Oceanography Department

Captain Dennis J. Whitford, USN
Associate Professor and Chair

The U.S. Naval Academy's Oceanography Department executes the largest undergraduate physical oceanography program in the nation. Within this context, the department's Academic Year 2000-2001 research productivity of meteorology, oceanography, and pedagogical research, was especially noteworthy. The department's five tenure track faculty, one Permanent Military Professor, and one externally funded research chair authored 16 refereed articles for publication and made 13 conference presentations, many of which included midshipmen as co-authors.

Thirteen midshipmen completed Independent Research courses under the mentorship of faculty advisors. These midshipmen formally presented their project results to the faculty and to members of the Academic Dean's staff at the end of each semester. Several of these midshipmen went on to present their results at national conferences. Midshipman 1/C Luke A. Whittemore's research project entitled "Mixed Layer Ocean Modeling: Upper Ocean Diurnal Cycles" assisted him in earning recognition as the 2001 Naval Intelligence Foundation Award winner as best Honors student among the five majors which offer an honors program, as well as the Captain C.N.G. Hendrix Oceanography Award winner as the top oceanography major student.

The thirteenth annual Oceanography Summer Yard Patrol (YP) Cruise aboard YP686 was conducted in June 2001. The cruise instructed 21 midshipmen in the rudiments of oceanographic data collection in the littoral environment, while simultaneously covering the seamanship and navigation requirements of the U.S. Naval Academy's Professional Development Division. Seventeen oceanographic stations were conducted, resulting in an extensive collection of biological, chemical, geological and physical oceanography samples and data, as well as meteorological observations. This was the department's third consecutive annual summer cruise where research-quality data was acquired for use by faculty to support publishable refereed research.

In July 2000, the department hosted the seventh Maury Project Summer Workshop for twenty-five K-12 science teachers from the nation and overseas. Enhancing the scientific foundations and teaching methodology for K-12 science teachers in the area of physical oceanography continued as the project's primary focus.

Dr. Kenneth S. Casey, our "Commander, Naval Meteorology and Oceanography Command (COMNAVMETOCCOM) Chair in Remote Sensing", which is an externally-funded position, continued his strong research efforts with several scientific articles submitted for publication in refereed journals.

Sponsored Research

Sea Surface Temperature and Sea Surface Height Variability in the North Pacific from 1993-1999

Researcher: Adjunct Assistant Professor Kenneth S. Casey
Commander, Naval Meteorology and Oceanography Command Research Chair
Sponsor: Command, Naval Meteorology and Oceanography Command (CNMOC)

Correlations between Advanced Very High Resolution Radiometer pathfinder sea surface temperature (SST) and TOPEX sea surface height (SSH) anomalies are calculated for the seven-year period 1993-1999 in the equatorial and North Pacific. These correlations provide measures of SSH and SST co-variability and are obtained using an empirical orthogonal function analysis separately on the two fields and a singular value decomposition method on both fields simultaneously. These correlations reveal distinct SST-SSH states: a warm, elevated period from January 1993 to December 1994; a cooler, lower phase spanning January 1995 through December 1996; and the strongly variable EI Nino Southern Oscillation (ENSO) period

spanning 1997-1999. The relationships between these SST-SSH states and the dominant interannual and interdecadal modes of Pacific variability are investigated through correlations with indices for the Southern Oscillation, Pacific-North American pattern, and Pacific Decadal Oscillation (PDO). When including the tropics, significant correlations with the interdecadal PDO pattern. Additionally, eddy kinetic energy (EKE) levels are used to characterize the surface flow variability during each of these periods. Much greater EKE values are seen in the vicinity of the Kuroshio Extension during 1997-1998 that in the earlier periods. No direct correlations are observed, however, between the climate indices and the average EKE in three subregions of the North Pacific or for the North Pacific as a whole.

Global and Regional Sea Surface Temperature Trends

Researcher: Adjunct Assistant Professor Kenneth S. Casey
Commander, Naval Meteorology and Oceanography Command Research Chair
Sponsor: Commander, Naval Meteorology and Oceanography Command (CNMOC)

Individual sea surface temperature (SST) anomalies are calculated using a satellite-based climatology and observations from the 1994 World Ocean Atlas (WOA94) and Comprehensive Ocean Atmosphere Data Set (COADS) to characterize global and regional changes in ocean surface temperature since 1942. For each of these datasets, anomaly trends are computer-analyzed using a new method that groups individual anomalies into climatological temperature classes. These temperature class anomaly trends are compared with trends estimated using a technique representative of previous studies based on five-degree latitude-longitude bins.

Global linear trends in the data-rich period between 1960 and 1990 calculated from the WOA94 data are found to be 0.14 ± 0.04°C decade^{-1} for the temperature class approach and 0.13 ± 0.04°C decade^{-1} for the five degree bin approach. The corresponding results for the COADS date are 0.10 ± 0.03°C decade^{-1} and 0.09 ± 0.03°C decade^{-1}. These trends are not statistically different at the 95\% confidence level. Additionally, they agree closely with both SST and land air temperature trends estimated from results reported by the Intergovernmental Panel on Climate Change. The similarity between the COADS trends and the trends calculated from the WOA94 dataset provides confirmation of previous SST trend studies, which are based almost exclusively on volunteer observing ship datasets like COADS.

Regional Linear trends reveal a non-uniformity in the SST rates between 1945-1970 and 1970-1995. Intensified warming during the later period is observed in the eastern Equatorial Pacific, the North Atlantic Subtropical Convergence, and in the vicinity of the Kuroshio Extension. Also, despite close agreement globally, localized differences between COADS and WOA94 trends are observed.

New Climatologies and Anomalies from Topex/Poseidon and AVHRR Pathfinder Data

Researcher: Adjunct Assistant Professor Kenneth S. Casey
Commander, Naval Meteorology and Oceanography Command Research Chair
Sponsor: Commander, Naval Meteorology and Oceanography Command (CNMOC)

New climatologies for sea surface height (SSH) and sea surface temperature (SST) are used to create improved anomaly maps from gridded TOPEX/Poseidon altimeter and Advanced Very High Resolution Radiometer (AVHRR) Pathfinder data. The climatologies are created by fitting a cosine function containing annual and semi-annual components to the time series of each parameter at each grid location. The annual and semi-annual components are then removed to yield anomaly time series between 1993 and 1999 for the globe at a resolution of one degree in latitude and longitude.

The annual and semi-annual amplitudes and phases for SSH and SST illustrate interesting features in the global patterns. Time series of the new anomalies are compared to more traditional anomalies created with climatological monthly means, and mean difference maps showing spatially coherent patterns are presented. Furthermore, a singular value decomposition is performed on the new anomalies and compared to a similar analysis using the traditional anomalies to illustrate the improvement in the anomaly data sets.

Pathfinder Sea Surface Temperature Biases and their Relation to Air-Sea Temperature Difference, Wind Speed, and Aerosols

Researcher: Adjunct Assistant Professor Kenneth S. Casey
Commander, Naval Meteorology and Oceanography Command Research Chair
Sponsor: Commander, Naval Meteorology and Oceanography Command (CNMOC)

Biases in NOAA/NASA Pathfinder Advanced Very High Resolution Radiometer (AVHRR) observations of sea surface temperatures (SST) are examined through collocation with in situ data from the 1998 World Ocean Database, the National Center for Environmental Prediction (NCEP) weekly SST analysis, Special Sensor Microwave Imager (SSM/I) wind fields, and the atmospheric absorbing aerosol estimates from the Total Ozone Mapping Spectrometer (TOMS). Relationships between the SST biases and air-sea temperature difference (ASTD), wind speed, and atmospheric aerosol content are characterized.

Observations indicate that when the ASTD is positive (air temperature greater than ocean temperature), then the Pathfinder bias tends to also be positive (Pathfinder SST greater that in situ SST). The converse is also observed. These results indicate a bulk versus skin SST effect in the Pathfinder dataset. Relationships between the wind speed and Pathfinder biases support this observation. Overall, daytime biases are positive while nighttime biases are negative, except at higher wind speeds when the biases are greatly reduced; wind-induced mixing disrupting the skin of the ocean is an explanation consistent with these observations. Global spatial and temporal patterns of ASTD variation are also examined through a comparison of the SSM/I wind fields with the Pathfinder biases.

Significant biases are also observed as a function of atmospheric aerosol content. Monthly climatologies of the daily TOMS atmospheric absorbing Aerosol Index (AI) were compared to similar climatologies of the difference between weekly AVHRR Pathfinder and NCEP blended ship and satellite SST fields. A strong spatial correspondence was identified between areas with high AI values and areas with a large Pathfinder minus NCEP SST bias. Since absorbing aerosols are not detected by the Pathfinder SST Algorithm, the reduction of the infrared energy reaching the AVHRR by the aerosols results in an underestimate of the satellite-derived SST, particularly in those areas which are not well-represented in the Pathfinder Matchup Database.

On The Spot Determination Of Ionic Copper In Natural Waters

Researcher: Professor John W. Foerster
Sponsor: Department of Defense (DoD)
Strategic Environment Research and Development Project

A major source of trace metal contamination in the marine environment is the copper containing anti-fouling coatings on ship hulls. This research proposes to examine the potential of using 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (Bathocuproine = BCP) embedded in the polymer, Nafion 117, as an ionic copper [Cu(I) and Cu(II)] sensing probe. BCP reacts with Cu(I) to give a very intense, visible and stable orange-complex with a unique spectroscopic signal. By adding a reducing agent, Cu(II) can be measured. Therefore, to be useful, the sensor must have

- parts per billion (ppb) detection limits,
- marine environmental immersion capability, and
- the ability to detect the Cu(I) and Cu(II) oxidation state, and
- be able to make reliable measurements in waters of varying salinities.

By this copper species differentiation, the possible sources of the copper such as effluent discharges, ship hulls, or natural sources can be determined. The measurements will allow for the determination of potential effects on the biota and how it will impact the water quality criteria imposed by Environmental Protection Agency. A simple to use, inexpensive monitoring system would aid in the implementation of the Uniform National Discharge Standards (UNDS) Act. This act will mandate some form of sensor/detection system that can address the role of speciation [Cu(I) and Cu(II)] marine environments. To address this need, this proposal has two major objectives. The first major objective is to develop an operationally simple to use and user friendly detection system that allows for the rapid assessment of the major copper ions in the marine environment (harbors, holding tanks, run off, etc.). Next, the second objective addresses the use of the sensor system to further the understanding of copper distributions and speciation in the marine environment with emphasis on those species which may adversely

affect marine environmental quality. Preliminary testing indicates that the Nafion membrane imbedded with BCP adequately detects ppb levels of ionic copper.

GEOSYM Display and Evaluation

Researcher: Professor Peter L. Guth
Sponsor: Topographic Engineering Center, Corps of Engineers

This project developed algorithms and software to display Geosym symbology for Vector Product Format (VPF) data sets. Geosym has been proposed by the National Imagery and Mapping Agency (NIMA) as the standard for the display of all VPF data. There is no software that can display Geosym, making an honest evaluation of the standard impossible. This project was developed to produce a stand alone program to evaluate Geosym, as well as to incorporate the display into TerraBase II.

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 systems, 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 extended the program's capabilities to use data bases and serve as a true geographical information system (GIS). A major training upgrade appeared with the 2 CD set for version 3 of the program, with versions 4 and 5 being released. There were over 46,000 downloads of the program from the U.S. Naval Academy website during the last year.

Sensitivity of a Navy Regional Ocean Model to Nested High-Resolution Atmospheric Model and Scatterometer Wind Forcing

Researcher: Commander Henry Jones, USN
Sponsor: Naval Postgraduate School (NPS)

This research conducted a sensitivity study of a Navy regional ocean model to variable forcing of a high-resolution atmospheric model and satellite scatterometer. The objective was to determine the impact of variable wind stress resolution (data refresh and grid spacing) in coastal areas and the gain in operational effectiveness of current/potential scatterometer satellites. This was accomplished using the wind stress derived from the Couple Ocean Atmospheric Prediction System (COAMPS) and Naval Oceanography Global Atmospheric Prediction System (NOGAPS) to drive the Navy's Pacific West Coast Ocean Model (PWC) during the period 7-20 January 1999. Five runs were made (1-NOGAPS, 4-COAMPS) with the fifth COAMPS run modified by synthetic scatterometer winds. PWC current velocity, temperature, salinity and sea surface height (SSH) output fields were compared with field data (California Cooperative Fisheries Investigation (CALCOFI), Coastal Ocean Highway Frequency Radar (CODAR), moored and drifting buoys and altimetry) using standard statistics, empirical orthogonal functions (EOF) and horizontal/vertical plots.

The Influence of Boundary Layer Dynamics and Thermodynamics on the Diagnosis of Near-Surface Wind Speed by Synthetic Aperture Radar

Researcher: Assistant Professor Todd D. Sikora
Sponsor: Office of Naval Research (ONR)

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 algorithm 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 bulk estimates of Marine Atmospheric Boundary Layer (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 algorithm.

Surface Wind Speed and Fluxes from Synthetic Aperture Radar

Researcher: Assistant Professor Todd D. Sikora (Co-PI)
Sponsor: National Aeronautics and Space Administration (NASA)

Exchanges between the ocean and atmosphere play an important role in moderating climate. A newly developed algorithm obtains surface buoyancy flux, friction velocity, and Obukhov length from Synthetic Aperture Radar (SAR) backscatter over (10-25 km) square areas of the ocean's surface. As well, non-neutral mean wind speed over (1 – 10 km) square regions can be derived from SAR backscatter. Due to its high spatial resolution and global coverage, SAR offers the potential for the development of air-sea flux climatologies. We therefore propose to validate and refine the SAR flux/speed algorithm extensively against buoy data, starting with moderately convective conditions found in the Gulf of Mexico and off of the U.S. coasts, but concentrating on the tropics. The latter comparison will focus on the 95W line of Tropical Atmosphere-Ocean (TAO) buoys spanning the equator, during the time of two research cruises. This region in the eastern equatorial Pacific plays an important role in such climate phenomena as El Nino. Turbulence data taken during the cruises will provide eddy correlation fluxes for comparison to those derived from SAR. As well, wind speed from the ship will be compared to non-neutral wind speed obtained from SAR. The proposed work has two central goals. First, we will improve algorithms which will ultimately make high-resolution surface fluxes and wind speeds available to the climate research community. Second, we will address the role of SAR-observed atmospheric variability, such as tropical rain cells, in modifying surface exchange. We therefore seek to improve the research community's understanding of and ability to quantify the inhomogeneous nature of tropical air-sea exchange.

The Maury Project – Exploring the Physical Foundations of Oceanography

Researchers: Associate Professor David R. Smith and
I.R. Greer (American Meteorological Society)
Sponsors: Commander, Naval Meteorology and Oceanography Command (CNMOC),
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-five 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. This year, numerous presentations were made to outside groups who have related educational outreach efforts.

Water in the Earth System

Researcher: Associate Professor David R. Smith
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. In the summer of 2001, 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 leaning course. This year, materials development and implementation of a pilot program in the Central Maryland region was a focus of the researcher.

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

Researcher: Associate Professor Mário E. C.Vieira
Sponsor: Porto University

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, ammonia.

Independent Research

Using Spaceborne Synthetic Aperture Radar to Forecast Polar Mesoscale Cyclones in the Bering Sea

Researcher: Assistant Professor Todd D. Sikora

The unpredictable weather and lack of *in situ* data in the Bering Sea warrants experimentation with new forms of forecasting tools in this 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.

Synthetic Aperture Radar as a Tool for Investigating 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 atmospheric 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 SAR shows promise to aid the forecaster and researcher in the study of marine-meteorological phenomena such as polar mesoscale cyclones

Co-occurrence of a Progressive Warm-fresh Oceanic Front with 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 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 direction and wind speed variability accompanied the MABL front. The sea surface roughness signatures of both fronts were detected by an X-band pulsed Doppler radar. Supporting data are used to identify each front detected by the radar and to calculate each front's velocity. In an attempt to explain the sea surface roughness variations associated with each front, the radar data are compared to corresponding variations in wind speed, wind direction, and air-sea temperature difference.

Anomalous Cloud Lines over the Mid-Atlantic Coast of the United States

Researcher: Assistant Professor Todd D. Sikora

This exploratory paper develops the basis for two hypotheses concerning the mechanism responsible for anomalous cloud lines often seen in Advanced Very High Resolution Radiometer imagery of the Chesapeake and Delaware Bays in cold air outbreak regimes. One explanation is that these cloud lines are forced in the same manner as Great Lakes lake-effect midlake cloud lines. An alternate, albeit more speculative, explanation is that at least some of the cloud lines in question are ship tracks.

Gravity Waves Can Directly Influence Surface-layer Stress during a Cold Air Outbreak, as shown by Synthetic Aperture Radar

Researcher: Assistant Professor Todd D. Sikora

Synthetic aperture radar (SAR) images of oceans and the Great Lakes have provided a highly detailed means of observing atmospheric boundary layer phenomena such as convection, land breezes, and internal gravity waves. This is possible because the backscattered radiation detected by SAR can be dominated by scattering from wind-driven capillary waves whose spatial variation is visible as patterns in the SAR images. In this paper, we present two case studies in which SAR images taken over Lake Superior demonstrate spatial variability in the surface wind stress created over the lake by coincident gravity waves and boundary layer convection during cold air outbreaks. Of particular interest is the direct influence of the gravity waves on the lake-surface stress, despite the intervening highly convective atmosphere, and the detailed view of the fetch dependence of that stress.

Research Course Projects

Water Soluble Mutagen Production During the Bioremediation Of Oil-Contaminated Soil

Researcher: Midshipman 1/C William C. Blodgett, USN
Adviser: Professor John W. Foerster

The illegal disposal of used motor oil on land or in waterways creates problems for the environment and people, as well as fish and wildlife. These contaminants leach into groundwater or otherwise contaminate the earth. Bioremediation is a natural process that uses microorganisms to transform harmful substances into non-toxic carbon dioxide, water and fatty acids. This study sought to determine if the bioremediation of naphthalene, a common polycyclic aromatic hydrocarbon found in used motor oil, also produced water-soluble mutagens. It was hypothesized that any resulting mutagenic material would be a product of naphthalene's transformation into Naphthol, a highly toxic hydrocarbon. Ten-fold extinction dilution bacterial counts revealed that a population of hydrocarbon-degrading bacteria biodegraded naphthalene over a three-week period. A modified Voges-Proskauer test with ultraviolet analysis indicated that the naphthalene was not biodegraded into Naphthol. An Ames (*Salmonella* mutagenicity test) assay detected frameshift mutations during the second week of experimentation, however, suggesting that the biodegradation of naphthalene produced a water-soluble, highly toxic, mutagenic substance.

A Comparison of Two Major East Coast Storms: March 12-14, 1993 and January 24-26 2000

Researcher: Midshipman 1/C Bradley K. Deafenbaugh, USN
Adviser: Associate Professor David R. Smith

By reviewing factors and conditions responsible for the 12-14 March 1993 superstorm and by analyzing the weather observations of the 24-26 January 2000 snowstorm, a comparison between the two snowstorms has been made which will hopefully aid military personnel and weather forecasters in understanding and predicting these powerful winter storms. The March 1993 storm was one of the most powerful and destructive storms of the century. It produced tremendous amounts of snowfall and precipitation, and caused massive amounts of damage from coastal flooding and high winds. The January 2000 storm produced record amounts of snowfall in several states, disrupting the lives of millions of people for several days. Significant analysis of the March 1993 storm has been performed by Kocin et al. (1995), but studies of the January 2000 storm have yet to be published in the literature. Using data reported by Kocin et al. (1995), the March 1993 storm will be compared to the January 2000 storm. A synoptic overview of both storms is presented, along with a general discussion of the development of East Coast marine cyclones.

A Comparison of Two Extratropical Cyclones: Case Studies of the 25 January 2000 Snow Storm *vs* the 31 January 2000 Ice Storm

Researcher: Midshipman 1/C Kathryn A.M. Estes, USN
Adviser**:** Associate Professor David R. Smith

Forecasting the precipitation type of extratropical cyclones is not an easy task. Meteorologists have long searched to find the variables that best distinguish an ice storm from a snow storm within an extratropical cyclone [An analysis of thickness fields can be important in determining whether rain, ice or snow occurs over a given area]. Thickness is related to the mean temperature of the atmospheric layer is liquid, freezing or frozen. The type of precipitation that occurs is dependent on temperature, since that will determine if the water in the layer. Unfortunately, this is not always the most reliable analysis for forecasting extratropical cyclone precipitation. An analysis of the temperature in an air column is another method used by meteorologists for precipitation prediction. The zero degree Celsius isotherm is a defining line for precipitation type, since falling snow precipitation will melt in temperatures above zero degrees Celsius. In addition, local temperature profiles of the region affected by extratropical cyclone precipitation can further assist meteorologists in making precipitation forecasts. This study will examine two cases of extratropical cyclones in January of 2000 to determine if there were discriminating factors for the why snow occurred in one and ice in the other.

Satellite Detection of Coccolithophore Blooms in the Gulf of Maine from 1981-2000

Researcher: Midshipman 1/C Kathryn Grof-Tisza, USN
Adviser: Adjunct Assistant Professor Kenneth S. Casey
Commander, Naval Meteorology and Oceanography Command Research Chair

Advanced Very High Resolution Radiometer (AVHRR) and Sea-viewing Wide Field-of-view Sensor images were analyzed to ascertain the temporal changes of Emiliania huxleyi coccolithophore blooms in the Gulf of Main between 1981 and 2000. Previous studies used data collected from specific cruise dates and correlated them with data collected from AVHRR and Coastal Zone Color Scanner (CZCS) to observe these blooms during the 1980's. These algae blooms can be detected from satellite imagery by their distinctive high reflectance and milky white appearance. Their high reflectance is primarily a function of the amount of backscatter from detached coccoliths as well as the small contribution of active E.huxleyi cell reflectance. This study concurs with previous studeis in identifying numerous blooms prior to 1991. After 1991, however, the blooms of E.huxleyi vanished from the Gulf of Main Region. Additionally, AVHRR sea surface temperature and salinity and nutrient values from the 1998 World Ocean Database were studied in order to explain the bloom variability in the Gulf of Maine. No significant conclusions could be drawn to explain the disappearance of E.huxleyi from the Gulf of Maine after 1991.

A Climatology of Cloudlines Associated with the Chesapeake and Delaware Bays

Researcher: Midshipman 1/C David M. Halverson, USN
Adviser: Assistant Professor Todd D. Sikora

Clouds lines associated with the Chesapeake and Delaware Bays are often seen in Advanced Very High Resolution Radiometer (AVHRR) imagery. Past research developed hypotheses concerning the mechanisms responsible for genesis of the cloud lines. One explanation is that they cloud lines are forced in the same manner as are Great Lakes mid-lake cloud bands. Namely, they result from converging land-breeze circulations. An alternate, albeit more speculative, explanation is that at least some of the cloud lines in question are ship tracks. In order to help quantify morphology of the cloud lines in question, an exhaustive climatological study has been undertaken using AVHRR and National Data Buoy Center data. This paper presents the results this climatological study. The typical cloud line forms during the cold season in post-cold frontal regimes. The corresponding atmosphere is characterized as having a large (order 10°F) air-sea temperature difference and a moderate wind (order 10 m/s) aligned nearly parallel to the long-axis of a bay.

Using Automated Weather Source Data to Develop a Mesoscale Observational Tool

Researcher: Midshipman 1/C Matthew E. Kucas, USN
Adviser: Associate Professor David R. Smith

Improving local forecast accuracy is a major goal of meteorological research today. Forecasters have traditionally relied upon numerical computer model output to provide information about local variations in weather conditions. However, operational models today still lack the spatial resolution necessary to predict small-scale differences. Fortunately, weather networks can fill the gaps and provide input data for the limited number of mesoscale forecasting models that are now available. These networks also provide data that can be used for developing observation-based tools to describe characteristic weather conditions in areas that remain unresolved in today's numerical computer models. This research uses Automated Weather Source (AWS) weather network data to develop a practical observational tool for local forecasting in the Chesapeake Bay region. Hourly weather observations made during five synoptic situations at twenty-two AWS weather stations are examined. These observations are used to calculate hourly means for both small and large geographical areas throughout the region. Station and geographical group data are compared to local airport weather data, and the results of these comparisons are summarized in five computer spreadsheets. This research has successfully produced an observational forecast tool for the Chesapeake Bay region that is useful for both forecasters and future researchers.

Publications

Journal (Refereed) Manuscripts

CASEY, Kenneth S., Adjunct Assistant Professor, "Pathfinder Sea Surface Temperature Biases and Their Relation to Air-sea Temperature Difference, Wind Speed, and Aerosols," EOS, *Transactions of the American Geophysical Union*, Vol. 81, No. 48, supplement, p.731.

Biases in NOAA/NASA Pathfinder Advanced Very High Resolution Radiometer (AVHRR) observations of sea surface temperature (SST) are examined through collocation with in-situ data from the 1998 World Ocean Database, the National Center for Environmental Prediction (NCEP) weekly SST analysis, Special Sensor Microwave Imager (SSM/I) wind fields, and the atmospheric absorbing aerosol estimates from the Total Ozone Mapping Spectrometer (TOMS). Relationships between the SST biases and air-sea temperature difference (ASTD), wind speed, and atmospheric aerosol content are characterized.

Observations indicate that when the ASTD is positive (air temperature greater than ocean temperature), then the Pathfinder bias tends to also be positive (Pathfinder SST greater than in situ SST). The converse is also observed. These results indicate a bulk versus skin SST effect in the Pathfinder dataset. Relationships between the wind speed and Pathfinder biases support this observation. Overall, daytime biases are positive while nighttime biases are negative, except at higher wind speeds when the biases are greatly reduced; wind-induced mixing disrupting the skin of the ocean is an explanation consistent with these observations. Global spatial and temporal patterns of ASTD variation are also examined through a comparison of the SSM/I wind fields with the Pathfinder biases.

Significant biases are also observed as a function of atmospheric aerosol content. Monthly climatologies of the daily TOMS atmospheric absorbing Aerosol Index (AI) were compared to similar climatologies of the difference between weekly AVHRR Pathfinder and NCEP blended ship and satellite SST fields. A strong spatial correspondence was identified between areas with high AI values and areas with a large Pathfinder minus NCEP SST bias. Since absorbing aerosols are not detected by the Pathfinder SST algorithm, the reduction of the infrared energy reaching the AVHRR by the aerosols results in an underestimate of the satellite-derived SST, particularly in those areas which are not well-represented in the Pathfinder Matchup Database.

GOULD, Frank G., Jr., Midshipman 1/C, (USN) and WHITFORD, Dennis J., Captain (USN) and Associate Professor, "Computer-Aided Visualization and Animation of Ocean Wave Dynamics," *Journal of Geoscience Education*, 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 MATLAB® 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.

GUTH, Peter L., Professor, "TerraBase II Computer Program," on Terrain Visualization with TerraBase II, Version 3.0 Software and Tutorial, U.S. Army Engineer School, CD-ROM 5-16, Fort Leonard Wood, MO, 2000.

This set of training CDs contains the TerraBase II Computer Program for terrain visualization and sample data to use the program. Because most of the data comes from the National Imagery and Mapping Agency, the CD set is classified for official use only. The CDs attempt to teach users about the capabilities and limitations of digital map data, and how that data can help military users to visualize terrain and use it for their tactical advantage. The program is geared to helping users at company and battalion level on standard desktop and laptop computers.

SIKORA, Todd D., Assistant Professor, "Using Spaceborne Synthetic Aperture Radar to Forecast Polar Mesoscale Cyclones in the Bering Sea," *Weather and Forecasting*, Vol.16, pp. 270-276, 2000.

The unpredictable weather and lack of in situ data in the Bering Sea warrants experimentation with new forms of forecasting tools in this 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.

SIKORA, Todd D., Assistant Professor, "Synthetic Aperture Radar as a Tool for Investigating Polar Mesoscale Cyclones," *Weather and Forecasting*, Vol.15, pp. 745-758, 2000.

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 atmospheric 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 SAR shows promise to aid the forecaster and researcher in the study of marine-meteorological phenomena such as polar mesoscale cyclones.

SIKORA, Todd, D., Assistant Professor, Porter, D. L., Babin, S. M., and Wisecup, M. D., "Co-occurrence of a Progressive Warm-fresh Oceanic Front With a Cool-moist Atmospheric Front at Duck, North Carolina," *Boundary-Layer Meteorology*, pp. 349-361.

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 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 direction and wind speed variability accompanied the MABL front. The sea surface roughness signatures of both fronts were detected by an X-band pulsed Doppler radar. Supporting data are used to identify each front detected by the radar and to calculate each front's velocity. In an attempt to explain the sea surface roughness variations associated with each front, the radar data are compared to corresponding variations in wind speed, wind direction, and air-sea temperature difference.

SIKORA, T. D., Assistant Professor, Young, G. S., O'Marr, E. E., and Gasparovic, R. F., "Anomalous Cloud Lines Over the Mid-Atlantic Coast of the United States," *Canadian Journal of Remote Sensing*, pp. 320-327.

This exploratory paper develops the basis for two hypotheses concerning the mechanism responsible for anomalous cloud lines often seen in Advanced Very High Resolution Radiometer imagery of the Chesapeake and Delaware Bays in cold air outbreak regimes. One explanation is that these cloud lines are forced in the same manner as Great Lakes lake-effect midlake cloud lines. An alternate, albeit more speculative, explanation is that at least some of the cloud lines in question are ship tracks.

VIEIRA, Mário E.C., Associate Professor, "The Douro Estuary (Portugal): a Mesotidal Salt Wedge," *Oceanologica Acta*, Vol. 23, pp. 585-594.

The Douro River drains a large part of the Iberian Peninsula before it flows into the Atlantic Ocean in northern Portugal. Although heavily dammed throughout its course, the Douro forms a mesotidal estuary in the last 22 km. No data had ever been collected in this estuary prior to 1994. An analysis of salinity data measured once a month in 1994 and current data obtained in the Fall of 1994 revealed a salt wedge estuary highly dependent on river discharge: strong vertical salinity stratification under conditions of low runoff, whereas during high river flows the whole estuary became a river. The tide in the Fall of 1994 was very close to a standing wave throughout the estuary; the tidal range, as high as 2.8 m at spring tides, was not powerful enough to destroy the vertical stratification. Tidal straining prevented mixing within the salt wedge during ebb; however, the column became vertically mixed at the end of flood. The salt wedge became arrested at three favored positions determined by the bathymetry. The salt intrusion, more sensitive to freshwater inflow than to tidal action, penetrated as far as 2/3 of the estuary's length. Residence times were estimated with a box model and were dependent on river discharge; they varied from 8 hours with early spring (March) inflows to 16 days under summer runoff conditions.

WHITFORD, Dennis J., Captain (USN) and Associate Professor, VIEIRA, Mario E.C., Associate Professor and WATERS, J.K., Associate Professor, "Teaching Time-series Analysis. I. Finite Fourier Analysis of Ocean Waves," *American Journal of Physics*, Vol. 69 (2001), pp. 490-496.

The introduction of students to methods of time-series analysis is a pedagogical challenge, since the availability of easily manipulated computer software presents an attractive alternative to an understanding of the computations, as well as their assumptions and limitations. A two-part pedagogical tutorial exercise is offered as a hands-on laboratory to complement classroom discussions or as a reference for students involved in independent research projects. The exercises are focused on the analysis of ocean waves, specifically wind-generated surface gravity waves. The exercises are cross-disciplinary in nature and can be extended to any other field dealing with random signal analysis. The first exercise introduces the manual arithmetic steps of a finite Fourier analysis of a wave record, develops a spectrum and compares these results to the results obtained using a fast Fourier transform (FFT). The second part of the exercise, described in the subsequent article, takes a longer wave record and addresses the theoretical and observed wave probability distributions of wave heights and sea surface elevations. These results are then compared to a FFT, thus linking the two pedagogical laboratory exercise parts for a more complete understanding of both exercises.

WHITFORD, Dennis J., Captain (USN) and Associate Professor, WATERS, Jennifer K., Associate Professor and VIEIRA, Mario E.C., Associate Professor, "Teaching Time-series Analysis. II. Wave Height and Water Surface Elevation Probability Distributions," *American Journal of Physics*, Vol. 69 (2001), pp.497-504.

This paper describes the second of a two-part series of pedagogical exercises to introduce students to methods of time-series analysis. While these exercises are focused on the analysis of wind generated surface gravity waves, they are cross-disciplinary in nature and can be applied to other fields dealing with random signal analysis. Two computer laboratory exercises are presented which enable students to understand many of the facets of random signal analysis with less difficulty and more understanding than standard classroom instruction alone. The first pedagogical exercise, described in the previous article, uses mathematical software on which the students execute the manual arithmetic operations of a finite Fourier analysis on a complex wave record. The results are then

compared to those obtained by a fast Fourier transform. This article, the second of this two-part pedagogical series, addresses analysis of a complex sea using observed and theoretical wave height and water surface elevation probability distributions and wave spectra. These results are compared to a fast Fourier transform analysis, thus providing a link back to the first exercise.

WHITFORD, Dennis J., Captain (USN) and Associate Professor, "Predicting the Depth, Across-Channel Location, and Speed Variability of Tidal Current Core Maxima at the Mouth of the Chesapeake Bay," *Journal of Coastal Research*, Vol. 17, No. 2, pp. 420-430.

Reasonable prediction of the depth, across-channel location, and speed variability of tidal current core maxima at the mouth of the Chesapeake Bay can be determined to first order without an extensive deployment of current meters. Fourteen tidal current data sets were acquired with a shipboard Acoustic Doppler Current Profiler (ADCP) on track lines across the Bay mouth. Data sets were representative of fortnightly tidal range variation (spring, neap, and transitional), as well as semi-diurnal tidal current cycle phases (ebb, flood, and slack) for the months of June and September in four different years. Data indicated tidal current maxima were contained within a narrow jet-like core with a horizontal scale of O(1-2 km) and vertical scale of O(10 m). The depth, across-channel location, and speed of the maxima varied with the semi-diurnal tidal current cycle phase, and to a much lesser extent, with the fortnightly variation of tidal range. This temporal variability is modeled by least squares using a sinusoidal function, related to the dominant tidal current harmonic constituent, and a third-degree polynomial curve fit. Prediction algorithms from both models result in correlation coefficients for depth (0.95), across-channel location (0.97), and speed (0.93). National Oceanic and Atmospheric Administration (NOAA) tidal current tables had a speed correlation coefficient of only 0.79 when matched to observations. Comparison correlation coefficients for depth and across-channel location from NOAA tidal current tables could not be determined since the tables do not provide this information. This method provides a first-order, empirical means for predicting the depth, across-channel location, and speed variability of tidal current core maxima under conditions of similar atmospheric forcing and freshwater input without long-term deployment of current meters at multiple depths and locations. The method is not site-specific. Therefore, it may be applied at other locations and could be especially beneficial to estuaries where there are no tidal current meters or published tidal current information.

WHITFORD, Dennis J., Captain (USN) and Associate Professor, "Teaching Ocean Wave Forecasting using Computer-generated Visualization and Animation: Part 1, Sea Forecasting," *Computers & Geosciences*, accepted for publication.

Ocean waves are the most recognized phenomena in oceanography. Unfortunately undergraduate study of ocean wave dynamics and forecasting involves mathematics and physics and therefore can pose difficulties with some students because of the subject's interrelated dependence on time and space. Verbal descriptions and two-dimensional illustrations are often insufficient for student comprehension. Computer-generated visualization and animation offer a visually intuitive and pedagogically sound medium from which to present geoscience, yet there are very few oceanographic examples. A two-part article series is offered to explain ocean wave forecasting using computer-generated visualization and animation. This paper, Part 1, addresses forecasting of sea wave conditions and serves as the basis for the more difficult topic of swell wave forecasting addressed in Part 2. Computer-aided visualization and animation, accompanied by oral explanation, are a welcome pedagogical supplement to more traditional methods of instruction.

In this article, several MATLAB® software programs have been written to visualize and animate development and comparison of wave spectra, wave interference, and forecasting of sea conditions. These programs also set the stage for the more advanced and difficult animation topics in Part 2. The programs are user-friendly, interactive, easy to modify, and developed as instructional tools. By using these software programs, teachers can enhance their instruction of these topics with colorful visualizations and animation without requiring an extensive background in computer programming.

WHITFORD, Dennis J., Captain (USN) and Associate Professor, "Teaching Ocean Wave Forecasting Using Computer-generated Visualization and Animation: Part 2, Swell Forecasting," *Computers & Geosciences,* accepted for publication.

This paper, the second of a two-part series, introduces undergraduate students to ocean wave forecasting using interactive computer-generated visualization and animation. Verbal descriptions and two-dimensional illustrations are often insufficient for student comprehension. Fortunately, the introduction of computers in the geosciences provides a tool for addressing this problem. Computer-generated visualization and animation, accompanied by oral explanation, have been shown to be a pedagogical improvement to more traditional methods of instruction. Cartographic science and other disciplines using geographical information systems have been especially aggressive in pioneering the use of visualization and animation, whereas oceanography has not. This paper will focus on the teaching of ocean swell wave forecasting, often considered a difficult oceanographic topic due to the mathematics and physics required, as well as its interdependence on time and space.

Several MATLAB® software programs are described and offered to visualize and animate group speed, frequency dispersion, angular dispersion, propagation, and wave height forecasting of deep water ocean swell waves. Teachers may use these interactive visualizations and animations without requiring an extensive background in computer programming.

Conference Proceedings

FOESTER, John W., Professor, "Satellite Analyses of the Air/sea Interactions During the Winter to Spring Transition in the North East North Pacific Ocean," *Proceedings of the Pacific Ocean Remote Sensing Congress,* Goa, India, 2000, Vol. II, pp.623-627.

Between March and May, wind patterns over the North Pacific Ocean change. This change is in response to the seasonal expansion of the North Pacific High Pressure Center. With this expansion, the winds shift directions affecting the North Pacific Ocean surface currents. Satellite analyses using the Advanced Very High Resolution Radiometer (AVHRR), the Coastal Zone Color Scanner (CZCS), and the Sea-Viewing Wide-Field Sensor (SeaWiFS), coupled to ship collected ground truth data, reveal measurable changes in the eastern boundary currents, and the river plumes entering the North East North Pacific Ocean (NENPO). The results of this study indicate that these shifts in the wind patterns affect an area in the NENPO of 3.3×10^5 km^2 area creating a change in current interactions. These interactions develop a strong biological signal. In the coastal zone, river plumes, such as the Columbia River, shift from a northerly flow, through westerly offshore to a southerly flow. The Columbia River alone influences 8.8×10^3 km^2 of the NENPO. Satellites allow for a synoptic view of the study area and help to define the air/sea interactions during the Winter through Spring transitional period in the NENPO.

SIKORA, Todd D., Assistant Professor and HALVERSON, David, Midshipman 1/C, USN, "A Climatology of Cloudlines Associated with the Chesapeake and Delaware Bays," *11th Conference on Interaction of the Sea and Atmosphere*, American Meteorological Society, San Diego, CA, 14-17 May 2001, pp. 35-36.

Clouds lines associated with the Chesapeake and Delaware Bays are often seen in Advanced Very High Resolution Radiometer (AVHRR) imagery. Past research developed hypotheses concerning the mechanisms responsible for genesis of the cloud lines. One explanation is that they cloud lines are forced in the same manner as are Great Lakes mid-lake cloud bands. Namely, they result from converging land-breeze circulations. An alternate, albeit more speculative, explanation is that at least some of the cloud lines in question are ship tracks. In order to help quantify morphology of the cloud lines in question, an exhaustive climatological study has been undertaken using AVHRR and National Data Buoy Center data. This paper presents the results this climatological study. The typical cloud line forms during the cold season in post-cold frontal regimes. The corresponding atmosphere is characterized as having a large (order 10°F) air-sea temperature difference and a moderate wind (order 10 m/s) aligned nearly parallel to the long-axis of a bay.

SMITH, David R., Associate Professor, and ROSENSWEET, A.C., Midshipman 1/C, USN, "An Analysis of the Influence of El Niño and La Niña on Tornado Occurrence in the United States," *12th American Meteorological Society Symposium on Global Change Studies*, Boston, MA, 2001, pp.165-168.

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 is not yet fully understood. This paper examines the effect of El Niño upon tornado formation in the United States. A comparison of annual tormado frequency data from years with high, low, and moderate levels of Multivariate El Niño Index provides evidence of a correlation between El Niño Southern Oscillation (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 to La Niña years should be conducted to complete the entire picture of this relationship.

SMITH, David R., Associate Professor, "Water in the Earth System (WES): A Report on First Year Activities," *10th American Meteorological Society Symposium on Education and the 17th International Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology*, Boston, MA, 2001, pp. J18-21.

Water in the Earth System (WES) is the newest educational initiative of the American Meteorological Society. WES is an innovative Internet-based distance-learning course directed toward precollege teachers, and funded by the National Science Foundation. This course approaches water and global water cycle processes from an Earth System Science perspective, utilizing an inquiry-based methodology consistent with the goals of the National Science Education Standards.

Initial steps included the development of written materials including a WES textbook and study guide, plus the course homepage. The WES text consists of twelve chapters each providing background information for one week of investigations of the flow of water and accompanying energy transformations within the Earth system. The WES study guide contains the first part of each week's learning activity; the second part is delivered in near-real time via the course homepage. Local Implementation Teams (LITs) were formed with a cadre of teachers who had participated in either Project ATMOSPHERE/DataStreme or the Maury Project. This past summer 35 of these teachers selected as LIT leaders attended an eight-day workshop on the basics of water in the Earth system and pedagogical aspects of the course. In addition, 35 other teachers who are WES LIT members attended either a Project ATMOSPHERE or Maury Project summer workshop to enhance their meteorological or oceanographic background. In preparation for national implementation of WES, all WES LIT members took the course as part of pilot testing during the Fall of 2000.

Beginning in January 2001, WES will be offered to approximately 250 teachers each semester for the next three years. These teachers will in turn assist their colleagues and students with valuable instructional materials on water in the Earth system. The impact of the activities during the first year was to provide the necessary foundation which will enable the program to accomplish its long-term goals.

SMITH, David R., Associate Professor, "How the Maury Project Supports Teaching and Learning About Marine and Coastal Environments," *10th American Meteorological Society Symposium on Education and the 17th International Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology*, Boston, MA, 2001, pp. J7-10.

The Maury Project has been an important element in the American Meteorological Society (AMS) education program since 1994. In its nearly seven-year tenure, over 175 educators from kindergarten through university levels have attended one of its two-week summer workshops at the U.S. Naval Academy. This unique partnership of AMS, the Naval Academy, the Navy and NOAA has provided a program of instruction that focuses on the physical foundations of oceanography. This paper summarizes how the Maury Project promotes the study of the marine and coastal environments, areas of vital interest to the agencies sponsoring this program.

The unique feature of the Maury Project is its focus on physical processes. Nearly all other teacher enhancement programs in oceanography have a strong biological component. Teachers who attend the Maury Project summer workshops are provided with a learning experience that enables them to understand the structure and dynamics of

the oceans and methods for measuring its physical properties. They learn about the agencies that are involved with oceanic research and operational activity and why the oceans are important to these agencies. In addition, resource materials in the form of modules are provided to the workshop participants so they can conduct workshops for their peers. These peer-training sessions have been a highly effective mechanism to distribute instructional materials to teachers both nationally and internationally. Modules include such topics as wind-driven circulation systems, deep ocean water waves, and coastal upwelling. To date, over 1000 Maury peer-training sessions have reached over 18,000 teachers both nationally and internationally. This partnership comprised of a professional society, scientific and operational agencies working as colleagues with the precollege educational structure provides an excellent model for enhancing the study of the marine and coastal environments.

SMITH, David R., Associate Professor, "Meeting Report on the Ninth American Meteorological Society Symposium on Education," *Bulletin of the American Meteorological Society*, Vol. 82, No. 2, pp. 295-303, 2001.

The American Meteorological Society held its Tenth Symposium on Education in conjunction with the 82nd Annual Meeting in Albuquerque, New Mexico. The theme of this year's Symposium was "enhancing public awareness of the atmospheric and oceanic environments". Thirty-six oral presentations and 38 poster presentations summarized a variety of educational programs or examined educational issues for both the pre-college and university levels. There was a special session on increasing awareness of meteorology and oceanography through popular and informal educational activities, as well as a joint session with the 17th International Conference on Interactive Information Processing Systems for Meteorology, Oceanography and Hydrology on delivery of scientific information on the world wide web pertaining to the atmosphere, the oceans, and the coastal zone. 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 Tenth Symposium on Education can be viewed in the October 2002 issue of the *Bulletin*.

Technical Reports, Books and Book Chapters

GUTH, Peter L., Professor, 2001, "Merging 10 & 30 m DEMs": 3D Artist, No. 43, p.6, 28.

This short note for graphics artists demonstrates how to merge digital elevation models with different resolutions to get the best possible results over an area of interest. The data is available free on the web, and the order of merging affects the results.

Presentations

CASEY, Kenneth S., Adjunct Assistant Professor and CNMOC Research Chair, "New Climatologies and Anomalies from TOPEX/Poseidon and AVHRR Pathfinder Data," Joint TOPEX/Poseidon and Jason-1 Science Working Team Meeting, Miami, FL, November 14-18, 2000.

CASEY, Kenneth S., Adjunct Assistant Professor and CNMOC Research Chair, "NOAA's Satellite-based Coral Reef Early Warning System for Predicting Tropical Ocean Warming, Bleaching, and Mortality," Ninth International Coral Reef Symposium, Bali, Indonesia, October 23-27, 2000.

FOERSTER, John, W., Professor, "Triggering an Harmful Algal Bloom," Coastal Zone Canada 2000, St. John, New Brunswick CA, September 5-9, 2000.

FOERSTER, John W., Professor and LaMontagne, Robert, "On the Spot Determination of Ionic Copper in Natural Waters. Partners in the Environment," SERDP Conference, Arlington, VA, November 26-29, 2000.

FOERSTER, John W., Professor, "Invasive Plants," Maryland Extension Service, Glen Burnie, MD, March 14, 2001.

FOERSTER, John W., Professor, "American Shad, A Biomarker," Shad Conference, National Aquarium, Baltimore, MD, May 7-9, 2001.

FOERSTER, John W., Professor, "Invasive Plants," Maryland Master Gardener Annual Workshop, College Park, MD, May 2, 2001.

FOERSTER, John W., Professor, "Herbs," Master Gardener Presentation, Annapolis, MD, April 26, 2001.

GUTH, Peter L., Professor, "GIS and History," History Department, U.S. Naval Academy, May 2001.

GUTH, Peter L., Professor, "MICRODEM/TerraBase II Mapping Program," Topographic Engineering Center, Corps of Engineers, Fort Belvoir, VA, March 2001.

GUTH, Peter L., Professor, "Quadrangle Level Geomorphometry from 51,000 USGS 1:24K Digital Elevation Models," Geological Society of America Abstracts with Programs, Vol.32, No.7, p. A-374, Reno, NV, 12-16 November 2000.

GUTH, Peter L., Professor, "MICRODEM/TerraBase II Mapping Program," Army Engineer School, Fort Leonard Wood, MO, December 18-21, 2000.

GUTH, Peter L., Professor, "MICRODEM/TerraBase II Mapping Program," Mid-Continent Mapping Center, U.S. Geological Survey, Rolla, MO, July 2000.

SIKORA, Todd D., Assistant Professor, "Satellite Remote Sensing of Various Marine Meteorological Phenomena," Department of Atmospheric and Oceanic Science, University of Wisconsin-Madison, Summer 2000.

SIKORA, Todd D., Assistant Professor, "Synthetic Aperture Radar Remote Sensing of Marine Meteorological Phenomena," Department of Earth and Atmospheric Sciences, Purdue University, Spring 2001.

SIKORA, Todd D., Assistant Professor, "Remote Sensing of Various Marine Meteorological Phenomena," Applied Physics Laboratory, University of Washington, Spring, 2001.

SIKORA, Todd D., Assistant Professor, "SAR Meteorology," U.S. Government SAR Users Symposium, Canadian Embassy, Washington, DC, Spring 2001.

SIKORA, Todd D., Assistant Professor, and Thompson, D. R., "Progress on Remotely Sensing Air-sea Fluxes Using Synthetic Aperture Radar," International Geoscience and Remote Sensing Symposium 2000, IEEE, July 23-28, 2000.

SIKORA, Todd D., Assistant Professor, Winstead, N. S., Thompson, D. R., and Mourad, P. D., "The Interaction of Atmospheric Gravity Waves and Convection as Observed by SAR," International Geoscience and Remote Sensing Symposium 2000, IEEE, Honolulu, HI, July 24-28, 2000.

SMITH, David R., Associate Professor, "Why Are The Ocean Sciences The Orphan Children of Science Education?," MARE Planning Meeting, Rutgers University, New Brunswick, NJ, September 13-15, 2000.

VIEIRA, Mário E.C., Associate Professor, "Observations at the Mouth of the Douro Estuary (Portugal)," Fall Meeting of the Atlantic Estuarine Research Society, Edgewater, MD, 9-11 November 2000.

VIEIRA, Mário E. C., Associate Professor, "Estuarine Dynamics," Porto University, Porto, Portugal, June 2001.

WHITFORD, Dennis J., Captain (USN) and Associate Professor, "Two Approaches to Undergraduate Research: Scientific and Pedagogical," Coastal Carolina University, Conway, SC, February 13, 2001.

WHITFORD, Dennis J., Captain (USN) and Associate Professor, "A Vision for a College of Marine Science," University of South Florida, St. Petersburg, FL, April 26, 2001.

WHITFORD, Dennis J., Captain (USN) and Associate Professor, "The Impact of Meteorology and Oceanography on Naval Operations," Lake Shore Rotary Club, Pasadena, MD, May 9, 2001.