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Analysis of Time Series Data from the Chesapeake Bay Mouth Cruises

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Research Scientist

The Chesapeake Bay is the largest estuary in the United States. The Bay's watershed is 166,534 km² (64,299 mi²), covering six states and the District of Columbia. On average, 76 km³ (2,500 m³/s) of fresh water enters the Bay each year. To better understand the many important processes that affect the Bay's health, the Center for Coastal Physical Oceanography (CCPO) at Old Dominion University (ODU) in Norfolk, Virginia, initiated monthly cruises across the Bay mouth. As climate and human impacts change, we must understand what is happening, and these cruises are one way to detect those changes. The Bay mouth is 25 km wide and features three main channels: the Beach channel located to the north; the Chesapeake channel; and the Thimble Shoal channel to the south. These channels allow the two-way exchange of fresh water and salt water between the bay and the coastal ocean.

We have been monitoring the mouth of the Chesapeake Bay since

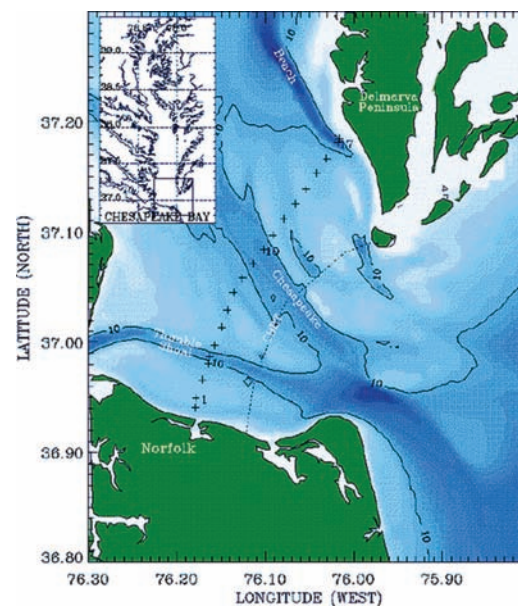


Figure 1. View of the Chesapeake Bay mouth showing the 20 Bay mouth stations, the CBBT and the three channels: the Beach channel located to the north; the Chesapeake channel; and the Thimble Shoal channel to the south.

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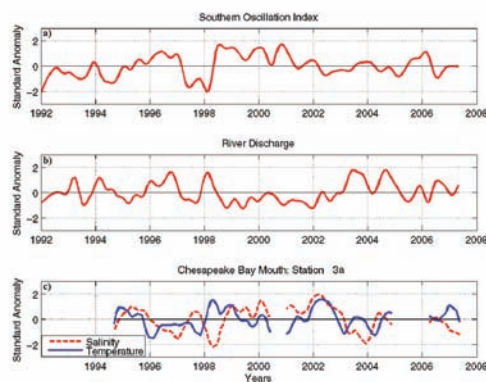
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April 1992. Cruises have been scheduled approximately every month during the high slack tide during the monthly spring tide. There have been 149 cruises completed since July 2007. A few months have occurred when a cruise was either unable to take place due to unsuitable weather conditions or were not available.

The maiden voyage of the first Chesapeake Bay mouth cruise was aboard the Research Vessel *Linwood Holton*. Owned by Old Dominion University for 30 years, the *R/V Holton* participated in the monthly Bay mouth cruises until 2002. In September 2002, the university announced that a new ship that would be taking the *Holton's* place, the *R/V Fay Slover*. A boat that wouldn't have been presumed to be able to accomplish the great task of the massive *R/V Holton* or the grand *R/V Slover* (55 ft length overall, 2x700 hp), the *ODU2* (23 ft length overall, 150 hp), achieved the impossible by also taking part in the monthly cruises during 2002.

During each cruise, hydrographic profiles are obtained at twenty stations that are laid out on a line approximately

Figure 2. Standard anomalies of the a) Southern Oscillation Index, b) river discharge, and c) water temperature and salinity at 1 m depth on station 3a.



parallel to the Chesapeake Bay Bridge-Tunnel (CBBT) (Fig. 1). The stations start at the southern part of the Bay mouth near Norfolk, Virginia, and the section continues northward toward Cape Charles Virginia. At each station, either the Sea-Bird Electronics (SBE) 25 CTD (conductivity, temperature, and depth) or SBE 19 Profiler CTD was used to collect temperature ($^{\circ}\text{C}$) and salinity (psu) with depth (m). The raw CTD data was corrected and averaged at one-meter intervals using the SBE Data Processing software. Using Matlab, a database within a structured file was created. Monthly mean and anomalies for each cruise were calculated.

For the Bay mouth stations, the anomaly was calculated for each one-meter depth interval. In Figure 2c, only the data at the first meter level was used. To help explain the variations in the Bay mouth anomalies, monthly mean time series of the Southern Oscillation Index (Fig. 2a) and the daily river discharge for the Susquehanna, Potomac and James Rivers that represents a total of 77% of the fresh water entering the Bay (Fig. 2b) for a similar period were employed. In order

to compare each of these data sets and those of the stations, standard anomalies were determined and run through a three-month, bi-directional Butterworth low-pass filter (Fig. 2).

The Chesapeake Bay mouth circulation patterns are influenced interannually by the amount of river discharge that is affected by the El Niño-Southern Oscillation (ENSO). During an observed El Niño year in 1997-1998, (negative Southern Oscillation Index) (Fig. 2a), temperatures in the Bay rose while there was a decrease in the river discharge that began in 1998 and lasted until 2002 (Fig. 2b). During this dry period (Fig. 3), the salinity in the Bay was higher than normal (Fig. 2c, 3a). In 2003 and 2004 there occurred a wet period with relatively large amounts of river discharge entering the

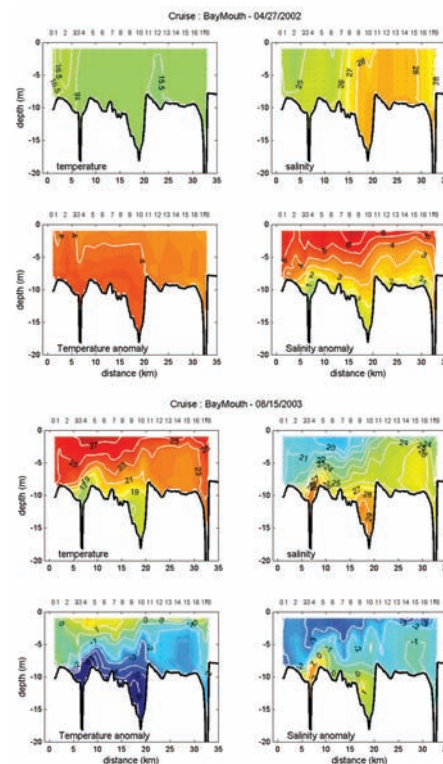


Figure 3. Temperature and salinity profile and their anomalies a) during the 2002 dry period, both anomalies high due to the lack of fresh water. The well mixed Bay is noticeable in the temperatures ranging from 15.5-16.5 $^{\circ}\text{C}$ and salinities ranging from 25-28. b) During the 2003 wet period, the salinity anomaly is negative due to the large amount of fresh water entering the Bay. Inflow of the relatively cold, salty ocean water appears in the channels while outflow is dominated over the rest of the mouth.

Bay (Fig. 2b). In comparison to the low discharge period, the hydrography during the high discharge is accompanied by decreases in both temperature and salinity (Fig. 2c, 3b.)

By analyzing the Chesapeake Bay Mouth data, the changes in the inflow, outflow, heating, cooling and the salinity variations can be studied to understand interannual changes within the Bay. An El Niño event is known to cause the water temperature to increase, a reduction in fresh water discharged into the Bay, and increased salinity concentrations. These observations may lead to a better understanding of future changes in the Bay with climate change.

For more information about CCPO's Chesapeake Bay Mouth cruises, please visit <http://www.ccpo.edu/~jlblanco/bmc>.



Samantha Sackett is originally from Manassas, Virginia in the D.C. metro area. After being accepted at ODU in 2003, she enrolled as a physical oceanography undergrad and plans to complete her bachelor's degree in December of this year.

When Samantha completed the senior level field studies class headed by Dr. Richard Zimmerman and Dr. Greg Cutter, she discovered a fascination for the field of research. Working with a team of other scientists, she learned how to complete a professional research project which began with the data collection and was completed with a paper and a formal presentation.

After participating on numerous Chesapeake Bay mouth cruises, which are open to both grad and undergrad students, Samantha jumped at the opportunity to work with the data that had been collected over more than 15 years. Funded by NODC, the project organized the years of data which had been gathered by the University.

Working at CCPO under Dr. Thomas Royer and Dr. Larry Atkinson, with the aid of Dr. Jose Blanco, Samantha learned about time series and some of the secrets of Matlab. Working in the friendly, laid-back environment of CCPO helped Samantha feel right at home.

Samantha loves to spend time with her family in Northern Virginia, volunteering at the SPCA, hiking in the mountains and going to the ocean that she enjoys studying so much.

“The ODU research cruise to the mouth of the Chesapeake Bay was a wonderful experience. The weather was perfect, and Dr. Blanco and the crew were friendly and knowledgeable about the vessel and equipment onboard. Participants were allowed to perform a CTD cast, which gave us a first hand look at the process behind how data is collected. Prior to the cruise I had considered a graduate degree at ODU in Oceanography. The cruise helped to confirm that decision.”

Keisha Wilkins, Research Associate
Center of Excellence in Remote Sensing Education and Research (CERSER)
Elizabeth City State University (ECSU)

(ECSU) student Travis Smith, ECSU/CERSER research associate Keisha Wilkinson the deck of the *R/V Fay Slover* with the CTD.



Notes from the Director



Change brings a sense of loss-of the past and the familiar-along with a sense of excitement-of the new and the unknown. After 16 years in Crittenton Hall, we have moved to a new building.

Crittenton Hall has been sold to local developers. Its fate is to be demolished to make room for several waterside condominiums. All who have visited or worked at CCPO know what a wonderful site it is.

The plans for moving were underway for more than a year. We waited to move until after the semester was over to avoid disrupting classes and exams.

A building dedicated to research has been built in the University Village area, just off the main campus. We occupy the third floor of the building, giving us a slight expansion in space along with some change in the character of the space we inhabit.

John M. Klinck

Boy Scout Oceanography Merit Badge Program

The Boy Scout Oceanography merit badge program in May had participants from Troop 1154 from Ashburn, VA; Troop 207 from Portsmouth, VA; and Troop 703 from Chesapeake, VA. The Oceanography merit badge program was coordinated through CCPO by Program Specialist **JULIE MORGAN** and Troop leaders Mike Tydings, Michael Prever, and D.J. Pauley, respectively. The program began with a presentation by CCPO Professor **EILEEN HOFMANN** that covered the academic portions of the Oceanography merit badge requirements. Video and pictures taken by CCPO scientists during Antarctic oceanographic cruises provided examples of how the academic ideas are implemented. One change made to the program was moving the classroom presentation to the National Oceanic and Atmospheric Administration (NOAA) Marine Operations Center, Atlantic, which is the facility in Norfolk where the Old Dominion University research vessel, the *R/V Fay Slover*, is docked. The use of the facility was made possible by Commander Philip Gruccio of NOAA. The ability to have the classroom and ship-based portions of the merit badge program at the same location greatly improved the logistics side of the merit badge program.

Following the classroom presentation, the scouts boarded the *R/V Fay Slover* for the ship-based part of the merit badge program. Marine technicians **PATRICK CURRY** and **LAURA GIBSON** met the scouts at the dock and welcomed them aboard the *R/V Slover*. After a safety briefing, the *R/V Slover* departed for a short trip on the Elizabeth River and around the Norfolk

harbor. **Captain RICHARD COX** answered questions and explained ship operations to the Scouts.

The scouts were divided into two groups for the field activities. One group deployed a CTD/Rosette system and collected water samples using the A-frame on the stern of the ship. The other group worked from the bow of the ship and deployed a Secchi disk to measure water clarity. The salinity profiles



Boy Scouts watch as Marine Technician Curtis Barnes monitors the CTD.

from the CTD casts showed low salinity (essentially freshwater) throughout the water column. The low salinity conditions likely resulted from the extended period of spring rains. The scouts also deployed a plankton net tow and a bottom mud grab. The net tow sample contained few copepods, no ctenophores, and very little phytoplankton. The limited plankton community may also have resulted from the low salinity conditions and the cool conditions of the previous weeks. However, there were enough copepods

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to give an idea of what they look like. The bottom mud sample yielded a few worm tubes. The scouts were very engaged in all aspects of the classroom and field activities.

Information on the Boy Scout merit badge program and descriptions of previous field trips are available on the CCPO



Boy Scouts deploy a Secchi disk from the R/V Fay Slover to measure visual water clarity.

Outreach web site (<http://www.ccpo.odu.edu/Outreach.html>). The program is popular as indicated by a long waiting list for upcoming programs.

Oceanography Day at Christ The King School

Christ The King (CTK) School in Norfolk, VA has made a commitment to developing a broad-based science curriculum. As part of the science education effort, marine science has been incorporated into science instruction for students in kindergarten, elementary grades, and middle school grades. As a supplement to classroom activities that are focused on marine science, an Oceanography Day program was held at CTK School on May 18,



Laura Gibson welcomes first graders to tour Humphrey the whale.

2007, which was attended by students, faculty, and parents.

The Oceanography Day program started with exhibits prepared by students in each grade that ranged from marine mammal dioramas, to computer-based studies of marine systems, to

research projects focused on the effects of marine debris and pollution. Exhibits for Oceanography Day that gave hands-on experience with oceanographic sampling equipment, a Chesapeake Bay simulation model, plankton samples, and sand grain size sorting were provided by CCPO. Additional exhibits and activities were provided by Amanda Wells, who is a public programs coordinator at the Norfolk Botanical Garden.

A popular activity was the Chesapeake Bay simulation model which was demonstrated by CCPO research scientist **MIKE DINNIMAN**. Figuring out how to adjust the winds and tides so that Norfolk is flooded was a fun application of the model for the students. CCPO Professor and Director **JOHN KLINCK** helped students measure grain size and **EILEEN HOFMANN** (CCPO Professor) oversaw viewing plankton under a microscope. **JULIE MORGAN** (CCPO program specialist) provided information on oceanography education and on some of the environmental issues of importance to marine systems. She also handed out key chains, pens and other items to students, which was very popular.



Mike Dinniman helps a middle school student use an interactive computer model to explore the physics of the Chesapeake Bay.

The focus of the CTK Oceanography Day was cetaceans. As part of this focus, the inflatable whale, “Humphrey the Humpback”, from the Department of Ocean, Earth and Atmospheric Sciences (OEAS) at Old Dominion University, was set up in the school parking lot. Humphrey is 55 feet long and is large enough for the children to walk through, which was a big adventure for the younger children. Humphrey was accompanied by OEAS graduate student, Amy Hansen, and research vessel mate, Laura Gibson. The highlight of the CTK Oceanography Day was the presentation to the assembled students and faculty by Dr. Steve Reilly from the NOAA Southwest Fisheries Science Center in La Jolla, CA. Dr. Reilly gave a presentation that highlighted the ecology and biology of whales and dolphins. Dr. Reilly’s talk was entertaining and informative and included recordings of whale sounds for many of the whales he described. The extended question and answer period following Dr. Reilly’s presentation indicated that the students had listened to the talk and were interested in studies of marine mammals.

The study of marine science and Oceanography Day are now an integral part of CTK school activities. The students and faculty are already looking forward to the program in May 2008.

Meeting and Workshop Report

American Meteorological Society Education Program Leaders meet at CCPO

Each year the leaders of the education program of the American Meteorological Society (AMS) meet during the week of July 4th to visit undergraduate campuses around the country and to compare notes on techniques to increase scientific literacy. Expanded information on the education program at AMS is available at their web site (www.ametsoc.org/amsedu/).

The meeting this year was hosted by CCPO at our new Innovation Research Park location. There were about 60 participants. They stayed at the Virginia House dorm at ODU and participated in several excursions to marine attractions in the local area (Virginia Aquarium, Nauticus, and USS Wisconsin). The group discussed the AMS Education program as well as new approaches to teach climate science. Several members of CCPO made presentations to the group on research being done at CCPO. **JOHN KLINCK** presented an overview of research at CCPO and discussed the ongoing Antarctic research projects. **LARRY ATKINSON** described oceanography of the Chesapeake Bay and the adjacent coastal waters. **ELIZABETH SMITH** discussed the current activity of the Chesapeake Bay Observing System.

Workshop on Modeling Shellfish Genetics

Survival and recruitment of marine bivalve larvae represent the interplay of physical and biological processes. While physical forces have received much attention, the roles that endogenous genetic and physiological processes within individuals play in recruitment variability have received almost no attention. Understanding genetic and physiological controls on the variability of growth and survival of larvae of the Pacific oyster (*Crassostrea gigas*) is the focus of a study being done by CCPO scientists **JOHN KLINCK** and **EILEEN HOFMANN** in collaboration with Dennis Hedgecock and Donal Manahan from the University of Southern California (USC) and Eric Powell from the Rutgers University Haskin Shellfish Research Laboratory. This project, funded by the National Science Foundation Biocomplexity Genetics in the Environment (GenEn) initiative, brings together investigators in the areas of genetics, physiology, population dynamics, mathematical modeling, and bioinformatics to undertake: 1) genomic and experimental studies of variation in survival and growth of *C. gigas* larvae; 2) functional analyses of candidate genes identified by a genomic analysis of *C. gigas* larvae; and 3) individual-based simulation

models of oyster larval dispersal and recruitment that are based on results from the experimental components of this project.

The component of this study being done at CCPO is focused on development of a genetics model that can be coupled to a traditional model of the growth and development of *C. gigas* larvae. The coupling between the genetics and larval growth models allows mapping of physiological function to specific genotypes. Explicit inclusion of genetic structure allows a mechanistic understanding of variability in larval growth, survival, and recruitment. A framework for the genetics model was developed during the first year of this project, which provided the basis for a workshop that was held at CCPO from May 29 to June 2, 2006. At this workshop, the model was tested through simulations that were compared to existing data sets and results from some of the experimental work being done by Dennis Hedgecock and USC graduate student Louis Plough. One objective of the workshop was to familiar-



Louis Plough, Dennis Hedgecock, and Eric Powell compare simulation of the genetics model during the recent workshop.

ize the USC group with the model code so that it can be used in a more “real time” mode with the experimental studies. By the end of the workshop, the genetics model was well on its way to acceptance and was yielding results that provide insight into the disappearance of specific alleles, changes in population heterozygosity, and the accumulation of recessive genes in the population. The focus of the modeling component of the project is now on coupling the genetics and *C. gigas* larval growth models.

As part of this project, a special session entitled, “Recruitment of Marine Larvae: Experimental and Modeling Studies,” was convened at the ASLO meeting that was held in Santa Fe, NM from February 5-9, 2007. The intent of this session was to bring together scientists from diverse disciplines in the fields of experimental biology and oceanographic modeling to provide a synthesis and exchange of information on approaches required for the study of the complex problem of recruitment in the marine environment. The work done to date in this project clearly shows that interdisciplinary studies are needed to advance understanding of recruitment in marine systems.

Publications

Ebbesmeyer, C.C., W.J. Ingraham, **T.C. Royer** and **C.E. Grosch**, "Tub Toys Orbit the Pacific Subarctic Gyre," *EOS, Trans. American Geophysical Union*, **88**(1), 2007.

Friedrichs, M.A.M., J. A. Dusenberry, L. A. Anderson, R. A. Armstrong, F. Chai, J. R. Christian, S. C. Doney, J. Dunne, M. Fujii, R. Hood, D. J. McGillicuddy Jr., J. K. Moore, M. Schartau, Y. H. Spitz and **J. D. Wiggert**, "Assessment of skill and portability in regional marine biogeochemical models: Role of multiple planktonic groups," *J Geophys. Res.*, **112**, C08001, doi:10.1029/2006JC003852, 2007.

Oey, L.-Y., **T. Ezer**, D.-P. Wang X.-Q. Yin and S.-J. Fan, "Hurricane-induced motions and interaction with ocean currents," *Cont. Shelf Res.*, **27**, 1249-1263, 2007.

Oey, L.-Y., **T. Ezer**, C. Hu and F. Muller-Karger, "Modeling and satellite observations of baroclinic tidal flows and inundation processes in Cook Inlet, Alaska," *Ocean Dynamics*, **57**, 205-221, 2007.

Powell, E.N. and **J.M. Klinck**, "Is oyster shell a sustainable estuarine resource?" *J. Shell. Res.*, **26**, 181-194, 2007.

Tejada-Martinez, A.E. and **C.E. Grosch**, "Langmuir turbulence in shallow water. Part 2. Large-eddy simulation," *J. Fluid Mechanics*, **576**, 63-108, 2007.

Presentations

Chapman, E.W., **E.E. Hofmann** and William R. Fraser, "Climate variability, Antarctic krill (*Euphausia superba*) spawning, and Adélie penguin (*Pygoscelis adeliae*) chick growth," oral presentation, 4th International Zooplankton Production Symposium, Hiroshima, Japan, May 28-June 1, 2007.

Druon, J.N., A. Mannino, **M.A.M. Friedrichs** and C. McClain, "Modeling the role of the semi-labile DOC in the export of carbon from the eastern U.S. continental shelf to the open ocean," oral presentation, American Society of Limnology and Oceanography Aquatic Sciences Meeting, Santa Fe, NM, February 4-9, 2007.

Friedrichs, M.A.M., **E.E. Hofmann** and the U.S. ECoS Team, "U.S. Eastern continental shelf carbon budget: modeling, data assimilation and analysis," oral presentation, American Society of Limnology and Oceanography Aquatic Sciences Meeting, Santa Fe, NM, February 4-9, 2007.

Friedrichs, M.A.M., M.-E. Carr, R. Barber, M. Scardi, and the PPARR Team, "Assessing model-derived productivity estimates for the tropical Pacific Ocean," oral presentation, Second Workshop on Skill Assessment for Coupled Biological/Physical Models of Marine Systems, Chapel Hill, NC, March, 2007.

Friedrichs, M.A.M., **E.E. Hofmann**, C. McClain and the U.S. ECoS Team, "U.S. Eastern continental shelf carbon cycling," oral presentation, NASA Ocean Color Research Team Meeting, Myrtle Beach, SC, April 11-13, 2007.

Friedrichs, M.A.M. "Assessing the costs and benefits of increasing ecosystem model complexity using data assimilation," oral presentation, Gordon Research Conference on Coastal Ocean Modeling, New London, NH, June 17-22, 2007.

Friedrichs, M.A.M. and the RTB team, "Assessment of skill and portability in regional marine biogeochemical models: the role of multiple planktonic groups,"

oral presentation, Ocean Carbon and Biogeochemistry Summer Workshop, July 2007.

Gatski, T.B., "A Temporal Large Eddy Simulation Approach for Turbulent Flows," oral presentation, Lehrstuhl fur Aerodynamik, TU, Munich, Germany, May 15, 2007.

Hofmann, E.E., E.N. Powell, J.N. Kraeuter, **J.M. Klinck** and V.M. Bricelj, "Can hard clam larval survivorship explain recruitment failure in Great South Bay: A modeling study," poster presentation, 4th International Zooplankton Production Symposium, Hiroshima, Japan, May 28-June 1, 2007.

Kamel, M., **Y.S. Husrevoglu**, **M. Dinniman**, **J.M. Klinck**, "Small-scale winds, polynyas and ocean properties in the Ross Sea," poster presentation, 2nd Antarctic Meteorological Observation, Modeling and Forecasting Workshop, Rome, Italy, June 26-28, 2007.

Klinck, J.M., **E.E. Hofmann** and E.N. Powell, "A model of the growth and development of *Crassostrea virginica* larvae," poster presentation, 4th International Zooplankton Production Symposium, Hiroshima, Japan, May 28-June 1, 2007.

Klinck, J.M. and **M. Dinniman**, "The importance of high spatial resolution for models of the Antarctic Coastal Circulation," oral presentation, 2nd Antarctic Meteorological Observation, Modeling and Forecasting Workshop, Rome, Italy, June 26-28, 2007.

Klinck, J.M., **Y.S. Husrevoglu** and **M. Dinniman**, "The influence of sea-ice and the Ross Ice Shelf on water properties," poster presentation, Fourteenth Annual WAIS Workshop, Sterling, VA, September 5-8, 2007.

Powell, E.N., **E.E. Hofmann**, **J.M. Klinck** and D. Hedgecock, "A coupled genetics-growth model for *Crassostrea gigas* larvae," oral presentation, 4th International Zooplankton Production Symposium, Hiroshima, Japan, May 28-June 1, 2007.

Qiu, Jifeng, Shinnosuke Obi and **T. B. Gatski**, "Evaluation of Diffusion/Transport Constraints for ARSM in Calculation of Fully Developed Rotating Channel Flow," oral presentation, 5th International Symposium on Turbulence and Shear Flow Phenomena, Munich, Germany, August 27-29, 2007.

Saba, V. S., **M.A.M. Friedrichs** and M.-E. Carr, "Update on the Fourth Primary Productivity Algorithm Round Robin (PPARR4)," oral presentation, Ocean Carbon and Biogeochemistry Summer Workshop, July 2007.

Smith, E., "Chesapeake Bay Observing System and Chesapeake Inundation Prediction System," oral presentation, Association of State Floodplain Managers Annual Meeting, Yorktown, VA, June 6, 2007.

Smith, E., "Chesapeake Bay Observing System Pilot Projects and Partnerships," oral presentation, Teacher Professional Development Institute and Student Water Quality Monitoring Project, Gloucester Point, VA, June 26-28, 2007.

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Smith, E., "An Overview of the Chesapeake Bay Observing System and Chesapeake Bay Interpretive Buoy System," oral presentation, American Meteorological Society DataStreme Atmosphere Precollege Teacher Enhancement and Leadership Training Institute, Norfolk, VA, July 2, 2007.

Tian, T., E.E. Hofmann, M.A.M. Friedrichs and J. O'Reilly, "Analyses of physical-biological interactions in the U.S. eastern continental shelf waters based on simulation model results," poster presentation, Old Dominion University Research Exposition, Norfolk, VA, April 5, 2007.

Wiggert, J.D., E.E. Hofmann and G.-A. Paffenhofer, "The effect of sampling preference and environmental conditions on the foraging success of oligotrophic copepod populations: A modeling study," poster presentation, 4th International Zooplankton Production Symposium, Hiroshima, Japan, May 28-June 1, 2007.

Graduations

Bin Zhang successfully defended his Ph.D. dissertation on April 26, 2007.

Title: Frontal variability in Drake Passage -- A modeling study

Advisor: J. Klinck

Members: A. Valle-Levinson, C. Grosch, T. Royer, J. Adam, S. Gille

Awards

Erik Chapman won first place in the Graduate Student Poster Competition at Old Dominion University's Research Expo on April 5, 2007 for his poster, "Modeling the influence of environmental variability on Antarctic Krill (*Euphausia superba*) lipid content and Adélie penguin (*Pygoscelis adeliae*) chick growth.

Fall 2007 CCPO Seminar Series

During the academic year, CCPO invites several distinguished scientists to present seminars on topics related to coastal oceanography. The lectures take place in Room 3200, Research Building 1 in Old Dominion University's University Village at 3:30 pm. on Mondays. Eileen Hofmann, professor of oceanography, coordinates the lecture series with the assistance of Gabriel Franke. Below is a schedule of lectures for the fall semester 2007. For more information or to be included on the mailing list for lecture announcements, please e-mail franke@ccpo.odu.edu or call (757) 683-5548. Specific lecture topics are announced one week prior to each lecture. Titles and abstracts of the seminars can be found at www.ccpo.odu.edu.

10 September
SIDNEY LEVITUS
NOAA/Ocean Climate Laboratory

22 October
KENNEDY PAYNTER
University of Maryland Center for Environmental Science

17 September
MONICA BRICELJ
Institute for Marine Biosciences, NRC, Canada

29 October
PATRICK NEALE
Smithsonian Environmental Research Center

24 September
JOSE-LUIS BLANCO
CCPO

5 November
BRIAN WARD
CCPO

1 October
ELIZABETH SMITH
CCPO

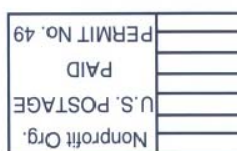
12 November
BRUCE CORLISS
Duke University

15 October
TAL EZER
CCPO

19 November
JAY PICKNEY
University of South Carolina

26 November
JULI HARDING
Virginia Institute of Marine Sciences

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