

ITP35 Overview

Deployment Location: 10/8/2009, 01:00 UTC at 77° 4.5'N, 135° 25.8'W

Recovery Location: 10/2/2010, 20:30 UTC at 79° 7' N, 155° 1' W

Duration: 360 days

Distance Traveled: 3635 km

Number of profiles: 1357 in 174 days

Other instruments: IMBB 2009-G, O-Buoy

ITP 35 was deployed on a 2.6 m thick ice floe in the Beaufort Sea as part of the Beaufort Gyre Observing System (BGOS) during the JOIS 2009 cruise on the CCGS Louis S. St. Laurent. On the same icefloe, a US Army Cold Regions Research and Engineering Laboratory (CRREL) Ice Mass Balance Buoy (IMB 2009G) and an autonomous atmospheric chemistry buoy (O-Buoy) were also installed. The prototype ITP included a MAVS current meter and operated on a pattern profiling schedule between 7 and 760 m depth each day. A communications problem between the profiler and surface package prevented the underwater data from being telemetered, but the data were rescued from the profiler the following year during the JOIS 2010 cruise when the ITP was successfully recovered.

ITP35 Deployment Operations

The third buoy deployment on the JOIS 2009 cruise was an Ice-Based Observatory (IBO) deployment consisting of an Ice-Mass Balance (IMB) buoy, atmospheric chemistry O-Buoy, and the first prototype ITP-V (ITP with Velocity) outfit with a Modular Acoustic Velocity Sensor (MAVS). During the morning reconnaissance by helicopter, it was difficult to visually estimate the thickness of the ice, because everything was covered by 6 to 12" of snow. We landed on a large floe with two relatively large plains (>100 m in diameter), but the first site surveyed was only 1.5 m thick. Unlike the large solid multiyear floes that existed in past years, this floe consisted of many small broken pieces that were refrozen together into a large mass. Taking care to avoid stepping into the refrozen cracks beneath the snow, the second plain was surveyed and found to be 2.5 m thick, so the IBO was deployed there while other scientists conducted detailed measurements about the ice floe.

In order to keep the MAVS probe pointed into the current to measure undisturbed flow and minimize Strouhal oscillation, fins were added to the profiler body (*Thwaites et al.*, 2011) so that a 24" diameter hole through the ice was required for the deployment. To drill this hole, and the hole for the 14" diameter O-buoy tube, a hot water drill ring apparatus was used, and the ice core removed with chainsaws. The hole for the O-Buoy was drilled first, took about an hour to complete, and the O-buoy lowered into the hole using the helicopter, and the superstructure was subsequently assembled on the ice.

The hole for ITP 35 also took about an hour to complete, and the ice core that was removed from the hole was without voids, attesting to the solidness of the site. While the day was brighter than during the previous day's deployment operations, air temperature dropped from -8 °C at the start to -18 °C by the end creating some mechanical difficulties. The profiler was exposed to the cold for nearly an hour while the fin was assembled, which took extra time as some of the plastic fin bolts became brittle and broke so had to be replaced and gingerly tightened so as not to crack. Fortunately, the inductive modem test passed after it was in the water and when the buoy was deployed.

The IMB was deployed concurrent with the ITP-V and after eight hours all ice operations were completed, and all personnel and gear were transported back to the ship as daylight waned.

References:

Thwaites, F.T., R. Krishfield, M-L. Timmermans, J.M. Toole, and A.J. Williams 3rd, 2011. Noise in Ice-Tethered Profiler and McLane Moored Profiler velocity measurements. *Proceedings of IEEE/OES/CWTMC Tenth Working Conference on Current, Wave, and Turbulence Measurement Technology*, Monterey, CA, 20-23 March 2011, 8 pages.

ITP35 Recovery Operations

After the deployment, the profiler on ITP-V 35 was only able to send the first CTD file to the surface package, but no other files. However, status and locations from the surface package were still regularly being received, so recovery of the system was very much desired to determine the cause of the communications failure and to recover any data from the prototype instrument. Consequently, after recovery of BGOS mooring B on October 1, a helicopter reconnaissance was undertaken to the latest location broadcast by the ITP-V and the unit was found intact in a refrozen lead, but without any evidence of the O-Buoy or IMB that were originally deployed nearby.

The following morning, another helicopter flight was conducted to the site to rig a handle, pickup sling, and flag to the buoy for recovery. The only way to recover the buoy, frozen into the ice as it was, would be to break the ice containing the system and recover the unit from the side of the ship. The Captain of the CCGS Louis St. Laurent skillfully guided the ship up to and over the buoy, which successfully disengaged the unit from the ice. A man basket was lowered to attach the winch line, and the surface package was brought on board. The wire was spooled onto the dual capstan winch used for the mooring recoveries and at the end of the wire, the profiler was found somewhat battered from dragging on shallow bathymetry sometime during its drift, but intact. The recovery operations from the side of the vessel took only 1 hour to complete. ITP 41 was deployed the same day not too far removed.

ITP35 Data Processing

The 1357 CTD profiles that were recovered from the ITP flash card were processed according to the procedures described in the ITP Updated Data Processing Procedures, and velocity as

described in *Cole et al. (2014)*. The processing parameters for ITP 35 are shown in the figures to the right. The profiler had only a few instances where it had trouble covering the full vertical extent of the profile and the CTD data were largely free of icing and biofouling.

Thermohaline staircases were present throughout the time series, enabling CTD lag corrections. The CTD sensors appeared to be very stable throughout the year-long deployment, all of the lags were in the typical range as previous systems and varied little over time. The potential conductivity adjustment began and took about a week to stabilize with only one significant deviation thereafter.

References:

Cole, S., M.-L. Timmermans, J. Toole, R. Krishfield, F. Thwaites, 2014. Ekman veering, internal waves, and turbulence observed under Arctic sea-ice. *Journal of Physical Oceanography*, Vol. 44, doi:10.1175/JPO-D-12-0191.1.

ITP35 Data Description

The ITP profiler was configured to operate on a pattern sampling schedule of vertical profiles interspersed with parked measurement intervals. Profiles were obtained every 4 hours to 150 m depth, with 2 of those extending to 750 m depth. Twice daily the profiler was parked near 6 m depth to sample for 40 minutes to observe turbulent fluctuations. In the surface package, the GPS receiver was powered hourly to obtain locations, and buoy temperature and battery voltage status were recorded.

The buoy drifted south then west through the BGOS mooring array without any data after the first CTD profile from the underwater unit reaching the surface package. A timing problem between the surface package and underwater unit due to the large size of the velocity files prevented the transfer of data. However, the profiler continued to obtain data reliably and store the information internally, finally ceasing to profile on March 31, 2010 because the flash card directory limit was reached, not due to power limitations or instrument failure. Later the underwater unit dragged on the Northwind Ridge, but fortuitously was not torn from the tether so that all of the data could be retrieved when the unit was recovered. See *Thwaites et al. (2011)* and *Cole et al. (2014)* for detailed descriptions of the velocity data including turbulence, Ekman veering, and internal wave results.

The plots below are of the final, calibrated, edited data (as opposed to the raw data presented on the active instrument pages).

References:

Thwaites, F. T., R. Krishfield, M.-L. Timmermans, J. M. Toole, and A. J. Williams 3rd, 2011. Flux Measurements from an Ice-Tethered Profiler: First Look. Proceedings, Oceans 2011-Santander Spain, 6-9 June 2011, IEEE/OES.

Cole, S., M.-L. Timmermans, J. Toole, R. Krishfield, F. Thwaites, 2014. Ekman veering, internal waves, and turbulence observed under Arctic sea-ice. *Journal of Physical Oceanography*, Vol. 44, doi:10.1175/JPO-D-12-0191.1.

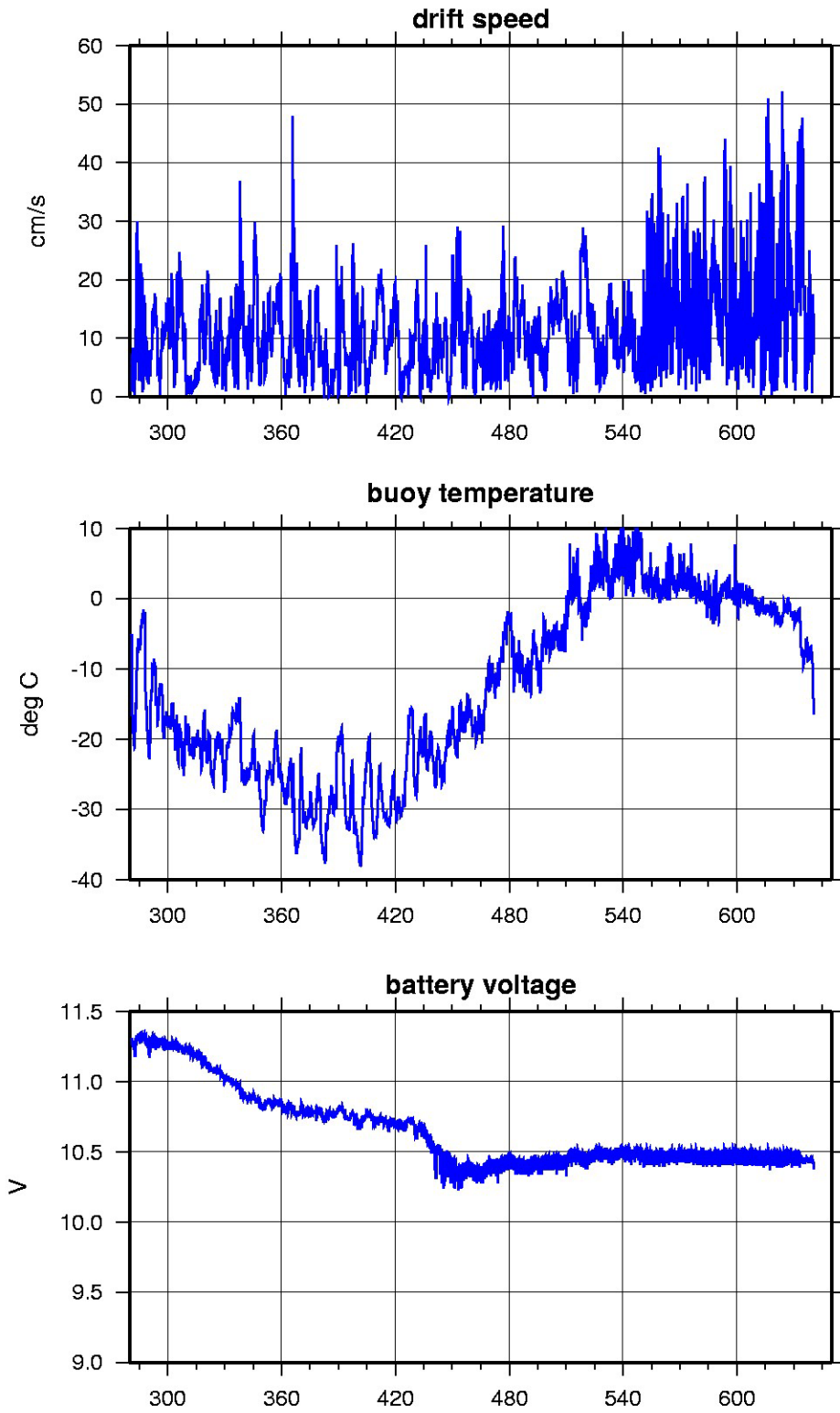
Level II hourly buoy location data in ASCII format: itp35rawlocs.dat

Level III 1-Hz processed profile data in MATLAB format: itp35cormat.tar.Z or itp35cormat.zip

Level III 1-db bin-averaged processed profile data in MATLAB format: itp35final.mat

Level III 1-db bin-averaged processed profile data in ASCII
format: itp35final.tar.Z or itp35final.zip

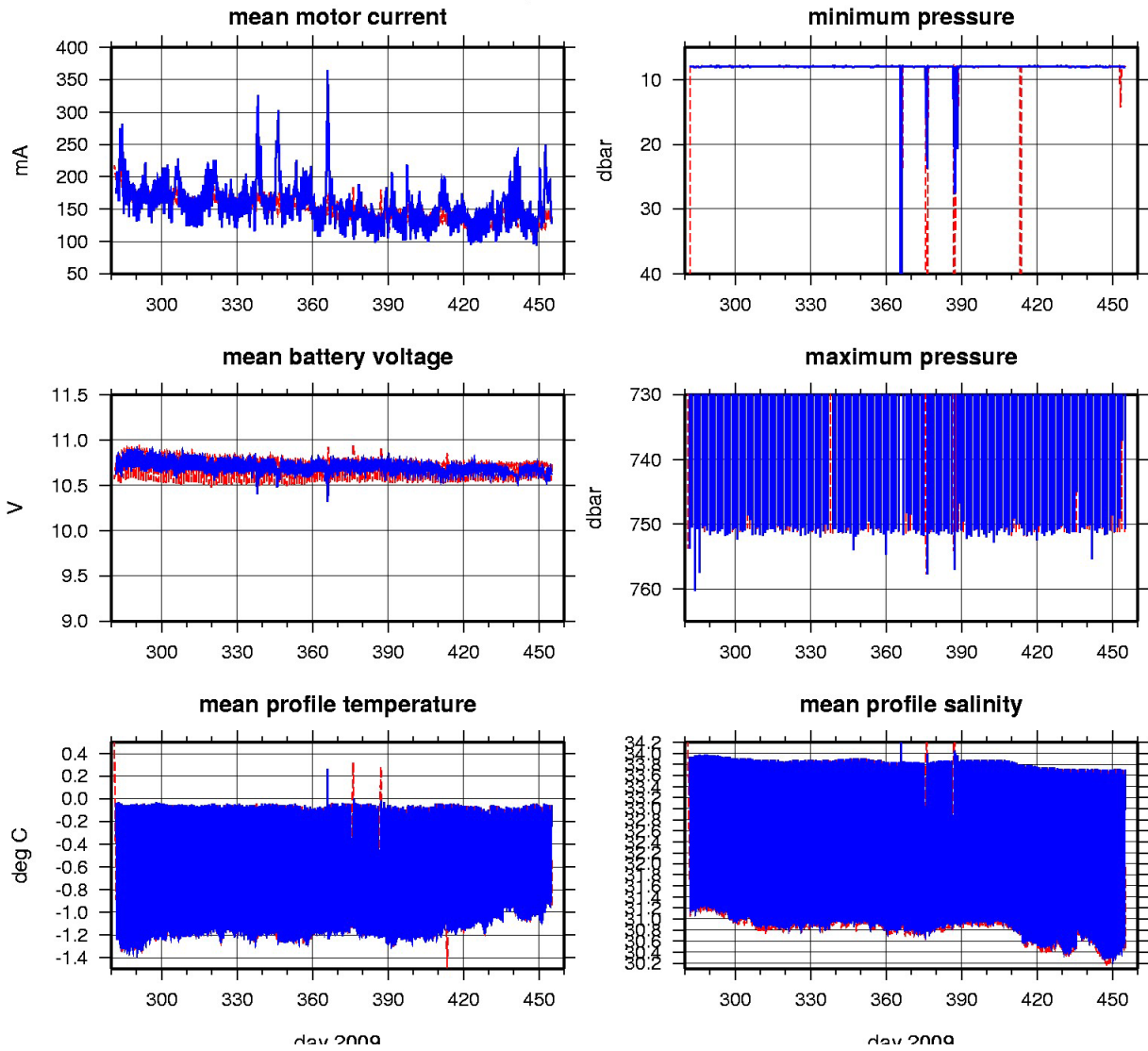
ITP35 Buoy Status (as of 2010/10/02)



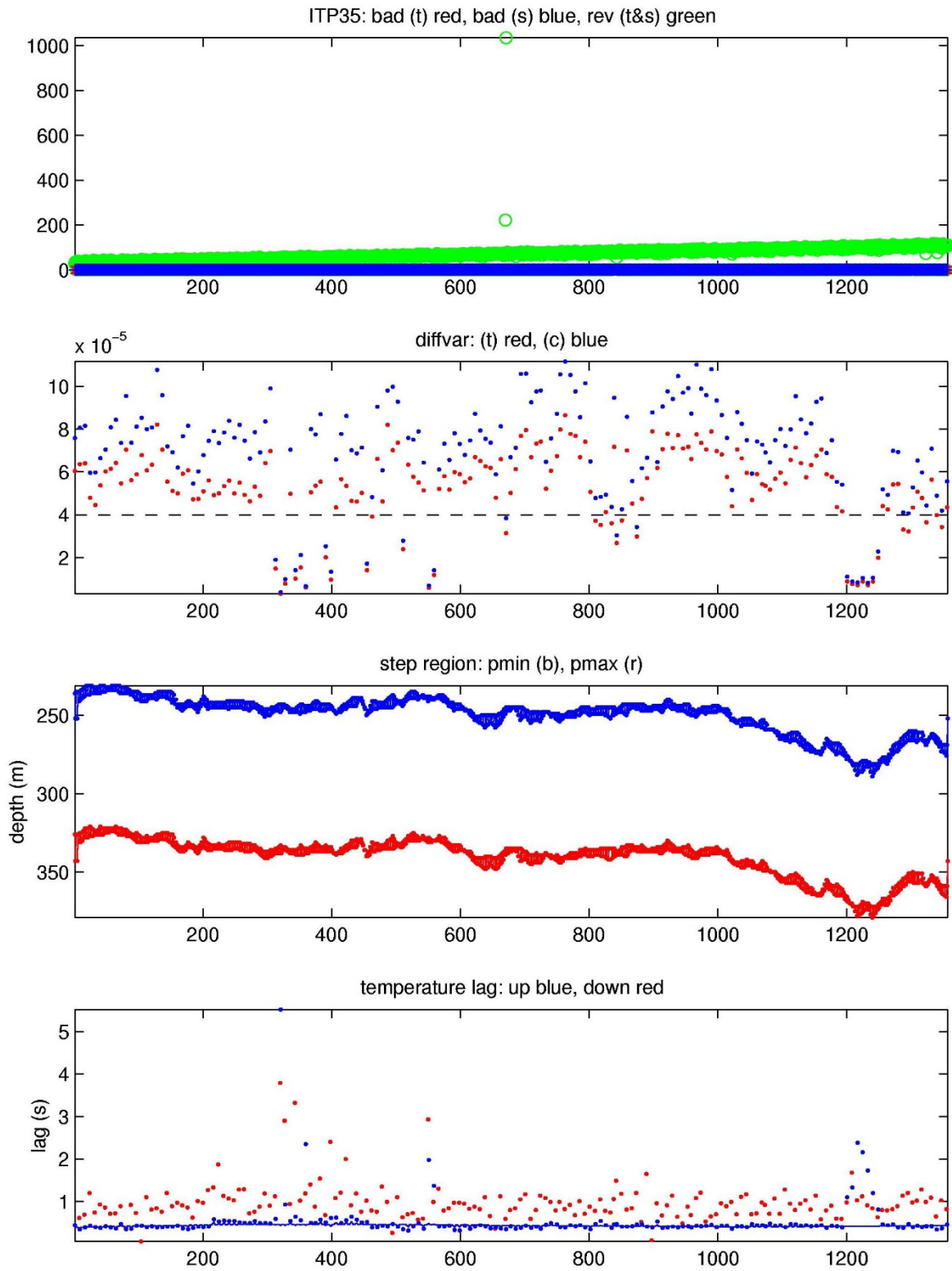
ITP Surface Buoy Status.

ITP35 Profiler Status (up to profile 1357)

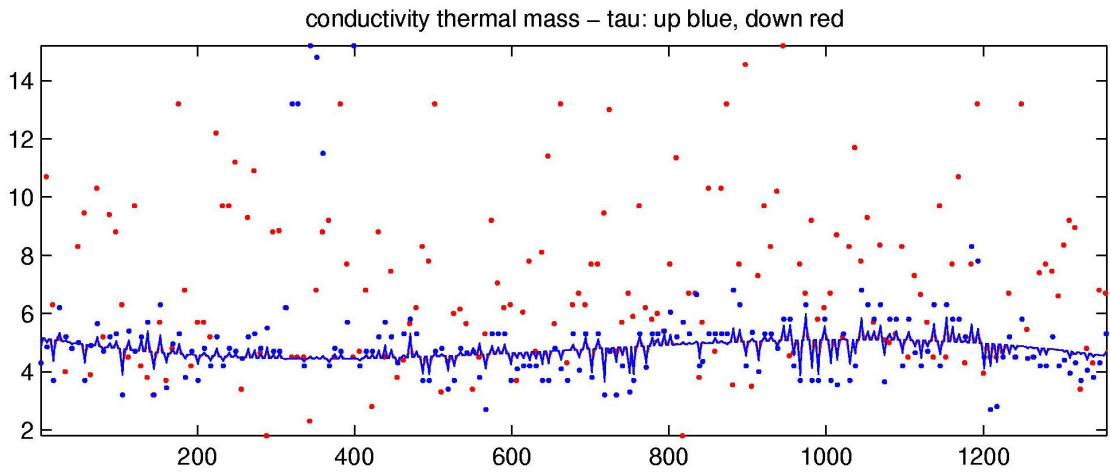
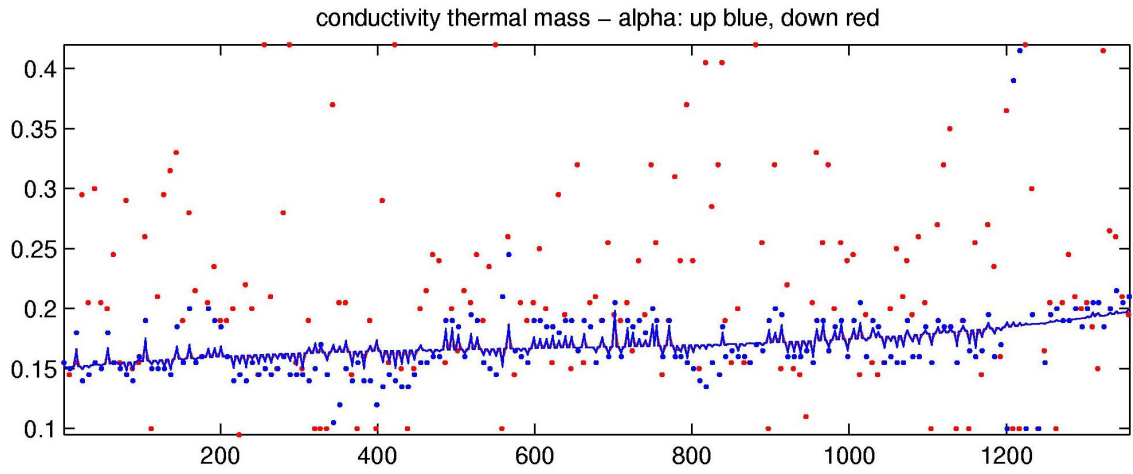
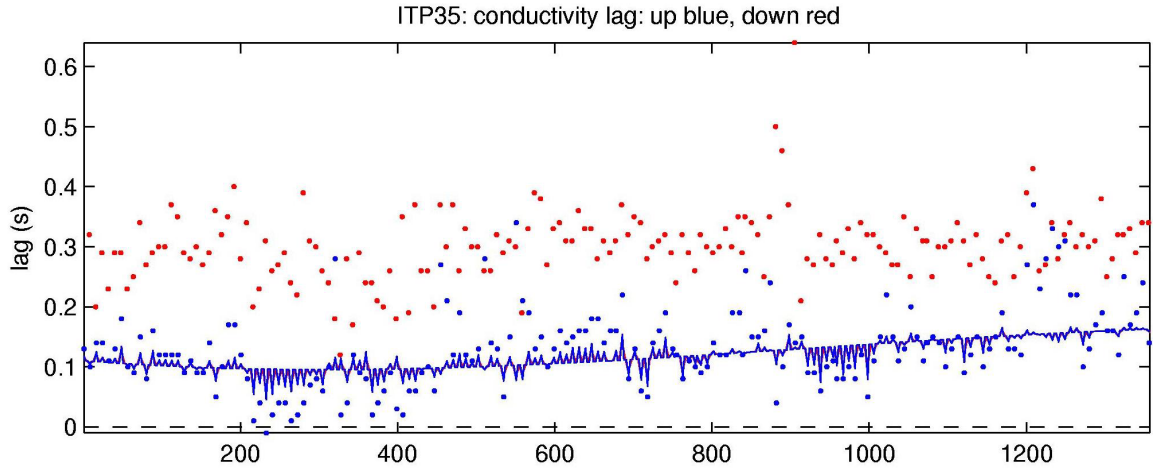
up solid, down dashed



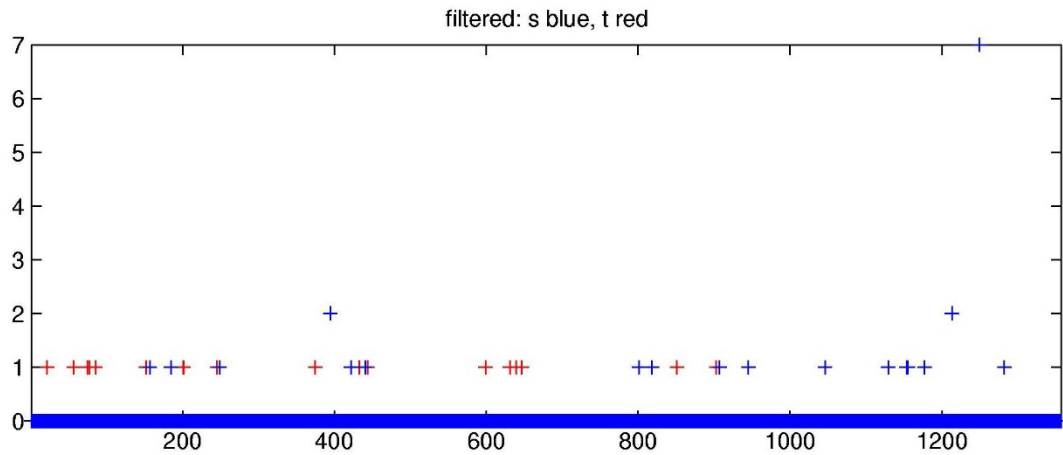
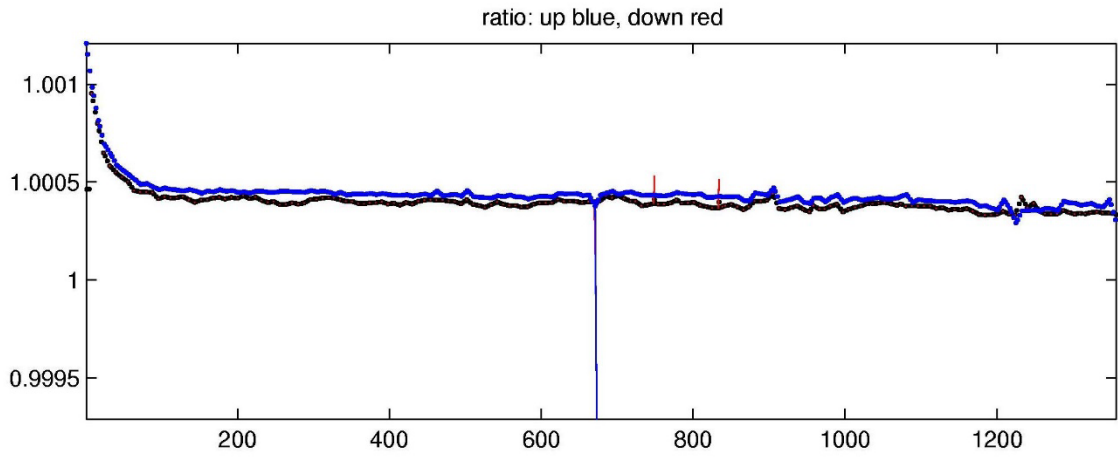
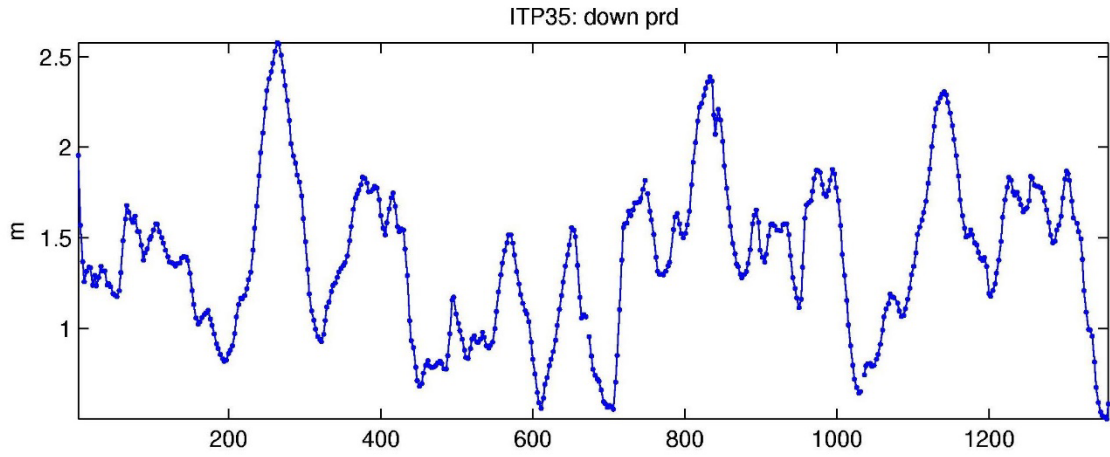
ITP profiler engineering data.



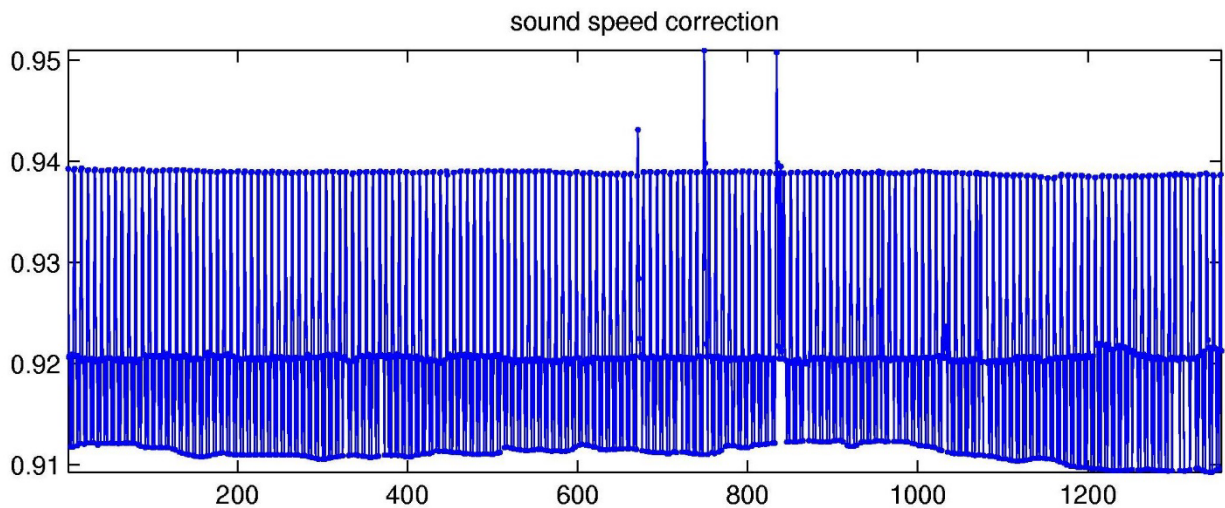
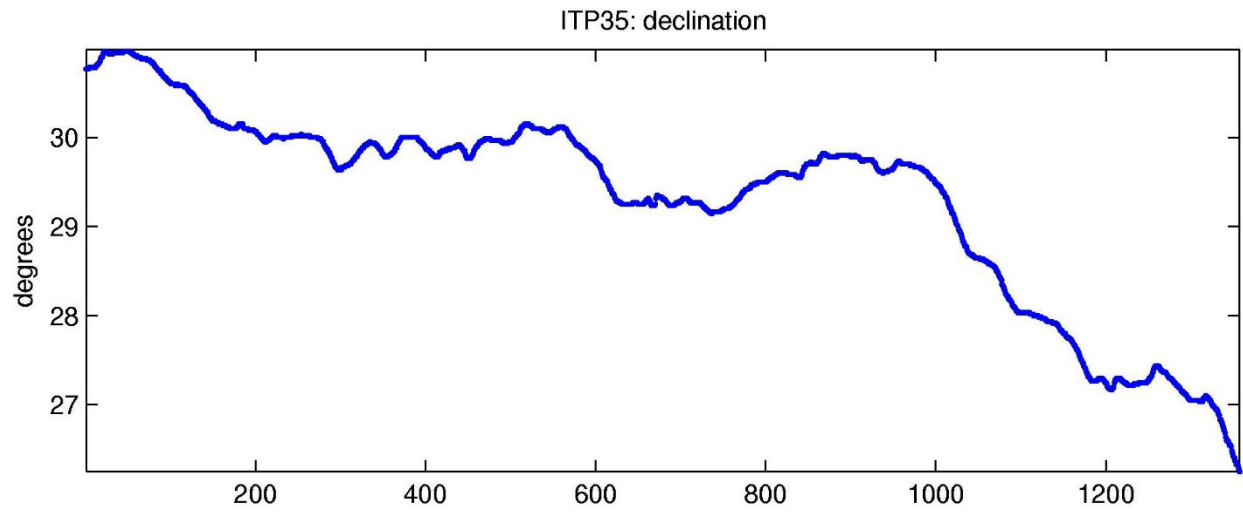
Top: number of bad points removed, Middle: variance of vertical difference of temperature and salinity in step region for up-going profiles, Bottom: temperature lag



Top: conductivity lag, Middle: conductivity thermal mass amplitude correction, Bottom: conductivity thermal mass lag correction.

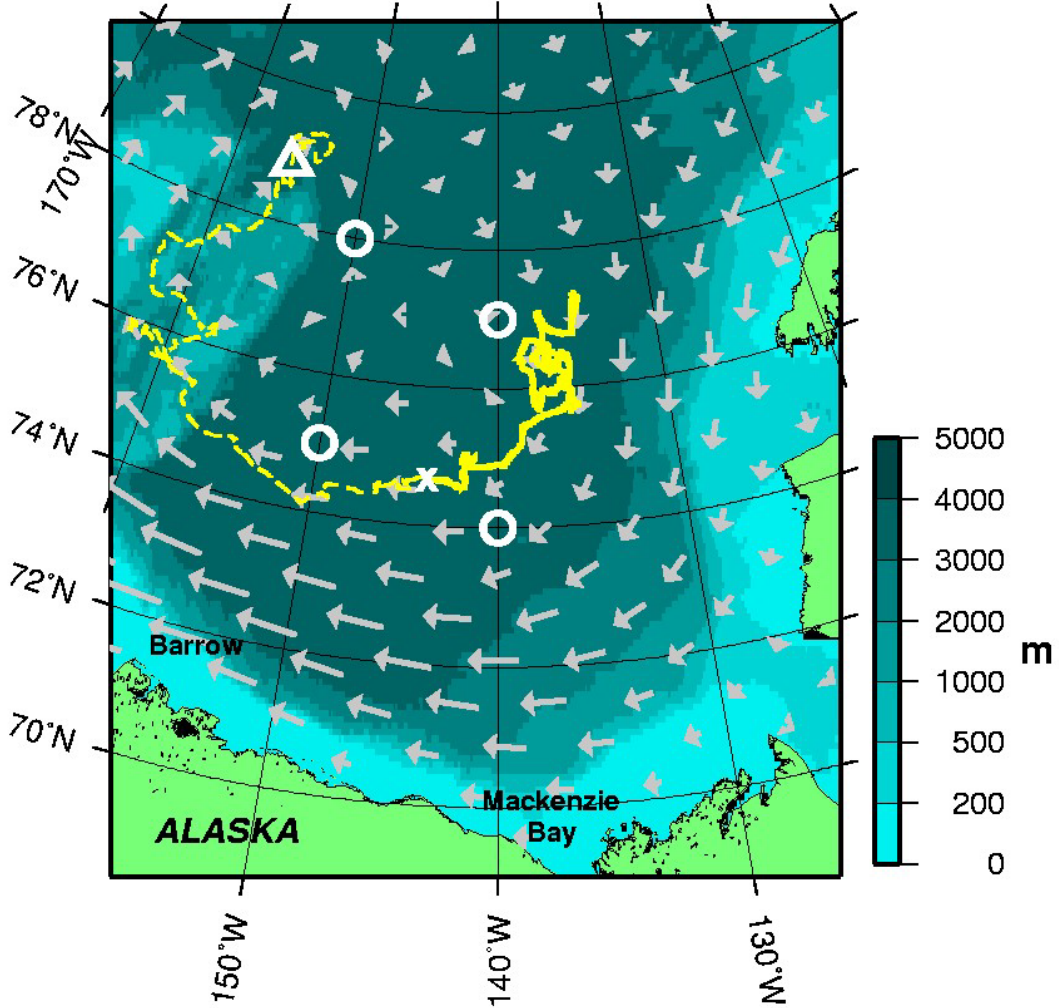


Top: down pressure deviation correction, Middle: salinity ratio adjustment, Bottom: Number of filtered spikes.



Top: Geomagnetic declination correction, Bottom: Correction due to sound speed.

ITP35 Drift Track (as of 2010/10/02)

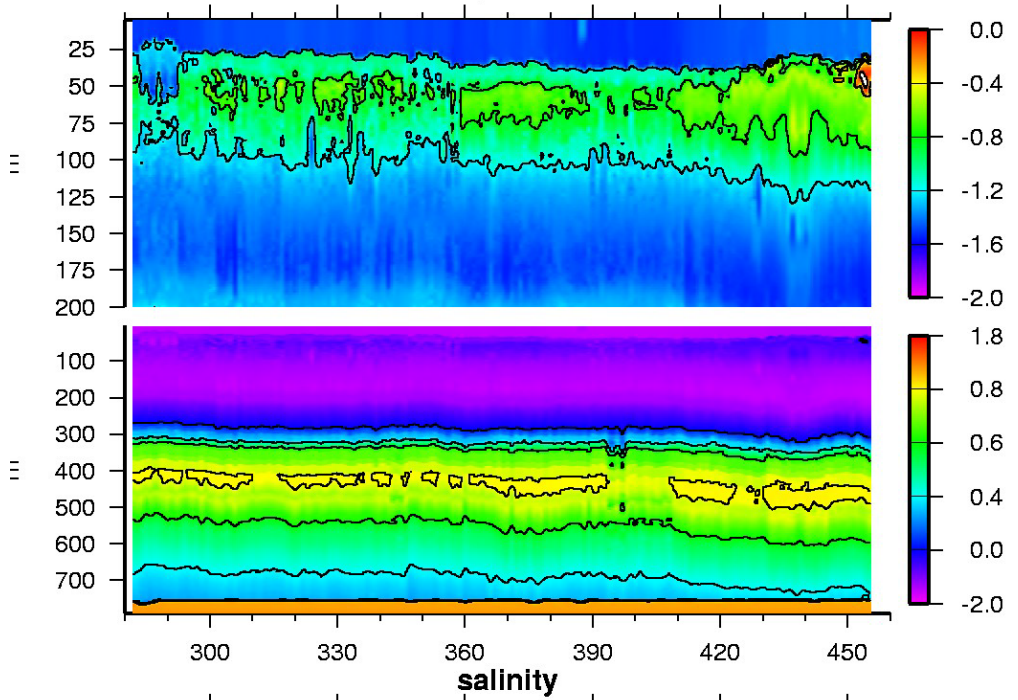


ITP drift (yellow line), last profile (cross), and last location (triangle), BGOS moorings (circles) and annual ice drift from IABP (grey vectors) on IBCAO bathymetry (shading).

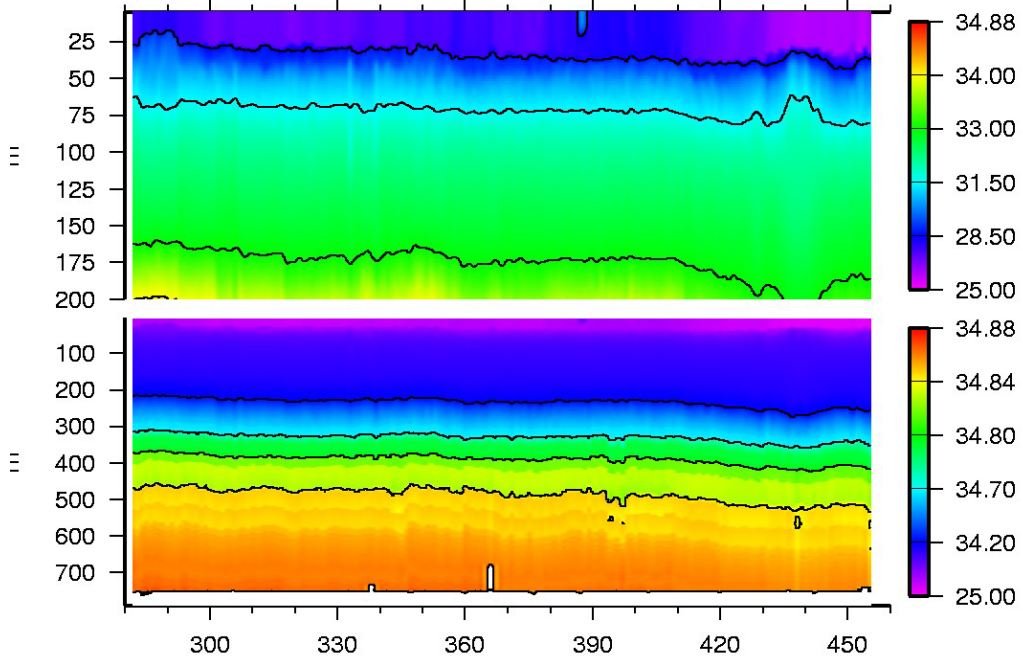
Plot of buoy locations.

ITP35 Up Profile Contours (to profile 1356)

temperature



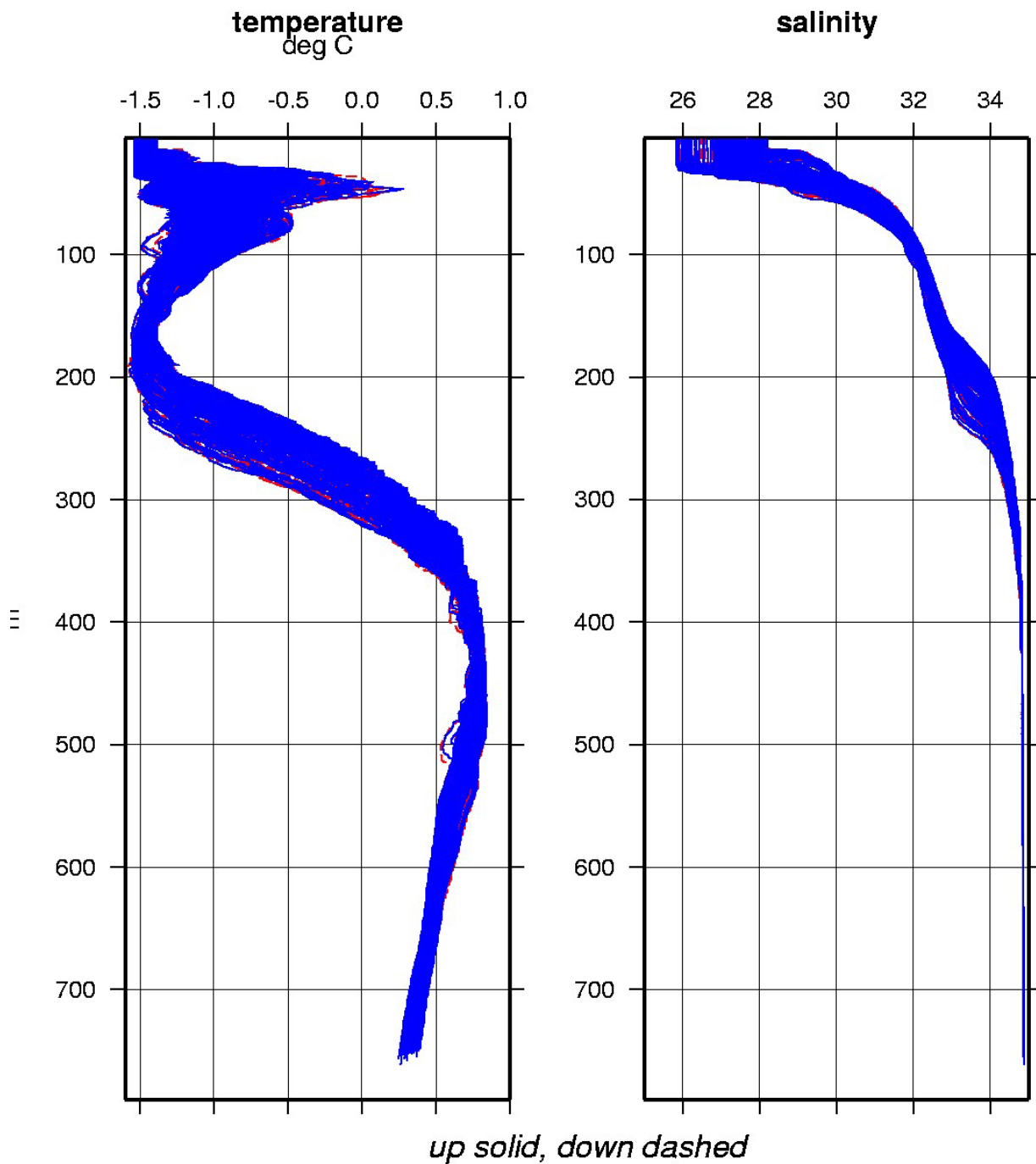
salinity



day 2009

ITP33 temperature and salinity contours.

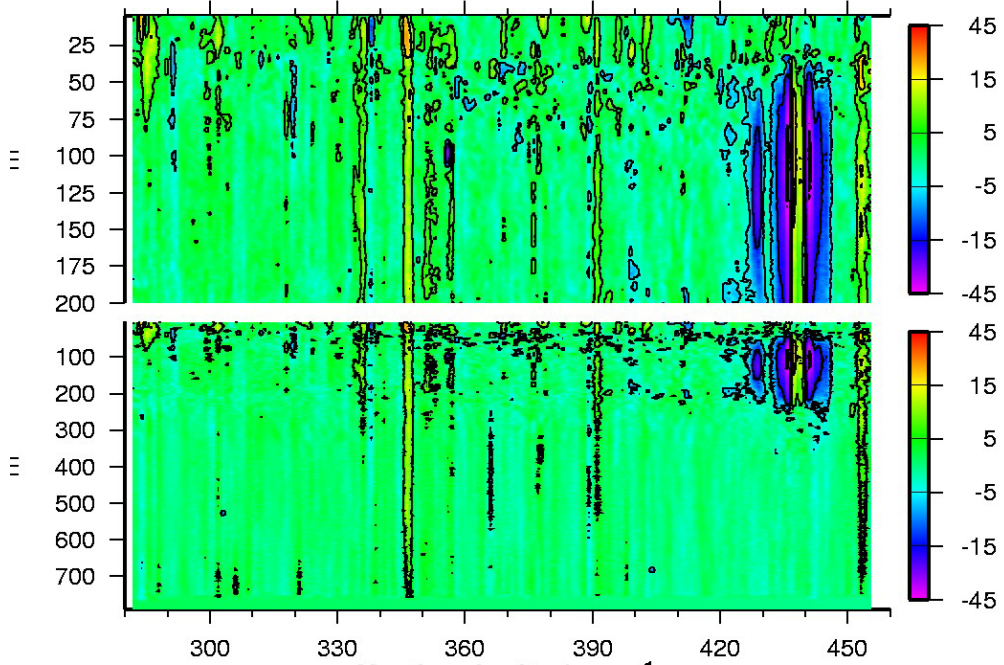
All ITP35 Profiles (up to profile 1356)



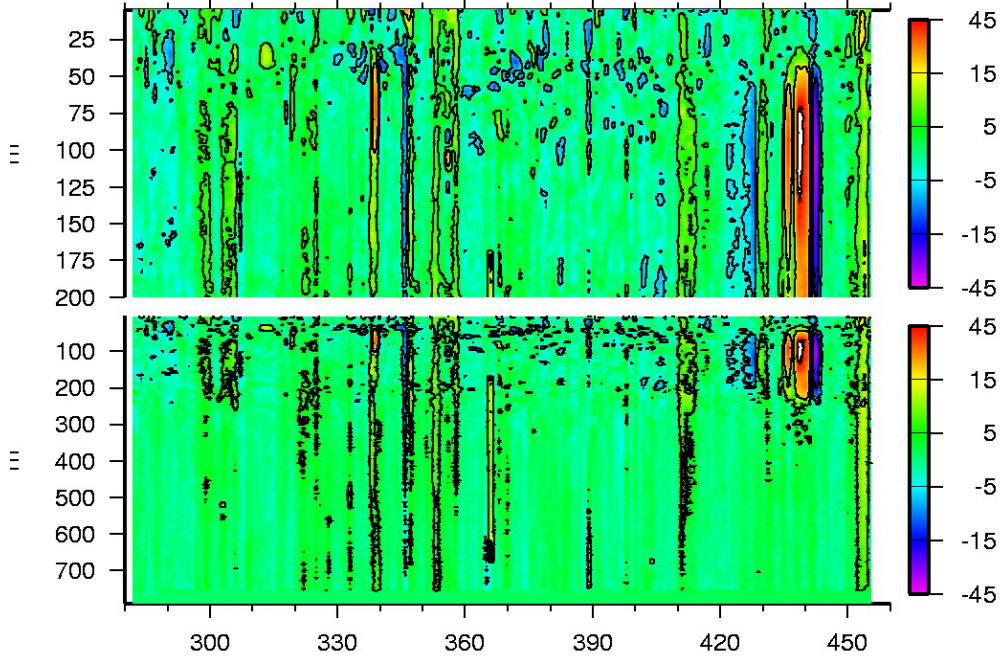
Composite plot of ITP temperature and salinity contours.

ITP35 Up Profile Contours (to profile 1356)

East velocity (cm s^{-1})



North velocity (cm s^{-1})



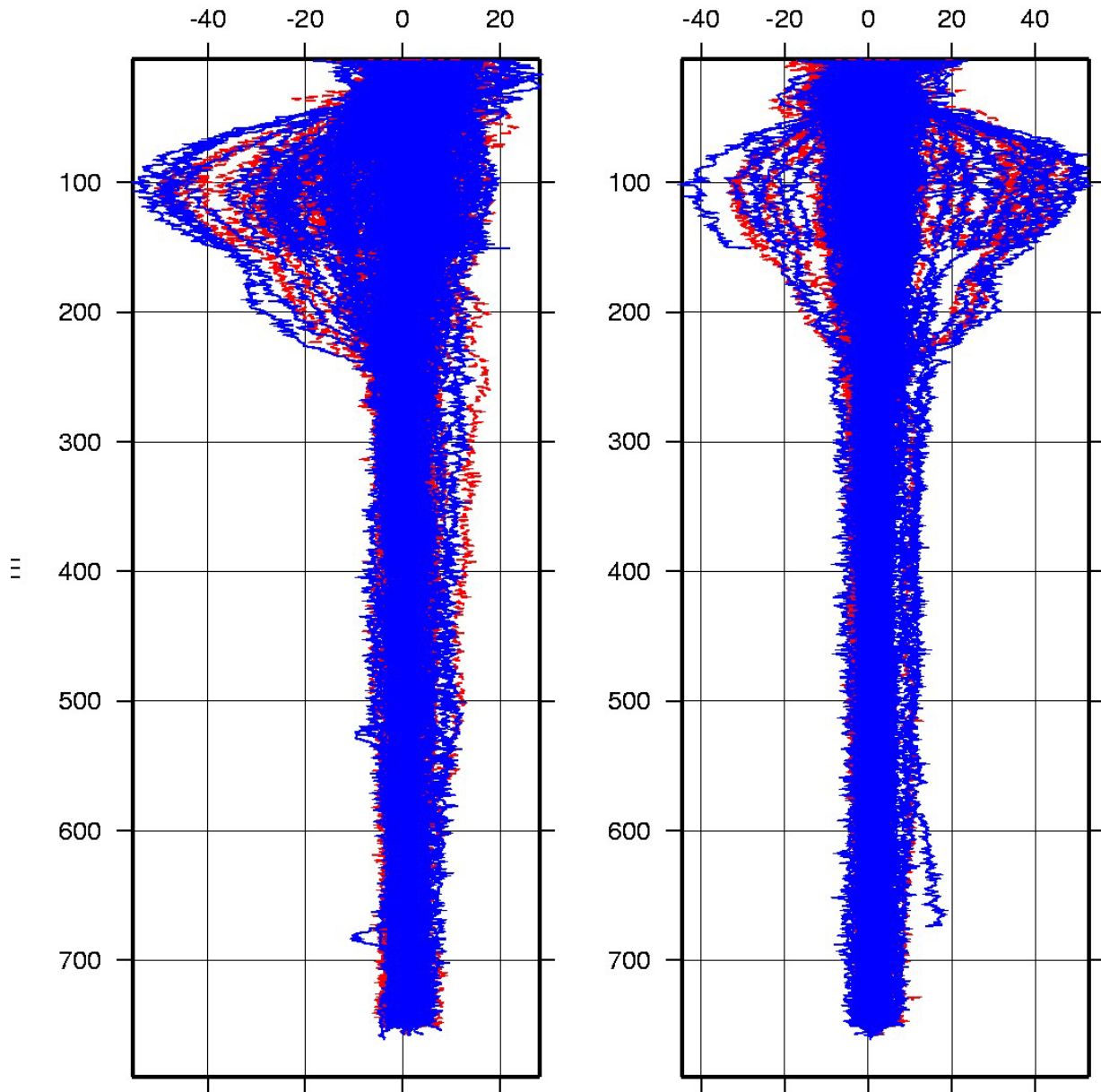
day 2009

ITP35 East and North velocity contours.

All ITP35 Profiles (up to profile 1356)

East velocity
cm s⁻¹

North velocity
cm s⁻¹



up solid, down dashed

Composite plot of East and North velocity profiles.



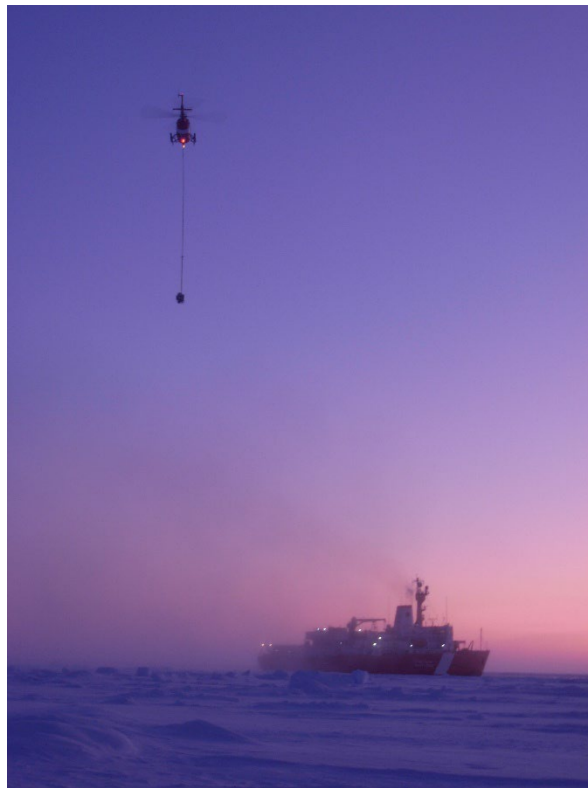
The CCGS Louis S. St. Laurent and ITP 35 shortly after deployment. (Rick Krishfield)



One year later, ITP 35 was found no longer on the same floe, but in a refrozen lead during a helicopter reconnaissance. (Kris Newhall)



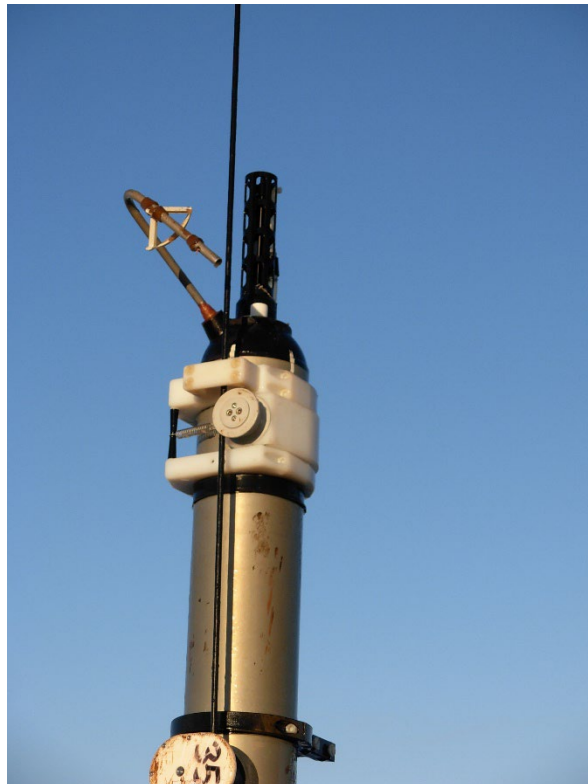
The ITP-V profiler is lowered into the 24" diameter hole to keep warm while the test of the inductive modem circuitry is performed. (Rick Krishfield)



The last slingload is transported back to ship as darkness approaches. (Rick Krishfield)



During the evening helicopter reconnaissance on October 1, ITP-V 35 is found intact and refrozen into a lead nearly one year after deployment. (Kris Newhall)



The profiler had evidently dragged on the bottom as it was covered in mud, and the MAVS sting was damaged. However, the integrity of the sealed cylinder remained intact, and all of the data was recovered from the internal memory card. (Rick Krishfield)