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

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LONG-TERM GOALS

Our long term goals are to better understand the interaction odf 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 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 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 staement or 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 was to be deployed in one of the falre tubes at the rear of the aircraft.

Due to continued delays with the CULPIS-x instrument pod, still under review with the USCG Aircraft Configuration Control Board, we have decided to pursue an alternate solution to gather thermal imagery of ocean water and sea ice by using a hand held thermal camera mounted during the flight on the interior of the aircraft near the rear ramp.

Work Completed

Partly using fund from this project, we have purchased an un-cooled thermal camera (VarioCam HD), manufactured by Jenoptik. The camera operates in the same way a normal (visual band) video camera operates, and includes an onboard battery and flash card data storage. The camera is high resolution (1024x768 pixel) and has a reference visual camera and GPS making it suited for standalone operation.

Our plan is to mount the camera internally in the aircraft so that it has a view of the ocean out of the rear cargo bay doors when they are opened for dropsonde and buoy deployment providing tens of minutes to a few hours of data, depending on frequency of air deployments. This camera mounting has the advantage of being simple, robust and more likely to be quickly approved by the ACCB. This type of deployment been tested this summer using a simple GoPro camera with good results, and after an ADA flight this August we installed the thermal camera and a trial mount for a ground test. Figure 1 shows photographs of our simple clamp mount and off-the-shelf camera tripod head, which was developed to attach to horizontal struts in the plane's bulkhead.

Figure 1. Two views of the test mounting of the handheld IR camera adjacent to the rear cargo door. The camera view of the ocean-ice surface is near nadir (straight down) when the cargo door is open for deployment of instruments during flight.

The camera can be operated by button push on the camera housing or through remote operation (via Ethernet cable) using a laptop. Both are possible operation scenarios for a trial on the C130, and the latter is preferred as a seated scientist can control camera operation and maximize the chance of high quality data. The implementation of this camera will require Coast Guard (ACCB) approval, though we are confident it will be quickly passed. Documentation is being currently prepared by USCG personnel and will be submitted shortly. We are cautiously optimistic it will be in time for the September flight to allow us to gather some test data to develop our analysis, including fine-scale floe size distribution, lead melt-water temperatures, and – when flying above the clouds – cloud top temperatures. Figure shows the view from the location of the proposed camera mount as seen by the GroPro camera.

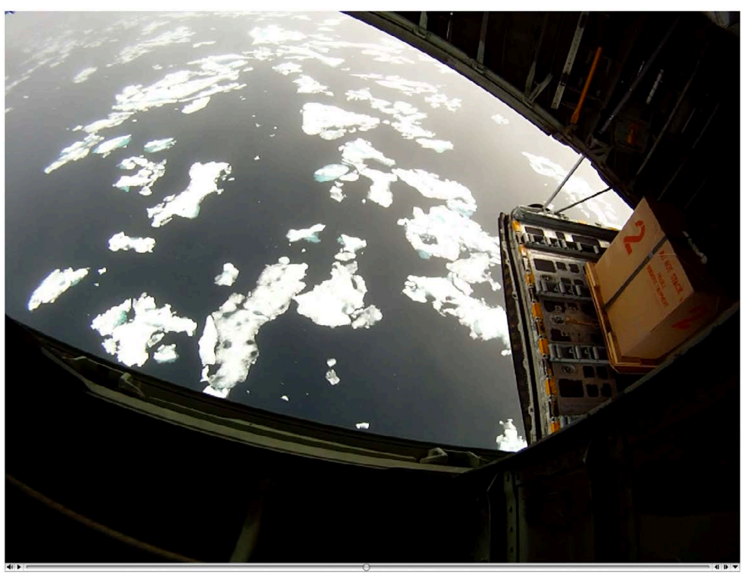

Figure 2. View out the open ramp from the proposed location of the VarioCam InfraRed camera. The large box ia an UpTempO buoy that is about to be deployed. The actual field of view of the VarioCam is much smaller and will mostly include just the open area at an oblique angle.

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: <u>Core</u> and Collaborating Projects of the SIZ Reconnaissance Survey Flights

Project	PI	Co-PIs	Observations/Activity on C-130 Flights
Ocean Profile Measurements During the SIZRS	***<u>Morison</u>***		Ocean expendable probes AXCTD & AXCP for T, S, V, internal waves/mixing
Clouds and the Evolution of the SIZ in Beaufort and Chukchi Seas	***<u>Schweiger</u>***	***<u>Lindsay, Zhang, Maslanik, Lawrence</u>***	Atmospheric profiles (dropsondes, micro-aircraft), cloud top/base heights
Arctic Ocean Surface Temperature project	***<u>Steele</u>***		Buoy drops for SLP, SST, SSS, & surface velocity
Visible and Thermal Images of the SIZ from the Coast Guard Arctic Domain Awareness Flights	***<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 Ice …..Winds	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, SIC=Sea Ice Concentration