Summer 2007

Circulation, Vol. 14, No. 1

Center for Coastal Physical Oceanography, Old Dominion University

Brian Ward
Old Dominion University

CCPO Circulation

a publication of the Center for Coastal Physical Oceanography

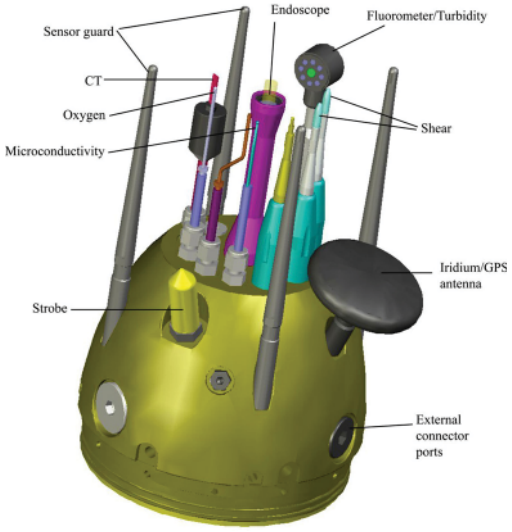
Summer 2007

Vol. 14 No. 1

In this issue:

Air–Sea Measurements in the Indian Ocean

by Dr. Brian Ward
Assistant Professor



The western Pacific and Indian oceans are home to the world's largest pool of warm water (in excess of 28-C). It is also home to the largest region of atmospheric deep convection which plays a key role in the global atmospheric circulation, being the area where air rises within Hadley and Walker cells, and where latent heat is released providing energy to set these global–scale circulations in motion.

During the boreal summer, this convection is most active over the Indian subcontinent, when the monsoon occurs. During the winter the maximum amount of convective activity is found south of the Equator over the Indian Ocean, and is generally referred to as the Madden-Julian oscillation (MJO). Convection in this region is modulated at many temporal scales, the most energetic being the interannual, seasonal and intraseasonal scales. Many studies have shown that there is a clear peak in the spectrum of this deep convective

Recent observations from a satellite-based, microwave SST sensor reveal daily to weekly variation in SST (up to 3 C), which had not been seen with infrared composite measurements. During the winter, Dr. Brian Ward was in the Indian Sea on the French vessel *R/V Suroît* as part of the CIRENE program. He is using the Air-Sea Interaction Profiler (ASIP) which he recently designed and constructed. It allows frequent (every 5 m) measurements of water structure in the upper 10 m of the ocean with a vertical resolution of mm's. He is addressing issues of diurnal changes in SST and its effect on the atmosphere along with the effect of organisms on heat trapping in the near-surface. He is testing the capability of ASIP to measure air-sea exchange and upper ocean dynamics.

(continued on page 2)

activity at time-scales between 20 and 60 days. At this time scale, there is also a spatial organization at large scale and a strong seasonality of the amplitude and characteristics of the intraseasonal variability of convection.

Recent observations have revealed large amplitude (up to 3K) SST variability in relation to the ISVC in the Indian Ocean. These large SST excursions were identified using the Tropical Rainfall Measuring Mission's (TRMM) Microwave Imager (TMI) Sea Surface Temperature (SST) dataset. The advantage of the microwave SST sensor over the more traditional infrared SST is that it can penetrate cloud, thereby allowing a more complete time series. Previous studies using the weekly SST climatologies analyses grossly underestimated the SST variability related to ISVC. This is probably due to the cloud screening effect in the infrared atmospheric window, which is a strong limiting factor when trying to estimate SST variations below atmospheric convection.

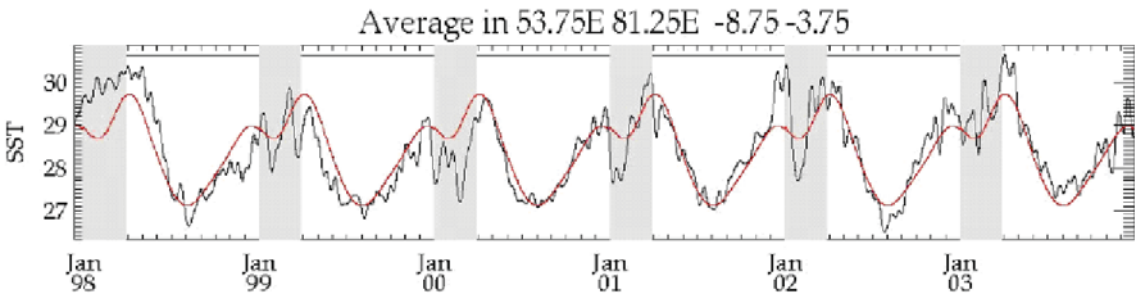


Figure 1. *Time series of the TIMI SST (C) in the CIRENE region from January 1998 to December 2003. The January-March period has been highlighted by grey shading. Red arrows indicate a large SST intraseasonal events associated with the MJO. The red thin line shows the climatological SST (courtesy of Jean-Philipe Duvel and Jérôme Vialard.)*

Several studies have suggested the importance of air–sea heat fluxes in driving the SST anomalies. An important feature to allow these strong SST variations is the shallow climatological thermocline between 5-S and 10-S. This shallow thermocline makes cold water available to cool the surface, while also strongly limiting the depth of the mixed layer, making it more responsive to surface forcing. The latitudinal position of maximum SST variability is the result of a consensus between the position of the region of maximum flux perturbation and the region where the thermocline is shallowest (between 5-S and 12-S). The 55-E–80-E, 10-S–3-S region (hereafter the CIRENE region) is very reactive to the MJO. The amplitude of the SST response is three times larger than in the western Pacific (not shown) where the COARE experiment was organized. The CIRENE region is thus an ideal location to evaluate air-sea coupling at the intraseasonal time-scales.

Almost every winter (except in early 1998, an El Niño year), this region was home to a strong cooling of SST, associated with very strong convective variability, shown in Figure 1. Heretofore there have been only satellite data and numerical modeling used to investigate the variability in these regions. No *in-situ* data is yet available to describe the vertical scale of these temperature anomalies and the modulation of the mixed layer depth during the MJO events. Such a dataset is required in order to determine precisely the mechanisms at work in the SST evolution.

The CIRENE campaign was conducted in January-February 2007 from the French vessel *R/V Surôıt*. The principal organizing institution was Laboratoire d'Océanographie Expérimentation et Approches Numériques Laboratoire (LOCEAN) in Paris (PI Jérôme Vialard). A CCPO scientist, I Brian Ward participated in this six week campaign with the Air-Sea Interaction Profiler (ASIP), which had been developed with funds from the National Science Foundation (NSF), and with three temperature-chain drifters, which was a collaboration with Woods Hole Oceanographic Institution (WHOI).

ASIP provided profiles of temperature, conductivity, shear, fluorescence/turbidity, and PAR over the full depth of the mixed layer. The spatial resolution of the measurements is subcentimeter, with profile intervals of 5 minutes. The thermistor chains provided mesoscale variability of SST and allowed us to establish the representativeness of the ASIP measurements.
The data from ASIP and the temperature-chains will address the following scientific questions:

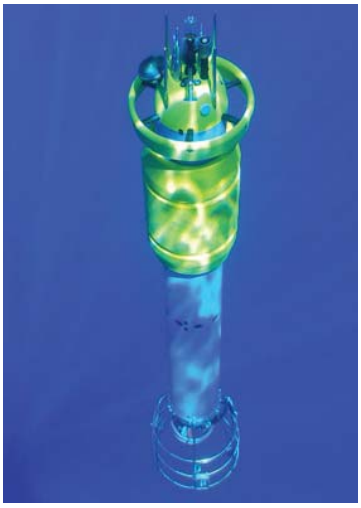


Figure 2. *Underwater photograph of ASIP during during one of its descents in the Indian Ocean.*

- The relative importance of local SST conditions and the diurnal cycle of the warm layer versus large scale atmospheric conditions.

- The biological contribution to heat trapping in the near–surface layer, and its role in the overall heat budget.

Acknowledgements
Participation on the CIRENE project, as well as development of the ASIP instrument, was funded with grants from the NSF (grant numbers 0525657 and 0241834, respectively).

Dr. Brian Ward received his Ph.D. from the National University of Ireland, Galway. His dissertation was on the skin temperature of the ocean. He received a two-year Marie Curie Fellowship from the European Commission to study at the Nansen Center/Geophysical Institute in Bergen, Norway.

With additional funds from the Norwegian Research Council, Dr. Ward developed the Skin Depth Experimental Profiler (SkinDeEP). He then moved to the University of Miami to work with Rik Wanninkhof on the Equatorial Pacific GasEx2001 experiment. He was also involved in a tank study at the Air-Sea Interaction Saltwater Tank (ASIST) to study the physics of the water surface molecular boundary layer.

In 2002, Dr. Ward moved to the Woods Hole Oceanographic Institution, where he further developed his research in air-sea interaction. He moved to Old Dominion University in 2006, where he is currently an assistant professor.

Ward's research is largely observation-oriented and is concerned with the exchange of heat and CO_2 transfer between the ocean and atmosphere. He has developed novel instruments which provide the means to study the small-scale, ocean surface processes responsible for air-sea exchange. These measurements are driven by the fact the processes that occur immediately at the ocean surface largely control the atmosphere-ocean fluxes. It is through these fluxes that the ocean communicates with the atmosphere and thus influences climate change.

CCPO People Profile

Bin Zhang is from a small, mountain-encircled village in Shandong province, China. He received his B.S. in geophysics at the University of Science and Technology of China in 1996 and his M.S. in physical oceanography at the Institute of Oceanology of Chinese Academy of Science, Qingdao, 1999. In the fall of 1999, he began his Ph.D at the Center for Coastal Physical Oceanography under the direction of Dr. John Klinck.

He is interested in numerical simulation of ocean circulation. His master's thesis involved tide-driven residual circulation in the Bohai Sea (Marginal Sea of China) using the Princeton Ocean Model. He has used the Regional Ocean Modeling System (ROMS) since his second year at CCPO. His Ph.D research focuses on the Antarctic Circumpolar Current (ACC) in the Drake Passage. The ACC is composed of three major fronts, and his study deals with the frontal dynamics using ROMS. Variable factors, such as the ACC transport, the topography, and the local wind stress have impact on the frontal locations. He hopes to find the relationship between these factors and the frontal locations and their variability in Drake Passage via numerical simulations.

He also works with Dr. Thomas Royer to calculate the freshwater transport in Gulf of Alaska. The estimation of first order geostrophic transport and the freshwater transport crosses the two lines perpendicular to the coast (Line P and Seward Line) and have been estimated from long-term hydrography measurements.

In the future, his research will expand his study region to the Southern Ocean to study frontal variability, dynamics, and long-term trends in the ocean using numerical tools and the real observations. He has found a postdoc position in the Ocean Modeling Group at Rutgers University.

Bin Zhang married Shuang Huang in 2001 at ODU when she was a student majoring in computer sciences. Shuang worked with Dr. Ann Gargett at CCPO for two years, and she currently works in a small financial company in King of Prussia, Penn. using her matlab skills learned at CCPO.

Bin's other interests include cooking, reading, playing badminton, and playing chess. He enjoys the life in Norfolk!

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 buillt 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

Boy Scouts from Troop 901 (Chesapeake, VA) and Troop 17 (Charlottesville, VA) were the most recent participants in the Oceanography merit badge program that is coordinated through CCPO by Program Specialist JULIE MORGAN and CCPO Professor EILEEN HOFMANN. The program began with a classroom presentation that covered various aspects of the oceanography merit badge requirements and provided descriptions of some oceanographic sampling equipment, such as a conductivity-temperature-depth (CTD) system and Niskin bottles, which the Scouts used in the field portion of the program. Video and pictures taken by CCPO scientists during Antarctic oceanographic cruises provided "real-world" examples, as well as entertainment.

The field portion of the merit badge requirements took place on the *R/V Fay Slover*, which is the Old Dominion University research vessel docked at the nearby National Oceanic and Atmospheric Administration facility. 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 by Patrick Curry, 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 on the outbound part of the trip.

For "hands-on" activities, the Scouts deployed a CTD/Rosette system and collected water samples. Unlike most CTD casts that have been done in the Elizabeth River, this cast showed low salinity (almost freshwater) throughout the water column. The low salinity conditions likely resulted from the heavy rains

Boy Scouts prepare to get under way on the R/V Fay Slover. on the dock at NOAA

(continued on page 5)

associated with the remains of Hurricane Ernesto, which passed over the Hampton Roads region the previous week. Next, the Scouts deployed a plankton net

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

tow and a bottom mud grab. The net tow sample contained few copepods and no ctenophores, which was different from previous net tows done in the Elizabeth River. The different plankton composition may also have resulted from the low salinity conditions. However, there were enough copepods for viewing with a microscope. One of the parent chaperones, Dr. Barry Condron, was most helpful in getting the binocular microscope to work. Sorting through the bottom mud sample yielded a few worm tubes – apparently even worms do not like low salinity conditions. The Scouts were very engaged in all aspects of the classroom and field activities. Some even helped the mates clean up after sampling!

The Boy Scout merit badge program has generated considerable interest, as described on the CCPO Outreach Web site (http://www.ccpo.odu.edu/Outreach.html). As a result, plans are now under way to expand the program to allow more Scouts the opportunity to earn the oceanography merit badge. The new program structure will be tested during the May 2007 program.

Southern Ocean GLOBEC Circulation and Hydrography Workshop

Oceanographic cruises undertaken as part of the U.S. Southern Ocean Global Ocean Ecosystem Dynamics (SO GLOBEC) Program acquired extensive circulation and hydrographic data sets from the western Antarctic Peninsula (WAP) continental shelf region in austral fall and winter of 2001 and 2002. These data sets include measurements from moored current meters, vessel-mounted profiling current meters, a microstructure profiler, drifters, floats, ship-based conductivity-temperature-depth (CTD) profilers, and meteorology sensors. As part of the synthesis and integration phase of the U.S. SO GLOBEC program, the National Science Foundation Office of Polar Programs recently funded a three-year project to analyze these data sets and develop computer models for synthesizing the observations. The overall goal of this project is to develop our understanding of the physical oceanography of this region to the point where models can reliably forecast regional changes that would be caused, for example, by larger-scale trends in air temperature and sea-ice distribution around Antarctica. This project is a collaboration among scientists from Woods Hole Oceanographic Institution (Bob Beardsley, Breck Owens, Dick Limeburner), Earth and Space Research (Robin Muench, Laurie Padman),

Participants at the Southern Ocean GLOBEC Circulation and Hydrography Workshop

Virginia Institute of Marine Science (Walker Smith), and CCPO (JOHN KLINCK, MIKE DINNIMAN, EILEEN HOFMANN). The project also includes participation from graduate students Carlos Moffat (Woods Hole Oceanographic Institution) and ANDREA PIÑONES (CCPO).

A workshop to initiate this project was held at CCPO November 15-17, 2006, with the goals of summarizing what we know about the processes that are active on the WAP shelf and to coordinate future work on remaining areas of uncertainty. The discussions were organized around various components of the physical characteristics of the region, including: 1) magnitude and extent of across-shelf transport of heat, salt, and nutrients; 2) structure of the WAP circulation; 3) dynamics of the WAP coastal current; 4) mechanisms for vertical exchange of water proper

(continued on page 6)

(continued from page 5)

ties between the surface layer and the deep water; and 5) controls on sea ice extent and concentration. The workshop participants concluded that, currently, the mechanisms of vertical and across-shelf exchanges are not sufficiently well understood for us to be able to reliably model the physical oceanography of the WAP shelf, or its influence on biological distributions and productivity. It was also determined that the WAP coastal current and flow under the George VI Ice Shelf (located in the southern half of the Antarctic Peninsula) were previously ignored features that may need to be considered.

Based on the workshop discussions, a conceptual model of the circulation of the WAP continental shelf was developed. This model includes what we now believe to be the important processes governing the flow of the WAP shelf, and provides a framework for testing hypotheses about flow dynamics through data analyses and numerical circulation modeling. The circulation model that presently exists for this region (Dinniman and Klinck, Deep-Sea Research II, 2004) is now being modified to include a larger region, higher spatial resolution, under-ice shelf dynamics, improved surface and lateral boundary forcing, and a coupled sea-ice model. Discussions at the workshop focused on details of these modifications. A general consensus emerging from the workshop discussions was that the processes that underlie the WAP shelf circulation are still relatively unknown and likely differ from those associated with other continental shelf regions, which makes this an exciting and interesting project.

Workshop on Hard Clam Modeling

The hard clam (*Mercenaria mercenaria*) is a commercially harvested species and is perhaps best known as the half-shell delicacy either in the littleneck or cherrystone form or as the primary ingredient in clam chowder. Abundance of this species is declining and the reasons for this extend beyond the simple explanation of over-exploitation of a resource. One potential cause for the hard clam declines is the deleterious effects of harmful algae, such as the brown tide alga (*Aureococcus anophagefferens*). This alga is known to inhibit feeding of suspension feeders and may cause recruitment failure and/or reduced survival of hard clam larvae and juveniles. Recently, CCPO scientists JOHN KLINCK and EILEEN HOFMANN began a collaborative study with Eric Powell and John Kraeuter from the Rutgers University Haskin Shellfish Research Laboratory (HSRL) and Monica Bricelj from the Institute of Marine Biosciences in Halifax, Nova Scotia. Funded by the NOAA Ecology of Harmful Algal Blooms (ECOHAB) Program, the project is designed to investigate the effects of brown tides on hard clam growth and survival. This project combines experimental and modeling efforts to explicitly examine the effects of brown tide on hard clam population dynamics in the Barnegat Bay, NJ, estuarine system. This area was chosen for the study because during the late 1990s and early 2000s the bay had extensive brown tides and the hard clam population in portions of the system was greatly reduced. The experimental efforts include laboratory studies on larvae, and size specific studies on growth and mortality of juvenile clams grown in two hatchery sites, one subject to brown tides and the other that has not experienced outbreaks.

The portion of this study being done at CCPO is focused on updating and refining numerical models for the growth and survival of post-settlement and larval hard clams. The development of a hard clam larvae model that includes explicit brown tide effects was done during a workshop that was held at CCPO June 26-30, 2006. At this workshop, experimental results, obtained by Monica Bricelj as part of this project, were used to develop parameterizations for the effects of brown tide on larval growth and survival processes. These parameterizations were included in the larval model and simulation results were tested against data sets. The process of developing and testing parameterizations involved educating the modeling part of the research team about experimental designs and implications of results. The results from the model re-

(continued on page 8)

Publications

Carr, M.-E., **M.A.M. Friedrichs** and the PPARR3 team, "A comparison of global estimates of marine primary production from ocean color," *Deep-Sea Research II*, **53**, 741-770, 2006.

Friedrichs, M.A.M., R. Hood, and **J. Wiggert**, "Ecosystem model complexity versus physical forcing: Quantification of their relative impact with assimilated Arabian Sea data,: *Deep-Sea Research II*, **53**, 576-600, 2006.

Hofmann, Eileen E., **John M. Klinck,** John N. Kraeuter, Eric N. Powell, Ray E. Grizzle, Stuart C. Buckner, and V. Monica Bricelj, "A Population Dynamics Model of the Hard Clam, *Mercenaria Mercenaria* Development of the Age- and Length-Frequency Structure of the Population," *Journal of Shellfish Research*, **25**(2), 417-444, 2006.

Hood, R., E. Laws, K. Moore, R. Armstrong, N. Bates, C. Carlson, F. Chai, S. Doney, P. Falkowski, D. Feely, M.A.M. Friedrichs, M. Landry, R. Letelier, D. Nelson, T. Richardson, B. Salihoglu, **J. Wiggert**, and M. Schartau, "Functional group modeling: progress, challenges and prospects," *Deep-Sea Research II*, **53**, 459-512, 2006.

Kumar, Ajoy, A. Valle-Levinson and **L. P. Atkinson**, "Overrunning of shelf water in the southern Mid-Atlantic Bight" *Progress in Oceanography*, **70**, 213-232, 2006.

Lipphardt, Jr., B.L., D. Small, A.D. Kirwan Jr., S. Wiggins, K. Ide, **C.E. Grosch**, and J.D. Paduan, "Synoptic Lagranian maps: Application to surface transport in Monterey Bay," *Journal of Marine Research*, **64**, 221-247, 2006.

Royer, Thomas C. and **Chester E. Grosch**, "Ocean warming and freshening in the northern Gulf of Alaska," *Geophysical Research Letters*, **33**, L16605, doi:10.1029/2006GL026767, 2006.

Smith, Walker O., Amy R. Shields, Jill A. Peloquin, Giulio Catalano, Sasha Tozzi, **Michael S. Dinniman**, Vernon A. Asper, "Interannual variations in nutrients, net community production, and biogeochemical cycles in the Ross Sea," *Deep-Sea Research II*, **53**, 815-833, 2006.

Vargas, Cristian A., **Diego A. Narvaez**, **Andrea Pinones**, Sergio A. Navarrete, and Nelson A. Lagos, " River plume dynamic influences transport of barnacle larvae in the inner shelf off central Chile," *Journal of the Marine Biological Association of the United Kingdom*, **86**, 1057-1065, 2006.

Presentations

Hood, R. R., S. W. A. Naqvi and **J. D. Wiggert**, "SIBER: Sustained Indian Ocean Biogeochemical and Ecological Research," Ocean Carbon Biogeochemistry Workshop, Woods Hole Oceanographic Institute, Woods Hole, MA, July 10-13, 2006.

Royer, T.C., "The North Pacific Ocean Climate During the Last Glacial Maximum," The 5th Paths across the Pacific conference, Sitka, Alaska, July 28, 2006.

Wiggert J.D. and R.G. Murtugudde, "Seasonal to interannual biogeochemical variability in the Indian Ocean: The importance of inter-regional connections and their modulation by climate modes" Ocean Carbon Biogeochemistry Workshop, Woods Hole Oceanographic Institution, Woods Hole, MA, July 10-13, 2006.

Andrés E. Tejada-Martínez and Cesar Mendoza, Alternating bars in transcritical flow, presented at the 7th International Conference on Hydroscience and Engineering, September 10-13, 2006, Philadelphia, PA.

Andrés E. Tejada-Martínez, **Chester E. Grosch** and **Thomas B. Gatski**, Temporal large-eddy simulation of unstratified and stratified turbulent channel flows, invited seminar, Laboratoire d'Études Aérodynamiques, UMR 6609 CNRS, Université de Poitiers, September 19, 2006, Poitiers, France.

Andrés E. Tejada-Martínez, **Chester E. Grosch** and **Thomas B. Gatski**, Temporal large-eddy simulation of unstratified and stratified turbulent channel flows, invited seminar, Laboratoire de Mécanique de Lille, Université des Sciences et Technologies de Lille, September 21, 2006, Lille, France.

Andrés E. Tejada-Martínez, **Chester E. Grosch** and **Thomas B. Gatski**, Temporal large-eddy simulation of unstratified and stratified turbulent channel flows, presented at the 5th Symposium on Turbulence, Heat and Mass Transport, September 25-28, 2006, Dubrovnik, Croatia.

(continued from page 6)

ceived considerable scrutiny from all participants and eventually managed to pass even the most skeptical of the research team. The hard clam model that resulted from the workshop clearly demonstrates the value of having everyone together and involved in the modeling process. Initial simulations from the hard clam larvae model show that exposure to toxic brown tide results in reduced recruitment success of hard clam larvae and reduced growth rates, and that brown tide can act as a strong natural selection agent thereby altering the population genotypic composition.

As part of this project, a special session entitled, "Managing Shellfisheries: Models, HABS and Other Current Issues," will be convened at the 2007 Estuarine Research Federation Meeting. The experimental and modeling results from this project will be integral to this session.

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

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

24 September
JOSE-LUIS BLANCO
CCPO

1 October
ELIZABETH SMITH
CCPO

15 October
TAL EZER
CCPO

22 October
KENNEDY PAYNTER
University of Maryland Center for Environmental Science

29 October
PATRICK NEALE
Smithsonian Environmental Research Center

5 November
BRIAN WARD
CCPO

12 November
BRUCE CORLISS
Duke University

19 November
JAY PICKNEY
University of South Carolina

26 November
JULI HARDING
Virginia Institute of Marine Sciences

CCPO Circulation is published three times a year. Please contact the editor for more information at 757-683-5548 or www.ccpo.odu.edu.

6CN05
The Center for Coastal Physical Oceanography
Old Dominion University
Norfolk, VA 23529
USA