

Visible and Thermal Imaging of Sea Ice and Open Water from Coast Guard Arctic Domain Awareness Flights

Ronald Lindsay
Applied Physics Laboratory, University of Washington
1013 NE 40th Street
Seattle WA 98105
phone: (206) 543-5409 fax: (206) 616-3142 email: lindsay@apl.uw.edu

Award Number: N00014-12-1-0266
<http://psc.apl.uw.edu>

LONG-TERM GOALS

Our long term goals are to better understand the interaction of sea ice with the regional and global climate and to improve the skill of predicting the evolution of the ice on daily to decadal time scales.

OBJECTIVES

The overall objective of the proposed research is to collect detailed information about the thermal and physical state of the ice and ocean surface in the Beaufort and Chukchi seas over at least two complete summer melt seasons in order to better understand the physical processes that control the melt, to better represent them in numerical models, and to better predict the seasonal evolution of the ice cover.

APPROACH

The Coast Guard Arctic Domain Awareness (ADA) flights based out of Kodiak Alaska offer a tremendous opportunity to conduct repeated detailed surveys of the sea ice conditions in the Beaufort Sea. ADA flights are conducted twice per month from March through November and offer an especially valuable opportunity in the April-July and October-November periods for which model initialization and evaluation data is critically needed, and ship observations are typically not possible. Therefore, our group proposes to use the ADA flights for Seasonal Ice Zone (SIZ) Reconnaissance Surveys. From the Coast Guard C-130s, we will conduct atmosphere, ice, and ocean observations and buoy deployments from spring into fall in a coordinated experiment with multiple SIZRS observations proposed by various investigators in our team. There will be a set of core measurements needed to 1) make complete atmosphere-ice-ocean column measurements across the SIZ, 2) make a section of ice conditions across the SIZ, and 3) deploy drifting buoys to give time series of surface conditions. The overall SIZRS sampling strategy provides a mix of (i) fixed repeat sections and (ii) flexible sampling depending on ice and ocean conditions.

We propose to design and construct a package of high resolution infrared and visible cameras that can operate on the ADA flights and to then analyze the information obtained to determine the SST, the ice concentration, and the floe size distributions in order to better validate and initialize sea ice prediction models. The fully autonomous Visual-Infrared Package (VIRP) will consist of cameras and associated

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 2012		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Visible and Thermal Imaging of Sea Ice and Open Water from Coast Guard Arctic Domain Awareness Flights				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Applied Physics Laboratory, University of Washington 1013 NE 40th Street Seattle WA 98105				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 5	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

instrumentation and data recording equipment. This project will be integrated with the rest of the SIZRS effort and will provide critical measurements of the ice and ocean surface needed for other projects in the group. One goal of the SIZRS project is to create a holistic description of the annual changes of the ocean, ice, and atmosphere in the SIZ with the aim of enhancing predictive capabilities.

Our revised statement of work proposed that we would purchase a high-resolution infrared camera that would be integrated and installed on the CULPIS-X instrument package that is being designed and built by Dr. Mark Tschudi at the University of Colorado. This means that only one instrument package will need to obtain approval from the Coast Guard to be deployed on the aircraft. We would also acquire satellite remote sensing data (MODIS and SSMI) for flight planning before flights and during and after flights for inclusion in the SIZRS-DC database. The CULPIS-X package will be deployed in one of the flare tubes at the rear of the aircraft. The figure below shows one of the tubes open.

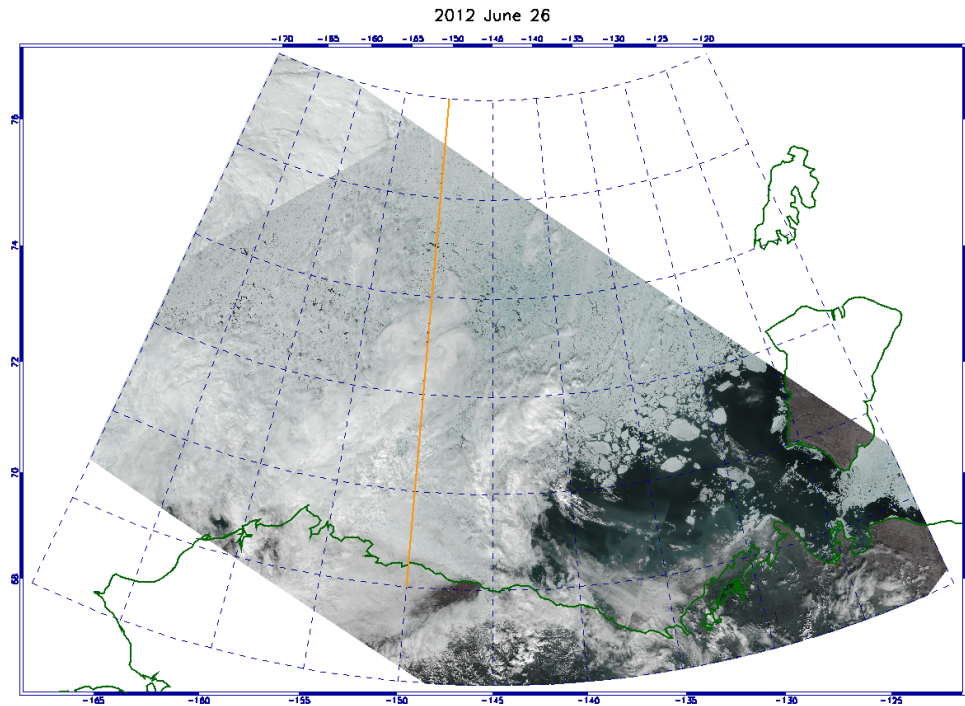


Flare tubes on the rear door of a C-130 aircraft where the CULPIS-X instrument package will be installed.

WORK COMPLETED

The CULPIS-X instrument package is still under review and final approval has not yet been obtained. We are delaying the purchase of the high-resolution camera until the final design is set and approval has been secured.

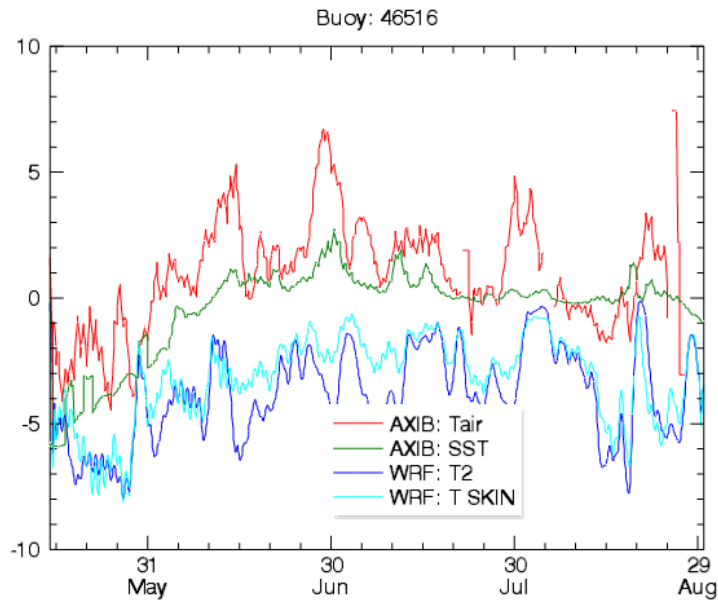
To date, five SIZRS flights have been conducted, one per month starting in May 2012. Below is an example of the MODIS images for the June flight.



MODIS images of the ice pack for the June 2012 flight. The orange line marks the 150W meridian which all of the flights follow.

RESULTS

In collaboration with a second SIZRS project, we have conducted high-resolution WRF model simulations of the weather in the vicinity of the SIZRS flights. A buoy that measure the 2.5-m air temperature and the sea surface temperature was deployed from one of the early flights. The following figure shows the air temperature and skin temperature from the buoy and from the WRF simulations. The WRF SST is prescribed based on the NOAA Reynolds Optimally-Interpolated SST product. It appears to be biased 2 to 5 C low with respect to the observations. While some of the low frequency variability is captured, some of the shorter term variability isn't. This shows the importance of our future SST work as input to weather and climate investigations. We will be able to better calibrate and evaluate the SST inputs for weather models.



Air and sea-surface temperatures from an air-dropped buoy and from WRF model simulations.

RELATED PROJECTS

This project is part of a broad collaboration of investigators concentrating on using the ADA flights to observe the seasonal ice zone and to investigate the marginal ice zone (where ice and open ocean interact). The following table lists these projects.

Table 1: Core and Collaborating Projects of the SIZ Reconnaissance Survey Flights

Project	PI	Co-PIs	Observations/Activity on C-130 Flights
<i>Ocean Profile Measurements During the SIZRS</i>	<u>Morison</u>		Ocean expendable probes AXCTD & AXCP for T, S, V, internal waves/mixing
<i>Clouds and the Evolution of the SIZ in Beaufort and Chukchi Seas</i>	<u>Schweiger</u>	<u>Lindsay, Zhang, Maslanik, Lawrence</u>	Atmospheric profiles (dropsondes, micro-aircraft), cloud top/base heights
<i>Arctic Ocean Surface Temperature project</i>	<u>Steele</u>		Buoy drops for SLP, SST, SSS, & surface velocity
<i>Visible and Thermal Images of the SIZ from the Coast Guard Arctic Domain Awareness Flights</i>	<u>Lindsay</u>	<u>Chickadel</u>	Vis and IR profiles (VIRP) for SST, FSD across SIZ
Ice thickness and character using CULPIS-X	<u>Tschudi</u> (UColorado)	<u>Maslanik,</u>	CULPIS-X Laser profiler for ice thickness, reflectance, skin temperature, Vis imagery
MIZMAS: Modeling the Evolution of Ice Thickness and Floe Size Distributions (FSD.....	Zhang	Schweiger, Steele	SIZRS observations (SAR/LDIP/MODIS/Landsat) for FSD. Integrate SIZRS observations & model
International Arctic Buoy Program	Rigor	Clemente-Colón & Vancas (NIC)	Drop buoys for SLP, temperature and surface velocity
Waves & Fetch in the MIZ	Thompson		Drop SWIFTS buoys measuring wave energy/dissipation
Assessment of Sea Ice Conditions	Rigor	Nghiem (JPL), Clemente-Colón (NIC), Wensnahan	SIZRS ground truth for sea ice assessment
Linkage of Sea IceWinds	Overland (PMEL)		Comparisons of SIZRS dropsonde data with ship launched balloons and 2014 P-3

AXCTD= Air Expendable CTD, AXCP= Air Expendable Current Profiler, SLP= Sea Level atmospheric Pressure, SST= Seas Surface Temperature, A/C= aircraft, FSD= Floe Size Distribution.