Coupling of Waves, Turbulence and Thermodynamics Across the Marginal Ice Zone

Tim Stanton
Oceanography Department
Naval Postgraduate School
833 Dyer Road
Monterey, CA 93943
phone: (831) 656-3144 fax: (831) 656-3144 email: stanton@nps.edu

Award Numbers: N0001413WX20105 and N0001413WX21061
http://www.oc.nps.edu/~stanton/fluxbuoy/index.html

LONG-TERM GOALS

Detailed process studies of the MIZ are necessary to build accurate Arctic region ice-ocean-atmosphere numerical models. Streove et al. (2007) provide an example of the challenges of modeling the Arctic ice-ocean-atmosphere system - current global circulation models under-predict the observed trend of declining sea ice area over the last decade. A potential explanation for this under-prediction is that models are missing important feedbacks within the ocean-ice system. Results from the proposed research will contribute to improving the upper ocean and sea ice physics contained in regional and global circulation models.

OBJECTIVES

1. Understand coupling of surface-wave-driven mechanical forcing and solar-radiation-driven thermodynamic forcing in the marginal ice zone.

Within the MIZ, the ocean-ice-albedo feedback mechanism is coupled to ice deformation and fracturing that results from the presence of surface wave orbital motions and non-linear sub-harmonics resulting from interaction with the MIZ. We are interested in exploring, over the course of a summer heating season, the relationships between wave action, open water fraction, ocean warming, ocean heat fluxes and ice melt rates in the MIZ. Is wave-action a crucial component of the positive feedback mechanism in the MIZ?

2. Identify forcing mechanisms and quantify vertical mixing rates at the base of the ocean surface layer across the marginal ice zone.

It is expected that mixing rates in open water areas of the Arctic are larger than in ice-covered areas due to presence of surface waves and the direct transmission wind stress to the upper ocean. Do enhanced vertical mixing rates at the base of the mixed layer in the open ocean and the MIZ make significant contributions to basal ice melting and the retreat of the sea ice cover?

3. Identify changes in in the atmospheric boundary layer and oceanic surface boundary layer in response to local ice-floe changes as the MIZ evolves.

As the mean thickness and strength of the winter ice pack changes with increased summer ice retreat (with less multi-year ice and thinner seasonal first year ice), the character of the floes and ice ridges are also expected to change. The resulting changes in both the atmospheric boundary layer and oceanic boundary layer hydraulic roughness (expressed as a bulk drag coefficient) need to be measured and modeled for use in regional coupled ocean/ice/atmosphere models.

APPROACH

1. Enhanced Autonomous Ocean Flux Buoys

Autonomous ocean flux buoys (AOFB) developed at NPS measure the vertical fluxes of heat, salt and momentum near the top of the ocean mixed layer to determine entrainment fluxes and summer time solar heating fluxes over annual time scales (Stanton et al, 2012, Shaw et al, 2008, http://www.oc.nps.navy.mil/~stanton/fluxbuoy). The buoys have two main components: a surface housing that sits on the ice and an instrument frame that hangs from the housing, by a series of torsionally-rigid poles, into the IOBL. The surface housing contains processing electronics, Global Positioning System (GPS) electronics, an Iridium satellite modem, GPS and Iridium antennae, and batteries. The instrument frame is outfitted with a downward looking 300 kHz Acoustic Doppler Current Profiler (ADCP, RDI Workhorse) and a custom-built 'flux package'. A 3D acoustic travel-time current meter sensor, with 0.5mm s^{-1} rms noise level), an inductive conductivity cell (± 0.002 mS cm^{-1}), a platinum resistance thermometer, and a fast-response thermistor (0.1 mK resolution) comprise the flux package sensor suite. These low noise, fast-response instruments are collocated within a $0.001m^3$ sample volume, and directly measure the turbulent fluxes of momentum, heat, and salt over approximately 40-minute long Reynolds averaging periods using the eddy-correlation techniques. A 16-element thermistor string measures finescale thermal structure between the 4m below the ice flux package and the ice. The previous AOFB design is being enhanced for the MIZ study with a bulk meteorology package, a shortwave incident radiation sensor, and a 3D acoustic anemometer providing atmospheric boundary layer stress and heat flux estimates. Two of these instrument systems will be deployed in the MIZ instrument cluster array in the Eastern Beaufort Sea in March 2014.

WORK COMPLETED

Work this year has been focused on construction of three met buoy packages to mount on top of the AOFB's, and the associated integration of the wave sensor, solar sensor and bulk met sensor into the existing store and forward data processing used in the flux buoys. Work is continuing on real-time processing of the 3D atmospheric velocitmeter which will return tilt and motion-corrected co-spectral estimates of $\langle u'w' \rangle$,$\langle v'w' \rangle$ and $\langle T'w' \rangle$ allowing vertical Reynolds Stress and heat flux measurments to be made in the atmospheric boundary layer. A MS student is currently assessing the wave measurements made by the enhanced AOFB. A CSUMB undergraduate student did a summer STEM internship working on a MATLAB-based processing chain for determining open water fraction and floe size distribution from high resolution visible and SAR images.

RESULTS

The first bulk met sensor equipped AOFB was deployed in the Beaufort Sea in late summer by our WHOI colleagues (Figure 1), and the meteorological and wave sensors reported data through the AOFB system. The two enhanced AOFB's to be deployed in March 2014 will have a 3D acoustic anemometer in the center position of the met 'tree'. A poster describing the image processing chain is being presented at the 2013 SCANAS conference. Lab and field tests performed on the AOFB wave sensor show excellent noise performance of both the inertial motion and tilt sensor outputs used in measurments of both ice flexure wave and ocean wave directional spectra.

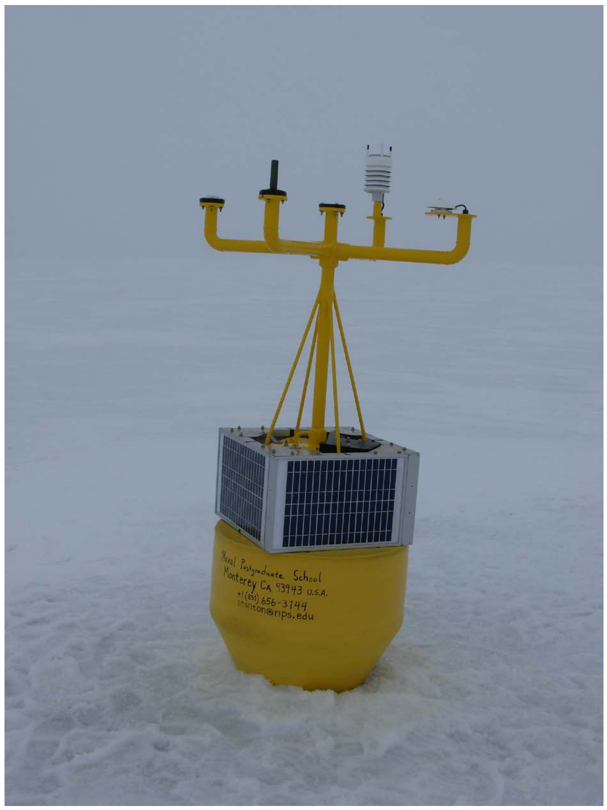

Figure 1. A Met-package AOFB deployed in the Beafort Sea.

IMPACT/APPLICATIONS

The meteorology and wave wave measurement enhnacements to the AOFB's have wide application in Central Arctic long term applications.

RELATED PROJECTS

This project is closely aligned with the NSF Arctic Observation Network with resource sharing and enhnacement of capabilities. In Particular, we have an ongoing collaboration with Rick krishfield and colleagues at WHOI in sharing deployment costs and co-location of AOFB and ITP resources.

REFERENCES

Shaw, W. J., T. P. Stanton, and M. G. McPhee, 2008, Estimates of surface roughness length in heterogeneous under-ice boundary layers, J. Geophys. Res., 113, C08030, 10.1029/2007JC004550.

Stanton, T. P., W. J. Shaw and J. Hutchings 2012, Summer Ocean-to-Ice Heat Flux in the Central Arctic: 2002-2010, J. Geophys. Res., 117, C07005, doi:10.1029/2011JC007871, 2012

PUBLICATIONS

Sommer, L, T. P. Stanton and B. J Shaw, Measuring Open Water Fraction and Floe Size Distribution In The Arctic Ocean Ice Pack Using High Resolution Satellite Images. SACNAS Conference, October 2013.