Title of Grant / Cooperative Agreement:	Implications of Changing Sea-Ice on Phytoplankton and Zooplankton Biomass and Community Structure in the Bering Sea
Type of Report:	Summary of Research
Name of Principal Investigator:	Colleen Mouw
Period Covered by Report:	August 1, 2010 - January 31, 2014
Name and Address of recipient's institution:	University of Wisconsin System, 21 N. Park St. Ste 6401, Madison, WI 53715-1218
NASA Grant / Cooperative Agreement Number:	NNX10AP10G

Reference 14 CFR § 1260.28 Patent Rights *(abbreviated below)*
The Recipient shall include a list of any Subject Inventions required to be disclosed during the preceding year in the performance report, technical report, or renewal proposal. A complete list (or a negative statement) for the entire award period shall be included in the summary of research.

Subject inventions include any new process, machine, manufacture, or composition of matter, including software, and improvements to, or new applications of, existing processes, machines, manufactures, and compositions of matter, including software.

Have any Subject Inventions / New Technology Items resulted from work performed under this Grant / Cooperative Agreement?	No ◉	Yes ○
If yes a complete listing should be provided here: Details can be provided in the body of the Summary of Research report.		

Reference 14 CFR § 1260.27 Equipment and Other Property (abbreviated below)
A Final Inventory Report of Federally Owned Property, including equipment where title was taken by the Government, will be submitted by the Recipient no later than 60 days after the expiration date of the grant. Negative responses for Final Inventory Reports are required.

Is there any Federally Owned Property, either Government Furnished or Grantee Acquired, in the custody of the Recipient?	No ◉	Yes ○
If yes please attach a complete listing including information as set forth at § 1260.134(f)(1).		

Attach the Summary of Research text behind this cover sheet.

Reference 14 CFR § 1260.22 Technical publications and reports (December 2003)
Reports shall be in the English language, informal in nature, and ordinarily not exceed three pages (not counting bibliographies, abstracts, and lists of other media).

A Summary of Research (or Educational Activity Report in the case of Education Grants) is due within 90 days after the expiration date of the grant, regardless of whether or not support is continued under another grant. This report shall be a comprehensive summary of significant accomplishments during the duration of the grant.

Implications of Changing Sea-Ice on Phytoplankton and Zooplankton Biomass and Community Structure in the Bering Sea

NASA Grant: NNX10AP10G
Period of Performance: 08/01/2010 – 01/31/2014

Final Report

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Goal:

The goal of this project is to understand how changing sea ice and other physical variability in the Bering Sea is impacting biomass and community structure of both phytoplankton and zooplankton. The project included *in situ* data collection of optical and biological data that was used to refine satellite algorithms and validate acoustical models for improved performance of phytoplankton and zooplankton community structure, respectively. Satellite imagery of physical and biological parameters were used to characterize spatial and temporal variability in the surface ocean while a coupled physical/ecosystem model is used to mechanistically understand whole water column processes associated with the surface variability.

This project aimed to address several research questions:

Question 1: How will changes in sea ice influence primary producers?

a) *How does sea ice extent, concentration and rate of spring retreat affect phytoplankton community composition and the allocation of primary production between different size groups?*
b) *What are the dominant physical and chemical ice-mediated controls on phytoplankton community structure and productivity and how are these controls changing with decreasing sea ice?*
c) *Is nitrate based new production significantly related to phytoplankton size-structure?*

Question 2: What affect does changing sea ice dynamics play on zooplankton?

a) *How does zooplankton size and community structure vary with sea ice mediated changes in bloom timing?*
    i. *Do phytoplankton blooms associated with late sea-ice retreat favor a zooplankton community dominated by euphausiids?*
    ii. *Do phytoplankton blooms associated with the early sea ice-retreat and ice free conditions favor a zooplankton community dominated by copepods?*

Question 3: Is there a clear relationship between phytoplankton bloom dynamics and community composition, zooplankton biomass and community structure and sea ice dynamics?

a) *How tightly coupled are these processes?*
b) *How have they changed over our data record and how may they change in the future?*

PROJECT OVERVIEW

Major Findings - *Cold Regime Variability*

While secular trends in warming or sea ice cover have not yet been documented in the Bering Sea, several decades of research have revealed significant differences in environmental conditions and Bering Sea ecosystem function during warm and cold climatological regimes (Stabeno *et al.*, 2012a, b). Shifts between these regimes, driven mainly by meteorological and atmospheric coupling with the Arctic (Hunt et al., 2010; Brown and Arrigo, 2012), typically occur on 3-7 year time periods. During the past three decades, the Bering Sea experienced distinct patterns of sea-ice melt-back associated with cold, followed by warm, and then cool periods (Overland and Stabeno, 2004). An exception to this cyclical pattern was the short spell of warm winter weather that followed the onset of the El-Niño in 1997 (Stabeno and Overland, 2001) and the cold winter that followed during the La-Niña of 1990. From 2000 to 2006 the Bering Sea experienced a warming trend, followed by a series of cold years from 2008-2012.

A unique aspect of the datasets collected and investigated as part of this project is that they were observed during a period of prolonged cold weather, during which the Bering Sea experienced extensive sea-ice formation in winter. What is notable is that trends and the behavior of sea-ice in the Bering Sea were in complete contrast to those observed in the Arctic Ocean, which witnessed record losses of sea-ice over the same period. Integrating biologic and hydrographic data from the mooring observations, has allowed the examination of the cold regime interannual variability of production in the southeastern Bering Sea (Stauffer et al., in prep). It was determined that interannual variability of primary and secondary production within individual climatic regimes can be significant and have implications for trophic relationships. Within the cold years included in this study, overall conditions in 2009 and 2011 were very different from those in 2012, driven largely by differences in ice extent and thickness, dates of ice retreat, and dates of increased stratification. Distinct differences were also apparent in the maximum mid-column chlorophyll *a* concentrations (Chl *a*) observed in each year. Sigler et al. (in review) suggested that the spring bloom occurs in April when ice is still present in that month, which it was in all the years included in this study. In the present dataset, however, the spring bloom, treated as a local maximum, only occurred in April in 2011, with shallow and mid-column blooms nearly co-occurring. In contrast, in 2012 there was an initial increase in mid-column Chl *a* in April, but maximum values were not attained until early May, and in 2009 biomass did not increase substantially until mid-May.

Each year, the extremely cold weather facilitated the formation of a "Cold Pool" (seawater temperature $<2^oC$), which was observed over the entire central Bering Sea shelf north of 57^oN (Goes et al. in press, Figures 1A,C). Although the presence of the "Cold Pool" enhanced stratification to the benefit of large long-chained diatom blooms in the shelf region (Stauffer et al., in review), it left the upper (<40 m) Bering Sea shelf water column completely nutrient depleted to the detriment of further phytoplankton growth (Figure 1B,D). Phytoplankton growth and biomass however varied greatly between years (Stauffer et al., in review) due to differences in localized sea-ice conditions. The results of our study also showed that if the Cold Pool was not eroded by energetic storms midway through summer, it acted as a barrier for upward fluxes as well as cross-shelf transportation of nutrients leaving the upper 35m completely devoid of nutrients. As a consequence, populations of large diatoms in the upper 35m were replaced by smaller prasinophytes, cryptophytes, haptophytes and a small percentage of smaller diatoms by mid-summer (Goes et al., in press, Figure 1E). Variable fluorescence measurements confirmed that these populations were physiologically stressed (Figure 2B,D).

Additionally, the presence of the Cold Pool resulted in greater CDOM photodegradation of the surface mixed layer in the summer that may have allowed light penetration to greater depths into the Cold Pool, where with nutrient availability resulted in large subsurface phytoplankton blooms (D'Sa et al., 2013). The phytoplankton communities at depth (~40m) revealed the presence of large diatoms which accounted for >80% of the biomass which at times was in excess of 20 mg m^{-3} Chl a (Figure 1F). These populations were largely confined to the sharp pycnocline located just above the Cold Pool and appeared to be remnants of diatom blooms that had sunk out of the water column during spring. The existence of this Chl *a* and diatom-rich layer over the entire Bering Sea layer led us (Goes et al. in press; in prep.) to posit that in addition to preventing the exchange of nutrients in the upper water column, the Cold Pool acts as a barrier for carbon export, preventing large diatoms from being available to benthic populations.

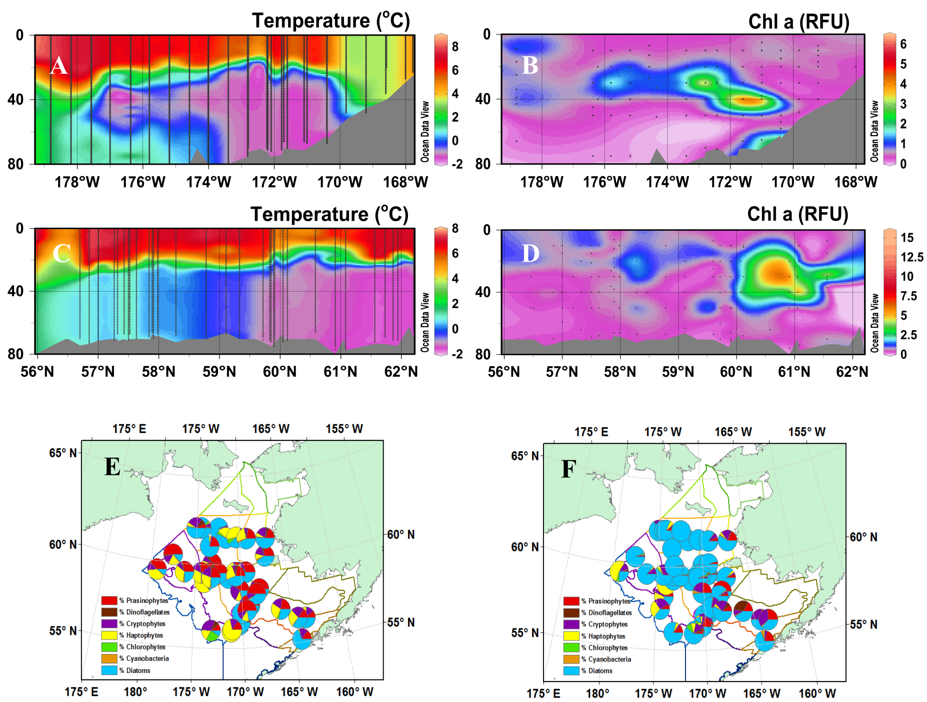

Figure 1. *Cold pool characterization and phytoplankton response. A and B) cross-shelf temperature and Chl a, C and D) along shelf temperature and Chl a, E and F) phytoplankton community composition at the surface and above the cold pool, respectively.*

Analysis of our data has also led us to posit that temperature could be an important determinant of the community structure of phytoplankton in the Bering Sea. Examination of relative composition of phytoplankton in relation to temperature revealed that diatoms generally preferred colder waters, in contrast to most other phytoplankton, which appeared to prefer warmer waters. On the basis of these results, we have posited that if the Bering Sea were to become warmer, benthic organisms would lose a key food source with potentially large consequences for fisheries.

We recently participated in cruises on board the South Korean vessel R/V *Araon* in July-August of 2012 when sea-ice extent was at its lowest. These ship-of-opportunity studies allowed us to collect valuable biological and bio-optical data that gives us immense confidence that our new BS_OC3 algorithm can provide Chl *a* that are more valid over large areas of the Arctic Ocean than the standard OC4 Chl *a* algorithm. These ship-of-opportunity studies also revealed the presence of large (29 mg Chl *a* m^{-3}) blooms of actively growing, chain forming diatoms such as *Chaetoceros socialis*, *Thallasiosira* sp. and *Leptocylindrus* sp. of diatoms at 40 m in the Chukchi Sea (Figure 2). The close resemblance of these species to those observed in the northern Bering Sea (Goes et al., in press) also raises intriguing questions whether the Bering Sea is providing the seed population for diatom blooms at depth (~40 m) in the Chukchi Sea and the western Arctic Ocean, and whether Bering Sea phytoplankton are replacing sympagic and under-ice populations of the Pacific Arctic Ocean, which is experiencing reduced sea-ice conditions.

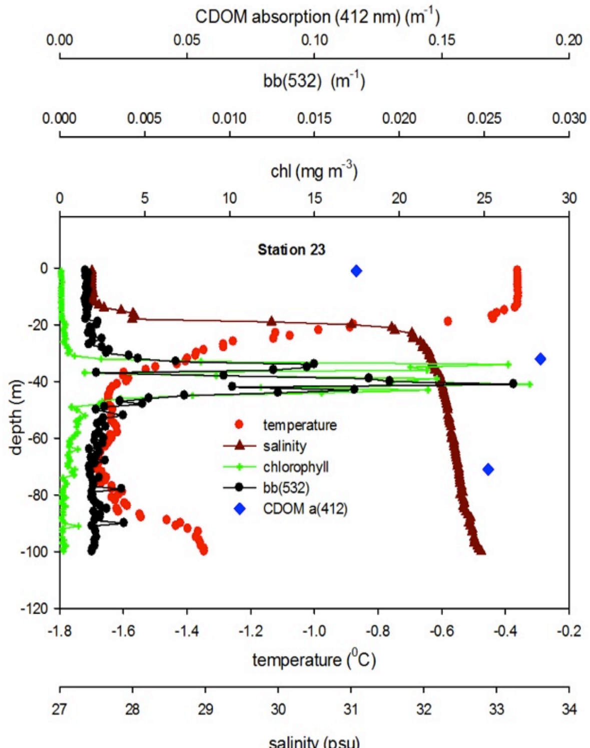

Figure 2. *Example of bio-optical properties (Chl a, CDOM absorption, particle scattering) derived optical profiler measurements during the 2012 western Arctic Ocean research cruise on the South Korean research vessel and icebreaker R/V Araon.*

The bulk of these subsurface blooms of phytoplankton are inaccessible to ocean color sensors (Arrigo et al., 2011), but their magnitude in terms of Chl *a* and carbon biomass makes them an extremely important community for understanding carbon cycling and the ecosystem dynamics of the western Arctic Ocean. Our future plans are to use the method of Sathyendranath and Platt (1989) that relies on remotely sensed Chl *a* signatures at the surface to infer phytoplankton biomass at depth. While some knowledge of photo-adaptation and nutrient-uptake kinetics is available for polar ice algae and under-ice phytoplankton, more realistic physiological rate parameters that are specific for high latitude phytoplankton present at depth will be required for estimating primary production and new production from space and for coupled bio-physical modeling of the ocean biogeochemical cycle. Obtaining improved estimates of phytoplankton physiological rate parameters for photosynthesis versus light (P vs. E), nutrient uptake kinetics, etc. that are specific for cold water phytoplankton are necessary first steps to assure that outputs from our coupled sea-ice ocean ecosystem model for the Arctic Ocean are more robust.

Field Data Summary

Support from NASA allowed us to participate in five ship-of-opportunity cruises on board U.S. and Japanese research vessels in the Bering Sea (2009-2012), and in two cruises on board the Korean Ice Breaker *R/V Araon* in the Arctic Ocean (2012 and 2013). Datasets from the cruises included inherent and apparent optical properties (Figure 3), continuous underway fluorescence-estimates of chlorophyll *a* concentration (Chl *a*), three phytoplankton phycobilipigment types and phytoplankton photosynthetic competency in the Bering Sea. During these cruises seawater samples were also collected for microscopic identification of phytoplankton and for High Precision Liquid Chromatography (HPLC) of pigments used for identifying major phytoplankton groups. Year-round moorings (September 2008-August 2012) equipped with active and passive acoustical instruments have allowed for the characterization of zooplankton biomass and community structure from acoustic backscatter (Sv and % composition time series) (Figure 4). Synthesis of these datasets have now aided in: 1) validation and fine-tuning of a coupled sea-ice physical-biological model developed as part of this project (Wang et al., 2013) (Figures 5, 6 and 7), 2) ocean color algorithm development for Chl *a* and CDOM (Naik et al., 2010, 2013; D'Sa et al., 2013) (Figure 8), and 3) constructing a comprehensive picture of the spring-summer seasonality of phytoplankton and zooplankton communities required for addressing questions outlined in our project.

a) How does sea ice extent, concentration and rate of spring retreat affect phytoplankton community composition and the allocation of primary production between different size groups?

b) What are the dominant physical and chemical ice-mediated controls on phytoplankton community structure and productivity and how are these controls changing with decreasing sea ice?

These datasets have been quality controlled and submitted to SeaBASS and are available to the community for ocean color algorithm development and validation activities. The Physical model code is maintained open source at: http://www.glerl.noaa.gov/about/pers/profiles/wang.html/CIOM/, whereas our Biological model code is currently being archived on SourceForge which is a web-based source code repository (see http://sourceforge.net).

Prior to this study, no database existed anywhere for the archiving of acoustic backscatter data obtained from scientific echosounders. Acoustic data is challenging to archive, as the datasets are large and multidimensional. Co-PI Jennifer Miksis-Olds worked closely with Chris Proctor at the NASA GSFC Ocean Biology Processing Group to create an additional database within the larger NASA SeaBASS database to accept and make acoustic backscatter data and all its accompanying metadata publically available.

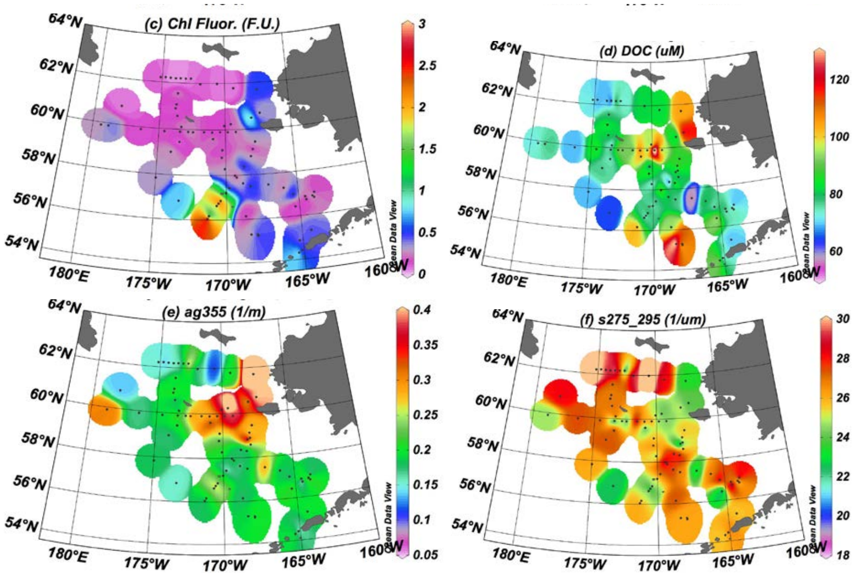

Figure 3. *Spatial distribution of chlorophyll fluorescence, DOC concentrations, absorption coefficient at 355 nm (a_g355) and spectral slope S in surface waters of the Bering Sea in the summer of 2008 (D'Sa et al. 2013).*

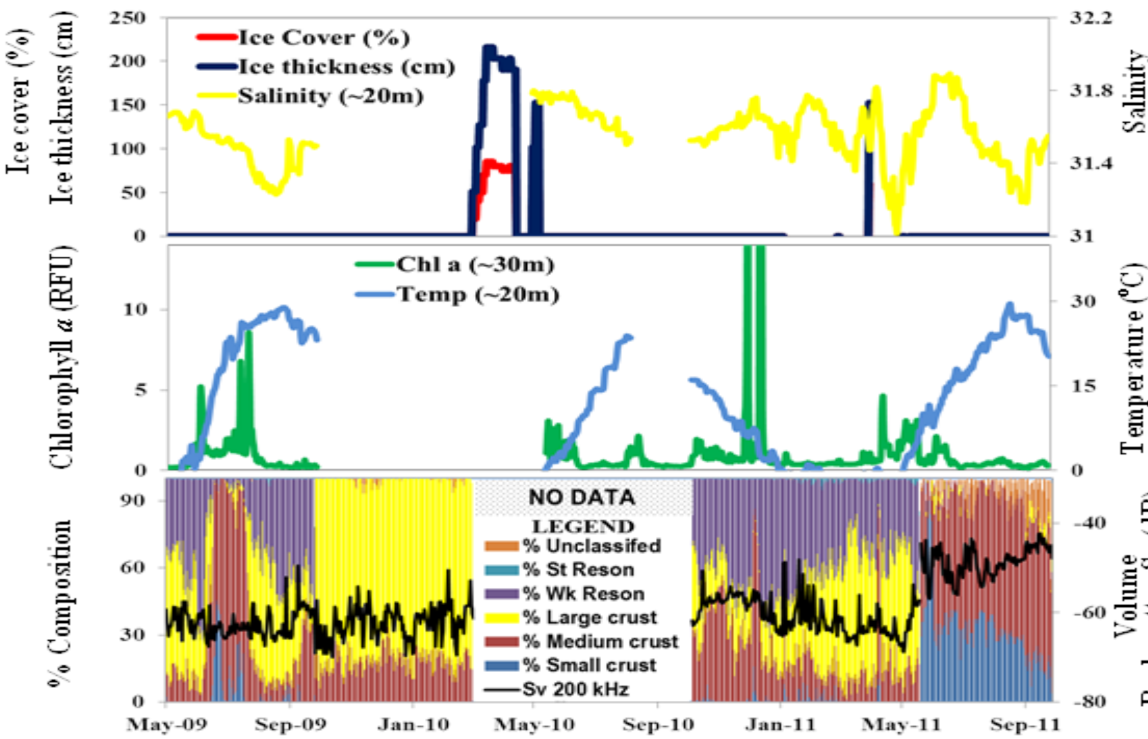

***Figure 4**. The combination of multiple datasets obtained from the M2 regions in the Bering Sea from 2009-2011. Detailed information is available to describe ice dynamics, physical features of the water column (temperature and salinity), and zooplankton/fish dynamics (level and community structure). The Chl a time series represents the level of primary production, but there is no information on phytoplankton community structure and photosynthetic competency to explain the dramatic shifts in zooplankton community structure during times of relatively stable levels of acoustic backscatter (Sv) and Chl a.*

Modeling Summary

Over the course of this project, we established a coupled ice-ocean-ecosystem model (CIOM) and ice-ocean-ecosystem model (***Ph***ysical-***Eco***system ***M***odel, ***PhEcoM***) in the Bering-Chukchi-Beaufort seas and ran the model for the field study years 2007-2013, and validated the model using both satellite and *in situ* measurements. The results of this effort are published for the 2007-2008 period (Wang et al., 2013). Another manuscript is planned that utilizes the field survey years (2010-2012) of this project and the NASA satellite standard data products and those developed as part of this project. Adding tides to investigate nutrient transport into the Chukchi Sea from the Bering Sea will further refine the ecosystem model.

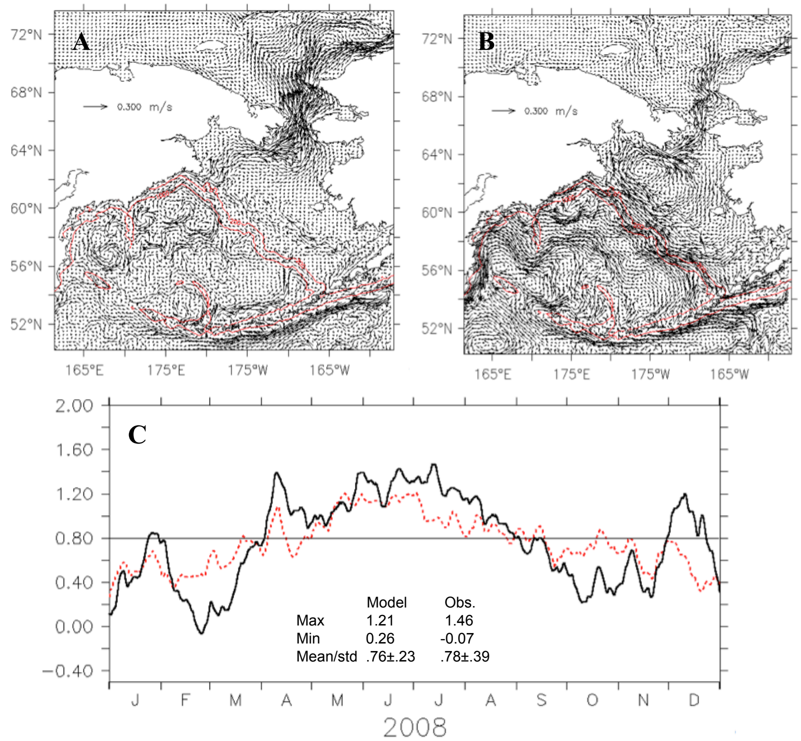

Figure 5. *CIOM-modeled upper 20-m average ocean circulation in A) July, B) March 2008. C) Comparison of simulated (dashed/red lines) and measured (solid/black lines) Bering Strait transport in Sverdrup (1 Sv=10^6 m^3 s^{-1}) in 2008 with 30-day moving average for both model output and measurements. The simulated transport statistics are given.*

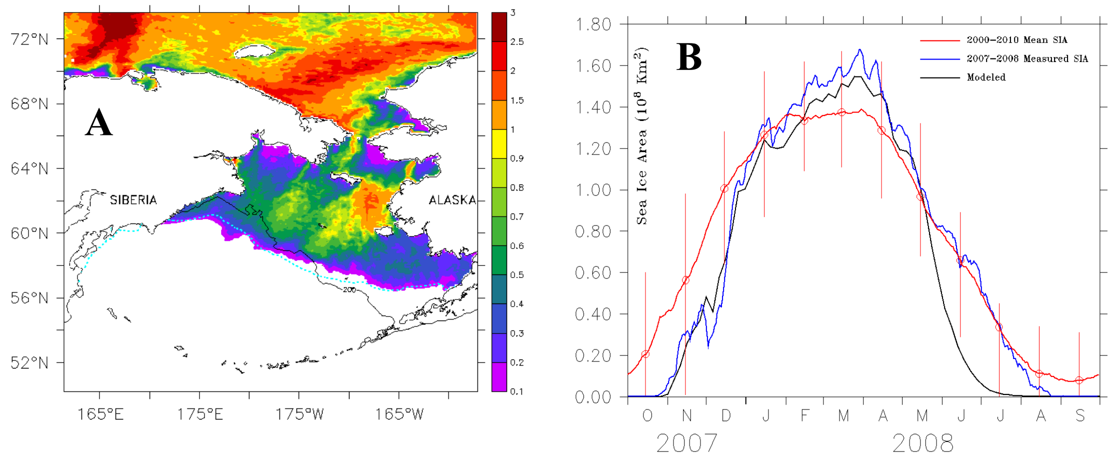

Figure 6. *Model and data ice comparisons. A) Modeled sea ice thickness (in meters) and satellite-measured sea ice edge (green dashed line) in March 2008. The 200 m isobaths is noted as a solid black line. B) Simulated sea ice area (black line) and satellite-measured sea ice area (blue) over the entire Bering and Chukchi Seas for 2007-2008. The red line denotes the 11-year average area and the red vertical bars denote the maximum and minimum ice areas during 2000-2011.*

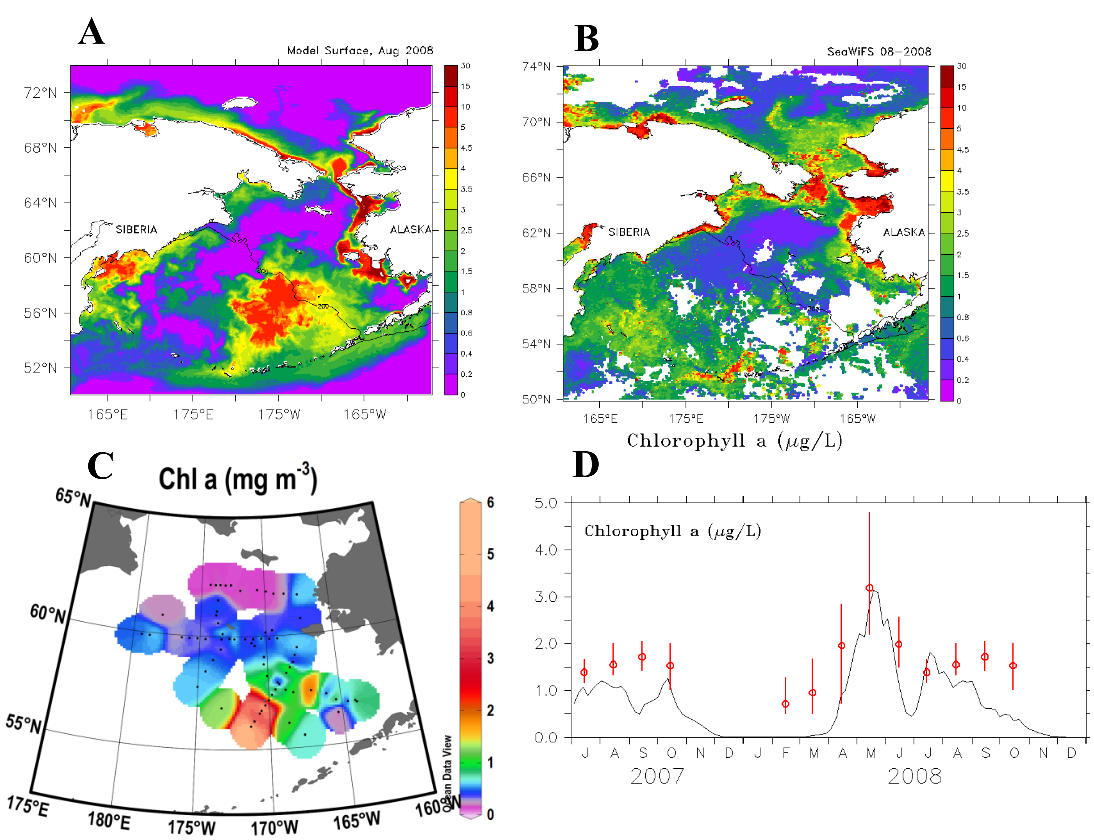

Figure 7. *Model data chlorophyll comparisons. A) Model simulated, B) SeaWiFS estimated, and C) surface in situ chlorophyll a measured in August 2008. Note*

that the near continuous measurements of chlorophyll at the surface (C) show the high chlorophyll patch that is reproduced by the model (A) near the shelf break, although the satellite-measurement (B) is not visible due to cloud cover. D) Model-domain averaged chl-a, as simulated by the PhEcoM (solid/black line) and measured by SeaWiFs (red circles). The vertical bars denote the monthly maxima and minima derived from the 2000-2010 data.

Satellite Summary

An absorption budget was determined (phytoplankton, non-algal particles (NAP) and colored dissolved organic matter (CDOM)) for the eastern Bering Sea during the summer that indicated the strong influence of CDOM absorption on the remote sensing reflectance and light attenuation in the water column. Results of our study indicated that for the standard OC4 algorithm, chlorophyll-a is overestimated at low concentrations due to higher CDOM absorption and underestimated at high concentrations due to specific absorption coefficient associated with phytoplankton package effect and size. A chlorophyll algorithm for the eastern Bering Sea for the summer was developed for MODIS using a 3-band algorithm (Naik et al., 2013; Figure 3).

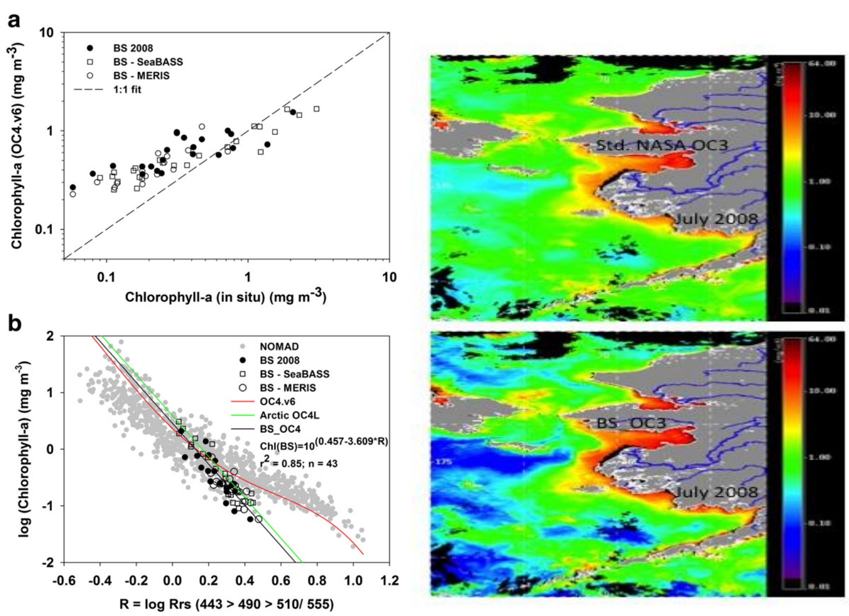

Figure 8. *Left Panel - Comparison of Chl a derived from the standard NASA algorithm (OC4.v6) with in-situ Chl a. Comparison of OC4.v6 (red solid line), the Arctic OC4L (Cota et al. 2004) (green line) with the Bering Sea BS_OC4 (black solid line) (Naik et al. 2013). Right Panel - A comparison of Chl a estimates obtained using the NASA OC3 (top) and the BS_BS_OC3 for MODIS ocean color of July 2008.*

We are also continuing evaluation and refinement of a variety of ocean color inversion algorithms (similar to Mouw et al., 2013) allowing for improved simultaneous retrieval of Chl *a*, CDOM and NAP that are needed to accurately retrieve changes in remote sensing reflectance associated with phytoplankton size structure (following Mouw and Yoder, 2010).

Education and Outreach Summary

The following table outlines the post-doctoral scholars (2), graduate (7) and undergraduate students (7) that have been involved with the project.

	Post-docs	**Graduate students**	**Undergraduates**
Michigan Tech University		Brice Grunert (Ph.D.)	
Columbia University	Beth Stauffer		Andrew Gross Ariel Tarell Maeve O'Connell
Louisiana State University	Puneeta Naik	Puneeta Naik (Ph.D.) Ishan Joshi (Ph.D.) Rajkumar Parthasarathy (M.S.) Prabakar Gunashekar (M.S.)	
Pennsylvania State University		Samuel Denes (Ph.D.) Julia Vernon (Ph.D.)	Nicole Marusco Samantha Tufano Amanda Murphy Michael Bollinger

Presentations from this Project

(PIs/staff are indicated in bold, students/post-docs are indicated in italicized bold with an asterisk)

D'Sa, E. J., J. Goes, P. Naik, C. B. Mouw, H. do R. Gomes, Summer bio-optical properties in the southeastern Bering Sea. International Ocean Color Science Meeting 2013, 6-9 May 2013.

D'Sa, E. J., J. Goes, *P. *Naik*, C. B. Mouw, and H. do R. Gomes. CDOM absorption and fluorescence optical properties in the southeastern Bering Sea during summers of 2008 and 2009. Ocean Sciences Meeting, Salt Lake City, UT, 20-24 February, 2012.

D'Sa, E., J. Goes, *P. *Naik*, C. Mouw, H. Gomes, CDOM optical properties in the southeastern Bering Sea during summer, NASA Carbon Cycle and Ecosystems Joint Science Workshop, Alexandria, VA, Oct. 2011.

Goes, J. I., E. D'Sa, H. do R. Gomes, **P. Naik*, A. Chekayaluk, S. Singh, S. Keith and R. Sambrotto (2009) Bio-Optical Investigations in the Eastern Bering Sea during the International Polar Year. *2009 NASA Ocean Color Research Team Meeting*, 4-6 May 2009, New York City, NY

Goes, J. I. H. do R. Gomes, K. Sasaoka, T. Saino (2010) The role of the Aleutian Low Pressure System in regulating phytoplankton biomass, primary production and export production across the subarctic Pacific Ocean basin. *PICES 2010 Annual Meeting North Pacific Ecosystems Today, and Challenges in Understanding and Forecasting Change* October 2010 Keynote Talk.

****Gross Andrew*** (2009) Undergraduate intern project at Bigelow Lab. *Iron enrichment impacts on phytoplankton populations of the subarctic Pacific and of the Bering Sea.* Andrew of Penn State University was a participant on board the FORV *Oshoro Maru*. He also received a travel award from the NSF to present his work at the ASLO meeting in Portland, Oregon, February, 2010

***Gross, A.R.*, J. I. Goes, H. do. R. Gomes**, S. Keith, **E. D'Sa** and S. Saitoh (2010) Effects of Iron Fertilization on Phytoplankton Ecosystems, *AGU, Ocean Sciences Meeting, Portland, Oregon*, Feb 2010. (poster)

Laws, E and **E. J. D'Sa**. Temperature effects on export production: current understanding and implications for the response of the ocean's biological pump to global warming, School of Coast and Environment Seminar, Louisiana State University, Baton Rouge, LA. 10 February, 2012 (seminar talk).

Miksis-Olds, JL (2014). Studying the Bering Sea: Understanding ecosystem dynamics in (sub)arctic waters. International Workshop on Arctic Ocean Tomography, Arlington, VA, January 14-16.

Miksis-Olds, JL, **Denes, SL*, Warren, JD (2012). A comparison of community structure from the southeastern and central Bering Sea shelf: insights gained from acoustic backscatter. Journal of the Acoustical Society of America 131: 3286.

Miksis-Olds, JL, Madden, LE (2012). The power of acoustics in ocean observing systems: A case study in the Bering Sea. Journal of the Acoustical Society of America 132: 1915.

Miksis-Olds, JL, Warren, JD (2011). Characterizing biological scatter before, during, and after a temporary ice retreat in the Bering Sea. Journal of the Acoustical Society of America 129: 2401.

****Naik, P.*, E. J. D'Sa**, **J. Goes**, and **H. Gomes**. Modeling of particulate absorption in the south-eastern Bering Sea. *Ocean Optics*, Anchorage, Alaska, 27 September-1 October, 2010.

****Naik, P.*, E. J. D'Sa, J. Goes, C. B. Mouw, and H. do R. Gomes**. Modeling of remote-sensing reflectance and diffuse attenuation coefficient in the southeastern Bering Sea. Ocean Sciences Meeting, Salt Lake City, 20-24 February, 2012.

****Naik, P.* and E. J. D'Sa**. Empirical orthogonal function (EOF) analysis of sea surface temperature (SST) and net primary productivity (NPP) in the eastern Bering Sea from MODIS. International Polar Year Conference 2012, Montreal, Canada, 22-26 April, 2012.

****O'Connell, Maeve.*** (2009) Undergraduate intern project at Bigelow Lab. Global Warming: Effects on Sea Ice in the Bering Sea and the resulting phytoplankton blooms, Adrian College, Michigan.

****Tarell, A.*, H. do R. Gomes, J. I. Goes** (2011) The effect of interannual sea-ice variability of phytoplankton communities in the Bering Sea. Report submitted to the Research Experience for Undergraduate (REU) Program at Lamont Doherty Earth Observatory, Sept. 2011.

Wang, J. and **H. Hu**, Modeling ice-covered marine ecosystem in the Bering and Chukchi seas. IUGG, Melbourne, June 28-July 7, 2011.

Wang, J., Modeling ice-ocean-ecosystem in the Bering and Chukchi Seas in 2004 and 2009 RUSALCA cruises. Pacific Arctic (Country) Group (PAG) Workshop, Nov. 5-6, 2012, Suzhou, China.

Hu, H. and **J. Wang**, Modeling sea ice and ecosystem in the Bering and Chukchi Seas. IAGLR, Cornwall, Canada, May 14-17, 2012.

Wang, J., Modeling ice-ocean-ecosystem in the Bering and Chukchi Seas in 2007-2008. Polar Research Institute of China, Nov. 9, 2012, Shanghai, China.

Publications from this project
(PIs/staff are indicated in bold, students/post-docs are indicated in italicized bold with an asterisk)

Deal, C.J. N. Steiner, J. Christian, J. Clement Kinney, K. Denman, S. Elliott, G. Gibson, M. Jin, D. Lavoie, S. Lee, W. Lee, W. Maslowski, **J. Wang**, and E. Watanabe (2013) Progress and Challenges in Biogeochemical Modeling of the Pacific Arctic Region. In: The Pacific Arctic Region: Ecosystem Status and Trends in a Rapidly Changing Environment, Co-Editors Grebmeier, J.M. and W. Maslowski, Springer Publishing, (in press)

D'Sa, E. J., J. I. Goes, H. Gomes, and **C. Mouw** (2013) Absorption and fluorescence properties of the eastern Bering Sea in the summer with special reference to the influence of a Cold Pool. *Biogeosciences Discussion*, 10, 1-46, doi: 10.5194/bgd-10-1-2013.

Goes, J.I., **Gomes, H. do R**., Haugen, E., McKee, K., **D'Sa, E**., Chekalyuk, A.M., Stoecker, D., Stabeno, P., Saitoh, S., and Sambrotto, R. (in press) Community structure and photosynthetic competency of summer time phytoplankton during the formation of a Cold pool in the Bering Sea. *Deep-Sea Research-II Bering Sea Ecosystem – Special Issue, North Pacific Research Board, doi 10.1016/j.dsr2.2013.12.004*

Goes, J. I., Gomes, H. do R., Wang, J., Hu, H., D'Sa, E., Miskis-Olds, J. and **Mouw, C.** (in prep.) Implications of the Bering Sea Cold Pool for carbon export and nutrient transport into the Arctic Ocean. To be submitted to *PLoS.*

Laws, E. A., **E. D'Sa, and **P. Naik***. (2011) Simple equations to estimate ratios of new or export production to total production from satellite-derived estimates of sea surface temperature and primary production. *Limnology and Oceanography: Methods*, 9, 593-601.

Miksis-Olds, J.L., Stabeno, P.J., Napp, J.M., Pinchuk, A.I., Nystuen, J.A., Warren, JD, ****Denes, S.L.*** (2013) Ecosystem response to a temporary sea ice retreat in the Bering Sea. *Progress in Oceanography* 111: 38-51. DOI: 10.1016/j.pocean.2012.10.010.

Moisan, T, **J. I. Goes**, P. Neale (2010) Mycosporine-like Amino Acids in Phytoplankton: Biochemistry, Physiology, and Optics, Phytoplankton Physiology, In: *Marine Phytoplankton* (Eds) W. T. Kersey, S.P. Munger, Chapter 4, 119-141, Nova Science Publishers, ISBN: 978-1-60741-087.

Mouw, C.B., D'Sa, E., and ****Grunert, B.*** (in prep) Ocean color inversion algorithm evaluation for the Bering Sea.

Mouw, C.B., D'Sa, E., Goes, J., Gomes, H., and ****Grunert, B.*** (in prep) Satellite determination of phytoplankton size variability in the Bering Sea.

****Naik P.,* E. J. D'Sa, J. I. Goes, H. R. Gomes, and C. Mouw** (2013) Light absorption properties of southeastern Bering Sea waters: analysis, parameterization and implications for remote sensing. *Remote Sensing of Environment,* 134, 120-134.

****Naik, P.*, and E. J. D'Sa** (2012) Phytoplankton light absorption of cultures and natural samples: comparisons using two spectrophotometers. *Optics Express*, 20:4871-4886.

Smirnov, A., B. N. Holben, D. M. Giles, I. Slutsker, N. T. O'Neill, T. F. Eck, A. Macke, P. Croot, Y. Courcoux, S. M. Sakerin, T. J. Smyth, T. Zielinski, G. Zibordi, **J. I. Goes**, M. J. Harvey, P. K. Quinn, N. B. Nelson, V. F. Radionov, C. M. Duarte, R. Losno, J. Sciare, K. J. Voss, S. Kinne, N. R. Nalli, E. Joseph, K. Krishna Moorthy, D. S. Covert, S. K. Gulev, G. Milinevsky, P. Larouche, S. Belanger, E. Horne, M. Chin, L. A. Remer, R. A. Kahn, J. S. Reid, M. Schulz, C. L. Heald, J. Zhang, K. Lapina, R. G. Kleidman, J. Griesfeller, B. J. Gaitley, Q. Tan, and T. L. Diehl (2011) Maritime aerosol network as a component of AERONET – first results and comparison with global aerosol models and satellite retrievals (2011) *Atmos. Meas. Tech*., 4, 583-597, 2011.

***Stauffer, B**., **J.** **I. Goes**, **H.do. R. Gomes**, K. McGee and P. Stabeno (in review) Comparison of spring-time phytoplankton community composition in two cold years from the western Gulf of Alaska into the southeastern Bering Sea. *Deep-Sea Research-II Bering Sea Ecosystem – Special Issue, North Pacific Research Board.*

Stauffer, B.A., **Miksis-Olds, J.L., Goes, J.** (in prep). Cold regime interannual variability of community composition of primary and secondary producers in the southeastern Bering Sea.

Stoecker, D. A. Weigner, **J. I. Goes** (in press) Microzooplankton Grazing in the Eastern Bering Sea in Summer. *Deep-Sea Research-II Bering Sea Ecosystem – Special Issue, North Pacific Research Board. 10.1016/j.dsr2.2013.09.007.*

Wang, J., X. Bai, D. Wang, D.R. Wang, **H. Hu**, and X. Yang (2012) Impacts of the Siberian High and Arctic Oscillation on the East Asia winter monsoon: Driving downwelling in the western Bering Sea. *Aquatic Ecosystems Health and Management, 15, 20-30.*

Wang, J., H. Eicken, Y. Yu, X. Bai, J. Zhang, H. Hu, D.-R. Wang, M. Ikeda, K. Mizobata, and J. Overland (2013) Abrupt Arctic Changes and Emerging Ice-Ocean Processes in the Pacific Arctic Region and Bering Sea, In: *The Pacific Arctic Region: Ecosystem Status and Trends in a Rapidly Changing Environment*, Co-Editors Grebmeier, J.M. and W. Maslowski, Springer Publishing (in press)

Wang, J., **H. Hu, J. Goes, J. Miksis-Olds, C. Mouw, E. D'Sa, H. Gomes,** D.R. Wang, K. Mizobata, S. Saitoh , and L. Luo (2012) Modeling seasonal variations of sea ice and Plankton in the Bering and Chukchi Seas during 2007-2008. *J. Geophys. Res., 118, doi:10.1029/2012JC008322.*

Cited Literature (not in the Publications from this project list)

Brown, Z. W., & Arrigo, K. R. (2012). Sea ice impacts on spring bloom dynamics and net primary production in the Eastern Bering Sea. *J. Geophys. Res*. doi:10.1029/2012JC008034

Cota, G. F., H. Wang, and J. C. Comiso (2004). Transformation of global satellite chlorophyll retrievals with a regionally tuned algorithm, *Remote Sens. Environ*., 90(3), 373-377.

Hunt G., Bond N., Stabeno P., Ladd C., et al. (2010). *Status and trends of the Bering Sea region, 2003–2008*. In: McKinnell S. M., Dagg M., ed. *The Marine Ecosystems of the North Pacific Ocean; Status and Trends. PICES Special Pub., 4; 2010. p. 196-267. 393 pp.*

Mouw, C. B., Chen, H., Mckinley, G. A., Effler, S., O'Donnell, D., Perkins, M. G., Strait, C. (2013). Evaluation and optimization of bio-optical inversion algorithms for remote sensing of Lake Superior's optical properties. *J. Geophys. Res.:Oceans*, *118*, 1696–1714.

Mouw, C., & Yoder, J. (2010). Optical determination of phytoplankton size composition from global SeaWiFS imagery. *J. Geophys. Res.*, *115*(C12018). doi:10.1029/2010JC006337

Overland, J.E. and P. J. Stabeno, (2004), Is the climate of the Bering Sea warming and affecting the ecosystem? *EOS* 85, 309 (2004).

Sathyendranath, S., Platt, T., Caverhill, C., Warnock, R., Lewis, M. (1989). Remote sensing of oceanic primary production: computations using a spectral model. *Deep-Sea Res.*, (3), 431–453.

Sigler, M., Stabeno, P.J., Eisner, L. B., Napp, J.M., Mueter, F.J. (in review). Spring and fall phytoplankton blooms in a productive subarctic ecosystem, the 1 eastern Bering Sea, during 1995-2011. *Deep Sea Res. II: Topical Studies in Oceanography, Bering Sea Special Issue.*

Stabeno, P.J., E. Farley, N. Kachel, S. Moore, C. Mordy, J.M. Napp, J.E. Overland, A.I. Pinchuk, and M.F. Sigler (2012): A comparison of the physics of the northern and southern shelves of the eastern Bering Sea and some implications for the ecosystem. *Deep-Sea Res. II,* 65–70.

Stabeno, P. J., Kachel, N. B., Moore, S. E., Napp, J. M., Sigler, M., Yamaguchi, A., & Zerbini, A. N. (2012). Comparison of warm and cold years on the southeastern Bering Sea shelf and some implications for the ecosystem. *Deep-Sea Res. II*, *65-70*(C), 31–45.

Stabeno, P.J., and J.E. Overland (2001): Bering Sea shifts toward an earlier spring transition. Eos Trans. AGU, 82(29), doi: 10.1029/01EO00185, 317, 321.