The Ice-Tethered Profiler Program: Making a Contribution to the Ocean Observing System at Polar Latitudes

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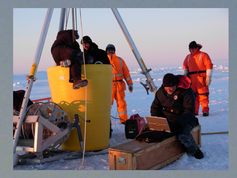
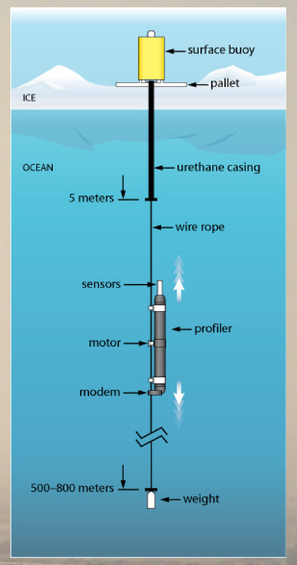
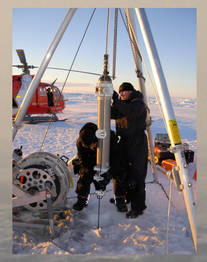


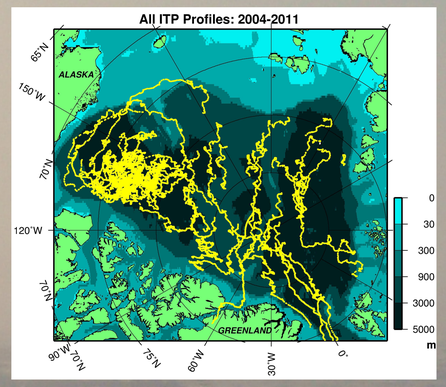


Schematic drawing of the ITP system with components labeled. The typical profiler contains a CTD, but prototypes have also been deployed with dissolved oxygen, biosensors (turbidity, chlorophyll a, CDOM, and PAR), and MAVS current probe.

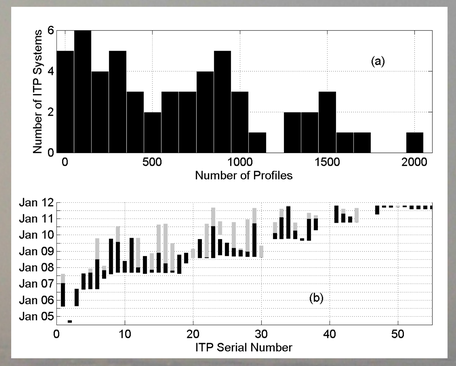
The ITP system consists of three main components: a surface instrument package that typically sits atop an ice floe (but can float in open water), a weighted, wire-rope tether of arbitrary length (up to 800 m) suspended from the surface package, and an instrumented underwater unit that travels up and down the wire tether transporting a sensor package through the water column. Full resolution data are telemetered to shore, making the instruments expendable.



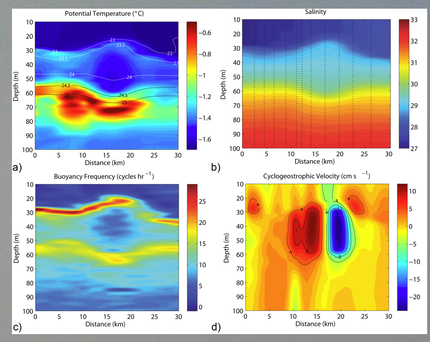
In the 7+ years since the first prototype Ice-Tethered Profiler was deployed, the ensemble of 50 ITPs fielded by researchers from 6 countries have returned more than 32,000 upper-ocean temperature and salinity profiles from the central Arctic, significantly increasing the number of high-quality upper-ocean water property observations available from the central Arctic. In addition, two systems have been deployed in the Southern Ocean.



Location of full- or partial-depth CTD profiles acquired by ITPs in the Arctic. The close spacing of the profile locations makes these points appear as continuous lines on the scale of this figure.

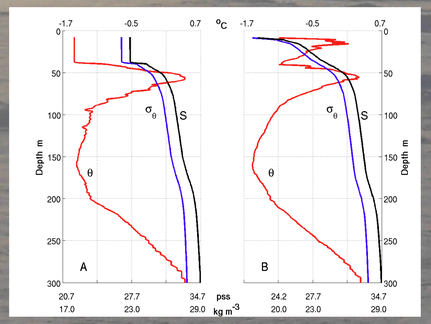


(a) Histogram of the number of CTD profiles exceeding 700 m in vertical extent obtained from individual ITP units. (b) Lifetimes of individual ITP systems. The black bars mark the time span during which data were received from the underwater vehicle; the gray bars show the lifetimes of the surface buoys. Gaps in the figure represent the 5 ITP systems deployed in the Southern Ocean or in lakes.

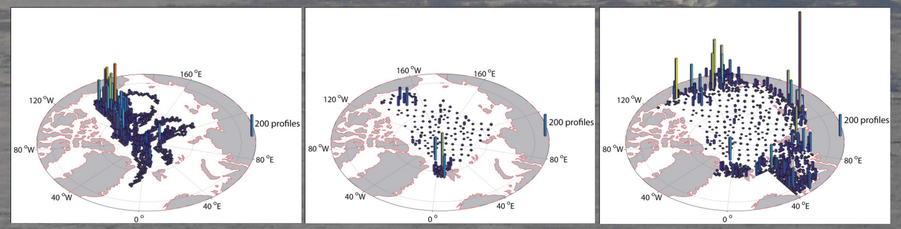


ITP-derived sections of (a) potential temperature, (b) salinity, (c) buoyancy frequency, and (d) cyclogeostrophic velocity through a pycnocline eddy in the Canada Basin. Lines of constant potential density (referenced to the surface) are shown in (a). The section is from west (left) to east, and dotted lines in (b) indicate profile locations. From Timmermans et al., 2008a.

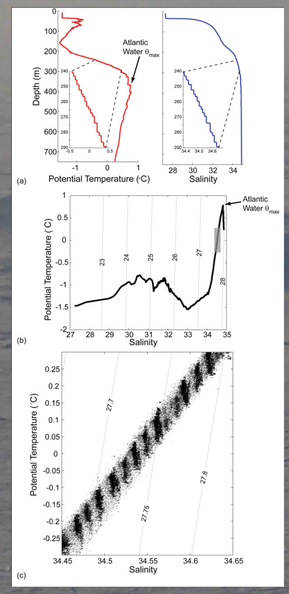
Of the 32,000+ profiles attempted, approximately 80% returned usable temperature and salinity data over a vertical interval greater than 700 m. Including those systems still operational (and thus biasing the following mean estimates low), the average lifetime of the ITP surface buoy (time over which telemetry is received) is 500 days; the average number of CTD profiles longer than 700 m received per instrument deployment is 741. Surface buoy over-rafting by convergent sea ice and tether dragging in shallow water are the most common termination modes.



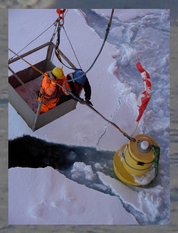
Representative vertical profiles of potential temperature (red), salinity (black) and potential density anomaly (blue) obtained from ITP 6 on April 30, 2007 (panel A) and September 13, 2007 (panel B). These were ITP 6 profiles 475 and 747, respectively; both were taken within 25 km of 76º 24' N, 140º 45' W. From Toole et al., 2010.



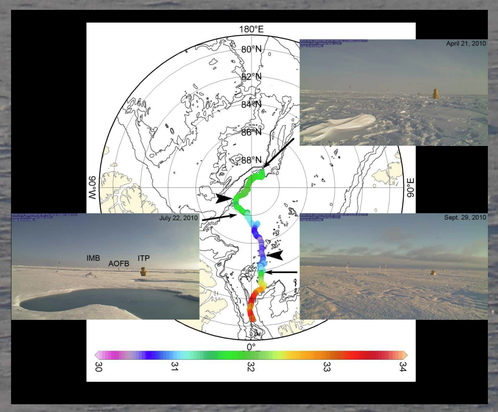
Bin-totals of the number of full-depth or partial CTD profiles acquired by ITPs since 2004 (left) and the corresponding figure for all available casts from the 1970s (right) and the subset of 1970s data where the ocean depth exceeded 760 m (middle). In all cases, the bins for the analyses were 55.5 km square. Bar coloring as well as bar height indicate the number of profiles in a bin; a reference bar is given for 200 casts in a bin. The 1970s station information derive from Timokhov and Tanis (1997, 1998).



(a) ITP profiles of potential temperature and salinity in the Canada Basin. The insets with expanded scales show the double-diffusive staircase. In these profiles, the Arctic surface mixed layer extends to about 40-m depth, with shelf-modified Pacific water from the Bering Strait immediately below. A strong thermocline denotes the boundary between the upper waters and the Atlantic Water. Within the thermocline, temperature and salinity increase monotonically with depth, a necessary condition for double-diffusive layering. (b) The corresponding potential temperature/salinity curve and lines of constant potential density anomaly (referenced to the surface). (c) Discrete potential temperature/salinity values from 1000 ITP profiles in the Canada Basin (~0.25-m vertical resolution), and lines of constant potential density anomaly (referenced to the surface). The region in potential temperature/salinity space is shown by the grey box in panel (b). Staircase mixed-layer properties tend to group along lines in potential temperature/salinity space; Timmermans et al. (2008b) show that individual mixed-layers are coherent for at least 800 km across the basin and persist for several years. After Timmermans et al. (2008b).



As frequently as possible, ITPs are deployed together with other autonomous buoy systems to sample a wide range of variables characterizing the Arctic ocean-ice-atmosphere-eco-system. We term such collection of buoys an Ice-Based Observatory (IBO). In total, 23 of the first 42 ITP systems deployed in the Arctic were accompanied by at least one companion instrument; 15 of these IBOs included 3 or more instrument systems. Prototypical IBOs, deployed annually in conjunction with the North Pole Environmental Observatory program, included NOAA Pacific Marine Environmental Laboratory Web Cams and Polar Area Weather Stations, Cold Regions Research and Engineering Laboratory Ice Mass Balance Buoys, Naval Postgraduate School Autonomous Ocean Flux Buoys and ITPs. The data from such IBOs are proving valuable for investigating local processes influencing the atmosphere-ice-ocean boundary layer systems as well as contributing to the larger-scale observing system.

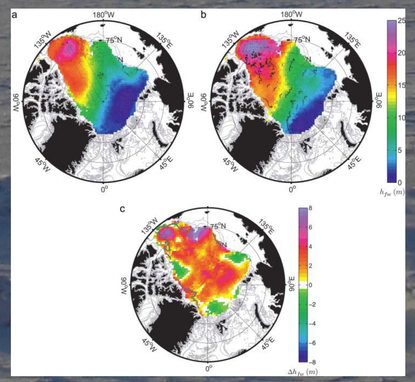


Drift track of an IBO between April 19, 2010 and November 10, 2011 indicating in color, the salinity at 10 m from the ITP in the instrument cluster. The 1000, 2500 and 3000 m isobaths have been plotted using the IBCAO grid. Images are from the NOAA/PMEL web camera installed on the same ice floe (see http://www.arctic.noaa.gov/gallery_np.html). Black pointers indicate the IBO location at the start and end of the melt period. From Timmermans et al. (2011).

ITP systems and companion instruments are continuing to be deployed under the banners of the US Arctic Observing Network (AON) and internationally under SAON (Sustaining Arctic Observing Networks) and country-specific programs. Like the international Argo float program, continuing effort is necessary to sustain the deep Arctic sampling effort and to initiate a more extensive program in the Southern Ocean.

More details and data are available at:

www.whoi.edu/itp



Objectively mapped observed freshwater inventory from the surface to the depth of the 34 isohaline for the deep Arctic Ocean during JAS: (a) 1992–1999 and (b) 2006–2008. The anomaly of 2006–2008 relative to 1992–1999 is shown in (c). The locations of measured salinity profiles used for the mapping are shown as black dots in (a) and (b). From Rabe et al., 2011.