Expanded Worldwide Ocean Optics Database

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LONG-TERM GOALS

The long-term objective is to provide a comprehensive worldwide optics database that includes data on a broad range of important optical properties, including diffuse attenuation, beam attenuation, and scattering. For the public version of the database, data from ONR-funded bio-optical cruises are given priority for loading into the database, but data from other scientific programs (NASA, NODC, NSF) and from other countries will also be routinely added to the Worldwide Ocean Optics Database (WOOD)[1]. For the operational Navy version of the database, forward area datasets, such as those collected in US Naval Oceanographic Office "military surveys" will be given priority.

OBJECTIVES

A main objective in FY10 has been to add the NASA world-wide monthly climatologies for chlorophyll concentration, and another objective was to publish a paper that documents the DoD-restricted version of WOOD. The US Navy has a special interest in locations such as the East China Sea, Yellow Sea, Gulf of Oman, and the Persian Gulf. As a result special attention is given to obtaining and loading data from such locations. An on-going objective is to develop more automated procedures for ingesting complex datasets, such as from hyper-spectral sensors or from high-density measurement systems like a glider or SeaSoar system[2]. Finally, assuring high data quality is a major objective, so substantial effort is given to removing noise, calibration shifts, and other data artifacts from the data.

APPROACH

The overall approach is to develop a public database that shall be easy to use, Internet accessible, and frequently updated with data from recent at-sea and satellite measurements. The database shall be capable of supporting a wide range of applications, such as environmental assessments, sea test planning, and Navy applications. The database shall include derived optical parameters so that if measured data are not available, the user can obtain values computed from empirical algorithms (e.g., beam attenuation estimated from diffuse attenuation and backscatter data). Uncertainty estimates will also be provided for the computed results.

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WORK COMPLETED

The main work accomplished this past year involved:

1)   adding the NASA monthly CHL climatology data to WOOD

2)   preparing/loading new bio-optical data into DoD-WOOD and into WOOD

3)   developing a hyperspectral editor

4)   submitting, revising, publishing a journal paper on DoD-WOOD

5)   developing software to provide other US Navy agencies a copy of DoD-WOOD on DVD

6)   adding a screen that requires WOOD users to provide information on themselves before they can access the database (allows for automated usage report generation)

More detailed descriptions of these accomplishments are included in the following paragraphs. Note: The DoD version of WOOD contains all the data in WOOD plus DoD-restricted data.

Adding the NASA monthly CHL climatology data to WOOD: The world-wide monthly 4.6 km resolution NASA MODIS chlorophyll climatology files were added along with a GUI to access the data (see example in Figure 1).
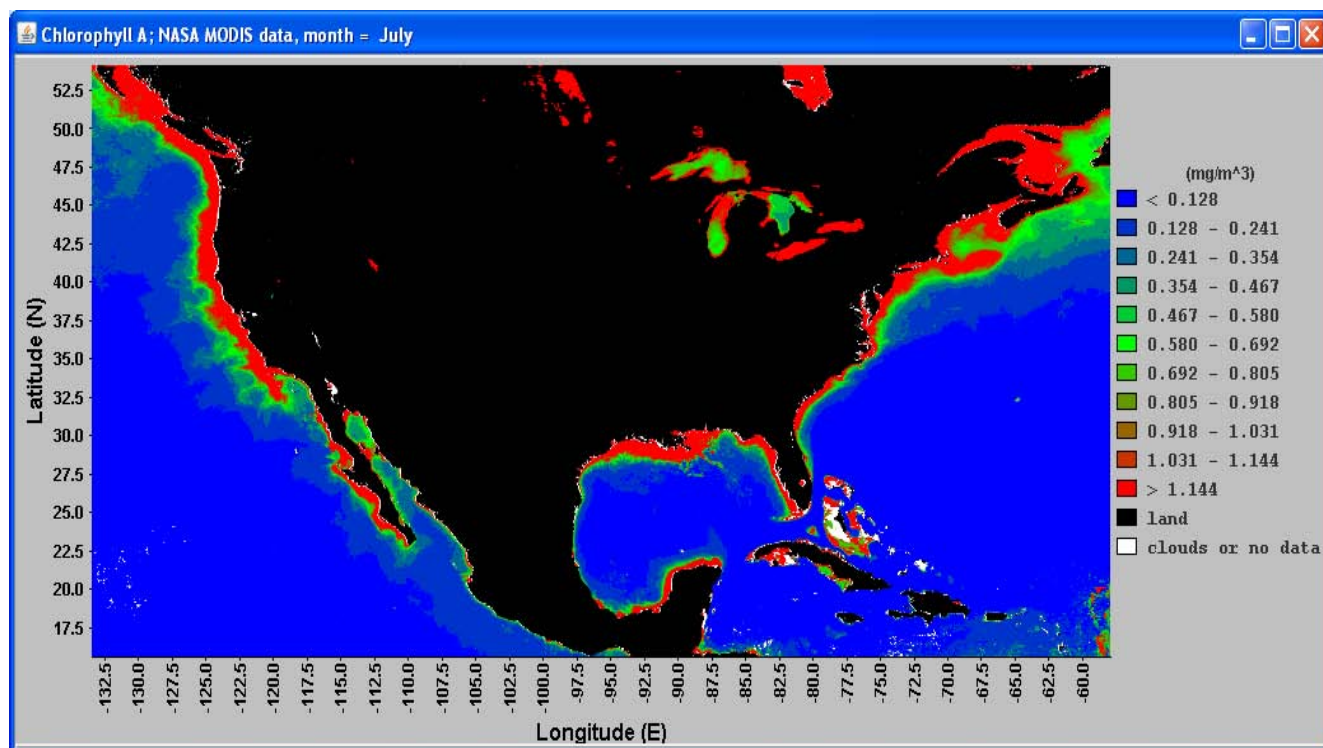

Figure 1. Example of CHL_α Monthly Climatology. This plot shows the high (red, >1 mg/m3) concentrations in the shallow coastal areas around North America and the extremely low (blue, <0.13 mg/m3) concentrations in the deep open ocean waters.

New Data Added to WOOD: With respect to the preparation and loading of new public datasets, the first eight rows in Table 1 summarize what has been accomplished since September 2009. The largest addition comes from NODC; Figure 2 show the > 15,000 CHL_a profiles obtained via CTD casts since 2005. Figure 3 shows the > 58,000 locations of CHL_a, Secchi depths, nutrients, salinity, and temperature profiles obtained from the NODC "OSD" data archive. Another major dataset that is almost ready to be loaded is the NASA SeaBASS[3] data acquired since June 2007 (SeaBASS data prior to June 2007 were already loaded into WOOD).
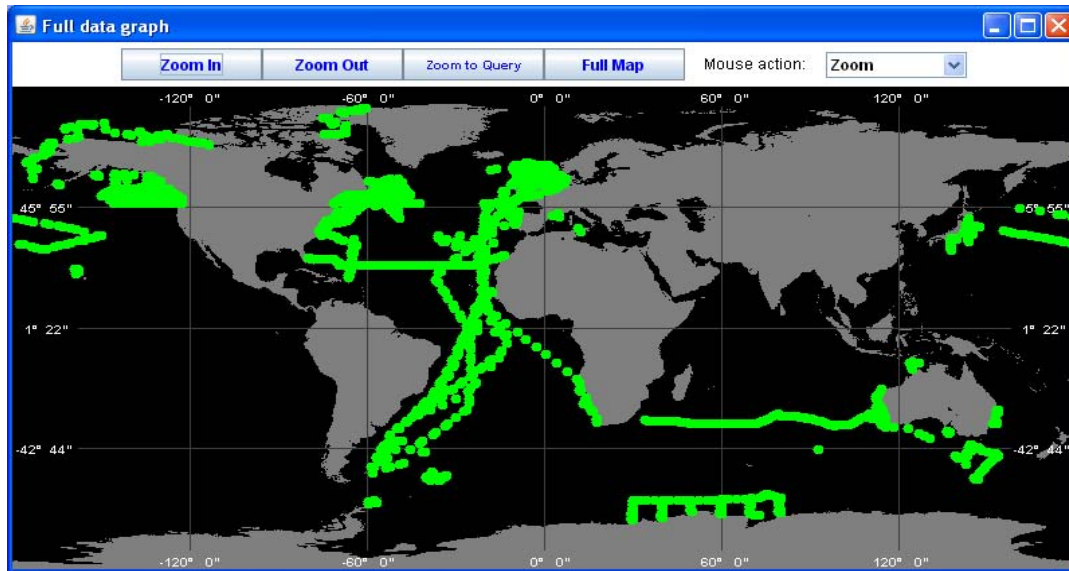

Figure 2. Locations of NODC CTD profiles having CHL_α data [N > 15,000].
The majority of the profiles are in the North and South Atlantic, but a cross-Indian and
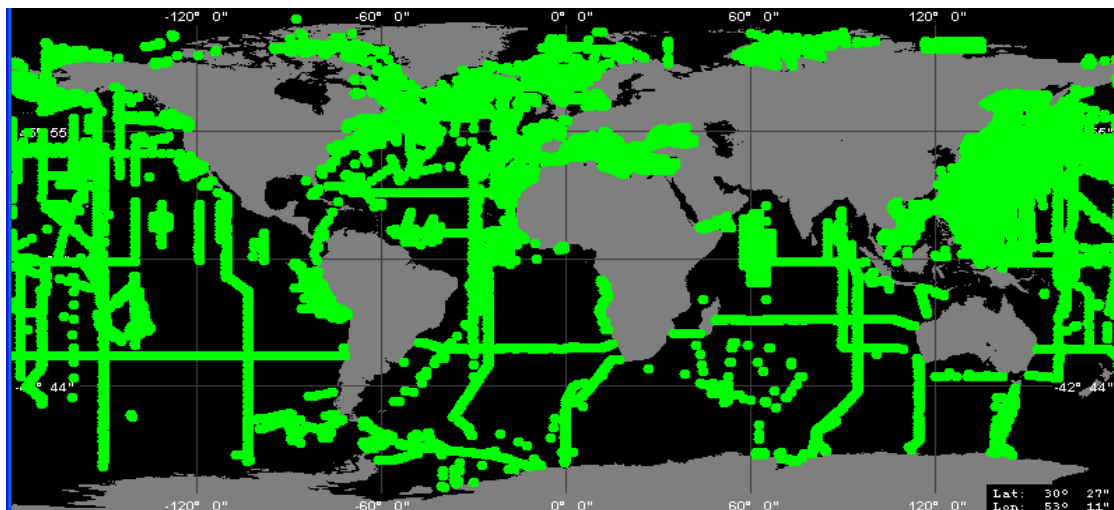***two cross-Pacific series are also included.***

Figure 3. Locations of NODC "OSD" (bottle sampled) profiles having CHL_α, nutrients, temperature,
and salinity data [N > 58,000]. New data exist in all the major oceans of the world.

Table 1. Summary of Data Loaded in WOOD (first eight rows) and into
DoD-WOOD (all rows) during the past 12 months.

Data Description	Example Numbers & Types of Profiles
July 2008 Alboran Sea glider data	Temperature, salinity, turbidity, CHL_a, & Kd 490 estimated from CHL_a *[N = 194 thinned profiles]*
ODEX Oct/Nov 1982 North Pacific	*CTD, c660, Kd488, & Ed(lamda) profiles [N=30]*
NODC OSD from WOD2005 to May 2010	*CHL_a, Secchi depth ,nutrients, Temperature, & Salinity profiles [N> 58,000]*
RV Knorr 1982 scanned report data	*CHL_a, K470, Temperature, & Salinity profiles [N=10]*
RV Eastward 1980 scanned report data	*CHLa, K470, Temperature & salinity profiles [N=20]*
RV Hatteras 1985 scanned report data	*CHLa, K470, Temperature & salinity profiles [N=16]*
USNS Bartlett 1982 scanned report data	*c487,c521,Ed495, K495, Temperature profiles [N=19]*
Jan 2005 Philippine Sea (NAVO Cruise 620105)	Temperature & Salinity, & multi-wavelength a,c *[N=23]*
July 2007 Philippine Sea (NAVO Cruise 620607)	Temperature, salinity, & multi-spectral a,c profiles
June/July 2005 Philippine Sea (NAVO Cruise 620505)	Temperature & multi-spectral Kd, Ed, Lu profiles
May 2004 Philippine Sea (NAVO Cruise 640404)	Temperature & multi-spectral a,c, Kd, Ed, Lu profiles

Kd = diffuse attenuation coefficient; either computed from downwelling (Ed) light or from an empirical relation with CHL. Lu is upwelling radiance, bb is optical backscatter, beam attenuation is "c."

Hyperspectral Editor: A college intern developed and documented a Matlab-GUI-based editor program that facilitates screening of hyperspectral data, such as the 100-wavelength "ac-s" being sold by WETLabs. This powerful editor automatically extracts representative wavelengths for initial viewing, but can apply the user's edits (such as interpolation across wild points and removal of spurious data regions) to other "nearby" wavelengths, or even to all available wavelengths. An example of the results of applying this editor to raw data are shown in Figure 4.
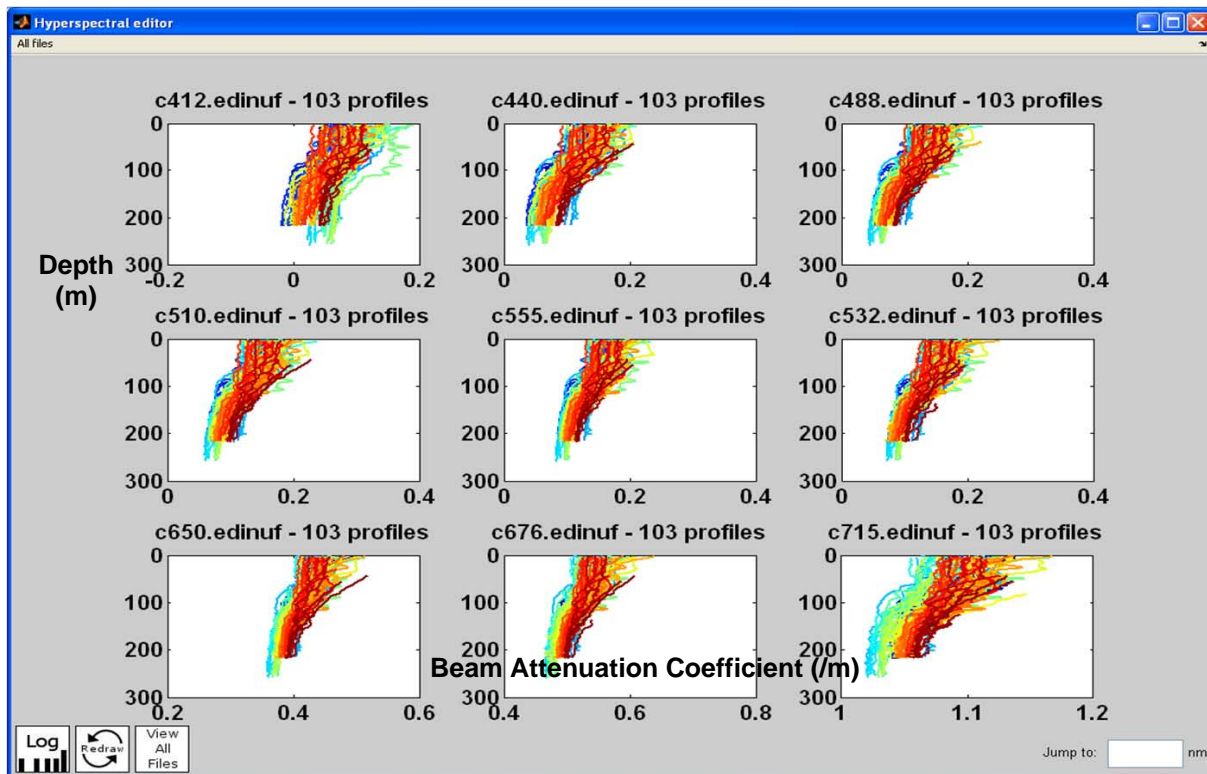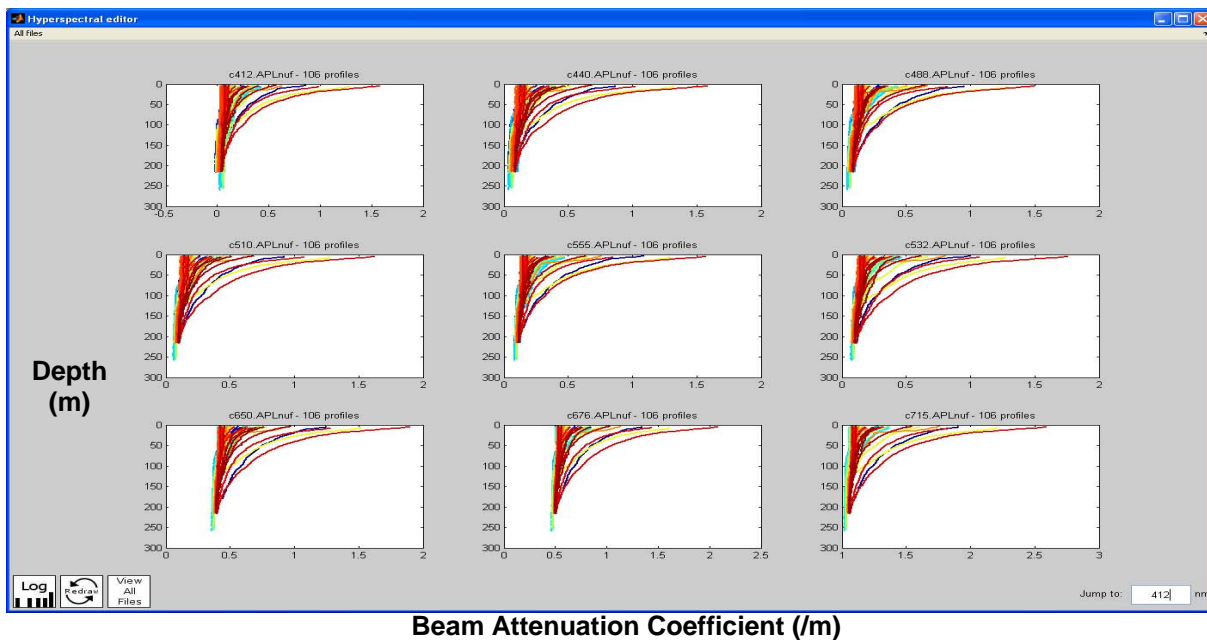
Figure 4. Hyper-Spectral Editor Displays: Top Panel = raw data; Bottom Panel = edited data (expanded scale). [The "bad" raw data are evidenced by an unrealistic exponential rise above values at ~0.2/m at 412nm; only the 412nm data were edited, but the changes were automatically applied across all wavelengths].

Preparing and Submitting a Journal Paper on DoD-WOOD: In order to increase the awareness of the DoD-WOOD across the US Navy, a paper was prepared and submitted to the *Journal of Underwater Acoustics* for publication in a special non-acoustics issue. (The paper is published in the July 2010 issue.)

Developing DVD-distributable version of DoD-WOOD: In order to expand the utilization of the DoD-WOOD, software was developed to allow other US Navy agencies (such as NAVOCEANO or Office of Naval Intelligence) to build a local copy of the database using a single DVD provided by JHUAPL. It is anticipated that subsequent updates to the database will also be distributed on DVDs.

Data Access Login Screen: Software was written and implemented that requires WOOD users to provide information on themselves before they can access the database. This feature has been invaluable in helping APL to generate automated usage reports.

Empirical Algorithms: Sample WOOD profile data from areas of naval interest (including the Yellow Sea, the Korean Straits, and the Sea of Japan) were sent to Eric Rehm (University of Washington) to test the use of his radiative-transfer-based software for estimating depth profiles of multi-wavelength absorption (*a*), beam attenuation (*c*), backscatter (*bb*), and total optical scattering (*b*) from downwelling irradiance ($Ed(\lambda)$) and upwelling radiance ($Lu(\lambda)$) depth profiles. Some significant results to date are as follows. First, using Ed and Lu, one can invert for *a* and *bb*, but not *b*. Second, because $c(\lambda)$ is well defined spectrally (an inverse power law exists with respect to wavelength), a single measurement of $c(\lambda)$, e.g., c(660 nm) from a standard beam transmissometer, can be used with a bio-optical model for $c(\lambda)$ to derive profiles of $b(\lambda)$.

RESULTS

Thousands of investigators from around the world have utilized the WOOD, which is routinely accessed by a wide variety of schools, colleges, universities, research institutes, and various DoD/US Government/State-Local Government agencies. Table 2 (shown on the next page) gives examples of DoD/US Government-related "hits" to the database, as well as non-government "hits."

As specific examples of US Navy use, the Environmental Support Systems Project within the SSBN Security Program used WOOD data to support eleven different US Navy tasks during GFY 2010. Analysts at NAVOCEANO Code NP33 (with whom the WOOD project maintains close ties) also use WOOD for operational support to the Fleet. Finally, WOOD has been used to directly support our ONR sponsor, Dr. Steve Ackleson. For example, in 2005 he requested an analysis of the ~ 30,000 K profiles in WOOD that exist on the continental shelf in order to determine the fraction of the world's continental shelves that are sufficiently clear to allow a bottom-mounted sensor to measure downwelling radiance.

Table 2. WOOD Usage Summary from September 2009 to July 2010

Partial List of Unique "Hits" to WOOD	
• 43 U.S. Government - DoD uses. • 18 U.S. Government - non-DoD uses. • 7 Foreign Government uses. • 28 Commercial uses. • 86 Educational/Research uses.	
DoD & DoD-related Users	**Non-DoD "Government"**
• JHUAPL • METRON • National Maritime Intel. Center (NMIC) • Naval Air Systems Command (NAVAIR) • Naval Research Lab Stennis Space Center (NRLSSC) • Optech International • QinetiQ North America • SPAWAR Systems Center • SRI International • US Navy	• NASA GSFC • National Coral Reef Institute • NOAA - NESDIS - NODC • UNESCO/IOC • American Association for the Advancement of Science
Academic & Commercial Users	**Non-US Government Users**
AChiba University (Japan) Cochin Univ of Science And Technology (CUSAT, India) College of Charleston Cornell University Florida Institute of Technology Marine Ecology Project Fraunhofer Institute for Optronics, System Technologies and Image Exploitation (IOSB) Harbor Branch Oceanographic Institution Illinois Institute of Technology (IIT) Institute of Environmental Physics (Germany) Nanjing University (NJU , China) National Cheng Kung University (NCKU, Taiwan) North Carolina State University Nova Southeastern University Pukyong National University (Korea) Rutgers University University of Bergen (Norway) University of Liverpool University of Washington Applied Physics Laboratory University Tuebingen (Germany) Weizmann Institute of Science (Israel) Wesleyan University	• French National Center for Scientific Research (CNRS) • National Institute of Oceanography (India) • Thales Underwater Systems (TUS, United Kingdom)

IMPACT/APPLICATIONS

WOOD is regularly used at JHUAPL to plan field exercises, support detectability studies, and conduct vulnerability analyses for the US Navy. In addition, the empirical relations derived under this grant have been used to provide critical input parameters to US Navy-related vulnerability modeling efforts. Beyond these immediate applications at JHUAPL, data from WOOD have been used by other DoD facilities and by graduate students working on dissertations. Furthermore, by requiring all projects funded by ONR's Ocean Optics Program to submit their data to the WOOD, ONR is ensuring that these valuable data continue to be available for current and future investigators. It is estimated that the availability of a single location, uniform-format optics database has provided significant cost savings to the US Navy in test planning and other naval applications. By providing the Navy and the research community with this resource, both types of users benefit from improved knowledge of the optical properties of the ocean. Access to historical optics data can also be useful for assessing newly acquired data. The two can be compared to see if the new results are atypical, and if so, one might go on to determine the cause (e.g. unusual forcing conditions, influx of a different water mass, or perhaps even an instrument calibration problem).

TRANSITIONS

The SSBN Security Program has added DoD-WOOD to its suite of environmental databases that it maintains under the Environmental Support System (ESS) Project at JHUAPL. The entire contents of WOOD, along with its wide array of graphical displays, satellite climatologies, and statistical outputs, have been copied to this clone of WOOD which will be regularly augmented with various DoD-restricted and classified datasets. A full copy of DoD-WOOD is being sent to NAVOCEANO, and other agencies (such as NAVAIR and ONI) have expressed interest in obtaining a copy as well. Finally, NASA has requested a full copy of the WOOD software used to display data over the internet.

RELATED PROJECTS

The project's Principal Investigator, Jeff Smart, is involved with several projects that regularly use DoD-WOOD data to plan US Navy field tests and to conduct vulnerability studies. Mr. Smart is a also associated with the ONR Littoral Warfare Advanced Development (LWAD) project that conducts numerous at-sea tests, including tests involving optics in overseas areas. Via the LWAD project, the WOOD project has obtained important optical data in the East China Sea, the Philippine Sea, and the Yellow Sea. WOOD also provides LWAD with optics data for test planning purposes. The JHU Applied Physics Laboratory works closely with the NASA SeaWiFS Bio-optical Archive and Storage System (SeaBASS) community in order to ensure that their bio-optical data are regularly added to the WOOD. In order to foster this relationship, US Navy permission was obtained to provide unclassified LWAD optics data (collected by JHU/APL scientists) to SeaBASS.

PUBLICATIONS

"World-wide Ocean Optics Database for DoD Applications," *J. of Underwater Acoustics* Vol **60**, 2010.

REFERENCES

[1] WOOD Website: http://wood.jhuapl.edu

[2] SeaSoar Website: http://www.chelsea.co.uk/Vehicles%20SeaSoar.htm

[3] SeaBASS website: http://seabass.gsfc.nasa.gov