Draft
ANDRILL Ross Ice Shelf Mooring Deployments December 2010

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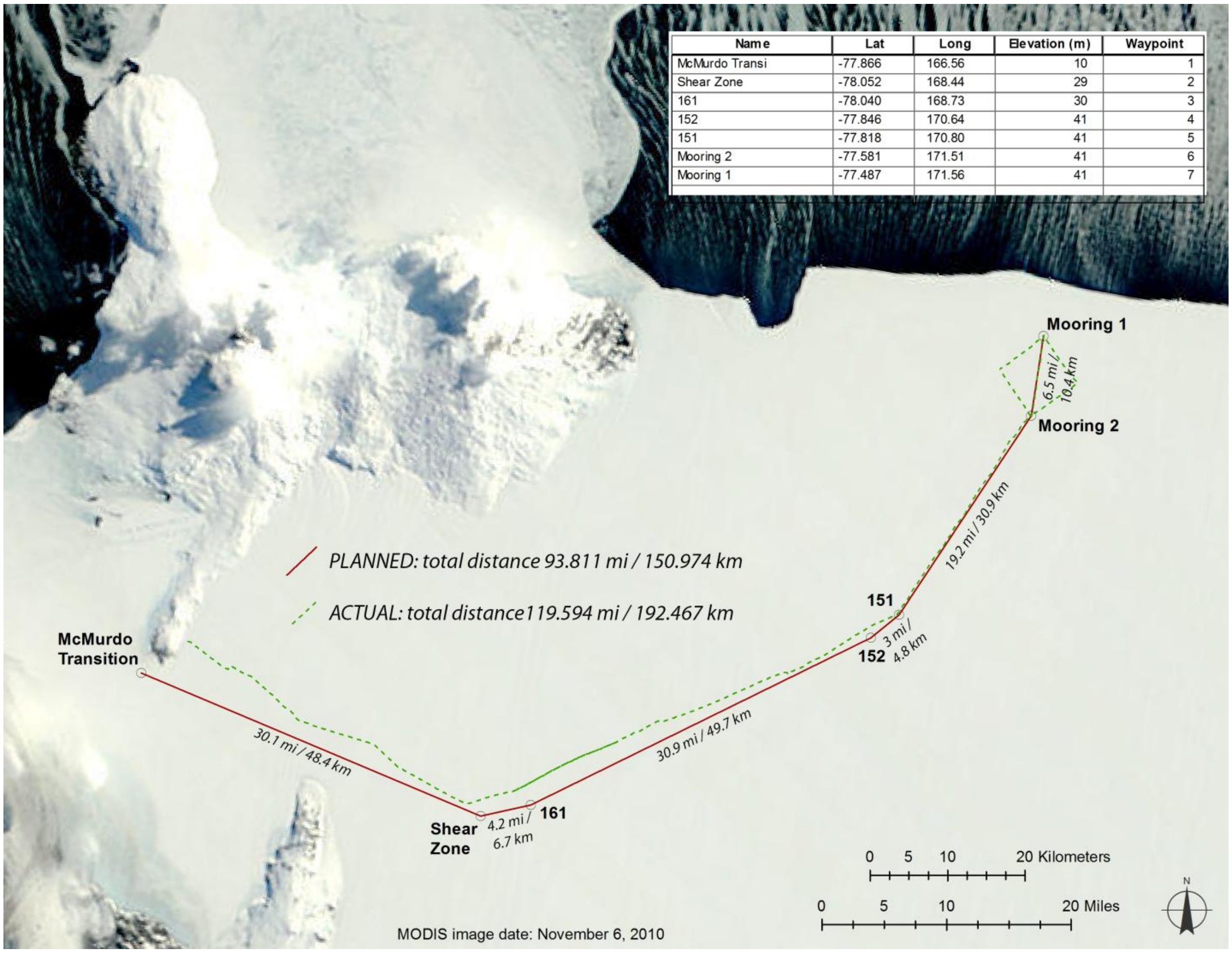
Ross Ice Shelf, Antarctica
December 5, 2010

Summary

This report documents field operations during the November-December 2010 austral summer deployment of 2 current meter moorings through the Ross Ice Shelf (RIS) into the seawater cavity under the shelf. The moorings are located at the ANtarctic geologic DRIlling (ANDRILL) Coulman High (CH) planned future drill sites near 77. 5^{o} S and 171.5^{o} E. Moored current (V), Pressure, Temperature and Conductivity (PTC) observations are now being made for 14 months in support of ANDRILL, an international program designed to investigate Antarctica's role in Cenozoic global environmental change (Rack, 2010). Drilling of sediment cores is planned by ANDRILL at the Coulman High site in 2013-14 to obtain direct records of stratigraphy from the Antarctic continental shelf during previous glacial and interglacial periods. The moored data will provide direct input for the successful engineering design of the ANDRILL drilling structures. Real time velocity and water property data from the moorings is served on http://www.whoi.edu/science/PO/coastal/ANDRILL_2010_Mooring/



Name	Lat	Long	Elevation (m)	Waypoint
McMurdo Transi	-77.866	166.56	10	1
Shear Zone	-78.052	168.44	29	2
161	-78.040	168.73	30	3
152	-77.846	170.64	41	4
151	-77.818	170.80	41	5
Mooring 2	-77.581	171.51	41	6
Mooring 1	-77.487	171.56	41	7

Figure 1. Ross Island, McMurdo Station, and M1 and M2 mooring locations at Coulman High on the Ross Ice Shelf.

The moorings and other environmental instrumentation were deployed cooperatively in late November and December, 2010 by New Zealand and U.S. personnel from the Woods Hole Oceanographic Institution (WHOI), the National Institute of Water and Atmosphere Research (NIWA), the Antarctic Research Centre, University of Victoria, Wellington, New Zealand, and the University of Nebraska Lincoln. A state of the art hot water drilling (HWD) system developed by ANDRILL was used to make several ice holes through the RIS approximately 264-m deep with a diameter of roughly 5-30 cm at each mooring site. After the HWD melted the ice hole, the fresh melt-water in the ice hole was relatively warm, fresh, stable, and low density water compared to the underlying sea water. Later, this stably stratified melt-water water in the ice hole lost heat, became super cooled, and mixed with the underlying oceanic water. Initially the low density melt-water in the 264-m deep ice hole floated with an air sea interface about 4 m higher than MSL.

M1 NIWA Mooring

Before the M1 NIWA mooring deployment a CTD cast was made in the ice hole with a weight tied 6 m below the cage and the instrument was lowered to the bottom until the tension decreased on the CTD wire.

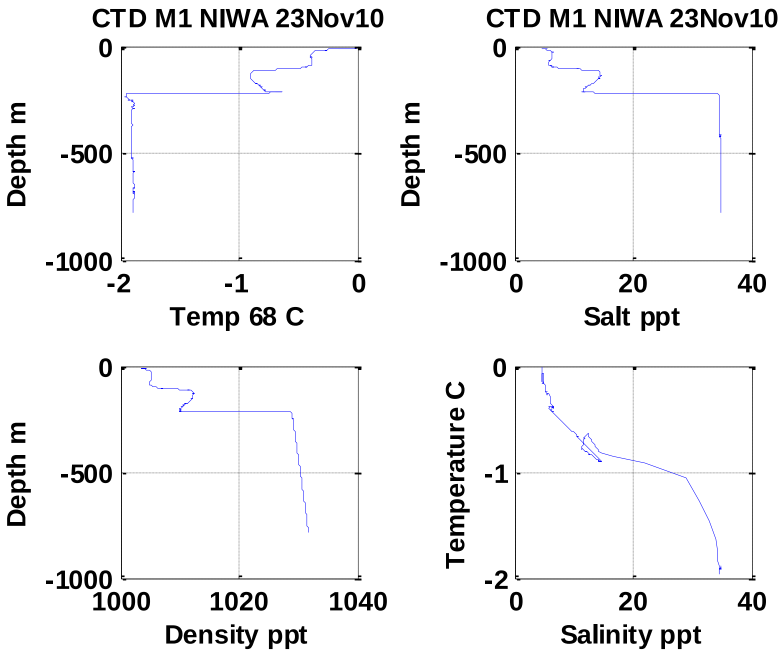


Figure 2. M1 mooring site CTD profile.

Depths were calculated from pressure and the local latitude of 77.5 S. The CTD cast gives the following results (Figures 3 and 4):

- The total maximum CTD pressure of 792.5 db indicates a depth of 782.7 m plus 6m to the bottom weight, giving a total depth at mooring M1 of 789 m relative to MSL.

- The CTD data showed an abrupt change in salinity and density at 219 m below MSL reflecting changing water properties at the bottom of the ice hole and thus the thickness of the ice from MSL to the bottom ice surface was 219 m.

- The thickness of the fresh-warm melt water in the ice hole was calculated by integrating the specific volume anomaly in the ice hole from the water surface to 219 m. The fresh melt-water air/sea level was 223.1 m above the lower surface of the RIS and thus 4.2 m above MSL. This water in the ice hole was unstable (from the CTD density), mixing was made by lowering and raising cameras and gravity corers through the ice hole, and the

- melt-water in the ice hole was pumped from the ice hole to other test holes for various other engineering test purposes. We assume local seawater will eventually filled the ice hole and the water level in the ice hole will be converge to local MSL on the nearby open ocean shelf 6 km to the north.

- The distance from the upper surface of the RIS to this fresh melt-water level was measured with a small float lowered down the ice hole to the water level was observed to be 41.2 m.

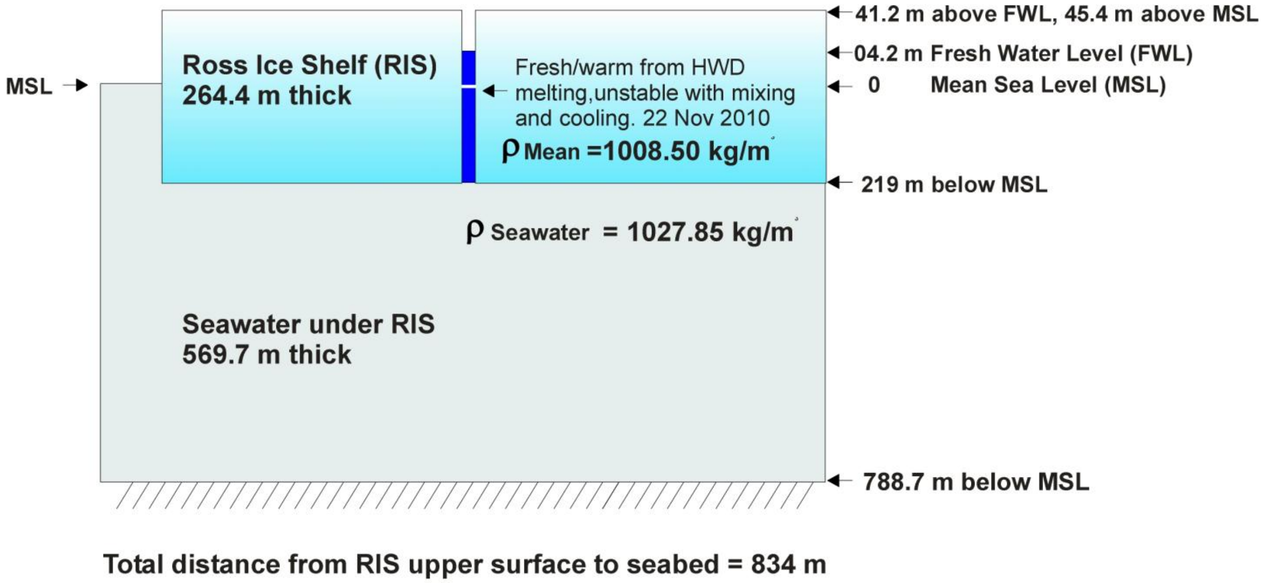


Figure 3. The geometry of the RIS at the NIWA M1 mooring site showing the melt-water surface 4.2 m above MSL in the ice hole.

The two Coulman High mooring sites M1and M2 are located approximately 10 km apart on the RIS (see Figure 1). The M1 RIS total thickness is 264-m overlying above 570-m of seawater in a cavity below the ice shelf. The total M1(M2) site depth (upper surface of the RIS to the sea floor) is 834-m (see Figure 3). The hot water drilling operation was the led by New Zealanders Jeremy Ridgen and Hedley Berge. A 220-m x 0.05 m diameter ice hole was typically completed in about 4 hours for the Inductive Modem ground wire and a 220 m x 0.30 m diameter ice hole was completed in about 24-48 hours for the main instrument deployment ice ice hole. Firn ice characterized the ice shelf above MSL. The NIWA M1 mooring consisted of five Nortek 6000-m Aquadopp

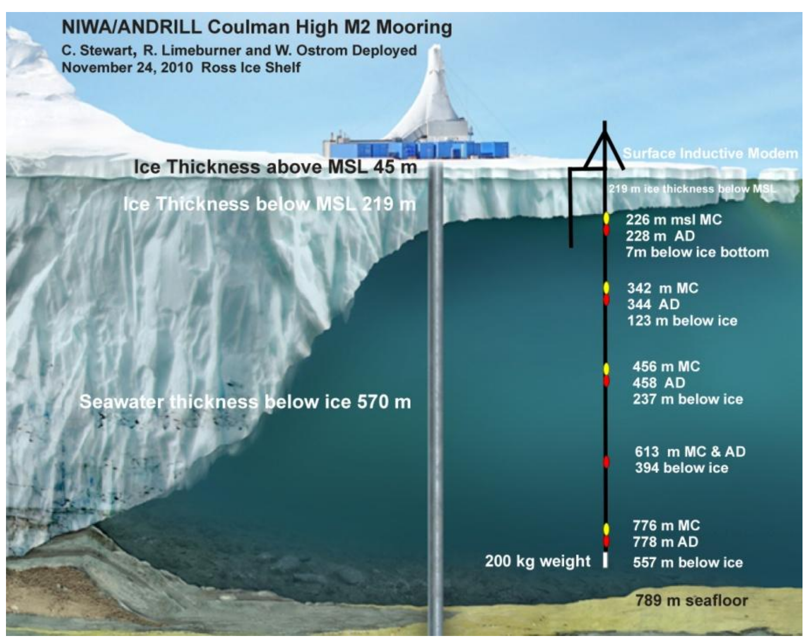


Figure 4. The NIWA M2 mooring deployed.

Inductive Modem current meters and four SeaBird Microcat Inductive Modem PTC recorders. The WHOI M2 mooring also had a surface inductive modem (SIM) card, Campbell CR1000 controller/logger, and Iridium switched circuit data telemetry. Both the M1 and M2 moorings were deployed with a WHOI designed Ice Tethered Profiler (ITP) tripod/winch system. We will return to Coulman High in January 2011 or 2012 to recover the moorings. The WHOI M2 mooring provides real-time data via Iridium and the edited data and preliminary data analysis on

http://www.whoi.edu/science/PO/coastal/ANDRILL_2010_Mooring/.

After the HWD penetrated through the RIS into the seawater cavity below the ice, the artificial melt-water level in the ice hole dropped about 6 m as the water level in the ice hole reached equilibrium with the open ocean. It is curious that this water level represents the top of a warm fresh column of stably stratified water in the ice hole that floats approximately 4-6 m above MSL. See Appendix 1.

After the M1 ice hole was opened up with the HWD, a Sony high definition movie camera system, called the Digital Optical Calibration Tool for Observing Roundness (DOCTOR) tool, was lowered into the ice hole to assess the physical dimensions of the hole at depth and to inspect the bottom sediments. Figure 4 shows a single frame of the movie as the camera descended into the seawater cavity from the ice hole. Note the groves worn into the side of the

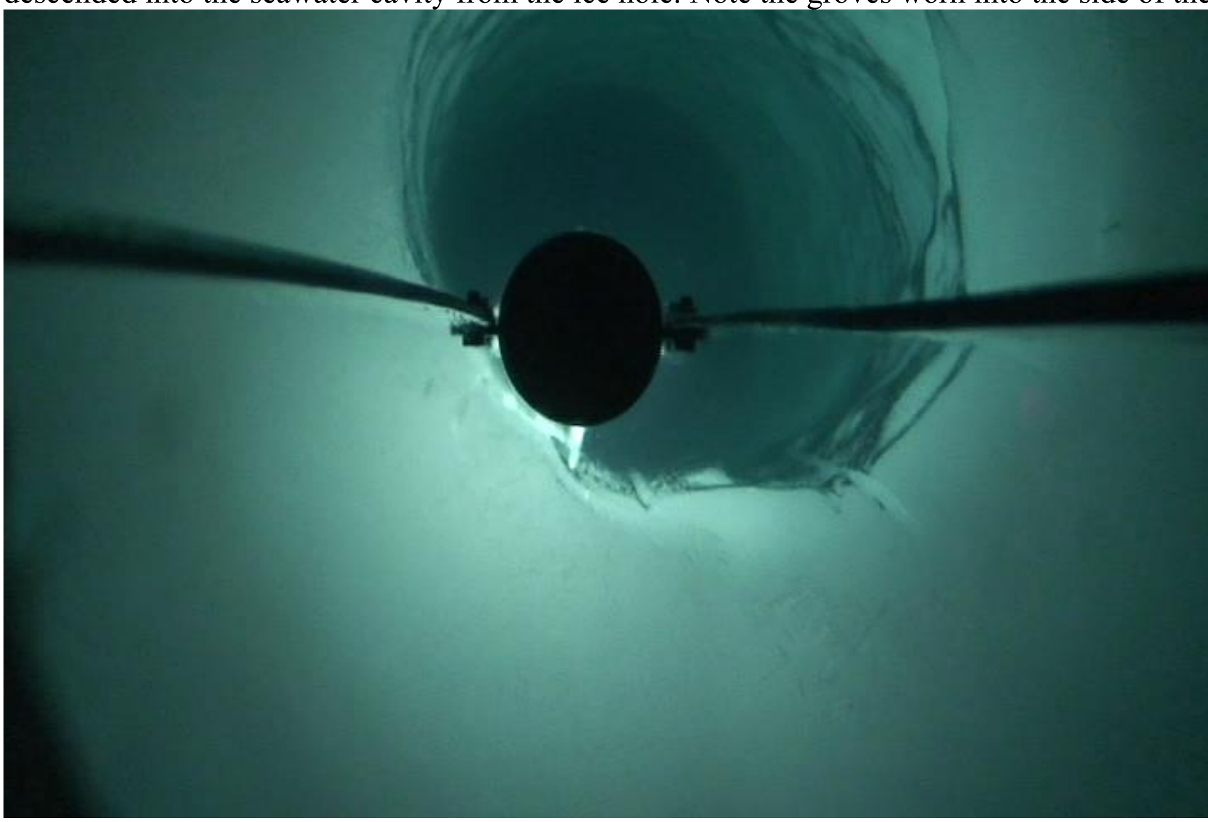


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Figure 5. Snapshot looking up of the bottom of the Ross Ice Shelf where the ice hole interfaces with seawater. A light facing away from the camera is approximately 1 m above the camera and mounted on 2 rigid metal bars.

ice hole, presumably by the spectra rope used to repeatedly lower and raise the gravity core tool and camera as the 20 cm/s current in the seawater cavity below the ice shelf dragged the cable to one side of the opening.

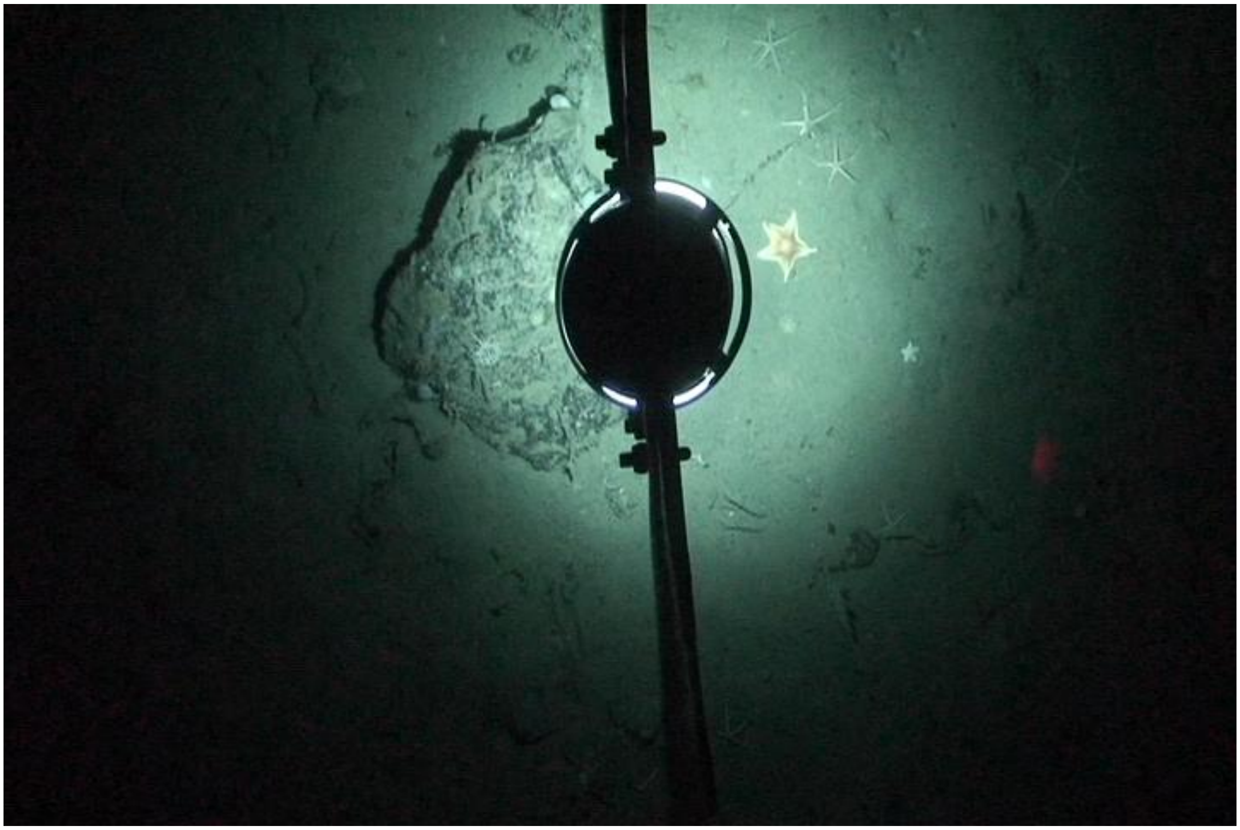

Figure 6. The seafloor beneath the Ross Ice Shelf at the Coulman High M1 mooring site. A boulder with approximate diameter of 200 mm is directly below the camera. Starfish on the seafloor are observed to be fleeing the descending camera in the movie.

The original movie of the camera descending into the ice hole and seafloor cavity can be viewed at http://www.whoi.edu/science/PO/coastal/ANDRILL_2010_Mooring/

M2 WHOI Mooring

Before the M1 NIWA mooring deployment a CTD cast was made in the ice hole with a weight tied 6 m below the cage and the instrument was lowered to the bottom until the tension decreased on the CTD wire.

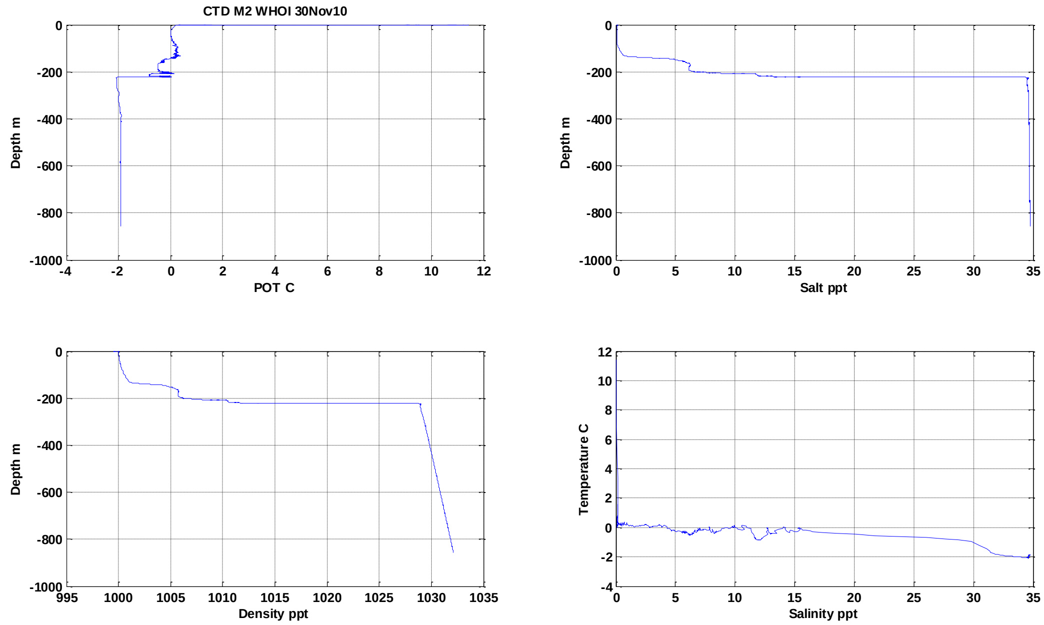

Figure 7. M2 mooring site CTD profile.

The WHOI M2 mooring consisted of five Nortek 6000-m Aquadopp Inductive Modem current meters and five SeaBird Microcat Inductive Modem PTC recorders (SBE 37IMP). The WHOI M2 mooring had a surface inductive modem (SIM) card, Campbell CR1000 controller/logger, and Iridium modem and antenna at the ice surface. Both the M1 and M2 moorings were deployed with a WHOI designed Ice Tethered Profiler (ITP) tripod/winch system. We will return to Coulman High in January 2011 or 2012 to recover the moorings. The WHOI M2 mooring provides real-time data via Iridium and the edited data and preliminary data analysis, will soon be served on http://www.whoi.edu/science/PO/coastal/ANDRILL_2010_Mooring/

After the HWD penetrated through the RIS into the seawater cavity below the ice, the artificial melt-water level in the ice hole dropped about 6 m as the water level reached equilibrium with the open ocean. It is curious that this water level represents the top of a warm fresh column of stably stratified water in the ice hole that floats approximately 5 m above MSL. See Appendix 1.

After the M2 ice hole was opened up with the HWD, a Sony high definition movie camera was lowered into the ice hole to assess the physical dimensions of the hole at depth and to inspect the bottom sediments. Figure 7 shows a single frame of the movie as the camera descended into the seawater cavity from the ice hole. Note the groves worn into the side of the ice hole, presumably by the spectra rope used to repeatedly lower and raise the gravity core tool and camera as the 20 cm/s current in the seawater cavity below the ice shelf dragged the cable to one side of the opening.

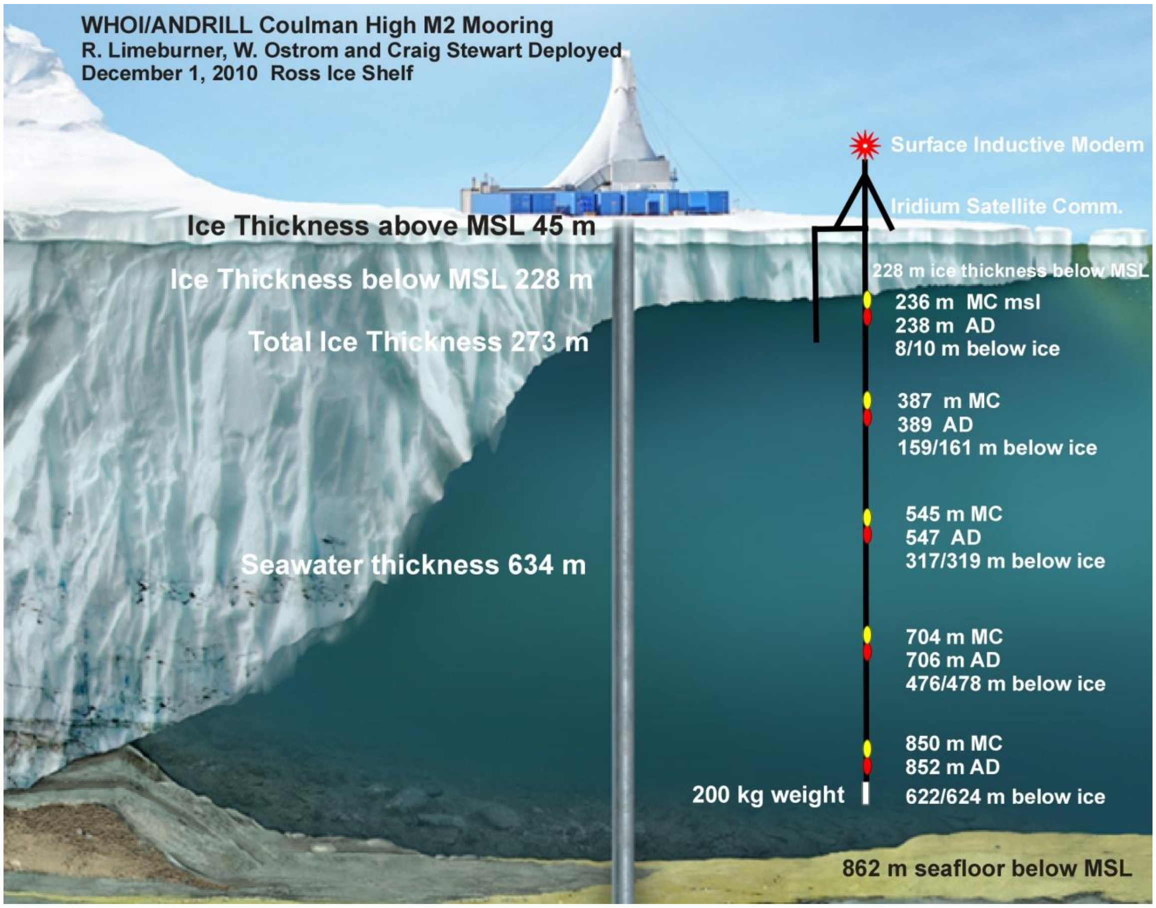

Figure 8. The WHOI M2 mooring.

The WHOI M2 Inductive modem ground return mooring was deployed on December 1 after melting a 0.1 m diameter by 220 m hole in the RIS in about 2 hours. The mooring was deployed from a tripod and Ice Tethered Profiler (ITP) winch by 0000 December 1, 2010.

Appendix 1. Assume there are no horizontal pressure gradients at the level of the bottom surface of the ice shelf between the open ocean 6 km to the north and the ice hole open to the atmosphere. Thus no horizontal pressure gradients p and $\frac{dp}{dy} = 0$ and $dp = \rho\, g\, dz$,

$$\rho_{seawater}\ g\ h_{seawater} = \rho_{freshwater}\ g\ h_{freshwater}$$

$$h_{freshwater} = h_{seawater}\ \rho_{seawater} / \rho_{freshwater},$$

where h is 219 m from a CTD profile in the ice hole, freshwater density is 1000 kg/m^3 and sea water density is 1029 kg/m^3

$$= 219 \times (1000/1029) = 225.1 \text{ m}$$

Thus the freshwater in the ice hole is 6.1 m above sea level and this height decreases to mean sea level as saltwater mixes into the hole.

References

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