
PROJECT SUMMARIES

PROCESS MODELING STUDIES OF THE CALIFORNIA CURRENT SYSTEM

Mary L. Batteen, Associate Professor

Department of Oceanography

Sponsor: National Science Foundation and Naval Postgraduate School

OBJECTIVE: The overall objectives of this research are to investigate the generation, stability, and maintenance of currents and eddies in the California Current System (CCS), and to better describe their contributing forcing mechanisms and their relative importance.

SUMMARY: Process-oriented modeling studies have been used to explore the roles of wind and thermal forcing, and coastal irregularities in the generation of currents and eddies in the CCS.

PUBLICATIONS:

Batteen, M.L., Buch, E.J., and Huang, M.-J., "On the Effects of Coastline Irregularities in Eastern Boundary Currents," *Proceedings of the 44th Eastern Pacific Ocean Conference*, Fallen Leaf Lake, CA, 17 September 1997.

Batteen, M.L., "Wind-Forced Modeling Studies of Currents, Meanders, and Eddies in the California Current System," *Journal of Geophysical Research*, Vol. 102, No. 102, pp. 985-1010, 15 January 1997.

Batteen, M.L. and Huang, M.-J., "The Effect of Salinity on Density in the Leeuwin Current System," *Research Activities in Atmospheric and Oceanic Modeling, CAS/JSC Working Group on Numerical Experimentation*, Vol. 25, 8.6, January 1997.

Buch, E.J. and Batteen, M.L., "Wind-Forced Modeling Studies of Currents, Meanders, Eddies, and Filaments of the Canary Current System," Naval Postgraduate School Technical Report, NPS-OC-97-004, June 1997.

Monroe, J.T. and Batteen, M.L., "A Large-Scale Modeling Study of the California Current System," Naval Postgraduate School Technical Report, NPS-OC-97-007, December 1997.

Vance, P.W. and Batteen, M.L., "Modeling Studies of Wind and Thermohaline Forcing on the California Current System," Naval Postgraduate School Technical Report, NPS-OC-97-005, June 1997.

CONFERENCE PRESENTATION:

Batteen, M.L., Buch, E.J., and Huang, M.-J., "On the Effects of Coastline Irregularities in Eastern Boundary Currents," 44th Eastern Pacific Ocean Conference, Fallen Leaf Lake, CA, 17 September 1997.

THESES DIRECTED:

Buch, E.J., "Wind-Forced Modeling Studies of Currents, Meanders, Eddies, and Filaments of the Canary Current System," Master's Thesis, Naval Postgraduate School, June 1997.

Monroe, J.T., "A Large-Scale Modeling Study of the California Current System," Master's Thesis, Naval Postgraduate School, December 1997.

Vance, P.W., "Modeling Studies of Wind and Thermohaline Forcing on the California Current System," Master's Thesis, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREA: Battleship Environments

KEYWORDS: California Current System

PROJECT SUMMARIES

ASSESSMENT OF THE IMPACT OF TRANSMITTED WAVEFORMS ON ENERGY SPREADING LOSS (ESL) ON THE AN/SQS-53C TACTICAL SONAR IN VARIOUS SHALLOW WATER ENVIRONMENTS

Robert H. Bourke, Professor
James H. Wilson, Professor
Department of Oceanography
Sponsor: Naval Undersea Warfare Center

OBJECTIVE: This is a continuation of a multi-year project to investigate the influence of bottom reverberation and energy spreading loss on the performance of the hull-mounted, mid-frequency sonar (AN/SQS-53C) in shallow water. The project has been extended to examine the expected performance of the 53C using various wave forms and to assess performance in two specific shallow water areas.

SUMMARY: The earlier efforts used the Generic Sonar Model (GSM) to develop estimates of the transmission loss (TL) and bottom reverberation level (RL) based upon geophysical input data from AREA F off the U.S. eastern continental shelf. This was followed by an investigation (Tanaka, 1996) into the cause and quantification of the time stretching of the echo level in shallow water, termed energy spreading loss (ESL). The time spreading of a 200 Hz-wide Blackman pulse at 3.5 kHz was modeled as a function of geoacoustic bottom type, water depth, sound speed profile, and source/receiver depth.

Currently, NPS student, LT Peter Smith, is studying the effect of various pulse shapes (Blackman, CW and HFM) on ESL for the shallow waters of Onslow Bay and Long Bay off the Carolina coast. These areas have served as test beds for the Navy's critical sea test studies and will continue to do so. They represent a stark contrast in that the former has only a thin sediment cover leading to highly reflective bottom interactions. The latter has a thick sediment cover. Tanaka (1996) has shown that a 5-8 dB difference can exist between these two extreme environments. Preliminary studies indicate that the wave form shape exerts little influence on ESL with pulse duration being a prime factor. Additionally, the effect of bottom slope (up and down) and water depth on ESL will be examined.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Shallow Water Acoustics, Onslow Bay, Long Bay, Energy Spreading Loss

DEVELOPMENT OF AN ARCTIC LOW FREQUENCY AMBIENT NOISE MODEL

Robert H. Bourke, Professor
James H. Wilson, Professor
Department of Oceanography
Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: The goal of this multi-year project is to develop a low frequency Arctic ambient noise model to predict extremely high and low noise conditions. Arctic ambient noise levels can vary over 20 dB in short time (hours) intervals and currently U.S. submarines operating in the Arctic Ocean have no reliable way to anticipate the occurrence of extremely low or high noise periods. Obviously, the two extremes in noise levels result in significantly different tactical employment of submarine sonar systems.

SUMMARY: An empirically-based model has been developed based on wind forcing to establish the source level spectral density related to ice fracture during pressure ridging activity. The PIPS model is in the process of being modified to produce output fields of energy dissipation rate as a direct measure of ridging activity. High resolution SAR data is being examined to understand and quantify the changes in the ice cover (leads/ridges) due to the passage of storms. Colleagues from University of Washington Applied Physics Laboratory, Jet Propulsion, and the Navy Ice Center are assisting in this latter effort which is the thesis topic of LT Marcus Speckhann.

PROJECT SUMMARIES

CONFERENCE PRESENTATION:

Bourke, R.H., Wilson, J.H., Collins, D.A., and Ehret, L., "Arctic Storm Ambient Noise Model," Ocean Atmosphere Ice Interaction Workshop, Virginia Beach, VA, 8-10 May 1997.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Arctic, Ambient Noise, Storms, Sea Ice, ANDES

CHAIR IN ARCTIC MARINE SCIENCE

Robert H. Bourke, Professor and Chair

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The Chief of Naval Research has established a Chair in Arctic Marine Science at the Naval Postgraduate School. The objectives of the Chair are to foster oceanographic research in the Arctic, acquaint naval officer students with Arctic problems, reduce results of pure research to operational usage, and publicize Navy interest in the Arctic.

SUMMARY: Professor Bourke served as administrator of the Chair handling such details as selecting Chair candidates, writing IPAs and proposals and setting up visits and seminars for the Chair incumbent.

CAPT Lawson Brigham USCG (Ret.) was the Chairholder during FY97. During CY97 CAPT Brigham provided several seminars, worked with Professor Bourke on sea-ice studies and continued with his research on remote sensing of sea ice and the inferred circulation in the Laptev Sea. He also attended several conferences dealing with the future use of the Northern Sea Route and wrote articles on this and navigation in ice-covered waters.

A search was conducted for the follow-on Chairholder. Professor William D. Hibler, III from Dartmouth College has been selected. He will be in residence from January 1998 to September 1998 and will conduct sea-ice modeling research in conjunction with Professors Bourke and Semtner.

PUBLICATIONS:

Brigham, L.W., "The Northern Sea Route, 1996," *Polar Record*, 33(187), 333-336, 1997.

Brigham, L.W., "Commentary: An International Polar Navigation Code for the Twenty-First Century," *Polar Record*, 33(187), 283-284, 1997.

CONFERENCE PRESENTATIONS:

Brigham, L.W., "Satellite Remote Sensing of Sea Ice in the Laptev Sea," 12th International Symposium of Okhost Sea and Sea Ice, Mombetsu, Hokkaido, Japan, 2-5 February 1997.

Keys, H.J.R., Jacobs, S.S., Brigham L.W., "The Ross Ice Shelf Continues its Record Northward Expansion," Symposium on Antarctica and Global Change: Interactions and Impacts, Hobart, Tasmania, Australia, 13-18 July 1997.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Arctic Ocean, Sea Ice

PROJECT SUMMARIES

ASSESSMENT OF ENVIRONMENTAL IMPACT OF ENERGY SPREADING LOSS IN SHALLOW WATER ON THE LOW FREQUENCY ACTIVE (LFA) SONAR SYSTEM

Robert H. Bourke, Professor

James H. Wilson, Professor

Department of Oceanography

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To determine the performance degradation due to energy spreading loss (ESL) at LFA frequencies in shallow water environments. Initially geoacoustic and water column data was used from an area where LFA measurements have been made, namely Tanner Bank off the southern California coast.

SUMMARY: Model runs were conducted in intermediate and shallow water depths and along an up-slope path to determine the role of ESL on sonar performance. Various pulse form shapes (Blackman and CW) and a pulse duration of 4 sec were used. At these long pulse durations, little time stretching of the signal was noted. ESL is an important parameter primarily for pulse durations associated with mid-frequency tactical sonars (~3 kHz). However, LFA detection ranges are so short in shallow water that reverberation will blank target detections over considerable distances if long pulse durations are used.

THESIS DIRECTED:

Adams, B.S., "An Analysis of the Effects of Energy Spreading Loss and Transmission Loss on Low Frequency Active Sonar Operations in Shallow Water," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Low Frequency Active Sonar, Energy Spreading Loss, Shallow Water Acoustics

RESEARCH OPPORTUNITIES FOR PROGRAM OFFICERS (ROPO) FOR DR. STEVEN R. RAMP "PROCESSES IN EASTERN BOUNDARY CURRENTS"

Robert H. Bourke, Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: To permit Dr. Steven R. Ramp to continue processing and analyzing data from several Navy-sponsored field programs in the California Current System (CCS) and to publish the results in the refereed literature.

SUMMARY: Dr. Ramp returned to NPS for several one-week stays during the year to work on two primary tasks, namely: (1) analysis and synthesis of data from the ONR-sponsored Eastern Boundary Current Accelerated Research Initiative and (2) commence a literature study of the circulation and dynamics of the South China Sea.

PUBLICATIONS:

Chumbinho, R., Haney, R.L., and Ramp, S.R., "Kinematics and Dynamics of a Cyclonic Eddy off Point Arena, CA," *Journal of Physical Oceanography*, in press.

Noble, M. and Ramp, S.R., "Subtidal Currents over the Central California Continental Slope: Evidence for Spatial and Temporal Variations in the Poleward Undercurrent," *Continental Shelf Research*, submitted.

Ramp, S.R., McClean, J.L., Collins, C.A., Semtner, A.J., Hays, and K.A.S., "Observations, Equations, and Modeling of the 1991-92 El Niño off Central California," *Journal of Geophysical Research*, 102, 5553-5582, 1997.

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Ramp, S.R., Rosenfeld, L.K., Tisch, T.D., and Hicks, M.R., "Moored Observation of the Current and Temperature Structure over the Continental Slope off Central California. Part I: A Basic Description of the Variability," *Journal of Geophysical Research*, in press.

Ramp, S.R. and Abbott, C.L., "The Vertical Structure of Currents Over the Continental Shelf Off Point Sur, CA, during Spring 1990," *Continental Shelf Research*, accepted.

Tisch, T.D. and Ramp, S.R., "Moored Observations of the Current and Temperature Structure over the Continental Slope off Central California. Part II: The Energetics of the Flow off Point Sur," *Journal of Geophysical Research*, in press.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: California Current System, Eastern Boundary Currents, Fronts and Eddies Coastal Oceanography, Ocean Modeling

INTERNATIONAL CONFERENCE IN SHALLOW-WATER ACOUSTICS

Ching-Sang Chiu, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVES: The long-term goal is to formulate and conduct a collaborative international experiment in the seas of China. Such an experiment will focus on studying the physics and variability of sound propagation and scattering that are unique to the coastal waters of the Asian Pacific region. The FY97 objective was to promote scientific exchange and establish a dialog between Asian and U.S. scientists who are active in shallow-water acoustics research.

SUMMARY: The approach was to hold an international conference in Beijing, China as an outgrowth from the Office of Naval Research (ONR) USA-China Conference in Shallow-Water Acoustics held at the Naval Postgraduate School in December 1995. An international conference in China could attract many of the top-notch Asian scientists to attend. It could help to establish a dialog between the Asian and U.S. underwater acoustics communities, and provide a forum to exchange and discuss the latest scientific ideas, approaches and results in shallow-water acoustics which might form the basis for future collaborative research efforts between the U.S. and Asian communities.

The principal investigator worked closely with the Chinese co-organizers to coordinate the conference logistics and plan the conference agenda and co-chaired the technical committee to assist in identifying topics for special sessions, selecting invited speakers, and session chairs, and assigning contributed papers to the appropriate sessions. He also served on an ONR delegation to visit several oceanographic and acoustic laboratories in China following the conference. The post-conference tour was designed to begin the development of an international steering group to formulate and execute a collaborative field study.

A major accomplishment is that the conference and the post-conference tour have led to a strong dialog with the Chinese, Japanese, Korean, Singaporean, Russian and Indian scientists. An international steering group workshop to investigate the scientific, engineering, and logistic rationales that might form the basis for a collaborative international experiment in the seas of China is now in the planning.

PUBLICATION

Chiu, C.-S. and Lynch, J. F., "Acoustic Tomography in Shallow Water: Issues, Methods and Experimental Results," *Proceedings of the International Conference on Shallow-Water Acoustics, 1997*, in press.

CONFERENCE PRESENTATION:

Chiu, C.-S. and Lynch, J.F., "Acoustic Tomography in Shallow Water: Issues, Method and Experimental Results," International Conference on Shallow-Water Acoustics," Beijing, China, 21-25 April 1997.

PROJECT SUMMARIES

DoD KEY TECHNOLOGY AREAS: Sensors, Environmental Quality

KEYWORDS: Shallow-Water Acoustics

MIDDLE ATLANTIC BIGHT (SHELFBREAK PRIMER) FIELD STUDY

Ching-Sang Chiu, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The objectives of this multi-year, multi-institutional field study in the Middle Atlantic Bight are to improve our understanding of the physical variability of the shelf break front south of New England, and to apply this improved knowledge to problems in acoustical propagation. To do this, detailed measurements of physical and acoustical properties during the contrasting summer and winter seasons have been made. These measurements are being related to physical and acoustical modeling studies. Results from these modeling efforts, tested against the observations, should be broadly applicable to shelf-break regions on a more global basis.

SUMMARY: The field program surveying the frontal region has just been concluded. The field work included two intensive three-week experiments, one in July 1996 (summer) and the other one in February 1997 (winter). Specifically, each of the two experiments successfully employed a suite of observational techniques including an acoustic tomography array consisting of multiple transceivers/sources and two vertical hydrophone arrays (VLAs) straddling the shelf-break front, several high-resolution, three-dimensional surveys of the frontal region with a SeaSoar, a shelf-to-slope hydrographic section, and moored arrays of ADCPs, current meters and thermistors. The resultant data set is both comprehensive and of high quality, and will allow for gaining fundamental insights into the oceanographic processes which influence acoustic propagation in a slope-shelf region. The measurements are being supplemented by model studies, both oceanographic and acoustic. The detailed analysis of the data and the modeling has begun in earnest, with an initial emphasis being upon understanding the oceanographic field through which the acoustic signals have propagated. NPS played a lead role in all phases of the study including experimental planning, data collection, data processing, acoustic modeling, and data analysis. Specifically, NPS has initiated modal processing, modeling and time-series analysis of the acoustic data in an effort to quantify the dominant space and time scales of the variability in the sound field and to relate the observed acoustic variability to ocean processes.

PUBLICATIONS:

Chiu, C.-S., Miller, C.W., and Lynch, J.F., "Optimal Modal Beamforming of Bandpass Signals Using an Undersized, Sparse Vertical Hydrophone Array: Theory and a Shallow-Water Experimentation," *IEEE Journal of Oceanic Engineering*, 22(3), 522-533, 1997.

Lynch, J.F., Gawarkiewicz, G.G., Chiu, C.-S., Pickart, R., Miller, J.H., Smith, K.B., Robinson, A., Brink, K., Beardsley, R., Sperry, B., and Potty, G., "Shelfbreak PRIMER - An Integrated Acoustic and Oceanographic Field Study in the Mid-Atlantic Bight," *Proceedings of the International Conference on Shallow-Water Acoustics*, Beijing, China, 1997, in press.

CONFERENCE PRESENTATIONS:

Beardsley, R.C., Brink, K.H., Caruso, M.J., Chiu, C.-S., Gawarkiewicz, G.G., Lynch, J.F., Miller, J.H., Pickart, R., Robinson, A.R., and Smith, K.B., "Shelfbreak PRIMER - An Integrated Acoustic and Oceanographic Field Study in the Middle Atlantic Bight," International Conference on Shallow-Water Acoustics, Beijing, China, 21-25 April 1997.

Chiu, C.-S. and Lynch, J.F., "Acoustic Tomography in Shallow Water," International Workshop on Ocean Acoustic Tomography, Yokosuka, Japan, 13-14 March 1997.

PROJECT SUMMARIES

Chiu, C.-S., Miller, C.W., and Lynch, J.F., "Optimal Modal Beamforming of Bandpass Signals Using an Undersized, Sparse Vertical Hydrophone Array: Theory and a Shallow-Water Experimentation," 3rd International Conference on Theoretical and Computational Acoustics, Newark, NJ, 14-18 July 1997.

Chiu, C.-S., Lynch, J.F. Gawarkiewicz, G.G., Pickart, R.S., Sperry, B., Miller, J.H., Smith, K.B., and Robinson, A.R., "Measurement and Analysis of the Propagation of Sound from the Continental Slope to the Continental Shelf," 134th Meeting of the Acoustical Society of America, San Diego, CA, 1-5 December 1997.

Gawarkiewicz, G., Pickart, R., Lynch, J.F., Chiu, C.-S., Smith, K.B., and Miller, J.H., "The Shelfbreak Front PRIMER Experiment," 133rd Meeting of the Acoustical Society of America, State College, PA, 15-20 June 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Environmental Quality

KEYWORDS: Littoral, Acoustics, Nowcast, Shelfbreak fronts

MONITORING WHALES USING THE PT. SUR ACOUSTIC ARRAY - A FEASIBILITY STUDY

Ching-Sang Chiu, Associate Professor

Curtis A. Collins, Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The objectives include: (1) To investigate the feasibility of locating and tracking distant California blue whales using a former SOSUS array and matched signal algorithms. (2) To explore the possibility of providing supplementary information on counts and transit paths of California blue whales. (3) To enhance the understanding of low-frequency sound propagation physics in a littoral environment.

SUMMARY: Detecting, classifying, localizing, and tracking vocalizing whales using receiver arrays at long ranges is a complex problem. It is a combined signal processing-acoustics-oceanography problem. First, knowledge of the loudness and frequency-time distribution of the different whale sounds is required for classification purposes. Equally important is the understanding of the basic structure and variability of the ocean sound channel. The ocean scrambles the vocalized signal by its multipaths as the signal propagates to a distant receiver. The ability to predict the mean and variance of the propagation is thus required to unscramble the received signal and to constrain the uncertainty.

In the summer of 1997, two three-day experiments were conducted to test the feasibility of acoustically detecting, classifying, localizing, and tracking blue whales at long ranges using a former SOSUS listening array located at the Naval Postgraduate School Ocean Acoustic Observatory (OAO) at Pt. Sur, California. During each experiment, full-array data were archived continuously at the OAO. In concert with the shore-based acoustic monitoring, an aircraft was assigned to locate blue whales in the Monterey Bay National Marine Sanctuary and to direct a research vessel to a whale site. The research vessel was manned with observers and instrumented with a towed hydrophone array to ground-truth the locations of the blue whales and classify the vocalized near-field signals. These shipboard measurements were required to provide a means to separate the source signal characteristics from the multipath signatures for the calibration and validation of broadband, model-based localization methods. Initial experimental as well as modeling results show great promise, which included assessments of the predictability, i.e., variability, of the vocalized sound and the uniqueness of the location-dependent multipath structure. Both are fundamental to the applicability of model-based algorithms.

CONFERENCE PRESENTATION:

Chiu, C.-S., Collins, C.A., Hager, C.A., Miller, C.W., Moore, T.C., Rocheleau, M.R., Lashkari, K., and Hayes, S., "A Feasibility Field Study of Monitoring Blue Whales Using the Pt. Sur Ocean Acoustic Observatory," 134th Meeting of the Acoustical Society of America, San Diego, CA, 1-5 December, 1997.

PROJECT SUMMARIES

THESIS DIRECTED:

Hager, C.A., "Modeling the Performance of the Pt Sur Hydrophone Array in Localizing Blue Whales," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Environmental Quality

KEYWORDS: Coastal, Acoustics, Whale Monitoring, Alternate Uses

DATA ANALYSIS FOR THE SWARM EXPERIMENT

Ching-Sang Chiu, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: The objective of this research is to characterize the internal waves and their impact on the spatial and temporal variability and coherence of acoustic transmissions in a shelf environment.

SUMMARY: During the summer of 1995, a multi-institutional field study called Shallow Water Acoustics in a Random Medium (SWARM) was conducted in the Mid-Atlantic Bight continental shelf region off the coast of New Jersey. Environmental and acoustic sensors were deployed as part of SWARM to measure and characterize the non-linear internal waves and their impact on the spatial and temporal coherence of the acoustic transmissions. As part of the environmental monitoring network, two bottom-moored, upward-looking Acoustic Doppler Current Profilers (ADCPs) were deployed. An oceanographic, modal, time-series analysis of the ADCP data reveals that: large-amplitude, nonlinear, internal wavepackets were generated at multiple sites near the shelfbreak; the generation mechanism was consistent with the lee-wave hypothesis of generation; the propagation characteristics were in good agreement with nonlinear soliton theory; and the power spectral density was spatially varying and changed markedly during the passage of these nonlinear waves. Based on these observations, a model of the induced sound-speed perturbations was developed. Using a coupled normal-mode propagation model, the temporal and vertical structure of the sound field were subsequently calculated for comparison to data obtained by a vertical line array.

PUBLICATIONS:

Apel, J., Badiy, M., Chiu, C.-S., Finnette, S., Headrick, R., Kemp, J., Lynch, J., Newhall, A., Orr, M., Pasewark, B., Tielbuerger, D., Turgut, A., von der Heyt, K., and Wolf, S., "An Overview of the 1995 SWARM Shallow Water Internal Wave Acoustic Scattering Experiment," *IEEE Journal of Oceanic Engineering*, 22(3), 465-500, 1997.

Chiu, C.-S., Ng, S.-L., and Denner, W.W., "Estimating the Properties of the Sound Field in a Shelf Region Near the Shelfbreak," *Proceedings of the 6th Western Pacific Regional Acoustics Conference, Volume 1*, 329-334, 1997.

CONFERENCE PRESENTATIONS:

Apel, J., Badiy, M., Chiu, C.-S., Finnette, S., Headrick, R., Kemp, J., Lynch, J., Newhall, A., Orr, M., Pasewark, B., Tielbuerger, D., Turgut, A., von der Heyt, K., and Wolf, S., "The New Jersey Shelf Shallow-Water Acoustic Random Media Propagation Experiment (SWARM)," International Conference on Shallow-Water Acoustics, Beijing, China, 21-25 April 1997.

Apel, J., Chiu, C.-S., Headrick, R., Lynch, J., Orr, M., Pasewark, B., and Wolf, S., "Acoustic Travel Time and Intensity Fluctuations Measured in the 1995 SWARM Experiment," 133rd Meeting of the Acoustical Society of America, State College, PA, 15-20 June 1997.

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Chiu, C.-S., NG, S.-L., and Denner, W.W., "Estimating the Properties of the Sound Field in a Shelf Region Near the Shelfbreak," 6th Western Pacific Regional Acoustics Conference, Hong Kong, 19-21 November 1997.

THESIS DIRECTED:

Ng, S.-L., "A Simulation Study of Acoustic Variability Due to Internal Solitary Waves on the Mid-Atlantic Continental Shelf," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Environmental Quality

KEYWORDS: Littoral, Acoustics, Internal Tides, Internal Waves

DEVELOPMENT OF THE PT. SUR OCEAN ACOUSTIC OBSERVATORY

Ching-Sang Chiu, Associate Professor

Department of Oceanography

Sponsors: SAIC, Cornell University, and Office of Naval Research

OBJECTIVE: The objectives are: (1) to preserve the functionality of the Pt. Sur SOSUS horizontal hydrophone array and (2) to convert the facility into a dual-use Ocean Acoustic Observatory for the purpose of undersea research.

SUMMARY: In 1995, the Pt. Sur Ocean Acoustic Observatory in the Monterey Bay National Marine Sanctuary was established, for the purpose of undersea research. Several sponsoring organizations have contributed greatly to this commendable community effort. Their contributions were in terms of hardware, reimbursable funding for electric and electronic maintenance, labor, and the conduct of high-quality research using the data.

In 1997, the development of the Pt. Sur Ocean Acoustic Observatory (OAO) was continued using reimbursable funding provided by SAIC, Cornell University and the Office of Naval Research. The 1997 OAO research projects include nuclear test ban treaty monitoring, coastal ocean circulation studies, and marine mammal studies. The latest accomplishment is the development of a full-array classified data archival capability. This enhanced capability will enable the conduct of both classified and unclassified research that require spatial beamforming using the horizontal array.

THESES DIRECTED:

Morvillez, T., "Monitoring Temperature Variability Along the California Coast Using Acoustic Tomography," Master's Thesis, Naval Postgraduate School, September 1997.

Smith, Amy, "Analysis of Modal Travel Time Variability due to Ocean Mesoscale Structure," Doctor of Philosophy Dissertation, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Environmental Quality

KEYWORDS: SOSUS, Alternate Uses, Acoustic Observatory

SHALLOW WATER ANALYSIS AND FORECAST SYSTEM FOR THE SOUTH CHINA SEA

Peter C. Chu, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: This is a two-year proposal for extending the currently existing NOMP research project to improve our South China Sea Shallow Water Analysis and Forecast System (SCS-SWAFS) with establishment of an open boundary

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diagnosis and to transition SWAFS-SCS from basic research and exploratory development to an operational system at NAVOCEANO. This is an important component of the recently developed Integrated Education/Research Program at NPS on Naval Ocean Analysis and Prediction. The goals are: (1) to investigate the underlying causes of the recently detected central South China Sea warm-core and cold-core eddies and their transient features and effects on the monsoon onset (scientific goal) and (2) to transfer SCS-SWAFS to Dr. Ruth Preller's Group at NRL-Stennis Space Center and in turn to Mr. Andy Johnson's Group at the Naval Oceanographic Office for operational use (operational goal).

SUMMARY: During the current year, the following tasks were completed: (1) a statistical model was developed to identify the South China Sea warm-core and cool-core eddies, and the thermal variability of the South China Sea and Yellow Sea; (2) a new technique, S-transform, for obtaining localized spectrum was developed and validated. (3) a parametric model was developed for obtaining physical characteristics (SST, mixed layer depth, thermocline depth, thermocline strength,...) from vertical profiles; (4) an optimization method was developed for determining the open boundary conditions of coastal models; (5) a new diagnostic model (P-vector Model) was validated; and (6) synoptic forcing functions were included into the SCS-SWAFS Model.

PUBLICATIONS:

Cai, W.J. and Chu, P.C., "Effects of Convective Instability Due to Incompatibility Between Ocean Dynamics and Surface Forcing," *Annals Geophysicae*, 15, 1,067-1,075, 1997.

Cai, W.J. and Chu, P.C., "Ocean Climate Drift and Interdecadal Oscillation due to a Change in Thermal Damping," *Journal of Climate*, 11, 2821-2833, 1996.

Cai, W.J., and Chu, P.C., "1997: A Thermal Oscillation Under a Restorative Forcing," *Quarterly Journal of the Royal Meteorological Society*, in press.

Chu, P.C., "The S-Transform for Obtaining Localized Spectra," *Journal of Marine Technological Society*, 29 (4), 28-38, 1996.

Chu, P.C., Wells, S.K., Haeger, S.D., Szczechowski, C., and Carron, M., "Temporal and Spatial Scales of the Yellow Sea Thermal Variability," *Journal of Geophysical Research*, 102, 5655-5668, 1997.

Chu, P.C., Fralick, C.R., Haeger, S.D., and Carron, M.J., "A Parametric Model for Yellow Sea Thermal Variability," *Journal of Geophysical Research*, 102, 10499-10508, 1997.

Chu, P.C., Fan, C.W., and Ehret, L.L., "Determination of Open Boundary Conditions from Interior Observational Data," *Journal of Meteorological and Oceanic Technology*, 14, 723-734, 1997.

Chu, P.C. and C.P. Chang, "South China Sea Warm Pool," *Advances in Atmospheric Sciences*, 14, 195-206, 1997.

Chu, P.C., Tseng, H.C., Chang, C.P., and Chen, J.M., "South China Sea Warm Pool Detected from the Navy's Master Oceanographic Observational Data Set (MOODS)," *Journal of Geophysical Research*, 102, 15761-15771, 1997.

Chu, P.C. and Fan, C.W., "Sixth-Order Difference Scheme for Sigma Coordinate Ocean Models," *Journal of Physical Oceanography*, 27, 2064-2071, 1997.

Chu, P.C., Lu, S.H., and Chen, Y., "Temporal and Spatial Variabilities of the South China Sea Surface Temperature Anomaly," *Journal of Geophysical Research*, 102, 20937-20955, 1997.

Chu, P.C., Fan, C.W., and Cai, W.J., "1997: Evaluation of P Vector Method Using Modular Ocean Model (MOM)," *Journal of Oceanography*, in press.

PROJECT SUMMARIES

Chu, P.C., Chen, Y.C., and Lu, S.H., "1997: On Haney-Type Surface Thermal Boundary Conditions for Ocean Circulation Models," *Journal of Physical Oceanography*, in press.

Steger, J., Collins, C.A., and Chu, P.C., "Circulation in the Archipelago de Colon (Galapagos Islands), November 1993," *Deep Sea Research*, 1996, in press.

CONFERENCE PRESENTATIONS:

Chu, P.C., "Effect of Drake Passage on the Brazilian Coastal Currents," Inter-American Institute for Global Change Workshop, Sao Paulo, Brazil, 11-14 April 1997.

Chu, P.C., "South China Sea Oceanography and Sampling Strategy," International South China Sea Monsoon Experiment (SCSMEX) Planning Meeting, Hong Kong, 15-18 September 1997.

Chu, P.C. and Lu, S.H., "Response of Radiative Fluxes to Tiny Random Sea Surface Temperature Disturbances," American Meteorological Society Ninth Conference on Atmospheric Radiation, Long Beach, CA, 2-7 February 1997.

Chu, P.C. and Lu, S.H., "Response of Hydrological Cycle to Tiny Random Sea Surface Temperature Disturbances," The American Meteorological Society 13th Conference on Hydrology, Long Beach, CA, 2-7 February 1997.

Chu, P.C., Chen, Y.C., and Lu, S.H., "On Haney-Type Ocean Surface Thermal Boundary Conditions," Oceanographic Society Meeting, Seattle, WA, 31 March-3 April 1997.

Chu, P.C., Chen, Y.C., and Lu, S.H., "Ice-Albedo Effect on the Global Climate Variability," 22nd General Assembly of the European Geophysical Society, Vienna, Austria, 21-25 April 1997.

Chu, P.C., Lu, S.H., and Chen, Y.C., "Effects of Drake Passage on the Global Climate Variability," 22nd General Assembly of the European Geophysical Society, Vienna, Austria, 21-25 April 1997.

Chu, P.C., Ehret, L.L., and Scott, J., "Multifractal Analysis of Ocean Mixed Layer Near the Norwegian Coast," 22nd General Assembly of the European Geophysical Society, Vienna, Austria, 21-25 April 1997.

Chu, P.C., Lu, S.H., and Chen, Y.C., "Simulation of Winter and Summer Monsoons over East Asia with a Nested Global-Regional Climate Model," 22nd General Assembly of the European Geophysical Society, Vienna, Austria, 21-25 April 1997.

Chu, P.C., Lu, S.H., and Chen, Y.C., "Simulation of Spring-to-Summer Monsoons over East Asia with an NCAR Regional Climate Model," 22nd General Assembly of the European Geophysical Society, Vienna, Austria, 21-25 April 1997.

Chu, P.C., Lu S.H., and Chen, Y.C., "Predictability of Climate Models - Sensitivity to Tiny Sea Surface Temperature Disturbances," 22nd General Assembly of the European Geophysical Society, Vienna, Austria, 21-25 April 1997.

THESIS DIRECTED:

Jimenez, G., "Diurnal Variation over the Tropical Monsoon Regions during Northern Summer," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Environmental Quality

KEYWORDS: P-Vector, Geostrophic Velocity, Beta-Spiral, Inverse Method, Primitive Equation Model, Turbulence Closure

PROJECT SUMMARIES

ENVIRONMENTAL EFFECTS ON NAVAL WARFARE SIMULATIONS

Peter C. Chu, Associate Professor

Department of Oceanography

Sponsor: Naval Oceanographic Office

OBJECTIVE: This is a three-year interdisciplinary and multi-institutional project pursued collaboratively among the NPS Naval Ocean Analysis and Prediction (NOAP) Lab, the NPS Wargame Lab, NAVOCEANO Ocean Modeling Division, and the Army's Coastal Engineering Research Center (CERC). The purposes of the project are: (1) to investigate environmental effects on the joint warfare simulations at various scales (e.g., theater level, technical level) and to incorporate the Navy's Meteorological and Oceanographic (METOC) data and models effectively into the joint warfare simulation models, such as RESA and mine warfare models obtained from COMMINWARCOM; (2) to estimate the value added of knowing the METOC data; and (3) to quantitatively analyze the value added of knowing the environment and to identify the measure of effectiveness of METOC knowledge.

SUMMARY: (1) Mine Counter Measure Simulation System (MCM96) was obtained from COMMINWARCOM and installed in the NPS Secure Computing and Simulation Laboratory. The principal investigator visited the Coastal System Station at Panama City, Florida and built up a collaborative relationship between NPS and the Coastal System Station. (2) MCM96 was tested under different METOC conditions. The sensitivity of save currents in the Mine Sweeping on the METOC data (Electric Depth versus Actual Depth, wave height) was obtained. (3) The sensitivity study of the Navy's Research, Evaluation, and Systems Analysis (RESA) wargame was finished (theater level simulation) to the METOC environment. A quantitative analysis scheme (entropy) was established to estimate the value added of knowing the METOC data and to identify the measure of effectiveness of METOC knowledge. These results will be included in the thesis study by LCDR Eric. (4) RESA was implemented for the Korea Peninsula region for several different weather scenarios representing various METOC conditions: wave height, wave direction, wind speed, wind direction, cloud cover, visibility, etc. The NPS Wargaming Lab used the weather scenario for the instruction purpose. (5) The Army's Post-Engagement Ground Effects Model (PEGEM) was installed and tested into the NOAP Lab. (6) A joint research effort was established on METOC information in mine warfare with SACLANT Undersea Research Center at La Spezia, Italy.

The primary results of this project have transferred to NAVO and NPS Wargaming Lab as a training tool to increase the sensitivity of modeling and simulation to environmental effects. Military personnel serving as NPS graduate students already studied these results through class work and thesis research. Furthermore, the results of the project were also used by NAVO to initiate a new mine warfare program.

CONFERENCE PRESENTATIONS:

Chu, P.C., Gottshall, E., and Halwachs, T., "Environmental Effects on Mine Counter Measures," 65th Military Operations Research Society Symposium, Quantico, VA, 10-12 June 1997.

Chu, P.C., "Importance of METOC Information in Military Operations," 65th Military Operations Research Society Symposium, Marine Corps Combat Development Command, Quantico, VA, 10-12 June 1997.

THESIS DIRECTED:

Jimenez, G., "Diurnal Variation over the Tropical Monsoon Regions During Northern Summer," Master's Thesis, Naval Postgraduate School, March 1997.

DoD TECHNOLOGY AREAS: Battlespace Environments, Environmental Quality

KEYWORDS: P-Vector, Geostrophic Velocity, Beta-Spiral, Inverse Method, Primitive Equation Model, Turbulence Closure

PROJECT SUMMARIES

LITTORAL ZONE NAVAL OCEAN PREDICTION SYSTEMS

Peter C. Chu, Associate Professor

Department of Oceanography

Sponsor: Naval Oceanographic Office

OBJECTIVE: The main objectives of this project are to develop a parametric model for regional sea T, S data analysis, to quantitatively determine temporal and spatial thermohaline variability, and to establish a diagnostic model for the regional seas, e.g., the South China Sea, the Japan Sea, and the Yellow Sea.

SUMMARY: During the current year the following studies were completed: (1) The South China Sea thermohaline variability has been identified from the Navy's Master Oceanographic Observational Data Set (MOODS) by analyzing more than 230,000 T, S profiles., a new phenomenon of the South China Sea warm pool. (2) The numerical simulation greatly enhances the understanding of the J Sea thermohaline variability and circulation. The model established in this project can be used widely for the other regional seas. (3) The P-vector method was validated. (4) The S-Transform was validated. (5) New difference schemes have been developed for littoral prediction systems.

PUBLICATIONS:

Cai, W.J. and Chu, P.C., "Effects of Convective Instability Due to Incompatibility Between Ocean Dynamics and Surface Forcing," *Annals Geophysicae*, 15, 1,067-1,075, 1997.

Chu, P.C., Wells, S.K., Haeger, S.D., Szczechowski, C., and Carron, M., "Temporal and Spatial Scales of the Yellow Sea Thermal Variability," *Journal of Geophysical Research*, 102, 5655-5668, 1997.

Chu, P.C., Fralick, C.R., Haeger, S.D., and Carron, M.J., "A Parametric Model for Yellow Sea Thermal Variability," *Journal of Geophysical Research*, 102, 10499-10508, 1997.

Chu, P.C., Fan, C.W., and Ehret, L.L., "Determination of Open Boundary Conditions from Interior Observational Data," *Journal of Meteorological and Oceanic Technology*, 14, 723-734, 1997.

Chu, P.C. and Chang, C.P., "South China Sea Warm Pool," *Advances in Atmospheric Sciences*, 14, 195-206, 1997.

Chu, P.C., Tseng, H.C., Chang, C.P., and Chen, J.M., "South China Sea Warm Pool Detected from the Navy's Master Oceanographic Observational Data Set (MOODS)," *Journal of Geophysical Research*, 102, 15761-15771, 1997.

Chu, P.C. and Fan, C.W., "Sixth-Order Difference Scheme for Sigma Coordinate Ocean Models," *Journal of Physical Oceanography*, 27, 2064-2071, 1997.

Chu, P.C., Lu, S.H., and Chen, Y., "Temporal and Spatial Variabilities of the South China Sea Surface Temperature Anomaly," *Journal of Geophysical Research*, 1997, 102, 20937-20955.

Chu, P.C., Chen, Y.C., and Lu, S.H., "On Haney-Type Surface Thermal Boundary Conditions for Ocean Circulation Models," *Journal of Physical Oceanography*, 1997, in press.

Chu, P.C., Fan, C.W., and Cai, W.J., "Evaluation of P Vector Method Using Modular Ocean Model (MOM)," *Journal of Oceanography*, 1997, in press.

CONFERENCE PRESENTATIONS:

Chu, P.C., Gottshall, E., and Halwachs, T., "Environmental Effects on Mine Counter Measure," 65th Military Operations Research Society Symposium, Quantico, VA, 10-12 June 1997.

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Chu, P.C. and Fan, C.W., "High-Order Coastal Ocean Modeling," Fifth International Conference on Estuarine and Coastal Modeling, Alexandria, VA, 22-24 October 1997.

Chu, P.C., "A Quick Assessment System for Coastal Environments," U.S.-U.K. Naval IEP B-6 Ocean Modeling Workshop, DERA Hasler, Gosport, U.K., 28-29 October 1997.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean Prediction, Littoral Zone, Thermohaline Variability, Parametric Model, Statistical Model

GLOBAL POSITIONING SYSTEM (GPS) ANTARCTIC LANDING SYSTEM: LANDING SYSTEMS COMMITTEE STUDIES

James R. Clynch, Research Professor

Department of Oceanography

Sponsor: NISE-East

OBJECTIVE: The aircraft landing system at the U.S. bases in Antarctica must be replaced in the next few years. GPS is the primary candidate system for use in this remote site. There are several special features about the local environment in polar latitudes that must be studied and validated before flight safety can be assured.

SUMMARY: The technical capability of a differential GPS system to meet the landing requirements in Antarctic has been demonstrated in an ongoing effort over five years. During 1997 the effort focused on following the FAA specification development process for the Local Area Augmentation System (LAAS) and assisting in the transition from Navy to Air Force air operations in Antarctica. The desire to have a landing capability beyond Category I has shifted focus from a Special Category I (SCAT I) system to LAAS. During the year Dr. Clynch attended two RTCA committee meeting on GPS landing system, met with the Air Force office in Boston, and participated in three meeting at Charleston SC. He also attended two GPS technical meetings to stay abreast of the civilian technology. He made site visits to two vendors.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Electronics, Sensors

KEYWORDS: GPS Aircraft Landing Systems

FUNDAMENTALS OF MAPPING, CHARTING, AND GEODESY (MC+G) REPORT

James R. Clynch, Research Professor

Department of Oceanography

Sponsor: National Imagery and Mapping Agency

OBJECTIVE: The objective is to update the NIMA (formally DMA) document "Geodesy for the Layman." This document was last revised in 1983. The advances in satellite geodesy and other fields need to be included.

SUMMARY: The document, "Geodesy for the Layman," DMA TR 80-003 has been used as an introduction to geodesy for many military and civilian workers at NIMA. First produced in 1957, this document needs to be updated to better serve its projected audience. It has also been widely used by civilians, especially by DoD contractors.

During 1997, the update of this document began with a user survey. This involved discussions with members of all three services, the Coast Guard, and DoD agencies. Persons at levels from Lieutenant to Captain (USN) who had or were currently having an interaction with this subject were contacted. People in the both the operations and education/training areas were included.

Based on these inputs, it was decided to produce a fairly extensive rework of this document. It needs to have both a lower level set of discussions for some and a more detailed mathematical summary for others. It was decided to add a more extensive introduction for the first and a set of appendixes for the latter.

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In addition to the changes in the substance of this document, it was desired to publish the update on the world wide web. Investigations into how to publish a document with substantial mathematical content were undertaken. It was decided that a PDF version was necessary.

Significant work on the update itself took place during 1997, especially in the area of the appendices. It is anticipated that this project will be completed in early 1998.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training, Battlespace Environments

KEYWORDS: Geodesy, Mapping

GLOBAL POSITIONING SYSTEM (GPS) SHIP REFERENCE SYSTEM

James R. Clynych, Research Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The objective of this project is to design and validate a GPS system to be used as a Differential GPS (DGPS) reference station on a ship at sea.

SUMMARY: This project is to establish the techniques necessary to achieve a 2 m or better absolute position on a ship using precise positioning system GPS receivers and other sensors. It is anticipated that the receivers will have to be run from atomic clocks and that an inertial system may be required. Once the system has been initialized, the position should be held to sub-meter accuracy. That is, the 2-meter level initialization errors will be biases in the operational position.

During 1997 the data from a 1996 at-sea experiment were analyzed. A second at-sea experiment was performed with all the elements of the proposed system. The results of the 1996 sea test were reported at the ION GPS-97 conference.

The PT SUR-96 experiment utilized simple 4 channel, single frequency military receivers (PLGRs). From this test, it was established that: (1) multipath errors will be significantly reduced for ships underway due to the ships motion moving the antenna through different multipath orientations and (2) the broadcast ephemeris error will be the principal error to be averaged down.

The PT SUR-97 experiment included three dual frequency PPS receivers, two single frequency PPS receiver, three civilian dual frequency receivers, and three attitude systems. The results of this test are under study.

PUBLICATION:

Clynych, J.R., "One Meter Positioning on a Ship with PLGR," *Proceedings of the ION GPS-97*, p. 973, Kansas City, MO, 16-17 September 1997.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Global Positioning System, GPS, Differential GPS

QUASI-LAGRANGIAN MEASUREMENTS OF THE CALIFORNIA UNDERCURRENT

Curtis A. Collins, Professor

Newell Garfield, Research Assistant Professor

Department of Oceanography

Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: To analyze and report the results from 26 neutrally buoyant RAFOS Lagrangian drifters which were launched in the eastern Pacific to investigate the flow of the California Undercurrent. Nine of these floats were entrained in the undercurrent, three exhibited flow reversal along the continental margin and the rest were entrained in subsurface anti-

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cyclonic eddies. The second year will be used to analyze current meter data from the Eastern Boundary Current Accelerated Research Initiative offshore site.

DoD KEY TECHNOLOGY AREAS: Sensors, Other (Environmental Effects)

KEYWORDS: California Current System, Subsurface Ocean Circulation, Lagrangian Statistics, Eastern Boundary Currents, Mesoscale Ocean Variability

DEVELOPMENT OF LITTORAL CURRENT DATA BASE IN THE ADRIATIC SEA

Curtis A. Collins, Professor
Pierre-Marie Poulain, Assistant Professor
Department of Oceanography
Sponsor: Naval Oceanographic Office

OBJECTIVE: The main objective of this project is to develop digital layers of information about currents in the Adriatic Sea that will be tactically useful for Mine Warfare (MIW) planning and operations.

SUMMARY: Various data sets on currents in the Adriatic Sea were acquired, assessed, deconflicted, analyzed, and interpreted in view of their inclusion into a common data base. These data sets comprise moored current meter data, shipboard and moored acoustic Doppler current profiler (ADCP) data, surface drifter and sub-surface float measurements. Useful statistics and summaries obtained from the acquired data and from ancillary information extracted from the literature were presented in the form of digital layers. The layers contain either provinced, point, or gridded information. The information presented in the layers include the forcing mechanisms, the current speed histograms, the peak tidal currents, the long-term drifts, the local current conditions, and related text and references.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean Currents, Adriatic Sea, Database

UPPER OCEAN CIRCULATION IN THE ADRIATIC SEA

Curtis A. Collins, Professor
Pierre-Marie Poulain, Assistant Professor
Department of Oceanography
Sponsor: Naval Oceanographic Office

OBJECTIVE: The main objective of this project is to analyze current observations in the Adriatic Sea collected by the Naval Oceanographic Office (NAVO) in 1993 and by the SACLANT Undersea Research Centre in 1994-1995. The goal is to describe the spatial structure and the temporal variability of the near-surface and intermediate-depth (300 m) currents and gain insights on the Adriatic basin dynamics.

SUMMARY: Current measurements using a ship-board Acoustic Doppler Current Profiler (ADCP) operated during various hydrographic surveys mostly conducted in the southern Adriatic and the Straits of Otranto areas were made available for the following time periods: January, February, November and December 1993, and December 1994, May and August 1995.

The raw ADCP data were processed using the CODAS3 software and a variety of graphical representations of the calibrated and edited current data were produced. The results reveal a significant intensification of the currents in the coastal and continental margin areas.

Tidal current analysis was conducted using a least-squares regression technique. The results indicate limited tidal currents with a maximum magnitude reaching 5 cm/s in the southwestern Adriatic for the M2 component. The ADCP observa-

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tions were compared to other ocean current observations (i.e., from moored ADCP's and from surface drifters) and to contemporaneous satellite sea surface temperature images. There is a good qualitative agreement between all the observations.

THESIS DIRECTED:

Brauns, B.A., "Adriatic Sea Current Observations Using Acoustic Doppler Current Profiler (ADCP) Measurements," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean Currents, Adriatic Sea, Straits of Otranto

LONG-TERM MONITORING OF CIRCULATION AND SEDIMENT-TRANSPORT PATTERNS NEAR THE SAN FRANCISCO DEEP-OCEAN DISPOSAL SITE

Curtis A. Collins, Professor

Department of Oceanography

Sponsor: Environmental Protection Agency

OBJECTIVE: The Environmental Protection Agency (EPA) has designated a deep-water site on the continental slope off San Francisco as a disposal site for dredge material from the greater San Francisco Bay. This was the first deep-ocean disposal site in the nation and involves a program of long-term monitoring of the site. Moorings to measure the movement of water and resuspended material near the disposal site will be made during the period November 1997 to November 1998.

SUMMARY: Moorings were deployed at three locations at and near the deep ocean disposal site on 11-12 November 1997 from the R/V *Point Sur*. Moorings included upward looking acoustic Doppler current meters at 100 m depth and standard current meters at 225, 400, 800, 2000 m, and 50 m above the bottom. Sediment traps were included at mid-depth (200 and 395 m) and near bottom. A near-bottom package consisting of vector-averaging current meters, temperature gradient measurements, and a transmissometer was included. The moorings are scheduled for recovery in November 1998. This is a joint project with the Dr. Marlene Noble, U.S. Geological Survey.

DoD Key Technology Area: Environmental Quality

KEYWORDS: Ocean Currents, Sediment Transport, Deep-Ocean Disposal

MESOSCALE VARIABILITY OF THE CALIFORNIA CURRENT

Curtis A. Collins, Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: This project was part of the Eastern Boundary Current (EBC) Accelerated Research Initiative (ARI). It extended the two-year time series of upper ocean current measurements at 37°-06.7'N, 127°-32.1'W from August 1994 to August 1996. The specific objective of these measurements was to resolve seasonal and mesoscale variability of ocean currents at this location. Since the location coincides with a TOPEX/Poseidon cross over, the temporal variability of observed velocity can be compared to that obtained from observations of the variability of the slope of the ocean's surface.

SUMMARY: Current meters were recovered on 27 August 1996. They were subsequently re-calibrated and the data processed. Data was provided to other EBC investigators and incorporated into analyses and comparisons of nearshore, slope, and offshore currents.

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Current measurements at 50 m extended only to February 1995, when the rotor became fouled by biological growth. At the other three depths, there was a high degree of coherence between the observations. Although the flow was less energetic than that measured during the previous two years, the strongest flow (~ 1 knot) appeared as a pulse of southward flow in January 1995, and resembled eddies observed at this site in April-May and November 1993. The spectrum of the 4-year record has a distinct peak at 100-days, a somewhat longer period than the 60-day motion which dominated the inshore locations.

RAFOS float measurements at intermediate depths (150-600 m) over the continental margin revealed a region of varying width of subsurface, poleward flow adjacent to the continental margin. The trajectories exhibited three patterns: poleward flow in the undercurrent, reversing, but predominately alongshore, flow adjacent to the continental margin, and farther offshore, anticyclonic motion accompanied by slow westward drift. Flow continuity of the undercurrent exists between Pt. Reyes and at least Cape Mendocino with an average speed dependent upon the float depth. Speeds were variable but common features were acceleration occurring to the south of Pt. Arena and deceleration to the north of Cape Mendocino. An important mechanism for floats, and water, to leave the undercurrent and enter the ocean interior is through the formation of submesoscale coherent vortices. Single particle statistics provide zonal and meridional eddy diffusivity estimates of 1970 and 1830 m²/s.

PUBLICATIONS:

Ramp, S.R., McClean, J.L., Collins, C.A., Semtner, A.J., and Hays, K.A.S., "Observations and Modeling of the 1991-1992 El Niño Signal off Central California," *Journal of Geophysical Research*, 102: pp. 5553-5582, 1997.

THESIS DIRECTED:

Steger, J. M., "Use of Ship-Mounted Acoustic Doppler Current Profiler Data to Study Mesoscale Oceanic Circulation Patterns in the Archipelago de Colon and the Gulf of the Farallones," Doctor of Philosophy Dissertation, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Ocean Currents, Tides, Mesoscale Eddies

POLAR SEA CONVECTIVE INSTABILITIES

Roland W. Garwood, Jr., Professor

Department of Oceanography

Sponsor: National Science Foundation

OBJECTIVE: The major scientific objective of this new four-year study is to understand the coupled ocean mixed layer-ice system response to the passage of atmospheric storms. The most intense surface cooling and wind stresses in the Arctic are associated with these storms, and their long-term accumulative effects on the heat and water budgets for the Arctic Ocean cannot be predicted without including: (1) realistic mixed layer physics; (2) ice thermodynamics; and (3) three-dimensional wind-driven ocean circulation. This proposed work builds on the previous project, "Enhancements to Deep Oceanic Convection in the Arctic System," in which the possibility of two kinds of oceanic conditional instabilities were demonstrated. These convection processes, termed "parcel" and "layer" instabilities may lead to significant deep oceanic convection and possible formation of bottom water. The initial energy source to trigger these instabilities may be provided by transient atmospheric forcing. Strong local cooling and wind stress may lead to parcel-type instabilities, and large-scale wind forcing is hypothesized to lead potentially to layer-type instabilities by a combination of mixed-layer upwelling, enhanced vertical turbulent mixing, and downwelling that will occur in response to the passage of atmospheric cyclones and anticyclones.

The principal method for the proposed research includes development and application of a hierarchy of numerical models, with a major milestone being the three-dimensional simulation of the upper ocean (temperature, salinity, circulation, and ice) response to passage of atmospheric storms. This numerical model will consist of an existing ocean primitive

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equation model with embedded turbulence-closure mixed layer and an ice model with realistic thermodynamics and mechanical properties. The embedded mixed layer will include the previously-neglected physics to predict the onset of conditional instabilities and possible formation of deep water.

SUMMARY: The realistic prediction of deep convection is necessary to understand the start of the global conveyor belt and the role of the oceans in climate change. A major deficiency in earlier ocean models has been the lack of adequate convection physics to realistically predict the correct temperature and salinity properties for the convectively-produced deeper water masses. During the first year of this modeling program, the inclusion of realistic storm forcing in the simulation of ocean convection will directly tie atmospheric forcing and ice thermodynamics to mixed layer dynamics and the start of the global conveyor belt in the Greenland-Iceland Seas. The results are leading to more realistic parameterization of subgrid convection of heat, mass, momentum, nutrients, and tracers in basin and global oceanic models.

CONFERENCE PRESENTATIONS:

Garwood, R.W., Jr., "Simulating the Response of Drifters to Polar Sea Convection," University of Washington Applied Physics Laboratory, Seattle, WA, 9 September 1997.

Garwood, R.W., Jr., Jiang, L., and Harcourt, R., "Simulation of Motion of Drifting Buoys, Organisms, and Tracers in the Polar Sea Mixed Layer," Arctic System Science OAI Workshop, Norfolk, VA, May 1997.

THESES DIRECTED:

Stone, R.E., "Deep Mixed Layer Entrainment," Master's Thesis, Naval Postgraduate School, March 1997.

Tramm, E.P., "A Study of the Surface Heat Budget of the Weddell Sea Using a Radiative Transfer Model During the Austral Winter 1994," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Environmental Quality, Modeling and Simulation

KEYWORDS: Ocean Turbulence, Air-Sea Interaction, Ocean Mixed Layer

SIMULATION OF LAGRANGIAN DRIFTERS IN THE LABRADOR SEA

Roland W. Garwood, Jr., Professor

Department of Oceanography

Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: The purpose of this study is to understand the motion and sensor response of drifting packages of scientific instruments in the Office of Naval Research's Accelerated Research Initiative (ONR-ARI) on Deep Oceanic Convection in the Labrador Sea. A key scientific objective is to understand the turbulent kinetic energy budget for free and forced deep oceanic convection. A primary method in developing an understanding of deep oceanic convection is by large-eddy simulation (LES), using a nonhydrostatic numerical model for geophysical turbulent flows.

SUMMARY: LES has been used to show that isobaric (Rossby-type) drifters will sense mean fields for temperature and velocity that will be biased by the tendency for the fixed-depth drifters to seek out and maintain position in zones of horizontal convergence. This result is very important for: (1) suggesting strategies for drifter deployment and (2) understanding the results from the ONR-ARI on deep convection that is presently occurring (winter 1997). An important corollary result is that the isobaric float-observed fluxes may be corrected by a predictable structure function, calculated by large-eddy simulation. These results have direct implications for the conduct of mine warfare and mine warfare counter-measures.

PROJECT SUMMARIES

PUBLICATIONS:

Garwood, R.W., Jr. and Harcourt, R.R., "The Oceanic Planetary Boundary Layer in the Polar Seas," *Workshop on Polar Processes in Global Climate, American Meteorological Society*, 4.2, 4 pp., Cancun, Mexico, 13-15 November 1996, 1997.

Jiang, L. and Garwood, R.W., Jr., "Effects of Topographic Steering and Ambient Stratification on Overflows on Continental Slopes: A Model Study," *Journal of Geophysical Research*, 18 pp., in press, December 1997.

CONFERENCE PRESENTATIONS:

Garwood, R.W., Jr., "Large-Eddy Simulation of the Response of Drifter/Sensor Bodies to Ocean Turbulence," U.S.-U.K. Ocean Modeling Workshop, DERA Haslar, Gosport, UK, 28-29 October 1997.

Garwood, R.W., Jr., "Simulating the Response of Drifters to Polar Sea Convection," University of Washington Applied Physics Laboratory, Seattle, WA, 9 September 1997.

Garwood, R., W. Jr., "Organized Structure of the Ocean Surface Turbulent Boundary Layer and the Implications for Air-Sea Interactions," Naval Research Lab Workshop on Ocean-Atmosphere Coupling, Monterey, CA, July 1997.
technical report:

Harcourt, R., Jiang, L., and Garwood, R.W., Jr., "Numerical Simulation of Drifter Response to Labrador Sea Convection," prepared for the Office of Naval Research, Code 322OM, 70 pp., June 1997.

THESIS DIRECTED:

Bramson, L.S., "Air-Sea Interactions and Deep Convection in the Labrador Sea," Master's Thesis, Naval Postgraduate School, December 1997.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Environmental Quality, Sensors, Surface/Under Surface Vehicles – Ships and Watercraft, Modeling and Simulation

KEYWORDS: Ocean Turbulence, Air-Sea Interaction, Ocean Mixed Layer

TROPICAL OCEAN MIXED LAYER SYSTEM

Roland W. Garwood, Jr., Professor

Arlene A. Guest, Oceanographer

Department of Oceanography

**Sponsors: National Oceanic and Atmospheric Administration and
National Science Foundation**

OBJECTIVE: The scientific objective of this three-year study is to understand the response of the tropical and equatorial ocean turbulent boundary layer system to unsteady atmospheric forcing on time scales from diurnal to annual. Numerical models are developed for and/or applied to tropical turbulent boundary layer and air-sea interaction problems. A principal goal is the verification and improvement of a generalized mixed layer/entrainment zone parameterization in Ocean Global Circulation Models (OGCM) that is physically consistent and globally valid. For this study, the surface layer mixing parameterization is used to explain the transition from the eastern and central Pacific mixed layer system to that of the western region, realistically responding to differences in local (wind and buoyancy flux) and advective (upwelling and zonal pressure gradient) forcing regimes.

SUMMARY: As part of the international Tropical Oceans Global Atmosphere Coupled Ocean Atmosphere Response Experiment (TOGA COARE), a hierarchy of numerical models was used to simulate and better understand the tropical ocean

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mixed layer system. In the third year of this multi-year study, progress has been made in understanding the importance of time and space resolution in representing mixed layer physics (Hone, 1997). Also, the importance of transient forcing for mixed-layer entrainment has been demonstrated with regards to biological productivity (Dusek, 1997). In the final phase of the project, two related studies are underway: (1) large-eddy simulation (LES) of temperature and salinity microstructure in the western Pacific warm pool and (2) use of the coupled ocean general circulation model with embedded mixed layer (OGCM/ML) to understand the interaction between large-scale 3-D circulation and mixed layer dynamics. The LES model has been used to simulate the equatorial turbulent boundary region and contrast the turbulence statistics with those derived from mid-latitude simulations. Langmuir-like wind-driven circulation has been shown to develop for mid-latitude cases. The LES model also predicts the fine-scale structure or microstructure associated with both time-varying surface forcing associated with wind bursts and heavy precipitation events. Extensive development of OGCM/ML, the embedded ocean general circulation-mixed layer model has been done. The improvement in the horizontal friction formulation from Laplacian to biharmonic has allowed much more realistic representation of mesoscale waves and eddies which modulate the entrainment zone activity, with the entrainment zone mixing depending on the shear enhancement or reduction attributable to the mesoscale motion. The simulations with new entrainment zone parameterization improve the representation of sea surface temperature and the vertical distribution of heat. It was also found that large-basin (20S - 20N, 140E - 110W), 25 km grid resolution simulations are necessary for both realistic mesoscale circulation and undercurrent evolution, especially when using real surface forcing data, and that the diurnal cycle in heat flux needs to be included for realistic vertical transport of heat and momentum.

CONFERENCE PRESENTATION:

Garwood, R.W., Jr., "Organized Structure of the Ocean Surface Turbulent Boundary Layer and the Implications for Air-Sea Interactions," Naval Research Lab Workshop on Ocean-Atmosphere Coupling, Monterey, CA, July 1997.

THESES DIRECTED:

Hone, D.M., "Time and Space Resolution and Mixed Layer Accuracy," Master's Thesis, Naval Postgraduate School, March 1997.

Dusek, D.P., "Ocean Mixed Layer Biological Response to Transient Ocean Events," Master's Thesis, Naval Postgraduate School, September 1997.

OTHER: The "NPS Mixed Layer Model" code has been requested and distributed to a variety of international researchers (FORTRAN package of subroutines).

DoD KEY TECHNOLOGY AREAS: Computing and Software, Environmental Quality, Modeling and Simulation

KEYWORDS: Ocean Turbulence, Air-Sea Interaction, Ocean Mixed Layer

INNER SHELF AND NEARSHORE WAVE TRANSFORMATION

Thomas H.C. Herbers, Associate Professor

Department of Oceanography

Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: The main objective of this project is to predict accurately the evolution of surface waves from deep water across the continental shelf to the beach.

SUMMARY: This continuing project is focussed on the effects of nonlinear wave-wave interactions and wave breaking on the evolution of wind-wave spectra across the inner continental shelf. A new theoretical model is under development that incorporates the effects of a gently sloping bottom and nonlinear interactions. A directional buoy and an array of nine

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bottom pressure recorders were deployed on the inner shelf offshore of Duck, NC, during the SandyDuck experiment, to test predictions of nonlinear interactions and estimate energy dissipation rates.

PUBLICATIONS:

Feddersen, F., Guza, R.T., Elgar, S., and Herbers, T.H.C., "Longshore Momentum Balances in the Nearshore," *Journal of Geophysical Research*, accepted with minor revisions.

Herbers, T.H.C., Elgar, S., and Guza, R.T., "Directional Spreading of Waves in the Nearshore," submitted to *Journal of Geophysical Research*.

Lentz, S.J., Herbers, T.H.C., Guza, R.T., Feddersen, F., and Elgar, S., "Momentum Balances on the North Carolina Inner Shelf," to be submitted to *Journal of Geophysical Research*.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effect)

KEYWORDS: Ocean Surface Waves, Nonlinear Interactions, Continental Shelf

WAVE EVOLUTION ON THE CONTINENTAL SHELF

Thomas H.C. Herbers, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The main objective of this project is to evaluate the energy balance of wind-generated waves in shallow water.

SUMMARY: In this new project the spectral energy balance of wind waves on the continental shelf will be evaluated with a field experiment scheduled to take place off Duck, NC, in the fall of 1999. Preparations are underway for the deployment of a coherent array of 5 internal recording bottom pressure sensors and 5 directional wave buoys in depths ranging from 20-40 m. The measurements will be used to verify theoretical predictions of nonlinear spectral energy transfers and estimate wave energy losses resulting from bottom friction and whitecaps.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effect)

KEYWORDS: Ocean Surface Waves, Nonlinear Interactions, Wave Breaking, Bottom Friction, Continental Shelf

PROPAGATION OF SURFACE WAVES ACROSS THE CONTINENTAL SHELF

Thomas H.C. Herbers, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The overall objective of this project is to evaluate and improve model predictions of the evolution of swell propagating across a continental shelf.

SUMMARY: The propagation of surface gravity waves over a wide, shallow continental shelf was investigated with data collected in the DUCK94 Nearshore Field Experiment. Four-month-long seafloor pressure records were obtained with a cross-shore array of 20 bottom-mounted and moored pressure sensors extending from the shoreline to the shelf break (87 m depth, 100 km from shore). The measurements span a wide range of conditions including several nor'easters, very energetic swells from Hurricane Gordon (maximum significant wave height 8 m), and periods of extremely low wave energy (minimum significant wave height 0.2 m). When swell energy levels were low or moderate, the swell energy varied weakly

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across the shelf, consistent with predictions of a linear propagation model. During high-energy conditions, strong attenuation of swell energy levels across the shelf was observed that is likely caused by bottom friction.

OTHER:

Herbers, T.H.C., Hendrickson, E.J., and O'Reilly, W.C., "Propagation of Swell Across a Wide Continental Shelf," manuscript in preparation.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effect)

KEYWORDS: Ocean Surface Waves, Continental Shelf, Swell

NEARSHORE WAVE PROCESSES Thomas H.C. Herbers, Associate Professor Department of Oceanography Sponsor: Office of Naval Research

OBJECTIVE: The main objective of this project is to develop a better understanding of the nonlinear transformation of waves shoaling on beaches.

SUMMARY: As ocean surface waves propagate from deep to shallow water, nonlinear wave-wave interactions transfer energy to phase-coupled harmonics, causing the characteristic steep, pitched-forward wave crests on beaches. A stochastic shoaling model for directionally spread wind waves propagating over a gently sloping beach with straight and parallel depth contours was developed based on weakly dispersive Boussinesq theory. A one-dimensional version of this model was validated with field data. Extensive measurements of the evolution of directional wave spectra across a natural beach were collected in the fall of 1997 during the SandyDuck Experiment.

PUBLICATIONS:

Herbers, T.H.C. and Burton, M.C., "Nonlinear Shoaling of Directionally Spread Waves on a Beach," *Journal of Geophysical Research*, 102, 21101-21114, 1997.

Lippmann, T.C., Herbers, T.H.C., and Thornton, E.B., "Gravity and Shear Wave Contributions to Nearshore Infragravity Motions," *Journal of Physical Oceanography*, accepted with minor revisions.

Norheim, C.A., Herbers, T.H.C., and Elgar, S., "Nonlinear Evolution of Surface Wave Spectra on a Beach," *Journal of Physical Oceanography*, in press.

CONFERENCE PRESENTATION:

Herbers, T.H.C., Norheim, C.A., Burton, M.C., Elgar, S., and Guza, R.T., "A Stochastic Model for Shoaling Waves," Waves in Shallow Water Environments Meeting, San Francisco, CA April 1997.

THESIS DIRECTED:

Norheim, C.A., "A Stochastic Model for Shoaling Waves," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Ocean Surface Waves, Nearshore Processes, Surf Zone

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NONLINEAR INTERACTIONS IN OCEAN SURFACE WAVES

Thomas H.C. Herbers, Associate Professor

Department of Oceanography

Sponsor: Washington State University

OBJECTIVE: The main objective of this continuing project is to evaluate the importance of nonlinear interactions in naturally occurring ocean surface waves.

SUMMARY: Although sophisticated nonlinear theories for ocean surface waves were developed more than 30 years ago, a detailed verification with field observations has not been reported. In this continuing project extensive ocean wave data sets are compared to nonlinear theory predictions. At about three times the frequency of the dominant wind waves, tertiary waves forced by nonlinear interactions between three wind-wave components are important. Trispectral analysis of data collected during a severe nor'easter (the significant wave height was about 5 m) indicates significant tertiary wave contributions to the bottom pressure field.

PUBLICATION:

Elgar, S., Guza, R.T., Raubenheimer, B., Herbers, T.H.C., and Gallagher, E., "Spectral Evolution of Shoaling and Breaking Waves on a Barred Beach," *Journal of Geophysical Research*, 102, 15797-15805, 1997.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Ocean Surface Waves, Nonlinear Interactions, Sea Floor Pressure

MODELING THE RESPONSE OF MONTEREY BAY TO DIURNAL WIND AND TIDAL FORCING

Le Ngoc Ly, Research Associate Professor

Jeffrey D. Paduan, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: Research includes validation of the Monterey Bay (MOB) coastal ocean model developed by Professor Ly and Princeton ocean model (POM) against observed diurnal current variations in Monterey Bay. The more recent developed MOB model includes data processing routines, a grid generation routine, a grid-model coupling package, and visualization routines. Its curvilinear, coastline-following (coastline fitted) orthogonal and nearly-orthogonal, multi-block grid options represent a new advance in coastal ocean modeling. The MOB and POM models will be forced with diurnal winds and tidal sea level oscillations observed in MOB and compared against surface current observations from a network of high frequency (HF) radar sites along the coast.

SUMMARY: The MOB curvilinear nearly-orthogonal grid model (multi-block grid code version with 131X131X25 grid points) for a single-block grid has been newly initialized. The summer diurnal MOB observed and mesoscale model (NCAR MM5) winds has been analyzed. A new 3-D MOB temperature and salinity fields of all available observational data has been generated and used in the model. A map of seasonal CODAR surface current location has been generated for studying CODAR data applications to the MOB model. Several numerical experiments were carried out, with and without, CODAR surface current data to study horizontal and vertical propagation of the information contained in the data. The propagation of information of two surface current components from the various data sets with various temporal and spatial resolutions, the effect of data insertion intervals, and conversion of the dynamic evolution to the true ocean are being studied.

Extensive work have been done on the HF radar (CODAR) data for Monterey Bay to produce maps of surface current variability at diurnal and semidiurnal periods. The dataset is most completed for the period of August through December, 1994. A rotated Monterey Bay POM domain has been produced so that simulations of sea breeze and tidal forcing can be accomplished using the offshore and alongshore open boundary conditions.

PROJECT SUMMARIES

PUBLICATIONS:

Benilov, A. Y. and Ly, L.N., "Dynamic Structure of the Upper Ocean Under Effects of the Surface Waves and their Breaking," *Physics of Fluids*, 1997, in review.

Ly, L.N. and Luong P., "A Mathematical Coastal Ocean Circulation System with Breaking Waves and Numerical Grid Generation," *Applied Mathematical Modeling*, 10, 633-641, 1997.

Ly, L.N. and Luong P. "A Coastal Ocean Circulation System and Its Application to the South China Sea," *VACETS Technical Journal*, Vol. 2, 6-16, 1997.

Ly, L.N. and Luong P., "Numerical Grids Used in a Coastal Ocean Model with Breaking Wave Effects," *Applied and Computational Mathematics: Topics in Partial Differential Equations*, J. Castillo, Carlos de Moura and V. Pereyra, (eds.), published by Birkhauser-Verlag, in press.

Ly, L.N., "A Numerical Study of Aerodynamic Roughness Lengths as Seen from Above and Below in Air-Sea Coupling," *Fluid Dynamics Research*, 1997, in press.

Ly, L.N. and Luong P., "Numerical Multi-Block Grids in Coastal Ocean Modeling," *Computational Physics*, 1997, in review.

Ly, L. N. and Jiang, L., Horizontal Pressure Gradient Errors of the Monterey Bay Sigma Coordinated Ocean Model with Various Grids," *Journal of Geophysical. Research* 1997, in review.

Ly, L.N., "Modeling Wave-Enhanced Turbulence in the Upper Oceanic Layer," *Physics of Fluid*, 1997, submitted.

Ly, L.N., "Numerical Modeling of Turbulent Dissipation Rate Under Surface Breaking Waves," *The Royal Society Proceedings: Mathematical and Physical Sciences*, 1997, in review.

CONFERENCE PRESENTATIONS:

Benilov, A. Yu., and Ly, L.N., "The Ocean Upper Layer with the Presence of the Surface Waves and Their Breaking," American Geophysical Union Spring Meeting, Transactions OS52A-10, Baltimore, MD, May 1997.

Ly, L.N., "Aerodynamic Roughness from Above and Below in Air-Sea Coupling," American Geophysical Union Fall Meeting, Transactions OS31A-9, San Francisco, CA, December 1997.

Ly, L.N. and Luong P., "On Numerical Grids Used in an Ocean Circulation Model with Breaking Wave Effects," Second Pan-American Workshop in Applied and Computational Mathematics, Brazil, September 1997.

Ly, L.N. and Luong P., "On Numerical Multi-Block Grids in Coastal Ocean Circulation Modeling," Fourth SIAM Conference on Mathematical and Computational Issues in the Geosciences, Albuquerque, NM, June 1997.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Environmental Effects, Data and Software, New Technique)

KEYWORDS: Monterey Bay Response, Wind and Tide Forcing, Nowcast/Forecast Systems, Data-Model Combination, Coastal Ocean Modeling, Numerical Grid Generation, Data Assimilation, HF Radar Ocean Currents

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INFLUENCES OF OCEAN SURFACE WAVES ON AIR-SEA SYSTEM

Le Ngoc Ly, Research Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The goal of this multi-year project which is expanded from the Office of Naval Research (ONR) sponsored project under the Marine Boundary Layer Program, "Effects of Ocean Surface Waves on Fluxes and Turbulence and Resulting Impacts on Coupling Modeling." The problem to be solved in this project is one aspect of air-wave-sea interaction modeling, which includes air-wave-sea model development of semi-empirical turbulence theory. The goal of this project is also to apply the developed models, theory to larger scale ocean and atmospheric models.

SUMMARY: In FY97 the focus was on improving recently developed Ly's (1995) air-wave-sea interaction model of semi-empirical turbulence theory by using new formulations of roughness lengths from above and below, and of surface wave parameterization through turbulent kinetic energy fluxes at the air-sea interface. The work in FY97 is also focused on validation of numerical model results by comparison to available datasets. Results of the study are published in a new series of publications.

PUBLICATIONS:

Benilov, A.Y. and Ly, L.N., "Dynamic Structure of the Upper Ocean under Effects of the Surface Waves and Their Breaking," *Physics of Fluids*, 1997, in review.

Ly, L.N. and Luong P., "A Mathematical Coastal Ocean Circulation System with Breaking Waves and Numerical Grid Generation," *Applied Mathematical Modeling*, 10, 633-641, 1997.

Ly, L.N. and Luong P. "A Coastal Ocean Circulation System and Its Application to the South China Sea," *VACETS Technical Journal*, Vol. 2, 6-16, 1997.

Ly, L.N. and Luong P., "Numerical Grids Used in a Coastal Ocean Model with Breaking Wave Effects," *Applied and Computational Mathematics: Topics in Partial Differential Equations*, J. Castillo, Carlos de Moura and V. Pereyra, (eds.), published by Birkhauser-Verlag, in press.

Ly, L.N., "A Numerical Study of Aerodynamic Roughness Lengths as Seen from Above and Below in Air-Sea Coupling," *Fluid Dynamics Research*, 1997, in press.

Ly, L.N. and Luong P., "Numerical Multi-Block Grids in Coastal Ocean Modeling," *Computational Physics*, 1997, in review.

Ly, L.N. and Jiang, L., "Horizontal Pressure Gradient Errors of the Monterey Bay Sigma Coordinated Ocean Model with Various Grids," *Journal of Geophysical Research*, 1997, in review.

Ly, L.N., "Modeling Wave-Enhanced Turbulence in the Upper Oceanic Layer," *Physics of Fluid*, 1997, submitted.

Ly, L.N., "Numerical Modeling of Turbulent Dissipation Rate Under Surface Breaking Waves," *The Royal Society Proceedings: Mathematical and Physical Sciences*, 1997, in review.

CONFERENCE PRESENTATIONS:

Benilov, A. Yu, and Ly, L.N., "The Ocean Upper Layer with the Presence of the Surface Waves and Their Breaking," American Geophysical Union Spring Meeting, Transactions OS52A-10, Baltimore, MD, May 1997.

Ly, L.N., "Aerodynamic Roughness from Above and Below in Air-Sea Coupling," American Geophysical Union Fall

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Meeting, Transactions OS31A-9, San Francisco, CA, December 1997.

Ly, L.N. and Luong P., "On Numerical Grids Used in an Ocean Circulation Model with Breaking Wave Effects," Second Pan-American Workshop in Applied and Computational Mathematics, Brazil, September 1997.

Ly, L.N. and Luong P., "On Numerical Multi-Block Grids in Coastal Ocean Circulation Modeling," Fourth SIAM Conference on Mathematical and Computational Issues in the Geosciences, Albuquerque, NM, June 1997.

DoD KEY TECHNOLOGY AREAS: Other (Environmental Effects, Environmental Physics and Software, New Technique)

KEYWORDS: Ocean Wave Effect, Wave-Fluxes Relation Air-Wave-Sea Interaction Theory, Air-Wave-Sea Modeling, Wave-Turbulence Relation, Air-Sea Boundary Layers

MODELING THE LONG-TERM TURBULENT CIRCULATION OF THE ARCTIC OCEAN AND THE SEA ICE

Wieslaw Maslowski, Research Assistant Professor

Yuxia Zhang, Research Associate

Albert J. Semtner, Professor

Department of Oceanography

Sponsor: National Science Foundation

OBJECTIVE: The main goal of this project is: (1) to develop an eddy resolving coupled Arctic ocean-ice model with proper connections to surrounding subpolar ocean environments and (2) to integrate the model for long enough time to determine the quasi-equilibrium turbulent circulation of the ice-covered Arctic Ocean as driven by multi-year observed atmospheric forcing using advanced parallel computers.

SUMMARY: This project started in October 1996 and it is a continuation of the earlier work supported by other sponsors. In this ongoing study a coupled ice-ocean model of the Arctic at resolution of 18 km and 30 levels was developed. The model will use increasingly high resolution in three dimensions and employ high-quality parameterizations of surface exchanges, ice dynamics, near-surface mixing, deep convection, and topographic interactions. Daily surface forcing has utilized re-analyzed datasets from forecast centers, and lateral exchanges with the subpolar North Atlantic and at Bering Strait will derive from comparably forced model of the remaining global ocean. An eddy-resolving simulation of 200 years has been completed and it will continue including implementation of a 9-km and 40 level grid. The equilibrium circulation with decadal variability is being analyzed to understand the physics of the Arctic Ocean and its sea-ice cover. Model results will continue to be analyzed and compared with the existing observations to evaluate the model and extend interpretation of the data. Significance of this research lies in better understanding of the Arctic Ocean as a physical system, enabling applications to biological, geochemical, and climate problems - and in practical predictive ability, clearly exceeding what is presently available.

PUBLICATIONS:

Dickson, R.R., Osborn, T.J., Hurrell, J.W., Meincke, J., Blindheim, J., Adlansvki, B., Vigne, T., Alekseev, G., Maslowski, W., and Cattle, H., "The Arctic Ocean Response to the North Atlantic Oscillation," *Proceedings of the Rosario Symposium on Polar Processes and Global Climate*, pp. 46-47, World Climate Research Program Office, Oslo, Norway, 1997.

Hunke, E.C. and Zhang, Y., "A Comparison of Sea Ice Dynamics Models at High Resolution." *Monthly Weather Review*, 1997, submitted.

Hunke, E.C. and Zhang, Y., "Comparison of Elastic-Viscous-Plastic and Viscous-Plastic Dynamics Models Using a High

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Resolution Arctic Sea Ice Model,” *Proceedings of the Rosario Symposium on Polar Processes and Global Climate*, pp. 97-99, World Climate Research Program Office, Oslo, Norway, 1997.

Newton, R., Maslowski, W., and Schlosser, P., “Freshwater Distribution in the Arctic: Comparing a High Resolution Model with Observations,” *Proceedings of the Rosario Symposium on Polar Processes and Global Climate*. p. 175, World Climate Research Program Office, Oslo, Norway, 1997.

Maslowski, W., Parsons, A.R., Zhang, Y., and Semtner, A. J., “High Resolution Arctic Ocean and Sea Ice Simulations: Ocean Model Design and Early Results,” *Journal of Geophysical Research*, submitted.

Maslowski, W., “Advanced Modeling of the Arctic Ocean and Sea Ice in Support of Global Climate Studies,” *Proceedings of the Global Change Workshop on Polar Processes*, ed: D. Martinson, pp. 93-96, American Meteorology Society, Boston, MA, 1997.

Maslowski, W., Zhang, Y., and Semtner, A., “Modeling Freshwater Sources, Their Distribution, and Sinks in the Arctic Ocean,” *Proceedings of Rosario Symposium on Polar Processes and Global Climate*, pp. 159-161, World Climate Research Program Office, Oslo, Norway, 1997.

Maslowski, W., Zhang, Y., and Semtner, A.J., “Coupled Modeling to Improve Understanding of the Arctic Ocean and its Sea Ice,” *Arctic System Science Ocean-Atmosphere-Ice Interactions All Hands Meeting and Planning Workshop*, p.48, eds: Codispoti, L.A., Grebmeir, J.M., and Ayers, L.A., ARCSS/OAII Report Number 6, Old Dominion University, Norfolk, VA, 1997.

Maslowski, W., Semtner, A.J., and Zhang, Y., “Advanced Modeling Studies of the Arctic Ocean and Sea Ice - Toward Better Understanding of the Arctic System,” *Modeling the Arctic System Workshop Report on the State of Modeling in the Arctic System Science Program*, pp. 24-25, Arctic Research Consortium of the U.S., Fairbanks, AK, 1997.

Maslowski, W., Zhang, Y., and Semtner, A.J. “High-Resolution Modeling of Circulation and Processes in the Arctic Ocean with Sea Ice,” *World Climate Research Programme Arctic Climate System Study Report on the ACSYS Sea-Ice/Ocean Modeling Workshop*, in print.

Paluszkiwicz, T., Skyllingstad, D., Becker, P., Maslowski, W., and Semtner, A.J., “Numerical Simulation of Convection in the Greenland Sea: The Role of Sea Ice, Eddy Heat Flux, and Surface Forcing,” *Proceedings of the Rosario Symposium on Polar Processes and Global Climate*, p. 183, World Climate Research Program Office, Oslo, Norway, 1997.

Peacock, N.R., Laxon, S.W., Scharroo, R., and Maslowski, W., “Improving the Signal to Noise Ratio of Altimetric Measurements in Ice-Covered Seas,” *EOS Transactions*, American Geophysical Union, 78(46), Fall Meeting Abstracts, p. 140, November 1997.

Schlösser, P., R. Bayer, G. Bonisch, B. Ekwurzel, M. Frank, S. Khatiwala, W. Maslowski, R. Newton, and W.M. Smethie, Jr., “New Insights into the Circulation and Freshwater Balance of the Arctic Ocean Derived from Multi-tracer Data Sets,” *Proceedings of the Rosario Symposium on Polar Processes and Global Climate*, p.239, World Climate Research Program Office, Oslo, Norway, 1997.

Semtner, A.J., “Global Ocean and Polar Regions: A Modeling Perspective,” *Proceedings of the Global Change Workshop on Polar Processes*, pp. 56-61, D. Martinson, (ed.), American Meteorology Society, Boston, MA., 1997.

Semtner, A.J., “Modeling Ocean Climate Variability with Emphasis on Polar Processes,” *Proceedings of the Rosario Symposium on Polar Processes and Global Climate*, pp.64-66, World Climate Research Program Office, Oslo, Norway, 1997.

Zhang, Y., Maslowski, W., and Semtner, A. J., “High Resolution Arctic Ocean and Sea Ice Simulations: Ice Model Design

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and Early Results,” 1997, provisionally accepted.

Zhang, Y., Maslowski, W., and Semtner, A., “Sea Ice Transport and Production, and Their Impact on Heat Flux in a High Resolution Arctic Ice-Ocean Model,” *Arctic System Science Ocean-Atmosphere-Ice Interactions All Hands Meeting and Planning Workshop*, p. 68, Codispoti, L.A., Grebmeir, J.M., and Ayers, L.A. (eds.), ARCSS/OAII Report Number 6, Old Dominion University, Norfolk, VA, 1997.

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Zhang, Y., Maslowski, W., and Semtner, A.J., “Sea Ice Transport and Production, and the Impact of Heat Flux in a High Resolution Arctic Ice-Ocean Model,” *World Climate Research Programme Arctic Climate System Study Report on the ACSYS Sea-Ice/Ocean Modeling Workshop*, in print.

Zhang, Y. and Hunke, C., “Recent Change of Arctic Sea Ice in a High Resolution Ice-Ocean Model Forced with 1979-93 ECMWF Reanalysis,” *Proceedings of the Rosario Symposium on Polar Processes and Global Climate*, pp. 301-303, World Climate Research Program Office, Oslo, Norway, 1997.

CONFERENCE PRESENTATIONS:

Maslowski W., Zhang, Y., and Semtner, A.J. “High-Resolution Modeling of Circulation and Processes in the Arctic Ocean with Sea Ice on Parallel Computers,” Department of Energy Computer Hardware, Advanced Mathematics, and Model Physics Meeting, San Antonio, TX, March 1997.

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Maslowski, W., “Advanced Modeling of the Circulation and Processes in the Arctic Ocean with Sea Ice in Support of Global Climate Studies,” Arctic Consortium of the U.S. 9th Annual Meeting, Washington, DC, June 1997.

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Schlusser, P. and Maslowski, W., “Freshwater, Tracers, and Modeling Results,” National Science Foundation Arctic System Science Study of Arctic Change Workshop, University of Washington, Seattle, WA, November 1997.

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lution Arctic Ice-Ocean Model,” World Climate Research Programme Arctic Climate System Study Sea Ice Thickness Workshop, Monterey, CA, April 1997.

Zhang, Y. and Semtner, A.J., “High Resolution Sea Ice Simulation and Comparison with SSM/I,” National Science Foundation SCORE Meeting on the Southern Ocean Oceanography, Tucson, AZ, December 1997.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Environmental Quality, Computing and Software

KEYWORDS: Ice/Ocean Circulation, Ice-Ocean Modeling, Model Validation

COMPARISONS OF THE LOS ALAMOS NATIONAL LABORATORY (LANL) PARALLEL OCEAN PROGRAM (POP) MODEL AND WOCE OBSERVATIONS

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Albert J. Semtner, Professor

Department of Oceanography

Sponsor: National Science Foundation

OBJECTIVE: To validate the very realistic global sixth-degree Los Alamos National Laboratory (LANL) Parallel Ocean Program (POP) model with observational data collected during the World Ocean Circulation Experiment (WOCE). This project is ongoing.

SUMMARY: Over the duration of the WOCE experiment (past 6 years), data were collected over extensive spatial and temporal scales in all ocean basins to provide a description of the global ocean circulation. The devised sampling strategy used one-time and repeat hydrography sections, current meter arrays, subsurface floats, volunteer observing ships (VOS), surface drifters, tide gauges, and satellite measurements in such a way to complement each other and provide more realizations in time and space. Subsets of this data were used to validate the POP model. In the Pacific, Eulerian and Lagrangian statistics from surface drifters were compared with co-located POP fields. Aspects of the overturning and interbasin thermohaline circulation such as the mean and variability of heat and water mass transports, water mass characteristics and their pathways were examined in the light observations, in particular those from WOCE. Efforts were concentrated in the South Pacific and South Atlantic oceans. In the southern Indian Ocean, the impact of the Indonesian through flow in POP was evaluated by constructing heat and salt budgets.

PUBLICATIONS:

Gordon, A.L. and McClean, J.L., “Thermohaline Stratification of the Indonesian Seas-Model and Observations,” *Journal of Physical Oceanography*, accepted with revision.

McClean, J.L., Semtner, A.J., and Zlotnicki, V., “Comparisons of Mesoscale Variability in the Semtner-Chervin Quarter-Degree Model the Los Alamos POP Sixth-Degree Model, and TOPEX/POSEIDON Data,” *Journal of Geophysical Research*, 102(C11), 25203-25226, 1997

McClean, J.L., Maltrud, M., and Semtner, A.J., “Comparisons of the LANL POP Model and Observations in the South Atlantic,” *International WOCE Newsletter*, 28, 5-7, 1997.

CONFERENCE PRESENTATIONS:

McClean, J.L., Maltrud, M., and Semtner, A.J., “Comparisons of the LANL POP Model and Observations in the South Atlantic,” World Ocean Circulation Experiment South Atlantic Workshop, Brest, France, 16-20 June 1997.

McClean, J.L., Maltrud, M., Semtner, A.J., Lemon, M., and Braccio, P., “Pacific Ocean Circulation in the LANL POP 1/6-

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McClellan, J.L. and Maltrud, M., “Overturning and Interbasin Thermohaline Circulation in the LANL POP Model,” 1998 Ocean Sciences Meeting, San Diego, CA, 9-13 February 1998.

THESIS DIRECTED:

Lemon, M.R., “Comparison of Los Alamos National Laboratory (LANL) Parallel Ocean Program (POP) Model Fields with Pacific Surface Drifter Measurements,” Master’s Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Ocean Circulation, Model Validation, Model/Data Synthesis

ROLE OF TIDAL FORCING IN DETERMINING THE INTERNAL WAVE SPECTRUM IN THE LITTORAL OCEAN

Jeffrey D. Paduan, Associate Professor

Department of Oceanography

Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: The goal of this project is to develop a method, using a three-dimensional primitive equation model with realistic bathymetry, for simulating the internal wave energy produced along the coast by the action of tides.

SUMMARY: This project is investigating the nature of internal wave spectra in the littoral ocean environment using existing moored velocity time series and simulated coastal time series produced by a three-dimensional, primitive equation numerical model with realistic bathymetry forced by tidal-period sea level oscillations. The project has very specific goals that relate to the Littoral Internal Wave Initiative (LIWI), which seeks to quantify the physics of oceanic internal waves on the continental slope and shelf and to develop predictive models of their spectral characteristics. Initial studies are being conducted in the Monterey Bay region, where there are many near-bottom current meter records. Furthermore, the topography of the Monterey Submarine Canyon is known to produce very strong, bottom-intensified internal tides, which are the main subject of the numerical model simulations.

PUBLICATIONS:

Kelly, K.A., Beardsley, R.C., Limeburner, R., Brink, K.H., Paduan, J.D., and Chereskin, T.K., “Variability of the Near-Surface Eddy Kinetic Energy in the California Current Based on Altimetric, Drifter, and Moored Current Data,” *Journal of Geophysical Research*, in press.

Petruncio, E.T., Rosenfeld, L.K., and Paduan, J.D., “Internal Tides in a Submarine Canyon: Part I: Observations from Monterey Bay,” *Journal Physical Oceanography*, in press.

THESIS DIRECTED:

Sires, J.G., “Lagrangian Measurements of Eddy Characteristics in the California Current System,” Master’s Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Ocean Currents, Tides, Internal Tides

PROJECT SUMMARIES

MODELING THE RESPONSE OF MONTEREY BAY TO DIURNAL WIND AND TIDAL FORCING

Jeffery D. Paduan, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The goal of this project is to validate a coastal ocean model using observations of strong diurnal and semidiurnal processes around Monterey Bay.

SUMMARY: This is applying new technologies to Navy coastal modeling activities. It includes validation of the Monterey Bay (MOB) coastal ocean model developed by L.N. Ly and the Princeton Ocean Model (POM) against observed diurnal current variations in Monterey Bay. The more recently developed Monterey Bay model includes data processing routines, a grid generation routine, a grid-model coupling package, and visualization routines. Its curvilinear, coastline-following (coastline fitted) orthogonal and nearly orthogonal, multi-block grid options represent a new advance in coastal ocean modeling. The system also includes a hybrid vertical grid that combines aspects of z-level and s-coordinate grids to better model surface and bottom boundary layers. MOB and the more widely used POM are being forced with diurnal winds and tidal sea level oscillations observed in Monterey Bay and compared against surface current observations from a network of high frequency (HF) radar sites along the coast.

PUBLICATIONS:

Fernandez, D.M., Graber, H.C., Paduan, J.D., and Barrick, D.E., "Mapping Wind Direction with HF Radar," *Oceanography*, Vol. 10, No. 2, pp. 93-95, 1997.

Paduan, J.D. and Cook, M.S., "Mapping Surface Currents in Monterey Bay with CODAR-Type HF Radar," *Oceanography*, Vol. 10, No. 2, pp. 49-52, 1997.

Paduan, J.D. and Graber, H.C., "Introduction to High Frequency Radar: Reality and Myth," *Oceanography*, Vol. 10, No. 2, pp. 36-39, 1997.

Paduan, J.D., Cook, M.S., and Fernandez, D.M., "Two-Dimensional Diurnal to Monthly Period Surface Currents in Monterey Bay from CODAR-type HF Radar," *Proceedings of the IEEE International Geoscience and Remote Sensing Symposium*, Singapore, pp. 1814-1816, August 1997.

CONFERENCE PRESENTATIONS:

Paduan, J.D., Rosenfeld, L.K., and Cook, M.S., "Diurnal Surface Current Fluctuations in Monterey Bay from CODAR-Type HF Radar," Monterey Bay National Marine Sanctuary Research Symposium, Santa Cruz, CA, March 1997.

THESIS DIRECTED:

Smith, M.S., "Comparison of Trajectories Generated by the NOAA Oil Spill Model to Trajectories Produced Using HF Radar-Derived Surface Currents in Monterey Bay," Master's Thesis, September 1997.

DoD KEY TECHNOLOGY AREAS: Sensors, Battlespace Environments, Modeling and Simulation

KEYWORDS: HF Radar, Ocean Currents, Tides, Sea Breeze

VARIABILITY OF THE SURFACE CIRCULATION

PROJECT SUMMARIES

AND TEMPERATURE IN THE ADRIATIC SEA

Pierre-Marie Poulain, Assistant Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The main goal of this project is to make effective drifter measurements of sea surface currents and sea surface temperature (SST) in the global Adriatic Sea in order to describe the spatial characteristics and the temporal variability of the surface circulation and the SST at inertial to seasonal scales. A related objective is to investigate some aspects of the response of the surface circulation and SST to atmospheric and boundary forcings. In particular, our goal is to study the characteristics of the wind-driven currents in relation to the surface wind forcing, obtained from wind measurements and from atmospheric model products. Another aim is to explore the role of eddies (versus mean currents) in transporting momentum and heat.

SUMMARY: The observational phase of this project began in August 1997 with the deployment of 20 CODE drifters and one GDP/MINIMET throughout the Adriatic Sea by colleagues of the Osservatorio Geofisico Sperimentale, Trieste, Italy. In-situ wind observations were made following the release of the GDP/MINIMET drifter. One CODE drifter was repetitively deployed and recovered off Ancona, Italy, in the area sampled by a newly-installed CODAR system in order to compare the surface velocity estimates obtained by the HF radar and CODE drifters.

The drifter data have been downloaded from Service Argos on a daily basis. After some pre-processing and data reduction, graphical representations of the drifter statistics, of the drifter trajectories and the temperature time series, etc. have been produced and updated every day in a dedicated world wide web page (<http://oc.nps.navy.mil/~drifter>). In four months, the drifters provided remarkable information on the circulation spatial structure and temporal variability both in the Adriatic Sea and in the northern Ionian Sea.

In order to complete a year-long monitoring of the Adriatic Sea, additional seasonal deployments are planned until spring 1998. The entire drifter data set will be interpreted and results will be published as part of the continuation of this project into 1998 and 1999.

CONFERENCE PRESENTATIONS:

Poulain, P.-M., Gacic, M., Sellschoop, J., and Niiler, P., "Recent Lagrangian Measurements of Surface Circulation in the Adriatic and Ionian Seas," American Geophysical Union 1998 Ocean Sciences Meeting, San Diego, CA, 9-13 February 1998.

Scarazzato, P. Ursella, L., Kovacevic, V., Gacic, M., Manca, B., Poulain, P.-M., and Fragiaco, C., "Progress in the Adriatic Sea Oceanography," International Conference on the Progress in Oceanography of the Mediterranean Sea, Rome, Italy, 17-19 November 1997.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Marginal Seas and Straits, Circulation

OCEANOGRAPHIC MEASUREMENTS IN THE ADRIATIC AND IONIAN SEAS

Pierre-Marie Poulain, Assistant Professor

Department of Oceanography

Sponsor: Naval Postgraduate School

OBJECTIVE: The main objective of this continuing project is to make effective drifter measurements of surface currents in the Strait of Sicily and the Ionian Sea in order to describe the variability of the surface circulation mesoscale structures and gain knowledge on their dynamics. A related goal is to analyze and interpret oceanographic data sets (mainly drifter measurements) collected by the PI in the Adriatic and Ionian Seas over the last few years.

SUMMARY: During 1997, a total of 17 satellite tracked drifters were successfully released in the Strait of Sicily from

PROJECT SUMMARIES

research vessels conducting hydrographic surveys and from ships of opportunity (ferries). As the drifters moved eastward with the prevailing Atlantic-Ionian Stream (AIS), they provided remarkable information on the circulation spatial structure and temporal variability both in the Strait of Sicily area and in the northwestern Ionian Sea. The structure of the AIS extending into an anticyclonic gyre in the northern Ionian and continuing as a strong meridional jet in the northeast Ionian is in good agreement with geostrophic circulation maps produced in the late 1980s. Seasonal variability of the surface circulation is also evident. In summer, the meandering AIS appears to be a strong and robust sub-basin scale feature south of Sicily. In contrast, the currents are dominated by smaller mesoscale eddy patterns in winter.

The drifter data were pre-processed and the drifter movements were depicted on a dedicated web page (<http://oc.nps.navy.mil/~drifter>) on a daily basis. In order to continue the long-term continuous monitoring of the Strait of Sicily circulation, additional deployments are planned in winter 1998. The entire drifter data set will be interpreted and results will be published as part of the continuation of this project into 1998.

PUBLICATIONS:

Kovacevic, V., Gacic, M., and Poulain, P.-M., "Eulerian Current Measurements in the Strait of Otranto and in the Southern Adriatic," *Journal of Marine Systems*, in press.

Poulain, P.-M. "Drifter Observations of Surface Circulation in the Adriatic Sea," *Journal of Marine Systems*, 1998, in press.

Poulain, P.-M. and Zanasca P. "Lagrangian Measurements of Surface Currents in the Northern and Central Adriatic Sea," *Ecosystems Research Report, The Adriatic Sea*, EU/Environment Series, Brussels, Belgium, in press.

Poulain, P.-M. and Zanasca, P. "Drifter and Float Observations in the Adriatic Sea (1994-1996) - Data Report," SACLANTCEN Memorandum, SM-340, SACLANT Undersea Research Centre, La Spezia, Italy, 1998, in press.

CONFERENCE PRESENTATIONS:

Pinto, R. L., Poulain, P.-M., and Chu, P., "A P-Vector Approach for Determining Absolute Geostrophic Circulation in the Strait of Otranto and the Southern Adriatic," American Geophysical Union 1998 Ocean Sciences Meeting, San Diego, CA, 9-13 February 1998.

Poulain, P.-M., Zambianchi, E., Sellschopp, J., and Ribera, M., "Lagrangian Measurements of Surface Circulation in the Straits of Sicily," Joint IAMAS/IAPSO Assemblies, Melbourne, Australia, 1-9 July 1997.

Sellschopp J, Robinson, A. R., Onken, R., Warn-Varnas, A., and Poulain, P.-M., "Quasi Permanent Flow Structures in the Sicilian Channel," XXII General Assembly of the European Geophysical Society, Vienna, Austria, 21-25 April 1997.

Zambianchi, E. and Poulain, P.-M., "Surface Circulation in the Straits of Sicily: A Lagrangian Description," International Conference on the Progress in Oceanography of the Mediterranean Sea, Rome, Italy, 17-19 November 1997.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Marginal Seas and Straits, Water Masses, Circulation

PROJECT SUMMARIES

LAGRANGIAN MEASUREMENTS IN ICELANDIC WATERS

Pierre-Marie Poulain, Assistant Professor
Department of Oceanography
Sponsor: North Atlantic Treaty Organization

OBJECTIVE: The main objective of this project is to analyze drifter observations in the Icelandic waters collected by the SACLANT Undersea Research Centre, La Spezia, Italy in 1991-1995 and by the Marine Research Institute (MRI) of Reykjavik, Iceland (1995-1998) in order to define the main pathways of the surface circulation and describe their eddy and seasonal variabilities. A related goal is to use and combine satellite thermal imagery with the in-situ drifter measurements to provide the most complete description of the mesoscale variability.

SUMMARY: The SACLANT drifter data set was combined with relatively cloud-free thermal infrared satellite images between October 1992 and September 1993 to describe the dynamic and thermal structures of the Iceland-Faroe Front system. The in-situ and remotely sensed data combined satisfactory to provide the best pictures of the frontal variability.

The drifter data sets up to the end of 1996 were processed to create low-passed, uniformly sampled trajectories. Seasonal maps of mean currents and eddy kinetic energy were produced. The Lagrangian nature of the drifters was exploited to estimate decorrelation time and length scales and eddy diffusivities in selected regions.

This project will continue into 1998 as more drifters will be released by MRI in winter 1998. Final processing and data interpretation (statistical analyses) will be conducted at the end of 1998 and early 1999 when all the drifters will have ceased to operate.

THESIS DIRECTED:

Arends, C.J., "Iceland-Faroe Front Structure and Variability," Master's Thesis, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Upper Ocean Circulation, Lagrangian Drifters, Icelandic Coastal Waters

SCIENTIFIC DEVELOPMENT OF A MASSIVELY PARALLEL OCEAN CLIMATE MODEL

Albert J. Semtner, Professor
Department of Oceanography
Sponsor: Department of Energy

OBJECTIVE: To develop detailed models of the global ocean circulation with all relevant physical processes important for prediction, as well as to validate the models against existing observations. To understand the physical processes in the ocean that affect oceanic predictability and climatic fluctuations and change.

SUMMARY: A global ocean model, capable of producing accurate forecasts out to the limits of climate predictability when properly coupled to a valid atmospheric model, has to be well designed and able to run on the advanced supercomputers of the future, which are expected to be of massively parallel design. The present research is moving an eddy-resolving model onto massively parallel computers, for coupled modeling related to CHAMMP. To guide the additional physical development of a comprehensive model, scientific study in three areas is now underway: (1) investigation of the physics of ocean heat transport; (2) inclusion of near-surface oceanic processes relevant to climate; and (3) examination of resolution requirements for ocean modeling. Last year, high-latitude process improvements and analyses of resolution effects were emphasized. A fully validated model was produced at project completion in late 1997.

PUBLICATIONS:

PROJECT SUMMARIES

Chervin, R.M., Craig, A.P., and Semtner, A.J., "Meridional Heat Transport Variability from a Global Eddy-Resolving Ocean Model," *Assessing Climate Change*, W. Howe and A. Henderson-Sellers, eds., Gordon and Breach Science Publishers, Roseville, Australia, 1997, in press.

Craig, A.P., Bullister, J.L., Harrison, D.E., Chervin, R.M., and Semtner, A.J., "A Comparison of Temperature, Salinity, and Chloro-Fluorocarbon Observations with Results from a One-Degree Three-Dimensional Global Ocean Model," *Journal of Geophysical Research*, 1997, in press.

Maltrud, M.E., Smith, R.D., Semtner, A.J., and Malone, R.C., "Global Eddy-Resolving Ocean Simulations Driven by 1985-94 Atmospheric Fields: Part I, Mean Circulation and Variability," *Journal of Geophysical Research*, 1997, provisionally accepted.

Maslowski, W., Parsons, A.R., Zhang, Y., and Semtner, A.J., "High-Resolution Arctic Ocean and Sea Ice Simulations: Part I, Ocean Model Design and Early Results," *Journal of Geophysical Research*, 1997, submitted.

McClellan, J.L., Semtner, A.J., and Zlotnicki, V., "Comparisons of Mesoscale Variability in the Semtner-Chervin Quarter-Degree Model, the Los Alamos POP Sixth-Degree Model, and TOPEX/POSEIDON Data," *Journal of Geophysical Research*, 102, 25203-25226, 1997.

Ramp, S.R., McClellan, J.L., Collins, C.A., Semtner, A.J., and Hayes, K.A.S., "Observations and Modeling of the 1991-1992 El Niño off Central California," *Journal of Geophysical Research*, 102, 5553-5582, 1997.

Semtner, A.J., Introduction to "A Numerical Method for the Study of the Circulation of the World Ocean," *Journal of Computational Physics*, 135,149-153 1997.

Semtner, A.J., "Very high-Resolution Estimates of Global Ocean Circulation, Suitable for Carbon-Cycle Modeling," *Proceeding of the Snowmass Global Change Institute on the Global Carbon Cycle*, Office of Interdisciplinary Earth Studies, Boulder, CO, 1997, in press.

Semtner, A.J., "Global Ocean and Polar Regions: A Modeling Perspective," *Proceedings of the Global Change Workshop on Polar Processes*, pp. 56-61, D. Martinson (ed.), American Meteorology Society, Boston, MA, 1997.

Semtner, A.J., "Modeling Ocean Climate Variability with Emphasis on Polar Processes," *Proceedings of the Rosano Symposium on Polar Processes and Global Climate* pp. 246-248, World Climate Research Program Office, Oslo, Norway, 1997.

Zhang, Y., Maslowski, W., and Semtner, A.J., "High-Resolution Arctic Ocean and Sea Ice Simulations: Part II, Ice Model Design and Early Results," *Journal of Geophysical Research*, 1997, accepted.

PRESENTATIONS:

"Recent Research Results on Ocean Simulation, Comparison with Observation, and Improvements in Predictions Methods," was presented in various forms in the following venues: Santa Barbara, CA, 20 February 1997; DoE-CHAMMP, San Antonio, TX, 3-6 March 1997; U.S.-JAPAN Workshop, Honolulu, HI, 10-13 March 1997; NSF Ocean Meeting, Boulder, CO, 7-8 April, 1997; ACSYS Conference, Monterey, CA, 9-10 April 1997; ARCSS OAIL, Virginia Beach, CA, 8-10 May 1997; SIAM Meeting, Albuquerque, NM, 16-18 June 1997; FNMOC Coupled Models, Monterey, CA, 9-10 July 1997; ACSYS Conference, Orcas Island, WA, 3-6 November 1997; Antarctic Meetings, Tucson, AZ, 1-4 December 1997.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

PROJECT SUMMARIES

KEYWORDS: Numerical Modeling, Ocean Prediction, Parallel Computing

SIMULATIONS AND RECONSTRUCTIONS OF GLOBAL OCEAN CIRCULATION WITH WELL-RESOLVED EDDIES FOR THE WOCE OBSERVATIONAL PERIOD 1991-97

**Albert J. Semtner, Professor
Department of Oceanography**

Sponsor: National Science Foundation and Naval Postgraduate School

OBJECTIVE: The goal is to further improve on the realism of numerical models of global three-dimensional ocean circulation with important currents and eddies resolved, to conduct simulations using the best available atmospheric forcing, and to assimilate satellite altimeter data in certain of the studies. This 5-year project runs until 1999.

SUMMARY: A model had been developed with $1/4 \times 2/5$ deg lat/lon grid and 20 vertical levels, with proper representation of coastlines and depths. Last year, a number of physical and numerical improvements were made, and ECMWF reanalyzed winds and heat and moisture fluxes were prepared as forcing. The model was used to simulate conditions of 1979-93, starting from earlier 1985-96 operationally forced calculations and applying the new fields of daily winds and fluxes. A massive amount of model output was compared with both in-situ and satellite observations and found to be in excellent agreement with what actually happened. The agreement of predicted surface height variability with that observed by NASA's superb TOPEX satellite altimeter was especially impressive. In addition, satellite data-assimilation efforts were completed which included the height data from both TOPEX and ERS satellites over the period 1992-95. Those results show improvements in the timing and amplitude of current fluctuations, as well as statistical improvements in the mean and variability—all calibrated against actual observations. Higher resolution models are being developed for use in further research.

DISSERTATION DIRECTED:

Tokmakian, R., "Assimilation of Satellite Altimeter Data into a Global Eddy-Resolving Model," Doctor of Philosophy Dissertation, Naval Postgraduate School, June 1997.

PUBLICATIONS:

Chervin, R.M., Craig, A.P., and Semtner, A.J., "Meridional Heat Transport Variability from a Global Eddy-Resolving Ocean Model," *Assessing Climate Change*, W. Howe and A. Henderson-Sellers, eds., Gordon and Breach Science Publishers, Roseville, Australia, 1997, in press.

Craig, A.P., Bullister, J.L., Harrison, D.E., Chervin, R.M., and Semtner, A.J., "A Comparison of Temperature, Salinity, and Chloro-Fluorocarbon Observations with Results from a One-Degree Three-Dimensional Global Ocean Model," *Journal of Geophysical Research*, 1997, in press.

Maltrud, M.E., Smith, R.D., Semtner, A.J., and Malone, R.C., "Global Eddy-Resolving Ocean Simulations Driven by 1985-94 Atmospheric Fields: Part I, Mean Circulation and Variability," *Journal of Geophysical Research*, 1997, provisionally accepted.

Maslowski, W., Parsons, A.R., Zhang, Y., and Semtner, A.J., "High-Resolution Arctic Ocean and Sea Ice Simulations: Part I, Ocean Model Design and Early Results," *Journal Geophysical Research*, 1997, submitted.

McClellan, J.L., Semtner, A.J., and Zlotnicki, V., "Comparisons of Mesoscale Variability in the Semtner-Chervin Quarter-Degree Model, the Los Alamos POP Sixth-Degree Model, and TOPEX/POSEIDON Data," *Journal of Geophysical Research*, 102, 25203-25226, 1997.

Ramp, S.R., McClellan, J.L., Collins, C.A., Semtner, A.J., and Hayes, K.A.S., "Observations and Modeling of the 1991-1992

PROJECT SUMMARIES

El Niño off Central California,” *Journal of Geophysical Research*, 102, 5553-5582, 1997.

Semtner, A.J., Introduction to “A Numerical Method for the Study of the Circulation of the World Ocean,” *Journal of Computational Physics*, 135,149-153 1997.

Semtner, A.J., “Very High-Resolution Estimates of Global Ocean Circulation, Suitable for Carbon-Cycle Modeling,” *Proceeding of the Snowmass Global Change Institute on the Global Carbon Cycle*, Office of Interdisciplinary Earth Studies, Boulder, CO, 1997, in press.

Semtner, A.J., “Global Ocean and Polar Regions: A Modeling Perspective,” *Proceedings of the Global Change Workshop on Polar Processes*, pp. 56-61, D. Martinson (ed.), American Meteorology Society, Boston, MA, 1997.

Semtner, A.J., “Modeling Ocean Climate Variability with Emphasis on Polar Processes,” *Proceedings of the Rosano Symposium on Polar Processes and Global Climate* pp. 246-248, World Climate Research Program Office, Oslo, Norway, 1997.

Zhang, Y., Maslowski, W., and Semtner, A.J., “High-Resolution Arctic Ocean and Sea Ice Simulations: Part II, Ice Model Design and Early Results,” *Journal of Geophysical Research*, 1997, accepted.

PRESENTATIONS:

“Recent Research Results on Ocean Simulation, Comparison with Observation, and Improvements in Predictions Methods,” was presented in various forms in the following venues: Santa Barbara, CA, 20 February 1997; DoE-CHAMMP, San Antonio, TX, 3-6 March 1997; U.S.-JAPAN Workshop, Honolulu, HI, 10-13 March 1997; NSF Ocean Meeting, Boulder, CO, 7-8 April 1997; ACSYS Conference, Monterey, CA, 9-10 April 1997; ARCSS OAI, Virginia Beach, CA, 8-10 May 1997; SIAM Meeting, Albuquerque, NM, 16-18 June 1997; FNMOC Coupled Models, Monterey, CA, 9-10 July 1997; ACSYS Conference, Orcas Island, WA, 3-6 November 1997; Antarctic Meetings, Tucson, AZ, 1-4 December 1997.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Numerical Modeling, Ocean Prediction

UNDERSTANDING SEASONAL TO DECADEAL CLIMATE CHANGES THROUGH THE COMBINED USE OF IMPROVED MODELS AND SATELLITE DATA

Albert J. Semtner, Professor

Robin Tokmakian, Research Assistant Professor

Julie McClean, Research Assistant Professor

Department of Oceanography

**Sponsors: National Aeronautics and Space Administration and
Cal Tech Jet Propulsion Laboratory**

OBJECTIVE: The goal is to use improved models and satellite data to understand climate changes on seasonal, interannual, decadal, and interdecadal time scales. The models to be used are capable of reproducing the mean ocean currents with correct magnitude and length scales, as well as the forced and spontaneous variability on many time scales.

SUMMARY: High-resolution global ocean models and satellite data are being used to define a set of indices that can be used to identify seasonal, interannual, and decadal changes in the climate of the World Ocean. Global models from 1/4-degree out to 1/10-degree grid size forced with reanalyzed wind stress and heat/freshwater fluxes and also having satellite derived bathymetry can be run with and without interannual changes in the buoyancy forcing. The model output is being compared to the TOPEX height fields and other satellite data to investigate variations in the thermohaline and wind-driven ocean circulation as related to global climate. Realizing that the satellite data is not available over multiple decades, the

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models provide an environment in which to place either the shorter time series of undersampled height, temperature, and ice data. The models will provide complete fields with which to determine whether or not indices related to surface variables are reasonable estimators of important climatic variations. This was the first year of the project.

PUBLICATIONS:

Maltrud, M.E., Smith, R.D., Semtner, A.J., and Malone, R.C., "Global Eddy-Resolving Ocean Simulations Driven by 1985-94 Atmospheric Fields: Part I, Mean Circulation and Variability," *Journal of Geophysical Research*, 1997, provisionally accepted.

McClellan, J.L., Semtner, A.J., and Zlotnicki, V., "Comparisons of Mesoscale Variability in the Semtner-Chervin Quarter-Degree Model, the Los Alamos POP Sixth-Degree Model, and TOPEX/POSEIDON Data," *Journal of Geophysical Research*, 102, 25203-25226, 1997.

Semtner, A.J., "Modeling Ocean Climate Variability with Emphasis on Polar Processes," *Proceedings of the Rosano Symposium on Polar Processes and Global Climate*, pp. 246-248, World Climate Research Program Office, Oslo, Norway, 1997.

Tokmakian, R.J., McClellan, J.L., and Semtner, A.J., "Understanding Seasonal to Decadal Climate Changes Using Models and Satellite Data," *AVISO Newsletter*, Toulouse, France, 1997, in press.

Zhang, Y., Maslowski, W., and Semtner, A.J., "High-Resolution Arctic Ocean and Sea Ice Simulations: Part II, Ice Model Design and Early Results," *Journal of Geophysical Research*, 1997, provisionally accepted.

CONFERENCES PRESENTATIONS:

"Recent Research Results on Ocean Simulation, Comparison with Observation, and Improvements in Predictions Methods," was presented in various forms in the following venues: Santa Barbara, CA, 20 February 1997; DoE-CHAMMP, San Antonio, TX, 3-6 March 1997; U.S.-JAPAN Workshop, Honolulu, HI, 10-13 March 1997; NSF Ocean Meeting, Boulder, CO, 7-8 April 1997; ACSYS Conference, Monterey, CA, 9-10 April 1997; ARCSS OAI, Virginia Beach, CA, 8-10 May 1997; SIAM Meeting, Albuquerque, NM, 16-18 June 1997; FNMOC Coupled Models, Monterey, CA, 9-10 July 1997; ACSYS Conference, Orcas Island, WA, 3-6 November 1997; Antarctic Meetings, Tucson, AZ, 1-4 December 1997.

DISSERTATION DIRECTED:

Tokmakian, R., "Assimilation of Satellite Altimeter Data into a Global Eddy-Resolving Model," Doctor of Philosophy, Naval Postgraduate School, June 1997.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Numerical Modeling

MIXED LAYER TURBULENCE MEASUREMENTS DURING THE ANZONE WINTER FLUX EXPERIMENT: ANZFLUX

Timothy P. Stanton, Research Associate Professor

Department of Oceanography

Sponsor: National Science Foundation

OBJECTIVE: The objectives of this research are to identify and model physical mechanisms responsible for maintaining anomalously thin winter ice cover over the central Weddell Sea. As large scale, winter-long polynias intermittently form in this area, the potential exists for massive ocean/atmosphere heat fluxes which can significantly effect the global heat budget

PROJECT SUMMARIES

and bottom water formation.

SUMMARY: During participation in the ANZFLUX experiment, deployed from the icebreaker *N.B. Palmer* during July and August 1994, two, one-week ice camps were established approximately 500 m from the ship on O(30 cm) ice to make direct heat, salt, and momentum flux measurements in the ocean mixed layer. Analysis is proceeding on the continuous profiling microstructure probe, a turbulence-resolving Broad Band Acoustic Doppler Current profiler, and three near-surface in situ temperature, salinity and 3 component velocity instrument clusters. These data show that strong turbulent coupling between the deep pycnocline and the surface ice occurs during the very high wind stress events which dominated the weather at the measurement site. High mixed layer heat fluxes during these events are further enhanced by dramatic shallowing of the pycnocline due to the presence of eddy features in the Central Weddell Sea. The continuous mixed layer and upper pycnocline profile measurements resolved the evolving mixed layer thermohaline structure, turbulent dissipation rates and very small vertical gradients of temperature and salinity, allowing heat fluxes and pycnocline diffusivity timeseries to be estimated.

An analysis of the pycnocline fluxes estimated from the field observations has been completed in collaboration with investigators at OSU, and submitted to JGR. A paper describing the turbulent structure of the sub-ice mixed layer and unique comparisons of dissipation measurement techniques will be submitted to JGR. These unique comparisons of acoustic doppler measurements of boundary layer turbulence using conventional geometry acoustic doppler profilers demonstrate a new application of acoustic doppler current profilers. A collaborative paper with Miles McPhee on a simple mixed layer flux parameterization is in progress, as is a collaborative paper estimating deep pycnocline fluxes due to double diffusion and cabling.

PUBLICATIONS:

Stanton, T.P., Padman, L., and Robertson, R.A., "Heat Fluxes Through the Permanent Pycnocline in the Eastern Weddell Sea," to *Journal of Geophysical Research*, 1997, submitted.

Stanton, T.P., "Observations of Shear Production and Dissipation Rates in the Upper Mixed Layer in the Weddell Sea," *Journal of Geophysical Research*, 1997, submitted.

CONFERENCE PRESENTATIONS:

McPhee, M.G. and Stanton, T.P., "Relating Flux and Dissipation Measurements in the Ocean Boundary Layer," American Geophysical Union Fall Meeting, 1997.

Padman, L, Stanton, T.P., and Muench, R.D., "Double-Diffusive Convection and Cabling in the Weddell Sea," American Geophysical Union Fall Meeting, 1997.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Ocean Mixed Layer, Antarctic Ocean Fluxes, Mixed Layer Dynamics

UPPER OCEAN EFFECTS ON THE SURFACE HEAT BUDGET OF THE ARCTIC

Timothy P. Stanton, Research Associate Professor

Department of Oceanography

Sponsors: National Science Foundation

OBJECTIVE: The objectives of this research are to measure the mixed layer and upper ocean heat fluxes over a one year period in the central Arctic Ocean. This work is a component of the multidisciplinary SHEBA program which has the objectives of improving parameterizations of the coupled atmosphere-ice-ocean system in the Arctic to improve the predictive capabilities of Global Climate Models. Two shorter process studies will focus on the role of ice keels in the surface heat

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balance, and the heat storage associated with summer leads.

SUMMARY: In October 1997, the SHEBA ice camp was established in the Central Beaufort Sea and an automated CTD and microstructure profiler was deployed to measure turbulent fluxes and the temperature/salinity structure of the upper ocean for a one year period as the ice camp drifted in response to surface wind forcing. The microstructure package was designed and built at NPS, and tested in September in Puget Sound.

Data from the daily profile timeseries are downloaded via a satellite link allowing checks of the extremely delicate micro-temperature sensors to be monitored, and the progress of the experiment to be analyzed. These daily data are assimilated into the database and visualization software allowing student thesis work on the analyses to proceed. More complete processing of the full timeseries has been implemented to accept the DAT tapes as they arrive from the ice station with each cruise rotation. Analysis of the upper ocean salinity structure has revealed evidence of very significant ice melting in the last few seasons, and this work has been submitted to GRL.

A unique, self contained portable ocean heat, salt, and momentum flux instrument has been completed and readied for deployment in an ice keel study in March 1998. This small battery operated instrument measures three component velocities, tilts, heading, temperature, salinity, and pressure allowing mixed layer fluxes to be determined in the ocean mixed layer over periods of up to two months. The flux probe will be used in both process studies mentioned in the objectives.

PUBLICATIONS:

McPhee, M.G., Stanton, T.P., Morison, J.H., and Martinson, D.G., "Freshening of the Upper Ocean in the Central Arctic: Is Perennial Sea Ice Disappearing?" Submitted to GRL, 1997.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Ocean Mixed Layer, Polar Oceans, Mixed Layer Dynamics

SPECTRAL WAVE DECAY DUE TO BOTTOM FRICTION ON THE INNER SHELF

Timothy P. Stanton, Research Associate Professor

Edward B. Thornton, Professor

Sponsor: Office of Naval Research

OBJECTIVES: The objectives of this research are to directly measure wave dissipation as surface gravity waves propagate across continental shelves. Observations of dissipation in the thin oscillatory bottom boundary layer, bottom morphology, and low frequency currents will be used to develop a spectral wave model of dissipation for use in shelf wave models.

SUMMARY: During the startup year of this 5-year DRI, a prototype acoustic doppler profiler (the BCDV) has been completed to measure the velocity structure, Reynolds stresses and shear in the thin wave-forced bottom boundary with cm resolution over an 80 cm range. This instrument was tested in Monterey Bay in May and November 1996, and deployed as a central component of the instrumented sled used at the SandyDuck nearshore experiment in September and October 1997. As the small scale morphology of sandy sediments profoundly affect bottom drag, an automated dual axis, coherent altimeter has been developed to repeatedly map the ripple field over a 2x4 m area centered on the BCDV profile measurement.

During the SandyDuck experiment, the instrumented sled was moved well offshore of the bar each day, presenting a wide range of wave forcing conditions representative of inner shelf conditions. This data set has allowed a preliminary analysis of inner shelf bottom friction and the effects of a mobile sediment bed to be started.

CONFERENCE PRESENTATION:

Stanton, T.P. and Thornton, E.B., "Spectral Wave Decay Due to Bottom Friction on the Inner Shelf," WISE Meeting, San Francisco, CA, April 1997.

PROJECT SUMMARIES

OTHER:

Turbulence-Resolving Coherent Acoustic Sediment Flux Probe, U.S. Navy Case Number 77525.

Stanton, T.P., "Observations of a Wave Forced Boundary Layer Over a Mobile Bed in the Surf Zone Using a Bistatic, Coherent Acoustic Doppler Profiler," Stanford University, Stanford, CA, June 1997.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Wave Dissipation, Shoaling Waves, Bottom Boundary Layers

INTERNAL WAVE AND TURBULENCE MEASUREMENTS DURING THE COASTAL OCEAN PROCESSES EXPERIMENT: COPE

Timothy P. Stanton, Associate Research Professor

Department of Oceanography

Sponsors: National Oceanic and Atmospheric Administration and Office of Naval Research

OBJECTIVE: The objectives of this research were to define the surface strain and internal mixing effects of high displacement, near-surface internal soliton packets over the continental shelf.

SUMMARY: In October 1995, our ocean turbulence group participated in the NOAA ETL sponsored Coastal Ocean Processes Experiment (COPE) by deploying three instrument systems from R/P FLIP for a three week period, 20 km off shore of Northern Oregon. A continuous profiling loose-tethered microstructure profiler measured high resolution temperature, salinity, and dissipation profiles with a 80 second cycle from the surface to a depth of 35 m. A rigid instrument frame suspended from one of FLIP's booms was equipped with five in situ temperature, salinity and 3 component velocity instrument clusters which spanned 3 to 8 m depth, while a high speed broadband ADCP extended the velocity and stress measurements to 50 m depth.

The measurement site had a 60 cph pycnocline at only 5 – 10 m depth, supporting the existence of extremely nonlinear soliton packets which were consistently observed on the leading edge of each semidiurnal internal tide displacement. The soliton packets had downward isopycnal displacements of up to 25 m from a 6 m start depth, significantly more non-linear than previous observations. A conference presentation was made at the February 98 Ocean Sciences meeting in San Diego and a manuscript describing a 3rd order KdV model of the soliton displacements has been prepared in collaboration with Lev Ostrovsky at the NOAA ETL, and has been submitted to GRL. The principal investigator also contributed to a joint paper with Bob Kropfli at NOAA/ETL describing the surface modulation of these solitons on X and K band radar frequencies. A comprehensive analysis of the upper ocean mixing and displacements due to the strong internal tide and solitons is being completed for submission to Journal of Geophysical Research.

PUBLICATIONS:

Kropfli, R.A, Ostrovsky, L.A., Stanton, T.P. Skirta, E., and Keane, A.N., "Relationships between Strong Internal Waves in the Coastal Zone and Their Radar Signatures," accepted by *Journal of Geophysical Research* 1997.

Stanton, T.P. and Ostrovsky, L.A., "Observations of Highly Nonlinear Internal Solitons of the Continental Shelf," 1997, submitted to GRL.

CONFERENCE PRESENTATIONS:

Krofli, R.A., Ostrovsky, L.A., and Stanton, T.P., "Relationships Between Microwave Backscatter and Strong Internal Wave Structure in the Coastal Zone," Ocean Sciences Meeting, San Diego, CA, February 1998.

Ostrovsky, L.A, Stanton, T.P., Kropfli, R.A, Skirta, E.A., and Keane, A.N., "Observations and Modeling of Strongly Non-

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linear Internal Waves in Coastal Oceans,” IAPSO, Melbourne, Australia, August 1997.

Stanton, T.P., Ostrovsky, L.A., and Kropfli, R. A., “The Stability and Contribution to Upper Ocean Mixing of Strongly Nonlinear SIW Observed Over the Continental Shelf,” Ocean Sciences Meeting, San Diego, CA, February 1998.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Ocean Mixed Layer, Internal Waves, Mixed Layer Dynamics.

NEARSHORE WAVE AND SEDIMENT PROCESSES

Edward B. Thornton, Professor

Timothy P. Stanton, Research Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: To predict the wave-induced three-dimensional velocity field and induced sediment transport over arbitrary bathymetry in the nearshore given the offshore wave conditions.

SUMMARY: The vertical distributions throughout the water column of 3-component mean, wave-induced and turbulent velocities, bubbles, and sediment concentrations were measured during the SandyDuck near shore experiment using an instrumented sled to study. The 3-component velocity field was measured every 5 cm over the bottom 1 m with a downward looking 1.2 MHz bistatic coherent acoustic Doppler velocimeter (1.6 cm resolution at 48 Hz) and in the upper water column with a 300 KHz upward looking coherent bistatic acoustic Doppler velocimeter every 8 cm (8 cm resolution at 48 Hz). In addition, the vertical distribution of the horizontal velocities were measured with an array of 8 electromagnetic current meters. A 2 m cross-shore array of optical backscatter instruments measured the coherence length scale and advection. The small-scale morphology, which acts as hydraulic roughness for the mean flows and perturbs the velocity-sediment fields, was measured from the sled with newly developed, in-house, x-y scanning altimeter, and with an array of 7 sonic altimeters mounted on the back of the CRAB. The primary mechanism for changes in moment flux which drives the near shore dynamics is due to the dissipation of breaking waves, the processes of which are only poorly understood. To improve understanding of breaking waves, the dissipation associated with bubble injection and depth of bubble penetration were measured with the two acoustic systems (1.2 MHz looking down and 300KHz looking up) and with a 3 m vertical array of 8 conductivity cells. An important component of the cross-shore sediment flux is due to the cross-shore mean flow (undertow), which is forced by wave set-up/down; the set-up was measured with an array of 14 manometer and 8 pressure sensors. Undertow is an integral measure of the turbulent Reynold’s stresses and wave radiation stresses and acts as a check for the detailed velocity measurements. The data are being compared with models developed under this program and in collaboration with other groups.

PUBLICATIONS:

Faria, A.F., Thornton, E.B., and Stanton, T.P., “Small-Scale Morphology Related to Waves and Current Parameters Across the Surf Zone,” *Proceedings of the 25th International Conference on Coastal Engineering*, ASCE, pp. 3391-3404, 1997.

Faria, A.G., Thornton, E.B., Soares, C., and Stanton, T.P., “Bed Shear Stress Coefficients Related to Bed Roughness Across the Surf Zone,” *Journal of Geophysical Research*, 103 (C2), pp. 3217-3232, 1998.

Lippmann, T. and Thornton, E.B., “The Spatial Distribution of Wave Rollers and Turbulent Kinetic Energy on a Barred Beach,” *Journal of Geophysical Research*, 1997, accepted.

Lippmann, T.C., Jorgensen, C.F., and Thornton, E.B., “Wave Slopes and Breaking Distributions in the Surf Zone,” *Journal of Geophysical Research* 1997, submitted.

PROJECT SUMMARIES

Stanton, T.P. and Thornton, E.B., "Reynolds Stress and Small-Scale Morphology Measurements During Duck94," *Proceedings of the 25th International Conference on Coastal Engineering*, ASCE, pp. 4079-4087, 1997.

Thornton, E.B., Swayne, J.L., and Dingler, J., "Small-Scale Morphology Related to Waves and Currents Across the Surf Zone," *Marine Geology* 145 (3-4), pp. 173-196, 1998.

CONFERENCE PRESENTATIONS:

Gallagher, E.L., Thornton, E.B., and Stanton, T.P., "Preliminary Observations of Bedforms during SandyDuck," Fall Meeting of the American Geophysical Union, San Francisco, CA, 1997.

Gallagher, E., Elgar, S., Guza, R., and Thornton, E., "Observations of Migrating Megaripples," Coastal Dynamics, Plymouth, England, 1997.

Garcez Faria, A., Thornton, E., Stanton, T., Herbers, T., Lippmann, T., Guza, R., and Elgar, S., "Cross-Shore and Longshore Currents over a Barred Beach: Observations and Modeling," Coastal Dynamics, Plymouth, England, 1997.

Lippmann, T.C., Herbers, T.H.C., and Thornton, E.B., "Cross-Shore Variability of Infragravity Waves in the Surf Zone," Fall Meeting of the American Geophysical Union, San Francisco, CA, 1997.

Lippmann, T., Herbers, T., and Thornton, E., "The Cross-Shore Variation of Infragravity Wave Pressure and Velocities in Shallow Water," Coastal Dynamics, Plymouth, England, 1997.

Thornton, E.B., "Field Experiments, NSTS to SandyDuck," University of Quebec, 1997.

Thornton, E.B., "SandyDuck Perspective," Fall Meeting of the American Geophysical Union, San Francisco, CA, 1997.

Thornton, E.B., Stanton, T., Tanihill, J., and Lippmann, T., "Anatomy of Breaking Waves Measured in the Field," Coastal Dynamics, Plymouth, England, 1997.

THESES DIRECTED:

Faria, A.F.G., "Nearshore Currents over a Barred Beach," Doctor of Philosophy Dissertation, Naval Postgraduate School, June 1997.

Morris, B., "Wave Set-up Measured in the Field," Master's Thesis, Naval Postgraduate School, March 1997.

Do KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Near Shore, Waves, Surf

WAVE SURFACE AND BOTTOM BOUNDARY LAYERS IN THE NEARSHORE

Edward B. Thornton, Professor
Timothy P. Stanton, Research Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The objectives of this research are to examine the dynamics of the water column in over the continental shelf and nearshore, regions where forcing is dominated by surface gravity waves and wind. Unique acoustic Doppler instruments will be used to look at a boundary layer turbulent properties.

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SUMMARY: Experiments were conducted in Monterey Bay in May and November 1996 with the objective of testing instrumentation to be deployed during SandyDuck and to acquire new data on a near planar beach with near normally incident, long period swell waves. New instrumentation included a manometer/pressure array to measure wave transformation and set-up, a vertical array of 8 conductivity cells to measure void fraction (to infer bubble concentration), and a Bistatic Coherent Doppler Velocimeter (BCDV) to measure the bottom boundary layer. Additional measurements include a vertical arrays of 9 em current meters, and 5 optical backscatter sensors, plus Dave Farmer using an acoustic resonator to measure bubble size. Analysis of the data is progressing.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Waves, Bottom Boundary Layer, Morphology

NEARSHORE CIRCULATION ON VARIABLE BATHYMETRY

Edward B. Thornton, Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: Develop models to predict the evolution of waves and currents in the nearshore due to waves, wind and tidal influences, and the changes in the bathymetry.

SUMMARY: Data previously acquired during the NSTS and Duck field experiments are being processed and made available for this study. The NSTS data were acquired on near-planar beaches at Torrey Pines (1978) and Santa Barbara (1980) CA, while the Duck, NC, data were acquired on a barred beach in a series of experiments Duck85, SUPERDUCK (1986), DELILAH (1990) and DUCK94. The data are of a dense cross-shore array of wave and velocity sensors, alongshore array(s) of velocity sensors, direction wave array(s) offshore, and well-measure bathymetry. Data focuses on when the bathymetry was 3-D.

PUBLICATION:

Reniers, A.J.H.M., Thornton, E.B., and Lippmann, T.C., "Effects of Alongshore Non-Uniformities on Longshore Currents Measured in the Field," *Journal of Geophysical Research*, 1997 submitted.

CONFERENCE PRESENTATION:

Sancho, F.E., Svendsen, I.A., Dongeren, A.R., and Thornton, E.B., "Numerical Modeling of Longshore Currents: Comparison with Field Data," 25th International Conference on Coastal Engineering, 1997.

DoD KEY TECHNOLOGY AREA: Other (Environmental Effects)

KEYWORDS: Waves, Near-Shore, Edge-Waves