LMG 24-01: PAL LTER Cruise 31
Weekly Science Report I, 26 – 31 December 2023

LTER: Ecological Response and Resilience to "Press-Pulse" Disturbances and a Recent Decadal Reversal in Sea Ice Trends Along the West Antarctic Peninsula

Cruise Overview (Dr. Deborah Steinberg, Chief Scientist):

The overall long-term objective of Palmer LTER is to understand the mechanistic linkages by which climate, physical oceanographic forcing and sea ice extent and duration control ocean productivity, food web processes, krill and penguin 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 food web from phytoplankton to penguins and whales. The annual oceanographic cruise (this is our 31st) provides a large-scale regional view of physical-trophic-biogeochemical processes in the region while also contributing to time series of ecosystem change in response to regional warming and sea ice loss.

This cruise is divided between 1) occupying the extended grid north of Palmer Station, 2) sampling the standard LTER grid 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, and 3) conducting three, ~3-day, plus three, 1-day, mechanistic process studies along the Peninsula (**Fig. 1**). The extended grid was added two years ago and is composed of four new grid stations and six underway stations (Figure 1, north of Palmer Station). These stations are located along the mid-shelf and Gerlache Strait, with the goal of understanding the ecosystem impact of the exchange between Bransfield Strait, heavily influenced by the cold Weddell Sea, and the relatively warm LTER study region. This year's process studies are focused on the relationships among bathymetry (submarine canyons), physical oceanographic forcing, nutrient distributions, phytoplankton and zooplankton community structure, and penguin and whale foraging. This year we will have a few shorter process studies in deep slope waters for comparison to the coastal process work.

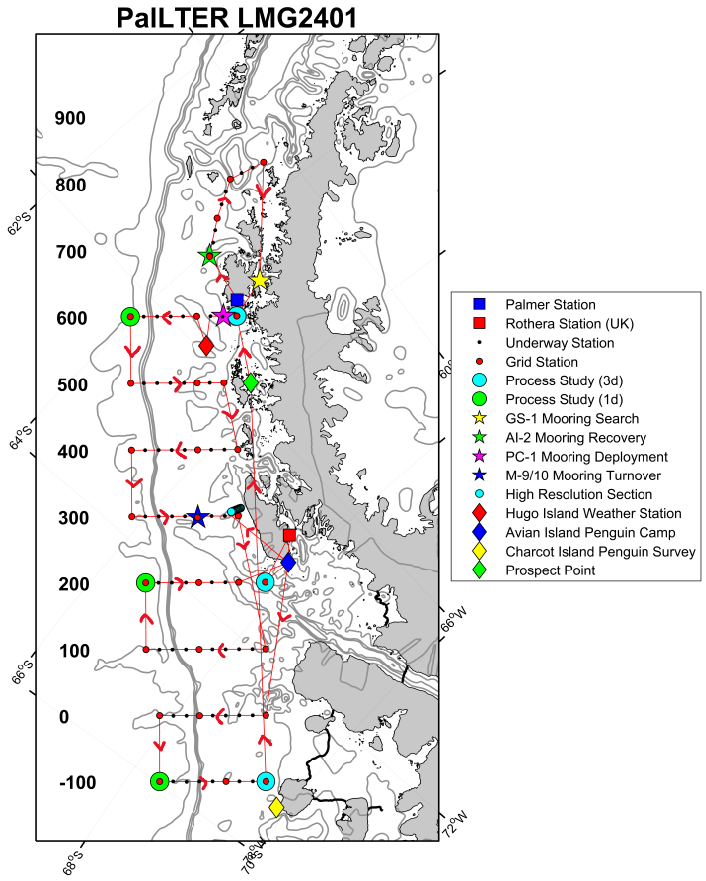

Figure 1. Cruise Plan. LTER Study region along the Western Antarctic Peninsula, showing extended grid stations north of Palmer Station and standard annual cruise grid stations. Stations and activities are as indicated in legend. Arrows indicate direction of ship track, beginning and ending at Palmer station.

This year, the science party is comprised of 18 people. During the preparations for the cruise and this first week, we have received excellent support from the six ASC personnel on board, Captain Stelly and the officers and crew of the *L.M.Gould*, as well as the staff in Punta Arenas, and at Palmer Station

This first report of LTER science starts on December 27 after we finished the port call at Palmer Station. This departure reflects a one-day delay due to icebergs blocking the ship.

First week of LTER Activities

This first week, we recovered the A1-2 mooring off the north-west coast of Anvers Island, completed the extended grid of stations north of Palmer Station, and began an extensive process station at Palmer Deep (Station 600.040) that includes two full grid stations (optics cast, CTD profile, net tows), a pair of day-night MOCNESS tows, a 24 hr. sediment trap deployment, seabird surveys, whale tagging and biopsies, and a successful acoustic survey using an EK-80 dual frequency system. We attempted, for the second year, to recover the GS-1 mooring in Gerlache Strait, but it was not recovered.

Group Reports

C- 021: Physical Oceanography (Dr. Carlos Moffatt, PI; U. Delaware)

Field Team Members: Michael Cappola (lead), Jake Gessay

C-021 operations this week were dominated by mooring operations. On 2023-DEC-27, we located and successfully recovered AI-2, which was located just to the north of Anvers Island. AI-2 was previously deployed on 2023-JAN-03, providing us with 358 days of data. The mooring surfaced in a large tangle, but the recovery team was still able to retrieve all sensors. It was configured with an upward facing Teledyne Workhorse 300khz Acoustic Doppler Current Profiler (ADCP), 2 SBE37 MicroCAT Conductivity and Temperature Recorders, 3 SBE39plus Temperature and Pressure Recorders, and 8 SBE56 Temperature Recorders. We are looking forward to downloading the data this week.

This mooring adds a year to our time series in the region and will help us understand the water mass interactions between the Bransfield Straight and the West Antarctic Peninsula shelf. The former is cold and influenced by the Weddell Sea, and the latter is warm and influenced by Circumpolar Deep Water. During our transit of the Extended Grid, we crossed this front between CTD casts 003 and 004 (**Figs. 2, 3**).

On 2023-DEC-30, we searched for GS-1, which is a mooring originally deployed in the Gerlache Strait that failed to surface during the LMG2301 cruise. Surprisingly, we were still able to communicate with the acoustic releases, but it was not in its original location. We moved to relocating the mooring and found that it was drug along the bottom over 4500 meters, most likely by an iceberg. We attempted to release several times, but it still failed to surface. We were preparing to move into a grappling operation, but two icebergs were bearing down on our path

limiting ships mobility. If there is time at the end of the cruise, we will return to this site and attempt to grapple GS-1 off the bottom.

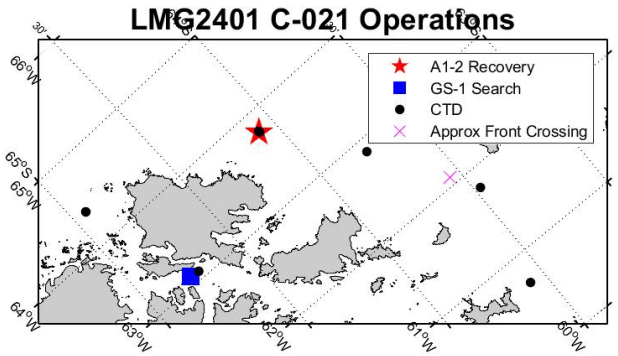

Figure 2. Map of C-021 Operations. The front location was derived using salinity from the ship's flow through system.

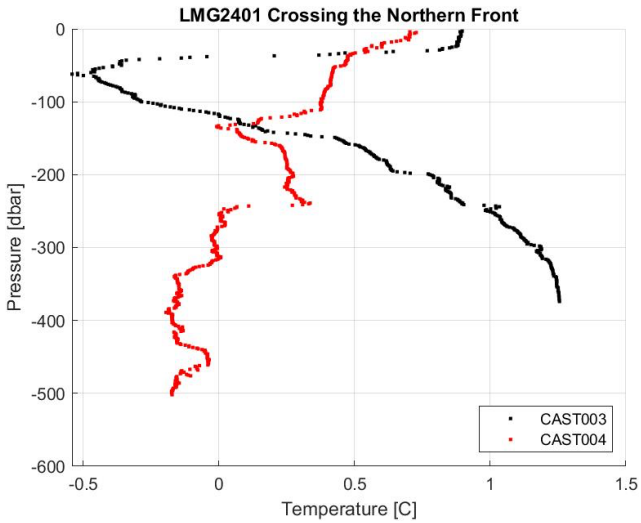

Figure 3. CTD temperature profiles on opposite sides of the front (X in Fig. 2).

C-045: Biogeochemistry (Dr. Ben Van Mooy, PI; Woods Hole Oceanographic Institution)

Field Team Members: Zephyr Girard (lead), Hannah Goldberg, Dr. Laura Mota, Rachel Davitt

During the first week of science on LMG2401, the Van Mooy group (**Fig. 4**) has undertaken both water column and sediment trap sampling. We completed sampling of the extended grid for our full suite of measurements, including: lipids, carbohydrates, particulate organic carbon (POC), nutrients, DIC/Alkalinity, oxygen isotopes, and flow cytometry. The extended grid sampling included full depth profiles at four stations, with underway stations between them. On the first day of Process Study 1 in the Palmer Deep, we deployed three Particle Interceptor Traps (PITs), which collect sinking material from 50, 100, and 200 meters for ~24 hours (**Fig. 5**). During the deployment there were issues in ballasting the highflyer – many thanks to the MTs and other support crew for their help in the successful operations! Samples for lipid, carbohydrate, and POC analysis will be collected in triplicate from each PIT depth, as well as gel traps for imaging fecal pellet flux by the Steinberg (C-020) zooplankton group.

Figure 4. Van Mooy Team in the Gerlache Strait (from left to right): Zephyr Girard, Hannah Goldberg, Rachel Davitt, Laura Mota; photo by Meredith Nolan

Figure 5. Deployment of drifting sediment trap at Process Study 1 in the Palmer Deep; photo by Laura Mota

C-019: Phytoplankton (Oscar Schofield, Rutgers, P.I.)

Field Team Members: Heather Forrer (lead), Jake Gessay, Mya Sharpe, Dr. Ahmed El-habashi

The phytoplankton component of the Palmer LTER focuses on understanding the spatial and temporal distributions and physiological ecology of phytoplankton along the WAP. Our field work on this LTER research cruise focuses on maintaining the core phytoplankton time series measurements, including Chlorophyll-a and High Performance Liquid Chromatography (HPLC) phytoplankton accessory pigment measurements, and photosynthetic quantum yields through the use of a Mini FIRe fluorometer (**Fig. 6**). We also compliment these measurements with discrete Imaging Flow Cytobot (IFCB) samples, allowing us to identify and enumerate WAP phytoplankton to genus, and sometimes to species-level. Additionally, we are conducting 48-hour, hourly time-step diel incubations at the process stations with the aim of better understanding the diel variability in the photo physiology of natural populations in the WAP, particularly if the diel variability is controlled by incident conditions or by an endogenous rhythm. Continuous underway ocean color (HyperSAS) optics and additional measurements of the hyper spectral absorption and attenuation of suspended particulate and dissolved matter through a dedicated optics cast complement our suite of measurements.

Thus far, it has been a productive week for the C-019 group. We sampled from 5 CTD casts with complementary optical casts during the extended grid. We also collected 13 underway samples during the transits between CTD stations including 7 high resolution IFCB samples for continuous

underway HyperSAS calibrations. Currently during the first process study, in the northern section (lines 600 – 400), we have commenced our first 48-hour incubation.

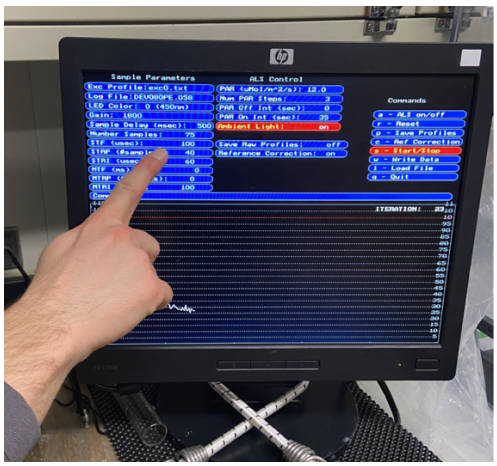

Figure 6. Using the Mini FIRe to construct a Photosynthetic Efficiency (PE) curve.

Hyperspectral measurements of ocean color:
During the Palmer Station Port Call (12/24 – 12/27), a Hyperspectral Acquisition System (HyperSAS) paired with an automated Solar Tracker was installed on the bow of the *Lawrence M. Gould* (**Fig. 7**). The goal of the HyperSAS is to record high-precision measurements of water-leaving spectral radiance and downwelling spectral irradiance in the hyperspectral range. The Solar Tracking capability maintains the correct pointing angle with respect to the sun, and thus permits autonomous operation. This instrument was provided by Heidi Dierssen's COLORS laboratory at U. Connecticut and will help the PAL LTER program and the C-019 laboratory associate ocean color with phytoplankton species and abundance. This data collection is also valuable ground-truthing in support of NASA's upcoming PACE satellite mission.

Figure 7. HyperSAS mounted on ship's bow (left) and sensor on the mast (right).

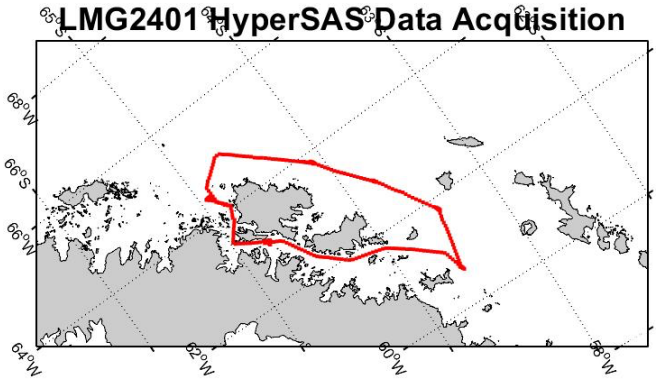

Figure 8. HyperSAS data collection thus far.

The HyperSAS includes three Satlantic/Seabird Hyperspectral Ocean Color Radiometers; one as an Lt sensor (s/n 261), one as an Li sensor (s/n 233), and one as an Es sensor (s/n 602). Both the Lt and Li sensors were installed on a Seabird Solar Tracker (s/n 0007), which was mounted on a

frame made of McMaster T-Slotted rails. The Es sensor was installed on the forward most mast of the Gould to prevent shadowing from the ship's structure (**Fig. 7**). A GPS antenna was attached to the top of the Solar Tracker, which is used to calculate the sun's location to rotate the tracker towards the best viewing angle. A power/telemetry cable was routed from the Boatswain's Locker, through a cable access pipe in the main deck. A logging computer, 12-volt DC power supply, and a Miniature Deck Unit (s/n 305), was installed in the Boatswain's Locker.

Michael Cappola (U. Delaware) planned the assembly and managed the HyperSAS operation and data collection, with shore support from Jessie Turner (U. Connecticut). Extensive help in assembly and was provided by Jake Gessay (U. Delaware), as well as the crew of the *Lawrence M. Gould*. So far, the HyperSAS has recorded 94 hrs. of continuous ocean color spectra, as the ship transited from Palmer Station into the Bransfield Straight and through the Gerlache Strait (**Fig. 8**).

C-020: Zooplankton (Dr. Deborah Steinberg, PI; Virginia Institute of Marine Science)

Field Team Members (Fig. 9): Deborah Steinberg (lead), Joe Cope, Meredith Nolan, Hannah Gossner, and Connor Shea

The objectives of our component in Palmer LTER are to understand the effects of climate change on zooplankton communities along the continental shelf of the west Antarctic Peninsula, and the role that zooplankton community structure plays in biogeochemical cycling of carbon and nutrients and in distribution of predators (penguins, whales). This year M.S. student Meredith Nolan is beginning her thesis research on the cruise, collecting samples and conducting experiments measuring heat shock proteins in krill and other zooplankton. We are also collaborating with the C-045 team to analyze composition of sinking particulate organic matter (POC) collected in the sediment traps, as part of Maya Thomas' Ph.D. thesis, and to analyze lipids in zooplankton and their fecal pellets. In addition to preserving samples along the LTER grid for taxonomic analysis, we will also freeze dominant animals for gut fluorescence and for future physiological measurements.

At each grid station, we perform a pair of net tows, first deploying a 2-m net with 700-µm mesh and then a 1-m net with 335-µm mesh. The larger net captures larger macrozooplankton (e.g., krill, salps), and the smaller net captures smaller mesozooplankton (e.g., copepods). Animals from the macrozooplankton tows are identified and counted on board, while the presence/absence of taxonomic groups is noted in the mesozooplankton samples (these samples will be quantified at our home institution).

In the first week, we completed all four sampling stations in the northern Extended Grid. These samples were dominated by the Antarctic krill *Euphausia superba,* which appears to have a bimodal size distribution this year (both large adults and juveniles) (**Fig. 10**). We found some differences in species composition after we crossed the front (**Figs. 2,3**) including presence of Antarctic Silverfish (*Pleurogramma antarctica*) at stations north of the front that were influenced by Weddell Sea water. Tows at station 600.040, in the Palmer Deep region, were also dominated by *E. superba,* but the salp *Salpa thompsoni* was also abundant. As in past years, during the first Process Study in the Palmer Deep region we conducted a bio-acoustic survey to map out aggregations of krill to explore relationships with whale distribution and penguin foraging

locations. The survey this year was a transect line from station 600.040 toward Palmer Station. Patches of krill were consistently shallow (15-20 m) along the transect, and a tow deployed in a patch detected by acoustics indicated the patches were a mix of *E. superba* and salps. To investigate depth distribution and diel vertical migration of zooplankton, at time of writing we are collecting paired day/night samples in Palmer Deep with the Multiple Opening-Closing Net Environmental Sensing System (MOCNESS). The MOCNESS has eight nets which we open at discrete depth intervals.

Figure 9. Steinberg team about to leave Palmer Station for LTER cruise (from left to right): Joe Cope, Hannah Gossner, Connor Shea, Meredith Nolan, Debbie Steinberg (on cruise), Maya Thomas (at Palmer Station); photo by Laura Mota.

Figure 10. Measuring krill; photo by Debbie Steinberg.

C-013: Seabird Component-LTER (Megan Cimino, PI; UC Santa Cruz and NOAA)

Field Team Members: Allie Northey (lead), Helena Dodge

The objective of C-013's component of this year's cruise is to continue the long-term data set of at-sea bird and mammal surveys to assess abundance and distribution across the LTER regional study grid. In addition, we plan to continue studies of Adélie penguins along the peninsula at Avian Island and if sea ice allows, Charcot Island. We hope to land on Hugo Island and Prospect point as well to get a more recent snapshot of the seabird/penguin populations in those locations.

The first week of bridge-based surveys conducted were along the Extended LTER Grid. For the extended grid, we conducted multiple stationary and transect surveys in which we observed a few large groups of Southern fulmars (**Fig. 11**), Chinstrap penguins in the water, at least two pods of orca whales, and multiple humpback whales. One of the orca whale pods had many Southern fulmars associated with them which was exciting to observe. Other species we have seen so far in the extended grid are giant petrels, Wilson's storm petrels, cape petrels, and black-browed albatross, all in relatively small numbers. We have had great viewing conditions for our bridge-based surveys a look forward to continuing good weather for the Palmer Deep Process Study.

Figure 11: Southern fulmar in flight

C-024: Cetacean Biology & Ecology (Ari Friedlaender, PI; UC Santa Cruz)

Field Team Members: Ross Nichols (lead), Dr. Jennifer Allen

This week, the Whalers began their efforts to conduct bridge surveys of marine mammals. This week, sighting have included heavy concentrations of humpback whales in the Gerlache and Bismark Straits as well as around Palmer Canyon, two sightings of Type B2 Killer Whales (Gerlache Ecotype; **Fig. 12**). Among humpback whales, feeding activities observed have included both surface lunge and bubble net feeding (**Fig. 13**). As well, surface breaching, peduncle throws, pec slapping and spy hopping has been observed among several animals. The whalers have deployed using small boat operations multiple times thanks to the continued support of the ASC/ECO staff and crew to collect photos, biopsy samples, and deploy tags. Photo identification data using fluke imagery has been collected on a total of thirteen humpback whales that will aid in the understanding of the movement and mixing of humpbacks across ocean basins. As well, the whaling group has collected 16 skin-blubber biopsy samples (14 humpback whales, 2 killer whale) that will be used to determine the sex of individuals, hormone markers for health and pregnancy, and will be integrated into our genetic database of over 2,500 samples from the Antarctic Peninsula region since 2010. Our group has also successfully performed 8 flights using our Unmanned Aerial System (drone) used to collect aerial photo and video that can be used for behavioral analyses, and assessment of body size and condition. Lastly, our group was incredibly successful on the evening of the 29th of December, and we successfully deployed two of our non-invasive motion/video/audio suction cup tags on two humpback whales in a group of three that was feeding (**Fig. 14**). These tags provide critical data on the foraging behavior and acoustics of whales in this region and outline times of the day/year when feeding is most important.

Figure 12. Two B2 ecotype killer whales observed north of Trinity Island. This ecotype feeds on penguins and is frequently observed in the Gerlache Strait.

Figure 13. Screenshot from a UAS video of 4 adult humpback whales performing a foraging behavior called Bubble Net feeding, encircling krill with bubbles. Taken near Palmer Station within Arthur Harbor, Antarctica

Figure 14. Motion and video suction cup tag deployed on a humpback whale near Palmer Station. Photo taken from our UAS.