Wave-ice interaction and the Marginal Ice Zone

Prof. Peter Wadhams
Department of Applied Mathematics and Theoretical Physics, University of Cambridge,
Wilberforce Road, Cambridge CB3 0WA, UK
phone: +44 1223 760372 fax: +44 1223 765900 email: p.wadhams@damtp.cam.ac.uk

Dr. Martin Doble
Laboratoire d'Océanographie de Villefranche, Université Pierre et Marie Curie, Paris VI
phone: +33 (0)493 763732 email: doble@obs-vlfr.fr

Award Number: N00014-12-1-0130
http://www.apl.washington.edu/project/project.php?id=miz

LONG-TERM GOALS

The long-term goal is to gain a full understanding of the physical processes involved in the interaction between ocean waves and a sea ice cover, in terms of scattering, attenuation, and the mechanical effects of the waves on the ice.

OBJECTIVES

The main thrust of our work in this project is to design, build and deploy a large number of wave-measuring buoys, subsequently using them to acquire an unprecedented volume of in-ice directional wave data. These data will be used by the modelling community to parameterise and understand the influence of incoming ocean waves on sea ice, including mechanical effects, and the effect of the ice on the waves (attenuation, spreading).

APPROACH

Our observations divide into (1) Attended process experiments, carried out using internally-recording high-data rate buoys; and (2) Survey experiments from autonomous deployed buoys, primarily during the summer ice breakup of 2014. The buoys are designed and built in collaboration with the British Antarctic Survey (UK), key personnel being Dr. Martin Doble (LOV/Ice Ocean) and Dr. Jeremy Wilkinson (BAS).

WORK COMPLETED

The overwhelming effort this FY was the build and deployment of 30 wavebuoys into the Beaufort Sea pack ice. The effort was extremely successful and divided into two phases:

1) **Airborne/ice camp operation out of Sachs Harbour, March 2014**. This was the main field effort for the MIZ programme, deploying a comprehensive suite of buoys in 4 clusters, using

‘fast and light’ ice camps as deployment platforms. 20 wavebuoys were deployed in the 4 clusters under our effort, each cluster in a “five dice” pattern of 5 km scale. Dr. Martin Doble (LOV/Ice Ocean) travelled to Yellowknife to complete final build of the buoys there, and subsequently joined Drs. Jeremy Wilkinson (BAS) and Dr. Ted Maksym (WHOI) on the ice camps to deploy these and other buoys. The wavebuoys proved extremely robust, even under prolonged and intensive convergent dynamics events. Of the 20 deployed, 13 are still operating at the time of writing (29 September 2014) and are currently undergoing freeze-in to their second winter’s pack ice.

Figure 1: One of the solar-powered wavebuoys deployed on ice from the Sachs Harbour ice camps

2) **Ship-based operation from the South Korean icebreaker “*Araon*”, in August 2014**. A further 10 buoys were built and shipped to Nome, Alaska to join the vessel. Dr. Martin Doble (LOV/Ice Ocean) deployed these using *Araon*’s helicopters to the north of the existing clusters, in a nested 1, 10 and 50 km scale array, centred around 77.6^{o}N, 146^{o}W, during the week-long drifting ice camp. Unfortunately a software issue with Iridium SIM cards prevented five of these 10 from uploading data, and these are now considered ‘lost’. The other five continue to transmit and are expected to last throughout the winter. The buoy deployments were co-ordinated with other GPS-reporting buoys, in order to build a multi-scale array for ice deformation studies. Other instruments making up the array include five BAS/SAMS ice mass balance buoys (IMBs), and four prototype air-droppable BAS SIESTA ice beacons. These were deployed by Dr. Phil Hwang (SAMS).

As we enter the second winter of operation, we have a total of 18 operational wavebuoys. Thus we can hope and expect to obtain a significant second set of GPS and wave data when breakup occurs during the summer of 2015.

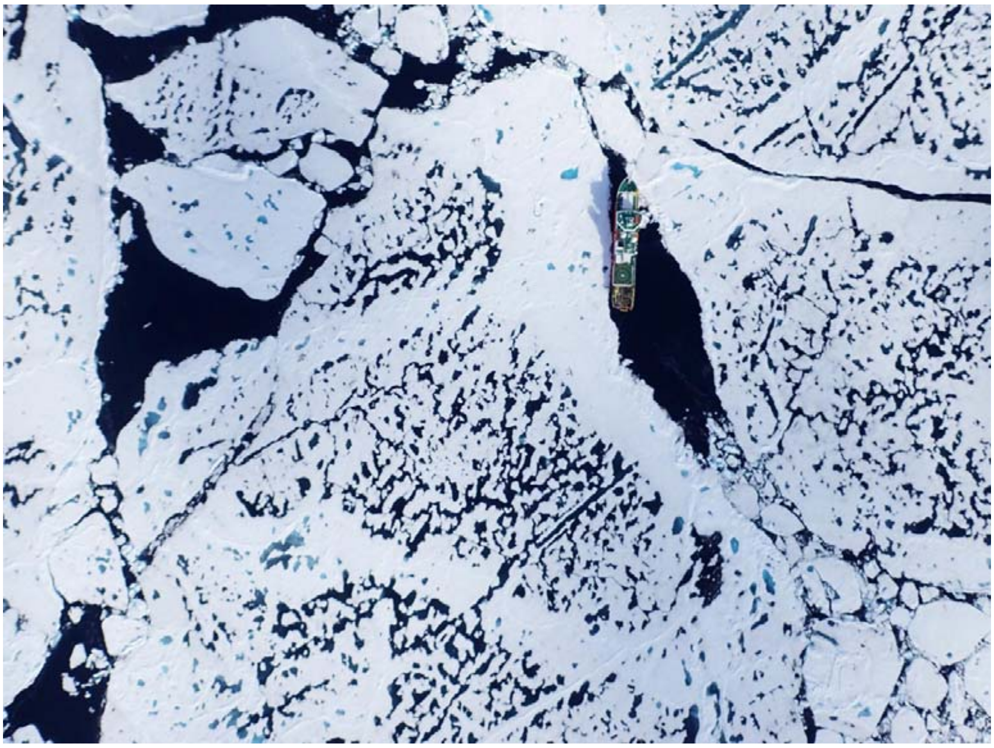

Figure 2: Aerial photograph of the Araon alongside the "ice camp floe"

RESULTS

Data has been streaming over the Iridium satellite network since deployment. To date the longest-lived buoys have completed more than 200 days operation, generating more than 40GB of data in total. We are now currently examining and QC'ing these data, prior to co-ordinating their analysis with the various other groups in the project. Synthesis of the wave data with GPS positions (dynamics), ice thickness, ocean and meterological parameters is essential to understand the complex interacting processes which are at play in the summer MIZ.

Data from the buoys has been characterised by three periods, as indicated in Figure 3:

- **Quiescence**: very little dynamics was observed by the wave sensors - essentially 'flatlining' from deployment (~ year day 72, March 13th) until the end of June (year day 180).
- **Compression/dilation**: most buoys displayed significant and long-term changes in attitude (tilt, roll) as the interior pack ice became mobile and started to respond to the large scale wind and current forcing (year days 180-225, early July until late August)
- **Release**: the weakened ice finally allowed the buoys to float independently in the increasingly low-concentration ice cover (late August - year day 225 - onwards)

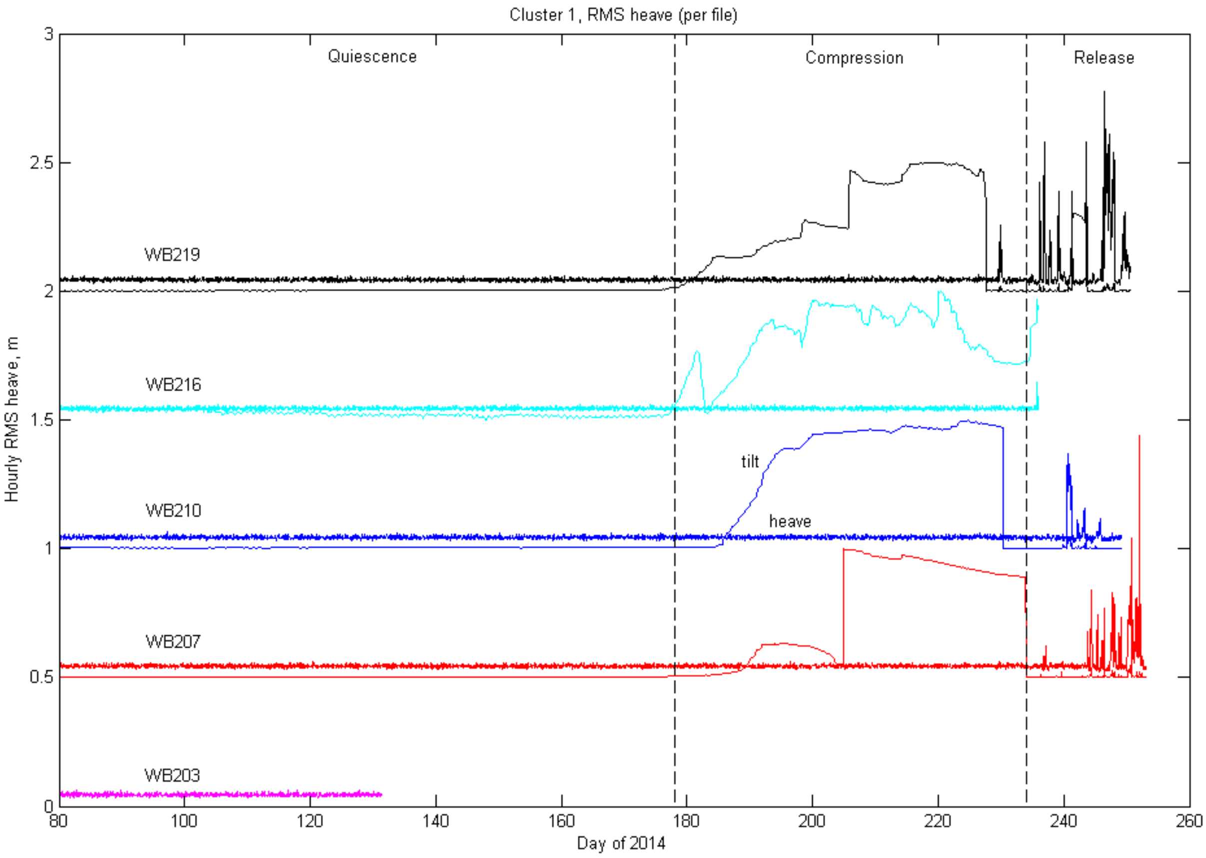

Figure 3: Heave experienced by the five buoys of Cluster 1, over the course of their deployment. The three periods of "quiescence", "compression" and "release" are indicated.

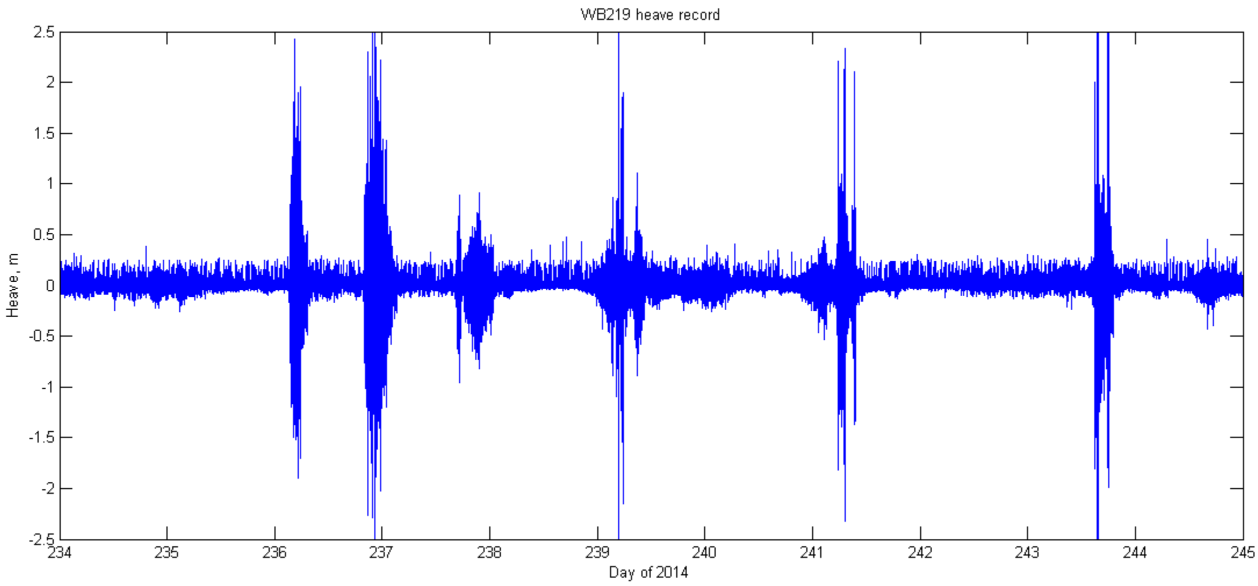

Figure 4: A more detailed view of 11 days heave record from WB219 (Cluster 1)

SURFACE TRUTH

During the ARCTIC SHIELD 2014 cruise of USCGC "Healy" to the Beaufort Sea, Prof Peter Wadhams directed the ship to the site of wave buoy WB212 at approximately 74°N, an element in Cluster 2, on August 20th. The buoy's on-board camera showed it in ice but with a tilted horizon. The actual situation (fig. 5) was that the buoy had half melted out of its installation site, and was now on a fragment of a floe that was melting fast. We were able to carry out three AUV under-ice operations using a Gavia AUV in the area, mapping the underside of the ice in three dimensions with multibeam sonar, and found that the rotting ice had a typical thickness of only 0.8 m. This is useful information since the IMB deployed with this wave buoy had long ago diverged in position, due presumably to the floe cracking between the buoy and the IMB, and is now several degrees away.

Figure 5: Wave buoy WB212 on floe fragment, August 20 2014

IMPACT/APPLICATIONS

The diverse and comprehensive suite of autonomous measurements performed this year represents a significant addition to the total data record of MIZ processes. These data will have significant impact on our understanding of Arctic MIZ processes as the consortium enters the synthesis and analysis phase for the remaining two years of the project.

RELATED PROJECTS

"Proving and improving wave models in the Arctic Ocean and its MIZ", Sea State DRI, Award Number N0014-13-1-0290