Annual Report for Period: 09/2010 - 08/2011
Submitted on: 06/23/2011
Principal Investigator: Ducklow, Hugh W.
Award ID: 0823101
Organization: Marine Biological Lab
Submitted By:
Ducklow, Hugh - Principal Investigator
Title:
Palmer, Antarctica Long Term Ecological Research Project

Project Participants

Senior Personnel

Name: Ducklow, Hugh
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Fraser, William
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Martinson, Douglas
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Baker, Karen
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Simmons, Beth
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Schofield, Oscar
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Steinberg, Debbie
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Stammerjohn, Sharon
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Doney, Scott
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Name: Montes-Hugo, Martin

Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Kahl, Alex
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Saba, Grace
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Sailley, Sevrine
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Lunau, Mirko
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Saenz, Ben
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Seguret, Marie
Worked for more than 160 Hours: Yes
Contribution to Project:

Graduate Student

Name: Fragoso, Glaucia
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Rukke, Kate
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Price, Lori
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Gorman, Kristen
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Guo, Jige
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Moeller, Heidi

Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Gaas, Brian
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Randall-Goodwin, Evan
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Mankoff, Ken
Worked for more than 160 Hours: No
Contribution to Project:

Name: Donovan, Joan
Worked for more than 160 Hours: No
Contribution to Project:

Undergraduate Student

Name: Gleiber, Miram
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Garzio, Michael
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Cermino, Meghan
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Savard, Steven
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Wiley, Sean
Worked for more than 160 Hours: No
Contribution to Project:

Name: Peterson, Robert
Worked for more than 160 Hours: No
Contribution to Project:

Name: Gates, Lara
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Coleman, Kaycee

Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Smoot, Caitlin
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Funkey, Carolina
Worked for more than 160 Hours: Yes
Contribution to Project:

Technician, Programmer

Name: Erickson, Matthew
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Waldron, Maggie
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Iannuzzi, Richard
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Cope, Joseph
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Patterson, Donna
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Blum, Jennifer
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Yeager, Kirstie
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Kerfoot, John
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Leonardis, Elizabeth
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Connors, James

Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Wanetick, Jerome
Worked for more than 160 Hours: No
Contribution to Project:

Name: Yarmey, Lynn
Worked for more than 160 Hours: No
Contribution to Project:

Name: Kortz, Mason
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Lima, Ivan
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Haskins, Tina
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Ryan, Sean
Worked for more than 160 Hours: No
Contribution to Project:

Name: Couto, Nicole
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Travers, Mark
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Ducklow, Kelsey
Worked for more than 160 Hours: Yes
Contribution to Project:

Other Participant

Name: Morgan, Tawna
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Smaniotto, Rick
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Rasmussen, Mark

Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Whiteley, Daniel
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Jones, Bethan
Worked for more than 160 Hours: Yes
Contribution to Project:

Research Experience for Undergraduates

Name: Cardman, Zena
Worked for more than 160 Hours: Yes
Contribution to Project:

Years of schooling completed: Junior
Home Institution: Other than Research Site
Home Institution if Other: University of North Carolina
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2009
REU Funding: REU supplement

Organizational Partners

Old Dominion University

Woods Hole Oceanographic Institution

Simon Fraser University

University of South Florida

University of Wisconsin-Madison

COSEE

University of California-San Diego Scripps Inst of Oceanography

Fredericksburg Christian School

Point Reyes Bird Observatory

Smithsonian Institution

Santa Clara University

University of Quebec

University of Michigan

University of South Florida St. Petersburg

University of Delaware College of Marine Studies

California Polytechnic State University

University of Minnesota-Twin Cities

British Antarctic Survey

Antarctic Climate and Ecosystems Coopera

Catholic University of Louvain

Lamont-Doherty Earth Observatory of Columbia University

Boston Museum of Science
Education/outreach outlet for presentations and public outreach

Harvard University Harvard Forest

University of New Mexico

Other Collaborators or Contacts

Alison Cawood Graduate Students CCE LTER
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Bill Sydemann Farallon Institute Advanced Ecosystem Research
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David Bailey, University of Glasgow, Glasgow, UK
David Kirchman, Univ of Delaware
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David Rind, NASA GISS
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Hamilton Fredericksburg Christian School, Staffford Virginia
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Mathew Oliver, University of Delaware, Lewes, Delaware, USA
Melissa Pitkin Point Reyes Bird Observatory
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Petra Heil, Australian ACE CRC
Rob Massom, Australian ACE CRC
Sarah Dahl Fredericksburg Christian Middle School
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Thomas Scott Snider
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Tony Worby, Australian ACE CRC
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Bettina Meyer, Alfred Wegener Institut
Mario Lebrato, Alfred Wegener Institut
Tsvetan Bachvaroff, Smithsonian Research Inst
John Reinfelder, Rutgers Univ

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

see attached file

Findings: (See PDF version submitted by PI at the end of the report)

see attached file

Training and Development:

Palmer LTER provides access for undergraduate, graduate and postdoctoral students to Antarctica and the research infrastructure provided by the US Antarctic Program. PAL-LTER also provides mentoring opportunities for our students. We rely significantly on undergraduate volunteers and REUs to conduct our research; thus college undergrads are exposed to, and participate in real scientific research in the field as well as in the lab.

Outreach Activities:

All LTER Sites are mandated to maintain a high level of outreach in their programs. We employ a half-time Education & Outreach Coordinator (Beth Simmons). From our website:

Our Education and Outreach program teams scientists with local scientific and educational facilities engaging the 'K through gray' community in both the process and the understanding gained from this research. We train undergraduates, graduate students, and postdoctoral scholars across disciplinary boundaries. Through collaborations with formal and informal science education organizations, we reach many schoolchildren each year, including local low-income and minority students.

Journal Publications

Ducklow, H.;, "Microbial services: challenges for microbial ecologists in a changing world", Aquatic Microbial Ecology, p. 13-19, vol. 53, (2008). Published,

Ducklow, Hugh W.;, "Long-term studies of the marine ecosystem along the west Antarctic Peninsula", Deep Sea Research II, p. 1945-1948, vol. 55, (2008). Published,

Ducklow, Hugh W.;Doney, Scott C.;Steinberg, Deborah K.;, "Contributions of Long-Term Research and Time-Series Observations to Marine Ecology and Biogeochemistry", Annual Review of Marine Science, p. 279-302, vol. 1, (2009). Published,

Ducklow, Hugh W.;Erickson, Matthew;Kelly, Joann;Montes-Hugo, Martin;Ribic, Christine A.;Smith, Raymond C.;Stammerjohn, Sharon E.;Karl, David M.;, "Particle export from the upper ocean over the continental shelf of the west Antarctic Peninsula: A long-term record, 1992-2007", Deep Sea Research II, p. 2118-2131, vol. 55, (2008). Published,

F. Millerand, GC Bowker, "Metadata Standard: Trajectories and Enactment in the Life of an Ontology", Formalizing Practices: Reckoning with Standards, Numbers and Models in Science and Everyday Life, p. , vol. , (2009). Published,

Friedlaender, A. S.;Fraser, W. R.;Patterson-Fraser, D. L.;Qian, S. S.;Halpin, P. N.;, "The effects of prey demography on humpback whale (Megaptera novaeangliae) abundance around Anvers Island, Antarctica", Polar Biology, p. 1217-1224, vol. 31, (2008). Published,

Gasol, JM;Pinhassi, J;Alonso-Saez, L;Ducklow, H;Herndl, GJ;Koblizek, M;Labrenz, M;Luo, Y;Moran, XAG;Reinthaler, T;Simon, M;, "Towards a better understanding of microbial carbon flux in the sea", Aquatic Microbial Ecology, p. 21, vol. 53, (2008). Published,

Geisz, Heidi N.;Dickhut, Rebecca M.;Cochran, Michele A.;Fraser, William R.;Ducklow, Hugh W.;, "Melting Glaciers: A Probable Source of DDT to the Antarctic Marine Ecosystem", Environ. Sci. Technol., p. 3958, vol. 42, (2008). Published,

Kirchman, David L.;Moran, Xose Anxelu G.;Ducklow, Hugh;, "Role of temperature and potential impact of climate change", Nature Reviews - Microbiology, p. 451-459, vol. 7, (2009). Published,

Montes-Hugo, MA;Ducklow, H;Schofield, OM;, "Contribution by different marine bacterial communities to particulate beam attenuation", Aquatic Microbial Ecology, p. 13-22, vol. 379, (2009). Published,

Montes-Hugo, Martin;Doney, Scott C.;Ducklow, Hugh W.;Fraser, William;Martinson, Douglas;Stammerjohn, Sharon E.;Schofield, Oscar;, "Recent Changes in Phytoplankton Communities Associated with Rapid Regional Climate Change Along the Western Antarctic Peninsula", Science, p. 1470-1473, vol. 323, (2009). Published,

Patterson, D. L.;Woehler, E. J.;Croxall, J. P.;Cooper, J.;Poncet, S.;Peter, H. -U.;Hunter, S.;Fraser, W. R.;, "Giant Petrel Macronectes halli and the Southern Giant Petrel M. giganteus", Marine Ornithology, p. 115-124, vol. 36, (2008). Published,

Ribic, C. A.;E. W. Chapman;W. R. Fraser;G. L. Lawson;P. H. Wiebe;, "Top predators in relation to bathymetry, ice, and krill during austral winter in Marguerite Bay, Antarctica", Deep Sea Research II, p. 485-99, vol. 55, (2008). Published,

Rind, D.;J. Jonas;S. Stammerjohn;P. Lonergan;, "The Antarctic ozone hole and the Northern Annular Mode: a stratospheric interhemispheric connection", Geophysical Research Letters, p. doi: 10.1, vol. 36, (2009). Published,

Shearn-Bochsler, V. D.;Green, E.;Converse, K. A.;Docherty, D. E.;Thiel, T.;Geisz, H. N.;Fraser, W. R.;Patterson-Fraser, D. L.;, "Cutaneous and diphtheritic avian poxvirus infection in a nestling Southern Giant Petrel (Macronectes giganteus) from Antarctica", Polar Biology, p. 569-73, vol. 31, (2008). Published,

Siniff, D. B.;Garrott, R. A.;Rotella, J. J.;Fraser, W. R.;Ainley, D. G.;, "Projecting the Effects of Environmental Change on Antarctic Seals", Antarctic Science, p. 425-35, vol. 20, (2008). Published,

Stammerjohn, S. E.;D. G. Martinson;R. C. Smith;X. Yuan;D. Rind;, "Trends in Antarctic Annual Sea Ice Retreat and Advance and their Relation to ENSO and Southern Annular Mode Variability", Journal of Geophysical Research, p. doi: 10.1, vol. 113, (2008). Published,

Stammerjohn, Sharon E.;, Douglas G.;Smith, Raymond C.;Iannuzzi, Richard A.;, "Sea ice in the western Antarctic Peninsula region: Spatio-temporal variability from ecological and climate change perspectives", Deep Sea Research II, p. 2041-2058, vol. 55, (2008). Published,

Straza, Tiffany R. A.;Cottrell, Matthew T.;Ducklow, Hugh W.;Kirchman, David L.;, "Geographic and phylogenetic variation in bacterial biovolume using protein and nucleic acid staining", Appl. Environ. Microbiol., p. 4028, vol. 75, (2009). Published,

Baker, Karen S.;Chandler, Cynthia L.;, "Enabling long-term oceanographic research: Changing data practices, information management strategies and informatics", Deep Sea Research Part II: Topical Studies in Oceanography, p. 2132-2142, vol. 55, (2008). Published,

Clarke, Andrew;Meredith, Michael P.;Wallace, Margaret I.;Brandon, Mark A.;Thomas, David N.;, "Seasonal and interannual variability in temperature, chlorophyll and macronutrients in northern Marguerite Bay, Antarctica", Deep Sea Research Part II: Topical Studies in Oceanography, p. 1988-2006, vol. 55, (2008). Published,

Martinson, Douglas G.;Stammerjohn, Sharon E.;Iannuzzi, Richard A.;Smith, Raymond C.;Vernet, Maria;, "Western Antarctic Peninsula physical oceanography and spatio-temporal variability", Deep Sea Research II, p. 1964-1987, vol. 55, (2008). Published,

McClintock, J.;H. W. Ducklow;W. Fraser;, "Ecological responses to climate change on the Antarctic Peninsula", American Scientist, p. 414-422, vol. 96, (2008). Published,

Meredith, Michael P.;Murphy, Eugene J.;Hawker, Elizabeth J.;King, John C.;Wallace, Margaret I., "On the interannual variability of ocean temperatures around South Georgia, Southern Ocean: Forcing byEl Nino-Southern Oscillation and the Southern Annular Mode", Deep Sea Research II, p. 2007, vol. 55, (2008). Published,

Montes-Hugo, M. A.;Vernet, M.;Martinson, D.;Smith, R.;Iannuzzi, R.;, "Variability on phytoplankton size structure in the western Antarctic Peninsula (1997-2006)", Deep Sea Research Part II: Topical Studies in Oceanography, p. 2106-2117, vol. 55, (2008). Published,

Ross, Robin M.;Quetin, Langdon B.;Martinson, Douglas G.;Iannuzzi, Rich A.;Stammerjohn, Sharon E.;Smith, Raymond C.;, "Palmer LTER: Patterns of distribution of five dominant zooplankton species in the epipelagic zone west of the Antarctic Peninsula, 1993-2004", Deep Sea Research II, p. 2086-2105, vol. 55, (2008). Published,

Smith, Raymond C.;Martinson, Douglas G.;Stammerjohn, Sharon E.;Iannuzzi, Richard A.;Ireson, Kirk;, "Bellingshausen and western Antarctic Peninsula region: Pigment biomass and sea-ice spatial/temporal distributions and interannual variabilty", Deep Sea Research II, p. 1949-1963, vol. 55, (2008). Published,

Vernet, Maria;Martinson, Douglas;Iannuzzi, Richard;Stammerjohn, Sharon;Kozlowski, Wendy;Sines, Karie;Smith, Ray;Garibotti, Irene;, "Primary production within the sea-ice zone west of the Antarctic Peninsula: I--Sea ice, summer mixed layer, and irradiance.", Deep Sea Research II, p. 2068-2085, vol. 55, (2008). Published,

Wallace, Margaret I.;Meredith, Michael P.;Brandon, Mark A.;Sherwin, Toby J.;Dale, Andrew;Clarke, Andrew;, "On the characteristics of internal tides and coastal upwelling behaviour in Marguerite Bay, west Antarctic Peninsula", Deep Sea Research Part II: Topical Studies in Oceanography, p. 2023-2040, vol. 55, (2008). Published,

Ainley, David;Russell, Joellen;Jenouvrier, Stephanie;Woehler, Eric;Lyver, Philip O, "Antarctic penguin response to habitat change as Earth", Ecological Monographs, p. 49-66, vol. 80, (2010). Published,

Amaral-Zettler, L. A.;.;Ducklow, H. W.;Huse, S. M.;, "A Method for Studying Protistan Diversity Using Massively Parallel Sequencing of V9 Hypervariable Regions of Small-Subunit Ribosomal RNA Genes", PLoS ONE, p. doi:10.13, vol. 4, (2009). Published,

Aronova, E.;K. Baker;N. Oreskes;, "From the International Geophysical Year to the International Biological Program: Big Science and Big Data in Biology, 1957-present", Historical Studies in the Natural Sciences, p. 183-224, vol. 40, (2010). Published,

Chapman, Erik W.;Hofmann, Eileen E.;Patterson, Donna L.;Fraser, William R.;, "The effects of variability in Antarctic krill (Euphausia superba) spawning behavior and sex/maturity stage distribution on Ad????lie penguin (Pygoscelis adeliae) chick growth: A modeling study", Deep Sea Research II, p. 543, vol. 57, (2010). Published,

Montes-Hugo, M.;C. Sweeney;S. C. Doney;H. W. Ducklow;R. Frouin;D. G. Martinson;S. Stammerjohn;O. Schofield;, "Seasonal forcing of summer dissolved inorganic carbon and chlorophyll a on the Western Shelf of the Antarctic Peninsula", Journal of Geophysical Research-Oceans, p. doi:10.10, vol. 115, (2010). Published,

O. Schofield;H.W. Ducklow;D.G. Martinson;M.P. Meredith;M.A. Moline;W.R. Fraser;, "How Do Polar Marine Ecosystems Respond to Rapid Climate Change?", Science, p. 1520-1523, vol. 328, (2010). Published,

Ainley, D.;Russell, J.;Jenouvrier, S.;Woehler, E.J.;Lyver, P.O???B.;Fraser, W.R.;Kooyman, G.L.;, "The derivation of a model ensemble useful to predict changes in penguin habitat", Ecological Archives, p. , vol. M080-00, (2010). Published,

Ainley, DG.;Jongsomjit, D.;Ballard, G.;Thiele, D.;Fraser, WR;Tynan, C.;, "Modeling the relationship of Antarctic minke whales to major ocean boundaries", Polar Biology, p. , vol. , (2011). Accepted,

Baker, Karen S.;Yarmey, Lynn;, "Data Stewardship: Environmental Data Curation and a Web-of-Repositories", International Journal of Digital Curation, p. , vol. 4, (2009). Published,

Bowker, Geoffrey C.;Baker, Karen;Millerand, Florence;Ribes, David;, "Toward Information Infrastructure Studies: Ways of Knowing in a Networked Environment", International Handbook of Internet Research, p. 97-117, vol. , (2010). Published,

Boyd, P. W.;Doney, S. C.;Strzepek, R.;Dusenberry, J.;Lindsay, K.;Fung, I.;, "Climate-mediated changes to mixed-layer properties in the Southern Ocean: assessing the phytoplankton response", Biogeosciences, p. 847-864, vol. 5, (2008). Published,

Boyd, P.W.;C.S. Law;S.C. Doney;, "Boyd, P.W., C.S. Law, and S.C. Doney, A climate change atlas for the ocean, Oceanography, in press (June 2011 issue).", Oceanography, p. 13-16, vol. 24, (2011). Published,

Buesseler, K. O.;McDonnell, A. Mp;Schofield, Oscar M. E.;Steinberg, Deborah K.;Ducklow, Hugh W.;, "High particle export over the continental shelf of the west Antarctic Peninsula", Geophysical Research Letters, p. 1-5, vol. 37, (2010). Published,

Chance, Rosie;Weston, Keith;Baker, Alex R.;Hughes, Claire;Malin, Gill;Carpenter, Lucy;Meredith, Michael P.;Clarke, Andrew;Jickells, Timothy D.;Mann, Paul;Rossetti, Helen;, "Seasonal and interannual variation of dissolved iodine speciation at a coastal Antarctic site", Marine Chemistry, p. 171-181, vol. 118, (2010). Published,

Chapman, E.W.;Hofmann, EE;Patterson, DL;Ribic, CA;Fraser, WR;, "Marine and Terrestrial Factors Affecting Adelie Penguin (Pygoscelis adeliae) Chick Growth and Recruitment off the Western 2 Antarctic Peninsula", Marine Ecology Progress Series, p. , vol. , (2011). Accepted,

Clarke, Andrew;Brierley, Andrew S.;Harris, Colin M.;Lubin, Dan;Smith, Raymond C.;, "Polar and ice-edge marine systems", Aquatic Ecosystems: Trends and Global Prospects, p. 319-333, vol. , (2008). Published,

Clarke, Andrew;Griffiths, Huw J.;Barnes, David K. A.;Meredith, Michael P.;Grant, Susie M.;, "Spatial variation in seabed temperatures in the Southern Ocean: Implications for benthic ecology and biogeography", Journal of Geophysical Research, p. , vol. 114, (2009). Published,

Doney, Scott C.;, "The growing human footprint on coastal and open-ocean biogeochemistry", Science, p. 1512-1516, vol. 328, (2010). Published,

Doney, Scott C.;Fabry, Victoria J.;Feely, Richard A.;Kleypas, Joan A.;, "Ocean Acidification: The Other CO2 Problem", Annual Review of Marine Science, p. 169-192, vol. 1, (2009). Published,

Ducklow, H.;A. Clarke;R. Dickhut;S.C. Doney;H. Geisz;K. Huang;D.G. Martinson;M.P. Meredith;H.V. Moeller;M. Montes-Hugo;O. Schofield;S.E. Stammerjohn;D. Steinberg;W. Fraser;, "Marine pelagic ecosystems: the West Antarctic Peninsula", Antarctica: An Extreme Environment in a Changing World (Book), p. , vol. , (2011). Accepted,

Ducklow, Hugh W.;Moran, X. Ag;Murray, A. E.;, "Bacteria in the Greenhouse: Marine microbes and climate change", Environmental Microbiology (Book), p. 1, vol. , (2010). Published,

Erdmann, Eric S.;Ribic, Christine A.;Patterson-Fraser, Donna L.;Fraser, William R.;, "Characterization of winter foraging locations of Ad??lie penguins along the Western Antarctic Peninsula, 2001-2002", Deep Sea Research II, p. 1710-1718, vol. 58, (2011). Published,

Friedlaender, Ari S.;Johnston, David W.;Fraser, William R.;Burns, Jennifer;Patrick N, Halpin;Costa, Daniel P.;, "Ecological niche modeling of sympatric krill predators around Marguerite Bay, Western Antarctic Peninsula", Deep Sea Research II, p. 1729-1740, vol. 58, (2011). Published,

Fritsen, Christian H.;Memmott, Jeramie;Stewart, Frank C.;, "Inter-annual sea-ice dynamics and micro-algal biomass in winter pack ice of Marguerite Bay Antarctica", Deep Sea Research II, p. 2059-2067, vol. 55, (2008). Published,

Gorman, K.;Erdmann, E.;Pickering, B.;Horne, P.;Blum, J.;Lucas, H.;Patterson-Fraser, D.;Fraser, W.;, "A new high-latitude record for the macaroni penguin (Eudyptes chrysolophus) at Avian Island, Antarctica", Polar Biology, p. 1155-1158, vol. 33, (2010). Published,

Hendry, Katharine R.;Meredith, Michael P.;r I.;Carson, Damien S.;Rickaby, Rosalind E. M.;, "The role of sea ice formation in cycling of aluminum in northern Marguerite Bay, Antarctica", Estuarine, Coastal and Shelf Science, p. 103-112, vol. 87, (2010). Published,

Hendry, Katharine R.;Rickaby, Rosalind E. M.;Meredith, Michael P.;Elderfield, Henry;, "Controls on stable isotope and trace metal uptake in Neogloboquadrina pachyderma (sinistral) from an Antarctic sea-ice environment", Earth and Planetary Science Letters, p. 67-77, vol. 278, (2009). Published,

Hipfner, JM;Gorman, KB;Vos, RA;Joy, JB;, "Evolution of embryonic developmental period in the marine bird families Alcidae and Spheniscidae: roles for nutrition and predation?", Evolutionary Biology, p. 179-189, vol. 10, (2010). Published,

Kahl, L. Alex;Schofield, Oscar;Fraser, William R.;, "Autonomous Gliders Reveal Features of the Water Column Associated with Foraging by Adelie Penguins", Integrative and Comparative Biology, p. 1041-1050, vol. 50, (2010). Published,

Kalanetra, Karen M.;Bano, Nasreen;Hollibaugh, James T.;, "Ammonia-oxidizing Archaea in the Arctic Ocean and Antarctic coastal waters", Environmental Microbiology, p. 2434-2445, vol. 11, (2009). Published,

Karasti, Helena;Baker, Karen S.;, "Digital Data Practices and the Global Long Term Ecological Research Program", International Journal of Digital Curation, p. 42-58, vol. 3, (2008). Published,

Karasti, Helena;Baker, Karen S.;Millerand, Florence;, "Infrastructure Time: Long-Term Matters in Collaborative Development", Computer Supported Cooperative Work - An International Journal, p. 377-415, vol. 19, (2010). Published,

Kuan Huang;Hugh Ducklow;Maria Vernet;Nicolas Cassar;Michael L. Bender;, "Export production and its regulating factors in the West Antarctica Peninsula region of the Southern Ocean", Global Biogeochemical Cycles, p. , vol. , (2011). Accepted,

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Books or Other One-time Publications

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Collection: LTER Children's Book Series
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Bibliography: Participatory Design Conference, Bloomington, IN

Web/Internet Site

URL(s):
http://pal.lternet.edu/
Description:
Project Website, contains Palmer LTER data archives at:
http://oceaninformatics.ucsd.edu/datazoo/data/pallter/datasets

Other Specific Products

Product Type:
Data or databases
Product Description:
All oceanographic data collected in Palmer LTER since 1990:
http://oceaninformatics.ucsd.edu/datazoo/data/pallter/datasets

Sharing Information:
Open-access via Internet. Data fully documented with associated metadata

Product Type:
Teaching aids
Product Description:
K12 Lesson Plans for teachers. All found: http://pal.lternet.edu/outreach/educators/instructional_materials_resources/
* Carlson K & Simmons B (2011) Ecosystem Illustrations
* Carlson K. & Simmons B. (2011) Animal identification cards
* Simmons & Soder (2011) Students explore how organisms in an ecosystem depend on one another.
* Simmons & Soder (2011) Students compare the temperature and salinities of the World?s Ocean
* Simmons & Deal (2011) Animal Classification: How animals of the same genus survive in two different ecosystems.
* Simmons & Deal (2011) How are populations of organisms in marine food webs affected by changes in the physical and biological properties of that ecosystem?

Sharing Information:
work with individual teachers on lesson planning and development

Product Type:
Teaching aids
Product Description:
Simmons (2011) Evidence of Change, NOAA Ocean Today kiosk project http://oceantoday.noaa.gov/
Sharing Information:
Public website

Contributions

Contributions within Discipline:
Oceanography: Palmer LTER is an oceanographic research program, contributing inter- and multidisciplinary research and data on the marginal sea ice zone of the West Antarctic Peninsula, on rapid climate change and ecosystem responses.

Contributions to Other Disciplines:
Science: As PAL LTER has expanded and diversified its observational capabilities in the past 3 years, we have become regarded as a model observing program for documenting and studying ocean climate change and ecosystem transformation. This has been shown recently by Ducklow's invited talk at the Southern Ocean Observing System session at the AGU Ocean science meeting and the recently published paper in Science by Schofield et al.

Information Management: We are contributing to the social sciences fields of science and technology studies, communication studies, and infrastructure studies as well as information sciences and history of science through partnerships that continue a unique longitudinal ethnography for LTER and Ocean Informatics (http://interoperability.ucsd.edu). A presentation at the annual meeting of the Society for Social Studies of Science in Rotterdam resulted in an invitation to contribute to a book on Collaboration in the Life Sciences. Visits were hosted for Florence Millerand (Dept of Communication; UQuebec) to work on an ethnographic monograph on Ocean Informatics and for Helena Karasti (Dept of Information Systems, UOulu) to join in a working group on infrastructure held at the Computer Supported Cooperative Work Conference in San Diego.

Contributions to Human Resource Development:
We train undergraduate, graduate and postdoctoral students in oceanography and marine ecology in the field (Antarctica) and laboratory at a number of Universities and Non-profit research institutions.

B-013 (Fraser):
Our field program has traditionally attracted technicians and students interested in further training and experience in a variety of areas, including field project planning and logistics, protocol development and implementation, and data management and analysis. Most of these individuals remain with our program for 3-4 years, and eventually seek positions with state and federal governments or pursue graduate degrees. Two of our former technicians, Tawna Morgan and Rick Smaniotto, moved into positions with the Prince William Sound Science

Center, Cordova, Alaska, and Montana Fish Wildlife and Parks, Bozeman, Montana, respectively.

In other developments, aspects of our public, posted long-term PAL seabird data were used, or are in use by other individuals as follows:

Nicole Casper, M.Sc. student, Western Washington University, using our decadal krill size-frequency data based on Ad??lie penguin diets for thesis development.

Jefferson Hinke, Ph.D. student, SCRIPPS/US AMLR Program, using our decadal Ad??lie penguin demographic data for dissertation development.

Lynch HJ, Fagan WF, Naveen R, Trivelpiece SG, Trivelpiece WZ. 2009. Timing of clutch initiation in Pygoscelis penguins on the Antarctic Peninsula: towards an improved understanding of off-peak census correction factors. CCAMLR Sci 16:149-165.

Contributions to Resources for Research and Education:

PAL-LTER participates in the LTER Schoolyard LTER Program to provide introductions to scientific research and opportunities to contribute to our research effort by K-12 students. See: http://schoolyard.lternet.edu/

Other educational contributions:

Training and collaboration with Scott Snider in the use of Final Cut Express is ongoing to facilitate the development of additional educational video podcasts for the Ocean Today kiosk projects.

The Power of Stories with two-time Grammy award winning artists Bill Harley ideas on how to use stories in your interactions with children. (April, 2011)

Collaboration with Dr. Herrid at the National Center for Case Study Teaching in science writing and development of instructional case studies for teaching.

Contributions Beyond Science and Engineering:

Conference Proceedings

Special Requirements

Special reporting requirements: None

Change in Objectives or Scope: None

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Contributions: To Any Beyond Science and Engineering

Any Conference

RESEARCH ACTIVITIES: Palmer LTER 2010-2011.

This is the third annual report for the fourth grant period of Palmer LTER (2008-2014, OPP 0823101). This report focuses on the activities undertaken by PAL since October, 2010.

Principal Personnel and Scientific Components (coPIs, grad students and postdocs)

- Hugh Ducklow, Lead PI (MBL, microbes and biogeochemistry.
    - Heidi Geisz, PhD student (VIMS, late 2010 graduation)
    - Catherine Luria, new Brown-MBL PhD student
    - Jennifer Brun, polar postdoc, co-advised with Matt Sullivan, U-Arizona
- Karen Baker (Scripps, Information Management, retiring June, 2011)
- James Conners (Scripps, Information Management, succeeding Karen)
- Scott Doney (WHOI, ocean modeling)
    - Sevrine Sailley, postdoc
- Doug Martinson (LDEO, physical oceanography)
- Mike Meredith (BAS-UK, physical oceanography)
- Bill Fraser (Polar Oceans Research Group, seabirds)
    - Kristen Gorman, PhD student (Simon Fraser Univ)
- Oscar Schofield (Rutgers Univ., primary production and optics)
    - Grace Saba, postdoc (PhD, VIMS 2010)
    - Mike Garzio, MSc student
    - Travis Miles, PhD student
- Rob Sherrell (Rutgers Univ., trace metals)
    - Marie Seguret, postdoc (PhD, Plymouth, UK 2009)
- Beth Simmons (Ocean Ingenuity, education and outreach)
- Sharon Stammerjohn (UCSC, sea ice and climate)
    - Evan Randall-Goodwin, UCSC PhD student
    - Ben Saenz Post-doc
- Debbie Steinberg (VIMS, zooplankton)
    - Kim Bernard, postdoc (PhD, Rhodes Univ, S. Africa, 2007)
    - Kate Ruck, MSc student
    - Lori Price, MSc student

Field Season. In April, 2011 we completed the third field season of the current award, and the 20th in the Palmer LTER program that commenced in 1991-92. The annual summer cruise (LMG 11-01, H. Ducklow, Chief Scientist) and summer season at Palmer Station were both successful. Field operations commenced at Palmer Station in mid-October and continued until the end of March with almost no interruptions. Details of the Palmer-based activities are provided below. The summer LMG cruise was entirely successful with no equipment losses or significant time loss due to weather or breakdown. During the cruise we visited Rothera Station to carry out joint scientific operations and visit with our BAS colleagues. A highlight of the Rothera visit was defeating the British hosts in the annual soccer game – an LTER first. We recovered and redeployed 3 SASSI physical oceanography moorings with conductivity and temperature sensors and current meters (see photo) and our sediment trap mooring that was deployed in March, 2010, after the recovery failure in January 2010. We hosted two guest investigators, Drs. Tim Hollibaugh (Univ of GA) and Lihini Aluwihare (Scripps). They conducted research on ammonium oxidizing Archaea and dissolved organic matter composition.

During the cruise we conducted three longer (~3-days each) process study stations near the Palmer Deep, and the Avian and Charcot Island penguin colonies. These are described in more detail below.

Photo: Physical oceanography mooring recovery at LTER Station 300.160 in high seas. Credit: Ken Legg, B-045.

Publications are listed in the **Findings** document.

Major Meetings, Boards and Workshops. We held our largest-ever annual meeting in Sheridan, MT in September 2010. In addition to the coPIs, 6 grad students and 5 postdocs attended and presented results from the previous season and other topics. **Ducklow** gave an invited presentation about PAL-LTER at the SCAR meeting in Buenos Aires, and also at the joint Argentina-German workshop, IM-Coast, a meeting about their joint research at Jubany Base. Through these activities, we're trying to build a coordinated international research program on the Antarctic Peninsula. This activity resulted in convening a joint workshop with BAS, Argentina, German, Dutch and US participants to be held in Cambridge, UK in July. **Ducklow, Fraser and Stammerjohn** participated in the National Academy/NRC Frontiers in Understanding Climate Change and Polar Ecosystems Workshop in Cambridge, MD. **Ducklow** is a member of the NRC Committee on Future Science Opportunities in the Antarctic and Southern Ocean and the UNOLS Polar Research Vessel Committee (Science Mission

Requirements Refresh Project). **Doney** was a presenter at the annual LTER Mini-Symposium at NSF. **Fraser** participated in an LTER Network Cross-Site synthesis workshop on Detecting and managing abrupt transitions in ecological systems convened at Harvard Forest in May. Ducklow continued participation in the LTER Network cross-site synthesis activity on The Disappearing Cryosphere, that resulted in a manuscript being submitted to BioScience, as part of a special LTER issue (see individual sections below). As this report was being prepared, **Ducklow, Martinson and Stammerjohn** attended the NRC Workshop on IPY Legacies. **Schofield** gave an invited talk at the Southern Ocean Gordon conference in Ventura California. **Schofield** also was a member of the NRC panel scoping out the ocean infrastructure required by the year 2030. Finally, we convened a data synthesis workshop at Lamont-Doherty to examine alternative derivations of mixed layer depth.

Individual Component Reports.

Information Management (Karen Baker, James Conners, SIO-UCSD).

Two types of additions and updates were made during this period: first to the information system and the project tool kit, and second to the data and web content. Work on DataZoo brought it into a stable third generation. Within the DataZoo information system a revision was made to EML to support links to the data. For the CTD data, both field processed and quality controlled data were made available via FileFinder, an application for delivery of large collections of files. The development of new tools includes a log analyzer to provide a snapshot of who is browsing and downloading files as well as a data format service to transpose data matrices for ease of subsequent analysis. Annual data uploads were performed including preparation and ingestion of event logs, participant lists, and core data to bring them into data policy compliance. In addition, a more routine process for monthly updates was developed and deployed. Three participants attended the annual meeting where a poster was presented and several working groups led including web services, unit registry, and governance working groups. Kortz worked for a month to develop the network personnel directory while a product oriented working group supported two meetings at the Network Office. As always, these activities have provided insight into developments relating to DataZoo. Information management collaboration and events with other information management sites are summarized in event flyers and posters uploaded into new media galleries on the PAL information management component web page. These effectively provide a history of the work and collaborations of information management.

Data availability and submission.

With few exceptions, most Palmer LTER data are being submitted to the DataZoo within the traditional two-year embargo period. This is to enhance intra-project data synthesis and availability of Palmer data to the wider community. Many datasets are current through 2010.

Education and Outreach (Beth Simmons, VIMS & Ocean Ingenuity).

Education and Outreach initiatives for Palmer LTER have focused on building a capacity to reach broader audiences. Our most far-reaching outreach efforts during the field season involved live video broadcasts to three elementary school classrooms from Torgersen Island at Palmer Station during the field season, a high quality video broadcast to a TEDx Pura Vida event in Costa Rica, several station tours to National Geographic Explorer ships and coordinated efforts with five field outreach blogs. The MBL's Logan Science Journalism Program continues to afford journalists an opportunity to be a part of polar research and broadcast our science into a

wide variety of science-oriented publications. Our participation in Ocean Night at the Cardiff Elementary school in San Diego California successfully extended our roots into four, second grade elementary classrooms and one multiage classroom. We donated over a hundred Sea Secrets books to the event and continue to engage with the teachers throughout the summer months. Our RET educators from last summer Jessie Soder (Alaska) and Beth Deal (Florida) aided us in the development of four new lessons including how scientists classify organisms and how two different species, from the same genus, require different environmental conditions to survive. With the help of artist, illustrator Kirsten Carlson over one hundred species identification cards from four different ecosystems were paired with ecosystem drawings and are now serving as tools to aid our younger audiences in making connections between the polar environment and their local marine ecosystems.

Other partnerships with larger facilities like the Aquarium of the Pacific's Teacher Open House and Boston's Museum of Science Earth Day are platforms to broaden our K – 12 Outreach program at multiple levels as well as the general public. These venues also provide opportunities for us to network with educational professionals and continue to grow our program. We continue to make available unique opportunities joining educators all across the U.S., from Alaska to the Caribbean to innovate, create and learn Palmer LTER science. Our children's book Sea Secrets is continuing to act as a vehicle to connect the public to our site science and strengthen our program. For example, the partnership with Hands Across the Sea, a non-profit charitable organization dedicated to raising the literacy levels of children is working with us more closely. Joining our other U.S. RET educators this summer, these Caribbean school Peace Corps volunteers and school principals will collaborate and develop instructional materials that motivate students to demonstrate connections between climate change on the western Antarctic Peninsula and learn about their local marine ecosystem while building literacy. Using dynamic video web conferencing tools we will connect these teachers with other U.S. LTER RET programs this summer and have educators sharing their experiences within a professional educational community. Our results and experiences along with the scientific evidence of learning about climate change will be showcased on the PAL LTER outreach web pages along with other instructional materials that have been in development. We will also share our program growth at the NMEA at Northeastern University in Boston Massachusetts this summer and draw those professionals to many of our new online resources for educators.

Our participation in the LTER children's book series program has facilitated collaboration with new LTER authors to channel four new books into publication. Additionally, as co-chair of the LTER Schoolyard Education committee, Simmons played an integral role in reinstating quarterly conference calls, improving communication among Schoolyard LTER education coordinators, reinstating an annual E/O coordinators meeting, and redesign of the Schoolyard web pages. Simmons also contributed to writing the education portion of the Strategic Implementation plan.

Publications and Products

Simmons (2011) Evidence of Change, NOAA Ocean Today kiosk project http://oceantoday.noaa.gov/

Activities and Lessons
All found: http://pal.lternet.edu/outreach/educators/instructional_materials_resources/

* Carlson K & Simmons B (2011) Ecosystem Illustrations
* Carlson K. & Simmons B. (2011) Animal identification cards

* Simmons & Soder (2011) Students explore how organisms in an ecosystem depend on one another.

* Simmons & Soder (2011) Students compare the temperature and salinities of the World's Ocean

* Simmons & Deal (2011) Animal Classification: How animals of the same genus survive in two different ecosystems.

* Simmons & Deal (2011) How are populations of organisms in marine food webs affected by changes in the physical and biological properties of that ecosystem?

Additional education and outreach activities are listed in the component reports below.

Sea Ice, Climate and Modeling (Sharon Stammerjohn, UC Santa Cruz).

This year's research activities involved (a) continued investigation of regional and circumpolar sea ice and climate assessments for PAL LTER; (b) analyses of PAL LTER underway data; (c) commencement of 1-D/3-D sea ice algal modeling to assess how trends towards earlier sea ice retreat and later advance in the PAL LTER region may be contributing to increased CO2 outgassing; and (d) initiation of 1-D ocean-ice modeling to assess bottom-up controls on ice-ecosystem interactions, focusing on sensitivity of mixed layer dynamics to physical forcing; and (e) a comparison of water mass structure in the WAP/PAL LTER region against the 'ASPIRE' (Amundsen Sea Polynya International Research Expedition) study area.

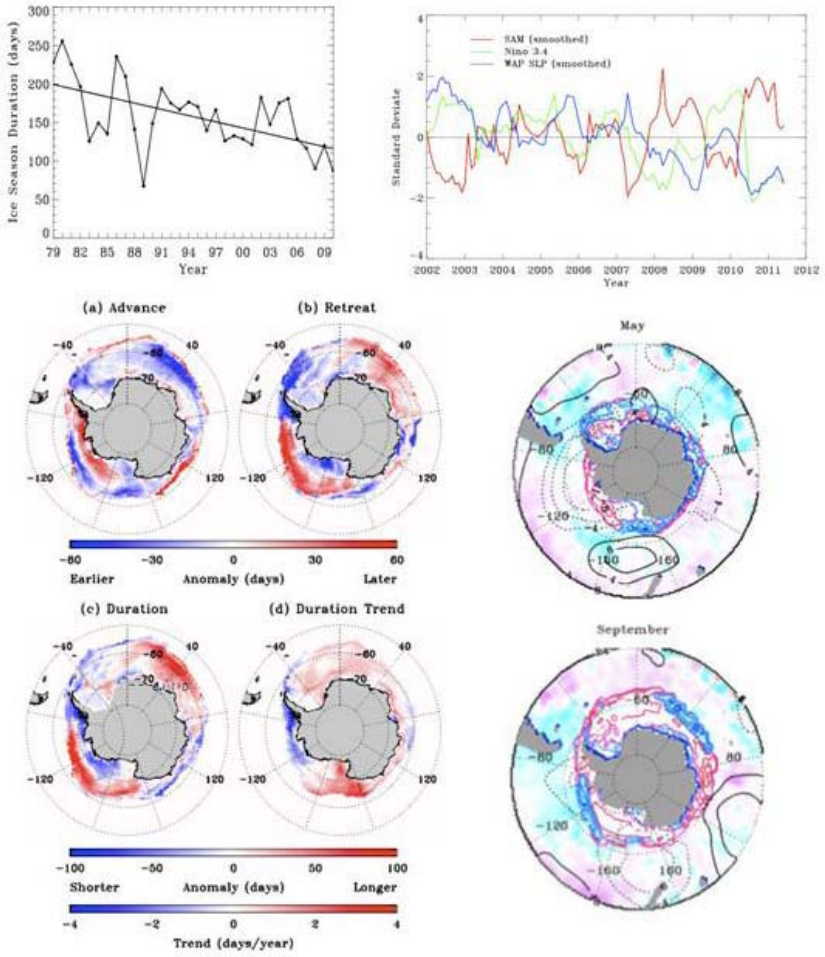


Figure 2. Clockwise from top left: (i) ice season duration for PAL LTER; (ii) climate indices for ENSO (the Nino3.4 index) and SAM (Marshall, 2003) against WAP sea-level pressure (SLP), showing 2010-11 to be a strong +SAM and La Nina, with low pressure in the WAP region; (iii) anomalies for sea ice advance, retreat and duration (a-c) against the 1979-2008 duration trend, showing late advance, early retreat and short ice season in the WAP region; and (iv) anomalies for SST (color shading), SLP (black contours) and sea ice concentration (color contours), showing warm SST, low sea ice & low pressures during the months of late advance and early retreat

These activities are each described in more detail below. (a) Although the sea ice season last year

(2009-10) showed a short-term recovery in PAL LTER winter sea ice extent (driven primarily by a late winter sea ice maximum and later than normal spring sea ice retreat), this year's sea ice season (2010-11) was the shortest on record for the PAL LTER 1992-2010 time series (second only to the all-time record low observed in 1989-90). The short sea ice season was in response to low-pressure conditions centered west of the WAP that were induced by +SAM conditions and the high latitude response to La Nina conditions in the tropical Pacific. The low pressures in turn contributed to strong northerly winds over the PAL LTER region, that fostered wind-driven delays in sea ice advance, and wind-assisted accelerations in sea ice retreat, as illustrated by Figure 2, reflecting our continued investigations of regional/circumpolar ice-climate assessments for the PAL LTER (see also Fogt et al. under research findings).

(b) This past year, my research assistant, Nicole Couto (3/2010 – 2/2011), spent considerable time and effort analyzing and q/a-ing PAL LTER ship's underway data (temperature, salinity, pCO2 and O2), an effort supported by both PAL LTER and my NASA project (*Improving Current Assessments and Future Predictions of Carbon Fluxes in the Southern Ocean as Mediated by the Dynamical Response of Ice-Ocean-Ecosystem Interactions to Climate Change*). Our overall objective was to update the pCO2/O2 analyses by former PAL LTER investigators, Dave Karl and Chris Carrillo. Following the approach described in Carrillo et al. (2004), we analyzed property-property relationships between pCO2(sat), O2(sat), SST, SSS and chl-a (the latter, from surface samples taken at discrete stations along the cruise track) to help distinguish the relative physical, chemical and biological controls on CO2 distributions. We will then analyze the space/time variability described by these variables within the context of yearly variability in physical forcing (e.g., timing of sea ice retreat, storms/winds, mixed layer depth) to test our hypothesis that the trends towards earlier sea ice retreat are weakening the rectification of CO2 fluxes by sea ice. We are in the process of summarizing these results for publication (with collaborators Colm Sweeney and others).

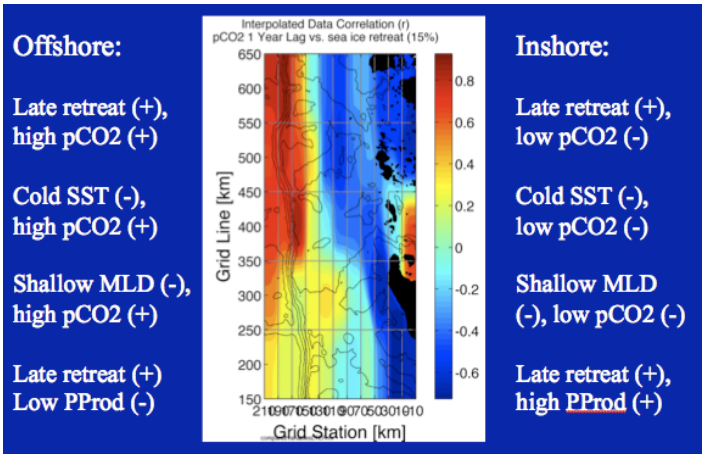


Figure 3 showing correlation map between pCO2 and timing of sea ice retreat (1990-2008) across the PAL LTER grid, e.g., strongly positive offshore (300-600 lines) and negative inshore. Included are on/offshore summaries of other correlations, where +/- indicates the anomaly sign contributing to the correlation.

Nicole also incorporated the underway pCO2 data into the PAL LTER grid analyses (e.g., Martinson et al., 2008) to explore space/time relationships between pCO2, sea ice retreat, SST, MLD, and primary production (**Figure 3**).

The on-offshore relationships are shown above, with interpretation as follows. (1) Offshore, between the 300 and 600 lines, when sea ice retreat is later than normal (positive anomaly), pCO2 is higher than normal (positive anomaly), despite the cooler than normal SST (which, by itself, would lower pCO2), but consistent with lower than normal primary production. In this scenario, MLD is also shallower than normal, which is consistent with a later sea ice retreat (i.e.,

less time for wind-induced mixing). The inference from these relationships is that the high pCO2 is due to recently exposed winter water (high in pCO2) and the lack of a significant biological draw-down, consistent with Smith et al (2008) who reported lower phytoplankton biomass offshore when sea ice retreat was later than normal. Smith et al. (2008) also suggested that wind-induced deep mixing might help relieve micronutrient limitation in the deeper waters away from the coast. (2) In contrast, inshore, we see the opposite relationships observed offshore. In general, a later than normal retreat inshore is associated with lower than normal pCO2, also consistent with lower than normal SST and shallower than normal MLD (due to later sea ice retreat). In turn higher than normal primary production is associated with later sea ice retreat, i.e., stronger biological drawdown of CO2. These on/offshore contrasts are striking and suggest very different sets of controls on air-sea gas exchange that we will continue to investigate in the modeling scenarios described next.

(c-d) The analyses of the underway data and the property-property relationships have helped to characterize the space/time variability of the relative physical, chemical and biological controls on CO2 distributions. We are now examining in greater detail the yearly variability in ocean mixed layer dynamics in relation to surface forcing variability (sea ice, winds) and the corresponding biological response. To assist in this effort, our project has hired Ben Saenz, a recent graduate from Arrigo's Biogeochemistry Lab at Stanford. For his Ph.D. thesis, Ben built, tested and ran a state-of-the-art sea ice algal model (both in 1-D and 3-D configurations), which he used to investigate spatial/temporal Antarctic sea ice algal dynamics and effects of e.g., snow and slush layers in simulating sea ice ecosystems. Through those efforts, Ben gained considerable programming experience and insights into the controls on primary production in the Southern Ocean, especially as mediated by sea ice. Ben is currently using his sea ice algal model to test how the observed trends towards later sea ice advance and earlier sea ice retreat in the PAL LTER study region may affect seasonal ice algal growth and available biomass seeding the water column during the spring sea ice melt and retreat.

Ben, with assistance from Scott Doney, also will be using a 1-D KPP ocean model (Large et al., 1994) coupled to a 1-D version of the CESM biology/biogeochemical model (e.g., Doney, 2003; Moore et al. 2002; 2004). Ben will run his sea ice algal model in parallel to test various aspects of the CO2 rectification hypothesis, in particular how a later autumn sea ice advance and earlier spring retreat (as observed through time) ultimately affects air-sea gas exchange via potential seasonal mis-matches in the biological response. Once we characterize the surface forcing and seasonal evolution in mixed layer dynamics that favor high/low phytoplankton biomass (e.g., with respect to wind forcing, timing of sea ice retreat, proximity to the coast, latitudinal gradients in day length), we can then relate those scenarios to zooplankton grazers and grazing dynamics to arrive at predictions of export production based on the specified bottom-up controls.

(e) Collaborative studies in the southern Bellingshausen and Amundsen Sea continue (as reported in last year's annual report) and involve analysis of ice-ocean interactions (in collaboration with Stan Jacobs, Xiaojun Yuan and more recently Patricia Yager) and seasonal ice mass balance changes (in collaboration with Ted Maksym and Steve Ackley). These collaborations help place PAL LTER/WAP observations into a broader circumpolar context, with particular focus on those regions in the Southern Ocean which show the largest sea ice decreases. Collaboration with Ted Maksym in particular brings new expertise to the PAL LTER regarding sea ice processes. Our objective is to combine snow and sea ice data collected on past cruises in the PAL LTER region with snow and sea ice data collected in the southern

Bellingshausen and Amundsen to investigate regional differences in ocean-atmosphere forcing of sea ice and the contribution of snow-ice to ice mass balance. Further, we (Martinson, Schofield and I) have submitted a proposal with collaborators Steve Ackley (UTSA), Ted Maksym (BAS) and John Toole (WHOI) to investigate the ocean-atmosphere controls on the 3-month increase in the ice-free season in the southern Bellingshasuen Sea (i.e., south of PAL LTER), where the strongest trends towards later sea ice advance and earlier sea ice retreat are observed. If successful, this will expand available ocean time series observations southward into a region where thick multi-year sea ice has virtually disappeared.

Graduate student Evan Randall-Goodwin is involved in a comparative study in the Amundsen Sea: the Amundsen Sea Polynya International Research Expedition (ASPIRE, Yager Lead PI). Late last year Evan participated in his first Antarctic research cruise (ASPIRE NBP10-05). He is now busy writing up results from that cruise which will comprise his Master's Thesis. Evan is specifically looking at meltwater contributions to water mass modification in the Amundsen Sea polynya region. However, he is placing those observations into a wider regional context, including the PAL LTER study region. Evan is already familiar with the PAL LTER study region and program, having attended the PAL LTER annual meeting in Montana last year, where he presented some analyses of the underway ship data, which are being incorporated into the pCO2/O2 analyses described above.

Invited Seminars

Stammerjohn, S. 2010. What is Polar Amplification of Global Climate Change? Invited presentation given at the 2010 Ken Norris Memorial Lecture, A Decade of Marine Science: Lessons Learned, UCSC's Seymour Center at Long Marine Lab, 7 October.

Stammerjohn, S. 2010. Rapid Regional Sea Ice Decline: Is this Polar Amplification of Global Climate Change? Three invited presentations given at: (1) California State University Monterey Bay (CSUMB) Coastal & Watershed Science & Policy M.S. Program Seminar Series, 20 September; (2) USC's Marine Biology and Biological Oceanography 2010-11 Seminar Series, 18-19 October; (3) the Synergy Lecture Series at UCSC, 21 October.

Physical Oceanography (Doug Martinson, LDEO; B-021).

My efforts are aimed at providing a complete assessment of the physical oceanography (including air-sea-ice interactions) that are relevant to the complex physical-biogeochemical system on the western Antarctic Peninsula. This includes overseeing the CTD data collection, processing and analysis for each LTER cruise, and helping design a coherent data analysis/modeling strategy for synthesizing our observations. Two particular foci of this year have been: (1) long term tracking of the ocean heat content of the UCDW (See also Findings; glaciologists have identified that the warming of this water mass is responsible for the accelerated rate of WAIS melt, via major ice stream draining into the ocean just upstream of our LTER sample grid), and (2) how does UCDW move onto the continental shelf in our sample grid from the ACC over the shelf, to provide heat and nutrients to the shelf (the focus of our PO mooring array on the shelf).

We have also maintained the core CTD operation, providing quality controlled data to the public web page within a year of collection.

Phytoplankton and trace metals (Oscar Schofield, Rob Sherrell, Rutgers; B-019).

2010-2011 was a productive year. The field effort was anchored by the extended effort conducted at both Palmer Station (October until April) and aboard the RV Gould (January). The B-019 LTER efforts continued the nearshore time series in partnership with the entire LTER field team, deployed gliders throughout the field season, conducted joint NSF/NASA efforts using a multi-AUV approach to study the grazing dynamics of penguins, trained British Antarctic Survey personnel on glider operations and conducted ocean acidification incubation experiments. Specific highlights are provided below.

Palmer Time Series

Wth the LTER team we conducted semi-weekly time series sampling at Palmer Station. The traditional data were complemented with a full suite of measurements of inherent and apparent optical properties. These measurements were expanded aboard the RV Gould. Partners from the National Oceanography Centre in the United Kingdom collected phytoplankton scanning electron micrograph slides. These slides were complemented with the traditional measurements of phytoplankton productivity, chlorophyll a concentrations, high performance liquid chromatography, fluorescence quantum yields, and trace metals. As these samples are analyzed the data are immediately uploaded into the LTER data zoo.

LTER glider operations.

The LTER glider operations were expanded during the last year. The increase in operations was enabled by leveraged funding from a complementary NASA Biodiversity program and a Moore Foundation grant. Glider operations included a long duration mission along the West Antarctic Peninsula. The mission was successfully completed by running a transect spanning the shelf from Palmer station to just north of Marguerite Bay. The data captured eddy transport across the shelf. The data have helped us refine our power budgets for the glider and will assist in allowing glider missions from Palmer Station to Rothera. One glider was maintained aboard the RV Gould and was deployed during the three process stations. Extended missions at Palmer Station were conducted in January. Three gliders were deployed, outfitted with a Satlantic fluorescence induction relaxation system, a WetLabs Teledyne ADCP, and an optical backscatter sensor. The gliders were deployed and swarmed over the Palmer Deep canyon. Within the glider swarms an autonomous underwater vehicle REMUS was deployed. The flight pattern of the REMUS was planned based on radio-tagged penguin foraging data. The high-resolution data suggested that the foraging dynamics were coupled to the tidal phase, which may serve to aggregate food into concentrated slicks. Glider operations will expand next year to include the BAS gliders. To that end, Rutgers glider technicians are conducting a glider training school in June to help our British partners to rapidly spin up their glider program.

LTER process stations.

A large experimental process study was conducted to assess the impact of variable CO2 on plankton dynamics during the field season. During the incubations, three large volumes were incubated at CO2 levels of preindustrial, present, and future conditions. Three incubations focused on the response of the phytoplankton and one of the incubations focused on adult krill. Phytoplankton showed variable responses to ocean acidification. The diatom populations in the southern area of LTER grid showed no response, however the phytoplankton populations at

Palmer station were sensitive to decreases in ocean pH. Pregnant krill also exhibited stress under low ocean pH.

Trace Metals

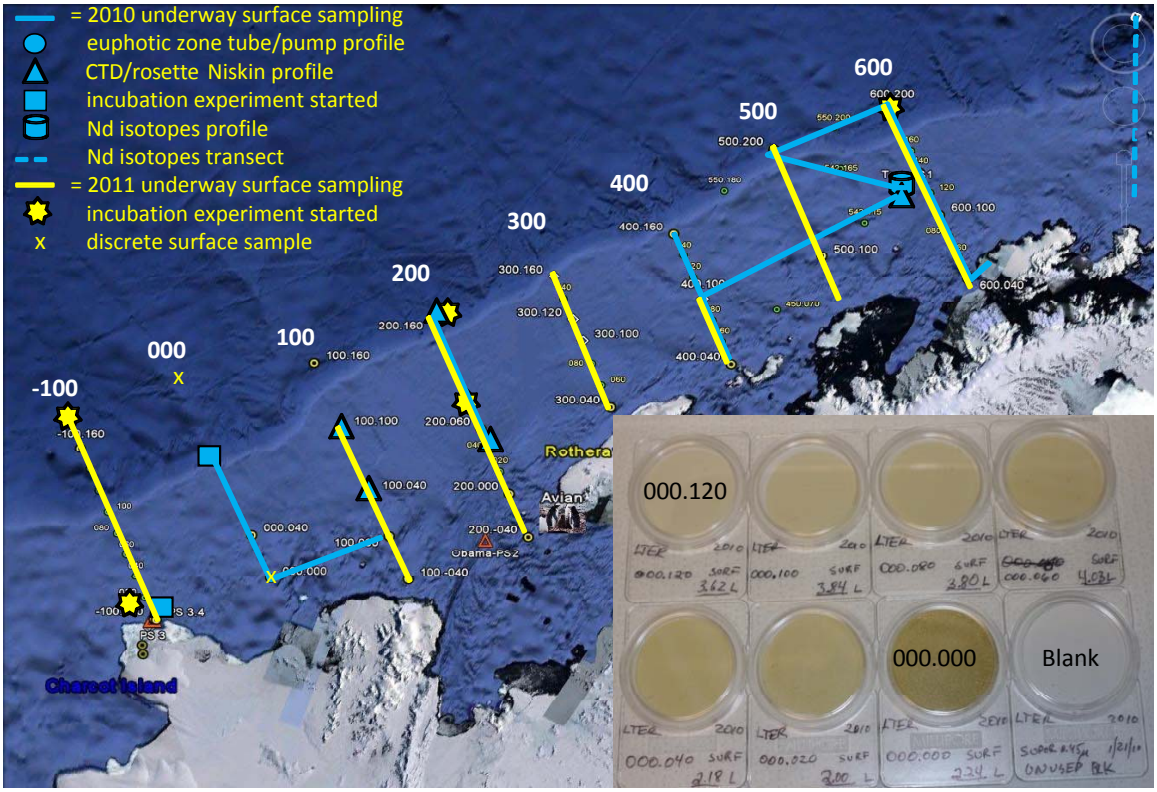


Figure 4. Map showing 2010 and 2011 sampling and experimental activities. On bottom right is a representative inshore-offshore transect of surface particulate matter.

During the past year we completed our dissolved Fe analyses for samples collected in January 2010, and for the first time ever determined ratios of Neodymium isotopes (with collaborator Per Andersson), a tracer for continental source metals. On the 2011 LTER cruise, we collected a complementary set of surface water samples and 30 more Nd isotope samples using our TM-clean "fish" system. We also carried out seven Fe addition experiments to determine the degree of Fe limitations at a number of representative stations within the LTER grid. To date, a subset of the 2011 samples have been run for Fe and other bioactive metals.

Invited Seminars

Schofield, O. (October 2010). Dawn in the age of robotic oceanography. (Taiwan Technology Conference plenary talk, National Kaohsiung Marine University, College of Ocean Engineering, Kaohsiung, Taiwan)

Schofield, O. (November 2010). My journey to study the world's oceans: The challenges/opportunities for the next generation of ocean explorers. Public Plenary to Mount Allison University (Sackville, Canada)

Schofield, O. (April 2011). Hot days along the western Antarctic Peninsula. Woods Hole Oceanographic Institution. (Falmouth, Massachusetts)

Schofield, O. (May 2011). Dawn in the age of robotic oceanography. University of Maryland Faculty Convocation. (Baltimore, Maryland)

Outreach

Schofield, O. (November 2010). My journey exploring the world's oceans. Princeton for a TIGER Talk to high school students. (Princeton, New Jersey)

Schofield, O., Glenn, S. M. (December 2010). The potential for the ocean observatories. United States State Department. (Washington DC)

Schofield, O. (March 2011). Exploring the world's Southern oceans. Princeton Plasma Lab's Science Saturday's to high school students. (Princeton, New Jersey)

Zooplankton and micronekton (Debbie Steinberg B-020).

This season the zooplankton group emphasized the role that zooplankton play in the biological pump (grazing, particle or fecal pellet production, and diel vertical migration), long-term changes in zooplankton community structure, and characterizing the zooplankton prey field in penguin foraging regions. At each station on the annual cruise we performed a pair of net tows for larger macrozooplankton (e.g., krill, salps; sorted onboard) and mesozooplankton (e.g. copepods). We also took samples at selected stations for macro/mesozooplankton lipid and gut fluorescence analyses, and microzooplankton (e.g., ciliates, flagellates) abundance and community structure. At the process study stations we performed depth-stratified zooplankton sampling using the MOCNESS (Multiple Opening-Closing Net Environmental Sensing System) to investigate depth distribution of the abundant taxa over a diel cycle. We performed dilution experiments to measure microzooplankton grazing, allowing us to quantify removal of primary producers by the zooplankton community. We performed additional fecal pellet production experiments with krill and salps to determine their role in export of organic carbon. Using an acoustic towfish we surveyed deep-canyon penguin feeding grounds to investigate penguin prey fields (part of post-doc Dr. Bernard's project).

Resident at Palmer Station this past season were project graduate students Lori Price and Kate Ruck, post-doc Kim Bernard, and graduate student volunteer Carolina Funkey. Activities there included intensive experiments quantifying microzooplankton grazing in the near-shore Palmer region, sampling for zooplankton lipid composition in penguin foraging areas to determine changes in food quality for higher predators, and characterization of local krill distribution using acoustics.

Sample analysis at VIMS continued for vertical flux of zooplankton fecal pellets from archived PAL time-series sediment trap samples, zooplankton lipids, and gut fluorescence. Quantification of microzooplankton samples across the LTER grid is complete for the 2010 season, and 2011 samples will be complete by this fall.

We collected a significant number of samples for collaborators on the cruise and at Palmer Station this year, including Dr. Rebecca Dickhut (VIMS; persistent organic pollutants in Antarctic food web), Dr. Bettina Meyer (AWI, genetic studies of *E. superba*), Dr. John Reinfelder (Rutgers, trace metals in zooplankton), Dr. Jose Torres (USF, Antarctic Silverfish-*Pleuragramma* distribution), and Mario Lebrato (AWI, gelatinous zooplankton sinking rates).

Steinberg has recruited a new PhD student for the project, Miram Gleiber, who will begin her dissertation work on time-series analysis of copepod community structure in the WAP at VIMS

this fall.

Invited Seminars

Steinberg D.K., S. E. Wilson, M. R. Gleiber, H. W. Ducklow, K. O. Buesseler "Ecosystem comparison of zooplankton effects on organic matter transport to the deep ocean". University of California, Santa Barbara, CA, Mar., 2011.

Outreach and Network Participation

D. Steinberg, L. Price - Presentation of zooplankton and Antarctic research to first graders at Magruder Elementary School (York County School District, VA) June 2011

D. Steinberg, L. Price, K. Ruck, K. Bernard, J. Cope- Marine Science Day at VIMS, Zooplankton Ecology Laboratory Exhibit and Demonstrations, May 2011

L. Price- Presentation of Antarctic research to fourth and sixth graders at Holiday Park Elementary School (Plum Borough School District, Pittsburgh) December 2010 and April 2011

K. Ruck- 'Palmer Long-Term Ecological Research Project (PAL-LTER)' presentation to Thomas Nelson Community College (VA) students, April, 2011

K. Bernard- Palmer Station, Acceptance speech for the Abercrombe & Kent Gift on board the M.V. Le Boreal at Palmer Station. Title: "Palmer Antarctica Long-Term Ecological Research Project: Looking back in time through marine ecosystem space", March 2011

K. Bernard- Live-feed presentation from Palmer Station during Angela Posada-Swafford's talk at the TedX Pura Vida conference in Costa Rica. Topic: "Palmer LTER research and Palmer Station", March 2011

K. Ruck and L. Price- Pal LTER cruise blog: http://vims.blogs.wm.edu/category/cruise-blog/ Jan 2011.

Microbes and Biogeochemistry (Hugh Ducklow BP-045).

The microbial biogeochemistry group conducted semi-weekly time series sampling operations at Palmer Station in close conjunction with the B-019 phytoplankton group. In addition to routine measurements of bacterioplankton abundance and production rates, we have added measurements of autofluorescent nanoplankton and picoplankton to our standard repertoire. All these abundance measurements are now achieved immediately following sampling on live samples using the Accuri C6 flow cytometer. We also performed weekly incubation experiments to quantify the net growth rates (production minus removal) of bacteria and phytoplankton. These experiments were performed in close cooperation with the two groups studying viruses at Palmer Station (Jennifer Brum, Polar postdoc and G. Steward group), with Steinberg's group studying microzooplankton grazing and bacterivory. Data from these three complementary studies will give us a much more detailed picture of bacterial dynamics than has been attained previously.

On the annual cruise we performed routine sampling for dissolved inorganic carbon, alkalinity, nutrients, particulate carbon and nitrogen, bacterial and nanoplankton abundance and bacterial production rates. In addition, we hosted Mr. Kuan Huang, who has been studying net community production in our study region for his PhD thesis at Princeton (M. Bender, advisor). Kuan's ecosystem-level estimates of NCP may significantly change our views of the primary production system in the peninsular region.

Invited seminars

2011 H. Ducklow. Carbon export and flow through bacterioplankton in polar seas: why are they so low? Invited seminar at Woods Hole Oceanographic Institution, April 2011

2011 H. Ducklow. Carbon export and flow through bacterioplankton in polar seas: why are they so low? Invited seminar at Lamont-Doherty Earth Observatory, Palisades NY, March 2011

2010 H. Ducklow. Rapid Climate Change and Ecosystem Response at Palmer Station, Antarctica. Invited seminar, Univ. of Washington Dept of Oceanography, Nov. 2010 Seattle WA.

Education activities:

Ohio State rising senior Kathleen Woods is working in our lab in Woods Hole this summer, analyzing field samples and working on data. Woods advisor at OSU is Berry Lyons (Dry Valleys LTER). ***Graduate Students:*** VIMS PhD student Heidi Geisz successfully defended her thesis and graduated in December. Her thesis is titled, "Current Levels and Long-Term Trends of Persistent Organic Pollutants (POPs) in Antarctic Seabirds and Fur Seals." Heidi is now a NOAA John Knauss Fellow in Washington DC. We continued sampling for Princeton PhD student Kuan Huang (supervisor of M. Bender). Kuan participated in our cruise and has a paper in review in JGR on his research. A new Brown-MBL PhD student, Catherine (Cat) Luria started in fall, 2010 and will conduct her research at Palmer and Rothera Stations.

Seabirds (Bill Fraser, Polar Oceans Research Group, BP-013).

The seabird research group operated in the Palmer Station region from October 2010 to May 2011, sampling daily as weather permitted, and focusing its core activities on the demography, foraging ecology and breeding biology of Adélie penguins. As in past seasons, basic ecological data on other seabirds and marine mammals in the Palmer area were opportunistically obtained to ensure the continuity of species-specific databases that originated in the early 1970s. In January, two group members participated in the annual LTER cruise (LMG 11-01), continuing surveys of seabirds and marine mammals to investigate their abundance and distribution relative to bathymetry and annual variability in regional oceanography. This cruise included a 5-day field camp on Avian Island, Marguerite Bay, and a second landing and brief exploration of Charcot Island south of Marguerite Bay in continuation of a unique time series that compares the foraging ecology of Adélie penguins (diets and at-sea foraging locations/dive-depth profiles based on ARGOS-linked transmitters) with similar data from Palmer Station. The 10/11 field season also observed an important collaboration with Dr. Matt Oliver (University of Delaware) and Dr. Mark Moline (California Polytechnic State University) to test long-established hypotheses that the foraging ecology of Adélie penguins reflects their dependence on the availability of predictable prey concentrations over ecological time. In this unique collaboration, we programmed AUV's with waypoints based on Adélie penguin satellite telemetry of summer feeding positions and dive-depth records to test this hypothesis by exploring the 3-dimensional foraging space of this species.

Invited Seminars

Fraser, WR. **2011**. Looking back in time through marine ecosystem space: Top predator perspectives on climate and change in the Western Antarctic Peninsula. March, Duke University Marine Lab, Beaufort, North Carolina, USA.

Fraser, WR. **2011.** Detecting and managing abrupt transitions in ecological systems. Workshop participant, May, Harvard Forest LTER, Petersham, MA, USA.

Education and Outreach:

a. A long-term collaboration with Fen Montaigne, freelance writer, produced a new book, *Fraser's Penguins, a Journey to the Future in Antarctica*, Henry Holt, 2010.
b. An ongoing collaboration with The Alder School, a K-6, one-room schoolhouse in remote, rural Montana resulted in an online video conference and interactive session with students and teachers from Torgersen Island, Palmer Station, followed by an on-site visit and presentation. The school used for its Antarctic lesson plan the PAL children's book *Sea Secrets*, a copy of which was provided gratis by PAL to the student body, 24 students.
c. A new collaboration with Linda Zajac, children's book writer, produced a new book manuscript on Adélie penguins, *Ice Birds in a Warming Land*, which won the PEN New England Children's Discovery Award and came in first place in the Florida State Writing Contest. The manuscript is currently under consideration by publishers.
d. Collaborations with science and other writers resulted in a variety of products, including:

    1. Video, Ocean Today,

       (http://oceantoday.noaa.gov/adeliepenguins).

    2. Blogs, Nature, Jane Qiu,

       (http://blogs.nature.com/cgi-bin/mt/mt-search.cgi?Template=nautilus&IncludeBlogs=32&search=%22Research+trip+to+the+Antarctic%22).

    3. Article, Science, Sara Reardon, (http://news.sciencemag.org/sciencenow/2011/04/melting-antarctic-ice-causing-pe.html?ref=hp).
    4. Article, Nature, Jane Qiu, Vol. 469: 145.
    5. Article, Nature, Yvon LeMaho, Vol. 468: 1034-1035.

Numerical Ecosystem Modeling (Scott Doney, WHOI).

Numerical Ecosystem Modeling:

The primary focus of WHOI modeling group over the last year has been on three tasks: synthesizing PAL-LTER data into a simplified end-to-end food web model using inverse modeling techniques; development of improved approaches for evaluating regional and global ecosystem model skill; and synthesis activities on climate change and ocean acidification impacts on marine ecosystems.

End-to-end Food Web Modeling:

Postdoc Sevrine Sailley is using an inverse analysis approach starting from an input biomass compartment structure and a set of specified biological rules to solve for the multiple fluxes within a food web using limited data inputs. The steady-state model solutions are internally consistent and mass conserving. The research build on earlier LTER modeling work by Daniels and Ducklow but includes revisions to the model structure, observational constraints to reflect current understanding of the system, and the numerical methods used to find inverse solutions.

Regional and Global Ocean Physical-Ecological-Biogeochemical Simulations:

Regional and global ocean simulations provide context for interpreting the interannual variability and trends in the PAL-LTER data and forecasting future climate change. Our main modeling tool is the ocean component of the Community Climate System Model (CCSM). As part of the new Marine Ecosystem Model Intercomparison Project (MAREMIP), we are working with international collaborators on a comprehensive scheme for comparing global marine ecosystem models and evaluating their skill relative to observations. This year we also completed the integration of a new historical hindcast simulation (1950s-2007) using the recently released CCSM-4 ocean model. The simulation has a factor of 10 improvement in spatial resolution and incorporates explicit sea-ice dynamics. We have started preliminary analysis of the Southern Ocean physical, biological and chemical dynamics in the hindcast simulation.

Climate Change and Ocean Acidification Impacts on Marine Ecosystems

Doney wrote a synthesis article on human perturbations of coastal and open-ocean biogeochemistry for a special issue of *Science* magazine. He also led the writing of a review article for *Annual Reviews of Marine Science* on climate change and ocean acidification impacts on marine ecosystems using as one of the case studies the large responses to warming and sea-ice retreat in polar ecosystems in the Arctic and West Antarctic Peninsula. Finally, he contributed to a perspective article for *Oceanography* magazine on how information on ocean climate change and biological responses can be communicated to stakeholders and policy makers using electronic atlases, drawing on recent work to create such a regional atlas for the Southern Ocean surrounding New Zealand.

Seminars, Workshops, Meetings

LTER-NSF Minisymposium: Understanding Climate Change Through Long-Term Ecological Research, National Science Foundation, Arlington VA, March 2011

2011 LTER Science Council Meeting, Jekyll Island, GA, May 2011

Doney also contributed to synthesis manuscript on Southern Ocean food web modeling that grew out of an Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) Workshop.

Outreach

As part of the project, Doney presented several talks on ocean acidification and climate change to non-traditional audiences.

Briefing for the Chief Scientist of the U.S. Government Accountability Office (GAO), June 2010.

NSF Joint Annual Meeting, Louis Stokes Alliances for Minority Participation-Bridge to the Doctorate Program, Washington DC, June 2010

U.S. Navy, Chief of Naval Operations Strategic Studies Group (CNO-SSG), Naval War College, Newport, RI, Oct. 2010

National Research Council Committee on Future Science Opportunities in the Antarctic and Southern Ocean, Woods Hole, MA, April 2011

RESEARCH FINDINGS: Palmer LTER 2010-11.

This brief Report highlights some recent results from field and lab-based research and data analyses, and also points out a few highlights from recent publications. Publications are listed at the end of the text, to avoid duplication in each section, and entered into the Fastlane publication database.

Information Management (Karen Baker, SIO-UCSD).

An ethnographic-oriented investigation of an example of collaborative information infrastructure development culminated in a published paper (Karasti et al, 2010). Our exploration and elaboration of the concept of infrastructure has informed and guided local information management efforts since 2002 (Bowker et al 2010). In practice, scaling associated with data access within our information environment and co-development of a web-service to permit exchange of data with another repository were carried out as a forward-looking design approach (Conners, 2010, 2011). Information management and technology in terms of the associated work and the role at sites are highlighted in Databits articles (Yarmey, 2010; Baker and Melendez-Colom, 2010; Haber, 2011; Baker and Kortz, 2011, Baker, 2011). Further, our lead and participation in all-site collaborative work within the LTER Network includes continuing development of the LTER unit registry, web services and the personnel directory (Kortz, 2010, 2011)). As part of the Information Management Governance Working Group, the development of Terms of Reference for the Information Management Committee, the Network Information Management Advisory Committee, and IMC working groups has been carried out (Baker et al, 2010). Despite an emphasis on governance decision-making over the last year, the history of the adoption of a network alias as a coordination device demonstrates a continuing reliance on informal processes within the IMC (Baker, 2011). Finally, we have initiated writing of three technical reports that provide us the opportunity to synthesize and communicate the work of information management. The topics include a monograph on the Ocean Informatics effort from 2003-2006, the use of the design studio for information systems work, and an overview of the information system DataZoo.

Education and Outreach (Beth Simmons):

Nothing to report this year.

Sea Ice and Climate (Sharon Stammerjohn).

(a) Fogt et al. (accepted, *BAMS*): In this (fourth) assessment of the 'State of Antarctic Climate', year 2010 was reviewed within the context of circumpolar climate anomalies, thus, an assessment useful for placing WAP climate anomalies in a broader spatial context. The austral winter of 2010 was characterized by low-pressure anomalies across high southern latitudes and enhanced circumpolar zonal flow, consistent with a strong positive Southern Hemisphere Annular Mode (SAM) index. Although this pattern weakened in September, it strengthened again in October and remained positive throughout the rest of the year. A La Niña began in the tropical Pacific in July, which further amplified the low-pressure anomalies particularly in the South Pacific/West Antarctic sector. Statistically, year 2010 was distinguished by a record +SAM for austral winter (June-August) followed by a record +SAM for November (based on the 50-year monthly index from Marshall, 2003). Record strong winds were recorded during June and October-November on the Antarctic Peninsula. In the Antarctic Peninsula region, there was a distinct shift from cooler conditions from the year before (from ~April 2009 onward) to above

average temperatures in February-March 2010 that persisted for the rest of 2010. Records of *zonally* averaged sea ice extent were observed from mid-June through late August and again from mid-November through early December, driven primarily by high sea ice extents in the eastern Weddell-Indian Sea sector and eastern Ross-western Amundsen Sea sector. In contrast, the Bellingshausen-eastern Amundsen Sea sector (including the PAL LTER study area) continued to experience record low sea ice extent and an anomalously short sea ice season (due to a late sea ice advance in autumn followed by an early sea ice retreat in spring).

(b) Fountain et al. (submitted, BioScience): This publication resulted from a workshop supported by the LTER Network office that brought together several LTER's to present and discuss various eco-environmental aspects of a shrinking cryosphere. The LTER study sites at high latitude or high altitude have all documented strong changes in the cryosphere, including decreases in sea ice extent, snow, and glaciers. Consequently, ecosystems that exist within, and depend on, the cryosphere have been changing. See additional summary in Ducklow's section below.

(c) Stammerjohn et al (2011, *DSRII*): This study was described in last year's annual report (having been 'accepted' at that time). However, the international collaboration continues, facilitated by a recent workshop sponsored by WCRP, SCAR to renew ASPeCt. Also, we continue to update the analyses reported in this paper, e.g., the combined satellite observations of SST, SIC and SLP (as discussed under Activities above), which proves to be very useful for capturing ice-ocean anomalies through the seasonal evolution of sea ice advance and retreat.

Physical Oceanography (Doug Martinson BP-021).

We have had excellent progress in both of our primary foci:

(1) We have identified a strip within the southernmost ACC that extends from our LTER grid to west of the Amundsen Sea Embayment where the major ice streams enter the sea. Combining our information with historical information in the swath we have documented that the UCDW heat content has increased exponentially, mimicking that warming of the global oceans (**Figure 1**).
(2) The mooring array data have allowed us to identify the mechanism by which UCDW enters the continental shelf. We find 20-30 eddies entering the shelf from the ACC where it brushes the shelf-slope break. They track along bathymetry and deliver water warmer than that appearing anywhere on the shelf outside of the eddies. They deliver the warm water to that portion of the shelf that shows the highest fraction of pure UCDW (which is occupying the center of the eddies).

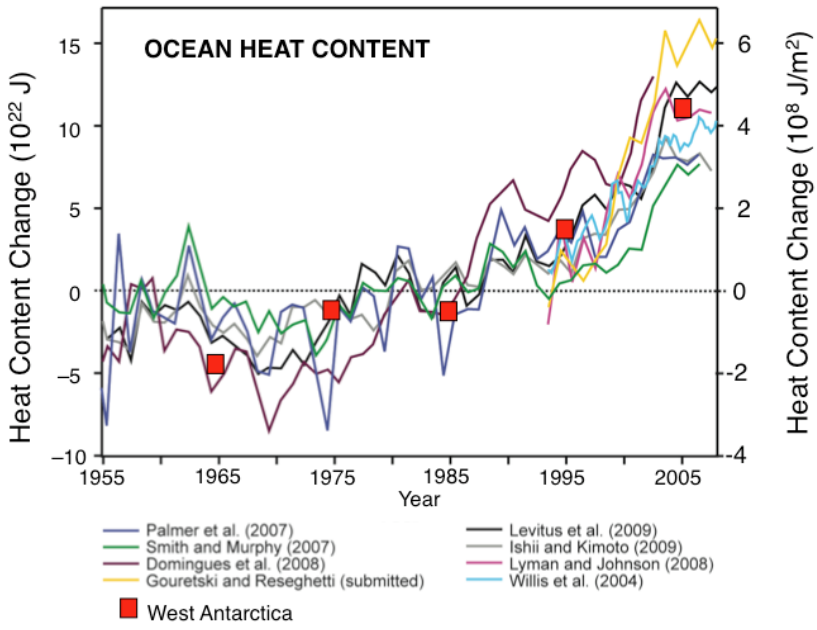
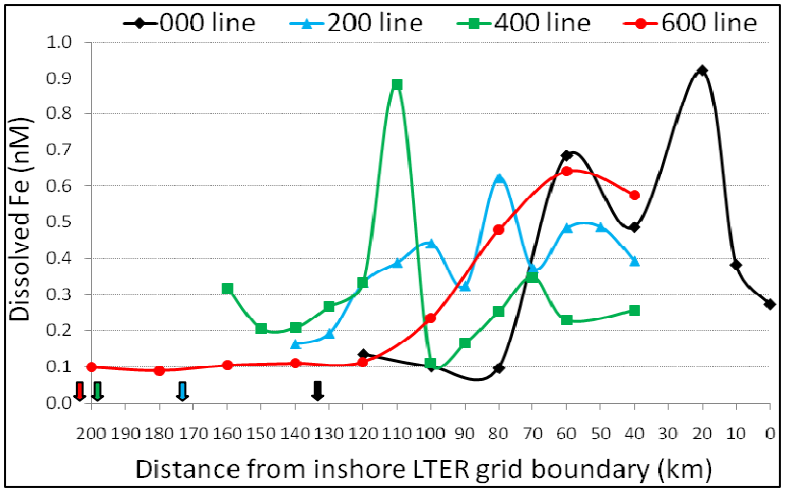


Figure 1: Upper Circumpolar Deep Water (UCDW) heat content (red solid squares) superimposed on results from 8 independent of global ocean warming studies.

Trace Metals (Rob Sherrell, B-019).



Results from 2010 look very interesting, and were presented in a poster at the 2011 Polar Marine Science Gordon Conference. Essentially, the dissolved Fe distributions show substantial spatial variations (**Fig. 2**) and are supported by the preliminary experimental results, leading to the conclusion that the shelf waters were Fe-limited in some regions in 2010 (outer shelf on 000 and 600 lines) but are Fe-replete in other outer shelf regions (200 and 400 lines) and all inner shelf regions. Nd isotope distributions suggest that continentally-sourced metals are mixed out across the shelf, and are exported to the open ACC upper water column beyond. Future work will focus on the depth variations and particulate concentrations of bioactive metals, pending additional funding outside of the LTER core program.

Figure 2. Dissolved Fe distribution on four inshore-offshore sampling lines in 2010. Note very low dissolved Fe on outer shelf of 000 and 600 lines. Colored arrows show shelf-slope break location for each grid line.

Zooplankton and micronekton (Debbie Steinberg B-020).

Zooplankton and biogeochemical cycling-

In our last report we described long-term changes in distribution and relative abundance of krill and salps, with a decrease in krill and an associated shift closer to shore, and an increase in salps, with a possible expansion over the shelf. We have now begun to examine how this will lead to changes in biogeochemical cycling and carbon export from surface waters. **Figure 3** shows how long-term changes in krill and salp abundance for the northern-most grid line translate into a change in C flux from fecal pellets. The decrease in krill and parallel increase in salps results in a ~3-fold increase in fecal pellet C flux over time. Thus changes in community structure from krill to salps may be leading to a more efficient biological pump in the WAP. In addition, since our last report this year we finished analyzing two years of macrozooplankton grazing data (2009 and 2010). Salps and pteropods were the dominant grazers in the shelf and offshore waters, while krill (*E. superba*) is the dominant grazer only in nearshore coastal waters. This may be a significant change in the food web compared to the past when krill were considered dominant grazers over the shelf as well.

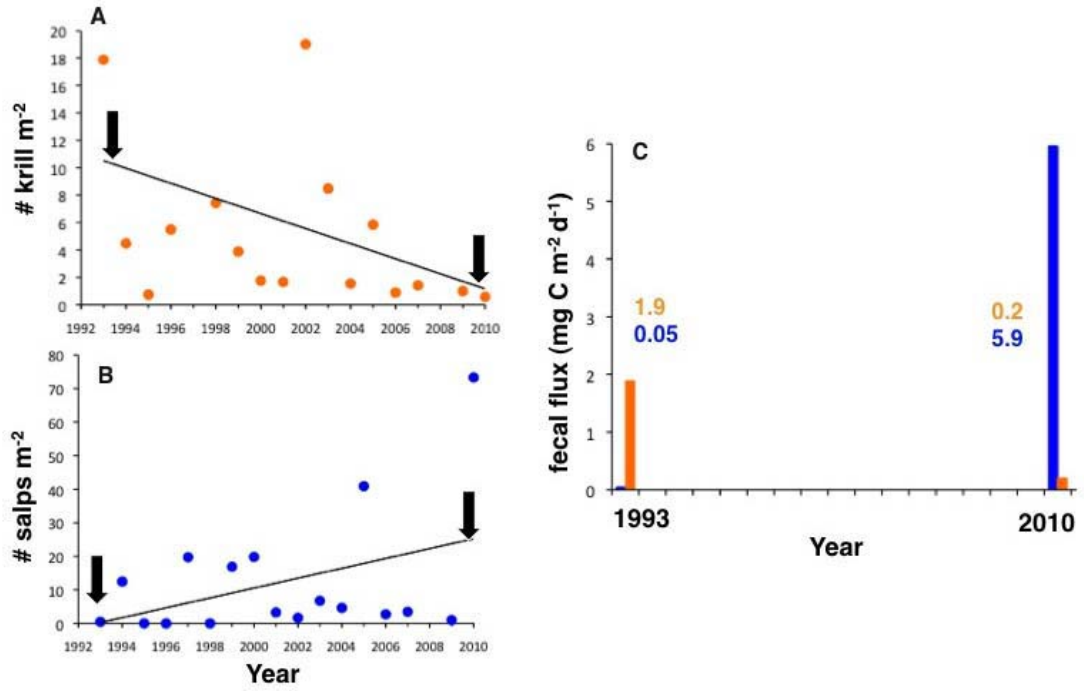


Figure 3. Changes over time in A) Antarctic krill (*Euphausia superba*) and B) salps (mostly *Salpa thompsoni*) in the WAP with associated change in fecal pellet flux (C). Each point in panels A and B is the mean of all stations along the northern-most sampling grid line (line 600) for each year. Arrows indicated on regression lines are krill or salp densities for which fecal pellet flux is shown in panel C. Fecal flux per individual per time was measured in our shipboard experiments and multiplied by animal density to obtain fecal flux shown in panel C (krill in orange, and salps in blue).

Krill distribution in near-shore canyons and penguin foraging areas-

Preliminary analysis of bioacoustics data for near-shore (Palmer Station) distribution patterns of krill indicates that bathymetry and possibly also tidal regime may play a role in structuring krill distributions. Relatively large aggregations of krill were found in the canyon that runs along the eastern boundary of the Palmer Station boating area and the deep bowl at the head of this

canyon, just off Cormorant Island (**Fig. 4**). Aggregations were between 80 and 100m and just a few meters off the sea floor, and Gentoo penguins, apparently feeding, were seen in these regions. Comparisons with glider physical data from O. Schofield, M. Oliver, and M. Moline suggest krill aggregations in the near-shore waters are a result of hydrodynamics. Diurnal tides force water from the Palmer Deep region up through the Bismarck Strait towards Anvers Island and local bathymetry might then act to entrain these aggregations. This may help explain penguin foraging patterns in the region.

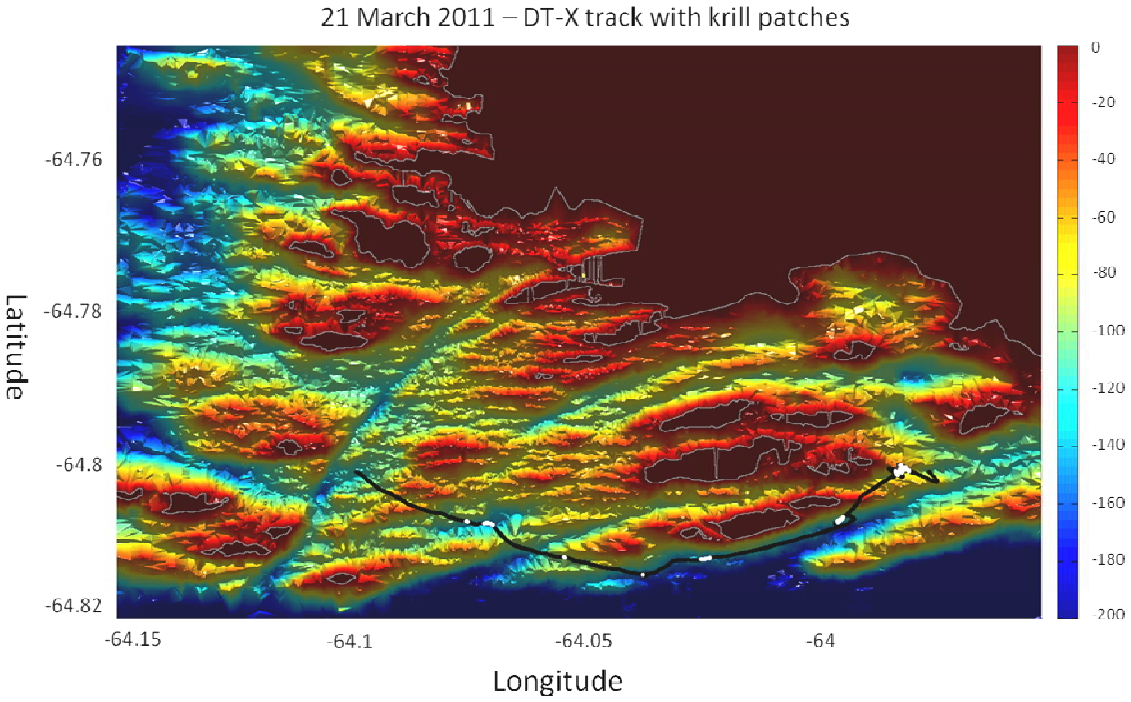


Figure 4. Near-shore krill aggregations in deep canyons near Palmer station. The boat track is shown in black, and krill aggregations in white. Track is overlaid on bathymetry map (scale on right in meters, land is dark brown).

Microzooplankton community structure and grazing-

We now have the most comprehensive data set of microzooplankton community structure and grazing available for the WAP. Analysis of microzooplankton community structure at three different depths (surface, chl *a* maximum, 100m) indicates significant depth and spatial differences in major microzooplankton taxonomic groups (**Figure 5**). In addition we found significant positive

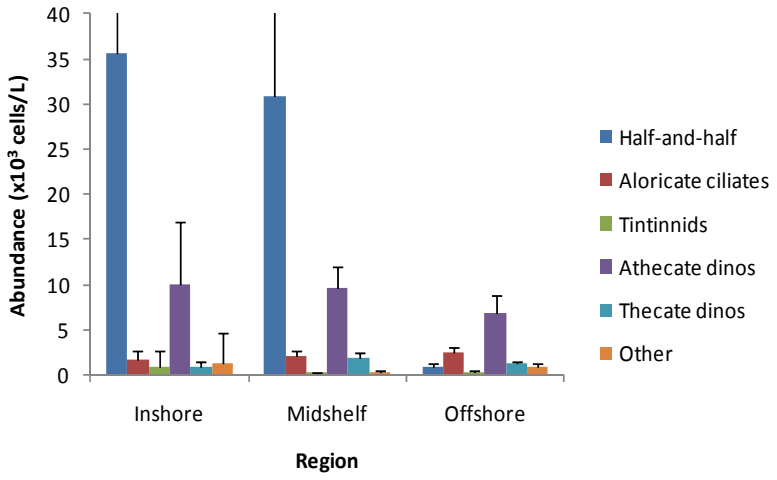


Figure 5. Abundance of major groups of microzooplankton in the WAP at 10m depth. "Half-and-half" indicates an unknown cell type (possibly a dinoflagellate) that we are currently trying to identify with the help of experts, which is very abundant and significantly higher inshore and over the shelf than past the shelf break. Aloricate ciliates were significantly higher offshore than over the shelf and inshore at this depth.

correlations between total microzooplankton abundance and chl *a* ($p=0.001$), POC ($p<0.0001$), and PON ($p<0.0001$). Experiments performed in cooperation with Ducklow using flow cytometric detection of prey at our process study stations on the cruise suggested that microzooplankton grazing on bacteria ranged from 0.08 – 0.43 d^{-1}, with grazing activity removing between 50 – 130% of bacterial production. All experiments indicated selective grazing on the larger, more active bacteria. Seven dilution experiments were also conducted in the near-shore, surface waters near Palmer Station in Feb – March 2011. Preliminary data show significant grazing rates on phytoplankton in four of the seven experiments, with grazing rates ranging from 0.10 – 0.51 d^{-1} and microzooplankton removing between 30 – 70% of primary production. Microzooplankton grazing on bacteria was calculated in all experiments, ranging from 0.05 – 0.34 d^{-1} with microzooplankton removing between 40 – 150% of bacterial production, and selectively grazing on the larger, more active bacteria.

Microbes and Biogeochemistry (Hugh Ducklow BP-045).

Factors Influencing Bacterial Community Structure.

In Ducklow et al. (2011, Aquatic Microbial Ecology, accepted), we report results of a mesocosm study performed in November 2008, in conjunction with our IPY project, "IPY: Bacterioplankton Genomic Adaptations to Antarctic Winter." The aim was to examine the role of inorganic nutrients and organic matter subsidies in structuring the bacterial community composition (BCC) near Palmer Station. In response to additions of ammonium, glucose or both together, changes in bulk properties (abundance, bacterial production rates) and BCC in ammonium-amended carboys were small relative to Controls, compared to the Glucose-amended treatments. Results were compared to field observations conducted as part of PAL-LTER since 2002 (Figure 5). BCC in day 0 and day 10 controls and +NH4 treatments were >72% similar when assessed by DGGE, LH-PCR and CE-SSCP fingerprinting techniques. Bacterial abundance increased by 2-10 fold and leucine incorporation rates increased 2-30 fold in the glucose treatments over 6 days. The BCC in carboys receiving glucose (with or without ammonium) remained >60% similar to day 0 controls at 6 days and evolved to <20% similar to day 0 controls after 10 days incubation (**Figure 6**). Increases in bacterial production rates and changes in BCC suggest that selection for glucose-utilizing bacteria was slow under the ambient environmental conditions.

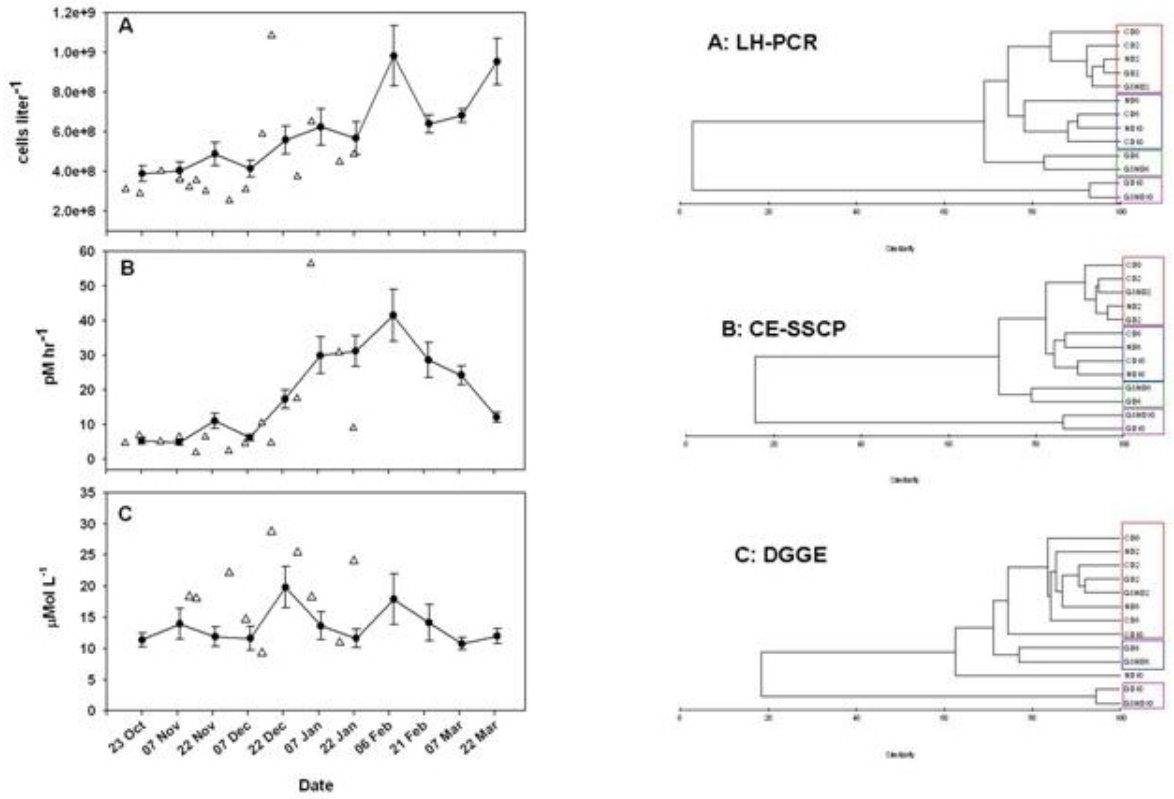


Figure 6. Left: Lines and closed circles: mean (climatological) bulk surface properties for Palmer Station site B, ± standard error, 2002-08. **A.** Bacterial abundance. **B.** Leucine incorporation rate. **C.** Semi-labile dissolved organic carbon (surface concentration with the deepwater background concentration of 39 µM subtracted). Open triangles in each plot are the observed data for 2006-07 (i.e., not averaged). **Right:** Similarity of bacterial communities from four experimental incubations analyzed by **A**, LH-PCR; **B**, CE-SSCP; and **C**, DGGE DNA fingerprinting. Relative intensities of bands/peaks were used for the cluster analysis based on the unweighted pair-group method with arithmetic averages (UPGMA) and Bray-Curtis distance. Samples are labeled by treatment (C, Control, N, ammonium, G, glucose, G&N, both) with the time (D0, D2 etc) included. Groups with >70% similarity are enclosed in boxes.

The results suggest that organic carbon enrichment is one principal factor influencing the observed winter-to-summer increase in bacterial abundance and activity. In contrast, BCC was relatively robust, changing little until after repeated glucose additions and prolonged (~10 d) incubation.

The Disappearing Cryosphere.

For the past several year, Ducklow has led an LTER Network-wide cross-site synthesis activity (e.g., **Figure 7**) to examine the nature, rates and consequences of cryosphere loss. The Cryosphere encompasses all the environments dominated by frozen water: glaciers, snow-covered landscapes, permafrost, and sea, lake and river ice. In Fountain et al (submitted) we review LTER and other research, bringing together for the first time, research on the ecological, biogeochemical band socioeconomic effects of cryosphere loss on ecosystems. We identify two principal aspects of ecosystem-level responses to cryosphere loss: trophodynamic alterations resulting from the loss of habitat and species loss or replacement; and changes in the rates and mechanisms of biogeochemical storage and cycling of carbon and nutrients, caused by changes

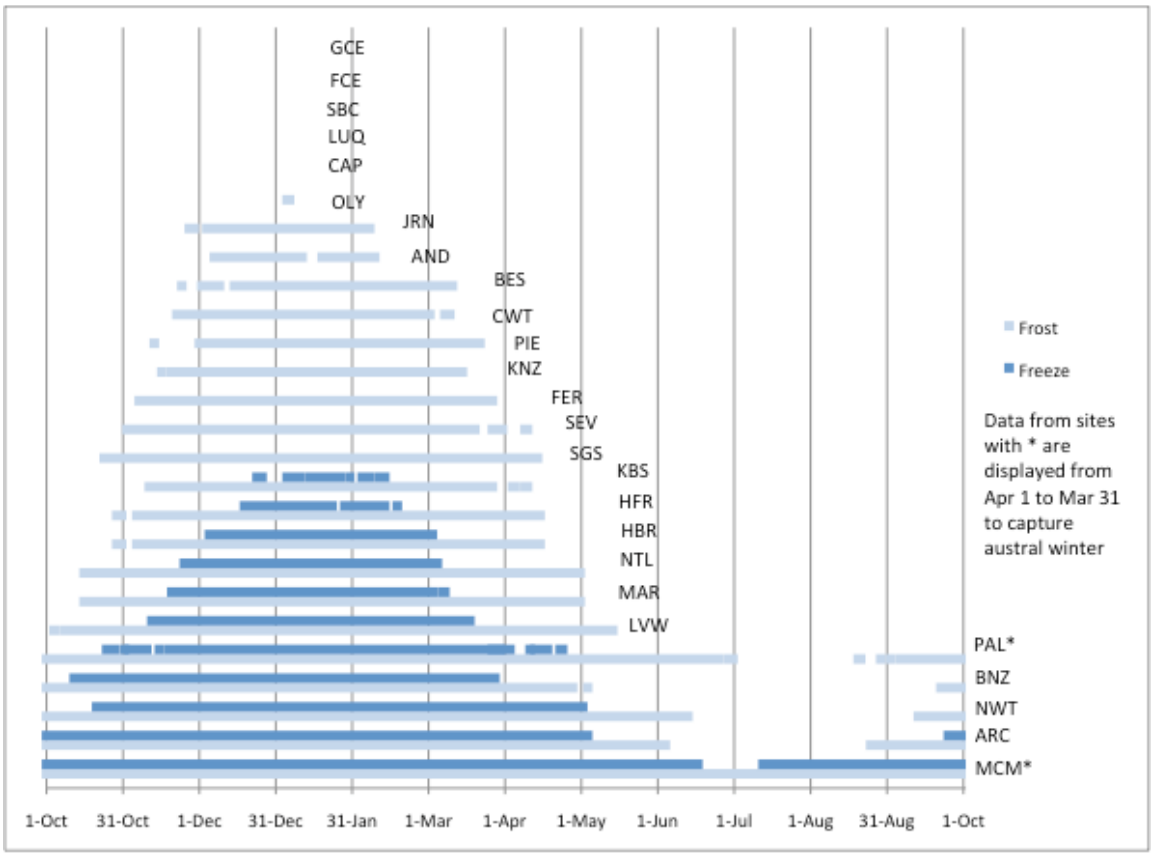


Figure 7. Duration of frost and freezing periods at LTER and related long-term research sites, based on climate records. Frost days are those with long-term mean daily minimum temperature <0°C; freeze days are those with long-term mean daily maximum temperature <0°C. Data from sites with * are displayed from Apr 1 to Mar 31 to align winter in N and S hemispheres. Figure compiled by Julia Jones, Andrews Forest LTER.

in physical forcings or ecological community functioning. These changes can be either a positive or negative impact on the biota depending on how they interact with the cryosphere. The important outcome, however, is the change and the response of the human social system (infrastructure, food, water, recreation) to that change. This latter area is still poorly understood, but has large implications, for example on drinking and irrigation water supplied by mountain snowpacks and glaciers.

Seabirds (Bill Fraser BP-013).

AUV's programmed as described in the Activities section showed that Adélie penguins precisely focused their summer foraging activities over regions characterized by deep bathymetry, bathymetrically-steered upwelling of warm Upper Circumpolar Deep Water and enhanced production (**Figure 8**). Analyses of dive-depth records, moreover, also showed that foraging intensity was predictably higher in these regions than in others throughout the season, suggesting some element of predictability in the structure and availability of the prey field. In the WAP, Adélie penguin breeding distributions are highly heterogeneous and it has long-been recognized that this heterogeneity is associated with near-shore deep bathymetry that may be indicative of physical and biological hotspots. The unique experiments and findings described for this field

season strongly support this idea, thus enhancing our understanding on how WAP physical and biological properties are distributed in time and space and how these distributions may interact mechanistically to structure marine ecosystem food webs.

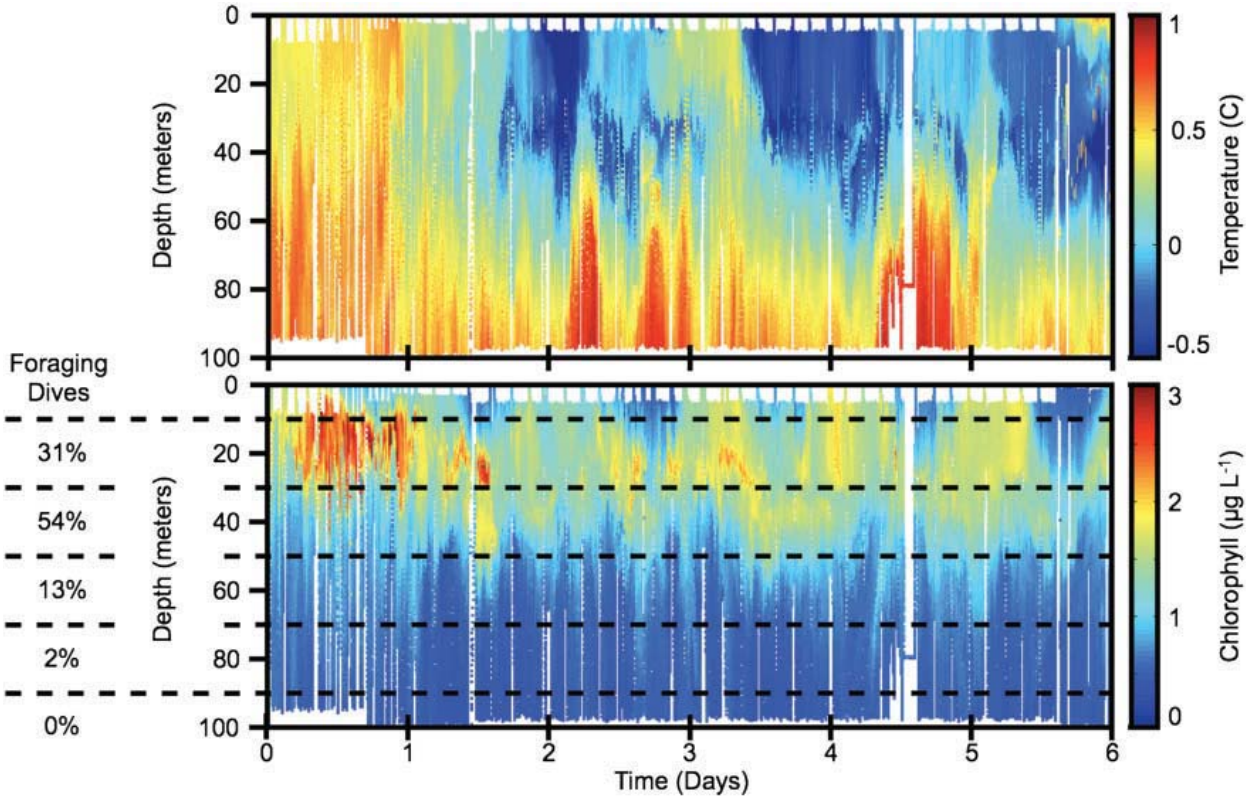


Figure 8. Temperature (top) and chlorophyll concentration (bottom) measured by the Slocum glider within the penguin 90% foraging kernels over the Palmer Basin. Within the 90% foraging kernel, the percent of penguin foraging dives to Eve depth bins is aligned with the chlorophyll data (modified from Kahl et al. 2010).

Numerical Ecosystem Modeling (Scott Doney, WHOI):

The primary focus of WHOI modeling group over the last year has been on three tasks: synthesis PAL-LTER data into a simplified end-to-end food web using inverse modeling techniques; development of improved approaches for evaluating regional and global ecosystem model skill; and synthesis activities on climate change and ocean acidification impacts on marine ecosystems.

End-to-end Food web Modeling:

Initial results from inverse modeling study were presented as a short section in a synthesis book chapter on PAL-LTER (Ducklow et al., in press). Ongoing work examines in more detail temporal trends from a 12-year time-series (1995-2006) for summer (Jan.-Feb.) from stations on the 600 line (North, near Palmer Station Adelie colonies) and 200 line (South, near Avian Island Adelie colonies). The inverse approach combines Palmer data with literature values to constrain flows in a specified food-web structure. We implemented a Monte Carlo based solution method that provides more robust estimates for flow rates. Specifically, we use measured primary

production, chlorophyll-*a* levels, and bacterial production to set three model fluxes. By assuming that primary production is proportional to chlorophyll-*a* amounts, we divide primary production into large (>20 m) and small (0.4-20 m) phytoplankton pools. We use krill and salp biomass, penguin populations, and the sediment trap record to constrain trophic and export fluxes. Measurements are converted to carbon fluxes per square meter and averaged over the feeding radius of the Adelie penguin colonies. In the North, where *Pleuragramma* (Antarctic silverfish, which feed on krill and are in turn consumed by penguins) do not comprise a significant portion of the food web, that pool is excluded from the analysis. The inverse model results are complemented by network indices to determine the predominant pathways for primary production (sinking, circulating through the food web, microbial loop).

Flow rates and pathways through the model food web are driven by both the magnitude and size distribution of observed primary production, which is input as a driving factor. The results of our inverse solutions suggest a role for both the "traditional" Antarctic food chain linking diatoms, krill, and penguins, and the microbial loop of small phytoplankton, microzooplankton and bacteria. Specific findings from the modeling work include:

- Bacteria have a very variable biomass from year to year, but bacterial production never exceeds 10% of the primary production. It is unclear whether there is insufficient DOM present for them to use or a strong grazing pressure.
- Despite four-fold variations in measured krill and salp biomass, most of the primary production in the model is grazed by microzooplankton, more than previously estimated. Microzooplankton has the potential to regulate phytoplankton biomass (growth rate close to that of phytoplankton), while krill is a link from primary producer to higher trophic level (fish and penguins). Flow through microzooplankton account for approximately 40% of total primary production, double the flow though krill. Flows through microzooplankton and krill do not display a statistically significant trend; in contrast the flow through bacteria has doubled in the northern WAP reflecting an alteration in the balance between grazing and recycling of matter.
- Salps are increasing in abundance with time in WAP waters (especially in the northern part of WAP) and are distinct from krill because they can prey on the smaller size fraction of phytoplankton and present high growth rate through asexual reproduction. Salps have no known predators and they efficiently repackage their prey into heavy fecal pellets with a high sinking rate. As such they can be considered to be a "dead-end" for carbon flow. Flows through salps are still one order of magnitude lower than those through krill, but if salp abundance in WAP water continues to grow it would enhance bacterial activity due to the release of DOC.
- In both North and South WAP, Adelies penguin have access to enough krill to support their basic metabolic needs, indicating the importance of other krill predators or prey quality for Adelies chicks.

Results from interannual comparison and network indices for dominant pathways:

- Primary production in the North (1995 to 2006) is highly variable both in magnitude (15 to 111 mmol C m^{-2} d^{-1}) and composition with the fraction due to large phytoplankton varying from 1.6% to 80%. However, the distribution of primary production to the different food web compartments does not show a strong response to this variation. Network indices indicate a

food web dominated by microzooplankton and bacteria with the microbial loop becoming predominant with time.

- Primary production in the South (1995 to 2006) shows weaker variation compared to the north, its magnitude being between 32 and 43 mmol C m^{-2} d^{-1} except in 1999 when it was 8 mmol C m^{-2} d^{-1}. In the South the fraction due to large phytoplankton varies from 22% to 68%. The dominant pathway and processes in South WAP are more variable compared to those for North WAP: the food web can be dominated by krill (herbivorous food web) in one year and by the microbial loop the next.

Regional and Global Ocean Physical-Ecological-Biogeochemical Simulations:

The MAREMIP Program "kick-off" meeting was held in Cambridge, UK in fall 2009 (co-chaired by C. Le Quere and S. Doney) attended by representatives from 11 different international groups (http://lgmacweb.env.uea.ac.uk/maremip/index.shtml). A work plan was developed for MAREMIP Phase-1:

- compiling field, laboratory and remote sensing data for different phytoplankton and zooplankton functional groups for model evaluation and parameterization development;
- creating standardized univariate and multivariate model-data skill metrics;
- integrating a suite of common model simulations (historical reconstructions);
- comparing simulated ecosystem dynamics between models and against observation.

A pilot MAREMIP Phase-0 is also underway for a subset of 4 models (CCSM-BEC, NEMURO, PISCES, and PlankTOM5). Preliminary results from MAREMIP Phase-0 analysis for phytoplankton were presented at the 2010 Ocean Sciences Meeting (Vogt et al., 2010; Hashioka et al., 2010). We are continuing a project with the Phase-0 models to intercompare simulate zooplankton distributions and dynamics. The project uses Jacobian matrices and their inverse to determine interaction strength between zooplankton and their prey. The general findings are:

- Simulated food webs and interactions among compartments (e.g., competition, predator-prey) can differ substantially from the stated intentions for the model construction.
- The interactions between zooplankton classes differ substantially in the models with two or more zooplankton: exclusion (PlankTOM5), competition (PISCES) and predation (NEMURO).

Climate Change and Ocean Acidification Impacts on Marine Ecosystems

The review article Doney et al. (*Ann. Rev. Mar. Sci., submitted*) examines the impact on marine ecosystems of rising atmospheric CO_2 and climate change, which are associated with concurrent shifts in temperature, circulation, stratification, nutrient input, oxygen content, and ocean acidification, with potentially wide-ranging biological effects. Population-level shifts are occurring due to physiological intolerance to new environments, altered dispersal patterns, and changes in species interactions. Together with local climate-driven invasion and extinction, these processes result in altered community structure and diversity, including possible emergence of novel ecosystems. Impacts are particularly striking for the poles and the tropics, because of the sensitivity of polar ecosystems to sea-ice retreat and poleward species migrations and the sensitivity of coral-algal symbiosis to minor increases in temperature. Mid-latitude upwelling systems, like the California Current, exhibit strong linkages between climate and species distributions, phenology, and demography. Aggregated effects may modify energy and material

flows and biogeochemical cycles, eventually impacting the overall ecosystem functioning and services upon which people and societies depend.

Boyd et al. (*Oceanography, in press*) advocate for ocean climate change atlases – which to bring together and compare disparate strands of information- to facilitate the process of science informing resource management strategies and policy. The article illustrates this approach using a regional atlas for the New Zealand Exclusive Economic Zone (EEZ). An atlas would build on customized suites of relevant environmental and resource data sets, providing an accessible format for conveying how climate change will manifest itself at a regional level across multiple dimensions. Spatial patterns of change for a range of marine environmental properties that impact biota—from pH to nutrient supply—could be readily communicated. The maps that form the regional atlas, in this case based on the output of climate-modeling predictions, can in turn be overlaid with other graphics produced from disparate sources of data, such as distributions of ocean biota—what species reside in each body of water?—as well as economic information, such as where they are harvested, and their economic value and ecological services. Augmenting GIS-based tools, the atlas also includes graphical information, from manipulation studies, on the vulnerability of a particular species or group to changing climate. Via an interactive graphical summary, this information then conveys complex issues, such as how the resident biota will respond to such changes and the resulting regional implications for water bodies of ecological and economic significance.

Murphy et al. (Prog. Oceanogr., submitted) consider the main ecological and modelling challenges faced in developing integrated analyses of the responses of Southern Ocean ecosystems to change, and propose steps to be taken towards the generation of large-scale models. Ecological research in the Southern Ocean is often centred on key species or localised systems, a tendency that is reflected in much of the modelling effort to date. To build on this, a systematic analysis of regional food web structure and function is required. At the same time, a range of mechanistic models that vary in resolution of ecological processes are needed to consider links across physical scales, biogeochemical cycles and feedbacks and the central role of zooplankton. Developing methodologies for scenario testing through a range of trophic levels of the effects of past and future changes will facilitate consideration of the underlying complexity of interactions and the uncertainty involved. To deal with the complex nature of interactions determining ecosystem structure and function will require new approaches, which we propose should be developed within a scale-based framework that emphasizes both physical and ecological scaling.

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Presentations at Conferences and Workshops: (students and postdocs underlined; coPIs in **bold**

Ducklow, H. W., Bernard, K., Erickson, M., Middaugh, N., Moran, X. A., **Schofield, O., Steinberg, D., Vernet, M.,** Sailley, S. 2011. PALMER LTER: WHY IS BACTERIAL PRODUCTION SUCH A LOW FRACTION OF PRIMARY PRODUCTION NEAR THE ANTARCTIC PENINSULA? ASLO Aquatic Sciences Meeting. San Juan PR Feb 2011

Ducklow; H., K. S. Baker; S. C. Doney; B. Fraser; D. G. Martinson; M. P. Meredith; M. A. Montes-Hugo; S. Sailley; **O. Schofield; R. M. Sherrell; S. E. Stammerjohn; D. K. Steinberg.** 2010. Marine Ecosystem Response to Rapid Climate Warming on the West Antarctic Peninsula (Invited). American Geophysical union Annual Meeting, San

Francisco, December 2010. Session GC43E-1004. Past and Present Dynamics of the Antarctic Peninsula Ice Cap System Posters (invited and submitted as a talk, session switched to all posters).

Ducklow, HW (invited). 2010. Rapid Climate Change and Ecosystem response at Palmer Station, Antarctica," Invited Opening Address, IMCoast Workshop, Cordoba Argentina 7-10 August, 2010 (European Science Foundation and Instituto Antarctica Argentina).

Ducklow, HW (invited). Rapid Climate Change and Ecosystem response at Palmer Station, Antarctica," Invited Keynote Presentation. SCAR Open Science Conference, Buenos Aires, 2-6 August, 2010.

Erickson, M. J., **Ducklow, H. W.,** 2011. DISTRIBUTION AND ABUNDANCE OF MARINE MICROBIAL COMMUNITIES NEAR THE WESTERN ANTARCTIC PENINSULA. Aquatic Sciences Meeting. San Juan PR Feb 2011.

Fraser, WR (invited). A landscape effect on Adélie penguin demography. **2010**. August, ESA Annual Meeting, Pittsburgh, Pennsylvania, USA.

Geisz, HN, Dickhut, RM, Cochran, MA, **Fraser, WR,** Patterson-Fraser, DL, **Ducklow, HW. 2010**. Persistent organic pollutants as tracers of Antarctic seabird ecology. September, First World Seabird Conference, Vancouver, British Columbia, Canada.

Geisz, HN, Dickhut, RM, Cochran, MA, **Fraser, WR,** Patterson-Fraser, DL, Goebel, ME. **2010**. Persistent organic pollutants as tracers of Antarctic seabird ecology. November, SETAC North America 31st Annual Meeting, Portland, Oregon, USA.

Lunau, M; Erickson, M; Waldron, M; **Ducklow, H W.** 2010. SHIPBOARD, NEAR-REAL-TIME ENUMERATION OF LIVING PHYTOPLANKTON AND BACTERIA ALONG THE WEST ANTARCTIC PENINSULA. ASLO Summer Meeting, Santa Fe, NM. (Poster).

Oliver, M, **Fraser, WR,** Irwin, A, **Schofield, O,** Kohut, J. **2010**. Satellite-driven analysis of climate mediated changes in Antarctic food webs. May, NASA Ocean Color Science Meeting, New York, New York, USA.

Séguret, M., M.P. Field, D. Sinclair, **O. Schofield, R.M. Sherrell**. 201. Evidence for iron limitation in shelf waters of the western Antarctic Peninsula, poster presented at Polar Marine Science GRC, Ventura CA, March 2011.

Ribic, CA, Ainley, DG, Ford, RG, **Fraser, WR,** Tynan, CT, Woehler, EJ. **2010**. Water masses, ocean fronts, and the structure of Antarctic seabird communities: putting the eastern Bellingshausen Sea in perspective. September, First World Seabird Conference, Vancouver, British Columbia, Canada.

Schofield, O., Oliver M., Moline, M., Kohut, J. (March 2011). The potential of using autonomous gliders to study the ecology of polar oceans. (Gordon Keenan Conference, Ventura, California)

Schofield, O. (October 2010). Understanding a changing water planet: Building the new automated ocean sensor networks. Pop Tech 2010 conference, special session on "Cloud Computing" (Camden ME)

Stammerjohn, S. 2010. Exploring Seasonal Sensitivities and Feedbacks in Regions of Rapid Sea Ice Decline, Invited plenary presentation given at the National Academy Sciences Workshop on *Frontiers in Understanding Climate Change and Polar Ecosystems*, Cambridge, MD, 24-25 August.

Steinberg D.K. "Zooplankton role in biogeochemical cycles: Progress and prospects for the future". Plenary talk, 5th International Zooplankton Production Symposium, Pucon, Chile, Mar., 2011. Invited.

Internet/Websites

K Baker (2010) Palmer Data Portal http://pal.lternet.edu/data/dataportal/

B Simmons (2010) Palmer LTER Cruise blog http://cce.lternet.edu/outreach/blogs/cruise/

B Simmons(2010) Palmer LTER Education/Outreach website

B Simmons(2010) LTER Google maps http://137.229.80.178/margaret/example_checkbox.html

Ocean Today kiosk project http://oceantoday.noaa.gov/

LTER Databits Newsletter:

Baker, K., 2010. Note on Category Formation. LTER Databits Newsletter, Feature Fall 2010.

Baker, K., N.Kaplan, and E.Melendex-Colom, 2010. IMC Governance Working Group: Developing a Terms of Reference. LTER Databits Newsletter, Feature Fall 2010.

Baker, K. and E.Melendez-Colom, 2010. Evolution of Collaboration in Ecology. LTER Databits Newsletter, Good Read Fall 2010.

Baker, K. and M.Kortz, 2011. LTER Information Management: Continuing Education and Site Change. LTER Databits Newsletter, Feature Spring 2011.

Baker, K., 2011. Wordle: Tool for Generating Text Visualization. LTER Databits Newsletter, Good Tools, Spring 2011.

Baker, K., 2011. Network Identity: 2009 All-Site Milestone and Reflection on Governance. LTER Databits Newsletter, Feature Spring 2011.

Baker, K., 2011. Information Management, Data Repositories, and Data Curation. LTER Databits Newsletter, Commentary Spring 2011.

Baker, K., 2011. Collaborative, Cross-disciplinary Learning. LTER Databits Newsletter, Good Reads Spring 2011.

Baker, K., 2011. A Special Issue of Science on Data. LTER Databits Newsletter, Good Reads Spring 2011.

Conners, J. Addressing Scaling Associated with Data Access. LTER Databits Newsletter, Feature Fall 2010.

Conners, J., 2011. Notes on Design. LTER Databits Newsletter, Commentary Spring 2011.

Donovan, J., 2011. Making Space for Information Management. LTER Databits Newsletter, Feature Spring 2011.

Haber, S., 2011. Technical Roles: Am I in IT? LTER Databits Newsletter. Feature Spring 2011.

Kortz, M., 2010. Enactment and the Unit Registry. LTER Databits Newsletter, Feature Fall 2010.

Kortz, M., 2011. Review: The PersonnelDB Design and Development Workshop. LTER Databits Newsletter, Feature Spring 2011.

Yarmey, L., 2010. Transitions and Comparisons. LTER Databits Newsletter, Feature Fall 2010.