(2)

AD-A225 107

SP 033:320:90

June 1990

Abstracts of Publications and Presentations, 1989

J. W. McCaffrey
Ocean Sensing and Prediction Division
Ocean Science Directorate

Approved for public release; distribution is unlimited.

Naval Oceanographic and Atmospheric Research Laboratory
Stennis Space Center, Mississippi 39529-5004

FEATURE MODELING: THE INCORPORATION OF A FRONT AND EDDY MAP INTO OPTIMUM INTERPOLATION-BASED THERMAL ANALYSES

Theodore J. Bennett, Jr.
Michael R. Carnes
Patricia A. Phoebus
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Lancelot M. Riedlinger
Planning Systems, Inc.
Slidell, LA

Abstract

Ocean acoustics are crucial to modern naval operations. Acoustics constantly change due to the variability in space and in time of the ocean thermal structure. Thus, a thermal analysis system that transforms irregularly sampled data from disparate sources into an analysis of the ocean thermal structure is of increasing importance. In a data-sparse environment such as the ocean, the key to obtaining realistic but cost-effective analyses is the use of all available data sources, as well as the most powerful data assimilation techniques.

Feature modeling is a powerful means of supplementing the limited in situ and remotely sensed data with our understanding of the oceanography of mesoscale ocean features. Initially, the data are used to map the location of mesoscale fronts and eddies. Schematic descriptions of the thermal structure of these features, called feature models, are subsequently used to represent them in the first-guess thermal field. In data-sparse areas, features that would otherwise be poorly resolved in the analysis are instead represented by these schematic models.

The Naval Ocean Research and Development Activity has developed feature models for Gulf Stream front and eddies, as well as an algorithm for the incorporation of the models into the first-guess field. The models were evaluated at the Fleet Numerical Oceanography Center within the Optimum Thermal Interpolation System (OTIS) framework. Subsurface thermal fields constructed via these feature models agree well with observed fields and are substantially more realistic than analyses produced using the current regional operational system, the Expanded Ocean Thermal Structure (EOTS) analysis. Because of the power of feature modeling, it has considerable relevance to other Navy-funded work in ocean modeling and remote sensing.

NORDA Report 242, April 1989. Approved for public release; distribution is unlimited.

FEATURE MODELING FOR THERMAL ANALYSIS

Theodore J. Bennett, Jr.
Michael R. Carnes
Patricia A. Phoebus
Ocean Sensing and Prediction Division
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Lancelot M. Riedlinger
Planning Systems, Inc.
Slidell, LA 70458

Abstract

Feature modeling is a powerful means to supplement the limited in situ and remotely sensed data with our understanding of the oceanography of mesoscale ocean features. The thrust of feature modeling is the incorporation of schematic descriptions of the thermal structure of these features into an ocean nowcast. This paper describes the feature models and modeling algorithm developed by the Naval Ocean Research and Development Activity.

Presented at Conference and Exposition on Marine Data Systems, April 26-28, 1989, New Orleans, Louisiana, in Proceedings

SURFACE TOPOGRAPHY OF THE GULF STREAM REGION DERIVED FROM GEOSAT ALTIMETRY

M. R. Carnes and J. L. Mitchell
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529-5004

Abstract

Altimetry data from the GEOSAT Exact Repeat Mission, which began in November 1986, has been processed to produce consecutive maps of surface topography for the Gulf Stream region at one-week intervals. The geoid heights along ground tracks used in the processing were derived as the one-year mean difference between surface height above a reference surface, measured by altimetry, and relative dynamic height at the sea surface, computed from a feature model based upon positions of the front and eddies obtained from satellite IR imagery. Surface heights at altimeter ground track positions spanning a complete GEOSAT 17 day repeat cycle were gridded to form each map using optimum interpolation. A video has been prepared showing adjacent maps of the feature-modelled and altimeter-derived surface topography. Relative merits of the two approaches are discussed.

Presented at the American Geophysical Union Fall Meeting, 4-8 December 1989, San Francisco, CA. Abstract published in EOS, October 24, 1989

SYNTHETIC TEMPERATURE PROFILES DERIVED FROM GEOSAT ALTIMETRY: COMPARISON WITH AXBT PROFILES

Michael R. Carnes, Jim L. Mitchell
Naval Ocean Research and Development Activity
Stennis Space Center, MS

P. W. deWitt
Fleet Numerical Oceanography Center
Monterey, CA

Abstract

Synthetic temperature profiles are computed from altimeter-derived sea surface heights in the Gulf Stream region. Empirical orthogonal functions and associated coefficients derived by deWitt (1987) for each month of the year from historical temperature and salinity profiles from the region surrounding the Gulf Stream northeast of Cape Hatteras provide the required relationship between surface height (dynamic height at the surface relative to 1000 dbar) and subsurface temperature. Sea surface heights are derived using two different geoids estimates, the feature-modeled geoid and the AXBT geoid, both described in Carnes et al. (1988). The accuracy of the synthetic profiles is assessed by comparison to 21 AXBT profile sections which were taken during 3 surveys along 12 GEOSAT ERM groundtracks nearly contemporaneously with GEOSAT overflights. The primary error statistic considered is the root-mean-square (RMS) difference between AXBT and synthetic isotherm depths. The two sources of the RMS error are the EOF relationship and the altimeter-derived surface heights. EOF-related and surface height-related errors are of comparable magnitude; each translates into about a 60 m RMS isotherm depth error, or a combined 80 m to 90 m error for isotherms in the permanent thermocline. EOF-related errors are responsible for the absence of the near-surface warm core of the Gulf Stream, and for the reduced volume of Eighteen Degree Water in the upper few hundred meters of (apparently older) cold-core rings in the synthetic profiles. The overall RMS difference between surface heights derived from the altimeter and those computed from AXBT profiles is 15 cm when the feature-modeled geoid is used and 19 cm when the AXBT geoid is used; the portion attributable to altimeter-derived surface height errors alone is 2 cm less for each. In most cases, the deeper structure of the Gulf Stream and eddies is reproduced well by vertical sections of synthetic temperature except for shifts in the positions of features in the periods between the AXBT drops and the GEOSAT overflights.

Accepted in June 1989 for publication by Journal of Geophysical Research

ESTIMATION OF SEA-ICE TYPE AND CONCENTRATION BY LINEARING UNMIXING OF GEOSAT ALTIMETER WAVEFORMS

Juanita Chase and Ronald Holyer
Remote Sensing Branch
Naval Oceanographic and Atmospheric Research Laboratory
Stennis Space Center, MS 39529

Abstract

The GEOSAT altimeter transmits a radar pulse toward earth, then measures earth reflected energy in a number of time gates. The signal amplitudes in successive gates create a "waveform", the shape of which is determined by the reflectance characteristics of the earth's surface. This study shows that over the polar ice cap, the type and concentration of sea ice can be related to GEOSAT return waveform shapes. Knowing that an altimeter waveform may be a mixture of returns from two or more ice types within the footprint, linear unmixing theory is chosen as the framework for analysis of waveform data. The mixing model assumes that data samples are linear combinations of a limited number of end members. Unmixing analysis therefore consists of identifying the number and nature of the end members, followed by an interpretation of the data set in terms of combinations of these end members. Estimates of ice type and concentration data derived from visual interpretation of passive microwave imagery and aereal photography, collected coincident with GEOSAT overpasses during MIZEX'87. Generally good agreement is observed between waveform-based ice information and the corresponding imagery "ground truth." This analysis has revealed some deficiencies in a current parameterization of waveform shape called the GEOSAT Ice Index. A new ice index formulation is proposed.

Accepted for publication by Journal of Geophysical Research-Oceans in December 1989

USE OF POLARIZATION METHODS IN EARTH RESOURCES INVESTIGATIONS

M. J. Duggin
S. A. Israel
V. S. Whitehead
J. S. Myers
D. R. Robertson

Abstract

Relatively little attention has been paid to the potential of polarization techniques to provide additional information for the mapping of earth resources, compared to the published work concerning other active and passive remote sensing systems. Recently, a substantial number of polarized light images of a variety of terrestrial scenes have been obtained from the Space Shuttle. A boresighted pair of Hasselblad cameras was used, in which polarization filters were fitted. The polarization directions were perpendicular to each other for the two cameras. Image pairs were acquired with one image being of maximum intensity, and the other showing minimum intensity. Selected pairs of images, obtained using black and white films, were digitized. The images were registered and compared, using digital image analysis techniques. Differences due to polarization were observed, these included intensity and contrast differences, together with differences in the spatial frequency, orientation and population of observable contrast boundaries. It was found empirically that some digital image analysis techniques enhanced the differences. A comparison of the enhanced difference images, obtained from the polarization pairs, with the intensity data that would have been obtained without the aid of polarization filters, confirms that a considerable degree of new, useful information may be obtained by the use of polarization techniques. This new information was most helpful in better defining the observed ground features in the cases studied. This is because the better definition of contrast boundaries, improvement of contrast across boundaries, improvement of shadow detail and reduction of noise level increases the useful information in an image, and improves its interpretability.

Presented at SPIE Conference on Polarization, San Diego, CA, August 7-11, 1989

MODELING SENSOR NOISE AND SYSTEM JITTER EFFECTS ON SIGNAL-TO-NOISE FOR MULTITEMPORAL IMAGE SEQUENCES

Michael J. Duggin and Ronald J. Holyer
Remote Sensing Branch
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529-5004

Abstract

A major problem in designing multichannel sensors, in determining optimum imaging conditions and in selecting appropriate analytical methods is knowing the impact of background clutter on signal-to-noise (S/N) ratio and therefore on the probability of target detection. In the case of a target moving over a ground scene viewed by a space-borne or airborne sensor, various temporal and spatial averaging methods have been used to improve this S/N ratio and to recognize targets.[1-4] Recognition depends upon a knowledge of the clutter power spectrum and of the dimensions, characteristics and attributes of potential targets. However, in the case of a dynamic clutter background, such as the sea surface, the signal-to-noise ration may vary with scene fluctuations, with sensor jitter and with variations in sensor noise. The power spectrum will also vary with time and with jitter. Further, not all sensors have a uniform sensitivity over their field of view.

Submitted to Optical Engineering, July 1989

A HOUGH TRANSFORM TECHNIQUE FOR EXTRACTING LEAD FEATURES FROM SEA ICE IMAGERY

Florence M. Fetterer
Ronald J. Holyer
Remote Sensing Branch
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Abstract

Infrared imagery from polar-orbiting satellites provides a synoptic and long term view of lead patterns in Arctic pack ice. The large quantity of satellite data in image form suggests the use of automated methods for compiling lead statistics from imagery. A Hough transform technique for the semi-automated extraction of lead orientation and spacing is described and first results are presented.

Presented at IGARSS 89 12th Canadian Symposium on Remote Sensing, Vancouver, Canada, July 10-14, 1989, in Proceedings

A SURFACE CURRENT METER WITH ARGOS TELEMETRY CAPABILITY

Florence M. Fetterer
Donald R. Johnson
Naval Ocean Research and Development Activity
Remote Sensing Branch
Stennis Space Center, MS 39529-5004

Abstract

An instrument for the remote acquisition of surface current data has been developed. The Surface Current Meter (SCM) is a slope following instrument measuring near-surface current speed and direction. Vector-averaged samples are logged into solid state memory and transmitted to the Argos satellite data collection and location system. The instrument and sampling scheme are described and data examples are presented.

The simple design of the SCM incorporates low-cost components. It can be deployed by hand using a lightweight mooring. These features as well as its telemetry capability suggest its use in difficult to reach areas, as a supplement to other instrumentation, and as an inexpensive survey current meter.

Presented at Conference and Exposition on Marine Data Systems, New Orleans, Louisiana, April 26-28, 1989, in Proceedings.

INTERPOLATING GEOSAT DATA TO A REGULAR GRID

D. N. Fox
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Abstract

GEOSAT altimetry which has been processed to sea surface topography represents a very sparse and asynoptic sampling of the oceanic mesoscale structure. The utility of this data to produce nowcasts and to initialize and update circulation model forecasts could be greatly improved by interpolation onto a grid which is regular in space as well as time.

A method to perform this interpolation based on spatial empirical orthogonal functions coupled with Fourier series in time is presented. A video of the sea surface topography in the western Gulf Stream region based on altimetry from the GEOSAT exact repeat mission will be shown.

Presented at the American Geophysical Union Fall Meeting, San Francisco, CA, 4-8 December 1989. Abstract published in EOS, Vol. 70, Number 43, October 24, 1989.

TOPS 3.0: AN UPGRADE TO OCEAN THERMAL ANALYSIS AND PREDICTION AT FNOC

John M. Harding
Naval Ocean Research and Development Activity
Ocean Sensing and Prediction Division
Stennis Space Center, MS 39529-5004

Paul W. May
Martin Marietta Data Systems
Fleet Numerical Oceanography Center
Monterey, CA 93943

Abstract

The Thermodynamic Ocean Prediction System (TOPS) uses Mellor-Yamada Level II mixing [1] and Ekman dynamics to forecast upper-ocean mixing and wind-drift advection. The U.S. Navy's Fleet Numerical Oceanography Center (FNOC) cycles TOPS with its operational, upper-ocean, thermal analyses for several regional areas. These include the northern and southern hemispheres, the eastern and western Mediterranean, and the Norwegian Sea. The analyses (or nowcasts) provide initial conditions to TOPS. The TOPS 24 hr. forecast, in turn, provides first-guess information to the following day's nowcast. TOPS thus provides up to three-day forecasts of the upper ocean thermal structure as well as an extra source of upper ocean information to the thermal analyses in data sparse areas.

Present versions (TOPS 1.0 and TOPS 2.1) limit applications to 63x63 grids associated with the standard FNOC polar stereographic grids. TOPS 3.0, major upgrade developed at the Naval Ocean Research and Development Activity (NORDA) and presently being implemented at FNOC, expands the application potential of TOPS. Greater modularity and reorientation of the major TOPS pre- and postprocessing to the 4-pipe Control Data Corporation CYBER 205 super-computer allows larger, variable-dimension grids.

We present results of TOPS 3.0 applied to the FNOC 125x125 mid-Pacific region (~50 km. resolution). Included are examples from the regional Diurnal Ocean Surface Layer model contained within the TOPS 3.0 run stream. This model provides additional information on diurnal variability within the mixed layer based on [2]. We also consider some near-term future upgrades to TOPS 3.0.

Presented at the Conference and Exposition on Marine Data Systems, New Orleans, Louisiana, April 26-28, 1989, in Proceedings

SURFACE CURRENT MODEL VALIDATION USING DRIFTING BUOYS

P. W. deWitt and R.M. Clancy
Ocean Models Division
Fleet Numerical Oceanography Center
Monterey, CA 93943-5005

J. M. Harding
Ocean Sensing and Prediction Division
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529-5004

Abstract

Several numerical models that calculate global surface currents are presently run at Fleet Numerical Oceanography Center. An inter-comparison of these models is ongoing using as ground truth the available drifting buoys that report through the Global Telecommunications System (GTS). Monthly tests are being conducted where the actual drift of approximately 40-50 buoys worldwide are compared to simulated buoy drift from the various models. The "skill" of an individual model is determined based on its relative performance with regard to persistence and, where available, climatology. Preliminary results indicate that the simulations using the surface currents produced by the Thermodynamic Ocean Prediction System (TOPS) model, coupled with a windage correction, consistently have skill in the open ocean compared to persistence.

Presented at the Conference and Exposition on Marine Data Systems, New Orleans, Louisiana, April 26-28, 1989, in proceedings

REPORT OF WORKING GROUP II--PHENOMENOLOGY

John Harding, Chairperson
Naval Ocean Research and Development Activity

Abstract

The charge of this working group was to construct phenomenological criteria for model evaluation, as well as model/model and model/data intercomparisons. The focus of these efforts is the North Atlantic Basin and its subregions.

Presented at the Summer Colloquium on Mesoscale Ocean Science and Prediction (1989), INO Technical Note, PROC-1, October 1989

REMOTE SENSING INPUT TO NAVY OCEAN NOWCASTS/FORECASTS

Jeffrey Hawkins
Pat Phoebus
Doug May

Naval Ocean Research and Development Activity
Remote Sensing Branch
Stennis Space Center, MS 39529

Abstract

Satellite oceanography has begun to satisfy the ever present demand for oceanic parameters over vast domains and short time-frames. Ships and buoys are not sufficient for a multitude of applications, especially Navy near real time efforts. The Naval Ocean Research and Development Activity (NORDA) is actively engaged in several projects to enhance the utilization of remotely sensed data. This is accomplished by assimilating satellite information with all other data sources to derive a superior product.

Each satellite sensor typically measures a number of parameters with varying degrees of accuracy. It is thus necessary to combine the advantageous aspects of each sensor in order to synergistically produce the best possible analysis, whether it be for sea surface temperature, three dimensional thermal structure, or sea ice, as described in this paper. The analysis can then serve as the initial conditions for forecast models used to plan future operations. Although timeliness is less critical for many ocean applications than for meteorological versions, it is still preferable to have as many sensors on one space platform in order to carry our inter-sensor corrections while viewing the same synoptic view below.

Presented at Oceans 89, September 1989, Seattle, Washington, in Proceedings.

GEOSAT ALTIMETER SEA-ICE MAPPING

Jeffrey D. Hawkins and Matthew Lybanon
(Invited Paper)

Abstract

Polar sea-ice measurements are reduced to a fraction of those required for accurate sea-ice analyses and forecasts by the harsh environment (intense cold, clouds, remoteness) encountered. This severe operational data void is now being partially filled by the U.S. Navy GEOdetic SATellite (GEOSAT) active microwave altimeter.

The 12 March 1985 GEOSAT launch enabled satellite oceanographers to continue the earlier sea-ice monitoring shown to be feasible with the GEOS-3 and SEASAT altimeters [1]. The large difference in return signals from a 13.5 GHz pulse over water versus over sea-ice permits the generation of an ice index that responds abruptly to sea-ice edges.

Sample Arctic and Antarctic operational sea-ice index plots are shown, depicting the current effort within the Remote Sensing Branch at the Naval Ocean Research and Development Activity (NORDA). This NORDA program provides graphical ice-index displays along GEOSAT nadir tracks to the Navy/National Oceanic and Atmospheric Administration (NOAA) Joint Ice Center (JIC) for assimilation into their sea-ice data bases. The altimeter's all-weather capability has been an important addition to the JIC data bases, since cloud cover can drastically curtail visible and infrared viewing, and passive microwave data has coarser resolution.

Ongoing research efforts are aimed at extracting additional sea-ice parameters from the altimeter waveform data, which contain information on the reflecting surface. Possibilities include discrimination between water, land, ice, combination water/ice, and water/land, as well as distinguishing various ice concentrations and possibly ice types. Coincident airborne passive microwave and synthetic aperture radar (SAR) data have been collected to test several methods which appear to be promising.

IEEE Journal of Oceanic Engineering, Vol. 14, No. 2, April 1989

FRAM STRAIT SATELLITE IMAGE DERIVED ICE MOTIONS

W. J. Emery and C. W. Fowler
CCAR Box 431
Univ. of Colorado
Boulder, CO 80309

J. Hawkins
NORDA Code 321
Stennis Space Center, MS 39529

R. H. Preller
NORDA Code 322
Stennis Space Center, MS 39529

Abstract

A series of 6 satellite images of the Fram Strait region, from April 1986, were used to compute sea ice motion from pairs of sequential images using the Maximum Cross Correlation (MCC) method (Ninnis et al., 1986). The resulting ice motion vectors were taken as a representation of the surface flow field derived objectively from the satellite imagery for applications of the U.S. Navy/NOAA Joint Ice Center. Various computational parameter settings, sensor channels and spatial filters were employed to optimize the retrieval of horizontally coherent ice motion in the presence of cloud contaminated imagery. Resulting vector motion fields were found to match well with subjectively "feature tracked" vectors for the same images thus verifying the validity of the objective MCC method of computing ice motion. Cross correlations were computed directly rather than using FFT methods to allow the computation of surface motion vectors close to shore. The MCC ice motion results were also compared with wind driven numerical model simulations of the region and with direct wind driving of the ice motion. Marked differences were apparent between the MCC image derived velocities and those either from the numerical model or inferred directly from the geostrophic wind field.

Submitted to JGR - Oceans, August 1989

RESPONSE OF THE GULF OF MEXICO TO HURRICANE GILBERT

Peter G. Black
N.O.A.A. - Hurricane Research Division
Miami, Florida 33149

Lynn K. Shay and Russell L. Elsberry
U. S. Naval Postgraduate School
Department of Meteorology
Monterey, California 93943

Jeffrey D. Hawkins
Naval Ocean Research and Development Activity
Bay St. Louis, Mississippi 39529

Abstract

A joint NOAA/Navy air-sea interaction experiment was conducted in the Gulf of Mexico from NOAA hurricane research aircraft before, during and after the passage of Hurricane Gilbert through the Gulf. The objective of the experiment was to assess the role of turbulent mixing and horizontal advection processes on near-inertial time scales in the ocean response to hurricanes. In this paper, the magnitudes of the sea-surface temperature (SST), mixed-layer depth (MLD), and mixed-layer current changes are documented. The experiment involved five flights: one prior to the storm, two within the storm and two after the storm made landfall. Measurements of the ocean current and temperature profile from the surface to 1500 m were made with Airborne Expendable Current Profilers (AXCP's) and of the temperature profile only to 300 m with Airborne Expendable Bathythermographs (AXBT's). A total of 92 AXCP's and 60 AXBT's were deployed from Sept. 14 to Sept. 19, 1988. To complement this data set, over 25 NOAA-10 high-resolution infrared satellite images over the Gulf were acquired during the period 13-20 Sept.

Little change in SST was observed over the 29oC water of the western Caribbean during Gilbert's explosive deepening to a record 885 mb on Sept. 13-14. However, a dramatic decrease in SST accompanied the storm's traverse of the Gulf of Mexico on Sept. 15-16 as it maintained its weakened state and dramatically altered wind structure following passage over the Yucatan Penninsula. A gradual basin-wide decrease in SST from 30oC to 28oC preceded the arrival of the storm. A further SST decrease to 25oC abruptly followed in e storm's wake over a 100-200 km wide area to the right of the storm, except for an area in the central Gulf dominated by a warm anticyclonic eddy. This pattern was graphically illustrated by enhanced, high-resolution, water vapor-corrected NOAA-10 satellite imagery. The small SST decreases in the Caribbean Sea and Gulf eddy water are attributed to the initial MLD's in excess of 70 m. The large SSt decreases across the undisturbed Gulf are attributed to the initial MLD's of less than 30 m. It is hypothesized that these are important factors to be considered in anticipating hurricane intensification cycles of deepening, filling or recovery from land effects.

(Response to the Gulf of Mexico to Hurricane Gilbert, continued)

Strong mixed-layer currents associated with gravity-inertia waves generated by the storm were measured to the right of the storm track 1.5 and 3 days after storm passage. Current magnitudes were on the order of 1.5 m/s. A reversal in current directions occurred immediately below the mixed layer with very strong vertical shears in the upper thermocline. Thus a large area of the Gulf was set in motion by Gilbert that persisted for 7-10 days after storm passage.

Presented at the 18th Conference on Hurricanes and Tropical Meteorology, San Diego, California, May 16-19, 1989

PROCESS STUDIES OF THE CIRCULATION DYNAMICS OF THE WESTERN MEDITERRANEAN SEA

G. W. Heburn
Naval Ocean Research and Development Activity
Stennis Space Center, MS, USA

Abstract

As seen in satellite IR and CZCS imagery, the circulation of the western Mediterranean Sea is very complex. The imagery reveals numerous eddies and current meanders, particularly along the north African coast. The circulation dynamics of the western Mediterranean are influenced by a number of physical parameter, i.e., wind stress, wind stress curl, inflow/outflow mass influx, temperature, salinity and topography.

A number of process studies using one and two active layer, reduced gravity models and two and three active layer, finite depth models have been conducted to study the effects of these various physical parameters on the circulation dynamics of the western Mediterranean. The results from these studies reveal that the complex western Mediterranean circulation is due to interactions between flows forced by the various forcing mechanisms. An overview of these results will be presented.

XIV General Assembly, European Geophysical Society, Annales Geophysicae, Barcelona, 13-17 March 1989, 1989 - Special Issue

VARIATIONS IN THE STRUCTURE OF THE ANTICYCLONIC GYRES FOUND IN THE ALBORAN SEA

George W. Heburn, Paul E. La Violette
Naval Oceanographic and Atmospheric Research Laboratory
Stennis Space Center, MS 39529-5004

Abstract

Historical satellite, aircraft, and in situ data have shown that two anticyclonic gyres (the western and eastern Alboran gyres) are major ocean features of the Alboran Sea. The examination of several years of satellite imagery indicates that large variations in the surface expression of these two gyres occur that on occasion one or the other gyre disappears (the disappearance of both gyres at the same time was not seen). The initial disappearance of either gyre occurs on a time scale of a week to 2 weeks, whereas the return may take from 3 weeks to 2 months. Various forcing mechanisms, i.e., winds, mass flux inflow through the Straits of Gibraltar and Sicily, and/or density, have been used in numerical ocean circulation models to study the dynamics of the western Mediterranean Sea. Various model results show relationships similar to those shown by the satellite imagery. However, no single forcing mechanism has been positively identified as the source of the disappearances, and the events may be a result of a combination of forcing mechanisms.

Submitted in 1989
Journal of Geophysical Research, Volume 95, Number C2, February 15, 1990

A GLOBAL APPROACH TO IMAGE TEXTURE ANALYSIS

R. J. Holyer
Ocean Sensing and Prediction Division
Ocean Science Directorate

Executive Summary

A new approach to image texture analysis is developed. The approach is based on linear unmixing of texture measures calculated over an entire image (called a global approach), as opposed to most present texture analysis techniques that compute texture over small neighborhoods (called a local approach). The new global paradigm is appropriate for images where spatial scales of the texture variability are large with respect to the pixel spacing, thereby making the local approach ineffective. Airborne passive microwave imagery of Arctic sea ice contain textures that vary with ice-type. These ice textures are of the type best treated by the global approach. Sea-ice imagery are used as test data to evaluate the global techniques that are developed. Pure, single ice-type images; synthetic mixtures formed by mosaicking pure ice-type subimages in known proportions; and naturally occurring mixture images are analyzed in the course of the study. Proportions of first-year, second-year, and multiyear ice within mixture images are retrieved with root-mean-square accuracies as low as 0.04 by the new method. This accuracy is adequate to be useful in many Arctic studies, but more important, the global technique seems promising for many other remote sensing and general image processing applications. Research areas that are required to advance the global method are enumerated. The most important advancement in support of the global method would be the development of new image texture measures that exhibit linear properties under mixing operations.

NORDA Report 238, March 1990. Approved for public release; distribution is unlimited.

A TECHNIQUE FOR FEATURE LABELING IN INFRARED OCEANOGRAPHIC IMAGES

N. Krishnakumar, S. Sitharama Iyengar
Department of Computer Science
Louisiana State University
Baton Rouge, LA 70803

Ron Holyer, Matthew Lybanon
Remote Sensing Branch
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Abstract

Thermal infrared images of the ocean obtained from satellite sensors are widely used for the study of ocean dynamics. The derivation of mesoscale ocean information from satellite data depends to a large extent on the correct interpretation of infrared oceanographic images. The difficulty of the image analysis and understanding problem for oceanographic images is due in large part to the lack of precise mathematical descriptions of the ocean features, coupled with the time varying nature of these features and the complication that the view of the ocean surface is typically obscured by clouds, sometimes almost completely. Towards this objective, the present paper describes a technique that utilizes a non linear probabilistic relaxation method for the oceanographic feature labeling problem. A unified mathematical framework that helps in solving the problem is presented. This paper highlights the advantages of using the contextual information in the feature labeling algorithm. The feature labeling technique makes use of a new, efficient edge detection algorithm based on cluster shade texture measure. This new algorithm is found to be more suitable for labeling the mesoscale features present in the oceanographic satellite images. The paper presents some important results of the series of experiments conducted at Remote Sensing Branch, NORDA on the NOAA AVHRR imagery data. The paper concludes with a motivation for using this technique to build an oceanographic expert system.

Fifth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology, Anaheim, California, January 29 - February 3, 1989

A TECHNIQUE FOR FEATURE LABELING IN INFRARED OCEANOGRAPHIC IMAGES

N. Krishnakumar, S. Sitharama Iyengar
Department of Computer Science
Louisiana State University
Baton Rouge, LA 70803

Ron Holyer, Matthew Lybanon
Remote Sensing Branch
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Abstract

Thermal infrared images of the ocean obtained from satellite sensors are widely used for the study of ocean dynamics. The derivation of mesoscale ocean information from satellite data depends to a large extent on the correct interpretation of infrared oceanographic images. The difficulty of the image analysis and understanding problem for oceanographic images is due in large part to the lack of precise mathematical descriptions of the ocean features, coupled with the time varying nature of these features and the complication that the view of the ocean surface is typically obscured by clouds, sometimes almost completely. Towards this objective, the present paper describes a technique that utilizes a non linear probabilistic relaxation method for the oceanographic feature labeling problem. A unified mathematical framework that helps in solving the problem is presented. This paper highlights the advantages of using the contextual information in the feature labeling algorithm. The feature labeling technique makes use of a new, efficient edge detection algorithm based on cluster shade texture measure. This new algorithm is found to be more suitable for labeling the mesoscale features present in the oceanographic satellite images. The paper presents some important results of the series of experiments conducted at Remote Sensing Branch, NORDA on the NOAA AVHRR imagery data. The paper concludes with a motivation for using this technique to build an automatic image interpretation system.

Accepted by Image and Vision Computing

AN EXPERT SYSTEM FOR INTERPRETING MESOSCALE FEATURES IN OCEANOGRAPHIC SATELLITE IMAGES

N. Krishnakumar, S. Sitharama Iyengar
Louisiana State University
Department of Computer Science
Baton Rouge, LA 70803

Ron Holyer and Matthew Lybanon
Remote Sensing Branch
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Abstract

Thermal infrared images of the ocean obtained from satellite sensors are widely used for the study of ocean dynamics. The derivation of mesoscale ocean information from satellite data depends to a large extent on the correct interpretation of infrared oceanographic images. The difficulty of the image analysis and understanding problem for oceanographic images is due in large part to the lack of precise mathematical descriptions of the ocean features, coupled with the time varying nature of these features and the complication that the view of the ocean surface is typically obscured by clouds, sometimes almost completely. Towards this objective, the present paper describes a hybrid technique that utilizes a nonlinear probabilistic relaxation method and an expert system for the oceanographic image interpretation problem. A unified mathematical framework that helps in solving the problem is presented. This paper highlights the advantages of using the contextual information in the feature labeling algorithm. The paper emphasizes the need for the feedback from the high level modules to the intermediate modules in an automatic image interpretation system. The paper presents some important results of the series of experiments conducted at Remote Sensing Branch, NORDA, on the NOAA AVHRR imagery data.

SPIE Applications of Artificial Intelligence VII, Volume 1095, Orlando, Florida, March 28-30, 1989

EDGE DETECTION APPLIED TO SATELLITE IMAGERY OF THE OCEANS

Ronald J. Holyer
Sarah H. Peckinpaugh

Abstract

A computer edge-detection algorithm is developed for automatic delineation of mesoscale structure in digital satellite IR images of the ocean. The popular derivative-based edge operators are shown to be too sensitive to edge fine-structure and to weak gradients to be useful in this application. The new edge-detection algorithm is based on the gray level co-occurrence (GLC) matrix, which is commonly used in image texture analysis. The cluster shade texture measure derived from the GLC matrix is found to be an excellent edge detector that exhibits the characteristic of fine-structure rejection while retaining edge sharpness. This characteristic is highly desirable for analyzing oceanographic satellite images. The method is evaluated on an Advanced Very High Resolution Radiometer (AVHRR) image of the Gulf Stream region.

IEEE Transactions on Geoscience and Remote Sensing, Vol. 27, No. 1, January 1989

RESULTS FROM A GLOBAL OCEAN MODEL IN THE WESTERN TROPICAL PACIFIC

Harley Hurlburt, John Kindle, E. Joseph Metzger
Naval Oceanographic and Atmospheric Research Laboratory
Stennis Space Center, MS 39529-5004

Alan Wallcraft
JAYCOR
Stennis Space Center, MS 39529-5004

Abstract

The circulation of the western equatorial Pacific is examined using the NOARL global ocean model on a .5 x .7 degree grid (lat, long). The model uses detailed coastline geometry including the islands resolved by the grid. The model is reduced gravity and includes thermodynamics and mixing. The model has been forced by the Hellerman-Rosenstein wind climatology and by winds from ECMWF (1980-1987). The discussion will focus on the Pacific west of the dateline and +-20 degrees Lat, including the Indonesian archipelago.

The model is able to represent detailed aspects of the circulation in the region. Results include 45-50 day oscillations with onset in the early spring. Annual migration of the trough in the sea surface height (SSH) between the North Equatorial Current (NEC) and the North Equatorial Countercurrent (NECC) reaches the highest latitude during the spring (8-9 N). This trough is gradually replaced by one at a lower latitude (4-6 N) that propagates westward across the region during June - Sept.

The split of the NEC at the Philippine coast into the Mindanoa current and the beginning of the Kuroshio current shows an annual variation of only 12.75 to 13.75 N. At 8 N the model Mindanoa current has a mean transport of 24 Sv with an opening in the S. Sula Sea and 36 Sv with it closed. At 18 N the Kuroshio has a mean transport of 28 (18) Sv with the S. Sula Sea open (closed). This indicates a net cyclonic flow around the Philippines, a flow which has little effect on the transports south of the Celebes Sea, east of 130E, and north of the Luzon Strait.

The Mindanoa current exhibits a 3-way split near the south end of the Philippines with one branch recirculating in the Mindanoa Eddy and a second (strongest) branch heading southward between Talaud and Sangihe Islands (126.5 E at 4 N) before joining the NECC. The islands and the topography play no role in this placement in the model. The 3rd branch proceeds westward through the Celebes Sea where some flow returns eastward north of Celebes Island, and some proceeds southward through the Makassar Strait. This flow again divides into Pacific-Indian Ocean throughflow and flow that returns northward east of the Celebes and Halmahera Islands where it joins the NECC. In the annual mean there is a westward coastal current along the New Guinea coast.

(Results from a Global Ocean Model in the Western Tropical Pacific, continued)

The region also exhibits several prominent eddies in the annual mean, the cyclonic Mindanao eddy centered at 7N, 130E with a secondary center north of Halmahera Island at 5N, 127-127.5 E, a cyclonic eddy at 137E, 6.5N, 770 km east of the Mindanoa eddy, an anticyclonic eddy at 3N, 132.5E, ENE of Halmahera, and a cyclonic (clockwise) eddy centered on Manus Island at 2S, 147E that is present in summer and fall. Cyclonic eddies are also prominent in the Solomon Sea and the Coral Sea. There are many more transient eddies.

These features tend to be present in all seasons but there is a great deal of variation in the location and amplitude (or even presence) of these features and in general temporal variability throughout most of the region, especially with 5 degrees of the equator from within the Celebes Sea to about 150E. The preceding results are for the upper ocean and were obtained using wind forcing from the Hellerman-Rosenstein monthly climatology.

Proceedings of the Western Pacific International Meeting and Workshop on Toga Coare, Nouméa, New Caledonia, May 24-30, 1989

LOW FREQUENCY SEA SURFACE TOPOGRAPHY VARIATIONS
IN THE MONSOON FORCED REGIME OF THE INDIAN OCEAN

Donald R. Johnson
Naval Ocean Research and Development Activity
Code 321
Stennis Space Center, MS 39529

Abstract

The objective of this study has been to investigate the low frequency (seasonal) coherent sea surface variation of the monsoon regime of the Indian Ocean in its relationship with basin scale wind stress. Time series of sea surface height (ssh) were calculated from GEOSAT altimeter crossover point differences over the central and northern Indian Ocean. Wind stress time series were calculated from the Fleet Numerical Oceanographic Center's global wind analysis. Using empirical orthogonal function techniques on synthesized wind analysis. Using empirical orthogonal function techniques on synthesized wind and ssh fields, eigenmodes of coherent variations were obtained and examined with respect to ocean and wind structures and to temporal history of the structures. In comparison to known characteristics of the Indian Ocean, the dominant first eigenmode provides a credible picture of organized motion. Attempts to predict seasonal ssh using computed eigenmodes were limited by the length of the data set, but were sufficiently encouraging for further pursuit.

Submitted to Journal of Geophysical Research, GEOSAT Special Issue, June 1989

SURFACE CURRENT MEASUREMENTS AT OCEAN FRONTS

Donald R. Johnson
Florence M. Fetterer
Space Oceanography Research Section
Naval Ocean Research and Development Activity, Code 321
Stennis Space Center, MS 39529

Abstract

Using a unique slope-following surface current meter, we have obtained measurements of near surface currents during the NORCSEX experiment in March, 1988. These instruments were tethered to subsurface floation on traditional taut wire moorings at three locations near ocean frontal areas. Several objectives of the experiment included supporting the deeper moored and acoustic doppler measurements with surface information, providing a bottom boundary condition for wind stress analysis, comparison with a CODAR and testing a newly developed ARGOS transmission capability. In this discussion, we provide a general overview of the measurement results.

Presented at IGARSS 89. 12th Canadian Symposium on Remote Sensing, Vancouver, Canada, July 10-14, 1989, in Proceedings

REVIEW AND COMMENTARY TO PAPER: AN OVERVIEW OF THE POLEWARD UNDERCURRENT AND UPWELLING ALONG THE CHILEAN COAST by T. Fonseca

Donald R. Johnson
Naval Ocean Research and Development Activity
Stennis Space Center, MS

Abstract

Fonseca synthesizes various pieces of broadly interdisciplinary data to form an interesting and credible picture of the Chilean coastal ocean. With a country 4270 km long, running in a nearly north/south direction across latitudinal changes from 8°S to 56°S, clearly the Chilean ocean provides an enormous challenge for that country's oceanographers. A number of Chilean universities, plus several government agencies and a small, but economically important oil industry that all engaged in a range of ocean-related science and engineering activities. If I have one negative comment about Fonseca's paper, it is that it does not include enough of the results of Chilean research activities, and consequently, does not provide an adequate view of the Chilean efforts in marine sciences.

Fonseca's paper presents three topics for consideration: the Peru-Chile Undercurrent (PCU), coastal circulation, and some concepts of ecological interactions with the PCU, upwelling and the Chilean fish stocks. My comments will take the same route.

Poleward Flows Along Eastern Ocean Boundaries, Coastal and Estaurine Studies, Vol. 34

LARVAL TRANSPORT AND ITS ASSOCIATION WITH RECRUITMENT OF BLUE CRABS TO CHESAPEAKE BAY

Donald R. Johnson
Naval Ocean Research and Development Activity
Space Oceanography Research Section, Code 321
SSC, MS 39529

Betty S. Hester
Naval Oceanographic Office
Acoustics Projects Division
Propagation Branch
SSC, MS 39522

Abstract

The blue crab (*Calinectes sapidus*) harvest in Chesapeake Bay has undergone large yearly fluctuations, creating hardships in the fishing industry and uncertainties in its management. It has previously been suggested that part of the fluctuation may be due to environmental influences during a sensitive period in their life history when blue crab larvae are planktonic outside the bay. During this period, they reside principally in the neuston where wind forced transport has the maximum influence. It is shown, through vector/scalar correlations of wind stress with harvest, that approximately 36% of the harvest variation can be accounted for by the wind patterns during the months from June through September. The influence of alongshore sea level slope and cumulative estuarine discharge (both relating to transport through pressure gradient forcing) on harvest were investigated, but the results were negligible, or ambiguous at best.

Estuarine, Coastal and Shelf Science (1989) Volume 28, Number 5, pp. 459-472, May 1989

LARGE SCALE SEA SURFACE TOPOGRAPHY RESPONSE TO WIND FORCING IN THE GINSEA USING GEOSAT ALTIMETRY

Donald R. Johnson
Remote Sensing Branch
NORDA, Code 321
Stennis Space Center, MS 39529

Abstract

Cross-over point difference data from the 16 month Pre-ERM GEOSAT mission were analyzed together with basin scale wind stress from the same period. Using complex empirical orthogonal functions (CEOF), the synthesized data set showed coherent patterns of variations indicating the locations of major currents and their comcomittant wind forcing. Applied to the northwestern Indian Ocean, the well-known Somali Current and Great Whirl system were clearly evident, giving validity to the analysis method. Applied to the GINSEA/North Atlantic, the Irminger Current and North Atlantic inflow were evident, increasing in strength with northward wind stress forcing. The Iceland/Faeroes Front was not apparent, however.

Presented at the European Geophysical Society XIV General Assembly, Barcelona, Spain, 13-17 March, 1989

VECTOR EOF ANALYSIS OF SSH AND WIND STRESS FOR THE GEOSAT PRE-ERM MISSION IN THE GULF OF MEXICO

D. R. Johnson
Naval Ocean Research and Development Activity
Code 321
Stennis Space Center, MS 39529

Abstract

Sea Surface Height (SSH) data collected during the Pre-exact Repeat Mission of the U.S. Navy's GEOSAT satellite were analyzed together with wind stress data from FNOC to determine basin scale patterns of coherent variability. Time series of SSH variations were formed from altimeter cross-over points in 3-degree diamond-shaped grids in the Gulf of Mexico (GOM). Similarly, wind stress time series were formed at selected grid points in the GOM and in the North Equatorial Trade wind region of the Atlantic.

The two sets of time series, one year in length, were subjected to Empirical Orthogonal Function analysis. The first EOF mode contained more than twice the variance of the second mode, with the largest amplitudes (eigenvectors) of the pattern occurring just west of the loop current intrusion for SSH and in the western and northern Gulf for wind stress. A comparison is made with similar combined data for the Northern Indian Ocean where ocean response to Monsoon winds is strong, and better understood. In addition to the EOF analysis, events are followed through the Gulf in both wind and SSH records.

Proceedings of the Chapman Conference on the Physics of the Gulf of Mexico, St. Petersburg Beach, Florida, 4-7 June 1989

THE DYNAMICS OF THE PACIFIC TO INDIAN OCEAN THROUGHFLOW

J. C. Kindle
H. E. Hurlburt
E. J. Metzger
Code 323
Naval Oceanographic and Atmospheric Research Laboratory
Stennis Space Center, MS 39529-5004

Abstract

The Indonesian throughflow is examined using the NOARL one-active layer reduced-gravity global model on a .5 by .7 degree grid. The model, which includes the effects of realistic coastline geometry, thermodynamics and mixing, is forced by the Hellerman-Rosenstein wind stress climatology and the ECMWF 1000 mb winds from 1980 to 1988. Emperical Orthogonal Function and Principal Estimator Pattern analyses of the wind stress curl and model sea level are utilized to examine the dynamics of the mean throughflow as well as the seasonal and interannual variability. A suite of experiments designed to determine the relative importance of remote and local forcing as well as the reflection of Rossby waves from the irregular, pourous western Pacific boundary and discussed.

Proceedings of the Western Pacific International Meeting and Workshop on Toga Coare, Nouméa, New Caledonia, May 24-30, 1989

THE 26- AND 50-DAY OSCILLATIONS IN THE WESTERN INDIAN OCEAN: MODEL RESULTS

John C. Kindle
J. Dana Thompson
Naval Oceanographic and Atmospheric Research Laboratory
Ocean Sensing and Prediction Division
Stennis Space Center, Ms 39529-5004

Abstract

The circulation of the western Indian Ocean is examined using a reduced-gravity model with one active layer and realistic basin geometry for the entire Indian Ocean north of 30°S. The Hellerman and Rosenstein monthly mean wind stress climatology is used to force the model. The numerical simulations reproduce the observed (Luyten and Roemmich, 1982) 26-day waves along the equator and the 50-day oscillations (Mysak and Mertz, 1984; Schott el al. 1988) between the equator and Madagascar. The 25 to 28-day oscillations of the model meridional velocity component agree with observed values of period, amplitude, wavelength, group velocity, and phase of the seasonal modulation. The model oscillations, which are excited in August and persist into February-March, are shown to be the result of Yanai waves generated between the western boundary and 50°E. During the southwest monsoon, the Yanai waves are initiated by a complex barotropic instability associated with the southern gyre. During the early stages of the northeast monsoon, the 26-day Yanai waves are generated by resonant forcing due to the intrusion into the equatorial waveguide of a standing, 800- to 900-km-wavelength meander of the eastward flow fed by the East African Coastal Current. Hence the simulation reveals that 26-day oscillations in the equatorial Indian Ocean are excited by mechanisms significantly different than that believed to be responsible for the 20- to 30-day oscillations in the equatorial Atlantic and Pacific oceans. The numerical simulation also shows a 50-day oscillation between the equator and Madagascar west of 50°E. This periodicity is due to Rossby waves generated by a barotropic instability associated with the East African Coastal Current beginning about April each year. No evidence of the 50-day period oscillation is found in a corresponding linear simulation. Hence the barotropic instability of the oceanic currents in this region is offered as an alternative to direct wind forcing as the generating mechanism for the observed 40- to 60-day oscillations in the western Indian Ocean.

Journal of Geophysical Research, Vol. 94, No. C4, Pages 4721-4736, April 15, 1989

TOPOGRAPHIC EFFECTS ON THE CIRCULATION
OF THE SOUTH INDIAN OCEAN

J. C. Kindle
Naval Oceanographic and Atmospheric Research Laboratory
Stennis Space Center, MS 39529

Abstract

The relative effects of islands and topography on the seasonal circulation of the southern Indian Ocean are examined. The numerical simulations use a one-active reduced gravity model and a two-layer model with full bottom topography forced by the Hellerman and Rosenstein wind stress climatology. The reduced gravity experiments show that the absence of a seasonal transport cycle off the north coast of Madagascar is not caused by the presence of islands to the east. The two-layer experiments indicate that the presence of abrupt topography associated with the Mascarene Ridge decreases the annual barotropic signal of the North Madagascar Current and increases the seasonal variation of the Southeast Madagascar Current. Furthermore, the two-layer experiments predict the existence of a significant seasonal variation of transport north of the Saya de alha Bank along the Mascarene Ridge; the signal (12 - 16 Sv in amplitude) is sufficiently large so that the model results may be tested by future observations. Finally, the differences between the seasonal variation of the Indian and North Atlantic Oceans are discussed.

Submitted for Publication to JGR

COMPARISON OF OBSERVATIONS AND NUMERICAL MODEL RESULTS IN THE INDONESIAN THROUGHFLOW REGION

Stephen P. Murray
Coastal Studies Institute and Department of Geology and Geophysics
Louisiana State University
Baton Rouge, LA 70803 - U.S.A.

John Kindle
Naval Oceanographic and Atmospheric Research Laboratory
Code 323
Stennis Space Center, MS 39529-5004 U.S.A.

Dharma Arief
Coastal Studies Institute and Department of Geology and Geophysics
Louisiana State University
Baton Rouge, LA 70803 - U.S.A.

Harley Hurlburt
Naval Oceanographic and Atmospheric Research Laboratory
Code 323
Stennis Space Center, MS 39529-5004

Abstract

Observations of currents, transport, sea level, and sea level slope in Lombok Strait and west Flores Sea in 1985 and 1986 have been compared to a simulation of the NOARL global ocean model in the Indonesian throughflow region. Despite the relatively coarse grid scale of the model compared to topographic length scales in the region, the model appears to be realistically reproducing many of the observed features. The predicted transport through the Lombok Strait, for example, agrees with detailed observations of phase and magnitude, especially when corrected for grid size limitations. The sea surface fluctuations and sea surface slopes predicted by the model agree within less than a factor of 1.5 with sea level changes and slopes observed on tide gauges. There do appear to be several cases of phase difference of several months between model and observations that require further investigation.

Proceedings of the TOGA/COARE Meeting and Workshop, Noumea, New Caledonia, 24-30 May 1989

WESTERN MEDITERRANEAN CIRCULATION EXPERIMENT: A PRELIMINARY REVIEW OF RESULTS

Paul E. La Violette, etc.
Naval Oceanographic and Atmospheric Research Laboratory
Stennis Space Center, MS 39529

Abstract

The purpose of the Western Mediterranean Circulation Experiment (WMCE) was to deduce spatial temporal variability in the circulation of the western Mediterranean Sea throughout the vertical water column from the Strait of Sicily to the Strait of Gibraltar. An international, multidisciplinary consortium of marine investigators was formed to address the following questions.

What are the major western Mediterranean circulation features and how do they vary in space and time? What are the physical forcing mechanisms? How can this knowledge be incorporated into numerical models? How does the circulation affect chemical, biological and optical processes in the western Mediterranean Sea?

The WMCE field study began in November 1985 with deployment of current meter moorings in the Strait of Sicily and Corsican Channel and an aircraft campaign in the Straits of Sicily and Gibraltar and along the Algerian coast. The field period ended in March 1987 with the recovery of current meter moorings from along the Algerian coast. The field campaigns were conducted to complement two independent, companion Mediterranean experiments: the Gibraltar Experiment [*Kinder and Bryden*, 1987] and POEM [Physical Oceanography of the Eastern Mediterranean; *Malanotte-Rizzoli and Robinson* [1988]).

Following the field efforts, the WMCE Symposium and Workshop was hosted by the Naval Ocean Research and Development Activity (NORDA) in March 1988 at Bay St. Louis, Miss. Papers resulting from the symposium are planned for publication in a special issue of the *Journal of Geophysical Research--Oceans*. Some of the major WMCE preliminary findings are presented here.

EOS Transactions, American Geophysical Union, Vol. 70, No. 31, August 1, 1989, Pages 756-8

THE SURFACE CIRCULATION OF THE BALEARIC SEA

Paul E. La Violette
Naval Oceanographic and Atmospheric Research Laboratory
Code 321
Stennis Space Center, MS 39529-5004

Joaquín Tintoré
Departamento de Fisica
Universitat de les Illes Balears
Palma de Mallorca, Spain

Jordi Font
Institut de Cie'ncies del Mar
Paseo Nacional
Barcelona, Spain

Abstract

Until recently, the surface circulation of the Balearic Sea has been viewed as largely cyclonic with a fairly quiescent central dome. However, recent studies involving ship data, tracked drifters, current meter moorings, and satellite imagery indicate that this sea has strong mesoscale variability and more complex general circulation. These studies, together with an examination of registered satellite imagery collected during the Western Mediterranean Circulation Experiment (WMCE), indicate that the surface circulation is strong year-round, and characterized by two permanent density fronts located on the continental shelf slope (the Catalan Front) and the Balearic Islands shelf slope (the Balearic Front). The Catalan Front is the more active of the two fronts. In the northern area, a plume of cold water is frequently observed moving southward along the continental slope region, shedding dipole eddies along the leading edge of the plume. In addition, the Catalan Front continuously spawns energetic filaments that appear to be associated with the plume of cool water. The likely mechanism of formation of these filaments is the deflection of the cold water by the regional submarine canyons.

Submitted in 1989
Journal of Geophysical Research, Volume 95, Number C2, February 15, 1990

THE SEASONAL VARIATION OF WATER MASS CONTENT IN THE WESTERN MEDITERRANEAN AND ITS RELATIONSHIP WITH THE INFLOWS THROUGH THE STRAITS OF GIBRALTAR AND SICILY

Giuseppe M. R. Manzella
Stazione Oceanografica
Consiglio Nazionale delle Ricerche
Stazione Oceanografica
La Spezia, Italy

Paul E. La Violette
Naval Oceanographic and Atmospheric Research Laboratory
Code 321
Stennis Space Center, MS 39529-5004

Abstract

An analysis of western Mediterranean current meter and historical hydrographic data suggests a direct relation in the seasonal inflows of Levantine Intermediate Water (LIW) through the Strait of Sicily and Atlantic Water (AW) through the Strait of Gibraltar. The analysis indicates that the seasonal extremes of the two inflows are phased 90^{0} apart. Thus LIW and AW alternate in accumulating in the western Mediterranean, the minimum LIW volume occurring during February-June and the maximum during July-December, with the extreme AW volumes reversed during these periods. It is suggested that during the period of maximum LIW volume, the ratio of the denser LIW to the lighter AW in the water column increases and, due to the resulting denser water column, the sea level of the western Mediterranean is lowered. The depressed sea level in turn causes an increase in the AW inflow through the Strait of Gibraltar. The seasonal AW inflow changes generated by these events are inferred to be primarily responsible for the year-round variability of the western Mediterranean surface layer circulation.

Submitted in 1989
Journal of Geophysical Research, Volume 95, Number C2, pp. 1559-1568, February 15, 1990

EDDIES AND THERMOHALINE INTRUSIONS OF THE SHELF/SLOPE FRONT OFF THE NORTHEAST SPANISH COAST

Joaquín Tintoré
Departmento de Fisica
Universitat de les Illes Balears
Palma, Spain

Dong-Ping Wang
Marine Sciences Research Center
State University of New York
Stony Brook

Paul E. La Violette
Naval Oceanographic and Atmospheric Research Laboratory
Code 321
Stennis Space Center, MS 39529-5004

Abstract

A low-salinity anticyclonic eddy was found during a field study of the shelf/slope front off the northeast Spanish coast in July 1983. The eddy was associated with a tongue of low-salinity, cold water that originated in the Gulf of Lions. Hydrographic stations indicated the presence of multiple salinity-inversion layers. In particular, a relative salinity maximum layer was found at the base of the eddy, which can be traced through the study area along the same isopycnal surface. This suggests the thermohaline intrusion of near-surface, warm, high-salinity, open-ocean water along the frontal boundary. The anticyclonic eddy was induced a strong upwelling and, consequently, a high biological production at the coast. Subduction along the coastal front seems to provide major transport of particulate material into the open sea.

Submitted in 1989
Journal of Geophysical Research, Volume 95, Number C2, pp. 1627-1633, February 15, 1990

COMMENT ON "STATISTICAL CALIBRATION WHEN BOTH MEASUREMENTS ARE SUBJECT ERROR: A SIMULATION STUDY"

Matthew Lybanon
Ocean Science Directorate
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529-5004

Short Communication

A recent article by Yum [1] described a simulation in which least-squares straight line fits to artificially generated data sets with errors in both measurement processes (i.e. x and y) were made, the resulting fits were used for predictions, and an "average squared error of prediction" was used to evaluate the results. In addition to four fitting procedures which all amounted to "ordinary" least squares, Yum tested "the Lybanon method" [2], apparently at a reviewer's suggestion, and reported that my method "diverges often". I was unable to duplicate those problems despite strenuous attempts, and his discussion of results with "the Lybanon method" is implausible on theoretical grounds. It appears that he did not implement the method correctly, so his comparisons of the results with those from the other methods are questionable. The case in which all measured quantities involve error certainly occurs often in practice, so this Journal's readers may be interested in some clarification of my assertions.

Computers ind. Engng Vol. 16, No. 4, pp. 571-573, 1989. Printed in Great Britain.

OPERATIONAL ALTIMETER-DERIVED OCEANOGRAPHIC INFORMATION: THE NORDA GEOSAT OCEAN APPLICATIONS PROGRAM

Matthew Lybanon
Pavel Pistek
Conrad Johnson
Remote Sensing Branch
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Abstract

The U.S. Navy's GEOSAT active microwave altimeter provides detailed, accurate oceanographic information. It measures global oceanic wind speeds and significant wave height, sea ice edge in the polar regions, and dynamic topography related to mesoscale ocean circulation. The Naval Ocean Research and Development Activity processed near-real-time GEOSAT data to monitor oceanic processes. In particular, the combination of topographic information from GEOSAT, synoptic sea-surface-temperature information from infrared imagery, and local information from bathythermographs provides valuable information on Gulf Stream circulation. The size of the area involved, the intensity of currents, and the rapidity with which changes occur previously limited our technical ability to observe the Gulf Stream and its attendant spin-off eddies, and to understand its dynamics. Long-term study with the information sources described above has given a more complete picture of the Gulf Stream region's mesoscale circulation than ever before achieved.

Journal of Atmospheric and Oceanic Technology, January 11, 1989

OCEAN FEATURE RECOGNITION USING GENETIC ALGORITHMS WITH FUZZY FITNESS FUNCTIONS (GA/F^3)

C. A. Ankenbrandt
B. P. Buckles
F.E. Petry
Department of Computer Science
Center for Intelligent and Knowledge-based Systems
301 Stanley Thomas Hall, Tulane University
New Orleans, LA 70118
(504) 865-5840

M. Lybanon
Remote Sensing Branch
Naval Ocean Research and Development Activity
NSTL Station, MS 39529

Abstract

A model for genetic algorithms with semantic nets is derived for which the relationships between concepts is depicted as a semantic net. An organism represents the manner in which objects in a scene are attached to concepts in the net. Predicates between object pairs are continuous valued truth functions in the form of an inverse exponential function ($e^{-\beta|\chi|}$). 1:n relationships are combined via the fuzzy OR (Max [...]). Finally, predicates between pairs of concepts are resolved by taking the average of the combined predicate values of the objects attached to the concept at the tail of the arc representing the predicate in the semantic net. The method is illustrated by applying it to the identification of oceanic features in the North Atlantic.

Presented at the Third Annual Workshop on Space Operations Automation and Robotics, in Proceedings of SOAR 89, NASA/JSC, Houston, TX July 25-27, 1989

SENSITIVITY OF ACOUSTIC TRANSMISSION-LOSS PREDICTION TO MIXED-LAYER HINDCASTS CALCULATED WITH DATA FROM OWS PAPA

Paul J. Martin
Naval Oceanographic and Atmospheric Research Laboratory
Stennis Space Center, MS 39529

Abstract

The Mellor-Yamada Level 2, Price, and Garwood mixed-layer models and the Passive Raymode acoustic model (version 5.0) were used to investigate the effect of short-timescale (12-48 hr) upper-ocean mixed-layer hindcasts on the prediction of acoustic transmission loss with data from OWS Papa (145°W, 50°N) in the North Pacific. Mixed-layer hindcasts were initialized and validated with BTs taken at Papa during 1961, and forced with surface wind stresses and heat fluxes estimated from surface meteorological observations. Monthly and annual mean and rms hindcast errors for sea-surface temperature, mixed-layer depth, sound-channel depth, and acoustic-detection range were compared with persistence. The annual rms hindcast errors for sea-surface temperature, mixed-layer depth, and sound-channel depth were consistently better than persistence with improvement over persistence of 5 to 30%. For frequencies between 500 and 8000 hz the improvement of the model hindcasts over persistence in terms of annual rms acoustic-detection range error ranged from 2 to 21%.

Submitted in 1989 for publication as a NOARL Report.

TESTING OF A SHIPBOARD THERMAL FORECAST MODEL II

P. J. Martin
Ocean Sensing and Prediction Division
Ocean Science Directorate

Abstract

This technical note describes results from the testing of a regional, upper-ocean, thermal forecast model being developed for shipboard use. The model is a synoptic mixed-layer model that can include advection by Ekman and geostrophic or externally provided currents, and is similar to the forecast model used in the Thermodynamic Ocean Prediction System (TOPS) at the Fleet Numerical Oceanography Center (FNOC). The model is designed to be initialized from a shore- or ship-based thermal analysis, and forced with a shore- or ship-based atmospheric forecast. The primary use of the model is to predict changes in upper-ocean stratification and mixed-layer depth caused by changing weather and diurnal solar heating. The tests include both single-site and regional studies. The single-site studies consist of short (12-48 hr) hindcasts that use data from the Mixed-Layer Experiment (MILE) and from ocean station Papa. The regional studies use data from the Iceland-Faeroes Front taken during a Naval Exercise in May 1987. Mean and rms hindcast and forecast errors are compared with persistence and in some cases climatology.

NOARL Technical Note 3, December 1989. Distribution authorized to DoD and DoD contractors only (administrative or operational use).

SOFTWARE USER'S MANUAL FOR THE SEA SURFACE TEMPERATURE ANALYSIS AND COMPOSITE PROGRAM

Douglas A. May
Remote Sensing Branch
Naval Ocean Research and Development Activity
Stennis Space Center, MS

Richard L. Crout
Helen Beresford
Barbara Ray
Planning Systems, Inc.
115 Christian Lane
Slidell, LA

Abstract

The Sea Surface Temperature Analysis and Composite (SSTAC) is a software module targeted for implementation on the Tactical Environmental Support System (TESS (3)) in 1990. The SSTAC calculates sea surface temperatures for selected ocean areas from digital satellite imagery collected from NOAA and DMSP polar orbiters. This Software User's Manual (SUM) provides the information necessary for an operator to successfully execute the software module. When executed, the module automatically screens land and cloud contaminated pixels from the images, calculating sea surface temperature for each cloud free pixel. Multiple images can also be selectively composited to generate the best cloud free SST image possible.

SSTAC Software User's Manual, May 15, 1989

SOFTWARE TEST DESCRIPTION FOR THE SEA SURFACE TEMPERATURE ANALYSIS AND COMPOSITE (SSTAC) PROGRAM

Douglas A. May
Remote Sensing Branch
Naval Ocean Research and Development Activity
Stennis Space Center, MS

Richard L. Crout
Helen Beresford
Barbara Ray
Planning Systems, Inc.
115 Christian Lane
Slidell, LA

Abstract

The Sea Surface Temperature Analysis and Composite (SSTAC) is a software module targeted for implementation on the Tactical Environmental Support System (TESS (3)) in 1990. The SSTAC calculates sea surface temperatures for selected ocean areas from digital satellite imagery collected from NOAA and DMSP polar orbiters. This Software Test Description (STD) identifies the input data, expected output data, and evaluation criteria necessary for formal testing of the SSTAC software module. When executed, the module automatically screens land and cloud contaminated pixels from the images, calculating sea surface temperature for each cloud free pixel. Multiple images can also be selectively composited to generate the best cloud free SST image possible. This document provides expected results when each of the module's functions are exercised.

SSTAC Software Test Description, May 15, 1989

THE SOFTWARE DETAILED DESIGN DOCUMENT (SDDD) FOR THE SHIPBOARD SEA SURFACE TEMPERATURE ANALYSIS AND COMPOSITE (SSTAC) PROGRAM

Douglas A. May
Remote Sensing Branch
Naval Ocean Research and Development Activity
Stennis Space Center, MS

Richard L. Crout
Helen Beresford
Barbara Ray
Planning Systems, Inc.
115 Christian Lane
Slidell, LA

Abstract

The Sea Surface Temperature Analysis and Composite (SSTAC) is a software module targeted for implementation on the Tactical Environmental Support System (TESS (3)) in 1990. The SSTAC calculates sea surface temperatures for selected ocean areas from digital satellite imagery collected from NOAA and DMSP polar orbiters. This Software Detailed Design Document (SDDD) provides a detailed description of all code, input files and output files inherent to the module. When executed, the module automatically screens land and cloud contaminated pixels from the images, calculating sea surface temperature for each cloud free pixel. Multiple images can also be selectively composited to generate the best cloud free SST image possible.

SSTAC Software Detailed Design Document, May 15, 1989

A REAL-TIME INTERACTIVE SHIPBOARD SYSTEM TO PROCESS INFRARED/VISIBLE SATELLITE DATA FOR OCEANOGRAPHIC APPLICATIONS

Douglas A. May
Jeffrey D. Hawkins
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529-5004

Richard L. Crout
Planning Systems, Inc.
115 Christian Lane
Slidell, LA 70458

Abstract

Data processing and image display software has been developed at the Naval Ocean Research and Development Activity (NORDA) for on-scene oceanographic analysis applications aboard ship. The software will utilize real time digital imagery from the National Oceanic and Atmospheric Administration (NOAA) and the Defense Meteorological Satellite Program (DMSP) polar orbiters to determine sea surface temperature patterns in specific ocean areas. The software screens cloud contaminated pixels from each image to enhance ocean features and produce a corrected sea surface temperature image. All imagery is fully registered to allow the overlay of a latitude/longitude grid and the compositing of multiple sea surface temperature image data sets to attain the best cloud free image possible in the area of interest. The composite function includes temporal compositing to redefine cloud-filled pixels with the latest available sea surface temperature data and also sensor compositing to combine satellite data from different sensors (AVHRR and OLS). This information is stored onboard for use as briefing aids and as input to other oceanographic analysis programs.

Proceedings 5th IIPS Conference, pp. 114-118, January 1989

PROGRAM PERFORMANCE SPECIFICATION FOR THE SHIPBOARD SEA SURFACE TEMPERATURE ANALYSIS AND COMPOSITE PROGRAM

Douglas A. May
Code 321
Naval Ocean and Research Development Activity
Stennis Space Center, MS 39529

Richard L. Crout
Planning Systems, Inc.
Slidell, LA 70458

Abstract

The Sea Surface Temperature Analysis and Composite (SSTAC) is a software module targeted for implementation on the Tactical Environmental Support System (TESS(3)) in 1990, to provide oceanographic information in support of shipboard weapon/sensor systems. The SSTAC calculates sea surface temperatures for selected ocean areas from digital satellite imagery collected by NOAA and DMSP polar orbiters. The module automatically screens land and cloud contaminated pixels from each image and calculates the sea surface temperature of each cloud free pixel. The module can also combine multiple image data sets into a composite image to generate the best cloud free SST image possible for a selected region of interest. This report provides an overview of the program and details its functional requirements.

NORDA Tech Note No. 450, June 1989. Distribution authorized to DoD and DoD contractors only.

COUPLED OCEAN-ATMOSPHERE MODELS: A STATE-OF-THE-SCIENCE REVIEW

B. E. McDonald
Ocean Sensing and Prediction Division
Ocean Science Directorate

Executive Summary

The history and status of ocean-atmosphere coupling investigations (models and observation) are reviewed to define issues that will affect the U.S. Navy's environmental modeling efforts in the next several year. Progress in coupled model development seemed slow up to about 1984, but, in the 5 years since, there have been breakthroughs in our ability to recover observed interactive phenomena on a global scale (i.e., El Niño and the Southern Oscillation). Interactive modes on the oceanic mesoscale are believed to exist, but efforts to confirm this belief are just beginning. Limits of current models are pointed out, and various strategies used to couple model dynamics across the air-sea interface are summarized. Global-scale coupled models require three-dimensional ocean dynamics to close the ocean's heat transport system. In contrast, operational forecasts on scales up to hundreds of kilometers in space and a few days in time may be dominated by vertical transport in the ocean mixed layer. Improvements may be realized by the inclusion of horizontal dynamics (at a modest expense compared to atmospheric model execution times), but the global data-gathering system is inadequate to provide initial conditions and data for assimilation. It is recommended that development of coupled research models for the ocean mesoscale be supported as a primary investigative tool until issues involving mesoscale coupling and data refinement are clarified.

NORDA Report 237, March 1990. Approved for public release; distribution is unlimited.

ACCURACY OF ADIABATIC MODE PREDICTIONS FOR ACOUSTICAL SCATTERING FROM BATHYMETRY

B. E. McDonald
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Abstract

Numerical results from two adiabatic mode theories are compared for scattering of trapped deep-ocean acoustic waves from bathymetric features (seamounts, islands, continental shelves). Each theory converts the 3D wave equation into a series of 2D horizontal wave equations for mode amplitudes of local vertical eigenfunctions, with mode coupling neglected. Approximate solutions of the 2D equations are generated along horizontal ray paths. Accuracy of each solution is measured numerically from the residual error in the 3D wave equation. The theories used in the comparison are: (1) the horizontal ray theory of Weinberg and Burridge [1]; and (2) a modified theory (Bernstein, et al. [2]) derived from the 3D variational principle applied to the restricted function space of adiabatic mode solutions. Results are evaluated for conditions descriptive of a long-range ocean acoustic propagation experiment [3]. (Work supported by the Naval Ocean R and D activity).

Presented at Second IMACS Symposium on Computational Acoustics, Princeton University, Princeton, New Jersey, U.S.A., March 15-17, 1989

ANALYSIS OF THE BIFURCATION OF THE KUROSHIO CURRENT USING A GLOBAL OCEAN MODEL

E. J. Metzger
H. E. Hurlburt
Naval Ocean Research and Development Activity
Code 323
Stennis Space Center, MS 39529-5004

A. J. Wallcraft
JAYCOR
Stennis Space Center, MS 39529

Abstract

A study of the bifurcation of the Kuroshio Current system has been performed using the NORDA one-active layer reduced gravity global ocean model; grid spacing is 0.5° (lat) x 0.7° (long). The model includes the effects of mixing and thermodynamics and is forced with the Hellerman-Rosenstein wind climatology.

Using either the annual mean or monthly mean wind stresses, the model simulates the bifurcation of the Kuroshio Current. The northern branch follows the subarctic frontal zone which lies along the annual mean and summertime mean zero wind stress curl lines. The southern branch follows the subtropical frontal zone which lies along the mean zero wind stress curl line in winter and where a relatively strong gradient exists in the annual mean wind stress curl pattern. Monthly mean winds increase the transport of the northern (southern) branch during summer (winter) by 10% (20%).

Two additional experiments were performed to illustrate the effects of wind stress curl on the model solution. Summer mean (April-Sept) and winter mean (Dec-Feb) wind climatologies derived from Hellerman-Rosenstein were used to force the model. The summertime winds increase the intensity of the northern branch and the current tracks closely to the zero wind stress curl line. Only a hint of the southern branch can be seen near the coast of Japan as the current quickly broadens and weakens offshore. The wintertime winds completely eliminate the northern branch of the Kuroshio wile the southern branch is intensified as it follows the strong gradient near the zero wind stress curl line.

Presented at the American Geophysical Union Spring Meeting, 10 May 1989, Baltimore, MD. Abstract published in EOS Vol. 70, No. 15, April 11, 1989

THE ESTIMATION OF GEOID PROFILES IN THE NW ATLANTIC FROM SIMULTANEOUS SATELLITE ALTIMETRY AND AXBT SECTIONS

Jim L. Mitchell
Naval Ocean Research & Development Activity
Stennis Space Center, MS 39529

Jan M. Dastugue
Planning Systems, Inc.
Slidell, LA

William J. Teague & Zachariah R. Hallock
Naval Ocean Research & Development Activity
Stennis Space Center, MS 39529

Abstract

Measurement of the surface topography associated with the ocean mesoscale is severely curtailed by unknown sea level gradients in the background geoid. Regional mean sea level surfaces and alongtrack profiles based upon altimetry alone represent a combination of the geoid and the temporal mean sea surface topography due to the circulation. In areas where the temporal mean circulation results in large amplitude topography (such as the Gulf Stream/NW Atlantic), the use of such mean surfaces or profiles for precise representation of the geoid is limited. Gravimetrically derived geoids typically do not have the desired precision for use in computing surface topography from satellite altimetry. We examine estimates of the alongtrack geoid profile based upon collinear altimetry and simultaneous Airborne Expendable Bathythermograph (AXBT) sections.

We examine a process which: (1) uses AXBT sections collected along altimeter groundtracks to estimate the "instantaneous" surface dynamic topography; (2) employs simultaneous satellite altimeter overflights to provide a measure of "instantaneous" sea level and; (3) arrives at a precise estimate of the alongtrack geoid profile by differencing the instantaneous altimetric sea level and the AXBT-derived dynamic topography. This technique is applied to several GEOSAT-Exact Repeat Mission (GEOSAT-ERM) groundtracks in the region of the NW Atlantic Regional Energetics Experiment (REX) using AXBT survey data collected in April and July 1987. Geoid profile estimates are repeatable between these two independent data sets to within 10-20 cm RMS. This is approximately the estimated noise level due to barotropic variability in the Gulf Stream region. These AXBT/GEOSAT-derived profiles provide a more consistent estimate of the alongtrack geoid gradient than do available gravimetric geoids.

Analysis of the statistics of the ensemble of collinear passes provides an estimated geographically uncorrelated orbit error of approximately 1-2m in the GEOSAT-ERM emphemeris. Orbit error is of very long wavelength relative to the NW Atlantic domain of this study, hence these AXBT/GEOSAT-derived

(The Estimation of Geoid Profiles in the NW Atlantic From Simultaneous Satellite Altimetry and AXBT Sections, continued)

alongtrack geoid profiles allow for computation of absolute surface topography (both mean and variable) over the NW Atlantic. The absolute surface topography so derived does not suffer significant contamination by either geographically uncorrelated or correlated orbit error.

Submitted to Journal of Geophysical Research, June 1989

NUMERICAL SIMULATION OF GULF STREAM EVOLUTION:
DATA AND FORECAST VIDEO COMPARISONS

J. L. Mitchell
D. N. Fox
M. R. Carnes
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529-5004

J. M. Dastugue
Planning Systems, Inc.
Slidell, LA 70458

Abstract

Video comparisons of numerical simulation of Gulf Stream evolution and verification data are presented. Using initial state fields of sea surface topography, as constructed from blended GEOSAT-ERM altimetry and IR imagery, a primitive equation numerical simulation of several weeks of Gulf Stream mesoscale structure evolution is illustrated in video format. Comparisons are made between simulations using 1/5-degree and 1/8-degree horizontal resolution models. The evolution of Gulf Stream meanders is markedly more realistic in the higher resolution model, while the ill effects of subgrid-scale viscosity are notably less. Comparisons are made between forecast and observed evolution using later verification sea surface topography data. The numerical simulations are found to produce forecast results which are superior to an assumption of persistence (i.e., no motion of the structure during the forecast period). The diagnosis of the simulation results and the comparison with verification data is greatly enhanced by the use of video time series of the regional sea surface topography. Further, comparisons between derived subsurface sections, such as temperature, salinity, and sound speed are facilitated by the video format.

Presented at the American Geophysical Union Fall Meeting, 4-8 December 1989, San Francisco, CA. Abstract published in EOS, Vol. 70, Number 43, 24 October 1989

REX AXBT DATA IN THE NORTHWEST ATLANTIC
DECEMBER 1986

W. J. Teague/Z. R. Hallock
Oceanography Division
Ocean Science Directorate

J. L. Mitchell
Ocean Sensing and Prediction Division
Ocean Science Directorate

J. M. Dastugue
Planning Systems, Incorporated
Slidell, Louisisna

Abstract

A major component of the field activities for the Northwest Atlantic Regional Energetics Experiment (REX) focuses on collecting and analyzing data from regional P-3 Airborne Expendable Bathythermography (AXBT) surveys. These surveys provide a description of the temperature structure associated with the mesoscale features in the REX area. This report describes the collection, processing, and preliminary analysis of these data, and presents plots of individual profiles and sections.

NORDA Technical Note 421, February 1989. Distribution authorized to DoD and DoD contractors only.

SEA SURFACE TOPOGRAPHIC VARIABILITY NEAR THE NEW ENGLAND SEAMOUNTS: AN INTERCOMPARISON AMONG IN SITU OBSERVATIONS, NUMERICAL SIMULATIONS, AND GEOSAT ALTIMETRY FROM THE REGIONAL ENERGETICS EXPERIMENT

Zachariah R. Hallock
Jim L. Mitchell
J. Dana Thompson
Naval Ocean Research and Development Activity
Stennis Space Center, Mississippi

Abstract

Intercomparisons are made among three sets of results for two regions of the Gulf Stream, upstream and downstream of the New England Seamount Chain (NESC); cbservational records from 12 inverted echo sounders with pressure gauges (IES/PGs), concurrent Geosat altimeter crossover point differences, and results from a primitive equation model of the region. Standard deviations of sea surface topography show generally good agreement for the three data sources. No significant difference between the upstream and downstream regions is observed in the actual data. IES/PG records and Geosat topographic variability have values of about 30 cm on both sides of the NESC, although model results show a discrepancy in the eastern region. Barotropic fluctuations account for about 30% of the total surface topographic variability and are only partially correlated with baroclinic fluctuations.

Journal of Geophysical Research, Vol. 94, No. C6, Pages 8021-8028, June 15, 1989

AN IMPROVED METHOD FOR COMPUTING GRAY-LEVEL, CO-OCCURRENCE-MATRIX-BASED TEXTURE MEASURES

Sarah H. Peckinpaugh
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529-5004

Abstract

This paper describes a machine-efficient approach to the computation of texture measures based on the gray-level co-occurrence matrix. Several measures will be discussed relative to the method. The Cluster Shade texture measure will be used for comparison with other implementations.

Submitted in 1989
IEEE Transactions on Pattern Analysis and Machine Intelligence

THE IMPACT OF THE WET TROPOSPHERIC CORRECTION ON THE INTERPRETATION OF ALTIMETER-DERIVED OCEAN TOPOGRAPHY IN THE NORTHEAST PACIFIC

Patricia A. Phoebus
Jeffrey D. Hawkins

Naval Oceanographic and Atmospheric Research Laboratory
Ocean Sensing and Prediction Division
Stennis Space Center, MS 39529-5004

Abstract

Atmospheric water vapor data derived from the Special Sensor Microwave/Imager (SSM/I) are used to make time coincident, wet tropospheric range corrections to GEOSAT altimeter data in the Northeast Pacific. The original and corrected sea surface height residuals along numerous tracks are examined to determine the impact of water vapor on the altimeter signal. Mesoscale feature analyses of corrected and uncorrected altimeter data are used to assess the impact of water vapor path lengthening in areas of low sea surface height variability. Results indicate that the horizontal spatial variations in the water vapor height corrections are frequently similar to true oceanographic gradients. Altimeter data interpretation is affected in several ways. The unaccounted-for presence of atmospheric water vapor may mimic or mask the true ocean features, and even small changes in the water vapor over short spatial scales can enhance a partially obscured feature. Analyses of all GEOSAT tracks crossing the area of interest in September 1987 clearly illustrate that water vapor frequently contaminates the ocean topography measurements, making the water vapor adjustment critical before the altimeter data can be successfully used to locate and identify mesoscale ocean features. Furthermore, the SSM/I and GEOSAT data must be closely matched in both space and time, a difficult task since it takes 3.5 days to obtain global SSM/I coverage with one operational sensor. To optimize the mesoscale oceanographic application of altimeter data, a bore-sighted radiometer should be included on all altimeter spaceborn platforms.

Accepted by JGR for GEOSAT special issue, Vol. 95, Number C3, Pages 2939-2952, March 15, 1990

TECHNICAL DESCRIPTION OF THE OPTIMUM THERMAL INTERPOLATION SYSTEM, VERSION 1: A MODEL FOR OCEANOGRAPHIC DATA ASSIMILATION

R. Michael Clancy
Ocean Models Division
Fleet Numerical Oceanography Center
Monterey, CA 93943

Patricia A. Phoebus
Ocean Sensing and Prediction Division
Ocean Science Directorate

Kenneth D. Pollak
Ocean Models Division
Fleet Numerical Oceanography Center
Monterey, CA 93943

Executive Summary

The Optimum Thermal Interpolation System (OTIS) is an ocean thermal analysis product developed for real-time operational use at the Fleet Numerical Oceanography Center. OTIS is expected to become the centerpiece of the Navy's ocean thermal analysis and prediction capabilities both ashore and afloat. It provides a rigorous framework for the synergistic combination of real-time data, climatology, and predictions from ocean mixed-layer and circulation models to produce the Navy's most accurate representation of ocean thermal structure on global and regional scales. OTIS is particularly well suited for utilization of remotely sensed data from satellites because of its ability to account for the relative accuracies of various types of data.

OTIS is based on the optimum interpolation (OI) data assimilation methodology. Basically, the OI technique maps observations distributed nonuniformly in space and time to a uniformly gridded synoptic representation, or analysis, of the target field. The analysis is constructed as a first-guess background field plus an anomaly relative to that field. The analyzed anomaly at a particular gridpoint is given by a weighted combination of observed and model-predicted anomalies, with the space-time autocorrelation function for the resolvable anomalies governing which observations contribute. The OI technique provides the optimum weights applied to each anomaly, such that the resulting analysis error will be minimized in a least-squares sense. The technique also provides an estimate of this error.

The basic inputs to OTIS are the statistics defining both the resolvable and subgrid-scale variability of the target field about the background field, the instrumental error characteristics of the measurement systems providing the observations, and the error characteristics of the forecast model that supplies the

(Technical Description of the Optimum Thermal Interpolation System, Version 1: A model for Oceanographic Data Assimilation, continued)

predictions. The end product is a statistically optimum gridded representation of the current ocean thermal structure, which may in turn be used to initialize prognostic thermodynamic and ocean circulation models, or to compute sound-speed profiles for input to ocean acoustic models.

NORDA Report 240, August 1989. Approved for public release; distribution is unlimited.

EXPANDED SYSTEM OPERATIONAL SPECIFICATION (ESOS) FOR THE TACTICAL ENVIRONMENTAL SUPPORT SYSTEM (TESS(3)) THREE-DIMENSIONAL OCEAN THERMAL STRUCTURE ANALYSIS

Patricia A. Phoebus
Ocean Sensing and Prediction Division
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529-5004

Richard L. Crout
Planning Systems, Incorporated
115 Christian Lane
Slidell, LA 70458

Abstract

The Three-dimensional Ocean Thermal Structure (TOTS) analysis is a software module targeted for implementation on the shipboard Tactical Environmental Support System (TESS(3)) in 1990, to provide oceanographic information in support of shipboard weapon/sensor systems. The TOTS analysis combines remotely sensed sea surface temperature data with other local observations, climatology, and ocean model products from shore to produce a three-dimensional real-time analysis of the ocean thermal structure within the battlegroup's area of interest. This analysis will be produced on grids small enough to resolve tactically significant mesoscale features such as ocean fronts and eddies. The resulting analyzed temperature field will be used as input to the range-dependent acoustic models resident in TESS(3).

NORDA Technical Note 422, January 1989. Distribution authorized to DoD and DoD contractors only.

AN OPERATIONAL GLOBAL-SCALE OCEAN THERMAL ANALYSIS SYSTEM

R. Michael Clancy and Kenneth D. Pollak
Fleet Numerical Oceanography Center
Monterey, CA 93943

Patricia A. Phoebus
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

James A. Cummings
Fleet Numerical Oceanography Center
Monterey, CA 93943

Abstract

The Optimum Thermal Interpolation System (OTIS) is an ocean thermal analysis product developed for real-time operational use at the U. S. Navy's Fleet Numerical Oceanography Center. It functions in an analysis-prediction-analysis data assimilation cycle with an ocean mixed-layer model, and is described in a companion paper (Clancy et al., 1989).

An operational test, involving comparison of OTIS against an existing operational ocean thermal structure model, was conducted during February, March and April of 1988. Qualitative comparison of the two products suggests that OTIS gives a more realistic representation of subsurface anomalies and horizontal gradients. Quantitative comparison of the two products with independent bathythermograph data to calculate apparent root-mean-square (RMS) errors indicate that OTIS gives a more accurate analysis of the thermal structure, with improvements largest below the base of the mixed layer. Regional differences in the relative performance of the models, which are probably related to the validity of the prescribed statistical parameters required by OTIS, are also noted from verification against the bathythermograph data. OTIS performs best relative to the existing model in the Indian Ocean, and poorest relative to this model in the eastern mid-latitude Pacific. In the latter area, however, both models exhibit their lowest error levels and perform best relative to climatology.

Subgrid-scale noise contaminates the apparent RMS error statistics and obscures the relative grid-scale accuracy of the models. A general technique is presented to estimate grid-scale RMS errors which are uncontaminated by subgrid-scale and instrumental noise in the observations. Application of the technique indicates that the grid-scale errors for OTIS are typically 20% less than those of the other model.

Accepted by the Journal of Atmospheric and Oceanic Technology as joint article.

SEA ICE FORECASTING MODELS AT THE FLEET NUMERICAL OCEANOGRAPHY CENTER

Ruth H. Preller
NORDA Code 322
Stennis Space Center, MS 39529

Kenneth D. Pollak
FNOC Code 42
Monterey, CA 93943

Abstract

Real time forecasting of ice motion, ice thickness and ice edge location (ice concentration) has been emphasized in recent years with operational models running at the Fleet Numerical Oceanography Center (FNOC). The Skiles model and the Thorndike and Colony model have been used to determine ice drift based on a relationship between geostrophic winds and ocean currents. The Gerson model is used to determine ice thickness at specific locations, based on a relationship between degree day accumulation and the growth and decay of ice. More recently, the Polar Ice Prediction System (PIPS), has become operational at FNOC. PIPS is based on the hydrodynamic/thermodynamic Hibler sea ice model (1980, Mon. Wea. Rev., 1944-1973). The ice model is driven by the daily forecast atmospheric fields from the Navy Operational Global Atmospheric Prediction System (NOGAPS). The PIPS domain includes the Arctic basin, the Barents sea and the northern half of the Greenland and Norwegian seas and uses 127 km grid resolution.

The PIPS model has the capability of forecasting ice concentration (ice edge), ice thickness and ice motion out to five days. A total of 15 graphic products are produced along with each day's forecast. The ice model is updated every seven days with ice concentration data from the Naval Polar Oceanography Center (NPOC). Trends predicted by PIPS for ice concentration and ice thickness show good agreement with data. In addition, statistical comparisons of PIPS ice drift to observed Arctic buoy drift show PIPS, rather than the free drift assumption, to be the better predictor of ice drift.

Presented at Conference and Exposition on Marine Data Systems, April 26-28, 1989, New Orleans, Louisiana, in proceedings

ASSIMILATION OF ICE CONCENTRATION DATA INTO AN ARCTIC SEA ICE MODEL

Abe Cheng
Sverdrup
Stennis Space Center, MS 39529

Ruth Preller
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Abstract

The Polar Ice Prediction System (PIPS) is an operational numerical model, based on Hibler's ice model [1979, J. Phys. Oceanogr., 9: 815-846; and 1980, Mon. Wea. Rev., 108: 1944-1973]. It has been run at the Fleet Numerical Oceanography Center (FNOC) for daily prediction of ice drift and growth/decay in the Arctic. The PIPS model is driven by atmospheric winds and pressure, ocean currents and deep oceanic heat atmospheric winds and pressure, ocean currents and deep oceanic heat fluxes, and is initialized once per week by the Naval Polar Oceanography Center's (NPOC) analysis of ice concentration. The existing initialization method replaces the PIPS model derived concentration with the NPOC analysis. This study describes a new method of blending available data with the model derived concentration field to obtain a more realistic updated field for initialization. In calculation, the continuity equation of ice concentration provides a mathematical structure for adding and constraining data via a nonlinear regression technique. The thermodynamic ice growth/decay in the continuity equation, caused by heat flux, is the sum of the temporal variation and the advective contribution. The method presented here transforms the continuity equation into a function of ice concentration, and then solves it using a finite difference method. The data used for this study include the NPOC weekly analysis, the model derived concentration, and satellite passive microwave measurements. Other related data can also be used. The final estimated ice concentration represents the best fit of the equation and the data. The weights of the nonlinear regression can be varied depending on grid locations, data sets, and seasons. The NPOC analysis at the ice edge, which is believed to be the most accurate, has been weighted to emphasize the superior accuracy.

Presented at Regional and Basin Scale Ice Ocean Modeling Workshop, 1989
Nansen Ice-Ocean Modeling Symposium, Bergen, Norway, 23-27 October 1989

PRESENT METHODS OF DATA ASSIMILATION IN THE U.S. NAVY'S SEA ICE FORECASTING MODELS

Ruth H. Preller
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529-5004

Pamela G. Posey
Berkeley Research Associates
P. O. Box 852
Springfield, VA 22150

Abstract

The U. S. Navy presently has two sea ice forecasting systems running on a daily operational schedule at the Fleet Numerical Oceanography Center. The first forecast system, the Polar Ice Prediction System (PIPS), covers the Arctic basin, the Barents Sea and the Greenland Sea using 127 km grid resolution. The second model, the Regional Polar Ice Prediction System-Barents (RPIPS-B), covers the Barents Sea and the western half of the Kara Sea using 25 km grid resolution. Both models are forced by atmospheric forcing from the Naval Operational Global Atmospheric Prediction System and monthly mean geostrophic ocean currents and deep ocean heat fluxes. The models are run daily making 120 hour forecasts of ice drift, ice thickness and ice concentration. Both models are updated, once per week, by assimilating digitized concentration data from the Naval Polar Oceanography Center. Accuracy in the digitized data as well as the timeliness of the data are shown to have a serious impact on the model forecasts.

Presented at Workshop on Regional and Mesoscale Modeling of Ice-covered Oceans, 1989 Nansen Ice-Ocean Modeling Symposium, Bergen, Norway, 23-27 October 1989, in Proceedings

THE REGIONAL POLAR ICE PREDICTION SYSTEM--BARENTS SEA (RPIPS-B): A TECHNICAL DESCRIPTION

Ruth H. Preller
Shelley Riedlinger
Ocean Sensing and Prediction Division
Ocean Science Directorate
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Pamela G. Posey
Berkeley Research Associates
Springfield, Virginia

Abstracts

The hydrodynamic/thermodynamic Arctic sea-ice model designed by W. D. Hibler of the Cold Regions Research and Engineering Laboratory (CRREL) has been adapted to the Barents Sea. This model is driven by atmospheric forcing from the Naval Operational Global Atmospheric Prediction System (NOGAPS) and oceanic forcing from the Hibler and Bryan coupled ice-ocean model. This high-resolution model (25 km), which covers the entire Barents Sea and the western half of the Kara Sea, uses a 6-hour time step. Development of this model required the design of new ice inflow/outflow boundary conditions, which use the ice thickness fields from the Polar Ice Prediction System (PIPS) when inflow is indicated. Model results show good agreement with such data as the Naval Polar Oceanography Center's (NPOC) analysis of ice concentration and concentrations derived from passive microwave data. The model has a tendency, however, to melt ice too quickly in summer and to grow it back too slowly in the fall. Planned improvements in the atmospheric and oceanic forcing should correct this problem. The high resolution of the Barents Sea model enables it to predict the ice edge, ice growth and decay, and the movement of ice near land boundaries with greater accuracy than does the PIPS model. The Regional Polar Ice Prediction System for the Barents Sea (RPIPS-B) is the forecast system designed to run at the Fleet Numerical Oceanography Center (FNOC) based on the Barents Sea ice model. RPIPS-B is updated weekly by the NPOC analysis of ice concentration. The forecast system, presently in its "operational checkout" phase, is being made ready for a winter-spring operational test.

NORDA Report 182, May 1989. Approved for public release; distribution is unlimited.

THE POLAR ICE PREDICTION SYSTEM--
A SEA ICE FORECASTING SYSTEM

Ruth H. Preller
Ocean Sensing and Prediction Division
Ocean Science Directorate
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Pamela G. Posey
Berkeley Research Associates
Springfield, Virginia

Abstract

The Polar Ice Prediction System (PIPS), based on the Hibler dynamic/thermodynamic sea ice model, was developed as an upgrade to the existing sea ice products available at the U.S. Navy's Fleet Numerical Oceanography Center (FNOC). It was also designed to provide new sea ice products that could be used as guidance by the Naval Polar Oceanography Center (NPOC). The operational testing of PIPS showed that the ice drift from the model was excessive in magnitude when compared to ice drift from Arctic buoys. As a result, the PIPS forcing was changed from planetary boundary layer model winds to geostrophic winds calculated from forecast surface pressures. Resultant PIPS ice drifts were more accurate than those calculated by the existing operational model--the Thorndike and Colony free-drift model. The operational test also indicated a need to reduce the model time step from 25 to 6 hours. Reducing the time step allowed for better resolution of atmospheric heat fluxes and improved the model's capability to predict ice edge location. PIPS results also showed great improvement when updated by an ice concentration analysis for the Arctic derived by NPOC. This updating technique is now an integral part of the PIPS system and takes place approximately once per week.

As a result of this testing and the associated improvements made to the model, PIPS was declared operational on 1 September 1987. Examples of PIPS output and results from model-data comparisons are presented.

NORDA Report 212, April 1989. Approved for public release; distribution is unlimited.

THE RESULTS OF TEST CASES EXAMINING THE EFFECTS OF ATMOSPHERIC FORCING IN LIMITED AREA ICE MODELS

Ruth H. Preller
NORDA Code 322
Stennis Space Center, MS 39529

Pamela G. Posey
Berkeley Research Associates
P. O. Box 852
Springfield, VA 22150

Abstract

Atmospheric forcing from the Naval Operational Global Atmospheric Prediction System has been used to drive the U.S. Navy's operational ice models, the Polar Ice Prediction System (PIPS) and the Regional Polar Ice Prediction System - Barents (RPIPS-B). Unlike many ocean circulation models which depend mainly on wind forcing, ice models are dependent on winds as well as atmospheric heating/cooling (fluxes, air temperatures and solar radiation). Comparisons of the ice model results with observations have shown that the model derived fields are highly sensitive to the atmospheric forcing. An excessively warm atmosphere can cause huge "ice melting" events while an atmosphere which is too cool can cause ice to grow where none has been observed. Wind forcing also plays a major role in the ice model results. Over the short periods of time used in a forecast, winds are dominant in determining ice drift. If the wind is inaccurate, modeled ice drifts are shown to reflect these inaccuracies. The resolution of atmospheric models are often of the order of hundreds of kilometers while the ice model's resolution is generally less than 100 km. Mesoscale features are often lost in the coarse resolution of the atmospheric forcing and are therefore missing from the ice model forecasts. Spectral models, which are presently replacing the primitive equation atmospheric models at the Fleet Numerical Oceanography Center, should provide better forcing for the Arctic. In addition, the resolution of these models will soon be doubled and provide more detailed forcing for the ice models.

Presented at Workshop on Regional and Mesoscale Modeling of Ice-covered Oceans, 1989 Nansen Ice-Ocean Modeling Symposium, Bergen, Norway, October 23-27, 1989, in Proceedings

APPLICATION OF SATELLITE OCEAN COLOR IMAGERY: PLAN AND WORKSHOP REPORT

Albert E. Pressman
Ronald J. Holyer
James L. Mueller
John M. Harding
Paul J. Martin
Robert A. Arnone
John E. Curtis
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Abstract

The report develops and proposes a five-year plan leading to operational implementation of satellite borne ocean color imagery for support of Naval operations. Eleven potential Naval applications are discussed and their role in specific warfare areas are cited. These applications are: Ocean Mesoscale Water Mass Differentiation, Quantitative Input to Mixed-Layer Models, Satellite Laser Communication, Bioluminescence Potential, Polar Ice Information, Oil Slicks, Sand Storms, Coastal Bathymetry, Guidance for Non-Acoustic Optical Detection, Aerosols for MCSST Corrections and E-O Weapons Guidance, and Ocean Optical Climatologies.

In addition to this plan, a workshop was held at USM on 29-30 November 1988. This workshop was attended by approximately 40 scientists representing a cross section of the Nation's experts. A report covering this subject is included.

NORDA SP 080:321:89, September 1989. Distribution authorized to DoD components only.

A 3-D COUPLED ICE-OCEAN MODEL

Shelly H. Riedlinger
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Abstract

A three dimensional ice-ocean model is being developed for ice-forecasting in the Arctic region. Particular emphasis is paid to sea ice distribution and ice edge location. The Hibler dynamic thermodynamic sea ice model is coupled to the Bryan/Cox multilevel baroclinic ocean model.

The coupled model is initially set-up and tested on the Polar Ice Prediction System (PIPS) Arctic grid which has a resolution of 127 km x 127 km (1.14° x 1.14°). This grid is used to test coupling techniques. The model is next expanded to the PIPS-45 grid. This grid has a resolution of 80 km x 80 km and includes all ice-covered seas from the North Pole to 45°N. The ocean model has 15 vertical levels from the surface to 5700 m. A daily time step is used.

Both versions of the ice-ocean model are initialized with Levitus seasonal climatology values for temperature and salinity. Fleet Numerical Oceanography Center forcing fields from 1986, which include solar radiation, longwave radiation, and geostrophic winds from surface pressures, are used to force the ice-ocean model.

The coupling is accomplished by using the heat flux, and salt flux, which is determined in the ice model from the growth rate of ice, as surface boundary conditions in the ocean model. The stress on the ocean surface is determined from the wind stress and the internal ice stress. The ocean model is then used to determine the temperature distribution in the ocean and the ocean currents which are feed back into the ice model. The method for coupling is taken after Hibler and Bryan (1987, J. Phys. Oceanogr., 17, 987-1015).

The ice-ocean model is integrated forward in time for one year. The results are compared with various weekly observations obtained from Naval Polar Oceanography Center analysis and the Norwegian Meteorological Institute maps. The general ocean circulation and current strength are also compared with data to determine how well the Arctic circulation is simulated by the ice-ocean model.

Presented at 1989 Nansen Ice-Ocean Modeling Symposium at Workshop on Regional and Mesoscale Modeling of Ice-covered Oceans, 23-27 October 1989, Bergen, Norway, in Proceedings.

SURFACE CURRENT AND WAVE MODULATION MEASUREMENTS OVER BOTTOM TOPOGRAPHY -- A COMPARISON WITH THEORY

Peter Smith
Donald Johnson
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Abstract

Aircraft and satellite-borne SAR's have successfully imaged a number of underwater topographic features through the modulation of surface waves that occurs over such bottom anomalies. A mechanism by which the perturbed flow might disturb the equilibrium of the ambient wave spectrum has been advanced by Alpers and Henning (1984). The basic assumptions are that the flow is nearly barotropic and the surface rate of strain results from acceleration and deceleration of the flow as determined by two dimensional flow conservation. These assumptions, and the resulting theory, provide a plausible explanation for the backscatter variations observed in the English Channel. In order to determine if this theory is appropriate for the wave modulations on Nantucket Shoals we conducted an experiment in Sept., 1987.

Four surface current meters were deployed in a line crossing the edge of a submerged ridge on the Shoals. Simultaneously, a drifting spar buoy, equipped with an array of capacitance wires, was deployed and allowed to drift through the current meter array and over the submerged ridge.

Analysis of this data is confined to a phase of the ebbing tide when the flow velocity was approximately 1 meter/sec and directed at a small angle to the ridge. Both the cross-ridge and along-crest components of flow experience a deceleration as the ridge is approached and subsequently crossed, with local minima occurring in both components near the top of the ridge.

The action transport equation is integrated, assuming the measured directional wave spectrum obtained by the spar buoy outside of the region of deceleration. The theory developed by Hughes (1978) is used. The surface rate of strain ($\partial u/\partial x$ and $\partial v/\partial x$ is prescribed by fitting a spline to the current meter data.

The dominant amplifying mechanism for $\lambda > 90$ cm is the trapping of ray trajectories by the minimum in $\partial v/\partial x$. For waves with $\lambda < 90$ cm, the dominant amplifying mechanism is straining by $\partial u/\partial x$. The theory correctly predicts the approximate location of the roughness transition.

Presented at IGARSS 89, 12th Canadian Symposium on Remote Sensing, Vancouver, Canada, July 10-14, 1989, in Proceedings

PORTABLE SOFTWARE DEVELOPMENT TOOLS

G. D. Stephenson
Remote Sensing Branch
Ocean Sensing and Prediction Division
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

Abstract

This work was performed to identify and evaluate techniques to develop portable software. The NASA Goddard Space Flight Center has invested heavily into solutions to this problem through their Transportable Applications Executive (TAE), Display Management Subsystem (DMS) and Common Data Format (CDF) packages. These software packages were obtained from NASA and implemented on the NORDA Code 321 VAX 8300 Digital Equipment computer system. A NORDA application was converted to utilize features of these packages for porting to other computer systems. Effort required to convert the application to run under TAE was minimal. Evaluation of implementing the converted application on another computer system has not been completed.

NORDA Technical Note 478, October 1989. Distribution authorized to DoD and DoD contractors only.

GULF STREAM PATH NEAR 67 W AND 58 W

W. J. Teague
Z. R. Hallock
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

J. M. Dastugue
Planning Systems Inc.
Slidell, LA 70458

Abstract

Estimates of Gulf Stream position and direction were computed at half-day intervals from adjacent Inverted Echo Sounder (IES) measurements (Teague and Hallock, 1989) as part of NORDA's Regional Energetics Experiment. These IES measurements were made from June 1985 to July 1986 with two arrays deployed near 67 W and 58 W, across the historical mean path of the Gulf Stream. Evolution of the Gulf Stream path estimated for each array is shown by video. Meander and eddy features are clearly visible at both locations.

Presented at the American Geophysical Union Fall Meeting, 4-8 December 1989, San Francisco, CA. Abstract published in EOS, Vol. 70, Number 43, October 24, 1989

THE LOOP CURRENT AND ITS ROLE IN THE DYNAMICS AND CIRCULATION OF THE GULF OF MEXICO

J. Dana Thompson, Harley E. Hurlburt
Naval Oceanographic and Atmospheric Research Laboratory
Code 323
Stennis Space Center, MS 39529-5004

A. Wallcraft
JAYCOR
Stennis Space Center, MS 39529-5004

Abstract

The Gulf of Mexico is an ideal basin to study ocean dynamics, containing many features of much larger mid-latitude domains. A major current system, the Loop Current, dominates the circulation of the basin. Large anticyclonic rings, cross-shelf exchanges, a highly energetic western boundary regime, and smaller cyclonic and anticyclonic eddies are at least in part energized by the Loop Current. The relatively small size of the Gulf and the relatively constrained inflow of the Loop Current makes the basin attractive from both a modelling and an observational perspective. Our basin understanding of the dynamics of the Gulf of Mexico developed in the last two decades from observations and detailed numerical model studies has shown that barotropic and baroclinic instability processes, potential vorticity conservation, and transport distributions through the Yucatan Straits are key elements in understanding the Loop Current behavior. The importance of large anticyclones that detach from the Loop Current in carrying momentum, vorticity, heat, and salt into the western Gulf are made clearer from the modelling studies. The need to measure the deep flow in the Gulf at inflow and outflow boundaries is also underscored by model experiments. Requirements for better model resolution, both horizontal and vertical, improved model physics, including proper interaction between the deep Gulf and the shelf/slope region, and new observational data for more extensive model/data intercomparisons are also discussed. Finally, some unrestrained speculation about prospects for observing and modelling the Gulf of Mexico during the next decade are offered.

Submitted in 1989
AGU, Tampa, Florida

HURRICANE-GENERATED CURRENTS ON THE OUTER CONTINENTAL SHELF, PART 1: MODEL FORMULATION AND VERIFICATION

Cortis Cooper
Conoco Production Engineering and Research
Houston, Texas

J. Dana Thompson
Naval Ocean Research and Development Activity
Stennis Space Center, Mississippi

Abstract

A numerical model is developed to simulate currents generated by hurricanes on the outer continental shelf and slope. Emphasis is on the mixed-layer response within a few hours of storm passage; however, some attention is given to the lower layer and shelf wave responses. The model is based on a layered, explicit, finite difference formulation using the nonlinear primitive equations including conservation of heat. The problem of topography intersecting the model layer is resolved by introducing artificial steps of the order of 100m where the layer intersects the slope. Model comparisons are presented for three Gulf of Mexico hurricanes using a 0.2° grid. For two of the storms, the model reproduces better than 80% of the observed velocity variance with correlation coefficients of greater than 0.8 for the mixed layer. Discrepancies in the comparisons are traced to unresolved local topography and nonstorm forcing such as warm-core rings. Further model simulations reveal that (1) substantial shelf waves were generated with phase speeds of 4 to 10 m s^{-1}, (2) the response is primarily baroclinic even in water as shallow as 200 m, (3) an entrainment law which scales with the velocity difference between the mixed layer and upper thermocline yields markedly better comparisons than one which scales with the wind stress, and (4) deviations from a straight-line storm path can significantly alter the response.

Journal of Geophysical Research, Vol. 94, No. C9, Pages 12,513-12,539, September 15, 1989

HURRICANE-GENERATED CURRENTS ON THE OUTER CONTINENTAL SHELF, PART 2. MODEL SENSITIVITY STUDIES

Cortis Cooper
Conoco Production Engineering and Research
Ponca City, Oklahoma

J. Dana Thompson
Naval Ocean Research and Development Activity
Stennis Space Center, Mississippi

Abstract

A numerical model described and verified in part 1 of this two-part series (Cooper and Thompson, this issue) is applied to study the sensitivity of hurricane-generated currents on the outer shelf and slope. Numerical experiments are performed in a simple basin with a straight shelf. The sensitivity of the response to changes in storm parameters, direction of storm approach, and topography is quantified. Response is measured in terms of the mixed-layer velocity and depth at sites along the storm track. Results reveal the most important factors are (in decreasing order) wind speed, storm translation speed, direction of storm approach, asymmetry in the wind field, entrainment parameterization, and advection at slower storm translation speeds. Response is largely insensitive (less than 10%) to radius of maximum wind, shelf and slope configuration, bottom friction, atmospheric pressure gradients, and further reductions in the model grid size. For a storm approaching cross shelf, the response is primarily baroclinic (greater than 90%) and only weakly dependent (less than 10%) on the water depth at the site.

Journal of Geophysical Research, Vol. 94, No. C9, Pages 12,540-12,554, September 15, 1989

A LIMITED-AREA MODEL OF THE GULF STREAM: DESIGN, INITIAL EXPERIMENTS, AND MODEL-DATA INTERCOMPARISON

J. Dana Thompson
Naval Ocean Research and Development Activity
Stennis Space Center, Mississippi

W. J. Schmitz, Jr.
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

Abstract

A primitive-equation, n-layer, eddy-resolving circulation model has been applied to the Gulf Stream System from Cape Hatteras to east of the Grand Banks (78°-45°W, 30°-48°N). Within the limitations of the model, realistic coastlines, bottom topography, and forcing functions have been used. A two-layer version of the model was driven by observed mean climatological wind forcing and mass transport prescribed at inflow. Outflow was determined by a radiation boundary condition and an integral constraint on the mass field in each layer. Specification of a Deep Western Boundary condition and an integral constraint on the mass field in each layer. Specification of a Deep Western Boundary Current (DWBC) was included in some model runs.

Six numerical experiments, from a series of over fifty integrated to statistical equilibrium, were selected for detailed description and intercomparison with observations. The basic case consisted of a flat bottom regime driven by wind forcing only. Realistic inflow transport in the upper layer was then prescribed and two different outflow specifications at the eastern boundary were studied in experiments 2 and 3. Three additional experiments involved (4) adding bottom topography (including the New England Seamount Chain), (5) adding a DWBC to experiment 4 with 20 Sv (Sv $\equiv 10^6$ m^3 s^{-1}) total transport, and (6) increasing the DWBC to 40 Sv. A brief discussion of the influence of parameter variations includes modifications of dissipation (lateral eddy diffusion and bottom friction) and stratification.

Results from the sequence of experiments suggest an important role for the DWBC in determining the mean path of the Gulf Stream and consequently the distribution of eddy kinetic energy, and the character of the deep mean flow. The most realistic experiment compares to within a factor of two or better with observations of the amplitude of eddy kinetic energy and rms fluctuations of the thermocline and sea surface height. Abyssal eddy kinetic energy was smaller than observed. The mean flow is characterized by recirculations to the north and south of the Gulf Stream and a deep cyclonic gyre just east of the northern portion of the New England Seamount Chain, as found in the data.

American Meteorological Society, Volume 19, Number 6, June 1989

BUOY-CALIBRATED WINDS OVER THE GULF OF MEXICO

Robert C. Rhodes
J. Dana Thompson
Ocean Dynamics and Prediction Branch
Naval Ocean Research and Development Activity
NSTL, Mississippi

Alan J. Wallcraft
JAYCOR
NSTL, Mississippi

Abstract

The large variability of the Gulf of Mexico wind field indicates that high-resolution wind data will be required to represent the weather systems affecting ocean circulation. This report presents methods and results of the calculation of a corrected geostrophic wind data set with high temporal and spatial resolution.

Corrected geostrophic wind was calculated from surface pressure analyses compiled by the Fleet Numerical Oceanography Center. The correction factors for wind magnitude and direction were calculated using linear regressions of observed Gulf buoy winds and geostrophic winds derived at the buoys. The regressions were performed for each month to determine the seasonal variability of the correction factors. The magnitude correction was found to be nearly constant (0.675) throughout the year, but the direction correction varied seasonally from 8.5 to 26.5 degrees.

The corrected geostrophic wind was calculated twice daily from 1967-1982 on a spherical grid over the Gulf, together with the corresponding wind stress and wind stress curl fields. The 12-hourly stress fields show large temporal variations of the wind field for both winter and summer months. The 12-hourly stress fields show large temporal variations of the wind field for both winter and summer months. Seasonal and monthly climatologies of the stress and corresponding curl show positive curl over the Yucatan and negative curl in the southwest Gulf, which are features not seen in any previous study of Gulf wind stress.

American Meteorological Society, Volume 6, Number 4, August 1989

WESTERN BOUNDARY CURRENTS IN NUMERICAL OCEAN MODELS

J. D. Thompson
Naval Ocean and Research Development Activity
Stennis Space Center, MS 39529

W. J. Schmitz
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

Abstract

A severe test of a numerical ocean model is its ability to properly account for the dynamics of narrow, highly time-dependent western boundary currents and associated mesoscale instabilities. Until recently a large fraction of the eddy-resolving model experiments which included the western boundary current on long time scales (months to years) were conducted in regular domains with idealized winds. The selection of precise geographical locations at which to compare model and observations was therefore not straightforward. Now both the models and the available data base have become sufficiently advanced so that modelers and observationalists have begun to intercompare their respective results. Models of western boundary currents are presently evaluated in part by their ability to simulate and describe mean fields, eddy statistics, sea surface variability from altimeters, potential vorticity distributions, mass transports and other observables from an improving (but still inadequate) data base. Recent successes (and a few failures) of numerical ocean models in simulating and aiding our understanding of western boundary currents are described. The ubiquitous problem of Gulf Stream separation is discussed in some detail.

Presented at the American Geophysical Union Spring Meeting (Invited), March 8-12, 1989. Abstract published in EOS, Vol. 70, No. 15, April 11, 1989.

MEAN SEA SURFACE AND VARIABILITY OF THE GULF OF MEXICO USING GEOSAT ALTIMETRY DATA

Robert R. Leben
George H. Born
Colorado Center for Astrodynamics Research
University of Colorado, Boulder

J. Dana Thompson
Ocean Sensing and Prediction Division
Naval Ocean Research and Development Activity
Stennis Space Center, MS

Abstract

GEOSAT Exact Repeat Mission (ERM) altimetric measurements of the sea surface height in the Gulf of Mexico are used to determine the mean sea surface height with respect to the ellipsoid and mesoscale variability along GEOSAT ground tracks in the Gulf for the time period from November 8, 1986 to November 25, 1988. The along track mean sea surface is determined using a regional crossover adjustment procedure, in which the tilt and bias of mean arcs are estimated using a least squares technique to minimize the height differences at crossovers points. A mean surface generated using the GEOSAT-ERM along track mean is calculated and contrasted with a previously derived mean surface determined using GEOS-3 and SEASAT crossover differences. This provides a first look at the variability in the mean between the time periods of 1987-1988 and 1975-1978. In addition, the along track mesoscale variability time series has been produced from the GEOSAT-ERM data set by using a robust orbit error removal algorithm to determine the variability of the sea surface height with respect to the along track mean. A surface generated using the RMS of this along track time series shows good qualitative and quantitative agreement with previous in situ observations in the region. This study demonstrates the potential of satellite altimetry for oceanographic studies of the Gulf of Mexico.

Submitted for review to JGR Oceans, July 1989

ON THE MEAN PATHS OF WESTERN BOUNDARY CURRENTS

D. E. Harrison
NOAA, PMEL
7600 Sand Point Way NE
Seattle, WA 981115

J. Dana Thompson
NORDA
Stennis Space Center, MS 39529

Abstract

A continuing problem in self-consistent basin scale numerical models studies of the subtropical and subpolar gyres is how to get the model western boundary currents to separate from the coast and to penetrate into the ocean interior in a way consistent with observations. The prevailing model behavior is for the currents to separate too far north, and to remain north of the observed trajectory well into the interior. Strong constraints exist on the mean path of a subtropical gyre western boundary current if it is to funnel water parcels back into a Sverdrup or topographic-Sverdrup interior circulation. These constraints are reviewed. The mean path, relative to the structure of the mean wind stress curl field, offers one perspective on the physics that may be at work to determine WBC behavior. We present the mean wind stress curl fields (results depend on how the stress is computed) and mean path information for the Gulf Stream and the Kuroshio, and offer some comments on strategies for improving model simulations of WBC trajectories.

Presented at the American Geophysical Union Spring Meeting, March 8-12, 1989.
Abstract published in EOS, Vol. 70, No. 15, April 11, 1989

ARCTIC STUDIES WITH COUPLED ICE-OCEAN MODELS

A. Warn-Varnas
Naval Ocean Research and Development Activity
Stennis Space Center, MS 39529

R. Allard
Berkeley Research Associates

Abstract

The upper ocean is modeled in the framework of a three-dimensional mixed-layer approximation and is coupled to the Hibler thermodynamic-dynamic ice model. Two different modeling approaches are used for the interior ocean. In one, the geostrophic velocity is obtained from an inverse, ß-spiral, type of model. In another, the barotropic velocity is calculated prognostically. Topography is included in both approaches. The model is initialized from Levitus climatology and is forced by NOGAPS atmospheric forcing. Studies of diurnal and seasonal response are performed. The nature of the boundary layer under ice, in the marginal ice zone, and open water is analyzed. Transmission of wind stress through the ice is considered. The resultant Ekman pumping and other forcings of the interior ocean are calculated. In the Greenland and Norwegian Sea areas, major changes in the behavior of the upper ocean are observed from the Arctic Basin outwards. Deep neutrally stable mixed layer tend to occur outside the MIZ. The heat and salt budgets of these regions are computed.

Proceedings of the 1989 Nansen Ice-Ocean Modeling Symposium, Bergen, Norway, October 23-27, 1989

Distribution List

Commanding Officer
Naval Oceanographic and
Atmospheric Research Laboratory
Code 100
Stennis Space Center, MS 39529

Commanding Officer
Naval Oceanographic and
Atmospheric Research Laboratory
Code 101
Stennis Space Center, MS 39529

Commanding Officer
Naval Oceanographic and
Atmospheric Research Laboratory
Code 110
Stennis Space Center, MS 39529

Commanding Officer
Naval Oceanographic and
Atmospheric Research Laboratory
Code 111
Stennis Space Center, MS 39529

Commanding Officer
Naval Oceanographic and
Atmospheric Research Laboratory
Code 200
Stennis Space Center, MS 39529

Commanding Officer
Naval Oceanographic and
Atmospheric Research Laboratory
Code 300
Stennis Space Center, MS 39529

Commanding Officer
Naval Oceanographic and
Atmospheric Research Laboratory
Code 113
Stennis Space Center, MS 39529

Commanding Officer
Naval Oceanographic and
Atmospheric Research Laboratory
Code 114
Stennis Space Center, MS 39529

Commanding Officer
Naval Oceanographic and
Atmospheric Research Laboratory
Code 125L
Stennis Space Center, MS 39529 (10)

Commanding Officer
Naval Oceanographic and
Atmospheric Research Laboratory
Code 125P
Stennis Space Center, MS 39529

Commanding Officer
Naval Oceanographic and
Atmospheric Research Laboratory
Atmospheric Directorate
Code 400
Stennis Space Center, MS 39529 (6)

Commanding Officer
Fleet Numerical Oceanography
Center
Monterey, CA 93943-5005 (2)

Commander
Naval Oceanographic Office
Stennis Space Center, MS 39529

Commanding Officer
Naval Research Laboratory
Washington, DC 20375

Commander, Naval Sea Systems
Command
Naval Sea Sys Com Headquarters
Washington, DC 20362-5101

Commander
Naval Air Systems Command
Naval Air Sys Com Headquarters
Washington, DC 20361-0001

Commander
Naval Facilities Eng Command
Naval Facilities Eng Command
Headquarters
200 Stovall St.
Alexandria, VA 22332-2300

Commander
Naval Air Development Center
Warminster, PA 18974-5000

Commanding Officer
Naval Coastal Sys Cen
Panama City, FL 32407-5000

Commander
Naval Ocean Systems Center
San Diego, CA 92152-5000

Commanding Officer
ONR Branch Office
Box 39
FPO New York 09510-0700

Commander
David W. Taylor Naval Research
Center
Bathesda, MD 20084-5000

Commander
Naval Surface Weapons Center
Dahlgren, VA 22448-5000

Commander
Naval Underwater Systems Center
Newport, RI 02841-5047

Commander
Naval Surface Warfare Center,
White Oak
10901 New Hampshire Ave.
Silver Spring, MD 20903-5000

Commanding Officer
Naval Civil Engineering Laboratory
Port Huneme, CA 93043

Commanding Officer
Fleet Anti-Sub Warfare Training
Center, Atlantic
Naval Station
Norfolk, VA 23511-6495

Commander
Naval Oceanography Command
Stennis Space Center, MS 39529-5004

Chief of Naval Operations
Navy Dept.
Attn: OP-71
Washington, DC 20350-2000

Asst. Secretary of the Navy
(Research, Engineering & Systems)
Navy Dept.
Washington, DC 20350-2000

Officer in Charge
New London Laboratory
Naval Underwater Sys Cen Det
New London, CT 06320

Superintendent
Naval Postgraduate School
Monterey, CA 93943

Director
Defense Mapping Agency Sys Cen
Attn: Code SGWN
12100 Sunset Hill Rd #200
Reston, VA 22090-3207

Director
Woods Hole Oceanographic Inst.
P. O. Box 32
Woods Hole, MA 02543

Director of Navy Laboratories
Rm 1062, Crystal Plaza #5
Dept. of the Navy
Washington, DC 20360

Director
Office of Naval Research
Attn: Dr. E. Hartwig, Code 112
Dr. E. Silva, Code 10D/10P
Code 12, Code 10
800 N. Quincy St.
Arlington, VA 22217-5000

Director
Office of Naval Technology
Attn: Dr. C. V. Votaw, Code 234
Dr. P. Selwyn, Code 20
800 N. Quincy St.
Arlington, VA 22217-5000

Technical Director
Office of Naval Research
Code 10
800 N. Quincy
Arlington, VA 22217

Technical Director
Office of Naval Technology
Code 20
800 N. Quincy
Arlington, VA 22217

Technical/Deputy Director
Commander, Naval Oceanography Command
Stennis Space Center, MS 39529

Director
Institute for Naval Oceanography
Stennis Space Center, MS 39529 (20)

Director
Cooperative Institute for Marine and Atmospheric Studies
4600 Rickenbacker Causeway
Virginia Key, FL 33149

Director (FCNC)
National Ocean Data Center
WSC1 Room 103
6001 Executive Blvd.
Attn: G. W. Withee
Rockville, MD 20852

Professor John Allen
College of Oceanography
Ocean. Admin., Building 104
Oregon State University
Corvallis, OR 97331

Dr. Richard Anthes
President
UCAR
1850 Table Mesa Dr.
Boulder, CO 80302

Dr. John Apel
Johns Hopkins University
Applied Physics Lab
Laurel, MD 20707

Professor Larry Atkinson
Department of Oceanography
Old Dominion University
P. O. Box 6369
1054 West 47th Street
Norfolk, VA 23529-0276

Dr. Ledolph Baer
NOS/NOAA
6010 Executive Blvd., Room 912
Rockville, MD 20859

Professor John Bane
Center for Marine Science
University of North Carolina
Venable Hall 045-A
Chapel Hill, NC 27514

Dr. Robert Beardsley
Dept. of Physical Oceanography
Woods Hole Oceanographic Inst.
Clark Building
Woods Hole, MA 02543

Dr. Ann Berman
Tri-Space
P. O. Box 7166
McLean, VA 20016

Mr. Landry Bernard
Code OS
Naval Oceanographic Office
Stennis Space Center, MS 39529

Dr. Buzz Bernstein
Cal Space
5360 Bothe Ave.
San Diego, CA 92122

Dr. Hugo Bezdek
Director, AOML
NOAA
15 Rickenbacker Causeway
Miami, FL 33149

Dr. Joseph M. Bishop
Chief Scientists Office/NOAA
16748 Tintagel Court
Dumfries, VA 22026

Dr. Peter Black
NOAA-AOML-HRD
4301 Rickenbacker Causeway
Virginia Key, FL 33149

Dr. Jackson O. Blanton
Skidaway Institution of
Oceanography
P. O. Box 13687
Savannah, GA 31416

Dr. Alan Blumberg
HydroQual Inc.
One Lethbridge Plaza
Mahwah, NJ 07430

Dr. Donald Boesch
Executive Director
LUMCON
Marine Research Center
Chauvin, LA 70344

Dr. William Boicourt
Horn Point Environmental Lab
University of Maryland
P. O. Box 775-Horn Point Road
Cambridge, MD 21613

Dr. George Born
Univ. of Colorado
Dept. of Aerospace Engineering
Sciences
Campus Box 429
Boulder, CO 80309-0429

CDR Lee Bounds
Code 228
Office of Naval Technology
800 N. Quincy Street
Washington, DC 22217-5000

Dr. Kenneth Brink
Dept. of Physical Oceanography
Woods Hole Oceanographic Inst.
Clark Building
Woods Hole, MA 02543

Dr. Mel Briscoe
Office of Naval Research
Code 12
800 N. Quincy
Arlington, VA 22217

Prof. David Brooks
Department of Oceanography
Texas A&M University
College Station, TX 77843

Dr. Murray Brown
Minerals Management Service (LE4)
1201 Elmwood Park Blvd.
New Orleans, LA 70123-2394

Dr. Otis Brown
Univ. of Miami
Center for Marine Studies
4600 Rickenbacker Causeway
Miami, FL 33149-1098

Dr. Kirk Bryan
GFDL/NOAA
Forrestal Campus, Rm. 346
Princeton University
Princeton, NJ 08544

Dr. B.P. Buckles
Department of Computer Science
Tulane University
New Orleans, LA 70118

Dr. Tony Busalacchi
NASA/Goddard Code 671
Greenbelt, MD 20771

Dr. Kathryn Bush
Planning Systems, Inc.
7925 Westpark Drive
McLean, VA 22102

Dr. Vince Cardone
Ocean Weather Inc.
5 River Rd., Suite 1
Cos Cob, CT 06807

Mr. Edward Chaika
Director, Office of Naval Research Detachment
Stennis Space Center, MS 39529

Dr. David Chapman
Dept. of Physical Oceanography
Woods Hole Oceanographic Inst.
Woods Hole, MA 02543

Dr. Robert Cheney
N/CG11
NOAA National Ocean Service
Rockville, MD 20852

Mr. Mike Clancy
Fleet Numerical Oceanography Center
Code 42
Monterey, CA 93943-5105

Mr. Leo Clark
Fleet Numerical Oceanography Center
Code 40B
Monterey, CA 93943-5105

Prof. Curtis Collins
Department of Oceanography
Naval Postgraduate School
Monterey, CA 93943

LCDR William Cook
Space and Naval Warfare Systems Command
Code PMW 141
2511 Jeff Davis Hwy.
Washington, DC 20363-5100

Mr. Jim Cornelius
Fleet Numerical Oceanography Center
Code 43
Monterey, CA 93943-5105

Dr. Peter Cornillon
University of Rhode Island
Graduate School of Oceanography
Narragansett, RI 02882

Dr. Richard L. Crout
Senior Scientist
Planning Systems, Inc.
PSI Science Center
115 Christian Lane
Slidell, LA 70458

Ms. Harriet Crowe
Director of Corporate Affairs
UCAR
1850 Table Mesa Dr.
Boulder, CO 80302

Dr. Tom Curtin
Office of Naval Research
Code 1122
800 N. Quincy
Arlington, VA 22217

Prof. Russ E. Davis
Scripps Inst. of Oceanography
University of California, San Diego
La Jolla, CA 92093

Dr. Pasquale Deleonibus
NOAA-NESS S/RE13
World Weather Bldg.
Washington, DC 20233

Mr. Webb DeWitt
Fleet Numerical Oceanography
Center
Monterey, CA 93943

Dr. David Evans
Office of Naval Research
800 N. Quincy St.
Arlington, VA 22217

Mr. Brooke Farquhar
NOARL Liaision Office
Crystal Plaza #5, Room 802
2211 Jefferson Davis Highway
Arlington, VA 22202-5000

Dr. Len Fedor
NOAA/ERL/WPL
R/E/WP5
325 Broadway
Boulder, CO 80303

Prof. S. M. Flatte
University of California, Santa Cruz
Division of Natural Sciences
Applied Sciences Building
Santa Cruz, CA 95064

Dr. Glenn Flittner
National Marine Fisheries Service
National Oceanic & Atmos. Admin.
1335 East West Highway, Room 5310
Silver Spring, MD 20910

Dr. Nick Fofonoff
College for Marine Studies
Univ. of Delaware
Lewes, DE 19958

Dr. George Forristall
Production Operation Res. Dept.
Shell Development Company
Houston, TX 77001

Mr. Paul Friday, Director
Ocean Services
NOS/NOAA
1825 Connecticut Avenue, NW
Washington, DC 20235

Dr. R. William Garwood
Naval Postgraduate School
Monterey, CA 93940

Prof. Michael Ghil
University of California at
Los Angeles
Department of Meteorology
Los Angeles, CA 90024

Dr. Scott Glenn
Peirce Hall, Room G2G
Harvard University
29 Oxford Street
Cambridge, MA 02138

Dr. Henry Greenberg
Bedford Institute of Oceanography
Box 1006
Dartmouth, NS, B2Y 4AE
CANADA

Dr. Michael C. Gregg
University of Washington
Applied Physics Laboratory
1013 40th St., NE
Seattle, WA 98159

Denise Hagan
NASA JPL
183-501
4800 Oak Grove Dr.
Pasadena, CA 91109

Dr. Dale Haidvogel
Chesapeake Bay Institute
Rotunda, Suite 340
711 North 40th Street
Baltimore, MD 21211

Dr. Glenn Hamilton
NOAA/NDBC
Building 1100
Stennis Space Center, MS 39529

Prof. Robert Haney
Department of Meteorology
Naval Postgraduate School
Monterey, CA 93943

Dr. Edward Harrison
PMEL/NOAA
7600 Sand Point Way, NE
Seattle, WA 98115

Dr. William Hibler, III
Thayer School of Engineering
Dartmouth College
Hanover, NH 03755

Dr. Nelson Hogg
Woods Hole Oceanographic Institute
Woods Hole, MA 02543

Dr. William Holland
National Center for Atmospheric Research
P. O. Box 3000
Boulder, CO 80307

Dr. Jim Hollinger
Naval Research Lab
Code 8311
Washington, DC 20375

Prof. S. A. Hsu
Coastal Studies Institute
Louisiana State University
Baton Rouge, LA 70803

Dr. Joseph Huang
NOS/NOAA
USB South, Room 615
1825 Connecticut Avenue, NW
Washington, DC 20235

Dr. Oscar Huh
Coastal Studies Institute
LSU
Baton Rouge, LA 70803-7527

Dr. S.S. Iyengar
Department of Computer Science
Louisiana State University
Baton Rouge, LA 70803-4020

Johns Hopkins University
Applied Physical Laboratory
Johns Hopkins Rd.
Laurel, MD 20707

Mr. Andrew Johnson
Code OST
Naval Oceanographic Office
Stennis Space Center, MS 39529

Dr. David Llewellyn Jones
Rutherford Appleton Lab
Chilton, Didcot
Oxfordshire, UK
OX11 OQX

Dr. Kristina Katsaros
Univ. of Washington
Dept. of Atmos. Sciences
AK-40
Seattle, Washington 98195

Dr. Thomas Kinder
Office of Naval Research
Code 1122ML
800 North Quincy Street, BCT #1
Arlington, VA 22217-5000

Prof. Dennis Kirwan
Old Dominion University
Norfolk, VA 23508

Dr. Frederick Kopfler
Gulf of Mexico Prog. Office
Environmental Protection Agency
Stennis Space Center, MS 39529

Dr. Richard Legeckis
NOAA/NESDIS
Mail Code E/RA13
Washington, DC 20233

Dr. Chin-Hwa Lee
Associate Professor
Department of Electrical & Computer Engineering
Naval Post Graduate School
Monterey, CA 93940

Dr. Richard Legeckis
NOAA-NESDIS
Stop L SE/RA13
Washington, DC 20233

Dr. Sidney Levitus
GFDL/NOAA
P. O. Box 308
Princeton, NJ 08540

Dr. Mark Luther
Florida State University
Tallahassee, FL 32396

Dr. George Maul
NOAA-AOML
4301 Rickenbacker Causeway
Virginia Key, FL 33149

Mr. Paul McClain
NESDIS
SRL (E/RA1)
Washington, DC 20233

Prof. George Mellor
James Forrestal Campus
Princeton University
P. O. Box 308
Princeton, NJ 08542

Dr. Robert Miller
Oceanography 208
Lamont-Donerty Geological Observatory
Dallisades, NY 10964

Dr. Paul F. Moersdorf
Commander, Naval Oceanography Command
Space Oceanography Programs
Stennis Space Center, MS 39529

Dr. Eugene Molinelli
Director, Environmental Acoustic Group
Naval Systems Division
Planning Systems Inc.
7925 Westpark Drive
McLean, VA 22102

Mr. Don Montgomery
Space and Naval Warfare Systems Command
Code PMW-141
2511 Jeff Davis Hwy.
Washington, DC 20363-5100

Prof. Chris Mooers
OPAL/EOS//SERB
University of New Hampshire
Durham, NH 03824

Dr. Richard Moore
Remote Sensing Lab.
University of Kansas
2291 Irving Hue Dr.
Lawrence, KS 66045

Prof. John Morrison
Marine Earth & Atmospheric
Science
North Carolina State University
Box 8208
Raleigh, NC 27695

Dr. Don Murphy
Research & Development
U.S. Coast Guard
Avery Point
Groton, CT 06340-6096

Prof. Pearn P. Niiler
Scripps Institute of Oceanography
University of California, San Diego
La Jolla, CA 92093

Prof. James O'Brien
Mesoscale Air-Sea Interaction Group
Mail Code B-174, Love 070
The Florida State University
Tallahassee, FL 32306-3041

Dr. D.B. Olson
University of Miami
RSMAS
Miami, FL 33149-1098

Dr. David Paskausky
Research and Development Center
US Coast Guard
Avery Point
Groton, CT 06340

Mr. Robert Peloquin
Office of Naval Research
Code 120M
Room 922, 800 N. Quincy
Arlington, VA 22217

Pennsylvania State University
Applied Research Laboratory
P. O. Box 30
State College, PA 16801

Dr. F.E. Petry
Department of Computer Science
Tulane University
New Orleans, LA 70118

Dr. George Philander
Geophysical Fluid Dynamics Lab.
Princeton Univ.
Princeton, NJ 08540

Mr. Bill Pichel
NOAA - NESDIS
E/SP13 WWB
Washington, DC 20233
Dr. Sam Pierce
Hughes Aircraft Co.
P. O. Box 92919
Airport Station
Los Angeles, CA 90009

Dr. James F. Price
Woods Hole Oceanographic
Institution
Woods Hole, MA 02543

Dr. Rene Ramseier
Atmospheric Environment Service
Dept. of Environment
473 Albert St.
Ottawa, Ontario K1A OH3
CANADA

Dr. Michele Rienecker
Goodard Space Flight Center
NASA, Code 671
Greenbelt, MD 20771

Prof. Paola Rizzoli
Dept. of Earth, Atm. Planetary Sci.
MIT 54-1420
Cambridge, MA 02139

Prof. Allan Robinson
Dept. of Earth & Planetary Science
Harvard University
Pierce Hall
29 Oxford Street
Cambridge, MA 02138

Prof. H. Thomas Rossby
Graduate School of Oceanography
University of Rhode Island
Kingston, RI 02881

Dr. Drew Rothrock
Polar Science Center
Univ. of Washington
4057 Roosevelt Way, NE
Seattle, WA 98105

Dr. James Rucker, Director
CROSS
Geology Department
University of New Orleans
New Orleans, LA 70148

Dr. Kenneth Ruggles
Systems West
17880 Dorris Drive
PO Box 222019
Carmel, CA 93922

Dr. George Saunders
Office of Health and Environmental Research, Office of Energy Research
Ecological Research Division, ERE-75
Department of Energy
Washington, DC 20545

Mr. Richard Savage
Hughes Aircraft Co.
8000 E. Maplewood Ave., Suite 226
Englewood, CO 80111-4999

Mr. Ken Schaudt
Marathon Oil Co.
P. O. Box 3128
Houston, TX 77253

Dr. William Schmitz
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

Prof. Jerry Schubel, Director
Marine Sciences Research Center
State University of New York
Stony Brook, NY 11794

Dr. Randall Shumaker
Director, Navy Center for Applied Research in Artificial Intelligence
Naval Research Laboratory
4555 Overlook Avenue, S.W.
Washington, DC 20375

Prof. William Sigmann
Dept. of Mathematical Sciences
Rensselaer Polytechnic Inst.
Troy, NY 12180

Dr. Thomas Spence
Division of Ocean Sciences
National Science Foundation
1800 G Street, NW, Room 609
Washington, DC 20550

Dr. Robert Spindel
University of Washington
Applied Physics Laboratory
1013 40th St., NE
Seattle, WA 98159

Dr. Larry Stowe
NOAA-NESDIS
Suitland Professional Center
Washington, DC 20233

Dr. Alan Strong
NOAA-NESDIS
Suitland Professional Center
Washington, DC 20233

Dr. Calvin Swift
Dept. of Electrical Computer
Engineering
University of Mass.
Amherst, MA 01003

Dr. Michael Thomason
Room 107 Ayres Hall
Computer Science Department
University of Tennessee
Knoxville, TN 37996

Dr. Ronald Tipper
Joint Oceanographic Inst.
Suite 800
1755 Massachusetts Ave., NW
Washington, DC 20036

Dr. Juri Toomre
Dept. Astro-Geophysics
University of Colorado
Boulder, CO 80302

University of California
Scripps Institute of Oceanography
P. O. Box 6049
San Diego, CA 92106

University of Texas at Austin
Applied Research Laboratories
P. O. Box 8029
Austin, TX 78713-8029

University of Washington
Applied Physics Laboratory
1013 NE 40th St.
Seattle, WA 98105

Dr. Evans Waddel
SAIC
4900 Water's Edge Dr.
Suite 255
Raleigh, NC 27606

Prof. John Walsh
Department of Marine Science
University of South Florida
140 Seventh Avenue South
St. Petersburg, FL 33701

Dr. Leonard Walstead
School of Oceanography
Oregon State University
Corvallis, OR 97331

Prof. John Wang
Division of Applied Marine Physics
RSMAS
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149

Mr. C. A. Weigand
Naval Eastern Oceanography Center
McAdie Building
U117
Naval Air Station
Norfolk, VA 23511

Dr. Alan Weinstein
Office of Naval Research
Code 1122
800 N. Quincy
Arlington, VA 22217

Dr. Frank Wentz
Remote Sensing Systems
1101 College Ave.
Suite 220
Santa Rosa, CA 94965

Dr. Warren White
University of California, San Diego
Scripps Institution of Oceanography
La Jolla, CA 92093

Dr. W. Stanley Wilson
NASA Headquarters
Code EBC-8
Washington, DC 20546

Dr. Robert Winokur
Oceanographer of the Navy
OP-096
34th and Massachusetts Ave., NW
Washington, DC 20392-1800

Prof. Carl Wunch
Dept. of Earth & Planetary Sciences
Room 54-1324
Mass. Institute of Technology
Cambridge, MS 02139

Prof. Klaus Wyrtki
Department of Oceanography
University of Hawaii
Honolulu, HI 96882

Prof. James Yoder
Graduate School of Oceanography
University of Rhode Island
Kingston, RI 02881

REPORT DOCUMENTATION PAGE

Form Approved
OBM No. 0704-0188

1. Agency Use Only *(Leave blank).*

2. Report Date. June 1990

3. Report Type and Dates Covered. Final

4. Title and Subtitle.
Abstracts of Publications and Presentations, 1989

5. Funding Numbers.
Program Element No. 62435N 61153N
Project No. RM35G84 03208
Task No. 0G0
Accession No. DN256002 DN394458

6. Author(s).
J. W. McCaffrey

7. Performing Organization Name(s) and Address(es).
Naval Oceanographic and Atmospheric Research Laboratory
Ocean Science Directorate
Stennis Space Center, Mississippi 39529-5004

8. Performing Organization Report Number.
SP 033:320:90

9. Sponsoring/Monitoring Agency Name(s) and Address(es). *
Office of Naval Research
800 North Quincy St., ONR Code 120M
Arlington, VA 22217

10. Sponsoring/Monitoring Agency Report Number.
SP 033:320:90

11. Supplementary Notes.*
Naval Oceanographic and Atmospheric Research Laboratory
Basic Research Management Office
Stennis Space Center, Mississippi 39529-5004

12a. Distribution/Availability Statement.
Approved for public release; distribution is unlimited.

12b. Distribution Code.

13. Abstract *(Maximum 200 words).*

This document presents abstracts of the 1989 publications and presentations of the Ocean Sensing and Prediction Division, Naval Oceanographic and Atmospheric Research Laboratory.

14. Subject Terms.
ocean prediction, remote sensing

15. Number of Pages. 97

16. Price Code.

17. Security Classification of Report	18. Security Classification of This Page	19. Security Classification of Abstract	20. Limitation of Abstract
Unclassified	Unclassified	Unclassified	SAR