HOTRAX 2005: Trans-polar observations of the morphological properties of Arctic sea ice

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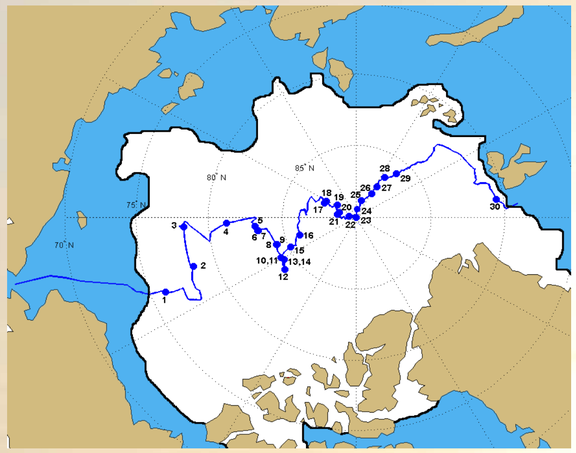
INTRODUCTION

Numerous ground-based and satellite observations of polar sea ice offer substantial evidence of a recent reduction in the areal extent and thickness of the Arctic ice cover. In an effort to analyze and quantify this change within the context of both an Arctic and a global climate system, the *Healy-Oden* Trans-Arctic Expedition 2005 (HOTRAX 2005) conducted a pan-Arctic survey of the stratigraphical, paleoclimatic, geological, and physical properties of the polar ice pack.

In light of the changing condition of the ice pack, a thorough understanding of the interrelationships between the ice cover and sunlight are of great significance. The Cold Regions Research and Engineering Laboratory (CRREL) of the U. S. Army Corps worked in conjunction with the University of Washington under the HOTRAX 2005 program to obtain a trans-Arctic dataset describing large-scale spatial variability of the morphological and optical properties of the summer ice pack. Research consisted of four broad classes of snow and ice activities: measurements made at ice stations; observations made while the ship was in transit; helicopter photography flights; and the deployment of autonomous ice mass balance buoys (IMB).

Snow depth, ice thickness, and light transmissions were measured at each of 30 ice stations along the cruise track, where ice cores and soot were also sampled. In-transit measurements included incident solar irradiance, spectral reflectance, surface temperature, and an ice watch, which described the ice cover at two-hour intervals. Aerial photographs were taken over the course of 11 helicopter flights. Autonomous IMB buoys were deployed at 3 locations.

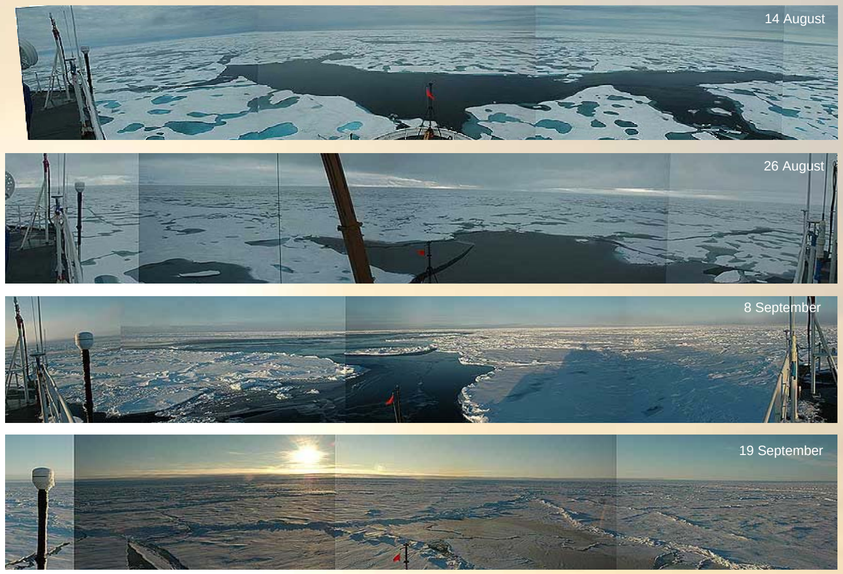


The USCGC Healy *and the Swedish icebreaker* Oden *departed from Dutch Harbor, Alaska on 5 August 2005, crossed the North Pole on 12 September 2005, and arrived in Tromsø, Norway on 30 September 2005. The icebreakers' 8200 km trans-Arctic course is denoted by the blue line. Ice stations are indicated by blue dots. The white area represents the total ice cover on 22 September 2005.*

ICE WATCH

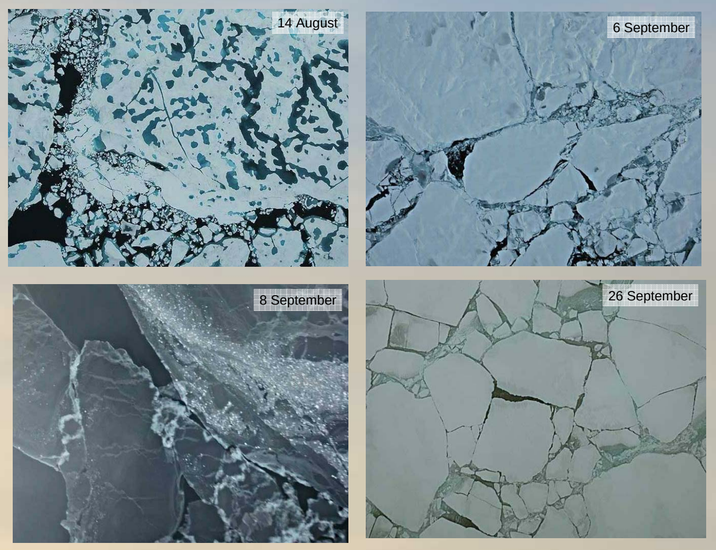
In transit visual ice observations revolved about the Ice Watch, which reported ice conditions, estimated ice thicknesses, classes and concentrations of the primary, secondary, and tertiary categories encountered using the ASPECT protocol on two-hour intervals. Panoramic images of the ice cover were simultaneously recorded in order to estimate total and multiyear ice concentrations. These data provide a broad spatial overview of the physical properties exhibited by the ice cover.

Measurements of incident solar irradiance, spectral reflectance, and surface temperature were also recorded in transit.



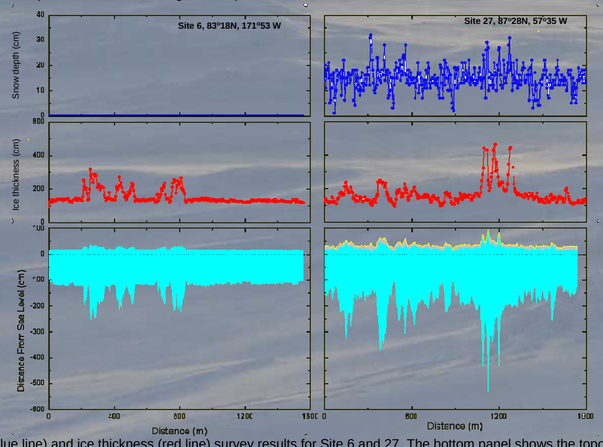
AERIAL OBSERVATION

Eleven helicopter photographic survey flights followed a modified rectangular flight pattern centered about the *Healy* in order to extend surface-based measurements to larger scales and to estimate the relative areal extent of melt ponds, ice floes, and leads. Flights were conducted at an altitude between 500 and 2,000 feet due to frequent low cloud ceilings. High-resolution digital photos taken of the ice pack recorded the change in surface conditions as summer transitioned to fall and as the cruise progressed northward.



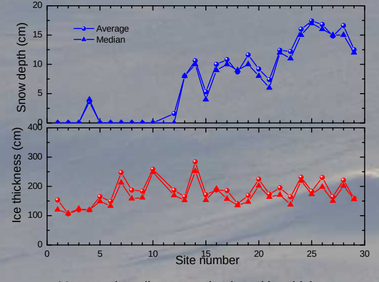
THICKNESS SURVEYS

Surface ice surveys followed horizontal transects which ranged from lengths of hundreds of meters to several kilometers, along which ice thickness and snow depth were measured every five meters. Ice thickness was determined using an EM-31 electromagnetic induction sensor, and snow depth was measured using a metal probe.



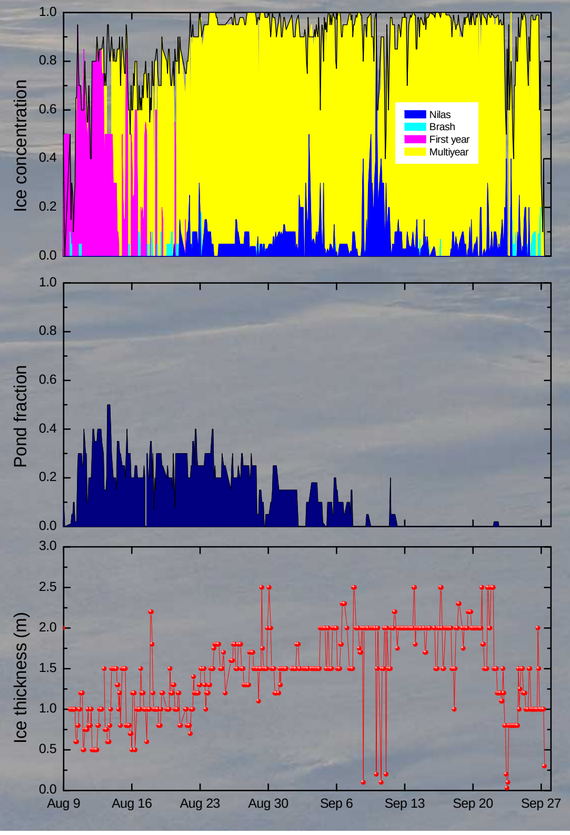
Snow depth (blue line) and ice thickness (red line) survey results for Site 6 and 27. The bottom panel shows the topography of each site. The average thickness was 150 cm at Site 6 and 220 cm at Site 27. There was no snow at Site 6 due to ongoing summer melt. Considerable spatial variability was evident at Site 27, with snow depths ranging from 1 to 35 cm and ice thickness from 150 cm to more than 600 cm. Thickness surveys were conducted at 23 ice stations during the cruise.

Ice thickness measurements: drilling in the foreground and conducting an EM-31 survey in the background



Mean and median snow depth and ice thickness from each survey site.

Pond fractions were large early in the cruise, concurrent with the southernmost latitudes and summer melt conditions at that time, reaching peak values of 0.5 and averaging at 0.25. Ice concentrations ranged from 0.8 to 1.0 above 79 N, save for an area between 88 25 N and 89 29 N, where on 8 September 2005, a large, atypical area of polynyas and thin young ice was observed. The thicknesses in the figure below are estimates of the average ice thickness of undeformed ice. Observations suggest a general latitudinal trend of increasing ice thickness moving northward, again omitting the open water and seasonal ice encountered between 88 25 N and 89 29 N.



AUTONOMOUS ICE MASS BALANCE BUOYS

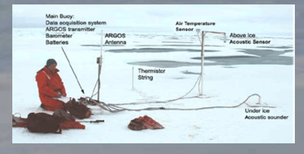
Buoy drift tracks from September 2005 to June 2006.

The ice mass balance is simply an expression of the melt and growth of the surface and bottom of a specific areal amount of ice, in addition to any precipitation that falls on that location.

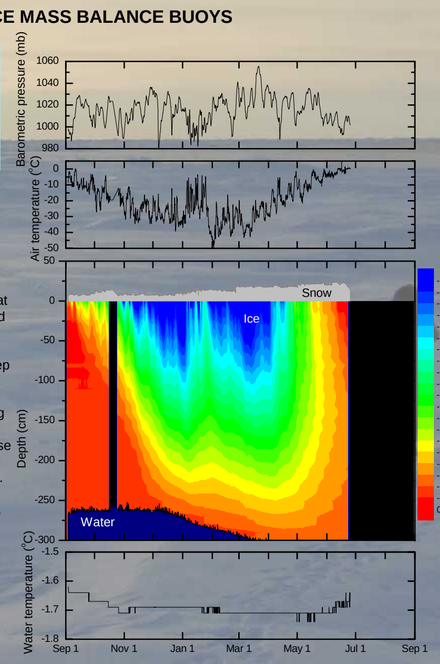
Although a simple thermodynamic concept, the IMB is a highly sensitive climatic indicator because it integrates the surface heat budget and the ocean heat flux. The IMB reflects short-term and long term changes in that a net warming results in thinner ice, while a net cooling produces thicker ice. Therefore, a thorough quantification of the temporal evolution of the IMB is the first step to understanding why the Arctic climate is changing.

Autonomous IMB buoys monitor the IMB by routinely measuring ice temperature, snow deposition and melt, ice growth, surface and bottom ice ablation position, and barometric pressure. These measurements are then transmitted by satellite and assembled into comprehensive sets of data, such as the graph on the right.

Three Autonomous IMB buoys were deployed during HOTRAX.



Schematic of ice mass balance buoy.



CONCLUSIONS AND FUTURE WORK

Early results indicate a large regional variability in ice morphology, extensive ponding throughout August, and thin ice in the western Beaufort Sea. Observations suggest a general latitudinal trend of increasing ice thickness moving northward. However, there was considerable longitudinal variability, as open water, nilas, and thin ice were observed near the pole at longitudes from 150 E to 170 E.

Further analysis of HOTRAX results in presently being conducted. A web page summarizing all data and metadata is forthcoming.

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