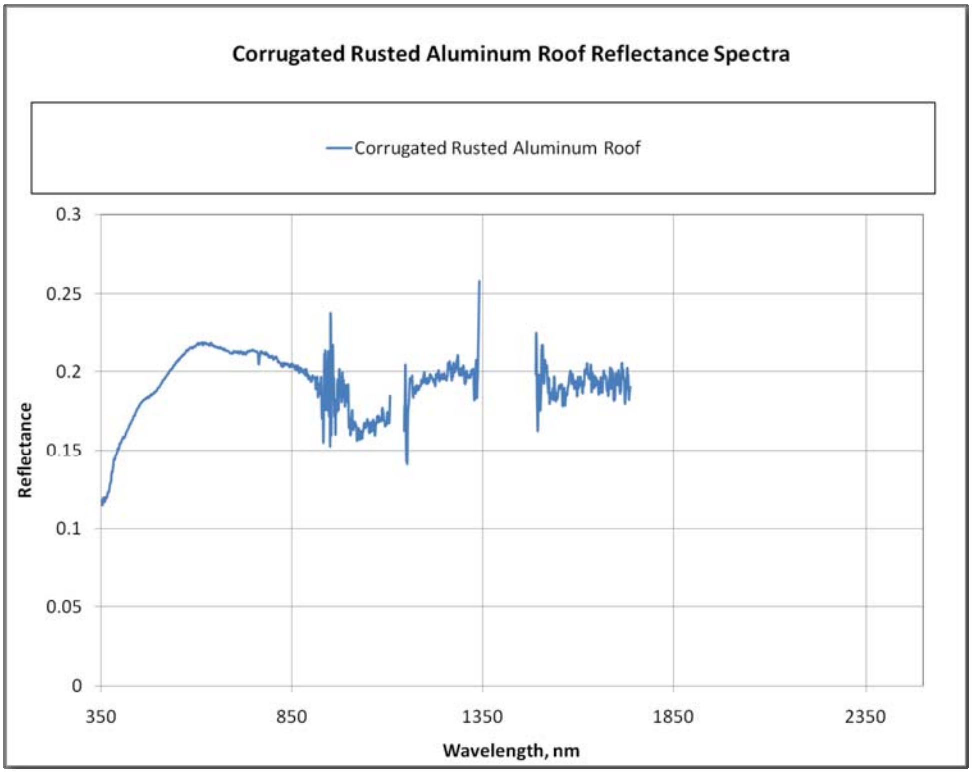

Leaf-Optics Vegetation Reflectance Spectra-Tinian- Cocos nucifera L.
Cocos nucifera L.-Dead -Bottom-Black #2
Cocos nucifera L.-Dead -Bottom-White #1
Cocos nucifera L.-Dead -Bottom-White #2
Cocos nucifera L.-Dead-Top-Black #1
Cocos nucifera L.-Dead-Top-Black #2
Cocos nucifera L.-Dead-Top-White #1
Cocos nucifera L.-Dead-Top-White #2
Cocos nucifera L.-Young Bottom-Black
Cocos nucifera L.-Young Bottom-White
Cocos nucifera L.-Young Top-Black
Cocos nucifera L.-Young Top-White
Reflectance
Wavelength, nm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
350
850
1350
1850
2350

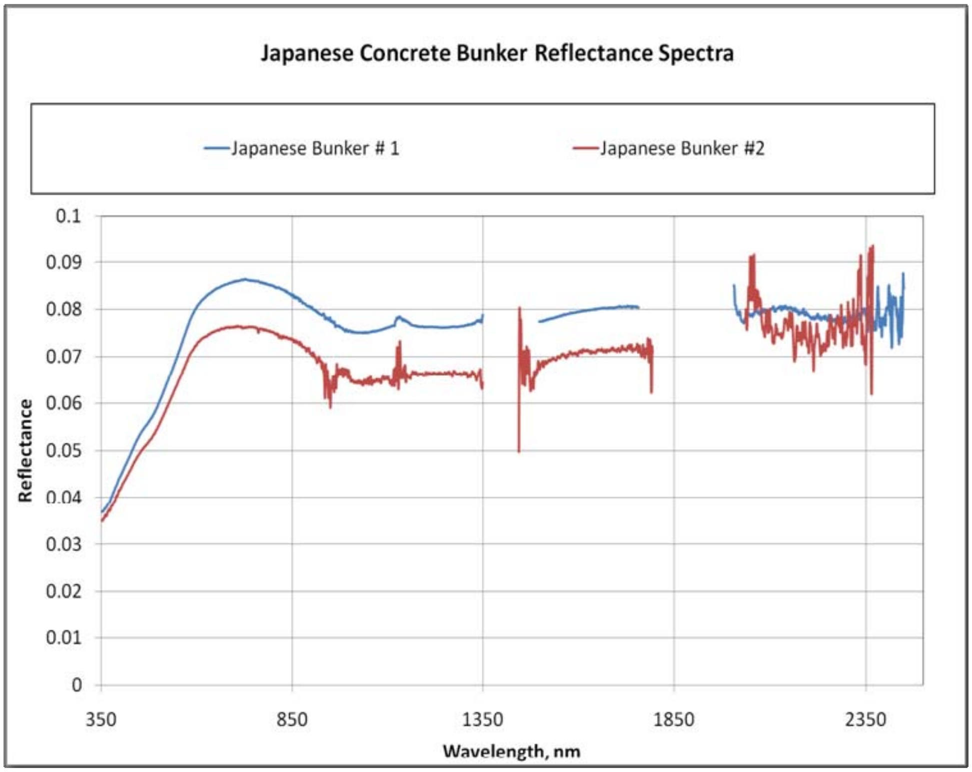

Leaf-Optics Vegetation Reflectance Spectra-Tinian-Pandanus tectorius Park.
Pandanus tectorius Park.-Bottom-Black
Pandanus tectorius Park.-Bottom-White
Pandanus tectorius Park.-Top-Black
Pandanus tectorius Park.-Top-White
Reflectance
Wavelength, nm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
350
850
1350
1850
2350

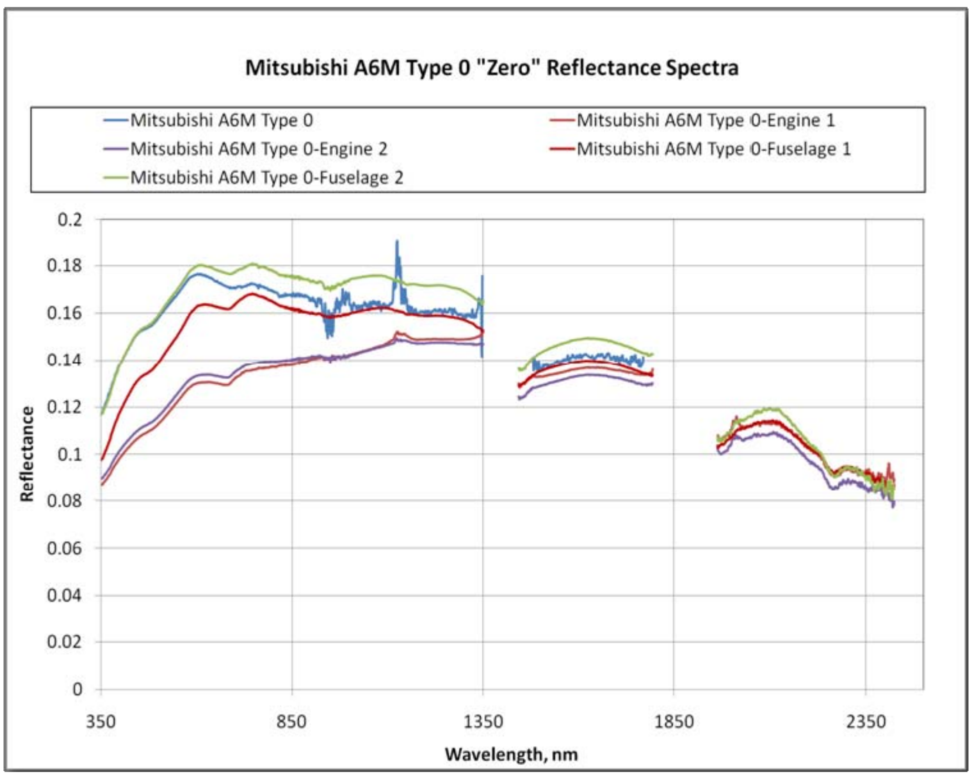

Leaf-Optics Vegetation Reflectance Spectra-Tinian-Tournefortia argentea L.
Tournefortia argentea L.-Bottom-Black
Tournefortia argentea L.-Bottom-White
Tournefortia argentea L.-Top-Black
Tournefortia argentea L.- Top-White
Tournefortia argentea L.-Juvenile-Bottom-Black
Tournefortia argentea L.-Juvenile-Bottom-White
Tournefortia argentea L.-Juvenile-Top-Black
Tournefortia argentea L.-Juvenile-Top-White
Tournefortia argentea L.-Mature-Bottom-Black
Tournefortia argentea L.-Mature-Bottom-White
Tournefortia argentea L.-Mature-Top-Black
Tournefortia argentea L.-Mature-Top-White
Reflectance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
350
850
1350
1850
2350
Wavelength, nm

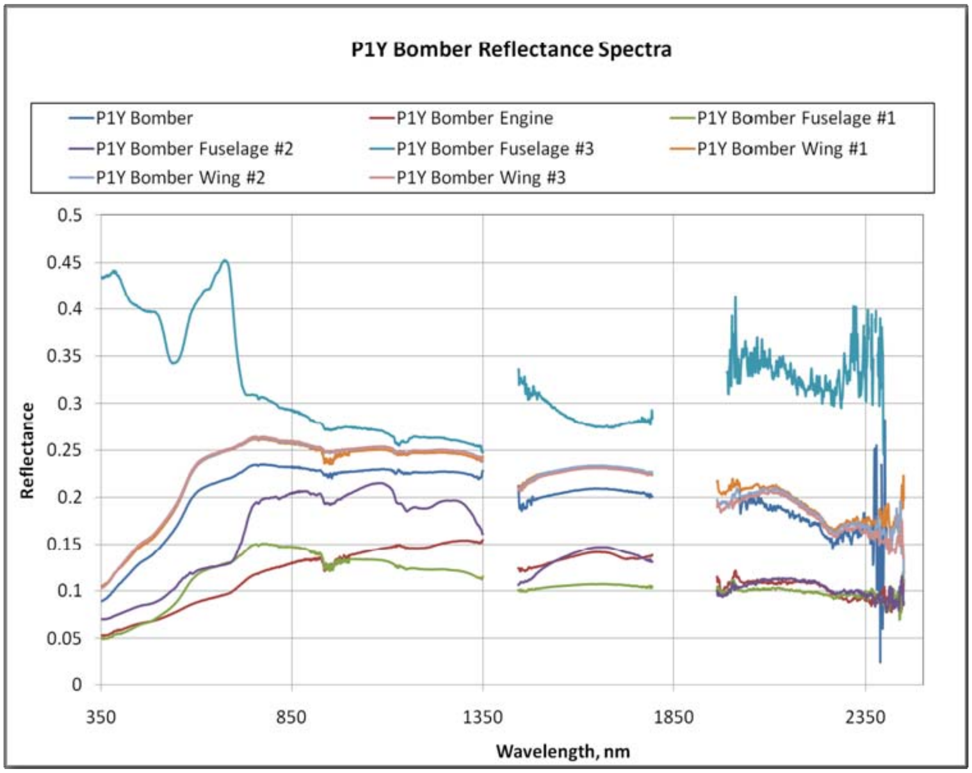
2.6 Man-Made Features/Relics

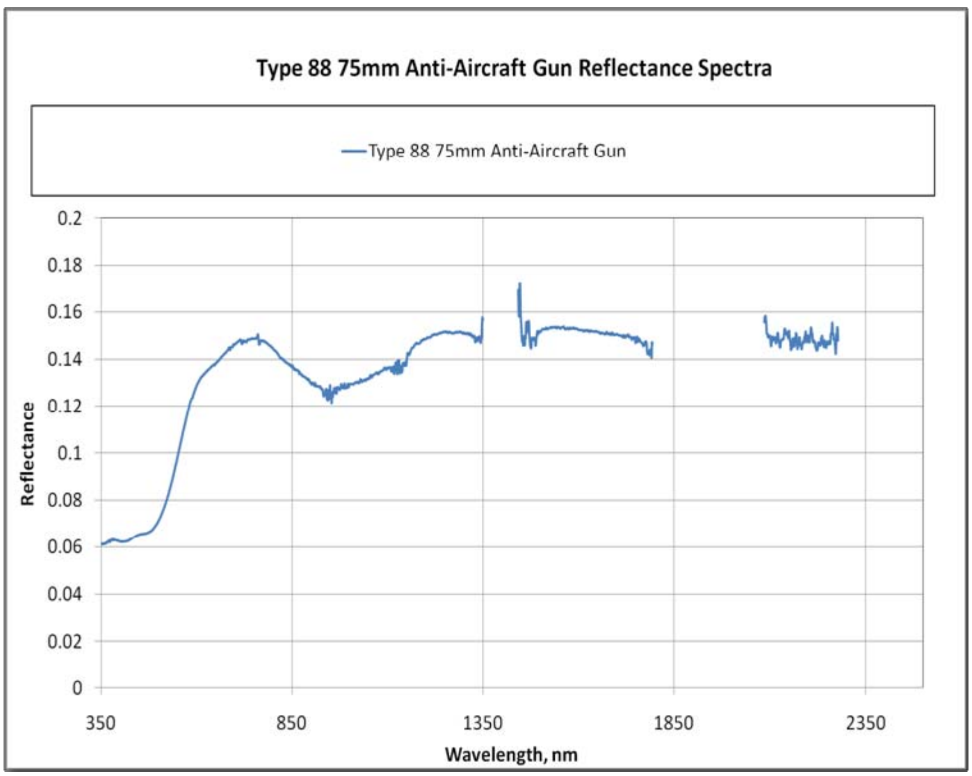
Man-made features and WWII relics were sampled during the campaign. These were sampled to support anomaly detection from the hyperspectral imagery. Man-made features and relics were sampled on Pagan on 2 March and 3 March 2010. Five features/relics were sampled with some features having been sampled on both days. All man-made features/relics are displayed in the graphs below.




Japanese Concrete Bunker Reflectance Spectra
Japanese Bunker # 1
Japanese Bunker #2
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Reflectance
350
850
1350
1850
2350
Wavelength, nm

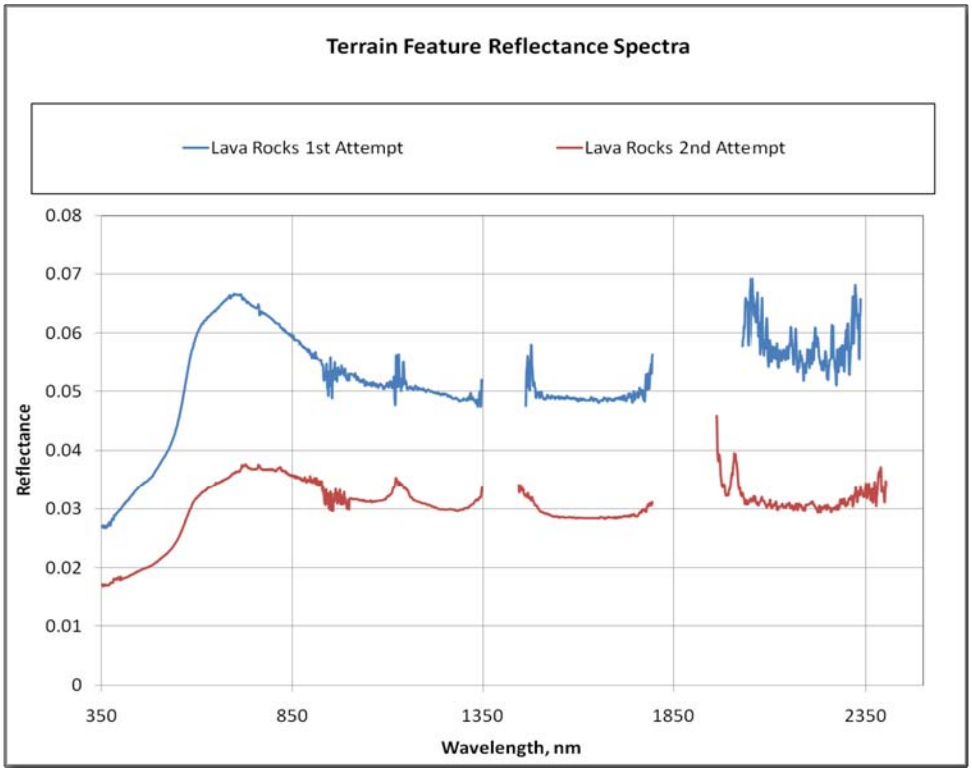

Mitsubishi A6M Type 0 "Zero" Reflectance Spectra
Mitsubishi A6M Type 0
Mitsubishi A6M Type 0-Engine 1
Mitsubishi A6M Type 0-Engine 2
Mitsubishi A6M Type 0-Fuselage 1
Mitsubishi A6M Type 0-Fuselage 2
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Reflectance
350
850
1350
1850
2350
Wavelength, nm


P1Y Bomber Reflectance Spectra
P1Y Bomber
P1Y Bomber Engine
P1Y Bomber Fuselage #1
P1Y Bomber Fuselage #2
P1Y Bomber Fuselage #3
P1Y Bomber Wing #1
P1Y Bomber Wing #2
P1Y Bomber Wing #3
Reflectance
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
350
850
1350
1850
2350
Wavelength, nm


Type 88 75mm Anti-Aircraft Gun Reflectance Spectra
Type 88 75mm Anti-Aircraft Gun
Reflectance
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
350
850
1350
1850
2350
Wavelength, nm

2.7 Terrain Features

On Pagan, an interesting airfield obstruction was created following the 15 May 1981 eruption that resulted in the evacuation of Pagan residents. Spectra of the solidified lava flow that cut the runway in half are displayed below. Only short take off and landing aircraft can use this field and imagery from this remote sensing campaign may be useful in updating aeronautical charts.



3 Spectra Comments

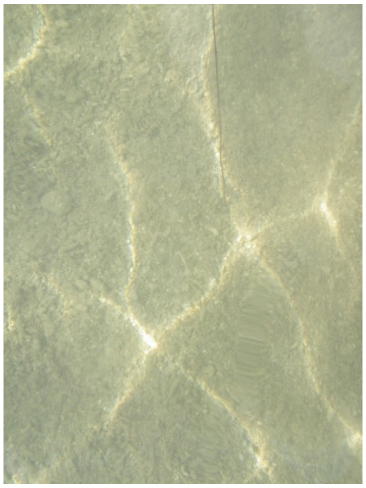
Comments concerning the capture of spectra were transcribed from field notes. Information that was gathered from the field includes environmental conditions, substrate type, and the types of instruments that were being operated. Since there were many note-takers during the experiment, field notes were not necessarily completed in a standard way. Notes are broken down by spectral type in accordance with Section 2. Sites are listed alphabetically by transect or position. Since most of the spectra were collected during dual mode operation, the base station that corresponds with each transect/position is also listed.

A standardized method for photographic documentation was used at all sites where spectra were collected. Documentation of these sites involved capturing approximately four photographs of the substrate immediately after spectra were collected. This was done in order to capture the substrate as it had appeared during spectroscopy, since the geotechnical measurements that followed disturbed the substrate. A representative photograph for each site is provided in the photograph column. Other photographs are archived in the project geodatabase.

3.1 Bathymetry (Shallow Water), NR=Not Recorded

Site Name/Description	Year	Month	Day	Time (Local)	Latitude (N)	Longitude (E)	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
GUDSWB (Base Station)	2010	3	9	15:10-17:32	N/A	N/A	N/A	N/A	Intermittent clouds	Partly Cloudy	NRL OLD	C	Dual	Base Station	N/A		N/A
GUDSWB-1	2010	3	9	15:12	13.4143345	144.6559006	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Shallow Water Bathymetry	110	SWBATHY, NRL new less then 1 second ahead of nrl old	
GUDSWB-1	2010	3	9	15:15	13.4143345	144.6559006	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Shallow Water Bathymetry	60	SWBATHY, NRL new less then 1 second ahead of nrl old base station	

					
big cobbles	big cobbles			PL ASD was used as the time source, the inundation was falling	PL ASD was used as the time source, the inundation was falling
245	180	360	350	495	495
Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry
Dual	Dual	Dual	Dual	Dual	Dual
C	C	C	C	C	C
NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds
Coraline Sands	Coraline Sands	Coraline Sands	Coraline Sands	Coraline Sands	Coraline Sands
N/A	N/A	N/A	N/A	N/A	N/A
144.6558904	144.6558904	144.6558796	144.6558796	144.6558618	144.6558618
13.41432531	13.41432531	13.41431343	13.41431343	13.41429801	13.41429801
15:18	15:21	15:25	15:27	15:31	15:34
9	9	9	9	9	9
3	3	3	3	3	3
2010	2010	2010	2010	2010	2010
GUDSWB-2	GUDSWB-2	GUDSWB-3	GUDSWB-3	GUDSWB-4	GUDSWB-4

					
spectra was swbathy, and the inundation was falling	the inundation was falling				
635	575	735	690	860	855
Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry
Dual	Dual	Dual	Dual	Dual	Dual
C	C	C	C	C	C
NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds
Coraline Sands	Coraline Sands	Coraline Sands	Coraline Sands	Coraline Sands	Coraline Sands
N/A	N/A	N/A	N/A	N/A	N/A
144.6558476	144.6558476	144.6559153	144.6559153	144.6559121	144.6559121
13.4142981	13.4142981	13.41425681	13.41425681	13.41424142	13.41424142
15:39	15:44	15:48	15:52	15:56	16:00
9	9	9	9	9	9
3	3	3	3	3	3
2010	2010	2010	2010	2010	2010
GUDSWB-5	GUDSWB-5	GUDSWB-6	GUDSWB-6	GUDSWB-7	GUDSWB-7

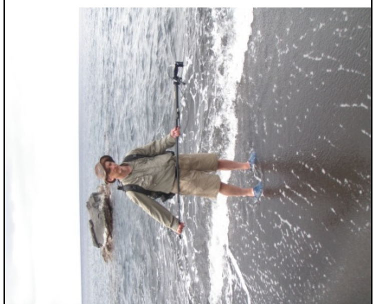
					
optimize at t =1610	optimize at t =1610	ASD PC was new	ASD PC was new	seagrass	seagrass
910	905	1015	1000	700	630
Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry
Dual	Dual	Dual	Dual	Dual	Dual
C	C	C	C	C	C
NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds
Coraline Sands	Coraline Sands	Coraline Sands	Coraline Sands	Coraline Sands	Coraline Sands
N/A	N/A	N/A	N/A	N/A	N/A
144.6559154	144.6559154	144.6559445	144.6559445	144.6559928	144.6559928
13.41421866	13.41421866	13.41417736	13.41417736	13.41416844	13.41416844
16:07	16:16	16:22	16:27	16:36	16:41
9	9	9	9	9	9
3	3	3	3	3	3
2010	2010	2010	2010	2010	2010
GUDSWB-8	GUDSWB-8	GUDSWB-9	GUDSWB-9	GUDSWB-10	GUDSWB-10

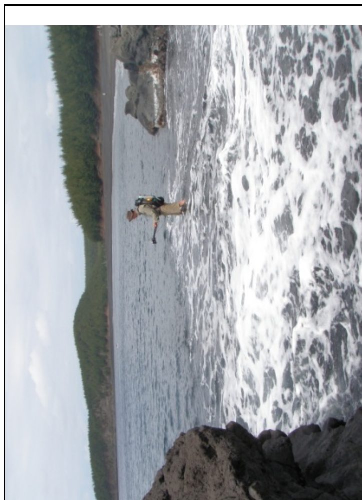
					
		reoptimize at 16:58	reoptimize at 16:58		
815	805	515	500	410	365
Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry
Dual	Dual	Dual	Dual	Dual	Dual
C	C	C	C	C	C
NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds
Coraline Sands	Coraline Sands	Coraline Sands	Coraline Sands	Coraline Sands	Coraline Sands
N/A	N/A	N/A	N/A	N/A	N/A
144.6558738	144.6558738	144.6560133	144.6560133	144.6560985	144.6560985
13.41424007	13.41424007	13.41416945	13.41416945	13.41413693	13.41413693
16:46	16:50	17:10	17:13	17:20	17:23
9	9	9	9	9	9
3	3	3	3	3	3
2010	2010	2010	2010	2010	2010
GUDSWB-11	GUDSWB-11	GUDSWB-12	GUDSWB-12	GUDSWB-13	GUDSWB-13

GUDSWB-14	2010	3	9	17:29	13.41413649	144.6561067	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Shallow Water Bathymetry	345		
GUDSWB-14	2010	3	9	17:32	13.41413649	144.6561067	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Shallow Water Bathymetry	325		

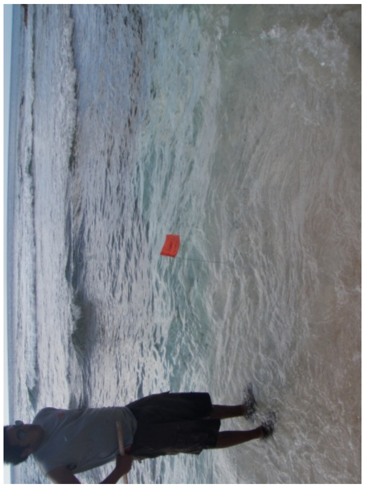
Site Name/Description	Year	Month	Day	Time (Local)	Latitude (N)	Longitude (E)	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PAB1T1, PAB1T2, Pagan_B1_swb (Base Station)	2010	3	2	9:46-12:14	N/A	N/A	N/A	N/A	Intermittent Clouds	Mostly Cloudy	NRL OLD	B	Dual	Base Station	N/A	ASD Base is ahead of new laptop by 1 second	N/A
Pagan_B1_swb	2010	3	2	10:08	NR	NR	N/A	Water with volcanic sand bottom	Not Recorded	Mostly Cloudy	NRL NEW	E	Dual	Shallow Water Bathymetry	180	Measurements done at various positions at south end of beach 1	Not Pictured
Pagan_B1_swb	2010	3	2	10:11	NR	NR	N/A	Water with volcanic sand bottom	Not Recorded	Mostly Cloudy	NRL NEW	E	Dual	Shallow Water Bathymetry	400	Measurements done at various positions at south end of beach 1	Not Pictured

Not Pictured	Not Pictured	Not Pictured	Not Pictured		Not Pictured
Measurements done at various positions at south end of beach 1	Measurements done at various positions at south end of beach 1	Measurements done at various positions at south end of beach 1	Measurements done at various positions at south end of beach 1	Measurements done at various positions at south end of beach 1	Measurements done at various positions at south end of beach 1
680	150	360	120	300	800
Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry
Dual	Dual	Dual	Dual	Dual	Dual
E	E	E	E	E	E
NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW
Mostly Cloudy	Mostly Cloudy	Mostly Cloudy	Mostly Cloudy	Mostly Cloudy	Mostly Cloudy
NR	NR	NR	NR	NR	NR
Water with volcanic sand bottom	Water with volcanic sand bottom	Water with volcanic sand bottom	Water with volcanic sand bottom	Water with volcanic sand bottom	Water with volcanic sand bottom
N/A	N/A	N.A	N/A	N/A	N/A
NR	NR	NR	NR	NR	NR
NR	NR	NR	NR	NR	NR
10:12	10:17	10:19	10:47	10:49	10:52
2	2	2	2	2	2
3	3	3	3	3	3
2010	2010	2010	2010	2010	2010
Pagan_B1_swb	Pagan_B1_swb	Pagan_B1_swb	Pagan_B1_swb	Pagan_B1_swb	Pagan_B1_swb

Not Pictured	Not Pictured		Not Pictured	Not Pictured	Not Pictured
Measurements done at various positions at south end of beach 1	Measurements done at various positions at south end of beach 1	Measurements done at various positions at south end of beach 1	Measurements done at various positions at south end of beach 1	Measurements done at various positions at south end of beach 1	Measurements done at various positions at south end of beach 1
30	wet sub	wet sub	1280	280	620
Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry
Dual	Dual	Dual	Dual	Dual	Dual
E	E	E	E	E	E
NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW
Mostly Cloudy	Mostly Cloudy	Mostly Cloudy	Mostly Cloudy	Mostly Cloudy	Mostly Cloudy
NR	NR	NR	NR	NR	NR
Water with volcanic sand bottom	Water with volcanic sand bottom	Water with volcanic sand bottom	Water with volcanic sand bottom	Water with volcanic sand bottom	Water with volcanic sand bottom
N/A	N/A	N/A	N/A	N/A	N/A
NR	NR	NR	NR	NR	NR
NR	NR	NR	NR	NR	NR
10:57	10:58	11:00	11:08	11:32	11:35
2	2	2	2	2	2
3	3	3	3	3	3
2010	2010	2010	2010	2010	2010
Pagan_B1_swb	Pagan_B1_swb	Pagan_B1_swb	Pagan_B1_swb	Pagan_B1_swb	Pagan_B1_swb

Pagan_B1_swb	2010	3	2	11:37	NR	NR	N/A	Water with volcanic sand bottom	NR	Mostly Cloudy	NRL NEW	E	Dual	Shallow Water Bathymetry	700	Measurements done at various positions at south end of beach 1	
Pagan_B1_swb	2010	3	2	11:40	NR	NR	N/A	Water with volcanic sand bottom	NR	Mostly Cloudy	NRL NEW	E	Dual	Shallow Water Bathymetry	80	Measurements done at various positions at south end of beach 1	Not Pictured

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
TNUL-Swb (Base Station)	2010	3	7	16:32-16:50	N/A	N/A	N/A	N/A	NR	NR	NRL OLD	F	Dual	Base Station	N/A	Change in plaque in base station	N/A
TNUL-swb 1	2010	3	7	15:42	15.08747732	145.6326811	N/A	Sand Bottom	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Shallow Water Bathymetry	0-80		
TNUL-swb 1	2010	3	7	15:45	15.08747732	145.6326811	N/A	Sand Bottom	Intermittent clouds	Partly Cloudy	NRL NEW	F	Single	Shallow Water Bathymetry	0-80		

					
				white limestone bottom	white limestone bottom
100-300	100-300	350-600	350-600	400-600	400-600
Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry
Dual	Dual	Dual	Dual	Dual	Dual
F	F	F	F	F	F
NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds	Intermittent clouds
Sand Bottom	Sand Bottom	Sand Bottom	Sand Bottom	Sand Bottom	Sand Bottom
N/A	N/A	N/A	N/A	N/A	N/A
145.6326577	145.6326577	145.6326485	145.6326485	145.6326378	145.6326378
15.08749775	15.08749775	15.08750201	15.08750201	15.08749797	15.08749797
15:49	15:51	15:54	15:56	16:01	16:03
7	7	7	7	7	7
3	3	3	3	3	3
2010	2010	2010	2010	2010	2010
TNUL-swb 2	TNUL-swb 2	TNUL-swb 3	TNUL-swb 3	TNUL-swb 4	TNUL-swb 4

					
dark rock ledge (brown/green)	dark rock ledge (brown/green)	dark rock ledge (brown/green)	dark rock ledge (brown/green)	white limestone with few colored rocks	white limestone with few colored rocks
250-500	300-600	300-900	250-550	670-720	610-750
Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry	Shallow Water Bathymetry
Dual	Dual	Dual	Dual	Dual	Dual
F	F	F	F	F	F
NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent Clouds	Intermittent clouds	Intermittent Clouds	Intermittent Clouds	Intermittent Clouds	Intermittent clouds
Sand Bottom	Sand Bottom	Sand Bottom	Sand Bottom	Sand Bottom	Sand Bottom
N/A	N/A	N/A	N/A	N/A	N/A
145.6326128	145.6326128	145.6325921	145.6325921	145.6325663	145.6325663
15.08750766	15.08750766	15.08753845	15.08753845	15.08749633	15.08749633
16:11	16:14	16:16	16:20	16:37	16:40
7	7	7	7	7	7
3	3	3	3	3	3
2010	2010	2010	2010	2010	2010
TNUL-swb 5	TNUL-swb 5	TNUL-swb 6	TNUL-swb 6	TNUL-swb 7	TNUL-swb 7

TNUL-swb 8	2010	3	7	16:44	15.08751532	145.6325375	N/A	Sand Bottom	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Shallow Water Bathymetry	820-1000		
TNUL-swb 8	2010	3	7	16:45	15.08751532	145.6325375	N/A	Sand Bottom	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Shallow Water Bathymetry	820-1060		

3.2 Calibration Panel

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PAAIRFIELD Black Panel (Base Station)	2010	3	3	8:45-8:51	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A	Base station for PAAIRFIELD Black Panel	Not Pictured
PAAIRFIELD Black Panel	2010	3	3	8:45-8:50	18.123868	145.760329	N/A	Black Panel	Intermittent Clouds	Partly Cloudy	NRL NEW	B	Dual	Calibration Panel	N/A	black panel at airfield on Pagan	

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PAAIRFIELD-White Panel (Base Station)	2010	3	3	9:07-9:14	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station		Base station for PAAIRFIELD White Panel	Not Pictured
PAAIRFIELD-White Panel	2010	3	3	9:07-9:14	18.123015	145.763487	N/A	White Panel	Intermittent Clouds	Partly Cloudy	NRL NEW	B	Dual	Calibration Panel	N/A	white panel at airfield on Pagan	

3.3 Geotechnical

3.3.1 GUDT1 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
GUDT1 (Base Station)	2010	3	10	10:09-11:28, 13:45-15:05	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	C	Dual	Base Station	N/A	Base Station for GUDT1 positions	Not Pictured
GUDT1-1	2010	3	10	10:09-10:12	13.4143322	144.6559402	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Geotechnical	N/A		
GUDT1-2	2010	3	10	10:15-10:22	13.41439544	144.6558182	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Geotechnical	N/A		

GUDT1-3	2010	3	10	10:24-10:27	13.41442853	144.6557808	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Geotechnical	N/A		
GUDT1-4	2010	3	10	10:29-10:32	13.41426918	144.6560377	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Geotechnical	N/A		
GUDT1-5	2010	3	10	11:11-11:28	13.41415559	144.6562252	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Geotechnical	N/A	changed battery opt at time 4	

GUDT1-6	2010	3	10	13:45-13:49	13.41228497	144.6584471	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Geotechnical	N/A		
GUDT1-7	2010	3	10	13:52-13:57	13.41224582	144.6584602	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Geotechnical	N/A		
GUDT1-8	2010	3	10	13:59-14:09	13.41222057	144.6584753	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Geotechnical	N/A		

		
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
C	C	C
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds
Coraline Sands	Coraline Sands	Coraline Sands
N/A	N/A	N/A
144.6585894	144.6586094	144.6586599
13.41212982	13.4120721	13.4120223
14:14-14:16	14:22-14:25	14:30-14:37
10	10	10
3	3	3
2010	2010	2010
GUDT1-9	GUDT1-10	GUDT1-11

3.3.2 GUTT1 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
GUTT1 (Base Station)	2010	3	10	13:50-17:05	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	C	Dual	Base Station	N/A	Base Station for GUTT1-1 positions	Not Pictured
GUTT1-1	2010	3	10	15:50-15:53	13.41720552	144.6479164	N/A	Rocks	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Geotechnical	N/A	DCP data not taken for this site. CBR correlation not applicable.	
GUTT1-2	2010	3	10	15:55-15:58	13.4171569	144.6479421	N/A	Rocks	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Geotechnical	N/A	DCP data not taken for this site. CBR correlation not applicable.	

		
DCP data not taken for this site. CBR correlation not applicable.	DCP data not taken for this site. CBR correlation not applicable.	
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
C	C	C
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds
Rocks	Rocks	Coraline Sands
N/A	N/A	N/A
144.6478628	144.6478818	144.6479374
13.41729273	13.41730541	13.41731853
16:03-16:06	16:11-16:19	16:23-16:28
10	10	10
3	3	3
2010	2010	2010
GUTT1-3	GUTT1-4	GUTT1-5

		
		DCP data not taken for this site. CBR correlation not applicable.
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
C	C	C
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds
Coraline Sands	Coraline Sands	Rocks
N/A	N/A	N/A
144.6479081	144.6478686	144.6479178
13.41733731	13.41734891	13.41711721
16:31-16:36	16:42-16:47	16:51-16:57
10	10	10
3	3	3
2010	2010	2010
GUTT1-6	GUTT1-7	GUTT1-8

GUTT1-9	2010	3	10	17:03-17:06	13.41727188	144.6478949	N/A	Rocks	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	Geotechnical	N/A	DCP data not taken for this site. CBR correlation not applicable.	

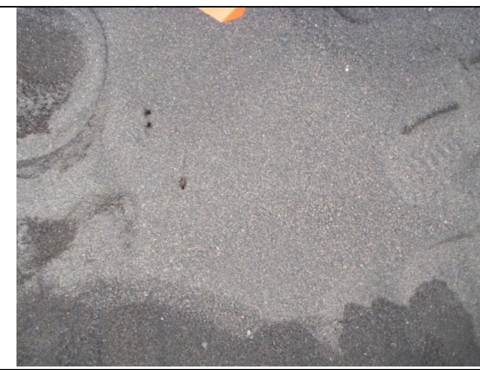
3.3.3 PAB1T1 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PABIT1, PABIT2, Beach1_swbathy (Base Station)	2010	3	2	9:46-12:14	N/A	N/A	N/A	N/A	Intermittent Clouds	Mostly Cloudy	NRL OLD	B	Dual	Base Station	N/A	ASD Base is ahead of new laptop by 1 second	Not Pictured
PABIT1-1	2010	3	2	9:46-9:54	18.13591717	145.7621286	N/A	Volcanic Sand	Intermittent clouds	Partly Cloudy	NPS	F	Dual	Geotechnical	N/A		

		
time 1 was saturated		time source was an NPS laptop,
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
F	F	F
NPS	NPS	NPS
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds
Volcanic Sand	Volcanic Sand	Volcanic Sand
N/A	N/A	N/A
145.7622249	145.7623479	145.7624398
18.13592383	18.13593106	18.13593075
9:57-10:02	10:05-10:11	10:15-10:20
2	2	2
3	3	3
2010	2010	2010
PAB1T1-2	PAB1T1-3	PAB1T1-4

		
time source was an NPS laptop,		possible saturation during time 2
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
F	F	F
NPS	NPS	NPS
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds
Volcanic Sand	Volcanic Sand	Volcanic Sand
N/A	N/A	N/A
145.7625196	145.7626235	145.7627292
18.13593047	18.13594539	18.13593897
10:40-10:42	10:43-10:47	10:48-10:56
2	2	2
3	3	3
2010	2010	2010
PAB1T1-5	PAB1T1-6	PAB1T1-7

3.3.4 PAB1T2 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PABIT1, PAB1T2, Beach1_swbathy (Base Station)	2010	3	2	9:46-12:14	N/A	N/A	N/A	N/A	Intermittent Clouds	Mostly Cloudy	NRL OLD	B	Dual	Base Station	N/A	ASD Base is ahead of new laptop by 1 second	Not Pictured
PAB1T2-1	2010	3	2	11:22-11:33	18.13753151	145.7620217	N/A	Volcanic Sand	Intermittent clouds	Partly Cloudy	NPS	F	Dual	Geotechnical	N/A		

		
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
F	F	F
NPS	NPS	NPS
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds
Volcanic Sand	Volcanic Sand	Volcanic Sand
N/A	N/A	N/A
145.7621082	145.7621936	145.7622812
18.1375414	18.13755089	18.13755955
11:34-11:48	11:50-11:53	11:54-12:01
2	2	2
3	3	3
2010	2010	2010
PAB1T2-2	PAB1T2-3	PAB1T2-4

PAB1T2-5	2010	3	2	12:02-12:06	18.13757006	145.7623571	N/A	Volcanic Sand	Intermittent clouds	Partly Cloudy	NPS	F	Dual	Geotechnical	N/A		
PAB1T2-6	2010	3	2	12:07-12:11	18.13757956	145.7624486	N/A	Volcanic Sand	Intermittent clouds	Partly Cloudy	NPS	F	Dual	Geotechnical	N/A		

3.3.5 PAB2T1 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PAB2T1- PAB2T1- 3(Base Station)	2010	2	28	9:28-9:55	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A	new ASD is one second ahead of old ASD, Time 2 aborted early so Time 3 is proper white plaque	Not Pictured
PAB2T1-4 (Base Station)	2010	2	28	9:59-10:06	N/A	N/A	N/A	N/A	Intermittent Clouds	Mostly Cloudy	NRL OLD	B	Dual	Base Station	N/A	Base station for position PAB2T1-4	Not Pictured
PAB2T1-5 (Base Station)	2010	2	28	10:10-10:15	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A	Base station for position PAB2T1-5	Not Pictured

Not Pictured		
Base Station was for PAB2T1 and T2 for March 1		
N/A	N/A	N/A
Base Station	Geotechnical	Geotechnical
Dual	Dual	Dual
B	B	B
NRL OLD	NRL NEW	NRL NEW
NR	Partly Cloudy	Partly Cloudy
NR	Other	Intermittent Clouds
N/A	Volcanic Sand	Volcanic Sand
N/A	N/A	N/A
N/A	145.7577879	145.7577879
N/A	18.12653795	18.12653795
14:14-15:06	9:28-9:34	9:42-9:46
1	28	28
3	2	2
2010	2010	2010
PAB2T1/PAB2T2 (Base Station)	PAB2T1-1	PAB2T1-2

		
	The time source was a new NRL ASD Laptop	
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
B	B	B
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent Clouds	Intermittent Clouds	Intermittent Clouds
Volcanic Sand	Volcanic Sand	Volcanic Sand
N/A	N/A	N/A
145.7577991	145.7577927	145.7577891
18.12641402	18.1263575	18.12628158
9:50-9:54	9:59-10:06	10:09-10:14
28	28	28
2	2	2
2010	2010	2010
PAB2T1-3	PAB2T1-4	PAB2T1-5

PAB2T1-6	2010	3	1	14:20-14:24	18.12620509	145.757785	N/A	Volcanic Sand	Clear	Clear	NRL NEW	F	Dual	Geotechnical	N/A		
PAB2T1-7	2010	3	1	14:26-14:31	18.12613198	145.7577656	N/A	Volcanic Sand	Clear	Clear	NRL NEW	B	Dual	Geotechnical	N/A		
PAB2T1-8	2010	3	1	14:33-14:38	18.12606032	145.7577512	N/A	Volcanic Sand	Clear	Clear	NRL NEW	B	Dual	Geotechnical	N/A		

PAB2T1-9	2010	3	1	14:39-14:47	18.12598246	145.7577364	N/A	Volcanic Sand	Clear	Clear	NRL NEW	B	Dual	Geotechnical	N/A		

3.3.6 PAB2T2 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PAB2T2-0 (Base Station)	2010	2	28	11:34-11:36	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T2-1 (Base Station)	2010	2	28	10:55-11:05	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T2-2 (Base Station)	2010	2	28	11:08-11:13	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T2-3 (Base Station)	2010	2	28	11:20-11:24	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T2-4 (Base Station)	2010	2	28	11:41-11:45	N/A	N/A	N/A	N/A	Clear	Clear	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T1/PAB2 T2 (Base Station)	2010	3	1	14:14-15:06	N/A	N/A	N/A	N/A	NR	NR	NRL OLD	B	Dual	Base Station	N/A	Base Station was for PAB2T1 and T2 for March 1	Not Pictured

		
sample was taken at waterline with all instruments in close procession, wind was increasing, off nadir plaque sampling	shadow on plaque, gun tipped a few degrees from nadir to create shadow	rover looking as same plaque as base station
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
B	B	B
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent Clouds	Intermittent Clouds	Intermittent Clouds
Volcanic Sand	Volcanic Sand	Volcanic Sand
N/A	N/A	N/A
145.7580101	145.7580131	145.7580285
18.12658962	18.12658191	18.12650164
11:31-11:36	10:55-11:02	11:08-11:13
28	28	28
2	2	2
2010	2010	2010
PAB2T2-0	PAB2T2-1	PAB2T2-2

		
tsunami warning canceled for testing region, wind increased during the morning, both ASD used the same plaque , both sensors tilted to avoid shadows.	both used the same plaque	continuation of T2 from 28-Feb-2010
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
B	B	F
NRL NEW	NRL NEW	NPS
Partly Cloudy	Partly Cloudy	Clear
Intermittent Clouds	Intermittent Clouds	Intermittent Clouds
Volcanic Sand	Volcanic Sand	Volcanic Sand
N/A	N/A	N/A
145.758043	145.7580476	145.7580473
18.12642163	18.12634342	18.12627314
11:20-11:24	11:41-11:45	14:23-14:25
28	28	1
2	2	3
2010	2010	2010
PAB2T2-3	PAB2T2-4	PAB2T2-5

		
continuation of T2 from 28	continuation of T2 from 28	continuation of T2 from 28-Feb-2010
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
F	F	NR
NPS	NPS	NR
Clear	Clear	Partly Cloudy
Intermittent Clouds	Intermittent Clouds	Intermittent Clouds
Sand with small sections of grass	Sand with small sections of grass	Volcanic Sand
N/A	N/A	N/A
145.7580472	145.7580421	145.7580341
18.12620528	18.12612543	18.12605149
14:30-14:34	14:45-14:54	14:59-15:05
1	1	1
3	3	3
2010	2010	2010
PAB2T2-6	PAB2T2-7	PAB2T2-8

PAB2T2-9	2010	3	1	14:54-14:59	18.12596905	145.7580274	N/A	Volcanic Sand	Clear	Clear	NRL NEW	B	Dual	Geotechnical	N/A	continuation of T2 from 28-Feb-2010	

3.3.7 PAB2T3 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PAB2T3-1 (Base Station)	2010	2	28	14:28-14:33	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T3-2 (Base Station)	2010	2	28	14:35-14:39	N/A	N/A	N/A	N/A	NR	NR	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T3-3 (Base Station)	2010	2	28	14:43-15:21	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T3-4 (Base Station)	2010	2	28	15:24-15:28	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T3-5 (Base Station)	2010	2	28	15:32-15:37	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T3-6 (Base Station)	2010	2	28	15:40-15:45	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured

PAB2T3-7 (Base Station)	2010	2	28	15:50-15:54	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T3-8 (Base Station)	2010	2	28	15:57-16:04	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T3-9 (Base Station)	2010	2	28	16:06-16:12	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T3-1	2010	2	28	14:28-14:32	18.12815641	145.7605288	N/A	Volcanic Sand	Clear	Partly Cloudy	NRL NEW	B	Dual	Geotechnical	N/A		
PAB2T3-2	2010	2	28	14:35-14:39	18.12812041	145.7605622	N/A	Volcanic Sand	NR	NR	NRL NEW	B	Dual	Geotechnical	N/A		

		
base station ASD died during second sampling	both ASD measured on the same plaque , off nadir to avoid shadows	spectic tube collected on rocks cobble near N, edge of beach
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
B	B	B
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Clear	Intermittent Clouds	Clear
Volcanic Sand	Volcanic Sand	Volcanic Sand
N/A	N/A	N/A
145.7606181	145.7606902	145.7606176
18.1280687	18.12802976	18.12810479
14:43-15:20	15:23-15:28	15:32-15:36
28	28	28
2	2	2
2010	2010	2010
PAB2T3-3	PAB2T3-4	PAB2T3-5

		
power of ASD was draining during last sampling	same plaque off nadir	
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
B	B	B
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Clear	Clear	Clear
Volcanic Sand	Volcanic Sand	Volcanic Sand
N/A	N/A	N/A
145.7607186	145.7607874	145.7608833
18.12800269	18.12795642	18.12788217
15:40-15:48	15:49-15:59	15:57-16:02
28	28	28
2	2	2
2010	2010	2010
PAB2T3-6	PAB2T3-7	PAB2T3-8

PAB2T3-9	2010	2	28	16:06-16:12	18.12782845	145.7609732	N/A	Volcanic Sand	Clear	Partly Cloudy	NRL NEW	B	Dual	Geotechnical	N/A		

3.3.8 PAB2T4

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PAB2T4-1 (Base Station)	2010	2	28	16:19-16:24	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T4-2 (Base Station)	2010	2	28	16:27-16:30	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T4-3 (Base Station)	2010	2	28	16:33-16:36	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T4-4 (Base Station)	2010	2	28	16:39-16:43	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T4-5 (Base Station)	2010	2	28	16:45-16:50	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB2T4-6 (Base Station)	2010	2	28	16:53-16:58	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured

		
transect is south of T3, closer to the middle of the beach	same plaque was used	same plaque was used
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
B	B	B
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Clear	Clear	Clear
Volcanic Sand	Volcanic Sand	Volcanic Sand
N/A	N/A	N/A
145.7603487	145.7604357	145.7605259
18.12790182	18.1278565	18.12780241
14:19-16:23	16:26-16:30	16:33-16:36
28	28	28
2	2	2
2010	2010	2010
PAB2T4-1	PAB2T4-2	PAB2T4-3

		
same plaque was used	same plaque was used	
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
B	B	B
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Clear	Clear	Clear
Volcanic Sand	Volcanic Sand	Volcanic Sand
N/A	N/A	N/A
145.7605921	145.7606511	145.760713
18.12775346	18.12770878	18.1276545
16:39-16:42	16:45-16:49	16:53-16:59
28	28	28
2	2	2
2010	2010	2010
PAB2T4-4	PAB2T4-5	PAB2T4-6

3.3.9 PAB2T5

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PAB2T5, PAB2T6 (Base Station)	2010	3	1	10:04-11:39	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A	Base station was used PAB2T5 and PAB2T6	Not Pictured
PAB2T5-1	2010	3	1	10:05-10:09	18.1268879	145.7588516	N/A	Volcanic Sand	Intermittent Clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A		
PAB2T5-2	2010	3	1	10:15-10:18	18.12682871	145.7588846	N/A	Volcanic Sand	Intermittent Clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A		

		
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
F	F	F
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent Clouds	Intermittent Clouds	Intermittent Clouds
Volcanic Sand	Volcanic Sand	Volcanic Sand
N/A	N/A	N/A
145.7589116	145.7589484	145.7589831
18.12677719	18.12668281	18.12660668
10:21-10:24	10:30-10:35	10:44-10:49
1	1	1
3	3	3
2010	2010	2010
PAB2T5-3	PAB2T5-4	PAB2T5-5

		
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
F	F	F
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent Clouds	Intermittent Clouds	Intermittent Clouds
Volcanic Sand	Volcanic Sand	Volcanic Sand
N/A	N/A	N/A
145.7590073	145.759037	145.7590578
18.1265202	18.12644714	18.12636286
10:58-11:01	11:02-11:07	11:10-11:14
1	1	1
3	3	3
2010	2010	2010
PAB2T5-6	PAB2T5-7	PAB2T5-8

PAB2T5-9	2010	3	1	11:16-11:21	18.12626031	145.7590917	N/A	Volcanic Sand	Intermittent Clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A		

3.3.10 PAB2T6

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PAB2T5, PAB2T6 (Base Station)	2010	3	1	10:04-11:39	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A	Base station was used PAB2T5 and PAB2T6	Not Pictured
PAB2T6-1	2010	3	1	10:05-10:08	18.12698031	145.7590507	N/A	Volcanic Sand	Intermittent Clouds	Partly Cloudy	NPS	B	Dual	Geotechnical	N/A		
PAB2T6-2	2010	3	1	10:14-10:18	18.12691993	145.7590821	N/A	Volcanic Sand	Intermittent Clouds	Partly Cloudy	NPS	F	Dual	Geotechnical	N/A		

		
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
F	F	F
NPS	NPS	NPS
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent Clouds	Intermittent Clouds	Intermittent Clouds
Volcanic Sand	Volcanic Sand	Volcanic Sand
N/A	N/A	N/A
145.7591167	145.7591603	145.7591996
18.12686186	18.12680306	18.12670728
10:24-10:30	10:38-10:41	10:47-11:04
1	1	1
3	3	3
2010	2010	2010
PAB2T6-3	PAB2T6-4	PAB2T6-5

		
sun was behind clouds for last 10 for time 1		
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
F	F	F
NPS	NPS	NPS
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent Clouds	Intermittent Clouds	Intermittent Clouds
Volcanic Sand	Sand with small sections of grass	Sand with small sections of grass
N/A	N/A	N/A
145.759226	145.7592434	145.759272
18.12663968	18.12655503	18.12647965
11:12-11:15	11:21-11:23	11:28-11:30
1	1	1
3	3	3
2010	2010	2010
PAB2T6-6	PAB2T6-7	PAB2T6-8

PAB2T6-9	2010	3	1	11:34-11:37	18.12639801	145.7593035	N/A	Sand with small sections of grass	Intermittent Clouds	Partly Cloudy	NPS	F	Dual	Geotechnical	N/A		

3.3.11 PAB4T1 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PAB4T1 (Base Station)	2010	2	27	15:20-16:09	N/A	N/A	N/A	N/A	NR	NR	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
PAB4T1-1	2010	2	27	15:28-15:37	18.12443952	145.7594712	N/A	Volcanic Sand	Overcast	Overcast	NRL NEW	D	Dual	Geotechnical	N/A	Water level at time 5 rose-no sample	
PAB4T1-2	2010	2	27	NR	18.12446619	145.7595108	N/A	Volcanic Sand	Overcast	Overcast	NRL OLD	B	Dual	Geotechnical	N/A	Base Station was one second ahead of new ASD, PAB4T1-2 kept the same filename because the sequence was recorded after the PAB4T1-1 was recorded. The sequence was done in alternating sets of 30.	

PAB4T1-3	2010	2	27	16:03-16:08	18.12447939	145.7595441	N/A	Volcanic Sand	Intermittent Clouds	Overcast	NRL NEW	D	Dual	Geotechnical	N/A	sample data was transcribed from another sheet collected by MJM	

3.3.12 PAB4T2 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PAB4T2-2 (Base Station)	2010	2	27	16:28-16:42	N/A	N/A	N/A	N/A	Not Recorded	Not Recorded	NRL OLD	B	Dual	Base Station	N/A	Base station for PAB4T2-2	Not Pictured
PAB4T2-3 (Base Station)	2010	2	27	16:51-16:55	N/A	N/A	N/A	N/A	Not Recorded	Not Recorded	NRL OLD	B	Dual	Base Station	N/A	Base station for PAB4T2-3	Not Pictured
PAB4T2-2	2010	2	27	16:13-16:28	18.12464225	145.7593191	N/A	Volcanic Sand	Intermittent Clouds	Mostly Cloudy	NRL NEW	D	Dual	Geotechnical	N/A	Base Unit saturated at 16:39, waves on PAB4T2 at 16:36	
PAB4T2-3	2010	2	27	16:51-16:55	18.12467301	145.7593636	N/A	Volcanic Sand	Intermittent Clouds	Mostly Cloudy	NRL NEW	D	Dual	Geotechnical	N/A		

3.3.13 PAB4T3 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PAB4T3, PAB4T4 (Base Station)	2010	3	1	16:04-17:01	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	F	Dual	Base Station	N/A	Base station for both PAB4T3 and PAB4T4	Not Pictured
PAB4T3-1	2010	3	1	16:04-16:08	18.12518654	145.7580606	N/A	Volcanic Sand	Intermittent Clouds	Partly Cloudy	NPS	E	Dual	Geotechnical	N/A		
PAB4T3-2	2010	3	1	16:12-16:14	18.12520971	145.7580546	N/A	Volcanic Sand	Intermittent Clouds	Partly Cloudy	NPS	E	Dual	Geotechnical	N/A		

PAB4T3-3	2010	3	1	16:19-16:21	18.12524166	145.7580464	N/A	Volcanic Sand	Intermittent Clouds	Partly Cloudy	NPS	E	Dual	Geotechnical	N/A	large cloud in front of the sun	
PAB4T3-4	2010	3	1	16:36-16:39	18.12528273	145.7580278	N/A	Volcanic Sand	Intermittent Clouds	Partly Cloudy	NPS	E	Dual	Geotechnical	N/A	clouds were near the sun	

3.3.14 PAB4T4 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PAB4T3, PAB4T4 (Base Station)	2010	3	1	16:04-17:01	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	F	Dual	Base Station	N/A	Base station for both PAB4T3 and PAB4T4	Not Pictured
PAB4T4-1	2010	3	1	16:36-16:40	18.12522716	145.7582568	N/A	Volcanic Sand	Intermittent Clouds	Partly Cloudy	NRL NEW	E	Dual	Geotechnical	N/A		
PAB4T4-2	2010	3	1	16:42-16:52	18.12524198	145.7582552	N/A	Volcanic Sand	Intermittent Clouds	Partly Cloudy	NPS	E	Dual	Geotechnical	N/A	very steep slope	

PAB4T4-3	2010	3	1	16:40-16:50	18.12526815	145.7582565	N/A	Volcanic Sand	Intermittent Clouds	Partly Cloudy	NRL NEW	E	Dual	Geotechnical	N/A		
PAB4T4-4	2010	3	1	16:56-17:00	18.12530585	145.7582533	N/A	Grass	Intermittent Clouds	Partly Cloudy	NPS	E	Dual	Geotechnical	N/A	listed as a grass surface	

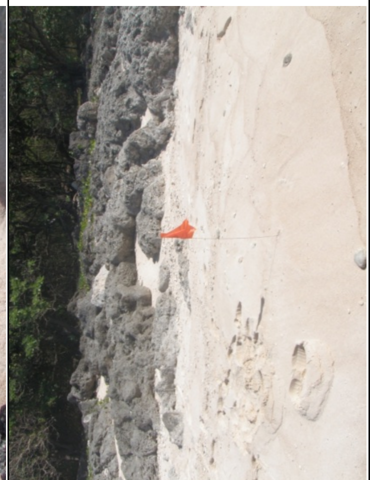
3.3.15 TNUBT1 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
TNUBT1(Base Station)	2010	3	5	10:45-11:53, 14:08-15:26	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	F	Dual	Base Station	N/A	Break in sampling from 11:53-14:08.	Not Pictured
TNUBT1-1	2010	3	5	10:24-10:50	15.07897683	145.6226699	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A	wind and rain during sampling	
TNUBT1-2	2010	3	5	10:58-11:19	15.07901674	145.6226816	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A	water came up in the middle of measurements	

		
	The terrain was described as rocky. Larger coralline sand pieces.	
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
F	F	F
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds
Coraline Sands	Coraline Sands	Coraline Sands
N/A	N/A	N/A
145.6227035	145.6227319	145.6227549
15.07896101	15.07905165	15.07903885
11:22-11:24	11:38-11:41	11:44-11:46
5	5	5
3	3	3
2010	2010	2010
TNUBT1-3	TNUBT1-4	TNUBT1-5

		
There was a rock on the beach it was very large, (perhaps limestone). CBR data not taken at this position.		
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
F	F	F
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds
Rock	Coraline Sands	Coraline Sands
N/A	N/A	N/A
145.622744	145.6225459	145.6225709
15.07901298	15.07892857	15.07889648
11:50-11:52	14:08-14:11	14:14-14:17
5	5	5
3	3	3
2010	2010	2010
TNUBT1-6	TNUBT1-7	TNUBT1-8

		
		Very near waterline, Geotech to move in quickly after spectral measurement, during time 2 water covered the sample
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
F	F	F
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds
Coraline Sands	Coraline Sands	Coraline Sands
N/A	N/A	N/A
145.6225573	145.6225044	145.622479
15.07885168	15.07888274	15.07893407
14:20-14:23	14:26-14:29	14:45-14:47
5	5	5
3	3	3
2010	2010	2010
TNUBT1-9	TNUBT1-10	TNUBT1-11

TNUBT1-12	2010	3	5	14:51-14:54	15.07882962	145.6225194	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A		
TNUBT1-13	2010	3	5	14:57-15:01	15.07883312	145.6224006	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A		
TNUBT1-14	2010	3	5	15:23-15:29	15.07876495	145.6223098	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A	Repositioned “mother” ship ASD for this point.	

TNUBT1-15	2010	3	5	15:32-15:36	15.0787844	145.6222906	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A		

3.3.16 TNUDT1 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
TNUDT1 (Base Station)	2010	3	6	?	N/A	N/A	N/A	N/A	NR	NR	NRL OLD	A	Dual	Base Station	N/A	data was written in pencil. Very hard to read	Not Pictured
TNUDT1-1	2010	3	6	14:19-14:25	15.0340388	145.6485798	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	A	Dual	Geotechnical	N/A	data was written in pencil. Very hard to read	
TNUDT1-2	2010	3	6	14:27-14:32	15.03395942	145.6485679	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	A	Dual	Geotechnical	N/A	data was written in pencil. Very hard to read	

TNUDT1-3	2010	3	6	14:34-14:38	15.03399356	145.6484384	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	A	Dual	Geotechnical	N/A	data was written in pencil. Very hard to read	
TNUDT1-4	2010	3	6	14:40-14:44	15.03389942	145.648543	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	A	Dual	Geotechnical	N/A		
TNUDT1-5	2010	3	6	15:01-15:06	15.03392426	145.6484896	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	A	Dual	Geotechnical	N/A		

TNUDT1-6	2010	3	6	15:15-15:28	15.03412045	145.6485429	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	A	Dual	Geotechnical	N/A		

3.3.17 TNUDT2 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
TNUDT2 (Base Station)	2010	3	6	?	N/A	N/A	N/A	N/A	NR	NR	NRL OLD	A	Dual	Base Station	N/A	Notes taken in pencil	Not Pictured
TNUDT2-1	2010	3	6	16:09-16:13	15.03444223	145.6485365	N/A	Damp Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	A	Dual	Geotechnical	N/A		
TNUDT2-2	2010	3	6	16:15-16:19	15.03441424	145.6484932	N/A	Coraline Sands	NR	NR	NRL NEW	A	Dual	Geotechnical	N/A		

TNUDT2-3	2010	3	6	16:20-16:23	15.03442785	145.6484408	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	A	Dual	Geotechnical	N/A		
TNUDT2-4	2010	3	6	16:25-16:28	15.03442357	145.6483936	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	A	Dual	Geotechnical	N/A		
TNUDT2-5	2010	3	6	16:30-16:33	15.03440282	145.6483363	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	A	Dual	Geotechnical	N/A		

3.3.18 TNUDT3 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
TNUDT3 (Base Station)	2010	3	7	9:29-10:15	N/A	N/A	N/A	N/A	Intermittent clouds	Partly Cloudy	NRL OLD	A	Dual	Base Station	N/A		Not Pictured
TNUDT3-1	2010	3	7	9:30-9:32	15.03489919	145.6483859	N/A	Coraline Sands	Clear	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A		
TNUDT3-2	2010	3	7	9:36-9:40	15.03502454	145.6483321	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A		

TNUDT3-3	2010	3	7	9:42-9:46	15.03500566	145.6482889	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A		
TNUDT3-4	2010	3	7	9:47-9:51	15.0349794	145.6482425	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A		
TNUDT3-5	2010	3	7	10:00-10:03	15.03495875	145.6481777	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A	file notes said point 4 in error	

TNUDT3-6	2010	3	7	10:09-10:15	15.03491627	145.6481462	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A	time 2 was saturated	

3.3.19 TNULT1 Positions

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
TNULT1, TNUL-Swb (Base Station)	2010	3	7	14:37-16:32	N/A	N/A	N/A	N/A	NR	NR	NRL OLD	A	Dual	Base Station	N/A		Not Pictured
TNULT1-1	2010	3	7	14:37-14:39	15.08745054	145.6326989	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	A	Dual	Geotechnical	N/A	during times 2and 3 a wave came into the sample	
TNULT1-2	2010	3	7	14:43-14:46	15.08742187	145.6327317	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	A	Dual	Geotechnical	N/A		

		
		changed plaque from A to F due to weather, reoptimize t=15:13, after sample 15:10
N/A	N/A	N/A
Geotechnical	Geotechnical	Geotechnical
Dual	Dual	Dual
A	A	F
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent clouds	Intermittent clouds	Intermittent clouds
Coraline Sands	Coraline Sands	Coraline Sands
N/A	N/A	N/A
145.6327557	145.6327882	145.6328096
15.08742594	15.08735569	15.08733047
14:53-14:56	10:48-10:51	15:09-15:16
7	7	7
3	3	3
2010	2010	2010
TNULT1-3	TNULT1-4	TNULT1-5

TNULT1-6	2010	3	7	15:04-15:07	15.08740443	145.6327039	N/A	Coraline Sands	Intermittent clouds	Partly Cloudy	NRL NEW	F	Dual	Geotechnical	N/A	the site was in the shade, plaque F was used because plaque A was in the sun	

3.4 *In-Situ* Vegetation

3.4.1 Guam

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
GUDT1 (Base Station)	2010	3	10	10:09-11:28, 13:45-15:05	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	C	Dual	Base Station			Not Pictured
GUDT1-12 (VEG)	2010	3	10	13:44-13:47	13.4121696	144.6586014	N/A	*Ipomoea pes-caprae*	Intermittent Clouds	Partly Cloudy	NRL NEW	C	Dual	In-Situ-Vegetation	N/A	no soil sample was taken, Beach Morning Glory	
GUDT1-13 (VEG)	2010	3	10	13:52-13:54	13.4122226	144.6585456	N/A	*Ipomoea pes-caprae*	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	In-Situ-Vegetation	N/A	leaf sample, Beach Morning Glory	

GUDT1-14 (VEG)	2010	3	10	15:02-15:04	13.41211637	144.6586582	N/A	*Hibiscus tiliaceus*	Intermittent clouds	Partly Cloudy	NRL NEW	C	Dual	In-Situ-Vegetation	N/A	the log site had Bush tree leaves, Beach Hibiscus	

3.4.2 Pagan

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
PAAIRFIELD-White Panel/Grass (Base Station)	2010	3	3	9:07-9:14	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	N/A		Not Pictured
Pagan-Grass	2010	3	3	09:12	18.1229167	145.7634287	N/A		Intermittent Clouds	Partly Cloudy	NRL NEW	B	Dual	In-Situ-Vegetation	N/A	Grass area surrounding white panel at Pagan	Not Pictured

3.4.3 Tinian

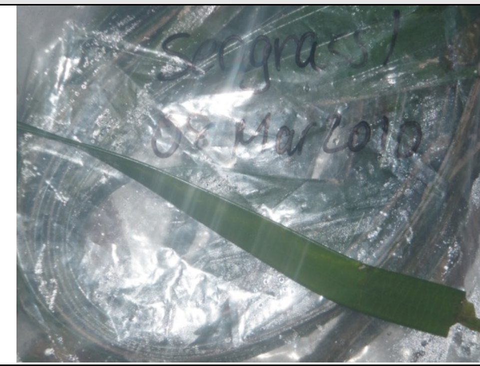
Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Depth, mm	Comments	Photograph
TNUDT3, Veg (Base Station)	2010	3	7	9:16-11:09	N/A	N/A	N/A	N/A	Intermittent Clouds	Partly Cloudy	NRL OLD	A	Dual	Base Station			Not Pictured
TNUD-vegetation-Dead Palm#1	2010	3	7	10:52-10:53	15.03460786	145.6480873	NR	*Cocos nucifera*	Intermittent Clouds	Partly Cloudy	NRL NEW	F	Dual	In-Situ-Vegetation	N/A	Dead plam tree leaf	
TNUD-vegetation-Dead Palm#2	2010	3	7	10:54-10:55	15.03454846	145.6480982	NR	*Cocos nucifera*	Intermittent Clouds	Partly Cloudy	NRL NEW	F	Dual	In-Situ-Vegetation	N/A	A different dead palm tree leaf	

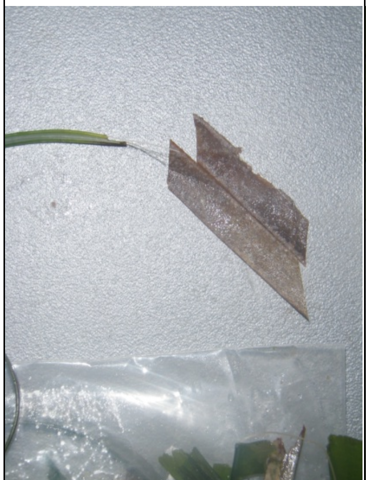
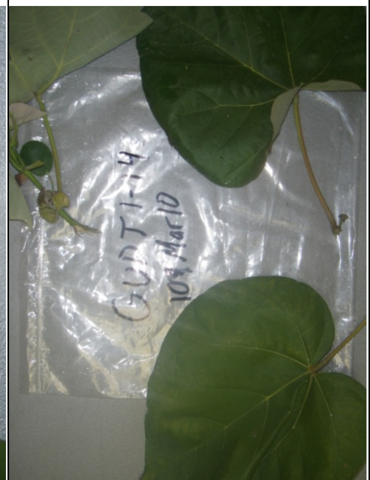
		
Small palm tree	Velvet soldierbush	Velvet soldierbush-shrub
N/A	N/A	N/A
In-Situ-Vegetation	In-Situ-Vegetation	In-Situ-Vegetation
Dual	Dual	Dual
F	F	F
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Partly Cloudy	Partly Cloudy
Intermittent Clouds	Intermittent Clouds	Intermittent Clouds
Cocos nucifera	*Tournefortia argentea*	*Tournefortia argentea*
NR	210 cm	NR
145.6480835	145.6482213	145.6481473
15.03458381	15.03465107	15.0347967
10:44-10:47	11:04-11:07	10:26-10:28
7	7	7
3	3	3
2010	2010	2010
TNUD-vegetation-Very Young Palm	TNUD-vegetation-Mature Velvet Leaf	TNUD-vegetation-Velvet Leaf

3.5 Leaf-Optics Vegetation

Leaf optic samples are listed in alphabetical order by species name. The original site description is in parentheses. Samples are separated by island. Latitude and longitude indicate the position where sampling occurred. Sky conditions are not applicable to leaf optic sampling so these columns were replaced with “Common Name” and “Scientific Name”. Also, the “Depth, mm” column has been substituted with “Leaf Optic Sample.” Leaf optic sample indicates the number of the sample during leaf optic sampling.

3.5.1 Guam

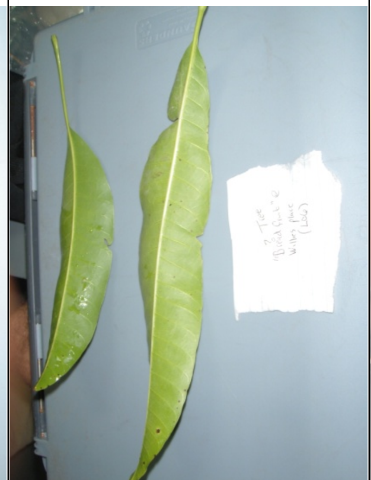
Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Common Name of Species	Scientific Name of Species	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Leaf Optic Sample	Comments	Photograph
Enhalus acoroides (GUD-SWB-10-LAB, LO1)	2010	3	11	23:19-23:25	13.41416945	144.6560133	NR	Vegetation	Tape Seagrass	Enhalus acoroides	NRL NEW	Leaf Optics Disk	Single	Leaf-Optics	1	Seagrass 1	
Enhalus acoroides (GUD-SWB-11-LAB, LO2)	2010	3	11	23:32-23:37	13.41413693	144.6560985	NR	Vegetation	Tape Seagrass	Enhalus acoroides	NRL NEW	Leaf Optics Disk	Single	Leaf-Optics	2	Seagrass 2	

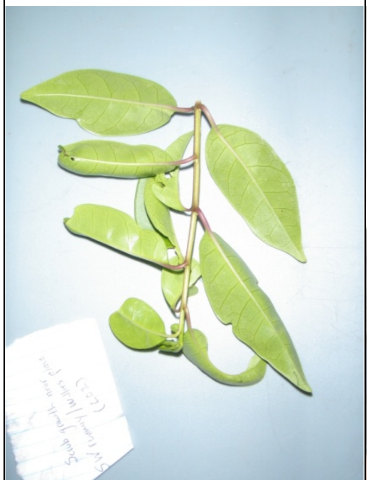
		
Seagrass 5	taken from position GUDT1-14	taken from position GUDT1-12
3	NR	NR
Leaf-Optics	Leaf-Optics	Leaf-Optics
Single	Single	Single
Leaf Optics Disk	Leaf Optics Disk	Leaf Optics Disk
NRL NEW	NRL NEW	NRL NEW
Enhalus acoroides	Hibiscus tiliaceus	Ipomoea pes-caprae
Tape Seagrass	Beach Hibiscus	Beach Morning Glory
Vegetation	Vegetation	Vegetation
NR	NR	NR
144.6561067	144.6585456	144.6586014
13.41413649	13.41222226	13.4121696
23:42-23:48	13:01-13:05	12:27-12:36
11	11	11
3	3	3
2010	2010	2010
Enhalus acoroides (GUD-SWB-11-LAB, LO3)	Hibiscus tiliaceus GUDT1-14 (VEG)-LO	Ipomoea pes-caprae GUDT1-12 (VEG)-LO

Ipomoea pes-caprae GUDT1-13 (VEG)-LO	2010	3	11	12:47-12:50	13.41211637	144.6586582	NR	Vegetation	Beach Morning Glory	Ipomoea pes-caprae	NRL NEW	Leaf Optics Disk	Single	Leaf-Optics	NR	taken from position GUDT1-12	

3.5.2 Pagan

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Common Name of Species	Scientific Name of Species	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Leaf Optic Sample	Comments	Photograph
Casuarina equisetifolia (.IRONWOOD_RUNWAY-LO1)	2010	3	2	21:57-22:07	18.124357	145.760548	NR	Vegetation	Ironwood	Casuarina equisetifolia	NRL NEW	Leaf Optics Disk	Single	Leaf-Optics	1	Leaf optics disk sample was collected by the runway, the	
Cocos nucifera (PALM-GROVE_BY_WILLYS.LO4)	2010	3	2	10:27-10:30	18.122222	145.760307	NR	Vegetation	Coconut Palm	Cocos nucifera	NRL NEW	Leaf Optics Disk	Single	Leaf-Optics	4	Collected in Palm grove by Willie's house, sw of beach 4,	

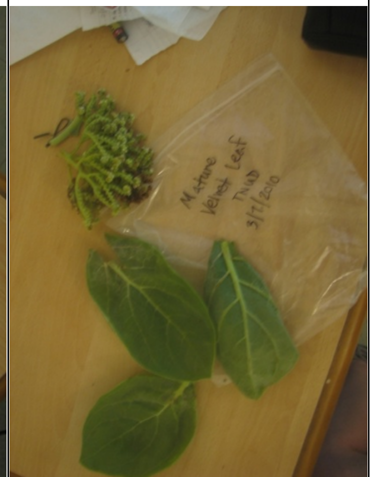
		
collected near Willie's house	collected at Willie's house	collected at Willie's house by a very big tree
5	6	7
Leaf-Optics	Leaf-Optics	Leaf-Optics
Single	Single	Single
Leaf Optics Disk	Leaf Optics Disk	Leaf Optics Disk
NRL NEW	NRL NEW	NRL NEW
Pandanus tectorius	Mangifera indica	Melochia villosissima var. compacta
Screw Pine	Mango Tree	Sayafe
Vegetation	Vegetation	Vegetation
NR	NR	NR
145.7600807	145.76024	145.7602228
18.12196388	18.12206555	18.12180037
10:34-10:37	10:38-10:41	10:43-10:46
2	2	2
3	3	3
2010	2010	2010
Pandanus tectorius (LO5)	Mangifera indica (LO6)	Melochia villosissima var. compacta (LO7)

	
Leaf optics disk sample near sw runway near Willie's place. Unidentifiable species	Unidentifiable species
2	3
Leaf-Optics	Leaf-Optics
Single	Single
Leaf Optics Disk	Leaf Optics Disk
NRL NEW	NRL NEW
No ID	No ID
No ID	No ID
Vegetation	Vegetation
NR	NR
145.7603479	145.7603163
18.12280333	18.12274237
22:10-22:16	22:19-22:24
2	2
3	3
2010	2010
Unidentifiable species #1 (Scrub # 1, LO2)	Unidentifiable species #2 (Scrub # 2, LO3)

3.5.3 Tinian

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Common Name of Species	Scientific Name of Species	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Leaf Optic Sample	Comments	Photograph
Cocos nucifera -Dead #1 (TNUD-LEAF-Dead Palm #1)	2010	3	8	9:19-9:22	15.03460786	145.6480873	N/A	Vegetation	Coconut Palm	Cocos nucifera	NRL NEW	Leaf Optics Disk	Single	Leaf-Optics	NR		
Cocos nucifera –Dead #2 (TNUD-LEAF-Dead Palm #2)	2010	3	8	9:02-9:05	15.03454846	145.6480982	N/A	Vegetation	Coconut Palm	Cocos nucifera	NRL NEW	Leaf Optics Disk	Single	Leaf-Optics	NR		

		
Young palm tree		Velvet leaf TNUD shrub 45 cm tall shrub, from 3/07/2010 Unai Dangkulo, Velvet soldierbush
NR	NR	NR
Leaf-Optics	Leaf-Optics	Leaf-Optics
Single	Single	Single
Leaf Optics Disk	Leaf Optics Disk	Leaf Optics Disk
NRL NEW	NRL NEW	NRL NEW
Cocos nucifera	Pandanus tectorius	Tournefortia argentea or Heliotropium foertherianum
Coconut Palm	Screw Pine (Pandanus)	Velvet Soldierbush
Vegetation	Vegetation	Vegetation
N/A	N/A	N/A
145.6480835	145.64774435	145.6481473
15.03458381	15.03425258	15.0347967
8:56-9:00	9:08-9:11	8:36-8:43
8	8	8
3	3	3
2010	2010	2010
Cocos nucifera –Young (TNUD-LEAF-Young Palm)	Pandanus tectorius (TNUD-LEAF-Screw Pine)	Tournefortia argentea (TNUD-LEAF-Velvet Leaf)

	
Juvenile velvet soldierbush	Mature Velvet soldierbush
NR	NR
Leaf-Optics	Leaf-Optics
Single	Single
Leaf Optics Disk	Leaf Optics Disk
NRL NEW	NRL NEW
Tournefortia argentea L. or Heliotropium foertherianum	Tournefortia argentea L. or Heliotropium foertherianum
Velvet Soldierbush	Velvet Soldierbush
Vegetation	Vegetation
N/A	N/A
145.6481067	145.6481878
15.03413317	15.03413945
9:14-9:17	8:46-8:53
8	8
3	3
2010	2010
Tournefortia argentea- Juvenile (TNUD-LEAF-Velvet Leaf Juvenile)	Tournefortia argentea-Mature (TNUD-LEAF-Mature Velvet Leaf)

3.6 Man-Made Features/Relics

Site Name/Description	Year	Month	Day	Time (Local)	Latitude	Longitude	Vegetation Height	Vegetation/Land Cover Type	Sky Conditions in Front of Sun	Cloud Cover	ASD Name	Plaque	Spectra Mode	Spectra Substrate Type	Comments	Photograph
Corrugated Aluminum (PAAIRFIELD-Corrugated Roof)(Base Station)	2010	3	2	17:58-18:00	N/A	N/A	N/A	N/A	Overcast	Overcast	NRL OLD	F	Dual	Base Station	base station for corrugates aluminum roof-evening 100302	Not Pictured
Japanese Bunker (PAAIRFIELD-Bunker) (Base Station)	2010	3	2	17:30-17:34	N/A	N/A	N/A	N/A	Overcast	Overcast	NRL OLD		Dual	Base Station	base station for bunker on evening of 100302	Not Pictured
Japanese Bunker (PAAIRFIELD Bunker)(Base Station)	2010	3	3	9:50-9:54	N/A	N/A	N/A	N/A	Intermittent clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	base station for bunker on morning of 100303	Not Pictured
Mitsubishi A6M Type 0 "Zero" PAAIRFIELD-zero (Base Station)	2010	3	2	17:48-17:50	N/A	N/A	N/A	N/A	Overcast	Overcast	NRL OLD	F	Dual	Base Station	base station for Japanese zero on evening of 100302	Not Pictured
Mitsubishi A6M Type 0 "Zero" PAAIRFIELD Japanese Zero (Base Station)	2010	3	3	10:29-10:35	N/A	N/A	N/A	N/A	Intermittent clouds	Partly Cloudy	NRL OLD	B	Dual	Base Station	base station for Japanese zero on morning of 100303	Not Pictured

Not Pictured	Not Pictured		
base station for bomber, aa gun, lava rock #1-evening 100302	base station for bomber on morning of 100303	a camera bumped the spacebar prior to optomize, the first 26 samples were not good	collected on an airstrip bunker
Base Station	Base Station	Feature/Man-Made	Feature/Man-Made
Dual	Dual	Dual	Dual
F	B	F	F
NRL OLD	NRL OLD	NRL NEW	NRL NEW
Overcast	Partly Cloudy	Overcast	Overcast
Overcast	Intermittent clouds	Overcast	Overcast
N/A	N/A	Corrugated Aluminum	Japanese Bunker
N/A	N/A	N/A	N/A
N/A	N/A	145.7602647	145.7668578
N/A	N/A	18.12193202	18.12070127
16:55-17:20	9:26-9:35	17:58-18:00	17:30-17:34
2	3	2	2
3	3	3	3
2010	2010	2010	2010
P1Y Bomber/Type 88 AA Gun (PAAIRFIELD-aagun, bomber, lava rock #1) (Base Station)	P1Y Bomber (PAAIRFIELD Bomber) (Base Station)	Corrugated Aluminum PAAIRFIELD-Willie's roof top	Japanese Bunker PAAIRFIELD-Bunker

		
the site was a bunker on an airfield, new asd used new asd is 1.5 seconds behind old ASD	collected on a Japanese Zero	Japanese 0
Feature/Man-Made	Feature/Man-Made	Feature/Man-Made
Dual	Dual	Dual
B	F	B
NRL NEW	NRL NEW	NRL NEW
Partly Cloudy	Overcast	Partly Cloudy
Intermittent clouds	Overcast	Intermittent clouds
Japanese Bunker	Mitsubishi A6M Type 0 "Zero"	Mitsubishi A6M Type 0 "Zero"
N/A	N/A	N/A
145.7668578	145.7613701	145.7613701
18.12070127	18.12289361	18.12289361
9:50-10:33	17:49-17:50	10:29-10:35
3	2	3
3	3	3
2010	2010	2010
Japanese Bunker (PAAIRFIELD-Bunker)	Mitsubishi A6M Type 0 “Zero” (PAAIRFIELD- Japanese Zero)	Mitsubishi A6M Type 0 “Zero” (PAAIRFIELD-Japanese Zero)

		
the site was a Japanese bomber	the site was a bomber on an airfield	collected on AA gun
Feature/Man-Made	Feature/Man-Made	Feature/Man-Made
Dual	Dual	Dual
F	B	F
NRL NEW	NRL NEW	NRL NEW
Overcast	Partly Cloudy	Overcast
Overcast	Intermittent clouds	Overcast
P1Y Bomber	P1Y Bomber	Type 88 75mm Anti-Aircraft Gun
N/A	N/A	N/A
145.7656213	145.7656213	145.7657999
18.12378772	18.12378772	18.12363029
17:08-17:13	9:26-9:38	17:15-17:16
2	3	2
3	3	3
2010	2010	2010
P1Y Bomber (Only P1Y Bomber Measurement) (PAAIRFIELD-Bomber)	P1Y Bomber (7 measurements) (PAAIRFIELD-Bomber)	Type 88 75mm Anti-Aircraft Gun (PAAIRFIELD-AAGUN)

3.7 Terrain Features

Photograph	Not Pictured	Not Pictured	
Comments	base station for bomber, aa gun, lava rock #1-evening 100302		collected on lavarock found on the airstrip
Spectra Substrate Type	Base Station	Base Station	Terrain
Spectra Mode	Dual	Dual	Dual
Plaque	F	B	F
ASD Name	NRL OLD	NRL OLD	NRL NEW
Cloud Cover	Overcast	Partly Cloudy	Overcast
Sky Conditions in Front of Sun	Overcast	Intermittent clouds	Overcast
Vegetation/Land Cover Type	N/A	N/A	Airstrip Lavarock
Vegetation Height	N/A	N/A	N/A
Longitude	N/A	N/A	145.7658117
Latitude	N/A	N/A	18.12356804
Time (Local)	16:55-17:20	9:58-10:15	17:19-17:20
Day	2	3	2
Month	3	3	3
Year	2010	2010	2010
Site Name/Description	PAAIRFIELD-aagun, bomber, lava rock #1 (Base Station)	PAAIRFIELD-Lava Rock # 2 (Base Station)	PAAIRFIELD- Lava Rock 1st Attempt

PAAIRFIELD-Lava Rock # 2nd Attempt	2010	3	3	9:58-10:10	18.12356804	145.7658117	N/A	Airfield-Volcanic Rock	Intermittent Clouds	Partly Cloudy	NRL NEW	B	Dual	Terrain	collected on lavarock found on the airstrip	

APPENDIX F

Underwater Spectroscopy

1 Introduction

Hyperspectral remote sensing has shown promise as a viable data source to support bathymetric surveys and mobility studies. Operational use of HSI depends on an improved understanding of the interactions of light with shallow water features and the associated controlling factors of light reflection and absorption for various coast types. For this reason, a DiveSpec was used to measure spectral reflectance in shallow water regions on Pagan, Tinian, and Guam. As an example, Figure F - 1 provides several underwater photographs for a sponge found on Tipalao Beach on Guam. Corresponding measurements of spectral radiance were

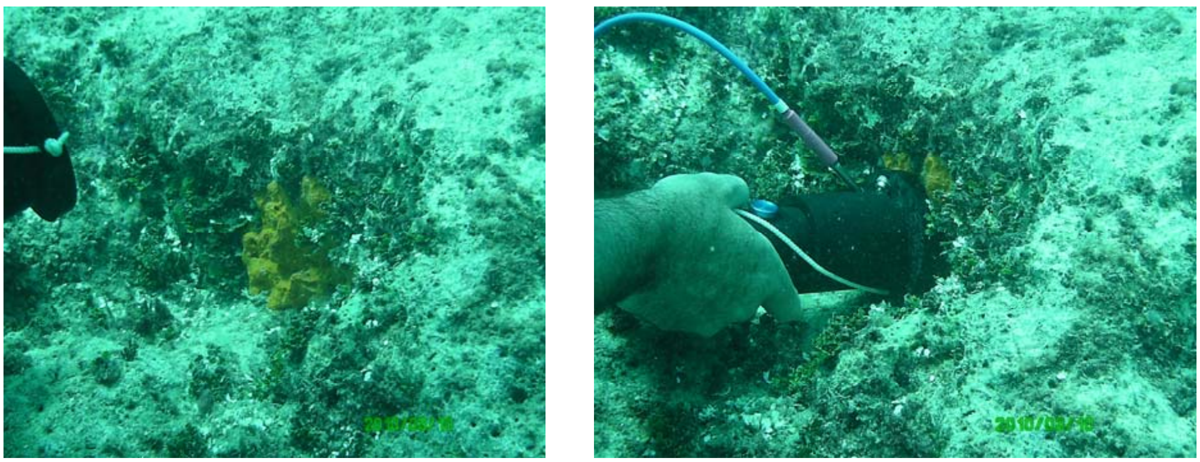


Figure F - 1. DiveSpec being used on a sponge found on Tipalao Beach, Guam. Approximately 128 species of sponges have been identified on Guam and the CNMI (Kelly et al., 2003). The left image is the target, a yellow to orange colored encrusting sponge. The right image depicts the DiveSpec probe being used on the target during sampling.

acquired underwater by using the same viewing geometry from a Spectralon® standard having an assumed Lambertian surface. The DiveSpec used these measurements for the *in situ* computation of reflectance, a relative unit. Figure F - 2 provides a typical reference and the associated reflectance curves for a sponge found on Tipalao beach, Guam.

Due to noise in certain regions of the spectra, the spectra have been smoothed to account for single value peaks and noise. To smooth spectra, a 15-point moving average was applied to raw data values. Graphs shown in Section 2 display the spectra after the moving average smoothing method was applied. However, in the project database Excel spreadsheet, the raw data values are included in the DiveSpec_Reflectance tab. We also found that the Savitky and Golay method is an improved but longer method for smoothing raw spectra.

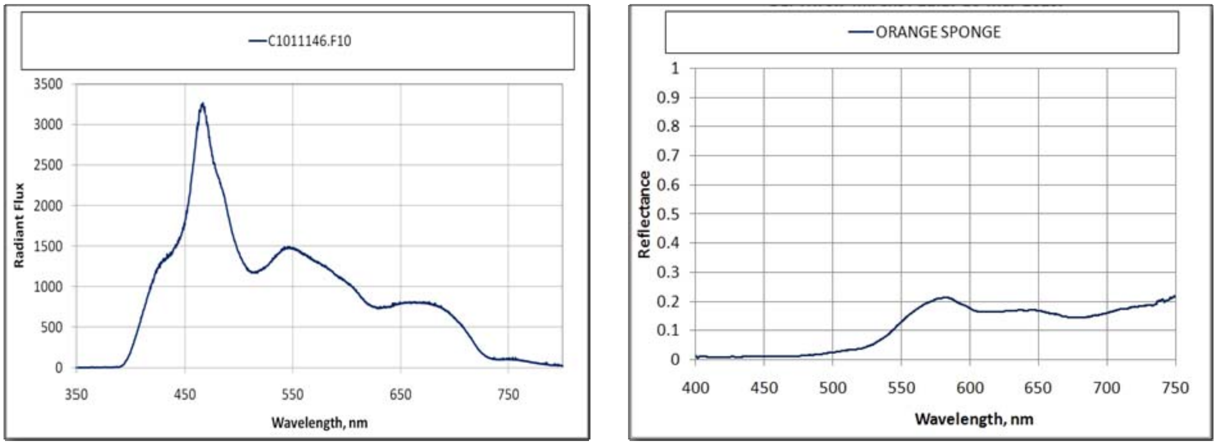


Figure F - 2. DiveSpec data for a sponge found on Tipalao Beach, Guam. The left graph is the reference measurement made underwater with a Spectralon® panel. The right graph depicts the resultant reflectance measurement (notice the peak around 582 nm). For this project, reflectance measurements can be used to identify and differentiate between bottom materials, e.g., between a sponge and surrounding algae, coral, and rock.

2 Underwater Spectra

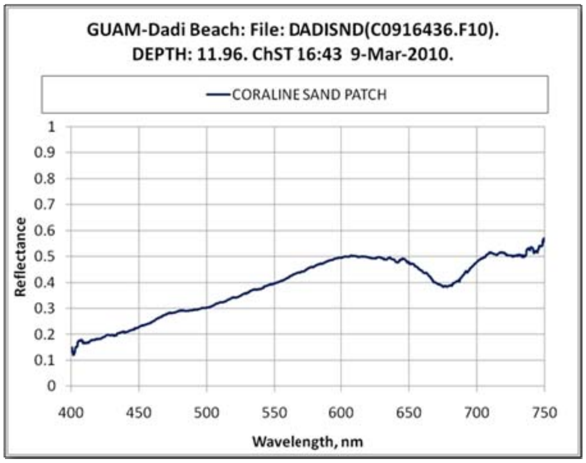
The following sections provide spectral reflectance curves for targets on Pagan, Tinian, and Guam. The curves highlight characteristic shallow water reflectance peaks and absorption troughs. A photograph of the target is provided as background information. These reflectance spectra and photographs have also been archived in the Mariana Islands project geodatabase. Original data was smoothed to reduce noise and is presented in the following graphs by study location.

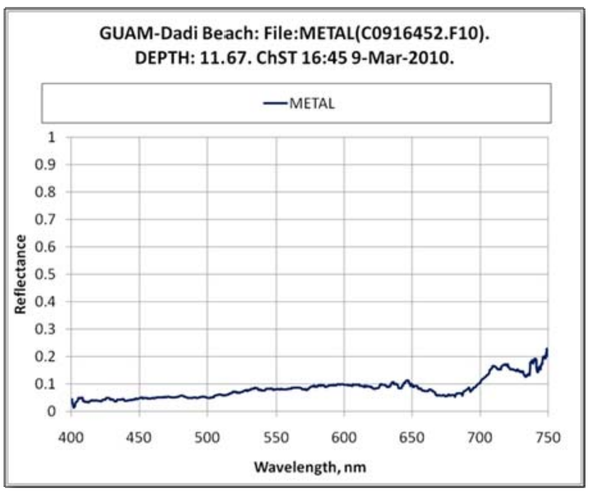
2.1 Guam

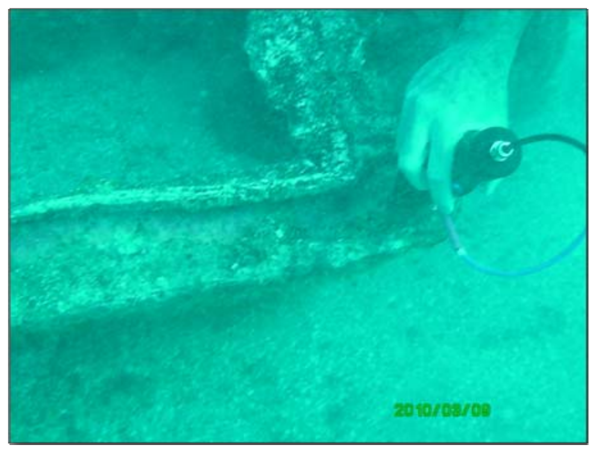
Spectra were collected in shallow water offshore of Dadi and Tipalao Beaches. Dadi Beach (13.41194º North Latitude and 144.65444º East Longitude) is located along the northern part of Agat Bay and contains a series of Japanese bunkers and a cave with two openings. Tipalao Beach (13.41556º North Latitude and 144.64472º East Longitude) is located along Tipalao Bay on the southwest coast between Tantapalo Point and Neye Island. A sewage diffuser is located offshore in relatively deep water. Spectra and underwater photographs highlight significant variation in the bottom (biodiversity) along the reef flat between Neye Island and the coast, and the patch reefs in North Agat Bay. Graphs are presented in chronological order.

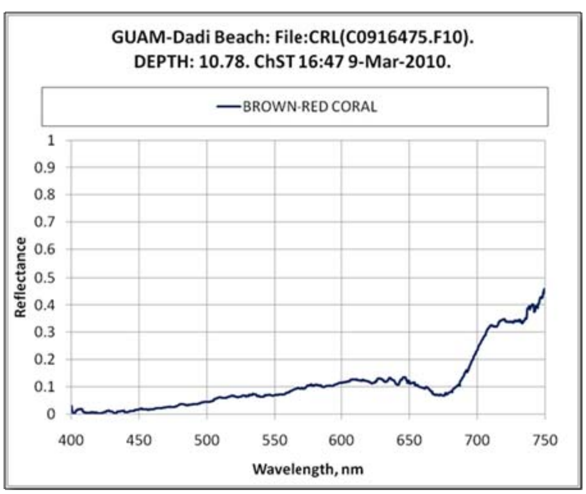
2.1.1 9-March-2010

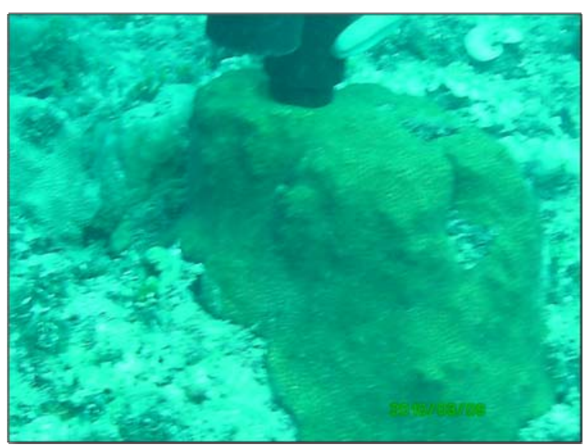
Reflectance Spectra | **Underwater Photographs**

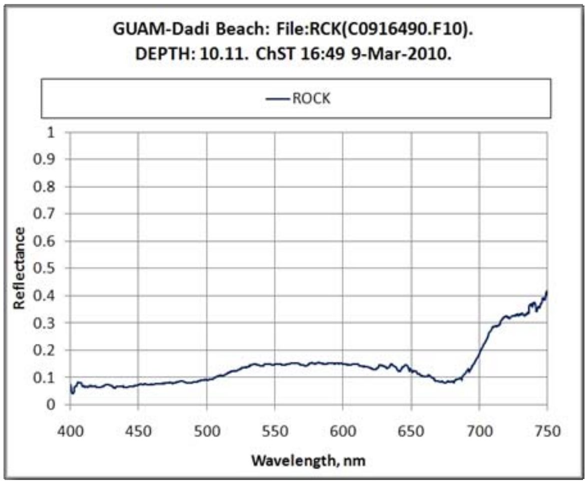




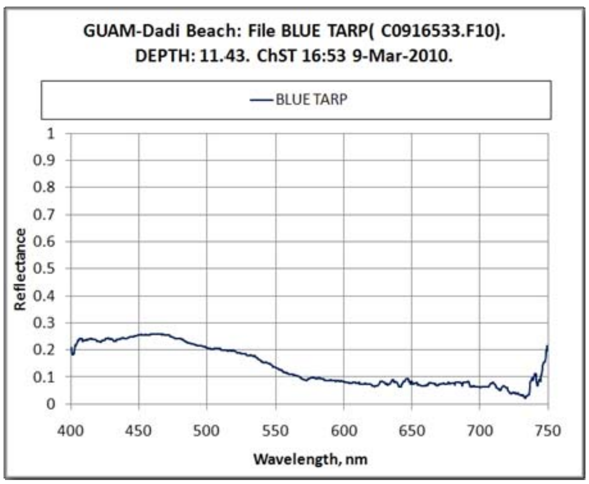


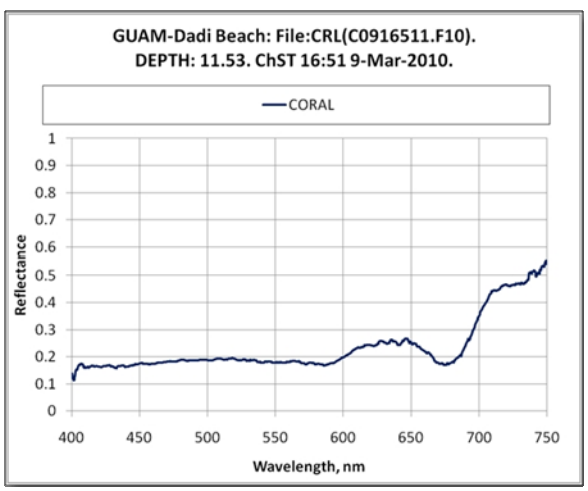






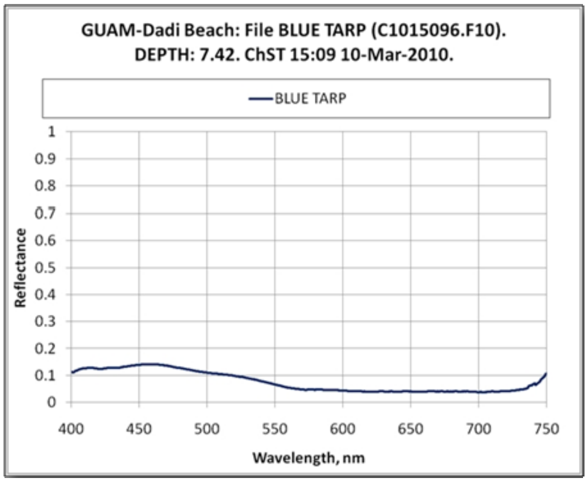
No Picture Available

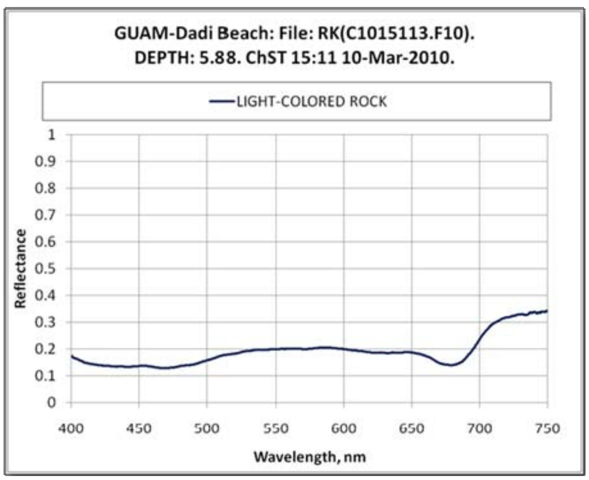


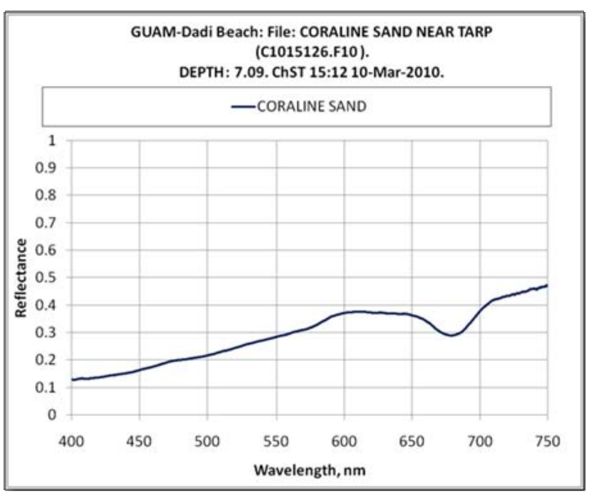


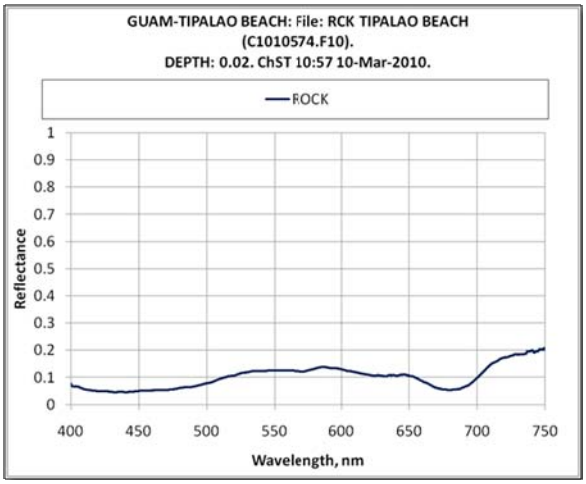
No Picture Available

2.1.2 10-March-2010

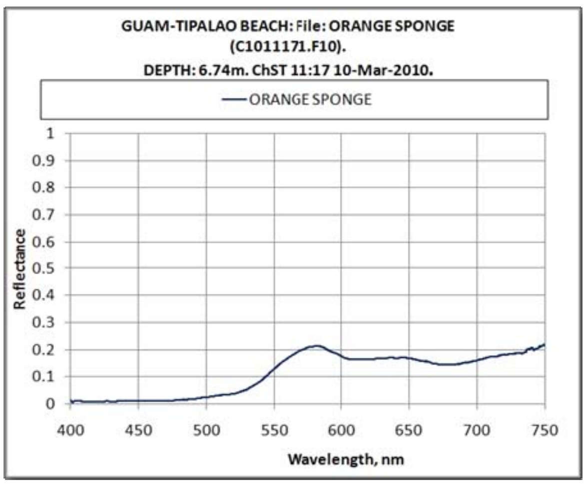







GUAM-TIPALAO BEACH: File: RCK TIPALAO BEACH
(C1010574.F10).
DEPTH: 0.02. ChST 10:57 10-Mar-2010.
ROCK
Reflectance
Wavelength, nm


2010/03/10

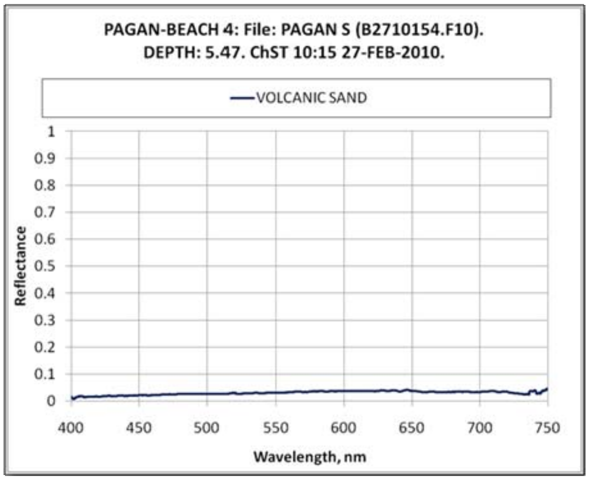

GUAM-TIPALAO BEACH: File: ORANGE SPONGE
(C1011171.F10).
DEPTH: 6.74m. ChST 11:17 10-Mar-2010.
ORANGE SPONGE
Reflectance
Wavelength, nm

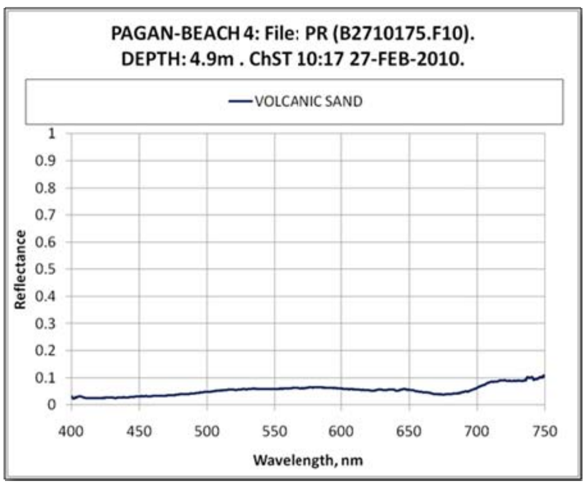
2.2 Pagan

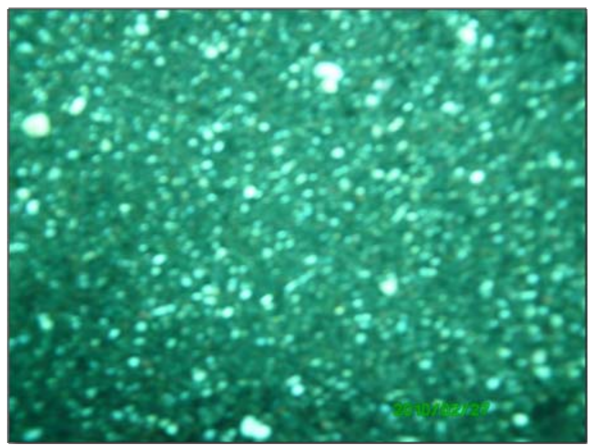
Underwater Spectra were collected in shallow water offshore of beaches located along the southwest coast of Pagan. Spectra and underwater photographs highlight significant variation in the bottom, including the presence of coralline algae, wreckage, and hard corals. Fringing reef development on Pagan was less than Guam and Tinian.

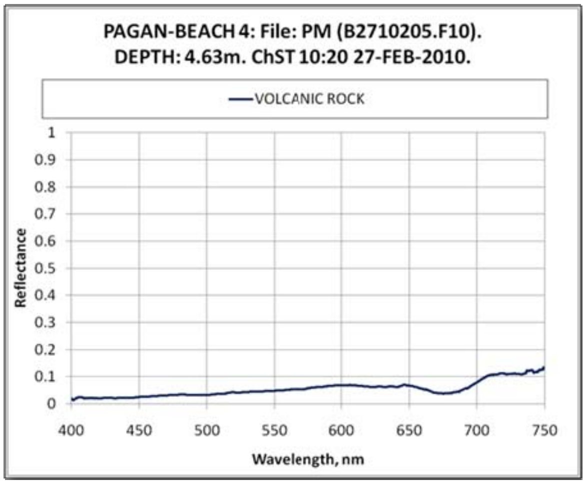
2.2.1 27-February-2010

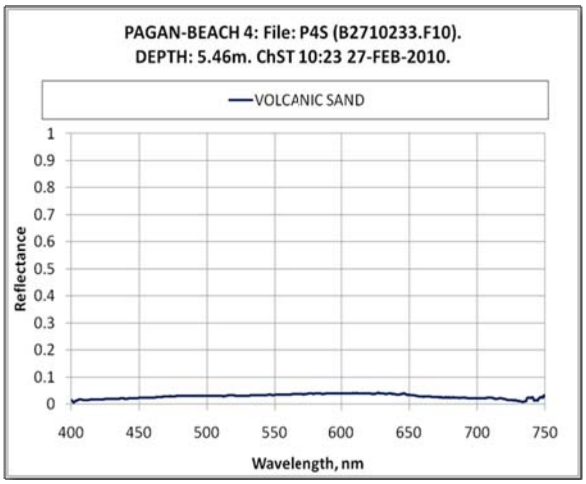
Reflectance Spectra | **Underwater Photographs**

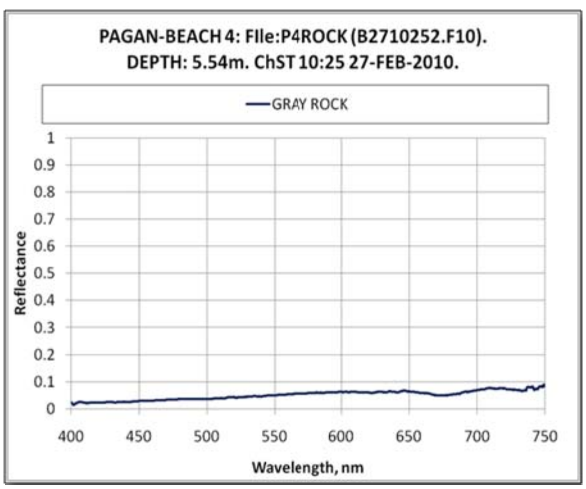


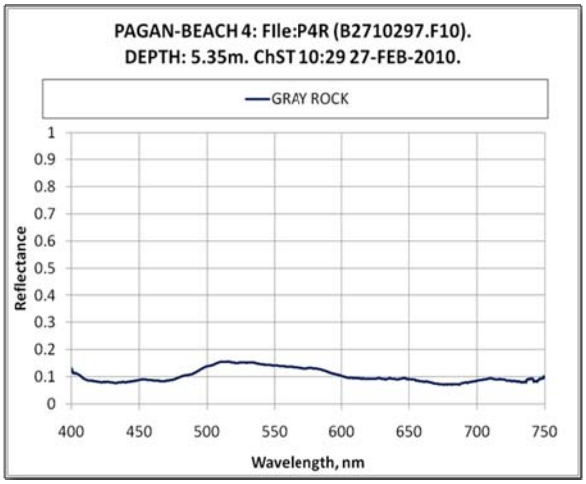


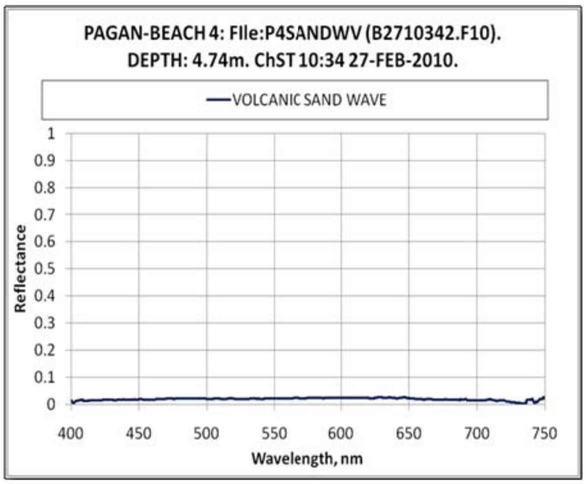


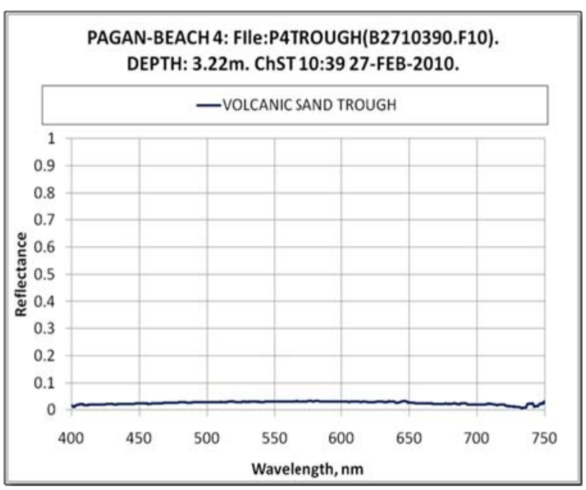

PAGAN-BEACH 4: File: PM (B2710205.F10).
DEPTH: 4.63m. ChST 10:20 27-FEB-2010.
VOLCANIC ROCK
Reflectance
Wavelength, nm
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
450
500
550
600
650
700
750

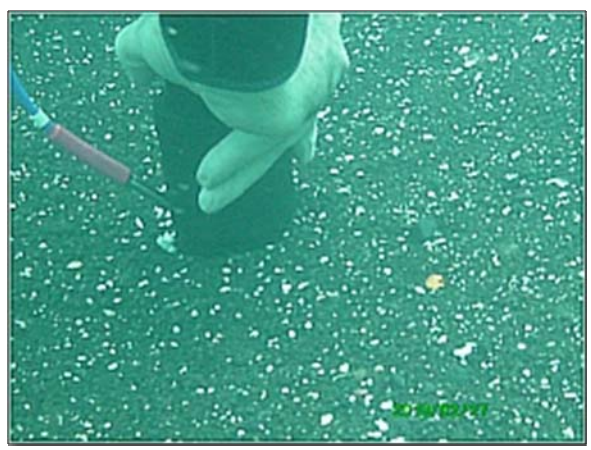

PAGAN-BEACH 4: File: P4S (B2710233.F10).
DEPTH: 5.46m. ChST 10:23 27-FEB-2010.
VOLCANIC SAND
Reflectance
Wavelength, nm
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
450
500
550
600
650
700
750

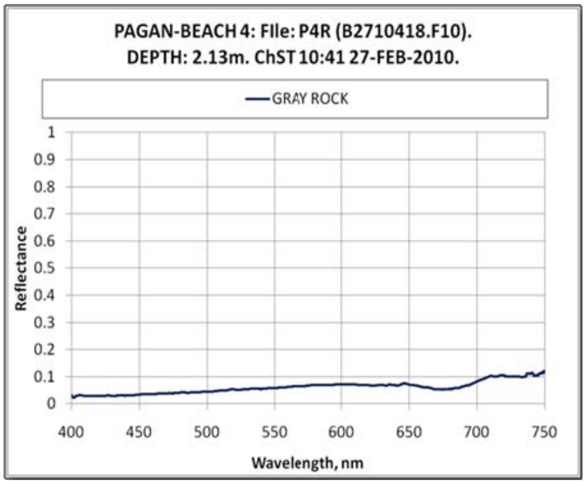

PAGAN-BEACH 4: FIle:P4ROCK (B2710252.F10).
DEPTH: 5.54m. ChST 10:25 27-FEB-2010.
GRAY ROCK
Reflectance
Wavelength, nm
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
450
500
550
600
650
700
750

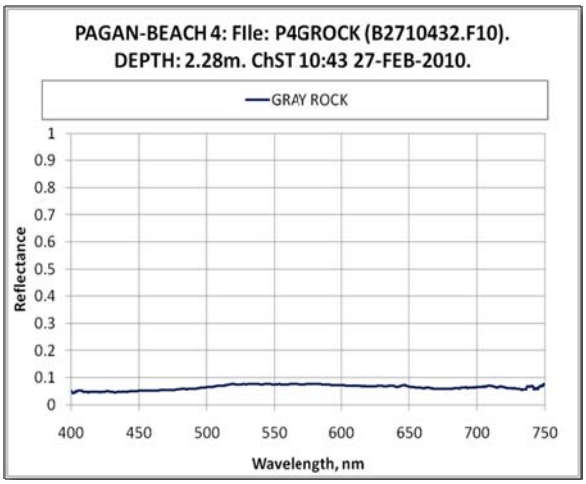

PAGAN-BEACH 4: FIle:P4R (B2710297.F10).
DEPTH: 5.35m. ChST 10:29 27-FEB-2010.
GRAY ROCK
Reflectance
Wavelength, nm


PAGAN-BEACH 4: FIle:P4SANDWV (B2710342.F10).
DEPTH: 4.74m. ChST 10:34 27-FEB-2010.
VOLCANIC SAND WAVE
Reflectance
Wavelength, nm


PAGAN-BEACH 4: FIle:P4TROUGH(B2710390.F10).
DEPTH: 3.22m. ChST 10:39 27-FEB-2010.
VOLCANIC SAND TROUGH
Reflectance
Wavelength, nm

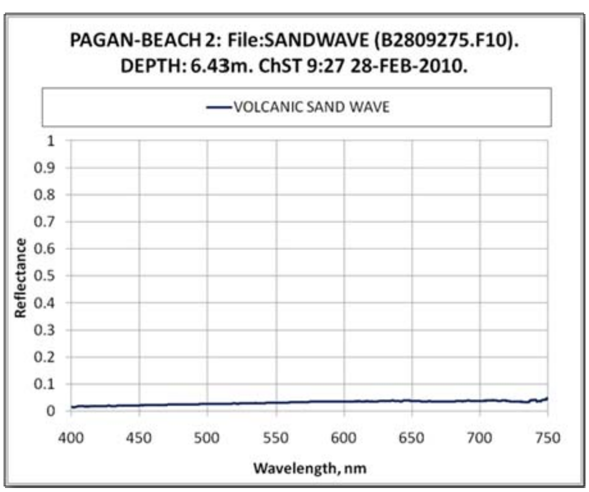


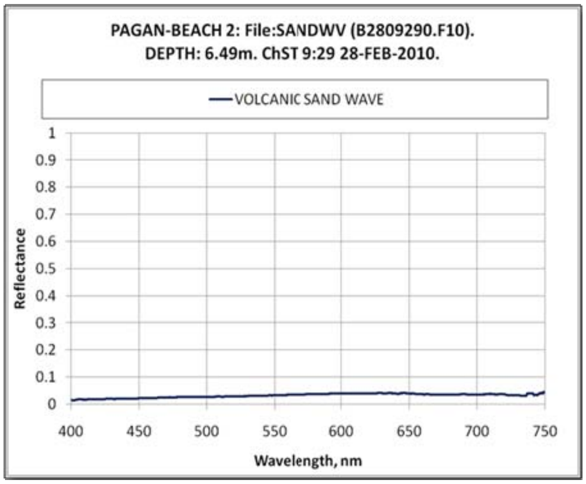


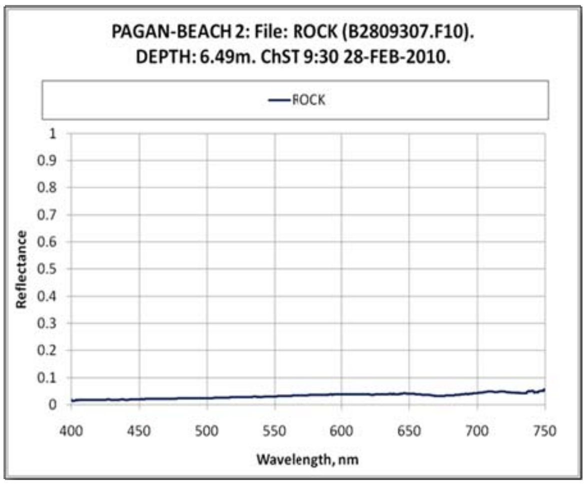


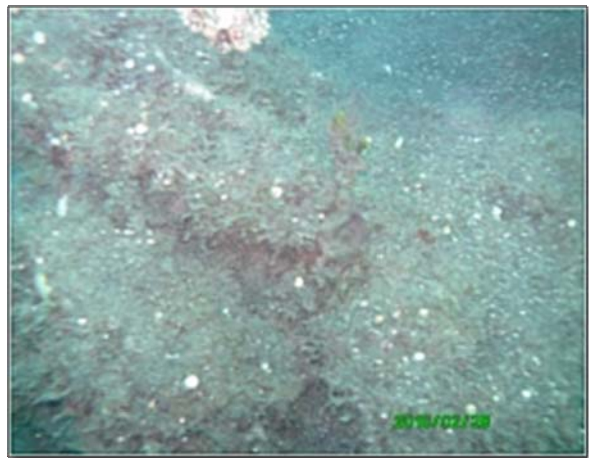
2.2.2 28-February-2010

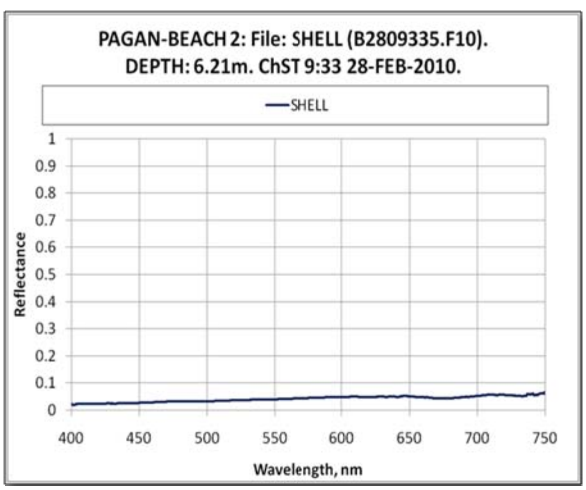
Reflectance Spectra **Underwater Photographs**



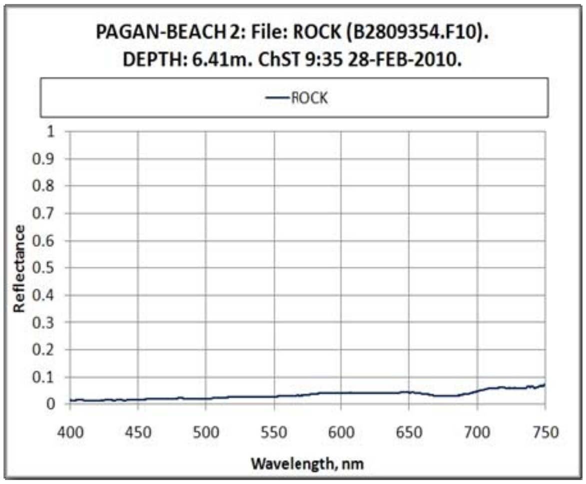

PAGAN-BEACH 2: File:SANDWV (B2809290.F10).
DEPTH: 6.49m. ChST 9:29 28-FEB-2010.
VOLCANIC SAND WAVE
Reflectance
Wavelength, nm
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
450
500
550
600
650
700
750

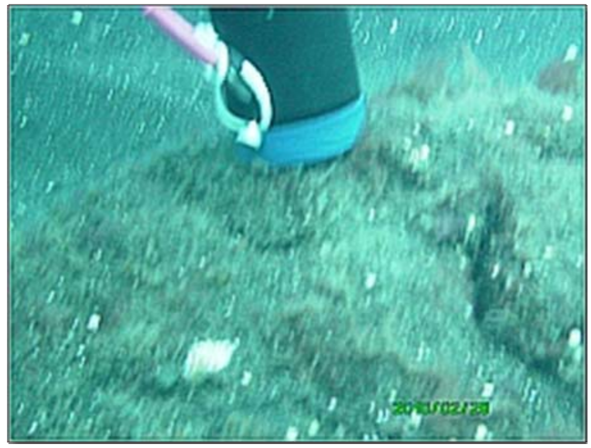

PAGAN-BEACH 2: File: ROCK (B2809307.F10).
DEPTH: 6.49m. ChST 9:30 28-FEB-2010.
ROCK
Reflectance
Wavelength, nm
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
450
500
550
600
650
700
750

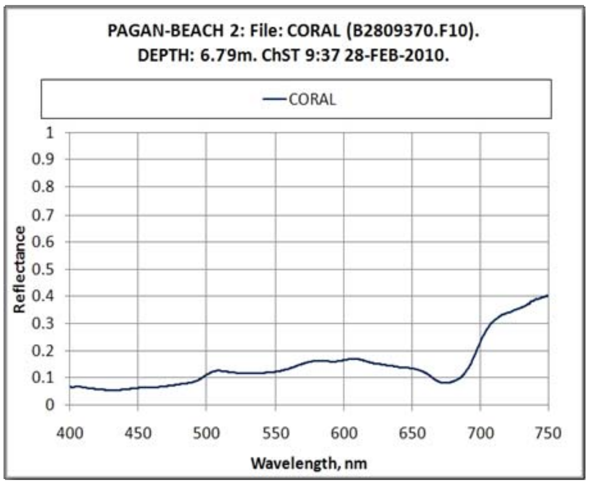

2010/02/28


PAGAN-BEACH 2: File: SHELL (B2809335.F10).
DEPTH: 6.21m. ChST 9:33 28-FEB-2010.
SHELL
Reflectance
Wavelength, nm
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
450
500
550
600
650
700
750

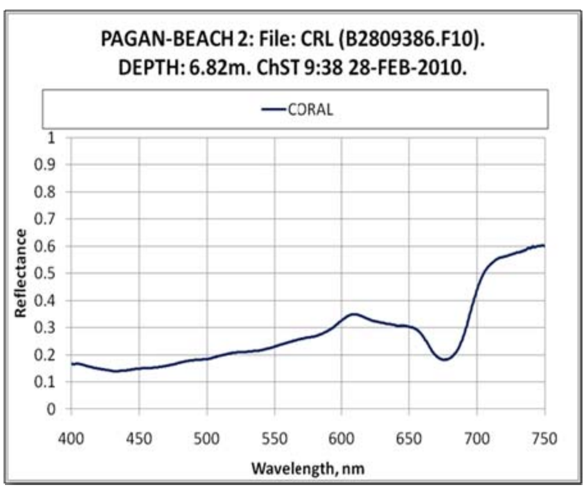

2010/02/28

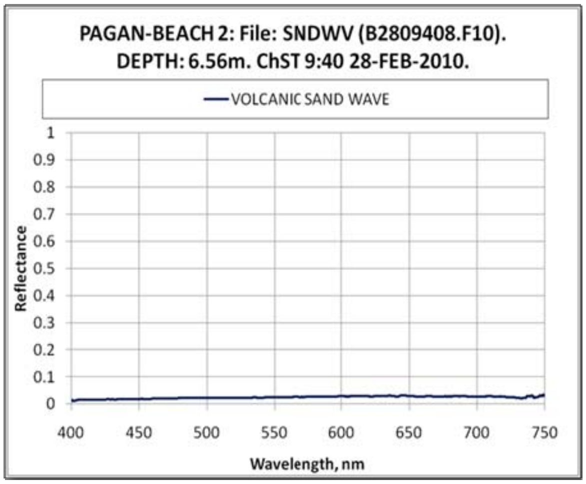

PAGAN-BEACH 2: File: ROCK (B2809354.F10).
DEPTH: 6.41m. ChST 9:35 28-FEB-2010.
ROCK
Reflectance
Wavelength, nm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
750

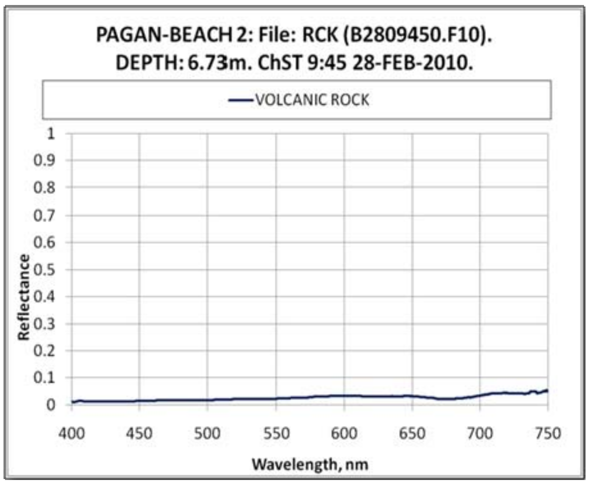

2010/02/28

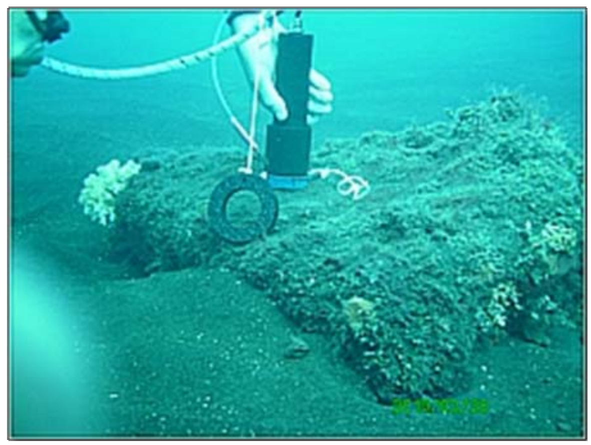

PAGAN-BEACH 2: File: CORAL (B2809370.F10).
DEPTH: 6.79m. ChST 9:37 28-FEB-2010.
CORAL
Reflectance
Wavelength, nm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
750

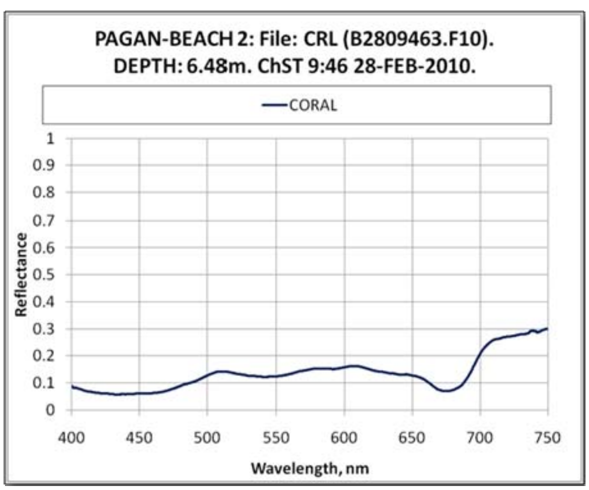

2010/02/28

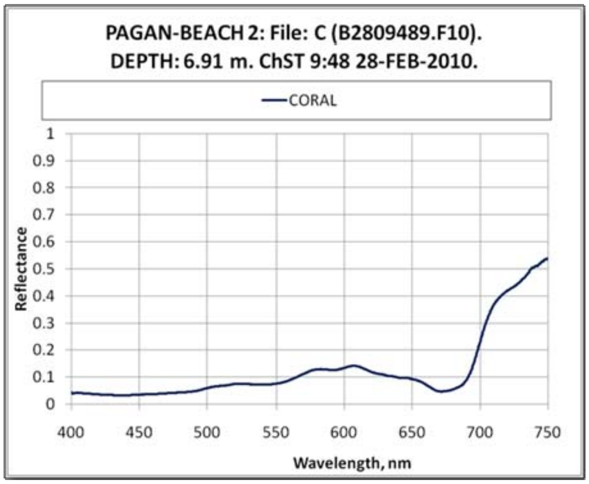

PAGAN-BEACH 2: File: CRL (B2809386.F10).
DEPTH: 6.82m. ChST 9:38 28-FEB-2010.
CORAL
Reflectance
Wavelength, nm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
750

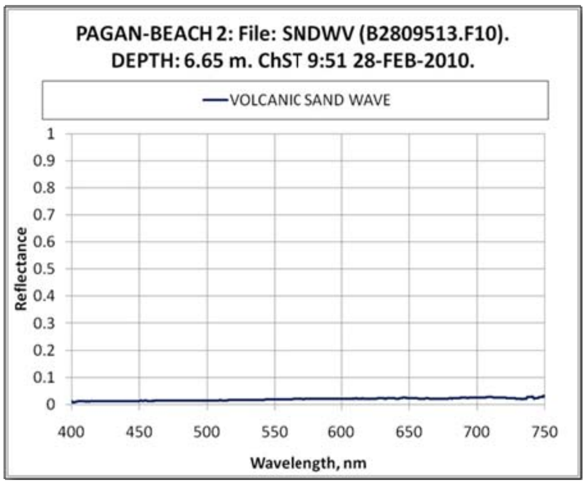

PAGAN-BEACH 2: File: SNDWV (B2809408.F10).
DEPTH: 6.56m. ChST 9:40 28-FEB-2010.
VOLCANIC SAND WAVE
Reflectance
Wavelength, nm

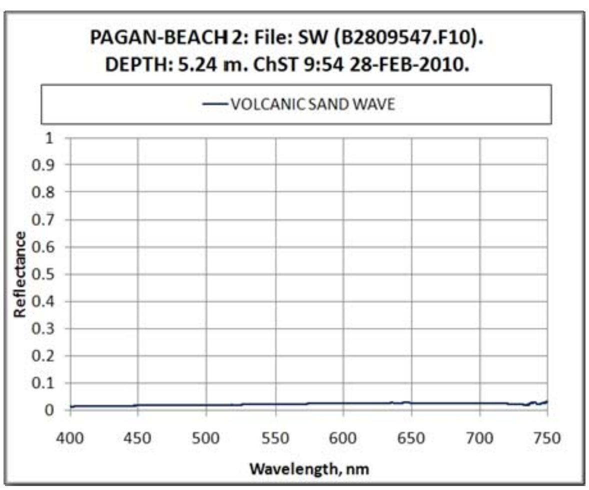

PAGAN-BEACH 2: File: RCK (B2809450.F10).
DEPTH: 6.73m. ChST 9:45 28-FEB-2010.
VOLCANIC ROCK
Reflectance
Wavelength, nm

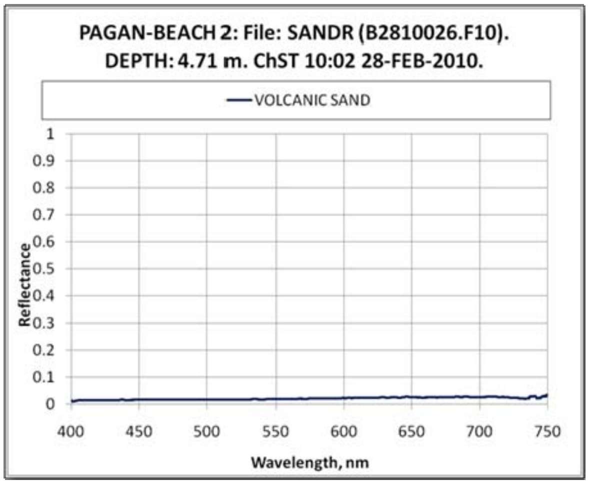


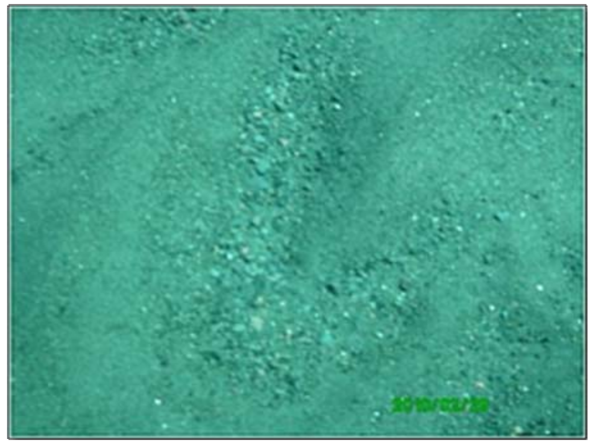

PAGAN-BEACH 2: File: CRL (B2809463.F10).
DEPTH: 6.48m. ChST 9:46 28-FEB-2010.
CORAL
Reflectance
Wavelength, nm

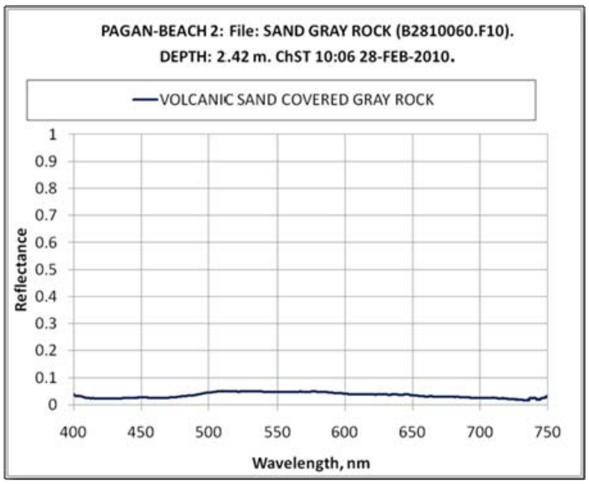

PAGAN-BEACH 2: File: C (B2809489.F10).
DEPTH: 6.91 m. ChST 9:48 28-FEB-2010.
CORAL
Reflectance
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
750
Wavelength, nm


PAGAN-BEACH 2: File: SNDWV (B2809513.F10).
DEPTH: 6.65 m. ChST 9:51 28-FEB-2010.
VOLCANIC SAND WAVE
Reflectance
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
750
Wavelength, nm

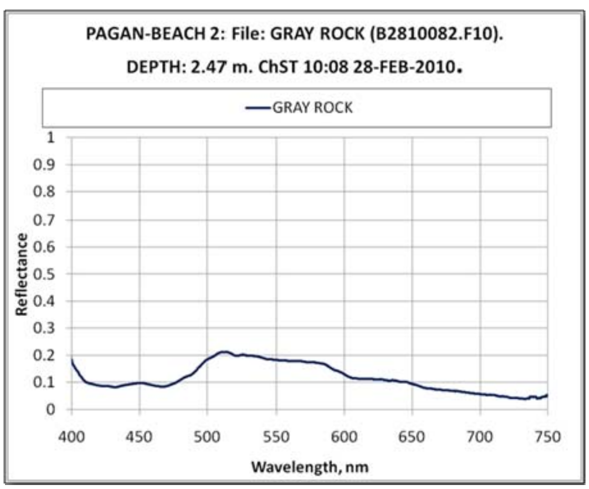

PAGAN-BEACH 2: File: SW (B2809547.F10).
DEPTH: 5.24 m. ChST 9:54 28-FEB-2010.
VOLCANIC SAND WAVE
Reflectance
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
750
Wavelength, nm



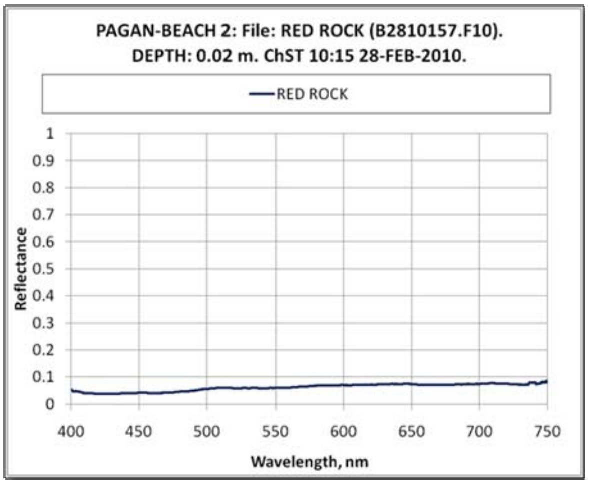




No Picture Available



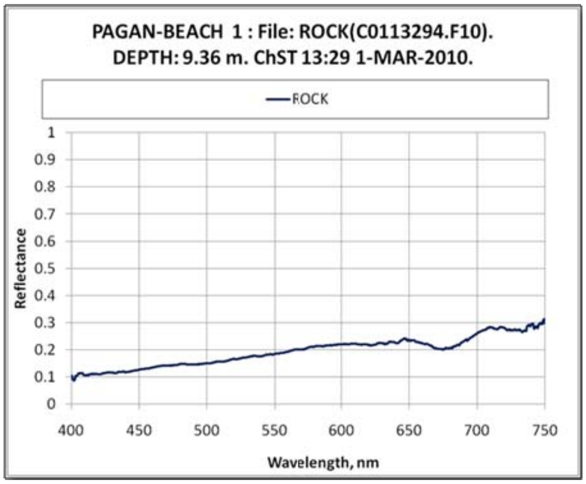
No Picture Available

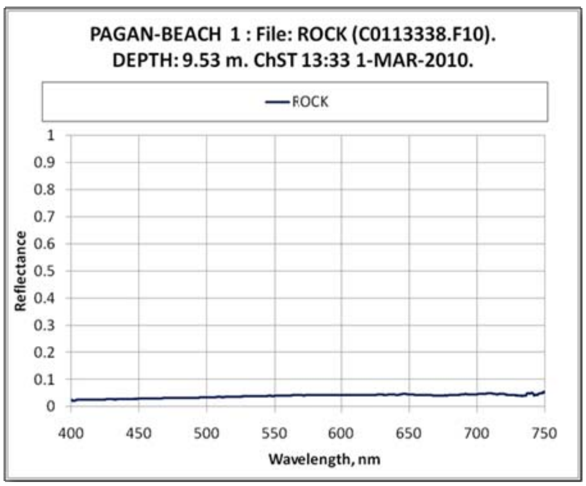


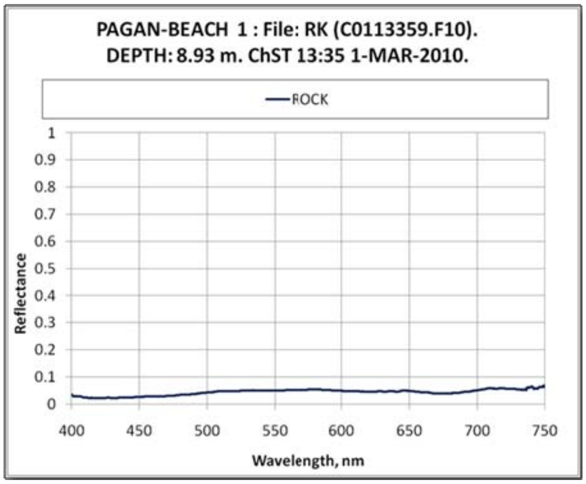
No Picture Available

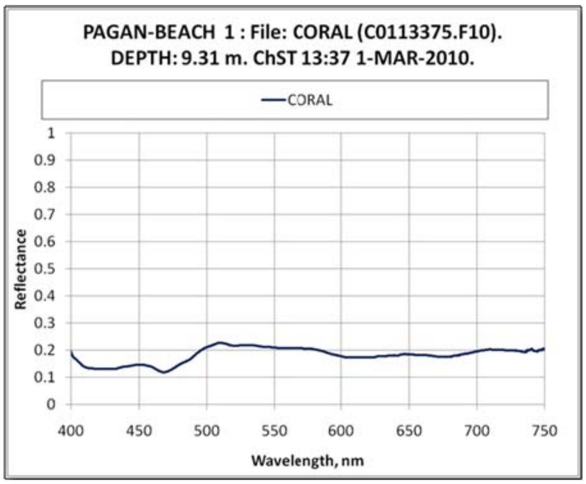
2.2.3 1-March-2010

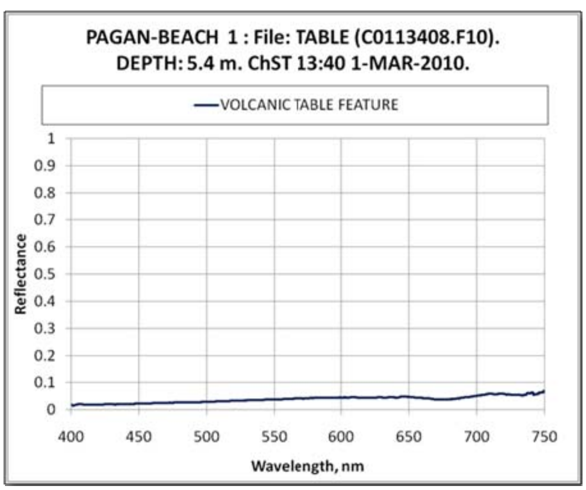
Reflectance Spectra | **Underwater Photographs**

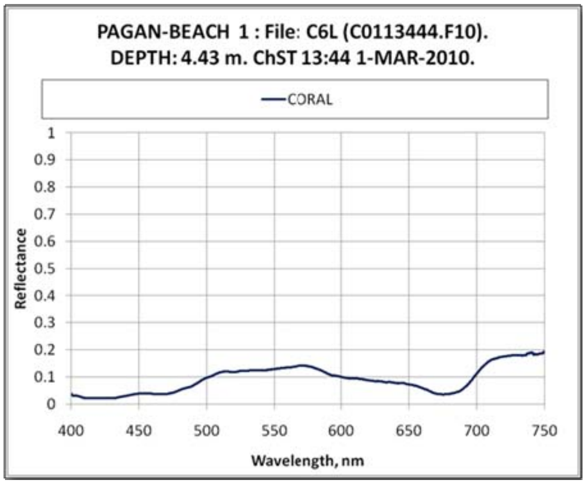





PAGAN-BEACH 1 : File: RK (C0113359.F10).
DEPTH: 8.93 m. ChST 13:35 1-MAR-2010.
ROCK
Reflectance
Wavelength, nm


PAGAN-BEACH 1 : File: CORAL (C0113375.F10).
DEPTH: 9.31 m. ChST 13:37 1-MAR-2010.
CORAL
Reflectance
Wavelength, nm


PAGAN-BEACH 1 : File: TABLE (C0113408.F10).
DEPTH: 5.4 m. ChST 13:40 1-MAR-2010.
VOLCANIC TABLE FEATURE
Reflectance
Wavelength, nm

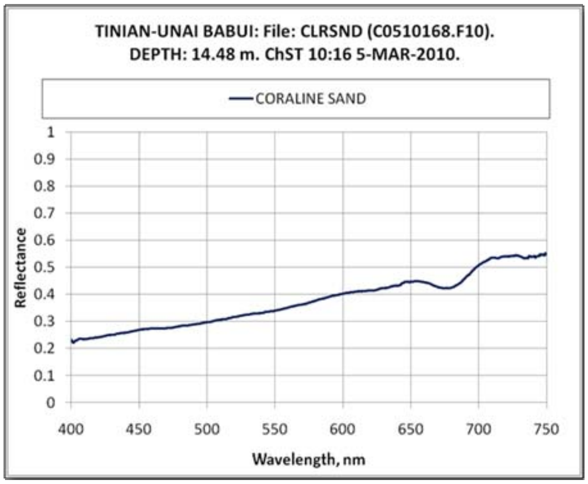

PAGAN-BEACH 1 : File: C6L (C0113444.F10).
DEPTH: 4.43 m. ChST 13:44 1-MAR-2010.
CORAL
Reflectance
Wavelength, nm
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
450
500
550
600
650
700
750

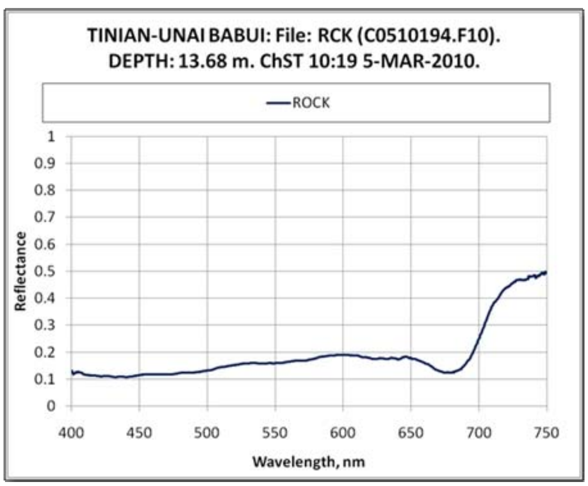
2.3 Tinian

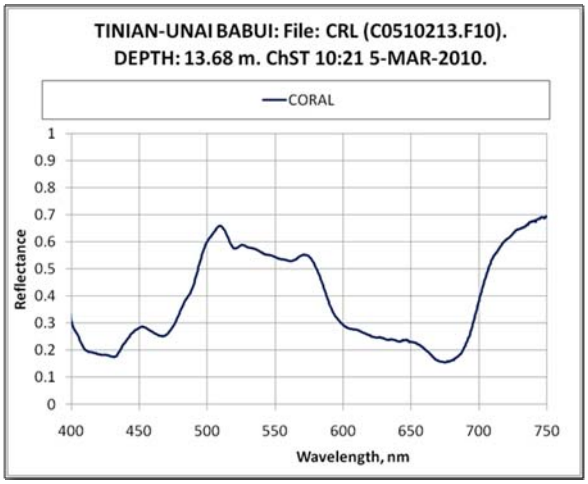
Coral reefs surround Tinian, but are more extensive on the western shore. During WWII, Marines landed across Unai Babui and Chulu (White 1 and 2), which are located on the northwestern part of Tinian. This remote sensing experiment focused on Unai Babui (located just north of Chulu), Lamlam (located just north of Babui), and Dangkolo (located on the east coast). Unai Dangkolo, also known as Longbeach, is a complex of beaches separated by narrow rocky outcrops and fronted by a single coral reef system. An accumulation of metal debris, including unexploded ordinance that was dumped from cliffs, was found near Faibus Point (aka Dump Coke North) on Tinian.

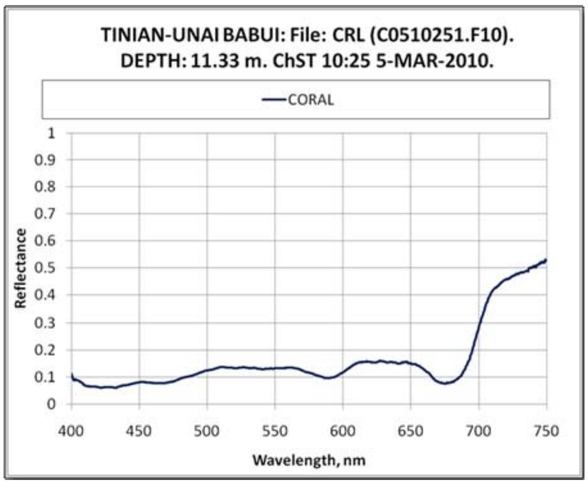
2.3.1 5-March-2010

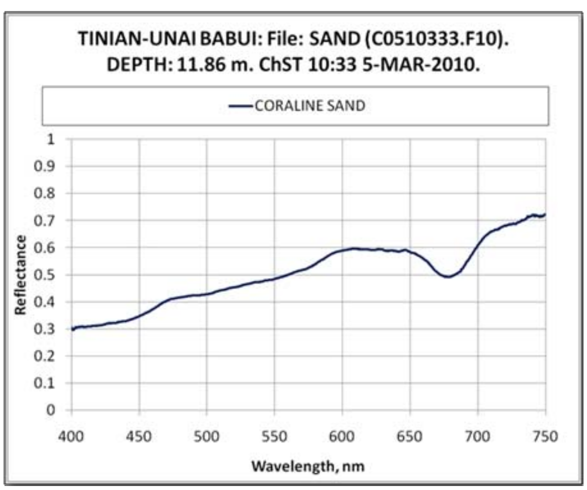
Reflectance Spectra | **Underwater Photographs**

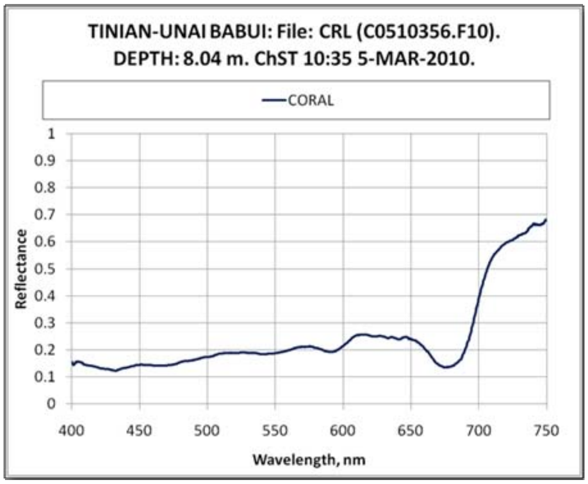


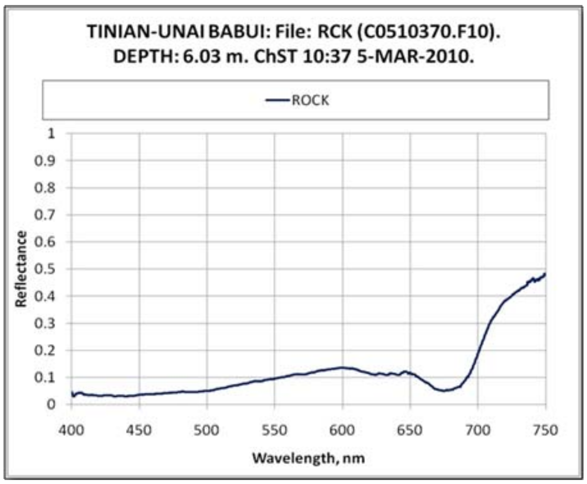


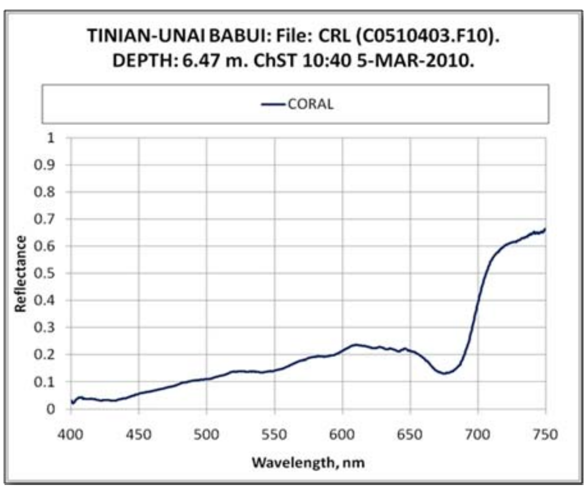

TINIAN-UNAI BABUI: File: CRL (C0510213.F10).
DEPTH: 13.68 m. ChST 10:21 5-MAR-2010.
CORAL
Reflectance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
450
500
550
600
650
700
750
Wavelength, nm

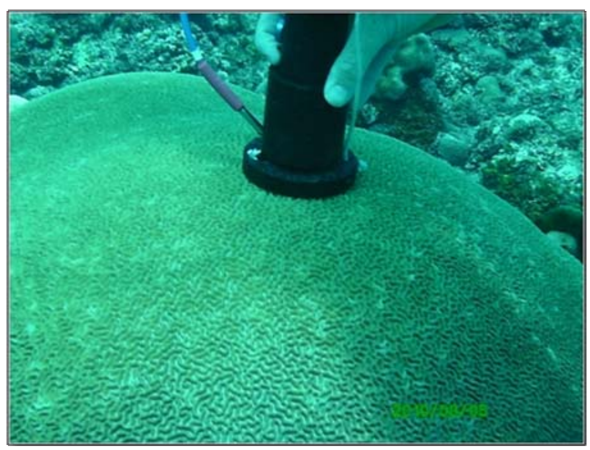

TINIAN-UNAI BABUI: File: CRL (C0510251.F10).
DEPTH: 11.33 m. ChST 10:25 5-MAR-2010.
CORAL
Reflectance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
450
500
550
600
650
700
750
Wavelength, nm

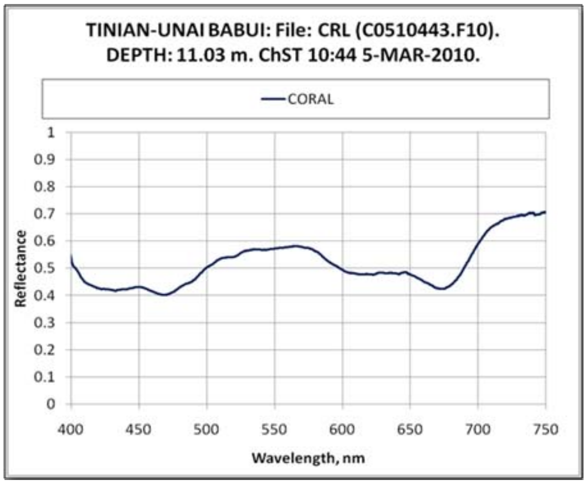

TINIAN-UNAI BABUI: File: SAND (C0510333.F10).
DEPTH: 11.86 m. ChST 10:33 5-MAR-2010.
CORALINE SAND
Reflectance
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
400
450
500
550
600
650
700
750
Wavelength, nm

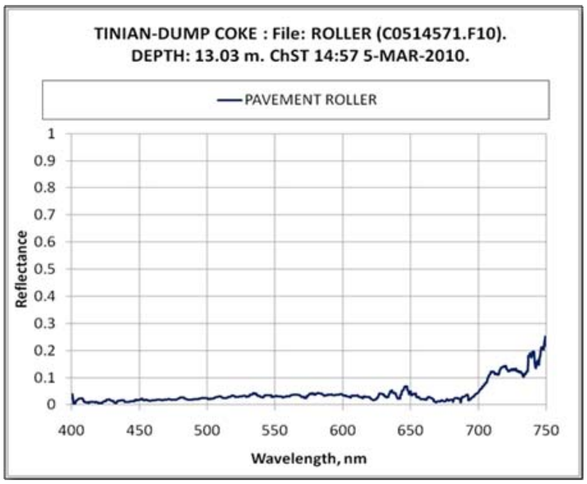

TINIAN-UNAI BABUI: File: CRL (C0510356.F10).
DEPTH: 8.04 m. ChST 10:35 5-MAR-2010.
CORAL
Reflectance
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
750
Wavelength, nm

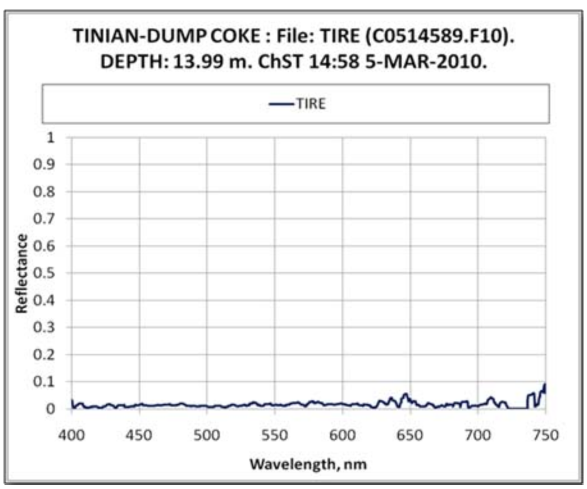

TINIAN-UNAI BABUI: File: RCK (C0510370.F10).
DEPTH: 6.03 m. ChST 10:37 5-MAR-2010.
ROCK
Reflectance
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
750
Wavelength, nm


TINIAN-UNAI BABUI: File: CRL (C0510403.F10).
DEPTH: 6.47 m. ChST 10:40 5-MAR-2010.
CORAL
Reflectance
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
750
Wavelength, nm



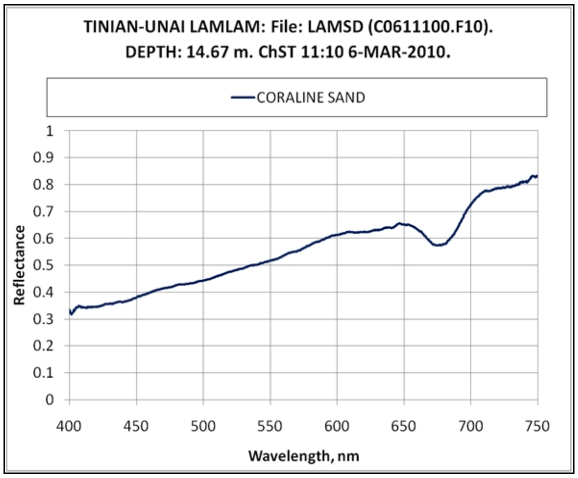

TINIAN-UNAI BABUI: File: CRL (C0510443.F10).
DEPTH: 11.03 m. ChST 10:44 5-MAR-2010.
CORAL
Reflectance
Wavelength, nm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
750


TINIAN-DUMP COKE : File: ROLLER (C0514571.F10).
DEPTH: 13.03 m. ChST 14:57 5-MAR-2010.
PAVEMENT ROLLER
Reflectance
Wavelength, nm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
750

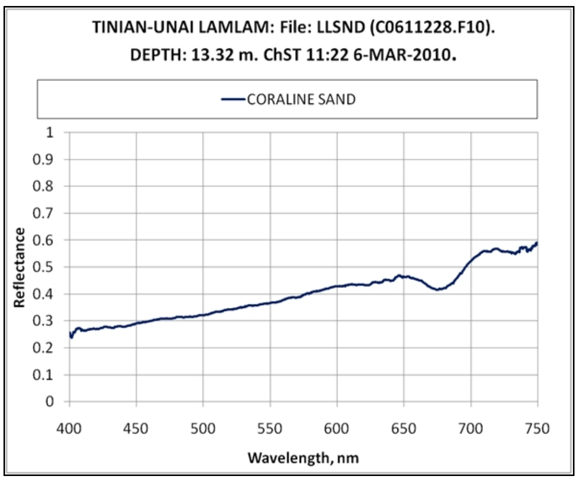

TINIAN-DUMP COKE : File: TIRE (C0514589.F10).
DEPTH: 13.99 m. ChST 14:58 5-MAR-2010.
TIRE
Reflectance
Wavelength, nm
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
400
450
500
550
600
650
700
750

2.3.2 6-March-2010

Reflectance Spectra | **Underwater Photographs**



No Picture Available



APPENDIX G

In Water Optical Profiles

1 Introduction

The In-water optical package measures, as a function of depth, physical properties (temperature and salinity), chlorophyll concentration, and optical properties in the water column. A dual-head ASD spectrometer was used to measure the remote sensing reflectance at select locations above the water surface. Measurements were taken during all three phases of the experiment. All data were collected from small craft in concert with measurements of bottom reflectance using an underwater spectrometer. Following in-water measurements the boat team commenced hydrographic survey operations in very shallow water.

2 Data

The physical properties of the water column are shown as a function of depth. In general, the optical properties showed little to no variation with depth, and hence only the surface values are shown. Three of the ASD spectra look contaminated; they rise unrealistically in the NIR portion of the spectrum. The cause of this is unclear. The backscattering to total scattering (bb/b) values, which are for particulate values only, also tend to be high in the green portion of the spectrum. This seems to be a characteristic of this particular instrument. They are included for reference. The optical properties and scattering graphs reflect the properties of the water surface. Table G - 1 lists the positional information of each site where data were taken. In the table, the station name is listed, the island, positional information, and the station type. For station type, sites that had just the spectra taken are listed as "Spectral" and sites that had inherent optical properties (IOP) are listed as "Spectral and IOP". Table G - 2 displays spectra of all sites and IOP information is displayed in Table G - 3. Figure G - 1 displays each position.

Table G - 1. In-water optics positional information.

Name	Island	Date	Lat	Long	Time (local)	Depth (m)	Station Type
G_BlueTarp	Guam	9-Mar-10	13.4115361	144.6556667	15:00	3	Spectral
G_Deep	Guam	9-Mar-10	13.4093686	144.6528119	16:02	10	Spectral and IOP
G_DadiMooring	Guam	10-Mar-10	13.4111961	144.6557750	15:05	5.2	Spectral
G_Sewage_Diffuser	Guam	10-Mar-10	13.4147864	144.6438714	13:16	40	Spectral and IOP
G_Tipalao	Guam	10-Mar-10	13.4166233	144.6466644	11:15	3	Spectral and IOP
P_IOP 1	Pagan	1-Mar-10	18.123500	145.758483	9:35	6.5	Spectral and IOP
P_IOP 2	Pagan	1-Mar-10	18.124983	145.755067	10:00	18	Spectral and IOP
P_IOP 3	Pagan	1-Mar-10	18.127500	145.758833	10:43	6.5	Spectral and IOP
P_IOP 4	Pagan	1-Mar-10	18.132650	145.757617	11:05	--	Spectral and IOP
P_IOP 5	Pagan	1-Mar-10	18.138617	145.760533	11:35	9	Spectral and IOP
P_Beach2_Sand	Pagan	3-Mar-10	18.126700	145.757717	9:40	1.5-2.5	Spectral
P_Beach4	Pagan	3-Mar-10	18.123817	145.758267	9:18	5.5	Spectral
P_Bluewater	Pagan	3-Mar-10	18.122583	145.754050	9:00	19.5	Spectral
T_Babui	Tinian	5-Mar-10	15.080467	145.621017	16:34	17.5	Spectral
T_Babui_Deep	Tinian	5-Mar-10	15.08135944	145.620004649	11:30	46-76	Spectral
T_DumpCove	Tinian	5-Mar-10	15.05188990	145.596759639	14:45	9	Spectral

T_IOP1	Tinian	5-Mar-10	15.08042383	145.621014124	10:40	15	Spectral and IOP
T_Lamlam	Tinian	6-Mar-10	15.089067	145.631400	11:31	15	Spectral and IOP
T_Lamlam_Deep	Tinian	6-Mar-10	15.08882014	145.622508483	14:31	--	Spectral

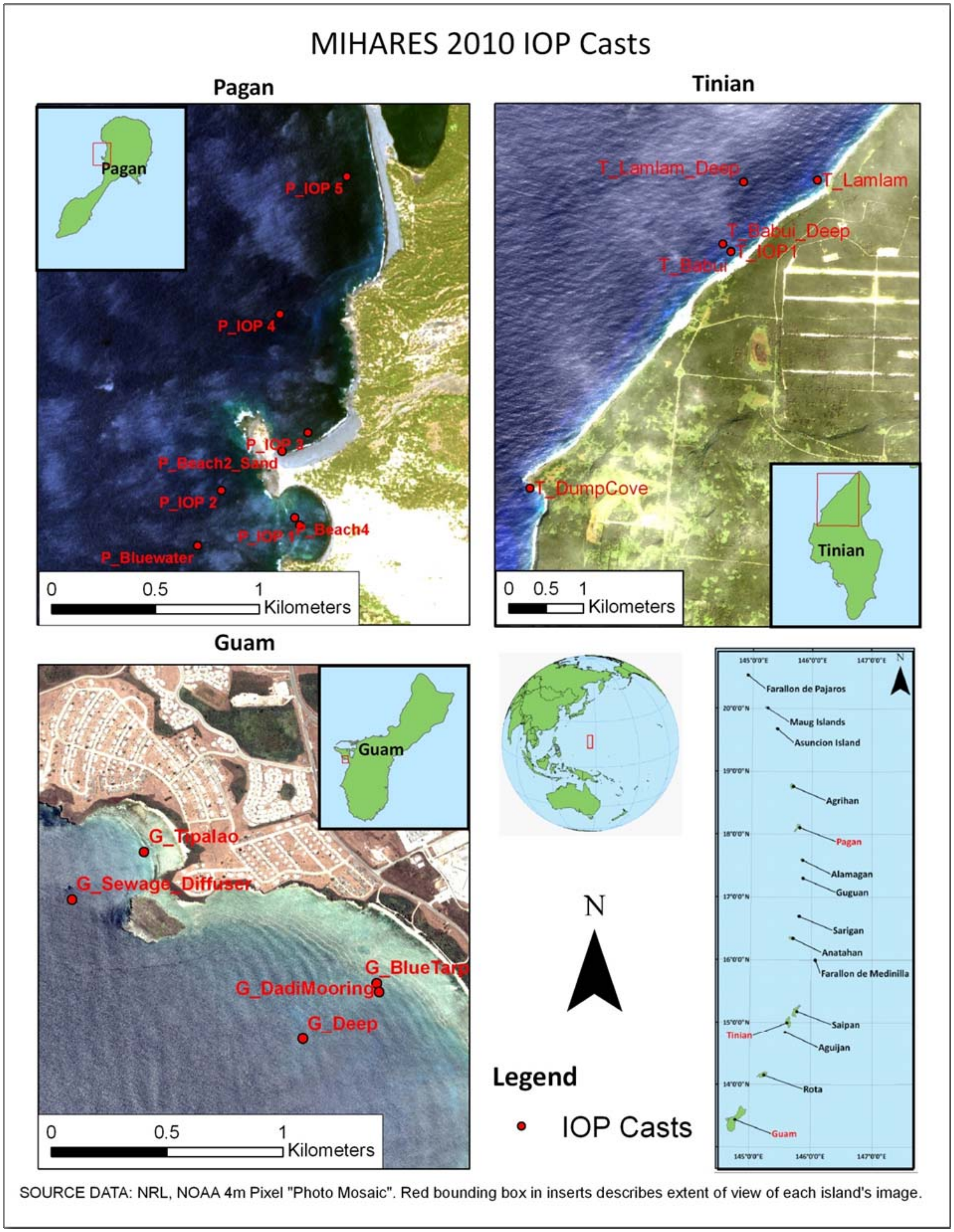


Figure G - 1. MIHARES 2010 IOP casts. In-water optical data were collected by a boat team.

Table G - 2. In-water optical profiles spectra.

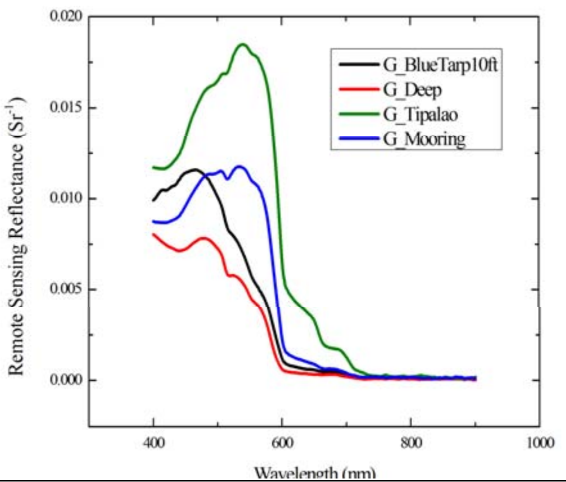
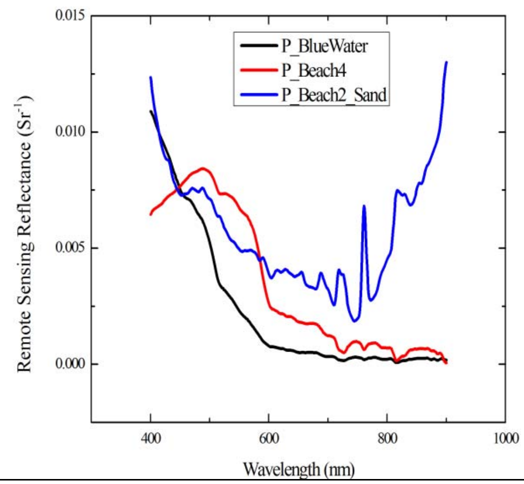
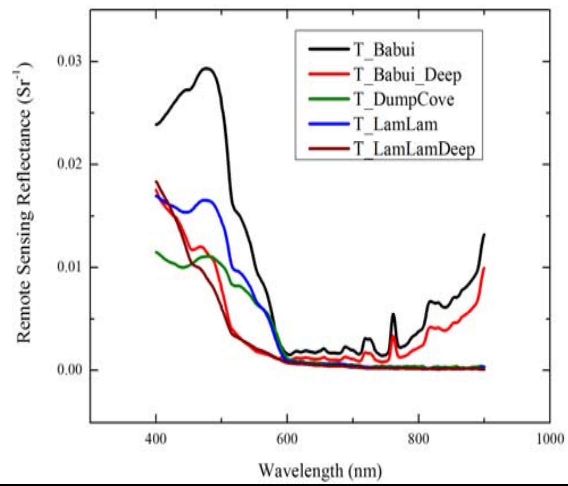
Guam	Pagan	Tinian
		

Table G - 3. Inherent optical properties.

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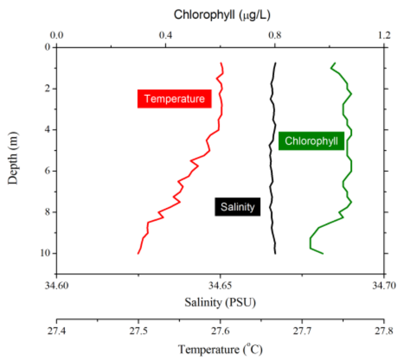
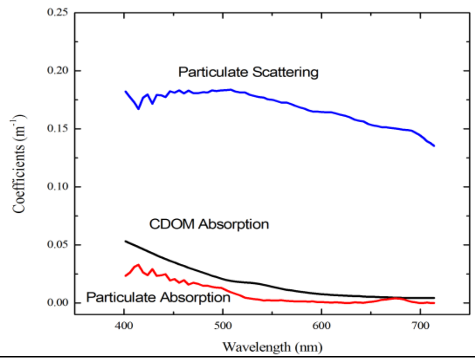
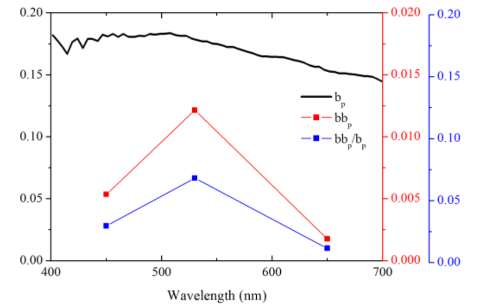
<tr><th>Position</th><th>Physical Properties</th><th>Optical Properties</th><th>Scattering</th></tr>
<tr><td>G_Deep</td><td>
</td><td>
</td><td>
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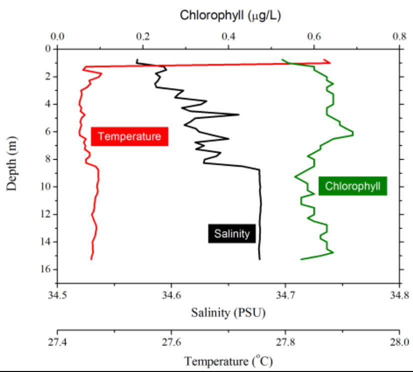
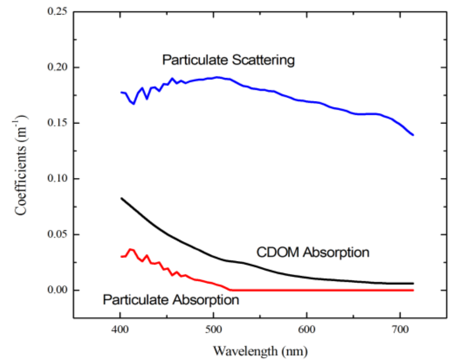
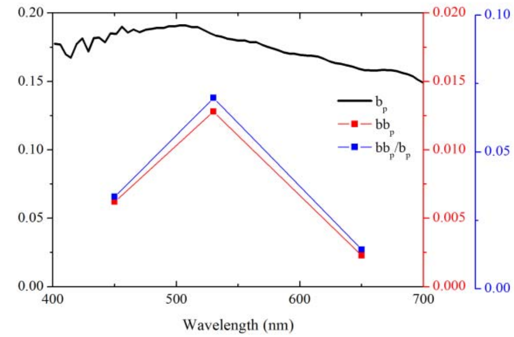
<tr><td>G_Sewage_Difuser</td><td>
</td><td>
</td><td>
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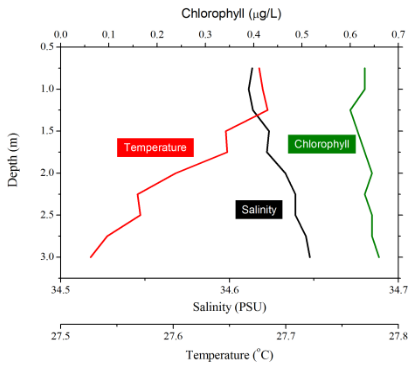
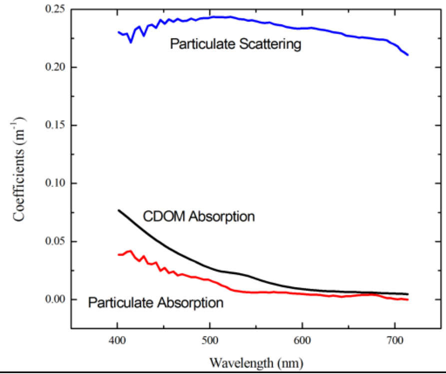
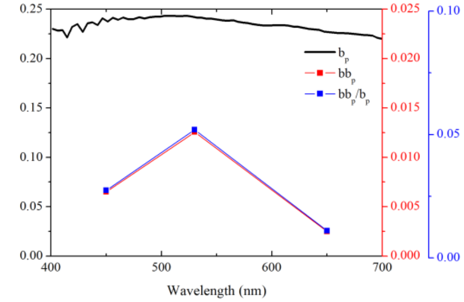
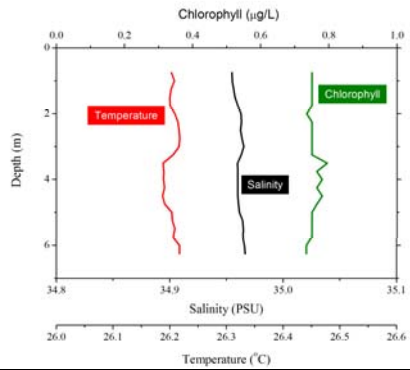
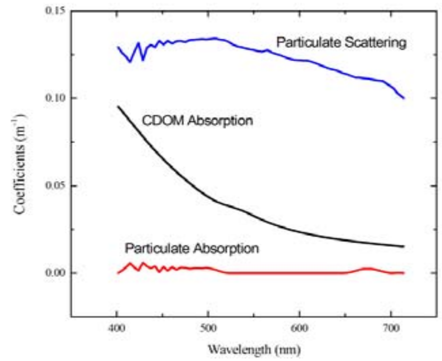
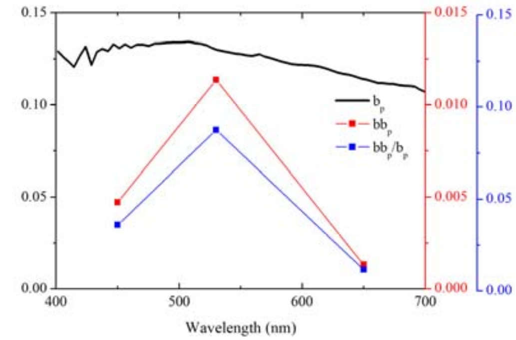
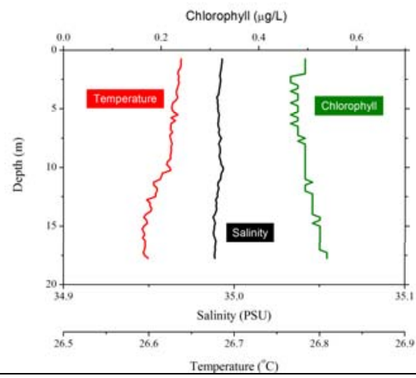
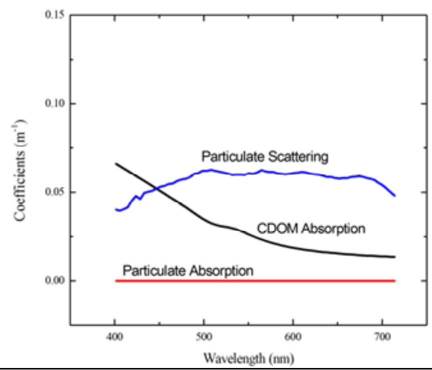
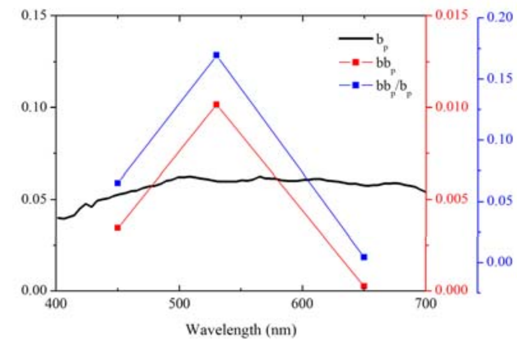
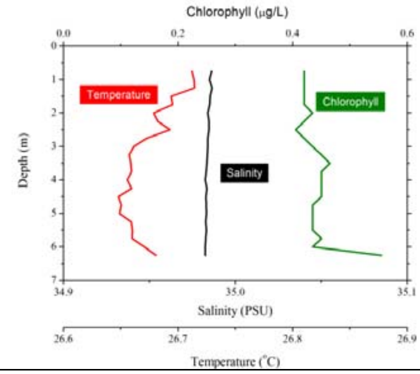
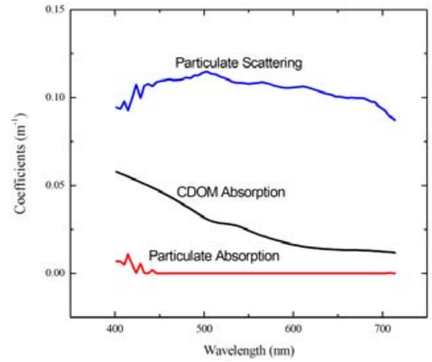
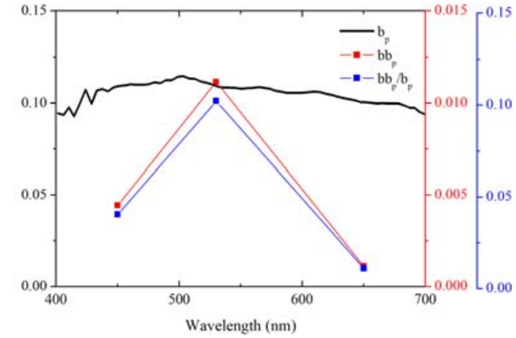
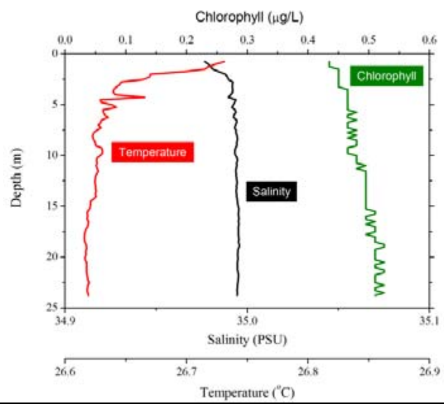
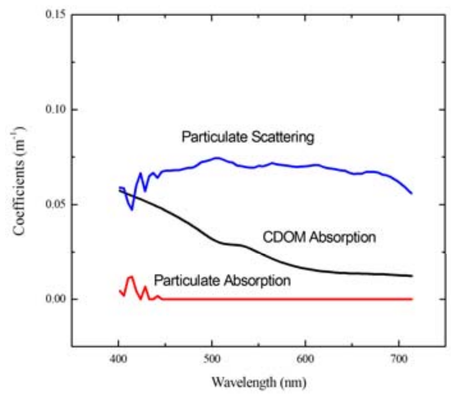
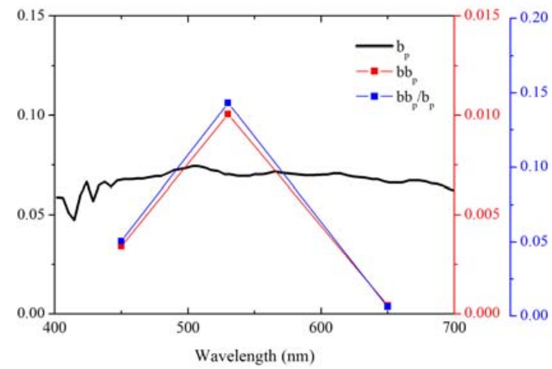
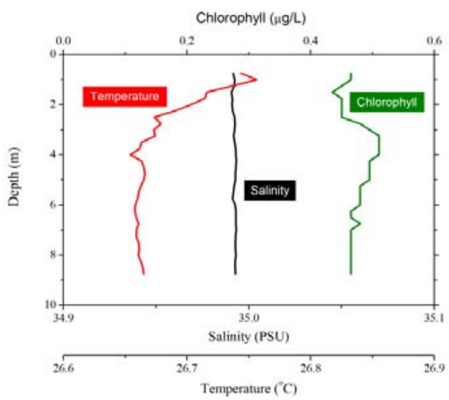
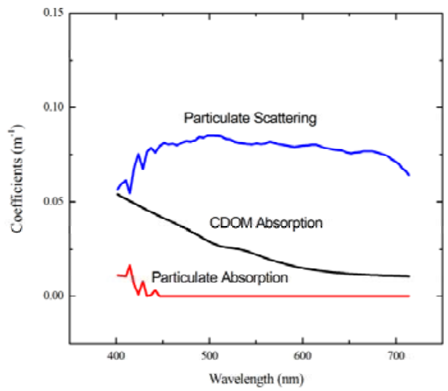
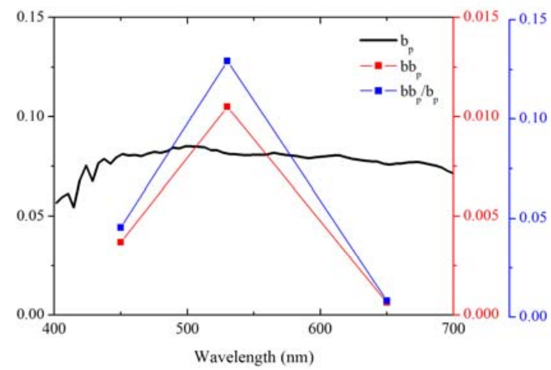
G_Tipalao			
Position	**Physical Properties**	**Optical Properties**	**Scattering**
P_IOP1			
P_IOP2			

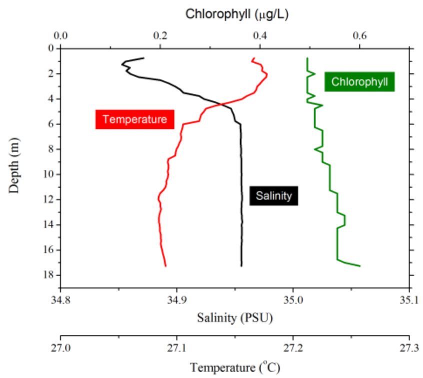
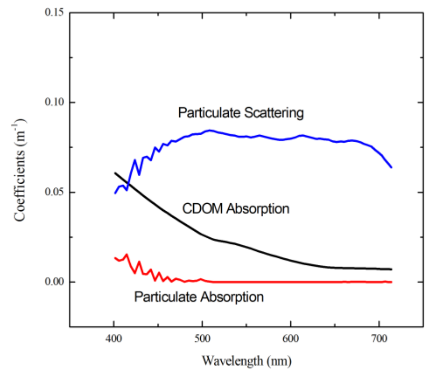
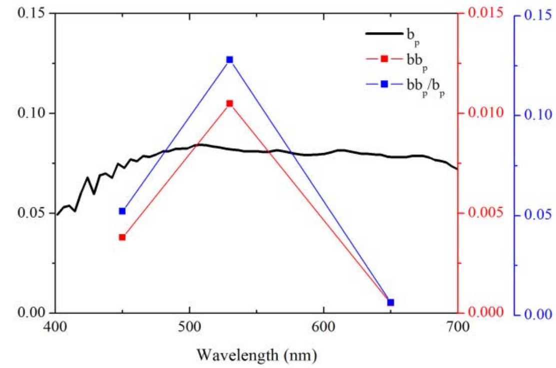
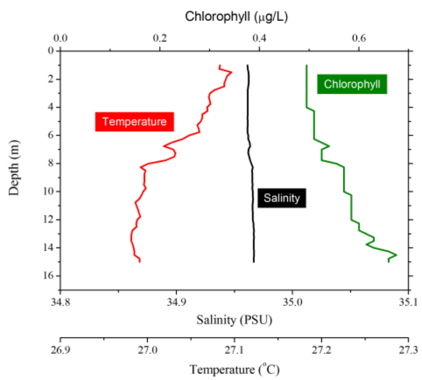
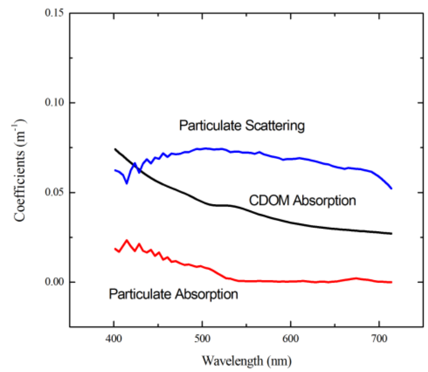
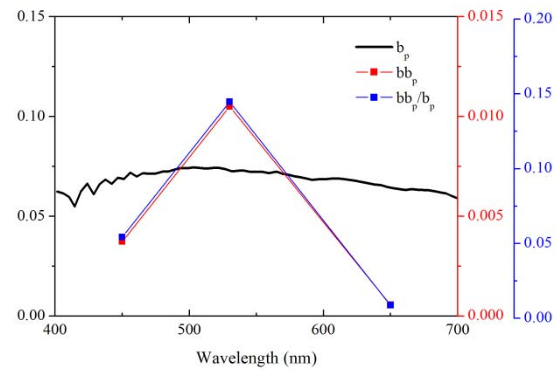
P_IOP3			

Chlorophyll (µg/L)
Temperature
Chlorophyll
Salinity
Depth (m)
Salinity (PSU)
Temperature (°C)

Particulate Scattering
CDOM Absorption
Particulate Absorption
Coefficients (m⁻¹)
Wavelength (nm)

b_p
bb_p
bb_p/b_p
Wavelength (nm)

Position	Physical Properties	Optical Properties	Scattering
P_IOP4			
P_IOP5			

Position	Physical Properties	Optical Properties	Scattering
T_IOP1			
T_Lamlam			

APPENDIX H

Dynamic Deflection Modulus

1 Introduction

A light weight deflectometer (LWD) is an instrument that includes components such as a weight-fix-and-release mechanism, guide rod, falling weight, steel spring, and a base plate with an embedded accelerometer. Once the weight drops, the spring provides the buffer system that transmits the load pulse to the plate resting on the material to be tested. The weight is raised to a fixed height that, when dropped, will impart the desired force pulse. After the weight has recoiled from the base plate, the resulting vertical surface deflection is measured.

The Zorn ZFG 2000 LWD, with a 10-Kg (22.05 lbs) weight and a 300 mm (11.8 in) diameter plate was used to conduct plate-bearing tests during MIRSC'10. The LWD was used to measure bearing capacity (dynamic deflection modulus), an important parameter to consider for soil under load. It is highly portable and was easily transported around the coastal zone. The Zorn ZFG 2000 provides a simple way to estimate bearing capacity and the recorder/printer device gives hard copy results in the field as well as recording data onto a chip card for uploading to a PC. The dynamic deflection modulus measurement (EVD [MN/m^2]) is the value used to estimate bearing capacity. Dynamic deflection modulus is calculated by the following equation;

Calculation of E_{vd} (Zorn, 2005):

The dynamic deflection modulus E_{vd} is calculated from the measured settlement s.

$$E_{vd} = \frac{22.5}{s} \quad \text{(300 mm plate and 10 kg load)}$$

$$E_{vd} = \frac{45}{s} \quad \text{(150 mm plate and 10 kg load)}$$

$$E_{vd} = \frac{33.75}{s} \quad \text{(300 mm plate and 15 kg load)}$$

Light weight deflectometer data are displayed below in tabular (Section 2) and graphical format (Section 3).

2 Light Weight Deflectometer Tabular Data

Data are presented below in alphabetical order by site name. Each site name contains descriptors which identifies the island, the locality and transect. For instance, the site name GUDT1-1 refers to a position on Guam (GU), on Dadi Beach (D), along transect 1 (T1) and at position 1 of that transect (-1). For sites on Pagan, the "PA" descriptor is designated, while sites on Tinian use the "TN" descriptor. For each site name, the table displays the island where the site is located, the local date, local time (ChST, UTC+10), single deflection values and the mean, dynamic deflection modulus (EVD [MN/m^2]), and trafficability condition. The trafficability condition is derived from a general binning scheme which rates the trafficability of the substrate. The binning scheme is as follows; values greater than 0 MN/m² but less than 8.2 MN/m² are determined as "bad" trafficability; values greater than or equal to 8.2 MN/m² but less than 14.9 MN/m² are determined as "poor" trafficability; values greater than or equal to 14.9 MN/m² but less than 21.6 MN/m² are determined as "fair" trafficability; values greater than or equal to 21.6 MN/m² but less than 28.3 MN/m² are determined as "good" trafficability; and values greater than 28.3 MN/m² are considered "excellent" trafficability areas.

Site Name	Island	Local Date	Local Time	Deflection [mm]				Evd [MN/m²]	Trafficability Condition
				single values			mean		
				s1	s2	s3	s		
GUDT1-1	Guam	10-Mar-10	10:17	1.725	0.879	0.810	1.138	19.8	Fair
GUDT1-2	Guam	10-Mar-10	10:30	5.558	3.317	1.985	3.620	6.2	Bad
GUDT1-3	Guam	10-Mar-10	10:39	0.210	19.069	2.129	7.136	3.2	Bad
GUDT1-4	Guam	10-Mar-10	10:58	1.855	0.968	0.868	1.230	18.3	Fair
GUDT1-5	Guam	10-Mar-10	11:35	6.985	2.326	0.948	3.420	6.6	Bad
GUDT1-6	Guam	10-Mar-10	13:51	6.280	1.702	3.331	3.771	6.0	Bad
GUDT1-7	Guam	10-Mar-10	13:59	1.769	1.711	1.483	1.654	13.6	Poor
GUDT1-8	Guam	10-Mar-10	14:11	11.734	2.729	2.172	5.545	4.1	Bad
GUDT1-9	Guam	10-Mar-10	14:22	5.256	2.965	2.496	3.572	6.3	Bad
GUDT1-10	Guam	10-Mar-10	14:33	4.610	2.463	1.725	2.933	7.7	Bad
GUDT1-11	Guam	10-Mar-10	14:49	6.867	2.017	1.710	3.531	6.4	Bad
GUTT1-1	Guam	10-Mar-10	16:08	0.203	0.180	0.188	0.190	118.4	Excellent
GUTT1-2	Guam	10-Mar-10	16:10	0.010	0.279	0.051	0.113	199.1	Excellent
GUTT1-3	Guam	10-Mar-10	16:18	0.213	0.150	0.142	0.168	133.9	Excellent
GUTT1-4	Guam	10-Mar-10	16:21	0.184	0.104	0.102	0.130	173.1	Excellent
GUTT1-5	Guam	10-Mar-10	16:30	2.015	1.022	0.879	1.305	17.2	Fair
GUTT1-6	Guam	10-Mar-10	16:47	3.273	1.785	1.185	2.081	10.8	Poor
GUTT1-7	Guam	10-Mar-10	16:57	1.369	0.604	0.484	0.819	27.5	Good

Site Name	Island	Local Date	Local Time	Deflection [mm]				Evd [MN/m²]	Trafficability Condition
				single values			mean		
				s1	s2	s3	s		
PAB1T1-1	Pagan	2-Mar-10	09:57	3.942	3.776	3.342	3.687	6.1	Bad
PAB1T1-2	Pagan	2-Mar-10	10:06	3.011	2.661	2.359	2.677	8.4	Poor
PAB1T1-3	Pagan	2-Mar-10	10:15	7.079	4.006	3.584	4.890	4.6	Bad
PAB1T1-4	Pagan	2-Mar-10	10:24	5.439	3.423	3.077	3.980	5.7	Bad
PAB1T1-5	Pagan	2-Mar-10	10:44	6.207	2.616	2.830	3.884	5.8	Bad
PAB1T1-6	Pagan	2-Mar-10	10:49	6.718	3.704	3.589	4.670	4.8	Bad
PAB1T1-7	Pagan	2-Mar-10	11:00	4.947	3.404	3.163	3.838	5.9	Bad
PAB1T2-1	Pagan	2-Mar-10	11:34	4.101	3.441	2.759	3.434	6.6	Bad
PAB1T2-2	Pagan	2-Mar-10	11:51	5.773	3.283	3.330	4.129	5.4	Bad
PAB1T2-3	Pagan	2-Mar-10	11:59	5.402	4.502	4.546	4.817	4.7	Bad
PAB1T2-4	Pagan	2-Mar-10	12:05	5.070	3.872	3.446	4.129	5.4	Bad
PAB1T2-5	Pagan	2-Mar-10	12:09	6.187	3.648	3.270	4.368	5.2	Bad
PAB1T2-6	Pagan	2-Mar-10	12:13	7.518	3.559	3.499	4.859	4.6	Bad
PAB2T1-1	Pagan	28-Feb-10	12:12	7.336	4.856	4.517	5.570	4.0	Bad
PAB2T1-2	Pagan	28-Feb-10	12:14	6.048	4.477	4.031	4.852	4.6	Bad
PAB2T1-3	Pagan	28-Feb-10	12:16	5.735	4.097	3.871	4.568	4.9	Bad
PAB2T1-4	Pagan	28-Feb-10	12:18	8.590	4.149	3.766	5.502	4.1	Bad
PAB2T1-5	Pagan	28-Feb-10	12:20	8.332	4.225	3.628	5.395	4.2	Bad
PAB2T1-6	Pagan	1-Mar-10	14:34	5.585	4.190	3.733	4.503	5.0	Bad
PAB2T1-7	Pagan	1-Mar-10	14:42	10.419	3.760	3.485	5.888	3.8	Bad
PAB2T1-8	Pagan	1-Mar-10	14:46	10.146	5.209	3.887	6.414	3.5	Bad
PAB2T1-9	Pagan	1-Mar-10	14:50	11.706	8.111	5.792	8.536	2.6	Bad
PAB2T2-0	Pagan	28-Feb-10	12:08	4.107	2.287	1.887	2.760	8.2	Poor
PAB2T2-1	Pagan	28-Feb-10	12:06	3.725	3.518	3.122	3.455	6.5	Bad
PAB2T2-2	Pagan	28-Feb-10	12:02	4.859	3.845	3.765	4.156	5.4	Bad
PAB2T2-3	Pagan	28-Feb-10	11:58	10.095	5.337	4.530	6.654	3.4	Bad
PAB2T2-4	Pagan	28-Feb-10	11:48	10.828	4.023	3.713	6.188	3.6	Bad
PAB2T2-5	Pagan	1-Mar-10	14:29	7.261	3.981	3.560	4.934	4.6	Bad
PAB2T2-6	Pagan	1-Mar-10	14:55	8.700	4.383	3.745	5.609	4.0	Bad
PAB2T2-7	Pagan	1-Mar-10	14:59	11.615	4.321	3.250	6.395	3.5	Bad
PAB2T2-8	Pagan	1-Mar-10	15:08	11.640	4.640	3.385	6.555	3.4	Bad
PAB2T2-9	Pagan	1-Mar-10	15:04	5.114	3.951	3.684	4.250	5.3	Bad

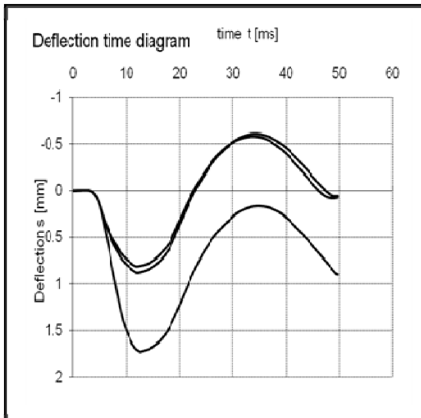
Site Name	Island	Local Date	Local Time	Deflection [mm]				Evd [MN/m²]	Trafficability Condition
				single values			mean		
				s1	s2	s3	s		
PAB2T3-1	Pagan	28-Feb-10	14:37	1.671	1.236	1.099	1.335	16.9	Fair
PAB2T3-2	Pagan	28-Feb-10	14:52	9.409	4.158	4.135	5.901	3.8	Bad
PAB2T3-3	Pagan	28-Feb-10	15:23	2.848	2.617	2.393	2.619	8.6	Poor
PAB2T3-4	Pagan	28-Feb-10	15:31	11.997	4.678	4.249	6.975	3.2	Bad
PAB2T3-5	Pagan	28-Feb-10	15:41	3.896	2.122	1.640	2.553	8.8	Poor
PAB2T3-6	Pagan	28-Feb-10	15:48	8.804	4.294	4.004	5.701	3.9	Bad
PAB2T3-7	Pagan	28-Feb-10	15:59	8.207	3.739	3.549	5.165	4.4	Bad
PAB2T3-8	Pagan	28-Feb-10	16:07	7.175	3.730	2.952	4.619	4.9	Bad
PAB2T3-9	Pagan	28-Feb-10	16:17	5.900	4.120	3.556	4.525	5.0	Bad
PAB2T4-1	Pagan	28-Feb-10	16:28	5.556	1.751	1.242	2.850	7.9	Bad
PAB2T4-2	Pagan	28-Feb-10	16:35	9.003	4.682	4.213	5.966	3.8	Bad
PAB2T4-3	Pagan	28-Feb-10	16:41	9.511	4.791	4.443	6.248	3.6	Bad
PAB2T4-4	Pagan	28-Feb-10	16:47	10.958	4.679	3.657	6.431	3.5	Bad
PAB2T4-5	Pagan	28-Feb-10	16:53	6.723	3.105	2.000	3.943	5.7	Bad
PAB2T4-6	Pagan	28-Feb-10	17:00	5.227	2.566	1.633	3.142	7.2	Bad
PAB2T5-1	Pagan	1-Mar-10	10:12	2.936	2.794	2.361	2.697	8.3	Poor
PAB2T5-2	Pagan	1-Mar-10	10:32	8.676	4.952	4.188	5.939	3.8	Bad
PAB2T5-3	Pagan	1-Mar-10	10:37	5.358	4.142	3.914	4.471	5.0	Bad
PAB2T5-4	Pagan	1-Mar-10	11:00	11.601	5.052	4.366	7.006	3.2	Bad
PAB2T5-5 # 1	Pagan	1-Mar-10	11:06	10.764	3.630	3.493	5.962	3.8	Bad
PAB2T5-5 # 2	Pagan	1-Mar-10	11:10	12.138	4.585	4.730	7.151	3.1	Bad
PAB2T5-6	Pagan	1-Mar-10	11:28	13.399	5.943	3.855	7.732	2.9	Bad
PAB2T5-7	Pagan	1-Mar-10	11:33	8.927	3.984	3.684	5.532	4.1	Bad
PAB2T5-8	Pagan	1-Mar-10	11:40	10.799	3.923	2.878	5.867	3.8	Bad
PAB2T5-9	Pagan	1-Mar-10	11:45	13.913	6.341	4.311	8.188	2.7	Bad
PAB2T6-1	Pagan	1-Mar-10	10:17	5.841	2.793	2.427	3.687	6.1	Bad
PAB2T6-2	Pagan	1-Mar-10	10:25	5.449	4.489	4.080	4.673	4.8	Bad
PAB2T6-3	Pagan	1-Mar-10	10:45	12.249	5.146	4.049	7.148	3.1	Bad
PAB2T6-4	Pagan	1-Mar-10	10:51	6.254	4.767	5.771	5.597	4.0	Bad
PAB2T6-5	Pagan	1-Mar-10	11:15	10.361	4.634	3.892	6.296	3.6	Bad
PAB2T6-6	Pagan	1-Mar-10	11:21	11.135	4.947	4.021	6.701	3.4	Bad
PAB2T6-7	Pagan	1-Mar-10	11:50	3.440	2.499	2.064	2.668	8.4	Poor
PAB2T6-8	Pagan	1-Mar-10	11:55	10.012	3.651	2.629	5.431	4.1	Bad
PAB2T6-9	Pagan	1-Mar-10	11:59	12.426	5.121	3.971	7.173	3.1	Bad

Site Name	Island	Local Date	Local Time	Deflection [mm]				Evd [MN/m²]	Trafficability Condition
				single values			mean		
				s1	s2	s1	s2		
PAB4T1-1	Pagan	27-Feb-10	15:42	2.549	2.735	2.301	2.528	8.9	Poor
PAB4T1-2	Pagan	27-Feb-10	16:00	3.303	2.450	2.105	2.619	8.6	Poor
PAB4T1-3	Pagan	27-Feb-10	16:17	4.396	3.873	3.879	4.049	5.6	Bad
PAB4T2-2	Pagan	27-Feb-10	16:45	1.159	0.893	0.587	0.880	25.6	Good
PAB4T2-3	Pagan	27-Feb-10	16:59	3.526	2.739	2.654	2.973	7.6	Bad
PAB4T3-1	Pagan	1-Mar-10	16:13	2.523	1.619	1.297	1.813	12.4	Poor
PAB4T3-2	Pagan	1-Mar-10	16:20	6.206	4.999	4.772	5.326	4.2	Bad
PAB4T3-3	Pagan	1-Mar-10	16:28	5.149	4.303	3.955	4.469	5.0	Bad
PAB4T3-4	Pagan	1-Mar-10	16:41	6.113	3.544	2.863	4.173	5.4	Bad
PAB4T4-1	Pagan	1-Mar-10	16:49	2.623	1.871	1.504	1.999	11.3	Poor
PAB4T4-2	Pagan	1-Mar-10	17:00	5.358	3.950	3.671	4.326	5.2	Bad
PAB4T4-3	Pagan	1-Mar-10	17:05	3.371	2.442	2.283	2.699	8.3	Poor

Site Name	Island	Local Date	Local Time	Deflection [mm]				Evd [MN/m²]	Trafficability Condition
				single values			mean		
				s1	s2	s1	s2		
TNUBT1-1, # 1	Tinian	5-Mar-10	11:18	6.320	2.805	1.674	3.600	6.3	Bad
TNUBT1-1, # 2	Tinian	5-Mar-10	11:20	8.243	3.251	2.465	4.653	4.8	Bad
TNUBT1-2, # 1	Tinian	5-Mar-10	11:26	0.648	2.086	1.288	1.341	16.8	Fair
TNUBT1-2, # 2	Tinian	5-Mar-10	11:28	7.830	2.942	1.732	4.168	5.4	Bad
TNUBT1-3	Tinian	5-Mar-10	11:31	7.847	4.270	3.803	5.307	4.2	Bad
TNUBT1-4	Tinian	5-Mar-10	11:48	1.703	1.286	1.051	1.347	16.7	Fair
TNUBT1-5	Tinian	5-Mar-10	12:00	5.163	2.252	1.606	3.007	7.5	Bad
TNUBT1-6	Tinian	5-Mar-10	13:58	0.605	0.217	0.338	0.387	58.1	Excellent
TNUBT1-7	Tinian	5-Mar-10	14:13	5.983	2.031	1.338	3.117	7.2	Bad
TNUBT1-8	Tinian	5-Mar-10	14:20	4.573	3.441	3.171	3.728	6.0	Bad
TNUBT1-9	Tinian	5-Mar-10	14:29	4.892	1.406	0.733	2.344	9.6	Poor
TNUBT1-10	Tinian	5-Mar-10	14:39	3.166	1.505	1.085	1.919	11.7	Poor
TNUBT1-11	Tinian	5-Mar-10	14:48	3.040	0.831	0.636	1.502	15.0	Fair
TNUBT1-12	Tinian	5-Mar-10	14:59	6.389	1.928	1.161	3.159	7.1	Bad
TNUBT1-13	Tinian	5-Mar-10	15:06	5.024	2.878	2.200	3.367	6.7	Bad
TNUBT1-14	Tinian	5-Mar-10	15:31	0.893	0.358	0.303	0.518	43.4	Excellent
TNUBT1-15	Tinian	5-Mar-10	15:39	0.415	0.303	0.264	0.327	68.8	Excellent
TNUDT1-1	Tinian	6-Mar-10	13:49	0.826	0.537	0.397	0.587	38.3	Excellent
TNUDT1-2	Tinian	6-Mar-10	14:07	6.129	2.803	1.994	3.642	6.2	Bad
TNUDT1-3	Tinian	6-Mar-10	15:25	6.246	2.173	8.051	5.490	4.1	Bad
TNUDT1-4	Tinian	6-Mar-10	14:52	5.244	3.927	2.043	3.738	6.0	Bad
TNUDT1-5	Tinian	6-Mar-10	15:13	6.120	2.505	3.534	4.053	5.6	Bad
TNUDT1-6	Tinian	6-Mar-10	15:43	3.703	1.208	1.039	1.983	11.3	Poor
TNUDT2-1	Tinian	6-Mar-10	16:14	1.675	0.683	0.558	0.972	23.1	Good
TNUDT2-2, #1	Tinian	6-Mar-10	16:21	10.069	41.88	2.639	18.19	1.2	Bad
TNUDT2-2, #2	Tinian	6-Mar-10	16:23	8.483	3.195	2.118	4.599	4.9	Bad
TNUDT2-3	Tinian	6-Mar-10	16:34	6.322	2.890	2.307	3.840	5.9	Bad
TNUDT2-4	Tinian	6-Mar-10	16:44	6.912	2.563	2.184	3.886	5.8	Bad
TNUDT2-5	Tinian	6-Mar-10	16:54	5.845	2.773	2.052	3.557	6.3	Bad
TNUDT3-1	Tinian	7-Mar-10	09:41	3.338	3.228	2.751	3.106	7.2	Bad
TNUDT3-2	Tinian	7-Mar-10	09:45	5.283	3.569	2.896	3.916	5.7	Bad
TNUDT3-3	Tinian	7-Mar-10	09:52	6.432	3.294	1.760	3.829	5.9	Bad
TNUDT3-4	Tinian	7-Mar-10	10:04	4.295	2.404	1.678	2.792	8.1	Bad
TNUDT3-5	Tinian	7-Mar-10	10:15	9.465	1.615	1.875	4.318	5.2	Bad
TNUDT3-6	Tinian	7-Mar-10	10:22	4.577	3.077	2.441	3.365	6.7	Bad

Site Name	Island	Local Date	Local Time	Deflection [mm]				Evd [MN/m²]	Trafficability Condition
				single values			mean		
				s1	s2	s1	s2		
TNULT1-1	Tinian	7-Mar-10	14:41	3.475	8.322	1.097	4.298	5.2	Bad
TNULT1-2	Tinian	7-Mar-10	14:48	12.332	2.634	2.348	5.771	3.9	Bad
TNULT1-3	Tinian	7-Mar-10	15:03	6.493	2.827	1.768	3.696	6.1	Bad
TNULT1-4	Tinian	7-Mar-10	14:58	1.625	0.887	0.649	1.054	21.3	Fair
TNULT1-5	Tinian	7-Mar-10	15:21	7.367	3.247	2.599	4.404	5.1	Bad
TNULT1-6	Tinian	7-Mar-10	15:11	8.158	4.328	2.618	5.035	4.5	Bad

3 Light Weight Deflectometer Graph Data



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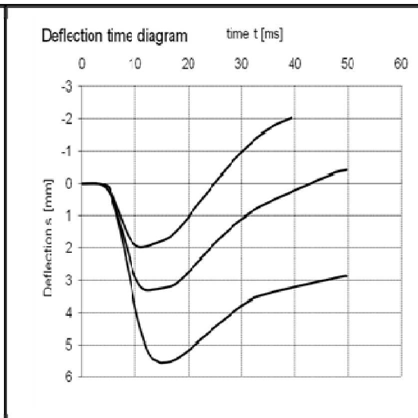

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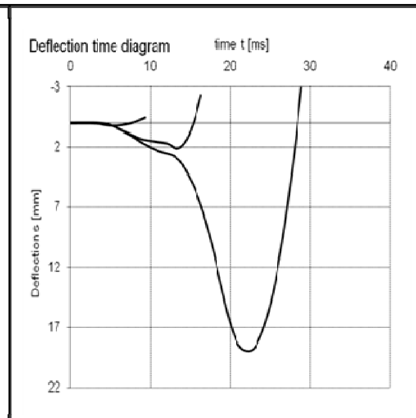

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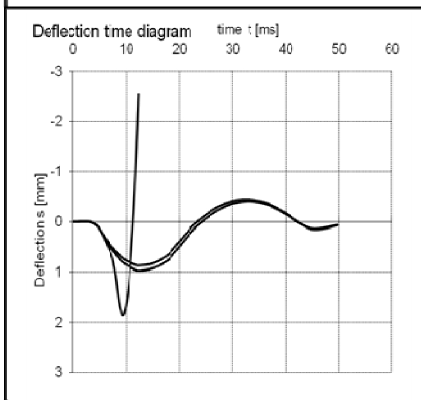

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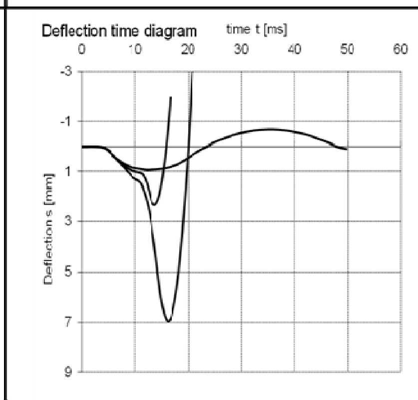

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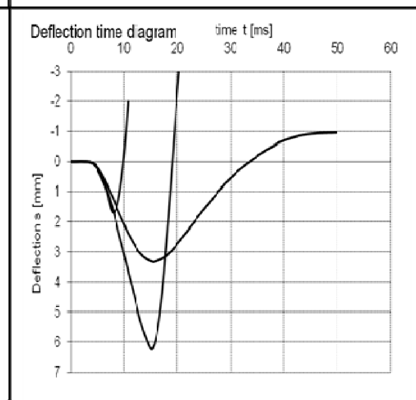
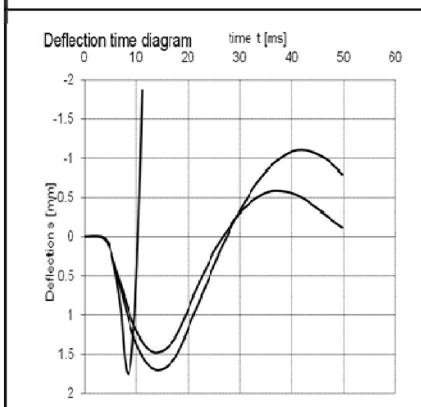


GUDT1-6



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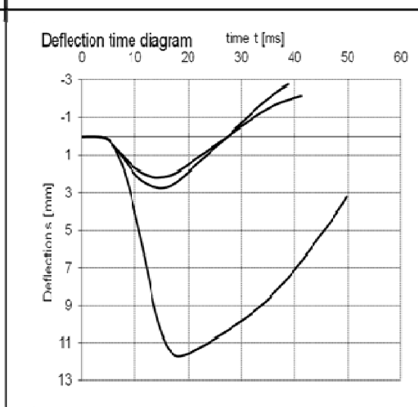

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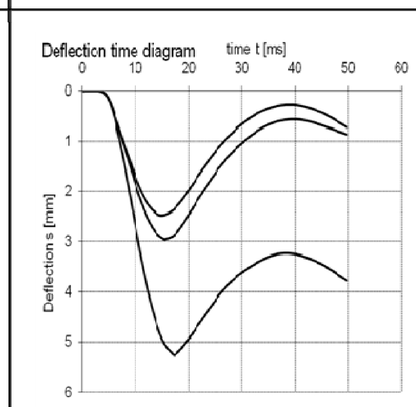

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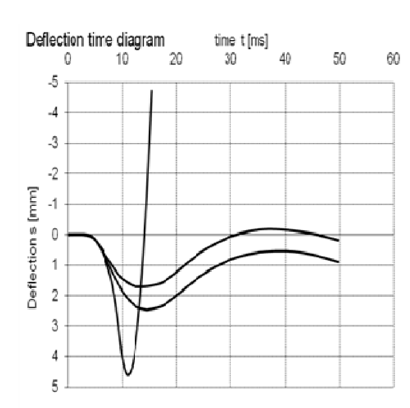

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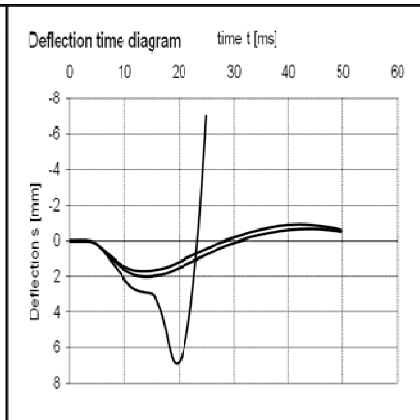

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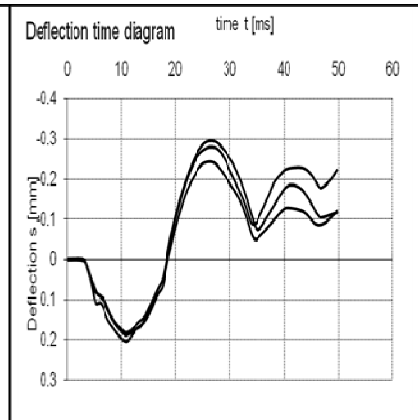
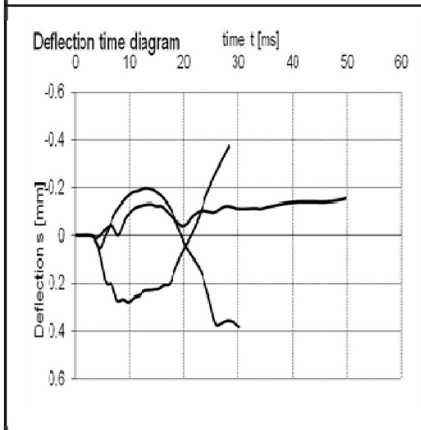


GUTT1-1



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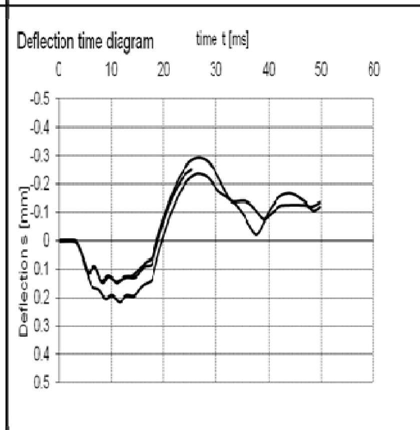

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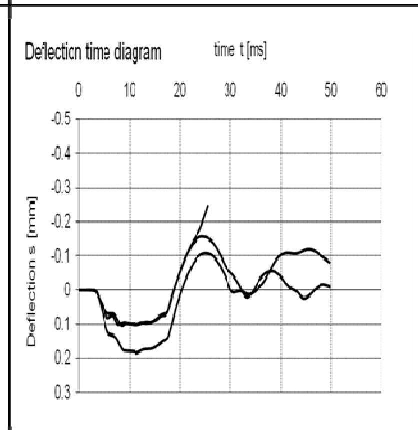

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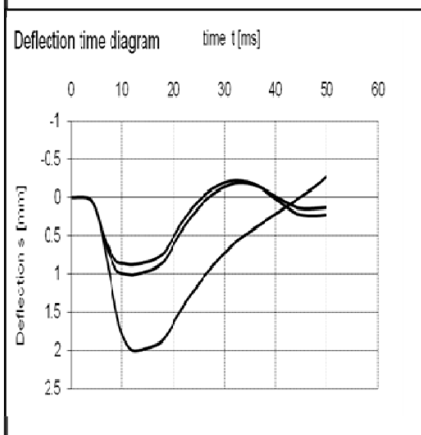

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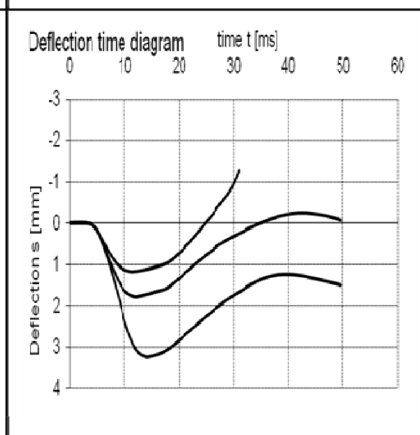

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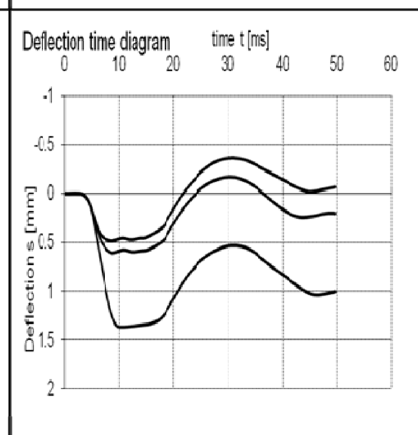

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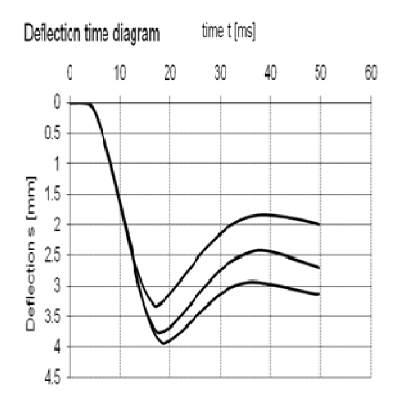

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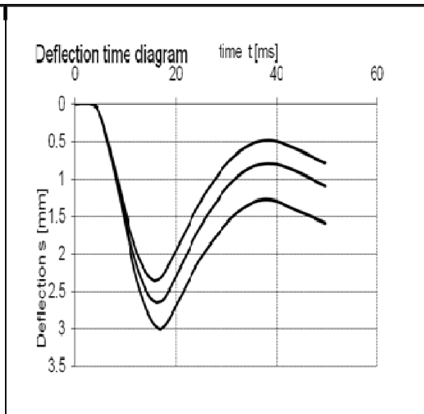

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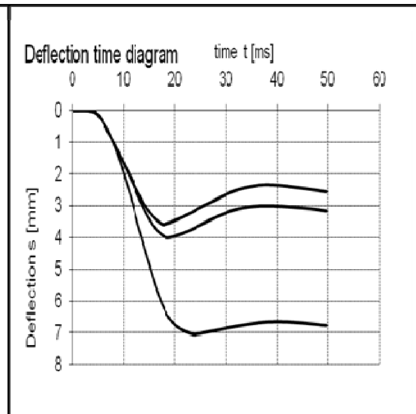

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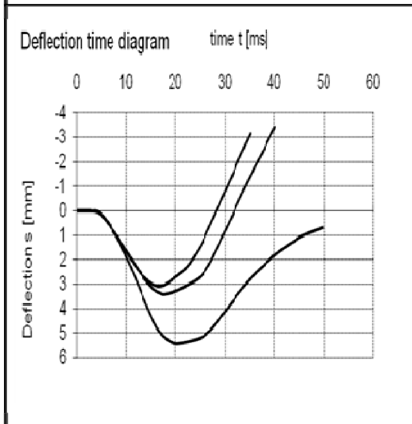

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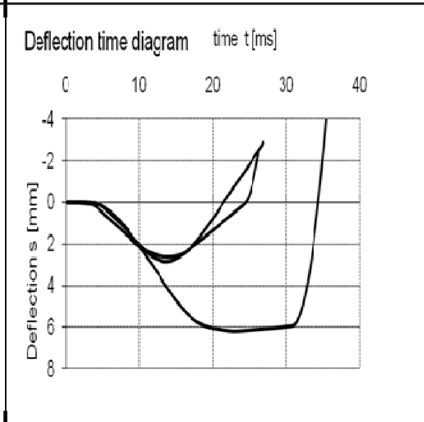

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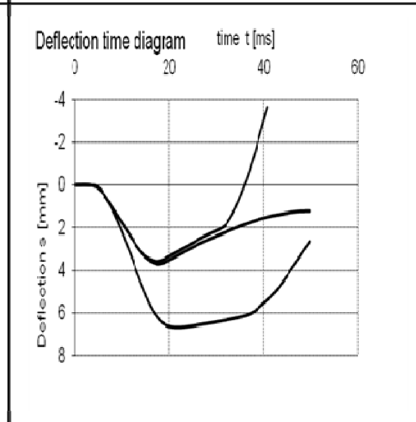

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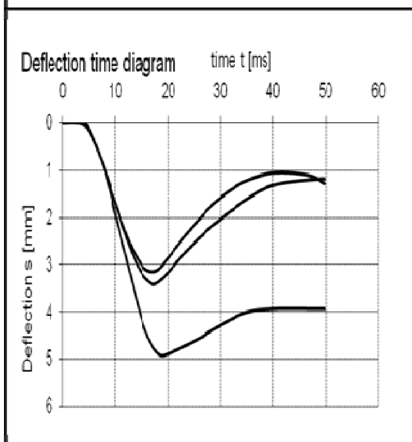

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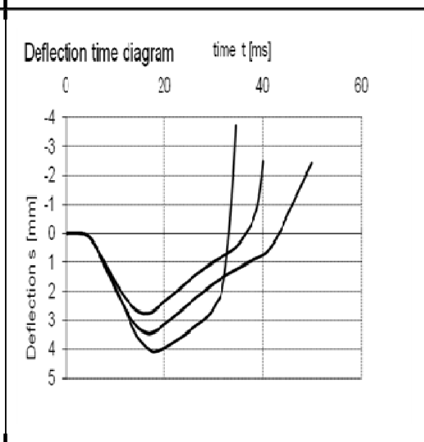

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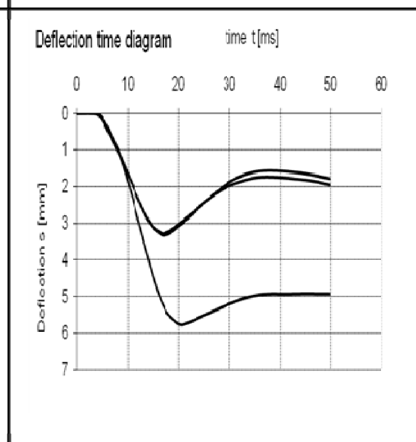
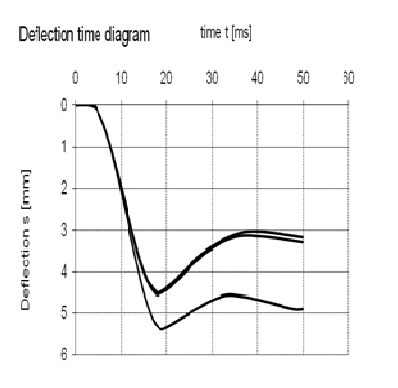
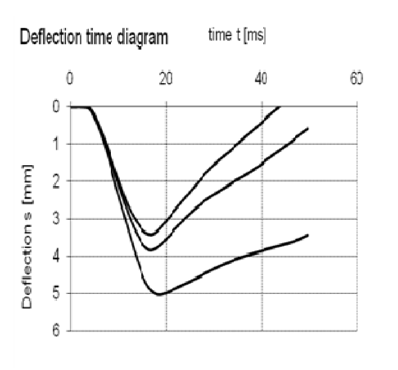


PAB1T2-2



PAB1T2-3



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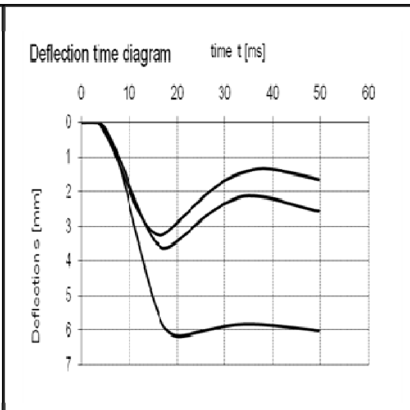

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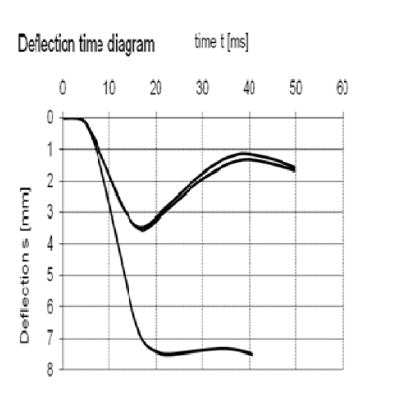
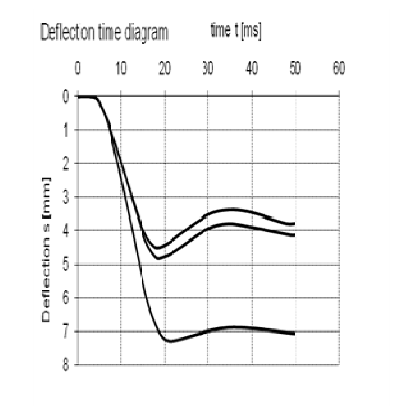


PAB1T2-6



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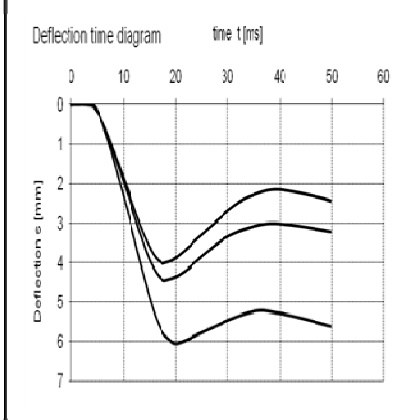

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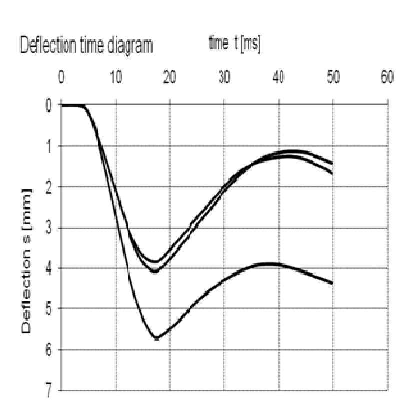

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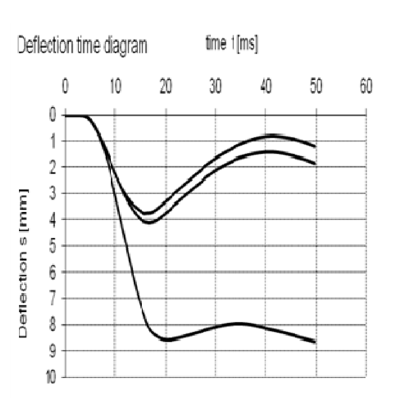

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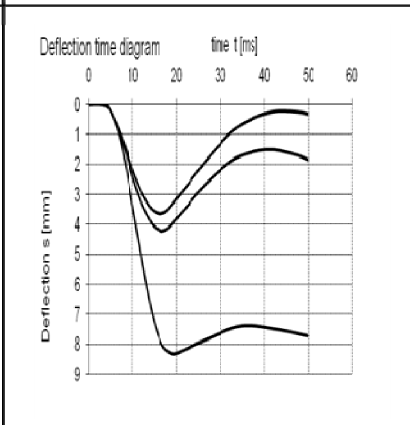

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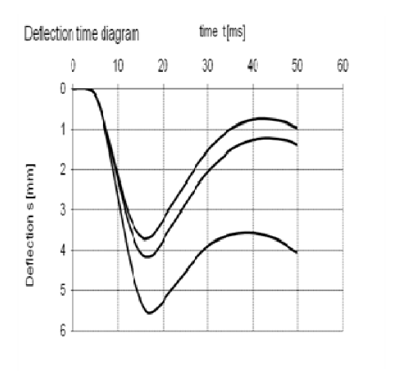

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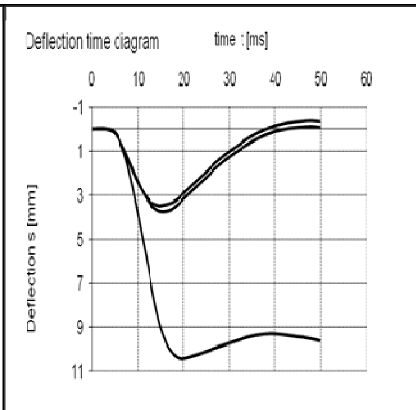

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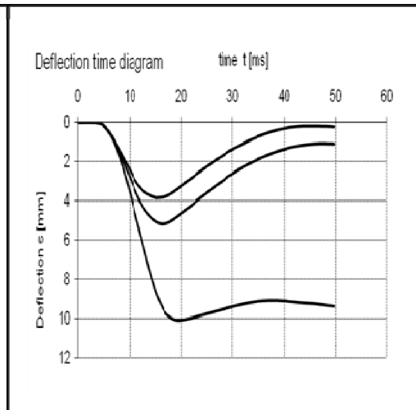

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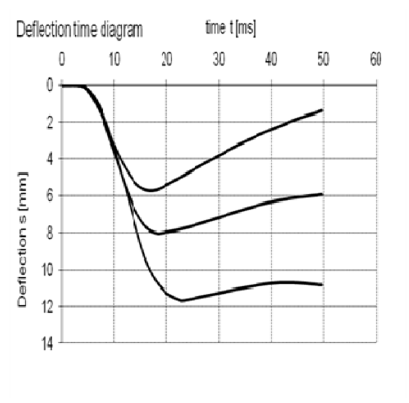

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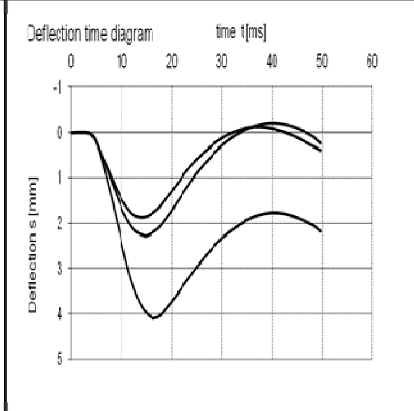

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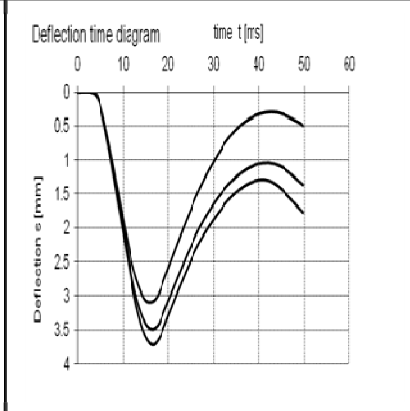

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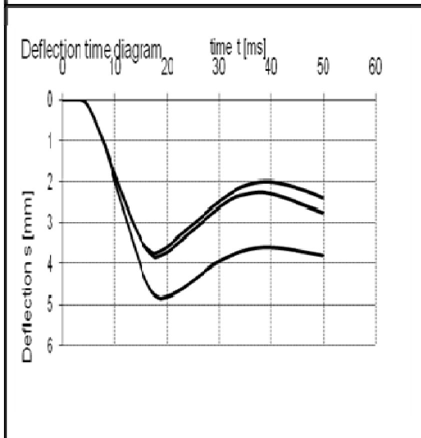

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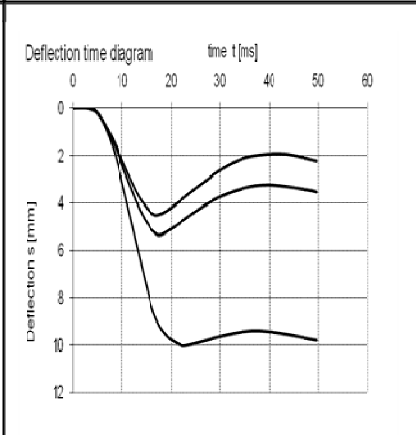

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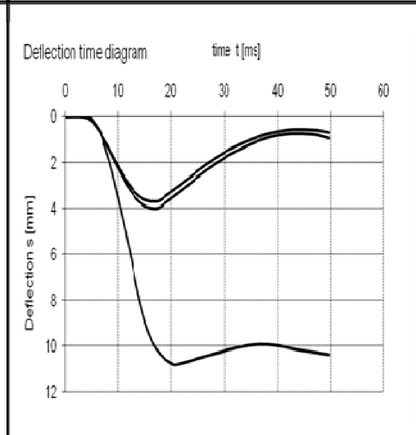

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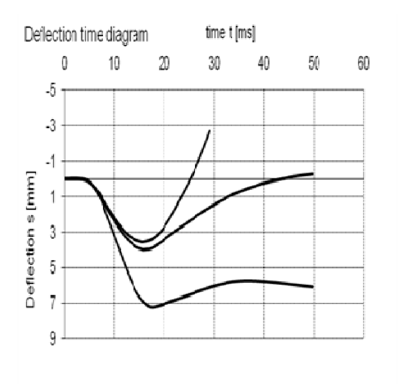

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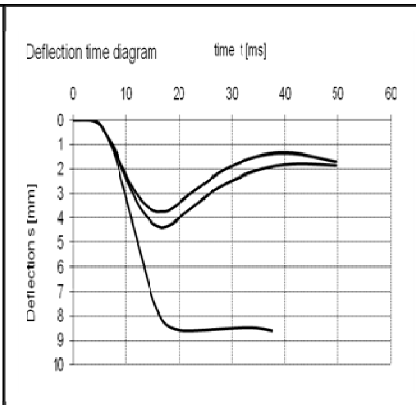

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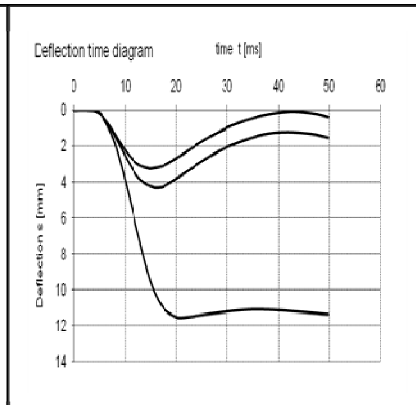

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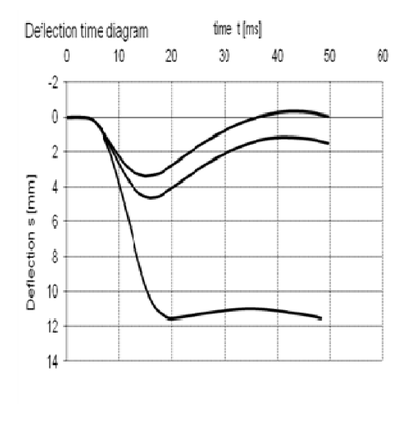

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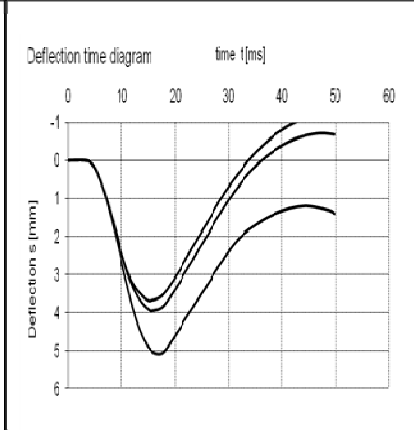

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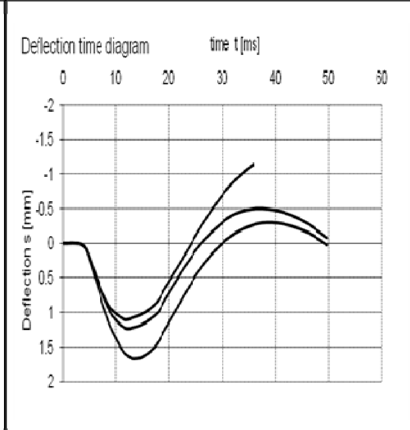

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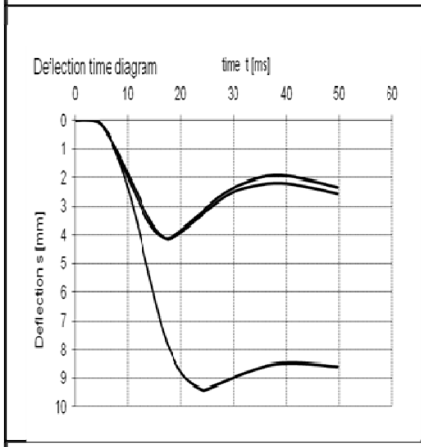

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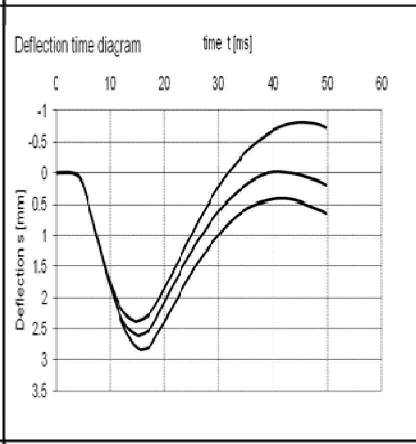

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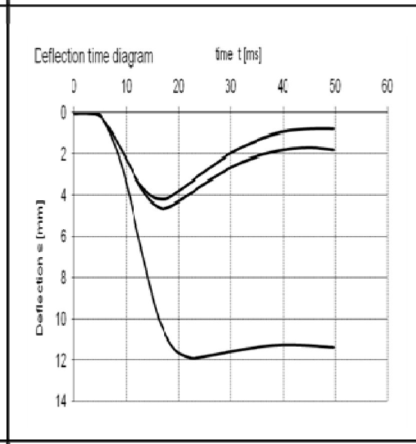

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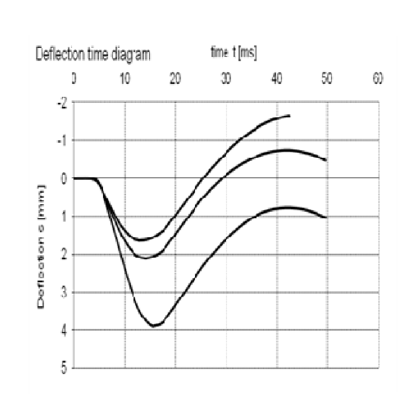

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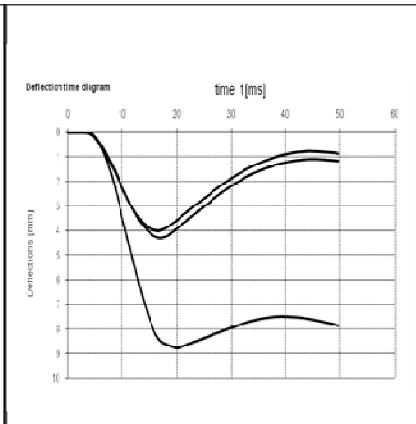

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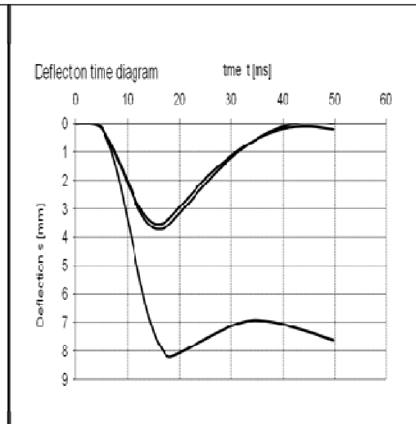

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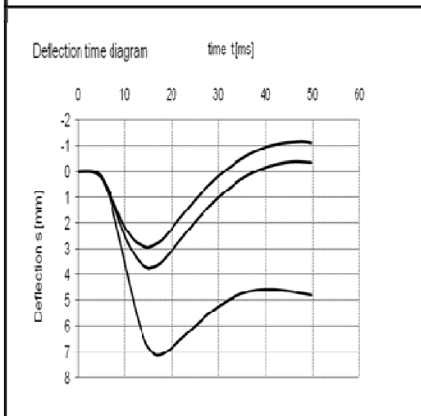

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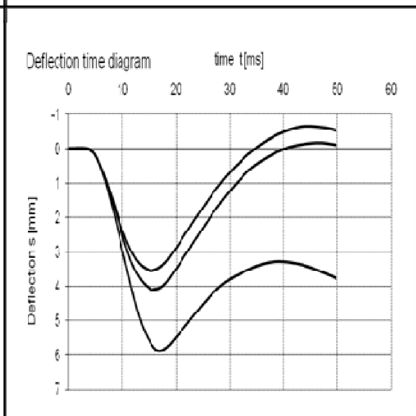

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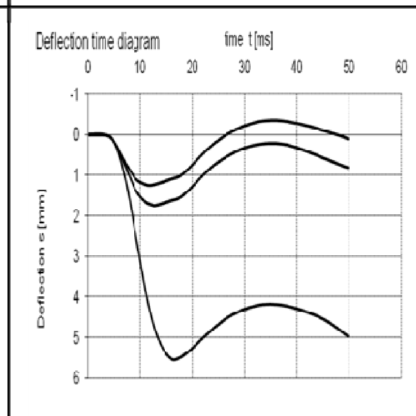

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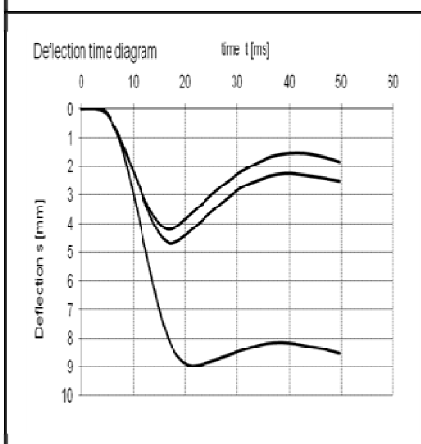

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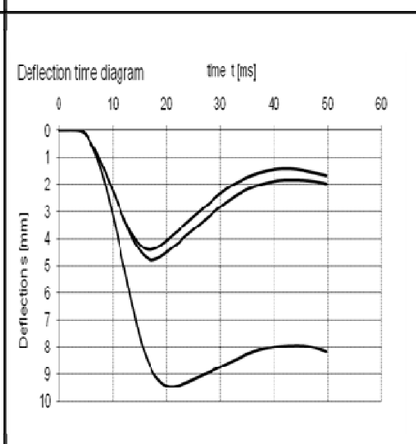

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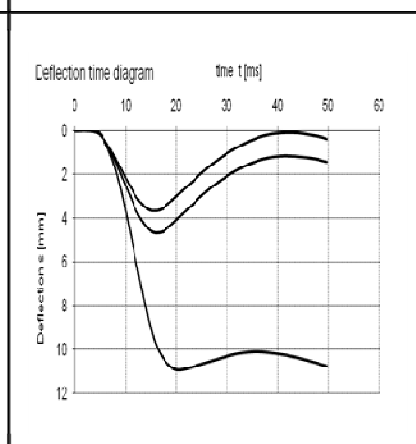

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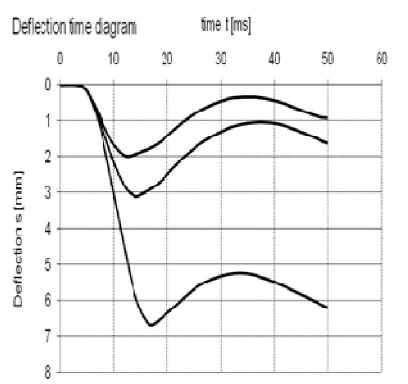

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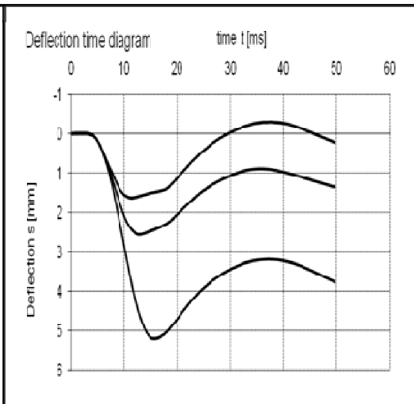

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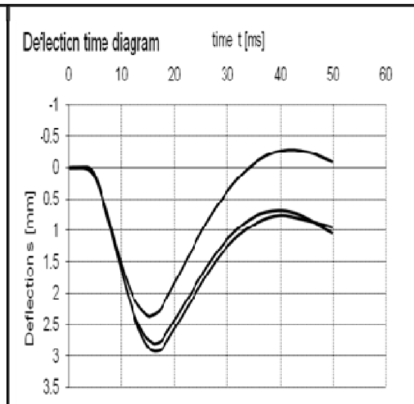

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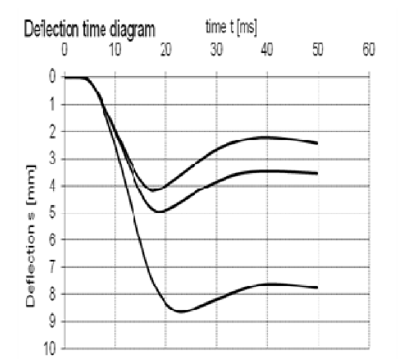

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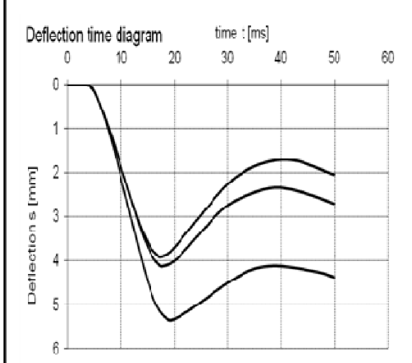

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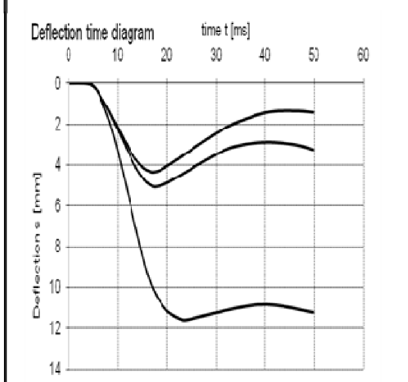

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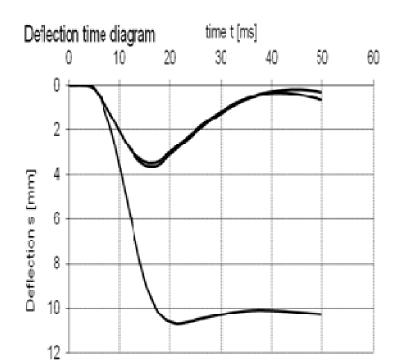

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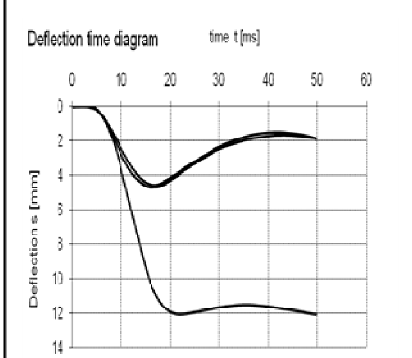

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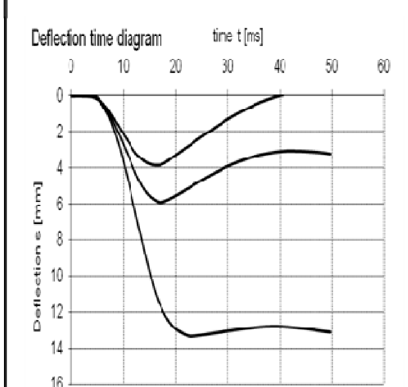

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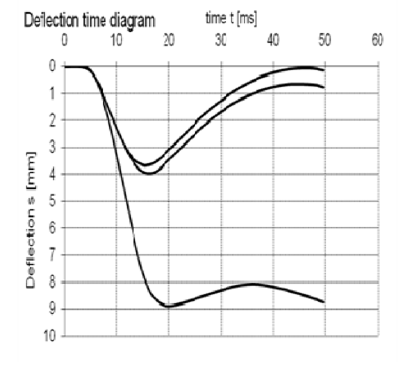

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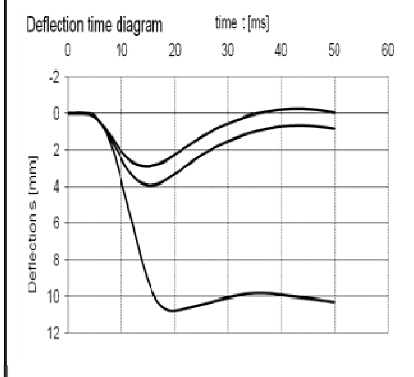

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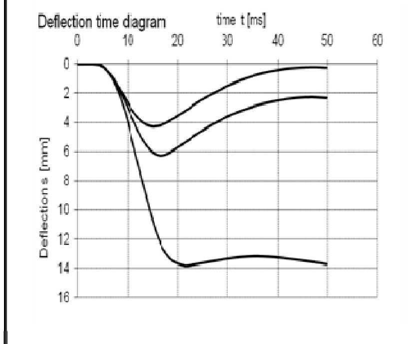

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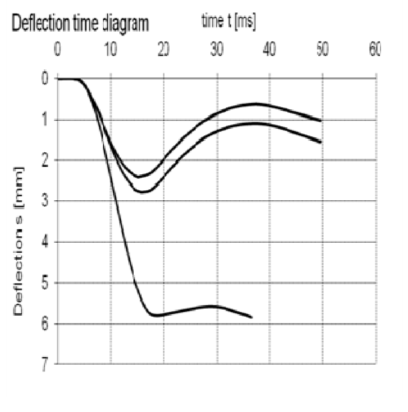

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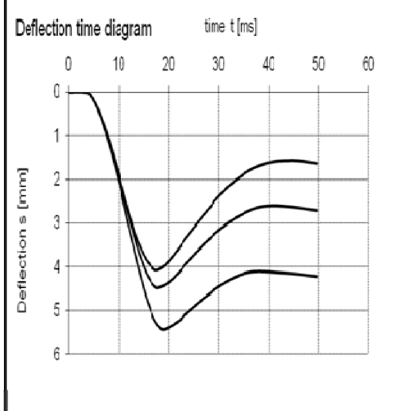

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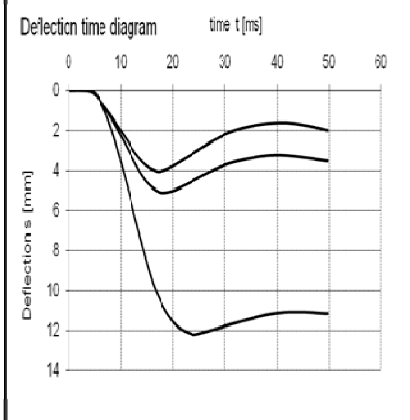

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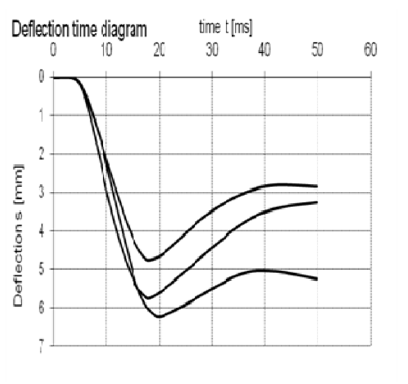

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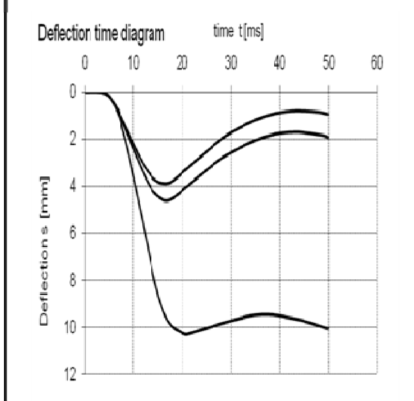

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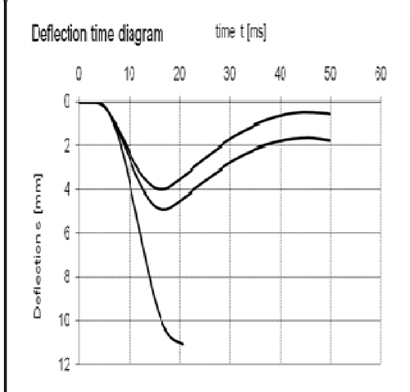

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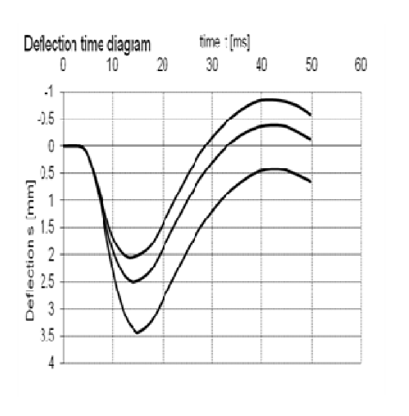

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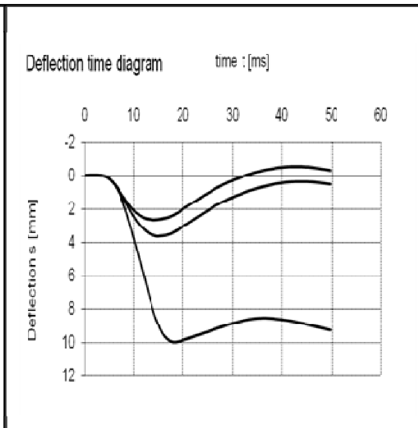

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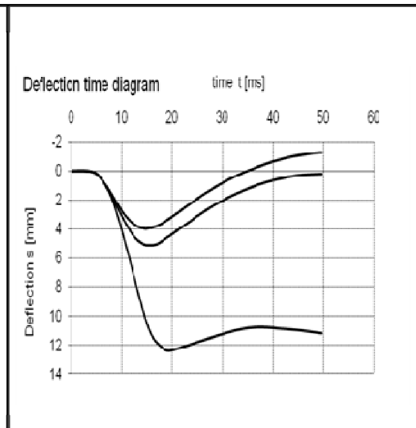

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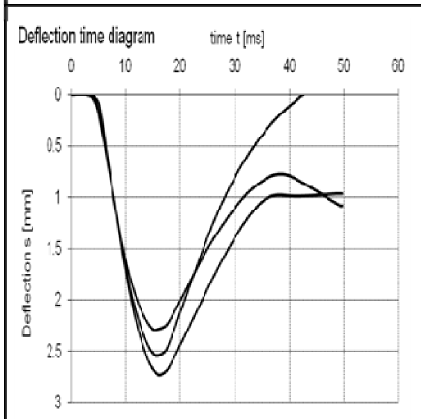

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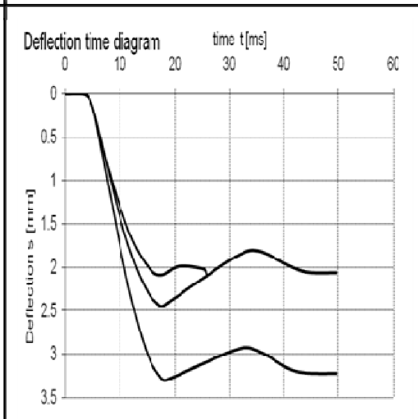

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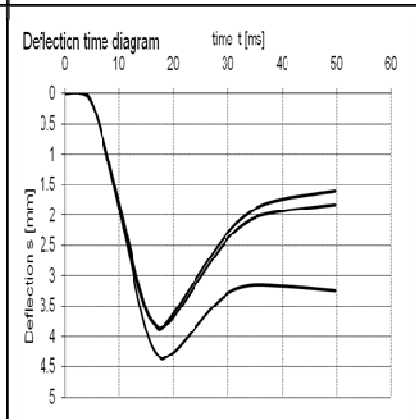

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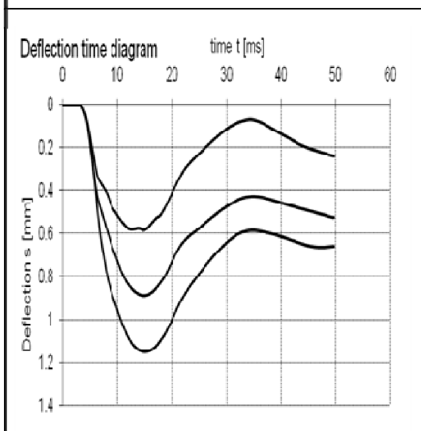

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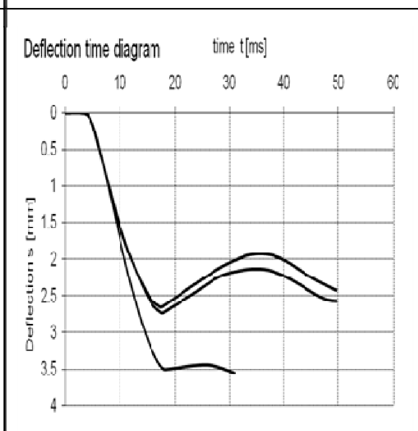

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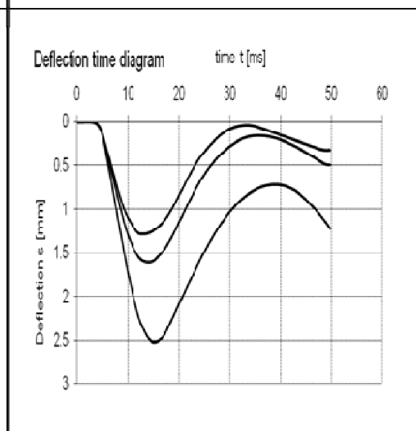

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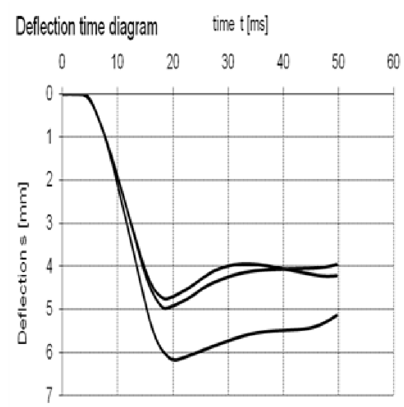

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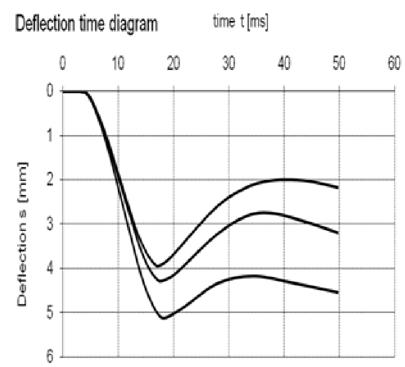

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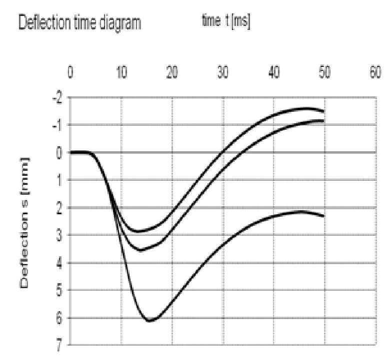

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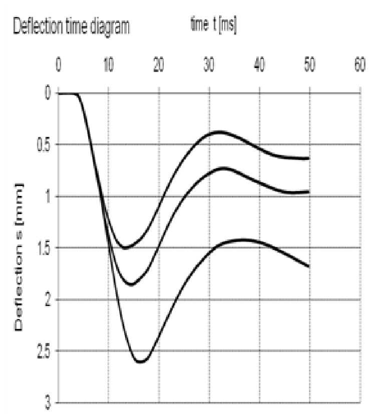

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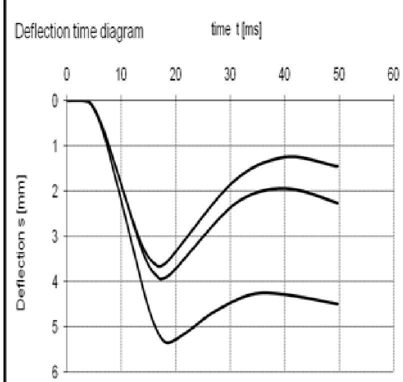

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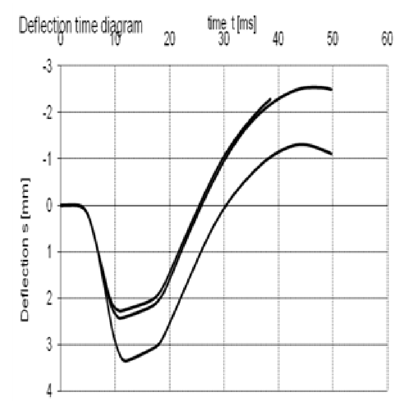

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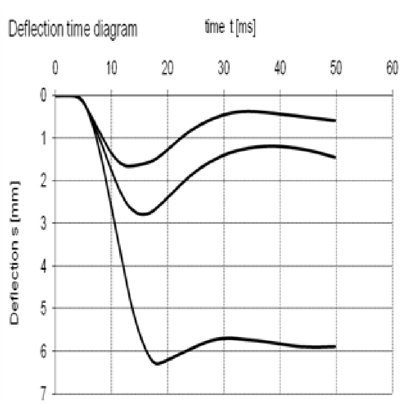

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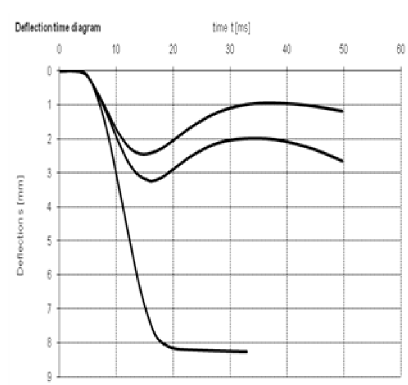

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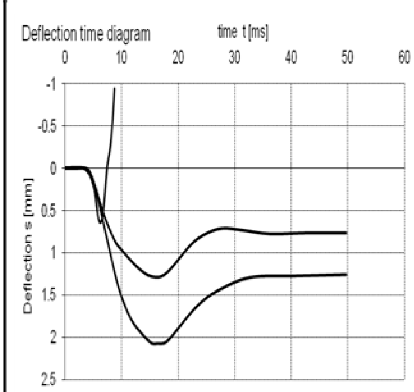

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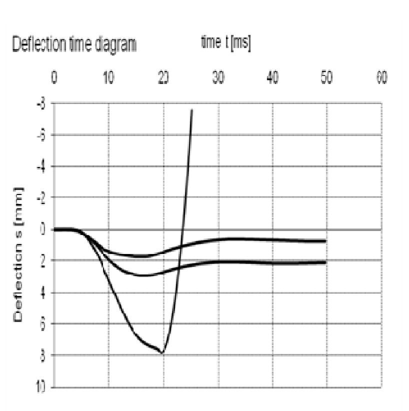

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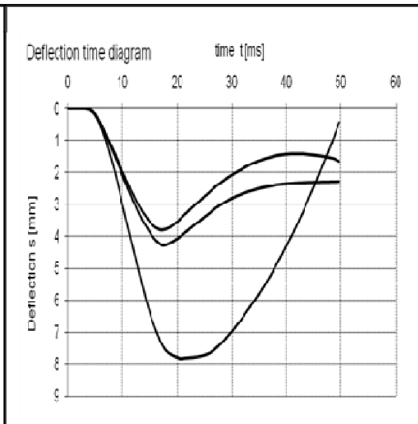

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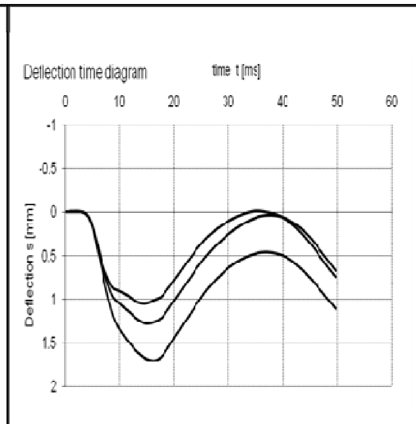

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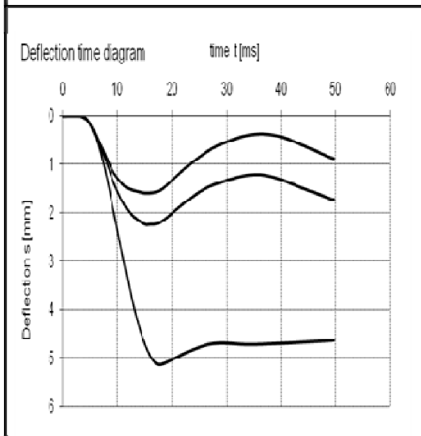

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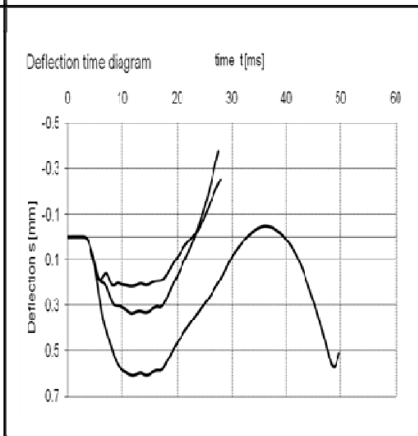

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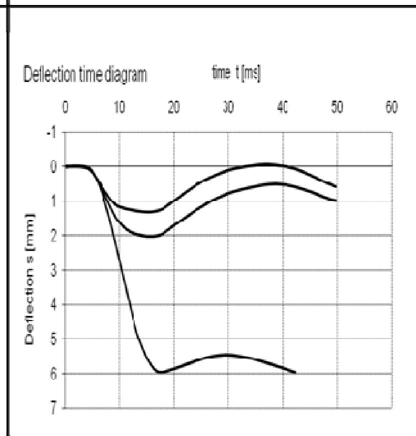

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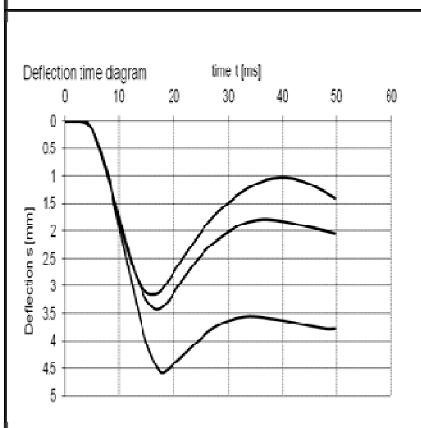

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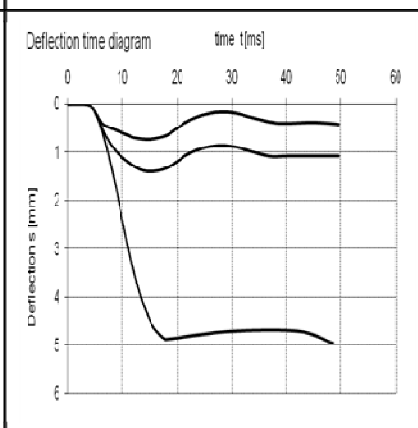

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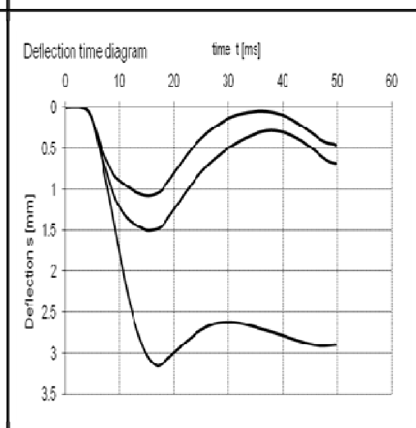

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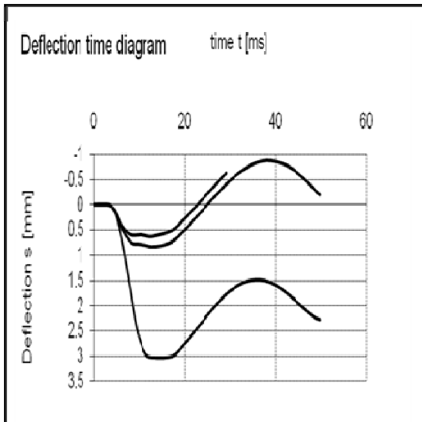

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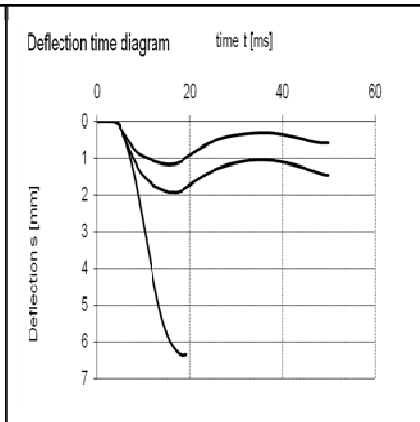

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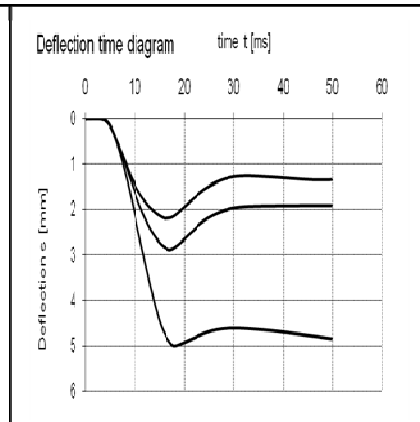

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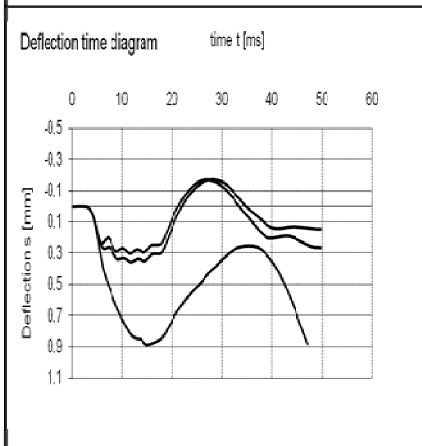

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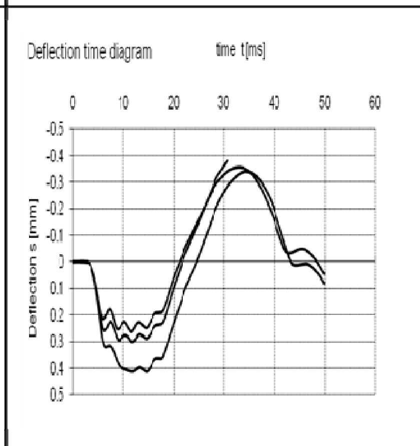

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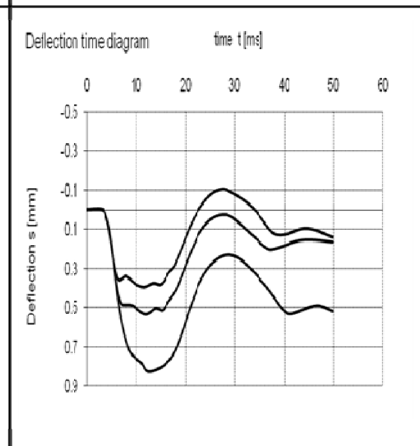

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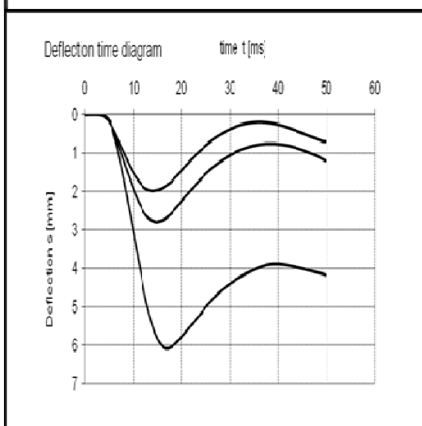

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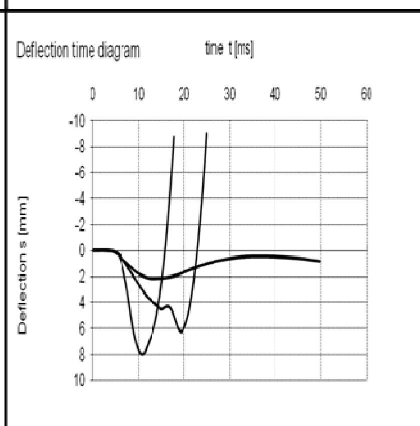

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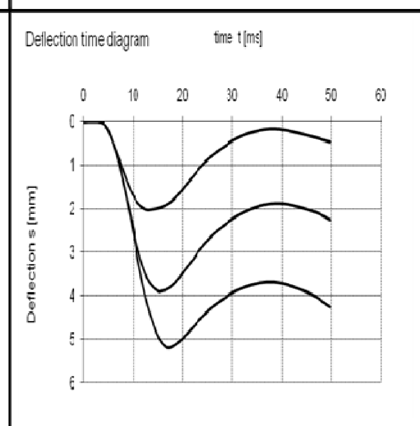
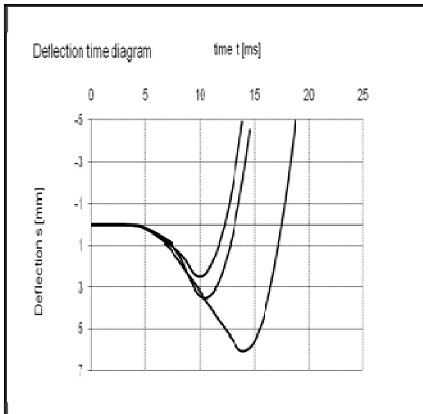


TNUDT1-4



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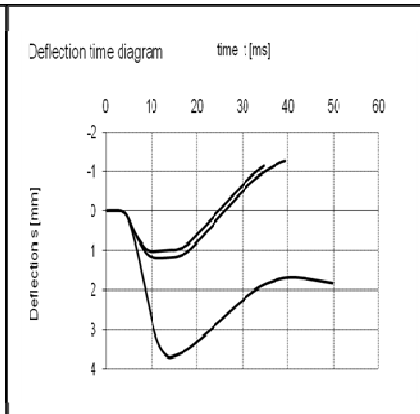

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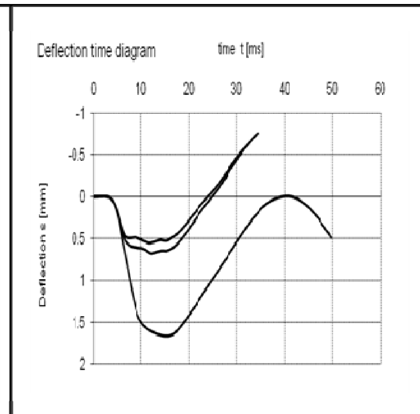

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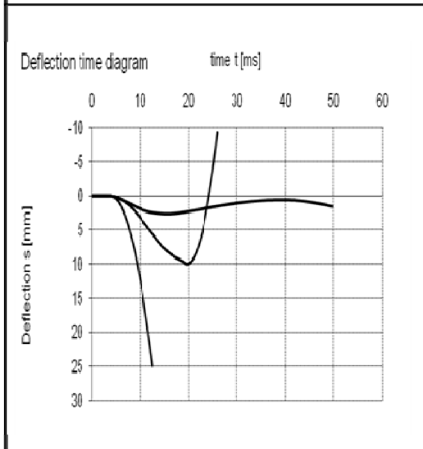
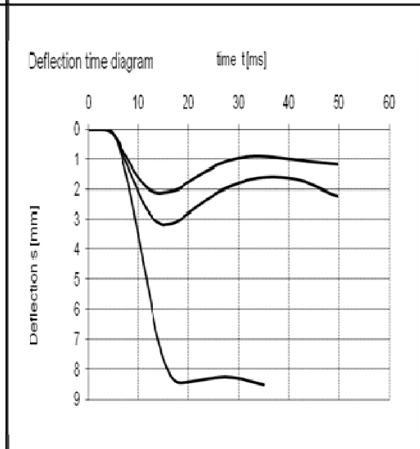


TNUDT2-2, #1



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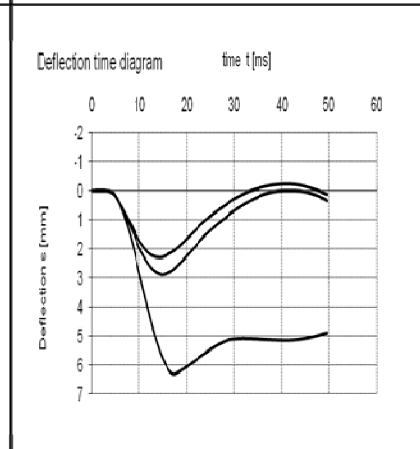

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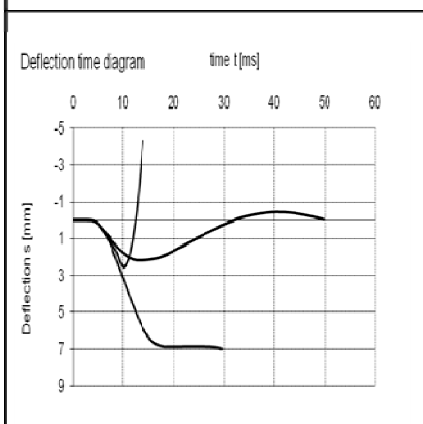

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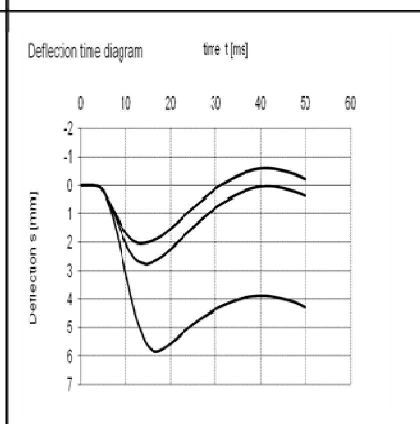

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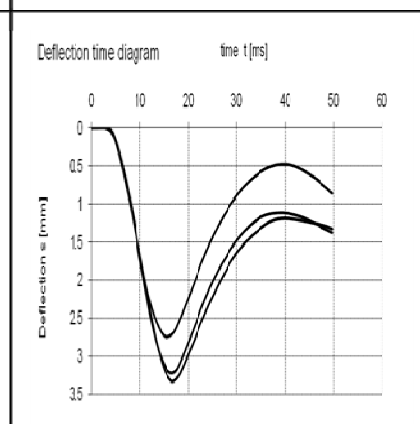

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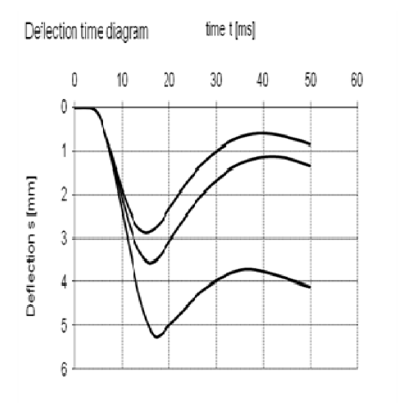

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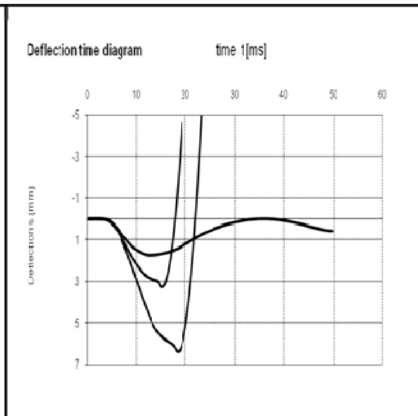

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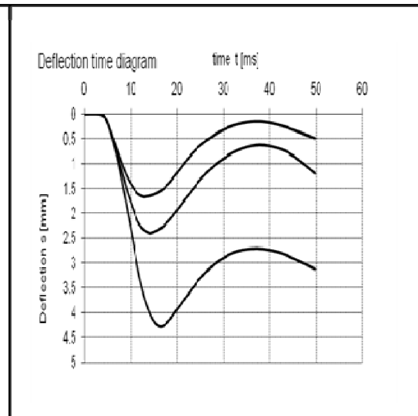

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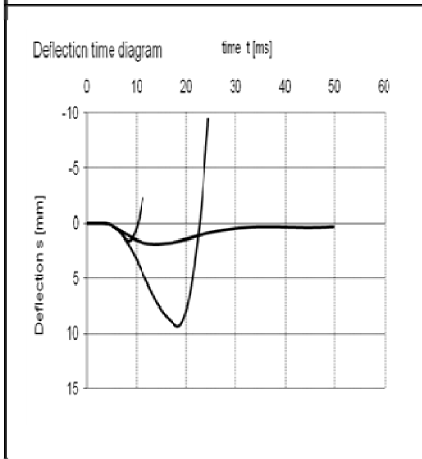

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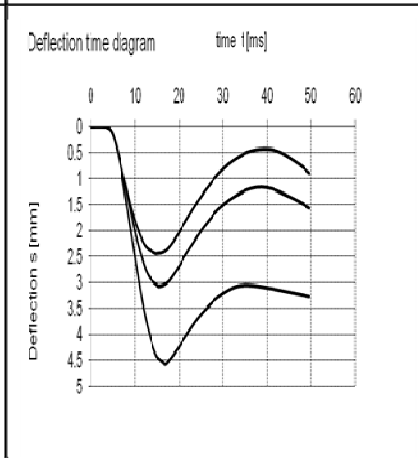
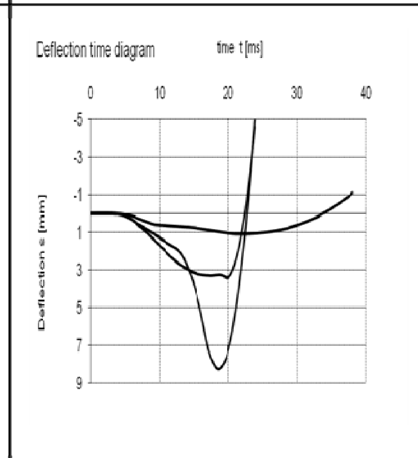


TNUDT3-6



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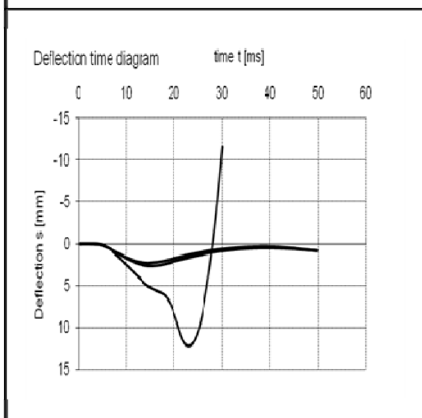

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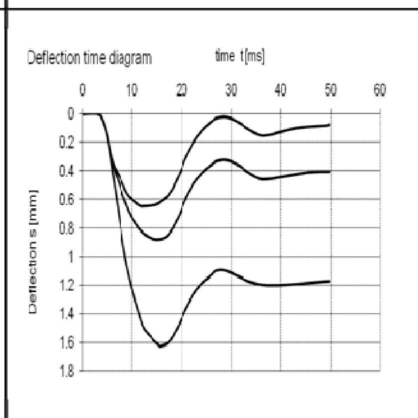

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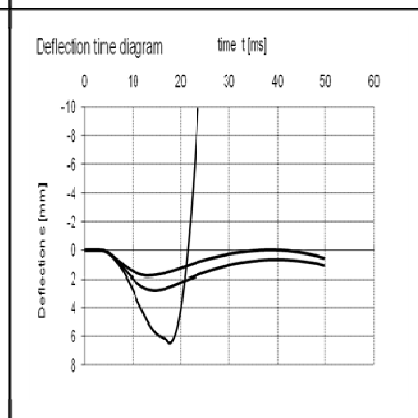

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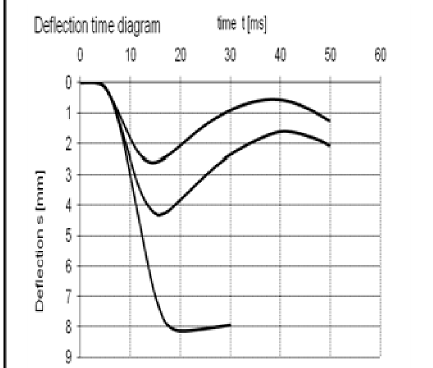

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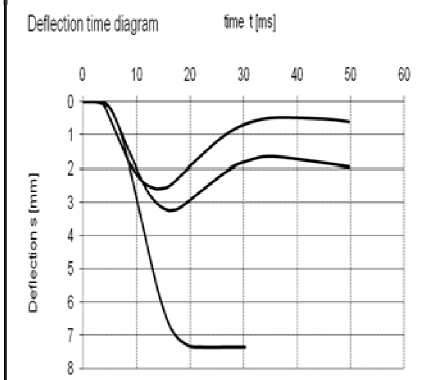


TNULT1-6

APPENDIX I

California Bearing Ratio

1 Introduction

California Bearing Ratio (CBR) is used as an empirical measurement of shear strength, one of the two failure mechanisms of soil under load. Combat engineers from Marine Wing Support Squadrons determine soil strength or bearing capacity values for expeditionary airfields before the beginning of aircraft operations. At bases and stations, physical scientists or specially trained civil engineer personnel may conduct these evaluations. In hostile situations, combat engineers attempt to conduct the evaluations under adverse conditions. Basically, the engineers determine strength using a Dynamic Cone Penetrometer (DCP), and then correlate the DCP readings to a CBR value for use in supporting operations.

The DCP is the current USMC and USAF standard for measurement of bearing strength for airfields. The use of the DCP is described in ASTM D 6951-03 (ASTM, 2003). The dual-mass DCP consists of a 5/8-in.-diameter steel rod with a steel cone attached to one end, which is driven into the soil by means of a sliding dual-mass hammer. The angle of the cone is 60°, and the diameter of the base of the cone is 0.79 in. For MI-HARES'10, the DCP is driven into the ground by dropping a 10.1-lb sliding hammer from a height of 22.6 in. The depth of cone penetration is measured at selected penetration or hammer-drop intervals and the soil shear strength is reported as the DCP index in millimeters/blow. Dynamic Cone Penetrometer test data are recorded in two columns, where the first column is number of blows and the second column is cumulative penetration in mm. In accordance with Army Field Manuals, CBR is computed using the following empirical equations;

$$CBR = 292 / PR^{1.12}$$

$$\text{CL soils: } CBR < 10\text{: } CBR = 1 / (0.017019*PR)^2$$

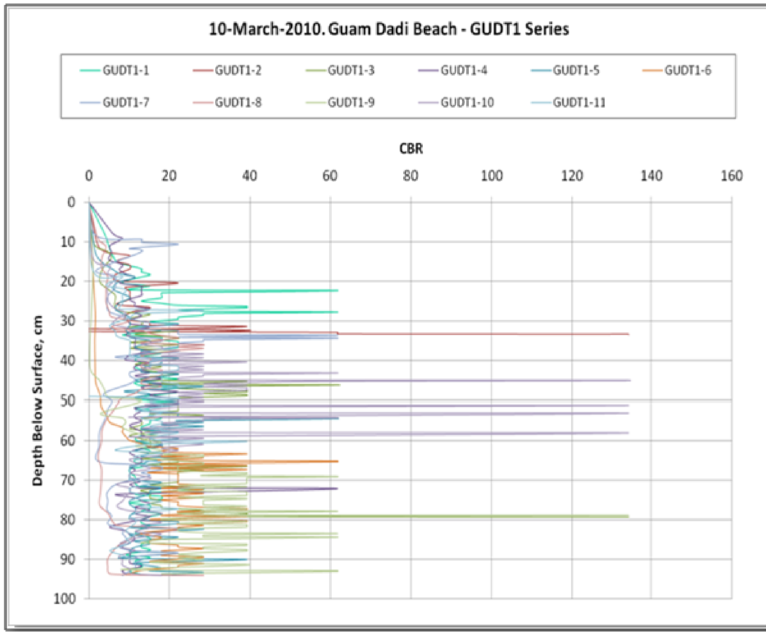
$$\text{CH soils: } CBR = 1/ (0.002871*PR)$$

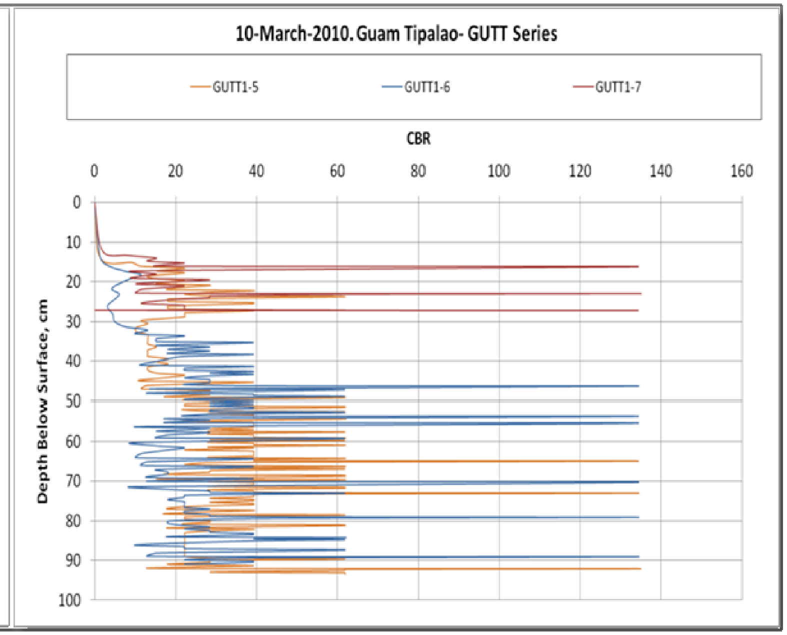
where:

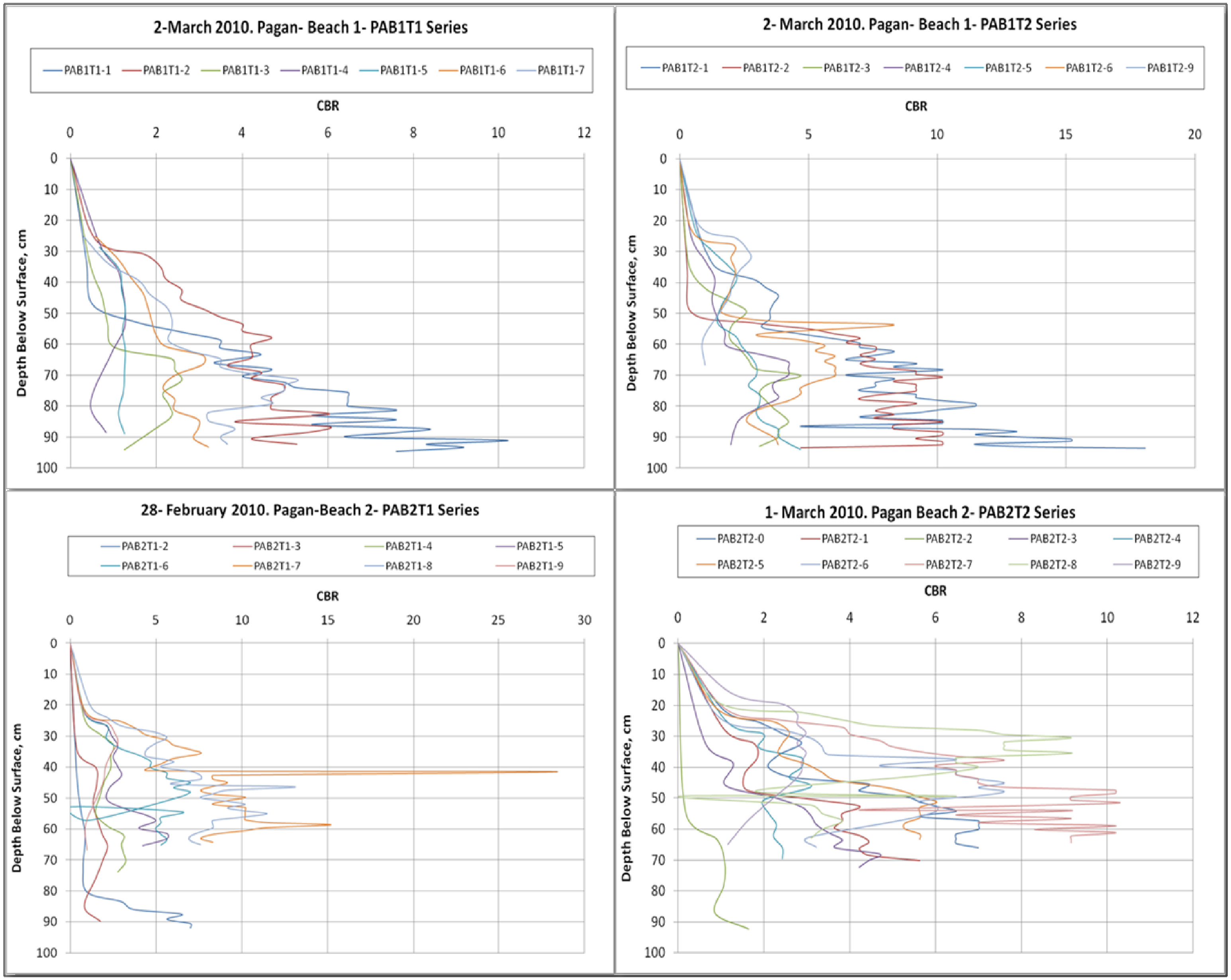
- PR is the DCP penetration rate in mm per blow.
- CL soils are gravelly clays, sandy clays, silty clays, and lean clays.
- CH soils are inorganic clays of high plasticity, including fat clays, gumbo clays, volcanic clays, and bentonite.

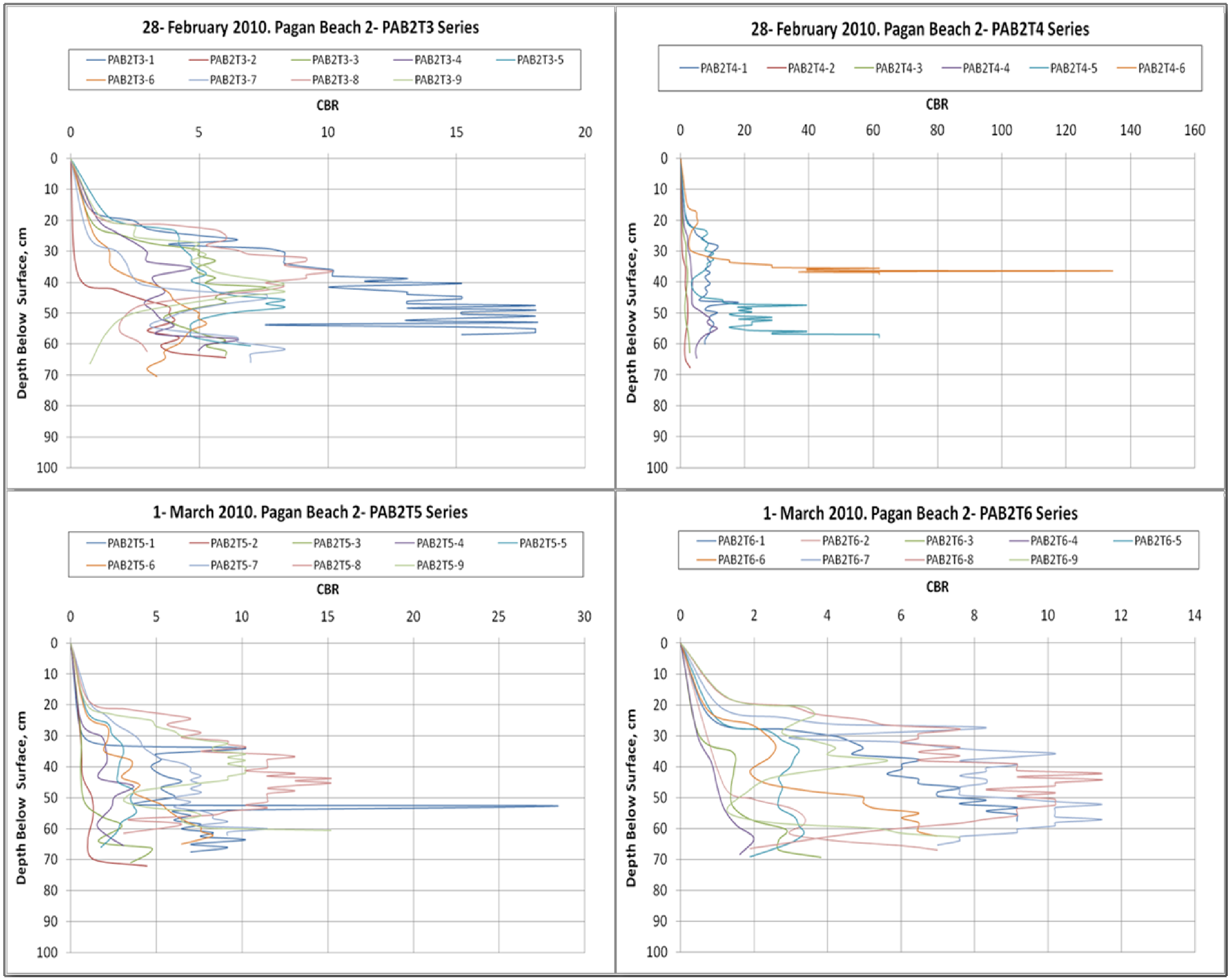
MI-HARES'10 demonstrates the utility of measuring CBR as a component of littoral penetration point classification and as a trafficability parameter. The CBR was plotted against depth (cm) and is displayed below in Section 2 for each substrate sample position. In the graphs on the following pages, the CBR is plotted on the *x*-axis and the depth below the surface in centimeters is plotted on the *y*-axis. Please note the *x* axis scale changes among the figures. Graphs are listed in alphabetical order by transect name.

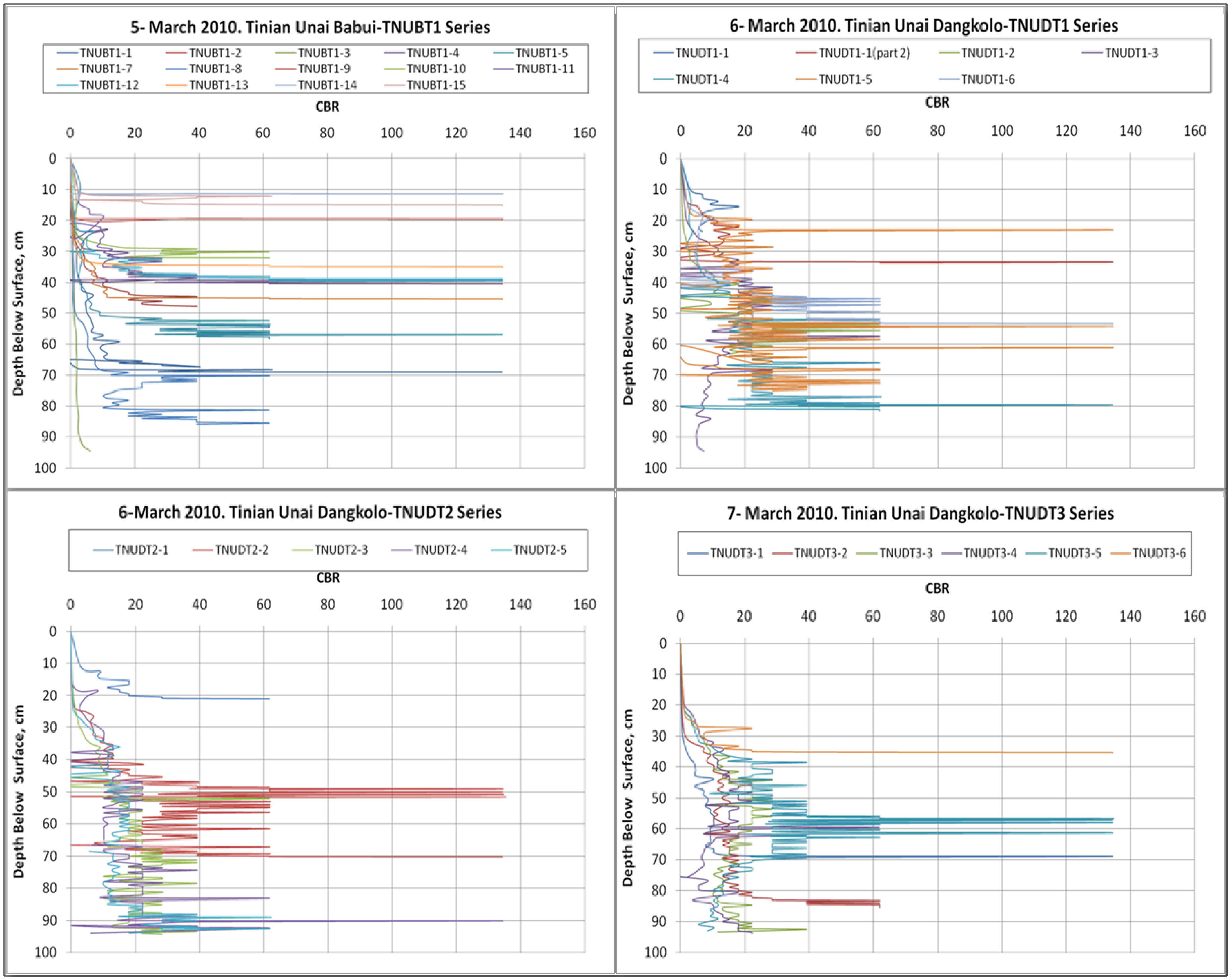
2 California Bearing Ratio Graphs

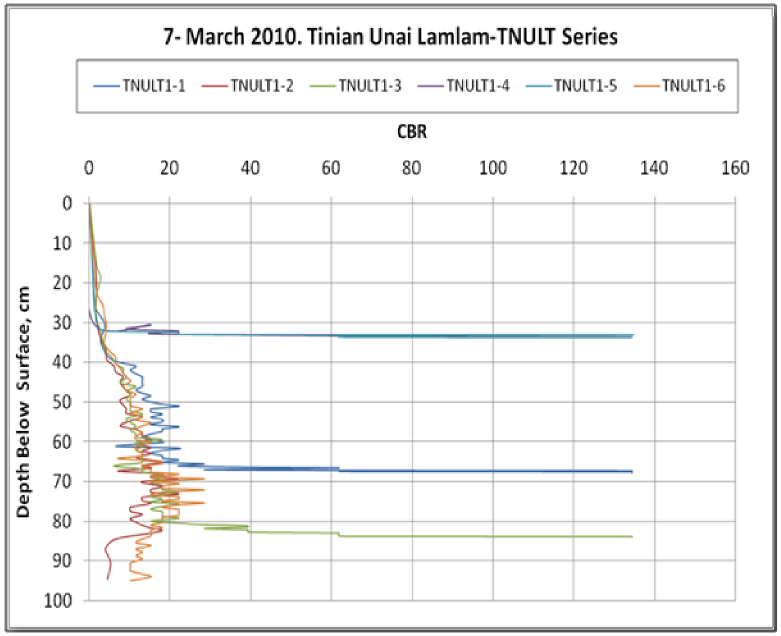





2-March 2010. Pagan- Beach 1- PAB1T1 Series
PAB1T1-1 PAB1T1-2 PAB1T1-3 PAB1T1-4 PAB1T1-5 PAB1T1-6 PAB1T1-7
CBR
Depth Below Surface, cm
2- March 2010. Pagan- Beach 1- PAB1T2 Series
PAB1T2-1 PAB1T2-2 PAB1T2-3 PAB1T2-4 PAB1T2-5 PAB1T2-6 PAB1T2-9
CBR
Depth Below Surface, cm
28- February 2010. Pagan-Beach 2- PAB2T1 Series
PAB2T1-2 PAB2T1-3 PAB2T1-4 PAB2T1-5 PAB2T1-6 PAB2T1-7 PAB2T1-8 PAB2T1-9
CBR
Depth Below Surface, cm
1- March 2010. Pagan Beach 2- PAB2T2 Series
PAB2T2-0 PAB2T2-1 PAB2T2-2 PAB2T2-3 PAB2T2-4 PAB2T2-5 PAB2T2-6 PAB2T2-7 PAB2T2-8 PAB2T2-9
CBR
Depth Below Surface, cm


28- February 2010. Pagan Beach 2- PAB2T3 Series
PAB2T3-1 PAB2T3-2 PAB2T3-3 PAB2T3-4 PAB2T3-5 PAB2T3-6 PAB2T3-7 PAB2T3-8 PAB2T3-9
CBR
Depth Below Surface, cm
28- February 2010. Pagan Beach 2- PAB2T4 Series
PAB2T4-1 PAB2T4-2 PAB2T4-3 PAB2T4-4 PAB2T4-5 PAB2T4-6
CBR
Depth Below Surface, cm
1- March 2010. Pagan Beach 2- PAB2T5 Series
PAB2T5-1 PAB2T5-2 PAB2T5-3 PAB2T5-4 PAB2T5-5 PAB2T5-6 PAB2T5-7 PAB2T5-8 PAB2T5-9
CBR
Depth Below Surface, cm
1- March 2010. Pagan Beach 2- PAB2T6 Series
PAB2T6-1 PAB2T6-2 PAB2T6-3 PAB2T6-4 PAB2T6-5 PAB2T6-6 PAB2T6-7 PAB2T6-8 PAB2T6-9
CBR
Depth Below Surface, cm


5- March 2010. Tinian Unai Babui-TNUBT1 Series
TNUBT1-1
TNUBT1-2
TNUBT1-3
TNUBT1-4
TNUBT1-5
TNUBT1-7
TNUBT1-8
TNUBT1-9
TNUBT1-10
TNUBT1-11
TNUBT1-12
TNUBT1-13
TNUBT1-14
TNUBT1-15
CBR
Depth Below Surface, cm
6- March 2010. Tinian Unai Dangkolo-TNUDT1 Series
TNUDT1-1
TNUDT1-1(part 2)
TNUDT1-2
TNUDT1-3
TNUDT1-4
TNUDT1-5
TNUDT1-6
CBR
Depth Below Surface, cm
6-March 2010. Tinian Unai Dangkolo-TNUDT2 Series
TNUDT2-1
TNUDT2-2
TNUDT2-3
TNUDT2-4
TNUDT2-5
CBR
Depth Below Surface, cm
7- March 2010. Tinian Unai Dangkolo-TNUDT3 Series
TNUDT3-1
TNUDT3-2
TNUDT3-3
TNUDT3-4
TNUDT3-5
TNUDT3-6
CBR
Depth Below Surface, cm


7- March 2010. Tinian Unai Lamlam-TNULT Series
TNULT1-1
TNULT1-2
TNULT1-3
TNULT1-4
TNULT1-5
TNULT1-6
CBR
0
20
40
60
80
100
120
140
160
Depth Below Surface, cm
0
10
20
30
40
50
60
70
80
90
100

APPENDIX J

Soil Properties

1 Introduction

Determining beach composition was an essential MI-HARES'10 task involving the collection of "grab samples" across the beach. Two of four standard soil tests were accomplished; (1) moisture content determinations and (2) grading or sieve analysis. Soil samples were collected with a corer to a critical depth of 3 inches (7.62cm). Samples were collected as quickly as possible and stored in zip-loc bags, to prevent the loss of moisture to evaporation. At Pagan, samples were placed in a cooler to keep the samples at a moderate temperature. Samples were then taken back to the lab in Tinian to determine soil moisture and grain size distributions. Guam sites were tested in a lab space at the Naval Base at Guam.

After soil samples were taken to the labs, quick and careful procedures were taken to determine soil moisture. The moisture content is expressed as a percentage and is the weight of wet soil minus the weight of dry soil divided by the dry mass of soil times one hundred. The soil moisture is determined by a similar protocol found in the Army Field Manual for materials testing (FM 5-472, NAVFAC MO 330,AFJMAN 32-1221(I)). Soil moisture determination is discussed further in Section 2. After soil moisture was determined, measurement of grain size distributions commenced. Soil grain size determination followed the procedures set by the Army Field Manual mentioned above by applying the mechanical (sieve analysis) method. The industry standard testing soil particle size of soils (ASTM D 422-63) requires a two step process in which a sedimentation process (hyrdrometer analysis) is used to analyze soil grains smaller than sieve No. 200, but FM 5-472 indicates adequate analysis will be accomplished without the use of the sedimentation process. Further discussion of grain size determination appears in section 3.

Soil moisture data and graphs are displayed in Section 4 while soil grain size distribution data and graphs are displayed below Section 5.

2 Soil Moisture Determination

The soil drying-by-oven technique is one of the most widely used gravimetric methods for measuring soil moisture (Schmugge, 1980). The microwave oven technique is described in ASTM D 4643-08.

2.1 Preparing the Soil Sample

The following protocol discusses the methodology for soil moisture content determination which was undertaken at the Tinian and Guam laboratory sites.

1. We opened windows to ensure good ventilation because of fumes from microwave baking of soil samples.
2. The weighing container was weighed prior to putting soil on the container. This value is needed for the calculation of soil moisture.
3. The wet/moist soil was placed on the container and the weight of soil and container is measured.

4. Drying the sample was done with an 800 W microwave oven. The appropriate steps for drying with a microwave oven are described below.

2.2 Soil Sample Drying in a Microwave Oven

The following lists the protocol followed in order to dry a soil sample in a microwave oven:

1. Place sample into microwave with a heat sink (brick) and run the microwave oven at 30% power for 1 minute.
2. Weigh the sample and return to microwave oven for 1 minute and reweigh. If the weight of the sample has changed, return to the microwave oven for 1 more minute.
3. Repeat the process until a constant weight is achieved.
4. Record the following measurements
   - (net weight) - (weight of container) = net soil weight
   - (dry weight) - (weight of container) = dry soil weight
   - (net soil weight) - (dry soil weight) = water weight
   - (water weight) ÷ (dry soil weight) = soil water content

(Typical drying times for a wet sample are less than 20 minutes. Water is the first component of the soil to heat and evaporate. If the sample is dry and microwave drying continues, the soil temperature will increase and oxidize organic matter. This is to be avoided as it would bias results.)

2.3 Soil Moisture Content Equations

The soil's moisture content (in percent) is calculated as the ratio of the mass of the water contained in the soil to the mass of the dry soil and multiplied by 100 (Black, 1965, Famiiglietti, 1998). The soil's moisture content (also referred to as water content) is an indicator of the amount of water present in a soil. By definition, moisture content is the ratio of the weight of water in a sample to the weight of solids (oven-dried) in the sample, expressed as a percentage (w). The equation can be seen in the box below. Note, however, that remote sensing observes the wet sample in the field and therefore is more closely related to normalization by the wet weight.

Soil Moisture Content Equation

$$w = \frac{W_w}{W_s} \times 100$$

Where:

w= moisture content of the soil (expressed as a percentage)

W_w = weight of water in the soil sample

W_s = weight of oven-dried-soil solids in the sample

3 Grain Size Distributions

After soil moisture is determined, samples are graded using a stack of appropriately sized sieves. For civil engineering applications, there is a specific series of sieve sizes. Those most commonly used to grade materials have openings varying from 125,000 µm down to 75 µm and are stacked one on top of the other; in our experiments we added sieves for particles as small as 25 µm (Tests are often described by identifying sieve sizes by their opening in millimeters followed by English aperture size: for example, 4.75mm (No. 4) sieve. All sieves have square openings.) For beach composition, the grading analysis is the most important of all the soil tests, since factors such as beach gradient can be estimated from grain size. In order to grade the sample properly, the sieving operation uses a mechanical shaker to obtain lateral, vertical, and jarring actions, which keep the sample moving continuously over the surface of the sieve. After sufficient shaking, the mass of each sieve size is determined on a scale or balance. Then, the total percentage of material passing each sieve is calculated. Percentages are calculated to the nearest whole number except for the amount of material finer than the 75 µm (No. 200) sieve, which is reported to the nearest 0.1 percent. If the total amount of material finer than 75 µm (No. 200) sieve is desired, it is determined by adding the mass of material passing the 75 µm (No. 200) sieve by dry sieving.

4 Soil Moisture Content

4.1 Tabular Data

Tabular data of sample soil moisture content are presented below. The sample name, date the sample was taken, and the island location of the sample are viewed in the left three columns. The next column (Sample Wet Weight (g)) is the weight of the pre-dried sample in grams. The Sample Dry Weight (g) column lists the weight of the sample (in grams) after successive microwave drying attempts have caused a leveling of the sample's weight. The Wet-Dry (g) lists the weight in grams of the Sample Wet Weight (g) minus the Sample Dry Weight (g). The Soil Moisture Column (*w*) % lists the values calculated when the Sample Dry Weight (g) column is subtracted from the Sample Wet Weight (g) column (the Wet-Dry (g) column) and divided by the Sample Dry Weight (g) column value and multiplied by 100.

Sample Name	Sample Date	Island	Sample Wet Weight (g)	Sample Dry Weight (g)	(Wet-Dry) (g)	Soil Moisture Content (*w*) %
GUDT1-1	10-Mar-10	Guam	559.68	471.28	88.40	18.76
GUDT1-2	10-Mar-10	Guam	540.93	447.01	93.92	21.01
GUDT1-3	10-Mar-10	Guam	745.59	671.18	74.41	11.09
GUDT1-4	10-Mar-10	Guam	476.84	389.96	86.88	22.28
GUDT1-5	10-Mar-10	Guam	614.96	551.67	63.29	11.47
GUDT1-6	10-Mar-10	Guam	442.16	419.51	22.65	5.40
GUDT1-7	10-Mar-10	Guam	442.54	362.75	79.79	22.00
GUDT1-8	10-Mar-10	Guam	408.41	392.71	15.70	4.00
GUDT1-9	10-Mar-10	Guam	477.40	456.41	20.99	4.60
GUDT1-10	10-Mar-10	Guam	671.79	591.15	80.64	13.64
GUDT1-11	10-Mar-10	Guam	346.94	336.46	10.48	3.11
Sample Name	**Sample Date**	**Island**	**Sample Wet Weight (g)**	**Sample Dry Weight (g)**	**(Wet-Dry) (g)**	**Soil Moisture Content (*w*) %**
GUTT1-5	10-Mar-10	Guam	550.61	521.44	29.17	5.59
GUTT1-6	10-Mar-10	Guam	455.58	434.27	21.31	4.91
GUTT1-7	10-Mar-10	Guam	608.02	566.39	41.63	7.35
Sample Name	**Sample Date**	**Island**	**Sample Wet Weight (g)**	**Sample Dry Weight (g)**	**(Wet-Dry) (g)**	**Soil Moisture Content (*w*) %**
PAB1T1-1	2-Mar-10	Pagan	543.20	514.76	28.44	5.52
PAB1T1-2	2-Mar-10	Pagan	386.80	381.28	5.52	1.45
PAB1T1-3	2-Mar-10	Pagan	458.40	447.27	11.13	2.49
PAB1T1-4	2-Mar-10	Pagan	524.50	511.64	12.86	2.51
PAB1T1-5	2-Mar-10	Pagan	374.69	364.91	9.78	2.68
PAB1T1-6	2-Mar-10	Pagan	420.26	406.26	14.00	3.45
PAB1T1-7	2-Mar-10	Pagan	408.56	392.12	16.44	4.19
Sample Name	**Sample Date**	**Island**	**Sample Wet Weight (g)**	**Sample Dry Weight (g)**	**(Wet-Dry) (g)**	**Soil Moisture Content (*w*) %**
PAB1T2-1	2-Mar-10	Pagan	529.23	507.34	21.89	4.31
PAB1T2-2	2-Mar-10	Pagan	429.66	419.55	10.11	2.41
PAB1T2-3	2-Mar-10	Pagan	474.11	468.75	5.36	1.14
PAB1T2-4	2-Mar-10	Pagan	400.04	385.15	14.89	3.87
PAB1T2-5	2-Mar-10	Pagan	447.60	433.73	13.87	3.20
PAB1T2-6	2-Mar-10	Pagan	408.50	397.05	11.45	2.88

Sample Name	Sample Date	Island	Sample Wet Weight (g)	Sample Dry Weight (g)	(Wet-Dry) (g)	Soil Moisture Content (*w*) %
PAB2T1-1	28-Feb-10	Pagan	466.14	436.26	29.88	6.85
PAB2T1-2	28-Feb-10	Pagan	479.96	454.75	25.21	5.54
PAB2T1-3	28-Feb-10	Pagan	373.41	366.27	7.14	1.95
PAB2T1-4	28-Feb-10	Pagan	449.77	432.37	17.40	4.02
PAB2T1-5	28-Feb-10	Pagan	373.54	364.07	9.47	2.60
PAB2T1-6	28-Feb-10	Pagan	409.64	399.69	9.95	2.49
PAB2T1-7	28-Feb-10	Pagan	402.30	395.21	7.09	1.79
PAB2T1-8	28-Feb-10	Pagan	473.15	468.70	4.45	0.95
PAB2T1-9	1-Mar-10	Pagan	496.70	483.26	13.44	2.78
Sample Name	**Sample Date**	**Island**	**Sample Wet Weight (g)**	**Sample Dry Weight (g)**	**(Wet-Dry) (g)**	**Soil Moisture Content (*w*) %**
PAB2T2-0	28-Feb-10	Pagan	432.95	369.37	63.58	17.21
PAB2T2-1	28-Feb-10	Pagan	452.83	413.46	39.37	9.52
PAB2T2-2	28-Feb-10	Pagan	407.84	388.33	19.51	5.02
PAB2T2-3	28-Feb-10	Pagan	437.32	422.75	14.57	3.45
PAB2T2-4	28-Feb-10	Pagan	340.75	336.07	4.68	1.39
PAB2T2-5	1-Mar-10	Pagan	417.82	405.22	12.60	3.11
PAB2T2-6	1-Mar-10	Pagan	476.47	461.50	14.97	3.24
PAB2T2-7	1-Mar-10	Pagan	507.39	498.94	8.45	1.69
PAB2T2-8	1-Mar-10	Pagan	538.01	524.74	13.27	2.53
PAB2T2-9	1-Mar-10	Pagan	558.32	550.03	8.29	1.51
Sample Name	**Sample Date**	**Island**	**Sample Wet Weight (g)**	**Sample Dry Weight (g)**	**(Wet-Dry) (g)**	**Soil Moisture Content (*w*) %**
PAB2T3-1	28-Feb-10	Pagan	453.36	414.98	38.38	9.25
PAB2T3-2	28-Feb-10	Pagan	534.15	504.55	29.60	5.87
PAB2T3-3	28-Feb-10	Pagan	547.90	525.42	22.48	4.28
PAB2T3-4	28-Feb-10	Pagan	525.82	509.95	15.87	3.11
PAB2T3-5	28-Feb-10	Pagan	475.75	455.10	20.65	4.54
PAB2T3-6	28-Feb-10	Pagan	449.82	436.99	12.83	2.94
PAB2T3-7	28-Feb-10	Pagan	427.19	416.35	10.84	2.60
PAB2T3-8	28-Feb-10	Pagan	478.25	467.51	10.74	2.30
PAB2T3-9	28-Feb-10	Pagan	425.43	423.08	2.35	0.56

Sample Name	Sample Date	Island	Sample Wet Weight (g)	Sample Dry Weight (g)	(Wet-Dry) (g)	Soil Moisture Content (*w) %*
PAB2T4-1	28-Feb-10	Pagan	456.39	427.77	28.62	6.69
PAB2T4-2	28-Feb-10	Pagan	448.38	435.65	12.73	2.92
PAB2T4-3	28-Feb-10	Pagan	479.56	462.80	16.76	3.62
PAB2T4-4	28-Feb-10	Pagan	448.00	437.06	10.94	2.50
PAB2T4-5	28-Feb-10	Pagan	476.03	465.43	10.60	2.28
PAB2T4-6	28-Feb-10	Pagan	531.08	518.21	12.87	2.48
Sample Name	**Sample Date**	**Island**	**Sample Wet Weight (g)**	**Sample Dry Weight (g)**	**(Wet-Dry) (g)**	**Soil Moisture Content (*w) %***
PAB2T5-1	1-Mar-10	Pagan	415.00	392.59	22.41	5.71
PAB2T5-2	1-Mar-10	Pagan	475.18	458.89	16.29	3.55
PAB2T5-3	1-Mar-10	Pagan	497.08	481.01	16.07	3.34
PAB2T5-4	1-Mar-10	Pagan	275.18	268.05	7.13	2.66
PAB2T5-5	1-Mar-10	Pagan	733.65	709.52	24.13	3.40
PAB2T5-6	1-Mar-10	Pagan	436.48	428.30	8.18	1.91
PAB2T5-7	1-Mar-10	Pagan	378.72	370.65	8.07	2.18
PAB2T5-8	1-Mar-10	Pagan	574.24	560.51	13.73	2.45
PAB2T5-9	1-Mar-10	Pagan	508.85	498.22	10.63	2.13
Sample Name	**Sample Date**	**Island**	**Sample Wet Weight (g)**	**Sample Dry Weight (g)**	**(Wet-Dry) (g)**	**Soil Moisture Content (*w) %***
PAB2T6-1	1-Mar-10	Pagan	462.02	442.58	19.44	4.39
PAB2T6-2	1-Mar-10	Pagan	375.72	365.02	10.70	2.93
PAB2T6-3	1-Mar-10	Pagan	495.29	478.94	16.35	3.41
PAB2T6-4	1-Mar-10	Pagan	361.08	349.46	11.62	3.33
PAB2T6-5	1-Mar-10	Pagan	527.94	513.23	14.71	2.87
PAB2T6-6	1-Mar-10	Pagan	518.68	508.33	10.35	2.04
PAB2T6-7	1-Mar-10	Pagan	667.48	649.35	18.13	2.79
PAB2T6-8	1-Mar-10	Pagan	550.75	536.6	14.15	2.64
PAB2T6-9	1-Mar-10	Pagan	533.53	518.38	15.15	2.92

Sample Name	Sample Date	Island	Sample Wet Weight (g)	Sample Dry Weight (g)	(Wet-Dry) (g)	Soil Moisture Content (*w*) %
PAB4T1-1	27-Feb-10	Pagan	800.18	724.66	75.52	10.42
PAB4T1-2	27-Feb-10	Pagan	600.78	590.05	10.73	1.82
PAB4T1-3	27-Feb-10	Pagan	545.34	542.17	3.17	0.58
Sample Name	**Sample Date**	**Island**	**Sample Wet Weight (g)**	**Sample Dry Weight (g)**	**(Wet-Dry) (g)**	**Soil Moisture Content (*w*) %**
PAB4T2-2	27-Feb-10	Pagan	614.11	530.60	83.51	15.74
PAB4T2-3	27-Feb-10	Pagan	636.35	632.25	4.10	0.65
PAB4T3-1	1-Mar-10	Pagan	376.76	351.08	25.68	7.31
PAB4T3-2	1-Mar-10	Pagan	288.91	287.39	1.52	0.53
PAB4T3-3	1-Mar-10	Pagan	466.96	465.50	1.46	0.31
PAB4T3-4	1-Mar-10	Pagan	427.08	421.21	5.87	1.39
Sample Name	**Sample Date**	**Island**	**Sample Wet Weight (g)**	**Sample Dry Weight (g)**	**(Wet-Dry) (g)**	**Soil Moisture Content (*w*) %**
PAB4T4-1	1-Mar-10	Pagan	547.59	505.98	41.61	8.22
PAB4T4-2	1-Mar-10	Pagan	626.95	594.65	32.30	5.43
PAB4T4-3	1-Mar-10	Pagan	353.19	352.37	0.82	0.23
PAB4T4-4	1-Mar-10	Pagan	385.99	383.05	2.94	0.77

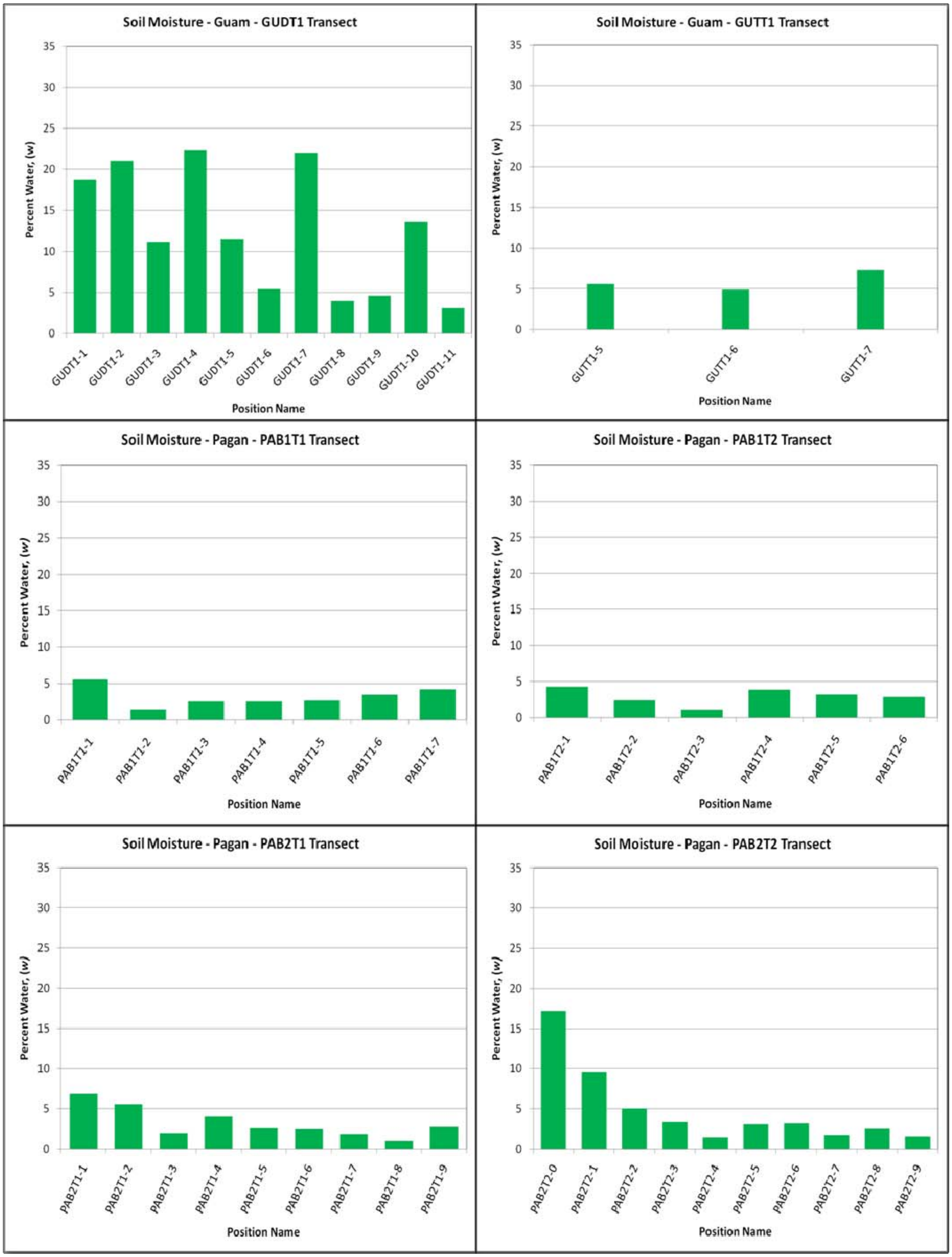
Sample Name	Sample Date	Island	Sample Wet Weight (g)	Sample Dry Weight (g)	(Wet-Dry) (g)	Soil Moisture Content (*w*) %
TNUBT1-1	5-Mar-10	Tinian	487.75	445.66	42.09	9.44
TNUBT1-2	5-Mar-10	Tinian	519.35	447.65	71.70	16.02
TNUBT1-3	5-Mar-10	Tinian	485.01	456.27	28.74	6.30
TNUBT1-4	5-Mar-10	Tinian	412.63	385.55	27.08	7.02
TNUBT1-5	5-Mar-10	Tinian	569.07	524.12	44.95	8.58
TNUBT1-7	5-Mar-10	Tinian	409.22	364.30	44.92	12.33
TNUBT1-8	5-Mar-10	Tinian	580.56	543.50	37.06	6.82
TNUBT1-9	5-Mar-10	Tinian	433.74	404.10	29.64	7.33
TNUBT1-10	5-Mar-10	Tinian	544.96	501.46	43.50	8.67
TNUBT1-11	5-Mar-10	Tinian	417.48	316.20	101.28	32.03
TNUBT1-12	5-Mar-10	Tinian	497.23	463.66	33.57	7.24
TNUBT1-13	5-Mar-10	Tinian	416.20	385.77	30.43	7.89
TNUBT1-14	5-Mar-10	Tinian	458.19	416.86	41.33	9.91
TNUBT1-15	5-Mar-10	Tinian	508.05	405.96	102.09	25.15
Sample Name	**Sample Date**	**Island**	**Sample Wet Weight (g)**	**Sample Dry Weight (g)**	**(Wet-Dry) (g)**	**Soil Moisture Content (w) %**
TNUDT1-1	6-Mar-10	Tinian	531.30	416.40	114.90	27.59
TNUDT1-2	6-Mar-10	Tinian	381.62	371.67	9.95	2.68
TNUDT1-3	6-Mar-10	Tinian	367.55	338.40	29.15	8.61
TNUDT1-4	6-Mar-10	Tinian	456.62	434.50	22.12	5.09
TNUDT1-5	6-Mar-10	Tinian	407.76	377.09	30.67	8.13
TNUDT1-6	6-Mar-10	Tinian	454.22	393.50	60.72	15.43
Sample Name	**Sample Date**	**Island**	**Sample Wet Weight (g)**	**Sample Dry Weight (g)**	**(Wet-Dry) (g)**	**Soil Moisture Content (w) %**
TNUDT2-1	6-Mar-10	Tinian	482.87	357.98	124.89	34.89
TNUDT2-2	6-Mar-10	Tinian	536.58	505.55	31.03	6.14
TNUDT2-3	6-Mar-10	Tinian	456.53	413.37	43.16	10.44
TNUDT2-4	6-Mar-10	Tinian	368.85	332.75	36.10	10.85
TNUDT2-5	6-Mar-10	Tinian	388.97	364.34	24.63	6.76
Sample Name	**Sample Date**	**Island**	**Sample Wet Weight (g)**	**Sample Dry Weight (g)**	**(Wet-Dry) (g)**	**Soil Moisture Content (w) %**
TNUDT3-1	7-Mar-10	Tinian	448.05	408.53	39.52	9.67
TNUDT3-2	7-Mar-10	Tinian	434.30	387.70	46.60	12.02
TNUDT3-3	7-Mar-10	Tinian	573.19	538.53	34.66	6.44
TNUDT3-4	7-Mar-10	Tinian	440.51	412.28	28.23	6.85
TNUDT3-5	7-Mar-10	Tinian	N/A	N/A	N/A	N/A

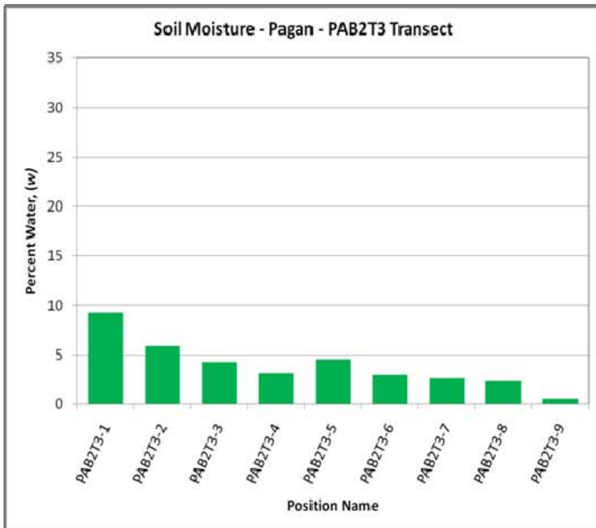
TNUDT3-6	7-Mar-10	Tinian	N/A	N/A	N/A	N/A

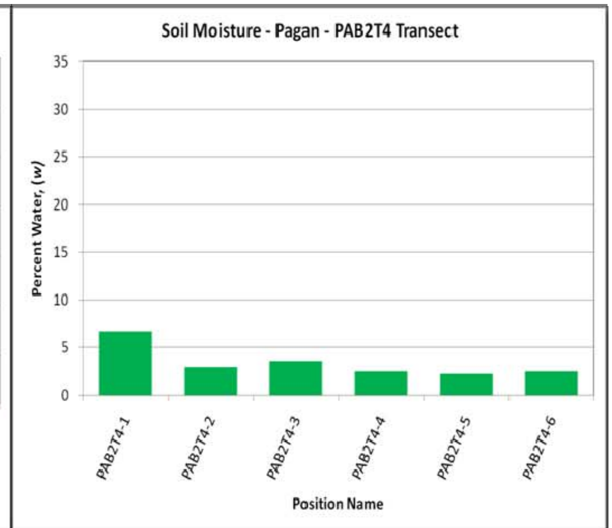
Sample Name	**Sample Date**	**Island**	**Sample Wet Weight (g)**	**Sample Dry Weight (g)**	**(Wet-Dry) (g)**	**Soil Moisture Content (*w*) %**
TNULT1-1	7-Mar-10	Tinian	459.65	356.11	103.54	29.08
TNULT1-2	7-Mar-10	Tinian	649.24	605.20	44.04	7.28
TNULT1-3	7-Mar-10	Tinian	456.97	434.95	22.02	5.06
TNULT1-4	7-Mar-10	Tinian	411.59	382.00	29.59	7.75
TNULT1-5	7-Mar-10	Tinian	525.52	486.33	39.19	8.06
TNULT1-6	7-Mar-10	Tinian	387.00	359.58	27.42	7.63

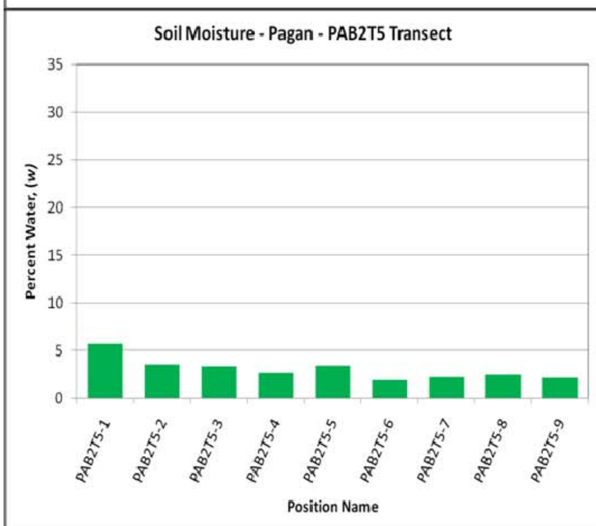
4.2 Soil Moisture Graphs

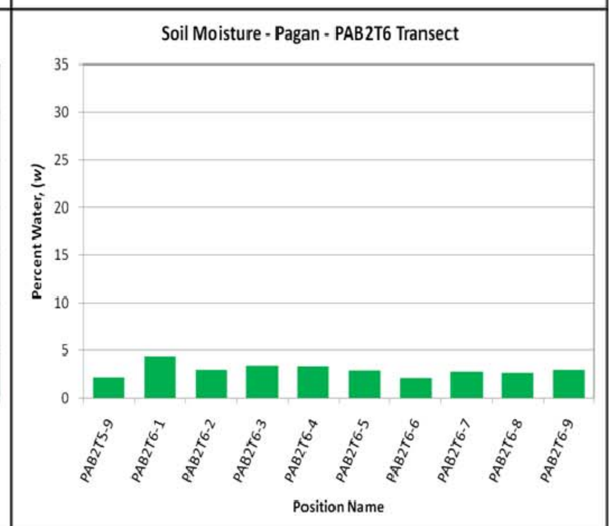
Soil moisture graphical figures are presented below and list the Percent water (*w*) on the *y*-axis, and the position name on the *x*-axis. Graphs are presented in alphabetical order by transect name. The transect name GUDT1 has its graph presented first while the transect name TNULT1 has its graph presented last. The position with the greatest percentage of water content (*w*) is position TNUDT2-1 (*w*=34.89%) while the position with lowest percentage of water content (*w*) is position PAB4T4-3 (*w*=0.23%). Typical for a majority of the transects on Pagan, positions with higher numbers refer to positions away from the water line (closer to interior) and lower numbers refer to positions closer to water (.*i.e.* PAB2T2-0 refers to a position closest to water, and PAB2T2-9 refers to a position closest to interior). Guam and Tinian differ from Pagan and did not typically have the same position naming scheme as this was due to narrow beaches on Guam (Dadi and Tipalao) and Tinian (Unai Babui and Unai Lamlam, but not Unai Dangkolo (wide)).

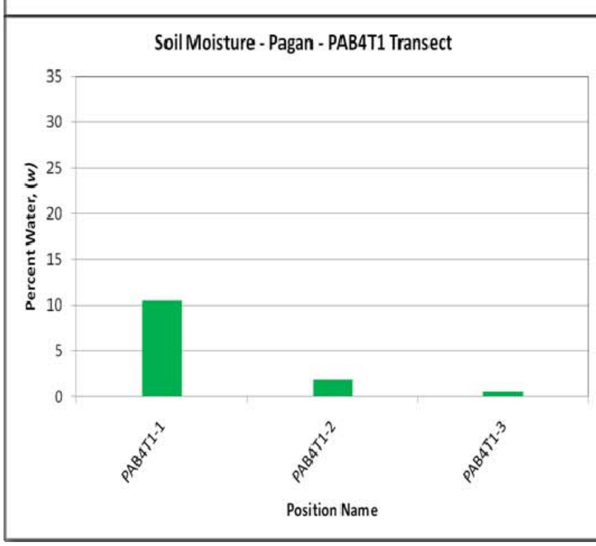

Soil Moisture - Guam - GUDT1 Transect
Percent Water, (w)
Position Name
GUDT1-1
GUDT1-2
GUDT1-3
GUDT1-4
GUDT1-5
GUDT1-6
GUDT1-7
GUDT1-8
GUDT1-9
GUDT1-10
GUDT1-11
Soil Moisture - Guam - GUTT1 Transect
GUTT1-5
GUTT1-6
GUTT1-7
Soil Moisture - Pagan - PAB1T1 Transect
PAB1T1-1
PAB1T1-2
PAB1T1-3
PAB1T1-4
PAB1T1-5
PAB1T1-6
PAB1T1-7
Soil Moisture - Pagan - PAB1T2 Transect
PAB1T2-1
PAB1T2-2
PAB1T2-3
PAB1T2-4
PAB1T2-5
PAB1T2-6
Soil Moisture - Pagan - PAB2T1 Transect
PAB2T1-1
PAB2T1-2
PAB2T1-3
PAB2T1-4
PAB2T1-5
PAB2T1-6
PAB2T1-7
PAB2T1-8
PAB2T1-9
Soil Moisture - Pagan - PAB2T2 Transect
PAB2T2-0
PAB2T2-1
PAB2T2-2
PAB2T2-3
PAB2T2-4
PAB2T2-5
PAB2T2-6
PAB2T2-7
PAB2T2-8
PAB2T2-9

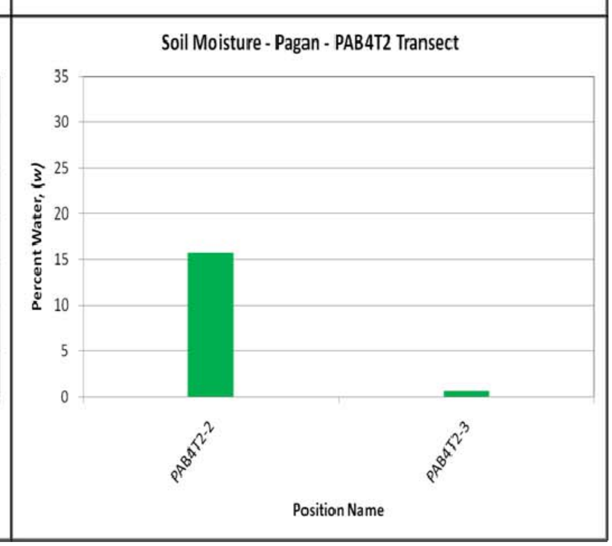

Soil Moisture - Pagan - PAB2T3 Transect
Percent Water, (w)
0
5
10
15
20
25
30
35
PAB2T3-1
PAB2T3-2
PAB2T3-3
PAB2T3-4
PAB2T3-5
PAB2T3-6
PAB2T3-7
PAB2T3-8
PAB2T3-9
Position Name

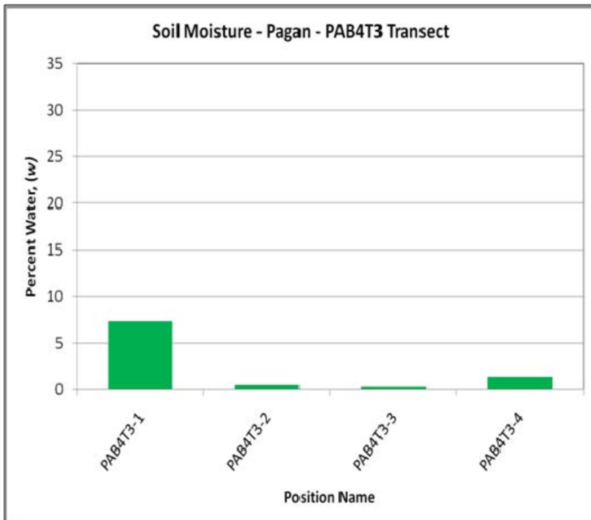

Soil Moisture - Pagan - PAB2T4 Transect
Percent Water, (w)
0
5
10
15
20
25
30
35
PAB2T4-1
PAB2T4-2
PAB2T4-3
PAB2T4-4
PAB2T4-5
PAB2T4-6
Position Name

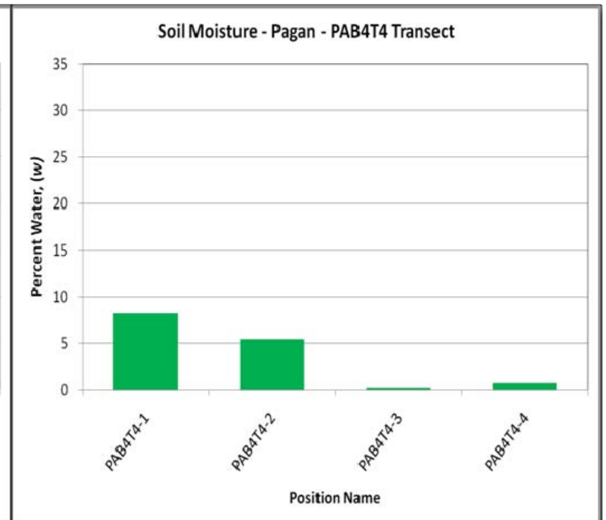

Soil Moisture - Pagan - PAB2T5 Transect
Percent Water, (w)
0
5
10
15
20
25
30
35
PAB2T5-1
PAB2T5-2
PAB2T5-3
PAB2T5-4
PAB2T5-5
PAB2T5-6
PAB2T5-7
PAB2T5-8
PAB2T5-9
Position Name

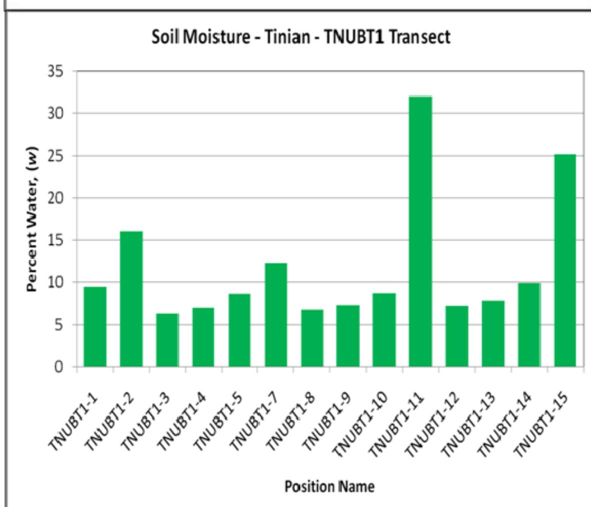

Soil Moisture - Pagan - PAB2T6 Transect
Percent Water, (w)
0
5
10
15
20
25
30
35
PAB2T5-9
PAB2T6-1
PAB2T6-2
PAB2T6-3
PAB2T6-4
PAB2T6-5
PAB2T6-6
PAB2T6-7
PAB2T6-8
PAB2T6-9
Position Name

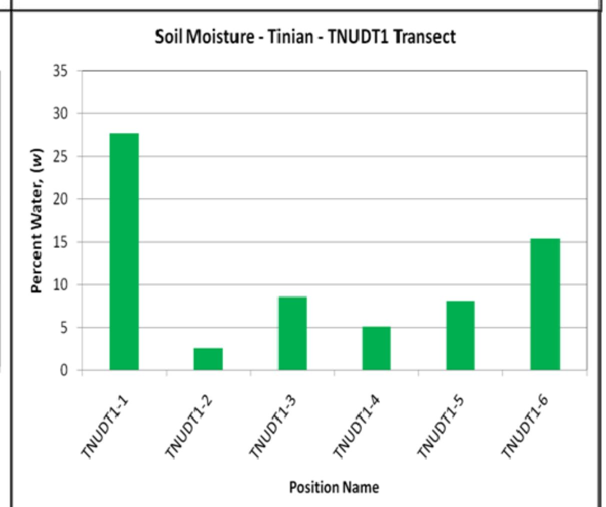

Soil Moisture - Pagan - PAB4T1 Transect
Percent Water, (w)
0
5
10
15
20
25
30
35
PAB4T1-1
PAB4T1-2
PAB4T1-3
Position Name

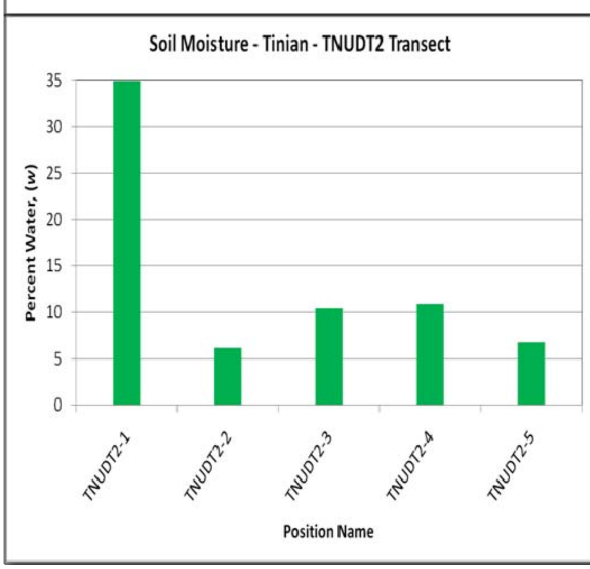

Soil Moisture - Pagan - PAB4T2 Transect
Percent Water, (w)
0
5
10
15
20
25
30
35
PAB4T2-2
PAB4T2-3
Position Name

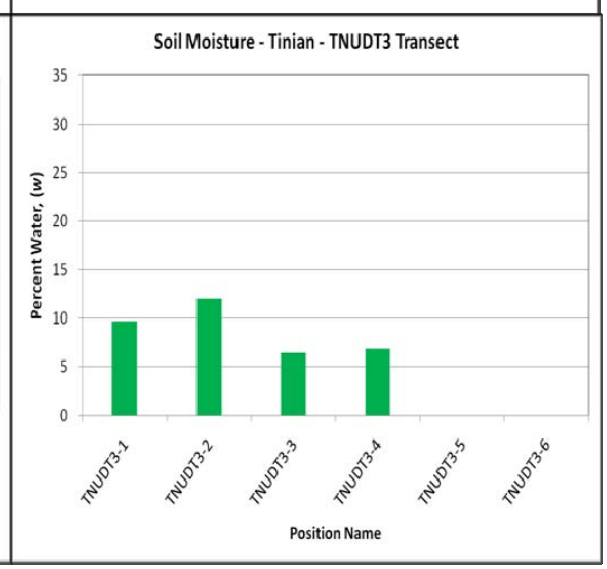

Soil Moisture - Pagan - PAB4T3 Transect
Percent Water, (w)
Position Name
PAB4T3-1
PAB4T3-2
PAB4T3-3
PAB4T3-4

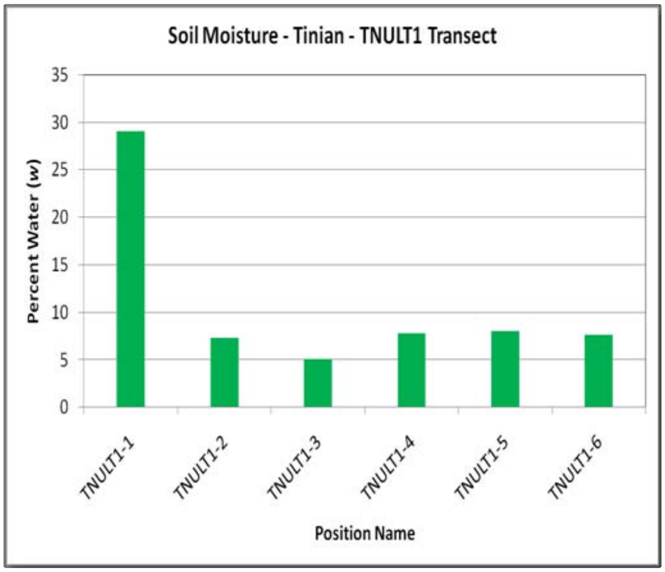

Soil Moisture - Pagan - PAB4T4 Transect
Percent Water, (w)
Position Name
PAB4T4-1
PAB4T4-2
PAB4T4-3
PAB4T4-4


Soil Moisture - Tinian - TNUBT1 Transect
Percent Water, (w)
Position Name


Soil Moisture - Tinian - TNUDT1 Transect
Percent Water, (w)
Position Name


Soil Moisture - Tinian - TNUDT2 Transect
Percent Water, (w)
Position Name


Soil Moisture - Tinian - TNUDT3 Transect
Percent Water, (w)
Position Name


Soil Moisture - Tinian - TNULT1 Transect
Percent Water (w)
35
30
25
20
15
10
5
0
TNULT1-1
TNULT1-2
TNULT1-3
TNULT1-4
TNULT1-5
TNULT1-6
Position Name

5 Soil Grain Size Distribution

5.1 Tabular Data

Grain size distribution data are listed on the following pages. The sample name, date, and island where the position was sampled are listed in the first three columns. The following columns list the sieve sizes (in µm) used in the grain size analysis of the samples. The column titled “Pan” is the bottom of the sieve stack and is a solid container. Values in this table are the percent of sample caught in the sieve.

Soil Grain Size Distribution Percent																						
Sample Name	**Date**	**Island**	**50000 µm**	**37500 µm**	**25000 µm**	**19000 µm**	**9500 µm**	**4750 µm**	**2360 µm**	**1180 µm**	**600 µm**	**425 µm**	**300 µm**	**150 µm**	**106 µm**	**90 µm**	**75 µm**	**63 µm**	**45 µm**	**25 µm**	**PAN**	**Total**
GUDT1-1	10-Mar-10	Guam	0	0	0	4	13	13	12	8	15	15	11	8	1 0	0		0	0	0	0	100
GUDT1-2	10-Mar-10	Guam	0	0	11	2	8	9	12	9	19	14	8	7	1 0	0		0	0	0	0	100
GUDT1-3	10-Mar-10	Guam	0	0	0	4	15	24	12	3	8	12	12	10	0	0	0	0	0 0		0	100
GUDT1-4	10-Mar-10	Guam	0	0	0	6	18	13	7	5	10	14	14	11	1	0	0	0	0 0		0	100
GUDT1-5	10-Mar-10	Guam	0	0	3	7	17	22	12	3	7	12	10	7	0 0	0		0	0	0	0	100
GUDT1-6	10-Mar-10	Guam	0	0	0	0	0	0	0	0	2	8	28	60	1	0	0	0	0 0		0	100
GUDT1-7	10-Mar-10	Guam	0	0	0	4	1	1	0	0	2	6	22	61	2	0	0	0	0 0		0	100
GUDT1-8	10-Mar-10	Guam	0	0	0	2	1	1	1	1	4	9	26	53	1	0	0	0	0 0		0	100
GUDT1-9	10-Mar-10	Guam	0	0	0	0	1	0	0	1	4	10	30	53	1	0	0	0	0 0		0	100
GUDT1-10	10-Mar-10	Guam	0	10	6	2	18	3	1	1	3	7	13	36	1	0	0	0	0 0		0	100
GUDT1-11	10-Mar-10	Guam	0	0	33	5	18	8	2	1	3	5 9		16	0	0	0	0	0 0		0	100

Soil Grain Size Distribution Percent																						
Sample Name	**Date**	**Island**	**50000 µm**	**37500 µm**	**25000 µm**	**19000 µm**	**9500 µm**	**4750 µm**	**2360 µm**	**1180 µm**	**600 µm**	**425 µm**	**300 µm**	**150 µm**	**106 µm**	**90 µm**	**75 µm**	**63 µm**	**45 µm**	**25 µm**	**PAN**	**Total**
GUTT1-5	10-Mar-10	Guam	0	0	0	0	0	5	10	17	30	22	14	2	0 0	0		0	0	0	0	100
GUTT1-6	10-Mar-10	Guam	0	0	0	0	25	16	8	13	19	11	6	1	0 0	0		0	0	0	0	100
GUTT1-7	10-Mar-10	Guam	0	0	0	0	7	9	11	11	20	18	17	5	0 0	0		0	0	0	0	100

Soil Grain Size Distribution Percent																					
Sample Name	**Date**	**Island**	**50000 µm**	**37500 µm**	**25000 µm**	**19000 µm**	**9500 µm**	**4750 µm**	**2360 µm**	**1180 µm**	**600 µm**	**425 µm**	**300 µm**	**150 µm**	**106 µm**	**90 µm**	**75 µm**	**63 µm**	**45 µm**	**25 µm**	**PAN**	**Total**
PAB1T1-1	2-Mar-10	Pagan	0	0	0	0	0	0	3	33	63	0	0	0 0		0	0	0	0	0	0	100
PAB1T1-2	2-Mar-10	Pagan	0	0	0	0	1	1	11	56	30	0	0	0	0	0	0	0	0 0		0	100
PAB1T1-3	2-Mar-10	Pagan	0	0	0	0	0	1	11	35	51	1	0	0	0	0	0	0	0 0		0	100
PAB1T1-4	2-Mar-10	Pagan	0	0	0	0	0	1	8	44	47	1	0	0 0		0	0	0	0	0	0	100
PAB1T1-5	2-Mar-10	Pagan	0	0	0	0	0	1	19	50	29	0	0	0	0	0	0	0	0 0		0	100
PAB1T1-6	2-Mar-10	Pagan	0	0	0	0	0	4	8	27	57	3	0	0 0		0	0	0	0	0	0	100
PAB1T1-7	2-Mar-10	Pagan	0	0	0	0	0	1	18	48	29	3	0	0	0	0	0	0	0 0		0	100

Soil Grain Size Distribution Percent																					
Sample Name	**Date**	**Island**	**50000 µm**	**37500 µm**	**25000 µm**	**19000 µm**	**9500 µm**	**4750 µm**	**2360 µm**	**1180 µm**	**600 µm**	**425 µm**	**300 µm**	**150 µm**	**106 µm**	**90 µm**	**75 µm**	**63 µm**	**45 µm**	**25 µm**	**PAN**	**Total**
PAB1T2-1	2-Mar-10	Pagan	0	0	0	0 0	0		0	8	92	0	0 0		0	0	0	0	0	0	0	100
PAB1T2-2	2-Mar-10	Pagan	0	0	0	0 0		22	22	29	25	1	0 0		0	0	0	0	0	0	0	100
PAB1T2-3	2-Mar-10	Pagan	0	0	0	0 0	0		1	30	63	6	1 0		0	0	0	0	0	0	0	100
PAB1T2-4	2-Mar-10	Pagan	0	0	0	0 0	1		9	47	39	3	1 1		0	0	0	0	0	0	0	100
PAB1T2-5	2-Mar-10	Pagan	0	0	0	0 0	1		10	54	32	2	0 0		0	0	0	0	0	0	0	100
PAB1T2-6	2-Mar-10	Pagan	0	0	0	0 0		24	26	27	24	0	0 0		0	0	0	0	0	0	0	100

Soil Grain Size Distribution Percent																						
Sample Name	**Date**	**Island**	**50000 µm**	**37500 µm**	**25000 µm**	**19000 µm**	**9500 µm**	**4750 µm**	**2360 µm**	**1180 µm**	**600 µm**	**425 µm**	**300 µm**	**150 µm**	**106 µm**	**90 µm**	**75 µm**	**63 µm**	**45 µm**	**25 µm**	**PAN**	**Total**
PAB2T1-1	28-Feb-10	Pagan	0	0	0	0	0 0		2	68	30	0	0 0		0	0 0		0	0	0	0	100
PAB2T1-2	28-Feb-10	Pagan	0	0	0	0	0 0		14	45	38	2	0 0		0	0 0		0	0	0	0	100
PAB2T1-3	28-Feb-10	Pagan	0	0	0	0	0 0		4	20	44	19	7	3	0	0 2		0	0	0	0	100
PAB2T1-4	28-Feb-10	Pagan	0	0	0	0	0 1		14	41	29	9	3 2		0	0 0		0	0	0	0	100
PAB2T1-5	28-Feb-10	Pagan	0	0	0	0	2 2		12	41	31	8	2 1		0	0 0		0	0	0	0	100
PAB2T1-6	28-Feb-10	Pagan	0	0	0	0	0 1		11	44	29	8	4 2		0	0 0		0	0	0	0	100
PAB2T1-7	28-Feb-10	Pagan	0	0	0	0	0 1		9	29	33	15	9	4	0	0 0		0	0	0	0	100
PAB2T1-8	28-Feb-10	Pagan	0	0	0	0	0 1		9	37	32	11	6	3	0	0 0		0	0	0	0	100
PAB2T1-9	1-Mar-10	Pagan	0	0	0	0	0 0		4	30	36	14	8	5	1	0 0		0	0	0	0	100

Soil Grain Size Distribution Percent																								
Sample Name	**Date**	**Island**	**50000 µm**	**37500 µm**	**25000 µm**	**19000 µm**	**9500 µm**	**4750 µm**	**2360 µm**	**1180 µm**	**600 µm**	**425 µm**	**300 µm**	**150 µm**	**106 µm**	**90 µm**	**75 µm**	**63 µm**	**45 µm**	**25 µm**	**PAN**	**Total**
PAB2T2-0	28-Feb-10	Pagan	0	0	0	0	0 0		0	11	50	18	11	8	1	0 0		0	0	0	0	100
PAB2T2-1	28-Feb-10	Pagan	0	0	0	0	0 0		1	30	53	8	4 4		0	0 0		0	0	0	0	100
PAB2T2-2	28-Feb-10	Pagan	0	0	0	0	0 0		3	27	46	14	7	3	0	0 0		0	0	0	0	100
PAB2T2-3	28-Feb-10	Pagan	0	0	0	0	0 0		4	36	41	12	5	2	0	0 0		0	0	0	0	100
PAB2T2-4	28-Feb-10	Pagan	0	0	0	0	0 1		9	40	34	10	4	2	0	0 0		0	0	0	0	100
PAB2T2-5	1-Mar-10	Pagan	0	0	0	0	1 3		23	38	22	7	4 2		0	0 0		0	0	0	0	100
PAB2T2-6	1-Mar-10	Pagan	0	0	0	1	1 5		21	42	20	5	2 1		0	0 0		0	0	0	0	100
PAB2T2-7	1-Mar-10	Pagan	0	0	0	0	1 5		20	34	21	8	5 3		0	0 0		0	0	0	0	100
PAB2T2-8	1-Mar-10	Pagan	0	0	0	0	0 9		22	23	23	10	6	4	1	0 0		0	0	0	0	100
PAB2T2-9	1-Mar-10	Pagan	0	0	0	0	0 0		9	43	28	10	6	3	0	0 0		0	0	0	0	100

Soil Grain Size Distribution Percent																						
Sample Name	Date	Island	50000 µm	37500 µm	25000 µm	19000 µm	9500 µm	4750 µm	2360 µm	1180 µm	600 µm	425 µm	300 µm	150 µm	106 µm	90 µm	75 µm	63 µm	45 µm	25 µm	PAN	Total
PAB2T3-1	28-Feb-10	Pagan	0	0	0	0	0 0		8	34	28	12	7	9	1	0 0		0	0	0	0	100
PAB2T3-2	28-Feb-10	Pagan	0	0	0	0	0 1		2	4	25	29	22	15	1	0 0		0	0	0	0	100
PAB2T3-3	28-Feb-10	Pagan	0	0	0	0	1	12	26	36	20	2	1 1		0	0 0		0	0	0	0	100
PAB2T3-4	28-Feb-10	Pagan	0	0	0	0	0 7		28	34	19	6	3 2		0	0 0		0	0	0	0	100
PAB2T3-5	28-Feb-10	Pagan	0	0	0	0	0 3		7	15	24	22	17	11	1	0 0		0	0	0	0	100
PAB2T3-6	28-Feb-10	Pagan	0	0	0	0	0 2		4	27	40	14	7	5	1	0 0		0	0	0	0	100
PAB2T3-7	28-Feb-10	Pagan	0	0	0	0	0 0		2	13	39	23	13	8	1	0 0		0	0	0	0	100
PAB2T3-8	28-Feb-10	Pagan	0	0	0	0	0 1		5	10	25	21	19	16	2	0 0		0	0	0	0	100
PAB2T3-9	28-Feb-10	Pagan	0	0	0	0	0 0		6	25	68	0	0 0		0	0 0		0	0	0	0	100

Soil Grain Size Distribution Percent																						
Sample Name	Date	Island	50000 µm	37500 µm	25000 µm	19000 µm	9500 µm	4750 µm	2360 µm	1180 µm	600 µm	425 µm	300 µm	150 µm	106 µm	90 µm	75 µm	63 µm	45 µm	25 µm	PAN	Total
PAB2T4-1	28-Feb-10	Pagan	0	0	0	0	1 4		5	5	31	30	15	9	0	0 0		0	0	0	0	100
PAB2T4-2	28-Feb-10	Pagan	0	0	0	0	0 0		0	3	30	34	21	11	0	0 0		0	0	0	0	100
PAB2T4-3	28-Feb-10	Pagan	0	0	0	0	0 1		5	22	36	20	10	6	0	0 0		0	0	0	0	100
PAB2T4-4	28-Feb-10	Pagan	0	0	0	0	0 0		5	22	35	18	11	7	1	0 0		0	0	0	0	100
PAB2T4-5	28-Feb-10	Pagan	0	0	0	0	0 4		10	22	30	15	9	7	1	0 0		0	0	0	0	100
PAB2T4-6	28-Feb-10	Pagan	0	0	0	0	0 1		4	11	25	20	18	16	2	0 0		0	1	1	0	100

Soil Grain Size Distribution Percent																						
Sample Name	**Date**	**Island**	**50000 µm**	**37500 µm**	**25000 µm**	**19000 µm**	**9500 µm**	**4750 µm**	**2360 µm**	**1180 µm**	**600 µm**	**425 µm**	**300 µm**	**150 µm**	**106 µm**	**90 µm**	**75 µm**	**63 µm**	**45 µm**	**25 µm**	**PAN**	**Total**
PAB2T5-1	1-Mar-10	Pagan	0	0	0	3	10	12	42	32	0	0	0	0	0	0	0	0	0	0	0	100
PAB2T5-2	1-Mar-10	Pagan	0	0	0	0	0 1		2	40	45	6	3	3	0	0	0	0	0	0	0	100
PAB2T5-3	1-Mar-10	Pagan	0	0	0	0	0 0		8	32	36	14	6	3	0	0	0	0	0	0	0	100
PAB2T5-4	1-Mar-10	Pagan	0	0	0	0	0 0		2	9	33	28	19	8	0	0	0	0	0	0	0	100
PAB2T5-5	1-Mar-10	Pagan	0	0	0	0	0 1		4	31	36	13	8	6	1	0	0	0	0	0	0	100
PAB2T5-6	1-Mar-10	Pagan	0	0	0	0	2 3		11	43	24	8	5	3	0	0	0	0	0	0	0	100
PAB2T5-7	1-Mar-10	Pagan	0	0	0	0	1 1		10	49	27	6	2	3	0	0	0	0	0	0	0	100
PAB2T5-8	1-Mar-10	Pagan	0	0	0	0	1 8		21	21	21	10	8	8	1	0	0	0	0	0	0	100
PAB2T5-9	1-Mar-10	Pagan	0	0	0	0	0 1		6	23	34	17	9	7	1	0	0	0	0	0	0	100

Soil Grain Size Distribution Percent																								
Sample Name	**Date**	**Island**	**50000 µm**	**37500 µm**	**25000 µm**	**19000 µm**	**9500 µm**	**4750 µm**	**2360 µm**	**1180 µm**	**600 µm**	**425 µm**	**300 µm**	**150 µm**	**106 µm**	**90 µm**	**75 µm**	**63 µm**	**45 µm**	**25 µm**	**PAN**	**Total**		
PAB2T6-1	1-Mar-10	Pagan	0	0	5	5	3 7		48	31	1	0	0	0	0	0	0	0	0	0	0	100		
PAB2T6-2	1-Mar-10	Pagan	0	0	0	0	0 1		17	63	16	2	1	0	0	0	0	0	0	0	0	100		
PAB2T6-3	1-Mar-10	Pagan	0	0	0	0	0 1		7	22	35	18	10	6	0	0	0	0	0	0	0	100		
PAB2T6-4	1-Mar-10	Pagan	0	0	0	0	0 0		2	15	34	21	17	11	1	0	0	0	0	0	0	100		
PAB2T6-5	1-Mar-10	Pagan	0	0	0	0	1 3		6	28	32	14	9	6	0	0	0	0	0	0	0	100		
PAB2T6-6	1-Mar-10	Pagan	0	0	0	0	0 6		21	30	23	9	6	5	1	0	0	0	0	0	0	100		
PAB2T6-7	1-Mar-10	Pagan	0	0	0	0	0 7		8	18	29	15	11	10	1	0	0	0	0	0	0	100		
PAB2T6-8	1-Mar-10	Pagan	0	0	0	0	0 3		6	20	25	16	13	13	2	0	0	0	0	0	0	100		
PAB2T6-9	1-Mar-10	Pagan	0	0	0	0	1 3		11	25	27	11	9	10	1	0	0	0	0	0	0	100		

Soil Grain Size Distribution Percent																						
Sample Name	Date	Island	50000 µm	37500 µm	25000 µm	19000 µm	9500 µm	4750 µm	2360 µm	1180 µm	600 µm	425 µm	300 µm	150 µm	106 µm	90 µm	75 µm	63 µm	45 µm	25 µm	PAN	Total
PAB4T1-1	27-Feb-10	Pagan	0	0	0	0	0	0	0	1	55	29	11	4	0	0	0	0	0	0	0	100
PAB4T1-2	27-Feb-10	Pagan	0	0	0	0	0	0	0	3	58	34	4	1	0	0	0	0	0	0	0	100
PAB4T1-3	27-Feb-10	Pagan	0	0	0	0	0	0	1	10	71	16	1	0	0	0	0	0	0	0	0	100
PAB4T2-2	27-Feb-10	Pagan	0	0	0	0	0	0	0	0	43	42	13	3	0	0	0	0	0	0	0	100
PAB4T2-3	27-Feb-10	Pagan	0	0	0	0	0	0	0	5	72	21	2	0	0	0	0	0	0	0	0	100

Soil Grain Size Distribution Percent																						
Sample Name	Date	Island	50000 µm	37500 µm	25000 µm	19000 µm	9500 µm	4750 µm	2360 µm	1180 µm	600 µm	425 µm	300 µm	150 µm	106 µm	90 µm	75 µm	63 µm	45 µm	25 µm	PAN	Total
PAB4T3-1	1-Mar-10	Pagan	0	0	0	0	0	0	0	5	64	7	12	10	0	0	0	0	0	0	0	100
PAB4T3-2	1-Mar-10	Pagan	0	0	0	0	0	0	1	14	74	9	1	0	0	0	0	0	0	0	0	100
PAB4T3-3	1-Mar-10	Pagan	0	0	0	0	0	0	0	12	80	6	1	1	0	0	0	0	0	0	0	100
PAB4T3-4	1-Mar-10	Pagan	0	0	0	0	1	6	5	10	46	10	4	5	3	3	2	2	1	1	0	100

Soil Grain Size Distribution Percent																						
Sample Name	Date	Island	50000 µm	37500 µm	25000 µm	19000 µm	9500 µm	4750 µm	2360 µm	1180 µm	600 µm	425 µm	300 µm	150 µm	106 µm	90 µm	75 µm	63 µm	45 µm	25 µm	PAN	Total
PAB4T4-1	1-Mar-10	Pagan	0	0	0	0	0	0	0	1	77	12	7	3	0	0	0	0	0	0	0	100
PAB4T4-2	1-Mar-10	Pagan	0	0	0	0	0	0	0	18	78	4	0	0	0	0	0	0	0	0	0	100
PAB4T4-3	1-Mar-10	Pagan	0	0	0	0	0	0	1	34	62	3	0	0	0	0	0	0	0	0	0	100
PAB4T4-4	1-Mar-10	Pagan	1	0	0	0	0	0	1	14	58	13	6	4	1	0	0	0	1	1	0	100

Soil Grain Size Distribution Percent																						
Sample Name	**Date**	**Island**	**50000 µm**	**37500 µm**	**25000 µm**	**19000 µm**	**9500 µm**	**4750 µm**	**2360 µm**	**1180 µm**	**600 µm**	**425 µm**	**300 µm**	**150 µm**	**106 µm**	**90 µm**	**75 µm**	**63 µm**	**45 µm**	**25 µm**	**PAN**	**Total**
TNUBT1-1	5-Mar-10	Tinian	0	0	0	0	0 1	1 2			22	41	30	3	0 0	0		0	0 0	0		100
TNUBT1-2	5-Mar-10	Tinian	0	0	0	0	0 0	0 0			13	40	41	6	0 0	0		0	0 0	0		100
TNUBT1-3	5-Mar-10	Tinian	0	0	0	0	3 1	0 1			25	47	22	2	0 0	0		0	0 0	0		100
TNUBT1-4	5-Mar-10	Tinian	0	0	0	0	3 1	2 4			42	29	14	4	0 0	0		0	0 0	0		100
TNUBT1-5	5-Mar-10	Tinian	0	0	0	0	0 0	0 1			17	42	34	5	0 0	0		0	0 0	0		100
TNUBT1-7	5-Mar-10	Tinian	0	0	0	0	0 0	0 0 8				36	47	9	0 0	0		0	0 0	0		100
TNUBT1-8	5-Mar-10	Tinian	0	0	0	0	0 0	0 1			28	37	29	4	0 0	0		0	0 0	0		100
TNUBT1-9	5-Mar-10	Tinian	0	0	0	0	0 0	0 1			21	39	34	5	0 0	0		0	0 0	0		100
TNUBT1-10	5-Mar-10	Tinian	0	0	4	0	16	8	3 7		59	3	0 0	0 0 0				0	0 0	0		100
TNUBT1-11	5-Mar-10	Tinian	0	0	0	0	1 1	1 2			24	36	31	5	0 0	0		0	0 0	0		100
TNUBT1-12	5-Mar-10	Tinian	0	0	0	4	32	42	17	3	1	0	0 0	0 0 0				0	0 0	0		100
TNUBT1-13	5-Mar-10	Tinian	0	0	4	9	13	7	3 4		35	19	5	0 0	0 0			0	0 0	0		100
TNUBT1-14	5-Mar-10	Tinian	0	0	0	0	7 2	1 2			36	34	16	1	0 0	0		0	0 0	0		100
TNUBT1-15	5-Mar-10	Tinian	0	0	0	0	0 0	0 0			11	40	42	7	0 0	0		0	0 0	0		100

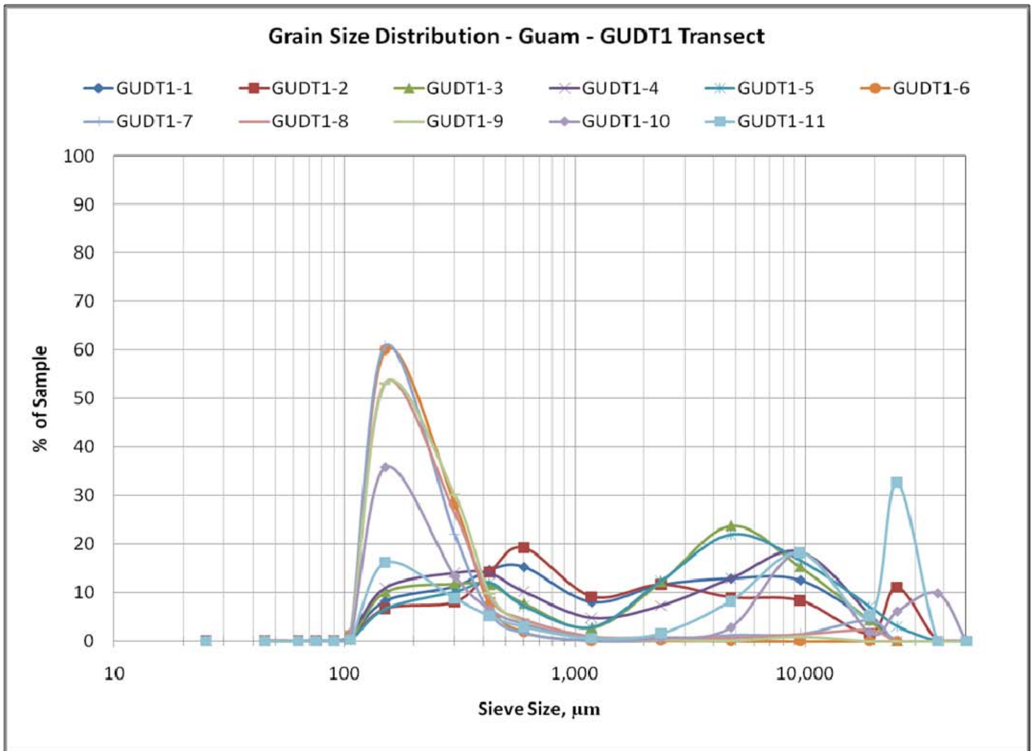
Sample Name	Date	Island	50000 µm	37500 µm	25000 µm	19000 µm	9500 µm	4750 µm	2360 µm	1180 µm	600 µm	425 µm	300 µm	150 µm	106 µm	90 µm	75 µm	63 µm	45 µm	25 µm	PAN	Total
Soil Grain Size Distribution Percent																						
TNUDT1-1	6-Mar-10	Tinian	0	0	0	0	3	8	12	17	37	9	10	5	0	0	0 0	0 0			0	100
TNUDT1-2	6-Mar-10	Tinian	0	0	28	2	18	46	5	0	0	0	0	0	0	0	0 0	0 0			0	100
TNUDT1-3	6-Mar-10	Tinian	0	0	0	14	9	5	9	13	29	10	8	3	0	0	0 0	0 0			0	100
TNUDT1-4	6-Mar-10	Tinian	0	0	14	5	21	24	12	4	13	5	2	1	0	0	0 0	0 0			0	100
TNUDT1-5	6-Mar-10	Tinian	0	0	0	3	7	9	7	7	26	17	18	6	0	0	0 0	0 0			0	100
TNUDT1-6	6-Mar-10	Tinian	0	0	0	0 3		6	7	8	30	14	20	10	0	0	0	0	0	0	0	100
Soil Grain Size Distribution Percent																						
Sample Name	**Date**	**Island**	**50000 µm**	**37500 µm**	**25000 µm**	**19000 µm**	**9500 µm**	**4750 µm**	**2360 µm**	**1180 µm**	**600 µm**	**425 µm**	**300 µm**	**150 µm**	**106 µm**	**90 µm**	**75 µm**	**63 µm**	**45 µm**	**25 µm**	**PAN**	**Total**
TNUDT2-1	6-Mar-10	Tinian	0	0	0	3	0	3	10	17	37	10	13	7	0	0	0 0	0 0			0	100
TNUDT2-2	6-Mar-10	Tinian	0	0	0	0	10	43	33	6	6	1	0	0	0	0	0 0	0 0			0	100
TNUDT2-3	6-Mar-10	Tinian	0	0	0	0	3	12	13	11	32	13	12	4	0	0	0 0	0 0			0	100
TNUDT2-4	6-Mar-10	Tinian	0	0	6	0	1	2	5	15	37	16	14	4	0	0	0 0	0 0			0	100
TNUDT2-5	6-Mar-10	Tinian	0	0	0	0	0	1	1	9	55	20	11	2	0	0	0 0	0 0			0	100

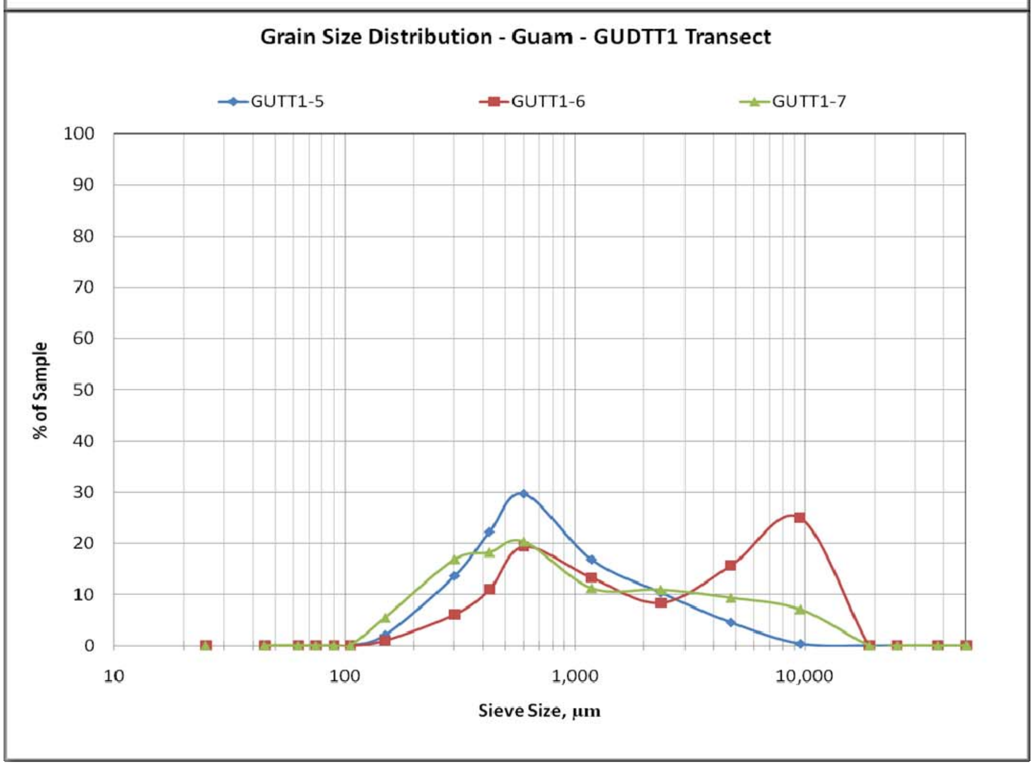
Soil Grain Size Distribution Percent																						
Sample Name	**Date**	**Island**	**50000 µm**	**37500 µm**	**25000 µm**	**19000 µm**	**9500 µm**	**4750 µm**	**2360 µm**	**1180 µm**	**600 µm**	**425 µm**	**300 µm**	**150 µm**	**106 µm**	**90 µm**	**75 µm**	**63 µm**	**45 µm**	**25 µm**	**PAN**	**Total**
TNUDT3-1	7-Mar-10	Tinian	0	0	0	0	0	11	46	35	8	0	0	0	0 0	0 0			0	0	0	100
TNUDT3-2	7-Mar-10	Tinian	0	0	0	0	3	8	7	25	52	5	0	0	0 0	0 0			0	0	0	100
TNUDT3-3	7-Mar-10	Tinian	0	0	0	8	10	16	8	11	25	12	9	1	0 0	0 0			0	0	0	100
TNUDT3-4	7-Mar-10	Tinian	0	0	0	0	7	6	15	26	35	7	3	1	0 0	0 0			0	0	0	100
TNUDT3-5	7-Mar-10	Tinian	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A N/A	N/A		N/A	N/A	N/A	N/A	N/A
TNUDT3-6	7-Mar-10	Tinian	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A N/A	N/A		N/A	N/A	N/A	N/A	N/A

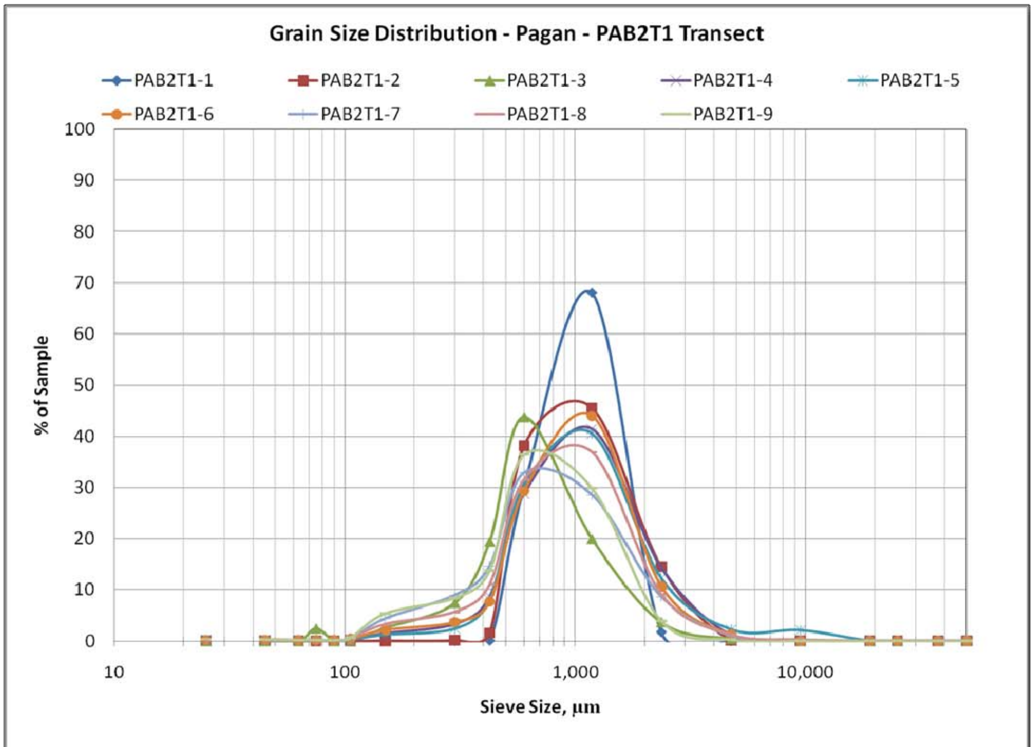
Soil Grain Size Distribution Percent																						
Sample Name	**Date**	**Island**	**50000 µm**	**37500 µm**	**25000 µm**	**19000 µm**	**9500 µm**	**4750 µm**	**2360 µm**	**1180 µm**	**600 µm**	**425 µm**	**300 µm**	**150 µm**	**106 µm**	**90 µm**	**75 µm**	**63 µm**	**45 µm**	**25 µm**	**PAN**	**Total**
TNULT1-1	7-Mar-10	Tinian	0	0	0	0	1	0	1	4	83	8	1	1	0 0	0 0			0	0	0	100
TNULT1-2	7-Mar-10	Tinian	0	0	18	2	5	3	8	21	41	1	0	0	0 0	0 0			0	0	0	100
TNULT1-3	7-Mar-10	Tinian	0	15	20	9	23	17	4	4	7	1	0	0	0 0	0 0			0	0	0	100
TNULT1-4	7-Mar-10	Tinian	0	0	0	0	0	0	0	7	65	17	7	4	0 0	0 0			0	0	0	100
TNULT1-5	7-Mar-10	Tinian	0	0	0	0	0	0	0	7	70	17	5	1	0 0	0 0			0	0	0	100
TNULT1-6	7-Mar-10	Tinian	28	0	16	8	14	7	4	4	14	3	1	1	0 0	0 0			0	0	0	100

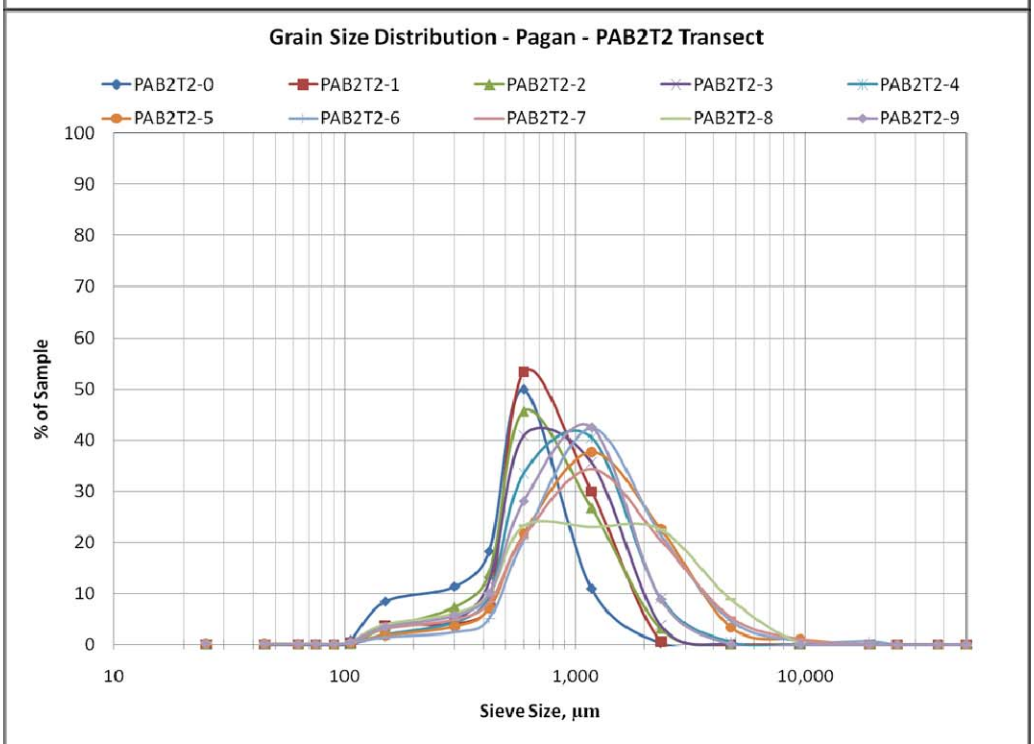
5.2 Grain Size Distribution Graphs

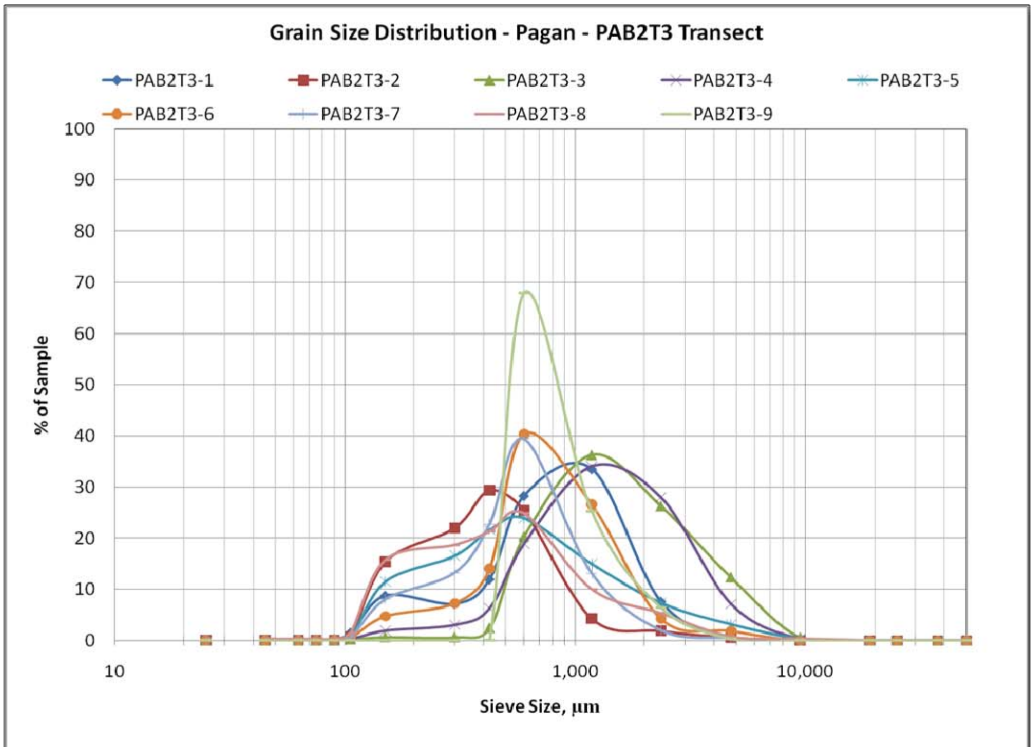
Graphs below present % of sample on the *y*-axis and sieve size (in µm) along the *x*-axis. The *x*-axis presents sieve size in logarithmic scale and each point along the line represents a sieve size. This is done to show the entire suite of sieve sizes used in grain size distribution analysis undertaken during the MI-HARES'10 experiment. Graphs are listed in alphabetical order by transect name.


Grain Size Distribution - Guam - GUDT1 Transect
GUDT1-1
GUDT1-2
GUDT1-3
GUDT1-4
GUDT1-5
GUDT1-6
GUDT1-7
GUDT1-8
GUDT1-9
GUDT1-10
GUDT1-11
% of Sample
Sieve Size, μm
10
100
1,000
10,000

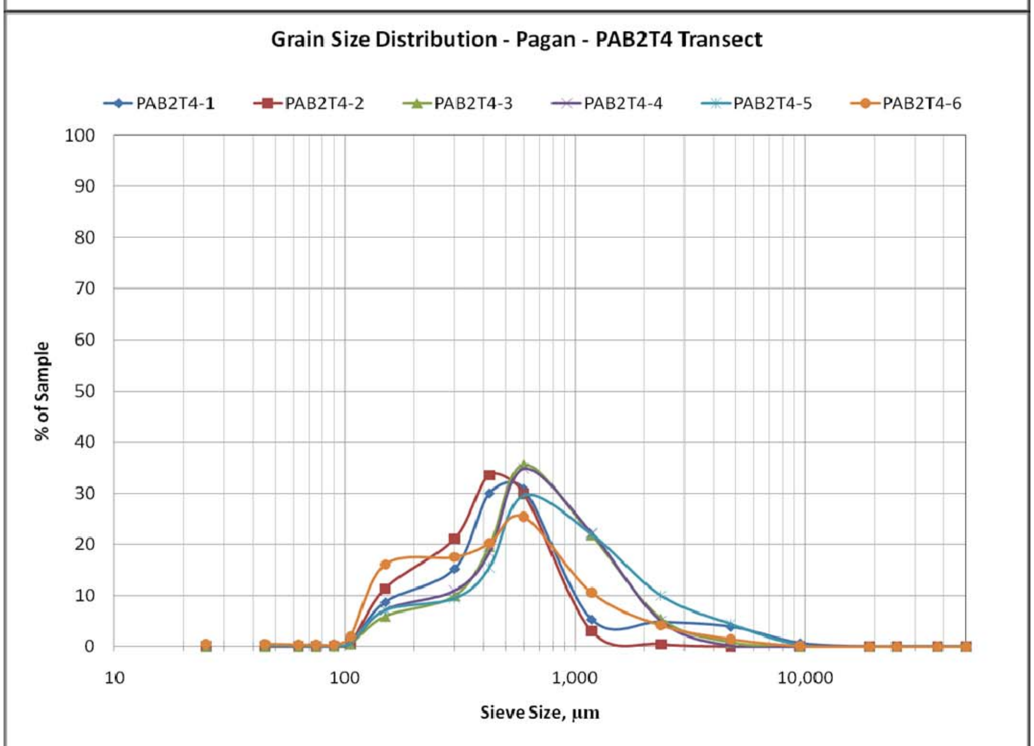

Grain Size Distribution - Guam - GUDTT1 Transect
GUTT1-5
GUTT1-6
GUTT1-7
% of Sample
Sieve Size, μm
10
100
1,000
10,000


Grain Size Distribution - Pagan - PAB2T1 Transect
PAB2T1-1
PAB2T1-2
PAB2T1-3
PAB2T1-4
PAB2T1-5
PAB2T1-6
PAB2T1-7
PAB2T1-8
PAB2T1-9
% of Sample
100
90
80
70
60
50
40
30
20
10
0
10
100
1,000
10,000
Sieve Size, µm

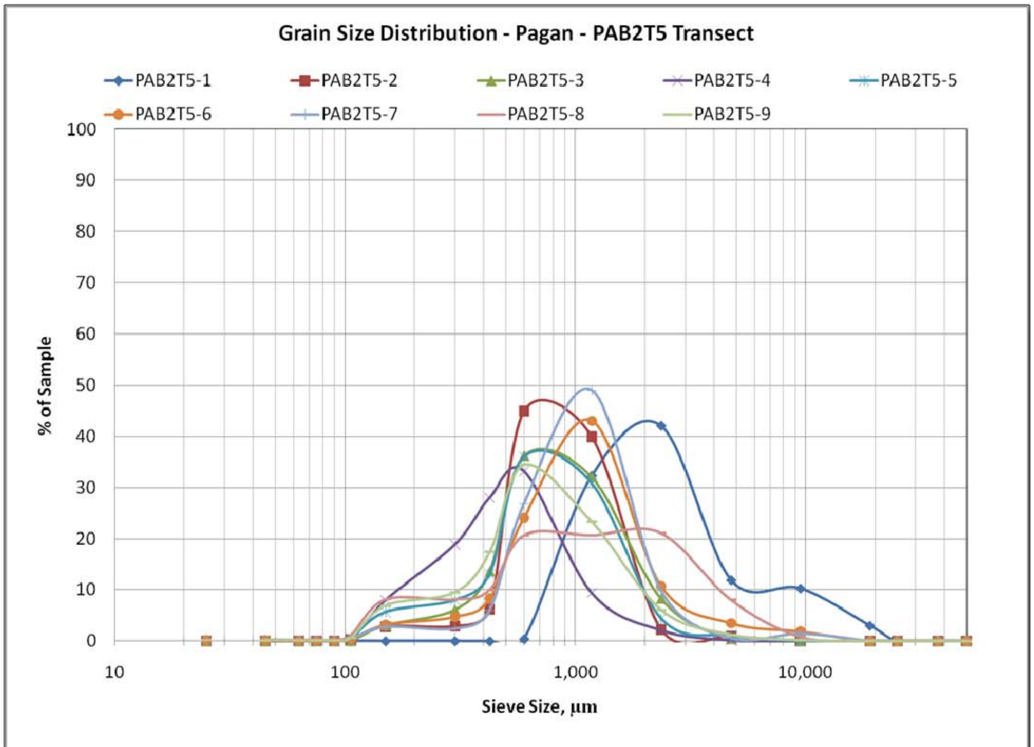

Grain Size Distribution - Pagan - PAB2T2 Transect
PAB2T2-0
PAB2T2-1
PAB2T2-2
PAB2T2-3
PAB2T2-4
PAB2T2-5
PAB2T2-6
PAB2T2-7
PAB2T2-8
PAB2T2-9
% of Sample
100
90
80
70
60
50
40
30
20
10
0
10
100
1,000
10,000
Sieve Size, µm

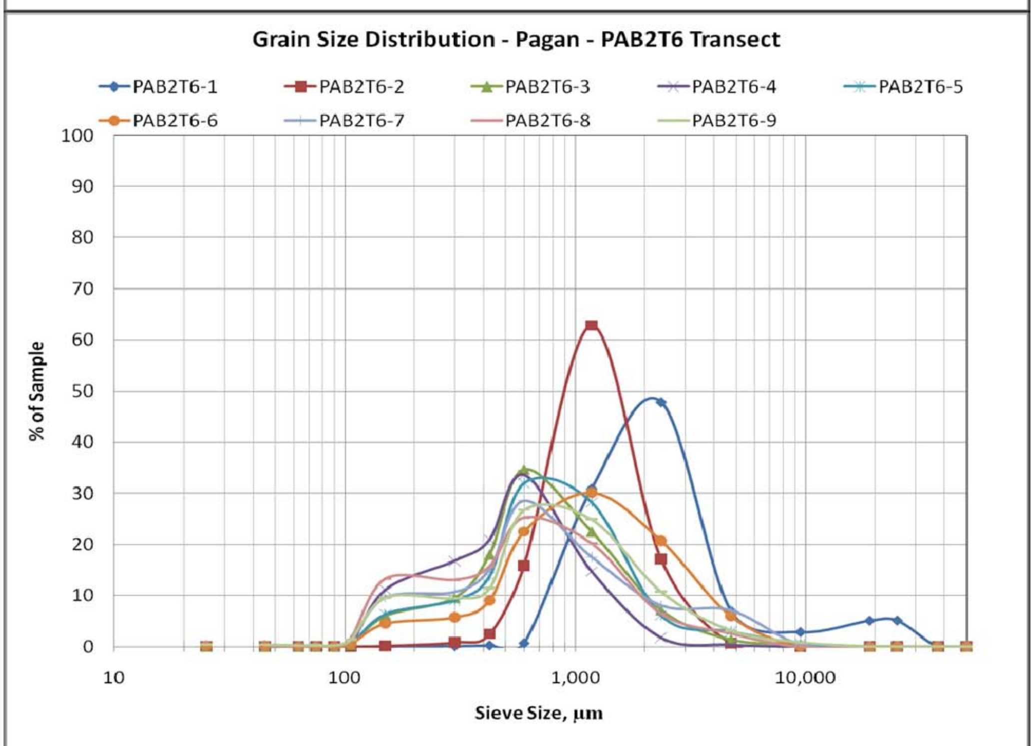


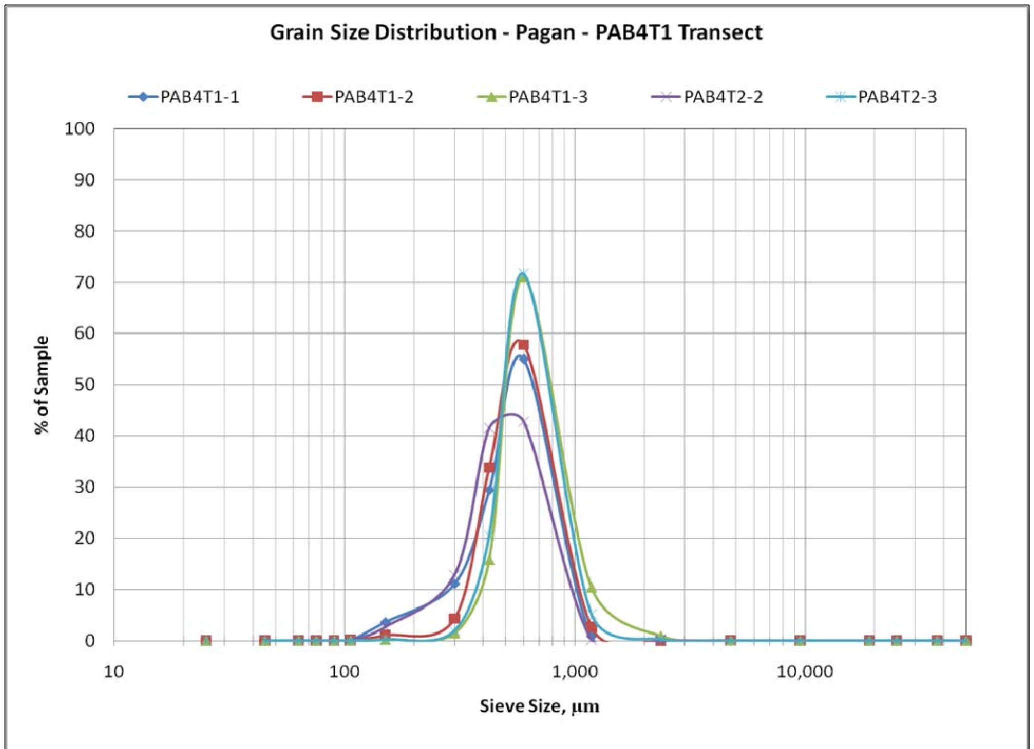
Grain Size Distribution - Pagan - PAB2T3 Transect
PAB2T3-1
PAB2T3-2
PAB2T3-3
PAB2T3-4
PAB2T3-5
PAB2T3-6
PAB2T3-7
PAB2T3-8
PAB2T3-9
% of Sample
Sieve Size, µm



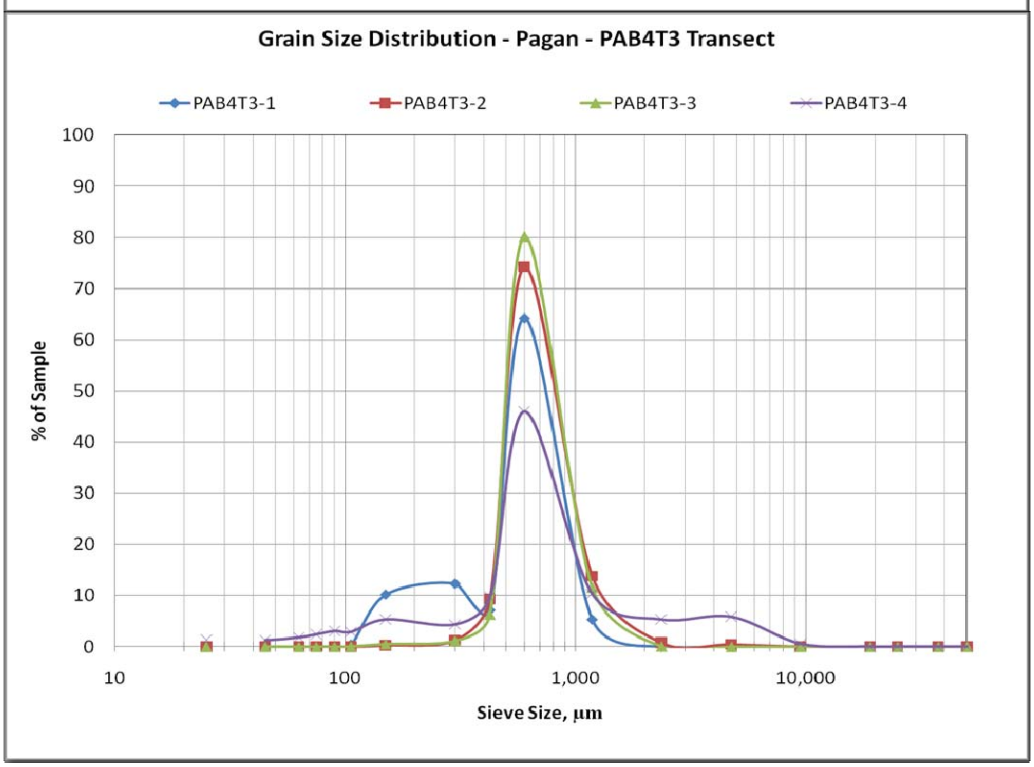
Grain Size Distribution - Pagan - PAB2T4 Transect
PAB2T4-1
PAB2T4-2
PAB2T4-3
PAB2T4-4
PAB2T4-5
PAB2T4-6
% of Sample
Sieve Size, µm


Grain Size Distribution - Pagan - PAB2T5 Transect
PAB2T5-1
PAB2T5-2
PAB2T5-3
PAB2T5-4
PAB2T5-5
PAB2T5-6
PAB2T5-7
PAB2T5-8
PAB2T5-9
% of Sample
Sieve Size, µm
10
100
1,000
10,000
0
10
20
30
40
50
60
70
80
90
100

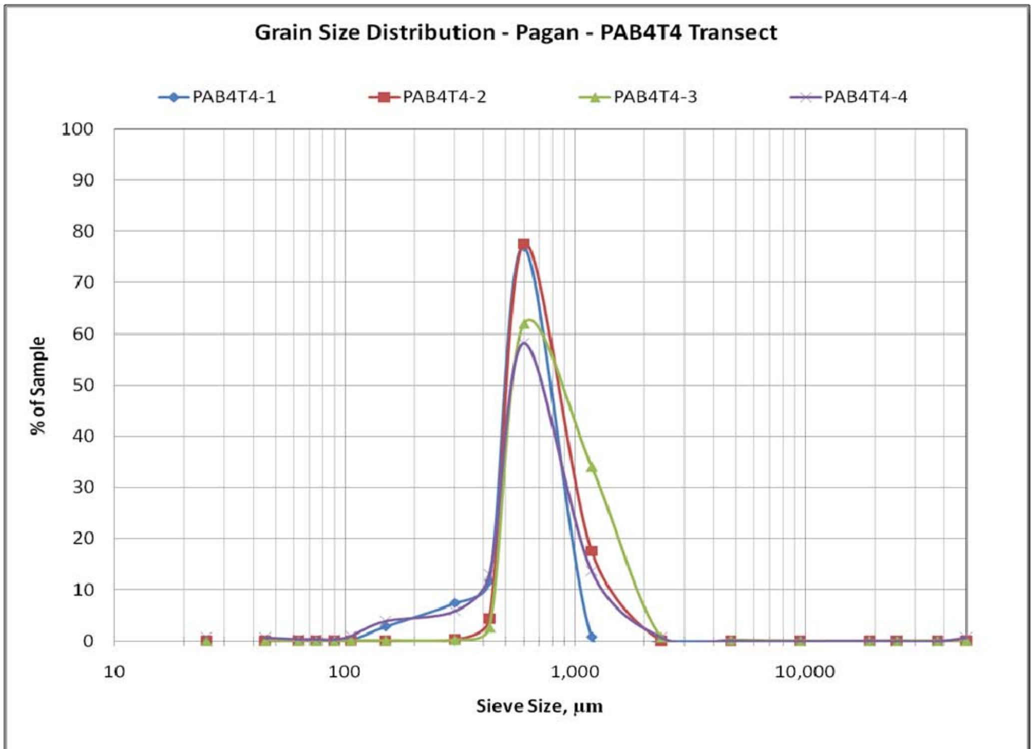

Grain Size Distribution - Pagan - PAB2T6 Transect
PAB2T6-1
PAB2T6-2
PAB2T6-3
PAB2T6-4
PAB2T6-5
PAB2T6-6
PAB2T6-7
PAB2T6-8
PAB2T6-9
% of Sample
Sieve Size, µm
10
100
1,000
10,000
0
10
20
30
40
50
60
70
80
90
100

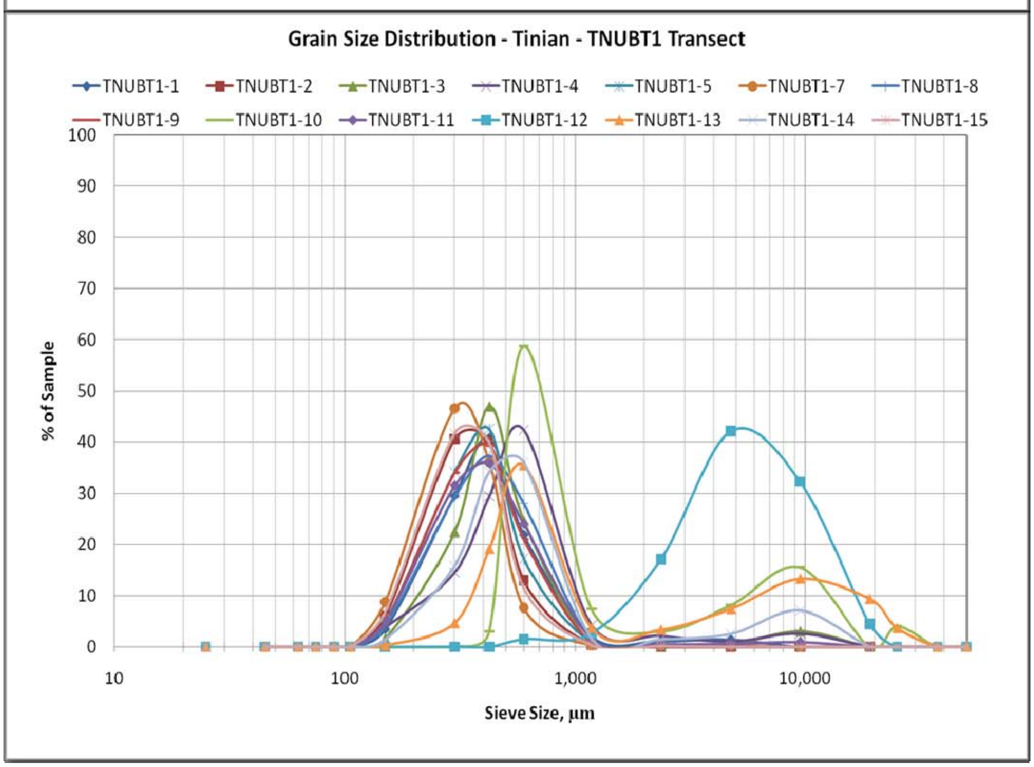


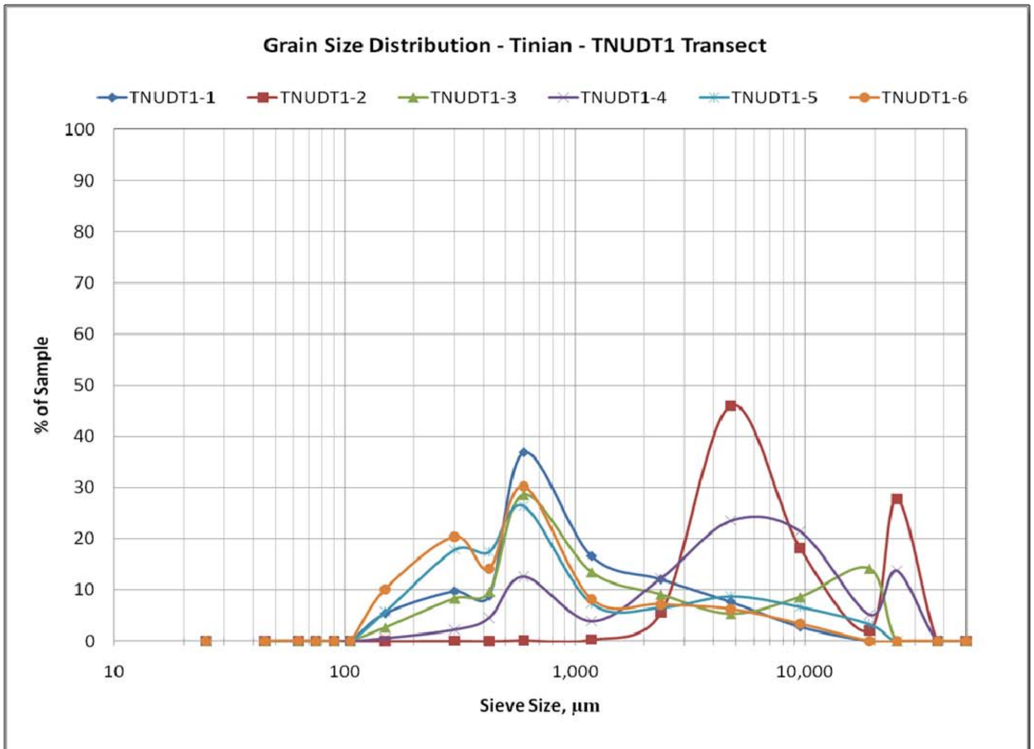
Grain Size Distribution - Pagan - PAB4T1 Transect
PAB4T1-1
PAB4T1-2
PAB4T1-3
PAB4T2-2
PAB4T2-3
% of Sample
Sieve Size, µm

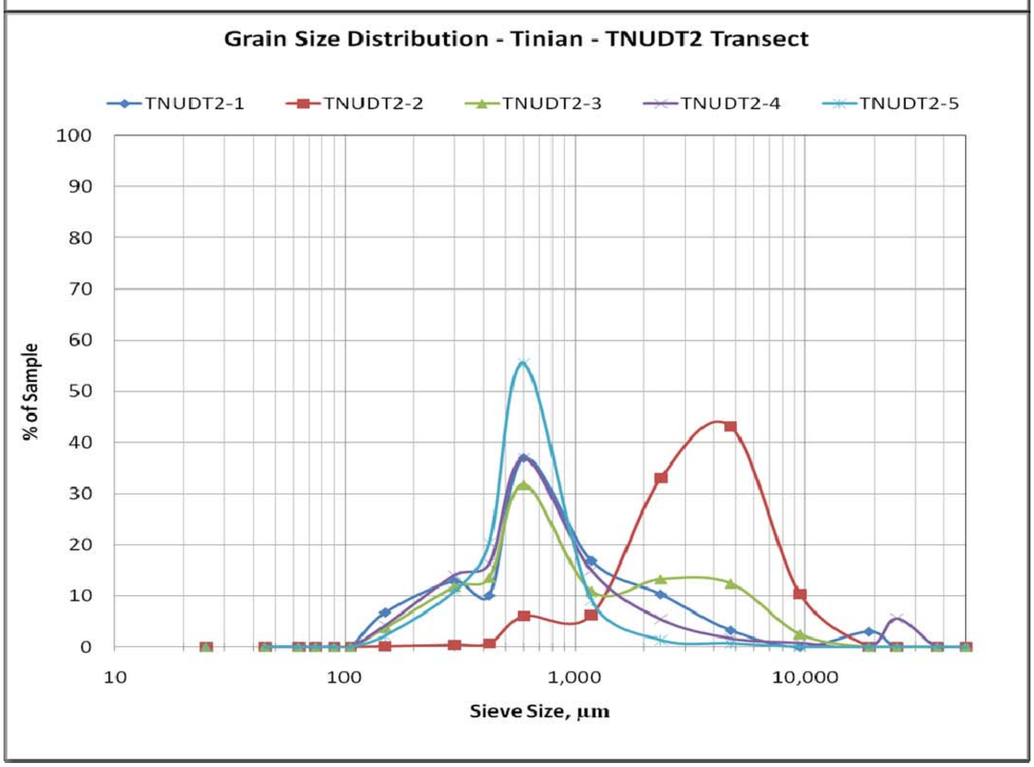


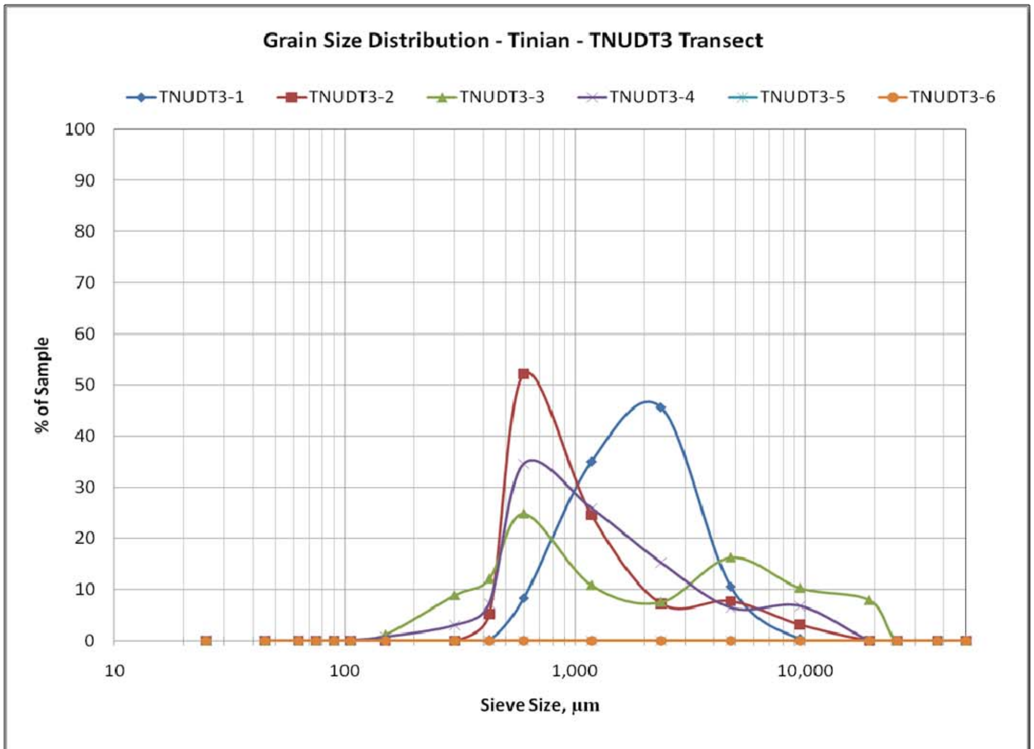
Grain Size Distribution - Pagan - PAB4T3 Transect
PAB4T3-1
PAB4T3-2
PAB4T3-3
PAB4T3-4
% of Sample
Sieve Size, µm


Grain Size Distribution - Pagan - PAB4T4 Transect
PAB4T4-1
PAB4T4-2
PAB4T4-3
PAB4T4-4
% of Sample
Sieve Size, µm
10
100
1,000
10,000

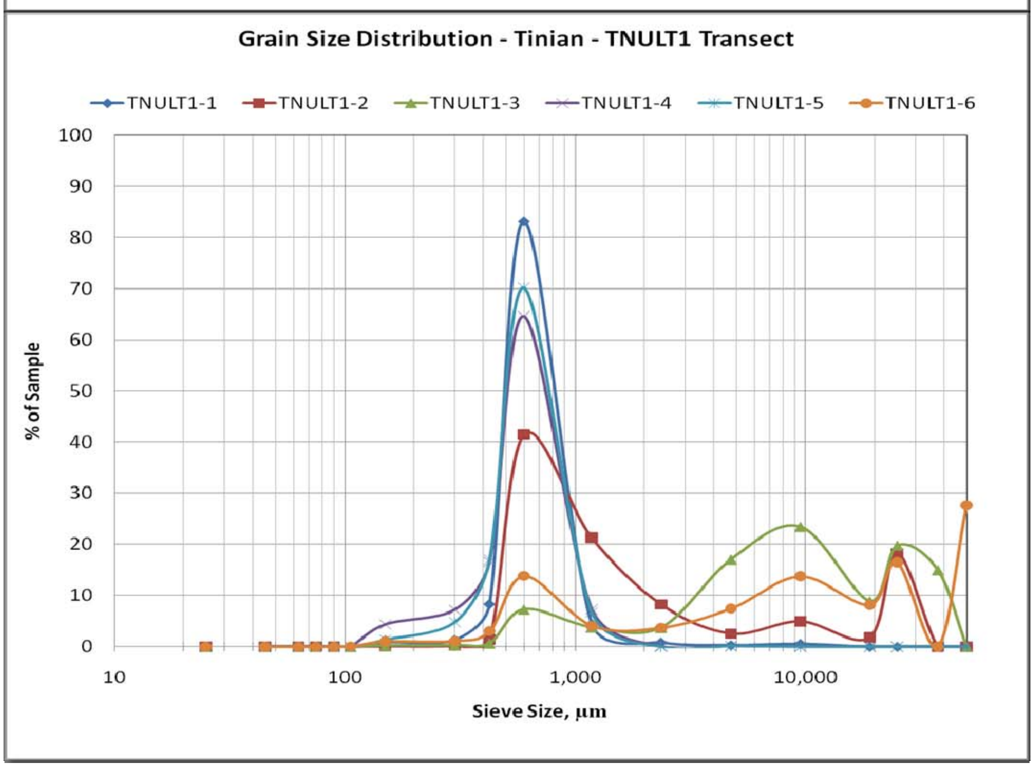

Grain Size Distribution - Tinian - TNUBT1 Transect
TNUBT1-1
TNUBT1-2
TNUBT1-3
TNUBT1-4
TNUBT1-5
TNUBT1-7
TNUBT1-8
TNUBT1-9
TNUBT1-10
TNUBT1-11
TNUBT1-12
TNUBT1-13
TNUBT1-14
TNUBT1-15
% of Sample
Sieve Size, µm
10
100
1,000
10,000


Grain Size Distribution - Tinian - TNUDT1 Transect
TNUDT1-1
TNUDT1-2
TNUDT1-3
TNUDT1-4
TNUDT1-5
TNUDT1-6
% of Sample
Sieve Size, µm
10
100
1,000
10,000


Grain Size Distribution - Tinian - TNUDT2 Transect
TNUDT2-1
TNUDT2-2
TNUDT2-3
TNUDT2-4
TNUDT2-5
% of Sample
Sieve Size, µm
10
100
1,000
10,000



Grain Size Distribution - Tinian - TNUDT3 Transect
TNUDT3-1
TNUDT3-2
TNUDT3-3
TNUDT3-4
TNUDT3-5
TNUDT3-6
% of Sample
Sieve Size, μm



Grain Size Distribution - Tinian - TNULT1 Transect
TNULT1-1
TNULT1-2
TNULT1-3
TNULT1-4
TNULT1-5
TNULT1-6
% of Sample
Sieve Size, μm

APPENDIX K

GPS Survey and Ground Control

1 Introduction

There are many places associated with the littorals that have been insufficiently mapped. Some regions are dangerous to enter, due to environmental conditions or hostilities, whereby flying over them at low altitude is out of the question. Areas such as Pagan are covered by clouds most of the time, making the planning of aerial photographic missions or the timing for collection of Satellite imagery very important.

In order to generate useful training maps for remote areas such as Pagan, cartographers will need satellite images, aerial photos, ground control points (GCPs), and a digital elevation model (DEM). For Pagan, training maps may not rely on optical images because the area is cloudy, but they might use stereo RADARSAT images, which can penetrate through clouds, to extract elevations and to create a map of the area.

The MI-HARES'10 remote sensing campaign included the collection of hyperspectral imagery, calibration and validation data and the development of surveyed ground control and photograph-identified control points. These measurements are described in this data report.

Collection of GCPs is critical in the creation of orthorectified products that can support military training. This study collected ground control on Pagan, Tinian, and Guam, which is listed here to benefit other researchers. These points can be used to assist those involved in developing DEMs with stereo pairs or efforts requiring tie points to allow a cartographer to stitch multiple images together.

Ground Control Points (GCPs) are accurately surveyed physical features that are clearly visible from aerial imagery. These points can be helpful in tying non-georectified aerial images to true positions on the Earth. For each of the three islands that were studied in the MI-HARES'10 campaign, GCPs and polygon layers were created from the GPS surveying.

Collecting a number of locations for known landmarks was crucial to orthorectification. For MI-HARES'10, airborne hyperspectral imagery was controlled using paneled control points, permanent monuments, and key terrain features. Most of the Ground Control Points (GCPs) were large enough to be observed in the aerial imagery. These surveyed points were used to accurately tie a remotely sensed image of the study area to its true location on the Earth's surface. This project's GCPs were collected from Global Positioning System (GPS) in the field, especially since at locations such as Pagan they could not be measured from any existing maps. This effort supports other projects that will rely on tie points, i.e., image measurements that connect the same locations in different, but overlapping, images. Tie points are features (e.g., several pixels that can be clearly identified) in one image that when identified in another image may be joined together. During the orthorectification process, the real world coordinates of all other points in the imagery are calculated based on the locations of the control points.

Very few GCPs were collected over water, so the image-to-image tie point method of co-registration was important for underwater and offshore features. The GCPs were collected on peninsulas, headlands and other types of key terrain whenever possible to allow for the best spatial solution during the georegistration process. They were also collected near concrete pads, surrounding vegetative areas, around craters, around structures, at street intersections, at corners of buildings, surrounding knolls, and on geodetic control monuments which could be associated with single pixels in digital scans.

In addition to using GPS units to measure ground control points, units were used to mark land data collection positions, position of bathymetric soundings, and precise elevation readings of water and beach terrain. Two GPS units manufactured by Trimble® and three kinematic GPS units manufactured by Ashtech® were used to mark locations during MI-HARES'10.

2 Trimble Pro-XH unit

2.1 Coordinate accuracy

Depending on the position of the nearest CORS stations', the accuracy of field collected positions can be determined. The majority of the positions measured during MI-HARES'10 had accuracy in the 15-30 cm range. Less accurate readings were obtained from the Pagan portion of the experiment (majority of readings in 30-50cm range) due to the remoteness of the island. Guam readings were the most accurate due to proximity to CORS stations, as the Island of Guam has two CORS stations.

Table K - 1. GPS coordinate accuracies obtained from Trimble® Pathfinder® Pro-XH.

Island	0-15cm	15-30cm	30-50cm	0.5-1m	1-2m	2-5m	>5m
Guam	53.35%	30.03%	14.18%	2.13%	0.33%	0.03%	0.00%
Pagan	0.01%	9.87%	45.74%	42.42%	1.88%	0.05%	0.00%
Tinian	20.60%	54.10%	16.32%	7.00%	1.93%	0.05%	0.00%
Average	**24.65%**	**31.33%**	**25.41%**	**17.18%**	**1.38%**	**0.04%**	**0.00%**

2.2 Bathymetric Soundings and Underwater Hazard Marking

Bathymetric soundings were undertaken during all phases of the experiment. A positional breakdown of the sounding data is displayed in Table K - 2. In the table, the name of the island, the location offshore of the island, the date the data were recorded, and the number of soundings are listed. The positions listed in Table K - 2 are displayed in Figure K - 1, where each sounding indicates the depth in meters below the surface.

Table K - 2. MI-HARES 2010 sounding position breakdown.

Island	Location	Date	Number of Soundings
Guam	Dadi Bay	10 Mar 2010	404
	Tipalao Bay	10 Mar 2010	405
	Total		909
Pagan	Beach 1 Offshore	1 Mar 2010	169
	Beach 2 Bay	1 Mar 2010	129
	Beach 4 Bay	27 Feb 2010	87
	Beach 4 Bay	1 Mar 2010	232
	Total		575
Tinian	Unai Babui	5 Mar 2010	105
	Unai Lamlam	6 Mar 2010	174

	Total	279

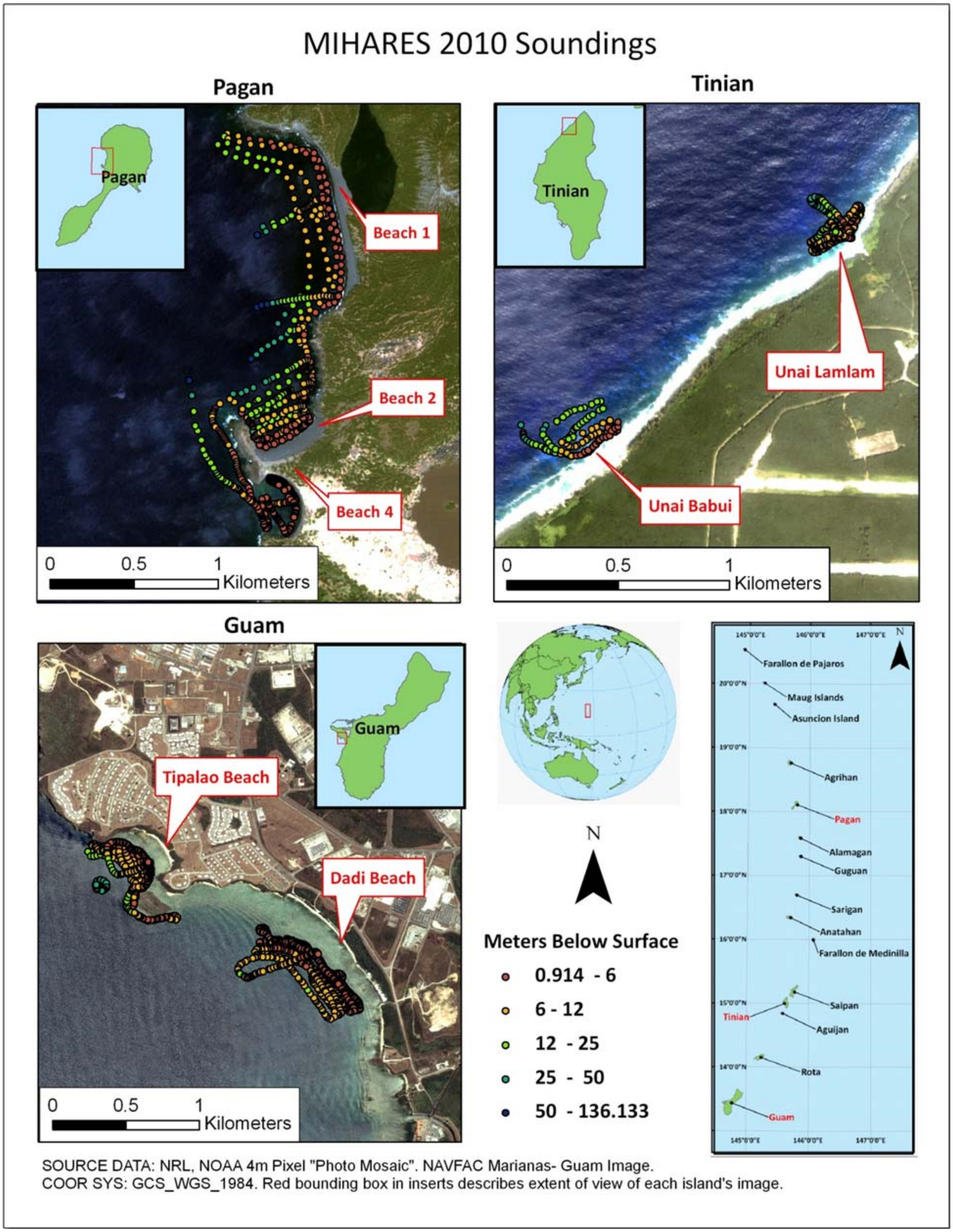


Figure K - 1. MI-HARES'10 bathymetry soundings. These data were collected via small boat and fathometer.

Underwater hazards were marked in Beach 4 bay of Pagan. These hazards, which are not visible from the water's surface and are not marked on charts, could severely damage boats coming ashore. Due to the M/V *Micronesian* crew member's local knowledge, they were able to navigate around such features. Figure K - 2 displays the underwater hazards as well as the channel which should be used for Beach 4 landings. These positions were collected while scientific divers were collecting underwater spectra. Divers indicated their positions to other members of the boat team who recorded the coordinates with a GPS unit.

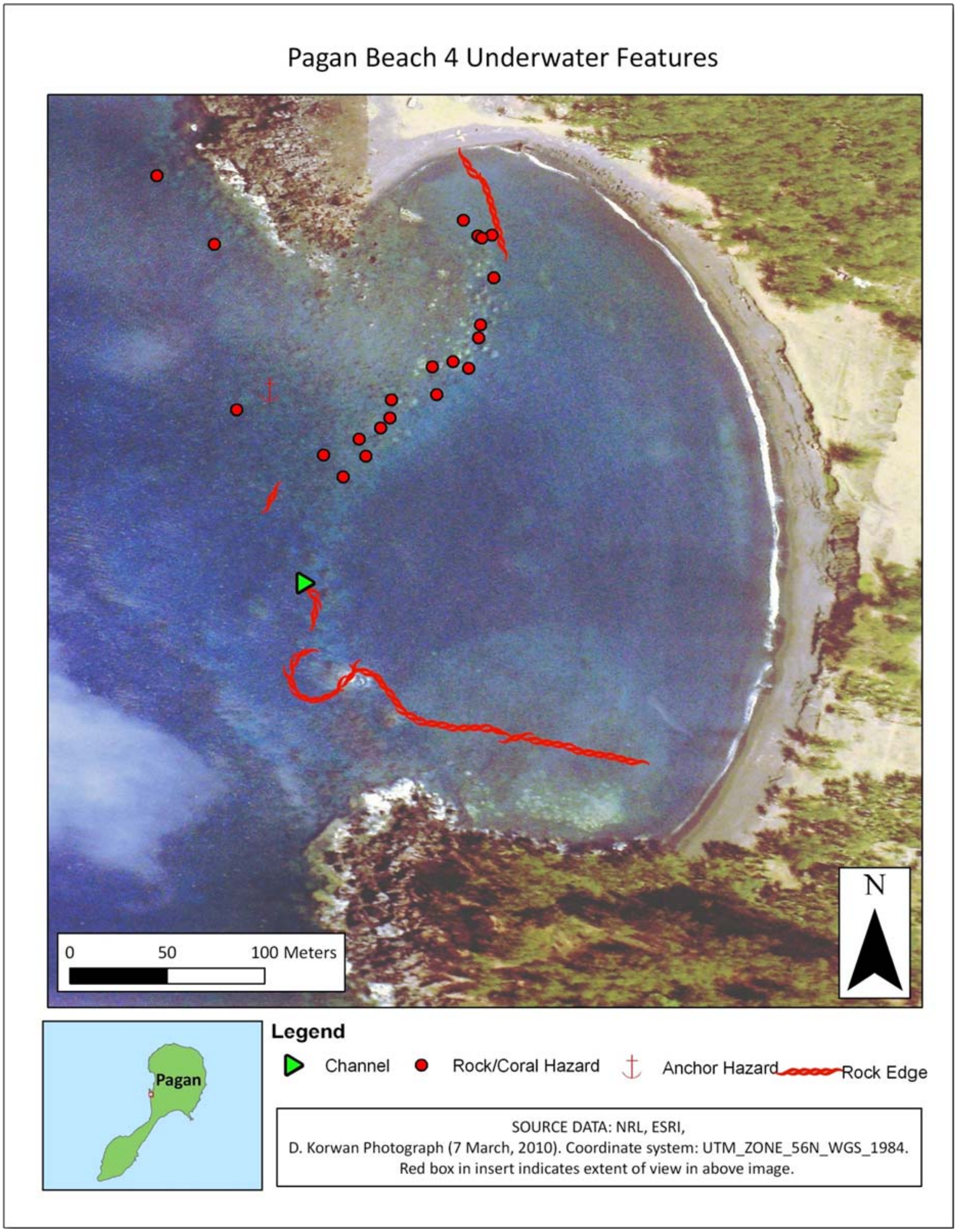


Figure K - 2. Bathymetric hazards on approach to Beach 4 on Pagan.

Blue 12-foot by 16-foot tarps were placed at various depths offshore of Dadi Beach in order to support anomaly detection experiments. Three tarps were placed offshore Dadi Beach, Guam on 9 March at depths of 3, 5.5, and 9.1 meters below the surface. Three tarps were also placed offshore Dadi Beach on 10 March at depths of 1.5, 7.3, and 10.7 meters. The three tarps placed on 9 March were imaged by airborne sensors, while the 10 March tarps were not imaged. Figure K - 3 displays the location of the underwater tarps offshore of Dadi Beach.

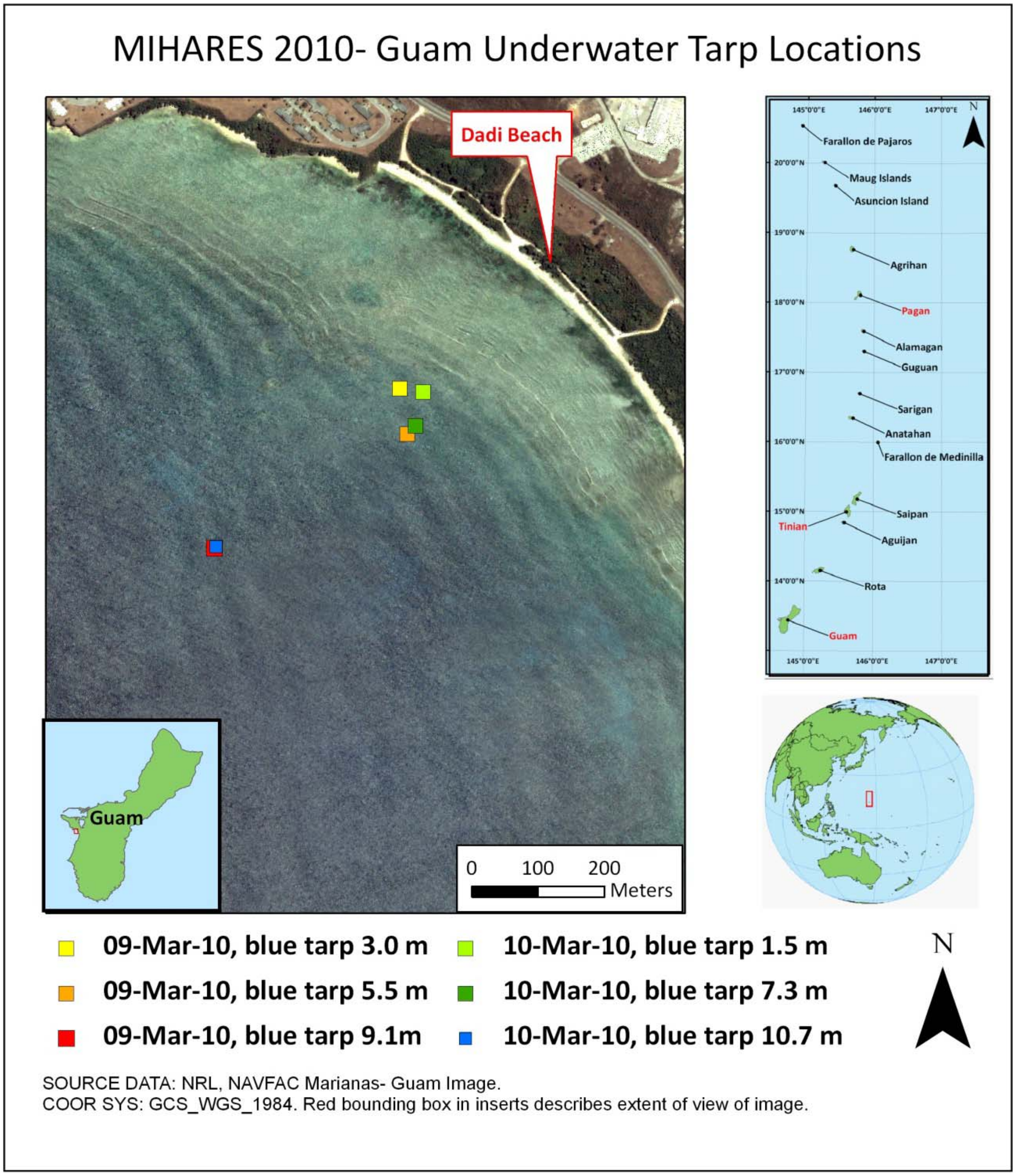


Figure K - 3. Guam underwater tarp locations. These tarps were used for anomaly detection.

2.3 Ground control

Positions and areas were marked with a Trimble® Pro-XH™ post-processing GPS unit that sampled at a rate of 1 sample for every 5 seconds. Point positions were marked after approximately 10 readings. Area polygons consisted of the operator walking slowly around features and stopping at the feature's corners for a longer period of time. In one case, a line feature was marked which represented a pipe approximately 1 ft in diameter.

Extensive ground control data taken with the Trimble® Pro-XH™ unit were taken on two islands. Data taken from 26 February to 3 March were taken on Pagan. Most data on this island were taken in regions surrounding the airfield and the bays west of the airfield. One area polygon was taken on the eastern side of Pagan. Surveys from 5 March to 8 March were taken on Tinian. Collections from 5 March to 7 March specifically support Cal/Val while data taken on 8 March was for the sole purpose of ground control. GPS data taken on Guam was more limited to a few NGS geodetic monuments, the Ashtech water level gauge, the beach profiles with the Ashtech rover unit, and the positions, using the Trimble® Pro-XH™ units, of geotechnical and spectral samples on Dadi and Tipalao Beaches.

2.3.1 Pagan

2.3.1.1 Point Features

Table K - 3 lists items that were marked in point feature mode. In the table, the ID, the description of the item marked, the time of presence (the amount of time the item was deployed), the local date, the height above ellipsoid in meters (GCS_WGS_1984), and the position of the item is displayed. The ID of each item is used as a label in picture and map figures. Figure K - 4 and Figure K - 5 display images of the items listed in Table K - 3. Figure K - 6 displays a map of the locations of the items listed in Table K - 3.

Table K - 3. List of GCPs marked as points during the Pagan portion of the remote sensing campaign.

ID	Description	Time of Presence	Local Date	Height Above Ellipsoid, m	Longitude	Latitude
0	GEOTARP_1 (center)	10FEB26-10MAR3	26-Feb-10	58.878	145.7605977	18.12386406
1	GEOTARP_2 (center)	10FEB26-10MAR3	26-Feb-10	64.998	145.7640858	18.12320108
2	JAPANESE BOMBER	Permanent	26-Feb-10	68.796	145.7656213	18.12378772
3	GEOTARP_3 (center)	10FEB26-10MAR3	26-Feb-10	69.260	145.7661894	18.12056144
4	JAPANESE_0_NO1	Permanent	26-Feb-10	62.092	145.7613707	18.12289202
5	CISTERN_1	Permanent	26-Feb-10	59.552	145.7615122	18.12208008
6	JAPENESE_MONUMENT 1	Permanent	26-Feb-10	48.175	145.7583441	18.12521914
7	SUN_PHOTOMETER_POSITION	10FEB26-10MAR3	26-Feb-10	62.263	145.7572575	18.12547243
8	PAGAN_CHURCH _B2_1	Permanent	28-Feb-10	62.432	145.7615648	18.12772574
9	PAGAN_CHURCH _B2_2	Permanent	28-Feb-10	57.672	145.7615843	18.12778411
10	ANCHOR_BEACH_2-(FLUKE)	Permanent	1-Mar-10	52.585	145.7578686	18.12640223
11	AA_GUN	Permanent	2-Mar-10	67.228	145.7657999	18.12363029
12	BUNKER_AIRFIELD	Permanent	2-Mar-10	69.169	145.7668578	18.12070127
13	BUNKER_SOUTH_OF_AIRFIELD	Permanent	2-Mar-10	60.404	145.7634686	18.12103419
14	BUNKER_SOUTH_OF_AIRFIELD _STHCR2	Permanent	2-Mar-10	57.065	145.761634	18.1221778

ID	Description	Time of Presence	Local Date	Height Above Ellipsoid, m	Longitude	Latitude
15	RUSTY_METAL	Permanent	2-Mar-10	53.256	145.7602647	18.12193202
16	NW CORNER BLACK CAL	Daily Deployment	3-Mar-10	57.920	145.7602899	18.12390905
17	NE CORNER BLACK CAL	Daily Deployment	3-Mar-10	58.249	145.7603791	18.12390048
18	SE CORNER BLACK CAL	Daily Deployment	3-Mar-10	56.653	145.7603689	18.12382058
19	SW CORNER BLACK CAL	Daily Deployment	3-Mar-10	57.236	145.7602845	18.12382542
20	NW CORNER BLUE TARP	10FEB26-10MAR3	3-Mar-10	64.066	145.7632338	18.12317127
21	NE CORNER BLUE TARP	10FEB26-10MAR3	3-Mar-10	62.520	145.7632684	18.12315924
22	SE CORNER BLUE TARP	10FEB26-10MAR3	3-Mar-10	63.402	145.7632556	18.12313466
23	SW CORNER BLUE TARP	10FEB26-10MAR3	3-Mar-10	63.134	145.7632217	18.12314844
24	SE CORNER WHITE CAL	Daily Deployment	3-Mar-10	62.670	145.7635094	18.12296169
25	SW CORNER WHITE CAL	Daily Deployment	3-Mar-10	64.664	145.7634287	18.12299167
26	NW CORNER WHITE CAL	Daily Deployment	3-Mar-10	63.419	145.7634547	18.12306855
27	NE CORNER WHITE CAL	Daily Deployment	3-Mar-10	63.601	145.7635382	18.12304288
28	NOAA MET STATION RG 99 2004	Permanent	3-Mar-10	58.155	145.7607347	18.12464149

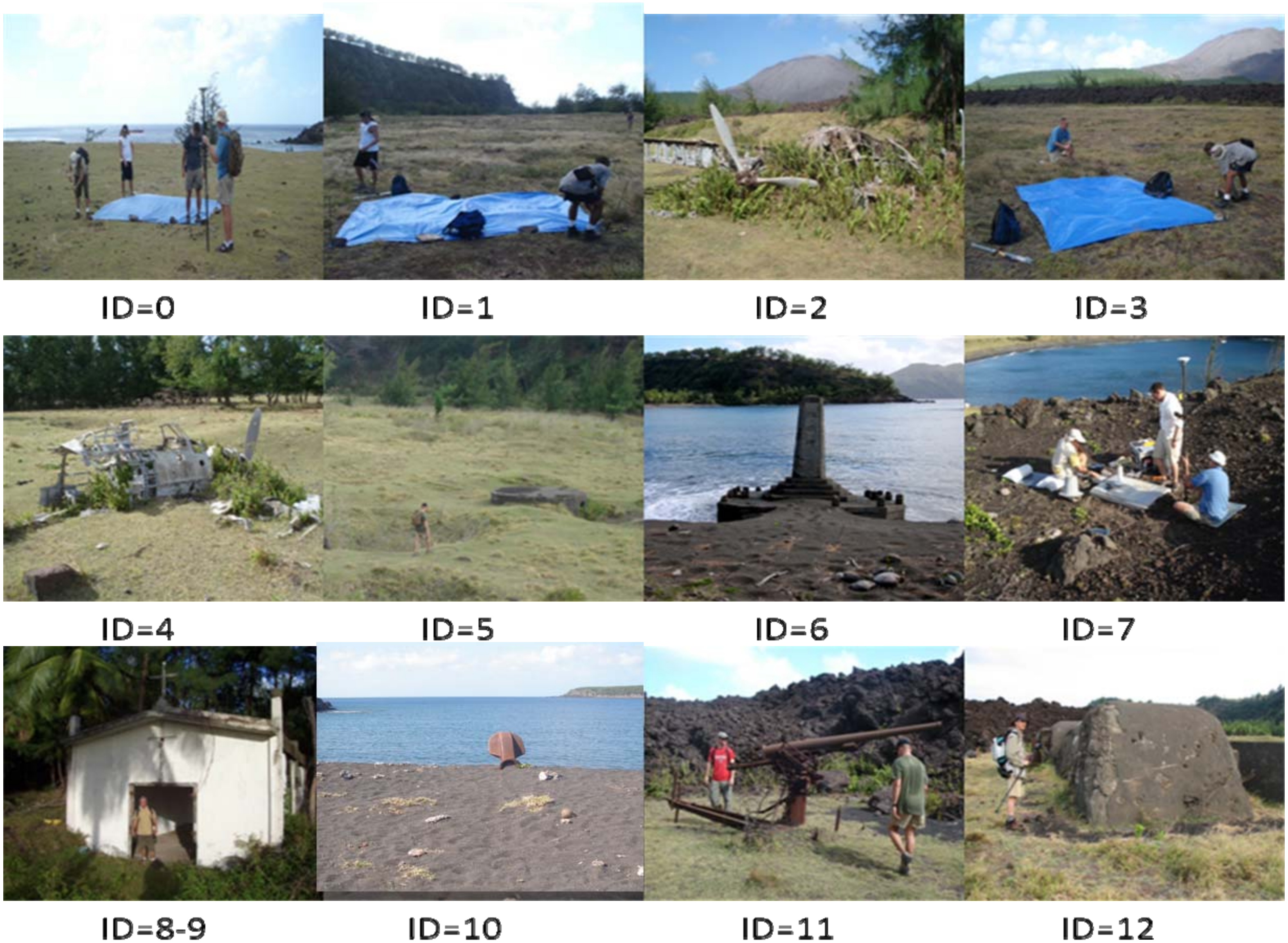


Figure K - 4. Pictures of GCPs marked as points on the island of Pagan.

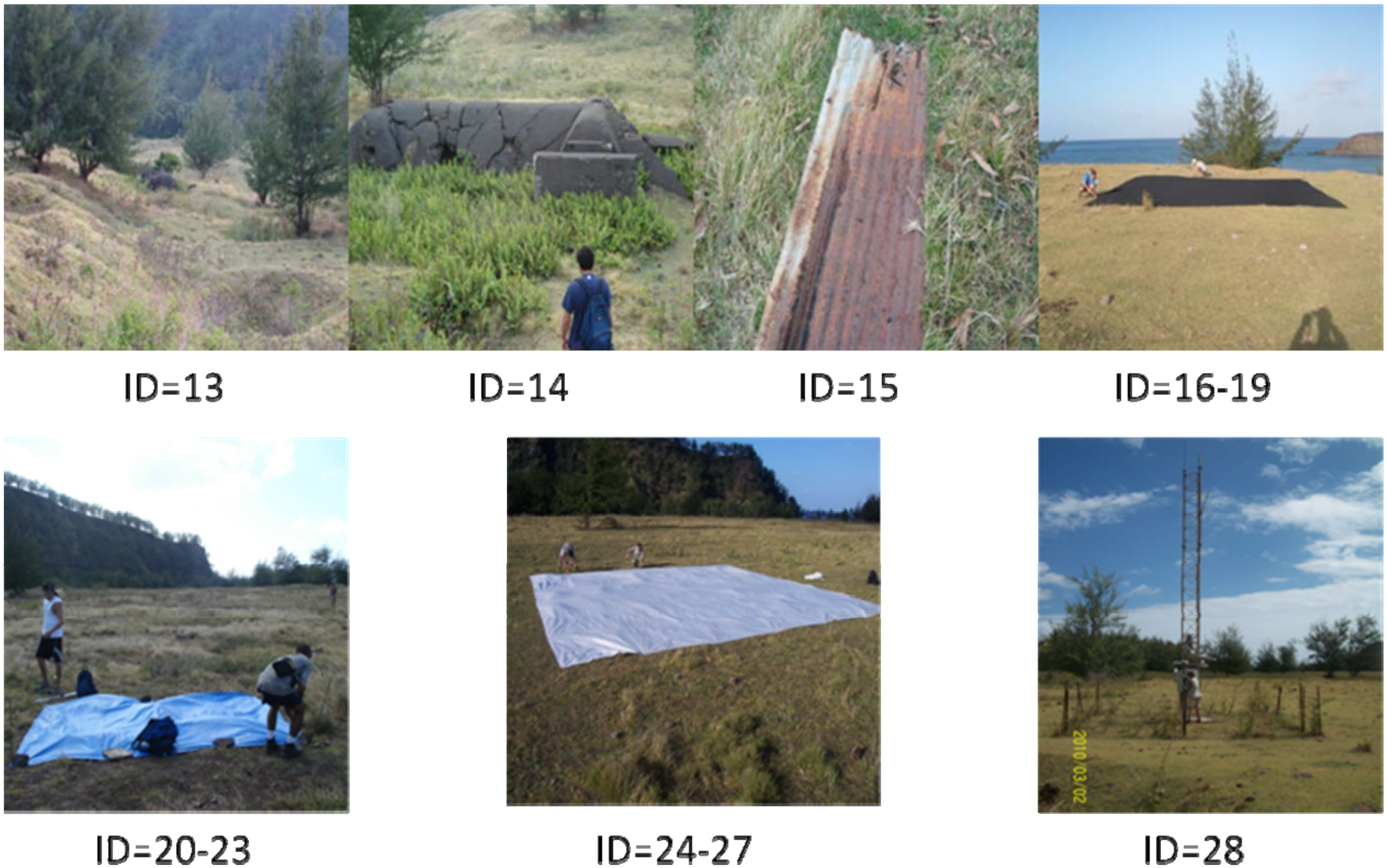


Figure K - 5. Pictures of GCPs marked as points on the island of Pagan.

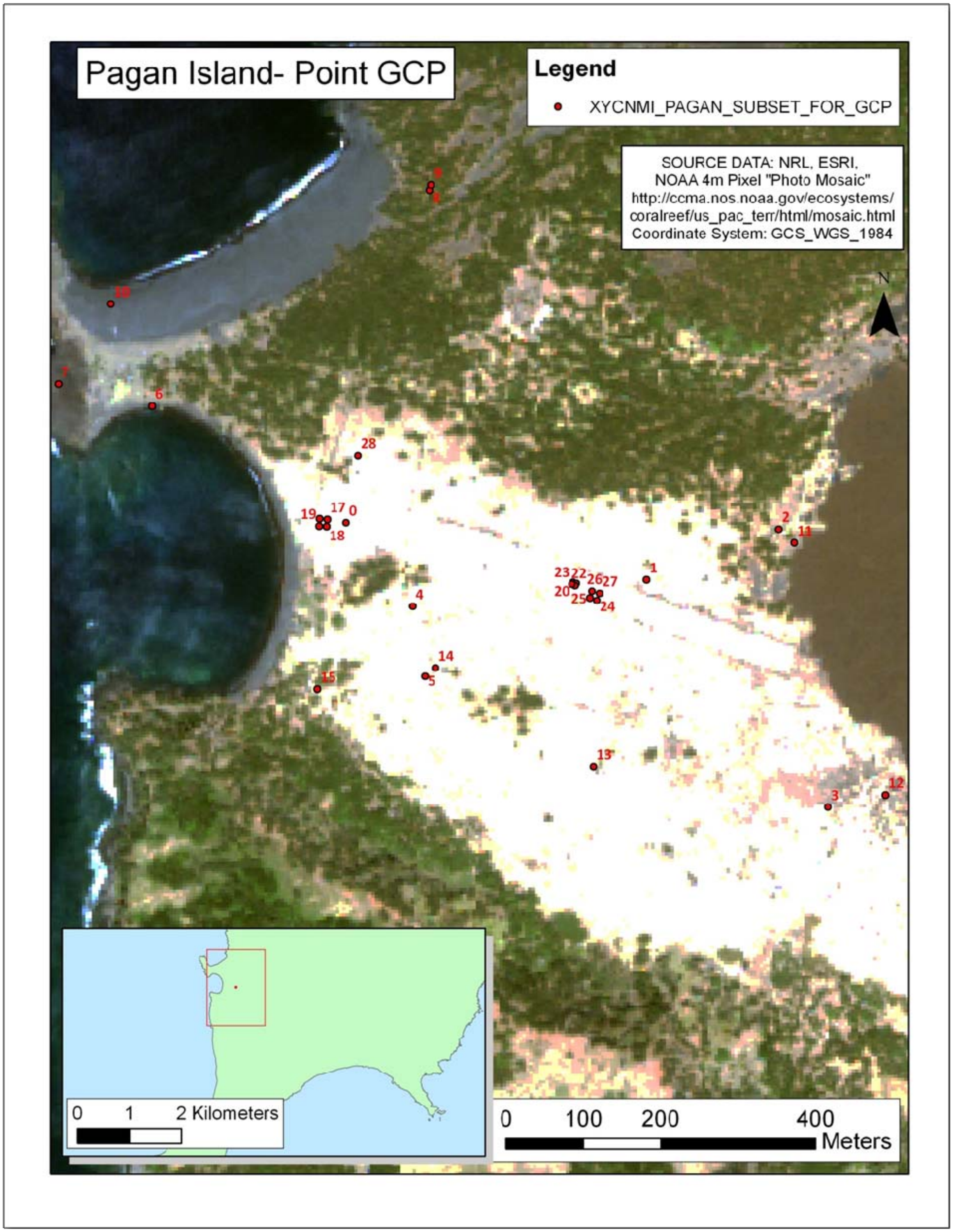


Figure K - 6. Map of GCPs marked as points on the island of Pagan.

2.3.1.2 Area Features

Table K - 4 lists items that were marked in area feature mode. In the table, the ID, the item's description, the time of presence, the local date, item's position based on the centroid of the surveyed polygon, and the area's perimeter and area in meters are listed. Figure K - 7, Figure K - 8, and Figure K - 9 display photographs of the items in Table K - 4. The ID label below each picture matches the ID field in the table containing that item's description. In some cases, items were sometimes marked as point and area features. In some figures, IDs will be listed with parentheses next to the ID number. The number and designator "Pt" in the parentheses refer to the item's point feature ID. The items listed in the table are displayed in a map in Figure K - 10.

Table K - 4. List of GCPs marked as area features on the island of Pagan.

ID	Description	Time of Presence	Local Date	Polygon Centroid Position		Area m^2	Perimeter m
				Longitude	Latitude		
0	JAPANESE_BUNKER_NE	Permanent	26-Feb-10	145.766205	18.120128	130	57
1	JAPANESE_BUNKER_CENTER_RUNWAY	Permanent	26-Feb-10	145.766938	18.120687	90	55
2	STRUCTURE_1	Permanent	26-Feb-10	145.757792	18.125514	40	32
3	CISTERN_WHITE_BEACH_REDO	Permanent	27-Feb-10	145.784887	18.11003	10	18
4	IRONWOOD_RUNWAY-LO1	Permanent	02-Mar-10	145.760548	18.124357	220	66
5	PALM_GROVE_BY_WILLYS_LO4	Permanent	02-Mar-10	145.760307	18.122222	230	65
6	TREE_WILLYS_BREADFRUIT?_LO6	Permanent	02-Mar-10	145.760213	18.122019	180	52
7	LO7-AREA	Permanent	02-Mar-10	145.760145	18.121774	220	59
8	WILLYS_HOUSE	Permanent	02-Mar-10	145.760423	18.121945	120	49
9	BUNKER_SOUTH_OF_RUNWAY	Permanent	02-Mar-10	145.763443	18.121044	240	75
10	BLACK_TARP	Daily Deployment	02-Mar-10	145.760314	18.123743	90	38
11	GEO_TARP_1	10FEB26-10MAR3	02-Mar-10	145.760592	18.123849	10	18
12	WHITE_PANEL	Daily Deployment	02-Mar-10	145.763485	18.123031	90	38
13	GEO_TARP_PELICAN_CASE_COVER	Daily Deployment	02-Mar-10	145.76324	18.123151	10	20
14	GEO_TARP_PELICAN_CASE_COV_GRAY	Daily Deployment	02-Mar-10	145.76031	18.124034	10	17

ID	Description	Time of Presence	Local Date	Polygon Centroid Position		Area m^2	Perimeter m
				Longitude	Latitude		
15	IRONWOOD	Permanent	03-Mar-10	145.760786	18.123213	3090	365
17	PAL M	Permanent	03-Mar-10	145.759956	18.122006	90	51
18	PAL M	Permanent	03-Mar-10	145.759854	18.121821	380	107
19	IRONWOOD	Permanent	03-Mar-10	145.760236	18.123183	380	119
20	IRONWOOD	Permanent	03-Mar-10	145.76148	18.124201	160	58
21	IRONWOOD	Permanent	03-Mar-10	145.761771	18.124344	90	41
22	CRATER-1	Permanent	03-Mar-10	145.761497	18.124465	140	49
23	CRATER-2	Permanent	03-Mar-10	145.761373	18.124525	120	55
24	CRATER-3	Permanent	03-Mar-10	145.760875	18.124681	50	39
25	CRATER-4	Permanent	03-Mar-10	145.760639	18.124706	90	37
26	FENCE AROUND NOAA METSTATION	Permanent	03-Mar-10	145.760732	18.124642	50	32
27	CRATER-5	Permanent	03-Mar-10	145.76079	18.124885	120	53

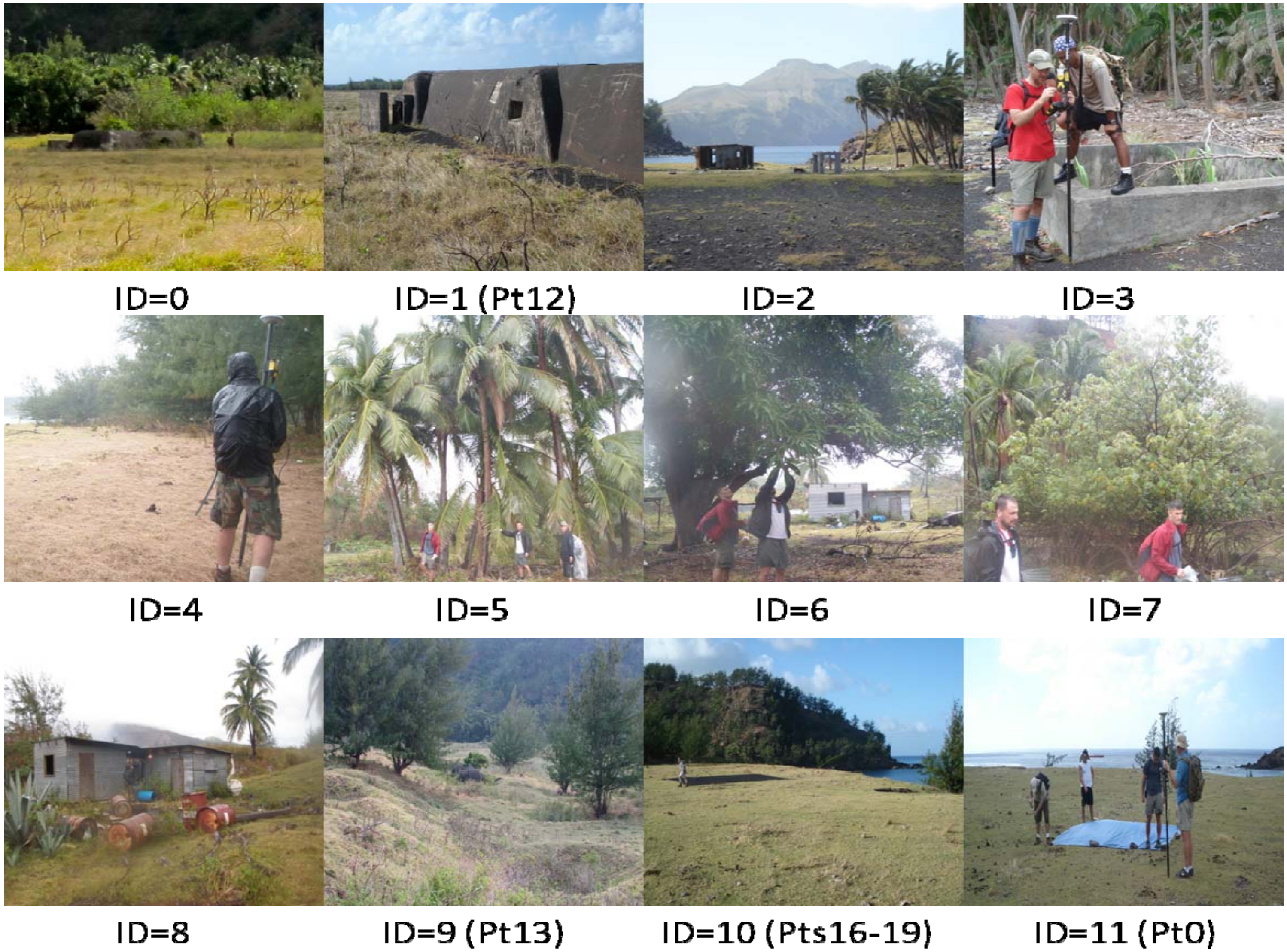


Figure K - 7. Pictures of GCPs marked as areas on the island of Pagan.

ID=12 (Pts24-27)

Not Pictured
Dimensions
3 ft X 2 ft

ID=13

Not Pictured
Dimensions
2 ft X 2 ft

ID=14

ID=15

ID=17

Not Pictured
Area = 380m^2

ID=18

Not Pictured
Area = 380m^2

ID=19

Not Pictured
Area = 160m^2

ID=20

Not Pictured
Area = 90m^2

ID=21

Not Pictured
Area = 140m^2

ID=22

Not Pictured
Area = 120m^2

ID=23

Not Pictured
Area = 50m^2

ID=24

Figure K - 8. Pictures of GCPs marked as areas on the island of Pagan.

ID=25

Not Pictured

Area = 90m²

ID=26

ID=27

Figure K - 9. Pictures of GCPs marked as areas on the island of Pagan.

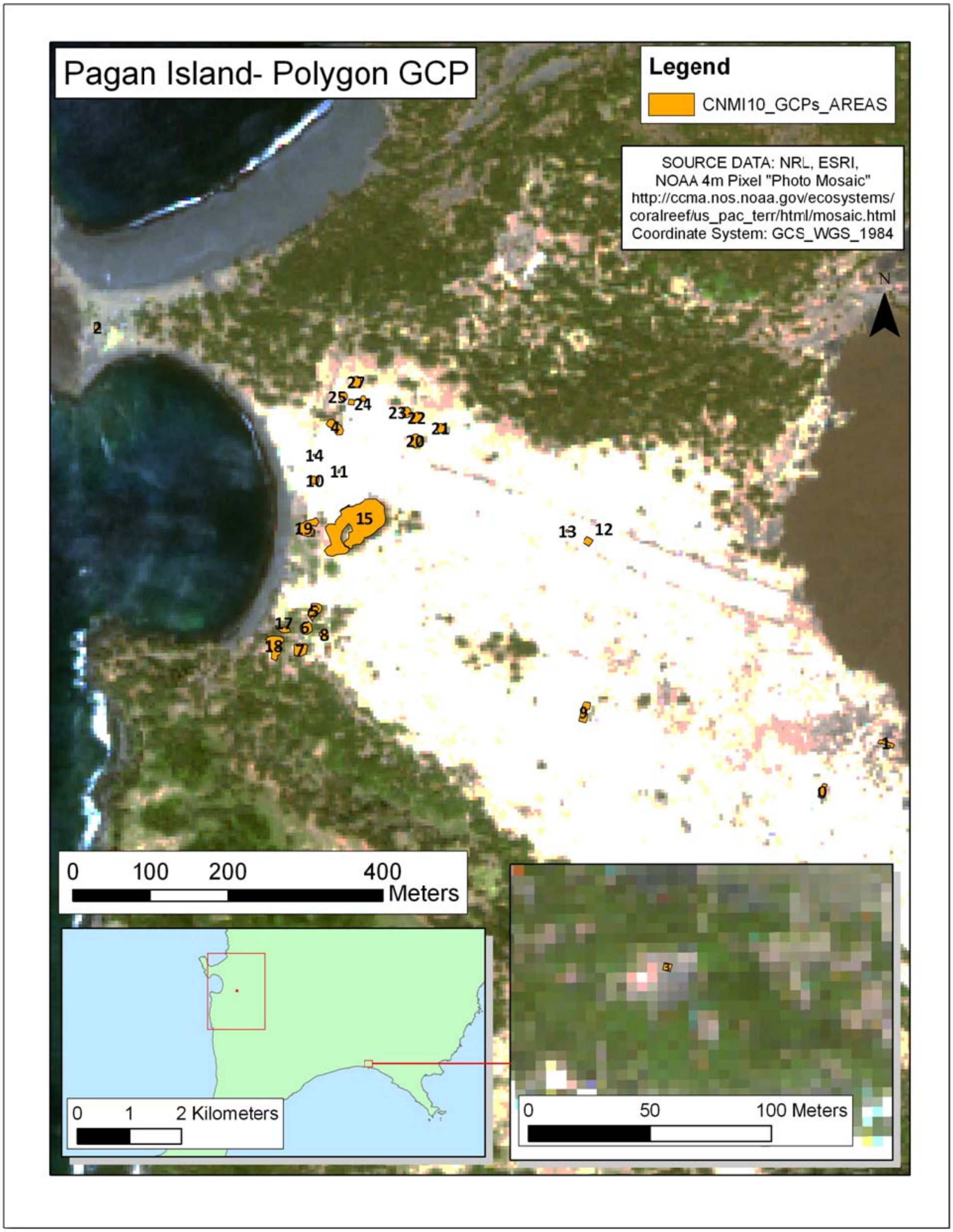


Figure K - 10. Map of GCPs marked as areas on the island of Pagan.

2.3.2 Tinian

2.3.2.1 Point Features

Table K - 5 list items that were marked in point feature mode on Tinian. In the table, the ID, the description of the item marked, the time of presence (the amount of time the item was deployed), the local date, the height above ellipsoid in meters (GCS_WGS_1984), and the position of the item is displayed. The ID of each item is used as a label in picture and map figures. Figure K - 11 and Figure K - 12 display images of the items listed in Table K - 5. Figure K - 13. Map of GCPs marked as points on the island of Tinian. Figure K - 13 displays a map of the locations of the items listed in Table K - 5.

Table K - 5. List of GCPs marked as points during the Tinian portion of the exercise.

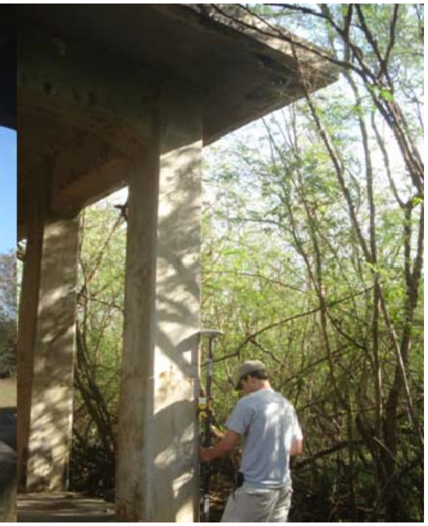
ID	Description	Time of Presence	Local Date	Height Above Ellipsoid, m	Longitude	Latitude
0	JAPAN_COM_1_NW	Permanent	8-Mar-10	120.922	145.6370556	15.02616
1	JAPAN_COM_1_SW	Permanent	8-Mar-10	128.303	145.6369698	15.02559
2	JAPAN_COM_1_SE	Permanent	8-Mar-10	121.515	145.6371196	15.02563
3	JAPAN_COM_1_NE	Permanent	8-Mar-10	120.508	145.6372098	15.02614
4	AIR_ADMIN_NW	Permanent	8-Mar-10	77.668	145.6321908	15.08076
5	AIR_ADMIN_SW	Permanent	8-Mar-10	76.362	145.6323104	15.08039
6	AIR_ADMIN_SE	Permanent	8-Mar-10	77.416	145.6324151	15.08041
7	AIR_ADMIN_NE_1	Permanent	8-Mar-10	76.202	145.6324947	15.0806
8	AIR_ADMIN_NE_2	Permanent	8-Mar-10	76.235	145.632471	15.08069
9	AIR_ADMIN_NE_3	Permanent	8-Mar-10	78.402	145.6323068	15.08079
10	AIR_OPS_SW	Permanent	8-Mar-10	75.213	145.6342044	15.07965
11	AIR_OPS_SE	Permanent	8-Mar-10	75.52	145.6342875	15.07968
12	AIR_OPS_NE	Permanent	8-Mar-10	81.516	145.6342924	15.0798
13	AIR_OPS_NW	Permanent	8-Mar-10	77.075	145.6341707	15.07977

Figure K - 11. Pictures of GCPs marked as points on the island of Tinian.

ID=8

ID=9

ID=10



ID=11

ID=12

ID=13

Figure K - 12. Pictures of GCPs marked as points on the island of Tinian.

Figure K - 13. Map of GCPs marked as points on the island of Tinian.

2.3.2.2 Area Features

Table K - 6 lists items that were marked in area feature mode on Tinian. In the table, the ID, the item's description, the time of presence, the local date, item's position based on the centroid of the surveyed polygon, and the area's perimeter and area in meters are listed. Figure K - 14, Figure K - 15, and Figure K - 16 display photographs of the items in Table K - 6 . The ID label below each picture matches the ID field in the table containing that item's description. Figure K - 17 displays a map of the items listed in Table K - 6.

Table K - 6. List of GCPs marked as areas on the island of Tinian.

ID	Polygon Name	Time of Presence	Local Date	Polygon Centroid Position		Area m^2	Perimeter m
				Longitude	Latitude		
0	LIMESTONE ROCK	Permanent	5-Mar-10	145.622302687	15.078730469	40	45
1	LIMESTONE ROCK	Permanent	5-Mar-10	145.622400902	15.078773872	10	12
2	LIMESTONE ROCK	Permanent	5-Mar-10	145.622816739	15.079218525	110	99
3	UNKNOWN BEACH VINE	Permanent	5-Mar-10	145.622944575	15.079226933	80	54
4	UNKNOWN BEACH VINE+	Permanent	5-Mar-10	145.622885599	15.079153097	Less than 5	2
5	UNKOWN BEACH TREE	Permanent	5-Mar-10	145.622861051	15.079157683	20	19
6	UNKOWN BEACH TREE	Permanent	5-Mar-10	145.622863492	15.079078301	70	60
7	UNKNOWN BEACH VINE	Permanent	5-Mar-10	145.622582856	15.078829931	30	30
8	UNKNOWN BEACH TREE	Permanent	5-Mar-10	145.622670635	15.078881453	40	30
9	PALM GROVE 1	Permanent	6-Mar-10	145.647925473	15.033821414	140	55
10	VELVET LEAF GROVE	Permanent	6-Mar-10	145.648157201	15.034088149	110	72
11	VELVET LEAF GROVE 2	Permanent	6-Mar-10	145.648069785	15.034248656	10	21
12	PALM GROVE 2	Permanent	6-Mar-10	145.647823678	15.034271102	210	85
13	screw pine pandanus tectorus	Permanent	6-Mar-10	145.647744348	15.034252582	30	26
14	palm grove 3	Permanent	6-Mar-10	145.647802228	15.034583778	220	102

ID	Polygon Name	Time of Presence	Local Date	Polygon Centroid Position		Area m^2	Perimeter m
				Longitude	Latitude		
15	velvet tree leaf 3	Permanent	6-Mar-10	145.647757142	15.034637386	10	19
16	velvetleaf tree 4	Permanent	6-Mar-10	145.647990946	15.034795096	30	24
17	velvetleaf grove 5	Permanent	6-Mar-10	145.648094568	15.034488827	70	47
18	VELVET_LEAF_SHRUB_AREA	Permanent	7-Mar-10	145.648150195	15.034788550	10	15
19	YOUNG_PALM_AREA	Permanent	7-Mar-10	145.648083659	15.034596111	10	12
20	VELVET LEAF MATURE	Permanent	7-Mar-10	145.648208734	15.034661319	10	15
21	HINODE_1	Permanent	8-Mar-10	145.639376102	15.055372950	850	220
22	BOMBPIT_1	Permanent	8-Mar-10	145.634032912	15.083668139	30	24
23	BOMBPIT_2	Permanent	8-Mar-10	145.634881658	15.083562747	30	25
24	AIR_CISTERN	Permanent	8-Mar-10	145.632596154	15.080530955	60	36
25	TANK_1_AREA	Permanent	8-Mar-10	145.614859464	15.065783494	30	25
26	SEABEES_AREA	Permanent	8-Mar-10	145.610062441	15.016749344	10	21
27	FUEL_TANK_1	Permanent	8-Mar-10	145.631352361	14.994340787	80	44
28	FLAG_PAD	Permanent	8-Mar-10	145.626452090	14.994253328	10	13
29	TIRE_1	Permanent	8-Mar-10	145.626575399	14.994224727	Less than 5	7

ID	Line Name	Time of Presence	Local Date	Corner of Line by street intersection		Length, m
				Longitude	Latitude	
Pipe_Line_North	Pipe_Line_North	Permanent	8-Mar-10	145.612976000	15.047239000	179

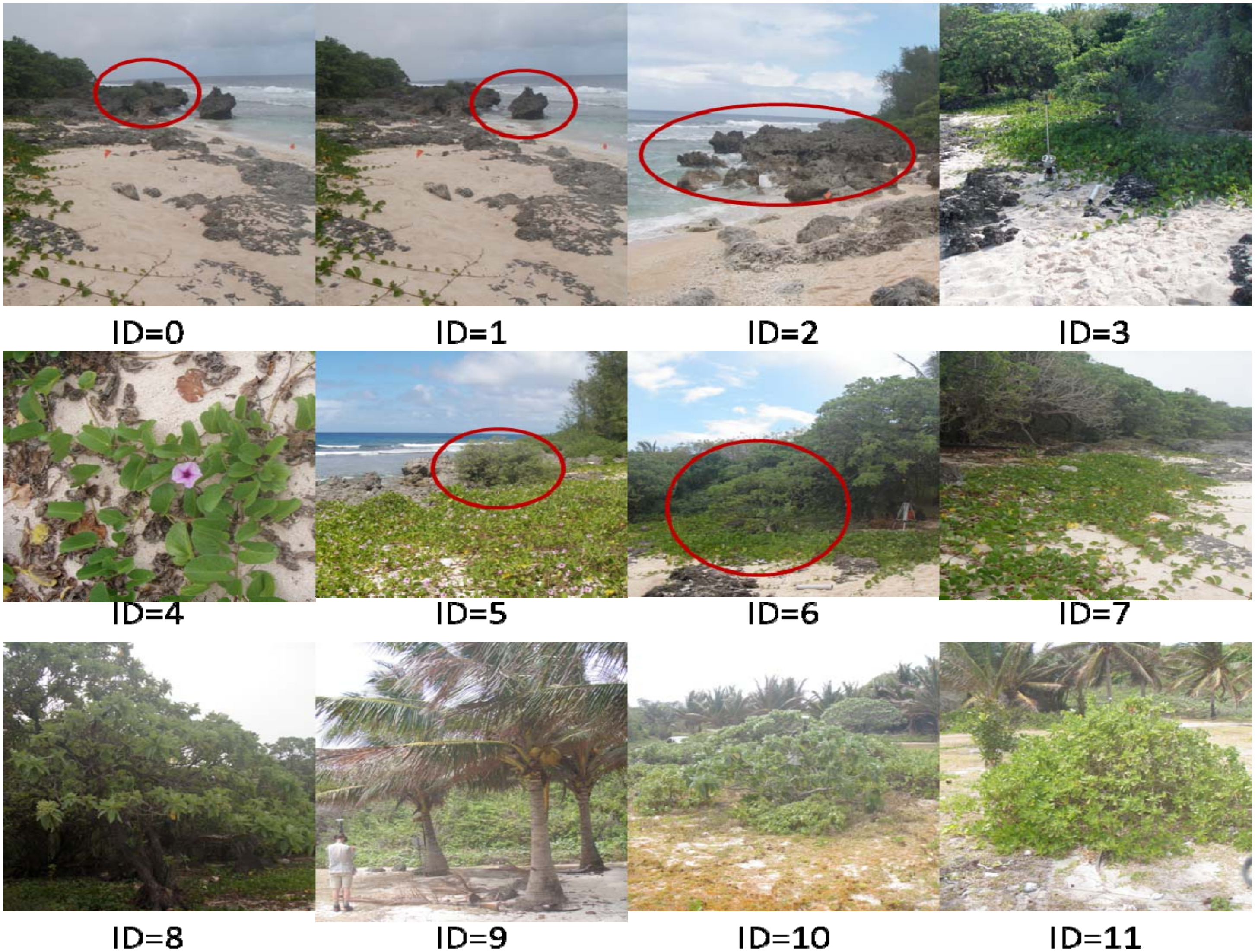


Figure K - 14. Pictures of GCPs marked as areas on the island of Tinian.

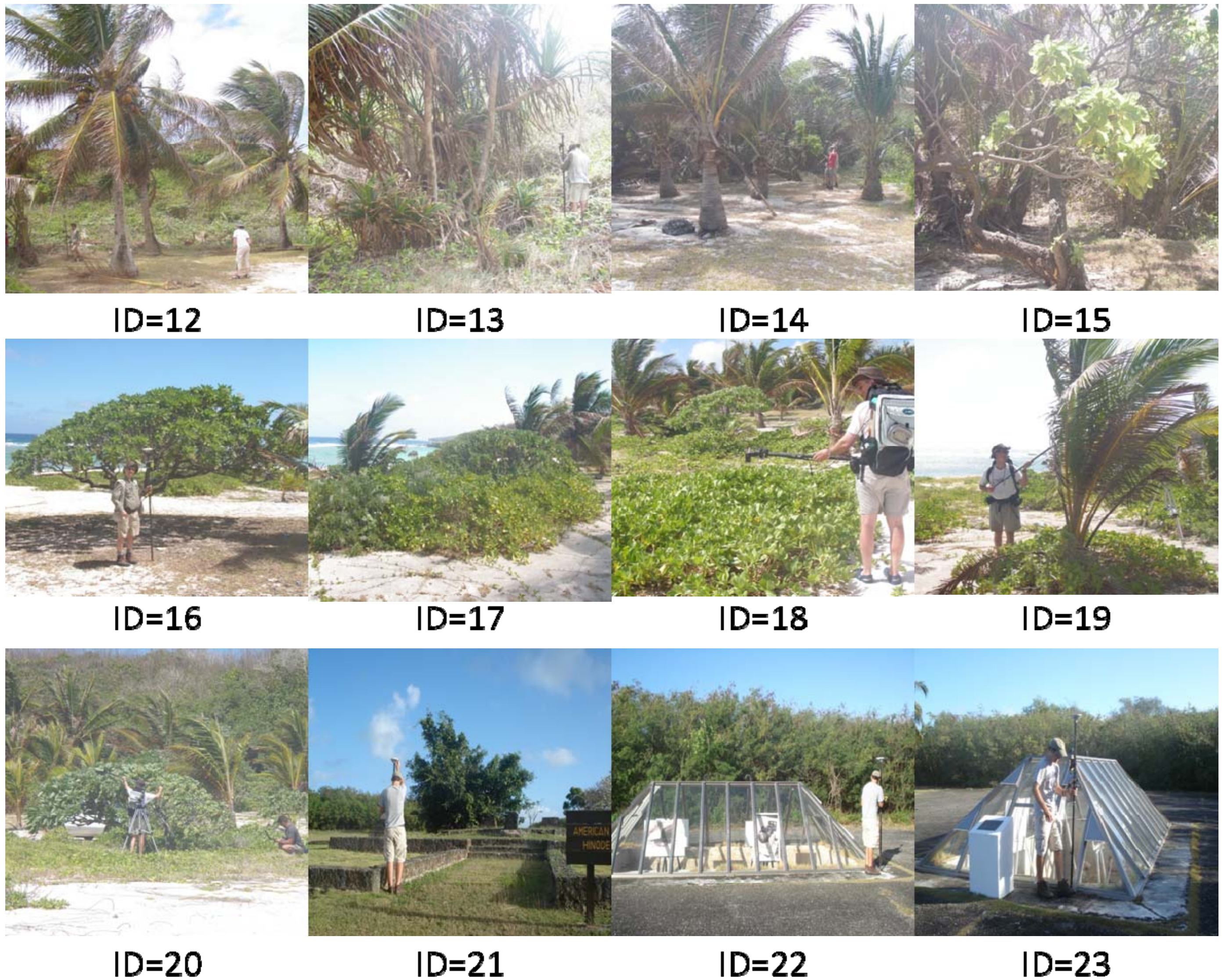


Figure K - 15. Pictures of GCPs marked as areas on the island of Tinian.

Figure K - 16. Pictures of GCPs marked as areas/line on the island of Tinian.

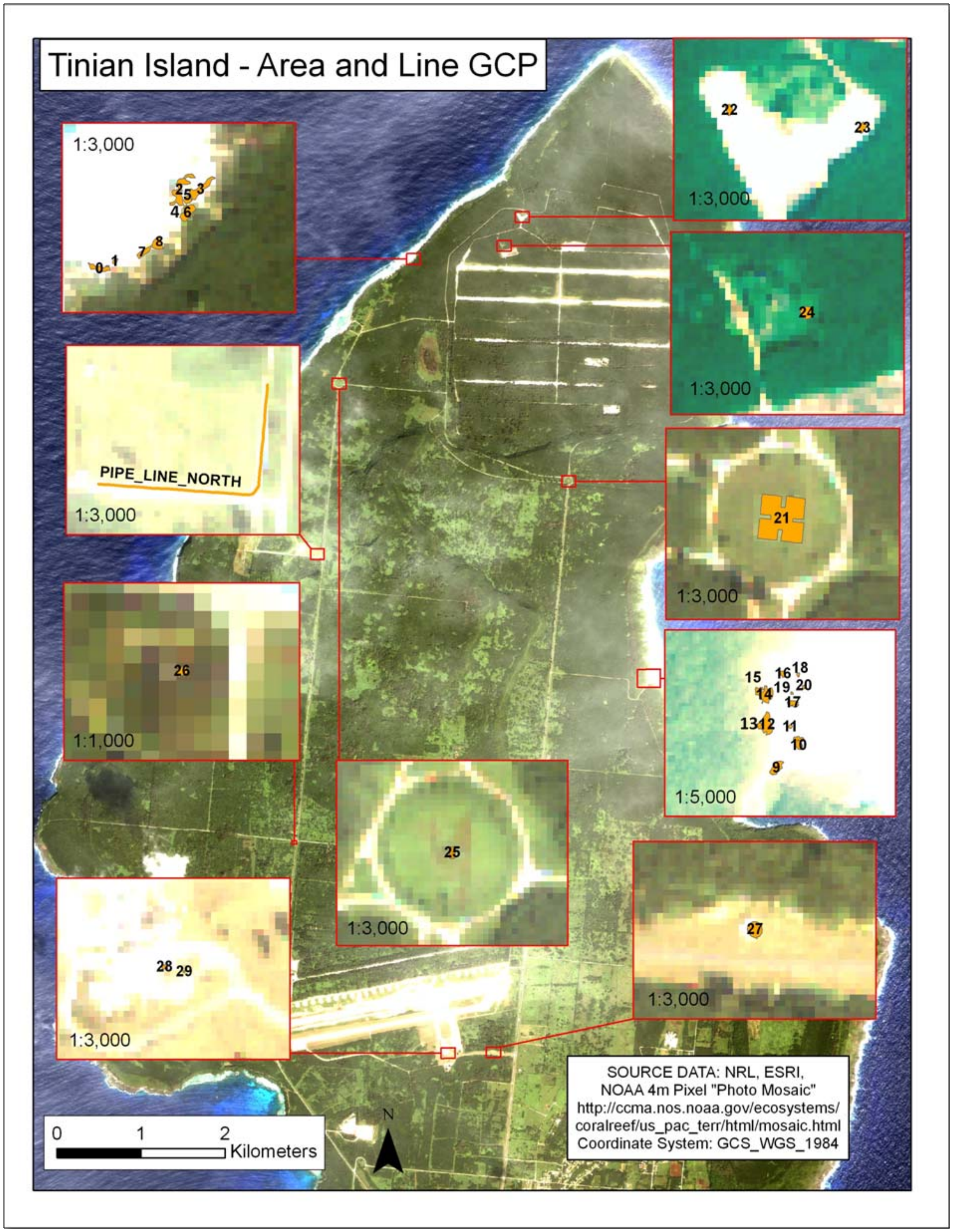


Figure K - 17. Map of GCPs marked as areas/lines on the island of Tinian.

3 Ashtech Z-Extreme GPS

3.1 Coordinate accuracy

The Ashtech® Z-Xtreme™ base station coordinate files were post-processed through the NGS maintained Online Positioning User Service (OPUS) website (NGS (b), 2010). Through OPUS, RINEX formatted GPS base station files are uploaded to the website and the user specifies the antennae type, height, and mode of processing, and OPUS returns the geocorrected position of the base station. The OPUS file returns the accuracy by reporting the peak-to-peak error, or, the difference between the maximum and the minimum value of a coordinate obtained from three baseline solutions, taking into account the three nearest CORS stations. The corrected position of the base station is given as the average position of the three CORS. The position that is reported and accuracies are reported using the International Terrestrial Reference System (ITRF). The OPUS website states that this system gives better accuracy in respect to peak-to-peak error than other coordinate systems such as North American Datum (NAD) 83, and this is due to CORS' ITRF coordinates being updated more frequently (NGS (b), 2010).

3.2 Base station unit (Alpha)

Base station positions and accuracies are displayed in Table K - 1. The table lists the unit name, island, date, position, and accuracies of those positions. The abbreviation HAE stands for height above ellipsoid.

Table K - 7. GPS coordinate accuracies of base stations obtained from OPUS processing.

Unit	Island	Date	Latitude	Latitude-Accuracy (m)	Longitude	Longitude-Accuracy (m)	HAE(m)	HAE-Accuracy (m)
Alpha	Guam	09-Mar-10	13.415927	0.152	144.655613	0.283	64.198	0.144
Alpha	Guam	10-Mar-10	13.415926	0.032	144.655613	0.055	64.177	0.079
Alpha	Guam	11-Mar-10	13.415926	0.067	144.655613	0.104	64.103	0.201
Alpha	Pagan	27-Feb-10	18.123982	0.041	145.760388	0.05	58.334	0.109
Alpha	Pagan	01-Mar-10	18.123982	0.026	145.760388	0.034	58.329	0.112
Alpha	Pagan	02-Mar-10	18.123982	0.007	145.760388	0.026	58.332	0.086
Alpha	Pagan	03-Mar-10	18.123982	0.037	145.760387	0.097	58.338	0.13
Alpha	Tinian	05-Mar-10	15.074683	0.042	145.634361	0.019	77.764	0.097
Alpha	Tinian	06-Mar-10	15.074683	0.015	145.634362	0.007	77.759	0.039
Alpha	Tinian	07-Mar-10	15.074683	0.01	145.634362	0.02	77.818	0.08

Base station locations are mapped in Figure K - 18, where the position on each island is indicated. The base station was placed at the western terminus of the airfield on Pagan, a WWII-era airfield on Tinian, and located on an NGS geodetic marker on Guam.

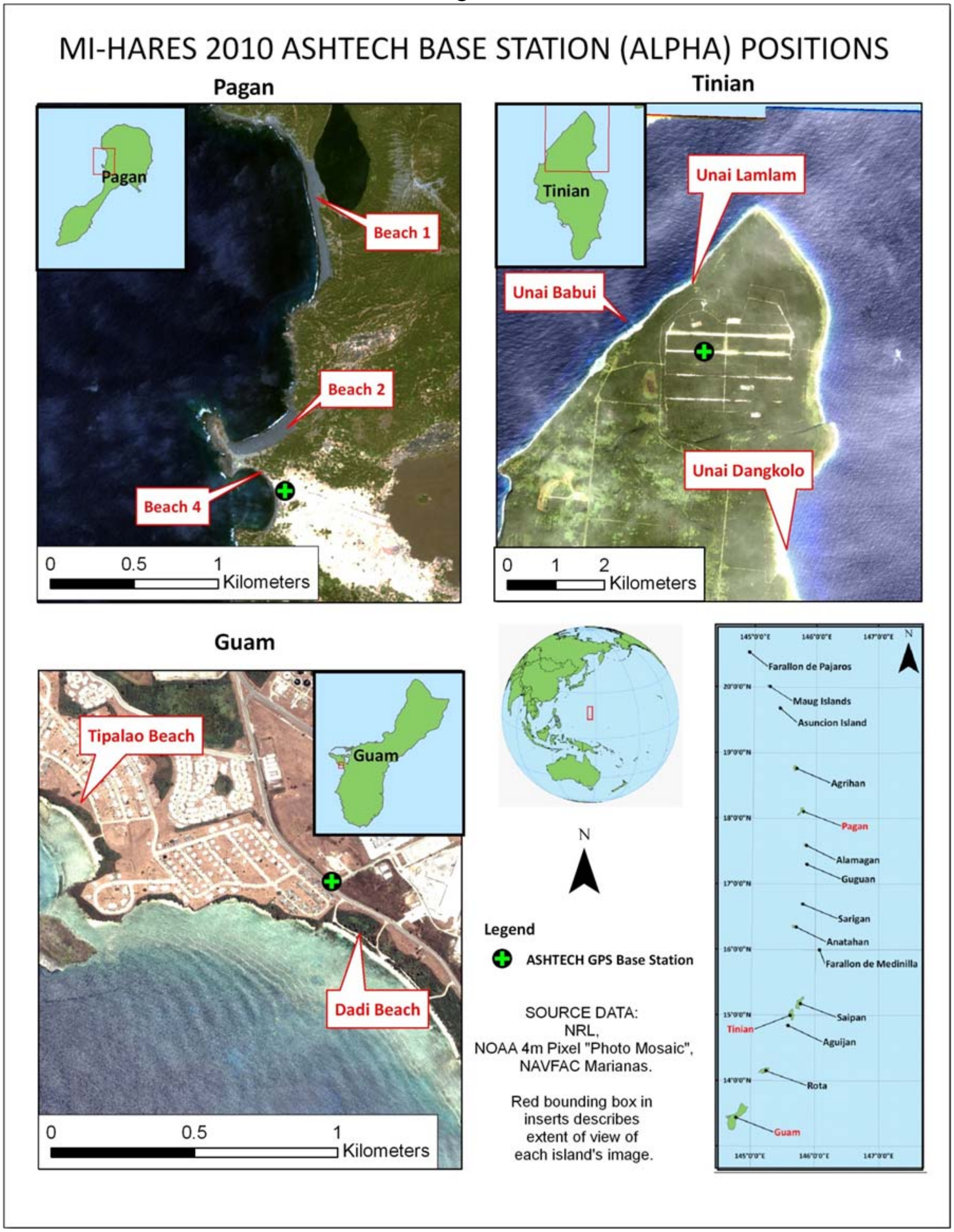


Figure K - 18. MI-HARES 2010 GPS base station positions.

The position of the base station is described visually in Figure K - 19. The base station was not photographed during measurement on Tinian, however the location of its placement is photographed.

Figure K - 19. Ashtech GPS base station locations Guam (left), Pagan (center), and Tinian (right).

3.3 Kinematic beach profile unit (Bravo)

An Ashtech® Z-Xtreme™ was used to survey beach areas by collecting latitudinal, longitudinal and elevation above ellipsoid (WGS_1984 Ellipsoid) data for each beach surveyed. Surveying involved an operator walking the unit (attached to a wheel at bottom) from beach interior areas until the operator was approximately 1 meter in the water. The operator would then continue this sample regimen length-wise until the subject area was covered. Sampling for the GPS unit was 1 Hz. Accuracies were less than the base station unit and were estimated to be less than 10 cm for all islands. Table K - 8 describes positional information collected from the experiment. The unit was used to mark geodetic markers, as well. Figure K - 20 displays the positions recorded via the beach profile GPS unit. The two geodetic marker positions are not present in the figure.

Table K - 8. Ashtech survey positional breakdown.

Island	Location	Local Date	Number of Readings
Guam	Ball Field Behind Tipalao	9 Mar 2010	420
	Dadi Beach	10 Mar 2010	28,255
	Tipalao Beach	10 Mar 2010	6,283
	Geodetic Marker Tidal 11 (13.4463 N 144,65661 E)	11 Mar 2010	1,385
	Geodetic Marker GGN 2752 (13.4050 N, 144.66278 E)	11 Mar 2010	1,113
	Guam Total		37456
Pagan	Beach 1	2 Mar 2010	21,965
	Beach 2 and Promontory	3 Mar 2010	15,496
	Beach 4	27 Feb 2010	10,321
	Beach 4	2 Mar 2010	8,538
	Pagan Total		56,320
Tinian	Unai Babui	5 Mar 2010	18,791
	Unai Dangkolo	6 Mar 2010	22,578
	Unai Lamlam	7 Mar 2010	10,945
	Tinian Total		52,314

Total	**MI-HARES 2010 Total**	**146,090**

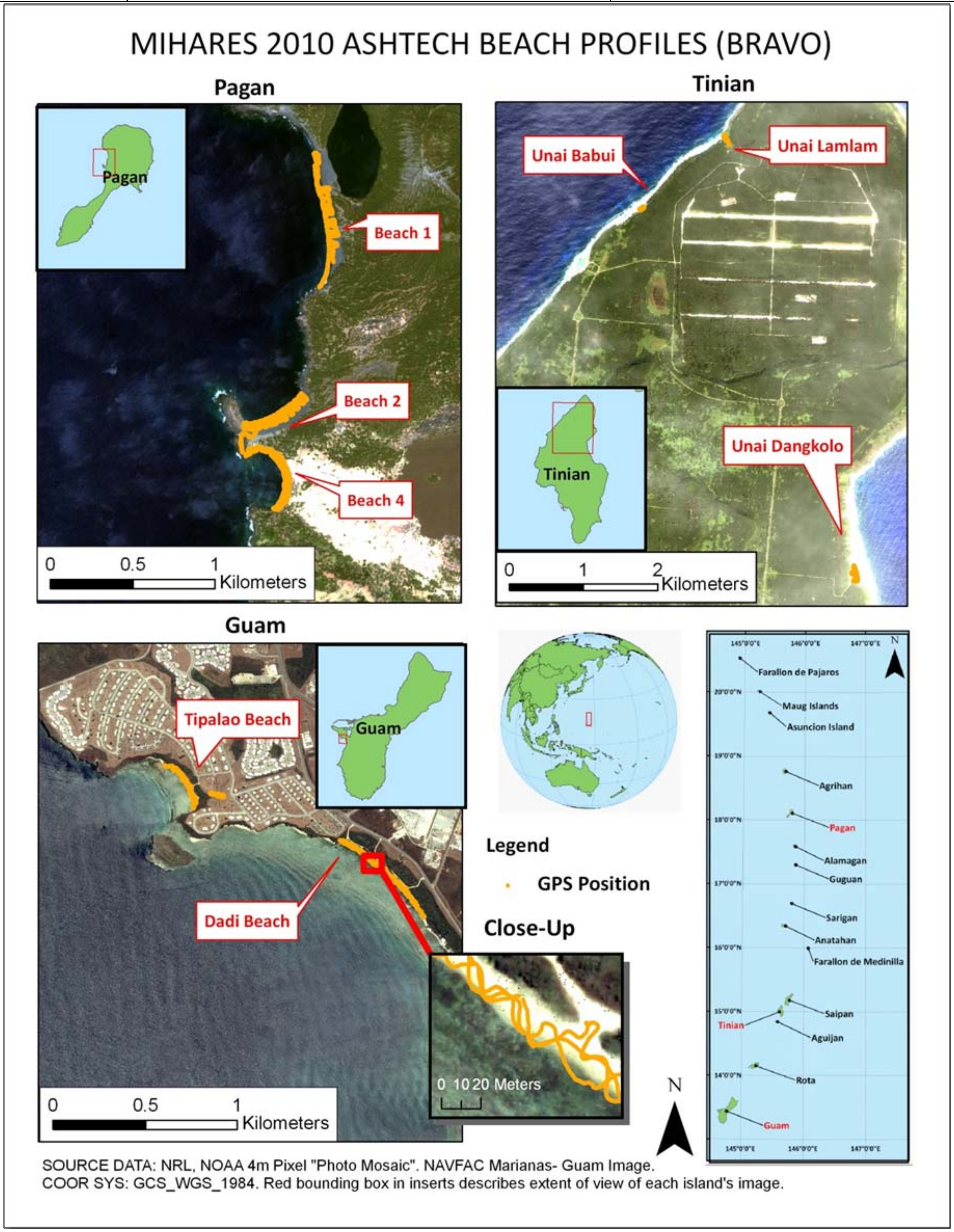


Figure K - 20. Ashtech kinematic GPS beach profile positions. Beach surveys involved an operator moving from beach interior to a depth of approximately 1 meter and continuing lengthwise until the beach area was covered. The "Close-Up" panel describes the sampling pattern where the operator moved from interior to depths of approximately 1 meter.

3.4 Water level unit (Charlie)

An Ashtech® Z-Xtreme™ was attached to a PVC buoy and collected water level data offshore each of the three islands during the experiment. Water level data collected during each phase of the experiment is described in Appendix L as well as data collected from additional tidal sources.

APPENDIX L

Water Level Data

1 Introduction

Water level data are important for calibration and validation and synchronizing imagery with the rising and falling tide. For this remote sensing campaign, an Ashtech® Z-Xtreme™ dual frequency Real-Time-Kinematic GPS was attached to a buoy and deployed in shallow water near Pagan, Tinian, and Guam landing beaches. High frequency water level data were averaged to 10-minute observations to determine vertical movements of the water, i.e. tides. After processing, buoy measurements were used to determine the tidal height in height (in meters) above ellipsoid (WGS_1984). These data are used to synchronize imagery-derived bathymetry and fathometer soundings taken in the selected study areas with the tide.

Neither predicted nor observed tide data are presently available since water level studies have not been conducted owing to the remoteness of the study area. According to the NOAA tides and currents website and the Observational Data Interactive Navigation (ODIN) interface, there are two land-based tide stations in Guam that are currently operational and contain reference and secondary station (NOAA (a), 2010) data for several sites not included in the remote sensing campaign. According to NOAA's National Data Buoy Center, there is also an operational Datawell® Waverider™ buoy located in 200m of water approximately 1 mile east of Ipan, Guam (NDBC, 2010). This buoy, which provides data intermittently, is maintained by the SCRIPPS Institute of Oceanography's Costal Data Information Program (CDIP) and is intended to record various surface wave parameters (CDIP, 2010). However, since the research area was located on the western side of the island, any water level data from the Pago Bay and NOAA buoy will not accurately characterize the research area's conditions. In order to determine water level fluctuations at study sites in Tipalao Bay and off of Dadi Beach, NOAA water level data from the Apra Harbor tide stations is most relevant. This station was used for tide predictions for the CNMI; time and height offsets at several CNMI secondary stations are based on Apra Harbor predictions. Tide predictions are available for Saipan, and Tinian. Information about each tidal station is displayed in Table L - 1.

Table L - 1. NOAA Tide Gauge Station/Buoy Information for Guam and the CNMI.

Station Location	Tanapag Harbor	Pago Bay	Apra Harbor	Saipan Harbor	San Jose Harbor	Ipan, Guam
Locality	Saipan	Guam	Guam	Saipan	Tinian	200m of water, East of Guam
Station ID	1633227	1631428	1630000	TPT2623	TPT2625	52200 (NOAA) 121 (SCRIPPS)
Latitude	15.2267N	13.4189N	13.4387N	15.2N	14.9667N	13.354N
Longitude	145.737E	144.785E	144.6539E	145.7167E	145.6167E	144.789 E
Operational	Removed 2001	Yes	Yes	No	No	Yes
Mean Range (m)	0.45	0.35	0.49	0.40	0.46	-
Spring Range (m)	0.67	0.55	0.73	0.58	0.55	-
Mean Tide Level (m)	0.41	0.33	0.43	0.37	0.30	-
Reference Station	Apra Harbor	N/A	N/A	Apra Harbor	Apra Harbor	N/A
High Tide-Time Offset	+ 21 minutes	N/A	N/A	+ 2 minutes	- 2 minutes	N/A
High Tide- Height Offset (m)	0.28	N/A	N/A	0.24	0.23	N/A
Low Tide-Time Offset	+ 15 minutes	N/A	N/A	+ 7 minutes	- 23 minutes	N/A
Low Tide-Height Offset (m)	0.30	N/A	N/A	0.24	0.10	N/A

The nine principal harmonic constants are useful in predicting tides or in applications such as tidal constituents and residuals interpolation (TCARI). Tidal constituents are provided in Table L - 2 in order to facilitate tide predictions with numerical models such as ADCIRC and PCTIDES, or to estimate the difference between Mean Sea Level (MSL) and Mean Lower Low Water (MLLW) with programs such as NOAA's TCARI. Having accurate tidal predictions and depth profiles from imagery-derived shallow water bathymetry is also useful for running models such as the Navy Standard Surf Model.

Table L - 2. Major tidal constituents. Semidiurnal and diurnal constituents are provided in order to understand the nature of the tides in the Mariana Islands.

	1630000 (Apra Harbor)			1631428 (Pago Bay)			1633227 (Saipan Harbor)		
Constituent	Amplitude	Phase	Speed	Amplitude	Phase	Speed	Amplitude	Phase	Speed
M_2	0.232	290.9	28.984	0.142	276.2	28.984	0.188	296.2	28.984
S_2	0.059	311.1	30.000	0.026	282.9	30.000	0.043	305.3	30.000
N_2	0.048	276.3	28.440	0.036	253.4	28.440	0.046	278.9	28.440
K_1	0.173	65.1	15.041	0.141	61.3	15.041	0.167	64.9	15.041
O_1	0.122	44.2	13.943	0.102	42.6	13.943	0.113	45.6	13.943
M_4	0.005	151.6	57.968	0.003	119.3	57.968	0.001	242.4	57.968
M_6	0.000	0.0	86.952	0	0	86.952	0	0	86.952
S_4	0.000	0.0	60.000	0.001	227.2	60.000	0.002	189.7	60.000
MS_4	0.004	202.9	58.984	0.003	168.3	58.984	0.003	261.6	58.984

These harmonic constants are the building blocks of the tide. The first five constituents are the main players that determine the type of tide. If the amplitudes for M_2, S_2, and N_2 are large compared to the amplitudes for K_1 and O_1, then tides in the region will be of the semidiurnal type (two highs and two lows each day); if K_1 and O_1 amplitudes are large compared to the others, then the tides will be of the diurnal type (one high and one low tide each day). Amplitude values are in meters, and phase values are in degrees referenced to UTC. The speed value indicates the rate change in the phase of a constituent, expressed in degrees per hour. Major tide constituents for CNMI and Guam stations can be accessed through NOAA's Tides and Currents website.

2 Tide Gauge/Wave Buoy Data

2.1 NOAA Station 1630000-Apra Harbor, Guam (Tide Gauge)

Accurate six-minute interval tide gauge data for Apra Harbor, Guam is displayed in graph format in Figure L - 1, Figure L - 2, and Figure L - 3. These data have undergone NOAA quality control procedures to verify harmonic predictions. Each graph displays water level (observed, predicted) and the residuals (i.e., the observed minus predicted values). The residuals are most likely caused by meteorological events (strong winds). Along the *x*-axis, the local date and time is provided, and along the *y*-axis, the water level in meters from Mean Lower-Low Water (MLLW) is displayed. The data are segmented into three parts, where part one displays dates 25 to 28 February, part two displays dates 1to 5 March, and part three displays data from 6 to 11 March, 2010. The plots have been extracted from the Apra Harbor tidal station information page on NOAA's Tides and Currents website (NOAA (b), 2010).

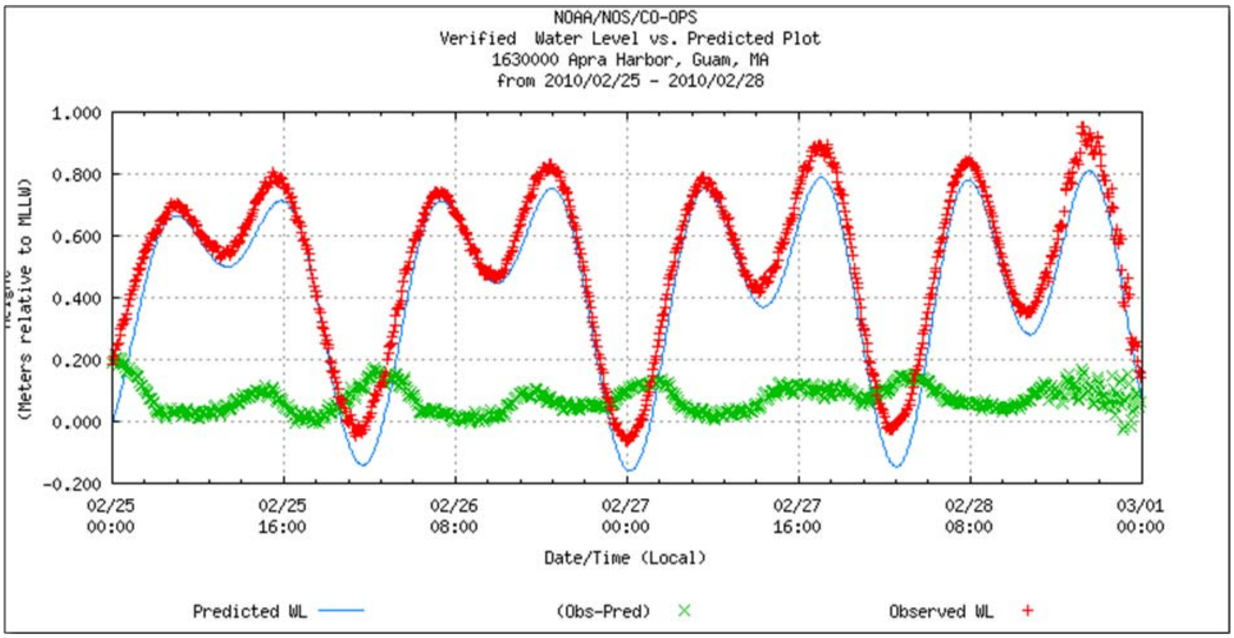


Figure L - 1. Water level information for Apra Harbor, Guam from 25 February through 28 February. The mixed, mainly semidiurnal nature of the tide is clearly depicted.

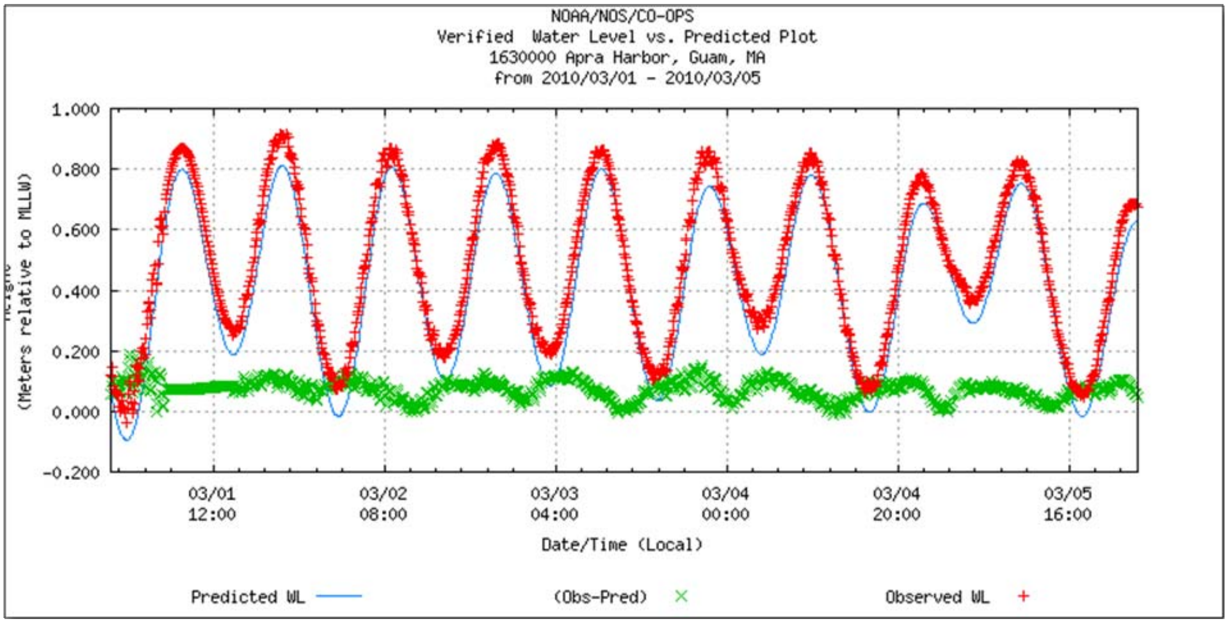


Figure L - 2. Water level information for Apra Harbor, Guam from 1 March through 5 March. The mixed, mainly semidiurnal nature of the tide is clearly depicted.

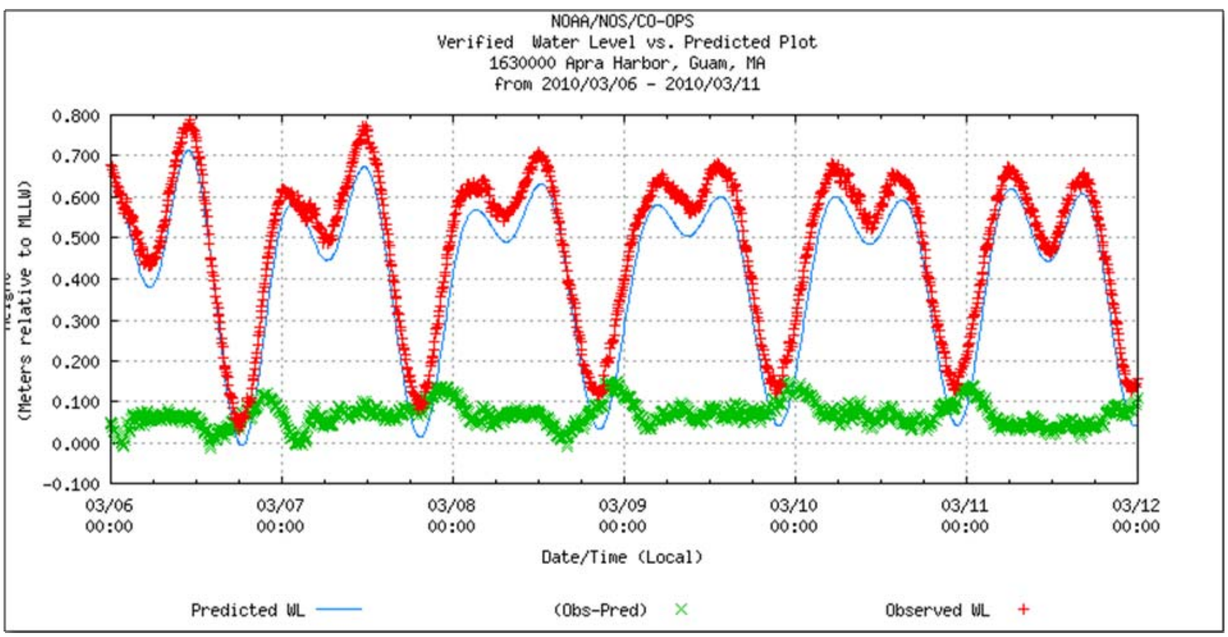


Figure L - 3. Water level information for Apra Harbor, Guam from 6 March through 11 March. The mixed, mainly semidiurnal nature of the tide is clearly depicted.

2.2 NOAA Station 1631428- Pago Bay, Guam (Tide Gauge)

Accurate six-minute interval water level data for the NOAA tide gauge station located at Pago Bay, Guam is presented in Figure L - 4 through Figure L - 6. These data have undergone NOAA quality control procedures to assess the quality of harmonic predictions. . The graphs are similar to the station at Apra Harbor, Guam and are broken into three periods. All three periods of data have been displayed, which covers the entire remote sensing campaign.

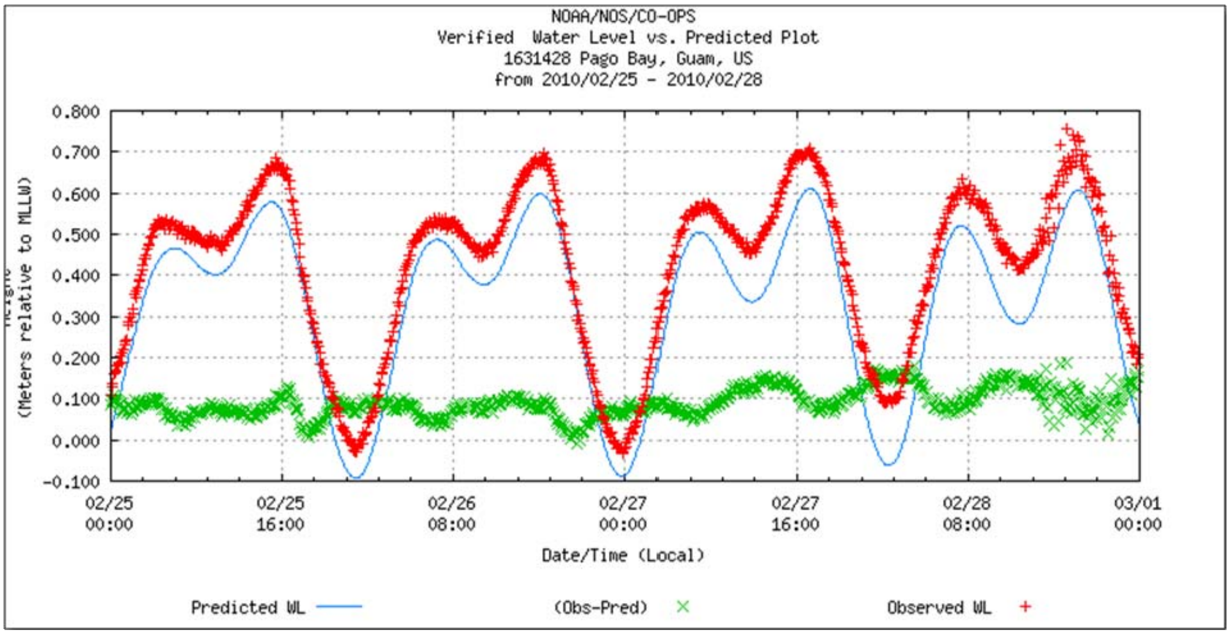


Figure L - 4. Quality controlled water level information for Pago Bay, Guam from 25 February through 28 February. The mixed, mainly semidiurnal nature of the tide is clearly depicted.

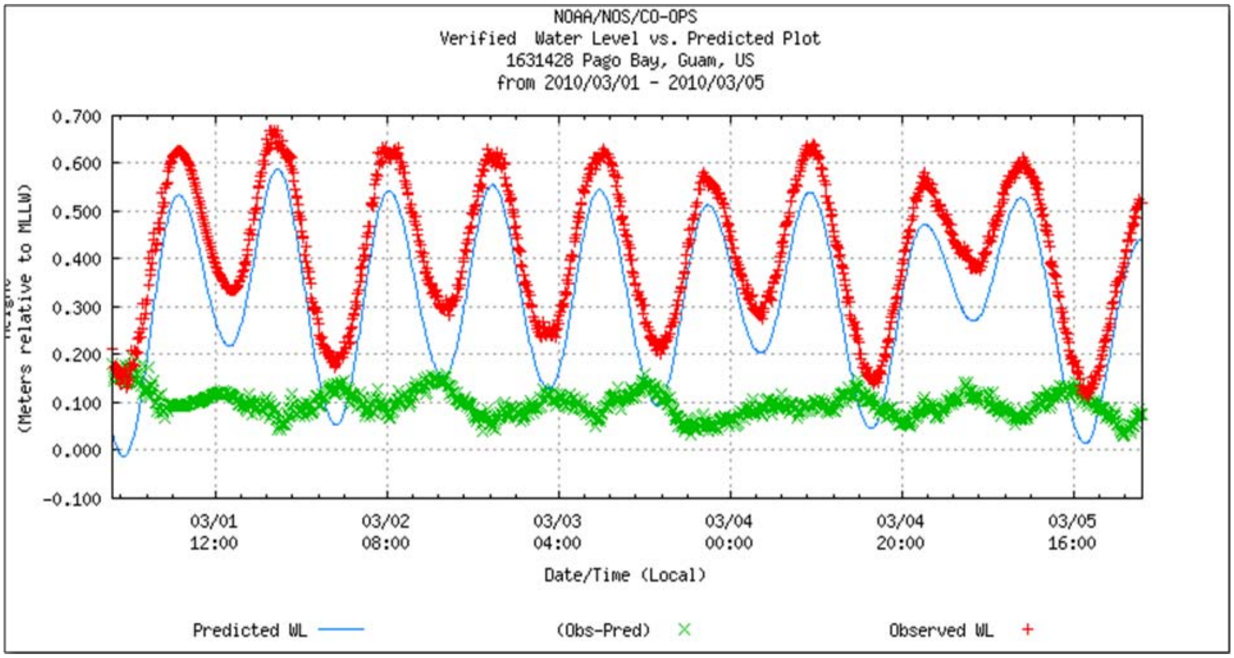


Figure L - 5. Quality controlled water level information for Pago Bay, Guam from 1 March through 5 March. The mixed, mainly semidiurnal nature of the tide is clearly depicted.

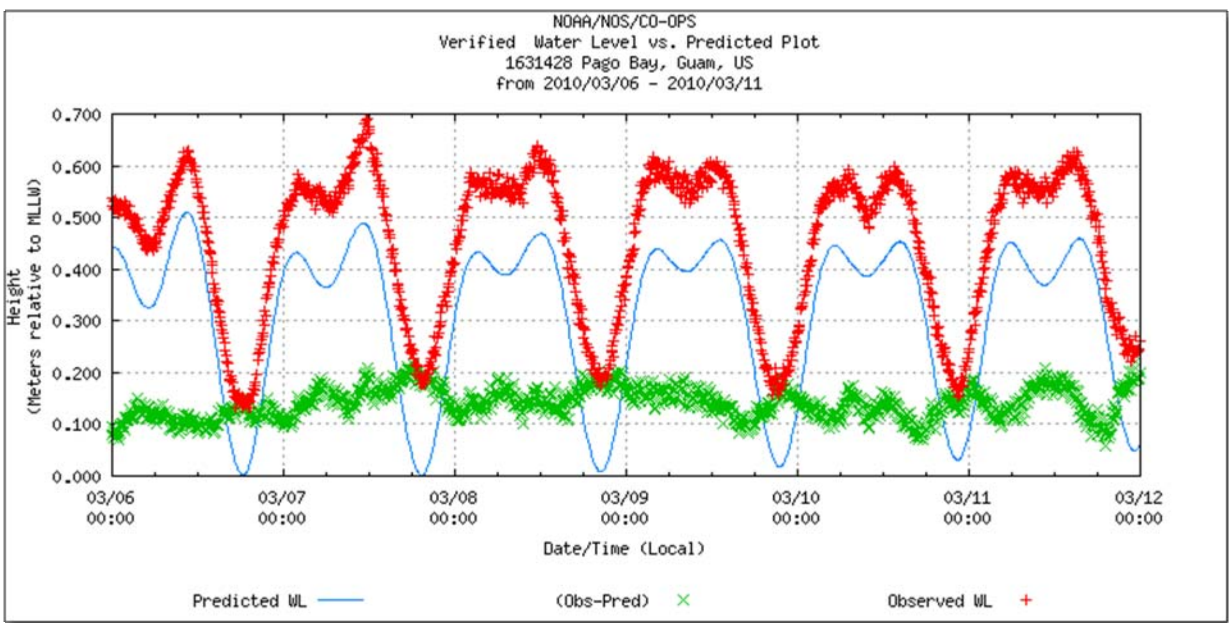


Figure L - 6. Quality controlled water level information for Pago Bay, Guam from 6 March through 11 March. The mixed, mainly semidiurnal nature of the tide is clearly depicted.

2.3 SCRIPPS Station 121/NOAA Station 52200-Ipan, Guam (Wave Buoy)

The SCRIPPS Institute of Oceanography's Coastal Data Information Program website contains information on the wave buoy (Station Number, 123456) located on the east coast of Guam. Data collected by this wave buoy includes wave energy, wave direction and sea temperature. The CDIP website displays a comprehensive list of products concerning the Datawell wave buoy (CDIP, 2010).

The significant wave height is the average height in meters of the highest one third of the waves during a 20-minute sampling period. In Table L - 3, the significant wave height is averaged for each day of the study period. Significant wave height is a general statistic which describes how rough sea conditions were on a certain day. These data were downloaded from the NDBC website (NDBC, 2010). Information on sea state is especially useful in atmospheric correction and assessing meteorological factors which may have impacted the tides, which are seen in NOAA's residual plots.

Table L - 3. Average significant wave height average per day as reported by SCRIPPS wave buoy located in Ipan, Guam.

Date	Average Significant Wave Height, m	Date	Average Significant Wave Height, m
25-Feb-10	1.46	4-Mar-10	2.10
26-Feb-10	1.92	5-Mar-10	2.18
27-Feb-10	2.61	6-Mar-10	2.39
28-Feb-10	2.93	7-Mar-10	2.45
1-Mar-10	2.49	8-Mar-10	2.35
2-Mar-10	2.12	9-Mar-10	2.13
3-Mar-10	1.82	10-Mar-10	2.21

Sea and swell heights are plotted in Figure L - 7, Figure L - 8, and Figure L - 9. These figures show significant wave height (in cm) for either sea or swell versus time in UTC. The significant wave height in cm is provided along the *y*-axis, while the time in UTC is noted along the *x*-axis. Guam is located in Chamorro Standard Time and is 10 hours ahead of UTC. The three figures provided below split the study period into three periods; 25-28 February, 1-5 March, and 6-10 March. This is done to give the reader an easier view of the data. Data are missing for 11 March since the wave buoy communication was shut-down temporarily.

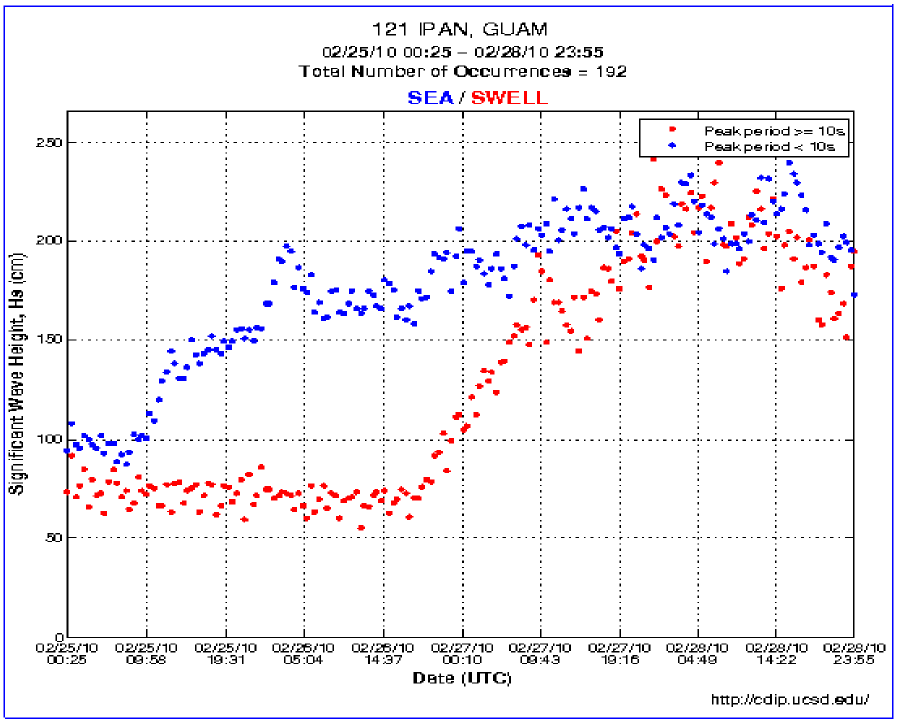


Figure L - 7. Sea and swell heights for SCRIPPS wave buoy from 25 February through 28 February.

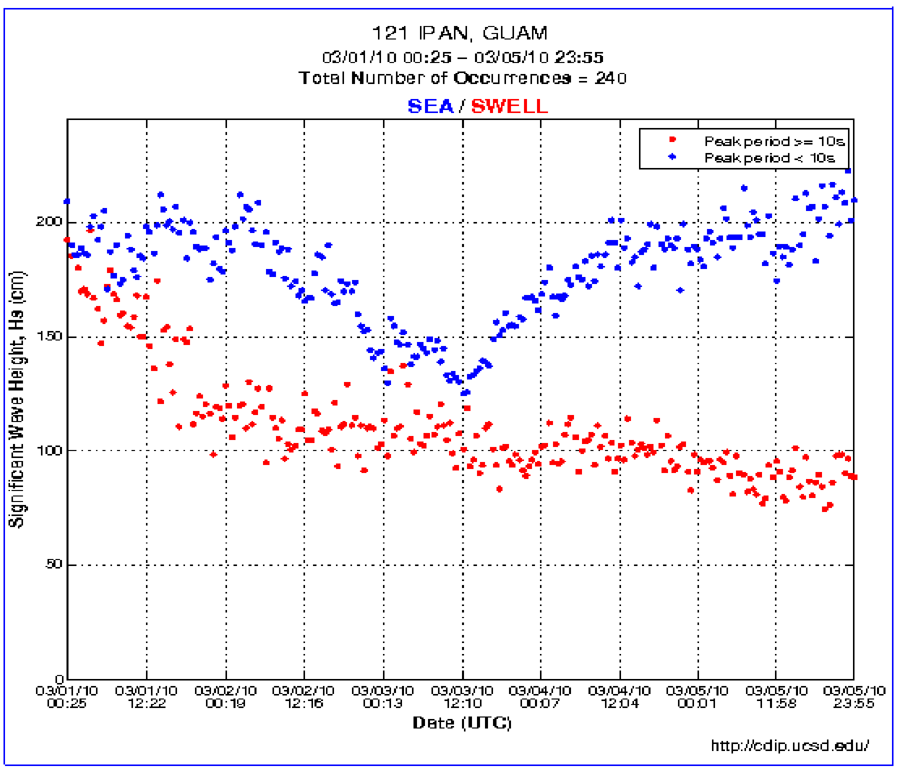


Figure L - 8. Sea and swell heights for SCRIPPS wave buoy from 1 March through 5 March.

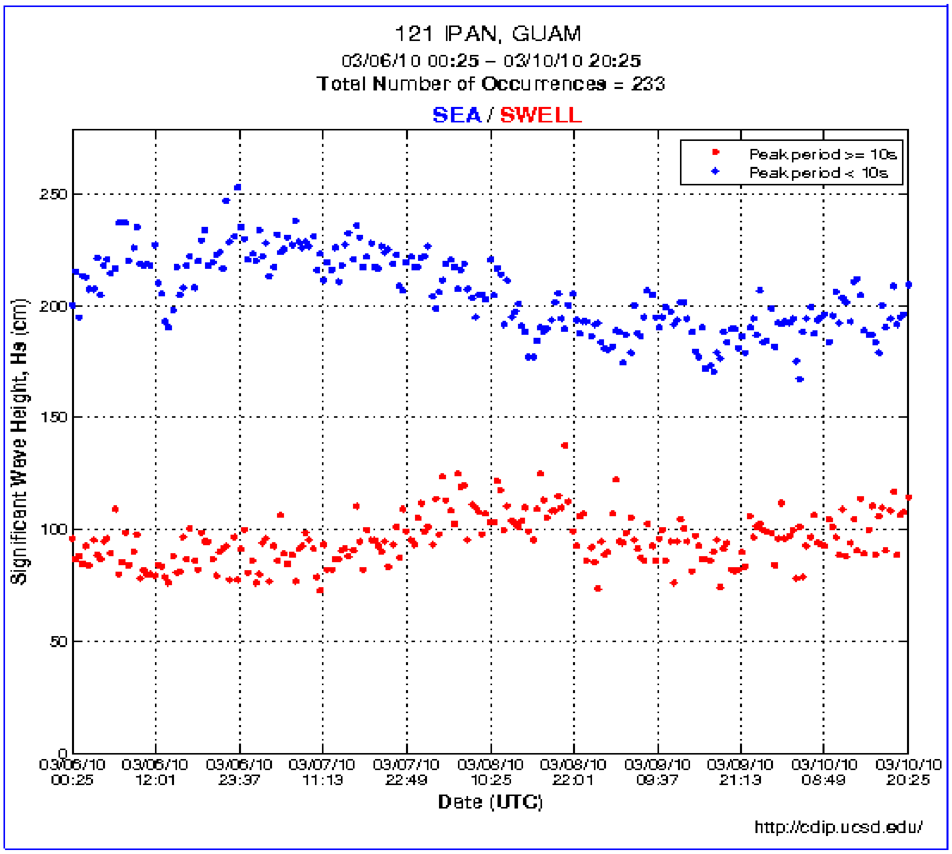


Figure L - 9. Sea and swell heights for SCRIPPS wave buoy from 6 March through 10 March.

3 MI-HARES'10 Collected Data

An Ashtech® Z-Xtreme™ dual frequency Real-Time-Kinematic GPS unit was used to measure water level height on Pagan, Tinian, and Guam. This GPS unit was attached to a wooden rest which was attached to a PVC plastic frame (Figure L - 10). The unit recorded height in meters above ellipsoid, latitude, and longitude to precisions of approximately 1 cm.

Figure L - 10. Ashtech® Z-Xtreme™ unit used as part of a buoy to measure water level height. The buoy was usually moored toward the center of the beach. It provided a useful reference for underwater spectrometry that occurred along right flank, center, and left flanks of the landing beach.

Information about the deployment of the water level buoy is displayed in Table L - 4. The water level buoy was deployed for a total of eight days with four of those days being on Pagan, two on Tinian, and two on Guam. The location of each buoy's placement changed with each day. It was always deployed outside of the surf zone to avoid errors associated with breaking waves. The average latitude / longitude are listed in the table to give an approximate location of the buoy. The period and amount of time the buoy was recording is also listed in the table. Sampling rates for the water level height was 1 Hz for all days with the exception of 27 February which was 0.05 Hz. Figure L - 11 displays the average location of each day. Figure L - 12 through Figure L - 15 display the water level height raw data as well as a 10-minute moving average trend line.

Table L - 4. Water level buoy deployment information.

Date	Island	Location (Closest Beach)	Average Latitude	Average Longitude	Logging Time Start (Local)	Logging Time Finish (Local)	Total Time	Comments
27-Feb-10	Pagan	Beach 4	18.1235618	145.7584442	9:02:40	14:08:20	5:05:40	Instrument error. Time of finish was prior to bathymetric survey. Sampling rate was 3 samples per minute (0.05Hz)
1-Mar-10	Pagan	Beach 2	18.12773689	145.75848882	10:28:01	18:02:35	7:34:34	
2-Mar-10	Pagan	Beach 1	18.13575853	145.76139986	8:38:31	17:09:54	8:31:23	
3-Mar-10	Pagan	Beach 4	18.12369659	145.75869929	7:23:01	12:02:05	4:39:04	
5-Mar-10	Tinian	Unai Babui	15.08027949	145.62052995	10:35:23	16:45:25	6:10:02	
6-Mar-10	Tinian	Unai Lamlam	15.08865540	145.63145754	9:19:05	14:47:53	5:28:48	
9-Mar-10	Guam	Dadi Beach	13.41020087	144.65314459	14:45:12	17:33:25	2:48:13	
10-Mar-10	Guam	Dadi Beach	13.40903316	144.65245003	10:12:01	15:58:31	5:46:30	

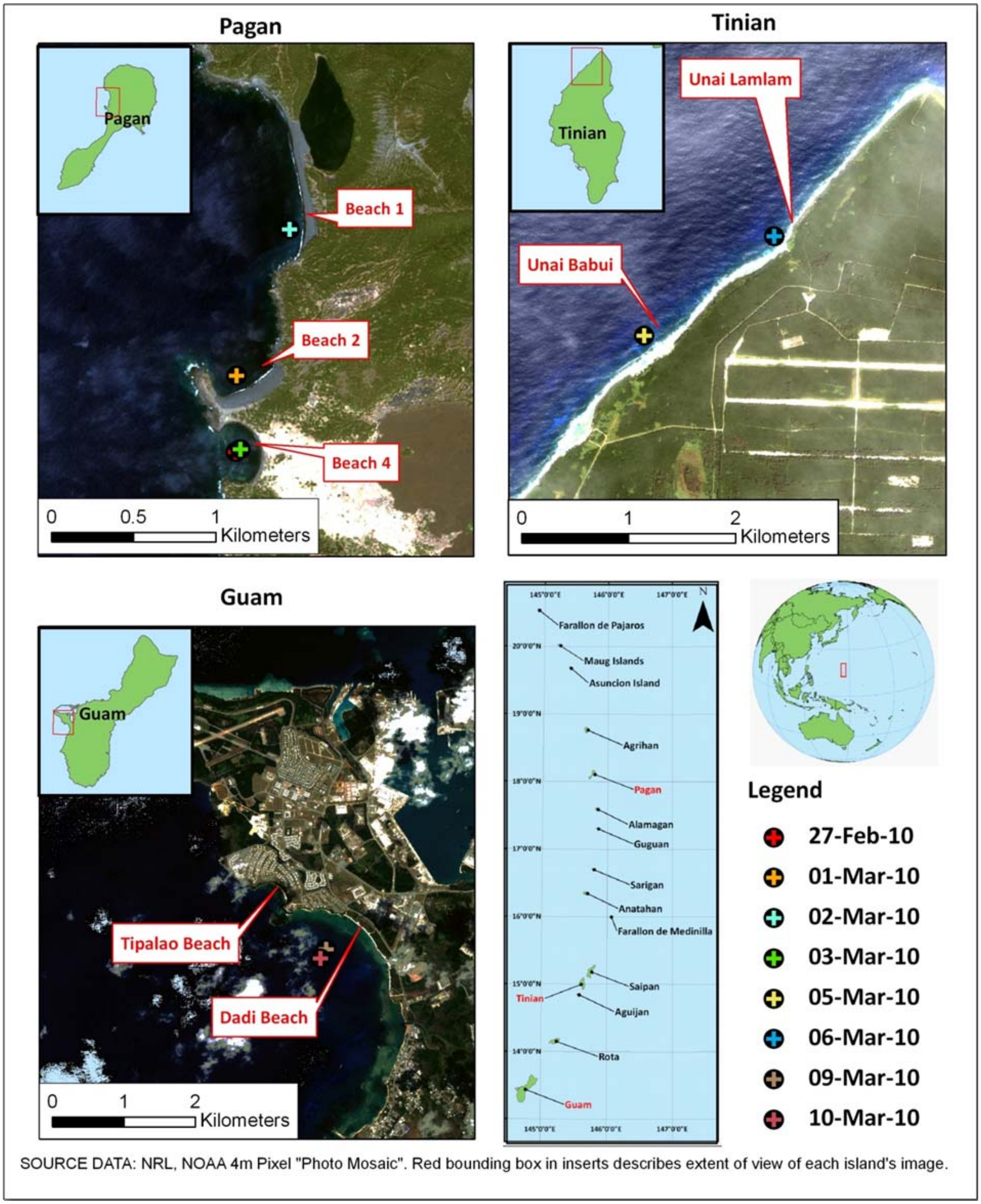


Figure L - 11. Approximate water level buoy positions. The average latitude and longitude for each day is displayed with a colored cross.

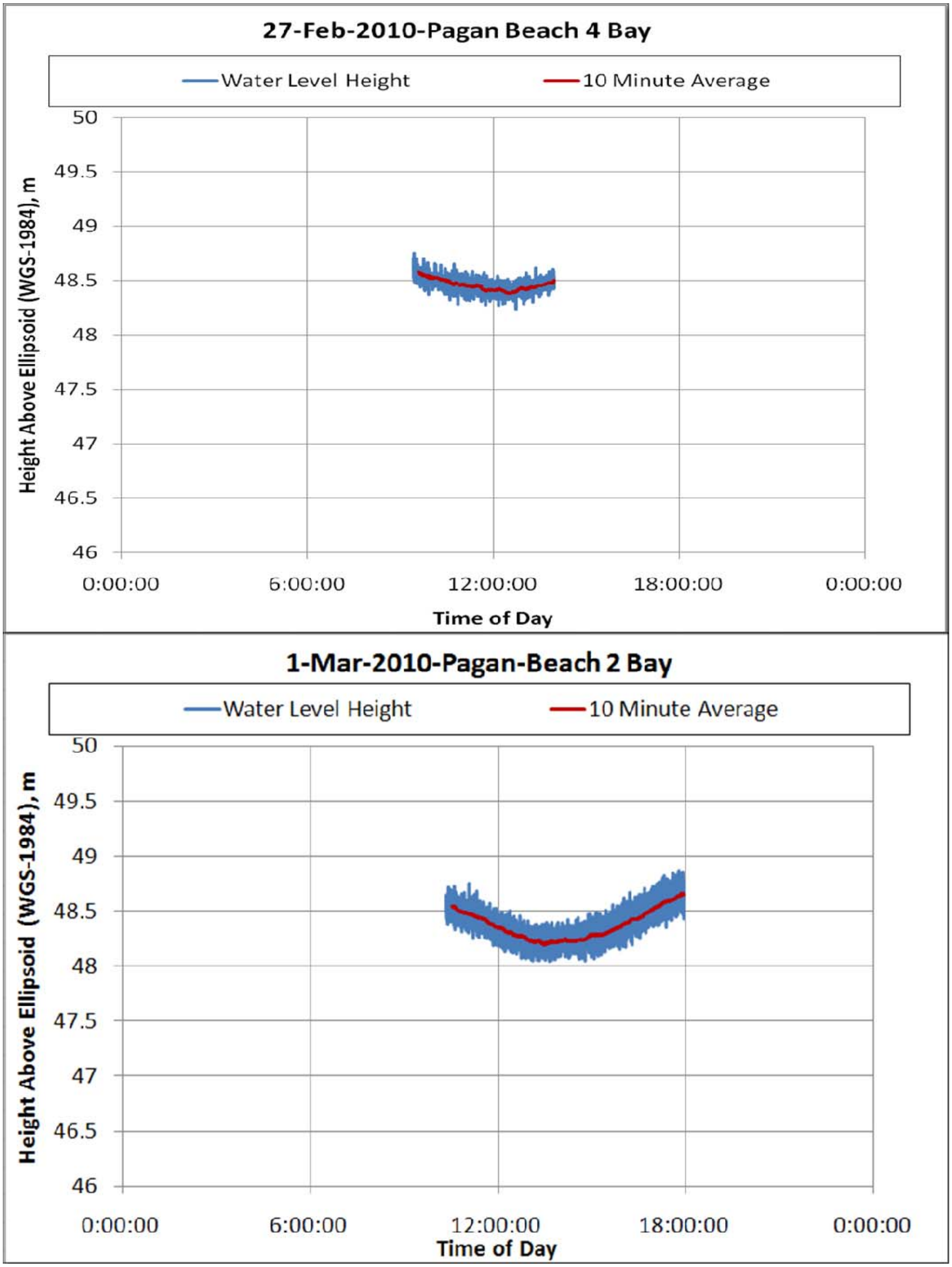


Figure L - 12. Water level height and 10-minute average for 27 February (top panel) and 1 March (bottom panel), 2010.

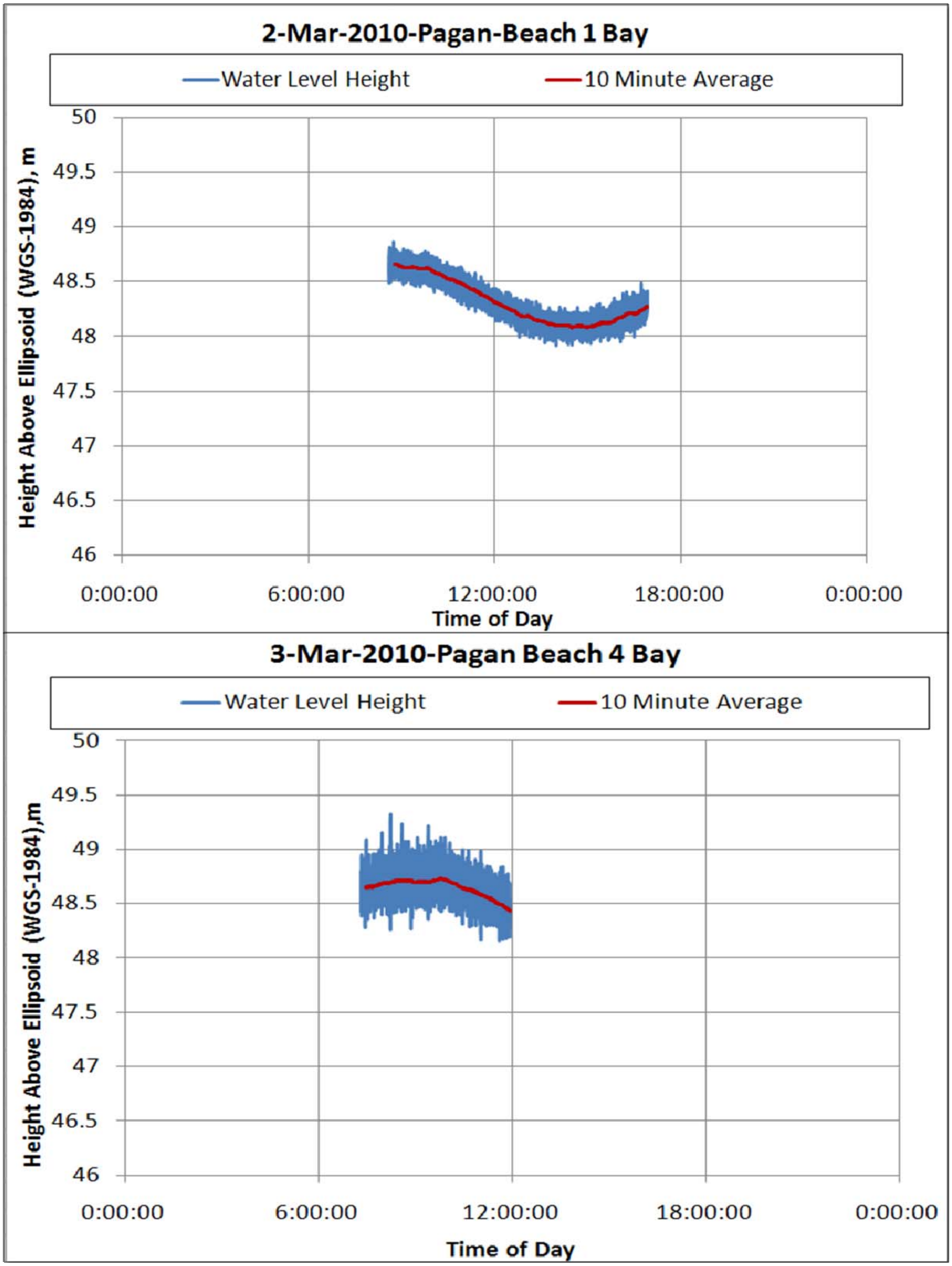


Figure L - 13. Water level height and 10-minute average for 2 March (top panel) and 3 March (bottom panel), 2010.

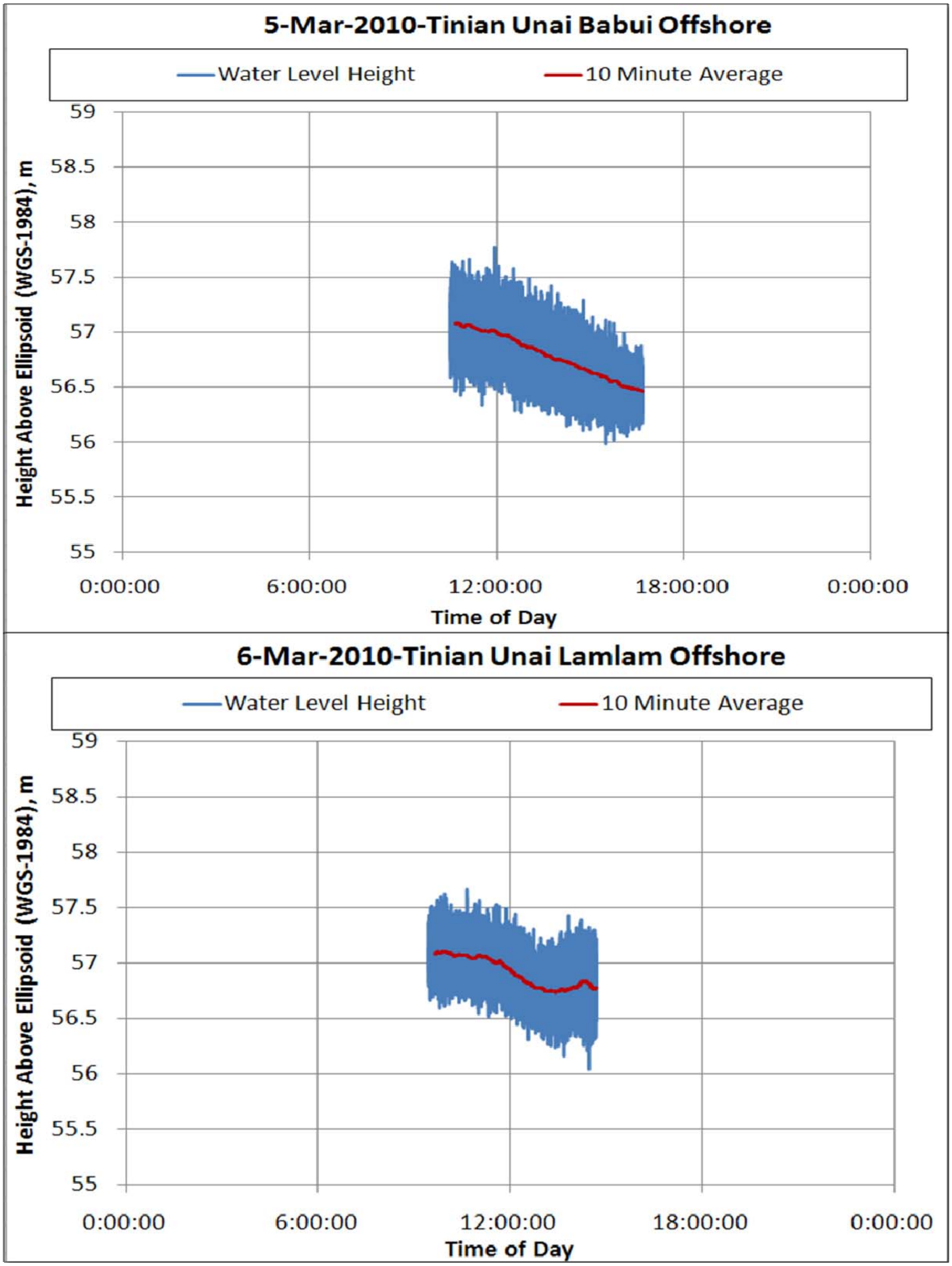


Figure L - 14. Water level height and 10-minute average for 5 March (top panel) and 6 March (bottom panel), 2010.

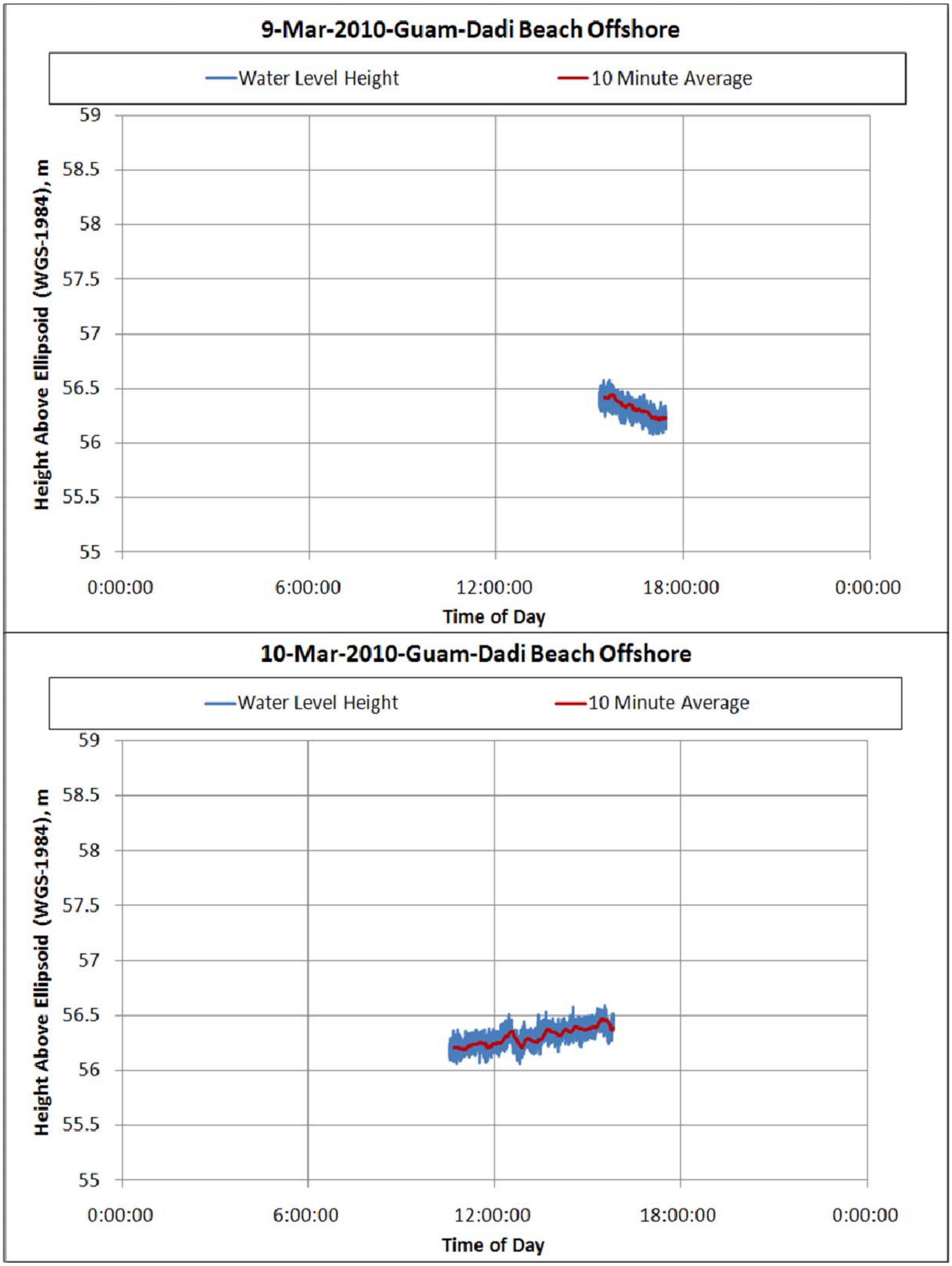


Figure L - 15. Water level height and 10-minute average for 9 March (top panel) and 10 March (bottom panel), 2010.

APPENDIX M

Sun Photometer Data

1 Introduction

The CIMEL® CE-150™ Sun Photometer's main purpose is to measure sun and sky radiance in order to derive total column water vapor, ozone and aerosols properties using a combination of spectral filters and azimuth/zenith viewing controlled by a microprocessor (CIMEL, (a) 2010). A CIMEL® CE-150™ Sun Photometer was positioned on Pagan, Tinian, and Guam during MIRSC'10. However, there were instrument problems during the Pagan portion of the exercise and no data were collected during that phase of the experiment.

2 Data

A CIMEL® CE-150™ Sun Photometer was positioned on Pagan (18°7'32" N, 145°45'26"E, 10m altitude) from 26 February until 3 March, on Tinian (15°04'29"N, 145°38'4"E, 18m altitude) on 7 March, and on Guam (13° 25' 48" N, 144° 38' 40" E, Altitude 10m) from 9 March until 11 March. No useable data was collected from the Pagan phase of the experiment. Tinian and Guam data were useable and incorporated into the AERONET website. Graphical displays in this appendix can be retrieved from the NASA AERONET website (NASA, (a), 2010; NASA, (b), 2010).

2.1 Tinian

Data were collected from 7 March, 2010 on Tinian. The Sun Photometer was placed in the center of runway number two (runway directly south of runway Able) and data were recorded from approximately 8:30 ChST (GMT +10) until 18:00 ChST. Cloud cover for this day was partly cloudy, without observable rain, and with warm temperatures (personal observation). A graphical display for 7 March, 2010 is presented in Figure M - 1. The figure displays Aerosol Optical Thickness along the *y*-axis, and time in hour in GMT along the *x*-axis. Each colored series represents optical thickness at wavelength in nanometers (nm). For example, the green series represents Aerosol Optical Thickness (AOT) at the wavelength 500 nm.

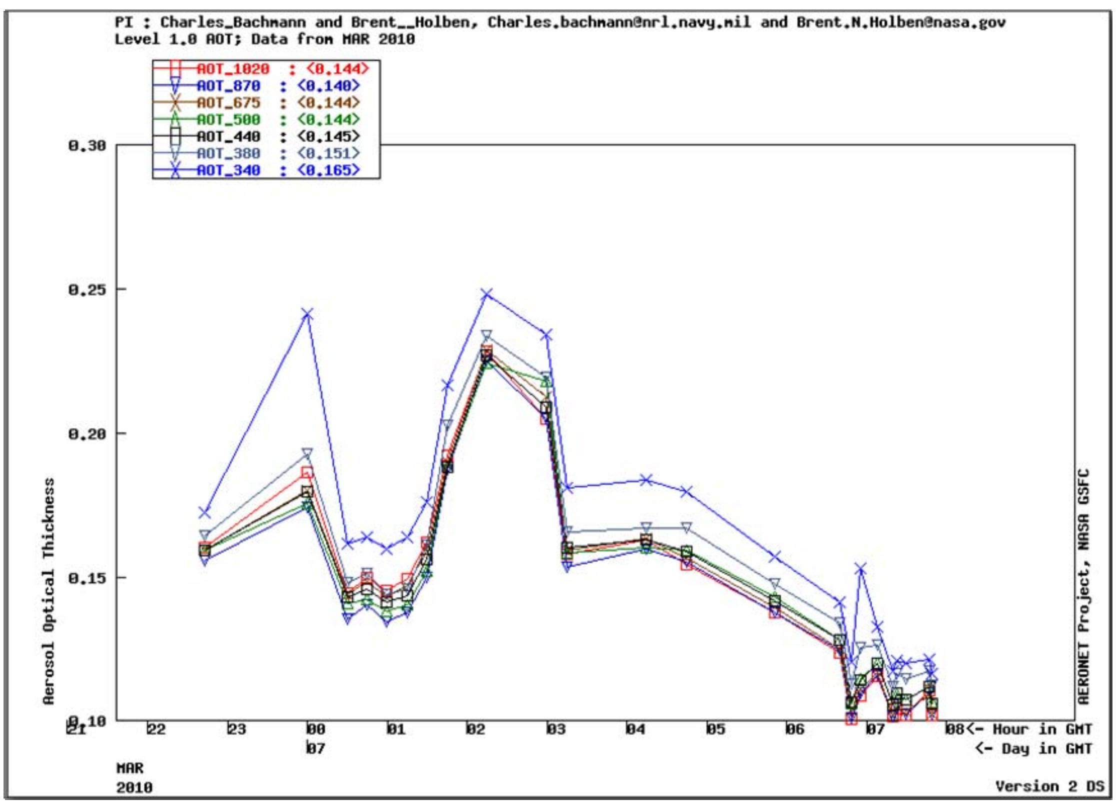


Figure M - 1. Aerosol Optical Thickness for 7 March, 2010.

2.2 Apra Harbor, Guam

Data were collected at the US Naval Base at Guam from 9 March to 11 March, 2010. The location of the unit was placed in a field located at (13° 25.8' N, 144° 38.667 E). Weather for 9 March included 40% average sky covered by clouds, observed light rain, and a high temperature of 86°F as reported for Guam International Airport by the National Weather Service station in Tiyuan, Guam. Weather for 10 March included 50% average sky covered by clouds, no observed precipitation, and a high temperature of 87°F and weather for 11 March included 30% average sky covered by clouds, no observed precipitation, and a high temperature of 88°F. More information on weather statistics can be viewed in Appendix

Graphs of Aerosol Optical Thickness versus time of day for Apra Harbor, Guam are displayed in Figure M - 2, Figure M - 3 and Figure M - 4.

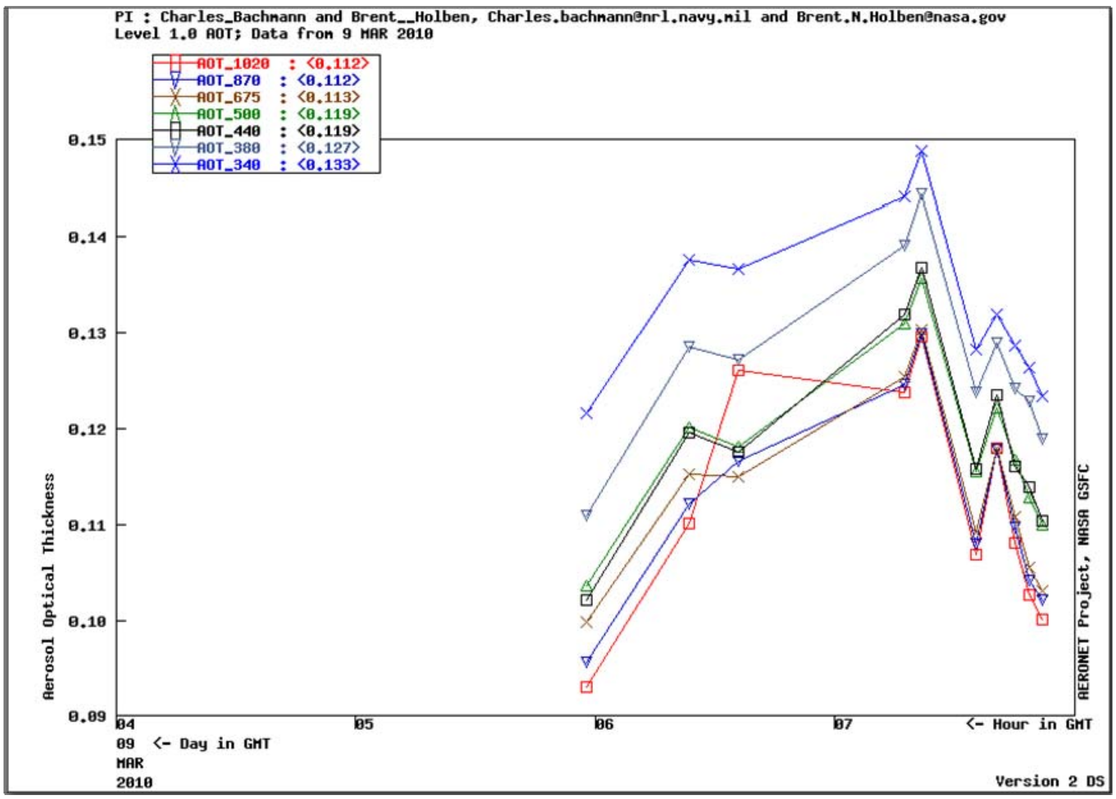


Figure M - 2. Aerosol Optical Thickness for 9 March, 2010.

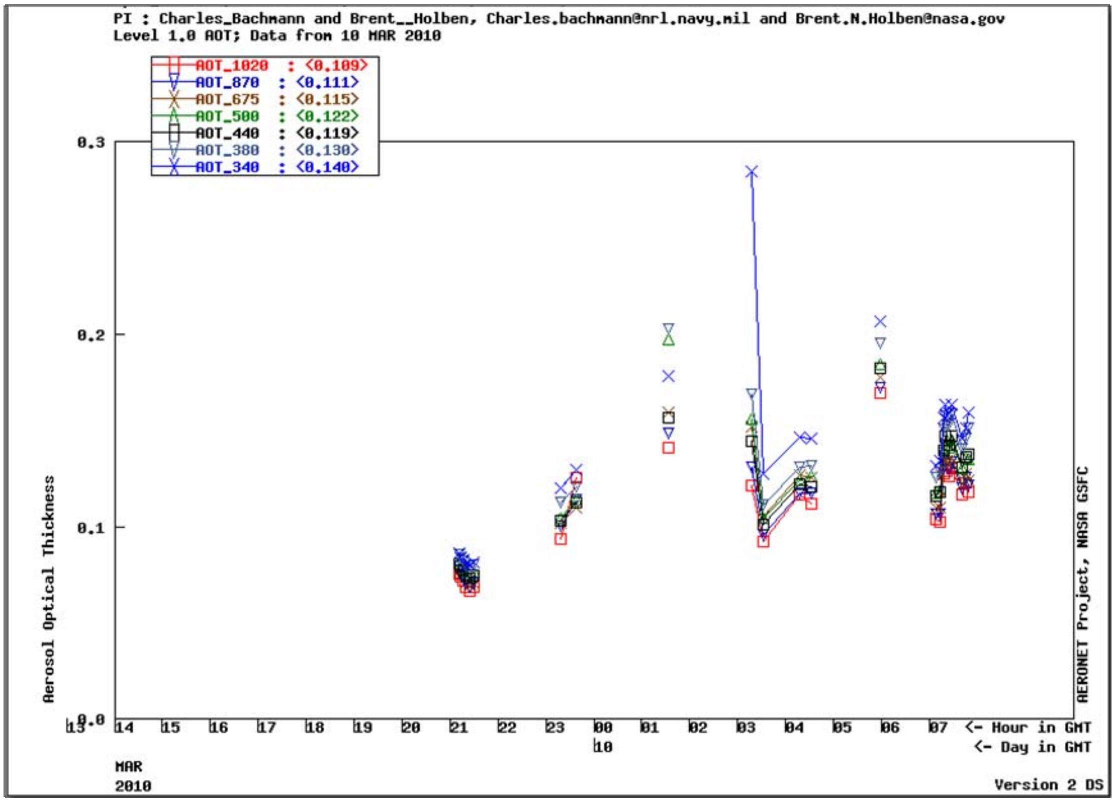


Figure M - 3. Aerosol Optical Thickness for 10 March, 2010.

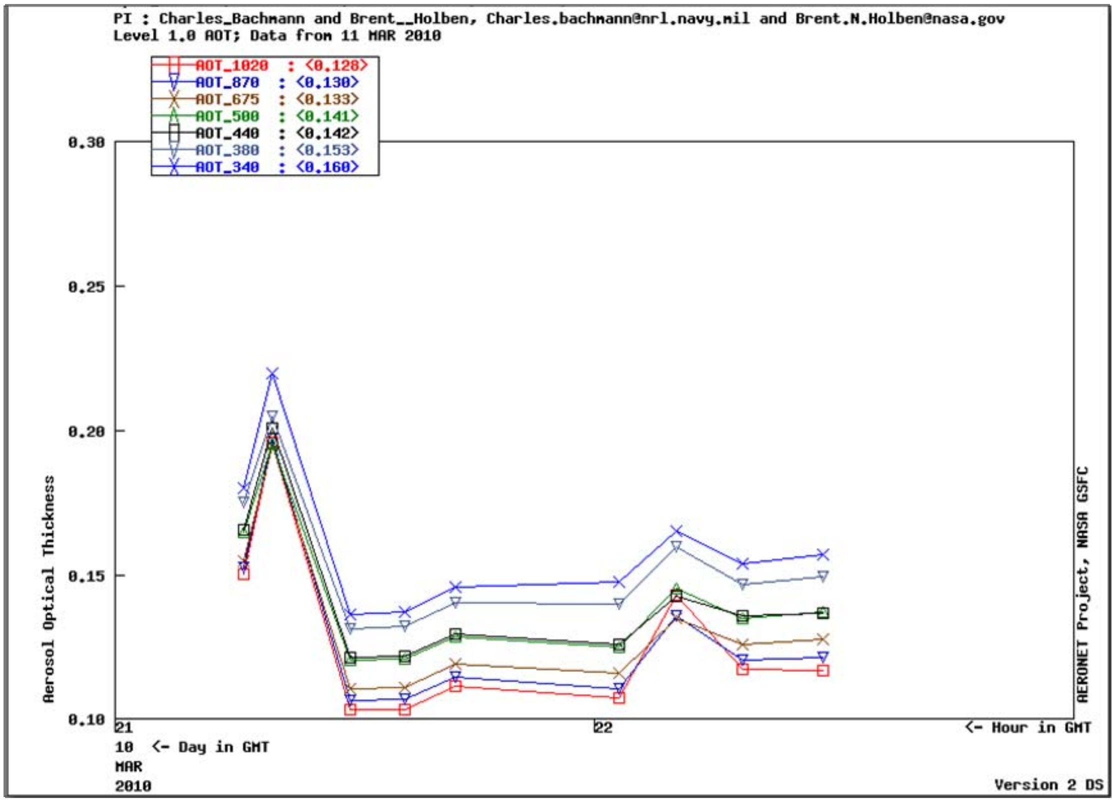


Figure M - 4. Aerosol Optical Thickness for 11 March, 2010.

APPENDIX N

Weather Data

1 Introduction

Weather record data are needed to characterize conditions during imagery collection and cal/val. Weather data can explain inconsistencies with field collected data and in quality control of imagery. Due to the remote location of work sites, there are sparse meteorological record locations. Pagan did contain a NOAA meteorological station (Handar type, WMO#91222) which records temperature, wind, pressure, and rainfall, but the instrument has needed repair since 2007. Tinian had a NOAA meteorological station, but for historical data records, Saipan provides a better archive. Each of the data tables in section 2 display subsets of CF6 preliminary local climate data for Saipan and Guam. The National Weather Service maintains a forecast office at Tiyan, Guam and provides limited data sources for the study area (NWS, 2010). The National Weather Service website provides historical data for stations located at the Coast Guard station on Saipan and at Guam International Airport. Data was obtained from NOAA on 5 May 2010. Information for each station is displayed in Table N- 1.

Table N- 1. National Weather Service CF6 Station Locations in Study Area.

Station Name	Latitude	Longitude
Guam International Airport, GU	13° 29'N	144° 48' E
Saipan/Isley (CGS), MP	15° 7'N	145° 44' E

2 Weather Record

2.1 Saipan-February 2010

M=Missing

	Temperature in °F				Precipitation in inches	Wind in Miles per Hour			Wind Direction in Compass Degrees		Sky/Weather	
Day	Max	Min	Avg	Departure	Water	Avg	Max-2 Min Period	Peak Wind	Max-2 Min Period	Peak Wind	Average Sky Cover from Sunrise to Sunset	Weather Type
16	84	75	80	M	0	13.2	18	23	70	50	40%	
17	M	M	M	M	M	M	M	M	M	M	M	
18	85	75	80	M	Trace	11.1	17	23	80	80	20%	
19	84	72	78	M	0.12	8.2	15	20	60	130	30%	Fog or Mist
20	87	76	82	M	0.01	12.2	20	24	90	80	60%	
21	85	74	80	M	0.35	12.6	23	26	80	80	50%	Fog or Mist
22	85	73	79	M	0	5.6	12	17	80	340	20%	
23	84	74	79	M	0	6.5	14	18	70	90	40%	
24	85	74	80	M	Trace	7.2	13	16	140	160	40%	
25	84	75	80	M	Trace	10.4	22	28	40	40	60%	
26	85	72	79	M	0.04	18.7	26	32	60	80	50%	Fog or Mist
27	85	72	79	M	0.14	18.2	29	36	90	80	50%	Fog or Mist; Smoke or Haze
28	86	75	81	M	Trace	20.4	26	32	70	80	70%	

2.2 Saipan-March 2010

M=Missing

	Temperature in °F				Precipitation in inches	Wind in Miles per Hour			Wind Direction in Compass Degrees		Sky/Weather	
Day	Max	Min	Avg	Departure	Water	Avg	Max-2 Min Period	Peak Wind	Max-2 Min Period	Peak Wind	Average Sky Cover from Sunrise to Sunset	Weather Type
1	85	75	80	M	0.01	15.8	23	29	60	80	60%	Fog or Mist
2	86	73	80	M	0.04	14.2	21	25	70	60	50%	Fog or Mist
3	M	M	M	M	0.11	8.9	17	18	50	40	60%	Fog or Mist
4	86	72	79	M	0.16	16.1	22	28	60	70	50%	Fog or Mist
5	85	73	79	M	0.18	19.3	30	37	90	90	60%	Fog or Mist; Smoke or Haze
6	86	76	81	M	0.01	18	26	33	80	80	50%	Fog or Mist; Smoke or Haze
7	86	76	81	M	Trace	19.6	28	33	70	70	50%	Fog or Mist
8	85	75	80	M	0.03	15.5	24	29	60	60	40%	Fog or Mist
9	86	73	80	M	0.14	14.3	24	31	70	70	50%	Fog or Mist; Smoke or Haze
10	87	77	82	M	Trace	15	22	25	80	70	30%	
11	86	77	82	M	0	16.3	24	29	70	70	20%	
12	85	76	81	M	0.01	16	23	28	60	60	40%	Fog or Mist
13	86	71	79	M	0.17	19.2	33	41	70	80	40%	Fog or Mist

2.3 Guam International Airport-March 2010

	Temperature in °F				Precipitation in inches	Wind in Miles per Hour			Wind Direction in Compass Degrees		Sky/Weather	
Day	Max	Min	Avg	Departure	Water	Avg	Max-2 Min Period	Peak Wind	Max-2 Min Period	Peak Wind	Average Sky Cover from Sunrise to Sunset	Weather Type
1	84	74	79	-1	0.3	11.5	22	28	50	80	70%	Fog or Mist
2	86	76	81	1	0.01	13.6	22	29	70	70	30%	
3	86	74	80	0	0	7.9	15	18	80	30	30%	
4	87	75	81	1	0.04	11.7	25	29	70	80	50%	Fog or Mist
5	84	75	80	0	0.37	12.9	24	31	80	90	50%	Fog or Mist; Smoke or haze
6	87	78	83	3	0.07	16.6	26	31	70	70	50%	Fog or Mist
7	86	75	81	0	0.14	16.2	26	33	60	80	50%	Fog or Mist
8	88	76	82	1	0.02	11.7	22	26	70	70	30%	Fog or Mist
9	86	75	81	0	0.05	12.4	21	28	60	70	30%	
10	87	76	82	1	0.04	11.2	21	25	60	100	40%	
11	88	77	83	2	0	15	26	32	70	70	30%	
12	89	77	83	2	0.04	14.7	26	30	60	60	30%	
13	88	76	82	1	0.03	15.8	26	32	70	70	40%	Fog or Mist

APPENDIX O

Geotagged and General Background Photographs

1 Introduction

Geotagged photographs include a global positioning system annotation on the image. These photographs provide a time series of the physical conditions that were observed at the time the photograph was taken. Efforts were made to capture images of the beach from the perspective of what amphibious assault personnel would see during ship-to-shore movement. Geotagged photographs were taken at Unai Dangkolo and Unai Lamlam on Tinian as well as Tipalao and Dadi landing beaches on Guam.

Site characterization via photography is critical to visually document the study area. Photographic documentation meets goals from simply recording the condition of a data collection site to enhancing details that may not be discernable to the human eye. For MI-HARES'10, there were numerous photograph sources. There were two NRL cameras and at least one personal camera for each person. Approximately 10GB of digital photographs were collected to help document the remote sensing campaign. Image subjects include background context shots for each of the three islands, major land and terrain features, and most importantly, data measurement sites. For the areas where measurements were taken, careful considerations were taken during photographic documentation to not disturb the station, especially the nearby vegetation and substrate.

Photography is stored in the project geodatabase and supports many applications from legal matters to military planning. Hand held imagery, aerial photography, satellite imagery, and other forms of remote sensing data can be used for environmental assessments, environmental litigation, property boundary and easement litigation, accident investigations, land management cases and numerous other applications. Photographic products could be taken during pre-D-Day amphibious reconnaissance of planned landing beaches and associated littoral areas within uncharted enemy territory. NRL's geotagged photographs are similar to information that could be obtained from hand held photography by recon Marines and Navy SEALS and possibly submarine periscope photography. The photography is especially useful to identifying obstacles and finding exits off the beaches that support inland maneuver. Geotagged photographs provide complementary data to other efforts relevant to charting and measuring water depths and coral heads, terrain inland; taking photographs and soil samples for trafficability assessments.

The following photographs describe general conditions on each island and provide context photographs for specific data collection stations.

2 Geotagged Beach Photographs

Photographs were taken with an Olympus® Stylus 1050 SW 10.1 megapixel camera and each position was simultaneously marked with a Trimble® ProXH GPS unit. Geotagged photographs relating to MI-HARES'10 were taken with the sole purpose of capturing significant portions of the landing beach, especially the flanks and center. Geotechnical and/or spectral measurements were not taken at all of the geotagged picture locations. Spectral measurement locations and their associated pictures are provided in Appendix E.

Efforts were made to capture the geotagged beach photographs facing onshore from the waterline. Geotagged beach photographs were taken at Unai Dangkolo and Unai Lamlam on Tinian during 7 March, 2010 and on Dadi and Tipalao Beaches on Guam during 10 March, 2010. Figure O - 1 displays the location of each geotagged image. Tables are also provided with photographs for landing beaches on each island, the location, the latitude, longitude, height, and time at which the photograph was taken. Geotagged photographs were not taken on Pagan owing to the availability of the survey equipment and primary boat, which was being used to ferry the science party to various beaches prior to use by the boat team to collect in-water optical measurements, water level data, and hydrographic survey data.

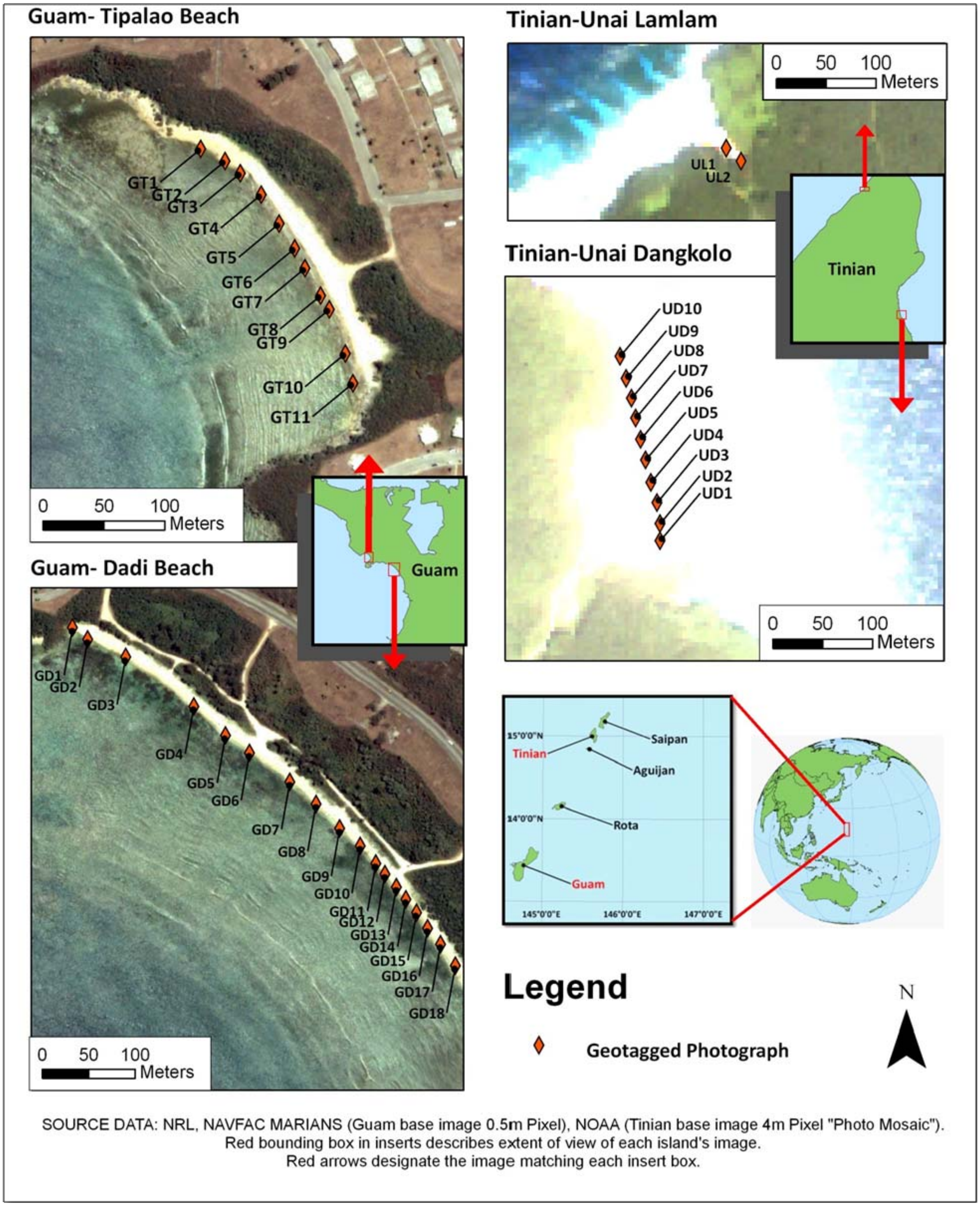


Figure O - 1. Geotagged beach photograph locations during MI-HARES'10.

2.1 Guam

Guam is the largest island in the Marianas with low rising hills toward the center and mountainous terrain to the south. It is surrounded by coral reefs and has about 126 km of coastline. Study sites were just south of Apra Harbor. Table O - 1 provides photographs for Dadi Beach and Table O - 2 provides photographs for Tipalao Beach.

Table O - 1. Geotagged photographs of Dadi Beach. Within the Dadi Beach area are remnants of a prehistoric settlement that survived into the latter part of the 17th century and Japanese beach defenses from WWII.

Name	Island	Location	Latitude	Longitude	Height Above Ellipsoid (WGS1984), m	Year	Local Date	Local Time	Photograph
GD1	Guam	Dadi Beach	13.41458275	144.6553951	56.262	2010	10-Mar-10	11:19:41 AM	
GD2	Guam	Dadi Beach	13.41447011	144.6555435	55.833	2010	10-Mar-10	11:28:16 AM	
GD3	Guam	Dadi Beach	13.41429891	144.6559106	56.19	2010	10-Mar-10	11:55:56 AM	

GD4	Guam	Dadi Beach	13.41382138	144.656571	56.295	2010	10-Mar-10	12:58:31 PM	
GD5	Guam	Dadi Beach	13.41353977	144.6568787	55.935	2010	10-Mar-10	12:56:01 PM	
GD6	Guam	Dadi Beach	13.41337134	144.6571116	56.474	2010	10-Mar-10	1:00:46 PM	
GD7	Guam	Dadi Beach	13.41309068	144.657503	56.622	2010	10-Mar-10	12:52:01 PM	
GD8	Guam	Dadi Beach	13.41287703	144.6577579	55.961	2010	10-Mar-10	12:49:31 PM	

GD9	Guam	Dadi Beach	13.41263785	144.6579868	56.36	2010	10-Mar-10	12:47:16 PM	
GD10	Guam	Dadi Beach	13.41247054	144.6581863	56.556	2010	10-Mar-10	12:45:06 PM	
GD11	Guam	Dadi Beach	13.41229845	144.658337	56.288	2010	10-Mar-10	12:23:01 PM	
GD12	Guam	Dadi Beach	13.41219652	144.6584271	56.253	2010	10-Mar-10	12:24:51 PM	
GD13	Guam	Dadi Beach	13.41207031	144.6585383	56.249	2010	10-Mar-10	12:27:26 PM	

GD14	Guam	Dadi Beach	13.41195394	144.658629	56.237	2010	10-Mar-10	12:29:51 PM	
GD15	Guam	Dadi Beach	13.41182267	144.6587306	56.027	2010	10-Mar-10	12:32:16 PM	
GD16	Guam	Dadi Beach	13.41167224	144.6588399	56.134	2010	10-Mar-10	12:34:41 PM	
GD17	Guam	Dadi Beach	13.41151808	144.6589654	55.635	2010	10-Mar-10	12:36:56 PM	
GD18	Guam	Dadi Beach	13.41131175	144.6591079	55.817	2010	10-Mar-10	12:39:46 PM	

Table O - 2. Geotagged photographs of Tipalao Beach. Extensive construction is being conducted inland from Tipalao Beach. In addition, treated effluent is discharged into the coastal ocean through the Tipalao Bay Outfall.

Name	Island	Location	Latitude	Longitude	Height Above Ellipsoid (WGS1984), m	Year	Local Date	Local Time	Photograph
GT1	Guam	Tipalao Beach	13.41815653	144.6470213	56.043	2010	10-Mar-10	3:40:06 PM	
GT2	Guam	Tipalao Beach	13.41806717	144.6472001	56.176	2010	10-Mar-10	3:42:16 PM	
GT3	Guam	Tipalao Beach	13.41797747	144.6473147	56.246	2010	10-Mar-10	3:44:36 PM	
GT4	Guam	Tipalao Beach	13.41781808	144.6474689	56.646	2010	10-Mar-10	3:46:56 PM	

GT5	Guam	Tipalao Beach	13.41760433	144.6476011	56.465	2010	10-Mar-10	3:49:16 PM	
GT6	Guam	Tipalao Beach	13.41742207	144.6477165	56.426	2010	10-Mar-10	3:51:36 PM	
GT7	Guam	Tipalao Beach	13.41727565	144.6477931	56.595	2010	10-Mar-10	3:54:11 PM	
GT8	Guam	Tipalao Beach	13.41707501	144.6479076	56.668	2010	10-Mar-10	4:00:46 PM	
GT9	Guam	Tipalao Beach	13.4169741	144.6479708	56.822	2010	10-Mar-10	4:05:31 PM	

GT10	Guam	Tipalao Beach	13.41664623	144.6480895	56.995	2010	10-Mar-10	4:08:36 PM	
GT11	Guam	Tipalao Beach	13.41642824	144.6481458	56.892	2010	10-Mar-10	4:10:31 PM	

2.2 Tinian

Tinian is a rugged limestone island located approximately 8 km southwest of Saipan. It has about 61 km of coastline with numerous cliffs, caves, and slumped boulders. Nearshore coral reefs surround the island and beach deposits consist of medium to coarse grain calcareous sands, gravel and rubble interspersed amongst exposed limestone rock. Accumulations of metal debris and tires, including unexploded ordinance, were found offshore of cliffs such as Faibus Point (Dump Coke). Table O - 3 provides geotagged photographs for Unai Dangkolo and Table O - 4 provides photographs for Unai LamLam.

Table O - 3. Geotagged photographs of Tinian taken during MIHARES'10.

Name	Island	Location	Latitude	Longitude	Height Above Ellipsoid (WGS1984), m	Year	Local Date	Local Time	Photograph
UD1	Tinian	Unai Dangkolo	15.03400267	145.6485463	58.294	2010	7-Mar-10	11:02:31 AM	
UD2	Tinian	Unai Dangkolo	15.0341581	145.648545	58.137	2010	7-Mar-10	11:03:51 AM	
UD3	Tinian	Unai Dangkolo	15.03434644	145.6485169	58.429	2010	7-Mar-10	11:05:11 AM	

UD4	Tinian	Unai Dangkolo	15.03452863	145.6484633	58.428	2010	7-Mar-10	11:06:31 AM	
UD5	Tinian	Unai Dangkolo	15.03472973	145.6484171	58.451	2010	7-Mar-10	11:07:51 AM	
UD6	Tinian	Unai Dangkolo	15.03491649	145.6483711	58.202	2010	7-Mar-10	11:13:01 AM	
UD7	Tinian	Unai Dangkolo	15.03510841	145.6483261	58.176	2010	7-Mar-10	11:14:21 AM	
UD8	Tinian	Unai Dangkolo	15.03528617	145.648287	58.023	2010	7-Mar-10	11:15:41 AM	

UD9	Tinian	Unai Dangkolo	15.03546386	145.6482421	57.966	2010	7-Mar-10	11:17:01 AM	
UD10	Tinian	Unai Dangkolo	15.03566418	145.6481841	57.997	2010	7-Mar-10	11:18:21 AM	

Table O - 4. Geotagged photographs of Unai Lamlam.

Name	Island	Location	Latitude	Longitude	Height Above Ellipsoid (WGS1984), m	Year	Local Date	Local Time	Photograph
UL1	Tinian	Unai Lamlam	15.08742537	145.6326888	58.073	2010	7-Mar-10	2:33:11 PM	
UL2	Tinian	Unai Lamlam	15.08730862	145.6328239	60.847	2010	7-Mar-10	2:32:31 PM	

3 General Background Photographs

3.1 Guam

The Guam portion of the campaign lasted three days and was the shortest of all the islands. The main focus areas of the study were Dadi Beach and Tipalao Beach, both situated south of Orote Peninsula on the Naval Base of Guam. Naval Base Guam acted as the main base for computing, equipment storage, and was used in soil analysis.

3.1.1 Dadi Beach

Figure O - 2 displays a panoramic view of Dadi Beach with the northern end of the beach visible at the right. A Japanese bunker system is present at the right. On the left of the image, the research team is visible. SAVs are quite abundant at this beach and start just offshore. The tidal range at this beach is quite minimal. The green line in the image indicates the direction of West.

Figure O - 2. Panoramic view of Dadi Beach (10 March, 2010).

3.1.2 Tipalao Beach

Tipalao Beach is situated to the northwest of Dadi Beach and is approximately 330 meters wide. As pictured in Figure O - 3 and Figure O - 4, the beach is very rocky and the presence of SAVs is not as abundant as compared with Dadi Beach. Figure O - 3 displays the extent of the beach to the left of the photographer if positioned at the entrance to the beach. In the figure, the red indicates the true direction viewed. Figure O - 4 displays the extent of the beach to the right of Figure O - 3. As is similar with Figure O - 3, a green line indicates the direction of West. A member of the research team is positioned in the right of the image to give perspective. Both images were captured on 8 March, 2010 local time.

Figure O - 3. Tipalao Beach panoramic view, where the approximate direction of observation is toward the south (red line) (9 March, 2010). Figure O - 4 shows the western extent, i.e., the land and seascape to the right of this image.

Figure O - 4. Tipalao Beach panoramic view, where the approximate direction of observation is toward the west (green line) (9 March, 2010). Figure O - 3 shows the southern extent (to left) of this image.

3.2 Pagan

There were many photographs taken of Pagan during the research effort. Greater than 2,000 photographs (approximately 4.18GB) were taken of island features, geotechnical sites, relics, and vegetation sites. Photographic documentation of this island was very important due to the remoteness of the island and the need for creating a project database. The island is extremely rugged and contains two active volcanoes. Most of the research effort concerned three beaches on the western side of the island. Figure O - 5 shows the western side of Pagan as viewed from the M/V *Micronesian* anchored in 70 feet of water offshore of two small bays on the southwestern side of the island. In the figure, two volcanoes are indicated with blue arrows, the general airfield location with red lines, and the position of Beach-4 with the orange trapezoid. Within an approximate 180° field of view, the vertical blue line shows observations toward the east while the red line indicates observation in a southern direction.

Figure O - 5. Panoramic view of western side of Pagan (26 February, 2010).

Six views of Pagan are visible in Figure O - 6. Pagan consists of volcanic black sands on the beacheas of the western side of the island (upper left) and white coralline sands on the eastern beaches (upper right). During a 1981 eruption, a large lava flow extended 3.5 km southwest of the peak to the airfield (middle right). A trail exists at the southeastern end of the airfield, and continues through the lava field and terminates in a precipice facing the Pacific Ocean. From the precipice, one can view the South Pagan Volcano over the isthmus connecting the north and south portions of the island (lower right). Most of the research team's efforts concerned three beaches and a grass runway and aprons on the western side of the island (lower left). Mt. Pagan is one of the most active volcanoes in the Pacific and dominates the geography of the northern portion of the island (middle left).

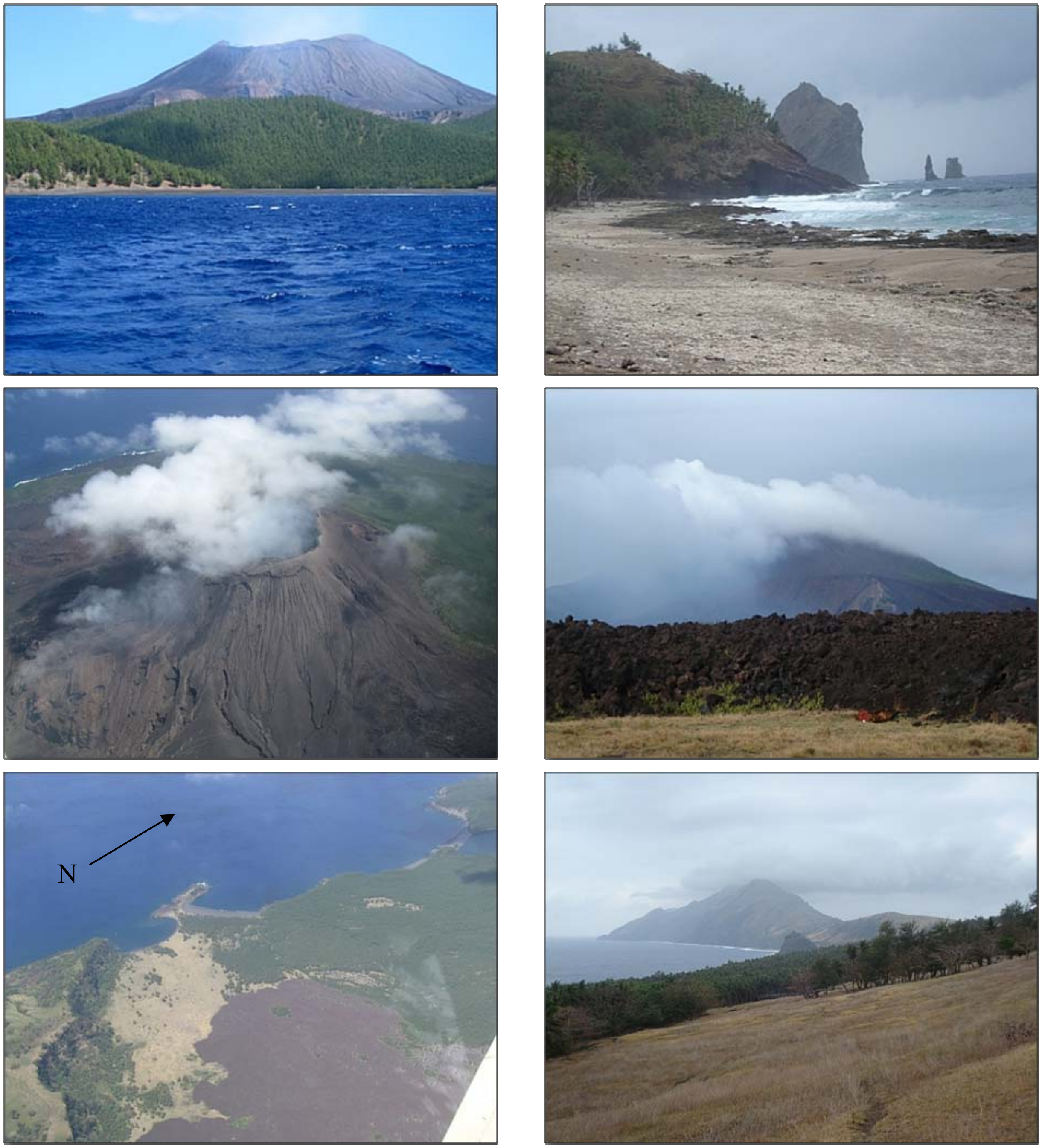


Figure O - 6. Images of Pagan. (Upper left) Mt. Pagan as viewed from offshore of Beach 1(28 February, 2010). (Upper right) View of rugged terrain and white coralline beach on eastern side of Pagan (27 February, 2010). The beach contains rock and reef structures which make beach landings via rigid-hulled inflatable boat (RHIB)/rigid-inflatable boat (RIB) a hazard. (Middle right) Mt Pagan viewed across southwestern lava field (27 February, 2010). (Lower right) A view of the southern portion of Pagan taken from the eastern side of the island (27 February, 2010). (Lower left) The three study beaches and the airfield can be viewed in this image (7 March, 2010). The beach at the upper right is Beach 1; the beach in the middle of the image north of the small peninsula is Beach 2; the small concave beach south of the small peninsula is Beach 4; and the airfield is the field area east of Beach 4. Notice the presence of the lava field which now obstructs the runway. (Middle left) Mt. Pagan viewed from the south.

3.2.1 Airfield

The airfield, situated east of Beach 4, was used for the placement of calibration panels (Figure O - 7), and the Ashtech GPS base station. The airfield (Figure O - 8) was in operation until 1981 when a volcanic eruption caused deposited lava on the runway, which made the runway too short for most fixed wing aircraft (upper left). A short take-off air ambulance located on Saipan is certified to use the Pagan airfield. Surrounding the airfield, Japanese World War II aircraft (upper right), bunkers (middle right), and armaments (lower right) can be viewed. Also, varying sized craters created from bombing raids by the U.S. Army Air Corps are also visible (lower left). Special caution was taken during the Pagan and Tinian phases of the remote sensing campaign owing to the threat of UneXploded Ordnance (middle left). A specialized metal detector was used in all study areas to identify potential UXO.

Figure O - 7. View of western end of airfield with black calibration panel and team (left-center) and Beach 4 (right center) (3 March, 2010).

Figure O - 8. Views of Pagan airfield. (Upper left) View of airfield looking east (26 February, 2010). Notice the lava field and people in front of the lava. (Upper right) Japanese Zero beside airfield (26 February 2010). (Middle right) Bunker at eastern end of airfield with lava present at left side of the image (26 February, 2010). (Lower right) Japanese anti-aircraft gun with lava field behind (2 March, 2010). (Lower left) Presence of craters beside airfield (26 February, 2010). (Middle left) Un-exploded bomb beside airfield (26 February, 2010).

3.2.2 Beach 1

Beach 1 is a 1 km black sand beach positioned at the west of the northern portion of Pagan. Figure O - 9 displays Beach 1 and the position of Laguna Sanhiyon (Figure O - 10).

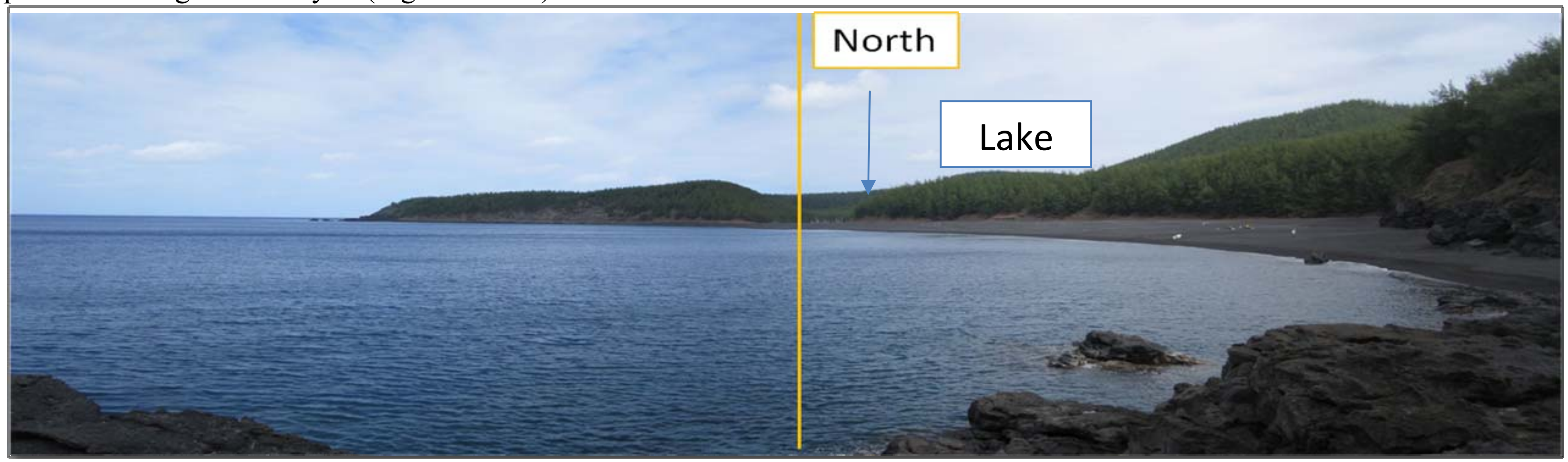


Figure O - 9. Beach 1 looking north (1 March, 2010). The lake (Laguna Sanhiyon) is situated to the east of Beach 1 and the blue arrow indicates the position of the Laguna Sanhiyon.

Figure O - 10. In these three images, Laguna Sanhiyon is visible.

3.2.3 Beach 2

Beach 2 is situated southwest of Mt. Pagan on the northern side of a small peninsula (Bandeera Peninsula). Figure O - 11 displays Beach 2 as well as its position related to other study areas during the campaign. Figure O - 12 displays a view from Beach 2 looking west towards the headland.

Figure O - 11. Panoramic view of Beach 2 and surrounding areas (28 February, 2010). Beach 1 is located north of Beach 2 and is indicated here with a green arrow. Beach 2 (indicate with purple) is approximately 500m long. A view toward the east is indicated by the blue line. The airfield is visible east of Beach 4 (orange arrows).

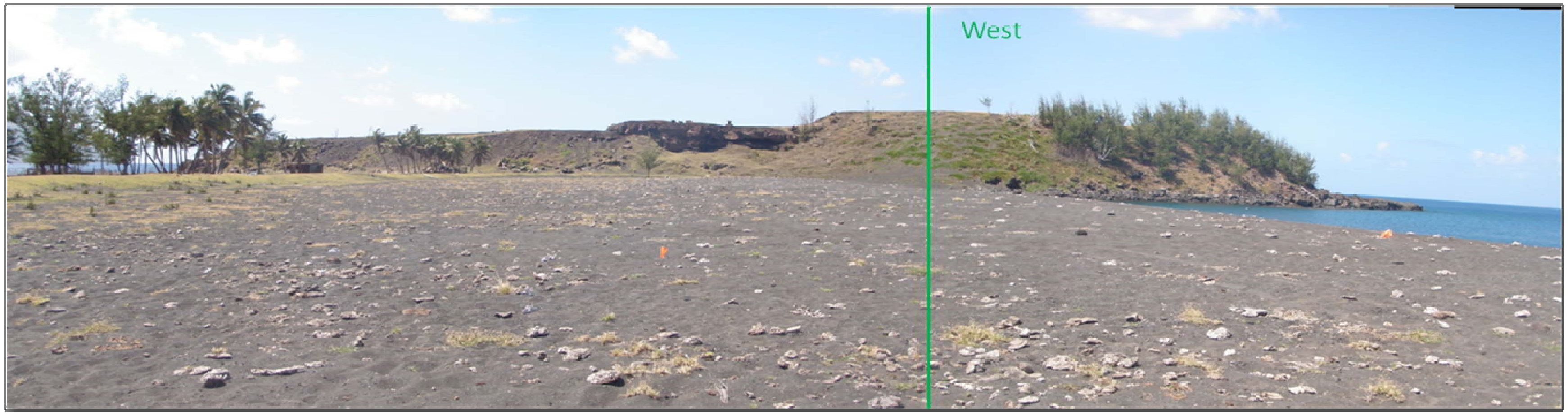


Figure O - 12. View toward the west from Beach 2 (1 March, 2010). Japanese fortifications were located inside the cliff. USGS (Pagan 1) and NOAA geodetic markers are cited on top of the headland.

3.2.4 Beach 4

Beach 4 is located south of Bandeera Peninsula and served as the many landing beach for the research teams. Various shacks, boats, and fuel barrels are present along the strand and a large Japanese memorial is being eroded away by surf along a steep section of beach. Figure O - 13 and Figure O - 14 display views of Beach 4 from the headland and an aerial view, respectively.

Figure O - 13. Beach 4 panoramic view as viewed from precipice (28 February, 2010). East is indicated by the blue line. The airfield is viewed in the center of the image.

Figure O - 14. Beach 4 aerial view (7 March, 2010). The presence of coral is evident by structures on left and right flanks of the beach.

3.3 Tinian

Efforts on Tinian included geotechnical survey of three beaches, marking historical buildings for ground control, and using Tinian International Airport as the home port for the airplane. Figure O - 15 provides various views of Tinian. The island is presently home to approximately 2,000 inhabitants and was the site of strategic military bases during WW II years. The northern part of the island contains structures from WWII, while areas in the south contain much of today's population (upper left). World War II era buildings were surveyed as a means of ground control for georectification of HSI (upper right). One of the WWII era runways was used for placement of the Ashtech® GPS base station and the CIMEL ® Sun photometer (middle right). Beach studies were completed on Unai Babui and Unai Lamlam on the western shore, and Unai Dangkolo on the eastern shore (lower right). Beaches are primarily white coralline, although the coast is very rugged with volcanic rock formations and cliffs (lower left). Bathymetric surveys were conducted (middle left) during favorable sea states.

Figure O - 15. Views of Tinian. (Upper left) View of Tinian International Airport with the town of San Jose in the distance (22 February, 2010). (Upper right) Team member using a GPS to mark WWII buildings for ground control points (8 March, 2010). (Middle right) WWII era runway used for placement of Ashtech® GPS base station (5 March, 2010). Northern portion of Tinian with CIMEL sun photometer/GPS base station, Unai Babui, and Unai Lamlam indicated (Unai Dangkolo not pictured) (4 March, 2010). (Lower left) Rugged coastline and cliffs located north of Unai Dangkolo (4 March, 2010). (Middle left) Boat used for bathymetric survey of Tinian waters (5 March, 2010).

3.3.1 Unai Babui

Unai Babui is situated on the northwestern coast of Tinian and the surface constituents include coralline sands and volcanic rock formations close to the surface. As is evident in Figure O - 16, coralline sands are deposited above volcanic rock formations. The strand habitat, a habitat which forces biota to conserve freshwater resources is depicted in Figure O - 17.

Figure O - 16. Panoramic view of Unai Babui (5 March, 2010). Observation toward the west is indicated by the green line. The boat team reported that the bottom is mainly characterized by limestone pavement with interspersed coral colonies and zones of submerged boulders.

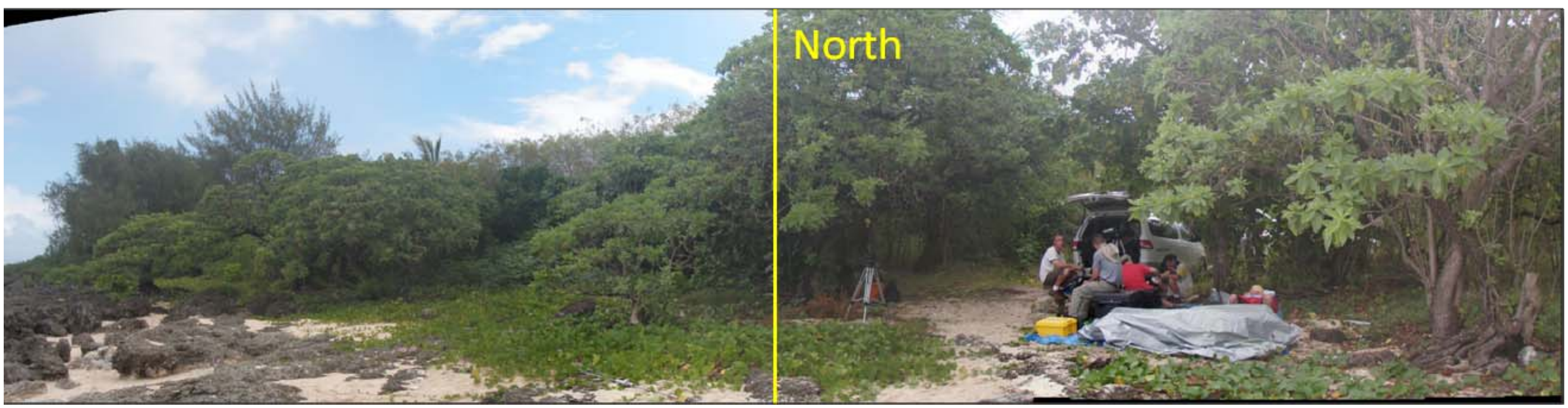


Figure O - 17. Panoramic view of strand habitat near Unai Babui (5 March, 2010). Observation toward the north is indicated by the yellow line. The strand habitat is characterized by high salt content and heavy winds**.** Plants in this habitat tend to have fuzzy, hairy, waxy, or succulent leaves.

3.3.2 Unai Dangkolo

Unai Dangkolo is situated on the east coast of Tinian and is approximately 1.4 km long. The beach is primarily comprised of white coralline sands (Figure O - 18). The beach is protected on the east by reef structures which are evident by viewing **Figure O - 19**.

Figure O - 18. Panoramic view of Unai Dangkolo with annotated directions (22 February, 2010). Mt. Tapochau (elevation=1,555 ft/ 474m) on Saipan is visible in the center of the image.

Figure O - 19. Aerial view of Unai Dangkolo with area surveyed indicated on image (4 March, 2010). The boat team was unable to survey this beach owing to severe seas in the Saipan Channel, the narrow strait which separates the south coast of Saipan from the north coast of Tinian.

3.3.3 Unai Lamlam

Unai Lamlam is a very small beach located north of Unai Babui on the northwest coast of Tinian. The beach is approximately 10m wide by 30m in length and surrounded by cliffs and rocky terrain on three sides. The size of the beach can be estimated by comparing the research team in Figure O - 20 to the terrain features. Beach structure primarily consists of white coralline sands with rock intrusions. The rugged environment surrounding Unai Lamlam and depicted in Figure O - 21made it a challenge to setup and operate instruments.

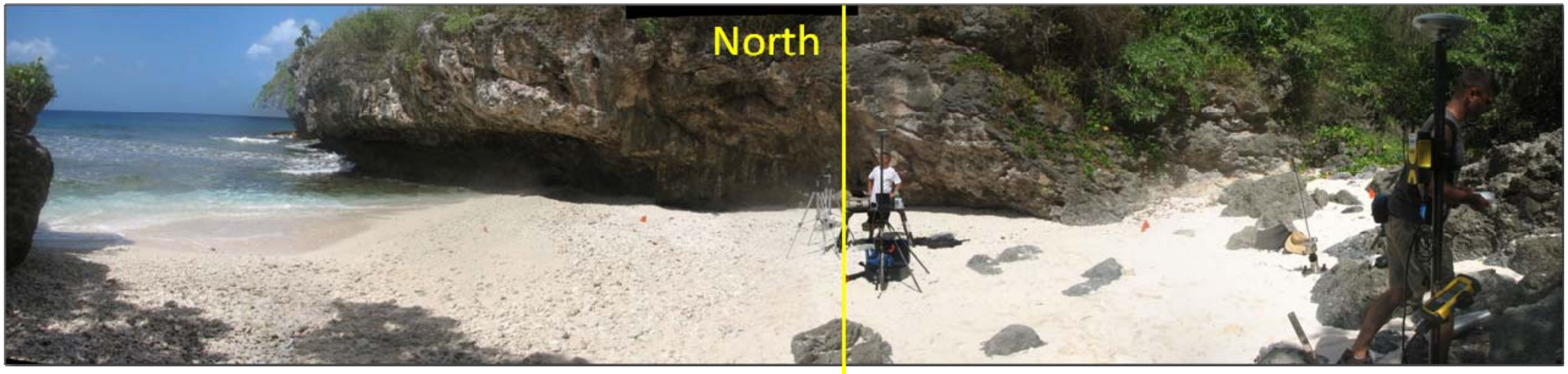


Figure O - 20. Panoramic view of Unai Lamlam with annotation showing observations toward the north (7 March, 2010).

Figure O - 21. View of Unai Lamlam from bathymetric survey vessel (7 March, 2010). Three sides of Unai Lamlam consist of cliffs and rocky terrain. Divers reported numerous submerged boulders.

3.4 Other Islands

The islands pictured in Figure O - 22 were not studied during MI-HARES'10, however, the inclusion of these photographs highlights the rugged terrain common to the Mariana Islands archipelago. Pictures were taken by various members of the science party on board the M/V *Micronesian*, during flights of the Piper PA31 Navajo, while island hopping aboard commercial airlines, and during bathymetric survey.

Figure O - 22. Mariana Island views. (Upper left) Alamagan (March 3, 2010). (Upper right) Sarigan (7 March, 2010). (Middle right) Anatahan central crater (4 March, 2010). (Lower right) Saipan's southeastern shore with Saipan International Airport visible at middle left (22 February, 2010). (Lower left) View of Saipan from western lagoon (22 February, 2010). (Middle left) View of Aguijan from offshore of Tinian (4 March, 2010).

3.5 M/V *Micronesian*

The M/V *Micronesian* was the 105ft vessel used to support research efforts on Pagan. The vessel was used to transport the research team and equipment from Saipan to Pagan and provided life support and working spaces. The team returned to Saipan on 4 March, 2010 and continued on to Tinian on the same day. Figure O - 23 displays various images of the M/V *Micronesian.*

Figure O - 23. M/V *Micronesian* was primarily used during the Pagan portion of the campaign. A sheltered bay was located on the western side of Pagan. (Upper left) M/V *Micronesian* with 30 ft work boat on port-stern is viewed in the Port of Saipan. The 30 ft vessel was used to complete a bathymetric survey of Tinian. (Upper right) The M/V *Micronesian* anchored offshore of Beach 4 at Pagan. (Lower right) The M/V *Micronesian* at anchorage offshore of Beach 4. South Pagan Volcano is visible at upper left. (Lower left) The M/V *Micronesian* in action deploying the rubber inflatable boat (RIB) used to collect in-water optical data and shallow water bathymetry near Pagan.