Wind Products for Use in Coastal Wave and Surge Models

by Zeki Demirbilek, Steven M. Bratos, Edward F. Thompson
Coastal Engineering Research Center

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Preface

This study was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), under the Coastal Flooding and Storm Protection Area of the Coastal Research Program, Work Unit 32683, "Wind Estimation for Coastal Modeling." Research was performed by the Coastal Engineering Research Center (CERC) of the U.S. Army Engineer Waterways Experiment Station (WES). Technical Monitors were Messrs. John H. Lockhart, Jr.; John G. Housley; Barry W. Holliday; and David A. Roellig. Ms. Carolyn M. Holmes of CERC was the Program Manager.

This report was prepared by Dr. Zeki Demirbilek, Mr. Steven M. Bratos, and Dr. Edward F. Thompson, all of the Coastal Oceanography Branch (COB), Research Division (RD), CERC. Dr. Thompson was Principal Investigator of the research work unit funding this study. Drs. Jon M. Hubertz, COB, and Robert E. Jensen, RD, also contributed to the study. The work was performed under the direct supervision of Dr. Martin C. Miller, Chief, COB, and Mr. H. Lee Butler, Chief, RD, and under the general supervision of Mr. Charles C. Calhoun, Jr., Assistant Director, CERC, and Dr. James R. Houston, Director, CERC.

Special acknowledgement is due to Mr. Andrew Johnson, Jr., Director, Ocean Technology Division, Naval Oceanographic Office (NAVOCEANO) for assisting with access to Navy computer facilities and to Mr. Terry Blanchard, Supercomputer Center, NAVOCEANO, for help related to the Navy database. Mr. Paul A. Wittmann, Ocean Models Division, U.S. Navy Fleet Numerical Oceanography Center, Monterey, CA, wrote the original version of the computer program for extracting surface wind products from the Interim Primary Oceanographic Prediction System (IPOPS) database.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.
1 Introduction

Background and Purpose

Winds over the ocean surface are the essential driving force in creating waves. They also have important effects on currents and nearshore water levels. Wind information is often used within the Corps of Engineers (CE) as input to numerical models of waves, storm surges, and circulation.

The National Oceanic and Atmospheric Administration (NOAA) and US Navy routinely produce global wind information. Significant recent advances in atmospheric modeling capabilities and operational numerical models within NOAA and the Navy have made available new and improved products applicable to CE hydrodynamic modeling. These products are potentially extremely useful in coastal hydrodynamic modeling. A few NOAA and Navy products have been used in past CE modeling efforts, but new products are now available in new formats. In particular, it is now feasible to obtain wind products in near real time.

The objective of this study is to facilitate the use of NOAA and Navy products in CE hydrodynamic models. Wind products for use with climatological and extreme event applications, using long term records of historic information, and real time applications are considered.

The CE standard spectral wind wave growth model WISWAVE 2.0 is used as a tool for evaluating wind products. The wave model is used in preference to surge or circulation models because wave growth occurs over open water and is characterized by time and space scales compatible with NOAA and Navy products.

This report includes a number of acronyms which are not often used in the CE. To assist readers in this regard, a comprehensive list of acronyms is provided in Table 1.
Table 1  
Acronyms Used in This Report

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE</td>
<td>Corps of Engineers</td>
</tr>
<tr>
<td>CEDRS</td>
<td>Coastal Engineering Data Retrieval System</td>
</tr>
<tr>
<td>CERC</td>
<td>Coastal Engineering Research Center</td>
</tr>
<tr>
<td>ECMWF</td>
<td>European Center for Medium-Range Weather Forecasts</td>
</tr>
<tr>
<td>FNOC</td>
<td>Fleet Numerical Oceanography Center</td>
</tr>
<tr>
<td>GMT</td>
<td>Greenwich Mean Time</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers</td>
</tr>
<tr>
<td>IPOPS</td>
<td>Interim POPS database</td>
</tr>
<tr>
<td>LSC</td>
<td>Large Scale Computer</td>
</tr>
<tr>
<td>NAVOCEANO</td>
<td>Naval Oceanographic Office</td>
</tr>
<tr>
<td>NDBC</td>
<td>National Data Buoy Center</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>NODDS</td>
<td>Navy Oceanographic Data Distribution System</td>
</tr>
<tr>
<td>NOGAPS</td>
<td>Navy Operational Global Atmospheric Prediction System</td>
</tr>
<tr>
<td>PFCS</td>
<td>Permanent File Computer System</td>
</tr>
<tr>
<td>POPS</td>
<td>Primary Oceanographic Prediction System</td>
</tr>
<tr>
<td>SPOP</td>
<td>Sun front end to POPS system</td>
</tr>
<tr>
<td>SSC</td>
<td>Stennis Space Center</td>
</tr>
<tr>
<td>SWADE</td>
<td>Surface Wave Dynamics Experiment</td>
</tr>
<tr>
<td>UTC</td>
<td>Universal Time Coordinate</td>
</tr>
<tr>
<td>WIS</td>
<td>Wave Information Studies</td>
</tr>
<tr>
<td>WISWAVE</td>
<td>Wave Information Studies Wave Model</td>
</tr>
<tr>
<td>3GWAM</td>
<td>Third Generation Wave Forecast Model</td>
</tr>
</tbody>
</table>

Previous Studies

Surface winds are typically the primary forcing mechanism for waves and surge during severe storms along the coast. Nearshore circulations are also strongly influenced by wind as well as tide. Because of its importance, the wind and its effect on nearshore hydrodynamics has received attention in many previous studies.

The problem of properly representing the effect of wind in nearshore hydrodynamic models may be separated into two parts. First, wind characteristics near the water surface must be estimated. Second, the coupling
between surface wind and water must be determined. Both of these problems are difficult to solve accurately. They have been the subject of many research studies.

Historically, the CE has most successfully solved the problem of estimating surface winds over the ocean by using atmospheric pressure fields and a parameterized surface boundary layer wind model (Resio et al. 1982). Pressure fields were obtained from NOAA and Navy sources and surface winds were estimated at the standard 10-m elevation.

As NOAA and Navy wind models have become more powerful and refined, the CE has begun to explore and use these information sources. The NOAA and Navy products offer promise to CE studies for major time and cost savings and improved accuracy. Navy surface wind estimates have recently been used for a wave hindcast along the Somalian coast (Bratos 1992), a wave hindcast for the Coast of Delaware (Cialone and Hubertz, 1992), and a comparison of the measured and hindcast wave conditions at Lake Worth and Hollandale, Florida (Hubertz and Brandon, 1992).

The Navy products pertinent to CE hydrodynamic models include two types of wind information: a surface stress parameter, and a surface wind. Thus there are two direct alternatives for driving hydrodynamic models. While most applications to date have relied on surface wind, some research studies have used stresses. In particular, Surface Wave Dynamics Experiment (SWADE) studies include extensive use of stresses, as discussed in Chapter 5. Vincent et al. (1992) investigated the performance of a third generation wave forecast model 3GWAM using Navy wind stresses.

The viability of surface stresses from an atmospheric model for use in wave modeling is also a concern in the European research community. Janssen et al. (1992) recently reviewed literature documenting inconsistencies between surface wind and stress produced by atmospheric models, especially for high wind speeds. Stresses have a tendency to underpredict wave height. Janssen, et al., also evaluated surface stresses and surface winds from the European Centre for Medium-Range Weather Forecasts (ECMWF) atmospheric model. Both wind products were used to drive the 3GWAM wave model. They concluded that the ECMWF stresses also underpredict wave height and attributed the problem to a flawed numerical integration scheme in the near-surface boundary layer of the ECMWF atmospheric model.

Drag laws

The effect of wind on the water surface is complex, requiring empiricism and simplifications in both wind and hydrodynamic numerical models. Momentum imparted by the wind to the water surface gives rise to waves and currents. In deep water, the effect of wind on a column of water can reach hundreds of meters below the surface. In shallow water, the whole water column may be affected. Concepts for linking near-surface wind action and water surface response are generally based on a drag law. A variety of drag
law formulations have been used. These concepts are reviewed in the following paragraphs. A more detailed discussion is given by Long and Hubertz (1988).

To consider the effect of winds on the sea surface, it is intuitive that the force imparted to the water increases with the mean wind speed. Hence, an estimation of wind effect based on an average wind speed just above or near the sea surface would be a first-order approximation. For typical low- to mid-altitude conditions, an idealized atmospheric boundary layer over the water surface provides estimates of the first-level planetary boundary layer winds above the air-sea interface. Inside this layer, wind frictional stresses are fairly constant, but wind speed within the boundary layer immediately above the sea surface can vary substantially due to elevation above the surface and difference between air and water temperatures. Surface winds are usually taken as a characteristic wind at the 10-m to 20-m elevation. The shear stress within the boundary layer is then empirically related to the characteristic wind speed. The usual relationship, known as the "quadratic drag law" or "bulk parameterization," is given by

$$T = \rho \, C_D \, U^2$$

where

- $T$ = surface stress
- $\rho$ = air density
- $C_D$ = drag coefficient
- $U$ = characteristic wind speed

Development of this drag law is discussed in the pioneering works of van Dorn (1953), Garratt (1977), and Reid et al. (1977).

Observed or predicted winds are usually adjusted as needed to match conditions required by hydrodynamic model formulations. The adjustments are also necessary so that the horizontal frictional stress remains nearly independent of elevation. A critical parameter affecting wave growth is the air-sea temperature gradient. Since this gradient information is often unavailable, the wind speed at a 10-m elevation under the condition of neutral stability ($\Delta T=0$) is often used to characterize the wind-stress causing waves. At sufficiently greater elevation above the sea surface, winds remain fairly uniform and are geostrophic. The adjustment height of 10-m is adequate for wave heights less than 3-m, and a 20-m height is more appropriate for wave heights between 3-m and 10-m.

Wind stress is the forcing mechanism for wave growth at the sea-air interface. According to Equation 1, the force acting on a fluid particle is proportional to the product of the particle's surface area, a drag coefficient, and the dynamic head ($\rho U^2$). Thus wind stress is proportional to the square of wind speed. The kinematic form of wind stress components may be expressed in terms of the adjusted wind speed as
\[ T_x = K \, U_{10}^2 \cos \theta \]  
\[ T_y = K \, U_{10}^2 \sin \theta \]

where

- \( T_x, T_y \) = components of surface wind stress
- \( K \) = dimensionless coefficient
- \( U_{10} \) = wind speed at a 10-m elevation over the water
- \( \theta \) = angle between the wind velocity vector and x-axis

The coefficient \( K \), which can be considered as equivalent to \( \rho C_D \) in equation 1, is generally a function of wind speed (van Dorn 1953 and Reid et al. 1977). For low to moderate wind speeds, \( K \) is given by (Reid et al. 1977)

\[ K = K_1 \quad \text{for} \quad U_{10} < U_c \]  
\[ K = K_1 + K_2 (1 - R)^2 \quad \text{for} \quad U_{10} > U_c \]  

where

\[ R = \frac{U_c}{U_{10}} \]  
\[ K_1 = 1.2 \times 10^{-6} \]  
\[ K_2 = 1.8 \times 10^{-6} \]

For large wind speeds if the ratio of air density to water density is \( 1.2 \times 10^{-3} \) or less (which is often a reasonable approximation), \( K \) approaches the limiting value of \( 3.6 \times 10^6 \). This value corresponds to a drag coefficient of about \( 3.3 \times 10^3 \).

Friction velocity within the immediate vicinity of the boundary layer overlaying the sea surface is related to wind speed at elevation \( z \) by the following form (Schlichting 1979)
\[ U_*^2 = \frac{T}{\rho} \]
\[ T = \mu \frac{\partial U_{10}}{\partial z} \]  \hspace{1cm} (5)
\[ \frac{U_{10}^2}{U_*^2} = \frac{z}{\nu} \]

where
- \( \mu \) = dynamic viscosity of air
- \( \nu \) = kinematic viscosity of air
- \( z \) = elevation above the water surface

With Equations 1-5, the drag coefficient may be defined in terms of \( U_{10} \) and \( U_* \) as

\[ C_D = \frac{U_*^2}{U_{10}^2} \]  \hspace{1cm} (6)

Thus the drag coefficient depends on wind speed and friction velocity. A number of empirical forms have been devised for this relationship (van Dorn 1953, Reid et al. 1977, Large and Pond 1981) for use in wind wave modelling.

The drag coefficient relationship adopted in WISWAVE 2.0 is of the following form:

\[ C_D = 0.001 \left( 1.1 + 0.035 U_{10} \right) U_{10} \]  \hspace{1cm} (7)

This form, although parabolic, nearly represents a straight line approximation of the drag coefficient versus wind speed for low values of wind speed. The relationship is different from several historical measurements for open ocean momentum flux by the eddy correlation (known also as the Reynolds flux) and dissipation methods (van Dorn 1953, Smith and Banke 1975, Garratt 1977, Yaglom 1977, Pond and Large 1978, Large 1979, Smith 1980, and Large and Pond 1981). The historical measurements have clearly demonstrated that drag coefficient reduced to 10-m height and neutral conditions is independent of stability and fetch but increases with wind speed above 10 m/sec. Below \( U_{10} = 10 \) m/s, \( C_D \) does not vary appreciably with wind speed and should remain essentially constant (Garratt 1977 and Smith 1980). The best constant should
be in the range $1.1 \times 10^{-3}$ to $1.3 \times 10^{-3}$ (Large and Pond 1981). Equation 7 simply fits a smooth line to $C_D$ for all wind speeds.

For coastal and shallow water locations, Garratt (1977) established the following relationship for drag coefficient based on extensive field measurements

$$C_D = 0.001 \ (1.1) \quad 1 < U_{10} \leq 10 \ m/sec \quad (8)$$

$$= 0.001 \ (0.44 + 0.065 \ U_{10}) \quad 10 < U_{10} \leq 26 \ m/sec$$

For open ocean situations, the following expressions, also obtained directly from field measurements, have been suggested and used extensively in offshore engineering (Smith 1980, Smith and Banke 1975, Large and Pond 1981)

$$C_D = 0.001 \ (1.11) \quad U_{10} \leq 10 \ m/sec \quad (9)$$

$$= 0.001 \ (0.44 + 0.063 \ U_{10}) \quad 6 < U_{10} < 25 \ m/sec$$

$$C_D = 0.001 \ (1.18) \quad U_{10} \leq 10 \ m/sec \quad (10)$$

$$= 0.001 \ (0.61 + 0.075 \ U_{10}) \quad 6 < U_{10} < 22 \ m/sec$$

$$C_D = 0.001 \ (1.14) \quad 4 < U_{10} \leq 10 \ m/sec \quad (11)$$

$$= 0.001 \ (0.49 + 0.065 \ U_{10}) \quad 10 < U_{10} < 26 \ m/sec$$

In essence, Equations 9-11 state that over the deep ocean, a constant neutral 10-m drag coefficient is an adequate description of most results throughout the wind speed range 2-12 m/sec, and a reasonable compromise would be to use $C_D = 1.1 \times 10^{-3}$ in the bulk formula for winds below 10 m/sec. For higher wind speeds in open seas, Equation 11 by Large and Pond (1981) is probably best accepted, though it is similar to Equations 9 and 10 at higher wind speeds.

**Procedure**

The study objective is met by, first, providing descriptions of the available products and procedures for accessing them. The NOAA products are discussed in Chapter 2 and Navy products in Chapter 3. Recently, upgraded weather information has become available from the Navy’s Fleet Numerical Oceanography Center (FNOC) daily weather forecast stream, disseminated to
the US Navy through a networking system. The FNOC database includes a variety of meteorological parameters at varying spatial and temporal resolution. Chapter 3 of this report provides detailed information about this product.

A smooth interface between meteorological data sources and wave and water level numerical models is a prerequisite for efficiency and user-friendliness in engineering studies. An interface between the Wave Information Study (WIS) wave model WISWAVE 2.0 and the FNOC meteorological database was developed in this study to facilitate routine CE applications. Computer routines were developed to take the raw Navy products and convert them to a form for direct input to the CE wave model WISWAVE. The interfaces are presented in Chapter 4.

Various Navy products were used to drive WISWAVE. The results were inter-compared with wave buoy measurements in Chapter 5 to evaluate the usefulness of the products for hydrodynamic modeling. Recommendations for products and procedures to be used in future CE hydrodynamic studies are given in Chapter 6.
2 NOAA Wind Products

The NOAA National Meteorological Center (NMC) routinely produces global wind estimates. The global grid can provide a resolution of about 1 deg in latitude and longitude. The NMC is developing methods for much finer resolution in selected regions. A characteristic fine-mesh resolution is 0.5 deg in longitude and 0.33 deg in latitude (Gemmill 1991).

The NMC produces two types of global forecast. The aviation (AVN) forecasts are run daily at 0000 UTC and 1200 UTC. Forecasts extend out to 3 days. Forecasts are issued after a 2.75-hr wait for arrival of data for assimilation into the 0-hr forecast. The AVN forecasts, used mainly for aviation purposes, are transmitted world-wide on the Global Telecommunications System. The medium-range forecasts (MRF) are run once per day from 0000 UTC. The forecasts, extending out to 10 days, are issued after a 6-hr data hold. A more detailed review of NMC global weather prediction systems was given by Kalnay et al. (1990).

The NMC wind products are discussed further as part of the SWADE experiment (Chapter 5). The NMC model provides wind estimates of sufficient quality to be useful in CE hydrodynamic modelling. However there is no convenient way at present for CE users to access that information in digital form. Therefore, the NMC products are not described in detail in this report.
3 Navy Wind Products

Description

Products related to surface winds which are available from the US Navy FNOC are described in this section. FNOC products related to surface winds are available from several Navy database sources. The sources are grouped in the following discussion into archived information covering a time period of multiple years (needed for climatological and extreme conditions) and recent information ranging from the most recent several months to present and forecast conditions. The following paragraphs provide a description of the information available and some relevant background on how the information is calculated by the Navy model.

The Navy's global numerical weather prediction is based on the Navy Operational Global Atmospheric Prediction System (NOGAPS). The first version of NOGAPS was a nine layer, finite difference model with horizontal resolution of 2.4° x 3.0° (Hogan and Rosmond 1991). After several improvements in physical parameterization and resolution, NOGAPS Version 3.2 was introduced in 1989. NOGAPS 3.2 is a global spectral model with 18 vertical levels. It produces output fields on grids with 2.5-deg and 1.25-deg horizontal resolution. The NOGAPS consists of components for data quality control, data assimilation, and initialization and forecasting. NOGAPS 3.2 is described by Hogan and Rosmond (1991). The planetary boundary layer model used in NOGAPS is similar to that of the ECMWF (Louis et al. 1982). The FNOC also operates a Navy Operational Regional Atmospheric Prediction System (NORAPS) for several regions of the world, including the Western Atlantic Ocean encompassing the U.S. coast. Additional information on NORAPS and NOGAPS is available from Bayler et al. (1991).

NOGAPS is an operational model used to drive a variety of the Navy's ocean, wave and ship and aircraft routing models. The model is run at 0000Z and 1200Z each day, forecasting a period of up to 72 hr. The "Z" indicates times are referred to Greenwich Mean Time (GMT), also known as the Universal Time Coordinate (UTC). Available data, measured and observed, are assimilated into the model at startup time. The startup time is labeled with
a forecast time of $t=0$. Fields at any times other than $t=0$ are forecast fields and have a forecast time of $t=3, 6, ..., 72$ hr.

All of the wind products discussed in this chapter are produced on the NOGAPS "global_73x144" and "global_288x144" grids. Both grids are based on spherical projections. The global_73x144, referred to in this report as the "coarse" grid, has a spatial resolution of 2.5° latitude and longitude increments. The global_288x145, or "fine" grid, has a spatial resolution of 1.25 deg. In Navy references, the coarse and fine grids are often referred to as the "regular" and "super" grids. In some Navy products, the regular grid is called the "spherical" grid, though both the regular and super grid are based on a spherical projection of the earth. Additional details of the grids are given in Table 2 and illustrated in Figure 1.

**Table 2**

<table>
<thead>
<tr>
<th>FNOC Global Grids</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Formal Grid Name</strong></td>
</tr>
<tr>
<td>global_73x144</td>
</tr>
<tr>
<td>global_288x145</td>
</tr>
</tbody>
</table>

1 Grid point at which (x,y) coordinate is (1,1).

**Archived data**

Archived surface wind information is available through FNOC for a period ranging from 1976 to the present. CERC’s WIS group has archived information from the period from 1976 to 1990 for CE use. Surface winds are at 19.5-m elevation and are presented in terms of U-V windspeed components in meters/sec. The winds are available on a global basis at a spatial resolution of 2.5 deg (corresponding to the coarse grid) every 6 hr. This wind product, labelled A29/A30 (U/V component) in the FNOC database, is obtained from atmospheric numerical models, including NOGAPS after 1981, which assimilate observed data from ships, buoys, and satellites.

**Recent data**

POPS. Surface fields are available on a component of the Primary Oceanographic Prediction System (POPS), an automated information system under the Commander, Naval Oceanography Command. POPS consists of two supercomputers and associated subsystems. One supercomputer is located at
Figure 1. Navy global grid boundaries
the Naval Oceanographic Office (NAVOCEANO) at Stennis Space Center (SSC), MS. The other supercomputer is located at FNOC in Monterey, CA. The two supercomputers are linked by a high speed data connection for efficient data transfer. A subset of the data available on the FNOC database is transferred to the Permanent File Computer System (PFCS) located at NAVOCEANO. A complete listing of the grids and fields available on the PFCS appears in Appendix A. The data may be accessed through any of the components of POPS at SSC including a Cray system known as the Large Scale Computer (LSC) and two Sun systems which serve as front ends to POPS on the LSC. The Sun systems are known as SPOP and POPS.

Two surface wind products are available from the PFCS. One is an unadjusted surface wind at an elevation 10 m in terms of U-V components (A58/A59). This wind product is not adjusted for any air/sea temperature differences. The units are generally in m/s but this is not always consistent as will be explained in the Access portion of this chapter. The other surface wind product is the surface wind stress in terms of U-V components (A60/A-61) with units of N/m².

Both the surface wind and wind stress are available on the coarse and fine grids. However the available resolution in time varies with the type of product and grid (Table 3). A surface pressure field (A01) at mean sea level in units of millibars is also available from the PFCS as indicated in Table 3.

### Table 3

<table>
<thead>
<tr>
<th>Grid</th>
<th>Surface Wind</th>
<th>Surface Stress</th>
<th>Surface Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time Increment¹</td>
<td>Longest Forecast</td>
<td>Time Increment¹</td>
</tr>
<tr>
<td>Coarse</td>
<td>6 hrs</td>
<td>72 hrs</td>
<td>12 hrs</td>
</tr>
<tr>
<td>Fine</td>
<td>12 hrs</td>
<td>24 hrs</td>
<td>3 hrs</td>
</tr>
</tbody>
</table>

¹ Time interval at which 0-hr forecasts are available; also the time increment for forecasting between 0 hrs and the longest forecast time.

NODDS. FNOC surface winds at 10-m elevation in units of knots, labelled A58/A59 (U/V comp) on the FNOC database, are available through the Navy Oceanographic Data Distribution System (NODDS). NODDS is a PC-based software interface to the mainframe FNOC database. The spatial resolution for this windfield is 2.5 deg. It is available every 12 hr. Only forecasts and the most recent analysis are available through NODDS. A pressure field, in millibars (labelled A01 on the FNOC database), is also available at 12-hr intervals.

The NODDS system is intended primarily to provide guidance to U.S. Department of Defense meteorologists and oceanographers. It provides access to a portion of the data available from the FNOC database in a user-friendly,
menu-driven format where details of the database and transfer of the fields is transparent to the user.

**Access**

**Archived**

The FNOC is an operational center, but it also maintains an archive of selected operational products. The archived products are accessible to the general public through NOAA’s National Oceanographic Data Center in Asheville, NC. Within CERC the information is available on tape from the WIS group. WIS presently has data from the years 1976 to 1990.

**NODDS**

To access data through NODDS, the NODDS software and documentation must be acquired from FNOC. CE users may also obtain the information from CERC. For users within the U.S. Department of Defense, inquiries may be directed to:

Commanding Officer  
Fleet Numerical Oceanography Center  
Monterey, CA  93943-5005  
Attn: Code 344

The CERC has a licensed copy of NODDS which may be shared on site, but the license forbids simultaneous access to the FNOC database by more than one user. In order to run the NODDS software the user must have a licensed copy of the communications software PROCOMM PLUS. Information is accessed interactively in the NODDS package by linking the user’s PC to the FNOC database via modem. Desired information is transferred to the user’s PC automatically. The information can be written in the form of a standard ASCII file if the user modifies the PLOTMAP.BAT program in NODDS. Step-by-step instructions for using NODDS are given in the documentation (U.S. Navy 1991, 1992).

**POPS**

Access to FNOC data on the PFCS is designed mainly for Navy users. Users must have an account on POPS and clearance to access the data. Sponsorship from a Navy office is a prerequisite for user accounts on POPS. With sufficient need and Navy support, a limited number of CE users have received permission to access POPS. Inquiries by qualified users about an account on POPS computers may be directed to the following Navy office:
Data transferred from FNOC to the PFCS at SSC is accessed through the Interim POPS database (IPOPS). Inquiries by qualified users about gaining access to IPOPS may be directed to:

Naval Oceanographic Office  
Code AM, Supercomputer Center  
Stennis Space Center, MS 39522

The interim set of subroutines included in IPOPS is designed to simulate a subset of POPS Prototype routines. IPOPS routines are intended for temporary use until a permanent database management system is available and tested with the IPOPS Data Base (DB) Prototype routines. IPOPS simulates several POPS DB Grid Data Routines (Table 4). Routines are also available which produce a listing identifying all grid fields contained within an IPOPS file. IPOPS provides Cray and Sun users at SSC and FNOC the capability to read gridded environmental fields which have been transferred from the FNOC-CYBER mainframes to the PFCS. Users may also write and read grid fields on their own files. Fields are available on the PFCS in a single random file created for each FNOC 12-hr watch (0-hr forecast every 12 hr). Additional details on extracting surface wind products from IPOPS are given in Appendix B.

In order to automate the process of retrieving wind data from IPOPS, a base program containing IPOPS subroutine calls, provided by IPOPS personnel, was modified to extract multiple wind fields given a user-defined time increment. The fortran program, named extwind.f, can be applied to either the coarse or fine grid. By editing the parameter statement and several other lines of program extwind.f, 10-m winds (A58/A59) or wind stresses (A60/A61) from either grid may be extracted for any time period. A complete listing of extwind.f is included in Appendix B. The lines which must be changed for each run are identified in the listing.
# Table 4

## POPS DB Grid Data Routines Included in IPOPS

<table>
<thead>
<tr>
<th>Name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOPN</td>
<td>Open grid data</td>
</tr>
<tr>
<td>GRD</td>
<td>Read grid data</td>
</tr>
<tr>
<td>GWR</td>
<td>Write grid data</td>
</tr>
<tr>
<td>GWRAS(^1)</td>
<td>Associative grid write(^1)</td>
</tr>
<tr>
<td>DBSTART(^1)</td>
<td>Start data base(^1)</td>
</tr>
<tr>
<td>DBSTOP(^1)</td>
<td>Stop data base(^1)</td>
</tr>
</tbody>
</table>

\(^1\) Inactive; provided only for compatibility with POPS.
4 Interface with CE Hydrodynamic Models

One objective of this study was to make NOAA and Navy products more accessible for use in CE wave, surge, and circulation models. The descriptions and access possibilities discussed in Chapter 3 provide a first step. Additional steps taken to make Navy products easily used in CE hydrodynamic models are described in the following paragraphs. The effort was focused mainly on WISWAVE because it is the CE model most likely to require winds over large spatial areas. Interface with archived NOAA buoy data, useful for evaluating model predictions, is also discussed.

Model Grid

Considerations in setting up WISWAVE are reviewed in the following paragraphs. A first step in using wind fields in WISWAVE 2.0 is creating a grid for the wind input and wave model. A grid may be generated on the CE Cray computer using software items developed in this study. The software takes advantage of map features available in the DISSPLA graphics package. The program mapgrid draws a map and overlays a grid of specified interval in longitude (x) and latitude (y). Files involved in using the program are summarized in Table 5.

<table>
<thead>
<tr>
<th>File Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>mapgrid.f</td>
<td>Fortran program to generate grid and shoreline display metafile</td>
</tr>
<tr>
<td>mapgrid.c</td>
<td>Shell file to run mapgrid and hpgl</td>
</tr>
<tr>
<td>hpgl.f</td>
<td>Fortran program to convert a metafile to HPGL format</td>
</tr>
<tr>
<td>dispop.inp</td>
<td>Parameter input file for use in DISSPLA</td>
</tr>
</tbody>
</table>

Chapter 4 Interface with CE Hydrodynamic Models
A detailed description of mapgrid and other associated programs, including run procedures and postprocessing steps is provided within the files. Comments in mapgrid give necessary information for using the program. The files are listed in Appendix C.

Output files are in HPGL format and may be transported into word processing software as graphics files. The files may be modified if necessary and printed using a standard laser printer. Sample plots are shown in Figures 2 and 3 for 2.5° x 2.5° and 1.25° x 1.25° grids used in this study. The mapgrid program includes options for displaying NDBC buoy locations on the gridded maps.

Figure 2. Coarse grid (2.5-deg resolution) for wave model test in north Atlantic ocean

The WISWAVE grid system is based on latitude and longitude lines with the origin located in the lower-left grid corner. Latitude lines correspond to rows of constant y-value on the grid, denoted by values of J with a maximum of JDMN. Longitude lines describe columns of constant x-value, and are referenced by values of I whose maximum is set to IDMN in the parameter
4-Wind Input File

The use of program `extwind.f` to extract surface wind products from IPOS was discussed in Chapter 3. Files created by `extwind.f` are based on FNOC's global grids. In order to interface the FNOC wind products to WISWAVE, a program was written which takes a user defined subgrid of the global wind product extracted from IPOS. The U-V components of winds or stresses are converted to windspeed and direction and written to a file in the format of the WISWAVE wind input file. The program, written in fortran, is named `popuvwindsw.f`.

The program `popuvwindsw.f` reads output from IPOS coarse or fine grids and creates a subgrid according to user defined parameters. Either surface winds or wind stresses may be specified. WISWAVE will accept only surface wind as input, but friction velocities are computed in WISWAVE from the

---

Figure 3.. Fine grid (1.25-deg resolution) for wave model test in north Atlantic ocean
surface winds to estimate wave growth. To make the IPOPS stresses suitable for input to WISWAVE, the program `popuvwinds.f` includes a procedure for converting stresses to surface winds. The procedure is an inverse of that in WISWAVE, so the stresses ultimately computed in WISWAVE are equivalent to the original FNOC stresses. The files required to run `popuvwinds.f` are summarized in Table 6. An example wind field derived from IPOPS is shown in Figure 4. Details of the program are given in Appendix D.

Figure 4.. Example wind field derived from IPOPS, 1200 hr, 14 Dec 92

Wave Model Execution

Execution of WISWAVE 2.0 is described in the user’s guide (Hubertz 1992) and is only briefly covered here. Although the general term "WISWAVE" is used to refer to the model in this report, a run with WISWAVE 2.0 requires a number of specific files (Table 7). File names other than those in the table may be used as desired, although the names must be specified consistently in program and shell files.
The files `para1.inc` and `para2.inc` contain critical parameters defining array dimensions. These files must reside in the same directory as the program being run. In addition to dimensions of the grid, the files include dimensions for frequency (if) and direction (ia and ig). Other parameter values are dimensions for the number of saved points (nobpts) and saved boundary points (n-bn). A complete description of all parameters that specify the details of a particular application are described in the WISWAVE user's guide (Hubertz 1992).

The WISWAVE program was modified in this study to create an additional output file, **fort.92**, which contains condensed output information for postprocessing. It includes station number, date of computation step, significant wave height, peak wave period, mean wave period, peak wave direction, wind speed, and wind direction in columnar format convenient for the postprocessing program `plotzd.f`. Only user-specified stations are included, which, in this study, are those nearest to NDBC buoys.
Buoy Data

Buoy measurements are highly desirable for verification of wave model results. The National Data Buoy Center (NDBC) data can be obtained by CE users from CERC's Coastal Engineering Database Retrieval System (CEDRS) (McAneny and Jones, 1992 and 1993). The format for archiving buoy data is described in Appendix E. For this study, individual buoy data were extracted from CEDRS in NDBC's "Record B" format.

The program buoy.f was developed to facilitate application of buoy data in wave modeling studies (Appendix E). Files involved in using the program are summarized in Table 8. The Record B buoy file is directly input to the program. The program separates out parameters in the Record B buoy data records of interest in hydrodynamic modeling and generates an output file containing only these parameters. The output file can be used as an input file to the postprocessing program plotzd.f.

<table>
<thead>
<tr>
<th>Table 8</th>
<th>Files for Extracting NOAA Buoy Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>File Name</td>
<td>Description</td>
</tr>
<tr>
<td>buoy.f</td>
<td>Fortran program to extract buoy data</td>
</tr>
<tr>
<td>buoy.c</td>
<td>Shell file</td>
</tr>
<tr>
<td>fort.1</td>
<td>Input buoy data</td>
</tr>
<tr>
<td>fort.2</td>
<td>Output file</td>
</tr>
</tbody>
</table>

Display of Results

In addition to standard WISWAVE postprocessing tools, a program, plotzd.f, was written to generate time series plots of model results and/or NDBC buoy measurements (Appendix F). The files needed to use plotzd.f are listed in Table 9. The WISWAVE output file fort.92 includes model results at selected stations nearest to buoys for comparison. To compare model estimates with buoy data or to simply plot the model time series, results from the appropriate station must be written to a new file, which can be generically referred to as station.92. The desired station may be separated from the others in fort.92 by using text editing capabilities or, alternatively, "sort" and "grep" utilities in the UNIX operating system on the Cray.

Buoy data files for postprocessing are created using the program buoy.f, as discussed earlier. The file station.92 and the corresponding output file from buoy.f serve as input to the postprocessing program plotzd.f. Both buoy and model station predictions should have corresponding start and end times, although plotzd.f is sufficiently general that it will process time series data of
any desired length. If no buoy measurements are available, the program will process only the model predictions; there is no need to specify null input.

<table>
<thead>
<tr>
<th>Table 9</th>
<th>Files for Plotting WISWAVE and NOAA Buoy Wind and Wave Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>File Name</td>
<td>Description</td>
</tr>
<tr>
<td>plotzd.f</td>
<td>Fortran program to plot wind and wave information</td>
</tr>
<tr>
<td>plotzd.c</td>
<td>Shell file</td>
</tr>
<tr>
<td>fort.2</td>
<td>Input buoy data</td>
</tr>
<tr>
<td>fort.92</td>
<td>Input WISWAVE information</td>
</tr>
</tbody>
</table>

The program **plotzd.f** displays the parameters wave height, period, and direction and wind speed and direction. Values of these parameters are plotted (y-axis) over a 24-hour time span (x-axis) for five days. An example for wave height is given in Figure 5. Thus **plotzd.f** produces five plots for each parameter per page. To process information for more than five days, only the parameter "ndays" in the parameter statement contained in the program need be changed. Similarly, if the time interval used for WISWAVE output is different than 1 hour, the parameter "ihrs" should be modified.

![Figure 5. Example wave and wind plot from plotzd.f](image)
5 Evaluation of NOAA and Navy Wind Products

SWADE Experiment

The SWADE experiment was conducted by a multi-agency, international group of scientists during 1 October 1990 to 31 March 1991. The primary objectives were to understand the dynamics of the evolution of the surface wave field and to determine the effect of waves on the air-sea transfers of momentum, heat, and mass (Weller et al. 1991). Field measurements of a variety of meteorological and sea state parameters were obtained from a dense array of buoys located off the middle Atlantic coast of the U.S. The measurements were augmented with wind information derived from a variety of sources including FNOC, NMC, ECMWF, and a manual kinematic analysis (Cardone et al. 1980).

The post-SWADE analyses include intercomparison of wind fields from different sources and evaluation of wave estimates derived from the various wind fields. Although the FNOC and ECMWF wind fields for SWADE are based on standard products, the NMC wind fields have been modified to increase spatial resolution. The SWADE analyses are still in progress. They indicate that the FNOC and NMC wind fields lead to useful wind and wave estimates, but the shortcomings of the wind forcing field still remain the largest source of error in predicting the sea state (Graher et al. 1991, Caruso et al. 1993). Jensen et al. (1991) reported promising wave estimates derived from the FNOC wind stress information.

Deep Water, Atlantic Coast

A special evaluation of Navy wind products available through the POPS system was conducted. These products were chosen because they are the most accessible and complete products presently available, as discussed earlier. The objectives of the evaluation were to:

(a) Check and verify the interfacing procedures.
(b) Evaluate WISWAVE results relative to the Navy wind parameters used (wind speed vs. wind stress) to create the input wind fields.
The model WISWAVE 2.0 was set up to run over the north Atlantic Ocean. Buoy measurements of wind and waves along the Atlantic coast were used for evaluation of model results.

Numerical grids used in WISWAVE 2.0 consist of latitude and longitude lines covering a significant area of the northwest Atlantic, including the entire eastern coastline of the United States. Grids developed for this study covered latitudes between $10^\circ$ and $65^\circ$N and longitudes between $5^\circ$ and $82.5^\circ$W. The program requires an input land-sea matrix and a water depth at each grid point designated as sea. Deepwater conditions were assumed in this study and depths for all sea grid points were set to 999 m. Thus only deepwater wave growth and propagation are modelled; wave shoaling and refraction are omitted. This simplification is justified considering the buoy locations. Also it allows the model vs. buoy wave comparisons to be a more direct evaluation of the quality of wind products, unaffected by assumptions about wave-bottom interactions.

Two grids were used in this study (Figures 2 and 3). The grids have different levels of spatial resolution, corresponding to the two levels of resolution in the Navy products (Table 10). Wave information was saved at selected grid points along the east coast of the United States. The output points include those grid points nearest to NOAA buoy sites (Table 11 and Figure 6).

### Table 10
**North Atlantic Grids Used with WISWAVE**

<table>
<thead>
<tr>
<th>Grid</th>
<th>Spatial Resolution</th>
<th>Grid Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>deg</td>
<td>km</td>
</tr>
<tr>
<td>Coarse</td>
<td>2.5</td>
<td>278</td>
</tr>
<tr>
<td>Fine</td>
<td>1.25</td>
<td>139</td>
</tr>
</tbody>
</table>

### Table 11
**NOAA Buoy Locations**

<table>
<thead>
<tr>
<th>NOAA Buoy Identification Number</th>
<th>Location</th>
<th>WISWAVE Grid Point</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Location</td>
<td>Location</td>
</tr>
<tr>
<td></td>
<td>Latitude</td>
<td>Longitude</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44004</td>
<td>38.5°N</td>
<td>70.7°W</td>
</tr>
<tr>
<td>44008</td>
<td>40.5°N</td>
<td>69.5°W</td>
</tr>
<tr>
<td>44009</td>
<td>38.5°N</td>
<td>74.6°W</td>
</tr>
<tr>
<td>44014</td>
<td>36.8°N</td>
<td>74.8°W</td>
</tr>
<tr>
<td>44025</td>
<td>40.3°N</td>
<td>73.2°W</td>
</tr>
</tbody>
</table>

1 These points were used from both coarse and fine WISWAVE grids for comparison with buoys.
Time periods for which both Navy information and buoy data were available were extremely limited at the time of this study. Access to the Navy POPS information had just been established; and, because of the time lag before buoy data are available, the POPS and buoy overlap was short. The approach taken was to process an initial 4-day time period (1-4 September 1992) to check and verify interfacing procedures and to form a first impression of the wind speed vs. wind stress comparison. Then a 5-day time period during a large, severe storm (10-14 December 1992) was processed to give a quantitative comparison between the effect of wind speed vs. wind stress as input to the wave model. This storm comparison was made possible by a special early release of NDBC buoy data.

**Initial evaluation**

Wind products for August 13 through September 15, 1992, were obtained from the Navy POPS database. Although the period of interest was September 1-4, the August wind information was needed to allow WISWAVE adequate spin-up time. Surface winds are available on a 6-hr time step for the coarse grid and a 12-hr time step for the fine grid (Table 3). The 10-m wind speed and direction were used.
The fine grid was also tested with wind stresses from the Navy database. Computer programs were developed to use stresses to create equivalent 10-m wind speeds and directions for input to WISWAVE, as discussed in Chapter 4. Stresses are available in 3-hour increments, so the stress-based 10-m winds were supplied to the wave model on a 3-hour time step.

The WISWAVE model was configured to use twenty frequency bands with corresponding mid-band periods ranging between 3 to 24 seconds. Sixteen 22.5° directional bands were used. Model results were output every hour to coincide with measured buoy data.

The wave model was run for the time period August 13 through September 15, 1992. Model results were saved for the entire period, but the days in August are considered as necessary spin-up. Model results were plotted and evaluated only for the period September 1-4, the days for which buoy data were available.

In the analysis and presentation of results, all times are referenced to GMT. Comparisons of model hindcast and NDBC buoy measurements include wave height, wave period, wave direction, wind speed, and wind direction. Wave parameters are defined in both model and buoy results as spectral significant wave height, peak period, and peak mean direction. Peak mean direction from WISWAVE is an energy weighted mean of all directions in the peak frequency band. The convention used for both wave and wind directions follows the Mariner's direction convention (used in WISWAVE), namely the direction the waves or wind are "coming from." For example, a 90° direction represents waves coming from the east and going toward the west.

Wave heights from WISWAVE are based on the sum of energy under the discrete spectrum, and thus, are an integrated quantity. Significant wave heights are obtained from NDBC buoys by a similar method. In terms of wave spectra, the significant wave height is proportional to the square root of the area under a spectral curve. For purposes of this study, predicted and measured wave heights can be considered as equivalent parameters.

Peak wave mean directions from WISWAVE are the energy-weighted mean of all wave directions in the peak frequency band, and therefore, are integral quantities. Peak mean direction is associated with the region of the spectrum containing the highest energy density. On the other hand, wave peak period (or dominant period) corresponds to the period associated with the peak spectral energy density, and therefore, is not an integrated or a mean quantity. It is much less stable statistically than the integral parameters. Large differences between measured and hindcast peak periods often occur when spectra have multiple peaks, indicating the simultaneous presence of seas and swells. Despite its limitations, the peak period parameter is widely used and accepted.

The NDBC buoys 44004, 44008, 44009, 44014, and 44025 were used to evaluate the model predictions (Figure 5). All of the buoys are capable of me-
asuring wind and waves. However wave direction measurement requires special sensors which are located only on buoys 44014 and 44025. Model predictions were compared to measurements at all 5 buoys, but results from only the directional buoys are presented in detail here for brevity.

Results from post-processing include individual plots of these parameters: wave height, wave dominant peak period and direction, and wind speed and direction versus time in hours. The plots include superimposed buoy data and model estimates on the same plot. Buoy data may have a time interval different than that used in the model predictions, but in all cases presented here, both had a 1-hour interval.

It is convenient to use an abbreviated designation for results pertaining to the two primary Navy wind products. The convention defined in Table 12 is used in the remainder of this chapter.

<table>
<thead>
<tr>
<th>Name</th>
<th>Explanation</th>
<th>Time Steps and Grids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method 1</td>
<td>Surface wind</td>
<td>6 hr (coarse)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 hr (fine)</td>
</tr>
<tr>
<td>Method 2</td>
<td>Surface stress</td>
<td>3 hr (fine)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Explanation</th>
<th>Time Steps and Grids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method 1</td>
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<td>6 hr (coarse)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 hr (fine)</td>
</tr>
<tr>
<td>Method 2</td>
<td>Surface stress</td>
<td>3 hr (fine)</td>
</tr>
</tbody>
</table>

Time series plots of wave height, wave period, wave direction, wind speed, and wind direction from WISWAVE using Method 1 and buoy 44014 on the coarse grid are shown in Appendix G. Overall, the comparison is good, but there are differences. For surface wind on the coarse grid, wave heights from the model are close to buoy measurements; there is a slight but consistent over-prediction by the model. Greater differences are evident for peak period; model predictions are higher than buoy measurements with differences generally less than about 4 sec. Wave direction estimated by the model is roughly 90° while the buoy shows almost a constant wave direction of about 180° for the entire four days span. Highest winds recorded by the buoy are near 8 m/s occurring at the start of the third day. The model indicates maximum wind speeds of 6 m/sec 24 hr later. Wind directions compare best on day 3. Differences in wind directions are not surprising given the low wind speeds.

For surface wind on the fine grid, model wave height estimates are closer to buoy data and are generally lower than with the coarse grid. Wave periods agree better with buoy data in the fine grid except over the first 24 hr. The tendency for model periods to exceed measurements is not evident. Model estimates for wave direction are higher than the coarse grid results, giving a better overall comparison. Wind estimates on the fine grid are very similar to those on the coarse grid. The coarse and fine grid points used here are colocated.
Similar comparisons between WISWAVE and buoy 44025 are given for winds derived by Method 1 on the coarse grid and fine grid (Appendix H). Wave parameter comparisons between model and buoy show the same general trends as in the earlier comparisons with buoy 44014. Wind parameters vary more between the coarse and fine grids.

Data from both directional buoys were also compared to model predictions based on winds from Method 2, that is, WISWAVE was driven with surface stress on the fine grid (Appendices G and H). Method 2 shows a noticeable tendency to give higher wind speeds than Method 1. As a consequence, Method 2 also gives higher wave heights. Method 2 results for the other parameters differ from those for Method 1 but do not show any strong tendencies relative to the buoy data.

**Storm evaluation**

The above comparisons were supplemented by special evaluation of a recent storm that damaged a large segment of the US Atlantic coast in December 1992. The WISWAVE model was run with sufficient spin-up time to give valid wave estimates for the time period 10-14 December, which includes the most intense part of the storm. Data from the five buoys were obtained by special request to NDBC. Although comparisons were made for all of the buoys, only the two directional buoys are included in this report.

Data from buoy 44014 are compared to model results from Method 1 on the coarse grid and fine grid (Appendix I). Wave heights are higher on the fine grid and generally compare more favorably with buoy heights. A notable exception is day 4, on which the fine grid lead to overestimates of wave height. The buoy recorded a maximum wave height of about 8 m near the beginning of day 2. The model maxima are 5 m and 8 m for the coarse and fine grids, respectively. Thus the fine grid lead to a significantly better estimate of maximum significant height due to the storm.

Wave period estimates by Method 1 on the fine grid are generally superior to those on the coarse grid in comparison to buoy periods. Wave directions from both grids compare favorably with buoy data, with the coarse grid producing a better overall comparison. Wind speeds on the fine grid show a tendency to be higher than those on the coarse grid. The trend is particularly evident on day 2, where the fine grid gives a close estimate of peak wind speed but overestimates winds for the remainder of the day. Wind direction is estimated slightly better on the fine grid, relative to the buoy.

Measurements from buoy 44025 are compared with model results from Method 1 on the coarse and fine grids (Appendix J). As with buoy 44014, the fine grid produces higher wave heights and a better estimate of the peak storm significant height than the coarse grid. However the fine grid does not consistently give better predictions throughout the storm. Wave periods are generally similar on both grids and compare reasonably well with the buoy periods. Wave directions from both grids are similar and generally within
30 deg of the buoy wave direction. Wind speeds tend to be higher on the fine grid than the coarse grid and they compare favorably with buoy measurements. Wind directions from both grids are similar, but the overall comparison is less favorable.

The above storm comparisons were repeated using Method 2 to generate the winds. The stress-based results are also given in Appendices I and J. The stress-based wave heights are generally higher than those from Method 1. They produce large overestimates of the maximum significant height during the storm at both buoys. Period estimates by Method 2 are slightly less satisfactory than those by Method 1. Stress-based wave directions are comparable to those based on Method 1. The stress-based wind speeds are high relative to those from Method 1 and the buoys. Wind directions from Methods 1 and 2 are similar.

Although time series comparisons are helpful in evaluating model performance, the CE is typically more concerned with climatological and design parameters. The Navy wind products cannot be fully evaluated in this sense in the present study because of the small data sample. This type of evaluation must be carried out in a future effort to fully validate the use of Navy products in CE applications.
6 Conclusions and Recommendations

The NOAA and Navy operational wind forecasting models are generating information with sufficient detail and accuracy to be useful for at least some aspects of coastal/hydraulic wave and surge modelling. The products from these organizations can greatly reduce the time and cost involved in preparing wind information for driving hydrodynamic models. They also present the possibility of running hydrodynamic models in near real time, which may be desirable during severe storms. The full range of application of NOAA and Navy products should be explored in future hydrodynamic modeling efforts.

The CERC has established on-line access to detailed Navy wind products. Global wind information can be retrieved as desired. Procedures for interfacing Navy products with hydrodynamic models have also been developed, particularly for the wave model WISWAVE. Thus Navy wind products for a selected study area can be promptly and efficiently extracted for input to wave and surge models. Similar access to NOAA products is not feasible at present.

The access and interface capabilities for Navy products have been tested for two weather conditions, a calm sea state during September 1-5, 1992, and a severe storm during December 10-14, 1992. The procedures are working correctly and efficiently. As the structure and file system of the FNOC wind database change in the future, CERC’s interface programs will need to be updated.

Preliminary evaluations of the Navy surface wind and surface stress in this and other recent CE studies indicate that both input options give reasonable wave estimates relative to buoy measurements. These products should be used routinely in future CE studies where appropriate. However they need to be evaluated over a much longer time period than that considered in this study to determine which products give the most reliable results.

It is strongly recommended that a systematic and comprehensive comparative study be conducted to investigate performance of the WISWAVE model using the Navy surface wind and surface stress products. It is also
recommended that the model performance be investigated in terms of effects of wind field variability in space and time.
References


Reid, R. O., Vastano, A. C., and Reid, T. J. (1977). "Development of Surge II program with application to the Sabine-Calcasieu area for Hurricane Carla and design hurricanes," Technical Paper 77-13, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.


Appendix A
Navy IPOPS/PFCS Grids, Products, and Parameters
# Table A1
## Current Grid Registered Geometry Descriptions

<table>
<thead>
<tr>
<th>ID Number</th>
<th>Geometry Name</th>
<th>Description</th>
<th>Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>global_73x144</td>
<td>Global</td>
<td>spherical</td>
</tr>
<tr>
<td>11</td>
<td>north_hemph_63x63</td>
<td>Northern Hemisphere</td>
<td>polar_stereo</td>
</tr>
<tr>
<td>12</td>
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<td>nkur_100x150</td>
<td>N. Kuroshio</td>
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1. From data base tables grid.geom and grid_reg.geom
2. Text string used an input to SUBROUTINE GOPN
3. Coarse grid used in this study

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^4 Fine grid used in this study
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<th>Level Description</th>
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<th>Parameter #2</th>
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1 Selected parameters of possible CE interest are included; information is from data base tables xnm1_grd, grid_parm, and grid_lv
2 Used as input to SUBROUTINE GRD to specify desired fields to extract
3 Used as input to SUBROUTINE GRD to specify level 1 and level 2

Sheet 1 of 3
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Sheet 3 of 3
## Data Being Transferred

### Table A3
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<th>Forecast Interval (hrs)</th>
<th>00Z Forecast</th>
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*Only grids likely to be of CE interest are listed; total size of one file (all grids) is 14246697 for 00Z forecast and 4008042 for 12Z forecast.*
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Example ipopsident Output

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Sheet 1 of 8

1 For brevity, information from only grids #10 and #64 is shown; information was obtained from file /u/e/lpopa/tnoc1992090212

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Appendix B
Extracting Surface Wind Products from IPOPS

This appendix contains detailed information about the procedures needed to access IPOPS and create a file of global information over a user-selected time period. The discussion of procedures is followed by a listing of the required fortran program extwind.f.

As part of this research project, CERC established a link to POPS through the Internet network. A user account on the LSC was accessed using the telnet command from a Unix workstation at CERC. There are three POPS subsystems available at SSC for IPOPS access, the SPOP (Sun frontend), the POPS (Sun frontend) and the LSC (Cray). For this project, all access to IPOPS was performed on the LSC.

The IPOPS fields for each FNOC 12-hr watch are available on the PFCS in a single random file. Files may be accessed using a path/file name in the following format:

/u/a/ipops/fnocyyyyymmddhh

where yyyyymmddhh represents the year, month, day, and hour (00Z or 12Z) of the watch on which the fields were produced. The IPOPS subroutines reside on the following libraries:

Sun: /u/a/ipops/sun/libvio.a
Cray: /u/a/ipops/cray/libvio.a

The compilation/load statement to access this library includes the following parameters on the f77(Sun) or cf77(Cray) statements:

f77 .... -lvio -L/u/a/ipops/sun ...
cf77 .... -lvio -L/u/a/ipops/cray ...
This library will access IPOPS data files created between 23 June 1992 and the present. IPOPS data files exist prior to this date but they may contain errors and should not be used.

Grid data arrays must be in single precision floating point format. Data are stored on disk in 32-bit IEEE (SUN) format. The Cray IPOPS routines will automatically convert between this format and the Cray format. Only read access will be available to the general user of FNOC IPOPS files. Both reads and writes may be done to files which the user creates with IPOPS routines. Some parameters in the IPOPS subroutines are modified or ignored. Parameters are described in the discussion of each IPOPS subroutine below.

Subroutine Description

This section describes the IPOPS subroutines, GOPN and GRD, and their parameters. DBSTART should be called once in the program before calling any other IPOPS routines. DBSTOP should be called before exiting the user program. These subroutines are provided for compatibility with the POPS DB Prototype.

GOPN opens the IPOPS Data file to read or write a grid. This subroutine must be called for each IPOPS file to be accessed. Up to 20 IPOPS files can be opened simultaneously. In order to read a different geometry type from a file already open, GOPN must be called again with the new type. GOPN uses Fortran Unit Numbers beginning with 51 and incrementing up to a maximum of 70. The subroutine call to GOPN contains the following parameters:

```
CALL GOPN (MDLTYPE, GEOMNM, DSETNM, OPNMODE, 
&           GRDHNDL, GEOM, PCKNULL, STATUS)
```

The parameters used in the call to GOPN are defined in the following list.

Parameters:

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<th>Description</th>
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<td>be passed to GRD &amp;GWR</td>
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GEOM     Unused        INTEGER*4
PCKNULL  Return argument: REAL
          Database NULL value
STATUS   Return argument: INTEGER

STATUS
0 = normal return, successful completion
< 0 = abnormal return, error occurred
> 0 = special return information, no error

If multiple IPOPS files are opened simultaneously, the appropriate GRDHNDL parameter value returned from GOPN for subsequent GWR and GRD calls must be used. The GRDHNDL value tells GWR and GRD which of the files opened is to be accessed on that call. Table A1 in Appendix A shows a list of grids available. The column labeled "GEOMETRY NAME" contains the text string used as the input argument GEOMNM in SUBROUTINE GOPN.

GRD reads a grid field. The subroutine call to GRD contains the following parameters:

CALL GRD (GRDHNDL, VRSNNM, PARMNM, LVLTYPE, LVL1, & LVL2, DATE, HOUR, FCSTPER, FBUFF, UNITS, STATUS)

Parameters used in the call to GRD are defined in the following list:

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</tr>
<tr>
<td>DATE</td>
<td>Year, Month, Day</td>
<td>INTEGER Array</td>
<td>DIMENSION (3)</td>
</tr>
<tr>
<td>HOUR</td>
<td>Hour of the day</td>
<td>DOUBLE PRECISION</td>
<td></td>
</tr>
<tr>
<td>FCSTPER</td>
<td>Forecast period</td>
<td>DOUBLE PRECISION</td>
<td></td>
</tr>
<tr>
<td>VRSNNM</td>
<td>Unused</td>
<td>CHARACTER*20</td>
<td></td>
</tr>
</tbody>
</table>
FBUFF  Return argument: REAL Array
      Array to receive DIMENSION (?) grid data

UNITS  Unused INTEGER

STATUS Return argument: INTEGER

STATUS
0 = successful read
100 = no more fields to read
-1 = failure to read

Table A2 in Appendix A shows a list of grid parameters by FNOC Catalog Number. The column labeled "POPS PARAMETER NAME" contains the text string for PARMNM, the name of the field to extract, which is input into SUBROUTINE GRD. The columns labeled "LEVEL DESCRIPTION - PARAMETER #1" and "LEVEL DESCRIPTION - PARAMETER #2" contain the numbers input into SUBROUTINE GRD as level 1 (LVL1) and level 2 (LVL2) numbers.

IPOPSID

There are two routines to list key identification information on all fields contained within a particular IPOPS file. The script, ipopsid, lists fields in the order that they were written into the file. The script, ipopsident, lists fields sorted alphabetically with the parameter name as the primary key. Both routines reside in the directory /u/a/ipops/xxx where xxx equals "sun" or "cray" depending on which system the user is using for execution. The following statements show usage of the routines on the LSC from the /u/a/ipops/cray directory:

<LSC> ipopsid /u/a/ipops/fnocyyyyymmddhh
<LSC> ipopsident /u/a/ipops/fnocyyyyymmddhh

A sample of an ipopsident output table is located in Appendix A (Table A4). The table contains parameter name and values for GEOM, the geometry (grid) ID number also listed in Table 1A, LVL1, LVL2, DATE, HOUR, FCST, forecast period, and LENGTH, the number of points in the grid.

Program Usage

In order to automate the process of retrieving wind data from IPOPS, a fortran program containing IPOPS subroutine calls discussed previously, provided by IPOPS personnel, was modified. The new program extracts multiple wind fields, given a user defined time increment, from the supergrid or regular grid. By editing the parameter statement and several other lines of the fortran program extwind.f, 10 meter winds (A58/A59) or wind stresses (A60/A61)
from either grid may be extracted for any time period. A complete listing of extwind.f is given later.

Parameters used in the IPOPS subroutine calls which require editing are located near the beginning of the program in a designated section. Key parameters are defined in comment statements. The PARAMETER statement, in which a number of key parameter values are specified, has the form

```
PARAMETER (NC=288, NR=145, DATE1=1992, DATE2=12,
1       IDAY1, IDAY2, ITAU1=0, ITAU2=9, ITAUINC=3,
2       igr=2, ifl=1)
```

The parameters are defined in the program listing later in this appendix. The values used in this example are typical for this study. The PARAMETER statement would need to be corrected as needed every time the program extwind.f is to be run.

Because the regular grid and the supergrid are stored so that the indexes that represent latitude and longitude are switched, two alternative dimension statements are given in the form:

```
c This statement is used for 1.25 deg. grids
    REAL UWND(NC,NR), VWND(NC,NR), LVL1, LVL2, PCKNULL

c This statement is used for 2.5 deg. grids
    REAL UWND(NR,NC), VWND(NR,NC), LVL1, LVL2, PCKNULL
```

The choice shown is the supergrid. To select the regular grid, the fortran comment character "c" must be added at the beginning of the second line above and deleted at the beginning of the last line.

The following example script file shows how to compile the fortran program, linking the IPOPS libraries, and run the resulting executable file. Note that the U-component is written to fortran unit 71 and the V-component is written to fortran unit 72.

```
# QSUB -eo
# QSUB -x
set -Svx
ja
cd $TMPDIR
cf77 -o extwind $HOME/extwind.f -lvio -L/u/a/ipops/cray
t extwind
t fort.71 /src/pops/a60s1201.g
t fort.72 /src/pops/a61s1201.g
t extwind	n extwind.o
tja -st
```
The script file `extwind.c` and the fortran program `extwind.f` may be copied from the directory `/u3/h2crosb0/ipops` on the Cray at the Waterways Experiment Station. The output data files can be transferred from the LSC to a local computer (Cray or Unix workstation) using the `ftp` command.
Listing of Program extwind.f

    c program extwind.f       Steven Bratos, December 1992
    c
    c
    c Program extracts FNOC wind products from the IPOPS database on
    c the Large Scale Computer (PFCS) located at NAVOEANO, Stennis
    c Space Center, MS. This must run on the LSC in order to access
    c the IPOPS database.
    c
    c This code is designed to extract U-V components of 10-meter wind
    c fields (A58/A59) or surface wind stress (A60/A61) from either
    c the global_73x144 (2.5 deg.) grid or the global_288x145 (1.25 deg)
    c grid.
    c
    c Parameter Definition
    c
    c NC = grid dimension
    c NR = grid dimension
    c DATE1 = year (example: 1992)
    c DATE2 = month (1,12)
    c IDAY1 = beginning day (1,31)
    c IDAY2 = ending day (1,31)
    c ITAU1 = beginning forecast hour (0)
    c ITAU2 = ending forecast hour (0,6,9)
    c ITAUNC = increment forecast hour (0,3,6)
    c igr = grid flag
    c     = 1 : global_73x144 (2.5 deg)
    c     = 2 : global_288x145 (1.25 deg)
    c ifl = field flag
    c     = 1 : wind stress
    c     = 2 : 10 meter wind
    c
    c (See IPOPS documentation for a list of following parameters)
    c GEOMNM = geometry name (example: global_73x144)
    c LVL1 = level 1 value
    c     = 10.0 for 10 meter wind
    c     = 0.0 for stress
    c PARMNM1 = name of u-component field to extract
    c PARMNM2 = name of v-component field to extract
    c For 10 meter winds
    c     PARMNM1='wnd_ucmp_ht_sfc'
    c     PARMNM2='wnd_vcmp_ht_sfc'
    c For wind stress
    c     PARMNM1='wnd_strs_ucmp'
    c     PARMNM2='wnd_strs_vcmp'
    c
    c GRID Parameters
c global_73x144 : NC=144,NR=73,igr=1

c global_288x145 : NC=288,NR=144,igr=2

c**********ALL REQUIRED EDITING DONE IN THIS SECTION ******

PARAMETER (NC=288, NR=145, DATE1=1992, DATE2=12, IDAY1,
1 I DAY2, I TAU1=9, I TAU INC=3, igr=2, ifl=1)

CHARACTER*20 LVLTYPE, MDLTYPE, VRSNNM
CHARACTER*50 DSETNM
CHARACTER*30 PARMNM1, PARMNM2, GEOMNM, UNITS
CHARACTER*4 OPNMODE
CHARACTER CDATE*10, aday*2, ahr1*1, ahr2*2, am*2
CHARACTER leadz*1, ada1*1, ada2*2, ah*2, EDATE2*1, FDATE2*2
INTEGER GRDHNDLDATE(3), STOPN, STRD, GEOM, DATE1, DATE2
DOUBLE PRECISION HOURTAU

This statement is used for 1.25 deg. grids

REAL UWND(NC, NR), VWND(NC, NR), LVL1, LVL2, PCKNULL

This statement is used for 2.5 deg. grids

REAL UWND(NR, NC), VWND(NC, NR), LVL1, LVL2, PCKNULL

Select parameters GEOMNM, LVLTYPE, LVL1, PARMNM1, PARMNM2

GEOMNM = 'global_288x145'
LVL1 = 0.0
PARMNM1 = 'wnd_strs_u cmp'
PARMNM2 = 'wnd_strs_v cmp'

leadz='0'
LVLTYPE = 'ht_sfc'
MDLTYPE = '
VRSNNM = '
OPNMODE = 'R'
LVL2 = 0.0
DATE(1)= DATE1
DATE(2)= DATE2

608 format(i2)
508 format(i1)
encode(4, 408, FDATE1) DATE1
if(DATE2 .lt. 10) then
encode(1, 508, FDATE2) DATE2
am = leadz/EDATE2
else
encode(2, 608, FDATE2) DATE2
am = FDATE2
end if
\begin{verbatim}
DO 801 iday=IDAY1,IDAY2
DO 800 ih=1,2
    ihh= 12 * (ih-1)
DATE(3) = real(iday)
HOUR   = real(ihh)
if( iday .lt. 10 ) then
    encode(1,508,ada1) iday
    aday = leadz//ada1
else
    encode(2,608,ada 2) iday
    aday = ada2
end if
if( ihh .lt. 10 ) then
    encode(1,508,ahr1) ihh
    ah = leadz//ahr1
else
    encode(2,608,ahr2) ihh
    ah = ahr2
end if

cdate = FDATE1//am//aday//ah

DSETNM = '/u/a/ipops/fnoc'//cdate

CALL DBSTART

c......Open DB file
   CALL GOPN(MDLTYPE, GEOMNM, DSETNM, OPNMODE,
   &      GRDHNDL, GEOM, PCKNULL, STOPN)

c.......Loop for each forecast time "itau"
   DO 300 itau=ITAU1,ITAU2,ITAUINC
      tau=real(itau)

c......Write date & itau to output files
   write(71,'(a10,i4)') cdate,itau
   write(72,'(a10,i4)') cdate,itau

c.......Read specified field/grid into UWND
   CALL GRD(GRDHNDL, VRSNNM, PARMNM1, LVLTYPE, LVL1,
   &         LVL2, DATE, HOUR, tau, UWND, UNITS, STRD)


c ---------- CKECK STATUS.................................
c
print *, 'open',stopn, 'read',strd

C-------- WRITE UWND to fortran unit 71 ---------------
IF( igr .eq. 1 ) then
IF( ifi .eq. 1 ) then
   WRITE (71,'(12f7.4)') ((UWND(i,j),j=1,NC),i=1,NR)
ELSE IF ( ifi .eq. 2 ) then
   WRITE (71,'(1x,I0f9.2)') ((UWND(i,j),j=1,NC),i=1,NR)
END IF
\end{verbatim}
ELSE IF ( igr .eq. 2) then
  IF ( ifl .eq. 1) then
    WRITE (71,'(12f7.4)') ((UWND(i,j),i=1,NC),j=1,NR)
  ELSE IF ( ifl .eq. 2) then
    WRITE (71,'(1X,10f9.2)') ((UWND(i,j),i=1,NC),j=1,NR)
  END IF
END IF
END IF

c........Read specified field/grid into VWND
CALL GRD(GRDHNDL, VRSNNM, PARMNM2, LVLTYPE, LVL1,
&            LVL2, DATE, HOUR, tau, VWND, UNITS, STRD)

c------- WRITE VWND to fortran unit 72 ------------------------
IF( igr .eq. 1) then
  IF( ifl .eq. 1) then
    WRITE (72,'(12f7.4)') ((VWND(i,j),j=1,NC),i=1,NR)
  ELSE IF ( ifl .eq. 2) then
    WRITE (72,'(1X,10f9.2)') ((VWND(i,j),j=1,NC),i=1,NR)
  END IF
ELSE IF ( igr .eq. 2) then
  IF ( ifl .eq. 1) then
    WRITE (72,'(12f7.4)') ((VWND(i,j),i=1,NC),j=1,NR)
  ELSE IF ( ifl .eq. 2) then
    WRITE (72,'(1X,10f9.2)') ((VWND(i,j),i=1,NC),j=1,NR)
  END IF
END IF

300 CONTINUE
800 CONTINUE
801 CONTINUE
STOP
END
Appendix C
Files for Generating a WISWAVE Grid

Shell File mapgrid.c

```bash
#QSUB -eo
#QSUB -IT 0:10:00
#QSUB -x
ja
set -vx
cd /u3/h2crozd7/winds/maps
cf77 -c mapgrid.f
dis77link -o mapgrid mapgrid.o
mapgrid
mv popfil.dat popfil
cf77 -c hpgl.f
dis77link -o hpgl hpgl.o
hpgl<dispop.inp
#--- ENTER NAME OF OUTPUT FILE
#--- ENTER LENGTH OF OUTPUT FILE NAME
#--- ENTER FILE MODE FROM THE FOLLOWING:
#--- 0) APPEND
#--- 1) NEW FILE
#--- 2) OVERWRITE
#--- 3) NO OVERWRITES
#--- 4) INCREMENT
#--- ENTER POST-PROCESSOR DIRECTIONS
rm mpgrid mapgrid.o popfil hpgl.o hpgl
ja -st
```
Program mapgrid.f

```fortran
program mapgrid.f  
  zeki demirbilek 12-2-92  
  
  this program plots the grid map of the Atlantic  
  and provides a mesh for generating a grid for WISWAVE  
  The input grid for WISWAVE consists of land & water boundary  
  matrix data.  
  
  to run this program:  
  qsub mapgrid.c <.....  shell file to compile & run  
  
  input:  
  modify mapgrid.f as necessary for your input, i.e.,  
  specify level 2 output stations to be used as boundary input.  
  these are specified as lon and lat and #  
  desired  
  insert new header info for plots,  
  decide x- and y-direction griding intervals (lon and lat,  
  respectively)  
  
  output:  
  result file will be called "output"; this is an hpgl file  
  rename "output" file to what you want,  
  Down load this file to your PC with ftp bring it down to PC (ftp  
  to your PC)  
  go to WP  
  alt+F9 (1,1,1)  
  c:\wp51\docs\zeki\out2.5  
  6 (choose 3)  
  7 (choose 4)  
  F7  
  shft+F7 (choose V to view first)  
  F7  
  1 (print the figure on HP LaserJet III)  
  you should a figure of the map  
  
  To generate the land-water matrix, use the gridded map you have  
  and follow instructions in the WISWAVE user guide.  
  
  common iwork (2000)  
  dimension x(33),y(33),x1(10),y1(10),x2(57),y2(57)  
  1,x3(26),y3(26)  
  Level 2 output station locations (x1,y1)  
  data x1/-77.5, -75.0, -72.5, -70.0,  
  * -67.5,-67.5,-67.5,-67.5,-67.5,/  
  data y1/30.0, 30.0, 30.0, 30.0, 30.0,  
  * 32.5, 35.0, 37.5, 40.0, 42.5/  
```

Appendix C  Files for Generating a WISWAVE Grid
call comprs
call metnam ('popfil',6)
call setdev(6,0)
call page (11.0,8.5)
call projct ('mercator')
call area2d (9.0,6.0)
call swissl
call sbdchr (90.0, 1.0, 002, 1)
call headin ('Atlantic Winds WU - 2.5 Degrees Grid$',100,2.0,1)
call headin ('Atlantic Winds WU - 1.25 Degrees Grid$',100,2.0,1)
call xname ('Longitude',9)
call yname ('Latitude',8)
call mapgr (-82.5,10.0,-5.0,10.0,10.0,65.0)
call mapfil ('north america')
c call headin ('Atlantic Winds WU - 2.5 Degrees Grid$',100,2.0,1)
call xname ('Longitude',9)
call yname ('Latitude',8)
call mapgr (-82.5,10.0,-5.0,10.0,10.0,65.0)
call mapfil ('north america')
c
Note: these may be substituted for buoys locations or something else if desired. Make sure you specify coords.
call marker(16)
call curve(x1,y1,10,-1)
call Hblank ('land',2000)
call grid (4,4) !for 2.5 degr grid: 10 deg inc/4 gives a 2.5 deg grid
call grid (8,8) !for 1.25 deg grid:10 deg inc/8 gives a 1.25 deg grid
call endpl (0)
call donepl
stop
c end

Program hpgl.f

C Program hpgl.f zeki demirbilek Dec 1992
C
C POST-PROCESSOR ROUTINE FOR DISSPLA
CHARACTER INFILE*20
DIMENSION IBUF(16),ITEMP(16)

IBUF(1)=5
CALL IOMGR(IBUF,-102)
DO II=1,16
    IBUF(II)=0
END DO
CALL QQLPRM('i.e. FOR FILE "OUTPUT01.DAT"',
* ENTER "OUTPUT01"$, ,IBUF)

CALL QQIPRM('i.e. FOR "OUTPUT01", ENTER
* "6"$, ITEMP)

IBUF(16)=ITEMP(1)
CALL IOMGR(IBM,-103)
CALL QQIPRM('ENTER FILE MODE$,IBM)
CALL IOMGR(IBM,-104)
CALL HP7475 (1)

CALL METNAM('popfil',6)
CALL DISPOP (0)

STOP
END

Example Input File dispop.inp

output
6
4

Appendix C Files for Generating a WISWAVE Grid
Appendix D
Interfacing Surface Wind Products from IPOPS with WISWAVE and Other Hydrodynamic Models

Procedures for extracting surface wind or surface stress information for user-selected areas from files in the Navy IPOPS format are discussed in this appendix. The extracted wind fields can be used as input to CE hydrodynamic models. Specific procedures for interfacing with the CE wave model WISWAVE are included. An annotated listing of the fortran program popuvwinds.f follows the discussion of procedures.

The program popuvwinds.f consists of a main program and two subroutines, FINDU10 and WNDCON. The main program reads output from IPOPS coarse or fine grids and creates a subgrid according to user defined parameters. Either surface winds or wind stresses may be specified. The main program incorporates a DO loop which iterates through the number of forecast wind fields, defined by the parameter ntau, for each 12-hour watch. The program continues to read windfields for successive watches until an end of file is detected.

Subroutine WNDCON converts windspeed components to windspeed and direction. Windspeeds are in meters/sec and directions are in the meteorological convention, following the WISWAVE conventions. WNDCON then writes the windfield with a date and forecast time header to a file in WISWAVE format.

Program options are controlled by parameters defined in an include file. This file must be located in the directory from which the program is being run. The following is an example of the include file para125.inc for the case of supergrid wind stress fields:
The user desired subgrid is defined by parameters rlong1, rlong2, rlat1, and rlat2. The value of these parameters establishes the subgrid in relation to the global grid. For subgrid purposes the global grid system is based on that shown in the main report. For the supergrid the longitude varies from -300° to 58.75° and for the regular grid it varies from -300° to 57.5°. The latitude varies from 90° to -90° for both the regular grid and the supergrid. For the example parameter statement shown above, rlong1 equals -82.5° and rlong2 equals -5.0°. Since the grid increment is 1.25° the resulting dimension for the longitude axis is MC = 63. From the same example, rlat1 equals 65.0° and rlat2 equals 10.0°. This results in a dimension for the latitude axis MR = 45.

For this study all popuvwinds.f runs were made on the Cray at WES. The following is an example of the script file popuv.c which can be used to run the program:

```
# QSUB -eo
# QSUB -x
set -Svx
ja
cd /tmp/wiswe
cp $HOME/pops/popuvwinds.f popuvwinds.f
ln /tmp/wispops/a60s1201.g
ln /tmp/wispops/a61s1201.g
cft77 popuvwinds.f
segldr popuvwinds.o -o popuvwinds
popuvwinds
mv fort.20 wis1201.g
```

The file includes links to the global wind stress components extracted from IPOPS and sent from the LSC to the Cray at WES. The output wind fields formatted for WISWAVE are written to fortran unit 20.

**Modification of Wind Stress for Use in WISWAVE**

Since the wave model WISWAVE 2.0 does not have an option for direct input of wind stress, a procedure for converting stress to 10-m wind speed, \(U_{10}\), and direction is included in the program in subroutine findul0.f. The drag law assumed is the same as in WISWAVE, but the inverse procedure is used. The subroutine is rather general, and may be used for other purposes, such as finding maximum conditions.

Subroutine findul0.f computes a matrix that contains the wind speed at 10-m height (\(U_{10}\) values) for various values of the friction velocity, \(U_.*\). First, hypothetical values of \(U_.*\) are created. The values of \(U_.*\) in the DO 2 loop start with
0.034, corresponding to a value of $U_{10} = 1$ m/sec, the lowest wind speed assumed for $U_{10}$. The largest $U_*$ in the loop is set to 5.033, corresponding to a value of $U_{10} = 250$ m/sec or greater, the highest wind speed assumed for $U_{10}$. The basic rule of thumb for relating $U_*$ to $U_{10}$ is as follows: $U_*$ values from 0.0337 ($\approx 0.034$ in the subroutine) correspond approximately to $U_{10}$ of 1 m/sec, $U_*$ of roughly 0.8 to $U_{10}$ of about 20 m/sec, and $U_*$ values between 1.0 and 5.0 are associated with high values of $U_{10}$, say $20 < U_{10} < 250$ m/sec.

To generate a look up table for all feasible values of $U_{10}$ from $U_*$, the drag coefficient relation used in the WISWAVE model is also employed in the subroutine `findu10.f`. The formula, expressed in terms of $U_{10}$, is given by:

$$C_D = 0.001 \left(1.1 + 0.035 \ U_{10}\right)$$

(1)

The equation may be written in more general form as

$$C_D = \text{fact} \ (\text{cof1} + \text{cof2} \ U_{10})$$

(2)

where

$$\text{cof1} = 1.1$$
$$\text{cof2} = 0.035$$
$$\text{fact} = 0.001$$

The formula used for relating $U_{10}$ to $U_*$ in the subroutine is

$$C_D = \frac{U_*^2}{U_{10}^2}$$

(3)

An expression for $U_*$ is derived from Equation 3 as

$$U_* = \sqrt{C_D \ U_{10}}$$

(4)

Substituting Equation 3 into Equation 2 yields a cubic equation of the form

$$U_*^2 = \text{fact} \ (\text{cof1} + \text{cof2} \ U_{10}) \ U_{10}^2$$

(5)

The solution of $U_{10}$ directly from Equation 5 requires either trial-and-error or a more formal iterative solution technique such as the Newton-Raphson method. The latter is implemented in subroutine `findu10.f`.

The first part of subroutine `findu10.f` solves Equation 5 for $U_{10}$. The derived values of $U_{10}$ are called "U10CAL", for the calculated $U_{10}$ values. Thus they can be distinguished from $U_{10}$ values obtained from the FNOC wind stresses.

Calculation of $U_{10}$ values from the FNOC wind stresses proceeds in the following manner. First, stresses are read as component x- and y- after these
have been transferred to CERC's CRAY platform. The $U_*$ values are constructed using the following definition of "shear velocity"

$$U_* = \frac{\sqrt{T_x^2 + T_y^2}}{\rho_{wv}}$$

In addition to the stress-based $U_*$ values, stress-based direction values are also computed in the subroutine. All calculations with stresses use a Cartesian reference frame. Directions in this frame represent "going toward" or "to".

The procedure in `findu10.f` continues with establishing a match between $U_*$ values and U10CAL pre-computed matrix data. That is, any stress-based computed $U_*$ value has a counterpart in the look-up tables (here a matrix of values) which contain the U10CAL values. From this matching, the $U_{10}$ values based on stresses are established. The matching is done through an indexing scheme, described within the subroutine. The resulting values will be the true $U_{10}$ data to be used for input to the WISWAVE.

Once the $U_{10}$ values are derived from the FNOC wind stresses, there are two alternative forms for saving them for use as input to WISWAVE. One alternative is to use the combination of $U_{10}$ and the stress based angles (derived and already converted to the WISWAVE angle convention in `findu10.f`). The second alternative is to decompose $U_{10}$ into x- and y-components, again using stress based angles. Either alternative is acceptable. The first alternative is more direct, but the second alternative may be easier for engineers in some applications. Both alternatives were tested and yielded equivalent stress-based wind input for WISWAVE, but only the second alternative is active in the following version of the program.

**Listing of Program popuvwinds.f**

```plaintext
c program popuvwinds.f Steven Bratos December 1992
c
c Program utility to read output from global 288x145 or
c global 73x144 grids output from IPOPS u-v wind or stress
c components and write desired subgrid in knots or meters/sec
c with date and tau id.
c
c Subroutine FINDU10 converts wind stress components to wind
c velocity (10m) components
c
c Subroutine WNDCON converts U-V components to wind speed &
c direction and writes a file formatted for WISWAVE
c
c Parameter Definition
c..........................
c NC = Global grid dimension (FNOC longitude axis)
```

D4

Appendix D Interfacing Surface Wind Products from IPOPS with WISWAVE and Other Hydrodynamic Models
C Global grid dimension (FNOC longitude axis)
C NR = Global grid dimension (FNOC latitude axis)
C MC = Subgrid dimension (longitude axis, e.g. WISWAVE)
C MR = Subgrid dimension (latitude axis, e.g. WISWAVE)
C ifl = Field flag
C = 1 for wind stress
C = 2 for 10 meter wind
C igr = Grid flag
C Parameter values for each grid are:
C
C global_73x144(regular) : NC=144, NR=73, igr=1
C global_288x145(super) : NC=288, NR=145, igr=2
C
C ntau = Number forecast times for a 12-hour watch (1,4)
C idc = Direction convention for output
C = 2 for Meteorological or Compass
C iun = Units convention for output
C = 1 knots
C = 2 meters/sec
C rlong1 = Longitude of subgrid western boundary
C (See Figure in text for grid system)
C Regular grid (-300.0 to 57.5)
C Supergrid (-300.0 to 58.75)
C rlong2 = Longitude of subgrid eastern boundary
C Regular grid (-300.0 to 57.5)
C Supergrid (-300.0 to 58.75)
C rlat1 = Latitude of subgrid northern boundary
C (90.0 to -90.0)
C rlat2 = Latitude of subgrid southern boundary
C (90.0 to -90.0)
C iovrlap = Control parameter to indicate whether subgrid overlaps
C the global grid boundary
C = 1 for no overlap
C = 2 for overlap

INCLUDE 'para125.inc'
PARAMETER (NC=288, NR=145, MC=63, MR=45, ifl=1, igr=2,
1 ntau=4, iun=2, rlong1=-82.5, rlong2=-5.0,
1 rlat1=65.0, rlat2=10.0, iovrlap=2, idc=2)

REAL UCMP(NR, NC), VCMP(NR, NC),
1 U(MR, MC), V(MR, MC), u10cal(5000)

COMMON /WIND/ U, V, idate, itau, u10cal

Appendix D Interfacing Surface Wind Products from IPOPS with WISWAVE and Other Hydrodynamic Models
READ (71,107,end=900) iy,im,id,ih,tau
READ (72,107,end=900) iy,im,id,ih,tau
itc= itc + 1
107    FORMAT(2x,4i2,i4)
IF(ifl .eq. 1) then
  READ (71,′(12f7.4)′) ((UCMP(i,j),j=1,NC),i=1,NR)
  READ (72,′(12f7.4)′) ((VCMP(i,j),j=1,NC),i=1,NR)
ELSE IF(ifl .eq. 2) then
  READ (71,′(1X,10f9.2)′) ((UCMP(i,j),j=1,NC),i=1,NR)
  READ (72,′(1X,10f9.2)′) ((VCMP(i,j),j=1,NC),i=1,NR)
END IF

c **************** regular grid (2.5 deg)*******************************
IF(igr .eq. 1) then
  IF(iovrlap .eq. 1) then
    jlog1= nint((rlong1 + 302.5)/2.5)
    jlog2= nint((rlong2 + 302.5)/2.5)
    ilat1= nint((rlat1 - 90.0)/2.5*(-1.) +1.)
    ilat2= nint((rlat2 - 90.0)/2.5*(-1.) +1.)
  DO 300 i=ilat1,ilat2
    DO 302 j=jlog1,jlog2
      U(i-ilat1+1,j-jlog1+1)=UCMP(i,j)
      V(i-ilat1+1,j-jlog1+1)=VCMP(i,j)
    302    CONTINUE
  300    CONTINUE
  ELSE IF(iovrlap .eq. 2) then
    jlog1= nint((rlong1 + 302.5)/2.5)
    jlog2= nint((rlong2 + 302.5)/2.5)
    ilat1= nint((rlat1 - 90.0)/2.5*(-1.) +1.)
    ilat2= nint((rlat2 - 90.0)/2.5*(-1.) +1.)
  DO 306 i=ilat1,ilat2
    DO 308 j=jlog1,jlog2
      j=jl-log1a+1
      U(i-ilat1+1,j)=UCMP(i,j)
      V(i-ilat1+1,j)=VCMP(i,j)
    308    CONTINUE
  306    CONTINUE
ENDIF

D6 Appendix D Interfacing Surface Wind Products from IPOPS with WISWAVE and Other Hydrodynamic Models
ilat1= nint((rlat1 + 90.)/1.25 + 1.)
ilat2= nint((rlat2 + 90.)/1.25 + 1.)

format(4i8)
DO 301 i=ilat1,ilat2,-1
DO 303 j=jlog1,jlog2
  U((i-ilat1)*(-1)+1,j-jlog1+1)=UCMP(i,j)
  V((i-ilat1)*(-1)+1,j-jlog1+1)=VCMP(i,j)
303 CONTINUE
301 CONTINUE
ELSE IF(iovr).eq. 2) then
  jlog1a= nint((rlong1 + 300.)/1.25 + 1.)
  jlog2a= 288
  jlog1b= 1
  jlog2b= nint((rlong2 + 300.)/1.25 + 1.)
ilat1= nint((rlat1 + 90.)/1.25 + 1.)
ilat2= nint((rlat2 + 90.)/1.25 + 1.)
DO 305 i=ilat1,ilat2,-1
DO 307 j=jlog1a,jlog2a
  jl=j-jlog1a+1
  U((i-ilat1)*(-1)+1,jl)=UCMP(i,j)
  V((i-ilat1)*(-1)+1,jl)=VCMP(i,j)
307 CONTINUE
DO 309 j=jlog1b,jlog2b
  U((i-ilat1)*(-1)+1,j-jlog1b+1+jl)=UCMP(i,j)
  V((i-ilat1)*(-1)+1,j-jlog1b+1+jl)=VCMP(i,j)
309 CONTINUE
305 CONTINUE
END IF
END IF

**** DATE ***********************
ihrtau= ih + itau
if(ihrtau .ge. 24.) then
  frac= real(ihrtau) - 24.0
  ifrac = int(frac)
  ihr= int((frac - real(ifrac)) * 24.0)
  id= id + ifrac
else if(ihrtau .lt. 24.) then
  ihr= ihrtau
end if
idate= iy*1000000 + im*10000 + id*100 + ihr
WRITE(30,*) idate , itau
WRITE(31,*) idate , itau
108 FORMAT(110,i4)
**c convert wind stress to wind speed**

```
IF (ifl .eq. 1) then
    CALL FINDU10
END IF
```

**c units conversion (iun =1 > knots; iun =2 > m/s)*****

**c**

```
V is sometimes in cm/s in which case must divide by 100 to convert to m/s
```

```
IF (iun .eq. 1) then
    DO 200 i= 1,MR
        DO 201 j=1,MC
            U(i,j)=U(i,j)/0.514444
            V(i,j)=V(i,j)/0.514444
        201 CONTINUE
    200 CONTINUE
ELSE IF (iun .eq. 2) then
    DO 400 i= 1,MR
        DO 401 j = 1,MC
            U(i,j)=U(i,j)
            V(i,j)=V(i,j)/1.
        401 CONTINUE
    400 CONTINUE
END IF
```

**c OUTPUT COMP**

```
DO 304 i=1,MR
    WRITE(30,*) (U(i,j),j = 1,MC)
    WRITE(31,*) (V(i,j),j=1,MC)
304 CONTINUE
```

**c CONVERT COMPS TO SPEED & DIRECTION**

```
CALL WINDCON
```

```
900 continue
STOP
END
```
SUBROUTINE WNDCON
  (Steve Bratos December 1992)

  Program converts uv (A58,A59) unadjusted 10 meter wind components in knots or m/s accessed from IPOPS via extwind.f to windspeed (m/s) and direction (compass) for WISWAVE.

  INCLUDE 'para125.inc'

  PARAMETER (NC=63, NR=45, idc=2, ifl=2, igr=2)
  DIMENSION U(MR,MC), V(MR,MC), wspd(MR,MC)

  COMMON /WIND/ U, V, idate, itau, ulOcal

  PI= 3.14159265
  radc= 180.0/PI

  DO 300 i=1,MR
    DO 400 j=1,MC
      wspd(i,j)=(U(i,j)**2+(V(i,j)**2)**.5
      IF( U(i,j) .eq. 0.) then
        U(i,j)= 0.1
      END IF
      IF( V(i,j) .eq. 0.) then
        V(i,j)=0.1
      END IF
      wdir(i,j)=radc*atan(V(i,j)/U(i,j))
      IF(U(i,j) .gt. 0. .and. V(i,j) .lt. 0.) then
        wdir(i,j)= 360. + wdir(i,j)
      ELSE IF(U(i,j) .lt. 0.) then
        wdir(i,j)= 180. + wdir(i,j)
      END IF
    END DO 400
  END DO 300

  WRITE(20,202) idate, itau
  202 FORMAT(iI0,i4)

  DO 500 i=1,MR
    WRITE(20,100) (wspd(i,j), j=1,MC)
    100 FORMAT(32f6.1)
    WRITE(20,101) (wspd(i,j), j=1,MC)
    101 FORMAT(32f6.0)
  END DO 500

  Appendix D Interfacing Surface Wind Products from IPOPS with WISWAVE and Other Hydrodynamic Models
DO 700 i=1,MR
   WRITE(20,101) (wdir(i,j),j=1,MC)
700   CONTINUE

900  continue
RETURN
END
SUBROUTINE FINDU10

          program findu10.f    zeki demirbilek December 1992

This program first computes a matrix that contains the wind speed at 10 m height, U10 values. This is done by creating hypothetical values of ustar. The values of ustar in do 2 loop start with ustar = 0.034 (which corresponds to U10 = 1 m/sec, the lowest wind speed assumed for U10). The largest ustar from do 2 loop is ustar = 5.033 (which corresponds to the U10 = 425 m/sec, the highest wind speed assumed for U10). Note that the basic rule of thumb for relating ustar to U10 is:

ustar = 0.0337 - 0.034 corresponds to U10 = 1 m/sec
ustar = 0.8 corresponds to U10 = 20 m/sec
1.0 < ustar < 2.0 corresponds to U10 > 20 m/sec

To generate U10 values from ustar, the drag coefficient used by Resio in the wiswave.f is used here. This formula when expressed in terms of U10 is given by:

Cd = (1.1 + 0.035 U10) * 0.001
where we define herein:
cof1 = 1.1
cof2 = 0.035
cfact = 0.001
and therefore, expression for Cd becomes

Cd = (cof1 + cof2 * U10) * fact

The formula used for relating U10 to ustar is:

Cd * (U10**2) = ustar**2
or to get ustar, take the sqrt of

ustar = sqrt(Cd) * U10

Substituting this second expression for ustar into the Cd gives a cubic equation given by:

ustar**2 = fact*(cof1 + cof2 * U10) * U10**2

To solve for U10 from this last equation, use Newton-Raphson iteration technique.

zeki demirbilek, December 1992, WINDS WU participation.
include 'paral25.inc'

dimension u10cal(5000),u10(NR,NC)
dimension U(MR,MC),V(MR,MC),strmg(MR,MC)
dimension ustr (MR,MC), ustdr(MR,MC)
c dimension wsnext(200,200)
c dimension wisdr(200,200),wdnext(200,200)

COMMON /WIND/ U,V,idate,itau,u10cal

c set coefficients, limits, and tolerances:
  nustr = 5000
  nustr2 = 2*nustr
  uzero=0.034
  fact = 0.001
  cof1 = 1.1
  cof2 = 0.035
  tol = 1.0e-05
  PI= 3.14159265
  radc=180./PI

c generate "nustr" values of ustar ranging from 0.034 to 5.033,
c in increments of 0.001:
  do 2 j = 1,nustr
    ustar = uzero + fact*(j-1)
    ustar2 = ustar**2
  C begin to solve for U10 iteratively using the Newton-Raphson
  c method:
    ujm1 = ustar2 ! value of u from previous iteration
    uj = ustar2 ! value of u at current iteration
    it = 0 ! index of iterations for Newton-Rapson method
  c define the function and its derivative for Newton-Raphson
  c method:
    1 func = (cof1*fact + cof2*fact * sqrt(ujm1)) * ujm1 - ustar2
    if (abs(func) .gt. tol) then
      deriv = (2.0*cof1*fact)*sqrt(ujm1) + (3.0*cof2*fact)* ujm1
      uj = ujm1 - func / deriv
      ujm1 = uj
      if(it .gt. nustr2) go to 3
      it = it + 1
    c print *,'it =',it, 'uold =',ujm1, 'unew=',uj
    go to 1
    else
      u10cal(j) = sqrt(uj)
    c print *,'it =',it, 'unew=',uj, 'u10cal=',u10cal(j)
endif
continue
write(*,*),'max # of iterations (=10,000)
* in the Newton-Raphson procedure for U1O is reached .

set density of air and tolerance values:
rhoa = 1.225
epss = 1.0e-10

c ++++++++ ustar calculations ++++++++ c
determine ustar: compute ustar values from fnoc stress data
c as:
do 5 i= 1,MR
   do 5 j= 1,MC
      IF( U(i,j) .eq. 0.) then
         U(i,j)= 0.001
      END IF
      IF(V(i,j) .eq. 0.) then
         V(i,j)=0.001
      END IF
      strmg(i,j)=sqrt(U(i,j)**2 + V(i,j)**2) ! (BRATOS 1/93)
      ustr(i,j) = (sqrt(U(i,j)**2 + V(i,j)**2))/rhoa
      ustr(i,j) = sqrt(ustr(i,j))
      c ustar(i,j) = atan2(V(i,j),U(i,j) + epss)
      c ustrdr(i,j)= radc *atan((V(i,j)+epss)/(U(i,j)+epss))
      if(U(i,j) .gt. 0. .and. V(i,j) .lt. 0.) then
         ustrdr(i,j)= 360. + ustrdr(i,j)
      else if( U(i,j) .lt. 0.) then
         ustrdr(i,j)= 180. + ustrdr(i,j)
      end if
   continue

c ++++++++ u10 calculations from ustar values ++++++++ c
match ustar values computed from fnoc stresses to
the calculated u10 values, u10cal. this is done by
determining the index (iustr) that takes ustr(i,j) values and
c relates them to the u10cal(iustr) values:
   umax =0.0
   do 7 i=1,MR
      do 6 j=1,MC
         iustr = 1000*ustr(i,j) - 33
         if (iustr .le. 0)   iustr = 1
         if (iustr .gt. nustr) iustr = nustr
         u10(i,j) = u10cal(iustr)
         wsnext(i,j) = u10(i,j) ! in wiswave notation
         c ---------- convert back to u-v velocity componnets(BRATOS 1/93)
         U(i,j)= u10(i,j) * (U(i,j)/strmg(i,j))
         V(i,j)= u10(i,j) * (V(i,j)/strmg(i,j))
if ul0 needs to be converted to knots (1 knot = 0.5196 m/s), activate the next statement. Remember that wiswave wants ul0 in m/sec.

ul0(i,j) = ul0/0.5196

for information purposes, find max speed for each date

if (ul0(i,j) gt. umax) then
  umax = ul0(i,j)
iout = i
jout = j
endif

continue
continue

+++

formats are:

13 format (i10,i4)
14 format (12f7.4)
15 format(5(12f7.4),3f7.4)
16 format (32f6.1) \same format as read(21,213) \ in wiswave
17 format (32f6.0) \same format as read(21,214) \ in wiswave
18 format (2x,'Idate = ',il0,' lout = ',i4,' Jout = ',i4,' Umax = ',f6.1,' (kt)',' Dir = ',f6.0,' (WIS)')
19 format (//,2x,'Total Dates Processed = ',i10)

RETURN

END
## NDBC Record Format Description

**RECORD NAME**

Meteorology Oceanography & Wave Spectra (File Type "291")

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Position</th>
<th>Length</th>
<th>Attributes</th>
<th>Use and Meaning</th>
</tr>
</thead>
<tbody>
<tr>
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<td>6</td>
<td>1</td>
<td>&quot;291&quot; (constant)</td>
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<td>NAME-IMPOSITION</td>
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<td>NAME-MEANING</td>
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<td>Six characters unique name of observation point</td>
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<td>ENVIRONMENTAL DATA RECORD</td>
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<td>5</td>
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<tr>
<td>ANEMOMETER HEIGHT</td>
<td>27</td>
<td>3</td>
<td>6</td>
<td>XXX - Height above water level or ground (meters to Tenths)</td>
</tr>
<tr>
<td>AIR TEMPERATURE</td>
<td>30</td>
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<td>7</td>
<td>XXXXX - Negative temperatures are preceded by a minus sign adjacent to temperature value Deg C to tenths</td>
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<td>DEW POINT</td>
<td>34</td>
<td>4</td>
<td>8</td>
<td>XXXXX - Degrees C to tenths</td>
</tr>
<tr>
<td>BAROMETER</td>
<td>38</td>
<td>5</td>
<td>9</td>
<td>XXXXX - Reduced to sea level (MB to tenths)</td>
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<tr>
<td>WIND SPEED (AVG) (AVG)</td>
<td>43</td>
<td>4</td>
<td>10</td>
<td>XXXXX - m/sec to hundredths</td>
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<tr>
<td>WIND DIRECTION</td>
<td>47</td>
<td>4</td>
<td>11</td>
<td>XXXXX - Degrees from true North to tenths</td>
</tr>
<tr>
<td>WEATHER</td>
<td>51</td>
<td>1</td>
<td>12</td>
<td>One-character weather code</td>
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<tr>
<td>VISIBILITY</td>
<td>52</td>
<td>3</td>
<td>13</td>
<td>XXXXX - Nautical miles to tenths</td>
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<tr>
<td>PRECIPITATION</td>
<td>55</td>
<td>4</td>
<td>14</td>
<td>XXXXX - Accumulation in millimeters</td>
</tr>
<tr>
<td>SOLAR RADIATION (ATMOSPHERIC)</td>
<td>59</td>
<td>3</td>
<td>15</td>
<td>XXXXX - Langley's/min to hundredths, wave length less than 3.6 microns</td>
</tr>
<tr>
<td>SOLAR RADIATION (ATMOSPHERIC)</td>
<td>62</td>
<td>3</td>
<td>16</td>
<td>XXXXX - Langley's/min to hundredths, wave length from 4.0 to 50 microns</td>
</tr>
<tr>
<td>SIGNIFICANT WAVE HEIGHT*</td>
<td>65</td>
<td>3</td>
<td>17</td>
<td>XXXXX - Corrected for low frequency noise, etc. (meters to tenths)</td>
</tr>
<tr>
<td>AVERAGE WAVE PERIOD*</td>
<td>68</td>
<td>3</td>
<td>18</td>
<td>XXXXX - Seconds to tenths</td>
</tr>
<tr>
<td>MEAN WAVE DIRECTION</td>
<td>71</td>
<td>3</td>
<td>19</td>
<td>XXXXX - Mean direction of dominant waves in whole degrees from true North</td>
</tr>
<tr>
<td>WATER LEVEL</td>
<td>74</td>
<td>4</td>
<td>20</td>
<td>XXXXX - From MLLW reference level, minus sign indicates below MLLW (meters to tenths)</td>
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</table>
### RECORD FORMAT DESCRIPTION

**RECORD NAME**: Meteorology Oceanography & Wave Spectra (File Type "291")

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<th>FROM-TO POSITION</th>
<th>MEASURED LENGTH</th>
<th>ATTRIBUTES</th>
<th>USE AND MEANING</th>
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<th>ATTRIBUTES</th>
<th>USE AND MEANING</th>
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<td>XXXX - Sea surface negative temperatures are preceded by a minus sign adjacent to temperature value - Deg C to hundredths</td>
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<td>PRACTICAL SALINITY (SEA SURFACE)</td>
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<tr>
<td>CONDUCTIVITY (SEA SURFACE)</td>
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<td></td>
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<tr>
<td>DOMINANT WAVE PERIOD*</td>
<td>94 3</td>
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<td></td>
<td>XXX - Seconds to tenths</td>
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<tr>
<td>MAXIMUM WAVE HEIGHT</td>
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<td></td>
<td>XXX - Meters to tenths</td>
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<td>XXX</td>
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<tr>
<td>WIND GUST</td>
<td>103 4</td>
<td></td>
<td></td>
<td>XXXX - Meters/sec to hundredths</td>
</tr>
<tr>
<td>WIND GUST AVERAGE PERIOD</td>
<td>107 2</td>
<td></td>
<td></td>
<td>XX - Seconds</td>
</tr>
<tr>
<td>WIND GUST</td>
<td>109 4</td>
<td></td>
<td></td>
<td>XXXX - Meters/sec to hundredths</td>
</tr>
<tr>
<td>WIND GUST AVERAGE PERIOD</td>
<td>113 2</td>
<td></td>
<td></td>
<td>XX - Seconds</td>
</tr>
<tr>
<td>WIND SPEED (58 MIN AVG)</td>
<td>115 3</td>
<td></td>
<td></td>
<td>XXX - Meters/sec to tenths</td>
</tr>
<tr>
<td>WIND DIRECTION (58 MIN AVG)</td>
<td>118 3</td>
<td></td>
<td></td>
<td>XXX - Whole degrees</td>
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</table>

* Significant wave height, average wave period, and dominant wave period are set to zero when significant wave height is less than 0.15 meters.

### NONDIRECTIONAL WAVE SPECTRA DATA RECORD (RECORD C)

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<tr>
<th>FIELD NAME</th>
<th>FROM-TO POSITION</th>
<th>MEASURED LENGTH</th>
<th>ATTRIBUTES</th>
<th>USE AND MEANING</th>
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<td>FILE DATE</td>
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<td>YMMDD of file generation</td>
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<td>RECORD TYPE</td>
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<td></td>
<td></td>
<td>Always 'C'</td>
</tr>
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<td>STATION</td>
<td>11 6</td>
<td></td>
<td></td>
<td>Six characters unique name of observation point</td>
</tr>
<tr>
<td>OBSERVED DATE</td>
<td>17 6</td>
<td></td>
<td></td>
<td>YMMDD (UTC)</td>
</tr>
<tr>
<td>OBSERVED TIME</td>
<td>23 4</td>
<td></td>
<td></td>
<td>HHHH (UTC) - End of met. data acquisition, rounded to beginning of nearest whole minute</td>
</tr>
<tr>
<td>END OF WAVE DATA ACQUISITION</td>
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<td></td>
<td></td>
<td>HHHH (UTC) - Rounded to beginning of nearest whole minute</td>
</tr>
<tr>
<td>BLANKS COUNT</td>
<td>31 3</td>
<td></td>
<td></td>
<td>X - Number of frequencies on this record</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Shell File buoy.c

```bash
#QSUB -eo
#QSUB -IT 0:10:00
#QSUB -IM 1mw
#QSUB -x
ja
set -vx
cd /u3/h2crozd7/winds/buoys
In 44025.b fort.1
make buoy
buoy
rm buoy.o fort.1
ja -st
```

Program buoy.f

```c
C Program buoy.f  zeki demirbilek Dec 1992
C PROGRAM TO SEARCH FOR WAVE INFORMATION IN
C B-DATA FORMAT
C CONTAINED IN NOAA BUOY INFORMATION (FORMAT
C ESTAB.1/30/91)
C
C DESCRIPTION OF VARIABLES IN THE NOAA BUOY
C RECORD TYPE "B" FILES
C OBTAINED FROM CEDRS RECORDS IS AS FOLLOWS
C IDBUOY = ID OF THE NOAA BUOY (skip first 10 characters
C in the record)
C IDATE = DATE (YYMMDDHHMM)
C IWS = wind speed (average; to hundreths)
C IWD = wind direction (average; deg from true north to
C in tenths)
C IWVHT = significant wave height (meters to tenths)
C IWVPR = average wave period (seconds to tenths)
C IWVDIR = mean wave direction (mean direction of dominant
C waves in whole degrees from true north)
C IWVDPRI = dominant wave period (peak period to tenths)
C IGUST = wind gust speed (m/sec to hundreths)
C IGSTAV = average wind gust period (seconds)
do 100 J=1,98
READ(1,5) IDBUOY,IDATE,IWS,IWD,IWVHT,IWVPR,
*IWVDIR,IWDPRI,IGUST,IGSTAV,JUNK
5 FORMAT(10x,16,I1G,16x,14,14,14x,13,13,13,20x,13,
*6x,14,12,11)
c extract winds information (ZD 12-05-92):
WS=IWS
WS=WS/100.
```
WD=IWD
WD=WD/10.
GUST = IGUST
GUST = GUST/100.
GUSTDR= IGUSTAV
c extract waves information (ZD 12-05-92):
HT=IWVHT
HT=HT/10.
AVPR=IWVPR
AVPR=AVPR/10.
AVDIR = IWVDIR
DOMPR=IDPR
DOMPR=DOMPR/10.
c write information to unit=2 file in the format described below:
if(j.eq.1) then
   write(2,102)
   format(**********)
   write(2,101)idbuoy
   write(2,103)
   format(**********/)
   101 format(‘NOAA BUOY = ’,i5)
   write(2,104)
   format(1x,’DATE’,8X,’Hs’,5X,’Tp’,3X,’Tav’,
   * 3x,’AveDir’,3x,
   * ‘WS’,5X,’WD’,5x,’GustVel’,2x,’GustDir’)
   write(2,105)
   format(13x,(‘m’),3x,(‘sec’),8x,(‘deg’),/)
   endif
WRITE(2,10) IDATE,HT,DOMPR,AVPR,AVDIR,WS,WD,
* GUST,GUSTDR
10 FORMAT(10,2X,F5.2,2X,F4.1,2X,F4.1,2X,F5.1,2X,F6.2,
* 2x,F6.2,2x,F6.2,2x,F6.2)
100 continue
STOP
END
Appendix F
Plotting WISWAVE and Buoy Wave and Wind Information

Shell File plotzd.c

```bash
#QSUB -q prime
#QSUB -eo
#QSUB -lm 4Mw
#QSUB -IT 1:00:00
#QSUB -x
ja
set -vx
cd /u3/h2crozd7/grd25
ln 44004.dat fort.2
ln sta1-25.92 fort.92
make plotzd
plotzd
rm fort.2 fort.92 plotzd.o plotzd.l plotzd
ja -st
#$ set default [h2crozd7.winds]
#$ assign 44004.dat for002
#$ assign sta1-25.92 for092
#$ fort plotzd.f
#$ disl plotzd
#$ run plotzd
#$ del/noconf *.obj;*
#$ del/noconf *.lis;*
```
Program plotzd.f

parameter (ndays = 5, ihrs = 1)
dimension nh(9000),ntpeak(9000),imnt(9000),navang(9000),
*iwsnow(9000),iwdnow(9000)
character*80 hdr

COMMON/bik1/time(9000),LOC(10),wh(9000),
* wp(9000),wh2(9000),wp2(9000)
COMMON/blk3/ide(9000),kdate(9000),ICOM, idbuoy
common/blk4/ht(9000),dompr(9000),avpr(9000),avdir(9000),
*ws(9000),wd(9000),gust(9000),gustdr(9000)
common/blk5/ht2(9000),dompr2(9000),avpr2(9000),avdir2(9000),
*ws2(9000),wd2(9000),gust2(9000),gustdr2(9000)

parameters to be set are: ndays
    ihrs

where

ndays = number of days. this is the same as number of
    plots per page (i.e., ndays =5 means there will be
    5 wave height, 5 wave period, 5 wave dir., etc.
    plots on a given page)

ihrs = number of hourly intervals wiswave model results are
    output
    i.e., ihrs=3 means model results output every 3 hours

READ BUOY DATA: ATTENTION READ NEXT FEW LINES
read buoy data: get "level 2" buoy data from CEDRS. Use buoy.f
program to extract information necessary for comparison
with the wiswave model. The buoy.f program will produce
buoy#.dat file.
use the later as buoy.dat (unit=2) to read buoy information:
    jrb=0
    j = jrb+1
    if(j.eq.1) then
        read(2,102) hdr !read headers
        format(a1)
        read(2,101)idbuoy
        read(2,102)hdr !read headers
        read(2,102) !read blank line
        format(12x,i5)
c read(2,102)hdr !read headers
c read(2,102)hdr !read headers
c read(2,102) !read blank line
c endif
c read(2,10,end=11) HT(j),DOMPR(j),AVPR(j),AVDIR(j),
* WS(j), WD(j),GUST(j),GUSTDR(j)
c FORMAT(12X,F5.2,2X,F4.1,2X,F4.1,2X,F5.1,2X,F6.2,
* 2X,F6.2,2X,F6.2,2X,F6.2)
c the following format was used only for the Dec 1992 storm buoy
c records:
read(2,*,end=11)dum1,dum2,ht(j),dompr(j),ws(j),dum3,
* wd(j),dum4,dum5,dum6,dum7,avdir(j)
go to 90
11 jb =j-1
print *, 'jb = ',jb
c
+++ READ WISWAVE MODEL RESULTS:
c ATTENTION READ NEXT FEW LINES
c ++++
c read wiswave model results: use fort.92 file generated by the
c wiswave model. sort this file and create individual file for
c each station. feed individual station files to this program
c as fort.92:
jrm=0
91 jrm=jrm+1
  j = jrm
  read(92,301,end=111)kdate(j),nht(j),ntpeak(j),imnt(j),
  *navangt(j),iwsnow(j),iwdnow(j)
301 format(5x,i8,lx,3i3,1x,i3,i3,l1x,i3)
  hti2(j)=nht(j)/10.
  dompr2(j)=ntpeak(j)*1.
  avpr2(j)=imnt(j)*1.
  avdir2(j)=navangt(j)*1.
  ws2(j)=iwsnow(j)*1.
  wd2(j)=iwdnow(j)*1.
go to 91
111 jm=j-1
print *, 'jm = ',jm
c
C set plot type parameter, icom:
c icom=1 plot wave heights
c icom=2 plot wave peak period
c icom=3 plot peak wave direction
c icom=4 plot wind speed
c icom=5 plot wind direction
c
ICOM=1

Appendix F  Plotting WISWAVE and Buoy Wave and Wind Information F3
CALL plot1(jb,jm,ndays,ihrs)
STOP
END

C*************************************************************************
C
C SUBROUTINE plot1(jb,jm,ndays,ihrs)
C dimension data1(9000),data2(9000),xdata(9000),ydata(9000),
* ydata2(9000),xdata2(9000),time2(9000)
C
C COMMON/blk1/time(9000),LOC(10),wh(9000),wp(9000),
* wh2(9000),wp2(9000)
C COMMON/blk3/ideate(9000),kdate(9000),ICOM, idbuoy
C common/blk4/ht(9000),dompr(9000),avpr(9000),avdir(9000),
* ws(9000),wd(9000),gust(9000),gustdr(9000)
C common/blk5/ht2(9000),dompr2(9000),avpr2(9000),avdir2(9000),
* ws2(9000),wd2(9000),gust2(9000),gustdr2(9000)
C
C required DISPOP statements:
C call comprs
C call metnam(‘popfil’,6)
C call setdev (6,0)
C call nocheck
C required DISSPLA statements for post processing:
C icom = 1
C if(jb.gt.jm) npts=jb
C if(jm.gt.jb) npts=jm
C loop to draw five plots per page. There will be 5-plots of wave
C heights on a page, 5 plots of periods, 5 for directions, 5 for
C wind speed, and 5 for wind direction. The parameter "icom"
C controls
C plot type:
16 call page (14.0,11.)
C call physor (1.5,9.1)
C call basalf (‘STAND’)
C CALL HEIGHT (.175)
C
C start to plot 5 plots on 1 page: j=1 for first plot on the page
C j=2 for 2nd plot on the page
C j=3 for 3rd plot on the page
C j=4 for 4th plot on the page
C j=5 for 5th plot on the page
C
C The parameter "j" controls the number of plots on a page. The
C number of plots on one page or as many pages necessary
C depends on the number of days buoy and model results are
C available. This may be controlled with the parameter "ndays".

ntot1=0
ntot2=0

Appendix F Plotting WISWAVE and Runw Wave and Wind Information
do 100 J=1, ndays
  c adjust origin for the next plot:
    if(J.ne.1) call orel (0., -1.66)
  c
  c set axes dimensions to be used in the call graf:
    xmax = 24.0*J
    xmin = xmax - 24.0
    call area2L (1.6, 1.11)
    call blsym
    call yaxang (0.0)
  c label axis & set up the graph:
    call xname (' ', 1)
    call xname ('TIME (hrs)', 100)
    call yname (' ', 1)
  c define y-axis label:
    if(icom.eq.1) call yname ('HT(m)', 100)
    if(icom.eq.2) call yname ('TP(s)', 100)
    if(icom.eq.3) call yname ('DR(deg)', 100)
    if(icom.eq.4) call yname ('WS(m/sec)', 100)
    if(icom.eq.5) call yname ('WD(deg)', 100)
  c
  c define min and max values for x- and y-axis and the increments:
    if(icom.eq.1) then
      CALL GRAF(xmin, 3., xmax, 0., 2., 10.)
    endif
  c
    if(icom.eq.2) then
      call graf(xmin, 3., xmax, 0., 6., 24.)
    endif
  c
    if(icom.eq.3) then
      call graf(xmin, 3., xmax, 0., 120., 360.)
    endif
  c
    if(icom.eq.4) then
      call graf(xmin, 3., xmax, 0., 10., 30.)
    endif
  c
    if(icom.eq.5) then
      call graf(xmin, 3., xmax, 0., 120., 360.)
    endif
  c
  c +++++++ Buoy data preparation begins here:
  c create x- and y-values to plot the buoy data over a 5 day
  c period. Plot one day at a time, and therefore, there will
  c be 5 plots per page. Note that buoy data is output hourly
  c (with a 1 hr interval)
    if(j.eq.ndays) then
      n1b = n2b + 1
  c
  Appendix F Plotting WISWAVE and Buoy Wave and Wind Information
n2b = jb
else
  n2b = 24*j
  n1b = n2b - 24 + 1
endif

c
c    prepare buoy data for call curve: note that buoy data is hourly
    so it need not be manipulated in some odd fashion.
c    first prepare the values for time-axis in 1-hour intervals over
c    a day (24-hr) period for plotting. these values will be
c    generated for "ndays" period. note that "ndays" equates to
    "nplots" per page:
xtime=0.0
day = 0.
nhrs = 24*j
do 1000 i=1,nhrs
time(i)=day + XTIME
xtime=xtime+1.0
IF(XTIME.GT.23) then
  xtime = 0.0
day = day + 24.
endif
1000 continue
c
c    start assigning x- (xdata) and y-values (ydata) of buoy
    points to be used in the call curve and determine the number
    of points (idout) call curve asks for:
c
    idout = 0
    do 50 i=n1b,n2b
      idout = idout + 1
      ntotl = ntotl + 1
      xdata(idout)=time(i)
      IF(ICOM.EQ.1) YDATA(idout)=ht(l) !buoy wave heights
      write(88,241) ntotl,idout,time(i),xdata(idout),ydata(idout)
      IF(ICOM.EQ.2) YDATA(idout)=dompr(l) !buoy peak period
      IF(ICOM.EQ.3) YDATA(idout)=avdir(l) !buoy mean direction
      IF(ICOM.EQ.4) YDATA(idout)=ws(l) !buoy wind speed
      IF(ICOM.EQ.5) YDATA(idout)=wd(I) !buoy wind dir.
    50 continue
c
c    ++++++++  Model data preparation begins here:
c    create x- (xdata2) and y-values (ydata2) to plot the model
    results over a five day period. Plot one day at a time,
c    and therefore, there will be 5 plots per page. Note that model
results will be in "ihrs" interval

if(j.eq.ndays) then
    n1m = n2m + 1
    n2m = jm*ihrs
else
    n2m = 24*j
    n1m = n2m - 24 + 1
endif


prepare time-axis for plotting:
xtime=0.0
day = 0.0

c compute time in hourly intervals for the entire number of days.

c note that time will later be made into "ihrs" intervals:

    nhrs =24*j
    do 1020 i=1,nhrs
        time2(i)=day + XTIME
        xtime=xtime+1.0
    IF(XTIME.GT.23) then
        xtime = 0.0
        day = day + 24.0
    endif
1020 continue

c start assigning x- (xdata2) and y-values (ydata2) to be

c used in the call curve:

c
    idout2 = 0
    do 150 i=n1m,n2m,ihrs
        idout2 = idout2 + 1
        ntot2 = ntot2 + 1
        xdata2(idout2)=time2(i)
        if(icom.eq.1) ydata2(idout2)=ht2(ntot2)!model wave heights
        write(88,2411)ntot2,idout2,time2(i),xdata2(idout2),
            *ydata2(idout2)
2411 format ('ntot2 =',i3,2x,'idout2 =',i5,2x,'time2 =',f6.2,
                *xdata2 = ',f6.2,2x, 'ydata2 = ',f6.2)
    if(icom.eq.2) ydata2(idout2)=dompr2(ntot2)!model peak period
    if(icom.eq.3) ydata2(idout2)=avdir2(ntot2)!model ave.dir.
    if(icom.eq.4) ydata2(idout2)=ws2(ntot2)!model wind speed
    if(icom.eq.5) ydata2(idout2)=wd2(ntot2)!model wind dir.
150 continue

idout2=idout2
C    print *,j = *, j, 'n1m = ', n1m, 'n2m = ', n2m,
    *    'idout2 = ', idout2
C
C ++++++++Plot headings and labeling
C define plot headings:
    if(j.eq.1.and.icom.eq.1) then
        call headin('Wave Height Buoy #44014 vs. Wiswave Model$'
        *100,1.26,2)
        call headin('Wave Period Buoy #44014 vs. Wiswave Model$'
        *100,1.12,2)
    endif
C
    if(j.eq.1.and.icom.eq.2) then
        call headin('Wave Period Buoy #44014 vs. Wiswave Model$'
        *100,1.26,2)
        call headin('Days Processed: Dec 10-15 1992; 1.25 Deg Grid$'
        *100,1.12,2)
    endif
C
    if(j.eq.1.and.icom.eq.3) then
        call headin('Wave Direction Buoy #44014 vs. Wiswave Model$'
        *100,1.26,2)
        call headin('Days Processed: Dec 10-15 1992; 1.25 Deg Grid$'
        *100,1.12,2)
    endif
C
    if(j.eq.1.and.icom.eq.4) then
        call headin('Wind Speed Buoy #44014 vs. Wiswave Model$'
        *100,1.26,2)
        call headin('Days Processed: Dec 10-15 1992; 1.25 Deg Grid$'
        *100,1.12,2)
    endif
C
    if(j.eq.1.and.icom.eq.5) then
        call headin('Wind Direction Buoy #44014 vs. Wiswave Model$'
        *100,1.26,2)
        call headin('Days Processed: Dec 10-15 1992; 1.25 Deg Grid$'
        *100,1.12,2)
    endif
C
C ++++++ Call curve to plot the points ++++++++ ++++++++ Call curve to plot buoy data:
    call curve(xdata,ydata,idout,0)
C
C call curve to plot model results:
    call dash
    call curve(xdata2,ydata2,idout2,0)
    call reset('dash')
c place buoy ID below if not wanted in the heading:
c if(j.eq.5) call messag('BUOY NO. = 44014$',
   1100,1.0,-1.0)
c if(j.eq.5.and.icom.eq.1) call messag('Wave Height$',
   1100,1.0,-1.25)
c if(j.eq.5.and.icom.eq.2) call messag('Peak Period$',
   1100,1.0,-1.25)
c if(j.eq.5.and.icom.eq.3) call messag('Mean Direction$',
   1100,1.0,-1.25)
c if(j.eq.5.and.icom.eq.4) call messag('Wind Speed$',
   1100,1.0,-1.25)
c if(j.eq.5.and.icom.eq.5) call messag('Wind Direction$',
   1100,1.0,-1.25)
c idate(1) = 1992
if(j.eq.5) call messag('DAYS PROCESSED: SEP 1-4
   *$',100,1.00,-1.75)
c if(j.eq.5) call intno(idate(1),3.917,-1.75)
c place plot labels after the last plot on a page. define the
 c positions (start and end points) and symbol types for plot
 c labels:
 if (j.eq. 5) then
call strtpt(5.,-1.)
call connpt(6.,-1.)
call messag('BUOY',100,6.2,-1.)
call dash
call strtpt(5.,-1.25)
call connpt(6.,-1.25)
call messag('WISWAVE (with wind stress)',100,6.2,-1.25)
call reset('dash')
endif
call endgr(0)
nread = nread + 1
100 continue
c stop individual plots on each page and terminate device
   ICOM=icom+1
call endpl(0)
if(ICOM.le.5) go to 16
 CALL DONEPL
 RETURN
dend
Appendix G
WISWAVE and NDBC Buoy Comparisons, Buoy 44014, 1-4 Sep 92

Figure G1. Significant wave height, 2.5-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)
Figure G2. Peak wave period, 2.5-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)

Figure G3. Peak wave direction, 2.5-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)
Figure G4. Wind speed, 2.5-deg grid; buoy (solid line), Navy surface wind (dashed line)

Figure G5. Wind direction, 2.5-deg grid; buoy (solid line), Navy surface wind (dashed line)

Appendix G WISWAVE and NDB Buoy Comparisons, Buoy 44014, 1-4 Sep 92
Figure G6. Significant wave height, 1.25-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)

Figure G7. Peak wave period, 1.25-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)
Figure G8. Peak wave direction, 1.25-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)

Figure G9. Wind speed, 1.25-deg grid; buoy (solid line), Navy surface wind (dashed line)
Figure G10. Wind direction, 1.25-deg grid; buoy (solid line), Navy surface wind (dashed line)

Figure G11. Significant wave height, 1.25-deg grid; buoy (solid line), WISWAVE with Navy wind stress (dashed line)
Figure G12. Peak wave period, 1.25-deg grid; buoy (solid line), WISWAVE with Navy wind stress (dashed line)

Figure G13. Peak wave direction, 1.25-deg grid; buoy (solid line), WISWAVE with Navy wind stress (dashed line)
Figure G14. Wind speed, 1.25-deg grid; buoy (solid line), Navy wind stress (dashed line)

Figure G15. Wind direction, 1.25-deg grid; buoy (solid line), Navy wind stress (dashed line)
Appendix H
WISWAVE and NDBC Buoy Comparisons, Buoy 44025, 1-4 Sep 92

Figure H1. Significant wave height, 2.5-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)
Figure H2. Peak wave period, 2.5-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)

Figure H3. Peak wave direction, 2.5-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)
Figure H4. Wind speed, 2.5-deg grid; buoy (solid line), Navy surface wind (dashed line)

Figure H5. Wind direction, 2.5-deg grid; buoy (solid line), Navy surface wind (dashed line)

Appendix H WISWAVE and NDBC Buoy Comparisons, Buoy 44025, 1-4 Sep 92
Figure H6. Significant wave height, 1.25-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)

Figure H7. Peak wave period, 1.25-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)
Figure H8. Peak wave direction, 1.25-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)

Figure H9. Wind speed, 1.25-deg grid; buoy (solid line), Navy surface wind (dashed line)

Appendix H WISWAVE and NDBC Buoy Comparisons, Buoy 44025, 1-4 Sep 92
Figure H10. Wind direction, 1.25-deg grid; buoy (solid line), Navy surface wind (dashed line)

Figure H11. Significant wave height, 1.25-deg grid; buoy (solid line), WISWAVE with Navy wind stress (dashed line)

Appendix H WISWAVE and NDBC Buoy Comparisons, Buoy 44025, 1-4 Sep 92
Figure H12. Peak wave period, 1.25-deg grid; buoy (solid line), WISWAVE with Navy wind stress (dashed line)

Figure H13. Peak wave direction, 1.25-deg grid; buoy (solid line), WISWAVE with Navy wind stress (dashed line)
Figure H14. Wind speed, 1.25-deg grid; buoy (solid line), Navy wind stress (dashed line)

Figure H15. Wind direction, 1.25-deg grid; buoy (solid line), Navy wind stress (dashed line)
Appendix I
WISWAVE and NDBC Buoy Comparisons, Buoy 44014, 10-14 Dec 92

Figure 11. Significant wave height, 2.5-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)
Figure 12. Peak wave period, 2.5-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)

Figure 13. Peak wave direction, 2.5-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)
Figure 14. Wind speed, 2.5-deg grid; buoy (solid line), Navy surface wind (dashed line)

Figure 15. Wind direction, 2.5-deg grid; buoy (solid line), Navy surface wind (dashed line)

Appendix I WSWAVE and NDBC Buoy Comparisons, Buoy 44014, 10-14 Dec 92
Figure 16. Significant wave height, 1.25-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)

Figure 17. Peak wave period, 1.25-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)
Figure 18. Peak wave direction, 1.25-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)

Figure 19. Wind speed, 1.25-deg grid; buoy (solid line), Navy surface wind (dashed line)

Appendix I WISWAVE and NDBC Buoy Comparisons, Buoy 44014, 10-14 Dec 92
Figure 110. Wind direction, 1.25-deg grid; buoy (solid line), Navy surface wind (dashed line)

Figure 111. Significant wave height, 1.25-deg grid; buoy (solid line), WISWAVE with Navy wind stress (dashed line)
Figure 112. Peak wave period, 1.25-deg grid; buoy (solid line), WISWAVE with Navy wind stress (dashed line)

Figure 113. Peak wave direction, 1.25-deg grid; buoy (solid line), WISWAVE with Navy wind stress (dashed line)
Figure 114. Wind speed, 1.25-deg grid; buoy (solid line), Navy wind stress (dashed line)

Figure 115. Wind direction, 1.25-deg grid; buoy (solid line), Navy wind stress (dashed line)
Appendix J
WISWAVE and NDBC Buoy Comparisons, Buoy 44025, 10-14 Dec 92

Figure J1. Significant wave height, 2.5-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)
Figure J2. Peak wave period, 2.5-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)

Figure J3. Peak wave direction, 2.5-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)
Figure J4. Wind speed, 2.5-deg grid; buoy (solid line), Navy surface wind (dashed line)

Figure J5. Wind direction, 2.5-deg grid; buoy (solid line), Navy surface wind (dashed line)
Figure J6. Significant wave height, 1.25-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)

Figure J7. Peak wave period, 1.25-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)
Figure J8. Peak wave direction, 1.25-deg grid; buoy (solid line), WISWAVE with Navy surface wind (dashed line)

Figure J9. Wind speed, 1.25-deg grid; buoy (solid line), Navy surface wind (dashed line)
Figure J10. Wind direction, 1.25-deg grid; buoy (solid line), Navy surface wind (dashed line)

Figure J11. Significant wave height, 1.25-deg grid; buoy (solid line), WISWAVE with Navy wind stress (dashed line)
Figure J12. Peak wave period, 1.25-deg grid; buoy (solid line), WISWAVE with Navy wind stress (dashed line)

Figure J13. Peak wave direction, 1.25-deg grid; buoy (solid line), WISWAVE with Navy wind stress (dashed line)
Figure J14. Wind speed, 1.25-deg grid; buoy (solid line), Navy wind stress (dashed line)

Figure J15. Wind direction, 1.25-deg grid; buoy (solid line), Navy wind stress (dashed line)
Winds over the ocean surface are the essential driving force in creating waves. Winds also have important effects on currents and nearshore water levels. Wind information is often used within the Corps of Engineers (CE) as input to numerical models of waves, storm surges, and circulation. The National Oceanic and Atmospheric Administration (NOAA) and the U.S. Navy routinely produce global wind information. Recent advances in atmospheric modeling capabilities and operational numerical models, particularly within the Navy, have made available new and improved products applicable to CE hydrodynamic modeling. Available products from NOAA and the Navy are described, including both climatological archives and real-time forecasting products. Interfaces to assist CE users in obtaining and using the Navy products are presented. Sources of surface wind (10-m elevation) information of greatest potential value for CE modeling are evaluated using the wave model WISWAVE and NOAA National Data Buoy Center measurements along the U.S. Atlantic coast. Necessary tools are provided and recommendations are given for further evaluation and use of Navy wind information in future modeling efforts.