Proving and Improving Wave Models in the Arctic Ocean and its MIZ

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LONG-TERM GOALS

The long term goal of the project is to gain a significant improvement in our ability to understand, and model, the processes by which ocean waves, generated in the increasing expanses of open water which surround the shrinking Arctic ice cover, interact with the surviving ice cover and modify its properties.

OBJECTIVES

Objectives of the projects are to:

- Validate and improve the ECMWF WAM model in the Arctic, which predicts wave spectra at the ice edge on the basis of wind duration and fetch aross the open water;
- Extend the capabilities of the wavebuoys developed under the related MIZ DRI;
- Broaden the range of physical processes which contribute to modelled wave attenuation in the MIZ

APPROACH

We make use of wave buoys developed under the MIZ DRI to carry out further specific experiments on wave reflection from ice floes and wave-induced ice breakup; we bring in the specific skills of colleagues who are skilled in wave-ice modelling (notably Dr Michael Meylan, Australia) to interact with the experimental program in order to improve the theory symbiotically.

WORK COMPLETED

Task 1.1: Validation of WAM and comparison with in-situ data.

Task 1.2: Taking WAM into the ice: Applying an enhanced WAM to delineate and track the extent and position of the wave-influenced zone.

Our paper on these tasks was accepted by the *Ocean Modelling* journal, following three rounds of revision, and shows the very good correspondence between the WAM model incorporating several simple enhancements and data from a single wavebuoy at the Antarctic ice edge. These improvements will be tested in the Arctic as data become available from this and the closely-linked MIZ DRI.

Task 2: Development and validation of improved attenuation models and parameterisations for the MIZ.

This work is being carried out by our colleague Dr Michael Meylan (Australia), who is adopting a novel statistical approach to modelling the directional spectrum within ice after multiple scattering. A review paper on progress with this new model is in preparation.

Task 3: An ice edge reflection experiment

This is a precision experiment using a set of buoys posirioned and maintained at short fixed distances ahead of, and behind, a distinct ice edge, in order to experimentally measure the reflection and scattering coefficient of single rows of ice floes. It is tentatively scheduled for 2015 aboard the R/V Sikuliak, unless an earlier opportunity can be found.

This experiment will include the precison instrumentation of a large floe undergoing stimulation by a simple planar wave (i.e. a floe near the ice edge and experiencing a long swell which has not been scattered). This is to test model mechanisms for breakup of large floes, an essential component to the way in which a quasi-equilibrium state of floe sizes is induced in an icefield experiencing rising waves. An opportunity to carry out a test of this method in the case of a very large tabular iceberg was offered in July-August 2012 by the BBC as part of the filming of the programme "Operation Iceberg" (shown on BBC2 TV, November 2012). The iceberg, some 8 km square and 100 m thick, was a product of the Petermann Glacier, grounded off Baffin Island, and was visited using the chartered R/V "Neptune". Participants from Cambridge were Dr Wadhams and Till Wagner (now of SIO). Other scientists on board included Dr Richard Bates (St Andrews University) and Dr Keith Nicholls (BAS), doing sonar sidewall mapping and ice drilling respectively.

A Waverider GP12 directional wave buoy was deployed in the ocean near the berg throughout the experiment, and recorded a persistent swell from the SE. An array of tiltmeters and GPS vertical movement sensors was placed on the berg near the edge. These recorded the berg response to the waves, and on one occasion a calving event occurred while the instruments were in place and being examined by Wadhams and Wagner. The berg gave a perceptible upward lunge as a piece some 800 m x 200 m, containing the instruments and the experimenters, broke off. The two possible mechanisms for this are flexural strain due to the incident swell, and an upward moment arm due to the creation of a wave cut around the berg edge followed by collapse of the unsupported above-water snow leaving a submerged ram. The flexural strain mechanism is identical to what must be a dominant mechanism in large floes, with the buoyancy mechanism less important in floes than bergs as it is only able to break off small ice cakes around the floe edge. We compared an elastic flexural model (Goodman et al., 1980) to the observations, with results to be reported at the 2013 Fall AGU, and a paper being prepared for submission.

RESULTS

We found in the iceberg experiment that the response of the berg was well described by flexural wave threory, though we are not yet sure if this was the prevalent mechanims. We showed that the WAM model is very suitable for the purpose of predicting ice edge wave energies, which makes its routine use in models and in operational analyses and predictions very appropriate.

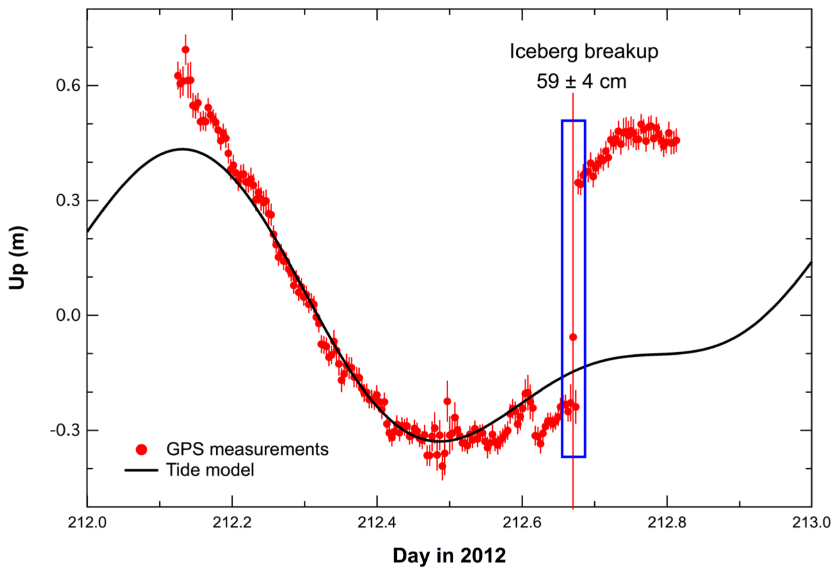

Fig.1. Heave response of iceberg fragment at moment of calving from main berg.

IMPACT/APPLICATIONS

Work done in this preliminary phase is very suggestive that improved scattering and flexural failure theory, when combined with WAM model input, may provide a very adequate picture of the behaviour of an MIZ icefield in waves.

RELATED PROJECTS

"Wave-ice interactions and the Marginal Ice Zone", MIZ DRI, Award Number N0014-12-1-0130

REFERENCES

Goodman, D. J., P. Wadhams and V. A. Squire (1980). The flexural response of a tabular ice island to ocean swell. *Ann. Glaciol., 1*, 23-27.

PUBLICATIONS

Doble, M.J. and J-R Bidlot, 2013. Wavebuoy measurements at the Antarctic sea ice edge compared with an enhanced ECMWF WAM: towards global waves-in-ice modelling. *Ocean Modelling*, **70**, 166-173, Special Issue on ocean surface waves, doi: 10.1016/j.ocemod.2013.05.012 [published, refereed]

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