Utilization of Ice-Tethered Profilers to Address Changing Arctic Conditions

John M. Toole, Richard A. Krishfield, Andrey Proshutinsky
Physical Oceanography Department

Carin Ashjian, Sam Laney
Biology Department

Mary-Louise Timmermans
Yale University

The Arctic is undergoing significant climate changes that include warming atmospheric and ocean temperatures, freshening of sea water, rising sea levels, melting permafrost and reduced sea ice. The rapid loss of permanent sea ice underscores the need for sustained, uninterrupted Arctic observations and analyses to understand and predict future Arctic changes. Some research suggests that atmospheric circulation, rising global temperatures and complex feedbacks between the sea ice and the ocean will lead to ice-free summers in the Arctic Ocean in as few as 10 years, while other studies indicate that the strong natural variability of the Arctic system will inhibit further loss of summer sea ice, at least in the near term. The coming years will be of great significance in Arctic research.

To investigate variations in the Arctic Ocean water properties below the permanent sea ice cover and begin to explore changes in the biological ecosystem, we developed the Ice-Tethered Profiler (ITP) system here at WHOI. The ITP system consists of a small surface capsule that sits atop an ice floe and supports a plastic-jacketed wire rope tether that extends through the ice and down into the ocean, ending with a weight (intended to keep the wire vertical). A cylindrical underwater instrument (approximately 6' in length) mounts on this tether and cycles vertically along it, carrying oceanographic sensors up and down through the water column. The system is designed to operate up to 3 years, but due to the extreme conditions, many ITPs are lost much earlier. However, because all data are sent to shore in real-time, instrument loss does not mean loss of data (as is the case with internally-recording sensors). To date, a total of 37 ITP systems have been deployed in the Arctic since the first prototype was launched in fall 2004. This effort represents the collaborative effort by investigators from France, Russia, Germany, England and the U.S., who have been funded by the National Science Foundation and European Union grants with key contributions from the Clark Arctic Research Initiative program for WHOI scientists. Collectively, these systems have now returned more than 25,000 temperature and salinity profiles of the upper ~750 meters of the water column throughout much of the permanently ice-covered central Arctic. The so-called Level 1 ITP data (basic processing but no human quality control) are available within hours of collection. Data sets are also subjected to a more intensive processing and quality control procedure; this version of the data is submitted to national archives for long-term storage and general distribution.

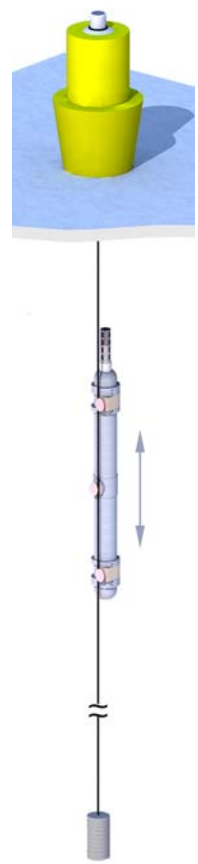

Figure 1: Schematic drawing (not to scale) of the WHOI Ice-Tethered Profiler (ITP) system.

Support from the Clark Arctic Research Initiative allowed us to participate in expeditions of the Russian Arctic and Antarctic Research Institute (AARI) and German Alfred Wegener Institute (AWI) to deploy ITPs in the Eurasian sector of the Arctic. By taking advantage of these cruise opportunities, we were able to collect data over broad sectors of the Arctic otherwise inaccessible to us. Moreover, relationships developed with AARI scientists during these expeditions laid the groundwork for future collaborations and continuing deployments of ITP systems in the Eurasian sector of the Arctic.

Another major effort that was funded by the Clark Arctic Research Initiative was the development of additional sensors to the basic ITP instrument to measure water properties that would shed light on biological ecosystem dynamics in the Arctic Ocean. A prototype ITP system with several bio-optical sensors was constructed and deployed in the Canada Basin north of Alaska. Unfortunately, the system was lost. However, a second-generation bio-optical sensor package has been developed that includes a shutter system designed to both minimize biofouling of the optical sensors and return reference information that should prove useful to track sensor drift. The bio-optical subsystem is now being tested here at WHOI with its first deployment slated for summer 2011.

In addition, the Clark Arctic Research Initiative supported a redesign of the ITP surface buoy package to better survive thin ice and open water. The summer of 2007 saw a historical minimum in sea ice extent, with the summer of 2009 a close second. In order to sample the ocean in regions of seasonal ice cover, we redesigned the surface buoy to support the system in open water and to better withstand ice ridging events during the fall freeze-up. Two prototype versions of the redesigned system were deployed in open water from a Russian vessel in the late summer of 2009. One of these systems (ITP # 37) is presently operating and sending data back to WHOI daily. The other stopped communicating in October of 2009, when we presume it was rafted over by ice. This experience prompted us to undertake another buoy redesign to enhance its ability to function in the marginal ice zone. This new design will be implemented in our new buoys that will be built in the coming year.

Beyond these technical aspects, the WHOI ITP program is already supporting a host of research activities by scientists around the world. One of our own research programs that is stimulated and supported by ITP data is focused on circulation and heat transport from the Arctic Ocean to the overlying sea ice – critical components in the delicate balance of sea ice and climate. One of the most significant recent changes to occur in the Arctic Ocean has been a warming of the Atlantic-derived water that lies beneath the surface waters that are in direct contact with the sea ice. This warming can potentially affect the ice cover where Atlantic Water heat is transported to the surface. With support from the Clark Arctic Research Initiative, we investigated the temperature and salinity of the Atlantic-derived water, based on measurements taken by the ITP. The observations from the central Canada Basin suggest that only a small fraction of the available Atlantic Water heat mixes into the overlying waters; most of the upper-ocean heat appears to derive from solar radiation entering the ocean through breaks in the sea ice. Our ongoing analyses are aimed at understanding the fate of the warm waters entering the Arctic from the Pacific and Atlantic Oceans, and the complex relationships between Arctic Ocean heat and fresh water dynamics and atmospheric circulation patterns and thermodynamics.

As a postscript, we note the recent deployment of a cluster of atmosphere, sea ice and ocean sensor systems near the North Pole in April of 2010. Included in the array was ITP #38, as well as a web camera system developed by colleagues at the Pacific Marine Environmental Laboratory. The web camera is trained on the other buoy systems in the cluster and returns multiple images per day. Shown below are select photos of the Ice-Based Observatory (Figures 2-4).

Figure 2: April 2010 – Installation of an ITP

Figure 3: July 2010 – Melt ponds develop

Figure 4: September 2010 – Winter returns to the Arctic

The ITP research team wishes to express their great thanks to the Clark family for their generous support of Arctic research at WHOI. The Clark Arctic Research Initiative grants we received have provided us great flexibility and the opportunity to collect novel observations at present and into the future.