Experimental Numerical Wave Prediction for The Northwest Atlantic Coastal Waters

Yung Y. Chao

National Centers for Environmental Predictions
National Weather Service, NOAA, USA

Abstract

Based on the WAM model, a multiple grids wave forecasting system has been developed for the Atlantic coast of the United States. Input winds to drive the system are derived from NCEP global atmospheric model for the coarse grid and the regional atmospheric model for fine grids. The system runs twice daily producing up to 36 hour forecasts. A preliminary comparison of model products with buoy measurements has shown reasonable agreement between the two. However, some defects of the model in the treatment of wave propagation, wave transformation and boundary values specification are detected.

1 Introduction

A wave forecasting system has been developed for the east coast of the United States and the Gulf of Mexico. The general objective of this system is to complement predictions of the present operational global wave model for the coastal areas. Since the present global model has a grid resolution of 2.5° by 2.5° , the resulting predictions can hardly describe wave conditions over the coastal areas in sufficient detail. A particular objective is to use this east coast model as a base to provide forecast guidance for selected locations along the east coast and the gulf coast where detailed description of wave fields are required. A specific example was that of providing forecast guidance for the Yachting Venue of the 1996 Summer Olympic Games off Savannah, Georgia.

In order to satisfy the abovementioned objectives within the constraint of computational economy and computer memory, it seems that a model which is capable of handling multiple grids system should be used. Furthermore, in view of frequent occurrence of hurricane and extra-tropical cyclone that affect the east coast and the gulf areas, the wave model must be able to provide adequate description of the sea state under rapidly varying weather conditions. In addition, consideration should also extend to its treatment of the effects of water depth as well as ocean currents on the transformation of surface waves. At present, the WAM model seems to be the closest to the requirements. The capabilities of the WAM model have been assessed in SWAMP(1985), SWIM (1985), WAMDI (1988) and Komen et al (1994). In fact, the model is currently being used at NCEP as the operational tool in global scales to make forecasts of the sea state. Therefore, the model is also used to develop an east coast regional wave forecast system.

In what follows, we describe first the forecasting system which has been developed. We then present the verification of predicted wave and wind parameters against buoy measurements for the month of July 1996, during which a few interesting events occurred.

2 The Wave Forecasting System

The system employs the WAM model Cycle-4 version software package (Günther, Hasselmann and Janssen, 1991). The model solves the energy balance equation for the frequency-direction surface wave spectrum. We have assumed that the water surface elevation is not a function of time and there are no currents involved (e.g., ignoring the existence of the Gulf Stream). Thus, the physics of the energy balance equation involves mainly spherical propagation, depth refraction, bottom dissipation, wind forcing, white capping, and wave-wave interactions.

The system consists of three grid systems named A-, B-, and C-grid. The A-grid has a grid size of 1° by 1°. It covers the Atlantic Ocean from latitude 78° S to 78° N and from longitude 100° W to 35° E. The purpose of this grid is to simulate swell which may propagate to the area of interest from the far north and far south of the ocean. It also serves to provide boundary conditions for the B-grid. The B-grid extends from 98° W to 65° W and from 15 ° N to 45° N. It covers the east coast, the Gulf of Mexico and the northern portion of the Caribbean Sea. The purpose of including the Caribbean Sea is to simulate hurricane waves generated in the region entering the gulf through the Yucatan Channel. The grid size is 1/4° by 1/4 °. A C-grid area specified, expands from land to 76° W and from 25° N to 35° N stretching from the tip of Florida to Cape Hatteras enclosing the Savannah waters. The grid resolution is 1/12° by 1/12°. The prognostic part of the wave spectrum has 25 frequencies and 12 directions (30° resolution) for all grid systems. The frequency is determined according to the logarithmic scale: $f(m)=1.1f(m-1)$, where f, is the frequency, m is the band number of the frequency. Thus with the minimum frequency (corresponding to the first frequency band) of 0.042 Hz, the maximum is 0.411 Hz. The computational time step for the source term is the same as the propagation term. For A-grid, the time step is 20 minutes. For B- and C-grid, 5 minutes and 2 minutes are used, respectively.

The required input data includes water depth and wind fields. The gridded depth fields are derived from bathymetry data of 5-minute grid-spacing obtained from the National Geophysical Data Center. Input wind fields, at 10 meters above the mean sea level, are obtained at three hour intervals from NCEP's operational atmospheric models: the global Avn-T126 model (Kanamitsu,et al. 1991) specified at one degree intervals for A-grid and the regional meso-Eta model which has a grid resolution of 29 km (Black,1994) for B- and C-grids.

The system runs twice daily after wind data from Avn model run at 00Z (and 12Z) and from Eta model run at 03Z (and 15Z) are obtained. Each cycle produces up to 36 hour forecasts at three hour intervals. For A-grid, a 12 hours hindcasting is performed by using analyzed wind fields to provide initial wave field for forecasting.

3 Result of Forecasts for July 1996

Trial operational runs of the system involving all three grids has been made. An evaluation of the model's performance against buoy measurements for July 1996 is chosen to present in this section since a few momentous events which caused concern with sea states occurred during the month. First, Hurricane Bertha swept through the east coast in middle July. Second, TWA Flight 800 crashed off the Long Island coast on the 17th. Finally, the yacht race of the 1996 Summer Olympics took place off the Savannah coast in July 22-August 2.

Figure 1 shows the time series plots of the wind speed(spd), wind direction(dir), significant wave height(Hs) and peak wave period (Tp) measured at NDBC buoy station 41004 and corresponding parameters at the same location from B-grid model (denoted as "egc") output for 24 hour forecast. Buoy 41004 is located offshore from the Summer Olympic site for yacht racing. The rise of high waves shown in the time series corresponds to the time when Hurricane Bertha swept over the east coast. Figure 2 shows the scatter plots and some error statistics for the same parameters. These statistics include the root mean square error (rms), mean bias error(bis), correlation coefficient(cor), and scatter index (sci) derived based on available number of data points denoted as " ndp". Similar displays for NDBC buoy station 44025 are shown in Fig. 3 and Fig. 4. Buoy 44025 is located off the Long Island southern shore near the location where the TWA Flight 800 crash occurred at about 00Z, July 18th (corresponding to 8 o'clock p.m. July 17th local time). In general, as can be seen from these figures, the model wave height agrees with the observed trend, even though model wind speed seems slightly over predicted, particularly when the hurricane was nearby. The model wave periods, however, are lower than observed most of the time.

Figure 5 shows 24 hour forecast of wave pattern, including the wave height contour, and mean wave period and direction, over the Savannah waters, in response to the hurricane Bertha generated wind field. The circular pattern of wave direction and low wave height in the vicinity of the hurricane center can be clearly observed. Figure 6 shows 24 hour forecast of wave pattern over the New York Bight for July 18th 00Z. The significant wave height near the airplane crash site is less than one meter and is consistent with measurement at nearby NDBC buoy 44025. Forecast waves propagate northward, with a mean period of about 5 seconds or so.

4 Concluding Remarks

A trial operational run of a forecast system developed based on the WAM model has been made. The result of a comparison of model output against buoy measurement has shown that the system, in general, can produce adequate sea state forecasts for the east coast of the United States.

Some defects in the model, however, have been detected. Although figures which indicate these problematic areas will not be shown in the present paper, the problems may be briefly summarized as follows.

(1) Near the boundary of a fine grid model, the wave height may show a zigzag pattern.

(2) When there are persistent north-south or west-east winds, peculiar streak - like wave height patterns occur along these dirctions.

(3) In water of limited depth, the wave height is usually over estimated.

In order to enhance reliability of the model, certain improvement and modification of numerical schemes relevant to the treatment of problematic areas may be needed. The concerned numerical schemes may include schemes such as boundary value interpolation, directional wave energy spreading and advection, depth refraction, as well as wave energy dissipation, and wave-wave energy transfer in shallow water.

References

Black, T.L.,1994: The New NMC mesoscale eta model: Description and forecast examples. *Wea. Forecasting,* **9**,265-278.

Kanamitsu, M., J.C. Alpert, K.A. Campana, P.M. Caplan, D.G. Deaven, M. Iredell, B. Katz, H.-L. Pan, J.Sela and G.H. White, 1991: Recent Changes Implemented into the Global Forecast System at NMC. *Wea. Forecasting,* **6**, 425-435.

Komen, G.J., L.Cavaleri, M. Donelan, K. Hasselmann, S. Hasselmann and P.A.E.M. Janssen, 1994: "Dynamics and Modeling of Ocean Waves", Cambridge University Press, Cambridge. 532 pp.

SWAMP group, 1985:An intercomparison study of wind wave prediction model, part 1: Principal results and conclusions, in:Ocean wave modeling; Plenum, New York, 256 pp.

SWIM group, 1985: Shallow water intercomparison of wave prediction models(SWIM). *Quart J. Roy. Meteor. Soc.* **111**, 1087-1113.

WAMDI group, 1988: The WA model - a third generation ocean wave prediction model. *J. Phys. Oceanogr,* **18**, 1775 -1810.

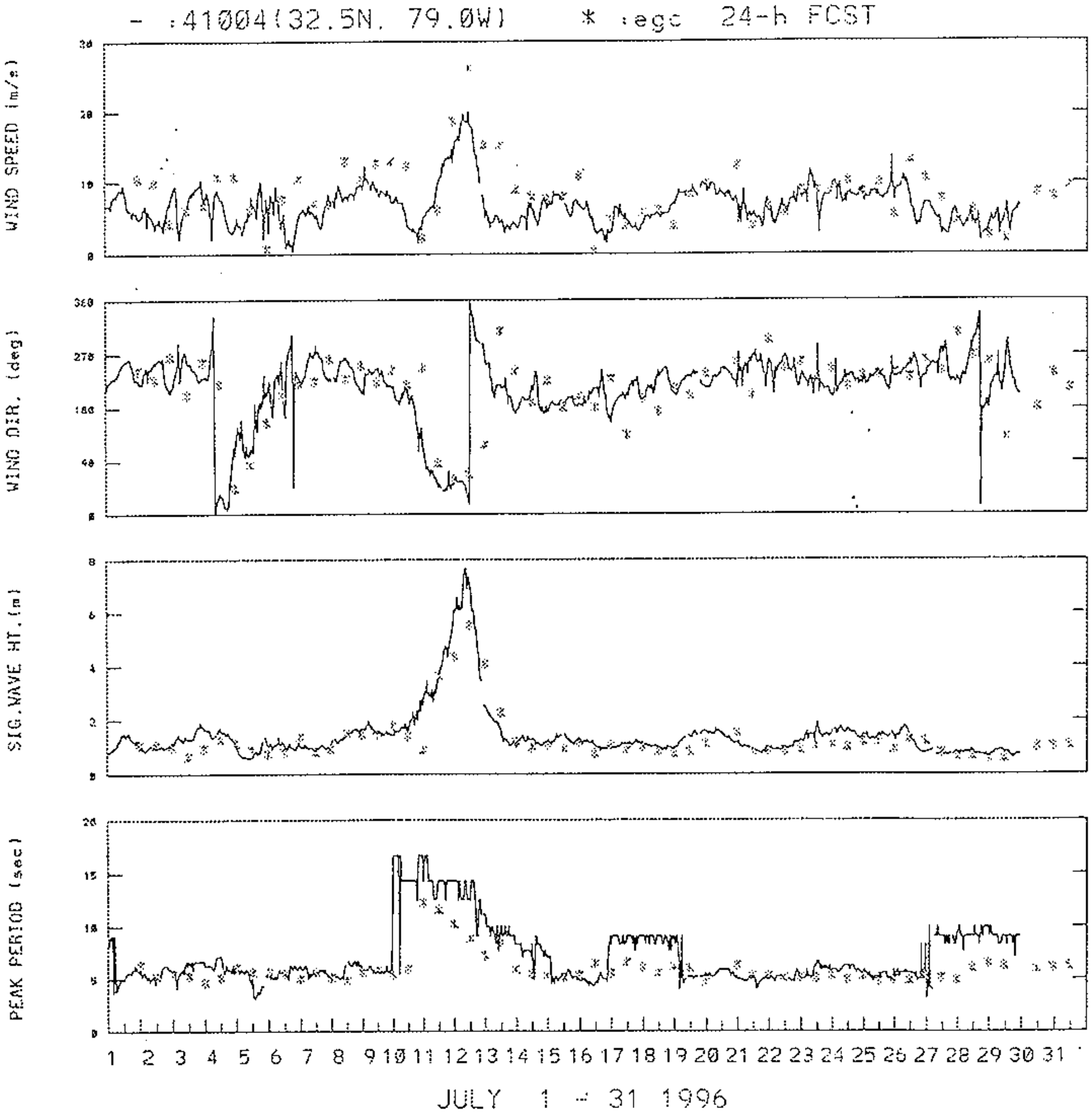


Fig. 1 Time series of wind and wave parameters of 24-hr model forecasts(* mark) and Buoy measurements(solid line)for July 1996 at NDBC station 41004.

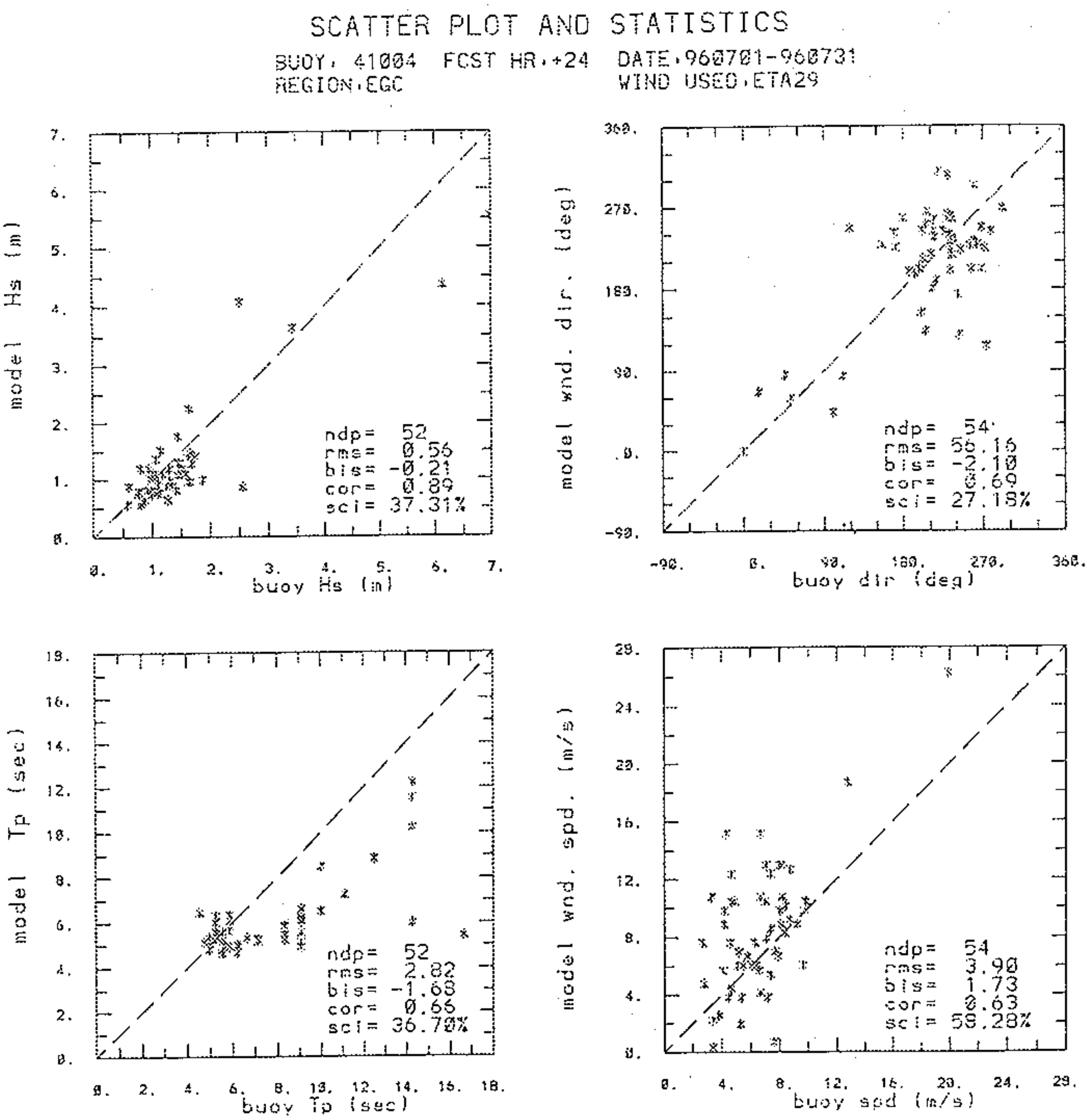


Fig. 2 Scatter plots and statistics corresponding to Fig.1 data.

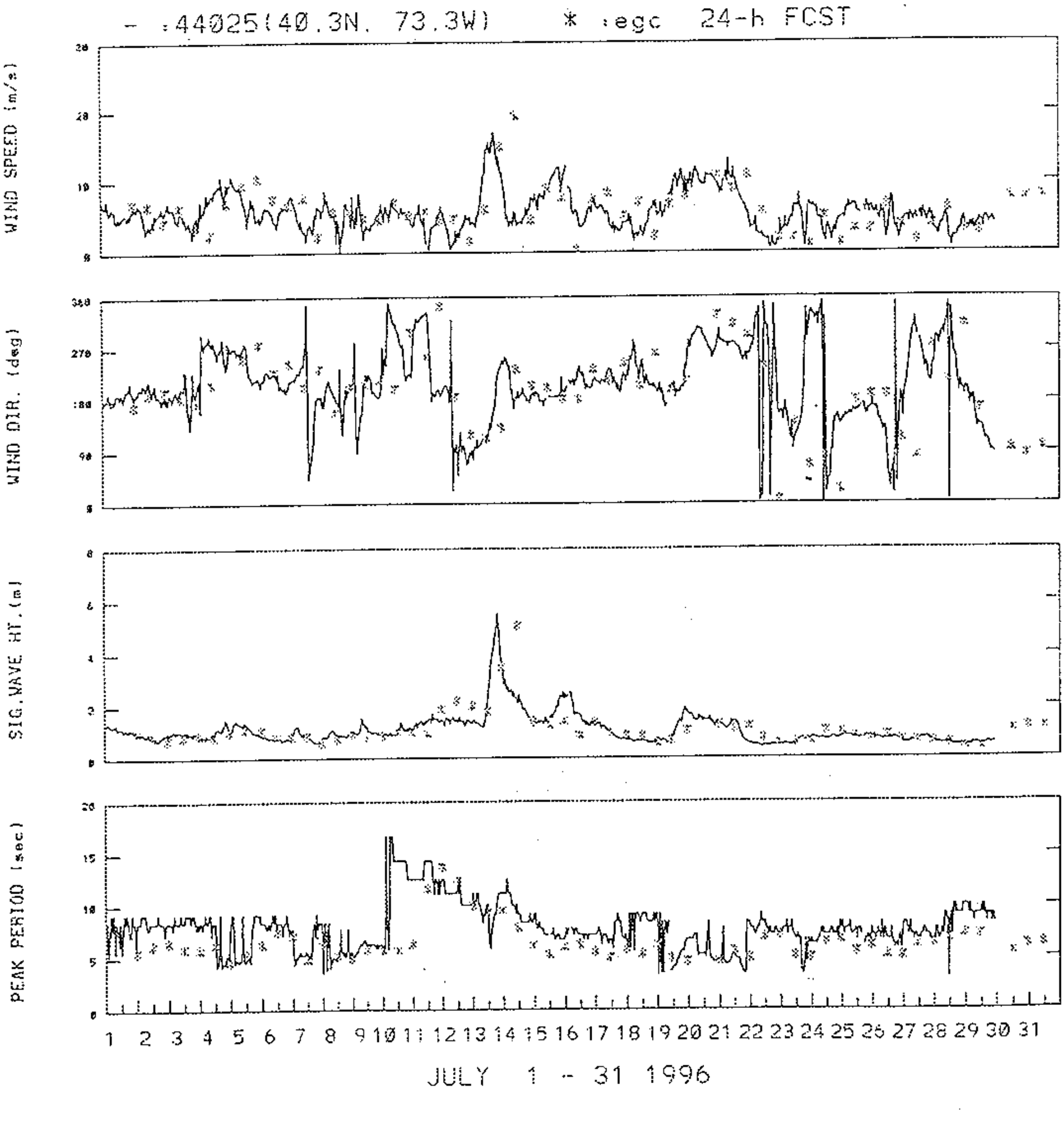


Fig. 3 Time series of wind and wave parameters of 24-hr model forecasts(* mark) and buoy measurements(solid line)for July 1996 at NDBC station 44025.

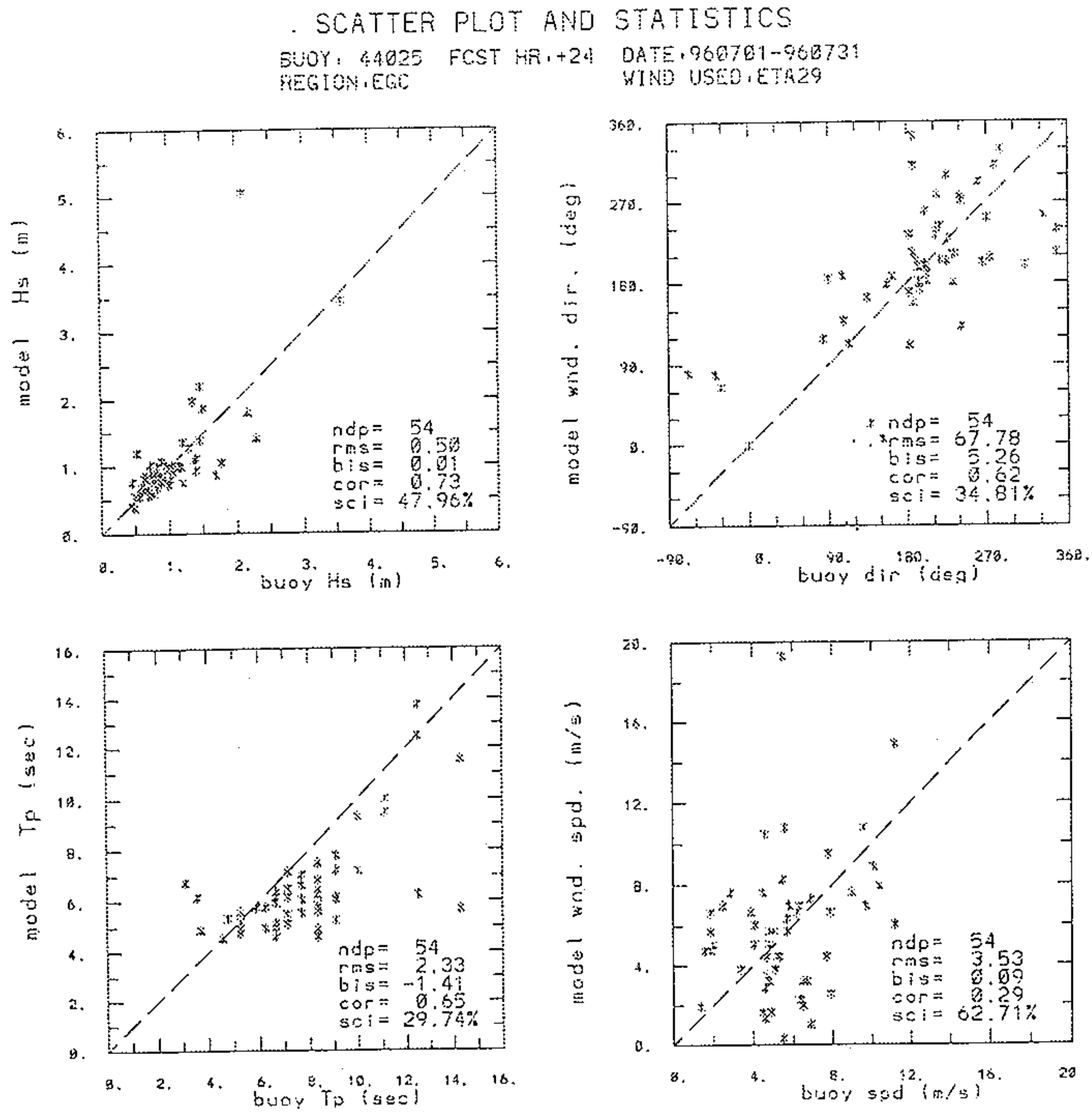


Fig. 4 Scatter plots and statistics corresponding to Fig.3 data.

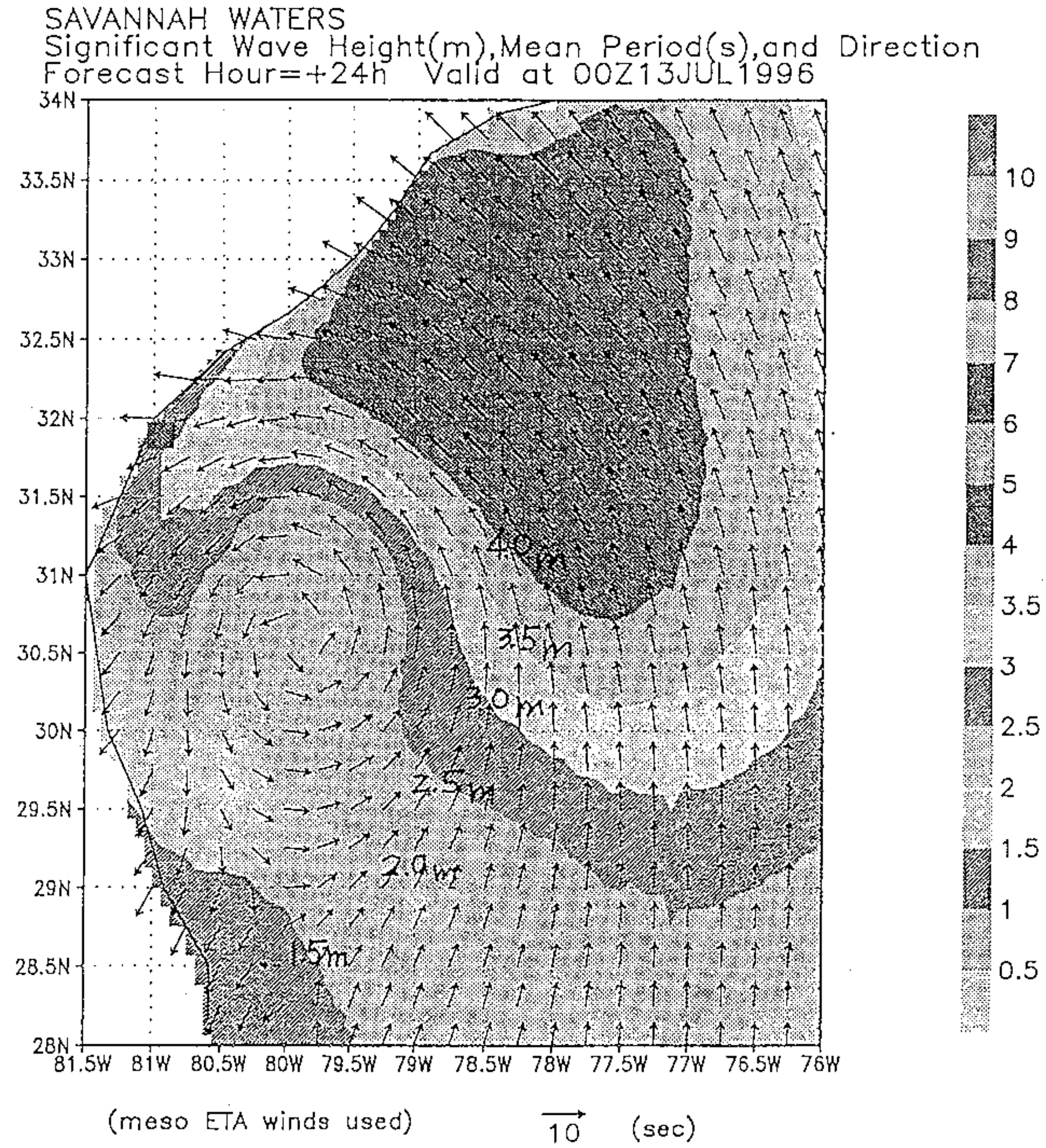


Fig. 5 An example of 24-hr forecast of wave pattern caused by Hurricane Bertha.

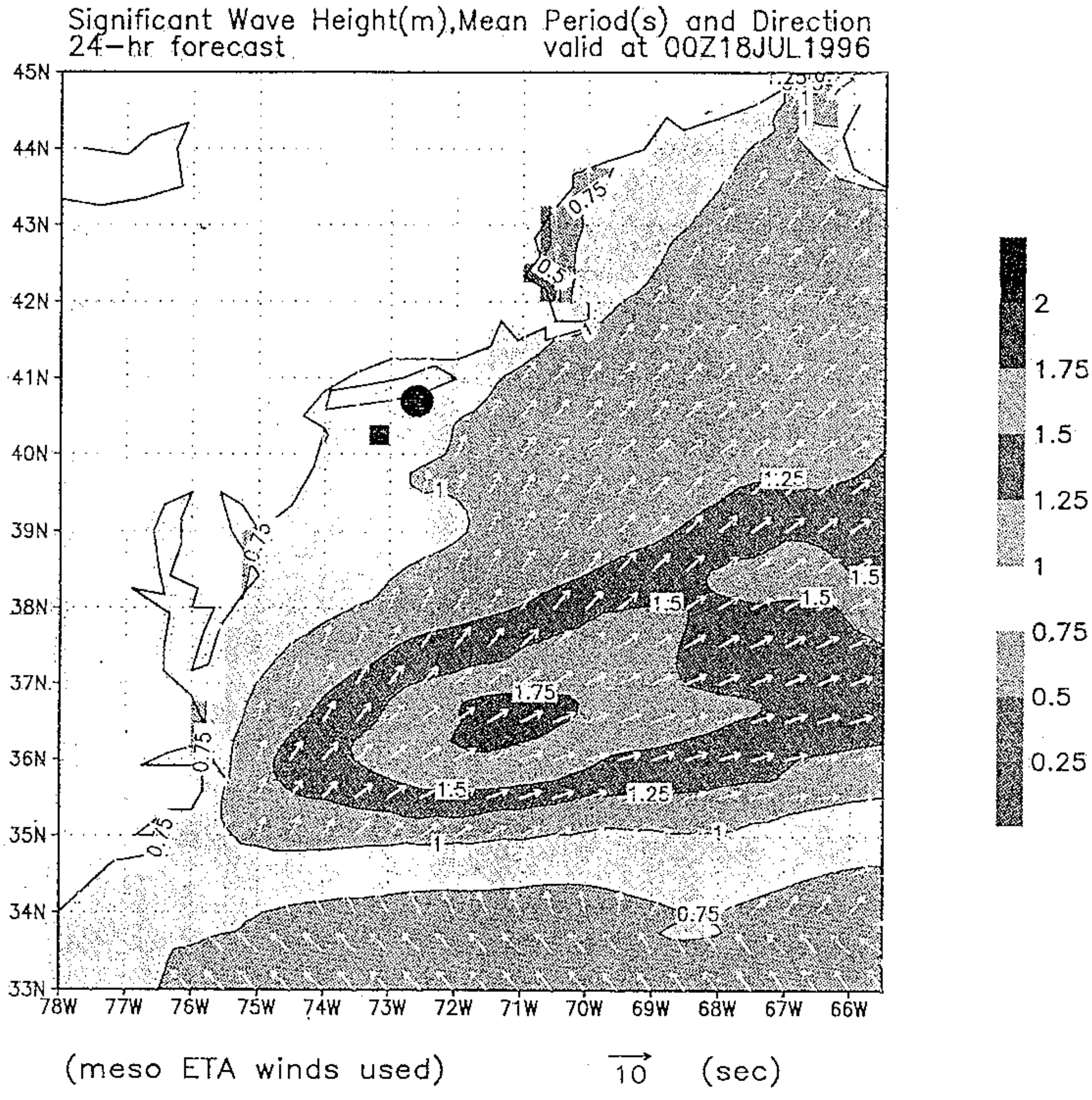
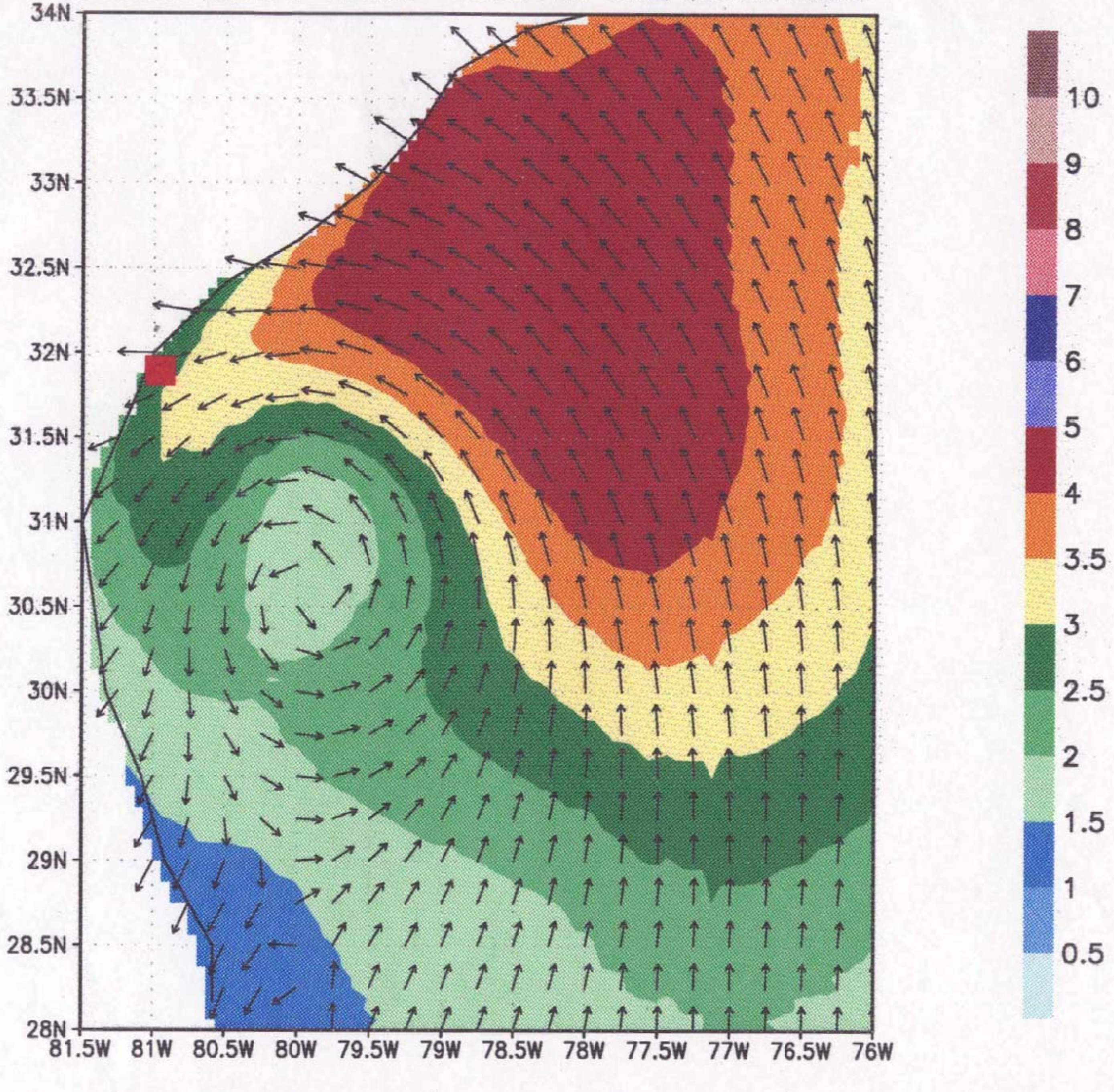


Fig. 6 24-hr forecast of wave pattern over the New York Bight for July 18,00Z(local time July 17, 8:00 P.M.). Solid circle: Plane crash site, Solid square: NDBC buoy 44025.

SAVANNAH WATERS
Significant Wave Height(m),Mean Period(s),and Direction
Forecast Hour=+24h Valid at 00Z13JUL1996



(meso ETA winds used) 10 (sec)

1997-1-3