Autonomous Underwater Vehicle Measurements Under Antarctic Sea Ice

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ABSTRACT

The March 2003 deployment of Autosub in the Antarctic was the first field study under the Autosub Under Ice programme of the UK Natural Environment Research Council. Several missions were run under sea ice in the western Bellingshausen Sea at depths ranging from 90 to 200 m. Data from the vehicle's upward-looking ADCP indicate a strongly oscillating horizontal velocity at and near the ice underside due to ocean swell. Swell period, height, direction, and directional spread are computed every 800 m from the ice edge to 10 km inward. Period-dependent attenuation of swell by sea ice is observed. Directional spectra show slow changes in swell properties during propagation through the ice pack.

CONCLUSIONS

To our knowledge, these are the first scalar and directional wave data collected by an AUV. We observe exponential attenuation of waves propagating through sea ice that depends on period. Mean period increases with distance from the ice edge. There appears to be refraction of the waves. Waves are more spread at higher frequencies, but for any one frequency, the spread does not seem to relate to distance from the edge. More under-ice runs and modelling are needed to confirm these observations, which are at odds with current scattering models.[4] This observational technique may also be useful for open water studies (e. g. coastal zones).

BACKGROUND

From 22 to 25 March, 2003, Autosub (Figure 1) completed four missions under sea ice north of Thurston Island (Figure 2). Autosub is a 7.5 m long, 1 m diameter battery-powered vehicle which carries several instruments. Here, only the Acoustic Doppler Current Profiler (ADCP) data from mission 324 will be discussed. Other variables include conductivity, temperature and depth; vehicle pitch, yaw, and roll; and velocities from a downward-looking ADCP.

ADCP:
- -3 mm polyethylene window
- -300 kHz RDI
- -4 beams 30° from vertical
- -2 sec cycle
  - -profile ping: 15 x 8 m bins
  - -surface ping: range, velocity

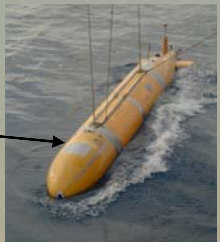
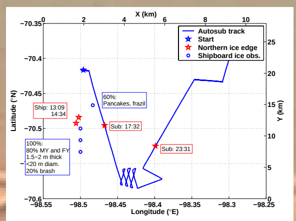


Figure 1: Autosub

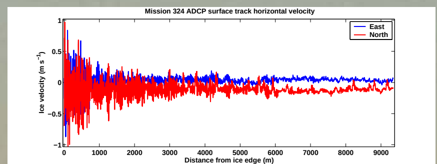
Surface track velocity and range were recorded from a distance of up to about 200 m beneath sea ice, while in open water the surface echo was too weak, even at 90 m. Thus ice draft, ice edge location, and the horizontal velocity of the ice surface were obtained. We consider the latter here.



Figures 2a and 2b: Location map and detail of mission 324

RESULTS

Horizontal surface track velocity generally shows periodicity in the range of 8-15 s, indicating the ice floes were surging and heaving with the swell. Floe diameters were less than 30 m, which is much less than the deep water swell wavelength (100-350 m). In this regime the floes very nearly follow the circular path of a point on the water surface. Figure 3 shows decreasing orbital velocity amplitude as the sub travelled further into the ice pack on 25 March, 2003. A similar decay was observed upon return. The mean ice drift was southeastward.



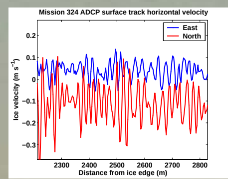


Figure 3a and 3b: Autosub ADCP ice velocity (a) and close up view (b)

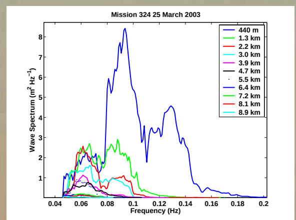


Figure 4: Wave height spectra

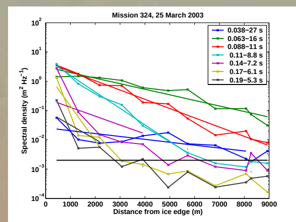


Figure 5: Attenuation by frequency band

For a surface gravity wave of amplitude *A* in deep water, the orbital speed of a particle at depth *z* is: $U_{orbital} = [\omega \exp(-kz)]A$ The dispersion relation is: $\omega^2 = \sqrt{gk}$. For an infinite number of waves of random phase, the spectrum of the complex velocity can be converted to a wave height spectrum: $S_{\eta\eta}(f) = [\omega \exp(-kz)]^{-2} S_{uu}(f)$. See figure 4. The spectral density of each frequency band decays exponentially with distance (Figure 5). The decay rates are within a factor of two of a July 1983 Greenland Sea buoy analysis and show a similar peak in attenuation at about 9 s.[1] The wave spectra also allow calculation of significant wave height and period from the wave spectrum using accepted definitions.[2,3] See figure 6.

Unique to this study is the calculation of the directional spectrum at closely-spaced locations. By calculating the spectrum of velocity along the *x*-axis as that axis is rotated around the half circle, we can find how the spectral density varies with direction as well as frequency (Figure 7). Wave pressure or surface height is needed to resolve the "coming or going" ambiguity present in our definition. This sum of incident and backscatter spectral density is similar in form to model calculations.[4] Mean direction and angular spread for any frequency and location are calculated from the directional spectrum (Figure 8). The wave direction shows a similar trend for most frequencies, but the spread depends more on frequency than distance from the ice edge.

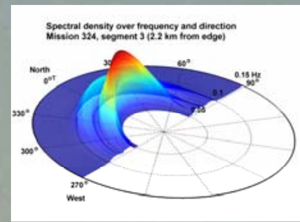


Figure 7: Directional spectrum

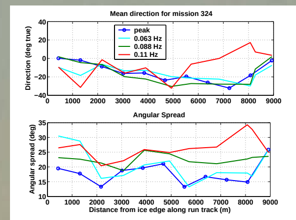


Figure 8a: direction
Figure 8b: spread

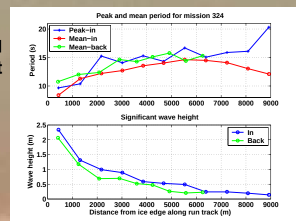


Figure 6a: period
Figure 6b: wave height

References

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