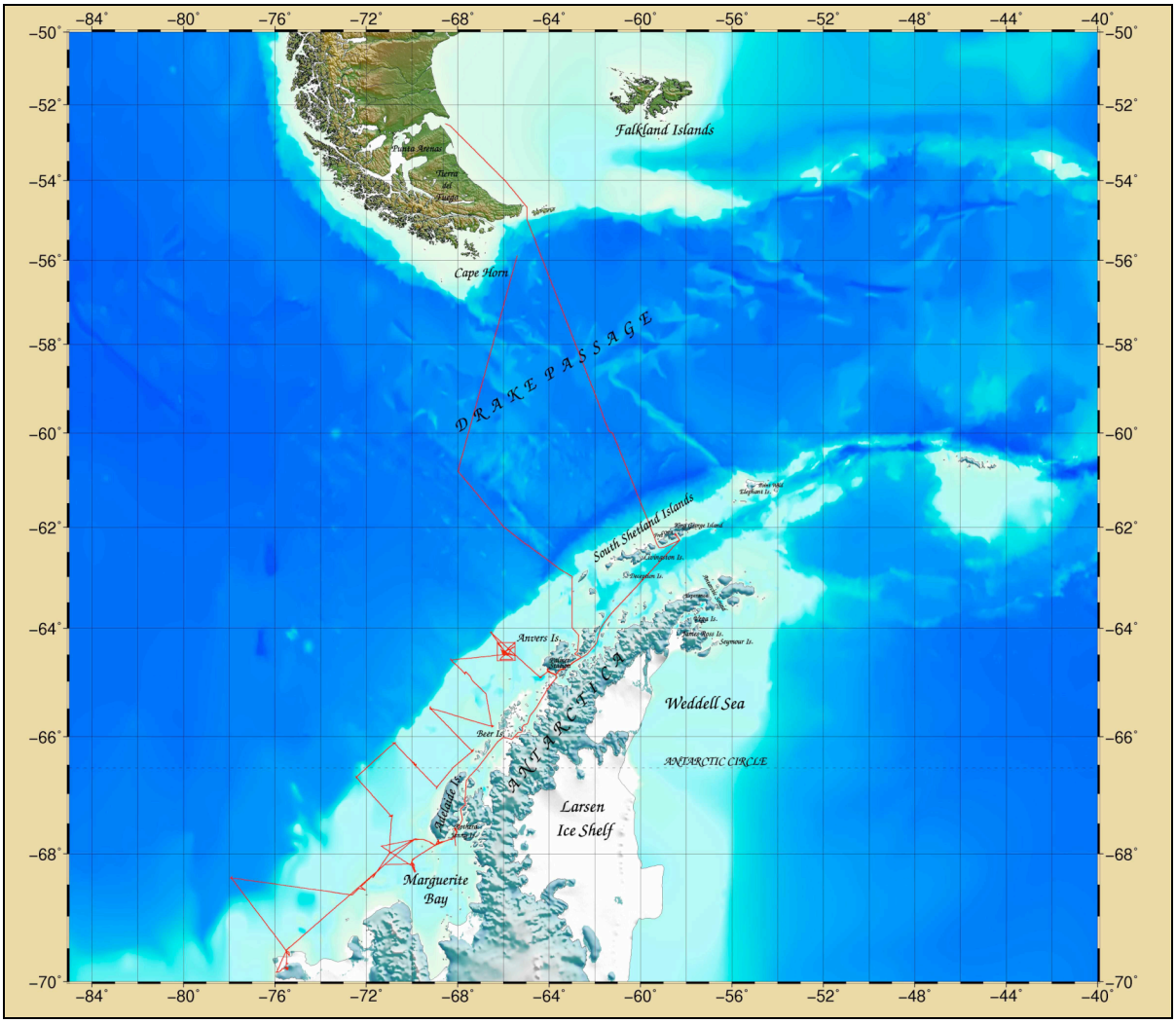
LMG0901 Final Cruise Report
Palmer, Antarctica Long-Term Ecological Research Project (PAL-LTER)

- 17th Annual Midsummer Oceanographic Research Cruise
- West Antarctic Peninsula continental shelf 64 to 70 South, 64 to 70 West
- 30 December, 2008 - 06 February, 2009
- *ARSV* Laurence M Gould (research vessel)
- **Project PI**: Hugh Ducklow, The Ecosystems Center, MBL, Woods Hole
- **Chief Scientist/Expedition Leader**: Douglas Martinson, Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY
- **Project Scientists**:
  - Debbie Steinberg, Virginia Inst of Marine Sciences, Gloucester, VA
  - Oscar Schofield, Rutgers Univ. New Brunswick, NJ
  - Bill Fraser, Polar Oceans Research Group, Sheridan, MT
    - Represented by Kristen Gorman, Simon Fraser University, Vancouver B.C.
- **Guest Investigator**: Ken Buesseler, WHOI.

Cruise Track:



PROJECT/CRUISE BACKGROUND:

Palmer LTER (PAL; http://pal.lternet.edu) is one of 26 sites in the NSF-sponsored US LTER Network (http://www.lternet.edu). PAL was established in 1990 and has been investigating the geophysical and ecological relationships among climate, sea ice, marine ecosystems and carbon cycling along the West Antarctic Peninsula (WAP) continental shelf. The project site headquarters is at Palmer Station, one of three research bases operated by the NSF and US Antarctic Program.

Palmer LTER scientists and their colleagues in the British Antarctic Survey have documented the WAP as the most rapidly warming region in winter on earth. The average *winter* temperature (June-July-August) has warmed by 6ºC since 1950, ~5.4 times the global average; 87% of the glaciers on the WAP are in retreat, contributing to global sea level rise; the perennial sea ice has disappeared since 1999 and the winter sea ice season has shortened by nearly 3 months (over 40%). The marine ecosystem is responding to this rapid regional climate warming at all levels of the food chain from phytoplankton and krill to penguins and seals, with changes in population sizes, biodiversity and rates of key ecological processes.

This 2009 cruise was the 17th austral summer cruise by the PAL LTER. It was the first since the 2008 NSF Award, with new PIs (Schofield and Steinberg), and the first to extend the grid farther south in response to advice from the 2005 NSF Site Review. The southward extension was the overarching goal of this cruise. The new PIs introduced a significant number of new technologies to the program. Specifically, from Schofield: a full bio-optics program and hyperspectral radiometry as well as the Slocum Webb glider. The glider, in addition to the 5 shelf thermistor moorings (Martinson) allow more continuous sampling in time and space, particularly useful for maintaining our more northern presence as the shipboard sampling moves south. The new technologies, and the recovery/refurbishment and redeployment of the moorings, were successful in all respects.

NOTABLE HIGHLIGHTS:

1. Cruise Support.

To no small extent, much of the cruise success was facilitated by the truly exceptional support from Raytheon and ECO personnel. This great support (including excellent food services day and night and all around pleasant interactions with all support personnel) helped make this cruise truly rewarding. The Raytheon personnel showed remarkable dedication, running instruments around the clock, and immediately rebuilding a net lost at the termination during the very first cast. Victor Shen and Mike Coons ran the CTD system as well as any, and were experts at quickly downloading the data from mooring sensors and reprogramming them for immediate re-deployment. Dan Powers and Chance Miller did great jobs on deck, and were quick to help with any repairs (especially on plankton nets), constructions, clean-up whatever was required, whenever required. Lily Glass performed admirably as the MST, helping to keep the labs safe, clean and running smoothly. Jamee Johnson helped keep all aspects of the work and support focused on our science.

The ship's crew helped in every aspect of the cruise. The captain (Joe Abshire), and mates (David Morse, John Higdon and Rick Taylor) took us where-ever the science required (e.g., into uncharted waters near Charcot Island). The crew was always available to run winches and help in any manner possible.

The entire science party wishes to thank all of the Raytheon and ECO personnel on board with our fullest gratitude and appreciation.

2. Charcot Island Process Study.

The main cruise objective was to extend our observational reach southward in order to better understand the magnitude of regional warming and ecosystem response migrating down the WAP. On 28 January LTER personnel accomplished the first shore landing on Charcot Island since the 1920's. The island was surrounded by moderate to heavy sea ice and large icebergs. This station was the farthest south the LMG has ever sailed (69 deg 49 min S).

Our new observations provide support for several hypotheses and predictions from our recent proposal: we confirmed the presence of persisting summer sea ice in this region. The B-013 team noted the presence of several small Adélie penguin colonies on Charcot Island and was able to deploy PTTs on adults and obtain other data from nesting and fledgling birds. Based on the location of these colonies relative to historical maps, they appear to be previously undiscovered and may be part of an expanding population on Charcot Island. At the same time, aboard the LMG we documented a deep canyon running up to within a few km of the island and obtained a full CTD cast in 576 meters. The CTD profile revealed the presence of Upper Circumpolar Deep Water (UCDW) derived from onshore ACC intrusions within the canyon. We have hypothesized that ACC exchange through the cross-shelf canyons in the WAP region fosters conditions favorable for successful penguin and other seabird and possibly mammal breeding. The simultaneous discovery of the penguins and canyon here at Charcot lend further support to our hypothesis.

3. Avian Island Process Study.

Ocean Station OBAMA. We completed an extended process study station, our second major such study (~67 deg 46 S, 68 deg 51 W). This spanned 3 days, including 20 January, so the project scientists decided to dedicate it to President Obama and his administration to recognize their vital interest in the problem of climate change and to celebrate the Inauguration. This station was near the penguin colony on Avian Island (itself at the head of the Marguerite Trough). The Rutgers Glider completed a 10-day mission, surveying the Avian foraging area extensively, then flying to Rothera, where BAS personnel retrieved her on 29 January. This is a new aspect of our MOU with BAS, and an important step toward establishing Glider Bases at Palmer and Rothera in support of future routine observations at heretofore unprecedented time and space scales.

These and other observations make the Station OBAMA/Avian Island area one of the most intensively-observed regions in the Southern ocean.

4. Particle dynamics and flux (B-045).

We completed 3 extended process stations in collaboration with B-045 Guest Investigator Ken Buesseler (WHOI). At each of these stations we successfully deployed drifting sediment traps over 3-day periods, and carried out simultaneous and complementary investigations of biogeochemical, microbial, phytoplankton and zooplankton processes influencing the sinking particle fields. The glider flew a course to provide a 3-dimensional image of the physical environment sampled by the drifter, and continuous CTD yo-yoing as the ship tracked the drifters provided additional physical details, achieving an unprecedented sampling density. These studies were added to PAL in specific response to the Midterm Review and Proposal Review recommendations that we strengthen the experimental and hypothesis-driven elements of our program. Among other significant accomplishments, we have now obtained floating trap and Thorium-234 data that will help us to better understand and quantify the LTER moored sediment trap time series.

5. Phytoplankton (B-019).

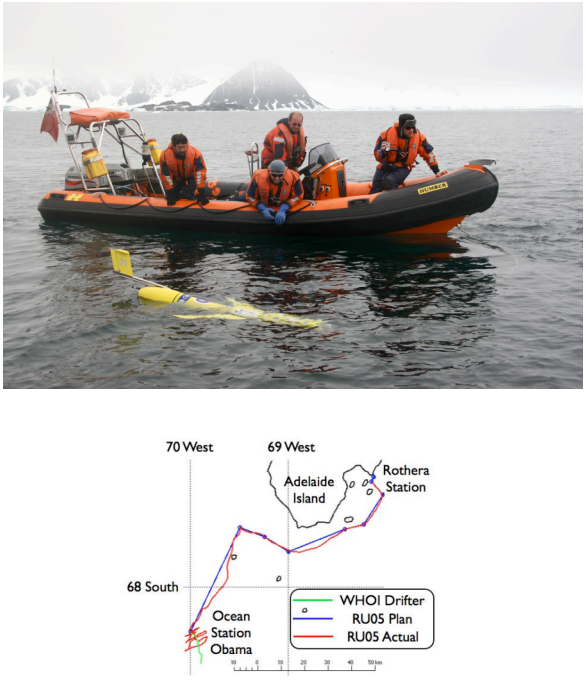


Figure 1. The recovery of the LTER glider at Rothera Station and its track during the 2009 RV Gould field season. The green represents the WHOI drifter and the glider (red line) was directed to fly a region representing the source water for material being collected by the sediment traps.

New technology and higher-frequency data will greatly assist in the interpretation of the traditional discrete depth phytoplankton data as well as accelerate improvement of a new suite of satellite algorithms for these waters. The addition of kinetic fluorometry will also assist the interpretation of the variability in the phytoplankton radio-labeled productivity measurements. These fluorometry measurements were made both on discrete samples as well as in surface mapping mode using the seawater intake line provided by the ship. The ship-based measurements were complemented by data collected with a Slocum Webb glider. The glider was deployed at Ocean Station Obama to support Lagrangian tracking of a drifting sediment trap, and undertake a hydrographic survey of a region frequented by radio-tagged penguins. In a proof-of-concept the glider was directed to within 1000 m of Rothera base allowing British Antarctic Survey personnel to recover the glider (Figure 1). This sets the stage for embarking on future Palmer to Rothera Station glider operations. This effort will expand in the coming year with funding provided by the Gordon & Betty Moore Foundation and a recently awarded NASA Biodiversity proposal. In all, this greatly expands the range of measurements collected by the

phytoplankton component of the LTER and by utilizing proven technologies ushers in a new era of mapping capabilities to complement the traditional phytoplankton measurements.

Scientifically the cruise collected an interesting range of data with preliminary analyses confirming a strong decreasing inshore to offshore gradient in primary production rates. Productivity values were of similar magnitude to past years providing confidence in the continuity of the time series given the personnel changes in the program. The stations with high productivity rates were mirrored with high values of Fv/Fm indicating healthy phytoplankton populations. The population structure will be assessed using the HPLC data which is currently being analyzed at Palmer Station. There is coherence between the optical fields and the phytoplankton productivity suggesting these waters are largely Case I waters. This is consistent with radioisotope measurements made during the cruise that dissolved organic matter production was only 3-5% of phytoplankton carbon fixation. Size fractionated productivity measurements suggest that over 95% of the phytoplankton were in the less than 20 micron size fraction.

6. Zooplankton (B-020).

Clear patterns in zooplankton distribution emerged over the course of the cruise including salps at the outer slope stations, significant krill numbers inshore, and a mix of krill and *Limacina* pteropods (pelagic snails) on the shelf. At the outer slope station 200.160 we sampled a salp "bloom" of a density two orders of magnitude higher than any that has been recorded by the LTER thus far (Figure 2). We performed salp fecal pellet production experiments at this station and once the data is analyzed we will be able to estimate the flux of POC due to this massive salp bloom. At the process study stations we also performed depth-stratified zooplankton sampling using the MOCNESS to investigate depth distribution of the abundant taxa over a diel cycle. There were clear diel migration patterns in both salps and some crustacea such as ostracods.

Microzooplankton grazing was insignificant in the northern process study stations, however we found significant/measurable microzooplankton grazing in the southern most process study station, with microzooplankton removing 10% of the primary production per day. We collected a comprehensive set (inshore to offshore, north to south) of frozen zooplankton samples for both gut fluorescence and lipid analyses. Gut fluorescence will be used to determine mesozooplankton grazing rates along the grid. The lipid analyses will be used to test our hypotheses concerning differences in energy content of krill and other zooplankton along the grid and the affect on higher trophic levels (penguins), and to investigate the plankton food web using lipid biomarkers.

Figure 2: ***Left panel:*** *Massive salp bloom collected at outer slope station (200.160). Preliminary analysis indicates that this catch was over an order of magnitude larger in density than reported in LTER salp climatology Chance Miller (left), Dan Powers (middle), Kate Ruck (right).* ***Above:*** *Zooplankton research assistants marveling at catch: Miram Gleiber (left) and Kate Ruck (right).*

7. Microbes (B-045).

Bacterial production rates were estimated from 3H-leucine incorporation at all CTD stations, in conjunction with the primary production assays. Preliminary assays indicate rates averaging about 40 mgC m-2 d-1, or around 4% of the primary production. Considering that phytoplankton excretion of DOM was 3-5% of the total PP, these two findings imply an addition source of labile DOC for bacterial sustenance. Samples were collected from surface to bottom at all stations for flow cytometric and total organic carbon analyses.

8. Physical Oceanography (B-021).

Moorings. We recovered and redeployed all 5 physical oceanographic moorings and downloaded the first year's observations from the new SASSI moorings. These data will provide new high temporal resolution observations of cross-shelf exchange processes as already noted above, and provide an indication of the spatial distribution of intrusions. The mooring near Renaud Island was relocated to the canyon adjacent to Charcot Island.

CTD. We made over 100 CTD casts; full-depth casts included complete bottle collection. Nutrients will be measured in all bottles allowing a more thorough water mass decomposition of shelf waters (including an estimate of the temperature decrease due to mixing, as opposed to fluxed to the atmosphere or glacial melt). This will allow a more complete budgeting of the ocean heat content change. CTD yo-yos will provide a clear indication of the time-scale of the ocean stratification (changes from cast to cast will give us an estimate of the uncertainty in each profile, as a snapshot in time).

8. LTER Grid.

In addition to these achievements (notably 3 3-day process stations), we still managed to occupy, and conduct full sets of hydrographic observations at 13 of our original (northern) LTER grid stations. Station selection was guided in part by Martinson's (B-021) optimal interpolation analysis (with Alexy Kaplan) that suggested the most important locations for subsampling the grid while minimizing lost variance in the full-grid field for T_{max} (which unfortunately, is not representative of ecological variables). This exercise lays the foundation for new strategies to observe and analyze oceanographic processes in the PAL (and other) regions.

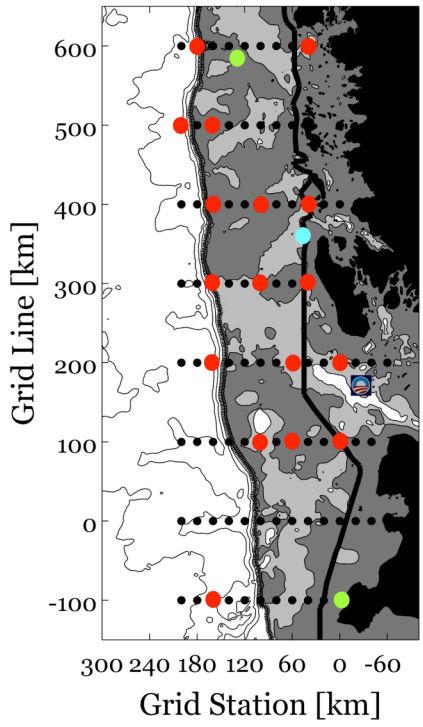


Figure 3: New LTER nominal sampling grid, now extended further south (including 100 through -100 lines). Stations occupied this first year of new grid are indicated by dots. Red dots are full stations, other colored dots show process stations (which also included full sampling) but due to their focused nature, limited the total number of nominal stations that could be occupied.

Specifically, full grid-stations occupied are shown in the above map. The original (northern) grid included annual occupation of the 200 to 600 grid lines, and the southern extension extended this down to -100 (where we occupied 5 of the new stations given the nominal spacing as used previously). Note that the green dot at -110.060 is our process station at Charcot Island, whose occupation was one of the more notable successes of the cruise, supporting long-held LTER hypotheses that the heads of submarine canyons integrate physical and biological oceanographic processes that promote establishment of Adélie penguin colonies over ecological time scales.