Oceanography Department

Captain Dennis J. Whitford, USN
Associate Professor
Chair

The U.S. Naval Academy's Oceanography Department has the largest undergraduate physical oceanography program in the nation. The program is anchored by only five tenure track faculty and complemented by six rotating military faculty and one externally-funded research faculty. Their combined meteorology and oceanography (METOC) scientific and pedagogical research productivity, especially when teamed with midshipmen, was quite impressive for the 1999-2000 research year.

Led by Associate Professor David R. Smith, the department commenced its research efforts by hosting its sixth Maury Project summer workshop in July 1999. Twenty-six K-12 science teachers from across the nation were introduced to physical oceanography teaching methodologies. Physical oceanography is recognized by pedagogical researchers as being more attractive to K-12 students than the more intimidating topics of physics, mathematics, and chemistry; yet it includes applications of all these fields. Thus these K-12 teachers will use physical oceanography to get their students excited about science and mathematics.

Fourteen midshipmen were directly involved in METOC research. Their research projects were cooperative efforts by the midshipmen and their research advisors. The projects introduced the midshipmen to the excitement and responsibility of data collection and analysis, as well as exposing the midshipmen to independent scientific thought and evaluation. At the end of each semester, these midshipmen presented their results to the department's faculty in a formal presentation. As a result of these efforts, several midshipmen went on to deliver oral and poster presentations at scientific conferences.

The annual Oceanographic Yard Patrol (YP) Summer Cruise aboard YP686 was conducted in June 2000. This cruise continued in its second year of acquiring research-quality data for two of our faculty. Data will be used to support publishable, refereed research.

All civilian faculty continued their strong research efforts with multiple articles submitted for publication.

Sponsored Research

Development of Specific Ion Probes for Use in Seawater

RESEARCHER: Professor John W. Foerster
SPONSOR: Naval Research Laboratory (NRL)

Research was conducted into developing polymer based specific ion probes for detecting chromium (VI) and lead in seawater. Both diphenylcarbizide (for Cr) and dithizone (for Pb) dyes was incorporated into an ionomeric membrane (Nafion) and a test developed for measuring these trace metal contaminants. This project is relevant to Navy environmental projects and shipyard contamination monitoring.

Use of a Nafion Membrane Probe for Quick, On-the-Spot Determination of Ionic Copper Contamination Levels in Natural Waters

RESEARCHER: Professor John W. Foerster
SPONSOR: Department of Defense (DoD)
Strategic Environmental Research and Development Program

A major source of trace metal contamination in the marine environment is the copper containing anti-foulant paints on ship hulls. An anti-fouling paint containing copper (I) presents a challenge to the environment because its design is to leach

continuously over a period of time. This study tests the hypothesis that the organic molecule, 2,9-dimethyl-4,7-diphenyl-1,10-phenanthrolinedisulfonic acid (Bathycuproinedisulfonic acid = BCS) is a reliable chemical to use in developing a sensor capable of measuring copper (I) in seawater. The purpose is to acquaint environmental users and managers with a system easily used to determine levels of copper contamination. A sensor system that will measure trace metal contamination quickly will help in the deployment of remedial methods to avert an environmental problem. The sensor must have

- parts per billion (ppb) detection limits,
- environmental immersion capability, and
- the ability to detect the copper (I) oxidation state.

Results of this study show copper one leaching at a rate of 1.2ppb/hour. After 2 hours Cu (I) begins to convert to copper (II). Both ions are toxic above very low ppb concentrations (<5.0ppb). Initially for the first 2 hours you have 100% copper (I) leaching into the water and by 20 hours the ratio is 38% copper (I) to 62% copper (II). The BCS chemical is a quick and relatively easy way to determine the concentration of copper (I) in marine and estuarine waters.

PROBE (Plankton Research on Bay Environments)

RESEARCHERS: Professor John W. Foerster and Captain Dennis J. Whitford, USN
SPONSOR: USNA Oceanography Department as part of Summer Cruise Program

Currents are the most potent factor in the mixing water. This is important because nutrients are depleted in the surface layers of the water and the currents will replenish these from depth. You can think of the Chesapeake Bay as a large mixing bowl. Currents from the ebb and flood of the tide, and from the inflowing freshwater create a mixing interface. Ecologists call this interface the edge effect (ecotone). This is a zone where two different environments mix together. The biological productivity is greater in the mixing area than in either of the environments on either side of the edge. In the case of the Chesapeake Bay, it is a type ii salt-wedge estuary. The predominant flow is tidal which supplies the energy and turbulence necessary to mix the inflowing waters with the outflowing waters. In the Chesapeake Bay, the mixing zone extends for 216km (180 mi). This develops a long, horizontal region of mixing. How the tidal currents interact and mix the waters is part of this study.

PAPA - Pipeline Automated Planning Aid II

RESEARCHER: Professor Peter L. Guth
SPONSOR: U.S. Army Quartermaster School

This work has added a pipeline planning tool to the Terra Base II program. The tool allows graphical selection of a pipeline route using digital NIMA map data, and then computes the required locations for pumping stations, overpressure relief, and the logistical requirements for the pipeline. The tool has been used in real world planning for pipeline requirements, and will be taught in the courses at the Quartermaster school.

TerraBase II: Computerized Terrain Analysis Training System

RESEARCHER: Professor Peter L. Guth
SPONSOR: U.S. Army Engineer School

TerraBase II is a training system to expose soldiers to the nature and types of digital terrain data, procedures for visualizing terrain, and integrating terrain into tactical planning. The program runs on standard desktop, laptop, and notebook computers with the Windows 95, 98 or NT operating system, and uses standard terrain data from the National Imagery and Mapping Agency. The program provides base maps for tracking situation, terrain computations (e.g. line of sight, slope for cross country mobility, sunrise/sunset), and 3D visualizations. The program integrates digital elevation models and satellite imagery. This year's work greatly increased the number of data sets the program used, increased the number of display and analysis options, and improved display capabilities. In particular the display options for vector map data were greatly improved.

The Influence of Dynamics and Thermodynamics on the Diagnosis of Marine Atmospheric Boundary Layer Statistics by Synthetic Aperture Radar

RESEARCHER: Assistant Professor Todd D. Sikora
SPONSOR: Office of Naval Research (ONR)

An algorithm for calculating marine atmospheric boundary layer statistics from synthetic aperture radar (SAR) 10m neutral wind imagery in the presence of convection is tested on 6 Radarsat images. The 6 Radarsat images are scenes from off the East Coast of the United States during the cold air outbreaks. Comparisons are made between the results for the Okukhov length of the SAR algorithm and those from a bulk flux algorithm, which uses corresponding buoy data as input. In general, the agreement is better, the more unstable the surface layer is defined by the Bulk Richardson Number. Deviations are better, the more unstable the surface layer as defined by the Bulk Richardson Number. Deviations range from 23% to two orders of magnitude. It is hypothesized that the effects of non-surface forced convection such as cloud radiative cooling and precipitation evaporation can lead to the SAR algorithm out performing the bulk flux algorithm. Potential sources of error for the SAR algorithm are discussed.

The Maury Project - Exploring the Physical Foundations of Oceanography

RESEARCHERS: Associate Professor David R. Smith
with I.W. Geer (American Meteorological Society)
SPONSORS: Commander, Naval Meteorology and Oceanography Command,
NOAA National Environmental Satellite,
Data and Information Service, and the Office of Naval Research (ONR)

The Maury Project is a teacher enhancement program on the physical foundations in oceanography for pre-college educators. Each year approximately twenty-six teachers are brought to the United States Naval Academy to attend a summer workshop where they learn about fundamental concepts in physical oceanography. This includes a combination of lectures, hands-on laboratory exercises, field experiences, and tours of oceanographic facilities. Upon completion of the summer workshop, these teachers return to their respective states where they conduct peer-training sessions for other teachers using materials developed by project staff.

Water in the Earth System

RESEARCHERS: Associate Professor David R. Smith
with I.W. Geer and J.M. Moran (American Meteorological Society)
SPONSOR: National Science Foundation (NSF)

Water in the Earth System is a teacher enhancement program on the role of water and water processes in the Earth system. This is a distance-learning course which uses the Internet to deliver instruction to pre-college educators. This summer, 35 teachers will be brought to Annapolis to attend a summer training workshop where they learn about fundamental concepts in meteorology, physical oceanography, and hydrology. Upon completion of the summer workshop, these teachers will return to their respective states where they will serve as the leaders for the local implementation teams that will mentor other teachers taking the distance learning course. This year the initial training workshop was planned.

A Study of Water Quality in the Douro River Estuary (Portugal)

RESEARCHERS: Associate Professor Mario E.C. Vieira and A. Bordalo (Porto University)
SPONSOR: Porto University (Portugal)

Based on the data collected in 1994 and a box model of the hydrodynamics of the Douro River estuary, exchange coefficients are estimated. Fluxes throughout the estuary are computed for the following parameters: chlorophyll, bacteria, planktonic viruses, nutrients, and ammonia.

Internal Tides in the Setúbal Canyon (Portugal)

RESEARCHERS: Associate Professor Mario E.C. Vieira, LCDR F. Coelho PN, and A. Clemente (Portuguese Hydrographic Institute)
SPONSOR: Portuguese Hydrographic Institute

The Setúbal submarine canyon starts its descent through the narrow Portuguese continental shelf at depths of about 50 m, attaining abyssal depths of 4000 m after running for about 100 km. This investigation focuses on the hydrodynamics at the head of the canyon and adjacent shelf through the analysis of hydrographic data taken by the Hydrographic Institute. The hypothesis is that tidal and atmospheric forcing determine the injection of energy from the open ocean into the canyon and onto the shelf, whereupon the vertical structure of the column responds at inertial and subtidal frequencies. A linear model is giving encouraging results. This is an ongoing project, started during the first investigator's sabbatical in spring 1998.

A Study of the Lower Douro River Estuary (Portugal) During One Tidal Cycle

RESEARCHERS: Associate Professor Mario E.C. Vieira and A. Bordalo (Porto University)
SPONSOR: Porto University (Portugal)

Observations of salinity, temperature, currents and oxygen concentration are made at 6 stations spread throughout the lower Douro estuary over one complete tidal cycle in May 2000. Longitudinal cross-sections of density and velocity elucidate the behavior of the salt wedge during a low river flow regime. Vertical profiles allow the study of stratification and its relationship to tidal forcing. Diffusive coefficients are calculated.

Independent Research

Testing the Extraction of Marine Atmospheric Boundary Layer Statistics from Synthetic Aperture Radar Using Comparisons with Bulk Statistics

RESEARCHER: Assistant Professor Todd D. Sikora

An algorithm has been developed to extract marine atmospheric boundary layer statistics, such as the Obukhov length and the surface buoyancy flux, from wind images derived from RADARSAT synthetic aperture radar (SAR) data. The algorithm has been tested against bulk-derived statistics from coincident buoy data from off the east coast of the United States. Agreement is encouraging. The rate of acquisition of RADARSAT SAR-derived wind imagery available to the investigators of the proposed research is scheduled to increase. Imagery will be available over the Gulf of Alaska as well as off the east coast of the United States in conjunction with the National Oceanic and Atmospheric Administration-sponsored Storm Watch program. Therefore the potential for robust testing of the SAR algotithm will exist. It is proposed that this testing take place. The proposed research should be viewed as a test of an algorithm that, if successful, can compete with the bulk estimates of MABL statistics from buoy data. Questions to be addressed include the influence of the surface wave state, the synoptic and mesoscale meteorological environment, pixel size, and the averaging window size of the SAR wind imagery on the performance of the SAR algotithm.

Synthetic Aperture Radar as a Tool for Investing Polar Mesoscale Cyclones

RESEARCHER: Assistant Professor Todd D. Sikora

Polar mesoscale cyclones are intense vortices that form in cold, marine air masses poleward of major jet streams and frontal zones. Synthetic aperture radar (SAR) should be considered as a potential tool for the study of polar mesoscale cyclones because of its ability to remotely sense, at least qualitatively, the high-resolution near-surface wind field independent of daylight and cloud conditions. Four case studies demonstrating this ability are presented. SAR imagery from the Canadian Space Agency's RADARSAT are compared to corresponding infrared imagery, surface analyses, and upper-air analyses. In three of the four case studies, it is argued that the addition of SAR imagery to the process of generating a manual surface analysis would have lead to a better product. Moreover, it is demonstrated that the SAR imagery reveals a host of marine-meteorological phenomena in the vicinity of the polar mesoscale cyclones including atmospheric gravity waves, roll vortices, and cellular convection.

Because of the high-resolution attributes of SAR imagery such as those demonstrated in the present research, SAR shows promise to aid the forecaster and researcher in the study of marine-meteorological phenomena such as polar mesoscale cyclones.

Observations of a Progressive Warm-Fresh Oceanic Front and a Cool-Moist Atmospheric Front at Duck, North Carolina

RESEARCHER: Assistant Professor Todd D. Sikora

This paper presents a unique set of observations of nearly coincident and progressive oceanic and marine atmospheric boundary layer (MABL) fronts in a coastal zone. The event was observed during the afternoon of 12 May 1996 at the United States Army Corps of Engineer, Coastal Engineering Research Center, Field Research Facility pier at Duck, North Carolina. The oceanic front was warm and fresh. Current and sea surface roughness variability accompanied the oceanic front. A marked MABL front preceded the oceanic front by several minutes and had characteristics of a sea breeze front. This MABL front separated warmer and dryer pre-frontal air from cooler and moister post-frontal air. Wind vector and sea surface roughness variability accompanied the MABL front. Radar backscatter from the sea surface is combined with supporting data to identify each front and calculate its corresponding velocity. Variations in radar backscatter from the sea surface across each front are compared to corresponding variations in wind speed, wind direction, and air-sea temperature difference.

Using Synthetic Aperture Radar in the Forecasting of Polar Mesoscale Cyclones

RESEARCHER: Assistant Professor Todd D. Sikora

The unpredictable weather and lack of in situ data in the Bering Sea warrants the experimentation with new forms of forecasting tools in the region. Synthetic aperture radar (SAR) is well suited for use in weather prediction in the Bering Sea because its radiation is mainly unattenuated by the atmosphere, can be used day or night, and can image the effects of the near-surface wind on the ocean surface. Of particular interest is the ability of SAR to image polar mesoscale cyclones (PMCs). These storms can form unexpectedly and contain winds that are dangerous to unsuspecting vessels at sea. SAR is currently being introduced to the National Weather Service Forecast Office Anchorage (NWSFOA) along with products derived from it. As a precursor to their use of the data, a meteorologist at NWSFOA was asked to produce a surface reanalysis for three days when SAR imaged PMCs. The results show that in these cases, the SAR data led to a significant difference between the original surface analysis and the reanalysis.

Satellite Synthetic Aperture Radar Signatures of Deep Atmospheric Convection over the Atlantic Ocean

RESEARCHER: Assistant Professor Todd D. Sikora

A case study of a particularly severe cold air outbreak over the North Atlantic Ocean is described. Nearly coincident RADARSAT satellite synthetic aperture radar and NOAA satellite Advanced Very High Resolution Radiometer imagery illustrate many interesting features of this cold air outbreak as it spread from the northeast coast of the United States to the Gulf Stream. In addition, National Weather Service rawinsonde data, National Data Buoy Center buoy data, and Woods Hole Oceanographic Institute Coastal Mixing and Optics mooring data are presented in support of a conceptual model of the marine atmospheric boundary layer processes involved in this outbreak. This conceptual model shows how this case is similar to that of a cold air outbreak over the Great Lakes. The clouds begin to appear some distance offshore and then increase in horizontal extent in the downwind direction, with a subsequent jump in size downwind of the Gulf Stream north wall. The SAR provides valuable information about the spatial scale of the eddies that aids in the interpretation of this case study.

Gravity Waves Can Directly Influence Surface-Layer Wind Stress in a Convective Boundary Layer

RESEARCHER: Assistant Professor Todd D. Sikora

Atmospheric internal waves (called "gravity waves" here) have been observed at all levels of the atmosphere where the air is stably stratified. Indeed, a region of stable stratification has been generally considered a prerequisite for not only the production but also the support of significant wind variations associated with gravity waves. Therefore, it should be difficult for gravity waves to manifest themselves in deep, well-mixed regions of the atmosphere such as within a highly convective atmospheric boundary layer. Here, we show two case studies over Lake Superior that indicate the superposition of terrain-forced gravity waves on a highly convective boundary layer during cold air outbreaks over Lake Superior. The first contains the superposition of gravity waves and cellular convection; the second contains the superposition of gravity waves and roll convection. These case studies are based on analysis of nearly coincident Advanced Very High Resolution Radiometer (AVHRR) and RADARSAT-1 Synthetic Aperture Radar (SAR) imagery, along with in-situ profile measurements. The simultaneous presence of gravity waves and convection is evident in both cloud patterns captured by AVHRR imagery and in lake-surface roughness variations captured by the SAR imagery. Of particular interest is the fact that wind variations associated with the gravity waves manifest themselves not only in the inversion where these features are generated - but also as surface wind speed variations on the surface of Lake Superior at the base of the convective boundary layer, where the atmosphere is well-mixed.

Research Course Projects

Differences in Bulk and Satellite-Derived SST and their Relation to Air-Sea Temperature Difference

RESEARCHER: Midshipman 1/C Andrew Ceniseroz, USN
ADVISER: Dr. Kenneth S. Casey
(Commander, Naval Meteorology and Oceanography Command Research Chair, CNMOC)

In situ observations extracted from the 1998 World Ocean Database containing air temperature and in situ sea surface temperature (SST) were collocated with satellite-derived skin SST from the Advanced Very High Resolution Radiometer Pathfinder algorithm to correlate air-sea temperature difference (ASTD) with skin-bulk SST differences, in an attempt to determine the relationship between ASTD and skin-bulk SST difference on a global scale. Results indicate that if the air temperature is warmer than the in situ SST (negative ASDT), then the satellite-derived skin SST is greater than the in situ SST (positive Pathfinder bias). Conversely, if the air temperature is cooler than the in situ SST (positive ASTD), then the satellite-derived skin SST is less than the in situ SST (negative Pathfinder bias). The dataset is analyzed for seasonal and latitudinal variations of this relationship. The relationship between bulk-skin SST differences and ASTD is compared to similar data from May and Holyer (1993) and an evaluation of the Pathfinder algorithm is discussed.

Mathematical Modeling of Atmospheric Gravity Waves

RESEARCHER: Midshipman 1/C James Cook, USN
ADVISER: Associate Professor David R. Smith

Scientific research frequently utilizes mathematical models to improve comprehension of complicated processes. Atmospheric gravity waves, free oscillations between density stratified layers, are one meteorological phenomenon that benefit from modeling techniques. They play a significant role in the atmosphere's energy balance and produce clear air turbulence. These wave interactions within the boundary layer are of special interest to weather analysts and the public at large. Beginning with the fundamental equations of motion and founding assumptions, solutions for gravity waves' horizontal and vertical velocities are derived. Two dimensional component velocities are plotted over time with the Mathematica program to gain insight into gravity waves' characteristic behavior.

Computer-Aided Visualization and Animation of Ocean Wave Dynamics

RESEARCHER: Midshipman 1/C Charles F. Gould, USN
ADVISER: Captain Dennis J. Whitford, USN

Ocean waves are the most recognized phenomena in oceanography. Students majoring in oceanography first encounter the complex mathematical theories of these surface gravity waves in upper level undergraduate and lower level graduate courses. Linear wave theory is the simplest theory which mathematically models these waves, yet its complex mathematical equations are often difficult and confusing to students. This difficulty is due to linear wave theory's inherent dependence on time and space along with its mixture of linear, hyperbolic, and trigonometric functions in its equations. As a result, verbal descriptions and two-dimensional illustrations are often insufficient for in-depth student comprehension. Thus, computer-aided visualizations and animations are a welcome pedagogical supplement to traditional methods of instruction.

We wrote a MATLAB7 software program to compute, visualize, and animate various ocean wave dynamics topics for instructional purposes. These topics include: water particle orbital paths, displacements, velocities and accelerations; static, dynamic and total sub-surface pressures; and velocity potentials and streamlines. By using our provided computer code, others may produce these visualizations of ocean wave dynamics without the benefit of an extensive background in computer programming.

Annapolis Hurricane Haven Study

RESEARCHER: Midshipman 1/C Joseph J.Kato, USN
ADVISER: Commander Raymond M. Robichaud, USN

The U.S. Navy recognizes the hazards that severe weather presents to ships in port. To minimize these hazards, the Marine Meteorology Division of the Naval Research Laboratory (NRL) periodically evaluates major ports for hurricane haven suitability. The goal of the Annapolis study is to provide guidance in assessing a hurricane's threat and likely impact on the Annapolis area to give captains an informed choice of options. The study includes useful port and climatology information, and model data that is presented to facilitate better understanding of a given situation. The climatological and model data was prepared by NRL. Interpretation of the data resulted in the following conclusion: although hurricanes rarely influence the area with severe weather, Annapolis should not be considered a haven. Should a major tropical cyclone pass close by, ships in the main anchorage would experience excessive winds. In the constricted channel of Chesapeake Bay, the danger of dragging anchor would necessitate movement of the ships from Annapolis.

Differences in Bulk and Skin SST and Their Relation to Wind Speed

RESEARCHER: Midshipman 1/C Patrick C. Marvil, USN
ADVISER: Dr. Kenneth S. Casey
(Commander, Naval Meteorology and Oceanography Command Research Chair, CNMOC)

In situ observations extracted from the 1998 World Ocean Database containing wind speed, bulk SST, and other parameters are collocated with satellite derived skin SSTs from the Pathfinder + erosion dataset in an attempt to correlate wind speed with bulk-skin SST differences. This collocation process yields a dataset for the years 1985 through 1990 that covers a large portion of the globe. This dataset is analyzed for trends between wind speed and bulk-skin SST differences. Overall statistics for all observations show no clear relationship.

Observations separated by day and night then grouped separately by latitude and month indicate daytime satellite skin SSTs tend to be warmer than their corresponding bulk SSTs, while nighttime satellite skin SSTs are colder during low wind speed conditions. Overall daytime bulk-skinSST bias (-0.03 degree C) is negative while the nighttime bias (0.15 degree C) is positive, consistent with a diurnal heating and cooling of the skin. At higher wind speeds the bias difference between day and night are much smaller, indicating that the wind disrupts the skin and reduces the diurnal effect.

The Influence of Surface Waves on Momentum Exchange

RESEARCHER: Midshipman 1/C Timothy McGeehan, USN
ADVISER: Lieutenant Michiko J. Martin, USN

As wind blows over the surface of the ocean, there is an exchange of momentum. This momentum flux can be only calculated directly by the direct covariance method, which is a simple calculation of the Reynolds stress. However, measuring the data that make up the inputs for this method is difficult to do on a moving platform, such as a ship at sea. Therefore, several other methods have been introduced to model the momentum flux using more easily measured variables. The bulk aerodynamic method and the inertial dissipation method are two of these methods. Using MATLAB and data collected by the Woods Hole Oceanographic Institution as part of the Coastal Mixing and Optics Program for the Office of Naval Research, these two models were simulated to determine the momentum flux for selected cases of rising and decaying seas. These results were compared to those obtained by the direct covariance method, which was used as a baseline. It was postulated that the bulk aerodynamic method would give skewed data due to the Charnock constant within it which assumes a fully developed sea, and the inertial dissipation method would be affected by the similarity theory on which it relies. It was found that both methods would be affected by the similarity theory on which it relies. It was found that both methods performed better for cases of rising seas than they did when compared to results using the whole record. The methods both gave similar momentum flux estimates to the whole record in cases of declining seas.

Anomalous Cloud Lines over the Chesapeake and Delaware Bays

RESEARCHER: Midshipman 1/C Erin O'Marr, USN
ADVISER: Assistant Professor Todd D. Sikora

Anomalous cloud lines over the Chesapeake and Delaware Bays have been observed in numerous National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer (AVHRR) images. These cloud lines tend to be oriented along the long-axis of the bays and stand out as being fundamentally different in shape and brightness from neighboring clouds. The Ocean Remote Sensing Group at the Johns Hopkins University Applied Physics Laboratory has archived AVHRR images covering the Chesapeake and Delaware Bays since 1996. Two years worth of this data has been reviewed and 75 cases of anomalous cloud lines associated with the Chesapeake and Delaware Bays have been found. We chose to concentrate this study on two robust cases. The first case is from 11 October 1996 and the second is from 23 October 1998.

Local National Weather Service Forecasters are aware of these cloud lines and they have speculated that the phenomena are the result of thermal plumes over the Bays during cold-air outbreaks. While this hypothesis is plausible, there is evidence that the cloud lines are anthropogenic in nature. We believe the cloud lines are ship-induced. We have connected the origins of the cloud lines in our case studies to diesel ships transiting up the Bays. Additional evidence is periodic geometrical irregularities found within several of the cloud lines and the up-bay growth of several of the cloud lines with time.

The Influence of El Niño and La Niña on Tornado Occurrence in the United States

RESEARCHER: Midshipman 1/C Adam Rosensweet, USN
ADVISER: Associate Professor David R. Smith

El Niño is a phenomenon that has far reaching implications for global climate. It influences a wide range of meteorological and oceanographic occurrences, but the totality of its effects are not yet fully understood. This paper examines the effect of El Niño upon tornado formation in the United States. A comparison of annual tornado frequency data from years with high, low, and moderate levels of the Multivariate El Niño Index provides evidence of a correlation between ENSO and the number of tornadoes within the country. Annual tornado frequency was found to increase during El Niño years. This result was especially true in the Midwest, the region often referred to as "Tornado Alley." Additional research about tornado intensity and the relationship during La Niña years should be conducted to complete the entire picture of this relationship.

Publications

FOERSTER, John W., Professor, "Copper Sensor System for Unattended Marine Operations II. Development of a Polymer Sensor and Field Tests," SPIE. 3856:128-139.

A major source of ionic copper [Cu(I) and (II)] trace metal contamination in the marine environment is the copper containing anti-fouling coatings on ship hulls. Tracing this contamination is difficult because the ionic copper released from these coatings complexes rapidly with organic and inorganic ligands in the water column. This research examines the potential for using the organic dye 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (Bathocuproine=BCP) embedded in the ionomeric polymer, Nafion 117, as a sensor for quickly measuring ionic copper in seawater. Results show the Nafion 117 containing BCP measures Cu(I) within 17% of measurements made with the Standard Method bathocuproine di-sulfonic acid (BCS) procedure. To measure total ionic copper with the membrane probe, the reductant, hydroxylamine-hydrochloride, is added to the sample. The use of the polymer with Bathocuproine (BCP) allows for a rapid optical measurement. Response times depend on the size of the membrane used. Presently, the optical comparator using a 2 x 3 cm ($6cm^2$) membrane takes 20 minutes to develop color. A comparator has no electronic parts and requires only a comparison of color depth to determine the level of ionic copper in the sample. This makes it useful for monitoring. Therefore, the Nafion 117 polymer impregnated with Bathocuproine (BCP) is a rapid method useful for detecting ionic copper released into the marine environment.

FOERSTER, John, W., Professor, "Runoff Induced Hazardous Algalblooms," The People, The Coast, The Ocean-Vision 2020 ASCE Coastal Zone 1999, pp. 241 - 244.

Coastal zone managers and regulators need a rapid analysis tool to assist in decisions concerning hazardous algal blooms (HAB). In recent years, the HAB have become a more frequent coastal zone problem. Many scientists and managers assume an HAB is a function of increased loading of the coastal marine environment with nitrates and phosphates. They assume that these nutrients, coupled with warm water temperatures and a brackish salinity contribute to the onset of a bloom. If this is true, why do the HAB not become a continuing and constant feature of water masses in the coastal zone? In most coastal zone regions, nutrients are in ample supply and environmental conditions are met in the summer. There must be other environmental factor(s) that induce this explosive growth. If so, what is this trigger and is it predictable? Searching for the existence of this "trigger," we test the hypothesis that runoff from intense summer storms creates the conditions leading to the HAB. To study this, we use climatological data, stream flow measurements, environmental data, satellite AVHRR data, and Weather Radar 86 collections for the summer of 1997 in the Pocomoke River/Pocomoke Sound area of the Central Chesapeake Bay. During August of 1997, the dinoflagellate, Pfeisteria piscicida, became a significant HAB. Intense, localized rainfall precedes both the August 6, and August 26, 1997, outbreaks and subsequent fish kills. During each storm event, the water temperatures drop 5°-6° C and then stabilize at a lower temperature. In this period of temperature stability, the Pfiesteria bloom. We conclude that localized intense rainfall events coupled to a stable lower temperature are a key useful for indicating the onset of an HAB. With Pfiesteria, food safety and public health are a primary concern. Therefore, since rainfall events and lower stable water temperatures seem to correlate with the Pfiesteria outbreaks, coastal zone managers have a tool to assist in making decisions and deploying treatments. In addition, we discuss some remedial solutions.

GUTH, Peter L., Professor, "Quantifying and Visualizing Terrain Fabric from Digital Elevation Models" in Diaz, J., Tynes, R., Caldwell, D., and Ehlen, J., eds., Geocomputation 1999: Proceedings of the 4th International Conference on GeoComputation, Fredericksburg, Virginia, USA, 25-28 July, 1999, CD-ROM ISBN 0-9533477-1-0. Available online at http://www.geovista.psu.edu/geocomp/geocomp99/index.htm.

Digital elevation models (DEMs) yield a terrain classification based on three variables: elevation, ruggedness, and topographic fabric or grain (tendency to form linear ridges). To quantify fabric, the analysis extracts eigenvectors and eigenvalues from a 3 by 3 matrix of the sums of the cross products of the directional cosines of the surface normals at each point in the DEM. This fabric measures a point property of the DEM and the underlying topographic surface, but the property depends on the size of the region considered. This property varies in a systematic way, both spatially over a region and at a single point as the region size varies. Visualizing this organization of topography requires a variety of graphical techniques, including contoured stereographic projections of surface normals, graphs showing the variation

in ruggedness and fabric strength as a function of analysis region size, colored maps showing the strength and orientation of the fabric, and contour or reflectance maps with the direction and strength of the fabric overlaid by vectors. Animations showing how these parameters vary with region size greatly assist in the analysis process.

GUTH, Peter L., Professor, (co-author), "Serving Spaghetti: Displaying Vector Data in a Soldier-friendly System," Proceedings of the Vector Moving Map Symposium, sponsored by the Naval Research Lab, Alexandria, VA, 3-4 August 1999. Available online at http://postoffice.nrlssc.navy.mil/mmc/Symposium/Proceedings/Frames.htm

TerraBase II provides a training system for introducing soldiers to digital topographic data. TBII attempts to intelligently and rapidly display data appropriately for warfighters. Original versions concentrated on raster data but a major effort in the summer of 1999 included vector data, both independently or overlaid on raster data. Vector data allows many choices for display, appropriate for the sophisticated user, but baffling to typical soldiers who just want the map data displayed on screen. Vector data needs smart reformatting to leave the GIS realm of fine cuisine and enter the foxholes as MREsCMaps Ready to Exploit.

SIKORA, Todd D., Assistant Professor, (co-author), "Testing the Diagnosis of Marine Atmospheric Boundary Layer Structure from Synthetic Aperture Radar," The Johns Hopkins Applied Physics Laboratory Technical Digest, 21, 94-99. (Invited paper)

A method for calculating Obukhov lengths and drag coefficients from high-resolution synthetic aperture radar (SAR)-generated wind speed imagery is tested. The wind imagery were created from six RADARSAT scenes collected off the East Coast of the United States during cold air outbreaks in the winter of 1997. Comparisons are made between the drag coefficient and Obukhov lengths obtained from the SAR method and those obtained from the Tropical Ocean-Global Atmosphere Coupled Ocean-Atmosphere Response Experiment 2.5 Bulk Algorithm which uses corresponding buoy data as input. In general, the drag coefficients are in good agreement. Agreement is less precise between the two methods when comparing Obukhov lengths. It is important that the SAR imagery be inspected for the signature of convection (mottling) before implementation of the SAR method. Potential sources of disagreement between the results of the two methods are discussed.

SIKORA, Todd, D., Assistant Professor, (co-author), "On the Extraction of Atmospheric Structure from Synthetic Aperture Radar Imagery," Preprints, International Geosciences and Remote Sensing Symposium 1999, IEEE, Hamburg, Germany, 28 June-2 July, 1972-1974. (Invited Paper).

Synthetic aperture radar (SAR) imagery can be converted to neutral wind imagery using a standard transfer function. Two methods have previously been presented which employ Monin-Obukhov and mixed layer similarity theory to produce Obukhov length, convective velocity scale, buoyancy flux, and stability corrected wind speed from the SAR-derived neutral wind imagery. These procedures are based on the variance and spectral shape of the neutral wind imagery which are functions of the degree of convection in the marine atmospheric boundary layer (MABL). The ability of SAR to reveal the existence of convection (made evident by mottling of the image) is, among the other things, a function of the MABL static stability and mean wind speed (the Richardson Number). In the presence of MABL convection, it is reasonable to expect that as the static stability and mean wind speed change, mottling variability will also change. An increase or decrease in MABL static stability will cause a corresponding decrease or increase in mottling variability, all else being equal. It is therefore reasonable to expect that there is a static stability/mean wind speed limit in SAR=s ability to detect the presence of MABL convection. This limit is when the mottling variability approaches zero but the MABL is still convective, not neutral. This poses a potentially serious problem when employing SAR for the above mentioned MABL techniques. The current research will quantify this potential problem by comparing SAR-derived estimates of Obukhov length with in situ estimates of Obukhov length under varying degrees Richardson Number.

SIKORA, Todd, D., Assistant Professor, (co-author), "Anomolous Cloud Lines over the Chesapeake and Delaware Bays," Preprints, Tenth Conference on Interaction of the Sea and Atmosphere, AMS, Fort Lauderdale, FL, 29 May - 2 June 2000, pp. 39-40.

Anomalous cloud lines over the Chesapeake and Delaware Bays have been observed in numerous National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer (AVHRR) images. These cloud lines

tend to be oriented along the long-axis of the bays and stand out as being fundamentally different in shape and brightness from neighboring clouds. The Ocean Remote Sensing Group at the Johns Hopkins University Applied Physics Laboratory has archived AVHRR images covering the Chesapeake and Delaware Bays since 1996. Two years worth of this data has been reviewed and 75 cases of anomalous cloud lines associated with the Chesapeake and Delaware Bays have been found. We chose to concentrate this study on two robust cases. The first case is from 11 October 1996 and the second is from 23 October 1998.

Local National Weather Service Forecasters are aware of these cloud lines and they have speculated that the phenomena are the result of thermal plumes over the Bays during cold-air outbreaks. While this hypothesis is plausible, there is evidence that the cloud lines are anthropogenic in nature. We believe the cloud lines are ship-induced. We have connected the origins of the cloud lines in our case studies to diesel ships transiting up the Bays. Additional evidence is periodic geometrical irregularities found within several of the cloud lines and the up-bay growth of several of the cloud lines with time.

SIKORA, Todd D., Assistant Professor, (co-author), "Anomalous Cloud Lines off the East Coast of the United States," Preprints, Ship Detection in Coastal Waters Three Day Workshop, AMRS, Nova Scotia, 31 May - 2 June 2000, available on-line at http://www.amrs.org/pdf%20files/sikora.pdf.

Anomalous cloud lines over the Chesapeake and Delaware Bays have been observed in numerous National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer (AVHRR) images. These cloud lines tend to be oriented along the long-axis of the bays and stand out as being fundamentally different in shape and brightness from neighboring clouds. The Ocean Remote Sensing Group at the Johns Hopkins University Applied Physics Laboratory has archived AVHRR images covering the Chesapeake and Delaware Bays since 1996. Two years worth of this data has been reviewed and 75 cases of anomalous cloud lines associated with the Chesapeake and Delaware Bays have been found. We chose to concentrate this study on two robust cases. The first case is from 11 October 1996 and the second is from 23 October 1998.

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SMITH, David R., Associate Professor, (co-author), "Meeting Report on the Eighth AMS Symposium on Education", *Bulletin of the American Meteorological Society*, 81(2), 305-312. (2000).

The American Meteorological Society held its Eighth Symposium on Education in conjunction with the 79th Annual Meeting in Dallas, Texas. The theme of this year's Symposium was "Enhancing Public Awareness of Weather and Climate Prediction". Forty oral presentations and 58 poster presentations summarized a variety of educational programs or examined educational issues for both the precollege and university levels. There was also a joint session with the 11th Conference on Applied Climatology and a special session on uses of educational technology for effective teaching and learning. Over 200 people representing a wide spectrum of the Society attended one or more of the sessions in this two-day conference. The program for the Eighth Symposium on Education can be viewed in the October 1998 issue of the *Bulletin.*

SMITH, David R., Associate Professor, (co-author), "Water in the Earth System(WES): An Online Distance Learning Program for Precollege Teacher Enhancement and Leadership Training," *Preprints of the 9th AMS Symposium on Education*, Amer. Meteor. Soc., Boston, MA, 62-64. (2000).

The American Meteorological Society (AMS) was recently awarded a major grant from the National Science Foundation to conduct a Teacher Enhancement Project with a strong leadership component. An innovative Internet-based distance-learning course directed toward precollege teachers will be developed and implemented nationwide. The course, Water in the Earth System (WES) Online, will incorporate inquiry-based instructional strategies and a holistic concept of Earth from oceanic, atmospheric and terrestrial water and problem-focused perspectives. Course participants will be prepared

as WES resource teachers. They will demonstrate, through investigations of the global water cycle, the value of Internet access to environmental information in classroom applications. All teachers involved will be prepared to promote Earth system studies across the school curriculum in support of the National Science Education Standards. The United States Naval Academy, the U.S. Navy, the National Oceanic and Atmospheric Administration, and the State University of New York at Brockport will provide assistance in the program. The project will develop and implement a graduate three credit-hour distance-learning course partially delivered by Internet that introduces over 1600 teachers to scientifi-cally authentic and pedagogi-cally sound learning activities. As WES resource teachers, the course partici-pants will interact with an estimated 16000 teachers (and 160000 students) in their home schools within two years of taking the course. A core group of 40 teacher Local Implementation Team leaders will be trained to provide course implementation and follow-up leadership.

SMITH, David R., Associate Professor, (co-author), "The Effect of El Niño on the Weather of U.S. Cities", *Preprints of the 11th AMS Symposium on Global Change Studies*, Amer. Meteor. Soc., Boston, MA, 113-116. (2000).

Studies have shown that El Niño alters the tracks of extratropical cyclones to the south over North America during the winter months. This shift from the normal tracks of storms results in differences in weather conditions. In this study an analysis of data sets for fourteen different stations across the continental United States was conducted to determine the effects of El Niño on the normal weather conditions of U.S. cities. The analysis was performed for the winter months of December 1997 through March 1998 to determine deviations from normal due to the changes associated with the 1997-1998 El Niño. This analysis was accomplished by calculating the deviations from 30-year normals for both temperature and precipitation on a monthly basis. All of these stations' weather changed due to the El Niño event. Furthermore, the results show that most stations experienced an increase in precipitation and temperature. Also, the southern-most stations deviated further from normal than did the northern-most stations.

SMITH, David R., Associate Professor, (co-author), "The Effect of La Niña on the Weather of U.S. Cities," *Preprints of the 11th AMS Symposium on Global Change Studies*, Amer. Meteor. Soc., Boston, MA, 109-112. (2000).

La Niña has been shown to shift poleward the tracks of extratropical cyclones traversing the North American continents during winter months. An analysis of extra-tropical cyclones during the winter of 1998-99 corroborates this phenomenon. Given such a shift from the normal track of winter storms, one would expect that this would have an effect on weather conditions. In this study, data sets for fourteen different stations across the United States was examined to determine the effects of La Niña on the normal weather conditions of U.S. cities. This study reveals the specific effects on the weather for these stations due to the 1998-99 La Niña. An analysis was completed for the period of December 1998 through March 1999, to determine the deviations from normal due to the changes associated with the 1998-99 La Niña. Temperature and precipitation data were collected for the period of interest.

Deviations from 30-year normal values for both temperature and precipitation on a monthly basis were calculated, plotted in a spreadsheet and graphed. Cooler and drier conditions were expected for the La Niña event. For the stations selected, the weather con-ditions did show significant deviations from normal due to the La Niña, but in many cases the temperatures were still above normal. The precipi-tation had much more distinct results. Most of the southern stations were much drier than normal, as nearly all storms passed to the north. The northern stations were either at or above normal as the storms tracked across the northern United States. The greatest deviations were experienced in stations along the west coast and most closely experienced the expected weather conditions for a La Niña event. This paper will present results collected during the winter of 1998-99 to determine the effect that the La Niña during this period had on the temperature and precipitation on fourteen stations in the United States compared to normal winter conditions. In addition, it will also examine variations in temperature and precipitation to the winter of 1997-98, an El Nino year, and to the winter of two other La Niña years (1988-89 and 1995-96).

SMITH, David R., Associate Professor, (co-author), "A Survey of College Women: Factors that Contribute to the Choice of a College Major," *Preprints of the 5th International Conference on School and Popular Meteorological and Oceanographic Education*, Australian Meteorological and Oceanographic Society, Melbourne, Australia, 128-131. (1999).

On the collegiate level, the number of women choosing to major in science, especially the physical sciences, traditionally has been disproportionately small. Studies suggest women choose science as a college major at only one-third the

number of their male counterparts. Furthermore, educational researchers have noted a significant number of women who change their major from science to another field before graduation. Clearly, this trend makes an important contribution to the under-representation of career women in scientific fields.

This study is an attempt to determine factors influencing the choice of a college major by women attending the United States Naval Academy. The Naval Academy, with a strong academic tradition in science, mathematics, and engineering, naturally attracts high school students who are interested in science. The admissions criteria at this institution are some of the most stringent in the country, requiring applicants to meet the very highest standards in academics, leadership, physical conditioning and character development. Moreover, since the Naval Academy traditionally has a highly technical core curriculum including courses in science, mathematics and engineering for all students regardless of major, this suggests that all prospective students selected for admission would have a pre-college academic background with sufficient rigor in mathematics and science to successfully complete the demanding program.

A survey of female students at the Naval Academy has been conducted. A questionnaire was distributed to women majoring in a science (Oceanography) and a humanities (English) discipline. The questionnaire was designed to determine their major and reason for choice, ultimate educational goals, involvements in athletics and extracurricular activities, role models, high school background and experiences, including science, mathematics and computer science courses. The questionnaire was distributed to all women in the three upper classes (freshmen do not have majors at the Naval Academy) for the Oceanography (N=70) and English (N=58) majors. The number of respondents was quite high (Oceanography: N=47; English: N=29), providing a reasonable sample size for this study. The results provide insight into why female students at the Naval Academy chose their major field of study and the factors which influence that choice.

SMITH, David R., Associate Professor, (co-author), "The Maury Project: A Five-year Retrospective," *Preprints of the 5th International Conference on School and Popular Meteorological and Oceanographic Education*, Australian Meteorological and Oceanographic Society, Melbourne, Australia, 125-127. (1999).

The Maury Project was established in 1994 by the American Meteorological Society (AMS) in cooperation with the United States Naval Academy. This is a pre-college teacher enhancement program on the physical foundations of oceanography, with primary funding from the National Science Foundation. Since its initiation both the Navy (Naval Meteorology and Oceanography Command and the Office of Naval Research) and NOAA (National Environmental Satellite, Data, and Information Service and the National Ocean Service) have become contributing members in this unique educational partnership. The primary activity of the Maury Project has been annual two-week summer workshops for teachers on various aspects of physical oceanography. The participant teachers then become peer-trainers, conducting workshops for their colleagues, normally at statewide science teachers conferences, using teacher guides on various topics on the physical aspects of oceanography as the subject matter area of the workshops. These workshops have reached thousands of teachers nationwide over the past five years.

The presentation will focus on the accomplishments of the Maury Project over the past five years, in an attempt to assess its contributions to science education.

Additionally, there will be a look at the future directions of the Maury Project. In particular, the Maury Project is exploring the development of a distance learning course using web-based instruction and activities utilizing actual oceanographic data bases to enhance teachers' background on the physical foundations of oceanography. Such an approach would enable the Maury Project to reach even greater numbers of teachers with the power and versatility of the Internet.

VIEIRA, M.E.C., Associate Professor, "The Long-term Residual Circulation in Long Island Sound," *Estuaries*, 23: 199-207. (2000).

Current meter data were acquired in Long Island Sound over a period of about six months in 1988 at six different transects. The averages of the low-passed residuals represent the contributions from tidal steering and density forcing. It is found that the long-term residual circulation starts out with a classical estuarine pattern at the Race. The flows into and out of the Sound are vertically partitioned by Long Sand Shoal; they gradually revert back to classical vertically layered estuarine circulation as the Central Basin is traversed. Further west, the bottom oceanic water becomes a westward flowing swift jet close to the Connecticut shore, while the East River water is constrained to flow eastward along the Long Island coast. Counterclockwise gyres, identified in the Eastern Narrows and Western Basins, may increase residence times of polluted East River water in the western Long Island Sound.

VIEIRA, M.E.C., Associate Professor, "Pre-college Outreach and Cooperative Programs in Oceanography at the U.S. Naval Academy," *Science Educator*, 9: 14-18, 2000.

The Oceanography Department of the United States Naval Academy (USNA) has embarked in a vigorous effort to support the advancement of education in Oceanography. The purpose is to provide opportunities for the academic and scientific communities to benefit from the expertise and resources available within the Department. Three specific programs will be discussed. The USNA Mentorship/Internship Program involves high school students with research projects being carried out by the Department's faculty. The Maury Project has been designed to enhance the background of pre-college science teachers in several topics in Oceanography, including the coastal and estuarine areas; the main part of the program is a two-week summer workshop including hands-on experience with day cruises in the Chesapeake Bay. A cooperative research project with the United States Environmental Protection Agency pooled resources to carry out a study of the Severn River estuary; midshipmen from the Oceanography Department and from other departments have been involved in collecting and analyzing the data in the classroom and in connection with special research projects. These programs are offered as paradigms suitable for adoption by other academic institutions.

WHITFORD, D. J., Captain (USN) and Associate Professor, "Observations of Current Flow Through the Mouth of the Chesapeake Bay," *Estuaries, Coastal and Shelf Science*, 49, 209-220, 1999.

Seven transects of the narrowly-constricted mouth of the Chesapeake Bay were made using an Acoustic Doppler Current Profiler (ADCP) and Conductivity-Temperature-Depth (CTD) sensor during the period September 16-21, 1996. Data were acquired while participating in the Chesapeake Bay Plume Outfall Experiment (COPE I). Seven CTD stations per transect were conducted across the 17 km wide mouth along with continuous high-resolution ADCP coverage. Although discontinuous, the transect data covered nearly all phases of a generic tidal current cycle. Comparison with wind velocities showed no significant meteorological forcing of currents during the transects. Fresh water discharge from the Bay was well above normal during this period. The resultant flow structure obtained from the ADCP is much more complete than was previously possible with point measurements. Analysis in all tidal phases revealed near-isothermal conditions with horizontal and vertical temperature differences across the mouth rarely exceeding 1.0 ^{o}C in any tidal phase, higher surface salinity to the north coupled with higher subsurface salinity in the Chesapeake Channel, and uni-directional flow from surface to depth. Horizontal and vertical current gradients were found to be quite strong, $O(10^{-3})\,s^{-1}$. A consistent feature found on nearly every ADCP transect was a subsurface flood current core and a surface ebb current core, both on the right side of the main channel in the direction of flow.

WHITFORD, D. J., Captain (USN) and Associate Professor (co-author), "Teaching Geoscience Courses Collaboratively using Compressed Videoconferencing Technology: An Experiment conducted between the United States Air Force Academy and the United States Naval Academy." *Proceedings of the American Meteorological Society's Ninth Symposium on Education*, January 9 – 14, 2000, Long Beach CA, pp. 134 - 136.

During the Spring, 1999 semester, the authors designed, planned, and conducted a series of interactive videoconference (IVC) sessions between the United States Naval Academy and the United States Air Force Academy. The sessions were designed to support a segment of a senior-level course at the United States Air Force Academy (USAFA) titled, The Application of Geosciences to Support Naval Operations and Joint Air Force-Naval Operations. One of the most exciting and beneficial instructional segments of the course were the IVC sessions of the United States Naval Academy (USNA). Although the course was designed primarily for USAFA students, the results of the experiment shed light on the potential of employing distributed or distance learning technologies at both institutions. This paper and the accompanying presentation will describe the design of a distance or distributed learning course, how IVC was integrated into the course, and the results of an assessment of the IVC sessions. In addition, the authors will describe the advantages and challenges of conducting IVC sessions and future plans for using this technology.

WHITFORD, D. J., Captain (USN) and Associate Professor, (co-author), "Computer-Aided Visualization and Animation of Ocean Wave Dynamics," *Journal of Geoscience Education*, 2000, vol 48, pp. 267-272.

Ocean waves are the most recognized phenomena in oceanography. Students majoring in oceanography first encounter the complex mathematical theories of these surface gravity waves in upper level undergraduate and lower level graduate

courses. Linear wave theory is the simplest theory which mathematically models these waves, yet its complex mathematical equations are often difficult and confusing to students. This difficulty is due to linear wave theory's inherent dependence on time and space along with its mixture of linear, hyperbolic, and trigonometric functions in its equations. As a result, verbal descriptions and two-dimensional illustrations are often insufficient for in-depth student comprehension. Thus computer-aided visualizations and animations, accompanied by concurrent oral narration, are a welcome pedagogical supplement to traditional methods of instruction.

We wrote a MATLAB7 software program to compute, visualize, and animate various ocean wave dynamics topics for instructional purposes. These topics include: water particle orbital paths, displacements, velocities and accelerations; static, dynamic and total sub-surface pressures; and velocity potentials and streamlines. By using our computer code, others may produce these visualizations of ocean wave dynamics without the benefit of an extensive background in computer programming.

Technical Reports

FOERSTER, John W., Professor, "Copper Sensor System for Unattended Marine Operations III: Detecting Copper (I) in the Marine Environment with Fiber Optic Technology," NRL REPORT #NRL/MR/6110-00-8442.

Since the ionic forms of copper(I) and copper(II) are toxic in the marine environment, a portable and easy to use, rapid measurement sensor capable of measuring parts per billion (ppb) levels of ionic copper [copper(I) and copper(II)] in the marine environment is needed. This study tests the hypothesis that the organic reagent bathocuproine (BCP) can be immobilized to develop a fiber optic sensor capable of measuring copper(I) in seawater. This work describes the response of a first generation fiber optic/copper(I) probe. Results indicate that the fiber optic probe has sensitivity in the ppb range with a lower detection limit of 17 ppb. In addition, reduction of copper(II) to copper(I) using hydroxylamine hydrochloride allows the fiber optic probe to determine total ionic copper.

Presentations

CASEY, Kenneth S., CNMOC Research Chair, "North Pacific Variability and Climate Patters During the 1997-98 ENSO Event," presented at the Joint TOPEX/Poseidon and Jason-1 Science Working Team Meeting, St. Raphael, France, October 1999.

CASEY, Kenneth S., CNMOC Research Chair, "Oceanic Variability and Climate Patterns from 1993-1998," EOS, Transactions of the American Geophysical Union, Vol 80, No 49, Supplement, p. 301, December 7, 1999, presented at the AGU Ocean Sciences Meeting, San Antonio, TX, January 24-28, 2000.

CASEY, Kenneth S., CNMOC Research Chair, "Satellite SSTs, Ocean "HotSpots" and Coral Bleaching (1982-1998)," EOS, Transactions of the American Geophysical Union, Vol 80, No 49, Supplement, p. 97, December 7, 1999. Presented at the AGU Ocean Sciences Meeting, San Antonio, TX, January 24-28, 2000.

FOERSTER, John W., Professor, "Runoff Induced Hazardous Algal Blooms," at the International Coastal Zone meeting in San Diego, CA, August 1999.

FOERSTER, John W., Professor, "Copper Sensor System for Unattended Marine Operations II. Development of a Polymer Sensor and Field Tests," at the Photonics East meeting in Boston, MA, September 1999.

FOERSTER, John W., Professor, "Inducing An Hazardous Algal Bloom," 5th Shallow Water Conference in Atlantic City, NJ, March 2000.

GUTH, Peter L., Professor, "Teaching Terrain Visualization with a Microcomputer: 100 Digital Topographic Maps Illustrating Physiographic Features," Geological Society of America National Meeting, Denver, CO, 25-28 Oct, 1999.

GUTH, Peter L., Professor, "I'll buy a Dip and Strike," Interactive microcomputer exercise to teach geologic map interpretation: Geological Society of America National Meeting, Denver, CO, 25-28 Oct, 1999.

GUTH, Peter L., Professor, "Serving Spaghetti: Displaying Vector Data in a Soldier-friendly System," Vector Moving Map Symposium, sponsored by the Naval Research Lab, Alexandria, VA, 3-4 August 1999.

GUTH, Peter L., Professor, "Quantifying and Visualizing Terrain Fabric from Digital Elevation Models," Geocomputation 1999, 4th International Conference on GeoComputation, Fredericksburg, Virginia, 25-28 July, 1999.

SIKORA, Todd D., Assistant Professor, (co-author), "On the Extraction of Atmospheric Structure from Synthetic Aperture Radar Imagery," Preprints, International Geoscience and Remote Sensing Symposium 1999, IEEE, Hamburg, Germany, 28 June - 2 July 1999.

SIKORA, Todd D., Assistant Professor, "Boundary Layer Similarity Theory Applied to SAR Wind Imagery," Presented at the Applied Physics Laboratory, University of Washington, 18 August 1999.

SIKORA, Todd D., Assistant Professor, (co-author), "Anomalous Cloud Lines over the Chesapeake and Delaware Bays," Preprints, Tenth Conference on Interaction of the Sea and Atmosphere, AMS, Fort Lauderdale, FL, 29 May - 2 June 2000.

SIKORA, Todd D., Assistant Professor, (co-author), "Anomalous Cloud Lines off the East Coast of the United States," Preprints, Ship Detection in Coastal Waters Three Say Workshop, AMRS, Nova Scotia, 31 May - 2 June 2000.

SMITH, David R., Associate Professor, (with M.C. Parke), "Anatomy of a Nor'Easter: Coping with Rapidly Developing Marine Cyclones," an invited presentation at the Safety at Sea Seminar, Annapolis, MD, (Mar 2000).

SMITH, David R., Associate Professor, (with S.F. Wood and A.M. Siegrist), "The Effect of La Niña on the Weather of U.S. Cities," presented at the 11th AMS Symposium on Global Change Studies, Long Beach, CA, (Jan 2000).

SMITH, David R., Associate Professor, (with S.F. Wood and M.J. Ledridge), "The Effect of El Niño on the Weather of U.S. Cities," presented at the 11th AMS Symposium on Global Change Studies, Long Beach, CA, (Jan 2000).

SMITH, David R., Associate Professor, (with I.W.Geer, J.M. Moran and R.S. Weinbeck), "The Educational Programs of the American Meteorological Society: Developing Partnerships to Enhance K-12 Science Education," presented at the Spring Meeting of the American Geophysical Union, Washington, D.C., (May 2000).

SMITH, David R., Associate Professor, (with I.W. Geer, J.R. Moran, R.S. Weinbeck, M. Ficek, J.P. Mulvany, and R.E. Hallgren), "The AMS Education Program," an invited presentation at the National Science Foundation, Arlington, VA, (Apr 2000).

SMITH, David R., Associate Professor, (with I.W. Geer and J.M. Moran), "The Educational Programs of the American Meteorological Society and the United States Naval Academy: Developing Partnerships to Enhance K-12 Earth Science Education with Navy METOC Assistance," an invited presentation to the Oceanographer of the Navy and Staff, Washington, D.C., (Apr 2000).

SMITH, David R., Associate Professor, (with I.W. Geer, J.R. Moran, and R.S. Weinbeck), "Water in the Earth System (WES): An Online Distance Learning Program for Precollege Teacher Enhancement and Leadership Training," presented at the 9th AMS Symposium on Education, Long Beach, CA, (Jan 2000).

SMITH, David R., Associate Professor, (with I.W. Geer and D.E. McManus), "An Overview of the Maury Project: Teaching the Physical Foundations of Oceanography to Teachers," at the 1999 National Marine Educators Association Annual Conference (Aug 1999).

SMITH, David R., Associate Professor, (with B. Jewell and D.E. McManus), "AMS Maury Project - Pressure blocks education workshop," at the 1999 NMEA Annual Convention, (Aug 1999).

SMITH, David R., Associate Professor, (with J. May-Brett and D.E. McManus), "AMS Maury Project - El Nino "ENSO-lyzer" education workshop," at the 1999 NMEA Annual Convention, (Aug 1999).

SMITH, David R., Associate Professor, (with I.W. Geer and D.E. McManus), "The Maury Project - A Five-Year Retrospective," at the 5th International Conference on School and Popular Meteorological and Oceanographic Education, (Jul 1999).

SMITH, David R., Associate Professor, (with P.K.L. Smith), "A Survey of College Women: Factors that Contribute to the Choice of a College Major," at the 5th International Conference on School and Popular Meteorological and Oceanographic Education, (Jul 1999).

VIEIRA, M.E.C., Associate Professor, "Destratification Processes in a Small Tributary Estuary," presented at the Spring meeting of the Atlantic Estuarine Research Society, Wilmington, NC, 9-12, (March 2000).

VIEIRA, M.E.C., Associate Professor, "The Douro Estuary: a Mesotidal Salt Wedge," presented at the 14th International Estuarine Research Federation conference, New Orleans, LA, 25-30, (September 1999).

WHITFORD, Dennis, J., Captain (USN) and Associate Professor, (co-author), "Teaching Geoscience Courses Collaboratively using Compressed VideoConferencing Technology: An Experiment conducted between the United States Air Force Academy and the United States Naval Academy," American Meteorological Society's Ninth Symposium on Education, Long Beach, CA, (January 2000).

WHITFORD, Dennis, J., Captain (USN) and Associate Professor, "Predicting Tidal Current Core Variability at an Estuary Mouth," Ninth Pacific Congress on Marine Science and Technology, Honolulu, HI, (June 2000).