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Preview of Award 1440435 - Annual Project Report

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Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1440435
Project Title:	LTER Palmer, Antarctica (PAL): Land-Shelf-Ocean Connectivity, Ecosystem Resilience and Transformation in a Sea-Ice Influenced Pelagic Ecosystem
PD/PI Name:	Hugh W Ducklow, Principal Investigator Douglas G Martinson, Co-Principal Investigator
Recipient Organization:	Columbia University
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Accomplishments

* What are the major goals of the project?

The Palmer Long Term Ecological Research (PAL) program seeks to obtain a comprehensive understanding of the Antarctic seasonal sea ice-influenced ecosystem – the climate, plants, microbes, animals, biogeochemical processes, ocean, and sea ice south of the Antarctic Polar Front (northernmost extent of ice-influenced water). Since its inception in 1990, the central hypothesis of PAL has been that the seasonal and interannual variability of sea ice affects all levels of the Antarctic marine ecosystem, from the timing and magnitude of primary production to the breeding success and survival of penguins

and whales. Our site on the western side of the Antarctic Peninsula (WAP) addresses multiple spatial and temporal scales from hemispheric, decadal, climate-relevant scales to regional and local, daily to seasonal, process-relevant scales.

*** What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities:

Cetaceans

To understand the demography (sex ratio, pregnancy rates) and breeding population identity of the whales that utilize the LTER study area as a feeding ground we collect skin and blubber biopsy samples as well as photographs of individual whale flukes. How the foraging behavior and movement ecology of these whales relates to the physical and biological features of the seascape we deploy location-gathering satellite-telemetry tags and link foraging locations with oceanographic data to determine the features that promote the necessary conditions for whales to feed.

At Palmer Station we collected quantitative data on the distribution and abundance of krill in the surrounding via transects areas using scientific echosounders. Over 127 hours of echosounder data were collected on 46 surveys. A total of 66 sightings of 136 humpback whales were made, including 23 calves. Skin and blubber biopsy samples were collected from 62 whales, all of these whales were also photographed and cataloged for individual identification. On the LMG, an additional 37 biopsy samples were collected and 7 satellite-linked location tags were deployed on humpback whales.

Seabirds

For the past two field seasons, the Seabird Component of the PAL-LTER has coordinated its activities through a collaboration with Dr. Josh Kohut, Lead PI for NSF award ANT 1326167, Impacts of Local Oceanographic Processes on Adélie Penguin Foraging Ecology Over Palmer Deep, otherwise recognized as the CONVERGE project. This project tests the hypothesis that oceanographic processes associated with Palmer Deep off Anvers Island create a regional hotspot that enhances the availability of prey to top predators, and as a result disproportionately affects key aspects of their ecology and biogeography. The CONVERGE project is a multi-platform field study that integrates a host of sophisticated ocean observing technologies with animal telemetry such that the latter in effect guides the real-time sampling of the former to develop 3-D profiles of the physical and biological marine environment in which predators are foraging. In this context, the major activities of the 2014/15 season included: deploying an oceanographic mooring at the most shoreward arm of the Palmer Deep that included acoustic sampling capabilities, establishing a High Frequency Radar (HFR) coastal surface current mapping network to investigate local circulation patterns over Palmer Deep (Fig. 1, 2), deploying five underwater gliders to inform and enhance oceanographic sampling of the predator foraging environment, completing 17 small-boat acoustic surveys targeting krill, deploying ARGOS-linked satellite telemetry and time-depth recorders (TDRs) on 22 Adélie and gentoo penguins to inform glider missions and obtaining 54 Adélie and gentoo diet samples to determine predator diet composition for comparison with acoustic and net sampling efforts.

Phytoplankton

Efforts focused on maintaining the LTER time-series, conducting glider missions, and providing complementary support to other NSF and NASA programs. A series of temperature experiments defined the temperature sensitivity of phytoplankton photophysiology at Palmer Station. During the last year, 3 Webb gliders were deployed over multiple missions, sampling 1940 kms over 99 days at sea.

Physical Oceanography

Shipboard CTD casts were acquired, processed and sent to the relevant scientific community databases. Our 4 moorings were successfully recovered (several instruments on one mooring were lost to the Gould's prop during recovery), serviced and redeployed.

Climate and sea ice

Efforts this past year were focused on understanding how regional and seasonal air-sea-ice interactions led to yet another year of record-breaking high sea ice extents in Antarctica (Fogt and Stammerjohn, 2015). Work continued on modeling ice-ocean-ecosystem interactions and the investigation of the role of deep ocean heat on sea ice dynamics (Saenz et al, drafted). We also continue to contribute to ongoing investigations of the ice-climate system on space/time scales relevant to polar marine ecology (Ducklow et al., 2015; Kavanaugh et al, 2015; Steinberg et al., 2015).

Microbial ecology and biogeochemistry

PhD student Hyewon Kim is focusing her thesis research on detailed time series analysis of bacterial production rates nutrients and dissolved organic matter for the 1992-2014 Palmer Station B,E datasets. PhD Student Cat Luria completing her thesis on microbial diversity in the LTER region. Postdoctoral fellow Jeff Bowman is investigating bacterial diversity and dynamics (see Findings). In collaboration with Nicolas Cassar (Duke Univ), we obtained high spatiotemporal resolution data on Oxygen/Argon distributions, in order to estimate net community production rates in the region. We also obtained experimental estimates of particle export from determinations of the Uranium-238/Thorium-234 disequilibrium.

Zooplankton

This season the zooplankton group again emphasized the role that zooplankton play in carbon and nutrient cycling, long-term changes in zooplankton community structure. This year we focused our efforts on the cruise sampling ice-edge zooplankton communities– shallower waters near the ice edge vs. ice-free, deep canyon waters in Marguerite Bay and near Charcot Island– to examine plankton community structure changes, and how this may affect biogeochemical cycling in these environments. In addition, we made a effort to complete the analysis of grazing and long-term changes in the copepod population (findings described below). Graduate student Miram Gleiber defended her M.S. thesis in summer 2014, and a new Ph.D. student working in the PAL LTER program, Patricia Thibodeau, started in my laboratory in fall 2014. Undergraduate student John Conroy analyzed ocean temperature-salp abundance relationships. The macrozooplankton on-line data are now up to date through 2014 on the Data zoo website.

Synthesis and modeling

Analyses were completed on seawater inorganic carbon measurements and end-to-end foodweb dynamics using an inverse modeling framework. Numerical modeling studies were conducted across a hierarchy of model resolution scales exploring ocean-atmosphere-sea ice dynamics (1-D water column model), regional physical circulation (Regional Ocean Model System, ROMS), and the impact of climate change on Southern Ocean biogeochemistry (Community Earth System Model).

Information Management

During the previous 1314 reporting period, the PAL LTER Information Management group revamped our local data management infrastructure in order to create a more stable long-term environment to improve the support of local science as well as improving broader access and availability of research data. This was done with the development of new databases, workflow protocols, standardized data processing scripts and documentation. The developments have been successfully utilized in this most recent reporting period, 1415. Processing and making data public has become more efficient, error-correction and dataset maintenance records have been supported by our process-tracking database and projects to improve data integration across relational datasets have been made possible. In addition, standardized data submission forms were developed and introduced (with iterations of improvement) and are currently being used to support more consistent and easier data documentation by the research community. System documentation efforts are currently underway to protect against information loss and preserve continuity through personnel turnover, as well as community-accessible documentation through the website to provide a reference for both current and new members of the scientific community.

Specific Objectives:

The specific objectives of this award are to answer the following questions with a strategically-designed program of oceanographic and ecological observations and experiments conducted at Palmer Station and along the western Antarctic Peninsula.

1. **Long-term change and ecosystem transitions.** What is the sensitivity or resilience of the ecosystem to external perturbations as a function of the ecosystem state?
2. **Lateral connectivity and vertical stratification.** What are the effects of lateral transports of freshwater, heat and nutrients on local stratification and productivity and how do they drive changes in the ecosystem?
3. **Top-down controls and shifting baselines.** How is the ecosystem responding to the cessation of whaling and subsequent long-term recovery of whale stocks?
4. **Foodweb structure and biogeochemical processes.** How do temporal and spatial variations in foodweb structure influence carbon and nutrient cycling, export, and storage?

Significant Results:

Cetaceans

Whale feeding aggregations were composed of multiple haplotypes, suggesting group-feeding behaviors, or associations are not based exclusively on maternal kin. We confirmed significant genetic differentiation between the AP and each of the breeding grounds except Colombia and a large apportionment from the AP to Colombia with a small apportionment to French Polynesia/Samoa, supporting a strong connection between a breeding ground and feeding area. Connectivity to French Polynesia was documented by an individual genotype match from the AP in the Society Islands, the first genotype match of French Polynesia to a feeding area.

We treated state-space filtered satellite location data from 17 humpback whales as first-order time-homogenous Markov chains to produce estimates of relative density and distribution across the WAP (**Fig. 1**, Feb-May 2013), revealing that humpbacks also use the southern portions of the WAP extensively during the summer months, including several bays and fjords.

Seabirds

Real-time surface current maps and an adaptive sampling effort provided unprecedented high resolution data on the influence of local tidal and other oceanographic processes on penguin foraging ecology. Although during strong storms currents were coherent with uniform flow across the foraging domain (Fig. 2a), the majority of current maps exhibited features such as eddies and fronts (**Fig. 2b**) that were likely important prey-concentrating mechanisms. Tagged Adélie penguins foraged towards a convergent feature associated with a front (Fig. 2c) and at the offshore edge of a coastal current (**Fig. 2d**). Analysis of Adélie penguin diving behavior during these foraging trips suggests that foraging strategies change near frontal regions, with individuals diving deeper in downwelling regions than in upwelling regions. This new observation, and the fact that strong storms may obscure frontal signatures (**Fig. 2a**) to foraging penguins, help us understand the factors that may drive variability between annual Adélie penguin foraging performance and breeding season success. If Adélie penguins rely on detecting frontal structures to locate prey, for example, and storm events obscure these features, breeding success may diminish accordingly through effects on parental foraging efficiency.

Phytoplankton

We found consistent spatial patterns of upper circumpolar deep water (UCDW) associated with deep bathymetric depressions. UCDW eddies were on the order of 10 km and contribute 10-33% of the heat flux required to balance the heat budget of the WAP. 8 years of glider data indicate that there is a robust relationship between the upper mixed layer depth and phytoplankton biomass (**Fig 3**). This relationship was consistent with data collected in the Amundsen and Ross seas, suggesting some broad parameterizations may be applied across Southern Ocean. Lower temperatures result in the phytoplankton showing high light photophysiological responses, consistent with cellular responses in terrestrial plants. Low phytoplankton biomass summers had a recurrent shift toward phytoplankton biomass dominated by flagellated cryptophytes, consistent with modeling studies and suggesting a potential shift to multivorous food web.

Physical Oceanography

Currents on the shelf adjacent to Marguerite Trough are coherent with the along-slope wind stress over a continuum of time scales (**Fig 4**). In the weather-band, the wind response is explained by canyon-upwelling theory. Seasonally, as the wind nears zero in April there is a velocity minimum and a collapse in stratification. This is interpreted as reduced upwelling and, therefore, reduced non-linear advection terms, consistent with observed relaxation towards linear potential-vorticity-conserving f/H contours. A glider and stability analysis reveal that UCDW intrudes as boluses with scales and vertical structure set by baroclinic instability in the shelf-break jet.

Climate and sea ice

Year 2014 was another sea ice record breaker, surpassing records in 2012 and 2013. The new record high for maximum winter sea ice extent was 20×10^6 km² in September 2014, 4 st dev above the 1981–2010 mean. The main regional contributors were the Weddell Sea in autumn and the Indian Ocean and Ross Sea in late winter and early spring. There is a marked regional nature to the atmospheric circulation anomalies, with air temperatures fluctuating frequently across the continent. For the WAP, 2014/15 saw an average ice season. Summer sea ice extent was average but high compared to 4 of the last 5 years (**Fig 5 left**), while autumn sea ice extent was well below average, followed by an average winter and spring. Time series of ice season duration for three coastal WAP regions shows the last 4-5 years with increasing ice

season duration and a marked reversal to the long-term decreasing trend (**Fig 5, right**). 4 years of grid-wide $\delta^{18}\text{O}$ data show marked yearly variability in *in situ* sea ice melt. $\delta^{18}\text{O}$ data from the higher latitude Amundsen Sea (AS) reveals substantially less net *in situ* sea ice melt but substantially greater accumulation of meteoric water. Both the WAP and AS continental shelves are bisected by deep troughs and both are experiencing relatively high glacial meltwater inputs.

Microbial ecology and biogeochemistry

We introduced the concept of metabolic inference; the systematic prediction of metabolism from phylogeny, and describe a complete pipeline (PAPRICA) for predicting the metabolic pathways likely to be found in a collection of 16S rRNA gene phylotypes. We applied this framework to 16S rRNA gene libraries from the LTER region, including surface and deep summer samples and surface winter samples. We found that metabolic structure differed between summer surface and winter and deep samples. While taxonomic variance between samples was primarily driven by low abundance taxa, metabolic variance was attributable to both high and low abundance pathways (**Fig. 6**). This suggests that clades with a high degree of functional redundancy can occupy distinct adjacent niches. Overall our findings demonstrate that inferred metabolism can be used in place of taxonomy to describe the structure of microbial communities.

Zooplankton

We investigated long-term trends (1993-2013) in copepod abundance and their relationships with sea ice, phytoplankton biomass and productivity, climate indices, and sea surface temperature. Copepods comprised on average 81% of total mesozooplankton abundance in the WAP; the copepod community was dominated by a few species that included *Metridia gerlachei*, *Oithona* spp., and *Calanoides acutus*. There was a significant long-term increase in total copepod abundance over time, with higher abundances in years with earlier sea ice retreat and higher phytoplankton biomass and productivity. Grazing and fecal pellet production experiments with the large dominant copepods (*Calanus propinquus*, *Rhincalanus gigas*, and *C. acutus*) revealed that copepods remove <1% of phytoplankton biomass (<1%) and 1-11% of daily productivity. Fecal pellet production rates were high; however ~58% of fecal pellets are retained in the surface layer. Daily carbon rations of ~1% indicated copepods fed on other carbon sources (protozoans and metazoans) to meet metabolic demands. However, during a phytoplankton bloom in 2014, grazing rates and daily C rations increased to 13%, indicating increased reliance on phytoplankton (**Fig 7**).

Synthesis and modeling

We found large variations in inorganic carbon consistent with freshwater inputs, seasonal biological carbon drawdown, and Upper Circumpolar Deep Water upwelling (**Fig. 8**). We also found substantial differences in reconstructed food-web dynamics and biogeochemistry between high and low chlorophyll regimes. We argue from model projections that future warming, stronger winds and increased open-ocean upwelling will cause marine export production to increase near Antarctica.

Key outcomes or Other achievements:

*** What opportunities for training and professional development has the project provided?**

PAL is currently training and supporting or providing research opportunities for 3 Postdoctoral Fellows, 12 PhD and 1 MSc students. We also hosted 8 undergraduate or recently graduated college students on our cruises and/or at Palmer Station

and in our laboratories.

Participation in the LTER Network also affords numerous opportunities for continuing education and career development. For example, the PAL LTER Information Manager, James Conners, continues to serve on the Information Management Executive Committee. Both James Conners and Jesse "Scott" Gordon attended the 2014 Information Management Meeting (Frisco, Colorado – concurrent w/ ESIP Federation Conference) in July of 2014. James Conners contributed to the Spring, 2014 LTER Databits issue with an article describing local experiences in data integration. In October 2014, James Conners represented PAL LTER, as a member of selected data managers and technologists at Scripps Institution of Oceanography, during a two-day meeting with representatives from Vietnam Ocean Data and Information Center (VODIC) to provide this group with consulting and an overview of current ocean data management systems.

*** How have the results been disseminated to communities of interest?**

Results have been disseminated through the traditional scientific outlets including peer-reviewed journal articles and book chapters, oral and poster presentations at regional and national meetings, and invited seminars at universities and research institutions. We have also presented our results to the public through various outlets including live videoconferences from Antarctica to K-12 schoolrooms. A professionally-produced feature film about our project, "Antarctic Edge-70 South" had its public theatrical screen premiere in New York and Los Angeles this spring. The film, directed and created under a NSF award to Dena Seidel, Rutgers University, is currently available on Netflix, Amazon Prime and iTunes. It has won several awards including best film at the Princeton Environmental Film Festival.

We have a new Education & Outreach Coordinator, **Janice McDonnell**, Rutgers University, who will be taking over from Beth Simmons. Janice and her team have many years of experience in Ocean Science outreach and will bring new contacts, tools and information to Palmer LTER. The following, extracted from another report, is an example of the sorts of activities she is planning. This work also involved PAL PI Bill Fraser.

The broader impacts integrated educators and over 950 students from 22 different schools grades 6-9 from NY and NJ into our science team. We had a broad range of educators participate including educators from a special needs magnet school as well as high performing STEM schools in the states of NY-NJ. We introduced these educators to the science and technology used over our field season during a week-long workshop held at Rutgers in August of 2014. With participation from the project scientists, the teachers were given tools to bring project CONVERGE to their students over the 2014-2015 school year. We presented the same materials to this broad range and entrusted them to modify, adapt and create new material that met their particular students needs. Consequently, all students participated productively in the project and were not insulted by predetermined grade band labels on the materials they worked with for the project.

In January the teachers and students virtually participated in the science with the deployed science team through a blog and a series of video connections. We published 28 posts that feature 249 photos and just over 30,000 words (see coseenow.net/converge). The blog has had 495 comments, including both questions and the answers we provided just over 52,261 page views with 7,877 users.

Students following the blogs also interacted directly with the scientist through 12 30-minute blackboard session VTCs. We also conducted two 1-hour VTCs with the general public via the Cornell Lab of Ornithology. They've attracted 4,882 total views so far (view count is growing because people are viewing archived videos of the sessions). We had 5,000 people log into the Cornell VTCs. We reached close to 7000 people through the VTCs conducted for CONVERGE. We would like to thank the incredible effort of Jeff Otten who supported the technical aspects of the call.

In April of 2015 we invited the students and teachers to share their own CONVERGE related science during a one-day science symposium hosted at Liberty Science Center in Jersey City New Jersey. The Project CONVERGE Student Research Symposium provided an opportunity for the students, who have been following and participating in the research, to present their own research projects related to this work and receive feedback from their peers and scientists. In addition, the scientists for the project participated in the symposium, sharing their own experiences and recent results with the students. Students working individually or in small groups submitted 165 proposals that resulted in student research projects and Science Fair like poster presentations. **Approximately 46% of the students used CONVERGE scientific data collected by the scientists for their investigations and poster. Of the proposals that used CONVERGE data: 31% used krill data from the biologist Dr. Kim Bernard, 27% used CODAR data from Dr. Josh Kohut and Dr. Peter Winsor, 27% used**

penguin data from Dr. Bill Fraser, and 16% used glider data from Dr. Matt Oliver. These results show significant progress in our objective to provide authentic inquiry as an important mechanism to develop interest in, motivation for, and identity with respect to science.

Next steps: The Palmer LTER Education and Public Outreach team, led by McDonnell will: 1) build capacity of LTER scientists in communicating and engaging with diverse audiences; 2) create scalable, in-person and virtual opportunities for educators and students to engage with Palmer LTER scientists and their research through data visualizations, data activities, educator workshops, webinars, and student research symposia; and 3) evaluate the outcomes of our education and outreach work and contribute to our broader understanding of science education practices. The majority of our efforts will go to designing and developing authentic data investigations using polar data from Palmer LTER that will be used in formal context (grades 6-16) and informally through partnerships with informal learning institutions and university Extension programs. We will work with expert science communicators to share Palmer research with public audiences.

*** What do you plan to do during the next reporting period to accomplish the goals?**

We will continue field research in Antarctica and in our labs, participate in educational programs at all levels, and pursue new outlets for public education.

Supporting Files

Filename	Description	Uploaded By	Uploaded On
figures for 2015 report.pdf	Graph plots in support in Significant Results (pdf)	Hugh Ducklow	08/11/2015

Products

Books

Harris, C.M. and Lorenz, K. and Fishpool, L.D.C. and Lascelles, B. and Cooper, J. and Coria, N.R. and Croxall, J.P. and Emmerson, L.M. and Fijn, R.C. and Fraser, W.R. and Jouventin, P. and LaRue, M.A. and Le Maho, Y. and Lynch, H.J. and Naveen, R. and Patterson-Fraser, D.L. and Peter, H.-U. and Poncet, S. and Phillips, R.A. and Southwell, C.J. and van Franeker, J.A. and Weimerskirch, H. and Wienecke, B. and Woehler, E.J. (2015). *Important Bird Areas in Antarctica 2015* Cambridge. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Book Chapters

Constable, A., Costa, D., Murphy, E., Hofmann, E., Schofield, O., Press, A., Johnson, N.M. and Newman, L. (2014). Assessing Status and Change in Southern Ocean Ecosystems. *Biogeographic Atlas of the Southern Ocean* C., De Broyer and P., Koubbi and H.J., Griffiths and B., Raymond and d', Udekem d'Acoz C.. Scientific Committee on Antarctic Research. Cambridge. 404-407. Status = PUBLISHED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes

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Conference Papers and Presentations

Inventions

Journals

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Licenses

Other Products

Audio or Video Products.

Feature film "Antarctic Edge-70 South" distributed by Netflix, iTunes, Amazon Prime, and theatrical screens in NYC, LA and several international film festivals. DVD available from First Run Productions, INC, NYC

Other Publications

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Websites

Palmer Antarctica Long Term Ecological Research Project

<http://pal.lternet.edu>

Project website listing project personnel, describing research and education activity, and archiving and serving data

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Ducklow, Hugh	PD/PI	3
Martinson, Douglas	Co PD/PI	3
Conners, James	Co-Investigator	6
Doney, Scott	Co-Investigator	2
Fraser, William	Co-Investigator	3
Friedlaender, Ari	Co-Investigator	6
McDonnell, Janice	Co-Investigator	2
Schofield, Oscar	Co-Investigator	2
Stammerjohn, Sharon	Co-Investigator	3
Steinberg, Deborah	Co-Investigator	5
Bowman, Jeff	Postdoctoral (scholar, fellow or other postdoctoral position)	5
Kavanaugh, Maria	Postdoctoral (scholar, fellow or other postdoctoral position)	4
Saenz, Ben	Postdoctoral (scholar, fellow or other postdoctoral position)	3
Fraser, Donna	Other Professional	3
Cook, Ben	Technician	5
Cope, Joseph	Technician	6
Farry, Shawn	Technician	5
Haskins, Christina	Technician	3
Iannuzzi, Richard	Technician	6
Lima, Ivan	Technician	1

McAtee, Carrie	Technician	5
Shelton, Naomi	Technician	9
Swaim, Zach	Technician	2
Waite, Nicole	Technician	4
Johnston, David	Staff Scientist (doctoral level)	3
Read, Andrew	Staff Scientist (doctoral level)	2
Carvalho, Ana Filipa	Graduate Student (research assistant)	6
Couto, Nicole	Graduate Student (research assistant)	6
Kim, Hyewon	Graduate Student (research assistant)	12
McKee, Darren	Graduate Student (research assistant)	12
Pickett, Erin	Graduate Student (research assistant)	6
Rohr, Tyler	Graduate Student (research assistant)	6
Schultz, Cristina	Graduate Student (research assistant)	6
Seth-Pasricha , Mansha	Graduate Student (research assistant)	2
Sontag, Philip	Graduate Student (research assistant)	2
Stone, Joshua	Graduate Student (research assistant)	2
Thibodeau, Patricia	Graduate Student (research assistant)	12
Kaplan, Rachel	Non-Student Research Assistant	5
Sullivan, Conor	Non-Student Research Assistant	5
Conroy, John	Undergraduate Student	6
Crews, Laura	Undergraduate Student	2
Floedino, James	Undergraduate Student	4
Mac, Frank	Undergraduate Student	3
Ordovas-Montanes, Maria	Undergraduate Student	2

West, Leigh	Undergraduate Student	2
Miner, Kimberly	Other	2
Vario, Chelsea	Other	2

Full details of individuals who have worked on the project:**Hugh W Ducklow****Email:** hducklow@ldeo.columbia.edu**Most Senior Project Role:** PD/PI**Nearest Person Month Worked:** 3**Contribution to the Project:** Principal Investigator**Funding Support:** Institutional support**International Collaboration:** No**International Travel:** No

Douglas G Martinson**Email:** dgm@ldeo.columbia.edu**Most Senior Project Role:** Co PD/PI**Nearest Person Month Worked:** 3**Contribution to the Project:** Co-investigator**Funding Support:** This award**International Collaboration:** No**International Travel:** No

James Conners**Email:** jconners@ucsd.edu**Most Senior Project Role:** Co-Investigator**Nearest Person Month Worked:** 6**Contribution to the Project:** Information Manager**Funding Support:** Scripps Inst of Oceanography**International Collaboration:** No**International Travel:** No

Scott Doney**Email:** sdoney@whoi.edu**Most Senior Project Role:** Co-Investigator**Nearest Person Month Worked:** 2**Contribution to the Project:** data synthesis and numerical modeling

Funding Support: Woods Hole Oceanographic Institution

International Collaboration: No

International Travel: No

William Fraser

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Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 3

Contribution to the Project: Leads all work related to seabird investigations

Funding Support: Polar Oceans Research Group

International Collaboration: No

International Travel: No

Ari Friedlaender

Email: ari.friedlaender@oregonstate.edu

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 6

Contribution to the Project: Leads all work related to marine mammal investigations

Funding Support: Oregon State University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Janice McDonnell

Email: mcdonnel@marine.rutgers.edu

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 2

Contribution to the Project: Education & Outreach Coordinator

Funding Support: Rutgers University

International Collaboration: No

International Travel: No

Oscar Schofield

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Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 2

Contribution to the Project: Leads all work related to phytoplankton investigations

Funding Support: Rutgers University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Sharon Stammerjohn

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Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 3

Contribution to the Project: research on sea ice and climate

Funding Support: University of Colorado

International Collaboration: No

International Travel: No

Deborah Steinberg

Email: debbies@vims.edu

Most Senior Project Role: Co-Investigator

Nearest Person Month Worked: 5

Contribution to the Project: Leads all work related to zooplankton investigations

Funding Support: Virginia Institute of Marine Science

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Jeff Bowman

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Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)

Nearest Person Month Worked: 5

Contribution to the Project: research on microbial diversity

Funding Support: Columbia University

International Collaboration: No

International Travel: No

Maria Kavanaugh

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Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)

Nearest Person Month Worked: 4

Contribution to the Project: data synthesis and numerical modeling

Funding Support: Woods Hole Oceanographic Institution

International Collaboration: No

International Travel: No

Ben Saenz

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Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)

Nearest Person Month Worked: 3

Contribution to the Project: research on sea ice and climate

Funding Support: University of Colorado

International Collaboration: No

International Travel: No

Donna Fraser

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Most Senior Project Role: Other Professional

Nearest Person Month Worked: 3

Contribution to the Project: Data Management

Funding Support: Polar Oceans Research Group

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 5 days; Antarctica - 0 years, 3 months, 0 days

Ben Cook

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Most Senior Project Role: Technician

Nearest Person Month Worked: 5

Contribution to the Project: Field Technician

Funding Support: Polar Oceans Research Group

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 5 days; Antarctica - 0 years, 5 months, 0 days

Joseph Cope

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Most Senior Project Role: Technician

Nearest Person Month Worked: 6

Contribution to the Project: Field and laboratory Technician

Funding Support: Virginia Institute of Marine Science

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Shawn Farry

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Most Senior Project Role: Technician

Nearest Person Month Worked: 5

Contribution to the Project: Field Team Leader

Funding Support: Polar Oceans Research Group

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 5 days; Antarctica - 0 years, 5 months, 0 days

Christina Haskins

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Most Senior Project Role: Technician

Nearest Person Month Worked: 3

Contribution to the Project: Assisted in project field logistics & glider missions

Funding Support: Rutgers University

International Collaboration: No

International Travel: No

Richard Iannuzzi

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Most Senior Project Role: Technician

Nearest Person Month Worked: 6

Contribution to the Project: programmer

Funding Support: Columbia University

International Collaboration: No

International Travel: No

Ivan Lima

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Most Senior Project Role: Technician

Nearest Person Month Worked: 1

Contribution to the Project: data synthesis and numerical modeling

Funding Support: Woods Hole Oceanographic Institution

International Collaboration: No

International Travel: No

Carrie McAtee

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Most Senior Project Role: Technician

Nearest Person Month Worked: 5

Contribution to the Project: Field Technician

Funding Support: Polar Oceans Research Group

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 5 days; Antarctica - 0 years, 5 months, 0 days

Naomi Shelton

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Most Senior Project Role: Technician

Nearest Person Month Worked: 9

Contribution to the Project: Field and laboratory Technician

Funding Support: Columbia University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 4 months, 0 days

Zach Swaim

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Most Senior Project Role: Technician

Nearest Person Month Worked: 2

Contribution to the Project: field team participant and data management

Funding Support: Duke University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Nicole Waite

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Most Senior Project Role: Technician

Nearest Person Month Worked: 4

Contribution to the Project: Assisted in field work at Palmer Station

Funding Support: Rutgers University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 4 months, 0 days

David Johnston

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Most Senior Project Role: Staff Scientist (doctoral level)

Nearest Person Month Worked: 3

Contribution to the Project: field team participant and data management

Funding Support: Duke University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Andrew Read

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Most Senior Project Role: Staff Scientist (doctoral level)

Nearest Person Month Worked: 2

Contribution to the Project: field team participant and data management

Funding Support: Duke University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Ana Filipa Carvalho

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Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: Works of data and gliders for PhD

Funding Support: Rutgers University

International Collaboration: Yes, Portugal

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Nicole Couto

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Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: Works of data and gliders for PhD

Funding Support: Teledyne Webb Research

International Collaboration: No

International Travel: No

Hyewon Kim

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Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 12

Contribution to the Project: research on biogeochemistry

Funding Support: Columbia University

International Collaboration: Yes, Korea, Republic Of

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Darren McKee

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Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 12

Contribution to the Project: research on physical oceanography

Funding Support: Columbia University

International Collaboration: No

International Travel: No

Erin Pickett

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Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: Using project data for MSc.

Funding Support: Polar Oceans Research Group

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 3 days; Antarctica - 0 years, 2 months, 0 days

Tyler Rohr

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Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: data synthesis and numerical modeling

Funding Support: Woods Hole Oceanographic Institution

International Collaboration: No

International Travel: No

Cristina Schultz

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Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: data synthesis and numerical modeling

Funding Support: Woods Hole Oceanographic Institution

International Collaboration: No

International Travel: No

Mansha Seth-Pasricha

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Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 2

Contribution to the Project: Assisted in field work onboard the LMG

Funding Support: Rutgers University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Philip Sontag

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Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 2

Contribution to the Project: Assisted in field work onboard the LMG

Funding Support: Rutgers University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Joshua Stone

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Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 2

Contribution to the Project: Assisted in field work onboard the LMG

Funding Support: Virginia Institute of Marine Science

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Patricia Thibodeau

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Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 12

Contribution to the Project: Field and laboratory work for PhD

Funding Support: Virginia Institute of Marine Science

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Rachel Kaplan

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Most Senior Project Role: Non-Student Research Assistant

Nearest Person Month Worked: 5

Contribution to the Project: Field and laboratory Technician

Funding Support: Columbia University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 6 months, 0 days

Conor Sullivan

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Most Senior Project Role: Non-Student Research Assistant

Nearest Person Month Worked: 5

Contribution to the Project: Field and laboratory Technician

Funding Support: Columbia University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 6 months, 0 days

John Conroy

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Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 6

Contribution to the Project: Assisted in field work onboard the LMG, and lab at home institution

Funding Support: Virginia Institute of Marine Science

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Laura Crews

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Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 2

Contribution to the Project: data synthesis and numerical modeling

Funding Support: Woods Hole Oceanographic Institution

International Collaboration: No

International Travel: No

James Floredino

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Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 4

Contribution to the Project: Assisted in field work at Palmer Station

Funding Support: Rutgers University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 4 months, 0 days

Frank Mac

Email: fmm63@scarletmail.rutgers.edu

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 3

Contribution to the Project: Assisted in field work at Palmer Station

Funding Support: Rutgers University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 4 months, 0 days

Maria Ordovas-Montanes

Email: m.ordov@yahoo.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 2

Contribution to the Project: data synthesis and numerical modeling

Funding Support: Woods Hole Oceanographic Institution

International Collaboration: No

International Travel: No

Leigh West

Email: ltw2110@columbia.edu

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 2

Contribution to the Project: Field team member

Funding Support: Field and laboratory Technician

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Kimberly Miner

Email: kimberleyrain@gmail.com

Most Senior Project Role: Other

Nearest Person Month Worked: 2

Contribution to the Project: Field team member

Funding Support: Columbia University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

Chelsea Vario

Email: Chelsea.L.Vario@dartmouth.edu

Most Senior Project Role: Other

Nearest Person Month Worked: 2

Contribution to the Project: Field team member

Funding Support: Columbia University

International Collaboration: No

International Travel: Yes, Chile - 0 years, 0 months, 4 days; Antarctica - 0 years, 2 months, 0 days

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Alfred-Wegener Institute for Polar and Marine Research	Other Organizations (foreign or domestic)	Bremerhaven Germany
British Antarctic Survey	Other Organizations (foreign or domestic)	Cambridge, UK
Cornell University	Academic Institution	Ithaca, NY
Detroit Zoological Society	Other Nonprofits	Detroit, MI
Duke University	Academic Institution	Durham, NC

Full details of organizations that have been involved as partners:

Alfred-Wegener Institute for Polar and Marine Research

Organization Type: Other Organizations (foreign or domestic)

Organization Location: Bremerhaven Germany

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

British Antarctic Survey

Organization Type: Other Organizations (foreign or domestic)

Organization Location: Cambridge, UK

Partner's Contribution to the Project:

Facilities
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution:

Cornell University

Organization Type: Academic Institution

Organization Location: Ithaca, NY

Partner's Contribution to the Project:

Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution:

Detroit Zoological Society

Organization Type: Other Nonprofits

Organization Location: Detroit, MI

Partner's Contribution to the Project:

Financial support

Collaborative Research

Personnel Exchanges

More Detail on Partner and Contribution:

Duke University

Organization Type: Academic Institution

Organization Location: Durham, NC

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

What other collaborators or contacts have been involved?

Nothing to report

Impacts

What is the impact on the development of the principal discipline(s) of the project?

Our project is recognized as one of the leaders in research on the impacts of climate change on ecosystems worldwide. Our findings and archived long term data are used by other investigators in oceanography, ecology and biogeochemistry as models to help guide research focusing on other environments and biomes. Research on climate and sea ice is used annually to contribute to State of Antarctica, State of the Climate and IPCC reports, and to inform new analyses of sea ice and meteorological trends.

What is the impact on other disciplines?

Our project is multidisciplinary, including research in oceanography, geophysics, meteorology, ecology, biogeochemistry, ornithology, mammalogy, microbiology, virology, genomics and other -omics, botany, zoology, numerical modeling, marine chemistry, marine biology and others. We're trying to figure out how we can extend our influence, and collaborate with new colleagues other disciplines, and how to incorporate theory and tools from disciplines further afield for our research and educational activities.

What is the impact on the development of human resources?

We provide unparalleled opportunities for exposing undergraduate, graduate and postdoctoral students and early career scientists to research activities in the Southern Ocean and at Palmer Station. Through our Education & Outreach program we incorporate Antarctic concepts and observations into classroom planning and curriculum design at the K-12 level. Students participate via live videoconference and use purpose-designed lesson plans built on local observations and data. Resources for teachers and based on real-time observations from live videocameras deployed near Palmer Station.

What is the impact on physical resources that form infrastructure?

We have pioneered the use of autonomous, long-term observing systems such as physical oceanographic moorings and autonomous underwater vehicles (AUVs) and ROVs in Antarctica. Our project is an integral component in the Southern Ocean Observing System (SOOS) and Ocean Observatories Initiative (OOI).

What is the impact on institutional resources that form infrastructure?

Our work has raised the profile of the western Antarctic Peninsula generally, and of Palmer Station in particular, as valuable resources for others who wish to conduct scientific research on climate change and marine ecology. We have contributed directly or indirectly to dozens of new scientists and students using the Station and LM GOULD for their research. Indeed, we have been so successful that NSF has limited or curtailed our own research time and space to make room for other projects.

What is the impact on information resources that form infrastructure?

The developments within Palmer LTER's data management component during the last year contribute to impacts on resources that form infrastructure through local products (data processing scripts, workflow design, relational models, etc.) developed with network standards and reusability in mind, and shared through professional meetings (IMC) and written forums (e.g., LTER Databits).

What is the impact on technology transfer?

Nothing to report.

What is the impact on society beyond science and technology?

Antarctic climate and ecosystem change is a powerful tool to engage the general public from school kids to Corporate CEOs, about climate change. In particular our new feature film, Antarctic Edge is being seen potentially by 10s of 1000s of new viewers. See products for details.

Changes/Problems

Changes in approach and reason for change

Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them

Nothing to report.

Changes that have a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.