Naval Postgraduate School
Monterey, California 93943-5138

NPS-09-02-024

SUMMARY OF RESEARCH 2001

Department of Meteorology
Graduate School of Engineering and Applied Sciences

Carlyle H. Wash
Chair

Kenneth L. Davidson
Associate Chair for Research

Approved for public release; distribution is unlimited
Prepared for: Naval Postgraduate School
Monterey, CA 93943-5000

NAVAL POSTGRADUATE SCHOOL
Monterey, California

RADM David R. Ellison, USN
Superintendent

Richard Elster
Provost

This report was prepared for the Naval Postgraduate School, Monterey, CA.

Reviewed by:

Danielle Kuska
Director, Research Administration

Released by:

David W. Netzer
Associate Provost and
Dean of Research

REPORT DOCUMENTATION PAGE

Form approved
OMB No 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 2002	Summary Report, 1 October 2000-30 September 2001

4. TITLE AND SUBTITLE
Summary of Research 2001, Department of Meteorology

5. FUNDING

6. AUTHOR(S)

Faculty of the Naval Postgraduate School

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

NPS-09-02-024

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
The views expressed in this report are those of the authors and do not reflect the official policy or position of the Department of Defense or U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited

12b. DISTRIBUTION CODE

A

13. ABSTRACT (Maximum 200 words.)

This report contains project summaries of the research projects in the Department of Meteorology. 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.

14. SUBJECT TERMS			15. NUMBER OF PAGES 69
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT Unlimited

NSN 7540-01-280-5800

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std 239-18

THE NAVAL POSTGRADUATE SCHOOL MISSION

Increase the combat effectiveness of the U.S. and allied forces and enhance the security of the U.S.A. through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense related challenges of the future.

TABLE OF CONTENTS

TABLE OF CONTENTS

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 Meteorology during 2001. The summary also contains thesis abstracts for those students advised by Meteorology faculty during 2001.

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, and maintains 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 2001, the level of research effort overall at the Naval Postgraduate School was 148 faculty work years and exceeded $48 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 FY2001, over 93% of the research program was externally supported. A profile of the sponsorship of the Naval Postgraduate School Research Program in FY2001 is provided in Figure 1.

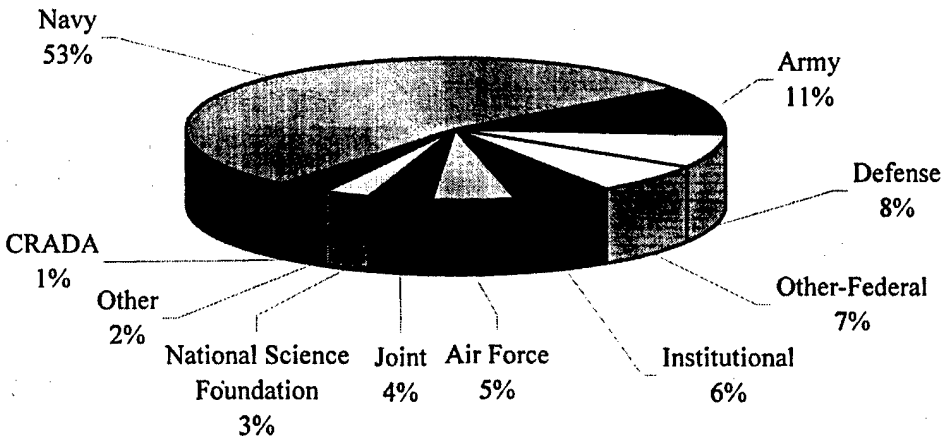


Figure 1. Profile of NPS Research and Sponsored Programs ($52M)

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 FY2001 is provided in Figure 2.

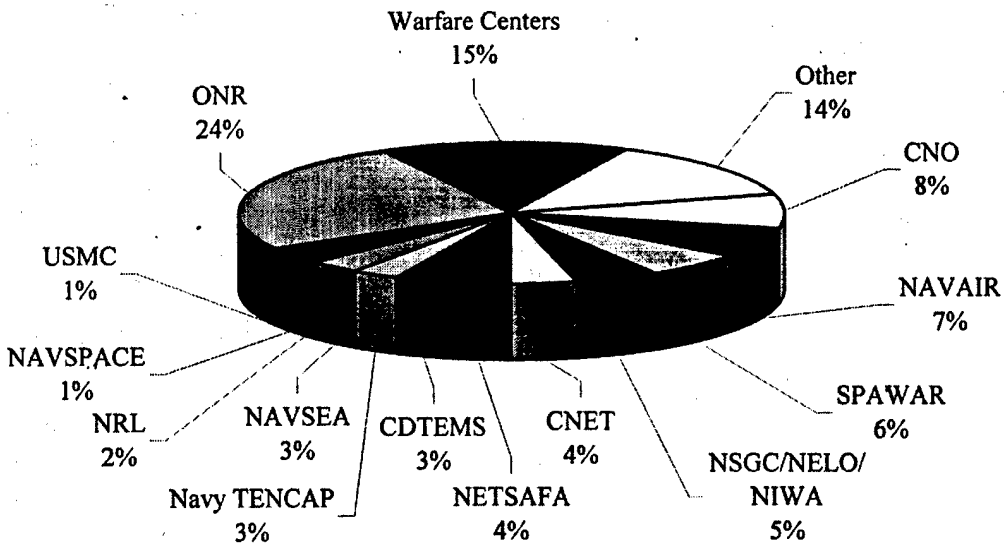


Figure 2. Navy External Sponsors of NPS Research and Sponsored Programs ($29M)

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

September 2002

DEPARTMENT OF METEOROLOGY

CARLYLE H. WASH
CHAIR

DEPARTMENT SUMMARY

OVERVIEW:

The Department of Meteorology provides graduate-level instruction in the science of meteorology and its application in support of military operations. To maintain expertise and provide support to student theses, the faculty performs research in the Navy-relevant areas of synoptic and dynamic meteorology, remote sensing, numerical modeling, tropical meteorology, boundary layer meteorology, and environmental effects.

Over 40 years ago, NPS was responsible for the establishment and flourishing of a Navy operational command on its campus. In 1959, the Naval Oceanographic Command moved its numerical prediction center to Monterey as a new operational command, the Fleet Numerical Weather Central (now, Fleet Numerical Meteorology and Oceanography Center-FNMOC). The Navy chose to move FNMOC to Monterey to take advantage of the presence of NPS with its large assembly of science faculty who are intimately familiar with Navy operational problems in meteorology and oceanography. For similar reasons, the Navy Environmental Prediction Research Facility (now the Marine Meteorology Division of the Naval Research Laboratory-NRL-Monterey), moved to Monterey in 1971. This further augmentation of meteorological and oceanographic scientists in Monterey, has made it the center of Naval environmental science.

The consequences of these moves are the substantial involvement of NPS faculty in research projects at NRL-Monterey and the enhancement of operational capabilities at FNMOC. Furthermore, personnel from the latter two organizations are able to take advanced courses at NPS, and officer-students at NPS can engage in thesis research on "real-life" applications relating environmental parameters to Naval operations.

CURRICULA SERVED:

- Meteorology
- Meteorology and Physical Oceanography
- Space Systems Operations
- Space Systems Engineering
- Electronic Warfare

DEGREES GRANTED:

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

RESEARCH THRUSTS:

- Synoptic, Mesoscale, and Coastal Meteorology:
  Distinguished Professor Russell Elsberry, Associate Professor Wendell Nuss, Professor Carlyle Wash, Research Assistant Professor Douglas Miller, Research Associate Professor Patrick Harr
- Numerical Weather Prediction (NWP):
  Professor Roger Williams, Research Associate Hway-Jen Chen, Research Assistant Professor Kevin Cheung, Research Assistant Professor Douglas Miller
- Environmental Analysis and Visualization:
  Research Associate Mary Jordan
- Air-Sea Interactions:
  Professor Kenneth Davidson, Professor Robert Haney, Research Associate Paul Frederickson
- Satellite and Ground Based Remote Sensing:
  Professor Phillip Durkee, Research Associate Kurt Nielsen
- Tropical Meteorology:
  Professor Chih-Pei Chang, Research Associate Hway-Chen, Research Associate Professor Patrick Harr, Research Assistant Professor Kevin Cheung

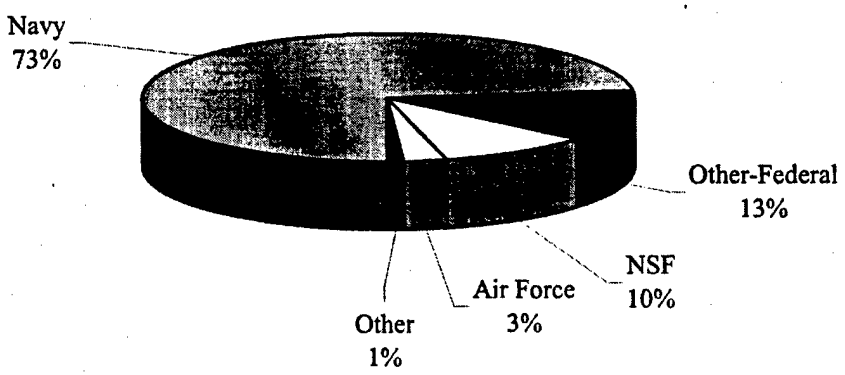
- Tropical Cyclone Motion:
  Distinguished Professor Russell Elsberry, Research Assistant Professor Kevin Cheung, Research Associate Professor Patrick Harr
- Boundary Layer Meteorology:
  Professor Kenneth Davidson, Associate Professor Qing Wang
- Climate Dynamics:
  Professor Chih-Pei Chang, Professor Roger Williams, Research Associate Hway-Jen Chen, Senior Lecturer Tom Murphee
- Atmospheric Factors in EM/EO Propagation:
  Professor Kenneth Davidson, Research Associate Professor Peter Guest, Research Associate Paul Fredrerickson
- Polar Meteorology:
  Research Associate Professor Peter Guest

RESEARCH FACILITIES:

- **IDEA Laboratory:** The Interactive Digital Environmental Analysis (IDEA) laboratory has Silicon Graphics workstations specifically designed and funded for instruction. The lab computers are used to analyze and display real-time satellite data and numerical model output.
- **Tactical Laboratory:** The Tactical Lab operates an SMQ-11 DMSP satellite receiver that collects and processes classified environmental data and runs military tactical decision aids used to support operations.
- **Synoptic Analysis and Forecasting Laboratory:** The Synoptic Analysis and Forecasting Lab uses a suite of computers and advanced display devices to provide local and global real-time meteorological data and numerical products for instruction and research in operational weather forecasting.
- **Atmospheric Boundary Layer Measurements Laboratory:** The Measurements Lab provides information from a special near-coastal observation site at Fort Ord in support of instruction and research in boundary layer and coastal meteorology. Present instrumentation includes two radar wind profilers, an automatic surface weather station, and rawinsonde systems.

RESEARCH PROGRAM (Research and Academic)-FY2001:

The Naval Postgraduate School's sponsored program exceeded $49 million in FY2001. Sponsored programs included both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Meteorology is provided below:



Size of Program: $2550K

FACULTY LISTING

Wash, Carlyle H.
Professor and
Chair
MR/Wx
656-2516
wash@nps.navy.mil

Davidson, Kenneth L.
Professor and
Associate Chair for Research
MR/Ds
656-2309/2563
davidson@nps.navy.mil

Chang, C. -P.
Professor
MR/Cp
656-2840
cpchang@nps.navy.mil

Guest, Peter
Research Associate Professor
MR/Gs
656-2451
pguest@nps.navy.mil

Murphree, Tom
Senior Lecturer
MR/Me
656-2723
murphree@nps.navy.mil

Chen, Hway-Jen
Research Associate
MR/Hj
656-3788
bonbon@nps.navy.mil

Haney, Robert
Professor
MR/Hy
656-7571
rlhaney@nps.navy.mil

Nielsen, Kurt
Research Associate
MR/Ne
656-1026
nielsen@ nps.navy.mil

Cheung, Kevin
Research Assistant Professor
MR/Kc
656-3430
kwcheung@nps.navy.mil

Harr, Patrick A.
Research Associate Professor
MR/Hr
656-3787
paharr@nps.navy.mil

Nuss, Wendell A.
Associate Professor
MR/Nu
656-2308
nuss@nps.navy.mil

Durkee, Philip A.
Professor
MR/De
656-3465
durkee@nps.navy.mil

Jordan, Mary S.
Research Associate
MR/Jr
656-3109
jordan@nps.navy.mil

Wang, Qing
Associate Professor
MR/Qg
656-7716
qwang@nps.navy.mil

Elsberry, Russell L.
Distinguished Professor
MR/Es
656-2373
elsberry@nps.navy.mil

McCarthy, John
Research Professor
MR/Mc
656-2295/4753
jmccarth@nps.navy.mil
mccarthy@nrlmry.navy.mil

Williams, R. Terry
Professor
MR/Wu
656-2296
rtwillia@nps.navy.mil

Frederickson, Paul
Research Associate
MR/Fd
656-2407
pafreder@nps.navy.mil

Miller, Doug
Research Assistant Professor
MR/Dm
656-3101
dmiller@ nps.navy.mil

SYSTEMATIC APPROACH TO TROPICAL CYCLONE TRACK FORECASTING

Lester E. Carr, III, Research Associate Professor
Russell L. Elsberry, Professor
Department of Meteorology
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The objective of this proposal is to provide Joint Typhoon Warning Center, Pearl Harbor, with the complete version of the systematic approach to tropical cyclone track forecasting, continue extension of the systematic approach to the other tropical cyclone basins, especially the Southern Hemisphere, Eastern/Central Pacific and the Atlantic regions.

SUMMARY: The Systematic Approach Forecasting Aid (SAFA) is an information management system to assist the forecaster in tropical cyclone track forecasting. This knowledge-based expert system has been developed over several years and was the subject of a beta test during 1999 (Carr et al, 2001). The first operational test of the SAFA system at the Joint Typhoon Warning Center (JTWC) in Hawaii was during the 2000 western North Pacific tropical cyclone season. A number of lessons-learned were gained from that test, both as to required SAFA system upgrades and the need for additional training materials. These items were the central focus of the effort in this project and the revised SAFA and improved training materials were delivered to JTWC during June 2001.

The second operational test during the 2001 western North Pacific season was a tremendous success. The JTWC 72-hour track forecast errors were 180 nautical miles compared to an expected value of 276 nautical miles based on the error reduction trend during the 1990s extrapolated to the year 2001. The post-season recap indicates that the SAFA system was applied more successfully and was clearly a major factor in the improved JTWC performance. Thus this project represents a successful transition of research to operations.

PUBLICATIONS:

Carr, L.E., III, R.L. Elsberry and J.E. Peak, 2001: Beta test of the Systematic Approach expert system prototype as a tropical cyclone track forecasting aid (SAFA). *Weather and Forecasting*, **16**, 355-368.

PRESENTATION:

Carr, L.E., III, R.L. Elsberry and M.A. Boothe, 2001: Status report on implementation of the Systematic Approach to tropical cyclone track Forecasting Aid (SAFA). 2001 Tropical Cyclone Conference, Honolulu, HI, 30 January–1 February 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Tropical Cyclone Track Prediction, Tactical Decision Aids

DYNAMICS OF NORTHWEST PACIFIC TROPICAL DISTURBANCES AND MONSOON

Chih-Pei Chang, Professor
Roger Terry Williams, Professor
Department of Meteorology
Sponsor: National Science Foundation

OBJECTIVE: To study the interactions between Asia/Australian monsoon and tropical disturbances, particularly the dynamics of the formation and intensification of tropical disturbances in the monsoon confluence region in the Northwest Pacific.

SUMMARY: The interactions between monsoon circulations and tropical disturbances in the Northwest Pacific, where the low-level mean flow is westerly in the west and easterly in the east, are studied with a barotropic model. Model results suggest that the scale contraction by the confluent background flow, the nonlinear dynamics, the beta-effect, and the large-scale convergence are important for the energy and

enstrophy accumulation near the region where the zonal flow reverses. The energy/enstrophy accumulation can be maintained with a continuous Rossby wave emanation upstream. The largest accumulation occurs when the emanating zonal wavelength is around 2000 km. Longer Rossby waves experience less scale contraction and nonlinear effects while shorter Rossby waves cannot hold a coherent structure against dispersive effects.

The nonlinear energy/enstrophy accumulation mechanism is significantly different from previous linear energy accumulation theories. In the linear theories this is primarily accomplished by the slowdown of the Doppler-shifted group velocity through the convergence of mean zonal advection, while in nonlinear dynamics the contraction of the zonal wave scale plays the crucial role. More importantly, after the initial energy increase by the wave accumulation, linear dynamics will lead to an eventual loss of wave energy to the mean flow due to the increase of zonal wavenumber near the critical longitude. Thus, without the presence of other forcing processes such as diabatic heating, the disturbances will decay. In nonlinear dynamics, the sharpening of the vorticity gradient as the waves approach the confluence zone leads to the development of disturbance asymmetries with respect to the central latitude. This effect is through the nonlinear interaction of Rossby waves with the planetary vorticity gradient. This development leads to a pair of vorticity centers that straddles the central latitude with the cyclone (anticyclone) in the north (south), and an elongated, weak westerly flow along the central latitude. This elongated westerly flow, which possesses a zonal wavenumber smaller than that in the linear cases, reverses the sign of the Reynold's stress and allows the energy to grow near the critical longitude, leading to intensified disturbances.

With a more realistic monsoon-like background flow, a northwestward propagation pattern with an approximately 8-day period and 3000 km wavelength is produced, in general agreement with observed disturbances in the Northwest Pacific. The intensified disturbance may disperse energy upstream, leading to a series of trailing anticyclonic and cyclonic cells along the northwestward propagation path. When an opposing current is present, the energy dispersion leads to the formation of new disturbances in the confluence zone by a vortex axisymmetrization dynamics. Thus, results indicate that the scale contraction and nonlinear effects may cause a succession of tropical disturbances to develop without disturbance-scale diabatic effects.

PUBLICATIONS:

Chang, C.-P., P.A. Harr and J. Ju, 2001: Possible roles of Atlantic circulations on the weakening Indian Monsoon-ENSO relationship. 14, *J. Climate*, **14**, 2376-2380.

Kuo, H.-C., J.-H. Chen, R.T. Williams and C.-P. Chang, 2001: Rossby Waves in Zonally Opposing Mean Flow: Behavior in Northwest Pacific Summer Monsoon. *Journal of Atmospheric Science*, **58**,1035-1050.

Li, T., Y. Zhang, C.-P. Chang and B. Wang, 2001: On the relationship between Indian Ocean SST and Asian summer monsoon. *Geophysical Research Letter*, **28**, 2843-2846.

Li, T.B. Wang, C.-P. Chang, 2001: Theories on the tropospheric biennial oscillation: A review. *Dynamics of Atmospheric and Oceanic Circulations and Climate*, eds: M. Wang et al, Chinese Academy of Sciences, China Meteorological Press, Beijing, 872.

PRESENTATIONS:

Chang, C.-P., P.A. Harr and J. Ju, 2001: North Atlantic oscillation/arctic oscillation and the weakening Indian monsoon-ENSO relationship. NASA-IPRC-CLIVAR Workshop on Decadal Climate Variability, Manoa, HI, 8-12 January 2001.

Chang, C.-P. and T. Li, 2001: Monsoon-ENSO relationships and monsoon biennial variability. WMO International Conference on Monsoon Forecasting from Days to Years, Delhi, India, March 2001. (Invited)

Chang, C.-P., Z. Wang, J. Ju and T. Li, 2001: Interactions of maritime continent winter monsoon, ENSO and Indian Ocean winds. The Third International Symposium on Asian Monsoon System, Okinawa, Japan, 11-14 December 2001.

Kuo, H.-C. and C.-P. Chang, Rossby Waves in Zonally Opposing Mean Flow: Behavior in Northwest Pacific Summer Monsoon. The Third International Symposium on Asian Monsoon System, Okinawa, Japan, 11-14 December 2001.

THESIS DIRECTED:

Miller, H.A., "The Contribution of Symmetrization to the Intensification of Tropical Cyclones," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY: Battlespace Environments, Modeling and Simulation

KEYWORDS: Monsoon, West Pacific, Tropical Meteorology, Tropical Cyclones, Climate

EAST ASIA MONSOON AND TROPICAL BIENNIAL OSCILLATION SYSTEM (PCFS)

Chih-Pei Chang, Professor
Department of Meteorology
Sponsor: National Science Foundation

OBJECTIVE: This project studies the interannual variations of the East Asia Monsoon, and their relationship with the tropical biennial oscillation of the coupled atmosphere-ocean system.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Tropical Meteorology, Monsoon, Atmosphere-Ocean Interactions, Tropical Biennial Oscillation

FORECAST OF CLOUD PROBABILITY IN SOUTHEAST ASIA: DEVELOPMENT OF A PROBABILITY OF CLOUD FORECAST SYSTEM

Chih-Pei Chang, Professor
Department of Meteorology
Sponsors: Singapore Ministry of Defense

OBJECTIVE: To study the behavior and predictability of monsoon disturbances affecting East Asia and adjacent regions using Navy's regional numerical forecast model.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Cloud Forecast, Monsoon, Southeast Asia, South China Sea

MONSOON DISTURBANCES OVER THE CHINA SEAS

Chih-Pei Chang, Professor
Hway-Jen Chen, Research Associate
Department of Meteorology
Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: The objectives are: (1) to study the structure and the dynamic and thermodynamic properties of the disturbances in the vicinity of the Southeast and East Asian monsoon region that stretches from Indian Ocean to the tropical western Pacific, including the South China Sea and Yellow Sea, which are of particular interest to naval operations; and (2) to study the ability and sensitivity of Navy operational numerical models in analyzing and predicting these disturbances.

SUMMARY: In order to identify major inadequacies of COAMPS over the monsoonal tropical oceans numerical experiments were conducted to simulate the pre-monsoon onset case of 13-15 May 1998 during the South China Sea Monsoon Experiment (SCSMEX).

One of the major errors is the overestimate of rainfall in tropical Indian Ocean. COAMPS has two options of cumulus parameterization schemes: the Kain-Fritsch scheme and the Kuo scheme. In several experiments the Kuo scheme led to rapid false degeneration of most tropical systems, so the Kain-Fritsch scheme was chosen. (A coding error in the K-F scheme that artificially increases the precipitation was discovered in the course of the experiment and was corrected.)

The East China subtropical front and Indian Ocean tropical convection are considered two of the most important systems that affect the onset of the South China Sea summer monsoon (Lau et al 2000). The locations of these two systems were reasonably well forecasted. However, the forecast precipitation of the tropical system (south of India) was unrealistically excessive (>275 mm for the maximum 0-24 hr accumulated precipitation). This problem may be associated with cumulus parameterization or the sea surface temperature data. The Kain-Fritsch scheme was designed for the mid-latitude convective system. Preliminary results suggests two possible sources of problems. The first is the relationship between the precipitation efficiency and the wind shear used in Kain-Fritsch scheme, which now is an empirical function obtained from mid-latitude cases. The other is the lifetime of the convective cloud, which is reciprocal to the environmental wind speed. Since the wind speed over tropical area is relatively small, the lifetime of the convective cloud may be overestimated. Ways to resolve these issues are being studied.

PRESENTATIONS:

Chen, H.J. and C.-P. Chang, 2001: Report of a COAMPS bug that caused an overestimate of precipitation in subroutines "kfdrive.F" and "kfpara.F." Informal note to NRL Marine Meteorological Division, 11 July 2001.

Chen, J. M, T. Li. and C.-P. Chang: South China Sea SST regulations. International Scientific Conference on SCSMEX, Shanghai, April 2001.

Kuo, H.C. and C.-P. Chang, 2001: Tropical vortex development in Northwest Pacific monsoon. International Scientific Conference on SCSMEX, Shanghai, April 2001.

DoD KEY TECHNOLOGY: Battlespace Environments, Modeling and Simulation

KEYWORDS: Numerical Weather Prediction, Tropical Meteorology, Monsoon, China Seas

MONSOON – ENSO INTERACTIONS

Chih-Pei Chang, Professor
Department of Meteorology
Sponsor: National Oceanic and Atmospheric Administration

OBJECTIVE: To study the structure of the interannual variations of the Asian-Australian monsoon and its relationship with El Niño – Southern Oscillations (ENSO).

SUMMARY: The relationship between Asian monsoon and ENSO was studied using data analysis, simple dynamic modeling and numerical modeling. The studies reveal complex interactions between different climate parameters and underscore the variable nature of the relationships at different time scales, from biennial to interdecadal. In particular, the relationship between ENSO and the Indian monsoon rainfall appears to be affected by the decadal changes of the North Atlantic Oscillation/Arctic Oscillation, rather than changes of divergent circulations in the Pacific. The tropospheric biennial oscillations and ENSO are also affected differently by the Indian Ocean sea-surface temperature anomalies.

PUBLICATIONS:

Chang, C.-P., P.A. Harr and J. Ju, 2001: Possible roles of Atlantic circulations on the weakening Indian Monsoon-ENSO relationship. 14, *Journal of Climate*, **14**, 2376-2380.

Li, T., C.W. Tham and C.-P. Chang, 2001: A coupled Air-Sea-Monsoon oscillator for the TBO. *Journal of Climate*, **14**, 752-764.

Li, T., Y. Zhang, C.-P. Chang and B. Wang, 2001: On the relationship between Indian Ocean SST and Asian summer monsoon. *Geophysical Research Letters*, **28**, 2843-2846.

PRESENTATIONS:

Chang, C.-P., P.A. Harr and J. Ju, 2001: North Atlantic oscillation/Arctic oscillation and the weakening Indian Monsoon-ENSO relationship. NASA-IPRC-CLIVAR Workshop on Decadal Climate Variability, Manoa, HI, 8-12 January 2001.

Chang, C.-P., Interdecadal variations of the relationship between ENSO and the Asian monsoon. interdecadal and interannual variations of East Asian Monsoon, Taipei, March 2001. (Invited)

Chang, C.-P. and T. Li, 2001: Monsoon-ENSO relationships and Monsoon Biennial variability. WMO International Conference on Monsoon Forecasting from Days to Years, Delhi, India, March 2001. (Invited)

Chang, C.-P., Interdecadal variations of the ENSO – Monsoon relationship. 8th Scientific Assembly of International Association of Meteorology and Atmospheric Sciences, Innsbruck, Austria, July 2001. (Invited)

Chang, C.-P., Z. Wang, J. Ju and T. Li, 2001: Interactions of maritime continent winter monsoon, ENSO and Indian Ocean winds. The Third International Symposium on Asian Monsoon System, Okinawa, Japan, 11-14 December 2001.

Li, T., Y.-S. Zhang, B. Wang and C.-P. Chang, 2001: Monsoon-ENSO relationship during the decaying phase of ENSO. The Third International Symposium on Asian Monsoon System Okinawa, Japan, 11-14 December 2001.

DoD KEY TECHNOLOGY: Battlespace Environments, Modeling and Simulation

KEYWORDS: Monsoon, El Nino, ENSO, Climate Variations, Tropical Meteorology

STUDIES IN TROPICAL CYCLONE FORMATION

Kevin K. W. Cheung, Research Assistant Professor
Russell L. Elsberry, Professor
Department of Meteorology
Sponsor: Hong Kong Croucher Foundation and Office of Naval Research

OBJECTIVE: To understand the physics of tropical cyclone formation and improve the skill of tropical cyclone formation forecasts using numerical weather prediction models.

SUMMARY: The physics of tropical cyclone formation was studied using existing operational analyses and forecast fields, and with numerical simulations. In the former approach, large-scale conditions associated with tropical cyclone formations, particularly in the western North Pacific where many naval operations are carried out, were examined using analyses from operational centers such as the Naval Operational Global Atmospheric Prediction System (NOGAPS). Several quantities (e.g., vertical wind shear, mid-level moisture, and convective instability) were computed to measure the potential for tropical cyclone formation. These measures were also found to be useful in determining successful and failed

forecasts of NOGAPS. Current work consists of examining satellite imageries to extract characteristic behavior of cloud clusters during tropical cyclone formations.

In the second approach, numerical simulations using the National Center for Atmospheric Research/Pennsylvania State University mesoscale model (MM5) were performed on historical cases of tropical cyclones. Such numerical simulations have the advantage of a well-controlled environment, and the flexibility of performing sensitivity studies with different physical parameters. The objective of this part of study is to understand the role of mesoscale convective systems in tropical cyclone formations. This is a continuing project, and related publications are anticipated in the coming year.

PUBLICATION:

Cheung, K.K.W. and R.L. Elsberry, Tropical cyclone formations over the western North Pacific in the Navy Operational Global Atmospheric Prediction System Forecasts. *Weather and Forecasting* (submitted).

PRESENTATION:

Cheung, K.K.W., A modeling study of mesoscale convective vortices in relation to tropical cyclone formation. International Conference on Mesoscale Meteorology and Typhoon, Taipei, Taiwan, 26–28 September 2001.

DoD KEY TECHNOLOGY AREA: Other (Meteorology)

KEYWORDS: Tropical Cyclone, Tropical Cyclogenesis, Numerical Modeling and Simulation

ATMOSPHERIC CORRECTIONS FOR GEODETIC QUALITY RADIO RANGING REAL DATA

Kenneth L. Davidson, Professor
Department of Meteorology
James R. Clynch, Research Professor
Department of Oceanography
Sponsor: Naval Postgraduate School Center for Reconnaissance Research

OBJECTIVE: Assess the role of atmospheric conditions, application of models and measurement capabilities in estimating tropospheric factors in global reconnaissance system performances.

SUMMARY: The primary goal was to establish limits on the noise (uncertainty) in radio frequency measurements that transit the atmosphere under the influence of temporal and spatial variations of the neutral atmosphere in space and time. The limitations at very low elevation angles for high altitude and space observation platforms were evaluated and quantified. Only the troposphere was considered, not the ionosphere. The results are applicable from about 500 MHz to 100 GHz. Atmospheric profile data from six world-wide locations were obtained in the form of balloon data. Two weeks of data were examined from Oakland, Vandenberg, San Diego, Sweden, Singapore and the Persian Gulf. Spatial variations were studied using the U.S. west coast sites. Ray tracing was used to examine the total delay and the bending for radio signals.

The primary quantity studied was the variation at each site. The natural variability will limit the utility of any model not driven with near real time data. At elevations below 2 degrees the effect were found to be significant. The variations were found up to 6 m in delay and 4 milliradians in bending below 0.6 deg. At 2 degrees the variations were 1.2 m and 0.8 mrad. Using data up to 600 km away (within the same air mass) reduced the variations above 1 degree by about 90 percent.

DoD KEY TECHNOLOGY AREAS: Sensors

KEYWORDS: Propagation, Refraction

EVALUATION OF MBL PROFILE ESTIMATION AND ESTIMATING EM/EO FACTORS TO AID OPERATING FORCES

K. L. Davidson, Professor
Department of Meteorology
Sponsor: Space and Naval Warfare Command

OBJECTIVE: Validate/verify the Tactical Drop-sondes (TDrop) to meet requirements for accurate and tactically significant measurements of temperature, moisture, and pressure within the lower marine atmosphere and evaluate technical information transfer and application for refractivity effects on CGs.

SUMMARY: Evaluation was performed to evaluate the performance of the *in situ* application on other methods, i.e. Lidar, M_AERI, on-board sensor, for estimating refractivity profiles, continuously. Further, to explore properties of near-surface layer with kite-borne sensors for purpose of evaluate sensor goals. The Naval Postgraduate School (NPS) carried out analyses of application of its near-surface refractivity model for inclusion within the SMOOS(R) system. This model computes near-surface refractivity profiles and the evaporation duct height from environmental measurements provided by the shipboard SMOOS(R) measurement system. The model refractivity profiles can then be input into propagation assessment programs such as AREPS to predict near-surface radar performance in the current environment, including the probability of detection of specific threats. The NPS model has been incorporated into the AREPS and into SMOOS(R) system software developed by the Johns Hopkins University, Applied Physics Laboratory (JHU/APL). NPS and JHU/APL persons prepared a draft "rules of thumb" document for AGs and Radar Systems Controllers for "Guidance for METOC Personnel" to aid AN/SPY-1 radar operators in evaluating environmental conditions.

PUBLICATIONS:

Davidson, K.L. and P.A. Frederickson, Estimating Near-Surface Atmosphere Properties that Affect Weapons Systems, *NPS Research*, Featured Article, June 2001.

Frederickson, P.A., K.L. Davidson, J. Stapleton, D., Shanklin, R. Wiss, T. Nguyen, E. Burgess III, C. Weeks, W. Thornton and T. Brown, Validation of AREPS propagation assessments using different evaporation duct models. Battlespace Atmospheric and Cloud Impact on Military Operations (BACIMO 2001) Conference, Fort Collins, CO, 10-12 July 2001. [Army Research Laboratory CD-ROM ARL-SR-01126, October 2001].

Frederickson, P.A., K.L. Davidson, J. Stapleton, D., Shanklin, R. Wiss, T. Nguyen, E. Burgess III, C. Weeks, W. Thornton and T. Brown, Validation of AREPS propagation assessments using different evaporation duct models. Ship Based Defense Demonstration, IAFCSE Task – MPME Wallops 2000 Final Review, Naval Surface Warfare Center, Dahlgren, VA, 3 October 2001.

PRESENTATIONS:

Davidson, K.L. and P.A. Frederickson, METOC Sampling for Rf/EO Propagation Assessment. Modernizing METOC Support to the Surface (AEGIS) Warfighter, Pearl Harbor, HI, 22-23 February 2001.

Davidson, K.L., Effects and Estimation of Near-surface atmosphere effects on Rf/EO propagation/system performance. Simulation Validation Working Group (SVWG) Bi-Annual Meeting, Naval Research Laboratory, Washington, D.C., 26-28 June 2001.

THESES DIRECTED:

Sommer, W., "Difficulties in Identifying and Evaluating Surface-based and Evaporative Duct Impacts, Masters Thesis," Naval Postgraduate School, March 2001.

Eckardt, M., "Assessing the Effects of Model Error on Radar Inferred Evaporative Ducts," Masters Thesis, Naval Postgraduate School, March 2002.

Robinson, S., "Case Study Supporting the Usefulness of TEP as a Naval Mesoscale Weather Radar," Masters Thesis, Naval Postgraduate School, March 2002.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors

KEYWORDS: Meteorological Measurement, Marine Atmosphere Boundary Layer

METOC DATA ACQUISITION (MORIAH/SMOOS(R))

K. L. Davidson, Professor
Department of Meteorology
Sponsor: Space and Naval Warfare Command

OBJECTIVE: Support acquisition strategy of a shipboard Meteorology and Oceanography parameter sensor system, MORIAH, by carrying out validation, verification and integration procedures. Prepare software documentation for acquisition and evaporation duct calculation.

SUMMARY: NPS evaluated and documented performance characteristics of MORIAH hardware and software for use in the complex METOC and electronic environment of a Navy warship. These were also done for MORIAH-like systems mounted on buoys deployed in coastal regimes in support of propagation tests. System performance evaluation was of characteristics of both the MORIAH hardware and acquisition and calculation/editing software. The algorithm for evaporation duct refractivity profiles using SMOOS(R)-type data was evaluated with buoy-based data collected in collection associated with the NSWC-DD directed Ship-Based Defense Demonstration, IAFCSE Task – MPME (Wallops 1998 & 2000), Sommers 2001, and Frederickson et al. 2001. The SMOOS(R) acceptable errors for all airflow and surface properties were used in an evaluation of the impact of the neutral profile assumptions within the Refractivity from Clutter (RFC) procedure, Eckardt 2002.

PUBLICATIONS:

Davidson, K.L. and P.A. Frederickson, Estimating Near-Surface Atmosphere Properties that Affect Weapons Systems. *NPS Research*, June 2001.

Frederickson, P.A., K.L. Davidson, F.K. Jones and D.L. Mabey, *SCI 2001 Sensor Technology Test; Preliminary METOC Data Atlas*, Naval Postgraduate School Technical Report, 19 December 2001, 83 pp.

Frederickson, P.A., K.L. Davidson, F.K. Jones and T. Neta, *NPS FLUX Buoy Data Report for the MUSE Deployment, August - September 2000*, Naval Postgraduate School Technical Report, 5 April 2001, 19 pp.

THESES DIRECTED:

Sommer, W., "Difficulties in Identifying and Evaluating Surface-based and Evaporative Duct Impacts," Masters Thesis, Naval Postgraduate School, March 2001.

Eckardt, M., "Assessing the Effects of Model Error on Radar Inferred Evaporative Ducts," Masters Thesis, Naval Postgraduate School, March 2002.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors

KEYWORDS: Meteorological Measurement, Marine Atmosphere Boundary Layer

REFRACTIVITY PROFILE COLLECTION DURING RED

K. L. Davidson, Professor
Department of Meterology
Sponsor: Naval Research Laboratory

OBJECTIVE: Characterize the low altitude refractivity conditions (particularly the height and strength of possible surface based ducts) that affect RF propagation along the FLIP-based Rf and EO propagation paths during the Roughness and Evaporation Duct experiment.

SUMMARY: Naval Postgraduate School (NPS) obtained launched rawinsondes and kite-borne sonde profiles from a small boat during the RED experiment conducted on the windward shore of Oahu in August-September 2001. The profiles were obtained during this experiment to provide information for interpreting radio frequency (RF) propagation measurements along a 26 km path between the *R/V FLIP*, moored 10 km off the north shore of Oahu, and a shore receiver station on Mokapu Peninsula and optical propagation measurements obtained along a 10 km path between *FLIP* and the north shore of Oahu.

The NPS measurement platform was the small vessel *Wailoa*. NPS obtained 190 individual near-surface (up to ~100 meters) kite-borne sonde profiles and 20 upper-air balloon-sonde profiles on eight different days during the experiment. Mean meteorological data were also obtained by Scripps-UCSD on the *Wailoa* during these eight days.

PRESENTATIONS:

Guest, P.S., K.L. Davidson, P.A. Frederickson and D.L. Mabey, Using instrumented kites to quantify atmospheric conditions during the RED experiment. National Radio Science Meeting (URSI), Boulder, CO, 7-10 January 2002.

THESES DIRECTED:

Mabey, D., "Variability of Refractivity in the Surface Layer Over the Sea," Masters Thesis, Naval Postgraduate School, March 2002.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors

KEYWORDS: Meteorological Measurement, Marine Atmosphere Boundary Layer, Optical Transmission, Rf Transmission

SCALING NEAR-SURFACE ATMOSPHERIC AND SURFACE WAVE INFLUENCES ON RADAR PROPAGATION OVER THE SEA (RED EXPERIMENT ANALYSES)

K. L. Davidson, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: Improve models for describing near horizon Rf/EO propagation over the ocean through evaluation of the Monin-Obukhov surface-layer scaling for near surface turbulence and refractivity gradients over ocean waves and surface roughness parameterizations.

SUMMARY: Analyses and interpretations were performed on measurements of near-surface refractive gradients, turbulent intensity, and surface wave data obtained during NPS flux buoy deployments from coordinated propagation experiments. These data were from combined collections of *in situ* meteorological and radar-frequency propagation data conducted off Wallops Island, VA during the spring (March through May) of 1998 and 2000. The EO data were from combined collections of *in situ* and propagation (EO) in San Diego Bay, CA and Duck NC from 1996 through 1998. Buoy data and EM and EO propagation data were also obtained during the RED experiment conducted in the late summer of 2001. Collaborative analyses/interpretations during preceding field experiment years emphasized mean airflow properties. Our own interpretations addressed the use of current bulk methods for estimating optical turbulence (C_n^2) and

scaling parameters (T_*, q_*, and u_*). Waves influences have been addressed to qualitatively identify the influence. Existing results demonstrate that current models perform well in unstable conditions but clearly not in stable conditions.

PUBLICATIONS:

Mahrt, L., D. Vickers, J. Sun, T. Crawford, G. Crescenti and P. Frederickson, Surface stress in offshore flow and quasi-frictional decoupling. *Journal of Geophysical Research (Atmospheres),* Vol. 106, pp. 20629-20639, 2001.

Jensen, D.R., S.G. Gathman, C.R. Zeisse, C.P. McGrath, G. de Leeuw, H.M. Smith, P.A. Frederickson and K.L. Davidson, Electrooptical propagation assessment in coastal environments (EOPACE) summary and accomplishments. *Optical Engineering*, Vol.40, pp. 1486-1498, 2001.

Frederickson, P.A. and K.L. Davidson, Observational buoy studies of coastal air-sea fluxes. *Journal of Climate*, January 2002.

Zeisse, C.R., A.E. Barrios, S.M. Doss-Hammel, G. de Leeuw, M. Moerman, A.N. de Jong, P.A. Frederickson and K.L. Davidson, Low altitude infared propagation over the ocean, *Applied Optics*, submitted 2001.

PRESENTATIONS:

Davidson, K.L. and P.A. Frederickson, Influence of ocean waves on near-surface turbulence and refraction profiles: scaling over waves. Abstracts of the National Radio Science Meeting (URSI), Boulder, CO, 10-13 January 2001.

Davidson, K.L. and P.A. Frederickson, Mid-Path near-surface atmospheric properties in the roughness and evaporation duct (RED) experiment. National Radio Science Meeting (URSI), Boulder, CO, 7-10 January 2002.

Guest, P.S., K.L. Davidson, P.A. Frederickson and D.L. Mabey, Using instrumented kites to quantify atmospheric conditions during the RED experiment. National Radio Science Meeting (URSI), Boulder, CO, 7-10 January 2002.

Davidson, K.L. and P.A. Frederickson, Near-surface meteorology descriptions and radar propagation. South Dakota School of Mines and Technology, 31 January 2002.

Davidson, K.L., P.A. Frederickson and D.L. Mabey, Mid-path near-surface atmospheric properties in the roughness and evaporation duct (RED) experiment, RED Experiment Data Workshop, San Diego, CA, 5-6 February 2002.

Frederickson, P.A. and K.L. Davidson, Observational (buoy-based) studies of the wave influence on air-sea fluxes. WCRP/SCOR Workshop on Intercomparison and Validation of Ocean-Atmosphere Flux Fields, Potomac, MD, 21-24 May 2001. [*WMO Technical Document No. 1083*, pp. 329-332, August 2001]

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors

KEYWORDS: Meteorological Measurement, Marine Atmosphere Boundary Layer, Optical Transmission, Rf Transmission, EM/EO Propagation

DEVELOPMENT AND VALIDATION OF MULTIPLE-SATELLITE DATA SETS FOR GLOBAL AEROSOL RADIATIVE FORCING

Philip A. Durkee, Professor
Department of Meteorology
Sponsor: National Aeronautics and Space Administration

OBJECTIVES: This project supported development of multiple-satellite aerosol optical depth retrieval methods for global-scale analysis of radiative forcing. Validation methods included data and experience gained in participation in numerous recent field programs.

SUMMARY: This was the third year of this three-year project. Extensive validation activities have been conducted using the ACE-2 and TARFOX data sets:

- Comparisons of surface, ship-board, and aircraft sunphotometers with satellite retrievals (TARFOX, ACE-2, Aerosols99/INDOEX).
- Tests of aerosol model assumptions against *in situ* aircraft measurements of aerosol properties such size distribution, composition, and resulting radiative properties.
- Validation within the context of complete column closure studies is continuing.
- Tests of the effects of sunglint and cloud screening techniques.

Regional analysis of optical depth including wavelength variation and variation statistics was conducted for the four recent aerosol experiments (ACE-1, TARFOX, ACE-2, and Aerosols99/INDOEX). Development of retrievals from combined NOAA AVHRR and GOES are in progress. Validation of these techniques includes observations from TARFOX, EOPACE, and recent observations off the U.S. West Coast.

Aerosol optical depth retrieval using combinations of AVHRR and GOES imagery was studied using data from the western Atlantic Ocean. Analysis demonstrated the need for specialized scattering phase functions when desert dust was the primary aerosol type.

PUBLICATIONS:

Durkee, P.A., K.E. Nielsen, P.J. Smith, P.B. Russell, B. Schmid, J.M. Livingston, B.N. Holben, C. Tomasi, V. Vitale, D. Collins, R.C. Flagan, J.H. Seinfeld, K.J. Noone, E. Öström, S. Gassò, D. Hegg, L.M. Russell, T.S. Bates and P.K. Quinn, 2000: Regional aerosol optical depth characteristics from satellite observations: ACE-1, TARFOX and ACE-2 results. *Tellus*, 52B, 484-497.

Gassò, S., D.A. Hegg, D.S. Covert, D. Collins, K.J. Noone, E. Öström, B. Schmid, P.B. Russell, J.M. Livingston, P.A. Durkee and H. Jonsson, 2000: Influence of humidity on the aerosol scattering coefficient and its effect on the upwelling radiance during ACE2. *Tellus*, 52B, 546-567.

Schmid, B., J.M. Livingston, P.B. Russell, P.A. Durkee, H.H. Jonsson, D.R. Collins, R.C. Flagan, J.H. Seinfeld, S. Gasso, D.A. Hegg, E. Ostrom, K.J. Noone, E.J. Welton, K.J. Voss, H.R. Gordon, P. Formenti and M.O. Andreae, 2000: Clear-sky closure studies of lower tropospheric aerosol and water vapor during ACE-2 using airborne sunphotometer, airborne *in-situ*, space-borne and ground based measurements. *Tellus*, 52B, 568-593.

Livingston, J.M., V.N. Kapustin, B.Schmid, P.B. Russell, P.K. Quinn, T.S. Bates, P.A. Durkee, P.J. Smith, V. Freudenthaler, M. Wiegner, D.S. Covert, S. Gasso, D. Hegg, D.R. Collins, R.C. Flagan, J.H. Seinfeld, V. Vitale and C. Tomasi, 2000: Shipboard sunphotometer measurements of aerosol optical depth spectra and columnar water vapor during ACE-2 and comparison with selected land, ship, aircraft, and satellite measurements. *Tellus*, 52B, 594-619.

Welton, E.J., K.J. Voss, H.R. Gordon, H. Maring, A. Smirnov, B. Holben, B. Schmid, J.M. Livingston, P.B. Russell, P.A. Durkee, P. Formenti and M.O. Andrea, 2000: Ground-based lidar measurements of aerosols during ACE-2: instrument description, results, and comparisons with other ground-based and airborne measurements. *Tellus*, 52B, 636-651.

Johnson, D.W., S. Osborne, R. Wood, K. Suhre, R. Johnson, S. Businger, P.K. Quinn, A. Wiedensohler, P.A. Durkee, L.M. Russell, M.O. Andreae, C. O'Dowd, K.J. Noone, B. Bandy, J. Rudolph and S.

Rapsomanikis, 2000: An overview of the Lagrangian experiments undertaken during the North Atlantic Regional Aerosol Characterization Experiment (ACE-2). *Tellus*, 52B, 290-320.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Satellite, Remote Sensing, Aerosol Processes, Atmospheric Radiation

HYMSIC PROJECT

Philip A. Durkee, Professor
Department of Meteorology
Sponsor: Secretary of the Air Force

OBJECTIVE: Develop atmospheric and oceanic analysis using satellite-measured radiance.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Satellite, Remote Sensing, Clouds, Aerosols

METOC DATA ASSIMILATION AND MODELING

Philip A. Durkee, Professor
Department of Meteorology
Sponsor: Space and Naval Warfare Systems Center - San Diego

OBJECTIVE: Develop atmospheric and oceanic analysis using satellite-measured radiance.

SUMMARY: This project produced verification and validation of the Satellite Marine-layer/Evaporation Duct Height (SMDH) technique under development by NAWC Point Mugu, California. The technique provides an estimate of the cloud-top height of stratocumulus clouds in the marine boundary layer for the area viewed by a polar orbiting weather satellite. The top of the marine boundary layer is the optimum coupling height for elevated ducts. Knowledge of the elevated duct height over the tactical battlespace is quite important. The SMDH technique is one component of a potential shipboard operational system to provide estimates of elevated duct height. The SMDH technique is verified using NOAA AVHRR satellite data and coincident rawinsonde or aircraft measurements from the 1987 FIRE and 1994 MAST data sets.

PUBLICATIONS:

Jordan, M.S. and P.A. Durkee, *Verification and Validation of the Satellite Marine-layer/Elevated Duct Height (SMDH) Technique*, Naval Postgraduate School Technical Report, NPS-MR-01-001, 2001, 26 pp.

THESIS DIRECTED:

McBride, M.B., III, "Estimation of Stratocumulus-Topped Boundary Layer Depth Using Sea Surface and Remotely Sensed Cloud-Top Temperatures," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Satellite, Remote Sensing, Clouds

SUPPORT FOR USWRP ASSOCIATE LEAD SCIENTIST

Russell L. Elsberry, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: This project is for Professor Elsberry to serve as the Associate Lead Scientist (Hurricane Landfall) for the U.S. Weather Research Program, which is sponsored by the Office of Naval Research. Professor Elsberry will carry out the duties of the Associate Lead Scientist as described in the terms of reference dated January 1999.

SUMMARY: The first task during 2001 was the arrangement of a day-long session with a poster session on tropical cyclone-related precipitation as part of the Symposium on Precipitation Extremes at the national meeting of the American Meteorological Society (AMS). In addition to the conference paper (Elsberry 2001a), a meeting summary (Elsberry 2001c) is to be published in the *Bulletin AMS*. A summary of the U. S. Weather Research Program plans was presented at an International conference (Elsberry 2001d).

The second task was to lead the Team that established the Joint Hurricane Testbed (JHT) at the National Hurricane Center. The JHT was designed following an earlier concept called the Hurricane Operational Transition (HOT) Center (Elsberry 2001f). Based on a limited call for proposals, nine projects were funded to move research to operations more rapidly and efficiently.

A journal article (Hirschberg et al. 2001) based on an earlier USWRP project was published. Two multiply-authored articles (Nagata et al. 2001a,b) related to testing various mesoscale models for a case of explosive development of a tropical cyclone were also published. A book chapter (Elsberry 2001b) describing the improvements in track forecast guidance also appeared in 2001.

PUBLICATIONS:

Elsberry, R.L., 2001a: Hurricane-related precipitation cannot be predicted on useful time intervals – only quantitative precipitation estimation makes sense. *Preprints, Symposium on Precipitation Extremes*, American Meteorology Society, Albuquerque, NM, 14-18 January, 381-385.

Elsberry, R.L., 2001b: Extratropical transitions of tropical cyclones – Pathway to operations. 2001 Tropical Cyclone Conference, Honolulu, HI, 30 January – 1 February 2001.

Elsberry R.L., 2001c: Proposed Hurricane Operational Transition (HOT) center. Presentation, Interdepartmental Hurricane Conference, Orlando, FL, 6 March 2001.

Elsberry, R.L., 2001d: USWRP hurricane landfall precipitation analysis and forecasting. Preprints, International Conference on Mesoscale Meteorology and Typhoons in East Asia, Taipei, Taiwan, 26-28 September.

Hirschberg, P.A., P.C. Shafran, R.L. Elsberry and E. A. Ritchie, 2001: An observing system experiment with the west coast picket fence. *Monthly Weather Review*, **129**, 2585-2599.

Nagata, M. and 20 co-authors, 2001: Third COMPARE Workshop: A model intercomparison experiment of tropical cyclone intensity and track prediction. *Bulletin of American Meteorology Society*, **82**, 2007-2020.

Nagata, M. and 20 co-authors, 2001: A mesoscale model intercomparison: A case of explosive development of a tropical cyclone (COMPARE III). *Journal Meteorological Society Japan*, **79**, 999-1033.

PRESENTATIONS:

Elsberry, R.L., 2001e: Extratropical transitions of tropical cyclones – Pathway to operations. 2001 Tropical Cyclone Conference, Honolulu, HI, 30 January–1 February 2001.

Elsberry R.L., 2001f: Proposed Hurricane Operational Transition (HOT) center. Interdepartmental Hurricane Conference, Orlando, FL, 6 March 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: U.S. Weather Research Program, Hurricane Landfall, Tropical Cyclones

TRANSITION OF DYNAMICAL MODEL TRACK PREDICTION EVALUATION SYSTEM

Russell L. Elsberry, Professor
Department of Meteorology
Sponsor: National Oceanic and Atmospheric Agency

OBJECTIVE: This proposal is to transition to the Tropical Prediction Center/National Hurricane Center a dynamical model evaluation expert system. The primary effort during the first year was to convert the code and conduct a beta test of the system. The objective during the second year is to produce a version suitable for operational testing.

SUMMARY: A limited conversion of the Systematic Approach Forecasting Aid (SAFA) code for the western North Pacific was accomplished for a beta test of tropical cyclone tracks forecasting in the Atlantic. This version of the code continued to use Navy sources for the dynamical model tracks and fields necessary to run the new code called Dynamical Model Evaluation System (DYMES). These fields were then transferred to the National Hurricane Center in Miami where LCDR Laura Salvador (Navy Liaison) tested the converted code on a workstation provided by this project. Application of DYMES at the Naval Postgraduate School was accomplished by Mark Boothe in a simulated real-time mode. Although a number of communication problems occurred, the first-year objectives were accomplished.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Tropical Cyclone Track Prediction, Expert System

USING THE SHEBA FLUX DATA TO IMPROVE REGIONAL AND GLOBAL CLIMATE MODELS

Peter Guest, Research Associate Professor
Department of Meteorology
Sponsor: National Science Foundation

OBJECTIVES: This is a collaborative effort to use the atmospheric surface layer data collected during the Surface Heat Budget of the Arctic (SHEBA) field program to develop ice-atmosphere exchange algorithms for local, regional and global model ice-atmosphere model of the Arctic.

SUMMARY: This continues an analysis of data collected during a field program that was performed from September 1997 to September 1998. The data set obtained represents the most comprehensive information on surface-layer properties ever obtained in the central Arctic. The project involves analysis of factors affecting the surface heat and momentum fluxes, including snow drifting, melting of the ice surface, radiation and cloud effects and the effects of nearby leads. These results are being incorporated into various models that simulate Arctic air-ice-sea interactions and their effects on regional and global climate.

PUBLICATIONS:

Andreas, T.L., C.W. Fairall, O.P.G. Persson and P.S. Guest, 2002: Probability distributions for the inner scale and the refractive index structure parameter and their implications for flux averaging. *Journal of Geophysical Research*, (in press).

Andreas, E.L., P.S. Guest, O.P.G. Persson, C.W. Fairall, T.W. Horst, R.E. Moritz and S.R. Semmer, 2002: Near-surface water vapor over polar sea ice is always near saturation, *Journal of Geophysical Research-Oceans*, (in press).

Curry, J.A., J.L. Schramm, A. Alam, R. Reeder, T.E. Arbetter and P.S. Guest, 2002: Evaluation of data sets used to force sea ice models in the Arctic Ocean, *Journal of Geophysical Research-Oceans*, (in press).

Intrieri, J.M., C.W. Fairall, M.D. Shupe, O.P.G. Persson, E.L. Andreas, P.S. Guest and R.E. Moritz, 2002: An annual cycle of Arctic surface cloud forcing at SHEBA. *Journal of Geophysical Research*, (in press).

Persson, P.O.G., C.W. Fairall, E.L. Andreas and P.S. Guest, 2002: Measurements near the Atmospheric Surface Flux Group tower at SHEBA: Near-surface conditions and surface energy budget, *Journal of Geophysical Research-Oceans*, (in press).

Uttal, T., J.A. Curry, M.G. McPhee, D.K. Perovich, R.E. Moritz, J.A. Maslanik, P.S. Guest, H.L. Stern, J.A. Moore, R. Turenne, A. Heiberg, M.C. Serreze, D.P. Wylie, O.G. Persson, C.A. Paulson, C. Halle, J.H. Morison, P.A. Wheeler, A. Makshtas, H. Welch, M.D. Shupe, J.M. Intrieri, K Stamnes, R.W. Lindsey, R. Pinkel, W.S. Pegau, T.P. Stanton and T.C. Grenfeld, 2002: The surface heat budget of the Arctic, *Bulletin of the American Meteorological Society*, **83**, 255-276.

PRESENTATIONS:

Andreas, E.L., P.S. Guest, O.P.G. Persson, C.W. Fairall, T.W. Horst and R.E. Moritz, 2001: Relative humidity measurements near saturation at temperatures well below 0°C. Preprint volume, 11th Symposium on Meteorological Observations and Instrumentation of the American Meteorological Society, Albuquerque, NM, 14-18 January 2001, 159-164. (Program in *Bulletin American Meteorology Society*, **81**, 2848-2855.)

Andreas, E.L., C.W. Fairall, P.S. Guest and O.P.G. Persson, 2001: The air-ice drag coefficient for a year over Arctic sea ice. Sixth Conference on Polar Meteorology and Oceanography, San Diego, CA, 14-18 May 2001.

Fairall, C.W., J.M. Intrieri, M. Shupe, P. Guest, E.L. Andreas and O.P.G. Persson, 2001: Cloud forcing of turbulent and radiative energy budgets on the Arctic ice cap: one year of data from the SHEBA experiment (invited talk). Sixth Conference on Polar Meteorology and Oceanography, San Diego, CA, 14-18 May 2001.

Guest, Peter S., O.P.G. Persson, E.L. Andreas and C.W. Fairall, 2001: What is the role of the sensible hear flux on the surface heat budget of the multi-year sea ice? (invited talk). Sixth Conference on Polar Meteorology and Oceanography, San Diego, CA, 14-18 May 2001.

Guest, P.S., A. Schweiger, T. Beesley, E. Andreas, C. Fairall and P.O. Persson, 2002: Atmospheric Forcing in PIPS 3.0, PIPS 3.0. Meeting, Fleet Numerical Oceanography and Meteorology Center, Monterey, CA, 23-24 January 2002.

Persson, O.P.G., C.W. Fairall, E.L. Andreas and P.S. Guest, 2001: Measurements of the surface energy budget on multi-year ice at SHEBA. Sixth Conference on Polar Meteorology and Oceanography, San Diego, CA, 14-18 May 2001.

Renfrew, I.A., G.W.K. Moore, P.S. Guest and K. Bumke, 2001: A comparison of surface-layer and surface turbulent-flux observations over the Labrador Sea with ECMEF analyses and NCEP re-analyses. Sixth Conference on Polar Meteorology and Oceanography, San Diego, CA, 14-18 May 2001.

DoD KEY TECHNOLOGY AREAS: Other (Meteorology)

KEYWORDS: Polar Meteorology, Air-Sea-Ice Interactions, Surface Fluxes

NUMERICAL HINDCASTS OF THE CALIFORNIA CURRENT

Robert L. Haney, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: The broad objective of this research is to support the Navy in the development of a reliable ocean modeling and prediction capability for the coastal oceans.

SUMMARY: During FY01 studies were completed in the California Current, in the Alboran Sea, and on the variability of the global thermohaline circulation. In the California Current a new explanation was offered for the offshore propagation of eddy kinetic energy recently observed by satellite data (Haney et al. 2001) and the three dimensional circulation and vertical velocity in several coastal jets and filaments observed in the ONR Coastal Transition Zone (CTZ) program (Haney and Hale 2001) were diagnosed and observed. In collaboration with Spanish colleagues, we identified several new eddy features in the Alboran Sea observed by Synthetic Aperture Radar (Font et al. 2002). Finally, in collaboration with a Spanish doctoral student and other colleagues, it was shown that a new nonlinear mechanism, stochastic resonance, makes the thermohaline circulation more likely to undergo significant fluctuations in response to variations in atmospheric forcing (Velez-Belchi et al. 2001).

PUBLICATIONS:

Haney, R.L., R.A. Hale and D.E. Dietrich, 2001: Offshore propagation of eddy kinetic energy in the California Current. *Journal of Geophysical Research,* **106,** 11709-11717.

Haney, R.L. and R.A. Hale, 2001: The use of digital filter initialization to diagnose the mesoscale circulation and vertical motion in the California coastal transition zone. *Journal of Marine Systems,* **29,** 335-363.

Velez-Belchi, P., A. Alvarez, P. Colet, J. Tintore and R.L. Haney, 2001. Stochastic resonance in the thermohaline circulation. *Geophysical Research Letters,* **28,** 2053-2056.

Font, J., S. Rousseau, B. Shirasago, E. Garcia-Gorriz and R.L. Haney, 2002: Mesoscale variability in the Alboran Sea: Synthetic Aperture Radar imaging of frontal eddies. *Journal of Geophysical Rsearch,* **107,** in press.

PRESENTATIONS:

Haney, R.L., R.A. Hale and D.E. Dietrich, 2001: Offshore propagation of eddy kinetic energy in the California Current. 13th AMS Conference on Atmospheric and Oceanic Fluid Dynamics, Breckenridge, CO, 4-8 June 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Coastal Transition Zone, Global Thermohaline Circulation

EVOLUTION OF TROPICAL CYCLONE CHARACTERISTICS

Patrick A. Harr, Research Associate Professor
Russell L. Elsberry, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: Tropical cyclone frequency, motion, and structure characteristics depend on a variety of environmental and internal factors. The primary objectives of this research are to identify these factors and determine how each impacts tropical cyclone characteristics.

SUMMARY: Tropical cyclone activity/inactivity may be related to mechanisms that act over a variety of space and time scales. It is hypothesized that the mechanisms responsible for clustering of tropical cyclone activity can be put into a framework of interactions between several modes of circulation variability. A wavelet analysis was used to define the dominant modes of low-level circulation and outgoing longwave radiation (OLR) variability over the western North Pacific in a time-frequency reference. Partitions have been identified to represent an intraseasonal mode (30-90 days), a western North Pacific monsoon trough mode (10-25 days), and a synoptic mode (2-8 days). A singular value decomposition (SVD) analysis was used to describe the primary patterns of large-scale variability associated with the covariance between circulation features and OLR identified with predominant peaks in spectral power. Based on circulation indices from data filtered for each frequency range, a cross-wavelet analysis defined periods of significant covariability between the frequency ranges. New circulation and OLR modes are defined based on separation of periods of significant interactions between frequency bands from periods when there are no interactions. The addition of these conditioned modes to the individual modes defined above increases the amount of explained variability in tropical cyclone activity.

The study of the extratropical transition of western North Pacific tropical cyclones (TCs) addressed the re-intensification stage during which the TC remnants develop as an extratropical cyclone. The relative contributions from midlatitude circulations and the decaying tropical cyclone were assessed with numerical simulations by removing the tropical cyclone remnants from the model initial conditions or displacing the remnants relative to the midlatitude circulation. Re-intensification is favored when the upper-level TC outflow enhances the equatorward entrance region of a downstream jet streak, and when the TC remnant circulation interacts with the lower-tropospheric baroclinic zone. Thus the interaction is not a static process, but a dynamic process in which both the TC and midlatitude circulation have a contribution.

An algorithm has been developed to detect and track in dynamical model fields those circulations that have become, or are forecast to become, tropical cyclones. Additionally, specific environmental conditions in the model analysis and forecast fields are attached to the tracked circulation. Threshold values of important environmental parameters associated with failed and successful model predictions of tropical cyclone formation are identified at each forecast range.

PUBLICATIONS:

Chang, C.–P., P.A. Harr and J. Ju, 2001: Possible roles of Atlantic circulations on the weakening Indian monsoon rainfall-ENSO relationship. *Journal of Climate*, **14**, 2376-2380.

Klein, P.M., P.A. Harr and R.L. Elsberry, 2001: Extratropical transition of western North Pacific tropical cyclones: Midlatitude and tropical cyclone contributions to re-intensification. *Monthly Weather Review* accepted pending minor revisions.

Jones, S.C., P.A. Harr, J. Abraham, L.F. Bosart, P.J Bowyer, B.N. Hanstrum, M.R. Sinclair, R.K. Smith and C. Thorncroft, 2001: The extratropical transition of tropical cyclones: Forecast challenges, current understanding and future directions. *Weather and Forecasting*, In revision.

PRESENTATIONS:

Harr, P.A. and R.L. Elsberry, 2001: An overview of heavy precipitation associated with the extratropical transition of tropical cyclones. *Preprints, Symposium on Precipitation Extremes:* Prediction, Impacts and Responses. American Meteorology Society, Boston, MA, 02108, 288-292.

Harr, P.A. and R.L. Elsberry, 2002: Prediction of intraseasonal variability in tropical cyclone activity over the western North Pacific Ocean. 25th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, 29 April-3 May 2002.

Doric, T., P.A. Harr and R.L. Elsberry, 2002: Assessment of the potential for prediction of tropical cyclone formation in the Navy global model. 25th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, 29 April-3 May 2002.

Klein, P.M., P.A. Harr and R.L. Elsberry, 2002: Extratropical transition of western North Pacific tropical cyclones: Midlatitude and tropical cyclone contributions to re-intensification. 25th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, 29 April-3 May 2002.

DoD TECHNOLOGY AREA: Environmental Quality, Modeling and Simulation

KEYWORDS: Tropical Cyclones, Midlatitude Cyclones, Numerical Weather Prediction, Extratropical Transition

GLOBEC - NORTHEAST PACIFIC CLIMATE CHANGE MECHANISMS

Tom Murphree, Senior Lecturer
Department of Meteorology
Sponsor: National Oceanic and Atmospheric Administration

OBJECTIVES: This project is designed to analyze long term weather and climate variations in the North Pacific – North American atmosphere and ocean, and the mechanisms that produce these variations.

SUMMARY: This project is part of the U.S. GLOBEC research program, funded by the National Science Foundation and the National Oceanic and Atmospheric Administration (NOAA). These projects are being conducted in collaboration with researchers in the Department of Oceanography at the Naval Postgraduate School (NPS) and at the Pacific Fisheries Environmental Laboratory (PFEL) of NOAA in Pacific Grove, CA. Our goal is to develop a better understanding of the intraseasonal to decadal variations of the atmosphere and ocean in the North Pacific – North American (NPNA) region. The work emphasizes the identification and description of the mechanisms that govern these variations (e.g., teleconnections form remote regions and their impacts on surface wind stress and moisture transports). This research involves dynamical analyses of observed, analyzed, and modeled atmospheric and oceanic fields. During 2001, the focus was on: (1) additional development and application of the Northern Oscillation Index (NOI) and other observational and model products; (2) diagnostic analyses of interannual to decadal variations of the atmosphere and upper ocean; (3) analyses of the simulation of these variations by a global ocean general circulation model; and (4) identification of the major atmospheric and oceanic mechanisms that link the NPNA region to southern and eastern Asia and the tropical Pacific. Some specific aspects of this work are described below.

Monthly updated climatologic and retrospective data were maintained for use in the project and by the GLOBEC research community. A current focus is developing data products from subsurface databases. Subsurface ocean variations may be: (a) large and persistent; difficult to infer from surface variations; and (c) a significant factor in the development of subsequent surface variations. In addition, the output from global ocean general circulation models are compared to observed fields, and developing data products based on the model output.

Decadal fluctuations in global climate are major climate events that can be identified by a number of climate indices, including the Northern Oscillation Index (NOI), and upper ocean temperature anomalies in the NPNA region. During the negative NOI phase, for example, NPNA temperatures are anomalously warm and NPNA surface wind stress is anomalously anticyclonic. The warm phase of this pattern has dominated since 1976. However, analyses indicate a regime shift toward the negative NPNA anomaly phase may have occurred in mid-1998. Results also indicate that decadal anomaly patterns are dynamically similar to those on interannual (e.g., El Niño/La Niña), seasonal, and intraseasonal (e.g., weekly to monthly variations of tropical and monsoon convection) scales.

A central question in the work is the degree to which variations in the NPNA region are triggered by vertical fluxes (e.g., those associated with *in situ* wind stress curl) versus lateral transports (e.g., those associated with atmospheric teleconnections, ocean planetary waves). Climatologic and anomalous variations in historical data sets and model output are currently being analyzed to quantify the roles of each. Early results indicate long-term variability in the NPNA region is a complex signal composed of both sources of forcing, but with wind stress curl and consequent geostrophic advections being especially important for large scale variations occurring on intraseasonal and longer time scales.

One hypotheses is that atmospheric and oceanic teleconnections explain much of the climate variability in the NPNA region. Recent research has identified specific locations – the central and western tropical Pacific, east Asia, and the Asian Arctic – where atmospheric teleconnections originate that

commonly affect the NPNA region on intraseasonal to decadal scales. Ongoing work is seeking to determine the relative role of each source, climatologically and for individual climate events, and the mechanisms by which atmospheric anomalies influence the upper ocean.

It is also hypothesized that the seasonal evolution of ocean conditions, and the atmospheric factors that force them, may be an analog to the development of interannual (e.g., El Niño/La Niña) and decadal (e.g., regime shift) ocean anomalies. Current focus is on analyses on understanding the seasonal response of the NPNA region to atmospheric forcing, and relating this relationship to anomalies on interannual and longer time scales, based on historical data and model output.

PUBLICATIONS:

Murphree, T., L. Feinberg, F. Schwing and R. Smith. 2001. Decadal Events in the Northeast Pacific. *Report of the U.S. GLOBEC Northeast Pacific California Current Scientific Investigators Meeting*. NEP GLOBEC Office, Corvallis, OR..

Schwing, F.B., T. Murphree and P.M. Green. 2002. The Northern Oscillation Index (NOI): a new climate index for the northeast Pacific. *Progress in Oceanography*, in press.

Schwing, F.B., T. Murphree, L. deWitt and P.M. Green. 2002. The evolution of oceanic and atmospheric anomalies in the northeast Pacific during the El Niño and La Niña events of 1995-2001. *Progress in Oceanography*, **53**, 115-139.

PRESENTATIONS:

Green-Jessen, P., F. Schwing, S. Bograd and T. Murphree. The seasonal cycle of upper ocean temperature of the west coast: local atmospheric forcing and Rossby wave propagation. Eastern Pacific Ocean Conference, Fallen Leaf Lake, CA, September 2001.

Green, P., F. Schwing, F. and T. Murphree. Wind stress curl and ocean conditions in the northeast Pacific: a mechanism for ocean climate change. Pacific Climate Workshop, Pacific Grove, CA, March 2001.

Murphree, T., B. Ford, F. Schwing and P. Green. Teleconnections from southeast Asia and the western tropical Pacific: their role in north Pacific and North American climatic variations. Pacific Climate Workshop, Pacific Grove, CA, March 2001.

Murphree, T. West coast weather and climate: the tropical connections. American Meteorological Society Chapter Meeting, Monterey, CA, December 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Environmental Processes, Environmental Monitoring, Environmental Modeling)

KEYWORDS: Atmospheric and Oceanic Variations, El Niño, GLOBEC, La Niña, Long Term Weather, North Pacific, Teleconnections, Weather and Climate Systems

CENTRAL CALIFORNIA MESONET FOR USE IN LAPS AND LOCAL MESOSCALE MODELING

Wendell A. Nuss, Associate Professor
Department of Meteorology
Sponsor: National Weather Service

OBJECTIVE: The objective of this project is to develop a mesoscale observing network from existing sources and utilize these data in the Local Analysis and Prediction System (LAPS) at San Jose State University and real-time MM5 forecasts at the Naval Postgraduate School. The data will also be used to conduct model verifications and mesoscale circulation studies.

SUMMARY: Data from a variety of observing networks are being gathered by NPS to develop a California mesoscale observing network (mesonet). Presently observations from the California Department of Forestry, National Weather Service, and various NPS run stations are being collected in real-time with stations from local air pollution districts and the California Irrigation Management Service being collected once per day. These observations a being shared with San Jose State University and the National Weather Service as well as being used to produce a local mesoscale wind analysis that is displayed on the web (http://www.weather.nps.navy.mil/wx/latest_mbay.gif). The mesonet data is being utilized to feed into the real-time mesoscale model forecasts done by NPS. Additional observations from the California Department of Water Resources were added to the mesonet. The data have also been reformatted into a standard form for easier distribution and use.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Coastal Meteorology, Mesoscale Modeling, Regional Forecasting

PRACTICAL LIMITS TO ATMOSPHERIC MESOSCALE PREDICTABILITY

Wendell A. Nuss, Associate Professor
Douglas K. Miller, Research Assistant Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: The objectives of this research are to determine the ability to numerically predict mesoscale coastal structures in a variety of synoptic scale situations and demonstrate for given small-scale structures the time ranges under which they might be considered predictable. The answer is probably dependent on the data assimilation system and one objective is to determine this sensitivity.

SUMMARY: A diagnostic study of the causes of differences in terrain enhanced precipitation due to slight changes in the topographic orientation has been completed and reveals that the precipitation is highly sensitive to the amplitude of moist mountain waves induced by the flow across the topography. When the flow more directly impinged upon the topography, higher amplitude mountain waves were observed. This resulted in more drying in the lee of the topography and a strong humidity gradient that forced greater precipitation in the model. When the flow was more parallel to the topography, a weaker flow across the mountain occurred and lower amplitude mountain waves. This resulted in more uniform moisture and less precipitation. The differences in cross-mountain flow were found to be the result of increased frontogenesis for the flow oriented more cross-mountain. The increased frontogenesis developed due to feedback during the preceding 12 hours. This sensitivity highlights the limits of mesoscale predictability for landfalling frontal systems.

The results from Kuypers (2000) suggested that the structure of the observational sample could substantially impact on the growth of forecast error. Consequently, experiments to test whether a sampling strategy optimized for the data assimilation system would consistently produce reduced forecast error was designed and carried out during the past year. The results of designing this sampling strategy revealed that extensive, scattered observations were necessary to define a wide variety of atmospheric structures. This highlighted the need to completely sample a wide range of wavelengths in the atmospheric structure. After extracting this optimal sample, a similar number of random observations were extracted and both sets were used to assimilate into the model to compare their impact on short-term forecasts. The results show that the optimal sampling consistently reduced error compared to random sampling. This suggests that the structure of a observational sample is very important to reduce error. While the targeting was based on defining the basic thermal structure of the forecast atmosphere, optimally sampling dynamically based sensitivity patterns from adjoint sensitivity or ensemble methods could also be done. This might improve the error reduction even more.

PUBLICATIONS:

Nuss, W.A. and D.K. Miller, 2001: Mesoscale Predictability under Various Synoptic Regimes. *Nonlinear Processes in Goephysics*, 25 .

PRESENTATIONS:

Nuss, W.A. and D.K. Miller, 2001: A Comparison of Mesoscale Forecast Accuracy using Random and a Simplified Targeting Approach. Preprints, Ninth Conference on Mesoscale Processes, Ft. Lauderdale, FL, 30 July–2 August 2001.

Nuss, W.A., 2001: Relationship between Synoptic Scale and Mesoscale Forecast Errors. PACJET Workshop, Monterey, CA, 24-26October 2001.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Data Assimilation, Predictability, Regional Forecasting

EASTERN PACIFIC OCEAN LAND-FALLING JETS STUDIES

Douglas Miller, Research Assistant Professor
Department of Meteorology
Sponsor: National Oceanic and Atmospheric Agency

OBJECTIVE: Assist in developing techniques for synthesizing data using a MacIntosh laptop computer onboard the P-3 and transmitting text and images via a new airborne satellite communications link. Test these new tools (laptop, software for graphics manipulation, and sending of messages via satcom) on flights during the "shakedown phase" of PACJET-2001 in January 2001.

The primary task under this contract is to serve as the on-board data synthesis focal point and prototype forecast product generator on all upcoming PACJET flights in 2001. The specific work requirements will be to sort through, as part of a team, a large number and variety of airborne observations gathered in a storm and to create useful image or text files which can relate important aspects of the storm structure to forecasters on the ground, given the limitations of communications bandwidth between the P-3 and the ground.

Prepare a brief written summary of his experience in that position, including examples of successes and problems, and recommendations for improving the performance during the proposed PACJET-2002 deployment.

SUMMARY: The 2000-2001 field phase of PACJET was successfully executed with each of the objectives completed by 1 April 2001. Changes have been implemented for upcoming field phases based on the experiences and recommendations made from observations during the 2000-2001 PACJET field phase.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: PACJET, Land-Falling Jets

ANALYSES OF AIRCRAFT MEASUREMENTS OF BOUNDARY LAYERS AND STRATUS CLOUDS IN THE ARCTIC

Qing Wang, Associate Professor
Department of Meteorology
Sponsor: National Aeronautics and Space Administration - Langley

OBJECTIVE: The objective of this project is to understand the inhomogeneity in the Arctic boundary layer as a result of low-level clouds and the ice surface features such as leads. The goal is to understand the magnitude and variation of surface turbulent fluxes in the total energy budget of the Arctic climate system. The study is part of the effort of FIRE-III/SHEBA.

SUMMARY: Aircraft measurements on boundary layer turbulence structure were made by the NCAR C-130 during the Beaufort Arctic Storms Experiment (BASE) in 1994 and during the Surface Heat Budget of the Arctic (SHEBA) experiment in 1998. Data from one flight during the BASE experiment have been analyzed to study the boundary layer inhomogeneity introduced by the presence of low-level clouds and the fractional cloud cover. It was found that the boundary layer thermodynamics were largely determined by the cloud-top height, since the presence of cloud generally resulted in one or two mixed layers below the cloud top. The two-mixed layer structure in some of the soundings is the result of multiple cloud layers, which is different from the decoupled boundary layers in the subtropical marine boundary layers. In addition, the presence of low-level cloud significantly increased the intensity of boundary layer turbulence. However, significant increase in the magnitude of surface flux in cloudy region compared to the clear region was not observed. Further study indicated that the small flux is caused by the small temperature or moisture perturbation. The turbulence spectra in the clear and cloudy regions indicated that the cloud layer alters the turbulence spectra significantly. Meanwhile, we have performed extensive data analysis for the C-130 measurements made during SHEBA to study the variation of boundary layer stratification and turbulence characteristics during the spring and summer periods. In this study, particular attention was paid to the role of cloud cover and leads on boundary layer turbulence structure.

PUBLICATIONS:

Wang, S., Q. Wang, R.E. Jordan and P.O. Persson, 2001: Interactions among longwave radiation of clouds, turbulence and snow surface temperature in the Arctic: A model sensitivity study. *Journal of Geophysical Research*, **106**, 15,323-15,333.

Wang, Q. and S. Wang, 2002: Cloud and turbulence in the Arctic Autumnal boundary layers, to be submitted to *Boundary Layer Meteorology*.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Boundary Layer Meteorology, Turbulence Structure, Arctic Research

EVALUATIONS OF SURFACE FLUX AND BOUNDARY PARAMATERIZATIONS IN COAMPS USING AIRCRAFT MEASUREMENTS

Qing Wang, Associate Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this project is to evaluate the surface flux and boundary layer parameterizations currently used in COAMPS using measurements from Japan/East Sea Experiment (JES).

SUMMARY: It is generally understood that boundary layer parameterization and surface flux parameterization interact nonlinearly in a mesoscale model. The atmospheric forcing to the ocean is thus affected by the boundary layer parameterizations even with perfect formulation of the drag and exchange coefficients. However, such effect has not been quantified. This project intends to evaluate the behavior of the model predicted boundary layer and surface flux in order to improve the model representation of the

lower atmosphere, particularly the surface fluxes. Simulations have been setup using COAMPS for the Japan/East Sea region at NPS for the month of Feb. 2000 during which period observations by the CIRPAS Twin Otter were available. Initial comparison between the observation and the COAMPS model simulation reveals the model tendency in under-predicting wind, temperature, surface stress, and latent heat fluxes in low to moderate wind conditions, while over-predicting most of these quantities in high wind conditions. The subgrid scale turbulent kinetic energy (TKE) is always under-predicted. To understand the model-observation discrepancy, more in-depth analysis of both the model and observed results are underway.

PUBLICATIONS:

Wang, Q., K. Rados, J.A. Kalogiros, H. Zuo, S. Wang, C. Friehe, D. Khelif and H. Jonsson, 2001: Boundary layer turbulence and surface flux parameterizations in a mesoscale model—verification with aircraft measurements. Ninth Conference on Mesoscale Processes, American Meteorology Society, Ft. Lauderdale, FL, 30 July—2 August 2001.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Surface Flux, Boundary Layer Parameterization, COAMPS, Aircraft Measurement

IMPLEMENTING AND TESTING ENTRAINMENT PARAMETERIZATION FOR STRATOCUMULUS-TOPPED BOUNDARY LAYERS IN COAMPS

Qing Wang, Associate Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this project is to improve the predictions for the stratocumulus-topped boundary layers as well as the cloud-free boundary layers from mesoscale models.

SUMMARY: This 2001 new project intends to first understand the inversion structure at the top of the stratocumulus-topped boundary layer and the fine-scale entrainment process from *in situ* observations. The COAMPS performance against the observed data was systematically evaluated. Within this effort, the feasibility and the successful rate of implementing explicit entrainment parameterization will be assessed and concepts of explicit entrainment parameterization in mesoscale model will be developed and implemented. In 2001, the investigators participated in the field measurement of DYCOMS-II that provides one of the several datasets to be used in the project for COAMPS evaluation. Initial analysis and COAMPS simulation are ongoing.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Stratocumulus-Topped Boundary Layer, Entrainment, Aircraft Measurements

IMPROVING SURFACE FLUX PARAMETERIZATION IN THE NAVY'S COAMPS

Qing Wang, Associate Professor
Department of Meteorology
Sponsor: Office of Naval Research and Naval Research Laboratory

OBJECTIVE: The objective of this project is to improve surface flux parameterizations, particularly in low-wind conditions.

SUMMARY: The NPS effort on this project focused on understanding the scale-dependence of surface flux and boundary layer parameterizations in high- resolution mesoscale models. Intensive analyses on COAMPS simulations of a post-frontal case observed during JES was performed. In particular, the investigators made spectral analyses to the model resolved field to understand the contribution of 'resolved'

large turbulence eddies to the ensemble turbulent fluxes at very high horizontal grid resolution (1 km and 0.5 km for the inner-most grid, respectively). These results are compared to direct measurements in the model domain. From this initial effort, we found: 1) The perturbations close to the smallest resolvable scale of the model are very sensitive to grid resolution. Compared to observations, these scales are not adequately represented in COAMPS, even though they are explicitly resolved. 2) The model parameterized turbulent fluxes, derived from ensemble turbulence statistics, are not sensitive to the grid resolution even though subgrid fluxes are observed to be strong functions of the cutoff wavelength. 3) There are large discrepancies between the parameterized and the observed SGS turbulence fluxes. All these results point to large uncertainties in the exchange coefficients in the surface flux parameterizations in high-resolution mesoscale models.

In 2001, NRL collaborators have made improvements to the surface flux scheme in COAMPS. The NPS effort also included testing the newly developed surface flux scheme and validating COAMPS simulations using multiple buoy data.

PUBLICATIONS:

Wang, Q. and D.P. Eleuterio, 2001: A comparison of bulk aerodynamic methods for calculating air-sea fluxes. Ninth Conference on Mesoscale Processes, American Meteorology Society, Fort Lauderdale, FL, 30 July–2 August 2001.

Wang, S., J. Doyle and Q. Wang, 2001: Improving surface flux parameterization at low wind speeds in the NAVY's COAMPS. Ninth Conference on Mesoscale Processes, American Meteorology Society, Fort Lauderdale, FL, 30 July–2 August 2001.

Wang, S. and Q. Wang, 2001: Surface flux and stratocumulus clouds in DECS: A mesoscale model study. Fourth Conference on Coastal Atmosphere, FL, 6-9 November 2001.

Whisenhant, M.K., Q. Wang, S. Wang and J. Doyle, 2001: Grid resolution and surface flux and boundary layer parameterizations in high-resolution mesoscale models. Ninth Conference on Mesoscale Processes, American Meteorology Society, Fort Lauderdale, FL, 30 July-2 August, 2001.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Surface Flux Parameterization, Mesoscale Modeling

UNDERSTANDING THE EVOLUTION OF STRATOCUMULUS CLOUDS IN THE COASTAL ZONE

Qing Wang, Associate Professor
Department of Meteorology
Sponsor: National Science Foundation

OBJECTIVE: The objective of this project is to examine the physical processes affecting the evolution of coastal stratocumulus clouds.

SUMMARY: During the first year of this project (1999), field measurements of the coastal stratocumulus and the associated boundary layer were made off the coast of Monterey using the CIRPAS Twin Otter research aircraft. In 2001, additional efforts were made in calibrating the wind/turbulence measurements by considering the effects of flow distortion. This effort results in new understanding of aircraft measured turbulence in general. A fully calibrated high-rate turbulence data is now available to collaborating research groups.

Efforts were made to study the interaction between the evolution of stratocumulus cloud and the coastal flow field. The effects of the coastal jet on the evolution of stratocumulus clouds were studied through analyses on the case observed on July 6. The variation of the cloud layer along a vertical crosssection due west from Monterey Bay was analyzed. It was found that the strong low-level coastal jet promoted the cloud decoupling from the surface layer and the cloud start thinning quickly. Two

decoupling mechanisms seem to be generated by the jet: i) the negative surface buoyancy flux because the curl of the surface wind stress in the area of the wind jet supports local upwelling which results in a cold pool of sea surface temperature and ii) the enhanced entrainment at cloud top due to wind shear. The decoupling cannot be the result of solar radiation absorption by the cloud alone because it happened in a limited zone only.

Within the same project, we continued the analysis from the previous year on the breakup mechanism of the coastal stratocumulus on the coast using continuous measurements from the Marine Atmospheric Measurement Lab (MAML) at NPS. The time evolution of the boundary layer vertical profiles of wind and temperature before and after the cloud breakup was analyzed. One dimensional simulation using a simple mixed layer cloud model, modified for simulating stratocumulus clouds over the coastal land, was performed to test hypotheses formed based on the observations. The results point to increases in cloud top entrainment and the accompanied warming and drying of the boundary layer air.

PUBLICATIONS:

Kalogiros, J. and Q. Wang, 2001: The California low-level coastal jet and nearshore stratocumulus, Conference preprints, Fourth Conference on Coastal Atmospheric and Oceanic Prediction and Processes, St. Petersburg, FL, 6-9 November 2001.

Kalogiros, J.A. and Q. Wang, 2002: Wind turbulence measurements in the atmospheric boundary layer using a radome-differential GPS System on a small research aircraft. Accepted by *Journal of Atmospheric Ocean Technology.*

Kalogiros, J.A. and Q. Wang, 2002: Aerodynamic effects on wind turbulence measurements with research aircraft. Submitted to *Journal of Atmospheric Ocean Technology.*

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Coastal Clouds, Boundary Layer Evolution, Aircraft Turbulence Measurement

COLLABORATIVE RESEARCH PROJECTS IN DIRECT SUPPORT OF FNMOC OPERATIONAL MISSION

Carlyle H. Wash, Professor
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: The broad objective of this research is to execute collaborative research projects with the Fleet Numerical Meteorology and Oceanography Center (FNMOC). The collaboration includes NPS Meteorology faculty, NPS students conducting thesis research, and FNMOC personnel. These joint projects address FNMOC operational needs and advance the understanding of marine meteorology.

SUMMARY: Two collaborative thesis projects were supported in FY00 funding. The first project was Improvements to METOC Analysis and Forecast Visualizations by LT Keith Barto. NPS thesis advisor was Professor C. H. Wash and FNMOC collaborator was Mr. Ralph Loveless. In this study, LT Barto incorporated high resolution (1 km) global topography data base into Joint METOC (released as version 3.4) and other FNMOC model and data displays.

The second project is: The Role of Weather in Class A Naval Aviation Mishaps FY 90-98 by LCDR Ruben Cantu NPS; thesis advisors were Professor C. H. Wash and Senior Lecturer Tom Murphree. In this study, 235 Class A Navy and Marine aviation mishaps involving aircrew error between FY90 and 98 were analyzed for role of weather. In addition to determining the overall role of weather, various aspects of the mishaps such as aircraft category, type of mishaps, type of weather and flight phase were investigated.

A third effort is underway. LT Todd Barnhill is working with Professor C. H. Wash and FMNOC advisor Mr. Dave Huff to modernize the FNMOC support and products used in ship routing and ship forecasting. This thesis will be completed in FY2002.

THESIS DIRECTED:

Barto, K., "Improvements to METOC Analysis and Forecast Visualizations," Masters Thesis, Naval Postgraduate School, September 2000.

Cantu, Ruben, "The Role of Weather in Class A Naval Aviation Mishaps FY90-98," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Operational Mission, Marine Meteorology, FNMOC Support

TAMS-RT VERIFICATION AND EVALUATION

Carlyle H. Wash, Professor
Department of Meteorology
Sponsor: Space and Naval Warfare Systems Command

OBJECTIVE: The technical objective of this project is to verify and evaluate NPMOC San Diego TAMS-RT and other COAMPS mesoscale forecasts using all available local and mesoscale data.

SUMMARY: This project has established a cassette tape archive of all TAMS-RT San Diego forecasts. In addition one thesis was completed. LCDR Gret Schmeiser, USN, investigated the ability of COAMPS to forecast the major East Coast cyclone of 24-26 January 2000. This storm was of particular interest due to the poor performance of many numerical and human forecasts. LCDR Schmeiser found COAMPS did provide a very accurate storm track and forecast of intensity. However, it failed, as did many other models, in resolving the associated heavy snow and precipitation bands. Some experimental forecasts using the new data assimilation system (NAVDAS) did have positive impacts on the forecasts.

CONFERENCE PAPER:

Wash, C.H. and G. Schmeiser, Verification and Evaluation of NOGAPS and COAMPS Analyses and Forecasts for the 25 January 2000 Cyclone. Preprints, Eighteenth Conference on Weather Analysis and Forecasting, Fort Lauderdale, FL, 30 July–2 August 2001.

THESIS DIRECTED:

Schmeiser, G.J., "Investigation of the 25 January 2000 East Coast Cyclogenesis," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOGY AREAS: Modeling and Simulation

KEYWORDS: Cloud Forecasting, Precipitation Forecasting, COAMPS, Mesoscale Modeling and Forecasting

BOUNDRY LAYER EFFECTS ON MESOSCALE PHENOMENA

R. Terry Williams
Department of Meteorology
Sponsor: Office of Naval Research

OBJECTIVE: To improve the simulation of boundary layer effects on fronts in coastal regions.

SUMMARY: Maritime frontogenesis was investigated with a two-dimensional model with a K-theory boundary layer parameterization. No moisture was included. It was found that much more intense cold

fronts were predicted over the ocean than over land due to a much smaller z_0 over water. The numerical solutions were similar to intense fronts that have been observed over the ocean.

It was found by numerical integration that boundary layer mixing has a strong effect on cold fronts moving over large-scale topography. In particular the fronts became stronger as they moved up the mountain slope, while the opposite happened when there was no boundary layer.

Unbalanced frontogenesis was examined by considering an initial temperature disturbance with no initial wind. The calculations were carried out with zero potential vorticity that corresponds to zero static stability in the initial state. A frontal discontinuity was obtained when the Rossby number was above a critical value. Otherwise a modified inertial oscillation was obtained.

PUBLICATIONS:

Blumen, W. and Williams, R. T., Unbalanced Frontogenesis. Part I: Zero potential vorticity. *Journal of Atmospheric Science,* **58**, 2180-2195, 1 August 2001.

Peng, M.S., Powell, J.H., Williams, R.T. and Jeng, B.-F., Boundary Layer Effects on Fronts over Topography. *Journal of Atmospheric Science,* **58**, 2222-2239, 1 August 2001.

PRESENTATIONS:

Williams, R.T., Modification of Frontal Dynamics by Topography. PACJET Workshop-2001, Monterey CA, 24-26 October 2001.

THESES DIRECTED:

McDougall, C., "Maritime Frontogenesis," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Numerical Models, Topographic Effects, Fronts

DEPARTMENT OF METEOROLOGY

2001
Faculty Publications and Presentations

PUBLICATIONS/PRESENTATIONS

JOURNAL PAPERS

Blumen, W. and Williams, R. T., Unbalanced Frontogenesis. Part I: Zero potential vorticity. *Journal of Atmospheric Science,* 58, 1 August 2001, 2180-2185.

Carr, L.E., III, R.L. Elsberry and J.E. Peak, 2001: Beta test of the Systematic Approach Expert system prototype as a tropical cyclone track forecasting aid (SAFA). *Weather and Forecasting*, **16**, 355-368.

Chang, C.P., P.A. Harr and J. Ju, 2001: Possible roles of Atlantic circulations on the weakening Indian Monsoon-ENSO relationship, *Journal of Climate*, Vol. **14**, pp. 2376-2380.

Cheung, K.K.W., Ensemble forecasting of tropical cyclone motion: comparison between regional bred modes and random perturbations, *Meteorology and Atmospheric Physics*, Vol. **78**, pp. 23–34, 2001.

Cheung, K.K.W., A review of ensemble forecasting techniques with a focus on tropical cyclone forecasting, *Meteorology Applications*, Vol. **8**, pp. 315–332, 2001.

Durkee, P.A., K.E. Nielsen, P.J. Smith, P.B. Russell, B. Schmid, J.M. Livingston, B.N. Holben, C. Tomasi, V. Vitale, D. Collins, R.C. Flagan, J.H. Seinfeld, K.J. Noone, E. Öström, S. Gassò, D. Hegg, L.M. Russell, T.S. Bates and P.K. Quinn, 2000: Regional aerosol optical depth characteristics from satellite observations: ACE-1, TARFOX and ACE-2 results. *Tellus*, 52B, 484-497.

Haney, R.L., R.A. Hale and D.E. Dietrich, 2001: Offshore propagation of eddy kinetic energy in the California Current. *Journal of Geophysical Research,* 106, 11709-11717.

Hirschberg, P.A., P.C. Shafran, R.L. Elsberry and E.A. Ritchie, 2001: An observing system experiment with the west coast picket fence. *Monthly Weather Review*, **129**, 2585-2599.

Gassò, S., D.A. Hegg, D.S. Covert, D. Collins, K.J. Noone, E. Öström, B. Schmid, P.B. Russell, J.M. Livingston, P.A. Durkee and H. Jonsson, 2000: Influence of humidity on the aerosol scattering coefficient and its effect on the upwelling radiance during ACE2. *Tellus,* 52B, 546-567.

Haney, R.L. and R.A. Hale, 2001: The use of digital filter initialization to diagnose the mesoscale circulation and vertical motion in the California coastal transition zone. *Journal of Marine Systems*, **29**, 335-363.

Jensen, D.R., S.G. Gathman, C.R. Zeisse, C.P. McGrath, G. de Leeuw, H.M. Smith, P.A. Frederickson and K.L. Davidson, Electrooptical propagation assessment in coastal environments (EOPACE) summary and accomplishments. *Optical Engineering*, Volume **40**, pp. 1486-1498, 2001.

Johnson, D.W., S. Osborne, R. Wood, K. Suhre, R. Johnson, S. Businger, P.K. Quinn, A. Wiedensohler, P.A. Durkee, L.M. Russell, M.O. Andreae, C. O'Dowd, K.J. Noone, B. Bandy, J. Rudolph and S. Rapsomanikis, 2000: An overview of the Lagrangian experiments undertaken during the North Atlantic Regional Aerosol Characterization Experiment (ACE-2). *Tellus,* 52B, 290-320.

Kuo, H.-C., R.T. Williams, J.-H. Chen and Y.-L. Chen, Topographic effects on barotropic vortex motion: no mean flow. *Journal of Atmospheric Science,* **58**, 15 May 2001, 1310-1327.

Kuo, H.-C., J.-H. Chen, R.T. Williams and C.-P. Chang, 2001: Rossby waves in zonally opposing mean flow: behavior in Northwest Pacific summer monsoon. *Journal of Atmospheric Science,* **58**, 1035-1050.

Li, T., Y. Zhang, C.-P. Chang and B. Wang, 2001: On the relationship between Indian Ocean SST and Asian summer monsoon. *Geophysical Research Letters,* **28**, 2843-2846.

Li, T., C.W. Tham and C.-P. Chang, 2001: A coupled air-sea-monsoon oscillator for the TBO. *Journal of Climate*, **14**, 752-764.

Livingston, J.M., V.N. Kapustin, B.Schmid, P.B. Russell, P.K. Quinn, T.S. Bates, P.A. Durkee, P.J. Smith, V. Freudenthaler, M. Wiegner, D.S. Covert, S. Gasso, D. Hegg, D.R. Collins, R.C. Flagan, J.H. Seinfeld, V. Vitale and C. Tomasi, 2000: Shipboard sunphotometer measurements of aerosol optical depth spectra and columnar water vapor during ACE-2 and comparison with selected land, ship, aircraft, and satellite measurements. *Tellus,* 52B, 594-619.

Mahrt, L., D. Vickers, J. Sun, T. Crawford, G. Crescenti and P. Frederickson, 2001: Surface stress in offshore flow and quasi-frictional decoupling, *Journal of Geophysical Research (Atmospheres)*, Vol. **106**, pp. 20629-20639.

Nagata, M., R.L. Elsberry and 19 co-authors, 2001: Third COMPARE Workshop: A model intercomparison experiment of tropical cyclone intensity and track prediction. *Bulletin of American Meteorology Society,* **82**, 2007-2020.

Nagata, M., R.L. Elsberry and 19 co-authors, 2001: A mesoscale model intercomparison: A case of explosive development of a tropical cyclone (COMPARE III). *Journal Meteorological Society Japan*, **79**, 999-1033.

Nuss, W.A. and D.K. Miller, 2001: Mesoscale predictability under various synoptic regimes. *Nonlinear Process in Geophysics,* 25.

Peng, M.S., Powell, J.H., Williams, R.T. and Jeng, B.-F., Boundary layer effects on fronts over topography. *Journal of Atmospheric Sciences,* **58**, 1 August 2001, 2222-2239.

Ritchie, E.A. and R.L. Elsberry, 2001: Simulations of the transformation stage of the extratropical transition of tropical cyclones. *Monthly Weather Review*, **129**, 1462-1480.

Schmid, B., J.M. Livingston, P.B. Russell, P.A. Durkee, H.H. Jonsson, D.R. Collins, R.C. Flagan, J.H. Seinfeld, S. Gasso, D.A. Hegg, E. Ostrom, K.J. Noone, E.J. Welton, K.J. Voss, H.R. Gordon, P. Formenti and M.O. Andreae, 2000: Clear-sky closure studies of lower tropospheric aerosol and water vapor during ACE-2 using airborne sunphotometer, airborne in-situ, space-borne and ground based measurements. *Tellus,* 52B, 568-593.

Uttal, T., J.A. Curry, M.G. McPhee, D.K. Perovich, R.E. Moritz, J.A. Maslanik, P.S. Guest, H.L. Stern, J.A. Moore, R. Turenne, A. Heiberg, M.C. Serreze, D.P. Wylie, O.G. Persson, C.A. Paulson, C. Halle, J.H. Morison, P.A. Wheeler, A. Makshtas, H. Welch, M.D. Shupe, J.M. Intrieri, K Stamnes, R.W. Lindsey, R. Pinkel, W.S. Pegau, T.P. Stanton and T.C. Grenfeld, 2002: The surface heat budget of the Arctic, *Bulletin of the American Meteorological Society*, **83**, 255-2765.

Velez-Belchi, P., A. Alvarez, P. Colet, J. Tintore and R.L. Haney, 2001. Stochastic resonance in the thermohaline circulation. *Geophysical Research Letters,* **28**, 2053-2056.

Wang, S., Q. Wang, R.E. Jordan and O.P. Persson, 2001: Interactions among longwave radiation of clouds, turbulence and snow surface temperature in the Arctic: A model sensitivity study. *Journal of Geophysical Research*, **106**, 15,323-15,333.

Welton, E.J., K.J. Voss, H.R. Gordon, H. Maring, A. Smirnov, B. Holben, B. Schmid, J.M. Livingston, P.B. Russell, P.A. Durkee, P. Formenti and M.O. Andrea, 2000: Ground-based lidar measurements of aerosols during ACE-2: instrument description, results, and comparisons with other ground-based and airborne measurements. *Tellus,* 52B, 636-651.

CONFERENCE PAPERS

Andreas, E.L., P.S. Guest, O.P.G. Persson, C.W. Fairall, T.W. Horst and R.E. Moritz, 2001: Relative humidity measurements near saturation at temperatures well below 0°C. Preprint volume, 11th Symposium

on Meteorological Observations and Instrumentation, American Meteorological Society, Albuquerque, NM, 14-18 January 2001, 159-164.

Cheung, K.K.W., A modeling study of mesoscale convective vortices in relation to tropical cyclone formation, Proceedings of the International Conference on Mesoscale Meteorology and Typhoon, Taipei, Taiwan, 26–28 September 2001, 151–152.

Elsberry R.L., 2001: USWRP hurricane landfall precipitation analysis and forecasting. Preprints, International Conference on Mesoscale Meteorology and Typhoons in East Asia, Taipei, Taiwan, 28 September 2001, 299-30426.

Elsberry, R.L., 2001: Hurricane-related precipitation cannot be predicted on useful time intervals – only quantitative estimation makes sense. Preprints, Symposium on Precipitation Extremes, American Meteorological Society, Albuquerque, NM, 14-18 January 2001, 381-385.

Harr, P.A. and R.L. Elsberry, 2001: An overview of heavy precipitation associated with the extratropical transition of tropical cyclones. Preprints, Symposium on Precipitation Extremes: Prediction, Impacts and Responses. American Meteorological Society, Boston, MA, 288-292.

Frederickson, P.A. and K.L. Davidson, Observational (buoy-based) studies of the wave influence on air-sea fluxes. WCRP/SCOR Workshop on Intercomparison and Validation of Ocean-Atmosphere Flux Fields, Potomac, MD, 21-24 May 2001. (WMO Technical Document No. 1083, pp. 329-332, August 2001.)

Frederickson, P., K. Davidson, J. Stapleton, D, Shanklin, R. Wiss, T. Nguyen, E. Burgess III, C. Weeks, W. Thornton and T. Brown, Validation of AREPS propagation assessments using different evaporation duct models. Battlespace Atmospheric and Cloud Impact on Military Operations (BACIMO 2001) Conference, Fort Collins, CO, 10-12 July 2001. (Army Research Laboratory CD-ROM ARL-SR-01126, October 2001)

Green-Jessen, P., F. Schwing, S. Bograd and T. Murphree. The seasonal cycle of upper ocean temperature of the west coast: local atmospheric forcing and Rossby wave propagation. Eastern Pacific Ocean Conference, Fallen Leaf Lake, CA, September 2001.

Harr, P.A. and Elsberry, R.L., An overview of heavy precipitation associated with the extratropical transition of tropical cyclones. Preprints, Symposium on Precipitation Extremes, Impacts, and Responses, Albuquerque, NM, 14-18 January 2001, 288-292.

Kalogiros, J. and Q. Wang, 2001: The California low-level coastal jet and nearshore stratocumulus. Conference preprints, Fourth Conference on Coastal Atmospheric and Oceanic Prediction and Processes, St. Petersburg, FL, 6-9 November 2001.

Murphree, T., L. Feinberg, F. Schwing, and R. Smith. 2001. Decadal events in the Northeast Pacific. Report of the U.S. GLOBEC Northeast Pacific California Current Scientific Investigators Meeting. NEP GLOBEC Office, Corvallis, OR.

Nielsen, K.E., P.A. Durkee, J. Rocha and B. Brown, 2001: Aerosol optical depth from satellite observations during ACE-Asia. Fall Meeting of the American Geophysical Union, San Francisco, CA, 11 December 2001.

Nuss, W.A. and D.K. Miller, 2001: A comparison of mesoscale forecast accuracy using random and a simplified targeting approach. Preprints, Ninth Conference on Mesoscale Processes, Ft. Lauderdale, FL, 30 July–2 August 2001.

PUBLICATIONS/PRESENTATIONS

CONFERENCE PRESENTATIONS

Andreas, E.L., C.W. Fairall, P.S. Guest and O.P.G. Persson, 2001: The air-ice drag coefficient for a year over Arctic sea ice. Sixth Conference on Polar Meteorology and Oceanography, San Diego, CA, 14-18 May 2001.

Carr, L.E., III, R.L. Elsberry and M.A. Boothe, 2001: Status report on implementation of the Systematic Approach to tropical cyclone track Forecasting Aid (SAFA). 2001 Tropical Cyclone Conference, Honolulu, HI, 30 January–1 February 2001.

Chang, C.-P., P.A. Harr and J. Ju, 2001: North Atlantic oscillation/Arctic oscillation and the weakening Indian Monsoon-ENSO relationship. NASA-IPRC-CLIVAR Workshop on Decadal Climate Variability, Manoa, HI, 8-12 January 2001.

Chang, C.-P. and T. Li, 2001: Monsoon-ENSO relationships and monsoon biennial variability. WMO International Conference on Monsoon Forecasting from Days to Years. New Delhi, India, March 2001.

Chang, C.-P., Interdecadal variations of the relationship between ENSO and the Asian monsoon. interdecadal and interannual variations of East Asian monsoon, Taipei, Taiwan, March 2001.

Chang, C.-P., Interdecadal variations of the ENSO – monsoon relationship. Eighth Scientific Assembly of International Association of Meteorology and Atmospheric Sciences, Innsbruck, Austria, July 2001.

Chang, C.-P., Z. Wang, J. Ju and T. Li, 2001: Interactions of maritime continent winter monsoon, ENSO and Indian Ocean winds. Third International Symposium on Asian Monsoon Systems, Okinawa, Japan, 11-14 December 2001.

Chen, J.M., T. Li. and C.-P. Chang: South China Sea SST regulations. International Scientific Conference on SCSMEX, Shanghai, China, April 2001.

Davidson, K.L. Effects and estimation of near-surface atmosphere effects on Rf/EO propagation/system performance. Simulation Validation Working Group (SVWG) Bi-Annual Meeting, Naval Research Laboratory, Washington, D.C., 26-28 June 2001.

Davidson, K.L., P.A. Frederickson and D.L. Mabey, Mid-path near-surface atmospheric properties in the roughness and evaporation duct (RED) experiment. RED Experiment Data Workshop, San Diego, CA, 5-6 February 2002.

Davidson, K.L. and P.A. Frederickson, Influence of ocean waves on near-surface turbulence and refraction profile: scaling over waves. National Radio Science Meeting (URSI), Boulder, CO, 10-13 January 2001.

Davidson, K.L. and P.A. Frederickson, METOC description and Rf/EO propagation. Modernizing METOC support to the surface (AEGIS) warfighter, Pearl Harbor, HI, 22-23 February 2001.

Davidson, K.L. and P.A. Frederickson, Mid-path near-surface atmospheric properties in the roughness and evaporation duct (RED) experiment. National Radio Science Meeting (URSI), Boulder, CO, 7-10 January 2002.

Davidson, K.L. and P.A. Frederickson, Near-surface meteorology descriptions and radar propagation. South Dakota School of Mines and Technology, 31 January 2002.

Doric, T., P.A. Harr and R.L. Elsberry, 2002: Assessment of the potential for prediction of tropical cyclone formation in the Navy global model. 25th Conference on Hurricanes and Tropical Meteorology, San Diego, CA, 29 April-3 May 2002.

Durkee, P.A., R. Kahn, T. Nakajima and C. Hsu, 2001: Satellite investigations during the ACE-Asia field program. Fall Meeting of the American Geophysical Union, San Francisco, CA., 11 December 2001.

Elsberry, R.L., 2001: Extratropical transitions of tropical cyclones – Pathway to operations. 2001 Tropical Cyclone Conference, Honolulu, HI, 30 January–1 February 2001.

Elsberry R.L., 2001: Proposed Hurricane Operational Transition (HOT) center. Interdepartmental Hurricane Conference, Orlando, FL, 6 March 2001.

Fairall, C.W., J.M. Intrieri, M. Shupe, P. Guest, E.L. Andreas and O.P.G. Persson, 2001: Cloud forcing of turbulent and radiative energy budgets on the Arctic ice cap: one year of data from the SHEBA experiment. Sixth Conference on Polar Meteorology and Oceanography, San Diego, CA, 14-18 May 2001.

Frederickson, P.A. and K.L. Davidson, Observational (buoy-based) studies of the wave influence on air-sea fluxes. WCRP/SCOR Workshop on Intercomparison and Validation of Ocean-Atmosphere Flux Fields, Potomac, MD, 21-24 May 2001. [WMO Technical Document No. 1083, pp. 329-333, August 2001.]

Frederickson, P.A., K.L. Davidson, J. Stapleton, D, Shanklin, R. Wiss, T. Nguyen, E. Burgess III, C. Weeks, W. Thornton and T. Brown, Validation of AREPS propagation assessments using different evaporation duct models. Ship based defense demonstration, IAFCSE Task – MPME Wallops 2000 Final Review, Naval Surface Warfare Center, Dahlgren, VA, 3 October 2001.

Frederickson, P.A., K.L. Davidson, J. Stapleton, D, Shanklin, R. Wiss, T. Nguyen, E. Burgess III, C. Weeks, W. Thornton and T. Brown, Validation of AREPS propagation assessments using different evaporation duct models. Battlespace Atmospheric and Cloud Impact on Military Operations (BACIMO 2001) Conference, Fort Collins, CO, 10-12 July 2001. [Army Research Laboratory CD-ROM ARL-SR-01126, October 2001].

Frederickson, P.A., K.L. Davidson, J. Stapleton, D, Shanklin, R. Wiss, T. Nguyen, E. Burgess III, C. Weeks, W. Thornton and T. Brown, Validation of AREPS propagation assessments using different evaporation duct models. Ship Based Defense Demonstration, IAFCSE Task – MPME Wallops 2000 Final Review, Naval Surface Warfare Center, Dahlgren, VA, 3 October 2001.

Green-Jessen, P., F. Schwing, S. Bograd and T. Murphree. The seasonal cycle of upper ocean temperature of the west coast: local atmospheric forcing and Rossby wave propagation. Eastern Pacific Ocean Conference, Fallen Leaf Lake, CA, September 2001.

Green, P., F. Schwing, F. and T. Murphree. Wind stress curl and ocean conditions in the northeast Pacific: a mechanism for ocean climate change. Pacific Climate Workshop, Pacific Grove, CA, March 2001.

Guest, P.S., O.P.G. Persson, E.L. Andreas and C.W. Fairall, 2001: What is the role of the sensible hear flux on the surface heat budget of the multi-year sea ice? Sixth Conference on Polar Meteorology and Oceanography, San Diego, CA, 14-18 May 2001.

Guest, P.S., A. Schweiger, T. Beesley, E. Andreas, C. Fairall and P.O. Persson, 2002: Atmospheric forcing in PIPS 3.0, PIPS 3.0. Meeting, Fleet Numerical Oceanography and Meteorology Center, Monterey, CA, 23-24 January 2002.

Guest, P.S., K.L. Davidson, P.A. Frederickson and D. Mabey, Using instrumented kites to quantify atmospheric conditions during the RED experiment. National Radio Science Meeting (URSI), Boulder, CO, 7-10 January 2002.

Hancy, R.L., R.A. Hale and D.E. Dietrich, 2001: Offshore propagation of eddy kinetic energy in the California Current. 13th AMS Conference on Atmospheric and Oceanic Fluid Dynamics, Breckenridge, CO, 4-8 June 2001.

Kalogiros, J. and Q. Wang, 2001: The California low-level coastal jet and nearshore stratocumulus, Fourth Conference on Coastal Atmospheric and Oceanic Prediction and Processes, St. Petersburg, FL, 6-9 November 2001.

Kuo, H.C. and C.-P. Chang, 2001: Tropical vortex development in Northwest Pacific monsoon. International Scientific Conference on SCSMEX, Shanghai, China, April 2001.

Kuo, H.-C. and C.-P. Chang, Rossby waves in zonally opposing mean flow: behavior in Northwest Pacific summer monsoon. Third International Symposium on Asian Monsoon Systems, Okinawa, Japan, 11-14 December 2001.

Miller, D.K. and F.L. Ludwig, 2001: A computationally efficient method for obtaining model forecast winds in the vicinity of complex coastal orography. Fourth Conference on Coastal Atmospheric and Oceanic Prediction and Processes, St. Petersburg, FL, 3-5 November 2001.

Miller, D.K. and D.L. Walters and A. Slavin, 2001: Evaluation of a turbulent mixing length parameterization applied to the case of an approaching upper-tropospheric trough. Ninth Conference on Mesoscale Processes, Ft. Lauderdale, FL, 30 July –2 August 2001.

Murphree, T., B. Ford, F. Schwing and P. Green. Teleconnections from southeast Asia and the western tropical Pacific: their role in North Pacific and North American climatic variations. Pacific Climate Workshop, Pacific Grove, CA, March 2001.

Murphree, T., L. Feinberg, F. Schwing and R. Smith. 2001. Decadal events in the Northeast Pacific. Report of the U.S. GLOBEC Northeast Pacific California Current Scientific Investigators Meeting. NEP GLOBEC Office, Corvallis, OR.

Nielsen, K.E., P.A. Durkee, J. Rocha and B. Brown, 2001: Aerosol optical depth from satellite observations during ACE-Asia. Fall Meeting of the American Geophysical Union, San Francisco, CA, 11 December 2001.

Nuss, W.A. and D.K. Miller, 2001: A comparison of mesoscale model forecast accuracy using random and a simplified targeting approach. 9th Conference on Mesoscale Processes, Ft. Lauderdale, FL, 30 July–2 August 2001.

Nuss, W.A. and D.K. Miller, 2001: Predictability of mesoscale quantitative precipitation. Symposium on Precipitation Extremes: Prediction, Impacts, and Responses, AMS Annual Meeting, Albuquerque, NM, 10-15 January 2001.

Nuss, W.A., 2001: Relationship between synoptic scale and mesoscale forecast errors. PACJET Workshop, Monterey, CA, 24-26 October 2001.

Persson, Ola P.G., C.W. Fairall, E.L. Andreas and P. S. Guest, 2001: Measurements of the surface energy budget on multi-year ice at SHEBA. Sixth Conference on Polar Meteorology and Oceanography, San Diego, CA, 14-18 May 2001.

Renfrew, I.A., G.W.K. Moore, P.S. Guest and K. Bumke, 2001: A comparison of surface-layer and surface turbulent-flux observations over the Labrador Sea with ECMEF analyses and NCEP reanalyses. Sixth Conference on Polar Meteorology and Oceanography, San Diego, CA, 14-18 May 2001.

Wang, Q. and D. P. Eleuterio, 2001: A comparison of bulk aerodynamic methods for calculating air-sea fluxes. Ninth Conference on Mesoscale Processes, American Meteorological Society, Ft. Lauderdale, FL, 30 July-2 August 2001

Wang, Q., K. Rados, J.A. Kalogiros, H. Zuo, S. Wang, C. Friehe, D. Khelif and H. Jonsson, 2001: Boundary layer turbulence and surface flux parameterizations in a mesoscale model—verification with

aircraft measurements. Ninth Conference on Mesoscale Processes, American Meteorological Society., Ft. Lauderdale, FL, 30 July-2 August 2001.

Wang S., J.D. Doyle and Q. Wang, 2001: Improving surface flux parameterization at low wind speeds in the Navy COAMPS. Ninth Conference on Mesoscale Processes, American Meteorological Society, Ft. Lauderdale, FL, 30 July-2 August 2001.

Wang, S., Q. Wang, 2001: Surface flux and stratocumulus clouds in DECS: A mesoscale model study. Fourth Conference on Coastal Atmosphere, FL, 6-9 November 2001.

Wash, C.H. and G. Schmeiser, Verification and evaluation of NOGAPS and COAMPS analyses and forecasts for the 25 January 2000 cyclone. Preprints, Eighteenth Conference On Weather Analysis and Forecasting, Fort Lauderdale, FL, 30 July-2 August 2001.

Whisenhant, M.K., Q. Wang., S. Wang and J. Doyle, 2001: Grid resolution and surface flux and boundary layer parameterizations in high-resolution mesoscale models. Ninth Conference on Mesoscale Processes, American Meteorological Society, Fort Lauderdale, FL, 30 July–2 August 2001.

Williams, R.T., Modification of frontal dynamics by topography. PACJET Workshop-2001, Monterey, CA, 24-26 October 2001.

TECHNICAL REPORTS

Frederickson, P.A., K.L. Davidson, F.K. Jones and D.L. Mabey, *SCI 2001 Sensor Technology Test: Preliminary METOC Data Atlas*, Naval Postgraduate School Technical Report, 19 December 2001, 83 pp.

Frederickson, P.A., K.L. Davidson, F.K. Jones and T. Neta, *NPS FLUX Buoy Data Report for the MUSE Deployment, August - September 2000*, Naval Postgraduate School Technical Report, 5 April 2001, 19 pp.

Guest, P.S. and K.L. Davidson, *Tdrop Airborne/Atmospheric Characterization Test (Phase III)*, Naval Postgraduate School Technical Report, NPS-MR-01-003, 47 pp.

Guest, P.S. and K.L. Davidson and P. Frederickson, *Analyses of TDrop Performance Parameters from Static and Dynamic Tests*, Naval Postgraduate School Technical Report, NPS-MR-01-004, 21 pp.

Jordan, M.S. and P.A. Durkee, *Verification and Validation of the Satellite Marine-layer/Elevated Duct Height (SMDH) Technique.* Naval Postgraduate School Technical Report, NPS-MR-01-001, 26 pp.

CONTRIBUTIONS TO BOOKS

Chang, C.-P. and T. Li, 2002: Tropical tropospheric biennial oscillation and ENSO. Selected Papers, 4th Conference on East Asia and Western Pacific Meteorology and Climate, *World Scientific Series on Meteorology of East Asia*, Vol. 1., pp. 167-179.

Elsberry, R.L., 2001b: Track forecast guidance in improvements for early warnings of tropical cyclones. In *Early Warning Systems for Natural Disaster Reduction* (J. Zschau and Am N. Kuppers, Eds.), Springer-Verlag (New York), pp. 165-181.

Elsberry, R.L. and L.E. Carr, III, 2002: Systematic approach for tropical cyclone track forecasting with dynamical model selective consensus. *East Asian and Western Pacific Meteorology and Climate*, World Scientific Press (Singapore), pp. 228-236.

Li, T.B. Wang, C.-P. Chang, 2001: Theories on the tropospheric biennial oscillation: A review. *Dynamics of Atmospheric. and Oceanic Circulations and Climate*, eds: M. Wang et al, Chinese Academy of Sciences, China Meteorological Press, Beijing, pp. 872.

DEPARTMENT OF METEOROLOGY

Thesis Abstracts

OBSERVATION ADJOINT SENSITIVITY AND THE ADAPTIVE OBSERVATION-TARGETING PROBLEM

Nancy L. Baker-DoD Civilian
B.S., Oregon State University, 1981
M.S., University of Washington, 1985
Doctor of Philosophy in Meteorology-December 2000
Advisors: Russell L. Elsberry, Department of Meteorology
Roger Daley, Naval Research Laboratory

This research introduces the adjoint of the data assimilation system, which together with the classical adjoint sensitivity problem, represents the two fundamental components of the complete forecast adjoint sensitivity problem. This adjoint of the data assimilation system is then used to investigate the sensitivity of the forecast aspect to the observations and background for idealized analysis problems, and finally a real-data case using the NAVDAS adjoint for a situation with unusually large 72-h forecast errors over the western United States during February 1999.

The observation sensitivity is largest when the observations are relatively isolated, assumed to be more accurate than the background, and the analysis sensitivity gradients are large in amplitude and have a spatial scale similar to the background error covariances. The observation sensitivity is considerably weaker for small-scale analysis sensitivity gradients. The large observation sensitivities suggest that adaptive observations near large-scale analysis sensitivity gradients have a greater potential to change the forecast aspect than observations near small-scale analysis sensitivity gradients. Therefore, targeting decisions based on the adjoint of the data assimilation system may be significantly different from targeting decisions based solely on the analysis sensitivity gradients. These results emphasize the importance of accounting for the data assimilation procedures in the adaptive observation-targeting problem.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Observation Sensitivity, Observation Adjoint Sensitivity, Adaptive Observations, Observation Targeting, Data Assimilation, Adjoint Methods

PARAMETERIZING SURFACE FLUXES IN THE ARCTIC

Anna C. Bryant-Lieutenant, United States Navy
B.S., University of South Carolina, 1996
Master of Science in Meteorology and Physical Oceanography-September 2001
Advisor: Peter Guest, Department of Meteorology
Second Reader: Qing Wang, Department of Meteorology

There is a need for computationally efficient methods to determine surface radiation in the Arctic based on surface parameters such as cloud presence, sun angle, temperature and other easily measured variables. This study uses data from the SHEBA project to verify simple radiation parameterizations and to compare with other locations. Skies during SHEBA were usually either totally clear or totally overcast, with low clouds predominating, especially in the non-winter seasons. This resulted in large changes in radiation every time the cloud coverage changed.

There was a large range in the skill of the parametric equations. The most accurate equations had average total errors of 9 Wm -2 , 14 Wm -2 , 22 Wm -2 and 59 Wm -2 for downwelling longwave in clear skies, cloudy skies, shortwave clear and cloudy skies respectively. Compared to the Weddell Sea (Antarctic) the average downward longwave radiation was greater for all sky conditions. Shortwave values were comparable to the Weddell Sea, although there was large variability.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: SHEBA, Surface Radiation, Arctic

THE ROLE OF WEATHER IN CLASS A NAVAL AVIATION MISHAPS

Ruben A. Cantu-Lieutenant Commander, United States Navy
B.S., New Mexico State University, 1989
Master of Science in Meteorology and Physical Oceanography-March 2001
Advisors: Carlyle H. Wash, Department of Meteorology
Tom Murphree, Department of Meteorology

Two hundred-thirty five Class A Navy and Marine (Naval) aviation mishaps involving aircrew error between FY90 and FY98 are analyzed for the possibility of being weather related. In addition to determining the overall role of weather, weather related mishaps are compared to aircraft category, mishap characteristic, the Naval Safety Center Human Factors (HFACS) taxonomy, and flight phase. In addition, weather related mishap trends have been analyzed. Results show 19% of mishaps involving aircrew error are weather related with helicopter category and controlled flight into terrain (CFIT) mishap characteristics having the largest percent of weather related mishaps for their respective groupings. Visibility related weather elements account for over half of all weather related mishaps, and nearly two-thirds of all weather related mishaps were judged to be preventable with a perfect weather forecast believed by the aircrew. These and other findings are presented to develop intervention strategies for reducing the number of weather related flight mishaps (FMs) per year.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Human Systems Interface, Other (Accident Analysis, Aviation Weather)

KEYWORDS: Naval Aircraft Mishaps, Human Factors, Human Error, Accident Classification, Accident Analysis, Aviation Weather

NUMERICAL PREDICTION OF MARINE FOG USING THE COUPLED OCEAN/ATMOSPHERE MESOSCALE PREDICTION SYSTEM (COAMPS)

John L. Dumas-Lieutenant Commander, United States Navy
B.S., University of Notre Dame, 1988
Master of Science in Meteorology and Physical Oceanography-March 2001
Advisor: Douglas K. Miller, Department of Meteorology
Second Reader: Wendell A. Nuss, Department of Meteorology

The U.S. Navy's requirement for a computer prediction system for marine fog and stratus dates back to the 1970s when meteorological models were being introduced to the fleet. The Naval Research Laboratory's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) is a leap forward in the Navy's numerical modeling ability but it still does not show great skill in fog forecasting. COAMPS has been "tuned," or adjusted for certain constants and parameterizations, so that it has the minimum error for the maximum area. This tuning is a common practice for all numerical models. The objective of this thesis is to determine if changes can be made to the existing COAMPS code based on reasonable physical experiments for a specific location to help solve the numerical fog forecasting problem. The effectiveness of these experiments was first measured by comparing a modeled cloud edge to satellite imagery of Monterey, California taken during a week in August 2000 under a variety of foggy conditions. Comparisons were also made with observations taken from an aircraft, land stations and a vertical profiler. The experiments, specifically those regarding changes to the autoconversion and turbulent kinetic energy schemes, showed that while a perfect solution has not been found, it is possible to modify the model physics codes and optimize its performance in a specific region.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Mesoscale Modeling, Model Verification, COAMPS, Fog, Stratus, Forecasting

EL NINO AND LA NINA EVENTS AND NORTH ATLANTIC TROPICAL CYCLONES

Paula E. Hildebrand-Lieutenant, United States Navy
B.S., United States Naval Academy, 1994
Master of Science in Meteorology and Physical Oceanography-March 2001
Advisor: Tom Murphree, Department of Meteorology
Second Reader: Patrick Harr, Department of Meteorology

The impacts of El Niño (EN) and La Niña (LN) events on North Atlantic tropical cyclones (TCs) were examined, and the physical mechanisms that produce these impacts. Composites of best-track data were constructed from the National Hurricane Center and reanalysis data from the National Centers for Environmental Prediction based on ten EN and ten LN events that occurred during 1970-1999. We analyzed the differences in the composite TC numbers, formation sites, and tracks during EN and LN events for several periods within the North Atlantic TC season (June-November).

The largest differences occurred in the middle (July-September) and late (September-November) portions of the TC season. Throughout almost all of the season, there were more TC formations during LN events than during EN events, especially in the tropical North Atlantic (about 10-20oN). However, in the late season, there were more formations during EN events in the subtropical North Atlantic (about 20-30oN). The formation site differences appear to have been mainly the result of lower vertical shear in the tropics during LN events, and lower vertical shear in the subtropics during EN events. The vertical shear differences over the tropical North Atlantic were mainly the result of anomalies in upper tropospheric heights and the tropical easterly jet associated with variations of the Asian summer monsoon. The vertical shear differences over the subtropical North Atlantic were mainly the result of an extratropical anomalous wave train extending from the western North Pacific to the North Atlantic.

The differences in formation sites appear to have led to TCs with longer tracks, longer residence times within a tropical environment, and greater intensities during LN events. There were a larger (smaller) number of TCs making landfall in the Gulf of Mexico and eastern U.S. during LN (EN) events during the late season. These differences appear to have been the result of: (1) more (fewer) low latitude formations during LN (EN) events; and (2) steering flows associated with the anomalous extratropical wave train that tended to guide TCs into (away from) the Gulf of Mexico and the east coast of the U.S. during LN (EN) events.

DoD KEY TECHNOLOGY AREA: Other (Environmental Modeling, Climate Monitoring)

KEYWORDS: El Niño, La Niña, North Atlantic Tropical Cyclones, Tropical Easterly Jet, Teleconnections, Wave Trains

CLASSIFICATION OF SUMMERTIME WEST COAST FOG AND STRATUS EVENTS AND THE DEVELOPMENT OF FOG AND STRATUS FORECAST TECHNIQUES

Greg S. Ireton-Lieutenant, United States Navy
B.S., University of North Carolina, Asheville, 1997
Master of Science in Meteorology and Physical Oceanography-September 2001
Advisor: Wendell A. Nuss, Department of Meteorology
Second Reader: Douglas K. Miller, Department of Meteorology

The fog and stratus that frequently plagues the West Coast in the summer months is responsible for a variety of impacts on everyday life, the greatest being on aviation. Many flight delays and cancellations that are experienced around the Pacific Rim are attributed to the development and evolution of the fog and stratus on the U.S. West Coast. This thesis studies the evolution of the fog and stratus events during the summer of 2000 through the use of geostationary, GOES-10, visual satellite imagery to develop a classification scheme. The synoptic-scale weather patterns as well as the mesoscale coastal regime were then associated with a type of stratus evolution. The Navy's mesoscale model, coupled ocean/atmosphere mesoscale prediction system (COAMPS), provided detailed simulation of 11 events to highlight the boundary layer evolution and its relationship to fog and stratus evolution. The fog and stratus classification scheme produced several consistent synoptic and mesoscale signals associated with stratus evolution. These

relationships provide some forecasting techniques that should aid forecasters with predicting the evolution of fog and status events.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Visual Satellite Imagery, COAMPS, Synoptic-Scale Weather Patterns

TROPICAL CYCLONE AND MID-LATITUDE CHARACTERISTICS AND PHYSICAL MECHANISMS CONTRIBUTING TO EXTRATROPICAL TRANSITION IN THE WESTERN NORTH PACIFIC

Peter M. Klein-Lieutenant Commander, United States Navy
B.S., Cornell University, 1988
M.S., Naval Postgraduate School, 1997
Doctor of Philosophy in Meteorology-December 2000
Dissertation Supervisor: Russell L. Elsberry, Department of Meteorology

This study of extratropical transition (ET) of tropical cyclones (TCs) in the western North Pacific examines 30 cases during 1 June through 31 October 1994-98 using Navy analyses, plus geostationary satellite visible, infrared, water vapor, and microwave imagery. Based on the similarity of all 30 ET cases in satellite imagery, a three-dimensional conceptual model of the transformation stage of ET is proposed to describe how these ET cases evolve into an incipient, baroclinic cyclone. A climatology of ET during the period studied is presented, and three levels of re-intensification (little, moderate, and deep) are defined based on storm intensity at the end of ET. The re-intensification stage in nine cases is studied via Navy Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS) control forecasts, simulations with the initial TC vortex removed, and simulations in which the initial TC vortex is displaced. These COAMPS simulations demonstrate that deep or moderate re-intensification depends on phasing of the poleward translating TC remnants with a critical region in which cyclogenesis is favored in the mid-latitude circulation. The mid-latitude circulation and TC contributions to the re-intensification stage are identified via superposition with the critical region and modification of its location and diagnostic values, respectively, and the combination of these contributions determines the final storm intensity at the end of ET.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Battlespace Environments, Command, Control, and Communications, Electronic, Electronic Warfare, Sensors, Modeling and Simulation, Other (Meteorological Support and Tactical Decision Aids)

KEYWORDS: Extratropical Transition of Tropical Cyclones, Transformation Stage, Re-intensification Stage, Critical Region, Petterssen Type-B Extratropical Cyclogenesis, Mid-latitude Circulation Contributions to Re-Intensification, Tropical Cyclone Contributions to Re-Intensification

A FINE RESOLUTION MODEL OF THE COASTAL EASTERN BOUNDARY CURRENT SYSTEMS OFF IBERIA AND MOROCCO

Antonio S. Martinho-Lieutenant, Portuguese Navy
B.S., Portuguese Naval Academy, 1992
Master of Science in Physical Oceanography-March 2001
Advisor: Mary L. Batteen, Department of Oceanography
Second Reader: R.T. Williams, Department of Meteorology

To investigate the role of wind forcing, bottom topography and thermohaline gradients on classical as well as unique features in the northern Canary Current system (NCCS), four experiments are conducted with a sigma coordinate primitive equation model. The first experiment, which investigates the pressure gradient force error, shows that velocity errors inherent in three dimensional sigma coordinate models can be successfully reduced from ~1 m/s to less than 0.5 cm/s in the NCCS. The second experiment, which investigates the effect of annual wind forcing on a flat bottom, accurately portrays classical eastern

boundary current features as well as unique NCCS features associated with a large embayment (i.e., the Gulf of Cadiz), poleward spreading of Mediterranean Outflow, and the generation of Meddies. Theadditional effect of bottom topography in Experiment 3 shows that topography plays important roles in intensifying and trapping the equatorward current near the coast, in weakening the subsurface poleward current and in intensifying eddies off the capes of Iberia. The use of full instead of horizontally averaged thermohaline gradients in Experiment 4 highlights the development of the Iberian Current off the Portugal west coast, a feature not seen in the previous experiments. This shows that thermohaline gradients play an important role for the formation of the Iberian Current.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Primitive Equation Model, Northern Canary Current System, Currents, Meanders, Eddies, Meddies, Filaments, POM, Sigma Coordinate

INVESTIGATION OF THE 25 JANUARY 2000 EAST COAST CYCLOGENESIS

Gregory J. Schmeiser-Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1990
Master of Science in Meteorology and Physical Oceanography-March 2001
Advisor: Carlyle H. Wash, Department of Meteorology
Second Reader: Patricia M. Pauley, Naval Research Laboratory-Monterey

On 25 January 2000, a rapidly developing cyclone tracked up the East Coast of the United States. Along with this system, 12 to 18 inches of snow fell on major cities from North Carolina to Washington DC. This snowstorm deserves special consideration because of the poor numerical and human forecasts it received.

The goal of this work is to analyze the performance of the Navy models, NOGAPS and COAMPS (West Atlantic) with the 25 January cyclogenesis event. Deficiencies with the model analyses and forecasts are identified and a diagnosis of critical model fields that led to these deficiencies is completed. Preliminary investigation of analyses and NOGAPS forecast runs with the new variational data assimilation system, NAVDAS, concludes the research.

The results of the research reveal that NOGAPS poorly forecast storm tracks while COAMPS showed more success. Both NOGAPS and COAMPS produced deficient short range upper-level height forecasts and had difficulty analyzing two prominent jet streaks. NOGAPS was not able to adequately analyze or forecast cold air damming and coastal frontogenesis, while COAMPS was more successful at resolving these features. COAMPS produced better precipitation forecasts than NOGAPS, but still showed deficiencies. Preliminary investigation of NOGAPS using NAVDAS shows promise.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Cyclogenesis, NOGAPS, COAMPS, NAVDAS

DIFFICULTIES IN IDENTIFYING AND EVALUATING SURFACE-BASED AND EVAPORATIVE DUCT IMPACTS

William L. Sommer-Lieutenant, United States Navy
B.S., University of Washington, 1992
Master of Science Meteorology and Physical Oceanography-December 2000
Advisors: Kenneth L. Davidson, Department of Meteorology
Peter S. Guest, Department of Meteorology

RF /EO propagation depends on environmental variability and is critical to weapons system employment. This study is based on combined METOC and radio frequency (RF) loss data collected off the east U.S. coast, Wallops Island, VA. Addressed are atmospheric measurement, propagation modeling, and interpretation errors and their impact on the ship's operations. Examined are the determination of the presence and character of surface-based and/or evaporative ducts, and the interpretation of the conditions using current generation TDAs. Questions raised are a) "How closely can we describe the propagation

conditions from surface combatants?" and, b) "Can the operator, who is neither a meteorologist nor a propagation expert, produce meaningful products for himself, independent of outside support?" Environment horizontal variability was a critical limiting factor in predicting observed RF losses with operational METOC measurements using an operational propagation model. In addition to surface-mounted METOC sensors aboard operational ships, rocketsondes were necessary to describe those features that limited predictability of observed RF losses. The results address the assumption of reciprocity for modeling/analyses purposes with horizontal variation. A conclusion is that the weapons systems operators' training must include familiarization with environmental awareness and self-assessment to utilize and exploit combined METOC data and propagation model predictions.

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

KEYWORDS: LKB, Paulus, Bulk Parameterization, Rocketsonde, Flux Buoy, Wallops Island, AREPS, RF Propagation, SEA W ASP, MORIAH, Refractivity, RF Propagation

INITIAL DISTRIBUTION

1.	Defense Technical Information Center 8725 John J. Kingman Rd., Ste. 0944 Ft. Belvoir, VA 22060-6218	2
2.	Dudley Knox Library, Code 013 Naval Postgraduate School 411 Dyer Rd. Monterey, CA 93943-5101	2
3.	Associate Provost and Dean of Research Code 09 Naval Postgraduate School Monterey, CA 93943-5138	2
4.	Chair Department of Meteorology Naval Postgraduate School Monterey, CA 93940-5000	5
5.	Associate Chair for Research Department of Meteorology Naval Postgraduate School Monterey, CA 93940-5000	5
6.	Dean, Graduate School of Engineering and Applied Sciences Code 07 Naval Postgraduate School Monterey, CA 93940-5000	1
7.	Provost and Academic Dean Code 01 Naval Postgraduate School Monterey, CA 93943-5000	1