Science Report for Week 3 of LTER 1701.

The LTER 1701 cruise departed Palmer Station on January 6, 2017. After a process study in week 1, the second week focused on mapping the standard sampling grid along the WAP. The progress to data is illustrated in Figure 1 by the red line. We have completed the 600, 500, 400, 300, 200, and 100 standard survey lines. We have also deployed and recovered the penguin team from Avian island. During the birder survey of Avian, the science team conducted both an inshore and offshore process study and collected a high resolution CTD survey of the 200 line to complement the inshore and offshore surveys. The focus of the process study was to compare contrast the night/day vertical migration differences between the coastal and marine end-members within our sampling region. We conducted a coordinated cross calibration of instrumentation onboard the Gould with United Kingdom scientists from Rothera base. After the Rothera station we conducted full station amount of work at ocean station Obama (a station repeatedly occupied over the last eight years). Upon completion, favorable ice allowed us to quickly steam to Charcot Island. Charcot Island is a critical study point, with a penguin colony (rediscovered by the LTER 2009) which is the one truly polar penguin analog within the grid. Heavy ice the prior 4 years did not allow us to visit. The Penguin component to LTER (see below) was able to conduct a full census, and the Gould completed 2 of 3 planned stations. The third station was not conducted as shifts in wind lead us to suspend operations and attempt to leave. Northeast wind has resulted in Gould currently being crowded by ice and the ship has continued attempt to reach open water over the last 6 days.

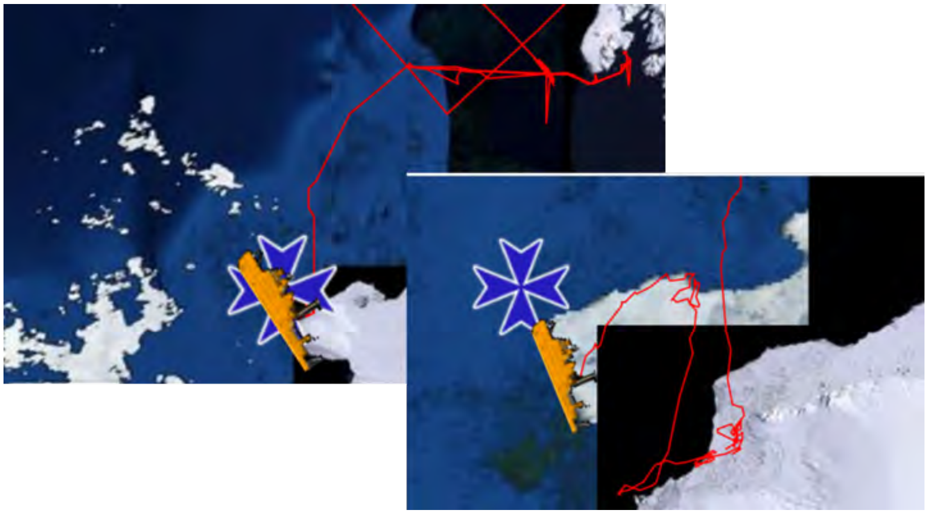

Figure 1. Map of the area covered during the last week of LTER 1701. Note Chacot is in placed over 5-kilometers out place on the digital maps.

C-021. Physical oceanography of the WAP (Douglas Martinson, Lamont Doherty Earth Observatory, Columbia University.

Field team Members: Darren McKee

With the slower schedule provided by the sea ice cover, The team has used the down time to program all of the sensors for this year's mooring array. Here I'll provide a motivation for (and description of) the array. The theoretical background and earlier results are from a manuscript in preparation (*McKee and Martinson*, in prep).

Our previous mooring deployments on the shelf reveal (amongst other things!) the following important properties of the horizontal flow: (1) Coherency between the wind and the current is high, particularly on the time scale of days; (2) the nature of the rotary coherency between the wind and current vectors is primarily of a parallel nature at those periods (along-coast winds strongly affect along-coast currents); (3) about 90% of the variance is depth-invariant (barotropic).

Our idea is that wind forcing is communicated to the currents via shelf waves. These waves are, in many ways, the natural time-dependent response to wind forcing on continental shelves. Qualitatively, if one imagines an impulsive wind burst up-peninsula, that will want to pull water away from the coast in an Ekman-upwelling sense. Because the continental shelf and slope have a topographic gradient, the vorticity of the water pulled away from the coast is changed as it enters deeper water. To conserve vorticity, in the Southern Hemisphere, this means the sea surface height anomaly will propagate with the coast to its left (so, from north to south on the WAP). By geostrophy, the resulting current anomalies associated with the sea surface height anomalies will be in the same direction as the wind forcing.

These waves have been shown to influence sea surface height around Antarctica, particularly at periods longer than about 10 days (e.g., *Kusahara and Ohshima*, 2009). The nature of the response is strong and unique because the continent provides a circumpolar waveguide along with a [potentially] circumpolar forcing. However, the waves have not yet been shown to influence the current at the shelf break. Based on our earlier data, we think the current is strongly affected by these waves: see *figure 2*.

This is important because if you affect the speed of that current, you change the way in which it interacts with curves in the isobaths along the slope and with canyons across the slope. If the current is slow, it may flow past topographic irregularities unaffected. But if the flow is accelerated and the Rossby number is large, the flow will interact with them and upwell onto the shelf. Therefore, the primary goal of this year's mooring array is to sample the shelf break current at three different grid lines: 070, 200, and 625. The horizontal spacing of the moorings and the sample rates of their instruments were chosen so as to resolve theoretical phase speeds of the velocity anomalies from north to south. Two of the moorings will sample currents at two depths (extrema in the baroclinic 1 normal mode), temperature at 15 depths (sufficient to accurately reconstruct vertical heat content), and salinity at 1 depth (at about 30 m so as to document evolution of the winter mixed layer and any latitudinal gradient therein). The third mooring is more sparsely equipped, owing to the inability to recover last year's mooring and turn around those sensors, but is still capable to contribute to our goals. This array of three moorings will work in tandem with the mooring placed by E. Shadwick (VIMS) at site 300.100 which, in addition to her biogeochemical sensors, has one of our current meters on it. That site serves as the 'gateway' of CDW intrusions onto the continental shelf (e.g., *Martinson and McKee*, 2012). Therefore, we will be able to see if the coincident anomalies at the shelf break are communicated onto the shelf-proper.

While this array serves very much as a process experiment, if we are able to provide any conclusive links between shelf and slope processes, we can extend them by proxy to the past. For example, site 300.100 has been occupied by current meter moorings since 2007 with only a few gaps. This will let us look at interannual variability and trends.

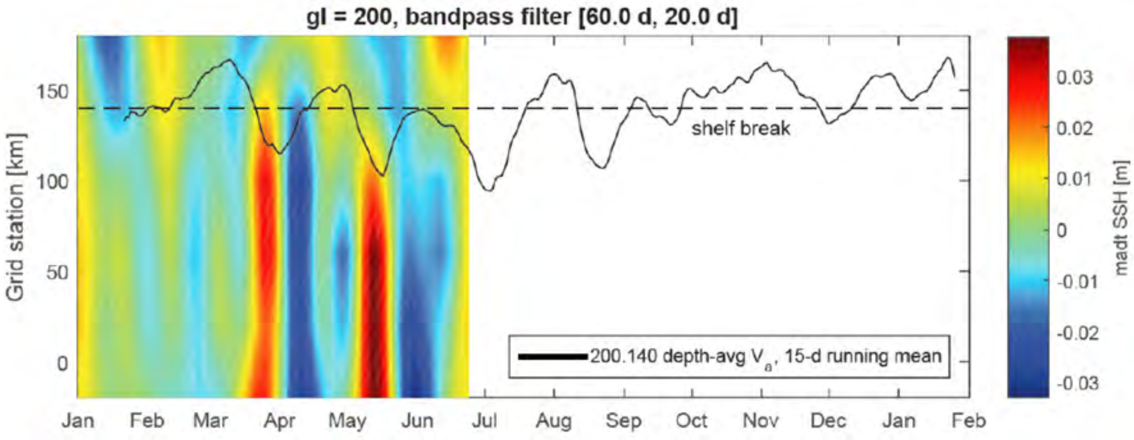

Figure 2: Shelf-wave signature in SSH and currents. Contours indicate time series of bandpass filtered SSH anomalies from altimetry gridded across the 200 line, available when sea ice is not present. Location of shelf break indicated as dashed line. The time series superimposed on the shelf break (units not shown) is a 15-day running mean of depth-averaged, de-tided, along-slope currents constructed from 7 current meters in the vertical at site 200.140 year 2013. Velocity anomalies coincide with SSH anomalies that emanate from the coast.

References:

- Kusahara, K. and Ohshima, K.I.: Dynamics of the Wind-Driven Sea Level Variation around Antarctica. *J. Phys. Oceanogr.*, 39, 658–674, 2009.
- Martinson, D.G. and McKee, D.C.: Transport of warm Upper Circumpolar Deep Water onto the western Antarctic Peninsula continental shelf. *Ocean Sci.*, 8, 433-442, 2012.
- McKee, D.C. and Martinson, D.G.: Wind-control of circumpolar deep water intrusions to the western Antarctic Peninsula shelf: Ekman dynamics and coastally-trapped waves, manuscript in preparation.

C-019: Phytoplankton and Primary Productivity Component (O. Schofield, Rutgers University; PI).

Field Team Members: Oscar Schofield, Paul Falkowski, Darren Mckee, Schuyler Nardelli, Jonathan Sherman, Anjali Suman.

The objective of our component is to obtain a mechanistic understanding of the bio-physical controls that determine the overall primary productivity and phytoplankton community composition along the Western Antarctic Peninsula. Specific focus areas include improved understanding how the interactions between the physics, nutrient availability drive the overall carbon fixation in the upper ocean and how that is related to the structure function of the higher trophic levels. Our routine measurements include discrete measurements of chlorophyll a, chemotaxonomic pigments via high performance liquid chromatography, fluorescence induction and relaxation kinetics to derive estimates of the optical cross section of photosystem II and the maximum quantum yield of electron transport, whole water carbon fixation rates. These discrete measurements are complemented with watercolumn bio-optical profiles of the absorption and attenuation properties at nine wavelengths, optical backscatter at a single wavelength, and chlorophyll and colored dissolved organic matter fluorescence. For this cruise we are also genomic samples (RNA and DNA) for Professor Adrian Marchetti at the University of North Carolina at Chapel Hill.

During the third week of operations we have collected our full suite of water column profiles of discrete measurements at 3 Stations, 2 of which were collected during the bird census at Charcot. These measurements have been complemented with a series deckboard iron addition experiments comparing inshore/offshore. We have found so far during deckboard daily ^{14}C incubations there is significant productivity across the grid, with the daily-integrated rates varying by a factor of 3. Conditions in Charcot yielded productivity in the mean values observed so far across the WAP LTER grid.

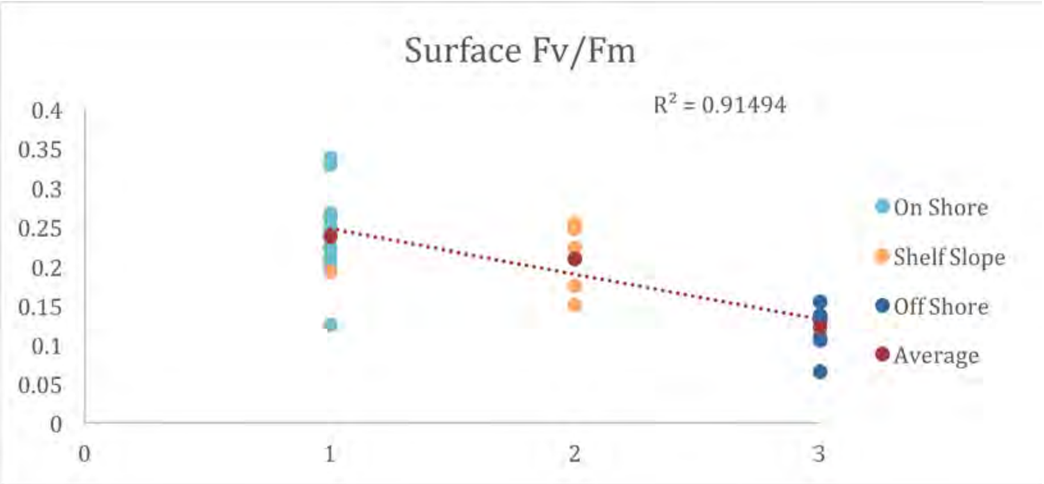

Figure 3. Surface Fv/Fm values from near shore to open water along LTER grid lines. Data obtained with MiniFIRe measurements at grid lines 100-600. X axis- [1] .000 grid point for onshore, [2].100 grid point for shelf slope and [3].200 grid point for off shore. Orange points represent the average for each

Figure 3 shows the cross shelf variability of the surface Fv/Fm measured by the Fluorescence Induction and Relaxation system (FIRe). There two conspicuous features in the figure. First there is a clear negative relationship with overall increasing Fv/Fm decreasing offshore. This is consistent with the standing hypothesis of trace (iron) nutrient limitation on the outer shelf. Another interesting feature is the overall low magnitude of the Fv/Fm ranging from 0.4 to 0.1. Healthy phytoplankton typically have yields closer to 0.6. We analysis possible mechanisms explaining this variability using the single turn-over flashes measurements as data is aggregated after the cruise.

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

Field Team Members: Hugh Ducklow, Naomi Shelton, Mary McElroy, Israela Musan, Tyler Rohr, and Marie Zahn.

As Week 3 began we completed underway sampling on the LTER 100 line, recovered the birders and proceed to Rothera. After Rothera we sampled our Station Obama in central Marguerite Bay, celebrating Obama's "Science Presidency" and his many initiatives to address climate change. Following Station Obama, we headed south, into the ice and toward Charcot Island. We had not been there since 2013, so it was an exciting prospect to be within range for the birders to access the Adelie colony, and for us to repeat several CTD/Net stations we occupied in the past. With recent stations added, we see that 2017 has the second-highest bacterial production in the 2003-17 observation period:

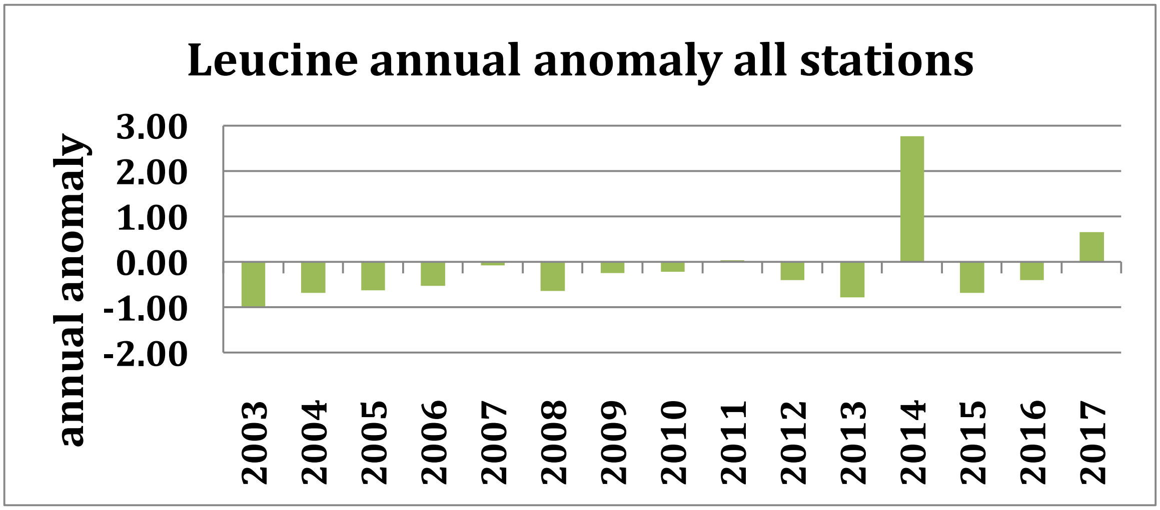

Figure 4. Annual anomalies for bacterial leucine incorporation rates for 2003-17 at LTER grid stations. Few stations south of the 200 line were occupied in 2016 due to heavy ice. This year's survey has not yet been completed.

This week we profile our team members Marie Zahn and Mary McElroy (figure X). Marie graduated with a BA in Environmental Biology from Columbia University in May 2016. Her interests in school were largely in ethnobotany where her undergrad thesis investigated how human relationships with nature—particularly the attitudes of First Nation individuals—influence people’s actions, using western redcedar (*Thuja plicata*) in British Columbia as a case study. Aside from school, she has also maintained a private practice as a manual therapist (a Rolfer) for the past five years. Marie intends to continue her studies in a graduate program but hasn’t decided on a specific research area. However, she is passionate about addressing climate change issues, whether it be through formal research or some form of advocacy or consulting work, perhaps through community outreach and science education. On our cruise, Marie conducts flow cytometric analysis of water samples on the night shift opposite Tyler.

Mary earned her Bachelor's degree in Environmental Biology from Barnard College where she worked with Hugh on her senior thesis investigating iron uptake mechanisms in marine diatoms. She now works as a coordinator and lab manager for undergraduate chemistry teaching labs at Louisiana State University and hopes to begin a PhD program addressing molecular marine ecology topics this fall. For C-045, Mary assists with regular CTD sampling on the LTER grid and manages the day shift for Team Thorium.

Next week: preliminary Thorium results plus Naomi & Hugh!

Figure 5 left: Marie Zahn (left) and Mary McElroy (right). Photo credit Tyler Rohr. Right: from L to R: Mary, Hugh, Marie and Israela.

B-020. Zooplankton Component (D. Steinberg, VIMS; PI)

Field Team Members: Joe Cope, Patricia Thibodeau, Jack Conroy, Kharis Schrage, Katie Westmoreland.

In this third week of the cruise we conducted a day-night pair of MOCNESS tows (Fig. 6) at the offshore/slope (200.200) station that we will compare with MOCNESS tows at the coastal Marguerite Bay (200.000) station. In the offshore MOCNESS (towed 0-1000m, vs. our standard 0-500m we do over the shelf) during the day we found a deep layer (300-400m) of *Rhincalanus gigas* copepods, and also the krill *Euphausia tricantha* (400-750m); salps were mostly between 100-300m. At night the salps migrated into the surface 0-200m and *E. tricantha* was found slightly shallower as well (~300-500m). There were some rare deep-sea amphipods and giant ostracods in the deepest layers (750-1000m) (Fig. 6). We also conducted our standard set of net tows at 200.200, 100.200, station Obama (167.-033), and Charcot Island (both a shallow, nearshore and a deeper canyon station). Of note is an abundance of *E. superba* and the crystal krill *E. crystallorophias* both in shallow waters near Charcot and in the Charcot canyon (I think we know what those penguins on Charcot are eating…) The *E. superba* here were smaller and less mature than those caught elsewhere during the cruise. It was also the first time we caught large numbers of crystal krill. We conducted 2 more fecal pellet production experiments with *E. superba* to compare krill-mediated export along the north-south and coast-offshore gradients.

Figure 6. Deep MOCNESS tow. Left, deploying the MOCNESS; right, a deep-sea amphipod, likely Cyphochyrus sp., collected between 750-1000m. (Photo credits-N. Shelton and D. Steinberg, respectively)

C-013:

PAL-LTER 1701 Cruise. SitRep 3, January 27, 2017

C-013 Seabird Component (W.R. Fraser, PI)

Field Team Members: Darren Roberts and Megan Roberts

The second and third week of the LTER provided opportunities to establish a field camp at Avian Island, as well as the ability to reach Charcot Island to survey the Adélie Penguin colony there. With the help of ASC staff we were able to establish a camp on Avian Island from the 15th to the 20th of January. Our work at Avian is focused primarily on the breeding success and foraging ecology of Adélie penguins, however we were able to use the limited access to the area to collect samples, and census multiple species for localized population dynamics as well as collect data on foraging. The same data is collected at Palmer and makes for a useful analysis of bird nesting and foraging at two sites with different sea ice characteristics on the WAP.

Figure 7. Adélie Penguin colonies at Avian Island.

While on Avian, we conducted breeding colony censuses of Adélie Penguins (Fig. 7), and weighed and measured crèched chicks. This year we will have the opportunity to compare ground counts with aerial images provided by the UAS operations done by the Duke Marine Lab. In order to better understand foraging we approach the problem from multiple angles. Diet samples from 30 adult Adélie penguins were collected in order to look at discreet foraging runs. This data provides interesting insight into foraging at Avian compared to the Palmer area over a short time scale. For long term analysis of fish consumption we collect excrement material from sediment traps to extract fish otoliths that have accumulated over the course of the year. Skuas often predate Adélie Penguin chicks leaving the feet and skeleton intact. These chick feet were collected for stable isotope analysis. This is used as another means of analyzing diets that covers a longer

Figure 8. A white morph of a Southern Giant Petrel with chick.

time span than the diets we collect while on island. We were also able to collect audio recordings of Adélie colonies which will be analyzed by the Duke Marine Lab.

Figure 9. A Blue Eyed Shag on Avian Island.

Full island surveys of nesting Southern Giant Petrels, and Blue Eyed Shags were completed. South Polar Skua fecal samples were collected and will be analyzed for fish otoliths to better understand Skua foraging. We collected boli from Blue Eyed Shags, primarily piscavores, to better understand what fish species are found in the general area, as well as to detect long term changes in Blue Eyed Shag diets. A marine mammal census was also conducted. The vast majority of marine mammals seen on Avian are Southern Elephant seals.

Charcot Island is the site of a small Adélie Penguin colony of which little is known. Sea ice is often a limiting factor for reaching Charcot, and this year we were able to make it to the island. Our goals were to count Adélie Penguin adults, chicks, and active nests. We also planned on weighing and measuring chicks, and collecting guano for diet analysis. The chicks were very far behind the colonies at Avian and in the Palmer area, and were too young to be weighed. In spite of that we were able to get informative data on the number of adults and chicks, as well as a good look at distribution of one chick and two chick nests. Anecdotally snow seemed high this year at Charcot, and this may or may not factor into what we found at the colony. The colony was photographed for review by Dr. Fraser. His analysis will be insightful.

Figure 10. An Elephant seal wallow on Avian Island.

We would like to sincerely thank the ASC staff that helped with the camp set up at Avian, and especially thank Lindsey Loughry, Oscar Schofield, Dave Johnston, and Julian Dale. Ms. Loughry and Dr. Schofield for their support and help achieving our main goal of establishing the camp at Avian Island. Dr. Johnston, and Mr. Dale for integrating the technology they are spearheading into our census and helping us in the daunting task of counting constantly moving animals on an island that is home to well over 120,000 birds.

Figure 11. L. Loughry and M. Roberts survey a portion of the colony on Charcot Island.

B-024 Whale Component (A. Friendlander, Oregon State University; PI)
Field Team Members: David Johnson, Julian Dale.

During the third week of the cruise the cetacean team (David Johnston and Julian Dale) conducted a third set of visual surveys and attempted to conduct UAS operations. UAS opertartions were precluded by unfavorable weather, however, visual surveys for whales generated an additional single sighting of humpback whales from the LMG.

The cetacean team, along with project PIs Hugh Ducklow and Debbie Steinberg, also participated in an opportunistic reconnaissance flight on a BAS Twin Otter over Marguerite Bay and around the shores of Adelaide Island, as part of the existing MOU between Duke University, Oregon State University and the British Antarctic Survey. The flight extended south across Marguerite Bay and along the coast of Alexander Island to assess coastal sea ice conditions towards Charcot Island. During this portion of the flight, one sighting of minke whales deep in pack was made (Figure 12). The second component of the flight was dedicated to a reconnaissance of Adelaide Island coast.

During this component, approximately 30 humpback whales were sighted, many of which appeared to be engaged in bubble net feeding (Figure 13).

Figure 12. Two minke whales surfacing in a lead in the sea ice margin of Marguerite Bay.

Figure 13. The remnants of a bubble net produced by two humpback whales off the coast of Adelaide Island