

Relationship Between Morphology and Hydrodynamics Below Arctic Sea Ice in the Vicinity of a Pressure Ridge Keel

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LONG-TERM GOALS

Drag generated as the wind pushes sea ice over the underlying ocean can be generated by flow distortion and separation over large roughness features on the underside of the ice (form drag) or by viscous stress and wakes past small-scale disturbances in a thin viscous or roughness sublayer. To date, there have been no studies in which concurrent hydrodynamic and high-resolution morphological measurements have been used to relate measured drag with directly-observed, under-ice morphology.

OBJECTIVES

Pressure ridge keel may occupy a significant fraction of the IOBL. The relatively large size of the keels (compared to roughness elements in the atmospheric boundary layer and the ocean bottom boundary layer, for example) makes the ridge keel problem unique. Turbulent processes in the vicinity of ridge keels, such as downstream wakes, may be a dominant source of drag and mixing in the IOBL (Skylvingstad et al 2003). The effects of a measured ice keel on the turbulent structure of the ocean mixed layer will be directly measured over a range of forcing conditions. Fine-scale morphological observations will allow estimation of the distribution of roughness elements which we will try to relate to the hydrodynamic transition from smooth to rough boundary layer flow, in which the roughness length z_0 changes from being dependent on surface stress to being directly proportional to the size of the roughness elements. Previous under-ice boundary layer studies have reported roughness length values in both of these regimes (Shaw et al 2008) but without direct observations of the local ice/ocean interface morphology.

APPROACH

A 7 day deployment of instruments at the APLIS ice camp in the Beaufort Sea in 2011 was executed. The experiment used existing technology to measure turbulence in the under-ice boundary layer and to map the under-ice morphology (Figure 1). A pair of 'flux packages' made point measurements of temperature, conductivity, and 3-D water velocity at sufficient spatial and temporal resolution to directly estimate the vertical fluxes of momentum, heat, and salt. The flux packages are custom-designed and built by our group at NPS, and have been used for under-ice turbulence observations in Arctic deployments for the last 9 years (e.g. Shaw et al., 2008, Stanton et al 2010, and see also

<http://www.oc.nps.edu/~stanton/fluxbuoy>). A 256 beam sector scan sonar was deployed to provide O(1cm) resolution measurements of the under-ice morphology. The system generates a series of vertical slices of ice morphology which can be reconstructed into a cm-resolution 3D map of the ice morphology.

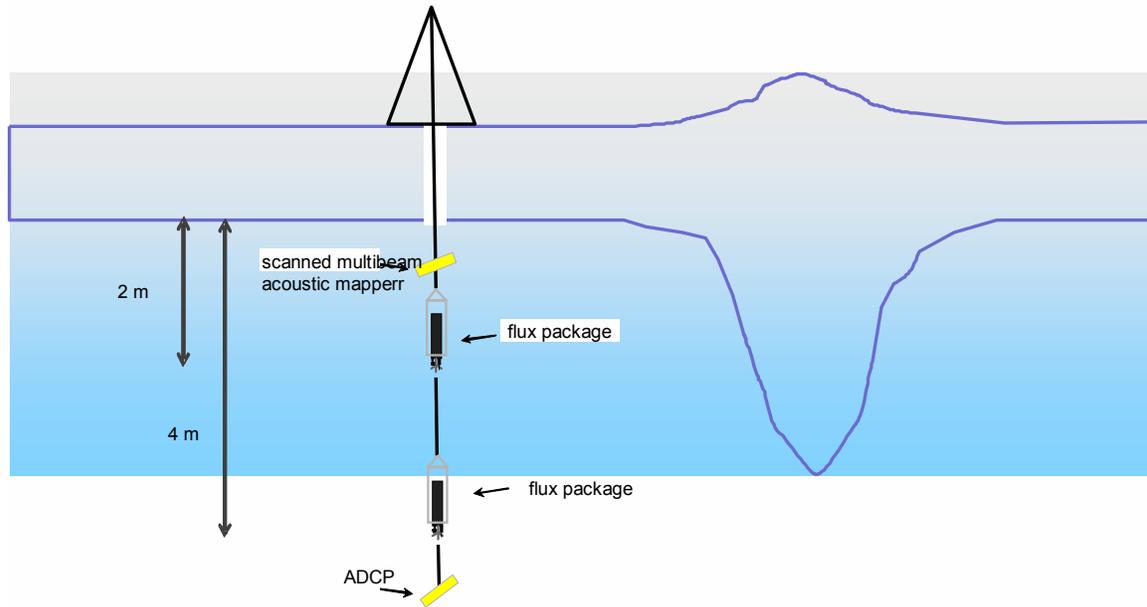


Figure 1 Schematic of the flux package installation near a ridge keel. The two sensors are deployed 2 and 4 m below the ocean-ice interface, but will be raised and lowered at hourly intervals such that the shallowest measurement volume is 0.5, 1, 1.5 and 2m below the surface.

WORK COMPLETED

Two NPS masters students traveled to the APLIS camp and deployed the NPS instruments between 17 and 23 March 2011. An 11m deep multiple block ice ridge was identified within the large ice floe the camp occupied, and the keel was imaged with 1400 sector scan sonar slices and an underwater camera from 4 directions around the keel. The turbulence frame was deployed from a small heated hut and ran continuously for 4.5 days using a sampling cycle moving the frame top between 1m below the surface, 2m above the keel depth, and 2m above the current mixed layer base depth every hour. This sampling strategy provided turbulent flux estimates from the two flux packages spanning the mixed layer. CTD casts to 60m depth resolved weak stratification within the ocean mixed layer which arose during low wind forcing (low ice speed) conditions.

RESULTS

A MS thesis analyzing the field results has been completed. Estimates of the ocean/ice drag coefficient were found to be as high as 0.08 in the wake of the ice keel, and as low as 0.002 for flow across the ice floe not affected by the ice keel. While strong forcing, high wind conditions were not encountered during this brief experiment, this data set is being further analyzed to study keel effects in lightly stratified flow. A paper describing this analysis is in preparation.

IMPACT/APPLICATIONS

This data set will be useful to parametrize ice keel induced drag in the ocean mixed layer, and modification of drag by weak stratification, for use in high resolution coupled ice/ ocean/atmosphere models.

RELATED PROJECTS

This project is closely aligned with the goals of the NSF Arctic Observation Network program, and the ONR Marginal Ice Zone DRI.

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.
- Skyllingstad, E. D., C. A. Paulson, W. S. Pegau, M. G. McPhee and T. P. Stanton, 2003. Effects of Keels on Ice Bottom Turbulence Exchange. *J. Geophys. Res.*, 108(C12), 3372.

PUBLICATIONS

Schmidt, B. K., Observations of Hydraulic Roughness and Form Drag in the Wake of a Ice Keel in the Arctic Ocean. MS thesis, Naval Postgraduate School, March 2012.