Autonomous sea ice mass balance observations in the Arctic Observing Network

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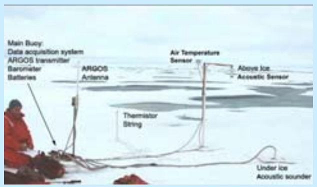
Introduction

There has been a marked decline in the summer extent of Arctic sea ice over the past few decades. The mass balance of the ice cover can enhance our understanding of this decline. The mass balance is an integrator of both the surface heat budget and the ocean heat flux. Because of the importance of the ice mass balance we are currently involved in developing and deploying a network of autonomous ice mass balance buoys (IMB) designed to observe changes in the mass balance of the ice cover. This work is being done as part of the Arctic Observing Network in collaboration with the North Pole Environmental Observatory, the Beaufort Gyre Environmental Observatory, and the Developing Arctic Modeling and Observing Capabilities for Long-term Environmental Studies Program. These buoys monitor changes in snow deposition and ablation, ice growth, and ice surface and bottom melt.

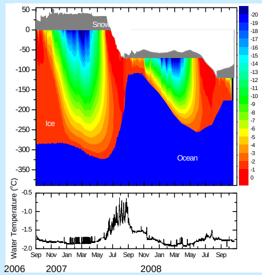
Measuring the ice mass balance

The mass balance of sea ice is simply the amount of ice growth during the winter and the amount of surface and bottom melt during the summer. During a field experiment it can be measured using an ablation stake and a thickness gauge to monitor the position of the surface and bottom.

The mass balance can also be measured autonomously using an ice mass balance buoy. Two acoustic sensors take the place of the ablation stake and thickness gauge and a string of thermistors measures vertical profiles of ice temperature. Data are recorded using a Campbell Scientific datalogger and are transmitted using the ARGOS satellite system.



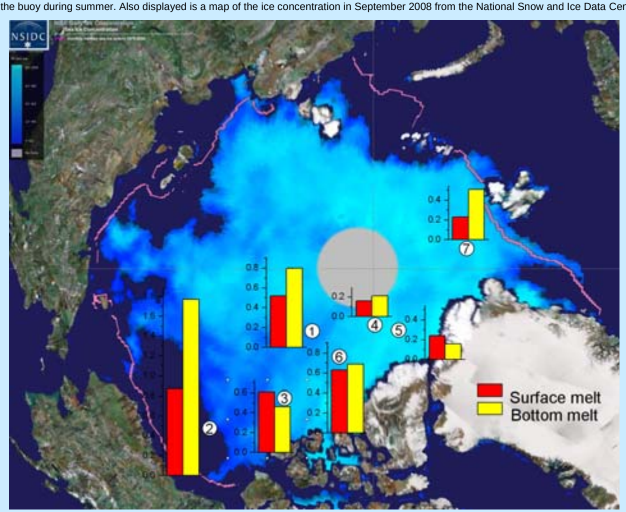
An ice mass balance buoy



Sample IMB results. The thick multiyear ice underwent a tremendous amount of bottom ablation in the summer of 2007 (2.1 m) and a large amount (0.9 m) in 2008.

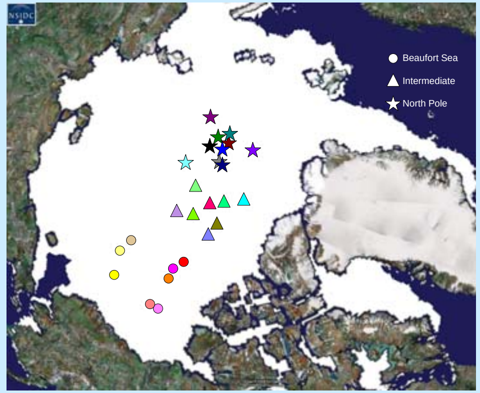
Results from IPY - 2008

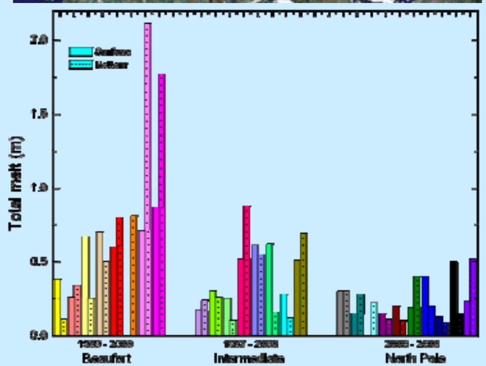
The total amount of surface (red) and bottom (yellow) melt during the summer of 2008 measured at seven ice mass balance buoys. Surface and bottom melting ranged from 0.1 to 3.17 m, with complete melting at buoy 2. The white dots denote an approximate position of the buoy during summer. Also displayed is a map of the ice concentration in September 2008 from the National Snow and Ice Data Center.

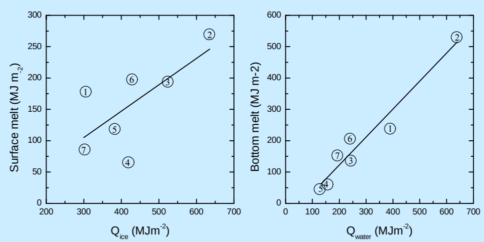


Comparisons and discussion

The plots below summarize surface and bottom melt measured at 27 sites between 1957 and 2008. Measurements were clustered near the North Pole (stars), Beaufort Sea (circles), and in between (triangles). The symbols are used to locate buoy positions at the start of summer. The symbols in the map are color coded with the results in the plots. North Pole buoys have the least amount of melting and show a modest increase in recent years. There have been large increases in bottom melting in the Beaufort Sea in recent years.





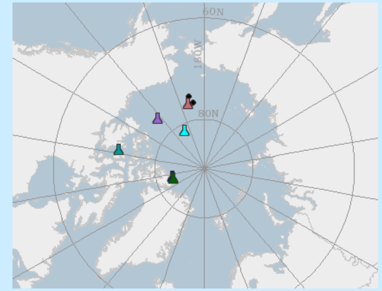


The amount of solar heat deposited in leads was computed using satellite derived ice concentration data and model estimates of incoming solar radiation. The figure above compares the a) heat used in surface melting (Qms) to solar heat input to ice (Qi) during the period of surface melting and b) heat used in bottom melting (Qmb) to solar heat deposited in open water (Qw). The straight lines are the linear least squares best – fit to the data. Results indicate:

1. Solar heating played a major role in the observed bottom melting.
2. There was ample solar heating for the observed melting.
3. Bottom melt increased roughly linearly with increasing solar heat input.
4. This absorbed solar heat was released gradually and through abrupt episodes.

Future direction

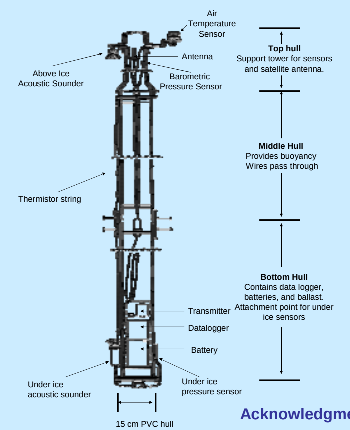
The map below depicts the buoys that are currently operating in the Arctic. We will be deploying 5 – 6 buoys per year as part of AON. The buoys are always collocated with other components of the Arctic Observing Network. We are always looking for ways to collaborate with other AON investigators, as well as other components of SEARCH. A region of particular interest is the ice pack north of Russia, which has been underrepresented in our previous buoy deployments.



Seasonal ice buoy

Minimum sea ice extent has been declining rapidly in recent years, but while late summer declines have grabbed headlines, recent trends in the decline of maximum winter ice extent have been much slower. This seasonally asymmetric sea ice decline has caused a shift in the predominant ice type in the Arctic Basin from perennial to seasonal ice. In recent years, first year ice has represented as much as 70% of the maximum winter ice extent in the Arctic, up from about 40% in 1985. With both trends and predictions pointing to further reductions in perennial ice the importance of seasonal ice in the Arctic system is growing, as is the need for an ice mass balance buoy that can be deployed in seasonal ice.

We have developed a prototype Seasonal Ice Mass Balance Bouy (SIMB) to address this need. The SIMB differs from the IMB in that it is designed around a single hull which contains all of the instruments and sensors rather than several isolated components deployed down separate holes. The SIMB floats upright with a strong righting moment and positions the sensors reliably in relation to sea level, even if it melts free. External wires are reduced to an absolute minimum, the system requires only a single hole be drilled in the ice, and ships in three pieces which can be readily assembled and installed by a team of two in under an hour. A test deployment from April – June 2009 at Barrow, AK has provided us with data to refine the design. We plan to deploy two SIMB in the drifting pack ice in 2010.



Photos of the SIMB prototype during its test deployment in Barrow, AK in spring of 2009.

Acknowledgments

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