



2000

Summary of Research 2000, Department of Oceanography

Faculty of the Department of Oceanography, Naval Postgraduate School

Office of the Associate Provost and Dean of Research, Naval Postgraduate School.

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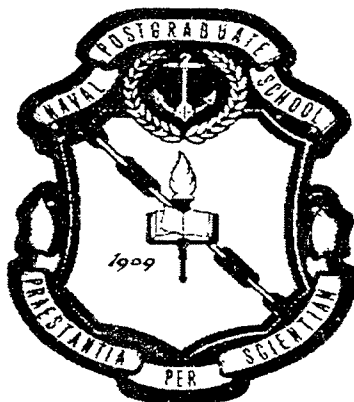
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Naval Postgraduate School
Monterey, California 93943-5138

NPS-09-02-007



***SUMMARY
OF
RESEARCH
2000***



Department of Oceanography

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Chair**

**Edward B. Thornton
Associate Chair for Research**

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Prepared for: Naval Postgraduate School
Monterey, CA 93943-5000

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Monterey, California

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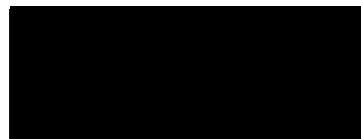
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This report contains project summaries of the research projects in the Department of Oceanography. A list of recent publications is also included, which consists of conference presentations and publications, books, contributions to books, published journal papers, and technical reports. Thesis abstracts of students advised by faculty in the Department are also included.

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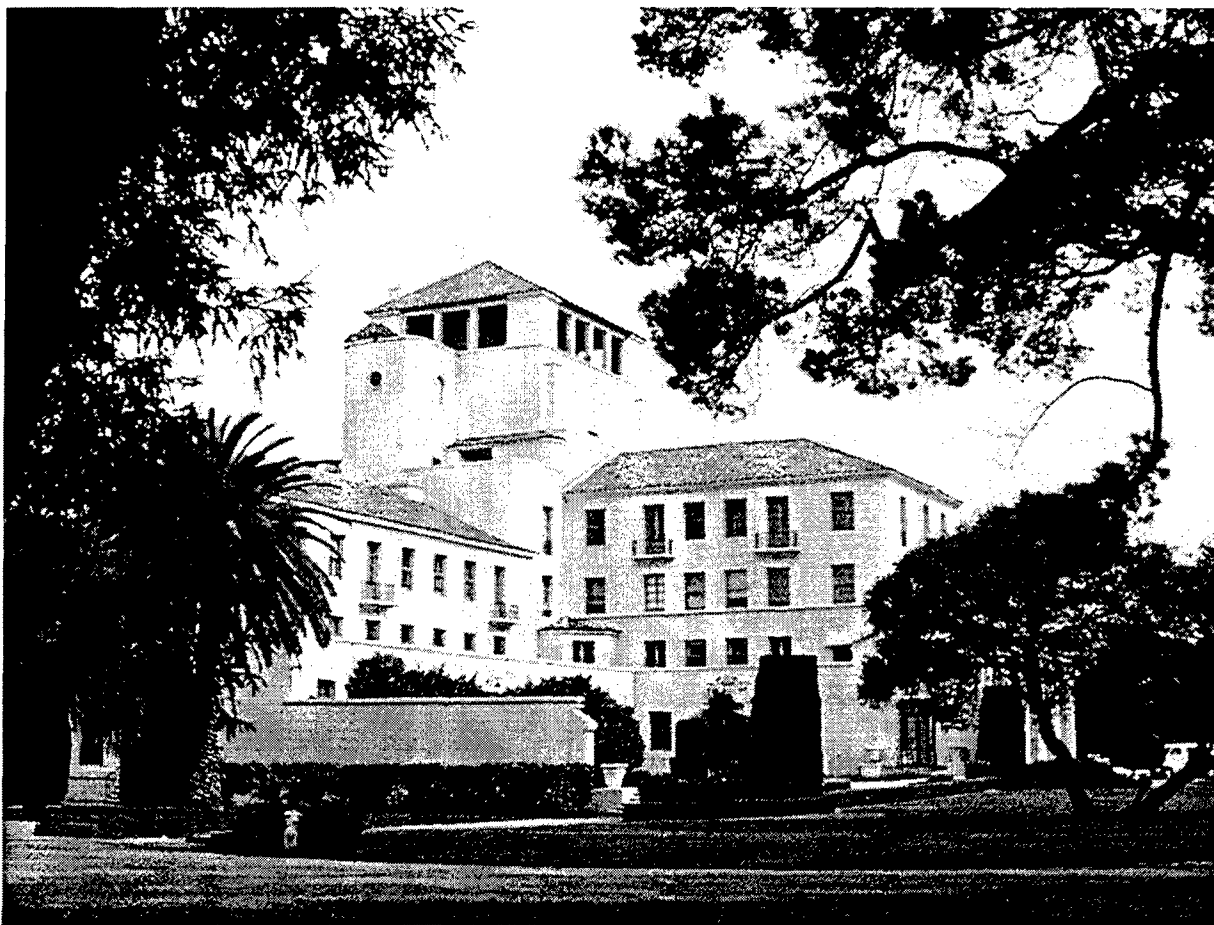


TABLE OF CONTENTS

Preface	xiii
Introduction	xv
Department Summary	3
Faculty Listing	5
Project Summaries	7
Coupled Ocean Acoustics and Physical Oceanography Observations in ASIAEX:	
The NPS Acoustic Component	7
Naval Postgraduate School OAO Test-Ban Treaty Monitoring	8
Ocean Acoustic Federation:	
California Current Monitoring using the NPS Ocean Acoustic Observatory	8
Environmental Effects on Naval Warfare Simulations	9
Mine Impact Burial Model Sensitivity Study	10
Determination of Coastal Ocean Sampling Rate and Its Impact on Mine Warfare Effectiveness	11
GPS Antarctic Navigation Applications	12
GPS Ship Reference System	12
Across-Margin Transport during the 1998 El Niño	13
Physical Oceanographic Conditions Off Central California in 1998	13
1999 Central California Hydrographic Surveys	13
Empirical Models of Tidal and Residual Ocean Currents in the Yellow and East China Seas	13
Sub-Mesoscale Coherent Vortices and California Undercurrent Dynamics	14
Long-Term Monitoring of Circulation and Sediment-Transport Patterns Near the San Francisco Deep-Ocean Disposal Site	14
Polar Sea Convective Instabilities	14
Simulation of Lagrangian Drifters in the Labrador Sea	15
Non-Hydrostatic Modeling of West Florida Shelf Flow and Tracers	16
Development of an Arctic Low Frequency Ambient Noise Model	17
Western Boundary Current Systems Virtual Poster Session	17
Improved Parameterizations of Triad and Quartet Interactions in Spectral Wind-Wave Models	18
Nearshore Canyon Experiment (NCEX)	19
Surface Gravity Waves on the Continental Shelf and Beach	19
Wave Evolution on the Continental Shelf	20
Spatial Coherence of Waves in Deep Water	21
Arctic Shelf and Ocean Paleo-Circulation Modeling Workshop at the Naval Postgraduate School	21
Coupled Bio-Physical Modeling of the Arctic Marine Response to Global Change	22
High-Performance Modeling of the Fully Global Ocean System and Its Variability	22
Modeling the Long-Term Turbulent Circulation of the Arctic Ocean and Its Sea Ice	22
Development of a New Arctic Ice-Ocean Prediction System	23
Comparisons of the LANL POP Model and WOCE Observation	23
Evaluations of the POP Model for Navy Forecasting Use	24
Swell Model Upgrade	24
Data Enhanced Modeling of Sea and Swell on the Continental Shelf	24
Comparison of Multi-System HF Radar Data from COPE-3	25
Diurnal to Seasonal Variability of Surface Ocean Currents from High Frequency Radar	25
The Innovative Coastal-Ocean Observing Network (ICON)	26
Evaluation of Ocean Surface Current Data from the Navy HF Surface Wave Radar	27
Globec Mapping the Evolution of Mesoscale Jets and Eddies in the Upwelling Ecosystem off Cape Blanco, Oregon	27
Modeling the Central California Coastal Upwelling System:	
Physics, Ecosystems and Resource	27
Modeling and Observations of Surface Waves in Monterey Bay	28
Lagrangian Data Analysis in Mesoscale Prediction Studies	28

TABLE OF CONTENTS

Lagrangian Measurements in Icelandic Waters.....	28
Mediterranean Surface Circulation Studies.....	29
Adriatic Sea Circulation: Tidal and Wind-Driven Currents in Croatian Coastal Waters.....	29
Globec: Moored Current Observations Along the Eureka LTOP Transect.....	29
ASIAEX Project Management.....	30
Internal Waves and Turbulence in Monterey Submarine Canyon.....	30
In-Situ Evaluation of Oceanographic Products for the METOC Community.....	31
Simulations and Reconstructions of Global Ocean Circulation with Well-Resolved Eddies for the WOCE Observing.....	31
Application of Parallel Ocean and Climate Models to Decade/Century Prediction.....	31
Development of a New Arctic Ice-Ocean Prediction System.....	32
Upper Ocean Effects on the Surface Heat Budget of the Arctic.....	32
Collaborative Research: The Role of Ice-Ocean Exchange in Ice-Albedo Feedback.....	32
Spectral Wave Decay due to Bottom Friction on the Inner Shelf.....	33
Development and Verification of a Comprehensive Community Model for Physical Processes in the Nearshore Ocean.....	33
Surf Model.....	34
Nearshore Wave and Sediment Processes.....	34
Megaripples in the Surf Zone.....	35
Modeling Dissipation within the Wave Bottom Boundary Layer.....	35
Interannual to Decadal Ocean Variability and Predictability.....	35
Antarctic Bottom Water, Polynyas, and the Antarctic Circumpolar Wave in High-Resolution Coupled GCMS.....	36
Publications and Presentations.....	37
Thesis Abstracts.....	49
Improving Maritime Situational Awareness through the Correlation of ELINT-Derived Ship Tracks and Sonar Time-Bearing Plots (U).....	51
Evolution of Bedforms on the Inner-Shelf.....	51
U.S. and Australian Mine Warfare Sonar Performance Assessment Using SWAT and Hodgson Models.....	52
High Frequency Sonar Components of Normal and Hearing Impaired Dolphins.....	52
Shallow Water Bathymetry at Lake Tahoe from AVIRIS Data.....	53
Inferring Bottom Acoustic Properties from AN/SQQ-32 Sonar Reverberation Data.....	53
Sand Bed Roughness in the Nearshore, Coast 3D Experiment, EGMOND AAN ZEE, The Netherlands.....	54
Internal Tidal Bores in the Monterey Canyon.....	54
Large Eddy Simulation of Interactions between Free Convection, Wind Driven Currents, and Baroclinicity in the Labrador Sea Deep Mixed Layers.....	55
Heat Fluxes Associated with Intrusions during the SHEBA Ice Station Drift.....	55
Drifter Observations of the Mediterranean Sea Surface Circulation.....	56
The Role of the Planetary Beta Effect on Currents and Meddies in the Northern Canary Current System.....	56
A Comparison of Output from the Los Alamos National Laboratory (LANL) Parallel Ocean Program (POP) Model with Surface Velocity Data from Drifting Buoys in the North Atlantic Ocean.....	57
Void Fraction Under Breaking Waves.....	57
Mine Burial in the Surf Zone.....	58
Effects of Thermohaline Gradients and the Columbia River Plume on the California Current System.....	58
Ambient Noise Characteristics during the SHEBA Experiment.....	59
Validation of the Mine Impact Burial Model Using Experimental Data.....	59
The Role of the Planetary Beta Effect on Currents and Eddies in the Leeuwin Current System.....	60

TABLE OF CONTENTS

Swell Transformation Across the Continental Shelf	60
Megaripple Migration in the Nearshore	61
Initial Distribution List	63

PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the four graduate schools (School of International Graduate Studies, Graduate School of Operations and Information Sciences, Graduate School of Engineering and Applied Sciences, and Graduate School of Business and Public Policy) and three Research Institutes (The Modeling, Virtual Environments, and Simulation (MOVES) Institute, Institute for Information Superiority and Innovation (I2SI), and Institute for Defense System Engineering and Analysis (IDSEA). This volume contains research summaries for the projects undertaken by faculty in the Department of Oceanography during 2000. The summary also contains thesis abstracts for those students advised by Oceanography faculty during 2000.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department Chair, or the Department Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the Naval Postgraduate School Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2099 (voice) or research@nps.navy.mil (e-mail). Additional information is also available at the RESEARCH AT NPS website, <http://web.nps.navy.mil/~code09/>

Additional published information on the Naval Postgraduate School Research Program can be found in:

- *Compilation of Theses Abstracts:* A quarterly publication containing the abstracts of all unclassified theses by Naval Postgraduate School students.
- *Naval Postgraduate School Research:* A tri-annual (February, June, October) newsletter highlighting Naval Postgraduate School faculty and student research.
- *Summary of Research:* An annual publication containing research summaries for projects undertaken by the faculty of the Naval Postgraduate School.

This publication and those mentioned above can be found on-line at:
<http://web.nps.navy.mil/~code09/publications.html>.

INTRODUCTION

The research program at the Naval Postgraduate School exists to support the graduate education of our students. It does so by providing military relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, to maintain the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focused graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at the Naval Postgraduate School consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- **Reimbursable (Sponsored) Program:** This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with government laboratories and universities, provides off-campus courses either on-site at the recipient command, by VTC, or web-based, and provides short courses for technology updates.
- **Naval Postgraduate School Institutionally Funded Research (NIFR) Program:** The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursably sponsored, and (4) to cost-share the support of a strong post-doctoral program.

In 2000, the level of research effort overall at the Naval Postgraduate School was 137 faculty work years and exceeded \$43 million. The reimbursable program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY2000, over 93% of the research program was externally supported. A profile of the sponsorship of the Naval Postgraduate School Research Program in FY2000 is provided in Figure 1.

INTRODUCTION

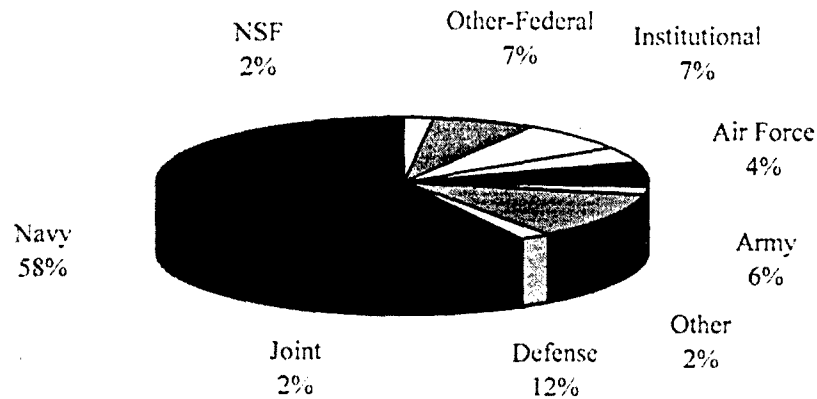


Figure 1. Profile of NPS Research and Sponsored Programs (\$43M)

The Office of Naval Research is the largest Navy external sponsor. The Naval Postgraduate School also supports the Systems Commands, Warfare Centers, Navy Labs and other Navy agencies. A profile of external Navy sponsorship for FY2000 is provided in Figure 2.

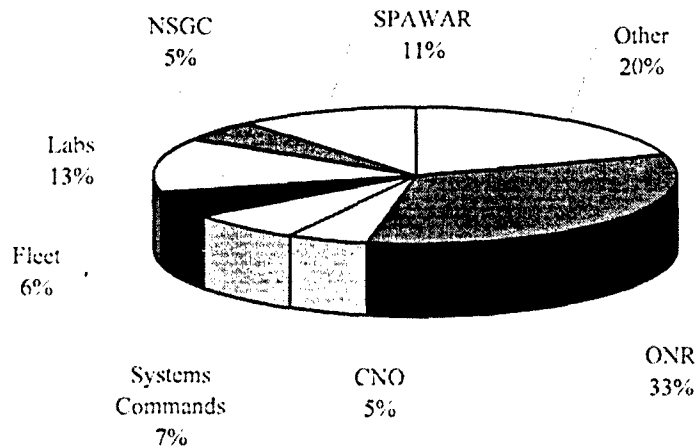


Figure 2. Navy External Sponsors of NPS Research and Sponsored Programs (\$25M)

These are both challenging and exciting times at the Naval Postgraduate School and the research program exists to help ensure that we remain unique in our ability to provide education for the warfighter.

DAVID W. NETZER
Associate Provost and Dean of Research

December 2001

**DEPARTMENT OF
OCEANOGRAPHY**

**ROLAND GARWOOD
CHAIR**

DEPARTMENT SUMMARY

OVERVIEW:

The Department of Oceanography has developed a broad research program focused on physical oceanography to meet the anticipated future needs of the Navy. Our basic research themes are the development of scientific capabilities to measure, analyze, and forecast fields of littoral ocean variables, which occur in association with synoptic/mesoscale processes over limited regional temporal domains. The areas of emphasis include coastal and near shore ocean dynamics, air-sea interaction phenomena and boundary currents. Regions of interest include the polar seas, coastal ocean regions and strategic straits of the world.

Our applied research themes are the application of analyses and forecasts of upper ocean synoptic/mesoscale variability to Naval operations. Areas of emphasis include the impact of littoral processes, eddies and boundary currents on ocean surveillance systems, the effect of coastal ocean response to storms on acoustic propagation and ambient noise and the impact that the wave climate exerts on near shore processes and beach character as it pertains to mine/mine countermeasure and amphibious warfare.

These research themes require the development of numerical ocean prediction and synoptic oceanography capabilities. They are achieved through employment of modern dynamical and mathematical principles, numerical and statistical methods, computational and graphical facilities, and in-situ remote sensing observations.

CURRICULA SERVED:

- Meteorology and Oceanography
- Operational Oceanography
- Oceanography
- Undersea Warfare
- Space Systems Operations and Engineering

DEGREES GRANTED:

- Master of Science in Meteorology and Physical Oceanography
- Master of Science in Physical Oceanography
- Doctor of Philosophy

RESEARCH THRUSTS:

- Acoustical Oceanography:
Professor Ching-Sang Chiu, Emeritus Professor Robert Bourke, Assistant Professor Arthur Parsons, Research Professor James Wislon
- Air-Sea Interaction and Ocean Turbulence:
Professor Roland Garwood, Research Associate Professor Tim Stanton, Professor Peter Chu, Professor Le Ly
- Coastal and Nearshore Oceanography:
Associate Professor Jeff Paduan, Distinguished Professor Ed Thornton, Associate Professor Thomas Herbers, Research Assistant Professor Edith Gallagher, Assistant Professor Pierre Poulain, Professor Curt Collins, Research Professor Steve Ramp, Research Associate Professor Leslie Rosenfeld
- Numerical Prediction and Data Assimilation:
Associate Professor Mary Batteen, Professor Bert Semtner, Research Associate Professor Julie McClean, Research Assistant Professor Robin Tokmakian, Research Assistant Professor Ramsey Harcourt, Research Associate Professor Wieslaw Maslowski, Assistant Professor Pierre Poulain, Senior Lecturer Arlene Guest, Research Associate Professor Le Ly
- GI&S and Navigation: Research Professor James Clynh, Assistant Professor Arthur Parsons

DEPARTMENT SUMMARY

- Polar Oceanography:
Research Associate Professor Wieslaw Maslowski, Research Assistant Professor Yuxia Zhang, Emeritus Professor Robert Bourke, Professor Roland Garwood, Research Assistant Professor Ramsey Harcourt

RESEARCH FACILITIES:

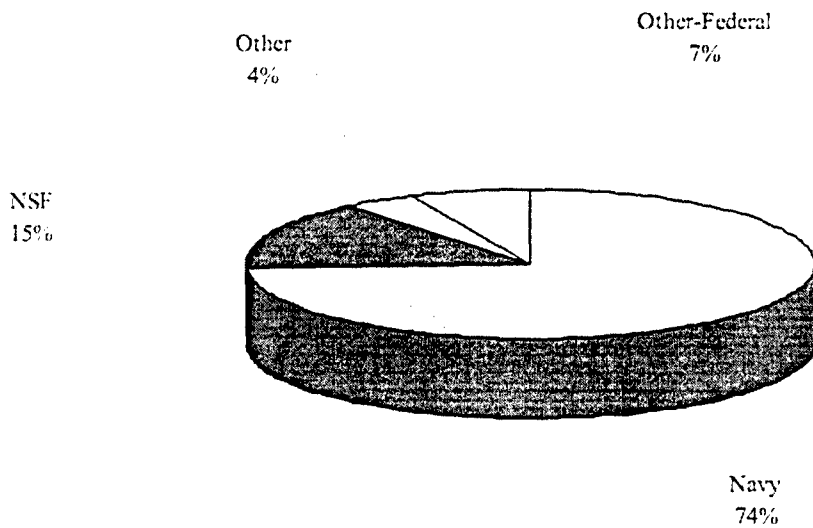
- Research Vessel *Point Sur*
- Ocean Acoustic Observatory at Point Sur
- Computer Graphics Laboratory
- Moored Equipment Laboratory
- Calibration Laboratory
- Tactical Environmental Support Laboratory

RESEARCH CHAIR:

- Office of Naval Research Chair in Arctic Marine Science

RESEARCH PROGRAM-FY2000:

The Naval Postgraduate School's research program exceeded \$43 million in FY2000. Over 93% of the Naval Postgraduate School Research Program is externally funded. A profile of the external research sponsors for the Department of Oceanography is provided below along with the size of the FY2000 externally funded program.



Size of Program: \$3977K

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PROJECT SUMMARIES

COUPLED OCEAN ACOUSTICS AND PHYSICAL OCEANOGRAPHY OBSERVATIONS IN ASIAEX: THE NPS ACOUSTIC COMPONENT

Ching-Sang Chiu, Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: This effort is part of a large, international program called the Asian Sea International Acoustic Experiment (ASIAEX). In close collaboration and coordination with other U.S. and Asia investigators participating in ASIAEX, we are carrying out comprehensive measurements and analysis of the different oceanographic factors affecting low frequency acoustic propagation in shelfbreak regions in the Northeastern South China Sea (SCS) and East China Sea (ECS). Specifically, the NPS acoustic research objectives are:

1. To understand the physics, variability and predictability of low-frequency sound pulse propagation along and across the NE SCS shelf-slope and the ECS Kuroshio front, including the dependence on frequency, source depth and path orientation, and the relations to water-column, bottom and sub-bottom structures.
2. To expand the acoustic knowledge acquired from previous shelf-slope experiments including shelfbreak PRIMER and SWARM, with added emphases on the horizontal properties of the sound field and the propagation physics, variability and coherence of higher-frequency transmissions.
3. To formulate and test a phase or time-based modal tomography inverse method for joint estimations of the water-column and sediment properties.

SUMMARY: The main experiment, to be carried out in 2001, was preceded by a pilot site survey in 2000. The purpose of the pilot site survey was to obtain adequate environmental information to support buoy/mooring engineering as well as acoustic modeling for optimizing the configuration for the main experiment. The pilot survey was successfully carried out in the spring of 2000. The pilot oceanographic and geoacoustic data were successfully used in modeling studies to optimize mooring and propagation geometry designs for the main experiment.

For the 2001 main experiment, the approach is to make simultaneous, high-resolution, very high-quality observations of both the acoustic propagation and physical oceanography in the experimental sites. Both moored and shipboard observations will be made, with sufficient spatial and temporal resolution to observe physical phenomena on horizontal scales of a few kilometers and time scales from subtidal to high frequency internal waves (with periods of a few minutes). Simultaneously, low frequency sound transmissions will be performed along and across the shelf using both moored and towed sources. The measurement and analysis will focus on the horizontal and vertical properties of the shallow-water sound field, their dependence on source depth and frequency, their relations to the water-column, bottom and sub-bottom structure, and the feasibility of a joint sediment-water-column inversion using tomographic techniques. Particularly, the acoustic measurements will be related to the oceanographic measurements through time-series analyses and modeling studies to gain insights into the detailed physics and variability of the acoustic propagation.

PUBLICATIONS:

SWARM Group (Headrick, R.H., J.F. Lynch, J.N. Kemp, A. Newhall, K. von der Heydt, J. Apel, M. Badiy, C. -S. Chiu, S. Finette, M. Orr, B. Pasewark, A. Turgot, S. Wolf, and D. Tielbuerger), "Acoustic normal mode fluctuation statistics in the 1995 SWARM internal wave scattering experiment," *Journal of the Acoustical Society of America*, 107 (1), 201-220, 2000.

SWARM Group (Headrick, R.H., J.F. Lynch, J.N. Kemp, A. Newhall, K. von der Heydt, J. Apel, M. Badiy, C. -S. Chiu, S. Finette, M. Orr, B. Pasewark, A. Turgot, S. Wolf, and D. Tielbuerger), "Modeling mode arrivals in the 1995 SWARM experiment acoustic transmissions," *Journal of the Acoustical Society of America*, 107 (1), 221-236, 2000.

Colosi J.A., Lynch, J.F., Beardsley, R.C., Gawarkiewicz, G., Chiu, C.S., and Scotti, A., "Observations of nonlinear internal waves on the New England continental shelf during summer shelfbreak," PRIMER, *Journal of Geophysical Research*, in press, 2000.

PROJECT SUMMARIES

Denner, W.W., Chiu, C.S., and Ramp, S.R., "Report on the Office of Naval Research Phase III International Workshop on Shallow-Water Acoustics, Alyeska Resort, Girdwood, AK, 12-15 July 1999," Naval Postgraduate School Technical Report, NPS-OC-00-001PR, 40 pp.

DoD KEY TECHNOLOGY AREAS: Sensors, Battlespace Environments

KEYWORDS: Littoral, Acoustics, Nowcast, Shelfbreak Fronts

NAVAL POSTGRADUATE SCHOOL OAO TEST-BAN TREATY MONITORING

Ching-Sang Chiu, Professor
Department of Oceanography
Christopher Miller, Research Assistant Professor
Undersea Warfare Academic Group
Sponsor: Center for Monitoring Research

OBJECTIVE: This proposal will provide the FY99 funding increment to continue the data collection effort at the Naval Postgraduate School Ocean Acoustic Observatory, Point Sur, on behalf of the Center for Monitoring Research and the Comprehensive Nuclear Test-Ban Treaty Organization.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Nuclear Test-Ban Treaty Monitoring

OCEAN ACOUSTIC FEDERATION: CALIFORNIA CURRENT MONITORING USING THE NPS OCEAN ACOUSTIC OBSERVATORY

Ching-Sang Chiu, Professor
Department of Oceanography
Curtis A. Collins, Professor
Department of Oceanography
Sponsors: National Ocean Partnership Program and Office of Naval Research

OBJECTIVE: To determine the feasibility of using ocean acoustic tomography to monitor the physical structure of the California Current System.

SUMMARY: During the period May 1999-May 2000, tomography and RAFOS transmissions from an HLF5 transmitter on Hoke Seamount were recorded at the Point Sur Ocean Acoustic Observatory and processed in the Coastal Ocean Acoustic Laboratory at the Naval Postgraduate School. In May 2000, we successfully recovered the Hoke mooring and replaced a RAFOS sound source to the west of Monterey on the R/V New Horizon. Historical hydrographic data as well as data collected during the mooring and retrieval cruises have been used to reconstruct the seasonal variability of the sound speed field between source and receiver.

The acoustic data has been processed and analyzed. The processed acoustic time series show stable and identifiable acoustic arrivals through out the year. The extracted time series of travel time representing direct measurements of the path averaged ocean temperature show seasonal variations that are consistent with historical data and theoretical concepts. A full-waveform inversion of the acoustic arrivals further reveals the spatial and temporal variations of the ocean heat contents.

PUBLICATIONS:

Orcutt, J., deGroot-Hedlin, C., Hodgkiss, W., Kuperman, W., Munk, W., Vernon, F., Worcester, P., Bernard, E., Dziak, R., Fox, C., Chiu, C.S., Collins, C.A., Mercer, J., Odom, R., Park, M., Soukup, D., and Spindel, R., "Long Term Observations in Acoustics - the Ocean Acoustic Observatory Federation," *Oceanography*, 13 (2), 57-63, 2000.

PROJECT SUMMARIES

Rago, T., Collins, C.A., Chiu, C.S., Worcester, P., and Castro, C.G., "Oceanographic Data from Sur Ridge (36.3°N, 122.4°W) to Hoke Seamount (32.1°N, 126.9°W), May 1999," Naval Postgraduate School Technical Report, NPS-OC-00-002, 58 pp., 2000.

Collins, C.A., Castro, C.G., Asanuma, H., Rago, T., Han, S.K., Durazo, R., and Chavez, F.P., "Changes in the Hydrography of Central California Waters Associated with the 1997-8 El Niño," submitted to *Progress in Oceanography*.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Environmental Quality

KEYWORDS: California Current, Acoustic Tomography, SOSUS

ENVIRONMENTAL EFFECTS ON NAVAL WARFARE SIMULATIONS

Peter C. Chu, Professor

Department of Oceanography

Sponsor: Naval Oceanographic Office

OBJECTIVE: This is a multi-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) The Mine Counter Measure Simulation System (MCM96) from COMMINWARCOM was installed and tested in the NPS Secure Computing and Simulation Laboratory. Various environmental effects on the mine counter measure have been investigated under different METOC conditions. (2) Mine Impact Burial Experiment (MIBEX) was conducted at Monterey Bay on May 23, 2000 using a simulated mine. During the experiment, we carefully observe mine track and mine burial depth while simultaneously take gravity cores. After analyzing the gravity cores, we obtain the bottom sediment shear strength data set. Such synchronous mine burial depth and shear strength data were used to evaluate the Navy's Impact Burial Prediction Model (IBPM) which creates a two-dimensional time history of a bottom mine as it falls through air, water, and sediment. The output of the model is the predicted burial depth of the mine in the sediment in meters, as well as height, area, and volume protruding. Model input consists of environmental parameters and mine characteristics, as well as parameters describing the mine's release. The MIBEX data show that the current IBPM model needs to be improved. (3) We established a joint research effort on METOC information in mine warfare with the Royal Navy, UK. (4) A littoral zone METOC prediction system has been established and evaluated.

PUBLICATIONS:

Chu, P.C., Fan, C. W., and Liu, W. T., "Determination of sub-surface thermal structure from sea surface temperature," *Journal of Atmospheric and Oceanic Technology*, 17, pp. 971-979.

Chu, P.C. and R.F. Li, R. F., "South China Sea isopycnal surface circulations," *Journal of Physical Oceanography*, 30, pp. 2419-2438.

Chu, P.C., Veneziano, J. M., and Fan, C. W., "Response of the South China Sea to tropical cyclone Ernie 1996," *Journal of Geophysical Research*, 105, pp. 13991-14009.

Chu, P.C. and Fan, C. W., "A staggered three-point combined compact difference scheme," *Mathematical and Computer Modeling*, 32, pp. 323-340.

PROJECT SUMMARIES

Chu, P.C., "P-vector spirals and determination of absolute velocities," *Journal of Oceanography*, 56, pp. 591-599.

Chu, P.C., Lan, J., and Strauhs, H., "A numerical simulation of the Japan/East Sea (JES) seasonal circulation," *Estuarine and Coastal Modeling*, 6, *American Society of Civil Engineering*, pp. 94-113.

Chu, P.C., Lan, J., and Fan, C. W., "Japan/East Sea (JES) circulation and thermohaline structure, Part 1 Climatology," *Journal of Physical Oceanography*, 31, pp. 244-271.

Chu, P.C., Lan, J., and Fan, C. W., "Japan/East Sea (JES) circulation and thermohaline structure, Part 2 A variational P-vector method," *Journal of Physical Oceanography*, in press.

Chu, P.C. and Chen, X. S., "Comparison between wave number truncation and horizontal diffusion methods in spectral models," *Monthly Weather Review*, 129, pp. 152-158.

Chu, P.C. and Fan, C. W., "A three-point sixth-order accuracy progressive finite difference scheme," *Journal of Atmospheric and Oceanic Technology*, in press.

Chu, P.C., Lu, S. H., and Chen, Y. C., "Evaluation of the Princeton Ocean Model using the South China Sea Monsoon Experiment (SCSMEX) data," *Journal of Atmospheric and Oceanic Technology*, in press.

Chu, P.C., "Toward accurate coastal ocean prediction," *Advances in Mathematical Modeling of Atmosphere and Ocean Dynamics*, Kluwer Scientific Publishing Co., in press.

Chu, P.C., Lu, S. H., and Fan, C. W., "An air-ocean coupled nowcast/forecast system for the east Asian marginal seas," *Advances in Mathematical Modeling of Atmosphere and Ocean Dynamics*, Kluwer Scientific Publishing Co., in press.

Chu, P.C., Chen, Y. C., and Lu, S. H., "Evaluation of Haney-type boundary condition using a global atmosphere-ocean coupled system," *Advances in Atmospheric Sciences*, in press.

Chu, P.C., Chen, Y. C., and Lu, S. H., "Second kind predictability in climate models," *Chinese Journal of Atmospheric Sciences*, in press.

THESIS DIRECTED:

Hilbert Strauhs, "A Numerical Study on Japan/East Sea (JES) Circulation and Thermohaline Structure," Masters Thesis, Naval Postgraduate School, September 1999.

DoD TECHNOLOGY AREAS: Battlefield Environments, Environmental Quality

KEY WORDS: Modeling and Simulation

MINE IMPACT BURIAL MODEL SENSITIVITY STUDY

Peter C. Chu, Associate Professor
Department of Oceanography
Sponsor: Naval Oceanographic Office

OBJECTIVE: The Mine Impact Burial Model has been developed by the Coastal System Station; subsequent upgrades have been made by the Naval Research Laboratory (NRL). Some of the major input parameters to the model are environment (sedimentation, shear strength, water depth), mine characteristics (shape, center of gravity, weight, and mine deployment parameters), deployment platform (ship, aircraft, submarine), speed of platform, angle of mine upon entering water, rotational velocity at time of deployment and others. The model has undergone limited validation in "R&D" experiments where most input parameters were carefully measured or monitored. Many of the input parameters will never be known for

PROJECT SUMMARIES

operational mine deployments; thus, even if the model is accurate using 'perfect' input parameters, it may not be useful if mine impact burial is sensitive to parameters that are seldom known in practice. The purpose of the effort described in this Statement of Work is to perform sensitivity tests with the model to evaluate which are the most critical input parameters necessary for accurate mine impact burial prediction.

SUMMARY: (1) Mine Impact Burial Experiment (MIBEX) was conducted at Monterey Bay on May 23, 2000 using a simulated mine. During the experiment, we carefully observed mine track and mine burial depth while simultaneously take gravity cores. After analyzing the gravity cores, we obtained the bottom sediment shear strength data set. Such synchronous mine burial depth and shear strength data were used to evaluate the Navy's Impact Burial Prediction Model (IBPM) which creates a two-dimensional time history of a bottom mine as it falls through air, water, and sediment. The output of the model is the predicted burial depth of the mine in the sediment in meters, as well as height, area, and volume protruding. Model input consists of environmental parameters and mine characteristics, as well as parameters describing the mine's release. The MIBEX data show that the current IBPM model needs to be improved. LT Timothy Smith completed her thesis on these problems under the guidance of the principal investigator (Prof. Peter Chu) for his MS degree. (2) A new research program "Mine Burial Prediction" was initiated at ONR. As leader for the impact burial team, Peter Chu actively participated in the program planning and experiment designing. He obtained an ONR grant to do the research and attracted NPS students (LT Timothy Smith, LT Carlos Cintron, and LT Tony Gilles, all USN) to do their theses in this program for their MS degree.

PUBLICATIONS:

Chu, P.C., Lu, S. H., and Y.C. Chen, Y. C., "Evaluation of the Princeton Ocean Model using the South China Sea Monsoon Experiment (SCSMEX) data," *Journal of Atmospheric and Oceanic Technology*, in press.

Chu, P.C., "Toward accurate coastal ocean prediction," *Advances in Mathematical Modeling of Atmosphere and Ocean Dynamics*, Kluwer Scientific Publishing Co., in press.

Chu, P.C., Lu, S. H., and Fan, C. W., "An air-ocean coupled nowcast/forecast system for the east Asian marginal seas," *Advances in Mathematical Modeling of Atmosphere and Ocean Dynamics*, Kluwer Scientific Publishing Co., in press.

THESIS DIRECTED:

Smith, T., "Effect of Bottom Shear Strength on the Mine Burial," Masters Thesis, Naval Postgraduate School, September 2000.

DoD TECHNOLOGY AREAS: Battlespace Environments, Environmental Quality

KEY WORDS: Mine Burial, Shear Strength, Ocean Survey, Ocean Variability

DETERMINATION OF COASTAL OCEAN SAMPLING RATE AND ITS IMPACT ON MINE WARFARE EFFECTIVENESS

Peter C. Chu, Professor

Department of Oceanography

Sponsor: Commander Naval Meteorology Oceanographic Command

OBJECTIVE: This three-year proposal for investigating (1) How much more oceanographic data are required to sample the coastal environment and (2) How much the warfighter gain in effectiveness by increasing the sampling rate.

PROJECT SUMMARIES

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Decorrelation Scale, Sampling Rate, Mine Warfare Effectiveness

GPS ANTARCTIC NAVIGATION APPLICATIONS

James Clynch, Research Professor

Department of Oceanography

Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: To assist in the planning and implementation of a differential GPS in Antarctica. Subjects will include aircraft landing systems, air traffic control, navigation calibrations systems, and communications requirement for such systems.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: GPS, Air Traffic Control

GPS SHIP REFERENCE SYSTEM

James Clynch, Research Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: To establish the techniques necessary to utilize a global positioning receiver aboard a ship as a reference system for differential GPS.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Global Positioning System, GPS, Differential GPS

NAVAL SURFACE WARFARE CENTER FIELD PROGRAM ASSISTANCE

James Clynch, Research Professor

Department of Oceanography

Sponsor: Naval Surface Warfare Center-Dahlgren

OBJECTIVE: Under a previous effort, the Naval Postgraduate School upgraded to Ashtech ZFX receivers to take data at 10 HZ and have enough internal memory to store data at the rate for one hour. The Naval Postgraduate School will program these units so that they will begin taking data using the desired configuration on power up during a one-week segment of the October/November 1999 experiments at Duck, NC. The Naval Postgraduate School will assist in the utilization of these receivers for precise positioning of the aircraft. It will check the instruments out pre-flight. The Naval Postgraduate School will download the data and provide it to NSWC. NPS may also do analysis on this data.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Global Positioning System, GPS, Differential GPS

PROJECT SUMMARIES

ACROSS-MARGIN TRANSPORT DURING THE 1998 EL NIÑO

Curtis Collins, Professor

Department of Oceanography

Sponsor: Monterey Bay Aquarium Research Institute

OBJECTIVE: Two intermediate moorings will be deployed across the continental margin off Monterey Bay during the period of January 1998 to December 1999. The moorings include current meters and sediment traps and provide measurements of across slope transport during El Niño conditions.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Sediment Transport, Eastern Boundary Currents, El Niño

PHYSICAL OCEANOGRAPHIC CONDITIONS OFF CENTRAL CALIFORNIA IN 1998

Curtis Collins, Professor

Department of Oceanography

Sponsor: Scripps Oceanographic Institute

OBJECTIVE: The strong El Niño conditions in the eastern tropical Pacific are propagating poleward along the West coast of the United States causing changes in the structure of the California current system and displacing Biota. This project provides for shipboard observations of subsurface conditions in the California current system off central California. Ocean currents, heat, salt and dissolved oxygen will be observed in May and November 1998. Observations will extend to 1000M and 400KM from shore. These data will be combined with similar observations scheduled for January, March, July and August. Results will be compared to an extensive Climatology that has been developed for central California waters.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: California Current, El Niño

1999 CENTRAL CALIFORNIA HYDROGRAPHIC SURVEYS

Curtis Collins, Professor

Department of Oceanography

Sponsor: San Jose State University Foundation

OBJECTIVE: Two surveys of central California waters will be conducted in 1999. This project provides support for carrying out these surveys, for calibrating CTD Salinity observations, and for data processing. Results will be archived at the U.S. Naval Oceanographic Office

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: California Current System

EMPIRICAL MODELS OF TIDAL AND RESIDUAL OCEAN CURRENTS IN THE YELLOW AND EAST CHINA SEAS

Curtis Collins, Professor

Department of Oceanography

Sponsor: Naval Oceanographic Office

OBJECTIVE: A procedure will be codified for systematic development of empirical models of ocean circulation and the associated databases. The method will be applied to the East Chin Sea and the Yellow Sea.

PROJECT SUMMARIES

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: East China Sea, Ocean Currents, Mine Warfare

SUB-MESOSCALE COHERENT VORTICES AND CALIFORNIA UNDERCURRENT DYNAMICS

**Curtis Collins, Professor
Department of Oceanography
Sponsor: Office of Naval Research**

OBJECTIVE: RAFOS float observations of intermediate depth flow in the Northeastern Pacific Ocean for the period of 1996-1999 will be processed and analyzed. Emphasis will be on the character of observed Mesoscale and Submesoscale flow pattern.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Eastern Boundary Currents, Ocean Currents, Mine Warfare

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

**Curtis Collins, Professor
Department of Oceanography
Sponsor: Environmental Protection Agency**

OBJECTIVE: To measure ocean circulation patterns at the San Francisco Deep-Ocean Disposal Site.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: California Current System, Gulf of the Farallones, Ocean Disposal

POLAR SEA CONVECTIVE INSTABILITIES

**Roland W. Garwood, Jr., Professor
Pascale Lherminier, National Research Council Research Associate
Ramsey Harcourt, Research Assistant Professor
Department of Oceanography
Sponsor: National Science Foundation**

OBJECTIVE: The major scientific objective of this five-year study is to understand the convective response of the coupled ocean mixed layer-ice system to the passage of atmospheric storms.

SUMMARY: Simulation of isobaric floats in Large-Eddy Simulations (LES) of winters 1994 in the Greenland Sea and 1996 in the Labrador Sea show that the bias in drifter-observed vertical velocity measurements bears also on the estimation of variances and vertical fluxes derived from drifter-observed temperature and salinity. Quantification of this bias is possible at least in the lower part of the mixed layer, provided that the horizontal divergence field is known.

The study of 1996 float data in the Greenland Sea and of ANZFLUX hydrographic profiles in the Weddell Sea led us to add a thermodynamic sea ice layer on top of the LES. All the second order non-linearities of the seawater equation of state (as thermobaricity and cabbelling) were included in order to better understand the relative effect of each. We see that cabbelling delays the growth of penetrative thermobaric plumes and favors the formation of an intermediate layer often observed in the Wedell Sea, but still unexplained.

PROJECT SUMMARIES

PUBLICATIONS:

Harcourt, R.R., Steffen, E.L., Garwood, R.W., and D'Asaro, E.A., "Fully Lagrangian Floats in Labrador Sea Deep Convection: Comparison of Model and Experiment," *Journal Physical Oceanography*, in press.

Lherminier, P., Harcourt, R.R., Garwood, R.W., and Gascard, J.C., "Interpretation of mean vertical velocities measured by isobaric floats during deep convective events," *Journal of Marine Systems*, 29 (1-4), pp. 221-237.

PRESENTATIONS:

Lherminier, P., Harcourt, R.R., Garwood, R.W., and Gascard, J.C., "Interpretation of mean vertical velocity measured by isobaric floats," 25th General Assembly of the European Geophysical Society, Nice, France, 24-28 April 2000.

Lherminier, P., "Interpretation of isobaric float measurements," Seminars at Naval Postgraduate School, 1 December 1999, and LODYC, Paris, France 21 December 1999.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Coupled Ocean Mixed Layer Ice System, Convective Instabilities

SIMULATION OF LAGRANGIAN DRIFTERS IN THE LABRADOR SEA

Roland W. Garwood, Jr., Professor

Pascale Lherminier, National Research Council Research Associate

Ramsey Harcourt, Research Assistant Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The long-term objective for this research is to use our improved knowledge of the turbulent kinetic energy (TKE), Reynolds stress, and scalar flux budgets to develop and test parameterizations of mixed layer dynamics and deep penetrative convection and overturning for inclusion in basin-scale oceanic general circulation models.

SUMMARY: The results on Rossby number scaling have clear implications for large-scale modeling. Deep convection in the Labrador Sea is significantly affected by planetary rotation, but not to such an extent that the dynamic length scale is set exclusively by surface buoyancy loss and the Coriolis parameter, as has been suggested in the literature. The effect of entrainment on mixed layer deepening remains significant, and a large-scale model that neglects penetrative convection by relying on simple convective adjustment underestimates the production rate of Labrador Sea water.

The simulations of Lagrangian floats in the Labrador Sea, and comparisons between model and actual float statistics, have demonstrated that the Drifting Lagrangian Floats (DLF) deployed in the Labrador Sea are an accurate and effective tool for measuring deep convection. The model-experiment comparisons have revealed unanticipated features of the dynamics of deep convection to be addressed in future research efforts.

Preferential sampling of convergence zones by isobaric floats bears upon all measurements obtained with these instruments. In general, values obtained for the variance and covariance of vertical velocity and temperature fluctuations along drifter trajectories are significantly reduced by comparison to their Eulerian counterparts. This reduction is the direct result of the biased sampling by isobaric drifters, which manifests in the appearance of net vertical fluid transport along drifter trajectories.

PROJECT SUMMARIES

PUBLICATIONS:

Harcourt, R.R., Steffen, E.L., Garwood, R.W., and D'Asaro, E.A., "Fully Lagrangian Floats in Labrador Sea Deep Convection: Comparison of Model and Experiment," *Journal of Physical Oceanography*, in press.

Lherminier, P., Harcourt, R.R., Garwood, R.W., and Gascard, J.C., "Interpretation of mean vertical velocities measured by isobaric floats during deep convective events," *Journal of Marine Systems*, 29 (1-4), pp. 221-237.

PRESENTATIONS:

Harcourt, R.R., Steffen, E.L., Garwood, R.W., and D'Asaro, E.A., "Fully Lagrangian Floats in Labrador Sea Deep Convection: Comparison of Model and Experiment," Nice, France, April 2000.

Harcourt, R.R., Steffen, E.L., Garwood, E.L., and D'Asaro, E.A., "Fully Lagrangian Floats in Labrador Sea Deep Convection: Comparison of Model and Experiment," Toronto, Canada, June 2000.

Harcourt, R.R., Kruse, D.M., Guest, P., and Garwood, R.W., "Large Eddy Simulation of Interactions Between Free Convection, Wind Driven Currents, and Baroclinicity in Labrador Sea Deep Mixed Layers," Toronto, Canada, June 2000.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Turbulent Kinetic Energy (TKE), Reynolds Stress, Scalar Flux Budgets, Mixed Layer Dynamics, Convection

NON-HYDROSTATIC MODELING OF WEST FLORIDA SHELF FLOW AND TRACERS

Roland W. Garwood, Jr., Professor

Ramsey Harcourt, Research Assistant Professor

Department of Oceanography

Sponsor: University of South Florida and the Office of Naval Research

OBJECTIVE: The objective for the proposed research is to calculate solutions for the turbulent nonhydrostatic flow regime on the West Florida shelf using Large-Eddy Simulation. These solutions will be used to help explain the three-dimensional optical properties of the water column by understanding the behavior of tracers and drifters deployed during field experiments.

SUMMARY: In collaboration with Kent Fanning and John Walsh of the University of South Florida the OPBL Laboratory of the Naval Postgraduate School is conducting numerical solutions for the turbulent nonhydrostatic flow regime on the West Florida shelf using Large-Eddy Simulation. These solutions are for times and locations appropriate to explain the optical properties of the water column by understanding the behavior of tracers and drifters deployed during field experiments with AUVs (autonomous underwater vehicles).

PUBLICATIONS:

Ly, L.N. and Garwood, R.W., Jr., "Numerical modeling of wave-enhanced turbulence in the oceanic upper layer," *Journal of Oceanography*, 56, pp. 473-483.

Ly, L.N. and Garwood, R.W., Jr., "An ocean circulation model with surface wave parameterization," *Applied Numerical Mathematics*, in press.

PROJECT SUMMARIES

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Environmental Quality, Sensors, Modeling and Simulation, Other (Oceanography)

KEYWORDS: Air-Sea Interactions, Tracers, Lagrangian Drifters

DEVELOPMENT OF AN ARCTIC LOW FREQUENCY AMBIENT NOISE MODEL

Roland Garwood, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To continue development of a low frequency ambient noise model for use by submarines operating under the Arctic Polar pack ice.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Arctic Ocean, Ambient Noise, Sea Ice

WESTERN BOUNDARY CURRENT SYSTEMS VIRTUAL POSTER SESSION

Arlene Guest, Senior Lecturer
Department of Oceanography
D. Randolph Watts
Kathleen A. Donohue
University of Rhode Island
Sponsor: Office of Naval Research

OBJECTIVE: An information-exchange gap exists between the initial planning-and-conduct stages and the eventual journal publication of scientific research. Our objective is to provide a mechanism to facilitate the exchange of ideas while they are "hot" and still being refined.

We conduct a series of web-based "Virtual Poster Sessions: individually focused on themes under the broad topic of Western Boundary Current Systems which provide the opportunity for rapid and broad distribution of research.

The home page <http://po.gso.uri.edu/wbc/> contains the essential components for the virtual poster session. A "poster" page presents invited and contributed posters treating observational, theoretical, and numerical modeling issues. For a given session we invite expert contributions for a particular theme. Similar to real poster sessions, contributions posted on the Western Boundary Current website do not receive prior peer review or significant editorial action. However, coinciding with posting each invited anchor article, we arrange for one or more peers to provide "invited comment," seeking some degree of cross-fertilization between observationalists, modelers, and theoreticians. Associated with each poster, a "forum" page promotes active participation by site visitors, who are encouraged to register, with "threaded discussions" which include questions, criticisms, and replies. A "living bibliography," the Western Boundary Current library, contains a "topical library" with entries from the poster contributors and pre-registrants as well as a "cumulative Western Boundary Current bibliography" consisting of a subset of citations to journal articles, which will be built up from sessions to session.

SUMMARY: A "warm-up" dress-rehearsal session began on 19 September 2000. The "Forum," "Search" engine, and "Registration" software are working smoothly. This "warm-up" session featured five posters. Home pages for the individual posters present an outline plus hyperlinked buttons that allow the visitor to easily navigate between sections.

We advertised the "dress-rehearsal" session to only a limited group (about 80 outside URI). In the initial week of the session, we received hits from 200 unique addresses, with 33 official registrants. Our overall impression is that the session was well received; several investigators inquired about submitting future poster after viewing the website.

With the major technical hurdles behind us, we are ready to focus on advertising and promoting the discussion forums. Participation in the discussion forums was less than we had hoped, in part due to the

PROJECT SUMMARIES

limited distribution list. We are seeking improvements such as (a) automating author notification by e-mail when a new comment is posted to a forum page, (b) allowing invited commentators to preview the posters so that their comments are online when the session is released, and (c) by holding a drawing for a prize from the pool of forum participants such as a t-shirt or mouse pad with the Western Boundary Current web page logo.

We hope that the web site will benefit students at the undergraduate and graduate level as well as the public, who would have a glimpse into the scientific process and the state of the art in this area of oceanography.

The virtual poster session provides investigators the opportunity to present their results to a worldwide audience with creative graphics, such as large numbers of color plots and animations, which would be impossible or prohibitively expensive in published journals.

We will conduct post-session interviews with the poster contributors and registrants to determine the impact and usefulness of the poster session: (1) Did they get useful feedback? Was it worth the effort?, (2) Would they encourage others to participate?, and (3) Did they learn anything?

Virtual Poster Sessions on other topics are being considered by other ONR PIs. The web templates, Forum, Registration, and Search engine scripts etc. are available to save them development efforts.

DoD KEY TECHNOLOGY AREAS: Other (Information Exchange)

KEYWORDS: Virtual Posters, Journal Publication, Research Results

IMPROVED PARAMETERIZATIONS OF TRIAD AND QUARTET INTERACTIONS IN SPECTRAL WIND-WAVE MODELS

Thomas H. C. Herbers, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The main objective of this project is to improve the representation of nonlinear wave-wave interactions in operational wave prediction models.

SUMMARY: It is well known that nonlinear wave-wave interactions are poorly represented in current operational wave prediction models (e.g., WAM, SWAN). In this project a team of scientists from the Naval Postgraduate School, the Army Corps of Engineers, David Taylor Model Basin, and Alkyon Hydraulic Consultancy and Research, are evaluating the shortcomings of existing models and developing and testing new approximations. A numerically efficient technique for computing the energy exchanges between four wave components in quartet interaction was validated through comparisons with exact numerical calculations.

PUBLICATIONS:

Herbers, T. H. C., N. R. Russnogle, and S. Elgar, Spectral energy balance of breaking waves within the surf zone, *Journal of Physical Oceanography*, 30(11), 2723-2737, 2000.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean Surface Waves, Nonlinear Interactions, Continental Shelf, Beach

PROJECT SUMMARIES

NEARSHORE CANYON EXPERIMENT (NCEX)

Thomas H. C. Herbers, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The objective of this research is to understand the effect of complex continental-shelf bathymetry on surface gravity waves and on the breaking-wave-driven circulation onshore of the irregular bathymetry.

SUMMARY: Abrupt shelf bathymetry can cause dramatic alongshore variations in waves, resulting in beaches with large waves located only a few hundred meters away from beaches with small waves. These along-coast changes in wave height and direction can force complicated circulation patterns, including alongshore flows that reverse direction across the surf zone and along the shoreline, and strong offshore-directed rip currents that may be an important mechanism for transport of water, sediment, and pollution between the surf zone and inner shelf. Models will be tested with observations of waves and currents made on the southern California coast near two steep submarine canyons. Model initial conditions (incident waves) will be acquired with a directional buoy located offshore of the canyons. The effect of the canyons on waves and wave-driven circulation will be measured with directional buoys near the canyons, and with pressure-gage and current-meter arrays deployed onshore of the canyons in 10- and 2.5-m water depths. Additional specialized arrays will be deployed to investigate wave reflection and scattering from the steep canyon walls, and cross-shore changes in surf zone circulation. Drifters will be used to estimate the location, flow speed, and offshore extent of rip currents. This project is a collaborative effort with Woods Hole Oceanographic Institution (PI Dr. Steve Elgar) and Scripps Institution of Oceanography (PI Dr. Robert T. Guza).

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean Surface Waves, Surf Zone, Nearshore Processes

SURFACE GRAVITY WAVES ON THE CONTINENTAL SHELF AND BEACH

Thomas H. C. Herbers, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

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 project is focused on the effects of nonlinear wave-wave interactions and wave breaking on the evolution of wind-wave spectra across the inner continental shelf and beach. Analysis of detailed wave shoaling measurements collected during the DUCK94 and SandyDuck (1997) experiments demonstrates the important role of nonlinear triad wave-wave interactions in the surf zone energy balance. Analysis of array measurements in shallow water shows significant deviations from the linear dispersion relation for surface gravity waves. A new nonlinear dispersion relation was derived and shown to be in good agreement with the field measurements.

PUBLICATIONS:

Feddersen, F., R. T. Guza, S. Elgar, and T. H. C. Herbers, "Velocity moments in alongshore bottom stress parameterizations," *Journal of Geophysical Research*, 105(C4), pp. 8673-8686, 2000.

Elgar, S., R. T. Guza, W. C. O'Reilly, B. Raubenheimer, and T. H. C. Herbers, "Wave energy and direction observed near a pier," *Journal of Waterway, Port, Coastal, and Ocean Engineering*, 127(1), pp. 2-6, 2001.

Lentz, S., M. Carr, and T. H. C. Herbers, "Barotropic tides on the North Carolina shelf," *Journal of Physical Oceanography* in press.

PROJECT SUMMARIES

Herbers, T. H. C., S. Elgar, N. A. Sarap, and R. T. Guza, "Nonlinear dispersion of surface gravity waves in shallow water," *Journal of Physical Oceanography*, accepted with minor revisions.

Noyes, T. J., R. T. Guza, S. Elgar, and T. H. C. Herbers, "Comparison of methods for estimating nearshore shear wave variance," submitted to *Journal of Atmospheric Oceanic Technology*.

PRESENTATIONS:

Orzech, M., Herbers, T. H. C., Elgar S., and Guza R. T., "Frequency-directional spectra of shoaling waves: model predictions and field observations," American Geophysical Union Fall Meeting, San Francisco, CA, December 2000.

Sheremet, A., Guza, R. T., Elgar, S., and Herbers, T. H. C., "Bound infragravity waves," American Geophysical Union Fall Meeting, San Francisco, CA, December 2000.

Noyes, T., Guza, R. T., Elgar, S., and Herbers, T. H. C., "Estimating shear wave variance," American Geophysical Union Fall Meeting, San Francisco, CA, December 2000.

THESES DIRECTED:

Tinder, C. V., "Swell Transformation Across the Continental Shelf," Master's Thesis, Naval Postgraduate School, June 2000.

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean Surface Waves, Nonlinear Interactions, Continental Shelf

WAVE EVOLUTION ON THE CONTINENTAL SHELF

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 evaluate the energy balance of wind-generated waves in shallow water.

SUMMARY: Six surface-following directional wave buoys and a coherent array of pressure sensors were deployed on the North Carolina continental shelf as part of the ONR SHOaling Waves EXperiment (SHOWEX) to investigate the transformation of wind waves and swell across a continental shelf. High-quality data was collected through a wide range of conditions including Hurricanes Floyd, Gert, and Irene with maximum wave heights in excess of 10 m. Detailed bottom information was collected during three cruises including sediment samples, sidescan surveys of small-scale bottom roughness and high resolution bathymetry. Preliminary analysis of the SHOWEX observations by Ph.D. student Fabrice Ardhuin using a new numerical model for wave evolution across the continental shelf demonstrates the important role of seabed ripples in the attenuation of swell. The measurements will also be used to verify theoretical predictions of nonlinear spectral energy transfers and estimate wave energy losses resulting from whitecaps.

PUBLICATIONS:

Ardhuin, F., T. H. C. Herbers, and W. C. O'Reilly, "A hybrid Eulerian-Lagrangian model for spectral wave evolution with application to bottom friction on the continental shelf," *Journal of Physical Oceanography*, in press.

Ardhuin, F., and T. H. C. Herbers, "Bragg scattering of random surface gravity waves by irregular sea bed topography," *Journal of Fluid Mechanics*, accepted with minor revisions.

PROJECT SUMMARIES

CONFERENCE PRESENTATIONS:

Ardhuin, F., Herbers, T. H. C., and O'Reilly, W. C., "Bragg scattering of surface gravity waves by bottom irregularities," American Geophysical Union Fall Meeting, San Francisco, CA, December 2000.

Jessen, P. F., Herbers, T. H. C., O'Reilly, W. C., Tinder C. V., and Ardhuin F., "Wave measurements on the North Carolina shelf during SHOWEX," American Geophysical Union Fall Meeting, San Francisco, CA, December 2000.

DOD KEY TECHNOLOGY AREA: Environmental Quality

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

SPATIAL COHERENCE OF WAVES IN DEEP WATER

Thomas H. C. Herbers, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The objective of this project is to determine how nonlinearity and directional spreading affect the spatial coherence and crest-length statistics of ocean surface waves.

SUMMARY: This project is part of the ONR Mobile Offshore Base (MOB) Program in which the feasibility of a large floating platform in deep water is examined. A major concern is the platform response to extreme wave conditions. The specific task of this project is to determine the spatial coherence of natural wind-generated ocean waves over distances of $O(1 \text{ km})$ (i.e. nominal platform dimensions). New techniques were developed to numerically simulate two-dimensional sea surfaces based on weakly nonlinear wave theory, and estimate wave crest-length statistics from the simulated sea surfaces. This project is a collaboration with Dr. Steve Elgar (Woods Hole Oceanographic Institution).

DOD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Ocean Surface Waves, Spatial Coherence, Wave Crest Lengths

ARCTIC SHELF AND OCEAN PALEO-CIRCULATION MODELING WORKSHOP AT THE NAVAL POSTGRADUATE SCHOOL

Wieslaw Maslowski, Research Associate Professor

Department of Oceanography

Sponsor: University of Illinois

OBJECTIVE: We propose to organize a workshop (~20 people) in Monterey, CA in April 1999, to explore the complex effects of eustatic and isostatic changes, ice-sheet coverage, fresh water inputs and variable sea-ice dynamics in the arctic on global ocean circulation during the past 20,000 years. This venue will access recent advances in Arctic Basin Oceanographic Modeling by the U.S. Navy, which provide a rapid means to evaluate many outstanding Paleo-Oceanographic and Climatic Hypothesis. The workshop will refine boundary conditions for the Arctic Ocean, surrounding shelf seas and channels for the past 20,000 years, providing new insight for evolving geophysical models of the climate system.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Arctic Basin, Paleo-Oceanographic, Climate Hypothesis

PROJECT SUMMARIES

COUPLED BIO-PHYSICAL MODELING OF THE ARCTIC MARINE RESPONSE TO GLOBAL CHANGE

Wieslaw Maslowski, Research Associate Professor
Roland Garwood, Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: In addition to modeling physical environment of interest to the SBI program, we propose to do the following:

- Provide results from this work to all interested and funded by the SBI program investigators as requested (both raw model output as well as processed results such as animation of various fields, time and space-averaged fields, etc).
- Establish a Website where description of model output and some results will be available and updated for viewing and downloading to all SBI program investigators and other interested scientists.
- Concentrate on the main area of interest extending from the Bering and Chukchi shelves across the shelf break into the Beaufort Sea; other regions of the Arctic Ocean might be included if needed.
- Collaborate with other program investigators in Phase I of this program in order to provide guidance and to establish communication and understanding of future requirements during the field project (I.E. Phase II) of this program.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Bering Shelf, Chukchi Shelf, Beaufort Sea, Arctic Ocean

HIGH-PERFORMANCE MODELING OF THE FULLY GLOBAL OCEAN SYSTEM AND ITS VARIABILITY

Wieslaw Maslowski, Research Associate Professor
Julie McClean, Research Associate Professor
Department of Oceanography
Sponsor: University of Alaska

OBJECTIVE: It is proposed to design and optimize a fully global, high-resolution ocean model including the Arctic and Southern Oceans, in order to advance science of inter-annual to decadal variability of the ocean system using the massively parallel CRAY T3E at the Arctic Region Supercomputing Center (ARSC).

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Arctic Ocean, Southern Ocean, Decadal Variability

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

Wieslaw Maslowski, Research Associate Professor
Albert Semtner, Professor
Yuxia Zhang, Research Assistant Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: The long-term turbulent equilibrium of the ice-covered Arctic Ocean, as driven by multi-year observed atmospheric forcing and properly connected to surrounding sub-polar ocean environments, will be determined using a coupled Arctic Ocean model running on advanced parallel computers. Comparison with existing observations will be made to evaluate the model and extend interpretation of the

PROJECT SUMMARIES

data. The significance of the 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.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Arctic Ocean, Sub-Polar Ocean Environments

DEVELOPMENT OF A NEW ARCTIC ICE-OCEAN PREDICTION SYSTEM

Wieslaw Maslowski, Research Associate Professor

Albert Semtner, Professor

Yuxia Zhang, Research Assistant Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: Work will continue on a high-resolution 9 km Arctic and subpolar ice-ocean prediction system. Improved dynamical formulations will allow the representation of oriented leads. Data assimilation methods will be implemented for ice velocity using optimal interpolation and for ice compactness using Newtonian Relaxation over the entire pack. Extensive numerical integrations will evaluate the methods for selection of a final product to transition to 6 to 4 researchers at Stennis Space Center.

DoD KEY TECHNOLOGY AREAS: Other (Environmental Simulation)

KEYWORDS: Sea Ice, Numerical Modeling, Supercomputing, Satellite Microwave

COMPARISONS OF THE LANL POP MODEL AND WOCE OBSERVATION

Julie McClean, Research Associate Professor

Albert Semtner, Professor

Department of Oceanography

Sponsor: National Science Foundation

OBJECTIVE: The very realistic global sixth-degree Los Alamos Nation Lab (LANL) Parallel Ocean Program (POP) model has been developed and is being run with realistic forcing for the on-going World Ocean Circulation Experiment (WOCE) period. It is proposed that WOCE observations be compared with output of this model. Specifically this would be done by extracting model fields co-located in both space and time with observations and performing analyzers to describe the statistics of the ocean circulation on both sets of fields using the same techniques, providing a direct comparison of results. In regions where the simulation behaves with an acceptable degree of realism as determined by these comparisons, a conceptual synthesis of model output and data will be used for interpretative and dynamical studies. The model fields can be used to complement the model domain both in space and time, providing a much larger source of information for these studies. In the cases where the model is found lacking, explanations for the deficiencies will be determined and improvements suggested for implementation in future simulation.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Model Validation, Ocean Circulation, Numerical Modeling

PROJECT SUMMARIES

EVALUATIONS OF THE POP MODEL FOR NAVY FORECASTING USE

Julie McClean, Research Associate Professor
Robin Tokmakian, Research Assistant Professor
Albert Semtner, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: It is proposed here to continue the two efforts currently in progress which examine the feasibility of using POP in a future global coupled system with predictive capability for Navy needs. A suite of fully global 1/3 degree POP runs forced with NOGAPS wind of different sampling frequencies is being run and evaluated using high frequency sampled data. The output from these runs will be compared with a similarly configured run forced with ECMWF winds. To determine whether POP is capable of producing the processes and features of importance to Navy prediction at sufficiently high resolution, a .1 degree North Atlantic version of POP, forced with daily NOGAPS winds, is underway. It will be evaluated using high-frequency data, particularly velocities from surface drifters collected from 1993-1997 along with measures established by DAMEE.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Numerical Modeling, Ocean Circulation, Forecasting

SWELL MODEL UPGRADE

William O'Reilly, Research Assistant Professor
Thomas Herbers, Associate Professor
Department of Oceanography
Sponsor: Naval Research Laboratory

OBJECTIVE: Recently Office of Naval Research Field Research has shown that linear spectral refraction theory is a viable method for predicting the propagation of directional wave spectra from deep to shallow water. A spectral refraction model is of immediate benefit to ongoing Navy research and military exercises in the vicinity of Camp Pendleton, CA and a useful future addition to the NAVO Suite of Wave Modeling Programs. The specific objective is to upgrade the spectral refraction model currently in use at NRL.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Ocean Waves, Continental Shelf, Wave Model

DATA ENHANCED MODELING OF SEA AND SWELL ON THE CONTINENTAL SHELF

William C. O'Reilly, Research Assistant Professor
Thomas H. C. Herbers, Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: To develop and test improved wave propagation and data assimilation methods that are compatible with the coastal wave prediction model SWAN and applicable to a wide range of geographic settings.

SUMMARY: Data assimilation methods are under development for the coastal wave prediction model SWAN. Currently SWAN and similar regional wave prediction models are nested within the global wave prediction model WAM. A drawback of this approach is that initialization errors (e.g., errors in WAM predictions owing to uncertainties in the wind field and inaccuracies in the propagation of waves over large distances) can seriously degrade the coastal model predictions. In this project new methods are implemented to enhance the quality of coastal wave predictions through the assimilation of in-situ (e.g.

PROJECT SUMMARIES

directional wave buoys) and remotely sensed (e.g., airborne and satellite radar systems) wave data collected at the offshore boundaries or within the model domain. This project is an ongoing collaboration with scientists from NRL-SSC.

PUBLICATIONS:

Herbers, T. H. C., E. J. Hendrickson, and W. C. O'Reilly, "Propagation of swell across a wide continental shelf," *Journal of Physical Oceanography*, 105(C8), pp. 19729-19737, 2000.

Noyes, T. J., R. T. Guza, S. Elgar, and T. H. C. Herbers, "Comparison of methods for estimating nearshore shear wave variance," submitted to *Journal of Atmospheric Oceanic Technology*.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Wave and Surf Forecasts, Data Assimilation

COMPARISON OF MULTI-SYSTEM HF RADAR DATA FROM COPE-3

Jeffrey D. Paduan, Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: This project will analyze data collected during the third field phase of the Chesapeake Outfall Plume Experiment (COPE-3). It will focus on surface current data from two CODAR/SEASONDE instruments deployed off Virginia Beach, VA during October and November 1997. Equally important, however, will be the comparison of these data with other near-surface current measurements collected simultaneously by two multi-frequency current radar (MCR) installations, by two ocean surface current radar (OSCR) installations, and by five bottom-mounted acoustic Doppler current profilers (ADCP) moorings.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Ocean Currents, Ocean Waves, Air-Sea Interaction

DIURNAL TO SEASONAL VARIABILITY OF SURFACE OCEAN CURRENTS FROM HIGH FREQUENCY RADAR

Jeffrey D. Paduan, Associate Professor

Department of Oceanography

Sponsor: National Science Foundation

OBJECTIVE: This research was drawn on data from a unique array of five HF radar systems around Monterey Bay: three CODAR-DEASONDE direction-finding systems and two Multi-Frequency phased array systems. We focused on the 2D surface currents and how they varied, both seasonally and daily, compared with measured winds and satellite AVHRR images. Data from the Multi-Frequency Radar sites was used to measure near-surface shear, which is difficult to do with in SITU Instrumentation. In addition, data from these systems, as well as simulations, was used to examine the sensitivity of Radar Algorithms to varying current and wave conditions.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Ocean Currents, Ocean Waves, Air-Sea Interaction

PROJECT SUMMARIES

THE INNOVATIVE COASTAL-OCEAN OBSERVING NETWORK (ICON)

Jeffrey D. Paduan, Associate Professor

Steven R. Ramp, Research Professor

Curtis A. Collins, Professor

Leslie K. Rosenfeld, Research Associate Professor

Department of Oceanography

Sponsor: National Ocean Partnership Program

OBJECTIVE: The ICON objective is to develop and integrate real-time observing systems into a nested, data-assimilating model of the Monterey Bay. The system will serve as a model for future coastal ocean monitoring and prediction networks and can be transported and applied to other geographic regions of high tactical interest. The project has many partners at other institutions.

SUMMARY: Several aspects of the data collection phase of this large, complex project were completed during FY2000. Surface buoys M3 and M4 were recovered during May and August 2000 respectively. The project received supplementary funding during FY2000 to cooperate with the Autonomous Ocean Sensors Network (AOSN) August demonstration project in the Monterey Bay. This was done via additional real-time in situ instrumentation and a series of overflights with the SPAWAR Navajo aircraft. Additional funding was also supplied for a triply-nested, very high resolution model run by partner Igor Shulman at the University of Southern Mississippi.

PUBLICATIONS:

Paduan, J.D., Rosenfeld, L.K., Ramp, S.R., Chavez, F., Chiu, C.S., and Collins, C.A., Development and maintenance of the ICON observing system in Monterey Bay, *Proceedings, Third Conference on Coastal Atmospheric and Oceanic Prediction and Processes*, New Orleans, LA, 3-5 November 2000.

Shulman, I., Wu, C.R., Lewis, J.K., Paduan, J.D., Rosenfeld, L.K., Ramp, S.R., Cook, M.S., Kindle, J. C., and Ko, D.S., 2000a: Development of the high resolution, data assimilating numerical model of the Monterey Bay, CA, in Spaulding, M. L. and Butler, H.L., (eds.), *Estuarine and Coastal Modeling*, pp. 980-994.

Shulman, I., Wu, C.R., Lewis, J.K., Paduan, J.D., Rosenfeld, L.K., Kindle, J.C., Ramp, S.R., and Collins, C.A., 2000b: High resolution modeling and data assimilation in the Monterey Bay area, *Continental Shelf Research*, submitted.

PRESENTATIONS:

Ramp, S. R., Chavez, F., Maffione, R.A., Rosenfeld, L.K., and Bahr, F., 2000: Real-time observations of the mesoscale variability in the California Current System from the NOPP/ICON buoys, American Geophysical Union Ocean Sciences Meeting, 24-28 January 2000, San Antonio, TX.

Shulman, I, Wu, C., Lewis, J.K., Paduan, J.D., Rosenfeld, L.K., Ramp, S.R., Kindle, J.C., and Ko, D., 2000: Development of the high-resolution data-assimilating model of the Monterey Bay, American Geophysical Union Ocean Sciences Meeting, 24-28 January 2000, San Antonio, TX.

Flynn, K.M., Maffione, R.A., Chavez, F.P., Ramp, S.R., Paduan, J.D., Rosenfeld, L.K., and Collins, C.A., 2000: Optical time-series data from the Monterey Bay Innovative Coastal-Ocean Observing Network (ICON), American Geophysical Union Ocean Sciences Meeting, 24-28 January 2000, San Antonio, TX.

Ramp, S.R., " Results from a real-time, bottom mounted acoustic Doppler current profiler (ADCP) on the continental shelf during the MOOS (MBARI Ocean Observing System) Upper-ocean Science Experiment (MUSE) 2000," presented at the first MUSE Symposium, Moss Landing, CA, November 2000.

PROJECT SUMMARIES

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Coastal Oceanography, Upwelling Fronts, Monitoring and Prediction, Real-time Data

EVALUATION OF OCEAN SURFACE CURRENT DATA FROM THE NAVY HF SURFACE WAVE RADAR

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

OBJECTIVE: This project was analyze data collected during initial shore-based testing of the new Navy High Frequency Surface Wave Radar (HFSWR) for its capability to measure surface ocean currents. Doppler Backscatter Spectra will be formed from HFSWR measurements off Pt. Loma in San Diego, CA for the purpose of estimating surface currents in the manner employed by existing shore-based HF ocean current radar systems. The HFSWR was developed to detect low-angle targets approaching a ship at sea. As such, it was not designed to collect and analyze Doppler Backscatter Spectra. The purpose of this project is to determine how well the HFSWR can be extended to also map surface ocean currents. One CODAR/SEASONDE system from the Monterey Bay HF radar network was deployed near the HFSWR for a period of a few days in order to obtain radial current MPAS from a well-tested HF radar system that was designed to measure surface currents.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Ocean Currents, Ocean Waves, Air-Sea Interaction

GLOBEC MAPPING THE EVOLUTION OF MESOSCALE JETS AND EDDIES IN THE UPWELLING ECOSYSTEM OFF CAPE BLANCO, OREGON

Jeffrey D. Paduan, Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: This research deployed a new application of high frequency (HF) radar instruments for extended range coverage of filaments and eddies in the California current system with specific application to the mesoscale jet and eddies in the upwelling system of Cape Blanco, OR in support of GLOBEC processes studies sited in that area.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Ocean Currents, Eddies, Filaments

MODELING THE CENTRAL CALIFORNIA COASTAL UPWELLING SYSTEM: PHYSICS, ECOSYSTEMS AND RESOURCE

Jeffrey D. Paduan, Associate Professor
Department of Oceanography
Sponsor: Monterey Bay Aquarium Research Institute

OBJECTIVE: We proposed to model the oceanographic processes within the Monterey Bay National Marine Sanctuary (MBNMS) at high resolution (KMS). A large body of observations is available from the region for model validation. The high-resolution coastal model will be nested within basin-scale and regional models. The model included physical, chemical and biological properties and was capable of assimilating data from satellites and in situ sensors. The model will focus on simulation the observed strong seasonal and inter-annual variations in oceanographic processes. The Naval Postgraduate School

PROJECT SUMMARIES

scientists participated through quality control and interpretation of physical oceanographic data sets from the Monterey Bay region.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Ocean Currents, Ocean Waves, Air-Sea Interaction

MODELING AND OBSERVATIONS OF SURFACE WAVES IN MONTEREY BAY

Jeffrey D. Paduan, Associate Professor
Ly Ngoc Le, Research Associate Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: This project investigated surface waves in Monterey Bay and their roles in air-sea momentum transfer and high frequency (HF) radar backscatter. These objectives were accomplished by extending the Innovative Coastal-Ocean Observing Network (ICON) program, which is ongoing under sponsorship of the National Ocean Partnership Program (NOPP). Critical air-sea measurements will be collected during summer and fall 1999 using a Flux buoy. Reynolds stresses, directional gravity wave spectra, and capillary wave spectra collected on the buoy will be compared to Doppler Backscatter Spectra measured by the existing HF radar network. This data was used to validate and refine a new turbulence sub model parameterization being developed for numerical circulation models based on surface wave characteristics. As part of this project, the turbulence model was incorporated within ongoing modeling and data assimilation efforts.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Ocean Currents, Ocean Waves, Air-Sea Interaction

LAGRANGIAN DATA ANALYSIS IN MESOSCALE PREDICTION STUDIES

Pierre-Marie Poulain, Assistant Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The main objective of this project was the development and application of new methods of investigation for the use of Lagrangian data in mesoscale problems. Particular focus was given to the use of Lagrangian data in coastal regions and semi-enclosed basins. Two specific studies are proposed using surface drifter in the Adriatic Sea and Sicilian Channel:

- The investigation and prediction of mesoscale processes in the two regions,
- The estimation of Lagrangian errors, which can be important for the intercomparison between data and model results.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Marginal Seas and Straits, Circulation, Drifters, Errors, Prediction

LAGRANGIAN MEASUREMENTS IN ICELANDIC WATERS

Pierre-Marie Poulain, Assistant Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The proposed drifter analyses will focus on surface currents around Iceland in order to define the main pathways and describe their eddy and seasonal variability. We processed individual drifter records to remove high frequency inertial/tidal signal before creating low-passed, uniformly sampled (6-

PROJECT SUMMARIES

hour interval) trajectories. We produced seasonal maps of mean currents and eddy kinetic energy at 1-degree longitude x .5-degree latitude resolution. The Lagrangian nature of the drifters was exploited to estimate decorrelation time and length scales and eddy diffusivities in selected regions. We also estimated array biases in the mean current estimates, which may be a limiting factor to obtaining accurate advection and diffusion rates. Higher statistics were also computed to estimate energy transfer rates between mean and eddy currents and to study the heat transport by the surface currents.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Upper Ocean Circulation, Lagrangian Drifters

MEDITERRANEAN SURFACE CIRCULATION STUDIES

Pierre-Marie Poulain, Assistant Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The spatial structure and the temporal variability of the surface circulation of the Mediterranean Sea were studied using a comprehensive drifter data set and ancillary satellite observation. First, seasonal maps of the Mediterranean surface mean currents and eddy variability will be compiled. Lagrangian statistics (eddy diffusivity, time and space scales) will also be estimated. Second, horizontal fluxes of momentum and heat near the surface of the Adriatic and Ionian Seas were estimated from the drifter and satellite data. They related to the surface atmospheric fluxes as provided by wind products and observations. Third, the drifter data will be combined with passive remote sensing data (sea surface temperature and ocean color) to study the mesoscale circulation in selected regional area, such as the Adriatic Sea and the straits of Sicily region. Finally, studies were conducted to compare modeled and observed near-surface drifter trajectories in the Adriatic with the goal of improving future drifter deployment strategies and of assessing model capabilities.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Circulation, Lagrangian Drifters, Remote Sensing, Mediterranean Sea

ADRIATIC SEA CIRCULATION: TIDAL AND WIND-DRIVEN CURRENTS IN CROATIAN COASTAL WATERS

Pierre-Marie Poulain, Assistant Professor

Curtis Collins, Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: The variability of the currents and water mass properties in the Adriatic Sea will be studied at the tidal/inertial to seasonal scales using a variety of Lagrangian, Eulerian and Satellite data sets.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Tides, Circulation, Sea Surface Temperature, Coastal Environment

GLOBEC: MOORED CURRENT OBSERVATIONS ALONG THE EUREKA LTOP TRANSECT

Steven R. Ramp, Research Professor

Department of Oceanography

Sponsor: National Oceanographic Atmospheric Agency

OBJECTIVE: The over-arching goal of the Global Ocean Ecosystems Dynamics (GLOBEC) Northeast Pacific Program (NEP) is to understand the effects of climate variability and climate change on the

PROJECT SUMMARIES

distribution, abundance and production of marine animals in the eastern North Pacific Ocean. The objective of the five-year Long-Term Observation Program (LTOP) moorings is to monitor the temporal and spatial variability of the currents and bottom temperature over the continental shelf off Oregon, from tidal to interannual scales, and relate this physical variability to long-term changes in the ecosystem.

SUMMARY: The first set of moorings were deployed during May 2000 and turned around during September 2000. The moorings will be recovered and redeployed during March 2001 and September 2001, and twice per year thereafter for 3 more years. One bottom-mounted instrument in a trawl-resistant housing was still on site but failed to surface on command. An effort to recover it using an ROV failed during November 2000 and a second attempt using a much better ROV will be made during summer 2001. The temperature and salinity data showed one very pronounced warm fresh event during June 2000 due to onshore advection of Columbia River Plume water from offshore. The autospectra showed a clear peak at 19 days, in addition to the usual tidal and inertial energy.

PRESENTATION:

Ramp, S.R., 2000: First results from the Global Ocean Ecosystems Dynamics (GLOBEC) Northeast Pacific (NEP) Long-Term moorings off the Rogue River, Oregon, presented at GLOBEC NEP Investigators Workshop, Corvallis, OR, November 2000.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Coastal Oceanography, Upwelling Fronts, Ecosystem Dynamics, GLOBEC

ASIAEX PROJECT MANAGEMENT

Steven R. Ramp, Research Professor
Ching-Sang Chiu, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: Dr. Ramp acted as the international scientific coordinator for the Asian Seas International Acoustics Experiment (ASIAEX), assisted by Dr. Chiu. He coordinated Office of Naval Research activities in the South and East China Seas during 2000 and 2001 with the People's Republic of China (PRC), Taiwan, Singapore, Korea, Japan and Russia. This involved planning and coordinating and ASIAEX International Workshop in Hawaii during June 2000, assisting with research vessel clearances, and an extensive planning trip to the PRC during fall of 2000. The major field efforts took place during Spring 2000 and Spring 2001. Dr. Ramp and Dr. Chiu also assisted the Office of Naval Research with the overall coordination of the data distribution and scientific analysis following the execution of the field program.

DoD KEY TECHNOLOGY AREAS: Other (Battlespace Dominance)

KEYWORDS: Coastal Oceanography, Environmental Acoustics, South China Sea, East China Sea

INTERNAL WAVES AND TURBULENCE IN MONTEREY SUBMARINE CANYON

Leslie K. Rosenfeld, Research Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: Determine the fine scale shape and level of the vertical wave number spectra for vertical displacement and horizontal velocity as compared with the open ocean Garrett-Munk model. Determine the spatial scale and heterogeneity of the internal wave field as a function of vertical, along-and across-

PROJECT SUMMARIES

canyon position. Determine the anisotropy of the internal wave field to evaluate where the dominant semidiurnal tide is best described as propagating, and where as standing.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Internal Waves, Turbulence, Submarine Canyons

IN-SITU EVALUATION OF OCEANOGRAPHIC PRODUCTS FOR THE METOC COMMUNITY

Leslie K. Rosenfeld, Research Associate Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: Evaluated the METOC community's use of oceanographic products in the METOC centers and facilities and, to the extent feasible, at sea and in the field. The emphasis will be on new products for use in the littoral zone.

DoD KEY TECHONOLGY AREAS: Battlespace Environments

KEYWORDS: METOC, Oceanographic Products

SIMULATIONS AND RECONSTRUCTIONS OF GLOBAL OCEAN CIRCULATION WITH WELL-RESOLVED EDDIES FOR THE WOCE OBSERVING

Albert J. Semtner, Professor

Department of Oceanography

Sponsor: National Science Foundation

OBJECTIVE: Two relatively complete global ocean models have already been used to simulate ocean circulation of 1985-89. Both models use a Mercator Grid for better resolution at high latitudes and employ a prognostic free surface with very realistic geometry. One model has a ¼ degree average grid and runs on an Y/MP; the other has a 1/6-degree average grid and runs on a CM-5. It is proposed to test improved physical formulations and to prepare analyzed wind fields and observed heat flux and freshwater fluxes for the models. Techniques will be tested to incorporate satellite altimeter data. Simulations will be conducted, with and without satellite data, for the WOCE observing period 1991-1997. A final integration used a ½ degree 40 level models. Model output was shared freely with others.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Simulations, Reconstructions, Ocean Circulation

APPLICATION OF PARALLEL OCEAN AND CLIMATE MODELS TO DECADE/CENTURY PREDICTION

Albert J. Semtner, Professor

Department of Oceanography

Sponsor: Department of Energy

OBJECTIVE: It is proposed to continue research initially funded under the CAHMMP program in order to advance the science of decade to century climate predication. Using models developed under CHAMMP, we will examine the variability and predictability of the climate system by a three-pronged approach. We will represent the state of the global ocean at high resolution on a new generation of computers, use and eddy active global ocean model having realistic natural variability, along with decadal atmosphere forcing, to find modes of decadal variability, their causes, and the predictability of such phenomena, and use a coupled climate model to explore decade to multi-century variability and to undertake climate predictions out to the limits of predictability.

PROJECT SUMMARIES

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Supercomputing, Environment, Prediction

DEVELOPMENT OF A NEW ARCTIC ICE-OCEAN PREDICTION SYSTEM

Albert J. Semtner, Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: Work was continued on a new, high-resolution (less than 10km) Arctic and Sub-Polar Ice Prediction System (PIPS 3.0). This coupled with air-ice-ocean model will include an ice model capable of resolving large leads and polynyas, and ocean and atmospheric boundary layers with improved flux parameterizations. Efforts will involve evaluating potential rheology and fracture mechanics mechanisms, determining validation procedures, and assessing required input data and data assimilation approaches.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Sea Ice, Numerical Modeling, Supercomputing, Satellite Microwave

UPPER OCEAN EFFECTS ON THE SURFACE HEAT BUDGET OF THE ARCTIC

Timothy P. Stanton, Research Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: This proposal was to determine mixed layer and upper pycnocline heat fluxes over a 14-month observation period as a component of the surface heat budget of the Arctic Ocean (SHEBA) experimental program.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Air-Ice-Sea Interaction, Oceanic Mixed Layer, Global Climate

COLLABORATIVE RESEARCH: THE ROLE OF ICE-OCEAN EXCHANGE IN ICE-ALBEDO FEEDBACK

Timothy P. Stanton, Research Associate Professor
Wieslaw Maslowski, Research Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: We proposed to utilize data sets collected during the SHEBA field program and other related programs (E.G. SCIEX) to study the processes controlling the Ice Albedo Feedback (IAF) mechanism over an annual cycle and their role in the ice-ocean-atmosphere interactions. We will quantify the impact of the interactions, develop, implement and test parameterizations of most critical processes using a series of models ranging from local process models to basin and global sea-ice-ocean models. The main goal of these activities is to improve simulation of the Pan-Arctic region in global climate models to advance their skill in climate change prediction.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: SHEBA, Ice Albedo Feedback, Pan-Arctic Region

PROJECT SUMMARIES

SPECTRAL WAVE DECAY DUE TO BOTTOM FRICTION ON THE INNER SHELF

Timothy P. Stanton, Research Associate Professor

Edward B. Thornton, Distinguished Professor

Department of Oceanography

Sponsor: Office of Naval Research

OBJECTIVE: Improve existing models for wave/current bottom boundary layer dissipation, and test model formulations with new field measurements. The measurements will be used to identify the essential physical processes and to represent them in a form that is both realistic and simple enough to incorporate into the Swan model framework.

THESES DIRECTED:

Dixon, D.B., "Evolution of Bedforms on the Inner-Shelf," Masters Thesis, Naval Postgraduate School, September 2000.

Lamb, D.R., "Heat Fluxes Associated with Intrusions During the SHEBA Ice Station Drift," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Waves, Wave Dissipation, Boundary Layers, Inner Shelf

DEVELOPMENT AND VERIFICATION OF A COMPREHENSIVE COMMUNITY MODEL FOR PHYSICAL PROCESSES IN THE NEARSHORE OCEAN

Edward B. Thornton, Distinguished Professor

Thomas H. C. Herbers, Associate Professor

Oceanography Department

Sponsor: Office of Naval Research

OBJECTIVE: The objective is to develop and validate a comprehensive community model for predicting waves, currents and evolving bathymetry in the nearshore region.

SUMMARY: The project is centered on the construction and extensive verification of a comprehensive community model aimed at predicting wave-driven physical processes in the nearshore region. The model will consist of four coupled modules that predict: (1) nearshore wave climate and resulting wave radiation stresses over an evolving coastal bathymetry, (2) wave-induced circulation including mean flows and infragravity fluctuations, (3) sediment transport and bottom bedform conditions, and (4) the resulting morphological evolution. Extensive field data collected at Duck, North Carolina and other sites are being used to test the models.

Professor Thornton's role in this project is to develop models for bedforms and associated enhanced bed friction and wave dissipation, and to provide field measurements of the vertical structure of currents to test models. He collaborated with John Allen at Oregon State University to examine the effects of changing tidal elevation on nearshore circulation. He has examined the migration and evolution of vortex wave ripples comparing the numerical model DUNE2 with field data.

Professor Herber's role is to develop stochastic models for predicting the nearshore wave climate and associated wave radiation stresses and to validate these models with existing field data. A model for wave shoaling evolution on a gently sloping beach based on a third-order statistical closure of Boussinesq equations (Herbers and Burton, JGR, 1997) is being extended through the surf zone. A heuristic parameterization of surf zone dissipation was completed and evaluated with field data. Improvements of the representation of infragravity waves in the model and an extension of the model to weak alongshore depth variations are currently underway. Model predictions of the nonlinear transformation of frequency and directional wave spectra are generally in good agreement with field data collected during DUCK94 and

PROJECT SUMMARIES

SandyDuck experiments. The model reproduces the growth of harmonic peaks in the spectrum followed by a flattening of the high-frequency tail, energy transfers to infragravity frequencies, and the attenuation of the spectral peak in the surf zone resulting from energy transfers to higher frequencies.

CONFERENCE PRESENTATIONS:

Newberger, P.A., J.S. Allen, and E.B. Thornton, "Model Studies of Tidal Elevation Changes on Nearshore Circulation," American Geophysical Union Fall Meeting, San Francisco, CA, December 2000.

Martin, S.D., E.B. Thornton and T.P. Stanton, "DUNE2D Modeling of Vortex Ripple Migration," American Geophysical Union Fall Meeting, San Francisco, CA, December 2000.

DOD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Nearshore, Waves, Surf, Currents, Morphology

SURF MODEL

Edward B. Thornton, Distinguished Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: It is proposed to transition the DELFI3D Wave, circulation and morphology model to improve the U.S. Navy's surf model. The present surf model is limited by the assumptions of simplified bathymetry and hydrodynamics. Improvements by the DELFI3D model will include allowing realistic bathymetry, an improved wave driver, 3D effects and the ability to predict morphology changes. The object of the proposal was to assess the accuracy and robustness of the model by comparing it with existing comprehensive field data, to make improvements where appropriate and to transition the model to be used by the Navy.

THESIS DIRECTED:

Kendall, R., "Seafloor Roughness in the Nearshore, Coast 3-D Experiment," Egmond ann Zee, Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Nearshore, Littoral Waves, Currents, Sediment Transport

NEARSHORE WAVE AND SEDIMENT PROCESSES

Edward B. Thornton, Distinguished Professor
Department of Oceanography
Sponsor: Office of Naval Research

OBJECTIVE: The scientific objectives are to predict the vertical distributions of velocity and stress, and associated sediments transport and morphologic changes due to waves and currents in the nearshore including breaking waves. We propose to continue modeling and analysis of data acquired during Sandyduck, to participate in a high energy surf zone experiment at Monterey and to participate in a prototype-scale laboratory experiment in the CIEM facility in Spain.

THESIS DIRECTED:

Plager, W.L., "Mine Burial in the Surf Zone," Masters Thesis, Naval Postgraduate School, September 2000.

PROJECT SUMMARIES

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Nearshore, Littoral, Waves, Currents, Sediment Transport

MEGARIPPLES IN THE SURF ZONE

Edward B. Thornton, Distinguished Professor
Edith L. Gallagher, Research Associate Professor
Department of Oceanography
Sponsor: National Science Foundation

OBJECTIVE: It was proposed to measure, analyze and model small-scale morphology, focusing on Megaripples (bedforms with heights up to 50cm and lengths of 1-10 m). Megaripple data and bottom stress measurements acquired during the Sandyduck experiment will be analyzed. It is proposed to participate in two Coast 3D comprehensive nearshore experiments in Holland (1998) and England (1999) using their WESP to mount our array of acoustic altimeters and side-scan sonar to measure megaripples in the nearshore. In addition, we measured bottom shear stress using Sontc ADVs. The data was analyzed to test predictive models and test hypotheses concerning the generation, orientation and effect on the hydrodynamics of megaripples.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Morphology, Ripples, Waves, Littoral Processes, Nearshore

MODELING DISSIPATION WITHIN THE WAVE BOTTOM BOUNDARY LAYER

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

OBJECTIVE: Improve existing models for wave/current bottom layer dissipation, and test model formulations with new field measurements. The measurements will be used to identify the essential physical processes and to represent them in a form that is both realistic and simple enough to incorporate into the Swan model framework.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Waves, Bottom Stress, Morphology

INTERANNUAL TO DECADEAL OCEAN VARIABILITY AND PREDICTABILITY

Robin Tokmakian, Research Assistant Professor
Albert J. Semtner, Professor
Julie McClean, Research Associate Professor
Department of Oceanography
Sponsor: National Aeronautics and Space Administration

OBJECTIVE: It is proposed to extend the research currently funded under TPEN NRA. We propose to continue this work further by combining eddy resolving ocean model simulations and altimeter data to understand how predictable the variability in the ocean is and how much of it is related to the sea surface height signal. These high-resolution ocean models result in better representations of strong ocean currents and their heat and salt transports, as well as forced and spontaneous modes of variability that limit predictability. Through the use of the long time series of reanalyzed surface forcing fields provided by the world's meteorological agencies, the evolution of the global ocean could be simulated for extended periods. The goal of the research will be accomplished by further analyses to determine the accuracy of ocean

PROJECT SUMMARIES

variability in simulations of 20 years with high resolution models, in part with T/P and JASON-1 data; conducting ensemble simulations with variations of forcing prediction runs of a coupled ocean-ice-atmosphere model with T/P and OPR JASON-1 altimetry data contributing to the initialization of model fields. The simulations will be conducted on non-NASA computers, which are available through complimentary research grants to the PIs.

DoD KEY TECHNOLOGY AREAS: Other (Environmental Prediction)

KEYWORDS: Environment, Prediction, Supercomputing, Satellite Altimetry

ANTARCTIC BOTTOM WATER, POLYNYAS, AND THE ANTARCTIC CIRCUMPOLAR WAVE IN HIGH-RESOLUTION COUPLED GCMS

Yuxia Zhang, Research Assistant Professor

Albert J. Semtner, Professor

Department of Oceanography

Sponsor: National Science Foundation

OBJECTIVE: To understand the effect of Antarctic polynyas on the ventilation of the abyssal ocean, and the role of Antarctic sea ice and Southern Ocean in global climate, using high-resolution global ocean, atmosphere, and sea ice models that are capable of depicting the coastal polynyas while still allowing their impact to spread into the world ocean.

SUMMARY: This three-year project is in its first of three years. We are collaborating with large climate modeling efforts at Los Alamos National Laboratory and at the National Center for Atmospheric Research. Extensive simulations are underway.

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DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Numerical Modeling, Southern Ocean, Parallel Computing

**DEPARTMENT OF
OCEANOGRAPHY**

**2000
Faculty Publications
and Presentations**

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**DEPARTMENT OF
OCEANOGRAPHY**

Thesis Abstracts

THESIS ABSTRACTS

IMPROVING MARITIME SITUATIONAL AWARENESS THROUGH THE CORRELATION OF ELINT-DERIVED SHIP TRACKS AND SONAR TIME-BEARING PLOTS (U)

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Master of Science in Meteorology and Physical Oceanography-March 2000

Advisors: James H. Wilson, Department of Oceanography

Robert H. Bourke, Department of Oceanography

Second Reader: Alan A. Ross, Navy Tactical Exploitation of National Capabilities (TENCAP) Chair

The purpose of this study was to facilitate the development of a dynamic acoustic noise model based upon correlation of shipping locations and tracks obtained from electronic intelligence (ELINT) and sonar time-bearing tracks from acoustic arrays. This marriage of tracking sources was achieved through the development of the Multiple-Intercept Data Fusion (MIDF) process during the analysis of ELINT and acoustic data collected during FBE-E (Fleet Battle Experiment-Echo). All 28 of the ELINT multiple-intercept tracks of U.S. assets available for comparison with ground truth were correctly identified as military platforms. Twenty-one vessels were correctly typed by category (e.g., DDG, CG) and 19 were accurately identified by hull name.

Correlation between ELINT tracks and acoustic tracks also yielded great success. Of the 28 multiple-intercept ELINT tracks, 23 (82%) were matched to acoustic tracks. Numerous examples were developed to show that when ELINT intercepts are absent, detectable acoustic signatures permit the continued tracking of a vessel. Likewise, the possibility exists to continue tracking a vessel with ELINT data should the acoustic plot become congested as in a near-shore environment. The marriage of ELINT and acoustic tracking methods provides great promise for improving the ship tracking capabilities of the warfighter.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: ELINT, Acoustic, Ship Tracking

EVOLUTION OF BEDFORMS ON THE INNER-SHELF

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Observations of the temporal evolution of the wave-formed ripples are analyzed in terms of geometric properties, migration rate, and forcing by wave and current velocities. Three weeks of bedform observations were obtained using underwater video of a sheet of laser light projected on the bed at the Monterey Bay Inner Shelf Observatory in thirteen-meter depth water. The bed consists of fine sand (mean grain size 0.12mm). Low to moderate narrow-band swell waves occurred during the observation period. Ripple geometry consisted of orbital and suborbital vortex wave ripples, and relic ripples left after larger wave events. The bedforms generally changed size and shape when the grain roughness Shields parameter exceeded a critical value of 0.04 with the exception of the last event bringing into question the appropriate value of Z_{crit} in nature. Ripple migration was offshore at rates of 2-10 cm/day during active sediment transport events. Skewness of velocities (low and high passed) were calculated to explain offshore ripple migration, but showed no preferred direction. Mean currents were weak and also showed no preferred direction. Significant positive (offshore) correlation was obtained between the short-wave envelope and infragravity waves indicating wave-group forced bound long waves (surf beat) combined with stirring by the short waves might explain the offshore sediment transport and ripple migration.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Ripples, Sediment Transport, Shields Parameter, Bound Long Waves

THESIS ABSTRACTS

U.S. AND AUSTRALIAN MINE WARFARE SONAR PERFORMANCE ASSESSMENT USING SWAT AND HODGSON MODELS

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The purpose of this thesis was to investigate a shallow coastal region to compile a detailed environmental picture of its sediment composition and water characteristics and from this model MCM sonar performance at the FBE-H exercise location as a means to determine what parameters exerted the greatest effect on performance. Seven parameters were intercompared to assess their sensitivity in detecting mines: bottom type, SSP, water depth/sonar depth, mine depth, frequency, sonars and models. Performance was assessed using several measures of effectiveness including the signal to noise ratio and initial detection range. Variations in these measures were analysed by investigating how TL and RL responded to changing parameters.

No one single parameter was identified that affected sonar performance significantly above all others. Of the environmental parameters considered, variations in bottom type exerted the most influence on TL and RL and ultimately on sonar performance. TL was clearly a significant factor when the bottom type is comprised of absorptive, fine-grained material. Of the sonar parameters, frequency exerted a significant impact on performance with TL the most sensitive term in this comparison. A higher TL associated with higher frequency reduced the signal level and consequently the bottom RL. The higher frequency displayed a stronger SNR than the lower frequency over short ranges, however the higher frequency was limited by TL at greater ranges with the lower frequency achieving greater initial detection ranges.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Reverberation, Bottom Backscatter, Mine Warfare, PC SWAT Model

HIGH FREQUENCY SONAR COMPONENTS OF NORMAL AND HEARING IMPAIRED DOLPHINS

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A data acquisition device was constructed and tested to obtain toothed whale (Bottlenose Dolphin and Beluga Whale) sonar signals and digitally store them to a PC hard drive. The device had the capability of capturing sonar signals by means of a two-hydrophone array, and a digital video camera in a submersible housing. Cooperation with marine biologists at SPAWAR Systems Center-San Diego enabled the sampling of three animals performing echolocation tasks. Their sonar signals, transmissions of rapid high frequency pulses called clicks, were recorded for further processing. Once the data was captured on video and hard disk drive, it was processed using MATLAB.

Data from three different toothed whales, a normal Bottlenose Dolphin, a Bottlenose Dolphin with a hearing impairment and a Beluga Whale, was analyzed. It was observed that the animals reduced the interval between clicks when they located a target. Correlating the signal data to the video data made this observation possible. It appeared the animals searched with widely spaced clicks, then narrowed the click period upon target detection. Also, it was noted that the frequency of isolated clicks decreased as click period decreased. However, the hearing impaired Dolphin maintained his click frequency regardless of click periodicity.

THESIS ABSTRACTS

DoD KEY TECHNOLOGY AREAS: Electronics, Sensors, Computing and Software

KEYWORDS: Marine Mammal Systems, Bio-SONAR, Mine Detection, Dolphin SONAR, Echolocation Signals

SHALLOW WATER BATHYMETRY AT LAKE TAHOE FROM AVIRIS DATA

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One of the United States Navy Oceanographic community's roles is to keep an accurate worldwide database of oceanic bathymetry. In the littoral zones, much of the data is out of date or is unavailable. Stuffle et al. (1996) utilized a method addressing shallow water areas using the Hyperspectral Digital Imagery Collection Experiment (HYDICE) sensor on a small region in Lake Tahoe. As a follow-on, this work used a different sensor, the Airborne Visible/InfraRed Imaging Spectrometer (AVIRIS) sensor, and covered a much larger area on the opposite side of the lake. Principle components analysis (PCA) of the region of interest (ROI) revealed nine spectrally unique water classes. *A priori* knowledge of one bottom type in this ROI allowed insertion of a known bottom reflectance spectrum into a derived computer algorithm that, using also diffuse attenuation coefficients from HYDROLIGHT and reflectance just below the water surface derived from AVIRIS data, allowed computation of the bottom depth. Results compared within 30% of depth from a USGS bathymetric chart. This method holds much promise in clear waters, and next needs to be tested in the coastal ocean environment.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: AVIRIS, Hyperspectral, Bathymetry, Lake Tahoe, Optical Properties of Water

INFERRING BOTTOM ACOUSTIC PROPERTIES FROM AN/SQQ-32 SONAR REVERBERATION DATA

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Inversion techniques are used to infer bottom geoacoustic properties using AN/SQQ-32 Reverberation Level (RL) data gathered by USS Avenger (MCM-1) in Rhode Island Sound in February 1993. Based on the hypothesis that the magnitude of backscattered energy is directly related to the acoustic reflectivity of the seabed, a statistical analysis of beam RL time series was conducted to determine its correlation with sediment geoacoustic character.

A technique was developed using the deviation of the RL for an individual ping/beam from an area-wide average RL to generate geographic maps illustrating bottom geoacoustic characteristics. Resulting plots of "relative reflectivity" not only agreed with the existing descriptions of sediment distribution, but also provided more detailed spatial representation of bottom geoacoustic distribution. This highlighted the gross inadequacies, particularly in spatial resolution, of existing information on bottom geoacoustic distribution.

These plots, when produced using appropriately small sample intervals, have sufficient spatial resolution to expose MCM clutter density information. Geographic maps of relative reflectivity can provide an invaluable aid to planning search strategy, a surveying tool to compare clutter densities, appropriate geoacoustic parameters for accurate model (including full wave) predictions, and a means of

THESIS ABSTRACTS

real time performance monitoring and assessment (providing the ability to revise and modify search strategy).

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

KEYWORDS: Acoustics, Reverberation, Bottom Backscattering, Geoacoustics, Oceanography, Inversion Techniques, MCM Sonar Operations, AN/SQS-32

SAND BED ROUGHNESS IN THE NEARSHORE, COAST 3D EXPERIMENT, EGMOND AAN ZEE, THE NETHERLANDS

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Sand bed roughness was measured in the nearshore during a variety of hydrodynamic conditions using an array of seven 1 MHz sonar altimeters mounted on the WESP (an amphibious vehicle used for measuring large-scale bathymetry) during the COAST 3D Experiment 1998, at Egmond aan Zee, The Netherlands. Corollary waves were modeled using the Thornton and Guza (1983) wave transformation model. Wave height and current measurements were made in the surf zone using pressure sensors and electromagnetic current meters, and offshore wave heights were measured using an advective wave-rider buoy. Measurements of sand bed roughness showed patterns similar to those observed by Clifton et al. (1971), but are highly variable both spatially and temporally with dependence on large scale morphology and wave and current conditions. Mobility number (Ψ) calculated from the modeled wave field and also from measured currents revealed that roughness is a function of Ψ . Roughness was observed to be highly variable at low Ψ (< 100) calculated from the modeled wave heights. As Ψ increased (100-150), roughness decreased gradually, but was still highly variable. As Ψ reached values greater than 150, roughness was restricted to the lowest observed values (< 3 cm) implying planar beds under sheet flow conditions.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Sand Bed Roughness, Megaripples, Ripples, Sediment Transport, Nearshore Processes, Morphology

INTERNAL TIDAL BORES IN THE MONTEREY CANYON

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A thirty-four day record of near-bottom temperature and horizontal velocity spanning the lower third of the water column from within Monterey Canyon was examined. The observed internal tide is highly non-linear with kinetic energy dispersed among numerous overtides near the bottom and more concentrated in the primary semi-diurnal constituent (M_2) higher in the water column. The bottom currents and temperature vary in strength over the record period, taking on the characteristics of an internal bore at times with large up-canyon accelerations accompanied by rapid temperature drops. The bores are nearly phase locked to the sea level variations and arrive at the measurement site ~ 8.6 h after high tide in Monterey, CA. They are evident in the velocity records up to at least 35-m above the bottom and may be accompanied by high frequency pulses that extend higher. The variation is not caused by direct forcing from the barotropic

THESIS ABSTRACTS

tidal range as the strongest bores do not exclusively occur during either the spring or neap phase of the barotropic tide. Speculation on the cause for the temporal variation centers on changes in mid-water stratification observed.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Internal Wave, Internal Bore, Tidal Bore, Internal Tides, Tides, Waves

LARGE EDDY SIMULATION OF INTERACTIONS BETWEEN FREE CONVECTION, WIND DRIVEN CURRENTS, AND BAROCLINICITY IN THE LABRADOR SEA DEEP MIXED LAYERS

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Understanding the dynamics of deep convection leading to the formation of deep water is important not only for studying the small-scale generation regions, but also for studying the global-scale thermohaline circulation. Large Eddy Simulation (LES) is used to model deep convection with an imposed mean horizontal density gradient of two different strengths and wind forcing from various directions, with strong surface cooling representative of the Labrador Sea. Results from these different cases are compared and analyzed to understand the effects of horizontal density gradients and wind direction on turbulence statistics for deep convection. Both the strength of horizontal density gradients and wind direction relative to the gradient affect mixed layer scalar variances, turbulent vertical fluxes, Vertical Turbulent Kinetic Energy (VTKE), and stability during deep convection.

Wind direction dominates over gradient strength in determining vertical flux magnitude with larger variation in strong gradient cases. Levels of VTKE are more dependent on gradient strength, with weaker gradients producing higher values of VTKE than stronger gradients regardless of wind direction. Wind direction does alter VTKE levels in the same manner as it alters vertical flux levels. The presence of a horizontal gradient is a stabilizing factor in areas of strong surface cooling.

DoD KEY TECHNOLOGY AREA: Other (Meteorology and Oceanography)

KEYWORDS: Large Eddy Simulation, Deep Convection, Labrador Sea, Baroclinicity

HEAT FLUXES ASSOCIATED WITH INTRUSIONS DURING THE SHEBA ICE STATION DRIFT

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A yearlong set of temperature and salinity profiles from the Surface Heat Budget of the Arctic (SHEBA) is analyzed to identify intrusions from the mixed layer to a depth of 150 meters. Ensemble averaged temperature and salinity profiles, spectral analysis of the vertical thermal structure, and bathymetry are used to divide the SHEBA ice station track into four regions: Beaufort Sea; Northwind Rise and break; Chukchi Plateau and break; Mendeleev Abyssal Plain. Average vertical gradients of temperature and salinity over intrusive features are used to calculate Turner angles and molecular heat fluxes. Bering Sea Summer Water dominates the structure in the temperature and salinity profiles of the Northwind Rise region, with a maximum temperature intrusion of 2.2°C. Cold intrusions penetrate the upper halocline in the Chukchi Plateau region. The width of the distribution of Turner angle in the vertical profiles is indicative of the degree of the interleaved structure. Mesoscale features and associated internal wave activity accompany highly variable vertical structure over the Northwind Rise and Chukchi Plateau regions. The role of

THESIS ABSTRACTS

intrusions in lateral mixing and lateral heat transport is discussed in context of the observed regional differences in water mass properties.

DoD KEY TECHNOLOGY AREA: Battlespace Environments, Modeling and Simulation

KEYWORDS: SHEBA, Intrusions, Heat Fluxes, Halocline, Double-diffusion, Turner Angle

DRIFTER OBSERVATIONS OF THE MEDITERRANEAN SEA SURFACE CIRCULATION

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Master of Science in Physical Oceanography-March 2000

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Since June 2, 1986, several institutions have conducted a variety of drifter studies within the Mediterranean Sea for scientific and operational purposes. The data from these studies include 521 individual drifters and span over 13 years. This thesis examines these data in an effort to better describe the Mediterranean Sea surface circulation. Interpretation of the data is conducted by calculating Eulerian and Lagrangian statistics and evaluating some of the errors they contain.

An Eulerian framework is employed that best represents the surface flow throughout the Mediterranean Sea as a combination of a deterministic mean and fluctuations due to temporal and mesoscale variability. The results of the Eulerian statistics are presented as charts of Mean Kinetic Energy (MKE), Eddy Kinetic Energy (EKE), mean flow, and velocity variance. Seasonality is analyzed in regions where temporal and spatial coverage of drifter observations is adequate. Drifter wind slippage errors and array biases are evaluated to possibly determine a valid correction. The Lagrangian statistics: diffusivity, velocity covariance, and integral time and space scales are computed.

The Eulerian and Lagrangian surface circulation statistics computed from the drifters are in general similar, but much improved and more accurate, to those presented in earlier works.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Mediterranean Sea, Surface Circulation, Drifter, Lagrangian Methods, Eulerian Methods

THE ROLE OF THE PLANETARY BETA EFFECT ON CURRENTS AND MEDDIES IN THE NORTHERN CANARY CURRENT SYSTEM

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Master of Science in Meteorology and Physical Oceanography-June 2000

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To investigate the role of planetary beta on classical as well as unique features in the northern Canary Current System (NCCS), four numerical experiments are conducted with varying Coriolis parameterizations (f -plane or Ξ -plane). The first two experiments use a closed boundary and annual salinity forcing for the Mediterranean Outflow (MO). The latter two experiments use an open Mediterranean Sea at the Strait of Gibraltar and seasonal forcing for MO to permit a more accurate investigation of the role of the beta effect on subsurface spreading of MO and Meddies. All four experiments use seasonal climatological winds and seasonal thermohaline gradients along the western boundary to force the model. Experiments run on a Ξ -plane (Experiments 2 and 4) accurately portray classical eastern boundary current (EBC) mesoscale features. In addition, these experiments depict unique NCCS features associated with a large embayment (the Gulf of Cadiz), poleward spreading of MO, and the generation of Meddies. Experiments run on an f -plane (Experiments 1 and 3) show the unrealistic dominance of a continuously strengthening equatorward jet that inhibits development of classical EBC and unique NCCS features. The complex upper

THESIS ABSTRACTS

layer and subsurface flow regimes of Experiment 4 most realistically portray currents, mesoscale features and Meddies similar to NCCS observations.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Primitive Equation Model, Northern Canary Current System, Currents, Meanders, Eddies, Meddies, Filaments, Mediterranean Outflow

A COMPARISON OF OUTPUT FROM THE LOS ALAMOS NATIONAL LABORATORY (LANL) PARALLEL OCEAN PROGRAM (POP) MODEL WITH SURFACE VELOCITY DATA FROM DRIFTING BUOYS IN THE NORTH ATLANTIC OCEAN

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Surface velocity fields from two configurations of the Los Alamos National Laboratory (LANL) Parallel Ocean Program (POP) model are compared to surface velocity data from satellite-tracked buoys in the North Atlantic. Separate analyses are conducted for each model configuration. In the first analysis, output from a 1/6-degree, 20-level model version is compared with five years (1993-1997) of drifter data, based on both Eulerian and Lagrangian statistics. In the second analysis, newly-available output from a 1/10-degree, 40 level version is compared to a two-year subset (1993-1994) of the data, and to 1/6-degree output over the same time frame. The latter comparison is based on Eulerian statistics alone.

The five-year comparison shows that the 1/6-degree model produces inaccuracies in some features, and generally underestimates velocity variance. Modeled Lagrangian time scales are too long, while the length scales are too short. The two-year comparison shows that at the higher vertical and horizontal resolution of the 1/10-degree model, there is a striking improvement in the spatial distribution of energy and resolution of the variance field.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Battlespace Environments

KEYWORDS: Numerical Modeling, Ocean Forecasting, Model Evaluations

VOID FRACTION UNDER BREAKING WAVES

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Bubble injection due to breaking waves within the surf zone is inferred by measuring void fraction using a 3 m vertical array of eight conductivity cells in conjunction with video pixel intensity. Void fraction errors associated with the conductivity measurements are examined, including vertical variations in the temperature and conductivity (measured), proximity effects near the surface, and estimates of the surface elevation using pressure sensors.

Energy loss is due to conversion of kinetic and potential energy of a wave to buoyant potential energy by the injection of air into the water column, which is then lost as the bubbles raise to the surface and escape to the atmosphere. Void fractions up to 40% were observed in intense breaking events penetrating to depths over 0.5 m confined within the crest-trough region. Production of potential energy due to buoyancy of bubbles was nearly instantaneous with the majority of energy dissipating within 0.25 s.

Pixel intensity qualitatively correlated with surface elevation and injection events. Crests in cross-shore intensity time stack plots are clearly visible and show good correlation with breaking events.

THESIS ABSTRACTS

However, pixel intensity values did not correlate quantitatively with surface elevation or production of buoyant potential energy.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Bubble Injection, Void Fraction, Energy Dissipation, Video Pixel Intensity

MINE BURIAL IN THE SURF ZONE

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The volumetric rate of scour and burial of a MK-83 mine by waves in the swash and surf zone were measured in two experiments. The beach was near planar with a 1:40 slope and mean grain size of 0.2 mm. The deep water significant wave height was about 2 m with peak periods of 13 sec. An Acoustic Doppler Velocimeter recorded orbital velocities of the waves. Three dimensional scour was measured manually and with video. Volumetric rate of scour over time relative to the volume of the mine was as high as one during the first hours of mine deployment. Maximum scour volume occurred at 6 hours after deployment and the scour changed from removal to fill after this time. The Shields parameter as a measure of total shear stress experienced by the sand bed was an order of magnitude greater than that required to initiate sediment transport. The mine was completely buried after 24 hours in the surf zone to a depth of 10 cm below the surface of the sand bed.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Mine Burial, Scour, Surf Zone, Mine Warfare

EFFECTS OF THERMOHALINE GRADIENTS AND THE COLUMBIA RIVER PLUME ON THE CALIFORNIA CURRENT SYSTEM

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Master of Science in Meteorology and Physical Oceanography-March 2000

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To study the combined effects of thermohaline gradients and the Columbia River plume on the ocean circulation of the California Current System (CCS), results from three numerical experiments of increasing complexity are examined. In all three experiments, seasonal climatological winds are used to force the model. In the first experiment, the effects of seasonal thermohaline gradients along the western boundary are evaluated. In the second experiment, the additional effects of thermohaline gradients along the northern and southern boundaries are investigated, while in the third experiment, the effect of the Columbia River plume on the CCS is explored. The results from the first two experiments show that thermohaline gradients associated with the North Pacific Central, Pacific Sub-Arctic, and Southern waters help to maintain more realistic temperatures and salinities in the CCS, particularly in the coastal regions. The third experiment shows that the Columbia River plume exhibits a strong seasonal signal with poleward flow close to the coast in winter and equatorward flow farther offshore in summer. The plume also has a significant impact on the near-surface stratification and baroclinic structure of the velocity field of the CCS from Washington to San Francisco.

THESIS ABSTRACTS

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Primitive Equation Model, California Current System, Currents, Meanders, Eddies, Filaments, Columbia River Plume

AMBIENT NOISE CHARACTERISTICS DURING THE SHEBA EXPERIMENT

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The ambient noise data recorded by two free-drifting buoys during the 1997-98 SHEBA experiment presented a unique opportunity to gauge the noise field of the Arctic Ocean in a unique and changing environment. The two buoys drifted in unison for 12 months, providing an hourly ambient noise data set between 50 and 1000 Hz. The drift pattern was divided into five legs in response to the season or major changes in the direction of ice flow. The two buoys exhibited similar median spectra for all frequencies. When examined on a seasonal basis, summer low frequency (< 200 Hz) noise levels were much closer to winter noise levels than past studies. This was mainly due to the low number of storms during the winter of 1997-98, which resulted in lower winter median noise levels. When compared with previous ambient noise studies in the Beaufort Sea, the SHEBA noise data were consistent with the concept that noise levels decrease (especially in summer) during the years when cyclonic atmospheric circulation dominates the west Arctic. Cross correlation analysis indicated a strong association of wind speed and wind stress to ambient noise. Locally measured wind stress (as opposed to that computed using the geostrophic wind) did not substantially improve the correlation with ambient noise. Two tools to conceptualize the Arctic noise field were employed during the SHEBA experiment: the use of RADARSAT with RGPS and the PIPS computation of energy dissipation rate. By comparing the output from these two systems with the ambient noise record, their effectiveness and usefulness as input to an Arctic ambient noise model could be determined. Several notable events in the winter and summer noise record were examined utilizing RGPS and PIPS. The event analysis confirmed the fact that distant noise sources can have an effect on a local noise field. RGPS and PIPS were not useful in the summer due to the open nature of the icepack.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Ambient Noise, SHEBA Experiment

VALIDATION OF THE MINE IMPACT BURIAL MODEL USING EXPERIMENTAL DATA

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Second Reader: Steve Haegar, Naval Research Laboratory

The Navy's Impact Burial Prediction Model creates a two-dimensional time history of a bottom mine as it falls through air, water, and sediment. The output of the model is the predicted burial depth of the mine in the sediment in meters, as well as height, area and volume protruding. Model input consists of environmental parameters and mine characteristics, as well as parameters describing the mine's release. The model user seldom knows many of these parameters, and those that are known may be of questionable precision. In order to run a realistic validation of the model, an experiment was conducted using a simulated mine and carefully controlled observations while simultaneously taking gravity cores. The model was then run and calculated results were compared to observed.

Final results showed the model tended to over predict burial depth by an order of magnitude due to a

THESIS ABSTRACTS

lack of sensitivity to hydrodynamic effects in the water column.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Mines, Sediment, Hydrodynamics, Mine Warfare

THE ROLE OF THE PLANETARY BETA EFFECT ON CURRENTS AND EDDIES IN THE LEEUWIN CURRENT SYSTEM

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Master of Science in Meteorology and Physical Oceanography-September 2000

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To investigate the effect of the role played by planetary beta in the generation and maintenance of the Leeuwin Current System (LCS), several numerical experiments are conducted with varying Coriolis parameterizations (f -plane or β -plane). The seasonal effects of thermal gradients, wind forcing and North West Shelf (NWS) waters are also systematically explored in the numerical experiments. Additionally, the generation mechanisms for undercurrents along both the western and southern coasts of Australia are investigated.

Although surface currents, undercurrents, and mesoscale activity are present in both the f -plane and β -plane experiments, those run on a β -plane show a more realistic depiction of these features due to the significant role played by the planetary beta effect in the LCS. The combination of thermal forcing, wind forcing, and NWS waters were found to be essential to maintain the highly seasonally varying LCS. Alongshore temperature gradients, which are generated at deeper levels by the strong flow of the Leeuwin Current, are sufficient to establish and maintain an equatorward (westward) undercurrent along western (southern) Australia.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Primitive Equation Model, Leeuwin Current System, Currents, Meanders, Eddies, Filaments

SWELL TRANSFORMATION ACROSS THE CONTINENTAL SHELF

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Master of Science in Meteorology and Physical Oceanography-June 2000

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A preliminary analysis of swell decay across the continental shelf was conducted using data from the SHOaling Waves EXperiment (SHOWEX). Six Datawell Directional Waverider buoys were deployed along a cross-shelf transect, offshore of Duck, North Carolina during an active hurricane season in the fall of 1999. Estimates of the frequency spectrum, $E(f)$, mean propagation direction, $\theta_{mean}(f)$, and directional spread, $\sigma_{\theta}(f)$, were obtained from the auto-, co- and quadrature spectra of the horizontal and vertical orbital displacements measured by the buoys. Twelve cases were analyzed including eight cases dominated by remotely generated long period swells arriving from various directions. The last four cases were characterized by active wave generation by strong winds on the continental shelf, including the passages of Hurricanes Floyd and Irene. Comparisons of significant wave heights of swell observed at all buoys show a consistent strong decay across the shelf supporting the major role of bottom friction in swell transformation. A decline in wave heights near the coast was also observed during the passage of hurricanes, due to limited fetch and enhanced bottom friction in shallow water. Estimates of θ_{mean} show the expected refraction of waves to shore-normal directions on the inner shelf. Estimates of σ_{θ} generally do not vary much across the shelf. However, a sharp increase of σ_{θ} across the inner shelf was observed for

THESIS ABSTRACTS

directionally narrow swells from Hurricane Gert, possibly due to wave scattering from bottom irregularities. In all cases, σ_θ was at a minimum at the spectral peak frequency.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Swell Transformation, Continental Shelf, Directional Wave Spectra, Wave Dissipation, Wave Buoy, Refraction

MEGARIPPLE MIGRATION IN THE NEARSHORE

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Seafloor morphology in the surf zone of a sandy ocean beach was measured nearly continuously for 45 days with a 1.4 X 1.4 m coherent array of 7 sonar altimeters. Migrating megaripples, seafloor bedforms with amplitudes of O(10-50 cm) and lengths of O(1-5 m), were observed in about 2 m water depth in the trough between a sand bar and the shoreline for a wide range of wave and current conditions. Megaripple migration speed and direction are estimated from the array data using cross-correlations between seafloor elevation time series observed along the cross- and alongshore array legs. Megaripples were shown to be aligned in a direction that maximized the gross sediment transport normal to the bedform crest (Rubin and Hunter, 1987; Gallagher, *et al.* 1998). It is hypothesized that megaripple migration rate is related to the net transport in the direction of bedform alignment. The speed of megaripple migration is compared with the magnitude of the velocity field normal to the bedform crest in the direction of the mean, wave orbital, and resultant velocities.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Megaripples, Sediment Transport, Nearshore Processes, Bedforms, Morphology

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