Oceanography Department

Captain Joseph W. Swaykos, USN
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 2003-2004 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 refereed articles and conference proceedings, and made conference presentations, many of which included midshipmen as co-authors. In addition, several students completed independent research courses under the mentorship of faculty advisers. These midshipmen formally presented their project results to the faculty and members of the Academic Dean's staff at the end of each semester. Some of these midshipmen went on to present their results at national conferences.

The Oceanography Department conducted its 16th annual summer oceanography cruise aboard Yard Patrol (YP) craft # 686 from 24 May to 17 June 2004. The midshipmen navigated nearly 600 nautical miles through the Delaware and Chesapeake Bays. This included one 239 nm overnight transit from Philadelphia to Norfolk through the C&D Canal. YP-686 also gathered oceanographic data throughout the Chesapeake Bay during this period. Significant professional training evolutions consisted of 4 precision anchorages, 5 pier-side moorings and 17 special Sea and Anchor details.

During the two weeks underway, the science teams on YP686 conducted 29 CTD casts, 29 PNF-300A casts and 7 plankton tows. Unfortunately, the ADCP was down during the cruise, but the Thermosalinograph was put into service during transits between port visits. Professional training ashore included ship simulator training at the Marine Safety International (MSI) complex and a visit to the Naval Atlantic Meteorology and Oceanography Center in Norfolk, VA. While at NAS Patuxent River, the midshipmen toured multiple aircraft (HX-21, VX-20, VX-23) and they also toured the Naval Test Pilot School.

In July 2004, the Oceanography Department hosted the 11th Maury Project Summer Workshop for twenty-three K-12 science teachers nationwide. 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.

Our colleague in the Commander, Naval Meteorology and Oceanography Command (COMNAVMETOCCOM), which is an externally funded chair in Remote Sensing, continued his strong research efforts with several scientific articles submitted for publication in refereed journals.

Sponsored Research

MicroDEM UAV Development Work

Researcher: Professor Peter L. Guth
Sponsor: Boeing Corporation

The intent of this research and development activity is to transform MicroDEM into a reliable, high performance mission planning tool tailored to the specific terrain analysis and visualization requirements of Future Combat Systems, Homeland Security Services, and other allied applications. This enhanced product, when integrated into Boeing's optimization and role-based access control framework, will become a key enabler for Adaptive Autonomous Networks. During this period we worked on new visualizations for displaying the coverage of moving sensors, showing the coverage of single targets as sensors moved, and worked on multi-threading of viewshed computations. We also investigated the use of ASTER data to fill in holes in the Shuttle Radar Topography Mission, and the effects of digital elevation model re-interpolation on the results of viewshed computations.

GIS/Remote Sensing Education for Midshipmen

Researcher: Professor Peter L. Guth
Sponsor: National Geospatial-Intelligence Agency

The efforts in this project continued to improve the GIS/Remote Sensing education provided to midshipmen at the U.S. Naval Academy. The project also provided an outreach to the Department of Defense, through continued development of algorithms and techniques to merge and display geospatial data in an intuitive way, and via purchases of equipment, data, and software to use in classes. Support of this project also provided for development of algorithms and techniques – by midshipmen (undergraduate students) - to merge and display geospatial data in intuitive projects. Honors students majoring in Oceanography used the components of this research and associated equipment in their independent research projects and some presented their findings at professional scientific conferences.

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

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

As the Navy focus shifts to littoral regions, higher resolution and re-locatable nested models have been developed to improve shallow-water operations. One of the scientific and technical challenges is to determine how much detail and accuracy in ocean wind data is needed to meet operational requirements. A series of experiments, each one of a 14-day duration, were performed to evaluate the sensitivity of a regional ocean model to low Navy Ocean Global Atmospheric Prediction System (NOGAPS) versus high-resolution Couple Ocean Atmospheric Model Prediction System (COAMPS) wind forcing including scatterometer data insertion into COAMPS using synthetic QuikSCAT (quick scatterometer mission) observations. Atmospheric model wind stress/wind stress curl and Pacific West Coast ocean model (PWC) surface and subsurface current/temperature model results were compared and analyzed. The results showed that there is significant sensitivity in sea surface current and wind stress variability to the choice of atmospheric model grid resolution and the insertion of high-resolution satellite data. In coastal areas, increasing atmospheric model produces a finer depiction of the variability observed near capes and promontories. Insertion of QuikSCAT data produces a statistical difference but no significant difference model fields. The ocean model runs have the expected climatological features and variability. The higher wind stress in COAMPS is translated to the ocean model in the form of higher velocity currents, closed circulations, higher EKE and better defined structure in vorticity. Comparisons to real observations, point to the fact that the approach, in which all regions are run with the same resolution, may not be an efficient use of computer resources.

Operational Modeling of the Marginal Ice Zone

Researchers: Adjunct Assistant Professor Edward L. Maksym,
Michael Van Woert, National/Naval Ice Center, Washington D.C.,
Max Coon, Northwest Research Associates, Bellevue WA,
and Leif Toudal, Denmark Technical University, Lyngby, Denmark
Sponsor: Commander, Naval Meteorology and Oceanography Command (CNMOC)

Forecasting and analysis of sea ice conditions is the most difficult in the marginal ice zone, but due to the proximity to maritime traffic, arguably the most important. The focus of this project was to improve operational analysis and forecasting sea ice products produced at the National/Naval Ice Center (NIC) through the assimilation of satellite ice concentration and drift.

Passive microwave observations of sea ice concentration were assimilated into a free-drift sea ice model to drive the ice thermodynamics. Model tuning and validation were carried out using a suite of synthetic aperture radar, visible and infrared satellite imagery, and in-situ observations of ice conditions from a 2001 cruise in the Barents Sea. Comparisons of the modeled ice growth and drift are compared with satellite derived ice drift from both visible and passive microwave, NIC ice charts, and drift vectors from the Navy's Polar Ice Prediction System (PIPS).

Results showed that prediction of ice drift is just as accurate as results from PIPS; more accurate if using a dynamic drag law parameterization. Distribution of ice types predicted by the model was, under certain conditions, more accurate than NIC ice charts.

This work spawned two additional projects for 2004-2005. The first is an analysis of satellite observations of ice extent, ice drift, sea surface temperatures, and surface winds. These variables will be analyzed in conjunction with the model to develop a more accurate sea ice edge forecast. The second will examine the interannual variability of the development of the ice edge in the Barents Sea. Model estimates of ocean heat flux near the ice edge will be used to investigate the effects of increased warm Atlantic Layer inflow into the Arctic associated with the Arctic Oscillation on the observed decrease in ice extent.

Snow Ice Formation on Antarctic Sea Ice

Researchers: Adjunct Assistant Professor Edward L. Maksym
and Martin Jeffries, Geophysical Institute, University of Alaska at Fairbanks
Sponsor: Commander, Naval Meteorology and Oceanography Command (CNMOC)

Snow ice (sea ice formed through the freezing of flooded snow) plays a significant role in the thickening of Antarctic sea ice in winter, yet precisely quantifying its role has proved difficult. Previous analysis determined that 15% to 38% of the total ice thickness has a meteoric ice component. Snow and ice thickness, textural analysis, and isotopic composition ($\delta^{18}O$, for determination of growth processes) from five cruises in the Antarctic are reanalyzed to more accurately determine the role of surface flooding in the formation of snow ice.

Using a variety of models of ice growth and compositional evolution, we suggested that the true contribution of flooding and refreezing to the mass balance might be significantly lower, *i.e.,* at 6% to 18% of the total ice thickness. However, in this study, we showed that such estimates are highly dependent on the thermophysical behavior of the vertical exchange of brine in the ice, about which little is known quantitatively. The uncertainty in these estimates suggest that our understanding of the mass balance of Antarctic sea ice and its snow cover remains incomplete and awaits a better understanding of the ice permeability evolution and other small scale sea ice processes.

Microstructure of Arctic Sea Ice

Researchers: Adjunct Assistant Professor Edward L. Maksym
Son Nghiem, Jet Propulsion Laboratory, Pasadena, CA and
Michael Van Woert, National/Naval Ice Center, Washington D.C.
Sponsor: Commander, Naval Meteorology and Oceanography Command (CNMOC)

The microstructure of sea ice from cores obtained in the Barents Sea in 2001 and the Beaufort Sea in 2003 was analyzed to support the development validation of microwave remote sensing algorithms. Digital images of thin and thick sections of the cores were processed to analyze the morphology of brine and air inclusion in the ice. Such structural information is critical in understanding the microwave signatures of the ice, as well as the evolution of ice permeability. Software has been developed to determine the statistical distribution of inclusions for each type of ice. Once processed, these data will be used at the Jet Propulsion Language to model the microwave signature of the ice and to compare with coincident measurements of microwave backscatter. The combined Barents/Bering Sea will be used to develop a statistical description of each observed ice type.

New Techniques to Determine Swimming Behavior of Crab Larvae in Response to Prey Patches

Researcher: Assistant Professor Cecily C. Natunewicz
Sponsor: Naval Academy Research Council (NARC)

The fundamental goal of ecology is to determine the factors that govern the distribution of organisms in time and space. While this process is fairly tractable in terrestrial habitats, it is extremely difficult in estuarine and marine systems due to the daunting cost and challenging logistics of sampling aquatic environments. Nevertheless it is crucial to understand

the factors that distribute aquatic organisms in time and space because those patterns may ultimately drive the population dynamics of estuarine species. This investigation used complementary laboratory and field studies to investigate the orientation of mud crab (*Rhithropanopeus harrisii* and blue crab (*Callinectes sapidus*) larvae relative to biological cues (i.e., potential prey). Although larvae were reared successfully in the laboratory in 2002, no gravid crabs were found in local (Hospital Point, Annapolis, Maryland) rocky habitat in 2003. Therefore, a field study of larval concentration with respect to temperature, salinity, and fluorescence (a proxy for phytoplankton concentration) served as the main source of data for the investigation. Crab larvae collected from a 2003 cruise were identified and enumerated in the laboratory and further laboratory and field investigations are planned for the future.

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

Researcher: Associate 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 nest steps in this research should be viewed as a test of an algorithm that, if successful, can compete with 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 algorithm.

Surface Wind Speed and Fluxes from Synthetic Aperture Radar

Researcher: Associate Professor Todd D. Sikora
Sponsor: National Aeronautical 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. This research investigated an extensive validation and refinement of the SAR flux/speed algorithm 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 focused on the 95W line of 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 Niño.) Turbulence data taken during the cruises provided eddy correlation fluxes for comparison to those derived from SAR. As well, wind speed from the ship was compared to non-neutral wind speed obtained from SAR. The work had two central goals. First: improving the algorithms - which will ultimately make high-resolution surface fluxes and wind speeds available to the climate research community. Second: addressing the role of SAR-observed atmospheric variability, such as tropical rain cells, in modifying surface exchange. This research is an on-going effort 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.W. Geer, American Meteorological Society
Sponsor: Commander, Naval Meteorology and Oceanography Command (CNMOC),
National Oceanic and Atmospheric Administration (NOAA), 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-four 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
and 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. During the summer, 35 teachers to attended a summer training workshop in Seattle, WA, where they learned about fundamental concepts in meteorology, physical oceanography, and hydrology. Upon completion of the summer workshop, these teachers returned 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.

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

Researchers: Associate Professor Mário E.C. Vieira
and Dr. Adriano Bordalo, Porto University - Portugal
Sponsor: Porto University

Based on the data collected in 1995 and a box model of the hydrodynamics of the Douro River estuary exchange coefficients were estimated. Fluxes throughout the estuary were computed for the following parameters: chlorophyll, bacteria, planktonic viruses. The analysis of the results is discussed in a paper submitted for publication in the journal *Estuarine, Coastal and Shelf Science* and now undergoing revision.

Independent Research

Modeling of Melt Pond and Ice Albedo Evolution

Researchers: Adjunct Assistant Professor Edward L. Maksym
and Hajo Eicken, University of Alaska at Fairbanks

Sea ice albedo is directly connected with the fraction of melt ponds covering the surface in the summer. For accurate predictions of ice extent and thickness under climate change scenarios, precise predictions of summer ice albedo are required. Yet no model is capable of realistically predicting the extent and distribution of melt ponds. Using new observations of melt pond fraction and ice morphology, a statistical description of melt pond dynamics was coupled with an ice growth and hydrological model. This pilot study aimed to determine the effects of variable snow deposition and meteorological conditions on the ice thickness and evolution of the ice albedo. While this project is in its initial stages, much of the ground work of model development has now been completed.

The Effect of Teleconnections from the ENSO Cycle on Climate in the Southeastern United States

Researchers: Assistant Professor Cecily C. Natunewicz
and Jonathan Hare, NOAA National Fisheries Service

Recent research has shown the strong impact of climatic forcing on Pacific fish stocks, yet relatively few studies have focused on the role of climate variation in driving the dynamics of Atlantic species. Nevertheless, global-scale climate forcing may potentially have significant effects on Atlantic populations, especially those in the Southeastern United States Atlantic Bight. In particular, teleconnections from the ENSO cycle may influence larval recruitment to Southeastern US estuaries. Specifically, high river discharge, anomalous wind patterns, and changes in the position of the Gulf Stream front may alter the circulation on the continental shelf and subsequently reduce the survival of shelf-spawned species by transporting larvae away from suitable nursery habitat inshore. Likewise cooler sea-surface temperatures may prolong larval development and potentially reduce larval survival. This study correlated time series of monthly Southern Oscillation Indices (50 years) with sea surface temperature; wind velocity and direction; and discharge from 12 rivers on the east coast of the U.S. to assess the potential influence of the ENSO cycle on transport and survival of winter-spawned fish larvae. Implications for the population dynamics of Atlantic menhaden, spot, Atlantic croaker, and pinfish, are being considered.

Meso-scale Distribution of Decapod Larvae in the Delaware Bay and on the Adjacent Continental Shelf

Researchers: Assistant Professor Cecily C. Natunewicz
and Charles E. Epifanio, University of Delaware

Physical and biological processes act in concert to form and maintain patches of plankton on a wide range of spatial and temporal scales. In this study we assessed the patchiness of 3 taxa of decapod larvae at a 10^4 m spatial scale. This spatial scale was chosen to discern changes in taxonomic distribution within different hydrodynamic regimes. In particular, we evaluated the potential for larvae released in areas of relatively weak subtidal circulation to be retained near the mouths of major estuaries. Blue crab (*Callinectes sapidus*), fiddler crab (*Uca spp*.), and xanthid crab (*Hexapanopeus angustifrons*) larvae were collected simultaneously at 3 sites near the mouth of Delaware Bay. One station was located within Delaware Bay, near the northern (New Jersey) shore (BAY); one within the estuarine plume, near Cape Henlopen, Delaware (PL); and one in the coastal ocean directly offshore of New Jersey (CNZ). Although time series of larval concentrations calculated from half-hourly plankton tows conducted at each station showed considerable heterogeneity, larval concentrations differed significantly between species at each station and among the three stations. Low concentrations of *C. sapidus* and *Uca* larvae were found at BAY and PL, yet significantly higher concentrations of these species were collected at CNZ. This result suggests that larvae released in areas of weak subtidal flow may be retained near the parent estuary. In contrast, the highest concentrations of *H. angustifrons* were collected at BAY, yet none were found at CNZ, supporting previous studies that have found that xanthid crab larvae are retained within Delaware Bay. The results of this study both illustrate meso-scale variability in crab larval distributions within Delaware Bay, and further support previous conceptual models of larval transport of *C. sapidus*, *Uca spp.* and *H. angustifrons* in the Middle Atlantic Bight.Formal statistical analysis of data collected on a previous research cruise.

Dynamics of Larval Patches: Spatial Distribution of Fiddler Crab Larvae in the Delaware Bay and Adjacent Waters

Researchers: Christopher Petrone, Lauren B. Jancaitis, and Charles E. Epifanio, University of Delaware,
Michael B. Jones, U.S. Environmental Protection Agency (EPA),
Assistant Professor Cecily C. Natunewicz, and Charles E. Tilburg, University of Georgia

This research was an investigation of the dynamics of patches of fiddler crab larvae (*Uca* spp.) in southern Delaware Bay and the nearby coastal ocean. The study encompassed all stages in the early life history of the crabs and included high-frequency sampling of newly hatched zoea larvae, detailed measurements of patch dimensions in the open waters of Delaware Bay and the coastal ocean, determination of trajectories of patches of zoeae using satellite technology, and observations of the characteristics of patches of megalopae as they were transported back into the estuary. Numerical-model simulations of the early stages of patch formation and compared model outcomes to real-world observations were conducted.

Results of earlier investigations have shown that fiddler crab larvae are hatched near the time of high tide during nocturnal spring tidal periods. The results in this study indicated that newly hatched fiddler crab larvae are exported from small tidal rivers in a long continuous stream lasting through the ensuing ebb-tide phase. These patches of larvae appear to result from synchronized spawning of large numbers of females. Along-stream dimensions of the patches at our sampling site were at least 8-9 km, and maximum densities of larvae were as high as 3×10^4 m^{-3}. Only part of each patch exited the river during the first ebb tide following hatching. Numerical simulations showed that the remaining portion of the initial patch exited the river during subsequent ebb tides following hatching. Upon reaching open waters of the Delaware Bay, the patches assumed quasi-circular shapes with apparent diameters ranging from about 500 to 1800 m. The numerical simulations showed a similar change in shape of patches as they entered the Delaware Bay. Trajectories of bay patches were strongly influenced by tidal circulation, which resulted in the transport of larvae back and forth along the shore of the bay at tidal frequency. Several patches of *Uca* larvae were also observed on the inner shelf near the mouth of the bay. Shelf patches contained substantial numbers of advanced-stage zoea larvae, supporting the notion that patches remain integral throughout the duration of larval development. Further support for this idea came from the observed patchy distribution of megalopae as they were transported back to juvenile habitat in marshes fringing the bay.

Applications of Synthetic Aperture Radar in Marine Meteorology

Researcher: Associate Professor Todd D. Sikora

This investigation reviewed many of the marine meteorological capacities of synthetic aperture radar (SAR). The attributes of SAR image analysis in the study of air sea interaction, providing examples of marine meteorological phenomena routinely imaged by SAR were examined, and discussions were held on how the scientific community can exploit this proven ability of SAR. The phenomena examined were organized by scale as follows: microscale cellular convection, microscale roll vortices, microscale gravity waves, mesoscale gravity waves, mesoscale convection, polar mesoscale cyclones, tropical cyclones, macroscale fronts and extra-tropical cyclones. In addition, a review of recent advances in the transfer of SAR images to high-resolution (order 100 m) near-surface wind speed images was conducted and a summary of the history and future of SAR as a meteorological tool was developed.

Marine Atmospheric Boundary Layer Cellular Convection and Longitudinal Roll Vortices

Researcher: Associate Professor Todd D. Sikora

This research described the phenomena of marine atmospheric boundary layer cells and rolls from a synthetic aperture radar (SAR) perspective. It examined their causes and structure, their signatures in SAR imagery, and what information can be extracted from those signatures. Knowledge of the spatial and temporal distribution, as well as intensity, of cells and rolls is particularly important to meteorologists and oceanographers. On the microscale (< 2 km) and mesoscale (2 km to 2000 km), cells and rolls can lead to organized convective precipitation. In mesoscale and macroscale (2000 km to 20,000 km) weather forecasting models, the spatial distribution of turbulent fluxes (and, hence, cells and rolls) appears as required terms in the governing equations. On very long temporal scales, the statistical representation of cells and rolls becomes important in climate modeling.

Mesoscale Stratocumulus Bands Caused by Gulf Stream Meanders

Researcher: Associate Professor Todd D. Sikora

Examination of visible and infrared imagery from geosynchronous and polar orbiter satellites revealed the occasional existence of mesoscale cloud bands of unusual width and area, originating over the open Northwest Atlantic Ocean during cold-air outbreaks. This phenomenon is of both dynamic and synoptic interest. As a dynamic phenomenon, it represents a mesoscale flow that is driven by transient surface features, meanders in the Gulf Stream. The forcing geometry and the resulting cloud pattern are similar in many respects to the anomalous cloud lines observed downwind of the Chesapeake and Delaware Bays in similar conditions. These open ocean cloud bands are often of a larger scale however, because the Gulf Stream meanders represent the largest-scale high-amplitude “coastal features” in the western North Atlantic. These cloud bands are of synoptic interest because, when present, they play a major role in determining the cloud pattern over much of this oceanic region.

Examination of surface and 850 hPa analyses demonstrated that these open ocean cloud bands occur during cold-air outbreaks and that they align approximately with the boundary-layer wind. Comparison of visible and infrared satellite imagery with contemporaneous sea surface temperature analyses derived from infrared polar orbiter satellite imagery revealed that the open ocean cloud bands originate at the upwind end of Gulf Stream meanders. Climatological data and synoptic observations from land and sea indicated that these events occur only during that part of the spring season in which coastal temperature differences are small but cold-air outbreaks continue to reach the Gulf Stream. Examination of this observational evidence suggested that these open ocean cloud bands result from mesoscale solenoidal circulations driven by the horizontal gradients in sea surface temperature caused by Gulf Stream meanders.

Use of Synthetic Aperture Radar in Fine-Scale Analysis of Synoptic-Scale Fronts at Sea

Researcher: Associate Professor Todd D. Sikora

The viability of synthetic aperture radar (SAR) as a tool for fine-scale marine meteorological analyses of synoptic-scale fronts was demonstrated. In particular, it was shown that SAR can reveal the presence of, and the mesoscale and microscale sub-structures associated with, synoptic-scale cold fronts, warm fronts, occluded fronts, and secluded fronts. The basis for these findings was the analysis of some 6000 RADARSAT SAR images from the Alaska SAR Demonstration data set, from the Gulf of Alaska, and analysis of RADARSAT SAR images from off the east coast of North America. This analysis yielded 158 cases of well defined frontal signatures: 22 warm fronts, 37 cold fronts, 3 stationary fronts, 32 occluded fronts, and 64 secluded fronts.

The Correction of Surface Layer Wind Speeds for Atmospheric Stratification and Height

Researcher: Associate Professor Todd D. Sikora

The comparison of SAR-derived wind speeds from scatterometer-based transfer functions and *in situ* or model wind speeds requires that both data sets represent the presence of equivalent atmospheric stratification and measurement height. The atmospheric surface layer dynamics underlying corrections to equivalent atmospheric stratification and measurement height were analyzed, and available methods for carrying out the corrections focusing on bulk flux algorithms available in the literature were reviewed.

Midshipman Research Course Projects

Lidar Analysis of the Hawaiian Island Coasts: Variations in Bathymetry with Age

Researcher: Midshipman 1/C Ian Drullard, USN
Adviser: Professor Peter L. Guth

Analysis of near shore bathymetry along the coast of five Hawaiian Islands, Hawaii, Maui, Molokai, Oahu, and Kauai, from the Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) system revealed geomorphic patterns related to island age. Study areas along the coasts of each island were chosen based on an equivalent amount of wind and wave action. The age of each coastal region was determined from geologic eruption records. The SHOALS randomly distributed soundings were gridded to form regular Digital Elevation Models (DEMs) for each island, and the DEMs were used to calculate area parameter statistics quantitatively describing the bathymetry. The statistics included elevation and slope moments, as well as directional indices, relief, and elevation relief ratio. The Hawaiian Islands vary progressively in age along the archipelago from Hawaii (25 ka), to Kauai, (4.75 Ma) The study area for Hawaii averaged a slope of 12.0° and a strength of 3.51, whereas the study are for Kauai averaged 2.8° and a strength of 6.42. Elevation slope plots for each study area show that the concentration of steep slopes for older islands occurs at deeper depths, farther from the shore, whereas that of younger islands occurs at shallower depths, nearer to the shore. Analysis of the coastal regions show that the older an island, the wider and more gradual the coastal slope and the smoother and flatter the bathymetry due to wind and wave erosion.

Effects of Snow Cover on Antarctic Sea

Researcher: Midshipman 1/C Matthew Watts, USN
Adviser: Adjunct Assistant Professor Edward L. Maksym

Snow cover plays an important role on the thin Antarctic sea ice due to relatively thick snow depths. Snow is a strong insulator, limiting vertical heat flux through ice and therefore limiting growth. Accurate thermal conductivity values for snow are difficult to predict, but are necessary for accurate modeling of ice growth. Data sets of ice and snow depths, surface and snow/ice interface temperatures were obtained on cruises aboard the R/V Nathanial B. Palmer in 1993, 1995, and 1998, in the Ross, Amundsen, and Bellingshausen Seas.

Apparent snow conductivity values, k_s, were calculated at each data point to evaluate the effect of snow insulation. Median k_s values for the 1993, 1995 (early), 1995(late), and 1998 cruises were 0.222 $Wm^{-1}K^{-1}$, 0.288 $Wm^{-1}K^{-1}$, 0.393 $Wm^{-1}K^{-1}$, and 0.267 $Wm^{-1}K^{-1}$, respectively, giving a mean value of 0.295 $Wm^{-1}K^{-1}$.

The median apparent k_s values for each cruise are significantly greater than measured in-situ thermal conductivity values, and more in line with values commonly used in modeling studies (~ 0.3 $Wm^{-1}K^{-1}$). This indicates that vertical heat flow is enhanced by about a factor of two.

This work is a significant contribution to our understanding of the effects of snow on sea ice, as it illustrates a gap in our understanding of the heat flow processes in the snow cover. This is of particular importance in predictions of sea ice extent in global warming scenarios.

Lunar Tidal Influences on the Occurrence and Propagation of Red Tide in the Gulf of Maine and Gulf of Massachusetts

Researcher: Midshipman 1/C Kaitlyn Longley, USN
Adviser: Assistant Professor Cecily C. Natunewicz

The co-occurrence of Red Tide blooms (*Alexandrium tamarense*) and lunar tidal cycles has been studied in a limited scope over the past thirty years. In this study we examine this phenomenon in the off-shore waters of the Gulf of Maine and Gulf of Massachusetts, where there is an annual occurrence of the toxic blooms. Although these blooms have been observed and documented, there are little reliable data available to predict the future occurrence and propagation of the blooms. This study expanded upon limited data concerning the Gulf of Maine Red Tide blooms and their association with lunar, and in particular, spring tides.

The co-occurrence of *A. tamarense* blooms and lunar tides were examined via Kolmogorov-Smirnov statistical tables, the chi-square, and Rayleigh tests following the protocol of Balch (1986). In contrast to previous studies that focused on specific stations within the Gulf of Maine for a limited time span or on a global scale with only informal observations of blooms, this study compared several years of bloom data from formal monitoring programs within the Gulf of Maine and Gulf of Mexico (ECOHAB) with lunar cycles in order to determine whether or not lunar cycles act to initiate blooms. Shellfish closings and complementary physical data illustrated that tidal currents did not likely cause re-suspension of *A. tamarense* cysts, and that the timing of red tides was not normally distributed relative to any particular part of the lunar cycle.

The Effect of Meteorological and Oceanographic Forcing on Transport of Larval Crabs

Researcher: Midshipman 1/C Allison Moon, USN
Adviser: Assistant Professor Cecily C. Natunewicz

Meteorological and oceanographic forcing in the Chesapeake Bay affects not only the circulation of water in the bay, but also the depth and distribution of small organisms such as larval crabs. Many species of crabs spawn in the lower bay, and prevailing seaward flow near the bay's mouth advects the larvae of a number of species into the open ocean. The larvae develop over the continental shelf, but are often recruited back into the bay by recurring southward wind events and accompanying across-shelf transport. Increased flow past larval settlement collectors during wind events and strong tides should result in the collection of greater numbers and more species diversity of crab larvae. In this experiment, daily

collections of physical data and crab larvae in the Severn River illustrated that strong wind events increased mean sea level, but had little effect on the number of larvae collected on artificial settlement substrata. Overall, very few larvae from only one crab species (*Rhithropanopeus harrisii*) were collected over two months, possibly due to increased rainfall causing greater seaward flow and low salinities that drive crabs further southward toward the Bay's mouth. Furthermore, the uncontrollable variables, including the destruction of the collection site by Hurricane Isabel and the placement of a barge directly within the river flow to a depth of 5m, renders the experiment inconclusive with respect to its initial purpose of determining the flow's effect on megalopae species and quantity. However, the physical data clearly support the relation between mean sea level and wind speed.

Quantification of Japanese Shore Crab Invasion in Ocean City Inlet, Maryland

Researcher: Midshipman 1/C Ian Rummel, USN
Adviser: Assistant Professor Cecily C. Natunewicz

The Japanese shore crab, *Hemigrapsus sanguineus*, is a recent (1988) invader of the East Coast of North America. Like its invasive predecessor, the European green crab *Carcinus maenas*, *H. sanguineus* is resistant to salinity changes, has a highly variable diet, and reproduces frequently, making it an ideal invader and competitor with local species. Although *H. sanguineus* has been documented along the US east coast, formal quantification of the crab in an important tourist destination, Ocean City, Maryland, had not been conducted. Therefore, the survey described herein provided spatial and temporal data of the occurrence of *H. sanguineus* in a rocky intertidal habitat to serve as a baseline for documenting the potential increase in the number of *H. sanguineus* individuals in Ocean City. To this end, during the fall of 2004, three 10m transect lines were laid from the lower to upper intertidal levels, and $1m^2$ quadrats along these lines were randomly selected for sampling. Sampling occurred within ~1 hour of low tide at 3-week intervals. After initial temperature and salinity measurements were collected at the site, all crabs in each quadrat were removed, identified, and measured, then returned to the quadrat. Specifically noted were species, carapace length and width, and the presence of any females carrying eggs. Percent cover of rocks and various algal species was used to extrapolate trends in the Japanese shore crab's preferred shelter type for this particular branch of the invasion. Data were used in conjunction with existing research to determine the progress of *H. sanguineus* in a representative developed coastal zone as well as its interactions with indigenous crabs and less-recent invaders.

A Comparison of Weather in U.S. Cities during the Winter of 2002-2003 to the El Niño's 1982-1983 and 1997-1998

Researcher: Midshipman1/C Margaret Sweeny, USN
Adviser: Associate Professor David R. Smith

The El Niño weather phenomenon has a large effect on the climate of regions around the world. El Niño has influenced storm tracks, weather patterns, temperature and precipitation. In this study, weather charts, temperature, precipitation and other observations were examined for fourteen U.S. Cities in order to chart the effects of the 2002-2003 El Niño. The monthly averages of these cities were compared to the El Niño of this year and previous El Niños. In addition, the MEI (Multivariable ENSO Index) of the 2003-2003 El Niño was examined at the cities of interest to better understand the correlation between the index and the observed weather. The month of February 2003 was examined in particular due to its unusually unseasonable and extreme weather. The result s of this study provided a better understanding and explanation of the weather associated with 2002-2003 El Niño season.

Mathematical Modeling of Double Diffusion Convection

Researcher: Midshipman 1/C Allison Berg, USN
Advisers: Associate Professor David R. Smith
and Professor Reza Malek-Madani (Mathematics Department)

Salt fingering, a product of double diffusion, is an oceanic small-scale phenomenon that is extremely prevalent in an oceanographic sense. The conditions for double diffusion exist when warm saline water is present over colder less salty water. Because seawater conducts heat one hundred times faster than it diffuses salt, the phenomenon of double diffusion occurs. If double diffusion is accurately modeled, then the ocean's temperature and salinity can be analyzed more effectively. In order to produce an accurate model, this study analyzed the governing equations in the following papers: Howard, L. N., and Veronis, G. (1987) and Merryfield, W. J., Holloway, G., and Gargett, A. E. (1998). This study then used the Galerkin Method to solve the initial boundary value problem and writes a mathematical program that will model oceanic salt fingering. The results served to analyze the phenomenon of double diffusion, and, in the future, will provide oceanographers a means to more effectively understand the ocean's temperature and salinity properties.

The Formation and Life Cycle of Convective Systems Using Mathematical Modeling

Researcher: Midshipman 1/C Andrew Straessle, USN
Advisers: Associate Professor David R. Smith
and Professor Reza Malek-Madani (Mathematics Department)

The causes behind the formation and the life cycle of the microburst phenomena are not completely understood. This project was designed in the hope of creating a model of the structure and life cycle of microburst systems based upon the equations of motion, mass continuity, and the first law of thermodynamics. Although a model was never fully reached, a better understanding of the atmospheric conditions that lead to the occurrence of convective systems has been gained using a two-dimensional squall line simulation.

Convective systems create strong wind shears environments surrounding updrafts and outflow winds and are a large contributor to aviation accidents every year. Constant advances have been made over the years regarding convective storms using techniques such as Doppler radar. Current numerical models are capable of reflecting atmospheric conditions surrounding certain convective systems but fail when applied to other more obscure systems such as wet microbursts. Continuous research is being done to find a model that works for all convective systems and the atmospheric conditions associated with them. In the first segment of this study, efforts were undertaken to gain an understanding of the mathematical computation to be taken into account in the model. In addition, research on conditions surrounding convective storms was investigated. In the second segment of the research, work was done to install, run, and understand the parameters of the Weather Research and Forecasting (WRF) model received from the National Center for Atmospheric Research. (This model is capable of depicting convective systems.) The graphing capabilities within EXCEL were used for this project to analyze the output received from the WRF model.

An Analysis of Condition that Produced Hurricane Isabel and its Effects on the Mid-Chesapeake Bay Area

Researcher: Midshipman 1/C Brandi Olson, USN
Adviser: Associate Professor David R. Smith

A significant amount of previous research has been conducted in order to investigate the weather factors leading up to the formation of hurricanes, especially during the Atlantic tropical storm season. There is not any research published on Hurricane Isabel yet, due to the fact it is such a recent weather occurrence (September 2003). In this research, a case-study approach was undertaken to analyze weather products available from the National Center for Environmental Prediction that describe the conditions preceding and during the landfall of Hurricane Isabel. In addition to analyzing the conditions during the formation of Isabel, this study focused on the characteristics, intensity, and track of the storm through the Atlantic until it came ashore in North Carolina. Finally, an analysis was conducted to determine the reasons that the hurricane produced such a sizeable storm surge and flooding, causing wide-scale damage in the mid-Chesapeake Bay region.

A Study of the Dynamics Governing Santee Basin

Researcher: Midshipman 1/C Gabriela Johnson, USN
Advisers: Associate Professor Mário E.C. Vieira and LT Bryan Black, USN

Two S4 current meters, two YSI6000 water quality devices, and a Seabird SBE-19 CTD were located underneath Hendrix Oceanography Laboratory, which is situated at the mouth of Santee Basin, and data were collected from 28 June 1997 until 4 September 1997. The basin is largely governed by the Severn River; such that anything that happens within or to the Severn River has a direct effect on Santee Basin. Thus, the physical parameters of the basin reflect those of the Severn River. However, since the basin is an enclosed body of water, it is susceptible to phenomena that would not occur in the river, such as seiches. In this research study, the data from 1997 was analyzed. It was determined that density was the largest driving force on characteristics within the Severn River estuary, and the wind played a secondary role in forcing the physical parameters of Santee Basin. While the forcing in the basin was relatively small during the study period, it was sufficient to drive a seiche that mixed it and decreased its stratification.

Northeastern U.S. Estuarine Eutrophication: A Review of Wastewater Nitrogen as a Form of Nearshore Aquaculture

Researcher: Midshipman 1/C Christopher Polnaszek, USN
Adviser: Associate Professor Mário E.C. Vieira

This environmental theoretical study addressed the question of whether or not it is possible to transport the materials and nutrients of wastewater away from an estuarine environment, where the effects are harmful and debilitating, to the edge of the continental shelf, where the effluent can be released effectively to seed the ocean with fertilizer and establish an economically viable artificial fishery. Every day along estuaries' watersheds, thousands of gallons of treated wastewater are dumped into the waterways with high concentrations of nitrogen and phosphorus. The overabundance of nutrients, or eutrophication, results in plankton blooms and destroys the estuarine ecology because the shallow waters cannot handle the large phytoplankton population. The destruction of the estuarine ecology is of importance for humans because the seafood industry relies on shellfish populations and fishery sustainability in these once fertile estuaries. In order to limit the damage to an economically viable ecosystem, an attempt to transport the nutrient rich wastewater away from the unhealthy coastal waters to the oligotrophic waters along the edge of the continental shelf might benefit both ecosystems. An offshore deep-sea structure could create an "upwelling zone" by injecting a large concentration of nutrients into the surface layer so they could be used by phytoplankton. These nutrients would be provided by collecting wastewater from treatment facilities along the Northeast and connecting them with overland and underwater pipes to the middle of the shelf in the Northern Middle Atlantic Bight. The phytoplankton and zooplankton would provide the base of a food web engineered or manipulated to produce commercially viable artificial fisheries, which are becoming more and more necessary as natural fisheries continue to be over-stressed.

Publications

Journal (Refereed) Manuscripts

Young, G. S., and SIKORA, Todd D., Associate Professor, "Mesoscale Stratocumulus Bands Caused by Gulf Stream Meanders," *Mon. Wea. Rev.*, Vol. 131, 2003, pp. 2177-2191.

Examination of visible and infrared imagery from geosynchronous and polar orbiter satellites reveals the occasional existence of mesoscale cloud bands of unusual width and area, originating over the open Northwest Atlantic Ocean during cold-air outbreaks. This phenomenon is of both dynamic and synoptic interest. As a dynamic phenomenon, it represents a mesoscale flow that is driven by transient surface features, meanders in the Gulf Stream. The forcing geometry and the resulting cloud pattern are similar in many respects to the anomalous cloud lines observed downwind of Chesapeake and Delaware Bays in similar conditions. These open ocean cloud bands are often of a larger scale however, because the Gulf Stream meanders represent the largest-scale high-amplitude "coastal features" in the western North Atlantic. These cloud bands are of synoptic interest because, when present, they play a major role in determining the cloud pattern over much of this oceanic region.

Examination of surface and 850 hPa analyses demonstrates that these open ocean cloud bands occur during cold-air outbreaks and that they align approximately with the boundary-layer wind. Comparison of visible and infrared satellite imagery with contemporaneous sea surface temperature analyses derived from infrared polar orbiter satellite imagery reveals that the open ocean cloud bands originate at the upwind end of Gulf Stream meanders. Climatological data and synoptic observations from land and sea indicate that these events occur only during that part of the spring season in which coastal temperature differences are small but cold-air outbreaks continue to reach the Gulf Stream. Examination of this observational evidence suggests that these open ocean cloud bands result from mesoscale solenoidal circulations driven by the horizontal gradients in sea surface temperature caused by Gulf Stream meanders.

Conference Proceedings

Geer, I.W., SMITH, David R., Associate Professor, Moran, J.M., Weinbeck, R.S., Mills, E.W., and Hopkins, E.J., "The Education Programs of the American Meteorological Society: A Strong Past, a Committed Present and a Bright Future," Preprints of the *6th International Conference on School and Popular Meteorological and Oceanographic Education* , Universidad Europea de Madrid, Madrid, Spain, 2003. (CD-ROM)

This paper is an overview of the educational programs of the American Meteorological Society (AMS). It includes descriptions of two summer workshops for teachers, three distance-learning courses for K-12 teachers, and a distance-learning introductory course in meteorology for undergraduate students in two- and four-year colleges. In addition, the AMS is working with the National Oceanic and Atmospheric Administration to promote meteorological and oceanographic education for underrepresented minority groups.

Geer, I.W., Moran, J. M., Weinbeck, R. S., SMITH, David R., Associate Professor, Hopkins, E. J., Blair, B. A., and Niebauer, J.H., "DataStreme Ocean: A New Distance-learning Course for Pre-college Teachers on the Basics of Oceanography," Preprints of the *13th AMS Symposium on Education*, Amer. Meteor, Soc., Boston, MA, 2004. (CD-ROM)

This paper is a summary of results compiled from a survey of eight years of Maury Project participants. This paper finalizes the outcome of the survey to gauge the effectiveness of the Maury Project as a teacher enhancement program. It also evaluates the quality of materials developed and if the participants use the materials in their classroom and to train other teachers.

GUTH, Peter L., Professor, "Ambush Movies and the Weapons Fan Algorithm: Military GIS Operations and Theory," *Proceedings of the International Conference on Military Geology and Geography*, West Point, NY, June 2003. (CD-ROM)

An ambush movie provides one of the most useful and specialized functions of MICRODEM. The user defines a route of travel, and at each point along the route, the program computes where ambushing forces could see the route by drawing a weapons fan. Each weapons fan is stored as a frame in the movie. A final summary image depicts the percentage of the route that can be seen from each potential ambush location. This function can be used offensively to plan an ambush, or defensively to determine the most dangerous locations along the route. Weapons fan algorithms fall into two categories: those that draw radials from the observer and compute intervisibility at defined points along the radials, and those that compute intervisibility between points in the DEM grid. We propose that a weapons fan algorithm should draw radials. Judicious selection of the angular spacing between rays, and the spacing between points along the radials, insures that intervisibility can be computed at every visible pixel on screen, at a higher resolution than with the DEM grid method, and in less computing time.

GUTH, Peter L., Professor, "Terrain Fingerprints: Statistical Analysis of Digital Elevation Models," *Proceedings ASPRS 2004 Annual Conference*, Denver, CO, paper # 71, 12 pages, May 2004, (CD-ROM).

Digital elevation models (DEMs) provide a vital background for many GIS operations by providing a 3D framework for display and analysis. We have analyzed the geomorphology recorded in DEMs from North America at a range of scales from 10 m to 100 m, and from USGS cartographic sources and satellite sources from NGA (SRTM) and NASA (ASTER). We have complete coverage of the old 1:250K USGS DEM, the new 1" NED, and

1" SRTM. We have partial coverage of 10 m USGS SDTS DEMs, 30 m level 1 and level 2 USGS SDTS DEMs, and ASTER DEMs. We have created a database of over 500,000 2½'x2½' tiles covering the United States for eight DEM series. The database also includes land cover, climate, and regional geology characteristics that we can relate to geomorphology. This enables us to create a terrain fingerprint for every location in the United States, keying on almost 50 variables like roughness/slope, curvature, elevation moments, and terrain organization. We can predict how these parameters change with the scale of the DEM, and how the different collection methods bias the fingerprint. This provides a major benefit for analysts needing to create highly accurate spatial models based on specific geographical locations, or to fill holes in data sets. In particular this will help with enhancing SRTM data in the rest of the world, where other DEMs are not available, and we can help predict what the terrain most likely looks like from its signature in the radar topography.

GUTH, Peter L., Professor, 2003, Geomorphometry of DEMs: Quality Assessment and Scale Effects: Geological Society of America Abstracts with Programs, Vol.35, no.7, paper 183-2, November 2003.

Digital elevation models (DEMs) provide a foundation for a variety of geological and geophysical operations. We have calculated a suite of over 35 geomorphic parameters for the United States for seven different DEM series (about 70GB compressed). We have created a database of over 450,000 2½'x2½' tiles covering the United States for each of the seven DEM series. The database includes land cover, climate, and regional geology characteristics that we can relate to geomorphology. Correlation matrices from a single DEM series confirm that a large proportion of the metrics that have been proposed really measure a single parameter, surface slope or roughness. Variogram, Fourier, and fractal methods have been resistant to automation, because they require special preprocessing, or subjective determination of linearity or trends in noisy periodic data. The most robust, independent, and interpretable parameters appear to be surface slope or roughness, terrain organization (the tendency of ridges and valleys to share a common orientation), and the elevation-relief ratio or hypsometric integral. Curvature moments contain a noisier signal due to DEM error and quantization effects. Correlations between series enable us to assess the effects of DEM scale and collection method on geomorophometric parameters. For example, compared to NED, SRTM computes steeper average slopes for flat areas because of the radar speckle, and gentler slopes for steep areas because of the overall smoothing of the radar DEM.

GUTH, Peter L., Professor, Oertel, Olaf, Bénard, Guillaume and Thibaud Rémy, "Pocket Panorama: 3D GIS on a Handheld device," (Bertolotto, M., ed.), *Proceedings of the 3rd International Workshop on Web and Wireless Geographical Information Systems*, (W^2GIS 2003), December 2003, Rome, Italy, pp 92-96, and *Proceedings of the 4th International Conference on Web Information,* Systems Engineering Workshops, December 2003, Rome, Italy, pp. 100-105.

Pocket Panorama, an original client-server application, provides mapping data and 3D terrain visualizations to a handheld Pocket PC. The Pocket PC acts as a client to a server PC, which contains all data and performs all display manipulations. The terrain visualization displayed on the client uses the GPS positions transmitted by the Pocket PC. All exchanges use the http protocol and remain independent of the network connection used. Within the United States, a networked Pocket PC can automatically obtain high resolution maps or aerial photography around its position with a single click of the stylus from the Terraserver web site.

Johnson, R., Henderson, S., Snow J., SMITH, David R., Associate Professor, Foster S., Mastie D., Ward D., Bergman J., and Pennington, "The NCAR Geoscience Education Professional Development Program," Preprints of the *6th International Conference on School and Popular Meteorological and Oceanographic Education*, Universidad Europea de Madrid, Madrid, Spain, 2003. (CD-ROM)

This paper describes the development of summer workshop for teachers conducted by the National Center for Atmospheric Research (NCAR). Two workshops were conducted in the summer of 2002 – one on Global Climate Change and the other on Modeling Techniques. Teachers from across the country attended these two workshops, which included exposure to the research conducted by scientists at NCAR at other institutions in Boulder, CO.

Moran, J.M., Geer, I. W., Weinbeck, R. S., SMITH, David R., Associate Professor, Hopkins, E. J., and Blair, B. A., "Water in the Earth System: A Teacher Enhancement Distance Learning Course," Preprints of the *6th International Conference on School and Popular Meteorological and Oceanographic Education*, Universidad Europea de Madrid, Madrid, Spain , 2003. (CD-ROM)

This paper describes the Water in the Earth System (WES) distance-learning course. WES is an interdisciplinary course combining topics in atmospheric and oceanic sciences and ground water hydrology to understand the water cycle in the Earth system. To date, this program has been taken by hundreds of teachers in the U.S., providing them with materials, activities, and near-real-time products pertaining to water processes.

Pandya, R.E., SMITH, David R., Associate Professor, Ramamurthy, M., Croft, P.J., Hayes, M.C., Murphy, K.A., McDonnel, J.D., Johnson, R.M., and Friedman, H.A., 11th AMS Symposium on Education, *Bulletin of the American Meteorological Society*, 2003, pp. 425-430.

The 11th American Meteorological Society (AMS) Education Symposium was held from 13-15 January 2002 in Orlando, FL, as part of the 82nd Annual Meeting of the American Metrological Society. The theme of the symposium was "Creating Opportunities in Educational Outreach in the Atmospheric and Related Sciences." Drawing from traditional strengths in meteorology and numerous national recommendations, the presentations and posters of the symposium highlighted three opportunities for reform. These opportunities build on partnerships between diverse educational stakeholders, efforts to make science education more like scientific practice, and strategies that place the atmospheric sciences within a larger, multidisciplinary context that includes oceanography, hydrology and earth-system science.

SMITH, David R., Associate Professor and Geer, I.W., "An Assessment of the Maury Project by its Participants (1994-2001): How are we doing?," Preprints of the *6th International Conference on School and Popular Meteorological and Oceanographic Education* , Universidad Europea de Madrid, Madrid, Spain, 2003. (CD-ROM) and Preprints of the *13th AMS Symposium on Education,* Amer. Meteor, Soc., Boston, MA, 2004. (CD-ROM)

This paper is a preliminary summary of results compiled from a survey of eight years of Maury Project participants. The intent was to determine how effective the Maury Project has been as a teacher enhancement program. It also evaluates the quality of materials developed and if the participants use the materials in their classroom and to train other teachers.

Book Chapters

GUTH, Peter L., Professor, "Terrain Organization Calculated From Digital Elevation Models," in Evans, I.S., Dikau, R., Tokunaga, E., Oi, H., and Hirano, M., eds., Concepts and Modeling in Geomorphology: International Perspectives, Terrapub Publishers, Tokyo, Japan, pp.199-220.

Digital elevation models (DEMs) cover a wide range of scales, and allow statistical analysis of geomorphometric parameters. At global or continental scale, DEMs covering rectangular quadrangles can be considered random samples. Average quadrangle values can be compared at different DEM scales, and for different physiographic provinces. Three independent variables provide valuable descriptions of terrain: average elevation, average slope, and the degree of terrain organization. DEMs with spacings of 30" (global coverage), 3" (continental United States), and 30 m (local United States) provide almost perfect correlations for average quadrangle elevation and slope, although the slope values increase as the DEM spacing decreases. The degree of terrain organization also correlates across DEM scales, but with lower correlation coefficients, especially in areas of lower relief. Terrain variables computed from 10 m and 30 m USGS Level 2 DEMs are essentially identical. Slope algorithms perform differently in different physiographic provinces, and the aspect algorithm performs poorly in low relief areas. Geomorphometric analysis can provide a rapid and effective assessment of DEM quality control, and should be integrated into the DEM production process.

SIKORA, Todd D., Associate Professor, Young, G. S., Beal, R. C., Monaldo, F. M., and Vachon, P. W., "Applications of Synthetic Aperture Radar in Marine Meteorology," in *Advances in Fluid Mechanics: Atmosphere – Ocean Surface Interactions*, (William Perrie, ed.), Wessex Institute of Technology, in press.

This chapter reviews many of the marine meteorological capacities of synthetic aperture radar (SAR). We first examine the attributes of SAR image analysis in the study of air sea interaction, providing examples of marine meteorological phenomena routinely imaged by SAR and discussions on how the scientific community can exploit this proven ability of SAR. Phenomena examined are organized by scale as follows: microscale cellular convection, microscale roll vortices, microscale gravity waves, mesoscale gravity waves, mesoscale convection, polar mesoscale cyclones, tropical cyclones, macroscale fronts and extra-tropical cyclones. Next, we provide a review of recent advances in the transfer of SAR images to high-resolution (order 100 m) near-surface wind speed images. Finally, we summarize the history of SAR as a meteorological tool and discuss its future.

SIKORA, Todd D., Associate Professor and Ufermann, S., "Marine Atmospheric Boundary Layer Cellular Convection and Longitudinal Roll Vortices," in *SAR Marine User's Manual*, (J. R. Apel, ed.), National Oceanic and Atmospheric Administration, in press.

This chapter describes the phenomena of marine atmospheric boundary layer cells and rolls from a synthetic aperture radar (SAR) perspective. It will examine their causes and structure, their signatures in SAR imagery, and what information can be extracted from those signatures. Knowledge of the spatial and temporal distribution, as well as intensity, of cells and rolls is particularly important to meteorologists and oceanographers. On the microscale (< 2 km) and mesoscale (2 km to 2000 km), cells and rolls can lead to organized convective precipitation. In mesoscale and macroscale (2000 km to 20,000 km) weather forecasting models, the spatial distribution of turbulent fluxes (and, hence, cells and rolls) appears as required terms in the governing equations. On very long temporal scales, the statistical representation of cells and rolls becomes important in climate modeling.

Presentations at Professional Meeting and Conferences

GUTH, Peter L., Professor, "Terrain Fingerprints: Statistical Analysis of Digital Elevation Models:," ASPRS 2004 Annual Conference, 23-28 May 2004, Denver CO.

GUTH, Peter L., Professor, Oertel, Olaf, Bénard, Guillaume and Thibaud Rémy, "Pocket Panorama: 3D GIS on a Handheld Device," 4th International Conference on Web Information Systems Engineering Workshops, December 2003, Rome, Italy.

GUTH, Peter L., Professor, "Terrain Fingerprints," ESRI-MUG Mid-Atlantic User Group Annual Conference, 14 November 2003, Reston, VA.

GUTH, Peter L., Professor, "Geomorphometry of DEMs: Quality Assessment and Scale Effects," Geological Society of America National Meeting, November 2003, Seattle, WA.

GUTH, Peter L., Professor, "Ambush Movies and the Weapons Fan Algorithm: Military GIS Operations and Theory," International Conference on Military Geology and Geography, 15-18 June 2003, West Point, NY.

JONES, Henry, Commander (USN) and Assistant Professor, Batteen, M.L., Collins, C.A., Nuss, W.A., and Miller, D.K., "Effects of High-Resolution Atmospheric Model and Scatterometer Wind Forcing on a Navy Regional Ocean Model," Annual Conference of the National Society of Black Physicists and Black Physics Students, 18-21 February 2004. (Invited speaker)

JONES, Henry, Commander (USN) and Assistant Professor, Batteen, M.L., Collins, C.A., Nuss, W.A., and Miller, D.K., "Effects of High-Resolution Atmospheric Model and Scatterometer Wind Forcing on a Navy Regional Ocean Model," OS32J-01, American Geophysical Union (AGU) Ocean Sciences Meeting, 26-30 January 2004, Portland, OR.

JONES, Henry, Commander (USN) and Assistant Professor, Batteen, M.L, and Martinho, A.C., "Comparisons and Contrasts of the California and Northern Canary Current Systems using Results from Terrain Following Coastal Ocean Models," OS31C-13, American Geophysical Union (AGU) Ocean Sciences Meeting, 26-30 January 2004, Portland, OR.

JONES, Henry, Commander (USN) and Assistant Professor, Batteen, M.L., Collins, C.A., Nuss, W.A., and Miller, D.K., "Sensitivity of a Navy Regional Ocean Model to High-resolution Atmospheric and Scatterometer Wind Forcing and Processes," 6-8 August 2003, Seattle, WA.

NATUNEWICZ, Cecily, C. Assistant Professor and Hare, J., "The Effect of Teleconnections from the ENSO Cycle on Climate in the Southeastern United States," American Geophysical Union (AGU) Ocean Sciences Meeting, 26-30 January 2004, Portland, OR.

SMITH, David R., Associate Professor and Geer, I.W., "An Assessment of the Maury Project by its Participants (1994-2001): How Are We doing?," 6th International Conference on School and Popular Meteorological and Oceanographic Education, July 2003, Madrid, Spain.

SMITH, David R., Associate Professor, Geer, I.W., Moran, J.M., Weinbeck, R.S., Mills, E.W., Hopkins, E.J., and Blair, B.A., "The Education Programs of the American Meteorological Society: A Strong Past, a Committed Present and a Bright Future," 6th International Conference on School and Popular Meteorological and Oceanographic Education, July 2003, Madrid, Spain.

SMITH, David R., Associate Professor, Geer, I.W., Moran, J.M., Weinbeck, R.S., Hopkins, E.J., and Blair, B.A., "Water in the Earth System: A Teacher Enhancement Distance Learning Course," 6th International Conference on School and Popular Meteorological and Oceanographic Education, July 2003, Madrid, Spain.

SMITH, David R., Associate Professor, Johnson, R., Henderson, S., Snow, J., Foster, S., Mastie, D., Ward, D., Bergman, J., and Pennington, P., "The NCAR Geoscience Education Professional Development Program," 6th International Conference on School and Popular Meteorological and Oceanographic Education, July 2003, Madrid, Spain.

SMITH, David R., Associate Professor, and Geer, I.W., "Evaluation of the Maury Project by its Participants," 13th American Meteorological Society (AMS) Symposium on Education, January 2004, Seattle, WA

SMITH, David R., Associate Professor, Geer, I.W., Moran, J.M., Weinbeck, R.S., Hopkins, E.J., Blair, B.A., and Niebauer, J.H., "DataStreme Ocean: A New Distance-learning Course for Pre-college Teachers on the Basics of Oceanography," 13th American Meteorological Society (AMS) Symposium on Education, January 2004, Seattle, WA.