LMG 16-01: 03 Jan -- 17 Feb. 2016 LTER Cruise 24
Weekly Science Report I

"Palmer Antarctica LTER (PAL): Land-Shelf-Ocean Connectivity, Ecosystem Resilience and Transformation in a Sea-Ice-Influenced Pelagic Ecosystem"

Cruise Introduction and Overview. This is the twenty-fourth consecutive January cruise of the Palmer LTER, starting in 1993. The first cruise utilizing the Palmer LTER Grid (see below) was aboard the RVIB Polar Duke in November 2001, but it is not included in this accounting. This is our second cruise under the current award. We are on the fifth six-year NSF-LTER award since PAL started in 1990 (NSF-PLR 1440435 to Columbia University). The overall long term objective of Palmer LTER is to understand the mechanistic linkages by which climate, physical oceanographic forcings and sea ice extent and duration control ocean productivity, food web processes, krill, penguin and cetacean recruitment and carbon biogeochemistry in the marginal sea ice zone of the western Antarctic Peninsula (WAP) region. The WAP is one of the most rapidly-warming regions on the planet, and we have documented responses throughout the foodweb from phytoplankton to penguins. The annual oceanographic cruise provides a large scale regional view of physical-trophic-biogeochemical processes in the region, and contributes to a time series of ecosystem transformation in response to regional warming and sea ice loss.

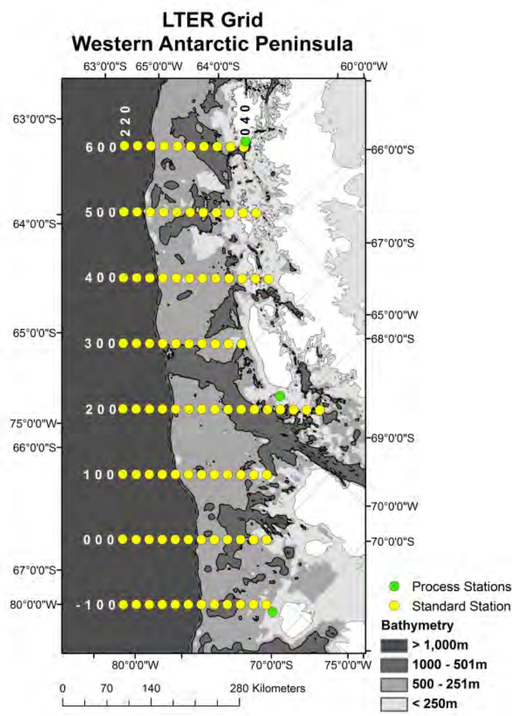

Figure 1. Map of LTER Study region along the Western Antarctic Peninsula, showing grid (yellow) and process study (green) stations occupied on annual cruises.

Our cruises are currently divided between 1) standard LTER stations along the regional grid extending from Palmer Station to Charcot Island and from the inshore coastal region to deep (>3000 m) water off the continental shelf break in the Antarctic Circumpolar Current (**Figure 1**), and 2) conducting three, 3-4 day mechanistic process studies along the Peninsula. This year's process studies are focused on the canyons as mechanisms of continental shelf-ocean-land connectivity; and how bathymetry (submarine canyons) and physical oceanographic forcing combine to link together the coastal and shelf subsystems of the Antarctic marine ecosystem. During the first few days of the cruise, we completed Process Study 1 in the vicinity of Palmer Deep Canyon (**Figure 2**). Stations were selected on the basis of previous current measurements and penguin tag locations, and to highlight characteristic regions of the canyon geography: canyon mouth, head and deepest central locations. Aspects of the process study are discussed in additional detail below. We were challenged by the extensive sea ice lingering in the Palmer region, with several large aggregations of pack ice in our study area (**Figure 3**), slowing ship speed and interfering with mooring recovery and preventing glider deployment. But the ice also provides opportunity: persistent summer sea ice furnishes insight on environmental conditions prior to extensive sea ice decline along the Peninsula. A key PAL objective is to understand the ecological and biogeochemical response to climate change and variability.

As always, we received outstanding help from ASC, Edison Chouest and Damco staff in Punta Arenas, at Palmer Station and aboard the ship. The annual LTER cruise is a large and complex operation and we benefit greatly from the hard work, accumulated expertise and corporate memory of many dedicated colleagues and friends. Our cruise stages over the winter holidays, placing extra burden everyone involved.

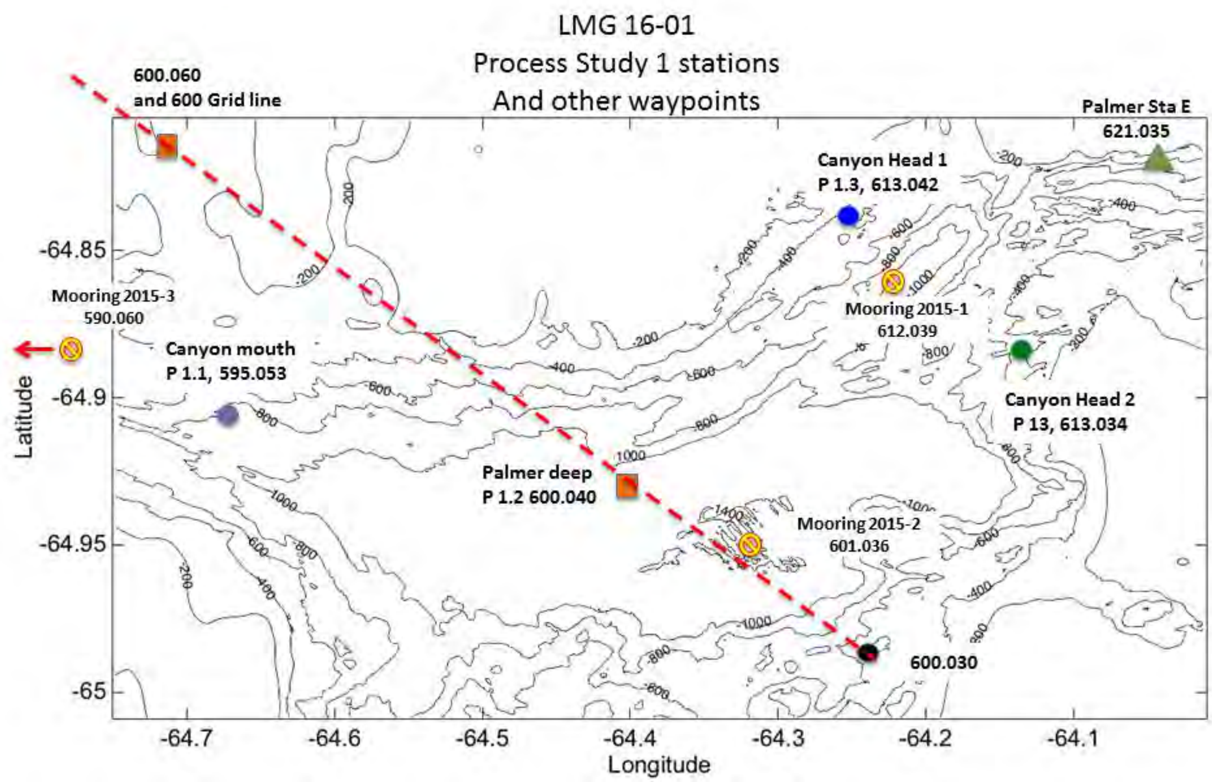

Figure 2. Map of the Palmer Deep region 10 nm from Palmer Station, showing bathymetry, mooring and hydrographic station locations.

Figure 3. Sea ice and icebergs viewed from ARSV LM GOULD near PAL Station 600.100, 15 January 2016.

Individual component reports:

C-013: Seabird Component (W.R. Fraser, PI)
Field Team Members: Carrie McAtee and Darren Roberts

The objective C-013's component of this year's cruise is to continue the long-term data set of at-sea bird surveys to assess abundance and distribution across the LTER regional study grid. In addition, we plan to continue studies of Adélie penguin breeding and foraging ecology at Avian Island, which is located approximately 600 km south of Palmer Station. This southern study area located in Marguerite Bay provides a higher latitude comparison with seabird studies conducted at Palmer Station. Mainly focusing on Adelie Penguins (but also Southern Giant Petrels, Blue Eyed Cormorants, South Polar and Brown Skuas) we will assess how and if annual environmental variability (e.g. sea ice and snow conditions) affects population trends, foraging success and diet, growth rates, survival and recruitment, as well as seasonal dispersal. If ice conditions allow we also plan to conduct similar fieldwork at Charcot Island. However, as ice images continue to roll in, it's looking more and more likely that we will instead be making day trips at other ice-free productive coastal areas where seabirds and marine mammals have been observed in the past.

We joined up with the Gould on the evening of the 13th after switching out from Palmer Station with whaler Doug Nowacek. Our first few days of work have consisted primarily of at-sea observations of seabirds and marine mammals along the 600 and 500 grid lines. The abundance and diversity of species observed has generally been low. Most transects have included Southern Fulmars, Souther Giant Petrels, and Crab-eater seals on ice flows. However, as expected, sightings and diversity have increased as we approach the shelf-break region and more coastal areas. Our most interesting sighting so far from the bridge was a Wandering Albatross.

Figure 4. South Polar Skua near Palmer Deep

C-019: Phytoplankton Component (O. Schofield, Rutgers; PI)
Field Team Members: Nicole Couto, Carly Moreno, Shungudzemwoyo Garaba, Kayla Evens, Emily Olson

The primary goals of the phytoplankton component of this project are to monitor the biomass, productivity, and health of the phytoplankton on the West Antarctic Peninsula. Our tools for achieving these goals are water filtration for chlorophyll and pigment concentration (biomass), ^{14}C-bicarbonate uptake experiments (primary production), and fluorescence induction and relaxation measurements (health). A central question of our group's research is whether light or nutrients limit the productivity on the WAP. To this end, we also measure the optical properties of the upper water column where phytoplankton photosynthesize using a hyperspectral radiometer that measures both upwelling and downwelling irradiance, and an instrument that measures light absorption and attenuation at various wavelengths.

This year the team is made up of Nicole Couto, a PhD student in Oscar Schofield's lab at Rutgers University, Carly Moreno, a PhD student at UNC Chapel Hill, Shungudzemwoyo Garaba, a post-doctoral researcher at University of Connecticut, Kayla Evens a Junior at New College of Florida, and Emily Olson, who recently received her Masters from University of Florida.

Shungu Garaba will focus on making optical measurements during the cruise. The investigations were motivated by advancements in marine optical technology which have led to a better understanding of how light interacts with optically active constituents of the ocean, including inorganic mineral solids, dissolved and particulate organic material. A suite of optical sensors (VSF-9, BBFL2, AC-S, and CTD) will be deployed in an optical cage at all the regular stations, and above-water radiometric quantities will be collected underway using shipborne radiometers (Fig. 1). Additionally, a LISST sensor is attached to the optical cage to obtain particle size distribution. Underway observations using the radiometers have been ongoing since the start of the cruise on 4 January. The optics measurements will be compared to airborne and satellite observations in an effort to improve bio-optical models and atmospheric correction.

C-020. Zooplankton Component (Debbie Steinberg, VIMS; PI)

Field Team Members: Joe Cope, Patricia Thibodeau, Anjali Bhatnagar, Andrew Corso, and Danielle Hall (Fig. 5).

The goal of our component is to analyze the effect that zooplankton community structure has on biogeochemical cycling of carbon and nutrients, and the effects of climate change on zooplankton communities on the continental shelf sea of the western Antarctic Peninsula. This year, with three process study stations, we are examining the role that zooplankton play in the biological pump and in nutrient cycling (grazing, particle or fecal pellet production, and diel vertical migration).

Figure 5. Zooplankton Field Team Members: Anjali Bhatnagar, Patricia Thibodeau, Joe Cope, Andrew Corso, and Danielle Hall.

During the first week, we concentrated our operations at a 3-day process study situated in the Palmer Deep canyon, near LTER grid point 600.040, as well as along the 600 and 500 grid lines. At each station we performed a pair of net tows, one for larger macrozooplankton (e.g., krill, salps) and one for smaller mesozooplankton (e.g., copepods). Animals from the macrozooplankton tows were identified and counted on board, while the presence/absence of taxonomic groups was noted in the mesozooplankton samples (and will be quantified at our home institution). The sea ice this year has presented a special challenge because our nets are easily shredded by captured ice (**Fig. 6**).

Figure 6. Zooplankton tow in sea ice.

To investigate depth distribution and diel vertical migration of zooplankton, we collected day/night samples with the Multiple Opening-Closing Net Environmental Sensing System (MOCNESS; now famous after being featured in the film 70 South). The MOCNESS has eight nets which we can open at discrete depth intervals. We also completed fecal pellet production rate experiments on *Euphausia superba* to continue our time series of the role that different zooplankton taxa play in particle export in the WAP. We collected specimens at selected stations for zooplankton gut fluorescence (a measure of grazing). We collected various taxa for the VIMS Invertebrate Collection. Krill were also collected to test for the presence of mercury.

As in several past years, during the first Process Study we conducted a bio-acoustic survey. The purpose is to map out aggregations of krill in the Palmer Deep canyon in order to explore relationships with whale distribution and penguin foraging locations. This is the first year that we used a more sensitive instrument and it revealed plankton structure that was not noted in the past. Two distinct bands were present in the acoustic output, one in the top 50m of the water column and one that roughly followed the sea bottom contour (**Fig. 7A**). The near surface band was blueish green, which signifies a weaker, or smaller, target. The deeper band was red, a larger target. Nets tows through these depths revealed that the shallow band consisted of the smaller krill *Thysanoessa* while the deeper band consisted of the larger Antarctica krill, *Euphausia superba* **(Fig. 7B).**

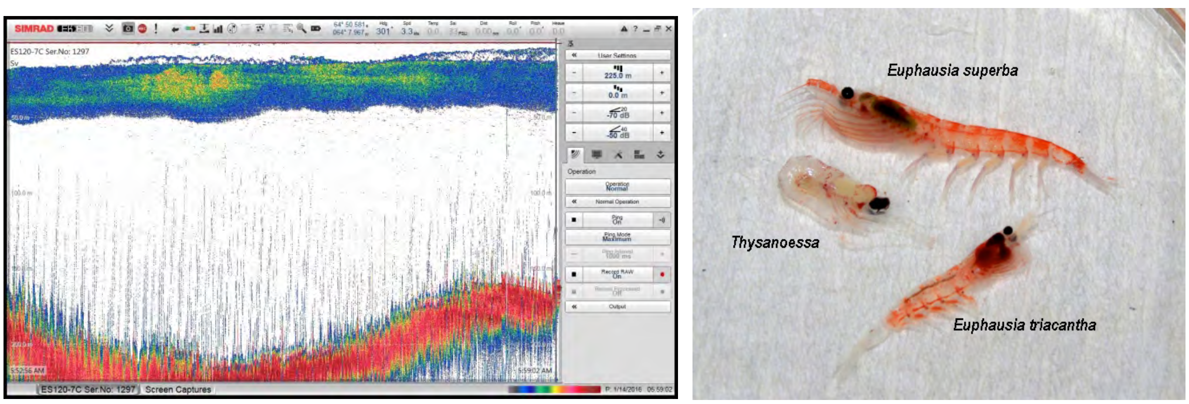

Figure 7. A (left) output from underway acoustic system. B(right) krill species encountered in tows.

C-024: Cetacean Biology & Ecology (A. Friedlaender, Oregon State University, PI).
Field Team Members: Erin Pickett, Oregon State University.
At Palmer Station: Doug Nowacek (Co-PI) & Logan Pallin.

The objective of this component of the Palmer LTER is to collect information on the distribution, movement patterns, behavior, and life history of whales around the Antarctic Peninsula to test ecological hypotheses regarding these top predators. We are interested in the most basic sense in understanding the demography and population structure of the whales that utilize this area as a feeding ground. To this end, we will be collecting skin and blubber biopsy samples as well as photographs of individual whale flukes. These data will be used to determine the sex ratio, pregnancy rates, breeding population identity and diet composition of humpback whales. We are also interested in the foraging behavior and movement ecology of these whales in relation to both physical and biological features of the seascape. In order to determine this, we will be deploying a number of location-gathering satellite-telemetry tags. The data from these instruments will allow us to determine location, movement patterns and broad scale behavior (e.g. feeding, traveling) of whales over long periods of time (months). By then linking the locations of foraging to oceanographic data collected under way and at stations we can begin to understand what features of the environment promote the necessary conditions for whales to feed. We are also deploying multi-sensor and video recording tags that collect high-resolution movement and kinematic data for ~24 hours. These tags allow us to quantify the foraging rates and activities of whales in a unique way. Likewise, we will also compare the amount of spatio-temporal overlap in foraging areas with other krill predators (e.g. Adelie penguins) to try and understand the interspecific interactions between these sympatric and krill-dependent animals.

During the first week of operations in the Process Study Site around the Palmer Deep Canyon we had great success in locating whales, collecting samples, and deploying tags. We collected 16 biopsy samples from humpback whales, deployed 6 satellite-transmitting tags, and one CATS video recording multi-sensor tag. Data from the satellite tags will be sent to the LMG over the coming days, and we are currently processing the data from the multi-sensor tag. Of note, nearly all of the whales that we encountered feeding were actively using bubble-nets to corral prey, a behavior unique to humpback whales. This is a dramatic and cooperative behavior seen in other feeding grounds and observed in Antarctica but this is the first time that we have the data to quantify and describe this in detail. Figure 8 shows an image of a humpback whale during a satellite tag deployment and biopsy collection.

Figure 8. Humpback whale with satellite tag and biopsy dart. The satellite tag is the small round silver ring in the forward portion of the dorsal fin. The silver and orange 'rocket' is the holder that the tag is placed in for deployment and once the tag has been inserted in the whale, the rocket bounces off and floats for retrieval. Below the satellite tag is the yellow and orange biopsy dart deployed via crossbow. The dart has a small 40 mm tip on the end that collects a small skin and blubber sample and then bounces off the whale and floats for retrieval and then archiving of the sample.

C-045: Microbial Biogeochemistry Component (H. Ducklow, Lamont Doherty Earth Observatory; PI).

Field Team Members: Hugh Ducklow, Naomi Shelton, Ribanna Dittrich, Emilie Schattman and Griffin Whitlock.

The objective of this component is to obtain a mechanistic understanding of the carbon cycle along the Western Antarctic Peninsula, and the roles of heterotrophic bacterioplankton and sinking particles in these geochemical transformations. We are also concerned with possible responses of the microbial foodweb and biogeochemical transformations to climate warming.

Our routine measurements include heterotrophic and autotrophic microbial abundance by flow cytometry conducted on-site, bacterial production by ^{3}H-leucine incorporation, as well as water column inventories of dissolved inorganic and organic carbon, particulate organic carbon and nitrogen and inorganic macronutrients. We are collecting samples for oxygen-18 analyses to determine glacial and meteoric inputs to seawater, in collaboration with LTER colleague Dr Mike Meredith (BAS-UK) Finally, we deploy a time-series sediment trap to collect settling particles and determine the export flux from the upper ocean.

We continue to estimate particle export from the upper 200 meters using in situ measurements of the ^{238}U:^{234}Th disequilibrium in the upper water column, research started by former postdoc Mike Stukel (now at Florida State). ^{234}Th measurements allow us to determine the export rate of ^{234}Th on particles that have sunk out of the water column during the roughly one month period of time prior to our occupation of a station. This measurement allows us to estimate carbon and nitrogen export, a key process contributing to atmospheric carbon storage in the deep sea. So far on this cruise we have measured ^{238}U:^{234}Th disequilibrium profiles at a total of 7 LTER stations. Team member Riba Ditttrich is our Thorium Person this year, up at all hours filtering vast amounts of seawater.

During the first week of operations, we conducted most of the aforementioned measurements at LTER grid stations on the 600, 500 and 400 lines and at all four Process Study 1 Stations. Preliminary results from leucine incorporation experiments at 10 stations suggest bacterial abundance and activity are moderately high, possibly in response to phytoplankton blooms triggered by the late sea ice retreat.

B-203: Trace Metals (Rob Sherrell, Rutgers University, PI).
Field Team Members: Jessica Fitzsimmons and Laramie Jensen (Texas A&M University)

The objective of the trace metals program is to determine the sources, sinks, and processes controlling the distribution of micronutrient (Fe, Zn, Mn, Cu, Cd, and Ni) and anthropogenic (Pb) trace metals along the scarcely studied West Antarctic Peninsula (WAP) and to determine the extent to which those micronutrient trace metals control phytoplankton production in this region. It is well understood that iron (Fe) is the nutrient most limiting phytoplankton production in the offshore waters of the Southern Ocean. However, the proximity of the WAP continental shelf waters to the continent and relatively shallow bottom sediments provides a direct, high concentration source of Fe to WAP waters via glacial and sea ice inputs and sedimentary fluxes, which can then be moved around and even offshore via the shelf-specific circulation pathways that have been studied by LTER for decades. Thus, investigating the mechanisms controlling the variable transition from high Fe, high productivity waters inshore to Fe-limited, low productivity waters offshore is a major goal of our study. The broader context for our study involves the ongoing warming of this region, with decadal-scale increases in glacial meltwater inputs and decreases in seasonal sea ice, especially along the northern WAP.

This cruise is the second of our two years of funded field sampling. Collecting seawater samples that have low concentrations of trace metals using a metal ship is challenging, and thus to avoid contamination we have a dedicated “trace metal clean” CTD/rosette system, and we sub-sample our trace metal-free Niskin bottles in a clean air “bubble” that we constructed out of plastic tarp, removing as many metal parts as possible (**Figure 10A**). Because of the unfortunate loss of the USAP trace-metal CTD/rosette before last year’s cruise, this year we deployed for the first time the brand new, replacement USAP trace metal CTD/rosette and polymer cable. Thanks to the hard work of the ASC MTs and ETs, this new system was effectively constructed, calibrated, and tested in the first hours of the cruise, and the new sensors, rosette, and cable are performing very well. We are still perfecting details of the altimeter calibrations and deciding whether to add additional ballast weight to our rosette. Nonetheless, in the first week of the cruise we have busily collected full profiles of dissolved and particulate trace metal samples at each regular station with great success.

Another objective of our sampling this week has been the clean collection of glacial meltwater samples at Palmer Station for trace metal concentration analysis (**Figure 10B,C**). We hypothesize that these glacial meltwater streams could be a temporally variable but important source of metals including Fe to local phytoplankton communities in nearshore regions. Mike Brown, a PhD student with the Schofield group at Palmer Station, has generously offered to continue to sample these glacial waters in a near-weekly time-series while we are away on the cruise, which will complement well the weekly seawater time-series seawater collection at Palmer Station E that the Schofield group is already completing on our behalf.

We are very grateful for the support of our LTER colleagues and the enthusiastically helpful and capable ASC technical staff.

Figure 10. Left: The clean-air and metal-free "bubble" constructed in the Hydrolab for trace metal clean sampling aboard the *LM Gould*. Middle: Texas A&M Assistant Professor Jessica Fitzsimmons with A&M graduate student Laramie Jensen sampling the glacial meltwater stream near its inception behind Palmer Station. Right: Jessica Fitzsimmons with Rutgers postdoc Amber Annett of the Schofield group sampling the glacial meltwater just before it enters the ocean.