Weddell Sea Moorings  
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1. Project Summary  
The world's deep oceans are filled with water masses formed at the continental margins of Antarctica. The Weddell Sea is a major source of these so-called Antarctic Deep and Bottom Waters. Relatively warm, salty water originating in the North Atlantic enters the Weddell Gyre to the east of the Greenwich Meridian as Circumpolar Deep Water (CDW). As it traverses the gyre, the CDW cools and freshens, mixing with Antarctic waters, feeding bottom water-forming processes on the continental shelves, and interacting with floating ice shelves to produce Weddell Deep and Bottom water types. Because these formation processes include heat exchange with the atmosphere and ice shelves, the properties of the water masses formed carry an imprint of any recent changes in atmospheric and shelf ice characteristics, including temperature, distribution of shelf and sea ice, and shifts in large scale wind stress patterns such as those associated with the Southern Annular Mode (SAM) and El Nino/Southern Oscillation (ENSO).  

The goal of this project is to observe the properties of the Weddell deep and bottom waters as they exit the Weddell system to contribute to the world’s deep ocean basins. Observations of this type are essential to understanding the oceanic component of the climate system, especially the exchange of heat and fresh water between the poles and equator. The data obtained over the course of a decade and more can be used to better understand deep water formation and long term changes in ocean circulation and their relation to the climate system. To obtain the necessary measurements, this project maintains an array of oceanographic moorings south of the South Orkney Islands in the Northwest Weddell Sea to provide a time series of the combined outflow (currents and temperature/salinity) of Antarctic Deep and Bottom Water drawn from various sites within the Weddell Sea. The observation sites were selected to monitor the integrated properties of the outflowing deep and bottom waters after they have traversed the key formation sites in the western Weddell Sea.
The moorings sites are visited approximately every 2 years, with ship time made available under the auspices of an Agreement of Cooperation between Lamont-Doherty Earth Observatory of Columbia University (LDEO) and the British Antarctic Survey (BAS). The agreement with BAS provides for sharing of equipment, personnel and data between LDEO and BAS, with BAS providing the ship time to do so. Under this agreement, by sharing material resources with BAS, we have been able to expand the mooring array to encompass the Orkney Passage to the east of the Orkney Plateau, a site of potential escape of Weddell Deep Water into the Southern Ocean. Our collaboration with BAS will continue, so this work is part of an international effort.

The data are made publicly available after retrieval from the moorings and suitable data processing has been completed. Real or near real time data reporting is not yet technically feasible for these sites as they are covered by pack ice for most of the year. The data are archived at the project web site http://www.ldeo.columbia.edu/res/div/ocp/noaa_cod/ and at the OceanSITES data portal [http://www.oceansites.org]. To date, the data have been used by diverse groups of ocean and climate modelers, educators and observational oceanographers. Publications and data from this project have been cited in more than 15 publications by other researchers.

![Figure 1. Weddell mooring locations, and schematic of deep and bottom water flow from source regions to the mooring array.](image-url)
2. Scientific and Observing System Accomplishments

This project generally addresses two Observing System deliverables:

• Ocean Heat Content and Transport, to better understand the extent to which the ocean sequesters heat; to identify where heat enters the ocean and where it emerges to interact with the atmosphere; and to identify changes in thermohaline circulation and monitor for indications of possible abrupt climate change

• Air-Sea Exchanges of Heat, Momentum, and Fresh Water, to identify changes in forcing functions driving ocean conditions and atmospheric conditions; and to elucidate oceanic influences on the global water cycle.

Deep and bottom water formation in the Southern Ocean plays a key role in the meridional overturning circulation of the oceans, and hence is a key component of the climate system. Observing and understand the variability in the formation processes over interannual and longer time scales is a crucial component of the climate observation system.

The Southern Ocean Observing System (SOOS) Implementation Strategy (Rintoul, et al. 2012, available at http://www.soos.aq) sets as a high priority sustained moored measurements of key passages in the Southern Ocean. The Western and Northern Weddell sites of deep and bottom water outflow are cited as key locations; the NOAA/ COD Weddell moorings are thus already contributing to the establishment of an international, sustainable Southern Ocean Observing System.

Plans for this reporting period included:

• Planning for and participation in a cruise on James Clark Ross in March 2014 to service the Weddell Orkney Plateau moorings
• upgrading of the existing data set and web products to include final data retrieved from the 2011 mooring recovery [pending discussions with our BAS colleagues, we hope to expand the publicly-available data to include the Orkney Passage moorings.]
• continued analysis of the Orkney Plateau and Orkney Passage time series in collaboration with our BAS colleagues.

Activities and Achievements

The main activities pursued during the reporting period were focused on preparations for and participation in cruise JR299 (RRS James Clark Ross, “JCR”) to service moorings M2 and M3 near the Orkney Plateau in the western Weddell Sea. JR299 departed Punta Arenas, Chile, on 8
March and arrived in Stanley, Falkland Islands on 26 April. P. Mele from LDEO sailed the cruise on behalf of our mooring project, with the goal of recovering and redeploying moorings M2 and M3, and collecting CTD profiles at the two sites to aid in instrument calibration. In addition to the usual mooring hardware, we provided a suite of recently calibrated instruments so that one mooring could be redeployed without delay after its recovery.

The austral autumn of 2014, like last year’s, experienced anomalously large sea ice extent in the western Weddell Sea. As the mooring operations were scheduled for the latter part of the cruise, the rapidly expanding ice cover became a serious concern. Having enough mooring hardware and instrumentation on board gave us great flexibility in planning the mooring operations in the face of potentially extreme ice conditions. We chose to recover M2 and then proceed directly to M3 on the chance that ice conditions at the more southerly M3 would still permit its recovery. The plan was to then deploy a new mooring at the site of M3, and return to M2 to redeploy that mooring using refurbished gear from M3.

M3 could not be recovered due to excessive sea ice, and it was left in place after interrogating the releases to confirm that they were still active. A new mooring (designated M3a for now) was deployed anchor first through the ice at a site approximately 2 km from M3. A new acoustic release and freshly calibrated instruments provided under this subcontract were essential to this deployment. Figures 1-3 below depict the rapidly evolving ice conditions at the mooring sites.
Figures 1-3 – sea ice cover from AMSR-2 data for 4, 6 and 9 April. M2 was recovered on 4 April. Recovery of M3 on 6 April was deemed impossible. Mooring M3a was deployed anchor first through the ice late on 6 April, located just a few km from M3 so it is not shown on the charts.

Data recovery from M2 was excellent, with all three instruments returning full 3 year records. Figure 4 shows 3-day-averaged, uncorrected data from M2. The raw data were sent from the JCR shortly after mooring recovery. As we have seen in previous records, M2 does not display a significant annual signal. However, this record does show a transition to lower near-bottom salinity of about 0.01 PSU occurring in mid-record. Instrumental artifacts cannot be ruled out until the instrument returns home for calibration.

Final data collected through 2011 have been posted to the OceanSITES archives. A preliminary version of the data newly recovered from M2 has also been posted.

In January 2014, we were invited by our BAS colleagues to join cruise JR310 during the 2015 season, currently scheduled for March 3 through April 12, 2015, during which we will redeploy M2, recover M3 and recover and redeploy M3a. The cruise is being conducted under the Dynamics of Orkney Passage Outflow (DynOPO) project, that, in addition to affording an opportunity to service M2, M3 and M3a, will expand and enhance the existing array of moored instruments in the Orkney Passage that we have maintained with our BAS colleagues for several years. Instruments from the recovery of M2 have returned to LDEO and will be sent out for calibration and any required servicing. Planning and materials acquisitions for JR310 began during this reporting period, concurrent with the mobilization and demobilization activities associated with the 2014 cruise JR299.

Data Availability

a. Are your data distributed in real time on the Global Telecommunications System? No
b. Where do your real time data reside? Are the data available online? Not available in real time
c. Where do your delayed mode data reside? Are the data available online?
d. When did you make your most recent data publicly available?
   Delayed mode data are received and processed at Lamont-Doherty Earth Observatory. The data are available online through the most recently acquired data (March 2014).
e. Where are your data archived and with what frequency? Processed data are archived approximately 12 months after the date of collection. Presently, data are archived at Lamont-Doherty Earth Observatory, utilizing the network’s mass storage archival system, and have been submitted to the OceanSITES data portal for public access and
archival at NDBC and IFREMER. Data are backed up at every stage of acquisition and processing on a weekly basis.

f. What is the web site where the data for your program can be accessed? If you haven’t updated your web site recently, please do so now. The data are currently available at http://www.ldeo.columbia.edu/res/div/ocp/noaa_cod/. This is a web portal for access to all of the NOAA COD funded moored data collected by the PI’s. The web site is updated every 6 months.

g. Have you successfully retrieved your program’s data from the website or Data Assembly Center where your data reside, just to ensure the accessibility of the data? If not, please do this now and address any problems with data access. Data access has been tested as of submission of this report. The recent data from M2 (2011-2014) were submitted to OceanSITES in October but do not yet appear there pending action by the site administrator.

h. Do you have any publications supported through COD funding? We encourage your bibliographies to be posted online.

A bibliography of PI publications and other relevant publications that cite this project is presented on the project website.

i. How are you tracking uptake and use of the data and products produced by your project? Some have found it helpful to establish a standard and recognizable name (e.g., Argo, OceanSITES)? We encourage this approach to improve the recognition, discoverability, and visibility of your project.

All data are submitted to OceanSITES and are publically discoverable via the OceanSITES portal.

j. How do you direct users of your data to acknowledge its use? Do web pages that provide data and products from COD support acknowledge CPO/COD support?

The project web page acknowledges COD support using the COD Standard Language.
Figure 4. Preliminary data recovered from mooring M2. Depths given are computed from average pressure measured at each instrument. Bottom depth at the mooring site is 3049 meters.
3. Outreach and Education

While this project does not have a specific education component, we continue to strive to engage undergraduate and graduate students in the data analysis activities as the time series data sets mature.

Public outreach is managed in part by The Earth Institute, Columbia University, which in addition to assisting with the LDEO annual Open House, maintains a web site with project information, announcements of education opportunities, research-related events, seminars and talks for the public.

4. Publications and Reports

4.1. Publications by Principal Investigators

None to report

4.2. Other Relevant Publications

The Weddell moorings program continues to receive widespread attention and the data are being used in publications. The following recent publications cite data from this project or publications in which project PI’s participated as authors:


5. Slides
Please attach up to three slides highlighting your project’s progress (including relevant notes and credits).