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THEORETICAL MODELS OF MARINE INFECTIOUS DISEASES AND THE EFFECTS OF CLIMATE VARIABILITY

BY JOHN KLINCK AND EILEEN HOFMANN

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Infectious diseases are those which can be passed from one individual to another. Many diseases in humans are of this type which cause both mild and severe epidemics (flu and smallpox are familiar examples). Because of the impact of epidemics on human society, a number of tools (models) have been developed to understand the spread of infectious diseases – the best known is by Kermack and McKendrick (1927), which analyzes the rate of spread of a disease through a population based on contact between infectious and susceptible individuals.

Recent changes in environmental conditions, mainly temperature due to the changing climate, have caused a number of infectious diseases to move to new locations or to change their effect on populations and ecosystems (see Altizer et al., 2013 for more details). This environmental effect makes analysis and prediction of disease processes more complicated. Warmer temperatures may allow pathogens to grow faster or speed up their biochemical processes. Also, it may allow them to survive later in the fall or even through the winter. Similarly, the host's processes may be affected (for better or worse) by changing temperature. The net effect of temperature changes on a disease requires careful analysis of the biological

processes in the host and pathogen. The simple ideas of the susceptible-infective disease models (following Kermack and McKendrick) need to be expanded to include metabolic processes of the organisms involved, as well as the details of the transmission and immunology processes under these changing conditions. New theoretical ideas and models are needed.

A variety of marine organisms (clams, oysters, corals, sea grass, sea urchins, trout, seals and many others; see Burge et al., 2014 for details) suffer from infectious diseases. **John Klinck** and **Eileen Hofmann** of CCPO have used numerical models over a number of years to study bivalves (oysters and clams) and their diseases. They have recently started a new project (with Eric Powell of the University of Southern Mississippi; Susan Ford, Dave Bushek, Ximing Guo, Daphne Munroe of Rutgers University Haskin Shellfish Research Laboratory; and Dale Haidvogel, Julia Levin, John Wilkin of the Institute of Marine and Coastal Studies, Rutgers University) to develop theoretical models of disease and disease transmission in marine bivalves using the eastern oyster and its diseases, dermo and MSX, both of which are caused by invasive parasitic protozoan pathogens, as a model system.

NOTES FROM THE DIRECTOR



John Klinck,
*Professor and
Director, CCPO*

In the past, the group at CCPO was interested mainly in physical, biological and chemical processes in the ocean, particularly in the shallower coastal or estuarine areas. In recent years, we have expanded our interest to include ocean influences on local sea level, glacial melt driven by oceanic heat sources, bivalves and their diseases and genetics and even economic and political effects due to oceanic processes. I think that this expansion of interests is the future of academic research. We will be required to talk to specialists from different backgrounds and with different experiences. Also, we will be required to provide information to the general public about what we are doing and why they should care (and support us). All of this will require a willingness to learn about ideas and issues outside of our traditional bounds. Activities at CCPO show that we are on the path to expanding our interests and expertise.

CCPO has experienced many changes within the department over the last few months. Dr. Suriyan Saramul graduated and has returned to Thailand to a university post. Ray Toll has brought his expertise to CCPO. New students and postdocs have arrived who are introduced in this (and future) newsletters. Miasia Meniffee has joined CCPO as the new office manager and newsletter editor. Welcome to all of the new folks and best wishes to all who have left to further develop their careers.

CCPO STUDENT SPOTLIGHT

BRYNN DAVIS

Brynn Davis, originally from Virginia Beach, Virginia, graduated with honors from Kempsville High School in 2009. She is now a senior at Old Dominion University, studying the biological concentration of Ocean, Earth and Atmospheric Science. She will receive her Bachelor of Science in May 2014. After falling in love with oceanography as a junior in high school, she came to ODU to further progress her love for science. Volunteering for the Oceans 2012 Conference at the Virginia Beach Convention Center introduced Brynn to Julie Morgan, a CCPO Program Specialist who further connected her to Dr. Eileen Hofmann. Brynn came to CCPO to work under Dr. Hofmann in January 2013.

Her research at CCPO includes creating a climatological distribution of the two primary mid-trophic level consumers of the Ross Sea, Antarctic krill and crystal krill. Even though she loves

her research here at CCPO, as a undergraduate, Brynn finds that time management between her classes and research is her most challenging obstacle. This research project at CCPO has introduced her to the beautiful and crucial polar environment while teaching her time management, conducting an independent research project, group management, and the extensive work that goes into submitting a paper to a scientific journal. Brynn is ecstatic to announce that she will presenting her research at the 2014 Ocean Sciences Meeting in Honolulu, Hawaii.

Her future plans are to publish her research, attend graduate school at Old Dominion University, be a part of a scientific cruise to Antarctica and to passionately continue her research of the antarctic food web. Brynn hopes to support CCPO and Old Dominion University with extraordinary research.



Brynn Davis,
*oceanography major at ODU
experiencing the grandure of
the Grand Canyon.*

CCPO SPOTLIGHT

RAY TOLL



Ray Toll,
*retired from the US Navy,
brings extensive observed and
data quality experience to*

In June 2013, **CAPT (ret) Ray Toll** began working at CCPO. He is a retired Navy Captain who served for over 26 years as a Naval Oceanographer. As such, he has been a part of many adventures on Navy ships, submarines and aircrafts as both a data provider and consumer, using the ocean science to support Naval missions at sea. Navy Oceanography is multi-disciplined as it includes meteorology, oceanography, mapping, charting and geodesy. The mission encompasses the top of the atmosphere to the bottom of the ocean.

Ray is from Cleveland, OH. He received his Bachelor's and Master's of Science degrees through the Navy in both Meteorology and Oceanography, and has been a long time advocate of CCPO. He is the Technical Coordinator for the NOAA US Integrated Ocean Observing System project entitled, *QA/QC of Real Time*

Ocean Data (QARTOD) (see www.ioos.noaa.gov/qartod). His team has just started working on water level, which he hopes will serve as a meaningful resource for the ODU Climate Change and Sea Level Rise Initiative.

Ray is on several boards of directors (Marine Technology Society and MARACOOS – www.maracoos.org), advocating for a national ocean enterprise. Effective December 17, 2013, he will begin his term on the Virginia Aquarium & Marine Science Museum Center Board of Directors. He also is the local chair of MTS Hampton Roads, and served as chair of OCEANS 2012, a meeting in Virginia Beach, VA. in which CCPO participates (see www.oceans12mtsieehamptonroads.org). Ray hopes to support CCPO in many ways, including working with the Navy and NOAA on a Cooperative Institute hosted by ODU.

JENNIFER GRAHAM

Dr. Jennifer (Jenny) Graham joined CCPO in June 2013, moving from the University of East Anglia (UEA). Her research interests focus mainly on high latitude physical oceanography, as well as the role of polar oceans in the global climate system. She completed her Ph.D. at UEA under the supervision of Karen Heywood and Dave Stevens, investigating the global climate impacts of changes in Antarctic Intermediate Water (AAIW). Using a coupled climate model, a series of experiments were performed in each of the major ocean basins, altering the temperature and salinity of AAIW. Results from these experiments were recently published in the *Journal of Climate*.

Following her Ph.D., Jenny stayed on at UEA to work with observational data from the southeastern Weddell Sea. Using a year-long time series of temperature, salinity and current data, she investigated the processes responsible for the seasonal cycle of water masses in the region.

Results from this study were published in the *Journal of Geophysical Research* earlier this year and will be presented at the 2014 Ocean Sciences Meeting.

Now a Post Doc. at CCPO, Jenny will continue to work with both models and observational data, but her attentions have turned to the West of the Antarctic Peninsula (WAP). One aim of this project is to use a higher resolution model to resolve important eddy processes in the region. This area was extensively studied during the Southern Ocean GLOBEC program, in which one focus was the intrusion of warm Circumpolar Deep Water (CDW) onto the shelf. Results of that program showed the importance of small eddies. Jenny is settling in well at CCPO, and we look forward seeing results from her new project, providing answers to some of these key questions.



Jennifer Graham,
*enjoys a sunny day during an
Antarctic cruise.*

Marine invertebrates are mostly sessile or have weak abilities to move, so contact models of disease transmission do not apply. We hypothesize that infectious particles are released by infected bivalves, either continually or when they die, which drift in the environment and are filtered by susceptible animals which become infected. Transmission of most diseases have an infectious dose response in which a certain inoculation of the pathogen is required for an individual to become infected. In filter-feeding bivalves, the pathogen would have to move across the gill membrane to get inside the body properly. The current understanding of the infectious processes is that particles accumulate on the gills until there is a sufficient density for one or more particles to invade the oyster tissue allowing the disease to develop.

Because of this infectious dose constraint, a low density infected population may not produce sufficient infectious particles to expand the infection; that is, the infectious particle concentration reduces due to diffusive spreading in the environment to the point that there is too small of a dose to spread the infection (dilution effect). As the population density increases, the dose will increase allowing more transmission. They propose that if the population density is high enough, filtration by all individuals will remove enough infectious particles from the environment reducing the dose to any susceptible individual to a level that is too small to cause an infection (over-filtering effect). This may be one reason why oyster diseases (dermo and MSX) were not a problem years ago when oyster density was much higher than it is today.

A theoretical model was developed for the representation of these disease processes appropriate to a volume of water containing a population of bivalves. This model is being expanded to allow spatial variability by combining the ROMS 3-D circulation model with the benthic bivalve/disease model and a free-drifting infectious particle model.

This project is a contribution to a NSF-funded Evolution and Ecology of Infectious Disease Research Coordination Network (EEID RCN) (see web link below). The marine disease RCN has identified changing ocean temperature and other environmental changes resulting from changing climate as contributors to changes in marine diseases.

These changes include shifts in locations, movement to new (naïve) host populations, increases

in virulence or mortality, changes in the structure and functioning of an ecosystem, among others. One objective the marine disease RCN is to develop theoretical models to understand and predict the effect of changing environmental conditions on various marine diseases. There is a sociological and economic element to this research as many of the host organisms have economic value (provide food or attract tourists) and thus support human activity.

As part of the marine disease RCN, CCPO will host a workshop in 2015 on the topic, "Applying circulation models to understand transmission dynamics of marine disease with a view toward predictive capability". We will discuss our new ideas about freely moving infective particles and how these ideas might be applied to other diseases and other circumstances, as well as evaluate other models developed for marine diseases.

Additional readings:

Altizer and others, Climate change and infectious diseases: From evidence to a predictive framework. *Science*, 341, 514, 2013.

Burge and others, Climate change influences on marine infectious diseases: Implication for management and society. *Annual Review of Marine Science*, 6, 249-77, 2014.

Ecology of Infectious Disease Research Coordination Network (EID-RCN). <http://www.eeb.cornell.edu/ecologymarinedisease/Home/Home.html>.

CCPO STUDENT SPOTLIGHT

ELLEN CAVA

LT Ellen Cava is in her second year of the Physical Oceanography Master's program here at Old Dominion University. In addition to being a student, she is an active duty US Coast Guard Lieutenant stationed at US Coast Guard Atlantic Area command in Olde Towne, Portsmouth. Her primary responsibility is contingency planning for natural and man-made events. Last year during the fall semester, when Hurricane Sandy made landfall, her command stood up a 24-hour support team to help the impacted units and provide status information up to the Presidential briefs. During that time, she was pulled from her Biological and Physical Oceanography classes. She was grateful for the support from she received from her professors and classmates.

Her greatest accomplishment during her academic career the combination of her coursework and her

dedication to her country. During the summer 2013 semester, she was enrolled in Partial Differential Equations while standing watches in her command center. Over that eight - week period, she had to stand twelve - 12-hour watches. This means that there were days she was up from 4 AM to stand watch from 5 AM until 5 PM, then make her way to class from 6 PM until 9 PM. Amazingly, she passed her course and qualified to be an Operations Unit Watchstander. Now, she monitors Coast Guard activity from the Gulf of Maine to the Caribbean, up through the Western Rivers and the Great Lakes.

She is enjoying with the Physical Oceanography program. It has greatly expanded her knowledge in all areas of oceanography. She is able to use this knowledge at work, especially in the annual preparations for hurricane season.



Ellen Cava,
*expands her understanding
of Oceanography at ODU in
support of the mission of the
US Coast Guard.*

ANDREW FOOR



Andrew Foor,
*gets experience with ocean
data from seals to analyze
ocean variations.*

Andrew Foor is a senior working towards a Bachelor's of Science with a concentration in physical oceanography. He came to Old Dominion University in Fall 2011 after a year of community college. His original plan at ODU was to graduate in oceanography and then enlist in the Navy as a meteorological or oceanographic technician. For the past year Andrew has had an internship at CCPO under Drs. Hofmann and Klinck, working with data from autonomous sensors placed on Antarctic seals.

The project involves looking for Circumpolar Deep Water (CDW) along the Antarctic Peninsula in the Bellingshausen Sea. The analysis will look at the variability of the current as it relates to changes in wind and air temperature. The goal of the project is to see if these autonomous sensors can be used to detect change in upper ocean water properties. His time at CCPO has been a

great experience. "I have learned more from my time here than my past three years combined. Many at CCPO have been amazing with their helpfulness and patience with my lack of understanding at times. Even the moments I might camp outside an office to get a couple questions answered by a certain person, but I will not mention any names...John Klinck." Andrew hopes to have a manuscript completed by the end of the year.



Crabeater seal with satellite tag that was attached as part of the US Southern Ocean Global Ocean Ecosystem Dynamics field program off the west Antarctic Peninsula. The seal tagging work was done by Dr. Dan Costa's research group from the University of California Santa Cruz. The ARSV L.M. Gould is shown in the background.
(Photo credit, D. Costa.)

Graduates

Suriyan Saramul (advisor: **Tal Ezer**), Ph.D. Dissertation: Observations and modeling forcing mechanisms for the coastal dynamics of the Upper Gulf of Thailand, 154 pp., December 2013.

Publications

- Akan, C, A.E. Tejada-Martinez, **C.E. Grosch** and G. Martinat, 2013. Scalar transport in large-eddy simulation of Langmuir turbulence in shallow water, *Continental Shelf Research*, 55, 1-16, doi: 10.1016/j.csr.2012.12009.
- Ashford, J.R., **T. Ezer** and C.M. Jones, 2013. River discharge predicts spatial distributions of beluga whales in the upper Cook Inlet, Alaska, during early summer, *Polar Biology*, 36, 1077-1087, doi: 10.1007/s00300-013-1330-8.
- Boesch, D.F., **L.P. Atkinson**, W.C. Boicourt, J.D. Boon, D.R. Cahoon, R.A. Dalrymple, **T. Ezer**, B.P. Horton, Z.P. Johnson, R.E. Kopp, M. Li, R.H. Moss, A. Parris and C.K. Sommerfield, 2013. Updating Maryland's sea-level rise projections, Special Report to the Maryland Climate Change Commission, University of Maryland, Cambridge, MD, pp. 22.
- Ezer, T.**, J.R. Ashford, C.M. Jones, B.A. Mahoney and R.C. Hobbs, 2013. Physical-biological interactions in a subarctic estuary: How do environmental and physical factors impact the movement and survival of beluga whales in Cook Inlet, Alaska?, *Journal of Marine Systems*, Vol. 111-112, 120-129, doi: 10.1016/j.jmarsys.2012.10.007.
- Ezer, T.**, 2013. Sea level rise, spatially uneven and temporally unsteady: why the U.S. east coast, the global tide gauge record and the global altimeter data show different trends, *Geophysical Research Letters*, 40(20), 5439-5444, doi: 10.1002/2013GL057952.
- Ezer T.** and L.Y. Oey, 2013. On the dynamics of strait flows: An ocean model study of the Aleutian passages and the Bering Strait, *Ocean Dynamics*, 63(2-3), 243-263, doi: 10.1007/s10236-012-0589-6.
- Gatski, T.B.** and J.P. Bonnet, 2013. *Compressibility, turbulence, and high-speed flow*, 2nd edition, Academic Press, Oxford.
- Munroe, D.M., **E.E. Hofmann**, E.N. Powell and **J.M. Klinck**, 2013. How do shellfisheries influence genetic connectivity in metapopulations? A modeling study examining the role of lower size limits in oyster fisheries, *Canadian Journal of Fisheries and Aquatic Sciences*, 70, 1813-1828, doi: 10.1139/cjfas-2013-0089.
- Munroe, D.M., **J.M. Klinck**, **E.E. Hofmann** and E.N. Powell, 2013. A modeling study of the role of marine protected areas in metapopulation genetic connectivity in Delaware Bay oysters, *Aquatic Conservation: Marine and Freshwater Ecosystems*, online: 20 September, doi: 10.1002/aqc.2400.
- Munroe, D.M., E.N. Powell, R. Mann, **J.M. Klinck** and **E.E. Hofmann**, 2013. Underestimation of primary productivity on continental shelves: evidence from maximum size of extant surfclam (*Spisula solidissima*) populations. *Fisheries Oceanography*, 22, 220-233, doi: 10.1111/fog.12106.
- Oey, L.Y., Y. Masumoto, Y. Miyazawa, N. Aiki, **T. Ezer**, and T. Waseda, 2013. Editorial – The 4th International Workshop on Modeling the Ocean (IWMO-2012), *Ocean Dynamics*, 30, 1345-1347, doi: 10.1007/s10236-013-0658-5.
- Piñones, A., **E.E. Hofmann**, K.L. Daly, **M.S. Dinniman** and **J.M. Klinck**, 2013. Modeling environmental controls on the transport and fate of early life stages of Antarctic krill (*Euphausia superba*) on the western Antarctic Peninsula continental shelf. *Deep-Sea Research I*, 82, 17-31, doi: 10.1016/j.dsr.2013.08.001.
- Piñones, A., **E.E. Hofmann**, K.L. Daly, **M.S. Dinniman** and **J.M. Klinck**, 2013. Modeling the remote and local connectivity of Antarctic krill (*Euphausia superba*) populations along the western Antarctic Peninsula, *Marine Ecology Progress Series*, 481, 69-92, doi: 10.3354/meps10256.
- Tejada-Martinez, A.E., N. Sinha, C. Akan, **C.E. Grosch** and G. Martinat, 2013. Surface dynamics in LES of full-depth Langmuir circulation in shallow water, *Physica Scripta*, T155, 014008, doi: 10.1088/0031-8949/2013/T155/14008.
- Thais, L., G. Mompean and **T.B. Gatski**, 2013. Spectral analysis of turbulent viscoelastic and Newtonian channel flows. *Journal of Non-Newtonian Fluid Mechanics*, 200:165-176.
- Thais, L., **T.B. Gatski** and G. Mompean, 2013. Analysis of polymer drag reduction mechanisms from energy budgets, *International Journal of Heat and Fluid Flow*, 43:52-61.

Presenatations

- Bromwich, D.H., K. Hines, L.S. Bai, **M.S. Dinniman**, E.P. Gerber, K.M. Hines, D.M. Holland, **J.M. Klinck**, J.P. Nicolas and C. Yoo. The ACCIMA Project – Coupled Modeling of the High Southern Latitudes. American Meteorological Society 12th Conference on Polar Meteorology and Oceanography, Seattle, WA, April 2013.
- Bromwich, D.H., L.S. Bai, **M. Dinniman**, E. Gerber, K. Hines, D. Holland, **J.M. Klinck**, J.P. Nicolas and C. Yoo. The ACCI MA Project – Coupled Modeling of the High Southern Latitudes. 27th International Forum for Research into Ice Shelf Process, Gregynog Hall, Powys, Wales, June 2013.
- Dinniman, M.S., J.M. Klinck** and W.O. Smith, Jr.. Sensitivity of Water Masses and Ice Shelf Basal Melt in the Ross Sea to Changes in the Winds and Atmospheric Temperatures. 12th AMS Conference on Polar Meteorology and Oceanography, Seattle, WA, April 2013.
- Ezer, T.**, How climatic changes in Atlantic Ocean currents affect local sea level rise and increase flooding. OEAS Departmental Seminar Series. Old Dominion University, Norfolk, VA, September 12, 2013.
- Ezer, T.**, On the connections between the Gulf Stream and sea level rise along the US east coast. Graduate School of Oceanography, The University of Rhode Island, Kingston, RI, September 20, 2013.
- Ezer, T.**, On the connections between the Gulf Stream and sea level rise along the US east coast. University of Delaware, Newark, DE, September 27, 2013.
- Ezer, T.**, On the impact of the AMOC on sea level rise: new evidence that a slowdown of the Gulf Stream is responsible for accelerating sea level rise along the US Mid-Atlantic coast. US AMOC/UK RAPID International Science Meeting, Baltimore, MD, July 18, 2013.
- Ezer, T.**, Sea level rise and the challenge of modeling water level in the Mid-Atlantic coast. MARACOOS Modeling Workshop, Washington, D.C., July 22, 2013.
- Ezer T.**, State of the science of rising sea levels and extreme storms. EU-American Conference: Transatlantic Solutions to Sea Level Rise Adaptation, Old Dominion University, Norfolk, VA, October 30, 2013.
- Ezer, T.**, Why climate change may cause an uneven sea level rise along the US east coast. Civil and Environmental Engineering Seminar, Old Dominion University, Norfolk, VA, November 8, 2013.
- Gatski, T.B.**, Turbulence Modeling for Compressible Flows. Von Karman Institute Lecture Series – High Speed Turbulence, Sint-Genesius-Rhode, Belgium, May 2013.
- Hofmann, E.E.**, Coupling across individuals, populations and human systems in marine ecosystem models. Invited lecture, CNRS Thematic School on Innovative Approaches in Marine Environment Modeling, Institut Universitaire Européen de la Mer, Brest, France, August 19-23, 2013.
- Hofmann, E.E.**, Productivity and Linkages in Southern Ocean Food Webs: Comparisons and Implications. Plenary presentation, Ocean Carbon and Biogeochemistry Summer Workshop, Woods Hole Oceanographic Institution, Woods Hole, MA, July 22-25, 2013.
- Hofmann, E.E.**, Southern Ocean Food Webs - Current Understanding and Challenges. Seminar, State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai, China, October 14, 2013.
- Klinck, J.M.**, Atmosphere-ocean coupling causing ice shelf melt in Antarctica, ACCIMA, CCPO Fall 2013 Seminar series, Norfolk, VA, November 25, 2013.
- Mack, S.**, Tidal effects in the Ross Sea: A look at the mesoscale using satellite data models. Invited seminar, Yale Atmosphere/Ocean/Climate Dynamics Seminar Series, New Haven, CT, October 31, 2013.
- Mack, S.**, L. Padman, S. Springer, **M.S. Dinniman** and **J.M. Klinck**. Tidal contribution to sea ice variability in the Ross Sea from AMSR-E satellite data modeling. 12th AMS Conference on Polar Meteorology and Oceanography, Seattle, WA, April 2013.
- McGillicuddy, D., P. Sedwick, **M. Dinniman**, T. Bibby, B. Greenan, **E. Hofmann**, **J. Klinck**, C. Marsay, W. Smith and B. Sohst. Iron Sources on the Ross Sea Continental Shelf: Initial Results from the PRISM Project, IAHS-IAPSO-IASPEI Joint Assembly, Gothenburg, Sweden, July 2013.
- Piñones, A., **E.E. Hofmann** and **M.S. Dinniman**. Transport and fate of Euphasiid larvae in the Ross Sea. XITH SCAR Biology Symposium, Barcelona, Spain, July 2013.

JUST THE FACTS (*continued*)

Presentations

Salmon, E., **M. Dinniman** and **E. Hofmann**. NPZD-iron lower level ecosystem model of the Ross Sea. 2013 Ocean Carbon and Biogeochemistry Summer Workshop, Woods Hole, MA, July 2013.

Sinha, N., Tejada-Martinez, A.E., N. Sinha, **C.E. Grosch** and G. Martinat. A K-profile parameterization of Langmuir turbulence in shallow water. American Physical Society, Pittsburgh, PA, November 2013.

St-Laurent, P., What determines the differences in basal melt between ice shelves in the Amundsen Sea? 2013 West Antarctic Ice Sheet (WAIS) Workshop, Sterling, VA, September 2013.

Tejada-Martinez, A.E., N. Sinha, **C.E. Grosch** and G. Martinat. LES of full-depth Langmuir circulation in a crosswind tidal current. American Physical Society, Pittsburgh, PA, November 2013.

Thais, L., G. Mompean and **T.B. Gatski**. Spectral properties of the turbulent flow of a viscoelastic fluid for reduced drag. 8th International Symposium on Turbulent Shear Phenomena, Poitiers, France, August 28-30, 2013.

Tuleya, B., Transatlantic Solutions to Sea Level Rise Adaptation: Moving Beyond the Threat. Old Dominion University, Norfolk, VA, October 30-31, 2013.

Yoo, C., L.-S. Bai, D.H. Bromwich, **M.S. Dinniman**, E.P. Gerber, K.M. Hines, D.M. Holland and **J.M. Klinck**. Impact of Stratospheric Ozone on Cross Shelf Exchange around the Antarctic. 2013 Fall AGU Meeting, San Francisco, CA, December 9-13, 2013.

CCPO Spring 2014 Seminar Series

CCPO invites distinguished scientists to present at our seminar series during the academic year. Eileen Hofmann, professor of Oceanography and newly elected Fellow of the American Geophysical Union coordinates the series. All seminars are conducted on the campus of Old Dominion University in the auditorium (room 1202) of the Engineering & Computational Sciences building. A brief reception precedes and the seminar begins at 3:30 p.m. Specific topics are announced one week prior to the seminar; abstracts can be found at www.ccpo.odu.edu/seminars_Spring2014.html.

DATES SPEAKERS

January 20	No Seminar - Martin Luther King, Jr. Day
January 27	Eileen Hofmann, CCPO
February 3	Ruoying He, North Carolina State University
February 10	David Legler, NOAA Climate Program Office
February 17	Nicholas Heavens, Hampton University
February 24	No Seminar - Ocean Sciences Meeting
March 3	No Seminar - Ocean Sciences Meeting
March 10	No Seminar - ODU Spring Break
March 17	Cindy Palinkas, Horn Point
March 24	Sarah Glaser, University of Denver
March 31	Jennifer Graham, CCPO
April 7	David Gwyther, University of Tasmania

<http://www.ccpo.odu.edu>

CCPO Website:

Email: mia@ccpo.odu.edu
Phone: (757) 683-4945

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CCPO CIRCULATION
THE CENTER FOR COASTAL PHYSICAL OCEANOGRAPHY
Old Dominion University
Norfolk, VA 23529 USA
6C0N05

