PALMER, ANTARCTICA
LONG TERM ECOLOGICAL RESEARCH PROJECT
SITE VISIT

13 – 17 November, 2005
Palmer Station, Antarctica and RVIB Laurence M GOULD

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PAL-LTER
Palmer Antarctica Long-Term Ecological Research Project
Site Visit 13-17 November 2005

NB: All scheduled events are uncertain due to disruption by ship schedule, weather and ice conditions. Schedule will be modified as necessary, possibly at short notice.

04 November		Depart USA
05 November		Arrive Punta Arenas, Night in hotel
06 November		Board and spend night on vessel
07 November		Sail. Time at leisure. We will put up posters in vessel corridors for viewing at your convenience.
08 November	TBA	Meeting aboard LM GOULD about oceanographic sampling (sea conditions and review team comfort permitting). Bridge open anytime and tours on request.
13 November	TBA	Arrival at Palmer Station. Station welcome, safety briefing, tour, orientation, welcome reception. Boating class (mandatory for field trips). Remainder of day free. Scope of day's events dependent on arrival time.
14 November.	0630-0800	Breakfast for site review team on station.
	0830-1200	PAL Science Presentations. Detailed program to follow.
	1200-1300	Lunch
	1330-1700	Field trips to islands, penguin rookeries, Arthur Harbor hydrostations. All trips by Zodiac, weather and ice permitting. May split in 2-3 groups.
	1730-1830	Dinner
	1900-2100	Poster session & meetings with grad students.
15 November.	0630-0800	Breakfast for site review team on station.
	0830-1200	PAL Science Presentations, continued.
	1200-1300	Lunch
	1330-1700	Field trips to islands, penguin rookeries, Arthur Harbor hydrostations. All trips by Zodiac, weather and ice permitting.
	1730-1830	Dinner
	1900-2100	Meetings and discussions TBA.
16 November.	0630-0800	Breakfast
	0830-1200	Final chance for field trips if delayed previous days. Otherwise, time for site review group to meet, deliberate and write.
	1200-1300	Lunch
	1400-1500	Debriefing with PAL PIs. Remainder of afternoon free.
	1700-1800	Dinner. Evening free.
17 November	0800	Ship departs.
21 November	TBA	Arrival in Punta Arenas

PALMER, ANTARCTICA
LONG-TERM ECOLOGICAL RESEARCH PROJECT

Project Start:	October, 1990. Funding cycles 90-96, 96-02, 02-08
Principal Investigators:	Robin Ross & Langdon Quetin UCSB (1990 – 1995)
	Ray Smith, UCSB (1996-2001)
	Hugh Ducklow W&M/VIMS (2002 -)
First Grid Cruise:	January, 1993 (13 consecutive cruises to Jan. 2005)

Current Investigators: * founding investigator

NAME	INSTITUTION	COMPONENT	JOINED
Smith, Ray*	UCSB	Biooptics, sea ice, ocean color & climate	1990 (ret)
Ross, Robin*	UCSB	Zooplankton & Micronekton	1990
Quetin, Langdon*	UCSB	Zooplankton & Micronekton	1990
Fraser, Bill*	PORG	Penguins & other seabirds	1990
Baker, Karen	SIO	Information Mgt., education & outreach	1992
Vernet, Maria	SIO	Phytoplankton & Pri. Prod	1994
Martinson, Doug	LDEO	Physical oceanography	1998
Ducklow, Hugh	VIMS	Microbes & Biogeochemistry	2002
Clarke, Andy	UK-BAS	Marine ecology & biogeochemistry	2002

Current Grad Students: * attending site visit

NAME	INSTITUTION	TOPIC	ADVISOR
Becker, Elizabeth	UCSB	Marine mammals & remote sensing	Smith
Geisz, Heidi*	VIMS	Trophic ecology of seabirds	Ducklow / Fraser
Kozlowski, Wendy	SDSU	Biooptics & phytoplankton	Vernet
Oakes, Stephanie*	UCSB	Krill feeding ecology	Ross/Quetin
Stammerjohn, Sharon	LDEO	Southern Ocean sea ice	Martinson
Chapman, Erik	ODU	Ecological modeling	Hofmann / Fraser
Myers, Kristen	VIMS	Antarctic microbial ecology	Ducklow

Current Long-term Staff: * attending site visit

NAME	INSTITUTION	ROLE	INVESTIGATOR
Rawls, Dawn	SIO	Scientific Editor	Baker
Simmons, Beth	SIO	Education Program Coord	Baker
Shaun Haber	SIO	IM	Baker
Jerry Wanetick	SIO	IM	Baker
Lynn Yarmey	SIO	IM	Baker
Quinby, Helen	VIMS	Technician & Logistics	Ducklow
Erickson, Matt	VIMS	Technician	Ducklow
Patterson, Donna	PORG	Scientist	Fraser
Ianuzzi, Rich	LDEO	Programmer / analyst	Martinson
Ireson, Kirk	UCSB	Programmer / analyst	Smith
Sines, Karie*	SIO	Technician	Vernet

Field Techs currently deployed at Palmer Station during site visit:

NAME	INSTITUTION	INVESTIGATOR	STATUS	IN FIELD
Middaugh, Nikki	VIMS	Ducklow	Lab Tech	Oct 05 – Apr 06
Koffman, Bess	VIMS	Ducklow	volunteer	Nov 05 – Feb 06
Sines, Karie	SIO	Vernet	Lab Tech	Oct 05 – Apr 06
Eam, Boreth	SIO	Vernet	volunteer	Oct 05 – Feb 06
Thomas, Austen	SIO	Vernet	volunteer	Oct – Dec 05
Horne, Peter	PORG	Fraser	Field Tech	Oct 05 – Feb 06
Montaigne, Fen	PORG	Fraser	volunteer, writer	Nov 05 – Mar 06
Blum, Jennifer	PORG	Fraser	Field Tech	Nov 05 – Feb 06
Gorman, Kristen	PORG	Fraser	Field Tech	Nov 05 - Mar 06
Huang, David	UCSB	Ross/Quetin	volunteer	Oct – Dec 05

1. SITE-BASED SCIENCE AT PALMER LTER. A BRIEF OVERVIEW*.

A. Publications and data.

Palmer LTER Publications and a more complete listing of all PAL-LTER contributions are on our new website at: http://pal.lternet.edu/. Manuscripts in preparation are available at: pal.lternet.edu/projects/05palmer/ The PAL-LTER database is also accessible at the main website.

B. Conceptual Background.

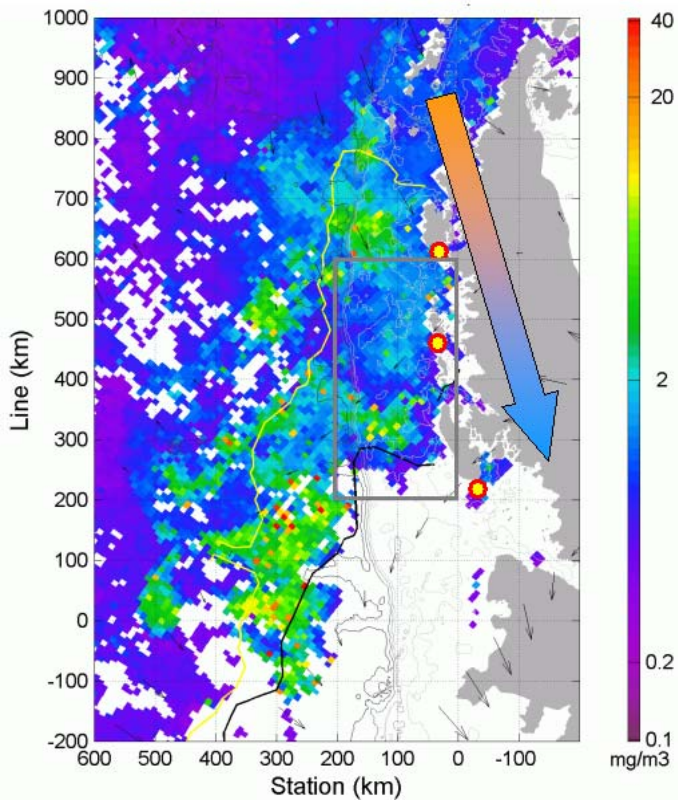


Figure 1. November 2004 sea ice (contiguous white areas), SeaWiFS ocean color (color and bar), wind (small arrows), penguin colonies (large dots) and climate migration on the West Antarctic Peninsula. The ocean color image shows an offshore ice edge bloom. The yellow and black lines show the ice edge at the beginning and end of the month. The gray box is the main sampling area (PAL Grid; see below). Our fundamental hypothesis is that as the cold dry continental polar system of the southern WAP changes to warm, moist maritime conditions, we will detect responses along that climate gradient (big arrow) in all or part of the ecosystem. The response, however, is complex as changes in trophic structure and elemental cycling are driven not only by climate migration but also modulated by teleconnections to the rest of the world's oceans, as exemplified by the multiple links found to ENSO, the Antarctic Dipole and SAM. Image processing Kirk Ireson and Ray Smith, UCSB-ICESS.

This overview emphasizes the motivation and approaches used in our studies. Results will primarily be presented in the site visit. The central tenet of PAL is that the annual advance and retreat of sea ice is the major physical determinant of spatial and temporal changes in the structure and function of the Antarctic marine ecosystem. Our observations, data analyses and synthesis activities have led us to a new understanding of the West Antarctic Peninsula (WAP) marine system. The WAP in the Palmer region is experiencing one of the most rapid rates of regional climate warming on the planet, and there are significant reductions in sea ice onset, extent and duration as a result of the warming. We now recognize the WAP as a premier example of a climate-sensitive region experiencing major changes in species abundance and composition. Changes in species range and distribution are occurring in response to regional climate change manifested here primarily as a southern migration of principal climate characteristics (climate migration; Figure 1). In effect, the cool, moist maritime system of the northern WAP is replacing the cold, dry continental, polar system of the southern WAP along the Peninsular climate gradient. This change is driven by regional warming, which is modulated by regional hydrography, sea ice processes and global teleconnections to lower latitude atmospheric variability. We seek to understand the full ecological implications of climate migration in the

* The sections in this briefing follow the NSF Guidelines for Site Reviews and LTER Renewal proposals.

WAP, and uncover the mechanisms linking them through teleconnections to global climate variability.

C. Scientific organization and sampling.

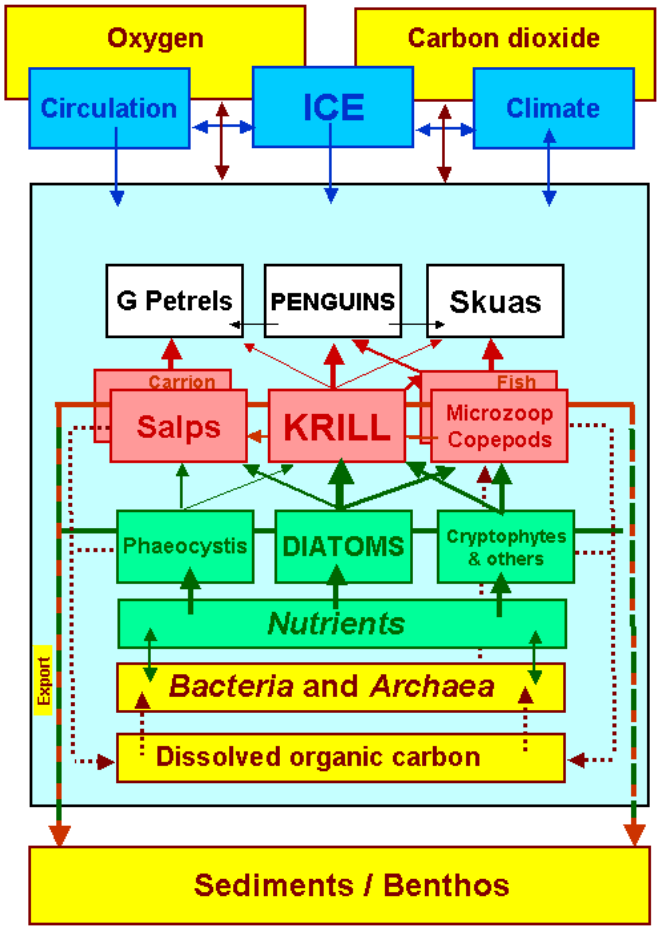


Figure 2. PAL research components and trophodynamic structure of WAP marine ecosystem. Yellow boxes: Microbial biogeochemistry component; Green boxes: Primary production; Red boxes: Zooplankton, including krill (prey component); White boxes: predator component (penguins and other seabirds); Blue boxes: Physical oceanography and Remote sensing (2 components). The remote sensing/biooptics component (not shown as separate boxes) also addresses ocean color (green boxes). For visual convenience, not all fluxes (arrows) are shown, and not all depicted arrows are measured explicitly in PAL. The carrion and fish components are not studied explicitly The classic Antarctic nutrient – diatom – krill – penguin foodchain is in the center of the diagram. Sedimentation and export are studied with the PAL sediment trap.

PAL has 6 research components (Figure 2)addressing the 5 LTER core areas plus Information Management / Outreach. Since its inception in 1990 PAL has included both regional-scale spatial and local-scale temporal sampling (Figures 3, 4). Our sampling program addresses multiple spatial scales within one regional scale sampling grid of ca 50 regularly occupied oceanographic stations at which core measurements are conducted, permitting repeated sampling on both seasonal and annual time scales, covering short and long-term ecological phenomena, and specific mechanistic studies (**Section D**). The sampling grid adds a unique strength to both the field and modeling programs as it unifies measurements across all field components and facilitates data integration. To date, there have been 13 (1993-2005) annual summer cruises and five additional cruises emphasizing fall, winter and spring processes. Protocols for core and other variables are documented and available online. Brief descriptions of the PAL Research Components are appended, and keyed to this diagram.

The PAL study area and sampling grid. The marine ecosystem of the Western Antarctic Peninsula (WAP) extends northeasterly for ~1500 km from the Bellingshausen Sea near 75° South, 80° West to the northern tip of the peninsula near 63° S', 60° W., and from the mostly glaciated coast to the southeast, about 300 km across the continental shelf averaging 430 m in depth to the shelfbreak to the northwest. The shelfbreak is defined by steep, rapidly deepening bathymetry between 750 and 3000 m (Figure 3). The glacially-sculpted coastline along the peninsula is highly convoluted, cut with numerous islands, deep basins, bays, fjords and a series of embayments often interconnected by channels, sometimes as deep as 900 m. The domain is divided into three sub-regions (continental slope, shelf and regions of Figure 3B) consistent with the bathymetry, ocean dynamics and water mass & biological distributions. The shelf ranges from 300-700 meters in depth and is bisected by deep depressions.

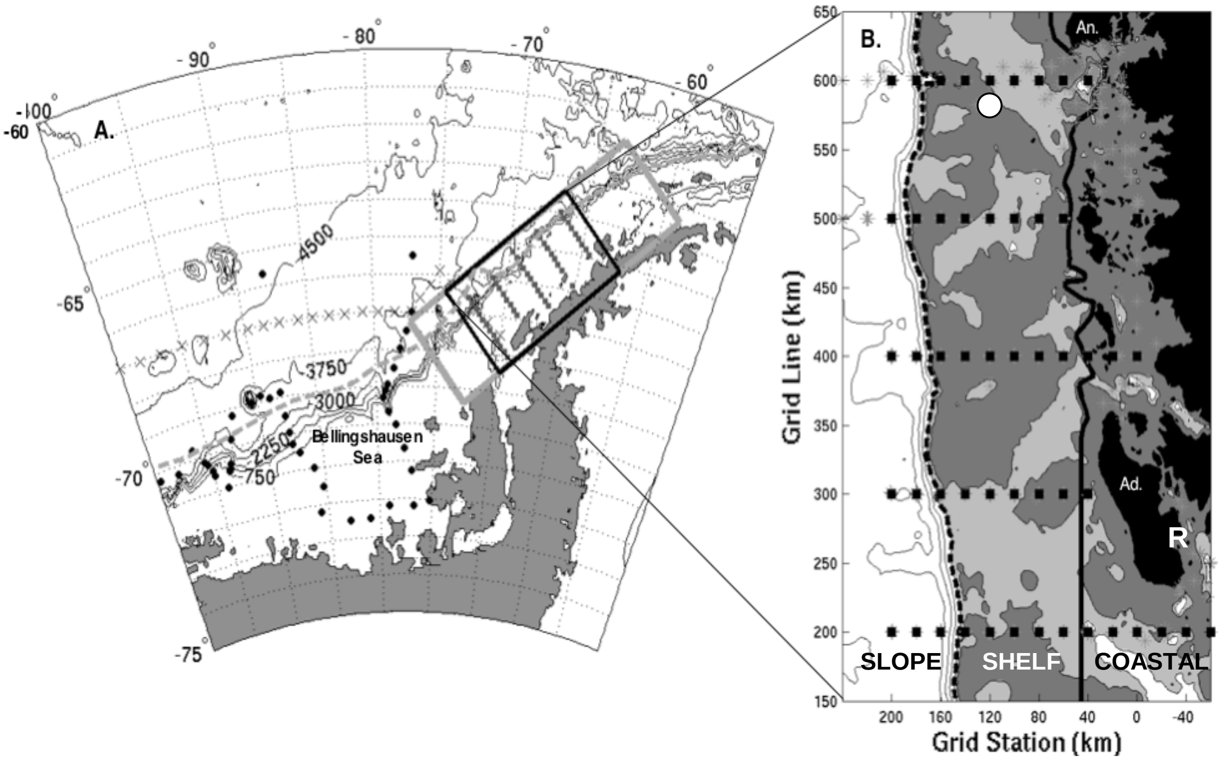


Figure 3. A. Study region along the WAP and nominal PAL LTER sampling grid (bold black box) imbedded in bigger full grid (bold grey box) with labeled contoured bathymetry (750 m intervals), climatological southern edge of Antarctic Circumpolar Current (dashed grey line); and PAL Grid hydrographic stations (small squares). **B.** PAL sampling grid with labels for gridlines on the ordinate, and for grid stations on the abscissa; bathymetry shaded (white ≥750m, 750< light-grey ≤450m, dark-grey <450m) and contoured (≥1500m @750m intervals); islands labeled: An. = Anvers Island, Ad. = Adelaide Island; continental **slope**-shelf break indicated by dashed bold line (slope to left) and **shelf-coastal** sub-regions separated by solid bold line; standard station locations (small squares) are indicated. White circle just off 600 line is PAL moored sediment trap. The R is location of the British Antarctic Survey's Rothera Station (see International Collaborations below).

The sampling grid (Fig. 3B) lies at the heart of PAL. A three-dimensional geo-referenced measurement system, our grid of oceanographic stations is an ecosystem observatory, which allows a scaling up to and statistical linkages with the 3-D global model grids. Sampling is conducted annually along vertical profiles through the water column at each hydrographic station (grid point). Our strategy for exploiting the grid data is described briefly in Section E below. The station locations in the sampling grid lie upon the intersection of 10 cross-shelf grid lines spaced 100 km apart and perpendicular to the coast and grid stations spaced 20 km apart across the shelf, along the grid lines. Grid lines are labeled according to their position in the grid relative to the southern-most sample location (e.g., the 200 line is 200 km from the southern-most line of the grid, starting near Alexander Island at ~69˚ S, ~73.6˚ W); station lines are labeled according to their cross-shelf distance from the average coast (e.g., the 040 line lies 40 km from the average coast). Individual stations are identified as ggg.sss, where the ggg is the grid line and the sss is the station line (e.g., station 600.080 lies 80 km offshore on the grid line 600 km up the peninsula). The annual sampling is confined to the 200-600 lines (highlighted in Figure 3B). Additional stations lying in the immediate coastal zone among passages and islands are behind the zero station line and numbered with negative station numbers (e.g., 200.-040 inside Marguerite Bay).

The PAL Grid is occupied every January in the Austral summer during a ~4 week cruise on the LM GOULD, providing a regional-scale, 3D snapshot and over time, multidisciplinary information on interannual variations in a wide suite of oceanographic properties and processes. A sediment trap moored near grid location 586.129 is recovered and redeployed each January, providing weekly to monthly resolution of particle sedimentation at 150 meters over the annual cycle.

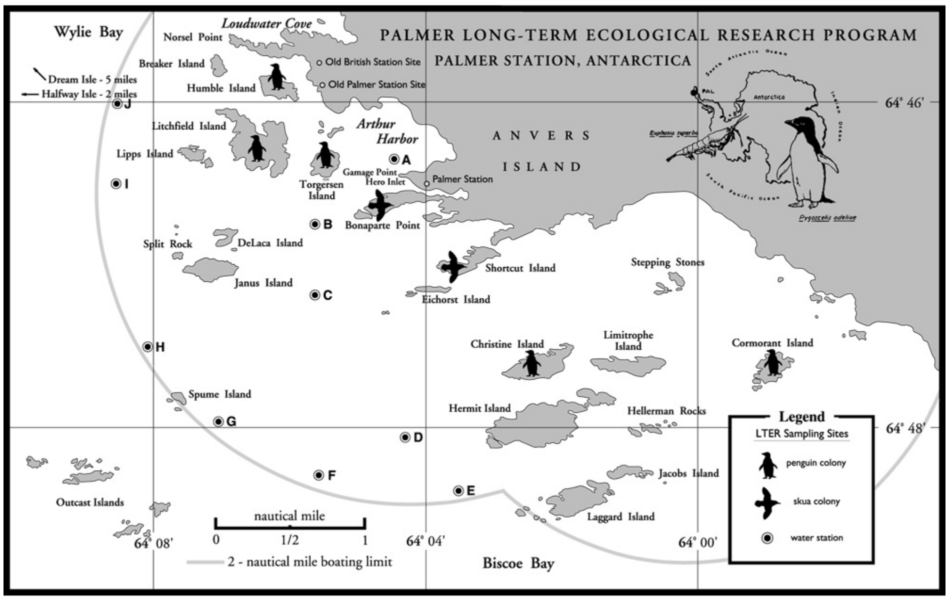


Figure 4. The local sampling area and seabird breeding sites near Palmer Station, Anvers Island. Local-scale study of penguin, giant petrel and skua colonies is conducted on the islands, and associated hydrographic and other water column sampling is performed semiweekly (Oct-April) at Stations B and E. Bioacoustic krill transects are A-E and F-J. This area will be visited during Site Review (weather permitting).

Local-scale seasonal sampling at Palmer Station. To understand seasonal cycles of nutrients, phyto- and zoo-plankton and microbes in connection with seabird breeding cycles, and to extend the temporal domain of our understanding, we conduct intensive studies based at Palmer Station each year (Figure 4). Sampling is performed semiweekly (weather and ice permitting) between late October and late March. Highlights of the regional- and local scale observations will be presented in posters aboard the vessel and at Palmer Station and in a series of cross-cutting talks at Palmer Station (emphasizing synthesis). In addition, field trips will be conducted by Zodiac to the principal sampling sites, as permitted by weather and ice.

Relation to conceptual Framework and Hypotheses. The Palmer sampling scheme was designed to address multiple scales of temporal/spatial variability, and thus is ideal to investigate climate migration and ecosystem response over a 1000 km region along the WAP with a marked climate gradient and differential patterns of phytoplankton productivity, zooplankton distribution and abundance, microbial processes and penguin foraging and breeding success. Ecosystem responses to climate change are more conspicuous in the north in contrast to less obvious changes in the south. Remotely-sensed observations of sea ice advance, duration, extent and retreat throughout the study region allow us to make direct comparisons of interannual scale linkages between ice, plankton and seabirds. The local-scale studies in the Palmer Station area provide a close look at seabird breeding, foraging, recruitment; seasonal-scale responses of lower trophic level processes to interannual and shorter-term variations in ice cover, and effects of varying environmental conditions (ice, food availability) on krill distribution and production (growth).

D. Short-term mechanistic experiments, empirical studies, etc.

PAL pursues a variety of shorter-term and mechanistic studies at Palmer Station and during the annual cruise in our larger study area. Some of these studies will be described in the posters and oral presentations and during the field trips. Each year we reserve about 3 days of the 28-day cruise for 3, 24-hour process-study stations (nominally located near the 3 penguin rookeries in the north, central and southern parts of the grid). Also during the cruise and at a time of peak penguin chick growth, we occupy a fine-spatial-resolution sampling grid (10 km x 20 km) in the foraging region near Palmer Station to observe the relationships among water column properties, krill distribution and penguin foraging. At Palmer Station groups perform experimental studies on the physiology and growth dynamics of bacteria, phytoplankton and krill. In recent years we have investigated release of dissolved organic carbon by phytoplankton and its coupling to bacterial uptake. We have also compared feeding rates of young Antarctic krill on surfaces and in the water column; collaborated with A. Murray of Desert Research Institute in the use of the 18S rDNA gene to characterize krill diet, and advanced the development of an index for feeding intensity in situ for Antarctic krill that may improve modeling of the impact of krill grazing on the phytoplankton community. Further collaboration with Murray involves characterizing the bacterial community in space and time. Finally we have also carried out a manipulative experiment by installing snow fences near Adèlie colonies on Dream Island, to test hypotheses relating snowfall-induced disturbances to penguin breeding success.

E. Modeling and Synthesis.

PAL does not have a separate modeling component. Modeling is accomplished within or between individual research components, and is one goal within Martinson's and Ducklow’s components. Martinson focuses on the ocean-sea ice interaction, and models that with a one dimensional physical model. To better compare with the PAL field data, Martinson, working with Jinro Ukita, improved the sea ice thermodynamics to better represent the sea ice during high frequency changes in the surface forcing, as frequently experienced in the WAP region. This improved model was published in 2001. An improvement to the ocean component was recently implemented by replacing the upper ocean mixing scheme with the well-respected Large et al., 1994, "KPP" mixing model, as part of Stammerjohn's PhD thesis. The coupling was aided by Large's participation during a visit to Lamont in 2003 where he worked closely with Stammerjohn to effect the coupling and test it successfully. Stammerjohn will continue work on this by comparing the seasonal development of the upper water column simulations relative to observations. She will also couple in an ecology model to evaluate our observationally-derived relationships between the physical processes and ecological responses.

Ducklow added ecological modeling activities as a tool for intercomponent synthesis when he joined PAL in 2002. We employed a familiar inverse approach to reconstruct objective descriptions of plankton flow structure (carbon and nitrogen cycling pathways among components as in Figure 2) from sparse measurements conducted during the January cruises and at Palmer Station. There will be a poster on this work at the Site Visit. The next step is implementing a time-dependent, coupled, circulation-ice-ecology-biogeochemistry simulation model for the PAL region, an effort to be undertaken by Stammerjohn, Ducklow and Martinson, in collaboration with Katja Fennel at Rutgers (who has an ecology model already coupled to the KPP model as it appears in the Martinson-Stammerjohn physical model, and who has expressed interest in such a collaboration).

We are now completing the first stages of a comprehensive synthesis of twelve years of observations on the sampling grid. Spatiotemporal patterns were quantified via an Empirical Orthogonal Function / Principal Components Analysis (EOF/PCA) of key data sets including several physical oceanographic and thermodynamic variables, sea ice properties (advance, extent, duration, retreat), primary production, ocean color, CO_2 and zooplankton abundance. This analysis allows more quantitative assessments of the covariability between variables, allowing us to formally test some of the underlying PAL hypotheses regarding these raelationships, and eventually derive their mechanisms. A suite of manuscripts describing this major exercise is being submitted to Deep-Sea Research II for a dedicated volume. Results will be presented at the Site Visit. These analyses provide an in-depth look at property distributions and key processes within the study region and further serve to place processes studied at Palmer in the context of the larger, regional-scale ocean circulation (Antarctic Circumpolar Current intrusions) and global-scale atmospheric variability (ENSO teleconnections). A number of important findings have been revealed that could not have been discovered without this long term analysis. For example, the grid data allowed us to determine the contribution to the strong WAP warming by the ocean (something difficult to do from single-cruise station data, but possible given the multiple years of grid occupation). Future efforts using the EOF approach (specifically, varieties of Canonical Correlation Analysis) will focus on interrelationships among different properties to uncover causal mechanisms (e.g., climate-ice-primary production-zooplankton-penguin interactions).

2. "NETWORK PARTICIPATION," INTERNATIONAL COLLABORATIONS AND SYNTHESIS ACTIVITIES.

Network Activities. Both PIs and graduate students have been active in various LTER Network-level activities. Two PIs and a graduate student attended the LTER Meeting of 100 in Nov 2004 to initiate development of the LTER synthesis proposal being written this fall, and K Baker became a member of several of the working groups. R Ross has been a member of the Network Information System Advisory Committee (NISAC) since fall of 2003. Ducklow co-organized the LTER scientific mini-symposium on Grand Challenges in the Marine LTER Sites at NSF in spring, 2005. Oakes represents PAL on the LTER Grad Student committee. S Oakes was part of a small group of graduate students that wrote a proposal to the Network Office to hold a graduate student meeting at the Andrews LTER site in April 2005. The goal was to bring together LTER graduate students to (1) learn about ongoing graduate research at other sites to foster cross-site collaboration, (2) conduct workshops to plan collaborative activities, and (3) conduct training workshops led by invited scientists.

International. A major element of our larger program involves a long-term collaboration with colleagues in the British Antarctic Survey based at Rothera Station, ~ 400 km south of Palmer Station. BAS Senior Scientist Andrew Clarke is a PI in PAL. The British Antarctic Survey have been undertaking year-round oceanographic sampling in Ryder Bay, northern Marguerite Bay, since 1997. This work comprises the Rothera Oceanographic and Biological Time-series (RaTS) project. It builds upon, and extends, the long-term nearshore oceanographic monitoring undertaken at Signy Island, South Orkney Islands from 1968 to 1994. The RaTS station can be viewed as an extension of the Palmer-LTER grid within Marguerite Bay, and allows us to compare seasonal water column dynamics at the northern (Palmer Station) and southern (RaTS) ends of our Palmer-LTER grid. Data are collected weekly from the RaTS station, when weather and ice conditions allow, providing information on benthic processes not studied at Palmer Station. Feeding activity is also measured in a range of benthic suspension feeders every two weeks, and samples are collected monthly in a range of common benthic taxa to determine reproductive status. The aim of the biological sampling is to relate key ecological processes to variability in the physical environment.

Analysis of remotely sensed data has shown that data taken at the RaTS station are representative of northern Marguerite Bay, and hence the southern end of the Palmer-LTER grid. The collaboration with the BAS RaTS programme thus provides a valuable year-round picture which is particularly useful in understanding the causes of interannual variability. Practical collaboration involves an annual visit by the Palmer-LTER team to Rothera, during which period the CTDs are compared with a joint cast, and a cross-calibration exercise occurs for both chlorophyll and isotope measurements. BAS has also provided aerial photography of Adelie penguin colonies in Marguerite Bay, which will allow testing of the hypothesis of a southward range shift in these birds.

Collaborative Interactions. Collaborative interactions between Palmer LTER PIs and other Southern Ocean researchers contribute to our understanding of the larger regional context for the ecosystem in this region west of the Antarctic Peninsula. For example, collaborative work has just begun on large scale distribution patterns of krill and salps during the summer months to test the hypothesis that krill are essentially a shelf break animal, and salps are a “low chl a species” (Atkinson, Pakhomov, Siegel, Ross and Quetin). Other developing collaborations involve a study of the relative growth rates of male and female krill (Kawaguchi, Siegel, Ross, Quetin, Trivelpiece), the use of PAL LTER data on salps in conjunction with a study of salp physiology conducted by P. Kremer and L. Madin, and a collaboration with A. Friedlander at Duke University who is comparing whale counts (Fraser), krill distribution (Quetin and Ross) and chl a distribution. Ducklow is collaborating with T. Hollibaugh (UGA) who is studying the ecology and distribution of nitrifying bacteria in the Peninsula region. We hosted the Hollibaugh group on LMG last January and will do so again this coming January. Ducklow is also collaborating with Alison Murray (DRI) on an ongoing study of bacterial diversity at Palmer Station. We are collaborating closely with a new project at Palmer Station led by P. Matrai (Bigelow Lab). They will be studying the physical and biological processes regulating DMS production and we will coordinate both routine sampling in the Palmer vicinity and experimental work with their group.

3. INFORMATION MANAGEMENT AND TECHNOLOGY.

Annual updates to the Palmer LTER data repository are a critical ongoing information management activity. In addition, with information management a multifaceted process changing along with today's technology and site science needs, we've initiated an Ocean Informatics Environment conceptual framework as an approach to information system sustainability, data interoperability, and collaborative design.

A new hardware implementation has been created as a contemporary infrastructure within the UCSD/SIO Integrative Oceanography Department supporting PAL data and services migration this year. Update and reorganization of the decade old file structure and its content continues. The informatics team consists of Karen Baker (information manager), Shaun Haber and Mason Koretz (web and data base designers), Lynn Yarmey (dictionary and metadata analyst), and Jerry Wanetick (computational center director and systems administrator). Recently PAL Information Management efforts have focused on implementing a second-generation information system drawing on research into and experience with site practices, federated network criteria, and metadata standards' requirements. After a decade of use, our approach shifts from focus on data capture and access to address community requirements such as metadata delivery and online data query as well as local unit and attribute dictionaries. In considering an information system as a whole, important system modules include the personnel directory, bibliographic collection, study metadata, and data catalog.

Amid a year of multiple transitions, the highest priority data management development task is enactment of a long-term, extensible metadata strategy, bridging text forms to a relational database strategy in conjunction with unit and attribute dictionaries. Alongside these activities, we carried out a Palmer web site redesign that includes a three tier template, stylesheets and update of dynamic elements such as the photo gallery, glossary, and sampling grid program under the new architecture.

Collaborative local activities included coordination with the co-located LTER California Current Ecosystem (CCE) site and California Cooperative Oceanographic Fisheries Investigations (CalCOFI) programs along with the Southern California Coastal Ocean Observing System (SCCOOS) program. Making use of a design studio approach along with strategic design teams and working groups has contributed to community efforts such as a joint data acquisition schema and promoted shared understanding across data types.

Together with science studies researchers, we are working to open up discursive practices and perspectives on data strategies and collaborative endeavors. Further, a contemporary approach to training recognizes design as a central element. Within education/outreach and information management, roles are developed synergistically, highlighting the common elements of information flow, exchange, and delivery.

4. SITE AND PROJECT MANAGEMENT

Research in the remote and hostile environment of the Antarctic entails special challenges as well as rewards. PAL research is supported almost exclusively through NSF's Office of Polar Programs Antarctic Biology and Medicine Program (OPP0217282 to VIMS) with institutional match funds from VIMS, SIO, and UCSB. Few other funding agencies or NSF programs support Antarctic research. H. Ducklow serves as Lead PI; the other PIs are distributed across the USA at other institutions. We rely heavily on electronic communications for day to day management of the program. All 8 PIs are equally involved in program management and decision making. Grant support is allocated equally among the 6 research components and IM/Outreach, with each group contributing $4000 per year to a central pool for meetings and contingencies etc. We rely on a scheduled monthly 1-2 hour conference call among all PIs for discussing and making key decisions about research and other issues. We have a week-long annual meeting, hosted by a different PI or institution on an informal rotating basis. Special workshops focusing on data analysis and manuscript preparation are also convened in most years. Longer-term strategic scientific research, management and personnel issues are considered at these meetings. Fieldwork at Palmer Station and aboard the ARSV LM GOULD provides additional (and sometimes unpredictably extended) venues for direct PI interactions. Although we are a very distributed LTER Site, we all maintain close contact on a daily to weekly basis.

Grants management is performed by the VIMS Office of Contracts & Grants (Jane Lopez, Director, jlopez@vims.edu). A matching grant from VIMS ($35K annually) provides funds for meetings and other management-related expenses. Ducklow employs a half-time project manager to assist with day to day business (Helen Quinby, quinby@vims.edu).

Unlike most other LTER Sites (except MCM), PAL does not control site access. All access decisions including exactly who can visit the site and when are made by NSF through the management and logistics subcontractor, Raytheon Polar Services Corp. (RPSC; http://www.rpsc.raytheon.com/). We work closely with RPSC via email and phone with designated points of contact, and via the annual RPSC/NSF Support Information Package (SIP) process for planning research logistics (http://polarice.usap.gov/index.htm). Longer term and strategic logistics issues are considered by the Palmer Area Users Committee (PAUC). 2-day PAUC meetings are held annually at RPSC headquarters. Ducklow currently chairs the PAUC and 2 other PAL PIs are usually members.

Non-LTER research at Palmer Station and aboard the research vessel is coordinated through the NSF proposal process and then through RPSC. Due to severe space and berthing limits at Palmer and on the vessel, research at Palmer Station can be a zero-sum game; a newly-funded project may necessitate limitations in existing programs like LTER. Access and logistics limitations also strongly influence the extent to which we can encourage use of the site by other scientists and students. Usually, such use can only be accomplished by having a guest investigator supplant PAL researchers for part of a season or on the annual cruise (see collaborative research above).

The MCM Site experiences all these same issues and we keep in close contact with MCM PIs.

5. EDUCATION AND OUTREACH

PAL Outreach and Education activities are supported by the Information Management/Outreach component of the core LTER budget (see Section 4 above) and NSF-Schoolyard LTER + Research Experience for Undergraduates (REU) awards; and necessarily involve a large volunteer contribution by PAL investigators and students. Our principal targets are the PAL graduate students, undergraduate interns and K-12 students. We recognize that we cannot do it all, and try to focus our activities accordingly.

Creating a gateway to learning about Antarctic research inspires Palmer Station's Education and Outreach program to make every effort to exploit the scientific research occurring in PAL. Creating this kind of context for learning immerses students in exploring the long-term physical, chemical and biological changes that take place within the Antarctic ecosystem. By demonstrating the relevancy of such research by PAL scientists, students are connected to environmental issues like climate change and atmospheric science, ecosystem sustainability, and biodiversity through the eyes of the researcher. This enables children to engage more deeply in environmental science, specifically global issues, encouraging a deeper understanding of the scientific inquiry process. Partnerships like this not only create an awareness of the Antarctic polar environment and help students develop their understanding of the environment, they also create parallels for students' understanding their own local environment and the changes that occur to create sustainability.

Palmer's Education and Outreach is motivated by questions like: How do we make large collections of scientific data and high performance visualizations available as educational resources in the classroom? Can these resources enable inquiry science learning while also giving children a global perspective on scientific issues? What are appropriate representations of this data for children? How do we transform this data? How can we support collaborative activity within the school and with real Palmer scientists?

Most recently, new perspectives from the implementation of assessment strategies in the classroom and with the general public have provided insight into creating a more meaningful context in which students learn from their experiences, engage in scientific inquiry and test the scientific concepts they learn in class. These challenges are being met through the development of the Palmer Education Framework. This organizational tool is bridging scientific research practice in the Antarctic with academic science teaching. The development of this type of infrastructure embodies an emergent notion of authentic science, identifies the needs of our community organization and connects to research and teaching in the classroom. It also supports the use of our repository of materials, improves the acquisition, use and retention of conceptual scientific knowledge through an inquiry-based learning model and supports the development of high-order thinking skills involved in learning science. Partnerships like the LTER network not only provide an ideal vehicle for interchange between these two fields but also encourage communities of individuals to interact and learn about science in ways that can transform authentic educational experiences in the classroom and improve education and outreach.

We participate in the NSF-OPP Artists & Writers Program and this year we will be working closely with a documentary film crew from the Canadian Broadcasting Corporation. Antarctica has become a hot tourist destination, increasing from 6000 visitors in 1992 to over 25,000 now, and we cooperate with other Palmer Station personnel to host and educate cruise visitors about the Antarctic, climate change and LTER. Approximately 25 vessels and 3300 tourists now visit Palmer Station each year and most attend some sort of scientific presentation. Over 1000 cruise passengers from smaller vessels visited the penguin colony on Torgersen Island, guided by Bill Fraser and his field team. Each year we distribute to a long list of students, teachers, families and friends popular Pictures of the Day during our summer research cruise (send us an email if you want to join the list).

Undergraduate and Graduate Students. Nearly every year, the Palmer LTER supports 2 or more REU students, with mentorship rotating among several of the PIs. Undergraduate volunteers join research teams in the Antarctic each season, experiencing first hand what oceanographic research in a multi-disciplinary group entails. Some of the undergraduates enroll for academic credit in fieldwork in oceanography or independent study. These internships are often instrumental in helping an undergraduate or recent undergraduate decide on their career paths. Our former volunteers become graduate students, teachers, marine technicians, and aquarists. At this time we have 5 graduate students who are either working or have worked at the site and are mentored by Palmer LTER PIs. A graduate student from Duke University expects to start working in the fall of 2005with several Palmer LTER data sets and looking at whale distributions.

Appendix 1. Palmer LTER Research Components.

The PAL Seabird Component (W. R. Fraser; white boxes in figure 2)

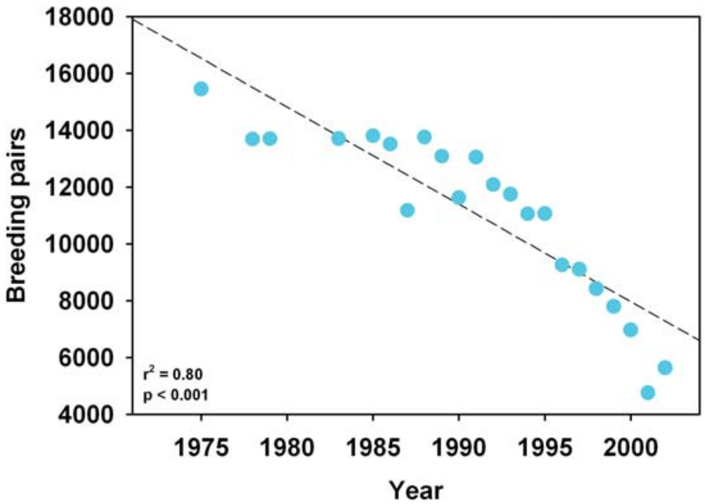


Figure A1. Decline of breeding Adélie penguin population at Palmer Station.

The primary role of the seabird component is broadly defined within the context of long-term research that seeks to identify and understand the factors that regulate the demography of Adélie penguins, their close relatives and predators. Experiments are focused on breeding chronology and biology, foraging ecology and population dynamics. The core, long-term data associated with these studies are derived primarily from local populations distributed over approximately 50 km^2 near Palmer Station. At-sea surveys of abundance and distribution of these and other seabirds over an area of approximately 80,000 km^2 provide a larger-scale context for these studies. This nested approach to hypothesis testing and development capitalizes on databases that span more than three decades, allowing the PAL seabird component to address a broad suite of ecological issues. These include interactions between climate migration and community structure, the effects of landscape geomorphology on biological populations, the mechanics of source-sink population dynamics, and establishing basic conceptual and empirical links between marine and terrestrial ecology.

The PAL Zooplankton and Micronekton Component (R. Ross & L. Quetin; red boxes)

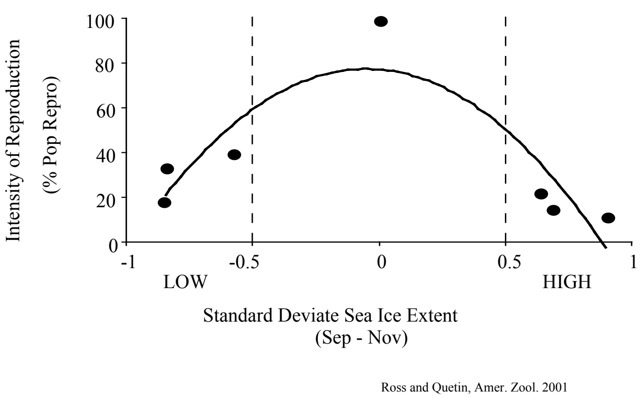


Figure A2. Krill reproduction is related to sea ice extent as are other processes, but it is maximized at neither very low nor high ice extent. In contrast the phytoplankton production, krill appear to optimize on the average ice extent.

Zooplankton and micro-nekton, particularly those > 0.2 mm in length, provide the main trophic link between primary producers and apex predators in the southern Ocean. Within the Palmer LTER study region, both oceanic and coastal zooplankton assemblages occur. The oceanic assemblage (generally in waters > 2000m) includes salps, whereas the coastal assemblages (shelf break and slope) includes several species of euphausiids, including Antarctic krill (*Euphausia superba*) and *Thysanöessa macrura*, and the herbivorous shelled pteropod, *Limacina helicina*. Over much of the shelf region both the oceanic and coastal assemblages occur in varying mixes year to year with no clear boundaries between zones. In parts of the PAL grid close to the continent, two species (larval Antarctic silverfish, *Pleuragramma antarcticum*, and the ice krill, *E. crystallorophias*) have been found in a zone of cold continental shelf water influenced by summer sea ice.

Temporal/spatial variability in the distribution and abundances of the zooplankton assemblages, in particular any changes in distribution, has been one focus of the research on zooplankton and micronekton. Sampling tools include 2 sizes of trawl, and bioacoustic transects with a 120 kHz echosounder. Simultaneous oblique tows and bioacoustic transects are conducted at all stations during the annual PAL cruise. During the spring and early summer, bioacoustic transects are conducted semi-weekly within the nearshore sampling region from a zodiac to document the acoustic biomass and 'packaging' of prey for the foraging penguins. Another focus is the population dynamics of Antarctic krill, an important prey item for many seabirds and seals, and environmental factors impacting its growth, reproduction and ultimately recruitment success. Seasonal sea ice dynamics have been documented as important factors in both reproduction and recruitment success of this species. Experiments measuring in situ growth rates are conducted to document variability in production (growth) on multiple time and space scales in relation to environmental variability, both seasonally (sampled by SCUBA and by net from the zodiac) and over the PAL grid (sampled by net from the ship).

The PAL Phytoplankton Dynamics Component (M. Vernet; green boxes)

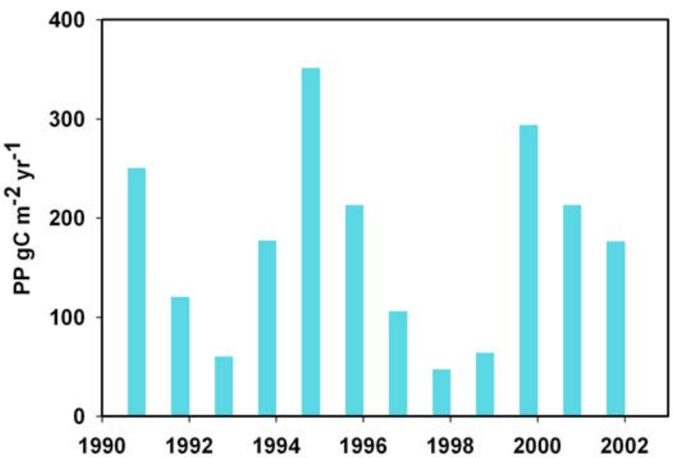


Figure A3. Annual (October to April) primary production at Palmer Station Stations B,E varies over nearly an order of magnitude with ~5 year periodicity.

The phytoplankton component is estimating phytoplankton production and loss terms, diversity, and physiology. Phytoplankton population growth is a function of photosynthesis minus respiration, grazing, sedimentation, advection, excretion and lysis. The average water column primary productivity of the WAP region is 162 ± 114 g C m^2 y^{-1} and is characterized by a strong temporal and spatial variability, with most of the production between October and April and high concentrations in coastal waters. The field sampling at Palmer Station and on the shelf are designed to understand the patterns of temporal and spatial variability. Experiments on grazing and DOC production are aimed at understanding carbon cycling through the food chain. Important physical parameters shown to influence phytoplankton include ultraviolet radiation and temperature and these factors are being introduced into seasonal models of phytoplankton productivity. In addition, the importance of species diversity with respect to susceptibility to grazing, to community composition, and to primary production are being evaluated since they are key factors in community composition and ecosystem function.

We focus on three phytoplankton loss terms that have ties to other components within the project: grazing (both by micro- and macrozooplankton), sedimentation and DOC excretion. Sediment trap data suggest that between 0.3 and 7% of the annual primary production on the grid sinks below 150 m depth. Between 2% and 47% of the annual primary production is grazed. The rest of the carbon must be recycled in the upper water column. Uneaten phytoplankton cells can also sink, in particular when under stress, transporting vegetative cells and resting spores to depth.

The PAL Microbial Ecology / Biogeochemistry Component (H. Ducklow; yellow boxes)

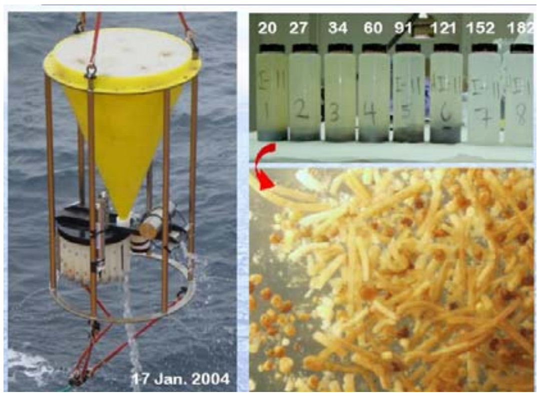


Figure A4. PAL sediment trap component. (A) recovery of the time series trap system in 2004. (B) trap collection cups showing material collected and day of year each was opened. Note abrupt transition from day 121 to 152; (C) material in cups, mainly krill fecal pellets.

Microorganisms < 1 μm long form an important ecosystem component at the base of Antarctic foodwebs and catalyze critical biogeochemical transformations in the carbon, nitrogen and other elemental cycles. The goal of the PAL microbial component is to document the long term trends and variability of bulk bacterial and *Archaeal* biomass and production rates in space and time. Observations have been made on the LTER sampling grid encompassing the offshore domain since 1993. More recently we initiated a semiweekly time series in the inshore regime near Palmer Station. The goal of the biogeochemistry component is to understand how climate change and ecosystem response impacts several key biogeochemical properties: dissolved oxygen, organic and inorganic carbon. The Southern Ocean is an important sink for atmospheric CO_2; our studies of the metabolically active gases are aimed at clarifying the linkages among biological and physical processes affecting CO_2 storage. Microbial oxidation of DOC is an important flow in marine ecosystems including the Antarctic and provides a link between microbial functioning and O_2/CO_2 cycles. The source/sink behavior of the ocean with respect to CO2 is influenced by the biological pump that transports biologically-fixed carbon to depth. The PAL sediment trap has measured particle export over the annual cycle since 1993.

The PAL Physical Oceanography Component (D.G. Martinson; blue boxes)

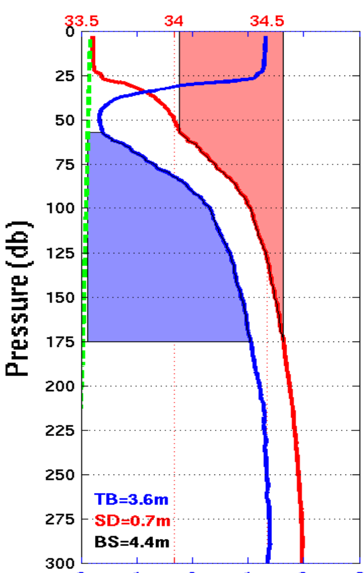


Figure A5. Vertical profiles of salinity (red) and temperature (blue) showing the thermal barrier and salt deficit, bulk properties that determine the contribution of sea ice formation and melting to water column stability.

The physical oceanography component takes responsibility for design, processing and analysis of hydrographic data. These data are used to describe the hydrography and circulation in the Palmer area in particular and the Western Antarctic Peninsula region in general. We are attempting to understand the interaction between the Antarctic Circumpolar Current (ACC) waters and the ocean-ice-atmosphere-ecology interactions on the WAP continental shelf. Some of our recent findings include: (1) Winter and summer average heat fluxes are well estimated by the robust integrated profile methods of Martinson and Iannuzzi (1998), winter average is ~30 Wm^{-2}; (2) Ocean heat flux is related to the ocean heat content of the upper layers of the Upper Circumpolar Deep Water (UCDW), delivered to the region as it appears over the continental slope (which is related to that over the shelf); (3) The ocean heat content of the UCDW has shown a large jump in its value (comparable to ~6 Wm-2 increase in winter ocean heat flux) sometime between the 1970s and 1990s, and it shows an increasing trend since 1998. We are experimenting with a variety of optimization techniques for estimating this contribution of ocean heat additional methods and focusing attention on developing circulation and coupled physical-biological models, and have developed software for integrating analyses across PAL components.

The PAL Remote Sensing, Climate and Biooptics Component (R. C. Smith & M. Vernet; blue boxes).

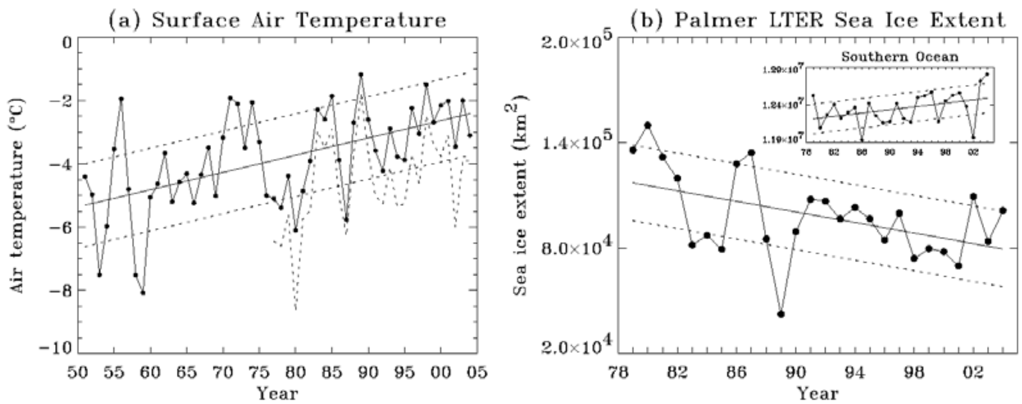


Figure A6. (A) Annual average air temperature recorded at Faraday/Vernadsky Station (65°15'S, 64°16'W) from 1951 to 2004. Annual average air temperature recorded at Rothera Station (67°34'S, 68°08'W) from 1977-2004 is shown by the dotted curve. (B) Annual average sea ice extent for the Palmer LTER Grid (maximum extent 2 x 10^5 km^2) and for the Southern Ocean (inset) from 1979 to 2004.

Satellite data complement surface observations and extend our ship-based and near-shore based observations both seasonally and regionally. In the context of this high latitude ecosystem we have made extensive use of satellite imagery to examine sea ice and ocean color. Passive microwave remote sensing of the Southern Ocean provides one of our most complete space/time records for the Palmer region because microwaves are neither limited by clouds nor winter polar darkness. Passive microwave data show the annual advance and retreat of sea ice, a dominant and distinguishing characteristic of this marine ecosystem. Freezing and melting of sea-ice affect the salinity, and hence density gradients, of the upper ocean. This, in turn, influences the vertical structure of phytoplankton distributions and abundance. In contrast to other areas in the Southern Ocean, the southern Bellingshausen Sea region (inclusive of the WAP region) sea-ice variability show (in spite of high interannual variability) both a decrease in concentration and duration consistent with the observed warming in this region (Fig ??).

Using SeaWiFS ocean color date, we evaluate the spatial and temporal variability of pigment biomass (estimated as chlorophyll-a concentrations). Satellite ocean color data are limited by clouds and polar darkness. Nevertheless, we have derived monthly mean chl-a concentrations from SeaWiFS data (making use of our own Southern Ocean algorithm) for those months when solar elevations permit these data to be obtained (Sept through March). In particular, we have evaluated the variability in chl-a in response to the spatial and temporal variability of sea ice extent (estimated from passive microwave satellite data) and wind forcing (estimated from NCEP reanalysis data). While the ocean color data record is relatively short (7 years) and contains high interannual variability, there are persistent spatial patterns that indicate important regional scale mechanisms influencing this marine ecosystem and that are consistent with several hypotheses relating patterns of phytoplankton biomass distributions to physical controls. Our observations show, for example, that the southern Antarctic Circumpolar Current front (SACCF) zone may have a more profound influence on the WAP area than previously thought.

With respect to ocean color satellite sensors, we have shown that bio-optical properties of Antarctic waters are significantly different than those at temperate latitudes. Spectral absorption and backscattering data have and will be used to test hypotheses concerning these unique bio-optical characteristics of Southern Ocean (SO) waters. To the best of our knowledge these are the first inherent optical property data to be obtained in the SO and we anticipate that these data will permit a quantitative assessment of hypotheses related to the optical properties of the SO. Our intent is to place our empirical SeaWiFS algorithm for the SO on a more analytical basis. Further, we are investigating whether or not we can detect shifts in phytoplankton functional groups that may be associated with climate variability that would not likely be detected by empirical algorithms alone. Our analysis also will test if the bio-optics of the WAP are representative of the rest of the SO.

The PAL Ocean Informatics & Social Informatics Component (K.S.Baker)

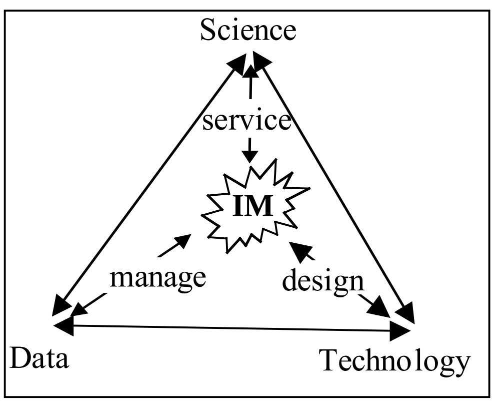
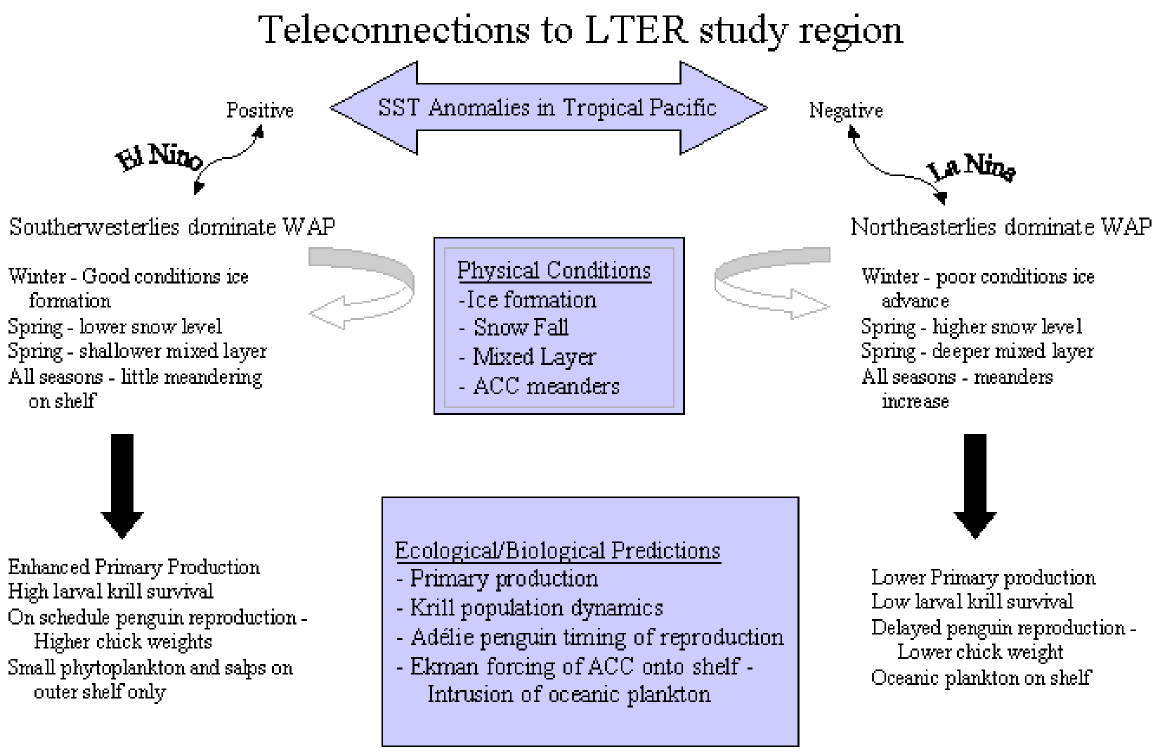


Figure A7. Information management providing support for and mediating between science, data, and technology.

PAL information management draws upon the work of Ocean Informatics and Social Informatics research supported by synergistic funding. The shared goal is to design an informatics environment that is sustainable and able to support long-term environmental research, data repositories, and information flows. Extended partnerships and strategic design teams shared with other data focused projects contribute significantly to design, development, and deployment of new applications for PAL information management and data integration endeavors. With social informatics partners, we are both making use of and working to open up a collaborative design approach to scaling data and infrastructure as well as to developing data and community interoperability strategies.

Appendix 2. Intellectual Evolution and Context of the Palmer LTER.

Although our initial concept of the importance of the effects of seasonal sea ice dynamics on the vitality of all levels of the pelagic ecosystem remains at the core of our research, we have a growing understanding of the complexities of the coupled atmosphere-ocean-sea ice-biota interactions. Our first working hypotheses were relatively simplistic, and focused on the extent of pack ice in winter as the sea ice variable with the most impact. This paradigm underwent a shift as we recognized that timing and duration of sea ice also had an impact at various levels of the ecosystem, and that the various components of the ecosystem responded differently to the same factor. Initially we recognized that other physical factors, such as variations in oceanic circulation, would also affect biological processes. Recent analyses have shown both the pervasiveness of warmer Upper Circumpolar Deep Water on the shelf, and interannual variability



in its horizontal extent, and a role for the UCDW suggested feedback with the atmosphere. We also became increasing aware of tropical/high latitude teleconnections, e.g. the links between Antarctic waters in the south east Pacific (waters west of the Antarctic Peninsula) and ENSO conditions in the tropical Pacific. As the long-term data sets increased, and analyses of climate data began to show statistically significant warming trends and a trend toward later and later sea ice formation in the fall, and that the Adelie penguin population numbers were decreasing around Anvers I., we were faced with the challenge of detecting trends against a background of strong interannual variability, decadal scales of variability, regime shifts, and/or long term cycles. We had to think about possible ecological responses to climate change, and what kinds of data we need both to detect current responses and to predict responses in the future. Our working hypotheses began to incorporate ideas about non-linear responses to changing conditions, about how changes in timing of life cycles of predator and prey could create ‘mismatches’ in the need for and availability of food, and optimal habitats defined by different suites of conditions depending on the species investigated. Midway through this third granting period we find ourselves on the threshold of being able to detect and interrelate responses in the pelagic ecosystem west of the Antarctic Peninsula.

PAL Working Hypothesis I: 1991-1996

Our central hypothesis states that many significant biological processes in the Antarctic marine environment are strongly affected by physical factors, particularly the annual advance & retreat of pack ice & variations in ocean currents. Our conceptual model of the interaction between these physical processes & the components of the ecosystem is based on our present knowledge of interannual variability in the extent of pack ice & in the reproductive success of the species that dominate energy flow.

Ho: We hypothesize that interannual variation in the extent of pack ice affects the vitality of ice edge phytoplankton, & associated krill & seabird populations.

PAL Working Hypothesis II: 1996-2002

The PAL program remains focused on understanding the ecological role of sea ice with the primary object being to gain a general understanding of the physical & climatic controls on interannual sea ice variability, the effects of this variability on trophic interactions, & the biogeochemical consequences thereof (PAL Group, 1996; Smith et al., 1995c). Our observational & experimental programs reflect this primary research goal.

Ho: Neither the presence nor the extent of annual sea ice in the PAL study area influences ecosystem structure & dynamics.

PAL Working Hypotheses III: 2002-2008

During PAL I and II, we detected a progressive poleward shift in the dominant climatic gradient along the West Antarctic Peninsula, observed a contemporary ENSO signal in sea ice patterns and primary productivity, and established a temperature trend we believe to be associated with observed global warming. In short, the atmospheric and marine fluids that support and sustain the ecosystems of the Palmer area are dynamic in time and space. At the inception of PAL, we established a measurement system along the West Antarctic Peninsula and in the environs of Palmer Station that permits us to study ecological dynamics as they vary in time and space in response to climate variation and climate change.

Ho(a): Climate migration associated with a warmer, more moist maritime regime that is becoming increasingly dominant along the north and central WAP region, is giving rise to ecosystem responses that take the form of changes in the abundance, distribution and community structure of all trophic levels.

Ho(b): Teleconnections to global scale atmospheric processes, with attendant quasi-periodic variability within this Antarctic marine ecosystem, modulates the observed longer term trends in climate and ecological processes.