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The Gulf of Alaska Regional Wave Model

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FIRST BULLETIN ON THIS SUBJECT

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This bulletin, written by Yung Y. Chao of the Marine Prediction Branch, Development Division, National Meteorological Center (NMC), describes the structure and performance of a new operational regional ocean wave forecast model for the Gulf of Alaska.

The model runs twice daily by using wind data derived from aviation runs of the NMC global atmospheric model. Model outputs for the projection hours 0, 12, 24, 36 and 48 are transmitted to the NWS Forecast Office in Anchorage in Gridded Binary (GRIB) format on NMC Storage Grid 214 (polar stereographic, 47.625 km grid size). Transmitted data include the significant wave height of wind-sea and swell combined, the period and direction associated with the peak energy component of the directional spectrum, the significant wave height, the mean period and mean direction of swell, and the mean period of wind sea. The model performance has been evaluated by means of statistical error analyses by using National Data Buoy Center (NDBC) buoy wave measurements as the standard of reference. Indications are that the model can provide good quality guidance forecasts.

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THE GULF OF ALASKA REGIONAL WAVE MODEL[1]

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1. INTRODUCTION

Accurate forecasts of wave conditions over the open oceans in general, and the coastal areas in particular, are required for the safety and efficiency of recreational and commercial activities at sea.

Currently, the National Weather Service (NWS) has one spectral wave model routinely forecasting wave conditions on the global oceans, including the Gulf of Alaska. It is the National OOceanic and Atmospheric Administration Wave Model (NOAA/WAM) (Chen 1995). This model provides 72-h forecasts, and the spectrum is described by 25x12 discrete frequency-direction spectral components at each of about 7,000 grid points. The grid mesh is 2.5 by 2.5 degrees in latitude and longitude, extending from 67.5°S to 77.5°N. The NOAA/WAM is a third-generation wave model[3].

Questions concerning the adequacy of using this model's output as guidance for realistic forecasts of wave conditions in the Gulf have been raised by concerned marine forecasters. Since it is designed to predict general wave patterns of the global-scale ocean, the output of this model cannot be accurate enough to describe small-scale, regional wave phenomena. Furthermore, this model only predicts waves in deep water. Waves near the coastal areas, where most human activities are concentrated, cannot be predicted by this model. The effects of bottom conditions on wave growth, transformation, and dissipation are excluded from its model formulations.

As a part of NMC's continuing effort to improve and extend wave forecasting capability over the coastal areas of the United States, a second generation[4], regional spectral ocean wave model applicable for both deep and shallow waters of the Gulf of Alaska was implemented April 19, 1994.

2. MODEL CHARACTERISTICS

The Gulf of Alaska regional wave model (GAK) solves a spectral energy balance equation involving wave growth by winds, refraction by bottom bathymetry, energy loss due to whitecapping and bottom friction, and parameterized wave-wave energy transfer. The structure of the wave model is essentially the same as the one that is currently operational for the Gulf of Mexico (Chao 1991). However, unlike the Gulf of Mexico which can be considered as an enclosed basin, the Gulf of Alaska is open to the Pacific Ocean. In this model, the effect of waves incoming from the Pacific is treated as the input boundary condition obtained from the NOAA/WAM.

A grid mesh of 30 by 30 n mi has been established for the Gulf region extending from 53°N to 61°N and 132°W to 155°W. A total of 30x18=540 grid points is required to cover the area. The grid points in the outer portion of the Gulf are overlaid on the global model grid points of 2.5 by 2.5 degree resolution in latitude and longitude. Wave spectra forecasts by the NOAA/WAM in this boundary zone at 3-h intervals

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[1] For a detailed description of the model structure and forecast performance, see Chao (1993).

[2] OPC Contribution No. 84

[3] A third generation wave model uses the most updated wave dynamics in wave generation, wave dissipation, and nonlinear energy transfer with no limitation on wave growth.

[4] A second generation wave model uses dynamics in wave generation, but the nonlinear energy transfer mechanism is over-simplified, and the wave growth is artificially limited by the Joint North Sea Wave Project (JONSWAP) spectrum (SWAMP Group 1985).

are interpolated and weighted linearly onto the regional grid in the boundary zone such that a smooth transition from 100% global wave data at the outer most grid points to 100% regional wave data at inner most grid points is achieved.

The model forecasts directional frequency spectra in 12 directional bands and 20 frequency bands. The computational time step is 30 minutes. It runs twice daily using winds at 10 m above sea surface deduced from the lowest sigma layer winds of the AVN. Each run begins with a 12-h hindcast which is followed by a 48-h forecast.

The gridded output from the model includes:

1. The significant wave height, peak energy direction and period of wind-sea and swell combined for all grid points at 0, 12, 24, 36, and 48 hours.

2. The significant wave height, mean period and direction of swell for all grid points at 0, 12, 24, 36, and 48 hours.

3. The significant wave height, mean period and direction of wind sea for all grid points at 0, 12, 24, 36, and 48 hours.

4. Directional spectra and the above wave parameters at selected grid points at 3-h intervals for verification and/or providing input boundary conditions for the site specific local wave models.

5. Directional spectra at all grid points at 0 hours to provide initial data for next cycle run.

From these output, items 1, 2, and the mean period of the wind sea for the projection hours 0, 12, 24, 36, and 48 are packed into the World Meteorological Organization GRIB code and transmitted to the NWS Forecast Office in Anchorage through a high speed telecommunication line where it is converted to various products for use in Alaska. It is not available anywhere else or by any other means.

3. FORECAST PERFORMANCE EVALUATION

As shown in Fig. 1, there are several data buoys which have been deployed in or near the Gulf of Alaska. Buoys No. 46001 and No. 46003 are operated by the National Data Buoy Center (NDBC), while the rest belong to the Canadian Atmospheric Environment Service, Marine Data Unit. Wind and wave data were acquired from these buoys during the period April 1, 1993, through September 30, 1993. From Buoy 46001, which is located near the center of the Gulf (56.3°N, 148.2°W), about 80% of the expected data were obtained while less than 30% were retrieved from the rest. These buoys were either in maintenance or in repair for most of the time period. The present statistical evaluation of the model performance, therefore, is made mainly from data obtained at Buoy 46001.

A statistical error analysis was performed on the significant wave height model output by using buoy measurements as the standard of reference. For the regional wave model, wave heights are taken from the grid point nearest to the buoy location. For the global wave model, wave heights are determined by interpolating the values from the surrounding four grid points. The evaluation was done by using the NOAA Ocean Wave (NOW) model which was the predecessor to the NOAA/WAM. The NOW model is a second generation wave model.

Since no single statistical index can provide a complete description of model performance, a series of statistical indices were calculated for this study. The indices consisted of the mean bias error (*BIAS*), root mean square error (*RMS*), correlation coefficient (*CR*), and scatter index (*SI*). A least squares regression analysis was also made to determine the best fit linear equation of the scatter diagram. Fig. 2 shows scatter diagrams of forecast and measured significant wave heights at 12, 24, 36, and 48 hours. As expected, the longer the projection hour, the less skill exhibited by the model. However, the level of skill is reasonably high.

The accuracy of the wave model forecast is strongly affected by the accuracy of the forecast wind, initial wind and wave conditions, and input wave data from the global wave model in the boundary zone. Figs. 3 and 4 show scatter diagrams for the wind speed and the wind direction, respectively, at the same projection hours as given in Fig. 2. As shown in Fig. 3, the correlation between forecast and measured wind speeds was not as high in Fig. 2; the *CR* at 12 hours was 0.83, while at 48 hours, the value dropped to 0.63. In contrast, as shown in Fig. 4 in which the minus sign on the *BIAS* indicates that the angle is measured counterclockwise from north, the forecast wind direction agrees better with the measurement. Though there was an increase in the amount of deviation of model forecasts from measurements as the projection time increased, the trend was not as strong as that of the wind speed. The *RMS* error in the wind direction at 12 hours was 17°, while the maximum value was 48° at 48 hours. These results indicate that the global atmospheric model may not be able to forecast the wind speed adequately over the Gulf of Alaska.

It is well known that the wind conditions in the Gulf of Alaska are quite complex due to the effects of existing steep mountains and extensive glaciers along the coast. A regional wind model capable of taking this special orographic influence into account may be necessary.

In Fig. 5, initial wind and wave conditions used in the wave model (for 0 hours) are shown. In general, the estimated wind speeds tended to be slightly higher than measured values. However, a *RMS* of less than 2 m/s, and a *CR* of as high as 0.93 indicate that the initialization procedure is adequate. The initial wave conditions, which are hindcast products of the analyzed wind field alone, without undergoing any data assimilation procedure, were slightly higher than measurements and were consistent with the trend of the analyzed wind speeds. Fig. 6 shows the results of the statistical analysis at buoy 46001 for the NOW model. In comparison with Fig. 2, it is obvious that the performance by the regional wave model was much better than the NOW model over the area of interest.

4. CONCLUDING REMARKS

The performance of NMC's Gulf of Alaska regional wave forecast model, implemented in April 1994, has been evaluated against buoy measurements for the months from April 1993 to September 1993. For up to 48-h forecasts, the *BIAS* of the significant wave height was 0.26 m, the *RMS* was 0.65 m, the *CR* was 0.85, and the *SI* was 0.3. In view of various factors affecting the accuracy of wave model forecasts, the results are considered to be acceptable.

The major factor that affects the accuracy of wave forecasts is input winds. The global atmospheric model which supplies the required wind input for the wave model does not have the required spatial resolution to treat complex orographic effects. Another factor that might contribute to the problem is the deficiency of the boundary wave condition provided by the global wave model, though its effect on the inner part of the Gulf of Alaska may not be significant.

The evaluation of model performance made in this report will continue. Further improvement of the model is possible. The following tasks are being undertaken toward achieving this goal:

1. Collect more verification data to reduce sampling variability and provide more definite results in a statistical sense. The results may also be used to tune the wave model.

2. Test wind products from regional atmospheric models, such as the Eta model, for possible improvement of the wind input to the wave model.

3. Assimilate wave data obtained from European Research Satellite 1 (ERS-1) altimeter, buoys, ships, and other surface marine observations into the wave model during the hindcasting stage.

5. REFERENCES

Chao, Y. Y., 1991: The Gulf of Mexico spectral wave forecast model and products. *Technical Procedures Bulletin*, No.381, National Weather Service, NOAA, U.S. Department of Commerce, 4 pp. [Available from the Office of Meteorology, NWS, Silver Spring, MD 20910.]

______, 1993: Implementation and evaluation of the Gulf of Alaska regional wave model. *OPC Technical Note*, National Weather Service, NOAA, U.S. Department of Commerce, 30 pp. [Available from the Development Division, NMC, Washington, D.C. 20233]

Chen, H. S., 1995: Ocean surface waves. *Technical Procedures Bulletin*, No. 426, National Weather Service, NOAA, U.S. Department of Commerce, 17 pp. [Available from the Office of Meteorology, Silver Spring, MD 20910]

The SWAMP Group, 1985: *Ocean Wave Modeling*. Plenum Press, New York, 256 pp.

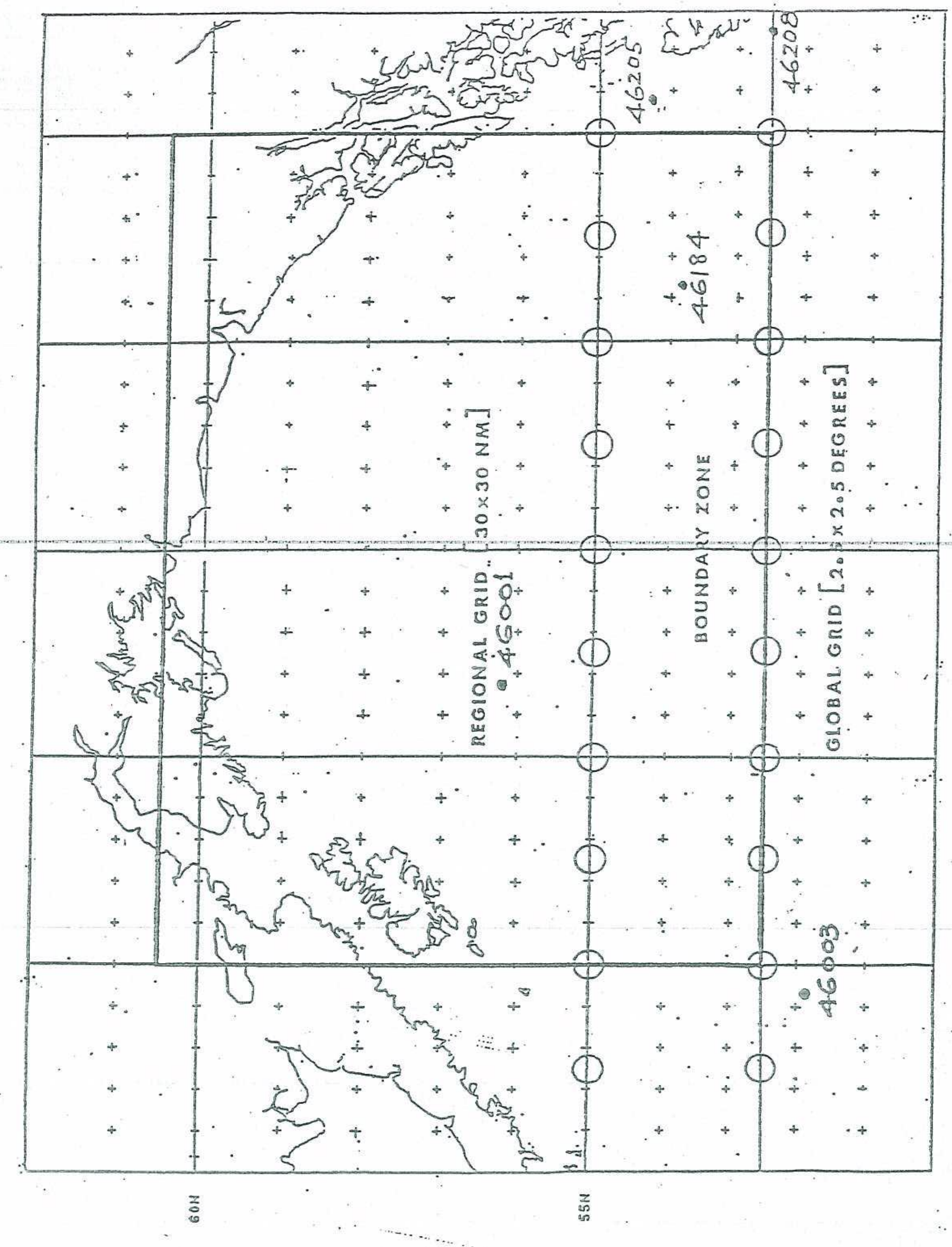


Figure 1. Area of interest.

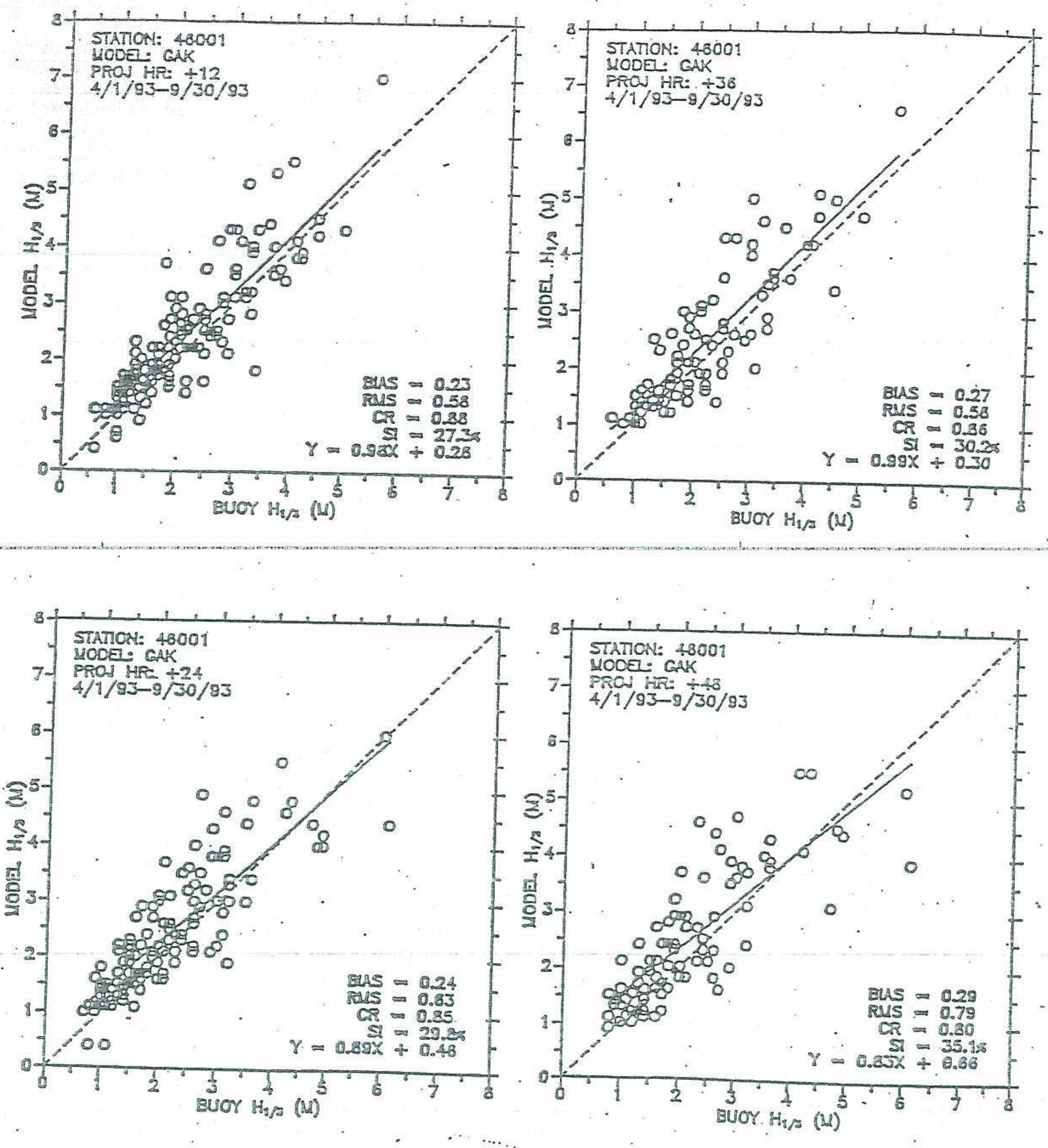


Figure 2. Scatter diagrams of GAK model forecast and buoy measured significant wave heights at Buoy 46001 for four projection hours.

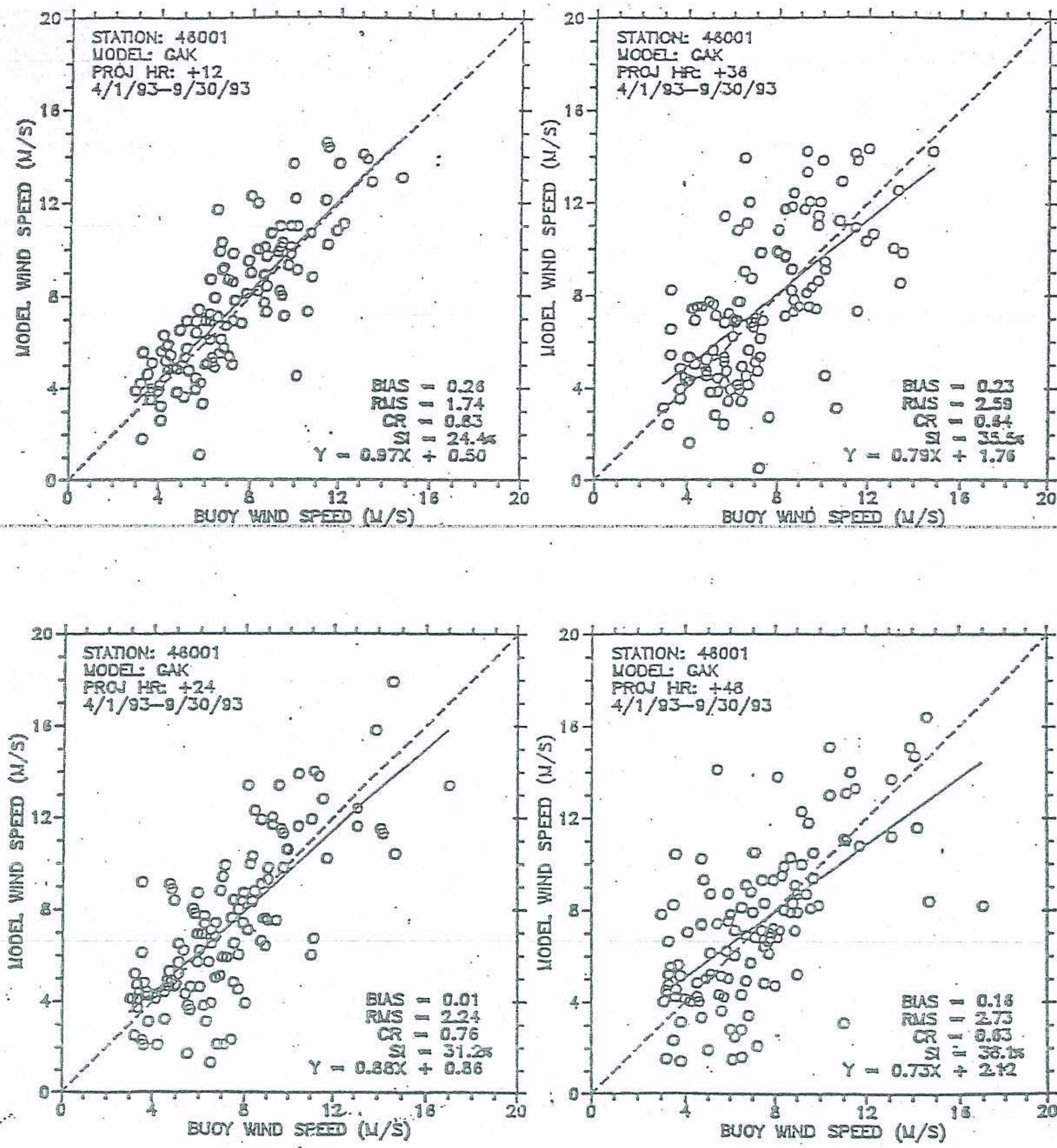
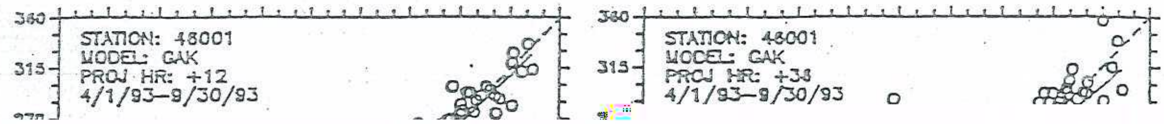


Figure 3. Scatter diagrams of model forecast and buoy measured wind speeds at Buoy 46001 for four projection hours.



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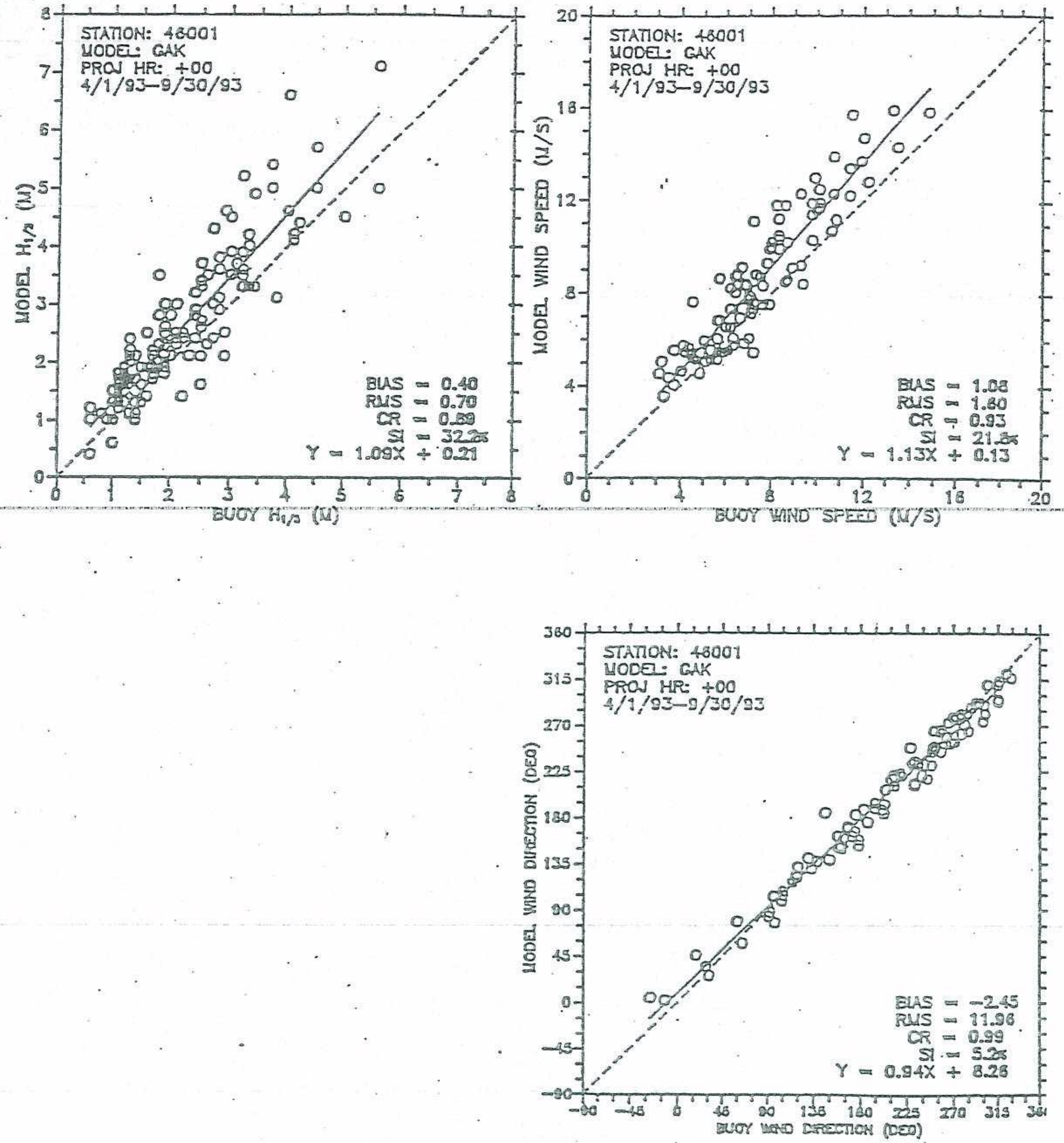

Figure 5. Scatter diagrams of the initial wave and wind conditions of the GAK model and buoy measurements at Buoy 46001.

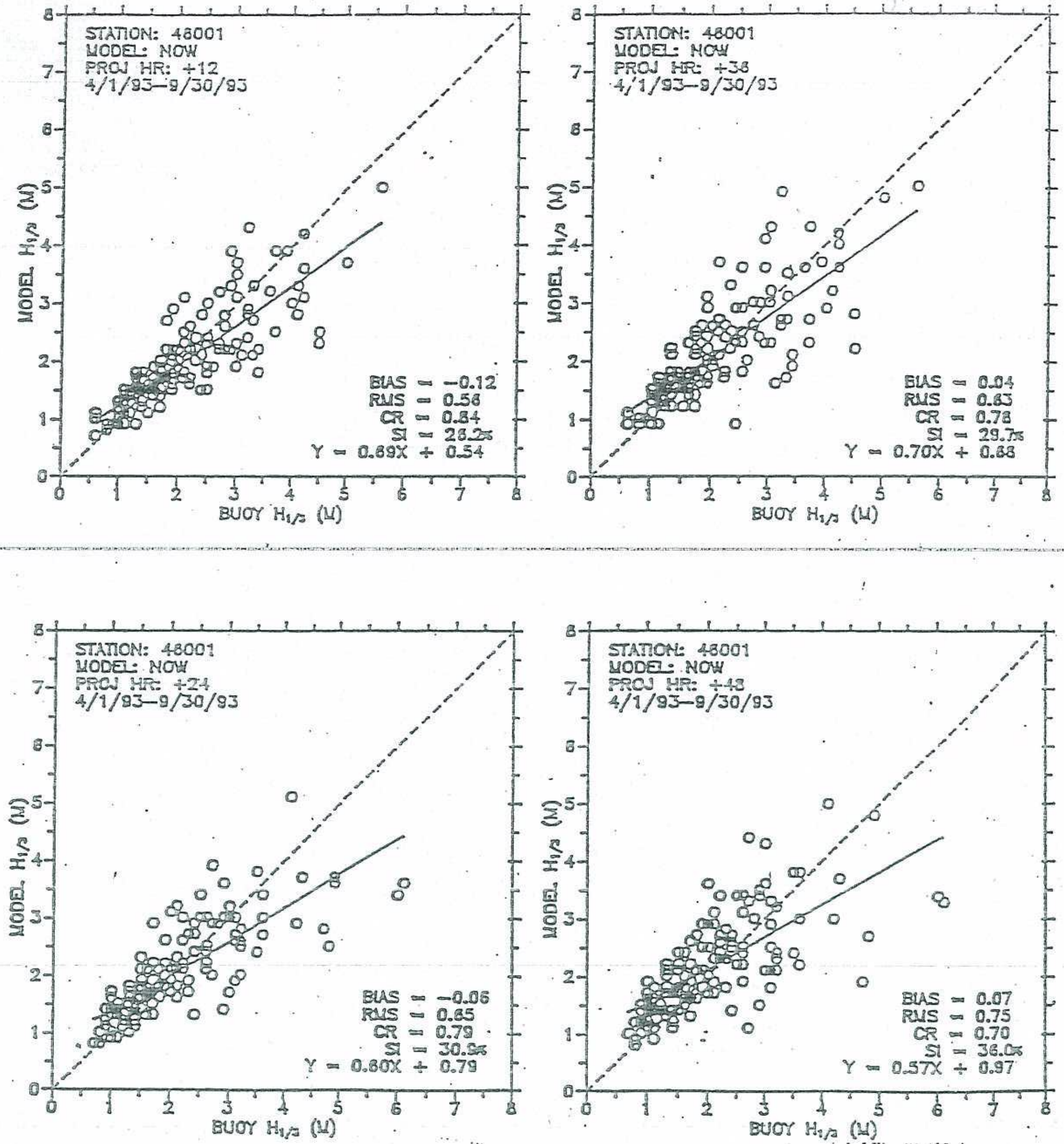

Figure 6. Scatter diagrams of NOW model forecast and buoy measured significant wave heights at buoy 46001 for four projections.