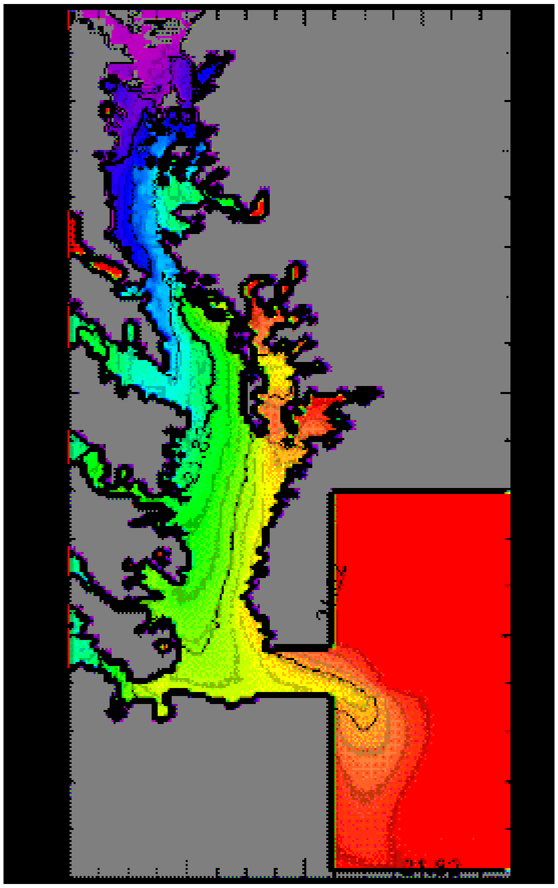
Fall 1994

Circulation, Fall 1994

Center for Coastal Physical Oceanography, Old Dominion University

CCPO Circulation, Fall 1994

Modeling Circulation and Larval Transport in the Chesapeake Bay



Picture Caption: *Surface salinity in Chesapeake Bay after 15 days of simulation. Fresh water indicated by darker blue colors and ambient shelf water indicated by red. The shelf domain is truncated for computational simplicity. Bathymetry dataset provided by Arnoldo Valle-Levinson.*

The Chesapeake Bay, the largest estuary in the United States, serves as nursery grounds and spawning areas for many species. The larvae of these species are usually widely distributed across varied horizontal and vertical length scales. Biological characteristics of the larvae, such as motile ability, buoyancy characteristics, and affinity for light or water mass characteristics, all contribute to the location of these larvae on fairly small spatial scales. Equally important, yet operating on larger scales, is the movement of these larvae by the local circulation. Modeling the larval transport due to the currents in the Bay and on the adjoining continental shelf is difficult due to this disparity between controlling scales, yet the results of such a modeling effort should provide new insights on the year-to-year survival of economically important species such as the blue crab (Callinectes sapidus). The latest modeling project of GLEN WHELESS, research assistant professor, will examine the effects of physical processes such as wind, tides, and runoff on the circulation in the Bay and on the shelf-to-Bay transport of estuarine-dependent biological species.

Circulation in the Bay is usually described as consisting of relatively freshwater near the surface flowing seaward atop more saline near-bottom water flowing in the opposite direction. The most buoyant water is usually found along the western side of the Bay due mainly to rotational influences. The mean flow in the Bay mouth and adjacent shelf is also rotationally affected, consisting of buoyant water outflowing at the surface along the southern reaches of the Bay and inflowing dense, saline shelf water confined to the northern side at depth. The outflowing buoyant water usually exhibits an initial anticyclonic turn (to the right in the northern hemisphere) after exiting the Bay mouth, becoming a right-bounded coastal plume and coastal current system. Seaward of the buoyant outflow area is an area of intense mixing as the fresh outflow merges with the more saline shelf water.

This circulation is driven by a combination of wind and tidal effects, as well as freshwater runoff inputs which directly affect the salinity field of the Bay. The salinity field is important as a flow generation mechanism due to the pressure forces from the resulting density field and is an excellent indicator of the circulation variability. The Bay salinity field and the associated estuary/shelf circulation arises primarily from freshwater runoff, the majority of which comes from the Susquehanna River with additional input from the Potomac, the James, the York, and other rivers. Bay circulation is also especially sensitive to wind and tidal forcing due to the shallowness and boundary dominated nature of the Bay. Flow in the Bay mouth may be increased or decreased based upon wind direction. Indeed, Glen's model results indicate that the Bay mouth density field is very sensitive to wind stress variablity, results which are borne out by recent Acoustic Doppler Current Profiler (ADCP) observations by ARNOLDO VALLE-LEVINSON, research assistant professor, showing variability associated with bathymetry, wind stress patterns, and tidal influences.

Results from a three-dimensional primitive equation ocean model using a realistic Chesapeake Bay bathymetry are shown in the figure. Fresh water was allowed to enter the quiescent model Bay from the Susquehanna River to drive the circulation. The salinity field after 15 days shows significant freshening along the western side of the upper Bay. A strong outflow plume in the Bay mouth region is also apparent. Experiments with variable wind stress and runoff amounts show that transport of material from and to the Bay is strongly influenced by the magnitude and duration of short-term wind events, and it is much less so by the strength of the runoff. Downwelling favorable winds from the north are capable of substantially changing the standard estuarine circulation pattern. Particle trajectories representing the path taken by passive larvae as they are moved by the flow indicate that wind forcing plays a large role in the ultimate fate of these larvae. The direction, duration, and timing of wind events control the transport of the larvae as the water column becomes strongly sheared, both vertically and horizontally. For those larvae whose vertical location in the water column is based on an active response to the salinity signal of Bay waters, wind forcing can exert control over their ability to enter the estuary indirectly by changing the salinity structure as well directly via drift.

Future directions of Glen's research efforts in the Bay include the addition of species' specific vertical behavior to the particle trajectory algorithm as well as the inclusion of real bathymetry over the adjoining continental shelf. This model is a first step towards building a comprehensive ecosystem model of the Chesapeake Bay at CCPO, and it will, in its final state, be coupled with state-of-the-art visualization and virtual reality techniques to render a Virtual Ecosystem Model.

The Mystery Photo

If you will remember in the summer issue of CCPO Circulation, we introducted to our readers THE MYSTERY PHOTO. Many of our readers who know ERIC POWELL had no problem guessing the face behind the feet. We have a lot of fun when Eric visits, and we especially have fun with the crazy socks and tennis shoes he is famous for wearing. Thanks to those individuals who responded to The Mystery Photo.

Visiting Scientist Profile

ERIC N. POWELL, professor in the Oceanography Department at Texas AM University, has long been a frequent visitor to CCPO. Eric's visits are part of a long-term collaboration with CCPO scientists, Eileen Hofmann, Margaret Dekshenieks, and John Klinck, on the development and implementation of a circulation-oyster population model. This research is primarily focused on understanding the processes that affect oyster populations in Galveston Bay, Texas and is part of a larger research effort to evaluate the effects of widening and deepening the Houston Ship Channel.

In addition to his oyster modeling research, Eric has published extensively in the areas of bivalve biology and ecology, taphonomy, paleoecology, and meiofauna biology. Also, Eric maintains an active field research effort. He and his research team, which includes Margaret Dekshenieks, recently conducted a series of submersible cruises in the Caribbean to recover and deploy bags of shells as part of an experiment to understand calcium carbonate dissolution processes.

The collaboration between Eric and CCPO scientists has been quite productive, resulting in several publications and numerous presentations at scientific meetings. However, Eric is best known at CCPO for his unusual socks and his predilection for chocolate doughnuts.

Notes from the Director

Regional Research at CCPO.

One of the goals of CCPO is to increase the funding for research in the region. As many of you know, it is difficult to get research funding for a specific geographic site such as the Chesapeake Bay. Our normal funding sources are for basic research and they are usually not tied strongly to a specific site, and in fact, being too site-specific is a disadvantage. To promote more basic research on the Bay, we have invested considerable funds on in-house research. By doing this, we have shown that there is still much to learn about the Bay and that CCPO scientists can do the research.

We recently completed a project for Sverdrup Engineering on behalf of the Chesapeake Bay Bridge Tunnel Authority. We obtained quality data on the flow of water through the bridge pilings and are also publishing the results in the peer reviewed literature. This is a good example of how basic and applied research can be combined to benefit economic development of the region.

CCPO will continue to promote basic research in the lower Bay and adjacent ocean through internal funding and an increasing level of Federal support. Larry P. Atkinson
Director, Center for Coastal Physical Oceanography

Do Ocean Current Exhibit Absolute Instability?

The distinction between absolute and convective instability was introduced by Briggs in 1964 for plasma instability. The same idea was put forward independently by Gaster in 1968 within the context of classical hydrodynamic stability theory. Although these ideas are now widely accepted, as shown by a major review article in Annual Review of Fluid Mechanics by Huerre and Monkewitz in 1990, they seem to be used little in geophysical fluid dynamics.

A few years ago, it occurred to CHET GROSCH, professor at CCPO and the Computer Science Department, that current systems which have large shear, such as the Equatorial Current-Undercurrent, might have absolute instabilities. Absolute and convective instabilities are most easily described in a frame of reference moving with the mean current speed. In such a frame, a flow is absolutely unstable if the response to an impulse in space and time is unbounded everywhere in space for large time. On the other hand, if the response to an impulse is a wave packet propagating downstream from the source with the waves forming the packet having growing amplitudes, the flow is convectively unstable. With the convective instability, the response decays to zero everywhere in space for large enough time. Of course, all of this analysis is done within the framework of linear stability theory. If absolute instabilities exist in a flow, they would appear as coherent structures spreading both upstream and downstream in the moving frame.

Chet began looking for absolute instability using a simple model of the Equatorial Current-Undercurrent. The analysis showed that absolute instability was possible, but there were many puzzling features. He therefore switched to a much simpler model: a two-layer quasigeostrophic current-undercurrent system. Using linear theory, Chet has shown that the instability can be either convective or absolute depending on the speed and direction of the undercurrent. He found that the puzzling features in the results for the Equatorial Current-Undercurrent system were caused by the branch cuts in the dispersion relation and the group velocity function.

As far as Chet knows, no one has ever studied the nonlinear behavior of an absolutely unstable flow. In order to do this for the model system, he wrote a code to solve the full equations for the perturbations. This code is fourth order in both space and time, and it is required by the need for very high accuracy in tracking unstable disturbances. Chet is now running sample cases, and in the future, he will return to the study of the Equatorial Current-Undercurrent system.

Student Profiles

AJOY KUMAR graduated with a Masters degree in physics from the University of Madras, India in 1987. He then joined the Remote Sensing Group at the National Institute of Oceanography, Goa, India. There he participated in a number of cruises in the Arabian Sea, Bay of Bengal, and the Indian Ocean, and he collected and analysed optical and hydrographic data. In addition, he processed and analysed CZCS data from the Arabian Sea, along the west coast of India.

In 1991, Ajoy started his graduate study at ODU under the guidance of G. T. Csanady. Ajoy's studies involve the use of CoastWatch sea surface temperature images and hydrographic data in a study of shelf and slope circulation in the southern Mid-Atlantic Bight. His dissertation will be entitled ``Offshelf Transport and Escape of Shelfwater in the Southern Mid-Atlantic Bight." He is also involved in a project with Larry Atkinson, for the Mineral Management Services, in which Ajoy uses CZCS imagery to characterize the Chesapeake Bay outflow on the shelf.

After graduation, Ajoy plans a postdoctoral tenure before returning to Goa, India to continue his research.

MARGARET MCMANUS DEKSHENIEKS received her undergraduate degree in environmental science from the University of Virginia in 1989. After graduation, Margaret held an assistant research position studying marine ecology in the Florida Bay. In the fall of 1989, she began her graduate studies at Old Dominion University and received her Masters in biological oceanography in the summer of 1991 and entered into the Ph.D. program under the instruction of Eileen E. Hofmann.

Margaret's dissertation is entitled, *The Importance of Recruitment Success and Post-Settlement Survival to the Population Structure of the Eastern Oyster*. This study involves using a coupled biological-physical model to investigate effects of changes in the physical estuarine environment on the population structure of the oyster. Specifically, her interests are modeling larval growth and behavior as they are affected by changes in the physical environment. Margaret's research interests have resulted in involvement with the National Shellfisheries Association as a student representative.

After graduation, she intends to pursue a postdoctoral position in oceanography.

Visiting Scientist Lecture 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, on Mondays at 3:30 p.m. EILEEN HOFMANN, associate professor of oceanography, coordinates the lecture series with the assistance of BEVERLY MITCHELL. Below is a schedule of lectures for the fall semester 1994. Please contact Beverly at (804) 683-4945 for more information or if you would like to be included on the mailing list for lecture announcements. Specific lecture topics are announced one week prior to each lecture.

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September 12
Harvey Marchant
Australian Antarctic Division

September 19
David Keyes
Old Dominion University

September 26 nn
Roger Mann
Virginia Institute of Marine Science

October 3
Geoffrey Motte
Old Dominion University

October 10
Stanford Hooker
NASA/GSFC
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October 17
Wendell Brown
University of New Hampshire

October 24
Carl Fisher
NOAA, Norfolk, VA

October 31
Grace Brush
Johns Hopkins University

November 7
Chester Grosch
CCPO

November 14
Victor Klemas
University of Delaware

November 21
Eileen Hofmann
CCPO

November 28
Elizabeth Smith
CCPO

Virtual Reality Research at CCPO

GLEN WHELESS and ARNOLDO VALLE-LEVINSON, both research assistant professors, recently showcased their virtual reality project entitled, ``A Walk through Chesapeake Bay," at SIGGRAPH '94 in Orlando this past July. Sponsored by the Association of Computing Machinery (ACM), SIGGRAPH is the annual meeting for those who use the latest computer graphics hardware and software in scientific, industrial, and entertainment applications. Attendees at this year's conference experienced cutting-edge scientific visualization by viewing virtual reality applications in the three on-site CAVE's (Cave Automatic Virtual Environment). Over the week-long conference, there were 43 such applications presented to groups of five viewers at a time. Among the other applications were projects dealing with 3D air traffic control, turbulence in flow over a flat plate, and the development of tornadoes along gust fronts.

The CAVE, powered by a Silicon Graphics Onyx parallel-processor computer, is a virtual reality visualization system comprised of high-resolution projection screens arranged in a 10-foot cube. Computer-generated images are then projected on three walls and the floor. Aural cues from sound files complete the virtual world. Developed by the National Center for Supercomputer Applications (NCSA) and the Electronic Visualization Laboratory (EVL) at the University of Illinois, the CAVE allows scientists to interact with virtual worlds created from observed data or simulations. A viewer wears a 6-degrees of freedom head tracker device and stereo-shutter glasses so that the correct projections and perspectives of 3D objects are presented as the viewer moves inside the CAVE. A wand (essentially a computer mouse) held by the viewer allows interaction with and navigation through the virtual environment.

The promise of this type of scientific visualization is exciting and extraordinary. For example, imagine examining the effects of circulation on the distribution of a larval fish swarm as it moves through the mouth of the Chesapeake Bay from the vantage point of one of the larvae. Or, envision viewing the transfer of momentum from wind to wave in the first few meters of the ocean surface and having the ability to move around in the data field for a different perspective of the process.

The CCPO CAVE project was a collaborative effort between CCPO researchers and Bill Sherman from NCSA and Chris Hartman from the University of Illinois Mathematics Department. A 3D graphical representation of a Chesapeake Bay bathymetry dataset, textured and colored according to depth, was displayed in the CAVE and upon which transparent 3D isosurfaces of Chesapeake Bay surface salinity observations were overlaid. Animating these isosurfaces showed the seasonal change of salinity throughout the Bay. Glen and Arnoldo's presentation began with a south-to-north descent from 100,000 feet and 20 miles south of the Bay mouth to a point just above the air-sea interface. Nearing sea level, the sounds changed from sea gulls to that of crashing surf. They flew up the Bay, pointing out landmarks, geography, and the 3D `signs' identifying the James and Potomac Rivers. Continuing the descent underwater, they crossed the air-water interface with an audible splash and hovered just under the translucent surface as the viewers were shown the main shipping channels of the Bay and the abrupt bathymetric variations. They then flew through the Bay, discussing the concepts of estuarine circulation and rotationally controlled flow. The trip ended with a quick ascent followed by a hover and an explanation of the Bay's seasonal salinity cycle, demonstrated by the animated salinity fields.

To their knowledge, this was the one of the first applications of this technology to examine oceanographic data. If you have access to the Internet and are running Mosaic, navigate to the URL

http://www.ccpo.odu.edu/vr.html

and look at the document Virtual Reality in Oceanography for more information.

ADK's Words Of Wisdom

All observations and calculations report numbers that have errors and/or round off. These uncertainties usually are expressed in absolute units or as percentages. The uncertainty in addition or subtraction of numbers is given by the addition of the absolute values of the uncertainties, while the uncertainty in multiplication or division is the magnitude of the percentage uncertainties.

Distinguished Visitors

Harvey Marchant and Ken Denman

During September 12--15, 1994, CCPO was honored with visits by HARVEY MARCHANT, from the Australian Antarctic Division in Kingston, Tasmania, Australia, and KEN DENMAN, from the Institute of Ocean Sciences in Sydney, British Columbia. During their visit, they worked on a chapter with Eileen Hofmann that will be included in a report issued in 1995 by the Intergovernmental Panel on Climate Change (IPCC). The IPCC was established in 1988 by the World Meteorological Organization and the United Nations Environment Programme to address the science aspects of climate change. The focus of the chapter is on marine biotic responses to environmental change and feedbacks to climate. It is one of several chapters designed to provide a current scientific assessment of climate change for terrestrial and marine systems.

Roger Hockney

ROGER HOCKNEY, a distinguished visitor from Great Britain, visited CCPO and the Department of Computer Science September 5--16, 1994. During his stay in Computer Science, Roger worked with Chet Grosch and Tarun Agarwal, of the Computer Science Department, on characterizing the performance of a large code now running on the 256 node CM5 at the Naval Research Laboratory. Roger also consulted with the networking group on benchmarks and performance evaluation for communication in networks of loosely coupled processors, such as workstations on a LAN. During his visit, he also gave two lectures at the Computer Science Department describing his recent research on benchmarking and performance evaluation. These lectures were entitled, ``The PARKBENCH Initiative for Public International Parallel Benchmarks" and ``Computational Similarity."

While at CCPO, Roger worked with Chet Grosch, A. D. Kirwan, Jr., and John Holdzkom on the Office of Naval Research ARI project on massively parallel applications. The goal of the project is to develop a particle-in-cell model for coastal circulation. In this approach, the equations governing the circulation are solved by calculating the motion of many particles rather than calculating the solutions at discrete geographic positions. The new approach should be very useful in studying small-scale processes and in modeling the dispersal of pollutants. See CCPO Circulation, Vol. 1, No. 3, for further details.

The collaboration focused on adapting methods Roger had used successfully in particle-in-cell models of plasmas to an oceanographic setting. Initial tests of the new approach have been very encouraging. For one of the benchmark simulations, the new approach runs substantially faster and is more accurate than the previous approaches. Further testing is in progress.

Grants/Contracts Awarded

L. A. CODISPOTI, ``Consolidating and Advancing Knowledge of the Chemical Oceanography of the Arctic Ocean," $520,517, Office of Naval Research.

E. E. HOFMANN, ``Assimilation of Ocean Color Measurements Into Physical-Biological Models," $130,000, NASA.

E. A. SMITH, ``AVHRR Pathfinder Ocean Data Validation," $383,690, NASA.

G. H. WHELESS, ``Modeling Inlet Processes and Alongshore Transport: Relationships to Biological Recruitment," $28,465, NOAA.

Presentations

L. P. ATKINSON and Takashige Sugimoto of the University of Tokyo, Japan, ``Low Salinity Water in the Northwest Pacific Ocean," The Oceanography Society meeting, Honolulu, HI, July 1, 1994.

L. P. ATKINSON, ``Nutrient Supplies to Continental Shelves," symposium titled, Modern Chemical and Biological Oceanography: The Influence of Peter J. Wangersky, Dalhousie University, Halifax, Nova Scotia, Canada, July 28-29, 1994.

E. E. HOFMANN, ``Aspects of Physical-Biological Models for Secondary Production Studies," The Benguela Ecology Program/JGOFS Modelling Workshop, Cape Town, South Africa, July 25-27, 1994.

E. E. HOFMANN, ``Assimilation of Data into Biological Models," The Benguela Ecology Program/JGOFS Modelling Workshop, Cape Town, South Africa, July 25-27, 1994.

E. E. HOFMANN, ``Aspects of Physical-Biological Models for Secondary Production Studies," invited presentation, The ICES Symposium on Zooplankton Production, Plymouth, England, August 15-19, 1994.

E. E. HOFMANN, ``Science in Antarctica: Application of Numerical Models," Annual Antarctic Orientation Conference, Xerox Document University, Leesburg, VA, September 8, 1994.

J. M. KLINCK, ``Size Class and Stage Based Numerical Models of Zooplankton Populations for Oceanic Environments," The Benguela Ecology Program/JGOFS Modelling Workshop, Cape Town, South Africa, July 25-27, 1994.

J. M. KLINCK, C. M. Lascara, and R. M. Ross, L. B. Quetin, and R. C. Smith, all three of University of California, Santa Barbara, ``Palmer LTER: Variability in the Pelagic Marine Ecosystem West of the Antarctic Peninsula," The ICES Symposium on Zooplankton Production, Plymouth, England, August 15-19, 1994.

C. M. LASCARA, J. M. Klinck, and E. E. Hofmann, ``The Use of a Lagrangian Model to Examine the Spatial Dynamics of Antarctic Krill, Euphausia superba," The ICES Symposium on Zooplankton Production, Plymouth, England, August 15-19, 1994.

E. A. SMITH and M. K. Hamilton and J. Vazquez, both of the Jet Propulsion Laboratory, ``A Statistical and Comparative Description of the NOAA/NASA Pathfinder Sea Surface Temperature Data Set," The Oceanography Society Pacific Basin Meeting, Honolulu, HI, July 19-22, 1994.

G. H. WHELESS and A. VALLE-LEVINSON, ``A Walk Through Chesapeake Bay," a virtual reality application for the Virtual Reality Room (VROOM) at SIGGRAPH '94, Orlando, FL, July 27, 1994.

G. H. WHELESS, ``Estuarine Ecosystem Modeling: Challenges and Directions in the Chesapeake Bay,'' Environmental Simulation Workshop 1994, Monterey, CA, August 19, 1994.

Publications

G. T. CSANADY, ``Vortex Pair Model of Langmuir Circulation,'' *Journal of Marine Research*, Vol 52(4), 559-581, 1994.

J. L. Pelegri, Universidad de Las Palmas de Gran Canaria, Canary Islands, Spain and G. T. CSANADY, ``Diapycnal Mixing in Western Boundary Currents,'' *Journal of Geophysical Research*, Vol. 99(C9), 18,275-18,304, September 1994.

M. Gaster, University of Cambridge, Cambridge, England, C. E. GROSCH, and T. L. Jackson, NASA Langley Research Center, Hampton, Virginia, ``The Velocity Field Created by a Shallow Bump in a Boundary Layer,'' *Phys. Fluids* 6 (9), 3,079-3,085, September 1994.

T. L. Jackson, Department of Mathematics, Old Dominion University, and C. E. GROSCH, ``Structure and Stability of a Laminar Diffusion Flame in a Compressible, Three-Dimensional Mixing Layer,'' *Theoretical and Computational Fluid Dynamics*, Vol. 6, 89-112, 1994.

E. E. HOFMANN and J. M. KLINCK, and E. N. Powell, S. Boyles, and M. Ellis, all three from Department of Oceanography, Texas AM University, ``Modeling Oyster Populations II. Adult Size and Reproductive Effort,'' *Journal of Shellfish Research*, Vol. 13(1), 165-182, 1994.

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