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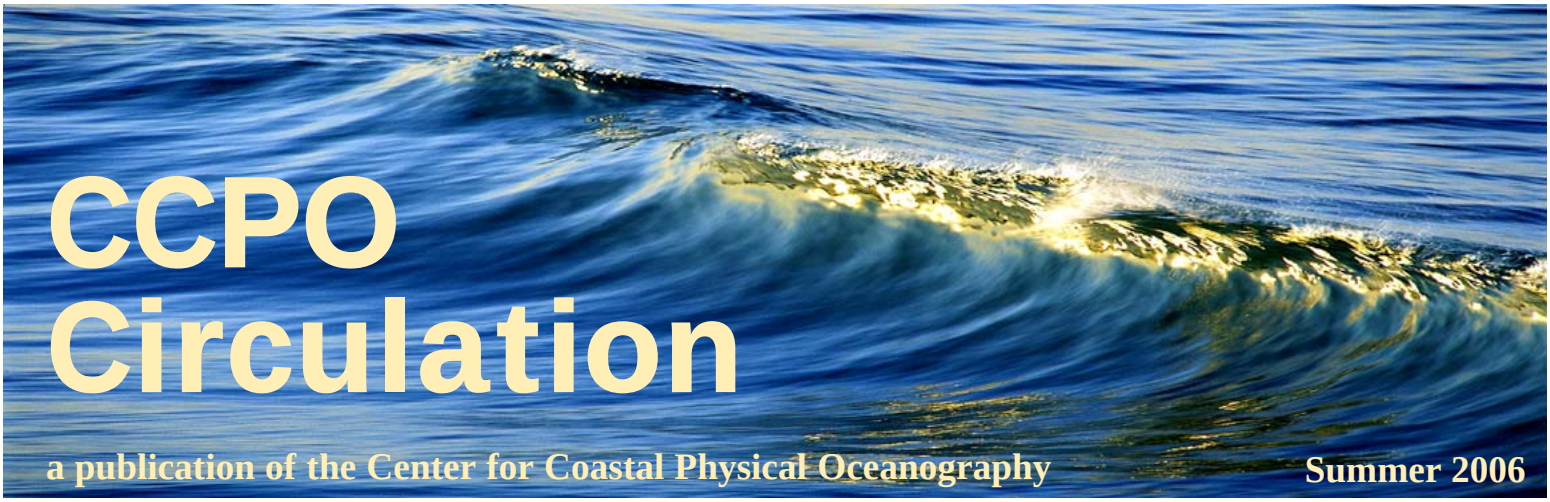
Center for Coastal Physical Oceanography, Old Dominion University

Michael Ott
Old Dominion University



CCPO Circulation

a publication of the Center for Coastal Physical Oceanography

Summer 2006

Vol. 13 No. 2

In this issue:

Chesapeake Bay Mouth Monitoring Program

by Dr. Michael Ott
Postdoctoral Research Scientist

The Chesapeake Bay, with a watershed covering an area of approximately 164,000 square kilometers, is the largest estuary in the United States and drains portions of six states. The mouth of the Chesapeake is now one of two connections between the Bay and the coastal waters of the adjacent continental shelf. The other, the Chesapeake and Delaware Canal, is 22 km long, 150 m wide, and 10 m deep, and connects the head of the Chesapeake Bay in the north with the Delaware River estuary. When it was built in 1829, there was a small but noticeable effect on the salinity in the northern reaches of the Chesapeake Bay.

Nevertheless, the mouth of the Chesapeake is the main link between the Bay and the open ocean. Freshwater draining into the Chesapeake, carrying with it nutrient and pollutant runoff, exits the bay in the surface layer at the mouth in the

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In April 1992, the Center for Coastal Physical Oceanography began a Chesapeake Bay monitoring program with the aim of determining monthly and interannual variability of temperature, salinity, and stratification. Profiles of temperature, salinity, beam transmission, oxygen, fluorescence, and photosynthetically-available-radiation (PAR) are made at 18 stations across the mouth, at spring high tide, nominally once a month using a standard SeaBird conductivity-temperature-depth (CTD) profiler. In addition, water samples are collected using the CTD rosette pictured above.

familiar estuarine exchange flow. In the lower layer, especially in the channels, the return flow of oceanic water maintains the long-term salt balance in the Chesapeake. The mouth itself is 25 km wide, with shoals about 8 m deep. Two channels deeper than 10 m provide deep communication with the ocean: Thimble Shoal Channel (16 m) and Chesapeake Channel (25 m). The average river discharge into the Chesapeake Bay is about 2500 m^3/s, with a July-October minimum of approximately 1000 m^3/s and a March-April peak of about 5000 m^3/s, although averages for individual spring months have reached twice that.

The Center for Coastal Physical Oceanography began a monitoring program in April 1992 with the aim of determining monthly and interannual variability of temperature, salinity, and stratification. Funding is provided by the Ocean, Earth and Atmospheric Sciences (OEAS) Department at Old Dominion University. Profiles of temperature, salinity, beam transmission,

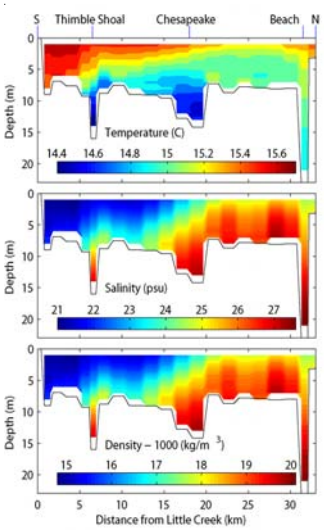

Figure 1. *Annual mean in temperature (upper panel), salinity (middle panel), and density (lower panel) between April 1992 and January 2005. The three channels are labeled on top, as are the South and North ends of the transect.*

oxygen, fluorescence, and photosynthetically-available-radiation (PAR) are made at 18 stations across the mouth at spring high tide, nominally once a month, using a standard SeaBird conductivity-temperature-depth (CTD) profiler. In addition, water samples are collected by a number of scientists using the CTD rosette. Colleagues at the National Aeronautics and Space Administration (NASA) analyze the water to measure chlorophyll in order to ground-truth satellite data. Several graduate students in the OEAS Department at Old Dominion University also collect water samples in support of their research.

OEAS graduate students, Frank Thomson and Stefan Heinemann, in Dr. Fred Dobbs' research group, perform monthly surveys for *Vibrio cholerae* (the bacterium that causes human cholera) along the Chesapeake Bay mouth. They collect one-liter water samples at the surface and near-bottom at four stations which span the Bay mouth and represent important topographic features such as deep-water channels. The water is collected from the rosette and stored in a cooler, in the dark, until it is processed upon return to the lab. There, the bacteria are cultured, counted, subjected to biochemical and molecular analyses, tested for resistance to antibiotics, and the *V. cholerae* isolates are archived. These results are compared to data, including nutrient and pigment concentrations, collected from other labs that sample at these same locations. In addition to obtaining data for graduate student dissertations and theses, the aim is to obtain preliminary data on *V. cholerae* dynamics within the lower Bay for use in future proposals.

Since March 2003, Katherine Filippino and Dr. Margaret Mulholland's research group have also collected surface and near-bottom water samples at the same four stations and perform preliminary processing, such as filtering, at sea. Analytical work in the lab determines the concentrations of many pigments and nutrients found in the water, including nitrate, nitrite, phosphate, silicate, ammonia, urea, total dissolved nitrogen and phosphorous, particulate nitrogen and phosphorous, dissolved free amino acids, chlorophyll "a" and dissolved inorganic carbon. The aim is to understand the nutrient and carbon cycles which are so important to biological productivity within the Chesapeake Bay. The ultimate

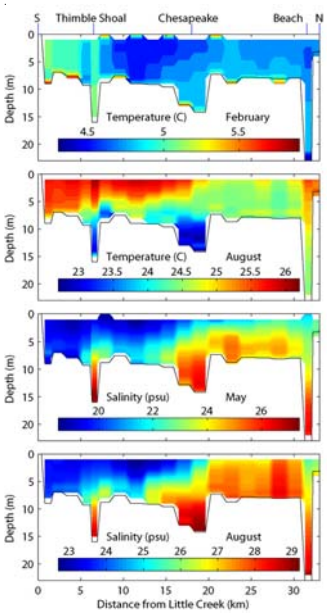

Figure 2. *Monthly means in temperature for February (first panel) and August (second panel), and in salinity for May (third panel) and August (fourth panel). Note the difference in scales between the months, particularly in temperature.*

goal, utilizing current data obtained from the onboard acoustic Doppler current profiler (ADCP), is to constrain the flux rates of nutrients and carbon at the mouth of the Bay, although obtaining these measurements may necessitate changes in the Chesapeake Bay Mouth Monitoring Program.

The temperature and salinity records from the CTD profiler are processed using SeaBird software: outlying data points are removed; any loops in the pressure due to waves and swell are removed; the temperature and salinity records are adjusted to account for the difference in response time of the instruments; and the results are smoothed. These processed values, which are available on the Chesapeake Bay Monitoring Program Internet site, are also averaged into 1-meter bins providing a more robust picture of the hydrography. Although there are noticeable interannual variations in temperature and salinity, and thus density, at the mouth of the Chesapeake, with 155 cruises since the monitoring program started in April 1992, it is possible to understand the basic annual cycle by averaging the binned data.

First, the monthly climatology is obtained, ignoring depths for which less than six realizations exist. These 12 results

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are then themselves averaged to obtain the annual mean (Figure 1). The mean temperature (upper panel) depicts warmer water at the surface due to solar insolation. Larger temperatures are also seen at the southern side of the mouth, consistent with the Coriolis effect: warmer surface water from river runoff is pulled to the right as it flows down the estuary, and cooler oceanic water returns in the deeper channels and to the northern side of the mouth. This is more clearly seen in the salinity (middle panel): fresher water on the south side and more saline on the north. It can clearly be seen that the density (lower panel) is controlled by the salinity, and not by the temperature.

Returning to the monthly means (Figure 2), the lowest temperatures are seen in February (upper panel), when solar insolation is low. During the winter months (December to March), there is also very little vertical variation in the temperature, consistent with a well-mixed condition. The highest temperatures at all depths are seen in August (second panel), and throughout

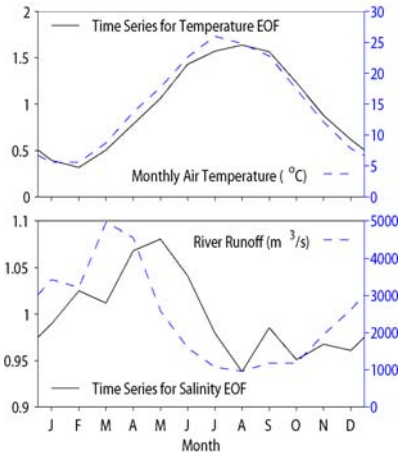


Figure 3. *Comparison of the mean annual cycles between the environmental forcing (dashed lines) and subsequent hydrographic response (solid lines), as represented by the time series corresponding to the first EOF pattern for temperature (upper panel) and salinity (lower panel).*

the summer months (July to September) there is a strong temperature gradient with depth. Salinity is lowest across the mouth in May (third panel), a month after the peak river discharge into the Chesapeake Bay, and highest in August (bottom panel) through October, after the discharge minimum.

Empirical orthogonal functions (EOFs) can be used to show how the mean annual cycle in temperature is driven by solar insolation and that of salinity is driven by river discharge. EOF analysis is a decomposition of a data set into a set of spatial patterns and corresponding time series, with each spatial pattern being orthogonal to the preceding patterns and accounting for as much variance in the data set as possible. It is similar to harmonic analysis, except that instead of using sines and cosines, the patterns are found from the data set itself. Typically, large data sets can be reduced to only a few EOF components, which hopefully describe physical processes.

For temperature, the first EOF pattern (not shown) matches the annual mean almost precisely and accounts for more than 99% of the variance in the monthly climatologies. The time series for the temperature pattern, with a minimum in late winter and a maximum in late summer (Figure 3, upper panel), agrees very well with the annual cycle of monthly mean air temperatures recorded at the Chesapeake Bay Bridge-Tunnel. The close fit, as well as the apparent slight lag, are consistent with local forcing of the temperature field. Similarly for salinity, the first EOF pattern matches the annual mean almost precisely. The agreement between the time series for salinity and the USGS monthly average runoff into Chesapeake Bay (Figure 3, lower panel) is almost as good, with the exception of a September anomaly in the observed salinity. The lag of observed salinity with respect to river discharge suggests that it takes about one month for variations in runoff to be felt at the Bay mouth.

Additional figures and analysis can be found at the recently revamped Internet site for the Chesapeake Bay Monthly Monitoring program, which can be found under the "Research" link on the main CCPO Internet page, or directly at: *http://www.ccpo.odu.edu/~mwott/baymouth/*. In addition, the raw CTD files, the processed data in MATLAB .mat files, and text files containing the binned data are available for download.

Thanks to Frank Thomson and K.C. Filippino for their input.

Fall 2006 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 109, Crittenton Hall, Old Dominion University 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 2006. 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*.

11 September
STEVE ACKLEY
University of Texas, San Antonio

18 September
SUBRAHMANYAM BULUSU
University of South Carolina

25 September
ROBERT TULEYA
CCPO

2 October
DAVID BUSHEK
Haskin Shellfish Research Laboratory

16 October
ANDRES TEJADA-MARTINEZ
CCPO

23 October
MARGARET MULHOLLAND
OEAS, Old Dominion University

30 October
EILEEN HOFMANN
CCPO

6 November
BORIS GALPERIN
University of South Florida

13 November
MARK BRUSH
Virginia Institute of Marine Science

20 November
PETER BERG
University of Virginia

27 November
THOMAS ROYER
CCPO

Notes from the Director

We scientists spend most of our time observing, learning, analyzing, collaborating, writing, and teaching. On occasion, we present our work casually to various non-technical groups, such as elementary and high schools, various local clubs, radio and TV stations and newspapers. This activity is commonly called "outreach."

Outreach is an important activity at CCPO as illustrated by several articles in this newsletter. The annual Blue Crab Bowl allows us to challenge high school students to learn more about the marine environment. We take school groups and Boy Scouts on short oceanographic cruises, letting them do a net tow, a bottom core and a hydro-cast. It is exciting to see their reactions to what they find. Visits to elementary schools can be equally exciting, as young children still have a sense of wonder about everything in the world.

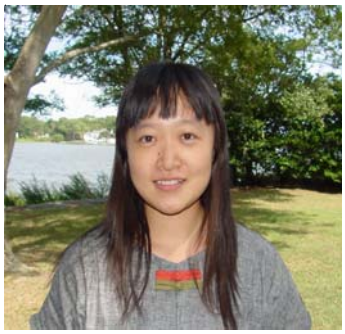
While in high school, I took a trip to Oak Ridge National Laboratory, where we visited several labs with the usual assortment of exotic and incomprehensible equipment. In one was a scientist (likely a postdoc), wearing blue jeans and a torn flannel shirt explaining, what he was doing. I don't remember his explanation, but I do remember that he was totally involved in his work. He was not the typical stiff scientist in a white lab coat that was the common image of scientists in cinema and television. I remember thinking at the time that I wanted to be a scientist, too.

Sometimes the most important, and rewarding, activity that we do as scientists is outreach. While it is difficult to know how these short exchanges will affect the path of another's life, it is fun to infect another person with our intense curiosity about the world.

John M. Klinck

CCPO People Profile

TIAN TIAN came to CCPO as a graduate student in August of 2005. She is from Qingdao, an eastern coastal city in China. She completed her bachelor's degree in oceanography at Ocean University of China and her master's degree in environmental science at the same university. During her graduate studies in China, she focused on water mass analysis and some mesoscale phenomena in the East China Sea. She also participated in two projects, "Circulation and Water Exchange in the Shelf Region of East China Sea" and "Ecosystem Dynamics and Sustainable Utilization of Living Resources in the East China Sea and the Yellow Sea." At the Second GLOBEC Open Science Meeting in Qingdao, Tian met **EILEEN HOFMANN**, who told her about the oceanography graduate program in Old Dominion University. Tian now works with Dr. Hofmann, researching physical-biological interactions which incorporate numerical modeling. Norfolk's mild and humid climate is so similar to Qingdao that Tian feels right at home. She enjoys going to museums and beaches in her spare time to enjoy the beautiful scenery.



Chesapeake Bay Governor's School–Warsaw Wins Blue Crab Bowl

Chesapeake Bay Governor's School, Warsaw Campus, captured the championship in the 2006 Blue Crab Bowl, held Feb. 11 at Old Dominion University.

The Blue Crab Bowl is the Virginia regional competition for the National Ocean Science Bowl (NOSB©). Despite winter storm warnings, nearly 70 students, from 14 high schools around the state, spent the day in heated competition. The winning team from Tappahannock won an all-expense-paid trip to the national competition to face 24 other regional champions in the 9th Annual National Ocean Sciences Bowl (NOSB®), May 13-15, in Pacific Grove, CA.

The Blue Crab Bowl is a cooperative effort between the Department of Ocean, Earth and Atmospheric Sciences and the Center for Coastal Physical Oceanography, Old Dominion University, and the Sea Grant Marine Advisory Program, Virginia Institute of Marine Science, College of William and Mary. More than 60 faculty, staff and graduate students from both institutions donated many hours of their time to ensure the success of this exciting event. ODU President, Dr. Roseann Runte, welcomed students to the contest and commended them on their hard work.

Using questions designed by marine scientists, the round-robin, double elimination contest tested students' knowledge of oceanography, geology, biology, and maritime history. During Saturday's event, the competition started with a field of 14 teams, with four emerging as top contenders by late afternoon. Winning first place, for the second year in a row, was the Chesapeake Bay Governor's School team from Tappahannock. Taking second place

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was Fauquier High School from Warrenton, Fauquier County. In third place was Broadwater Academy from Exmore, Northampton County. Fourth place went to Churchland High School in Portsmouth, a school competing for the first time this year.

Coach Kevin Goff (far right) and the winning Chesapeake Bay Governor's School team. This team includes students from three schools(from right to left): Luke Bessler, junior from Lancaster High School; Tiffany Lee, senior from Essex High School; Abby Hughes, senior from Rappahannock High School;and Jonathan Lee, junior from Essex High School.

Local sponsors of the regional Blue Crab Bowl include Virginia Sea Grant, Old Dominion University's Office of Institutional Advancement and Admissions, Old Point National Bank, Chesapeake Bay National Estuarine Research Reserve in Virginia, Virginia Aquarium and Marine Science Center, Hood College, Life Net-Virginia Beach, Hampton Inn Norfolk Naval Base, and the VIMS Marine Advisory Program

Boy Scout Oceanography Merit Badge Program

The Boy Scout oceanography merit badge program that took place on May 20 included participants from Troop 159, Herndon, VA; Troop 191, King George, VA; and Troop 901, from Chesapeake, VA. The scouts were accompanied by Scoutmasters and parent chaperones, some of whom included Mike Reeve from Troop 159 and Mark Hill from Troop 901. Local organization and logistics were handled by **JULIE MORGAN**, CCPO program specialist.

The academic portion of the Oceanography merit badge requirements was done at CCPO with a classroom presentation by CCPO professor, **EILEEN HOFMANN**. The presentation included descriptions of oceanographic sampling equipment, such as a conductivity-temperature-depth (CTD) system and Niskin

Two Boy Scouts deploy a plankton net from the stern of the R/V Fay Slover.

bottles. Pictures and video of oceanographic research undertaken by CCPO scientists in the Antarctic provided "real-world" examples of how oceanographic sampling is done.

The R/V *Fay Slover*, which is the Old Dominion University research vessel docked at the nearby National Oceanic and Atmospheric Administration facility, was used for the field trip portion of the merit badge program. Marine technician **LAURA GIBSON** met the scouts at the dock and provided a safety briefing and orientation before going onboard the ship. On the ship, the scouts met Captain **RICHARD COX** and marine technician supervisor **CHRIS POWELL**. Also CCPO professor **JOHN KLINCK** joined the scouts at the ship to provide an additional person to answer questions about oceanography. After the R/V *Slover* departed for a short trip along the Elizabeth River, Captain Cox invited small groups of the scouts to join him on the bridge to see ship operations. Julie Morgan took on the job of chronicling the trip through photographs, which are on the CCPO Outreach Web site (*http://www.ccpo.odu.edu/Outreach.html*).

Soon after leaving the dock, the scouts saw numerous ocean racing boats (i.e., cigarette boats) speed past the R/V *Slover*. The speed of these boats and the wake they produced were impressive. After a short boat ride, the scouts deployed a CTD/ Rosette system and collected water samples. Following these activities, the scouts deployed a plankton net tow and a bottom mud grab. The net tow sample contained numerous copepods and ctenophores that the scouts looked at with a microscope. Sorting through the bottom mud sample yielded lots of worm tubes (some with worms), oyster shells, shell fragments, and one hard clam. The shells provided souvenirs for some scouts.

While other scouts look on, a Boy Scout examines a hard clam from a bottom mud sample.

As of the May 2006 program, over 150 Boy Scouts have received the oceanography merit badge since the program started in 2004. The interest in the oceanography merit badge program is indicated by the number of requests that are received, which have resulted in a full schedule through September 2008.

Eighth Grade Class Trip on the R/V *Slover*

One of the field trips taken by the eighth grade class from Christ The King (CTK) School in Norfolk, VA is a short oceanographic cruise on the Old Dominion University research vessel, the R/V *Fay Slover*. The cruise, which took place on April 11, provided an opportunity for hands-on learning experiences that complement concepts that are taught in the classroom. This year, 35 CTK students participated in the field trip. The number of students resulted in two short cruises so that there would be opportunities for nearly everyone to participate in shipboard activities. CCPO scientists **JOHN KLINCK** and **ERIK CHAPMAN** provided shuttle service to and from the ship for the students.

At the ship, marine technician **LAURA GIBSON** provided a safety briefing and orientation for the students. After getting underway, Captain **RICHARD COX** and mate **PATRICK**

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CURRY showed the students aspects of ship operations. CCPO scientist **EILEEN HOFMANN** and CCPO program specialist **JULIE MORGAN** went along to answer questions and to provide assistance. The students were accompanied on both cruises by Joe Ebert, who teaches seventh and eighth grade science at CTK School.

Three students from Christ The King School prepare to deploy a CTD/ Rosette system to collect water samples from the R/V Fay Slover.

After the R/V *Slover* got underway, the students enjoyed a short trip down the Elizabeth River. After some sightseeing, the students did a CTD cast, a plankton net tow, a bottom mud grab, and then collected water samples with Niskin bottles hung on a wire. The students deployed and retrieved the equipment with the assistance and oversight of Laura Gibson and Patrick Curry. On the second cruise, marine technician supervisor **CHRIS POWELL** joined the cruise to do some trouble-shooting on the CTD system. Checking out the sample from the net tow with a microscope allowed the students to see the diversity of plankton that live in the Elizabeth River. A spring bloom was ongoing in the Elizabeth River and as a result there were numerous phytoplankton and zooplankton species collected in the net tow, as well as fish eggs. The bottom mud sample contained many worm tubes, most of which were empty.

The eighth grade class cruise on the R/V *Slover* is part of a marine sciences-oriented science module for students at CTK School. This is part of a larger effort by the faculty to incorporate marine science concepts into the overall curriculum at CTK School.

Oceanography Day at Christ The King School

Marine science-based themes are regarded by science educators as being one of the more effective and appropriate mechanisms to engage students in science because of the integrated nature of the discipline. The experiences at Christ The King (CTK) School in Norfolk, VA show that this is accurate. During academic year 2005/06, the faculty at CTK School continued to develop a curriculum that incorporates marine science into science instruction for students in kindergarten, elementary grades, and middle school grades. The curriculum follows from a pilot program that was started in academic year 2003/04 with the encouragement of Ms. Miriam Cotton, school principal, and the CTK School faculty. Following from the classroom activities, an Oceanography Day program was held at CTK School on May 19, 2006, which was attended by students, faculty, and parents.

The Oceanography Day program included exhibits by each grade that showed the projects created by students during the school year. These ranged from hats that were made to represent marine animals to marine mammal dioramas to computer-based studies of marine systems. CCPO provided 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. CCPO research scientist **MIKE DINNIMAN** demonstrated the Chesapeake Bay simulation model. The students had fun adjusting the winds and tides so that Norfolk was inundated with water. CCPO professor and director **JOHN KLINCK** helped students measure salinity with a refractometer and CCPO graduate student **SINAN HUSREVOGLU** oversaw viewing plankton under a microscope and sorting the sand samples. **EILEEN HOFMANN** (CCPO professor) and **JULIE MORGAN** (CCPO program specialist) provided information on oceanography education and on some of the environmental issues of importance to marine systems. Their exhibit also included shells and preserved marine specimens that the students could touch, as well as key chains, pens, and other items, provided by Dana Oblak of the Department of Ocean, Earth and Atmospheric Sciences, that were given to the students.

A popular exhibit was the marine mammal skulls and skins that were provided by Dr. Dan Costa from the Ecology and Evolutionary Biology Department at the University of California, Santa Cruz. Dr. Costa showed the students the differences in the marine mammal skulls and explained how some of these differences were special adaptations by the animals. The animal skins were also popular, especially the one from the polar bear.

Dr. Dan Costa explains the structure of the lower jaw of an Orca to Christ The King School students.

The highlight of the CTK Oceanography Day was the presentation to the assembled students and faculty by Dr. Costa entitled, "A Cruise to the Antarctic." The presentation provided a description of a cruise that Dr. Costa did to the west Antarctic Peninsula region as part of the U.S. Southern Ocean Global Ocean Ecosystem Dynamics Program. Dr. Costa gave an entertaining and informative account of shipboard activities and also showed the students what is involved in studying seals in the Antarctic. He showed videos of capturing a crabeater seal for scientific study, a seal feeding under the sea ice, and a seal playing with divers while they were doing under-ice sampling. The extended question and answer period following Dr. Costa's presentation indicated that the students had listened to the talk and were interested in studies of marine mammals.

Marine science concepts will continue as part of the science curriculum at CTK School in 2006-07. The study of marine systems and Oceanography Day are now regarded as an integral part of school activities.

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Tejada-Martinez, Andres E., **Chester E. Grosch**, and **Thomas B. Gatski**, "Temporal Large Eddy Simulation of Unstratified and Stably Stratified Turbulent Channel Flow," *Turbulence, Heat and Mass Transfer*, **5**, 2006.

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Tuleya, Robert, "Hurricane Model Transitions to Operations at NCEP/EMC," oral presentation, 60th Interdepartmental Hurricane Conference, Mobile, AL, March 21, 2006.

Tuleya, Robert, "Hurricane WRF Model Transitions to Operations at NCEP/EMC: Sensitivity of results to surface fluxes and convection," oral presentation, 27th Conference on Hurricanes and Tropical Meteorology, Monterey, CA, April 24-28, 2006.

Tuleya, Robert, "Global Warming and Hurricanes," Planalytics Consumer Conference, The Impact of the 2006 Hurricane Season on the Consumer, New York, NY, June 15, 2006.

Committee Meetings

Ann Gargett
ORION Sensors Subcommittee Meeting, Washington, D.C., January 30-February 1, 2006.

Regional Cabled Observatory Draft Network Design Meeting, Seattle, WA, March 1-2, 2006.

Eileen Hofmann
Appointed to National Research Council Committee on Strategic Advice on the U.S. Climate Change Science Program, July 26-27, 2006.

Larry Atkinson
ICES Study Group for Management of Integrated Data, Copenhagen, Denmark, January 30-February 1, 2006.

Awards and Special Mentions

CHRIS POWELL, Marine Technician Supervisor, acted as an engineering judge for the Mid-Atlantic Regional remotely operated vehicle (ROV) competition on April 8 at Old Dominion University. The remotely operated vehicle competitions organized by the Marine Advanced Technology Education) Center and the Marine Technology Society's ROV Committee challenge teams across the U.S. and Canada with designing and building vehicles to accomplish tasks based on science, exploration, and industry missions taking place in the real world.

For the past three years, CCPO has provided exhibits for Christ The King School's Oceanography Day, which give hands-on experience with oceanographic sampling equipment, a Chesapeake Bay simulation model, plankton samples, and sand grain size sorting. Sinan Husrevoglu, CCPO doctoral candidate, assists a student placing a sample of Lafayette River water on the microscope stage. The magnified image from the microscope which contained motile fish larvae and zooplankton (mainly copepods) was then displayed on the laptop screen.

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Editor.....Gabriel Franke
Technical Editor....Julie R. Morgan

Old Dominion University
Changing Lives for 75 Years

6CN05
The Center for Coastal Physical Oceanography
Old Dominion University
Crittenton Hall
786 W. 52nd Street
Norfolk, VA 23529
USA

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