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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
OCEAN PRODUCTS CENTER

TECHNICAL NOTE*

OCEAN PRODUCTS CENTER PRODUCTS REVIEW SUMMARY FOR 1988

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OPC CONTRIBUTIONS

No. 1. Burroughs, L. D., 1986: Development of Forecast Guidance for Santa Ana Conditions. National Weather Digest, Vol. 12 No. 1, 8pp.

No. 2. Richardson, W. S., D. J. Schwab, Y. Y. Chao, and D. M. Wright, 1986: Lake Erie Wave Height Forecasts Generated by Empirical and Dynamical Methods -- Comparison and Verification. Ocean Products Center Technical Note, 23pp.

No. 3. Auer, S. J., 1986: Determination of Errors in LFM Forecasts Surface Lows Over the Northwest Atlantic Ocean. Ocean Products Center Technical Note/NMC Office Note No. 313, 17pp.

No. 4. Rao, D. B., S. D. Steenrod, and B. V. Sanchez, 1987: A Method of Calculating the Total Flow from A Given Sea Surface Topography. NASA Technical Memorandum 87799., 19pp.

No. 5. Feit, D. M., 1986: Compendium of Marine Meteorological and Oceanographic Products of the Ocean Products Center. NOAA Technical Memorandum NWS NMC 68, 93pp.

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No. 7. Burroughs, L. D., 1987: Development of Open Fog Forecasting Regions. Ocean Products Center Technical Note/NMC Office Note. No. 323., 36pp.

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No. 9. Auer, S. J., 1987: Five-Year Climatological Survey of the Gulf Stream System and Its Associated Rings. Journal of Geophysical Research, Vol. 92, No. C11, pp11,709-11,726.

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OCEAN PRODUCTS CENTER
PRODUCTS REVIEW SUMMARY FOR 1988

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ABSTRACT

This report is a summary of the performance evaluation of selected operational marine weather and oceanographic products produced by the OPC through calendar year 1988. It also gives information about changes to existing products or procedures and about new products.

INTRODUCTION

The Ocean Products Center (OPC) conducts a review of the performance of operational products on a monthly basis. This report summarizes the CY 1988 performance statistics for selected products. It is designed to give information about the quality of the guidance products, changes in the products or in the procedures used to produce them, and new products implemented during the year. This is the first of a series of reports that will be issued annually. When appropriate, some case studies will also be included in these reports.

The report is divided into four sections. There is a section that details significant changes in product generation methods. The next section introduces new products. The third section gives statistical information. Currently, only information about the open ocean wind and wave products and about ice accretion is given. Eventually statistical data on other products will be included in future reports as the data are developed. The last section presents two case studies that show how the wind and wave products performed in specific instances. For a full description of the structure of the OPC and the suite of products produced see Feit (1989).

CHANGES IN PRODUCTS

Marine Meteorology

After an extensive evaluation the operational boundary layer winds, which were based on the boundary layer model of Cardone (1978), were replaced with the Aviation Model's (Sela, 1988) lowest sigma layer winds reduced to 20 m by assuming a log profile in a neutrally stable constant flux surface layer. The Cardone model was heavily tuned to eliminate a negative bias problem, but the tuning was done during the summer season; when the season changed more tuning was necessary (see Fig. 1). The evaluation showed the lowest sigma layer winds reduced to 20 m did better than those from the Cardone method and didn't have a problem with seasonal changes, *i.e.* did not require constant tuning. The change took place in May. In September the wind depiction on AFOS was changed from streamlines and isotachs to wind barbs at gridpoints as requested by the field (Fig. 2).

The ice accretion forecasts were extended to all the Northern Hemispheric polar regions in April when the Marine Significant Weather Chart came on line.

Ocean Waves

In May the wind input to the NOAA Ocean Wave (NOW) model was changed, and Cardone' s algorithm was replaced with a simpler one which reduced the lowest sigma layer winds to 20 m with a logarithmic profile. The NOW Model (Esteva, 1989) is a second generation global spectral ocean wave model valid only in deep water. This model is essentially based on Cardone's formulation (Greenwood *et. al.*, 1985).

Evaluation of the NOW model forecasts against buoys showed them to have a high bias. It was determined that the swell portion of the spectra was not being properly attenuated, thus a swell attenuation term was introduced in August. The result was to reduce the bias to about 0.5 m.

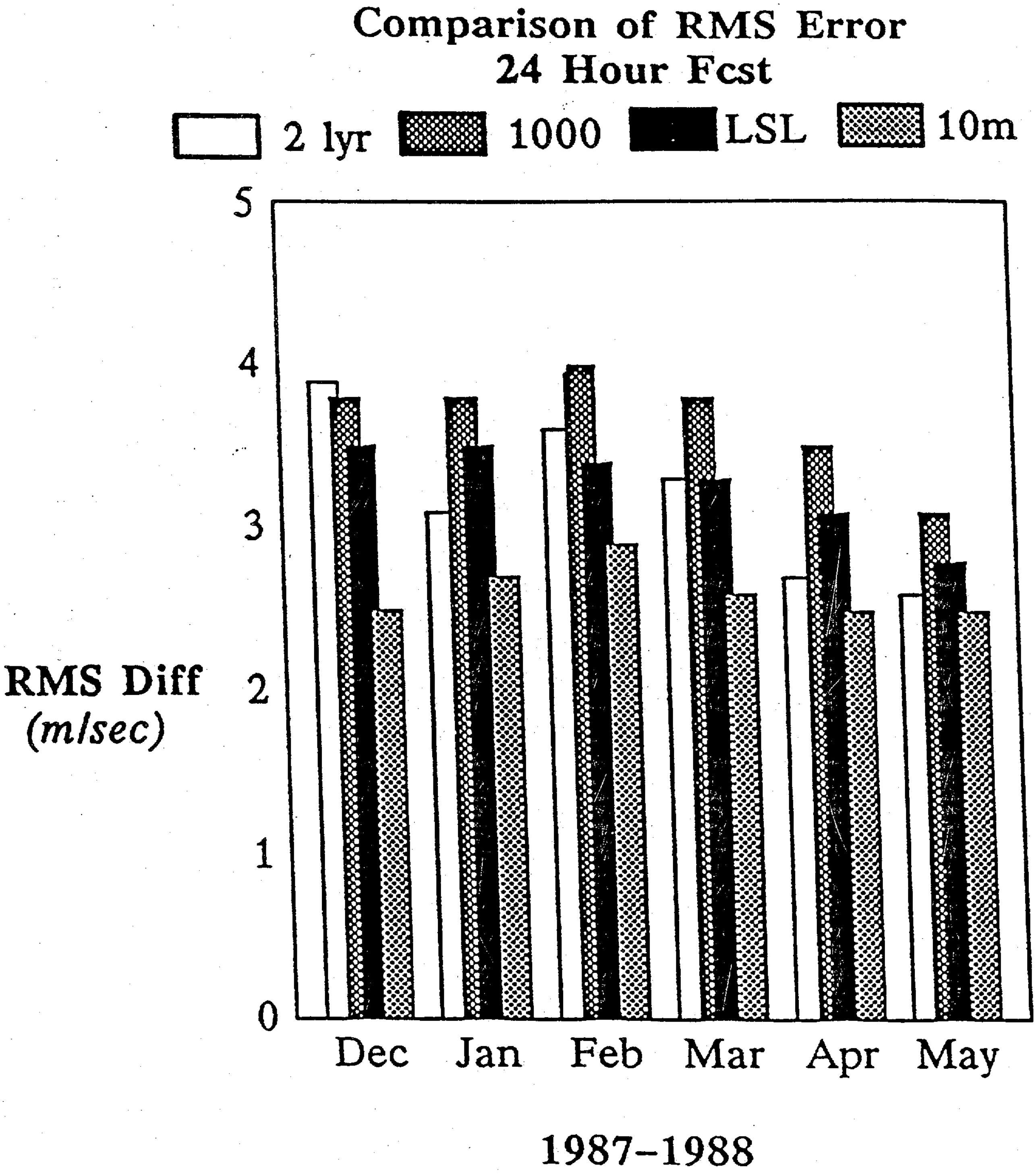

Figure 1: Comparison of RMS errors for the 24-h forecast wind against buoy observations. The 1000 is the 1000 mb wind out of the Aviation Model, the LSL is the MRF lowest sigma layer wind, the 10m is the lowest sigma layer wind of the MRF reduced to 10 m, and the 2 lyr is the Cardone boundary layer wind. The operational wind changed from the Cardone method to the lowest sigma layer wind reduced to 10 m in May. Note that in all months shown, the Cardone wind had consistantly higher RMS errors than the 10m.

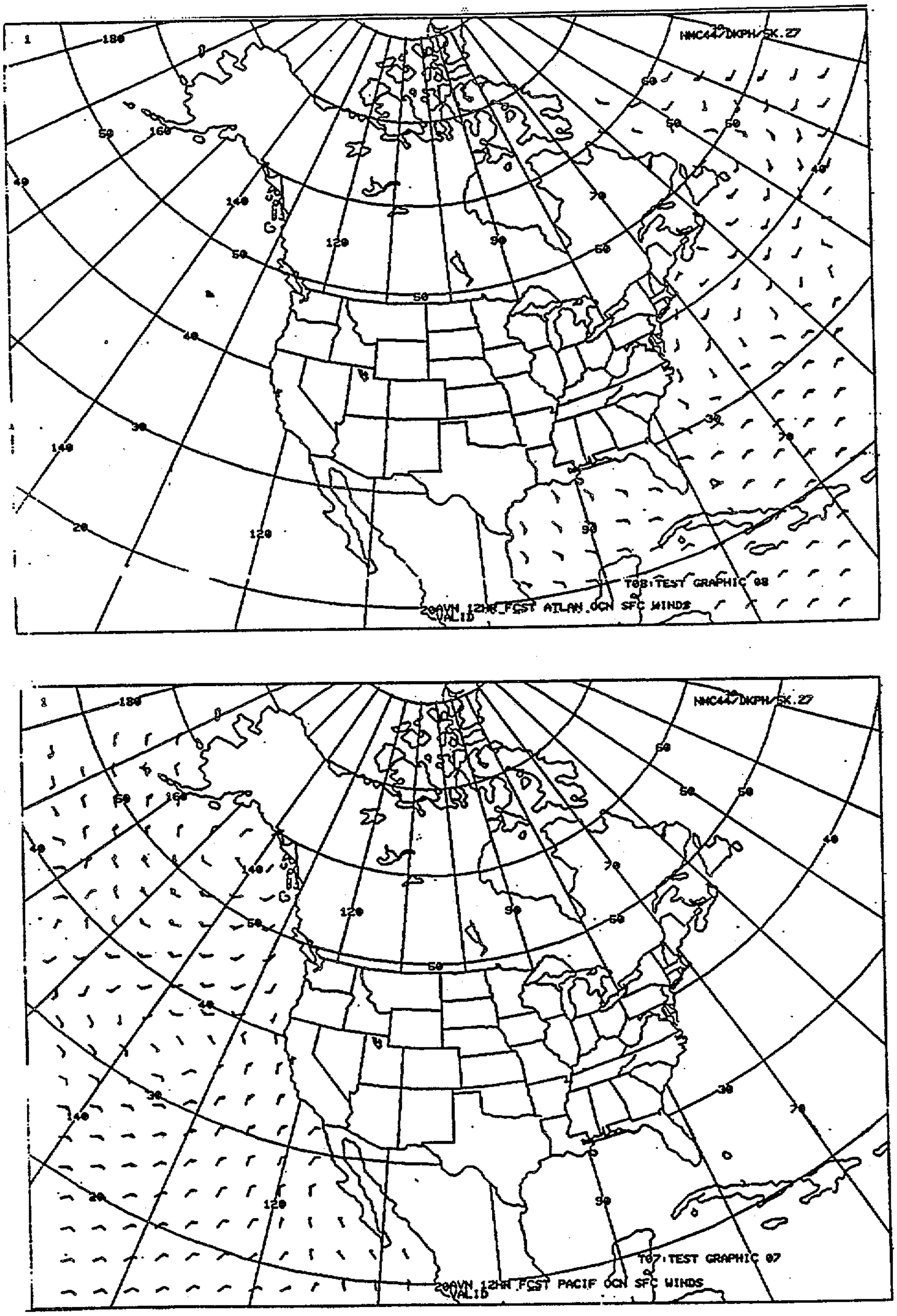

Figure 2: Global ocean surface wind forecasts derived from Aviation Model lowest sigma layer winds reduced to 20 m (nominal ship instrument height) as presented on AFOS. (a) Atlantic section. (b) Pacific section.

Sea Ice

Two PC driven digitizer board systems for sea ice message generation were installed at the Joint Navy/NOAA Ice Center (JIC). The new systems consist of a large digitizer board to read hardcopies of ice analyses, specialized menus to simplify message generation and software to handle several different message formats and special purpose users. A similar system was also installed for Navy special projects. Initiated use of DMSP/SSMI data in the analyses.

Thermal Structure

In October a test comparing a parallel interactive computer produced ocean feature analysis with the operational hand analysis was done. The results showed the interactive system to be as good as or better than the hand analysis. As soon as a dedicated PC can be purchased, the interactive system will be implemented operationally.

Quality Control

Version 5 of the Quality Improvement Performance System (QUIPS II) was implemented in November. This version has cruise plot and data manipulation capabilities. Currently sea level pressure is being tracked globally. If the pressure is greater than 4 mb different from the first guess pressure field, it is flagged and changed if possible. No latitudinal dependency has been built into the system yet. According to current usage, about 10 percent of the observations are flagged. QUIPS II is used in conjunction with the Combined Ocean and Marine Product Analysis and Scheduling System (COMPASS). COMPASS is primarily a data management system.

NEW PRODUCTS

Marine Meteorology

In April the Marine Significant Weather Chart was launched. It is a composite of most of the OPC products. Included on the chart are significant wind speeds at 10 kt intervals from 25 kt, significant wave heights at 8 ft intervals from 8 ft, ice edge limit, ice

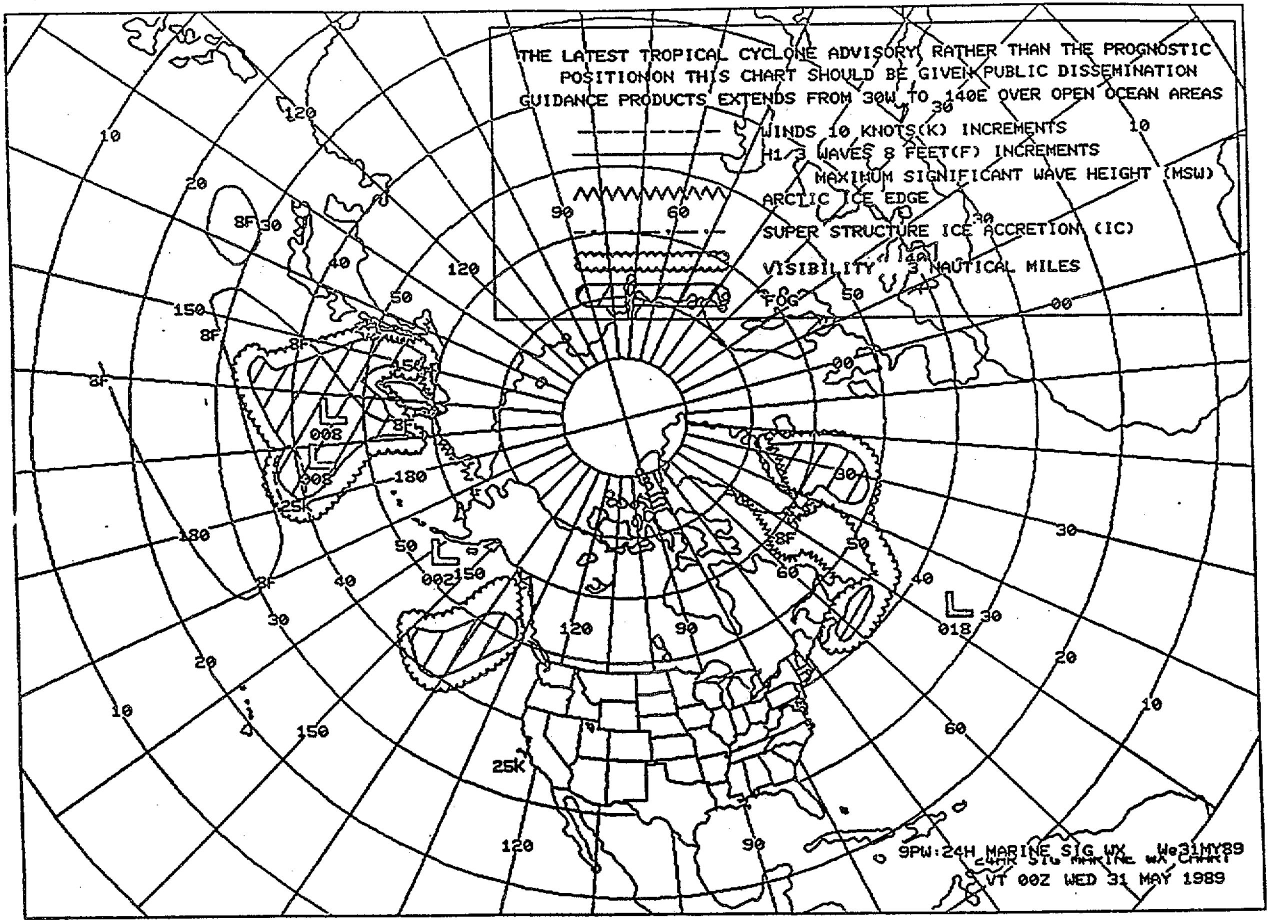

Figure 3: Sample Marine Significant Weather Chart.

accretion limit, location of highs and lows, fog limits and the limit of visibility less than or equal to 3 n mi. It is created interactively on the Intergraph system and sent out on AFOS. Forecasts are made at 24-h intervals from 24 through 72 hours on the 0000 UTC cycle only. Eventually forecasts will be sent out on both cycles and by other means to the Pacific and Alaska regions. An example is shown in Fig. 3.

In September an open ocean fog and visibility system was implemented. The system consists of statistically derived regional (3 Atlantic and 4 Pacific) forecast equations. The equations are "perfect prog" equations and are applied with Aviation Model output. The equations are tuned for each projection with the use of thresholds. This helps to eliminate model induced biases (Burroughs, 1989). The output from the system is added to the

Marine Significant Weather Chart on AFOS from April through September. Visibilities of 3 n mi or less and fog are depicted.

Ocean Waves

In August the NOAA Regional Ocean Wave (NROW) model was implemented in the Gulf of Mexico. It is also a second generation spectral wave model that takes into account bottom topography and shallow water processes. It is designed to bring a deep water wave into shallow water. The model replaced the Techniques Development Laboratory (TDL) empirical wave model. The model was implemented only after intensive evaluation had taken place. It uses Nested Grid Model (NGM) (Hoke *et. al.*, 1989) 1000mb geostrophic winds reduced to 10 m by the Cardone algorithm. It produces output at 12-h intervals out to 48 hours.

PRODUCT STATISTICS

Wind, wave, and ice accretion statistics are given in this section. Eventually statistics for sea surface temperatures (SST) and SST anomalies, ice advance and recession, fog and visibility, and coastal and Great Lakes winds will be added. At present the statistics for these products are being developed or automated. Monthly statistics are not planned for the ice accretion product because of a paucity of data; however, seasonal statistics are presented.

Monthly Boundary Layer Wind Statistics

A boundary layer model (lowest sigma level winds reduced to 20 m) wind forecast is routinely issued out to 72 hours. Two statistics are used to evaluate these analyses and forecasts: bias and root mean square (rms) error. For verification buoy winds at 18 locations (5 in the Atlantic, 3 in the Gulf of Mexico, and 10 in the Pacific - none in shallow water) are compared with model wind forecasts (lowest sigma level winds reduced to 10 m). Figure 4 shows the bias in m/sec for the period November 1987 through December 1988. There is a seasonal dependence associated with the strength of the winds. In general after May the biases are lower because of the change in the system. There is a persistent negative bias in the initial wind field which may be due to its assimilating ship and buoy observations directly onto the 1000 mb surface without any adjustment for differences in height between the ship and the 1000 mb surface. The result of this is to produce winds in the lowest sigma layer which are too low. The model does appear to overcome this deficit by the 24 hour forecast.

Figure 5 shows the root mean squared (rms) errors in the boundary layer winds for the same time period as above. Again there is a seasonal variation related to the strength of the winds.

Monthly Ocean Wave Statistics

NOW Model. Three statistics are used to analyze NOW model performance: bias, rms, and correlation coefficient. The latter was introduced in March. Significant wave height (SWH) observations from 14 deep water buoys (5 Atlantic, 3 Gulf of Mexico, and 6 Pacific) are used to compute the statistics in fig. 6. Comparisons are made with the Navy's Global Spectral Ocean Wave Model.

Figure 6a shows the bias in meters. The NOW model has a larger bias than the GSOWM from December 1987 through December 1988. Even after the change in the wind a high bias in the NOW model remained. This was primarily because of the lack of swell attenuation, and the change in August reduced the bias slightly.

The rms error is shown in fig. 6b. The rms error for the NOW model is larger throughout the 13 months than the GSOWM; however, there is a down trend throughout 1988, particularly after the aforementioned changes were introduced. The aberration in September is probably due to the influence of Hurricane Gilbert on the Gulf of Mexico buoys. From December 1987 to December 1988 the NOW model has shown marked improvement, and is now nearly comparable to the GSOWM.

The correlation coefficient is shown in fig. 6c. The comparison between the NOW model and GSOWM is mixed. After the August change the NOW model does better than GSOWM most of the time. The aberration in September noted above is also apparent.

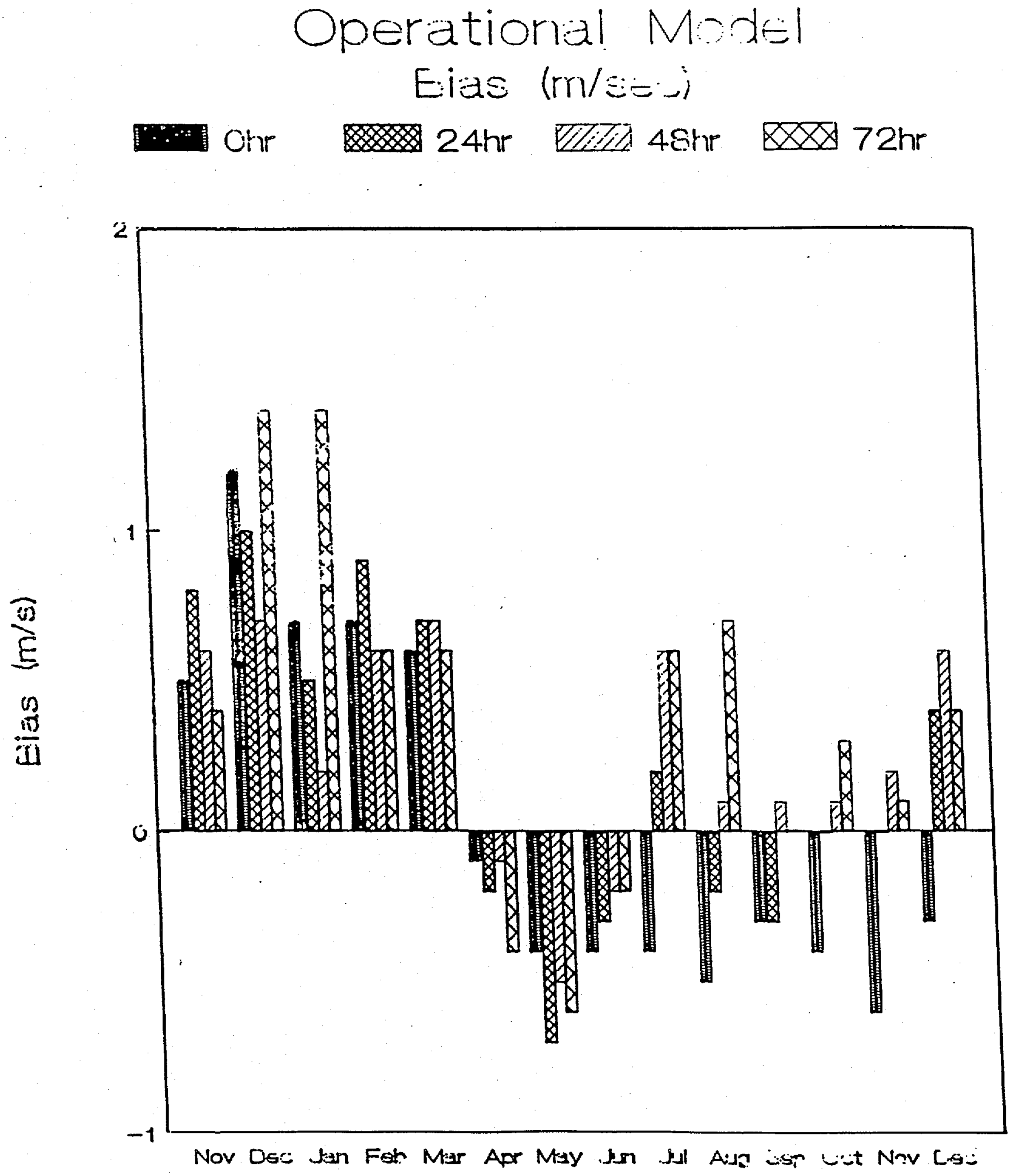

Figure 4: Biases in the boundary layer winds used in the NOAA Ocean Wave Model. Biases are in m/sec and are for the 00-, 24, 48, and 72-h projections. Statistics are for November 1987 through December 1988.

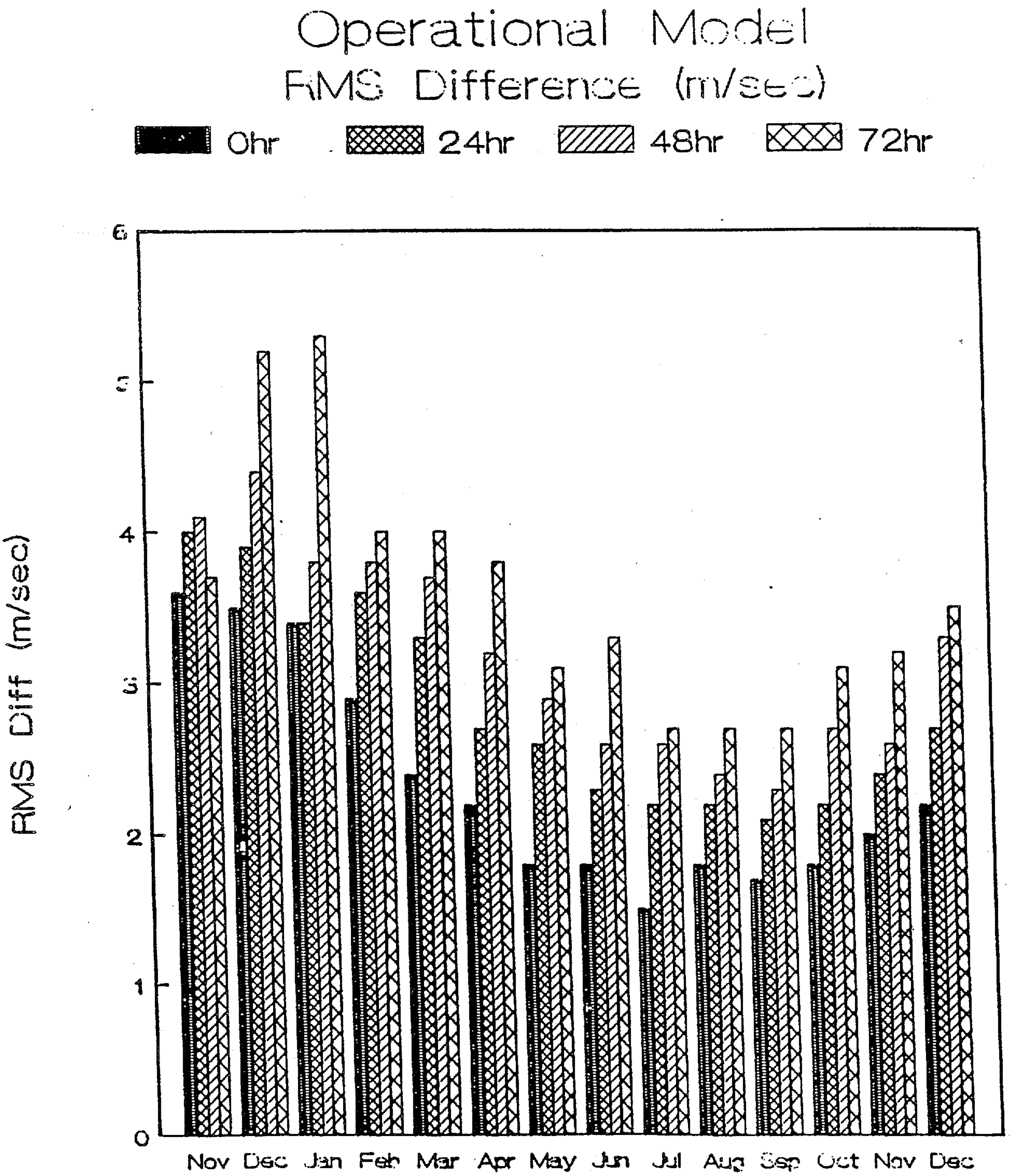

Figure 5: Same as Fig. 4 except for root mean squared errors.

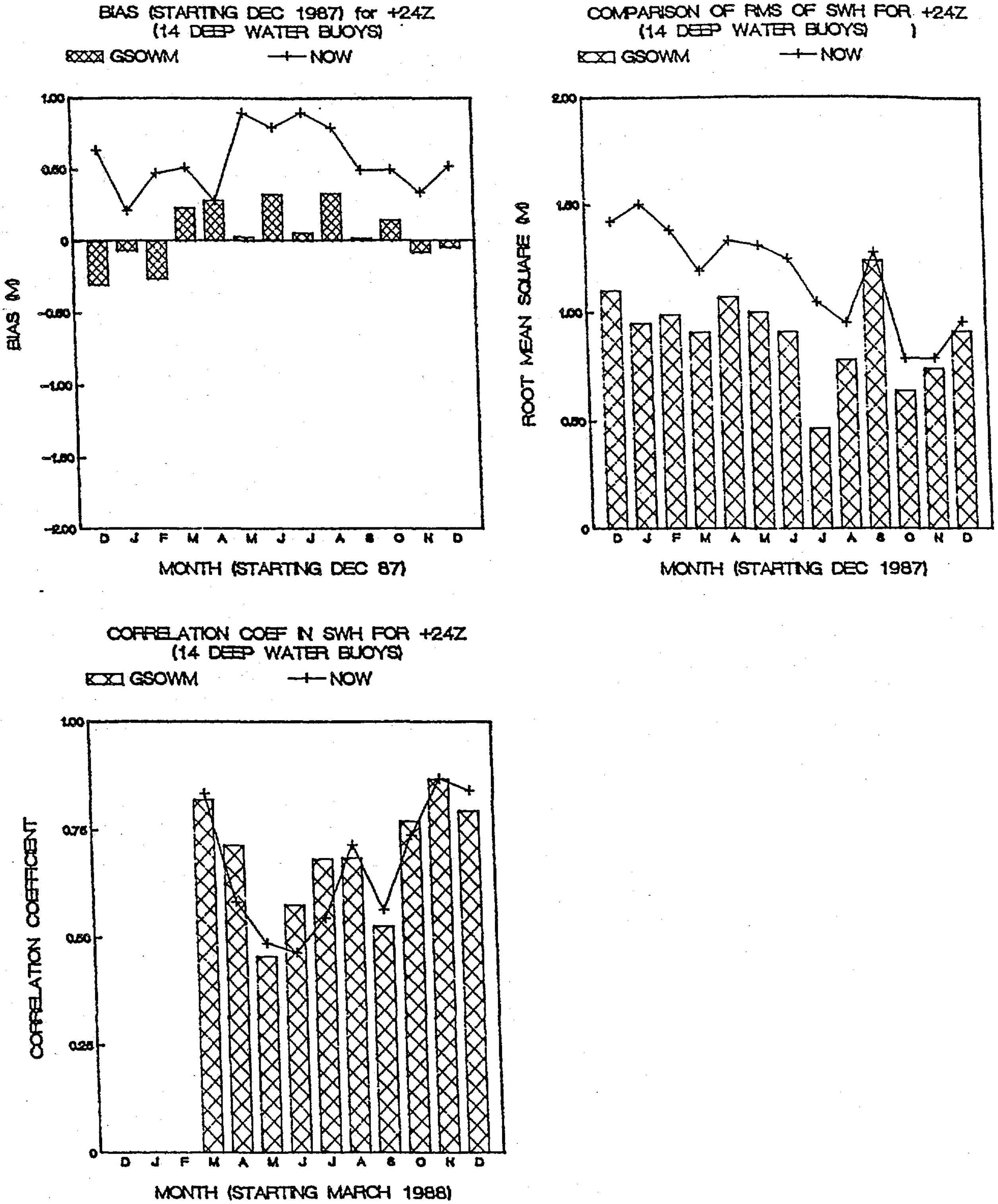

Figure 6: Comparison of wave statistics for the NOAA Ocean Wave Model (NOW) and the Navy's Global Spectral Ocean Wave Model (GSOWM). Statistics include bias (m) (a), root mean squared error (RMS) (m) (b), and correlation coefficient (COR) (c).

NROW Model. The NROW model (Chao, 1989) was implemented in August in the Gulf of Mexico. It was run in parallel for a year prior to its implementation, so statistics are shown in figs. 7 and 8 from October 1987 through December 1988. Comparisons are made with the NOW model, GSOWM, and the TDL model. Statistics are given for a deep water buoy (42001) and a shallow water buoy (42015). The TDL model was retired in August when the NROW model was implemented, and no statistics are given after July. Because of the implementation in August, no statistics are given. The statistics shown are the same as for the NOW model above. Bias and rms are in meters.

In the early stages of testing (fig. 7) the NROW model showed a consistently negative bias whose magnitude is generally larger than the other models at the deep water buoy. After adjusting model parameters at implementation the bias was significantly reduced. The rms is generally as good as if not better than the other models except in September and November. In September the statistics were adversely affected by Hurricane Gilbert. The NROW is not presently designed to handle hurricane winds due to the implicit limitations in Cardone's boundary layer model which is used in deriving the 10 m winds from the NGM. In addition, the proximity of the boundary of NGM's C-grid to the southern edge of the Gulf of Mexico might be introducing boundary related errors in the winds over the Gulf. Hence, other wind inputs are being considered to ameliorate these problems.

At the shallow water buoy (fig. 8) only the GSOWM, NROW, and TDL models are compared for bias and RMS error. Most of the time, the NROW is better than or on par with the other models and, for correlation, is better than the other models in most months.

Seasonal Ice Accretion Statistics

In a special observation effort, observations of the presence or absence of ice accretion (icing) in the Gulf of Alaska were taken by fishing vessels, cargo ships, and tugs twice a day. From these observations, the occurrence or non-occurrence of icing was tabulated. It was reported as light, moderate, or heavy, but due to the subjectivity of the observations only the presence or absence of icing was noted.

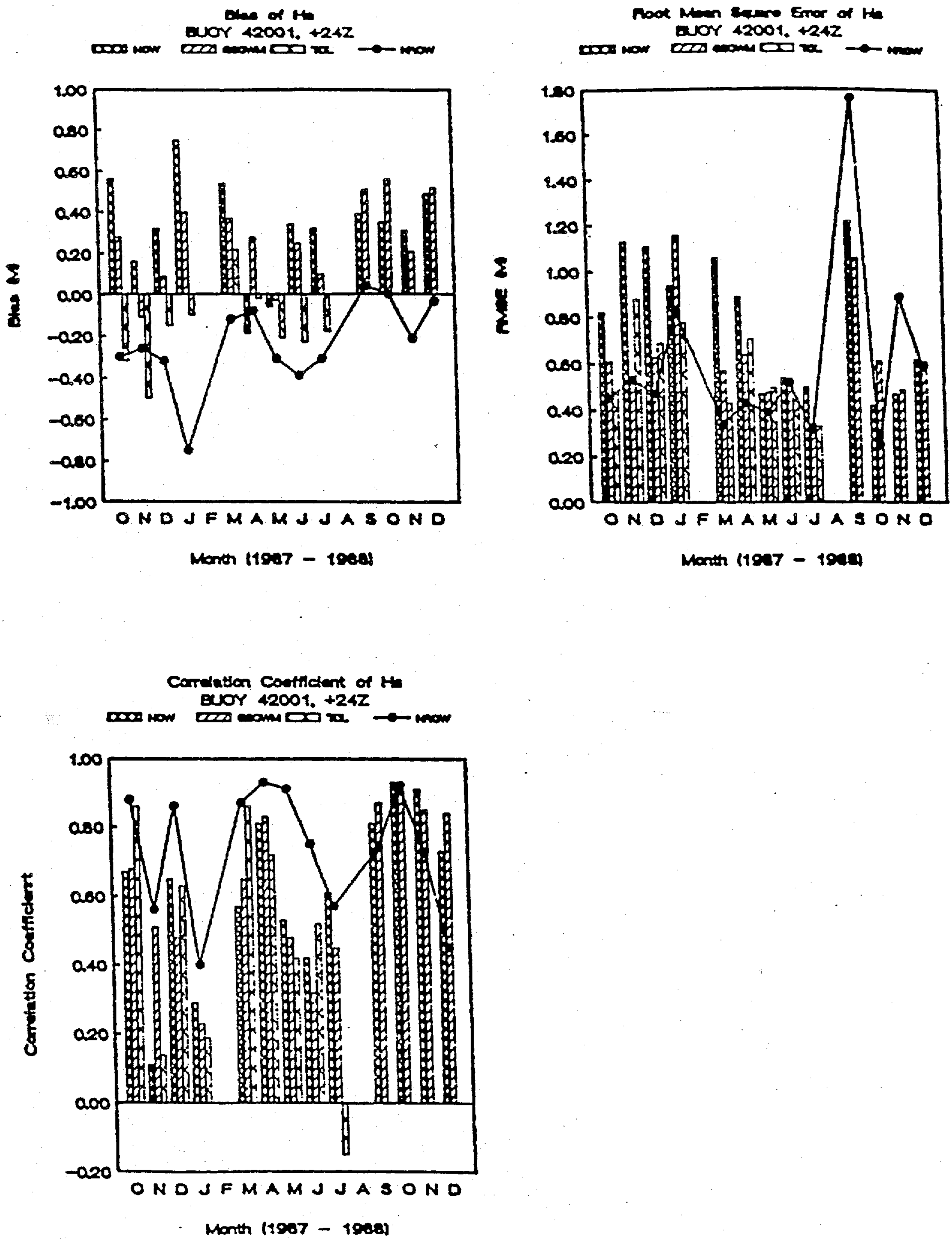

Figure 7: Comparison of wave statistics for the NOAA Regional Ocean Wave (NROW) model, NOW model, Techniques Development Laboratory's model (TDL), and the GSOWM at buoy 42001 for October 1987 through December 1988. Statistics computed are the same as in Fig. 6.

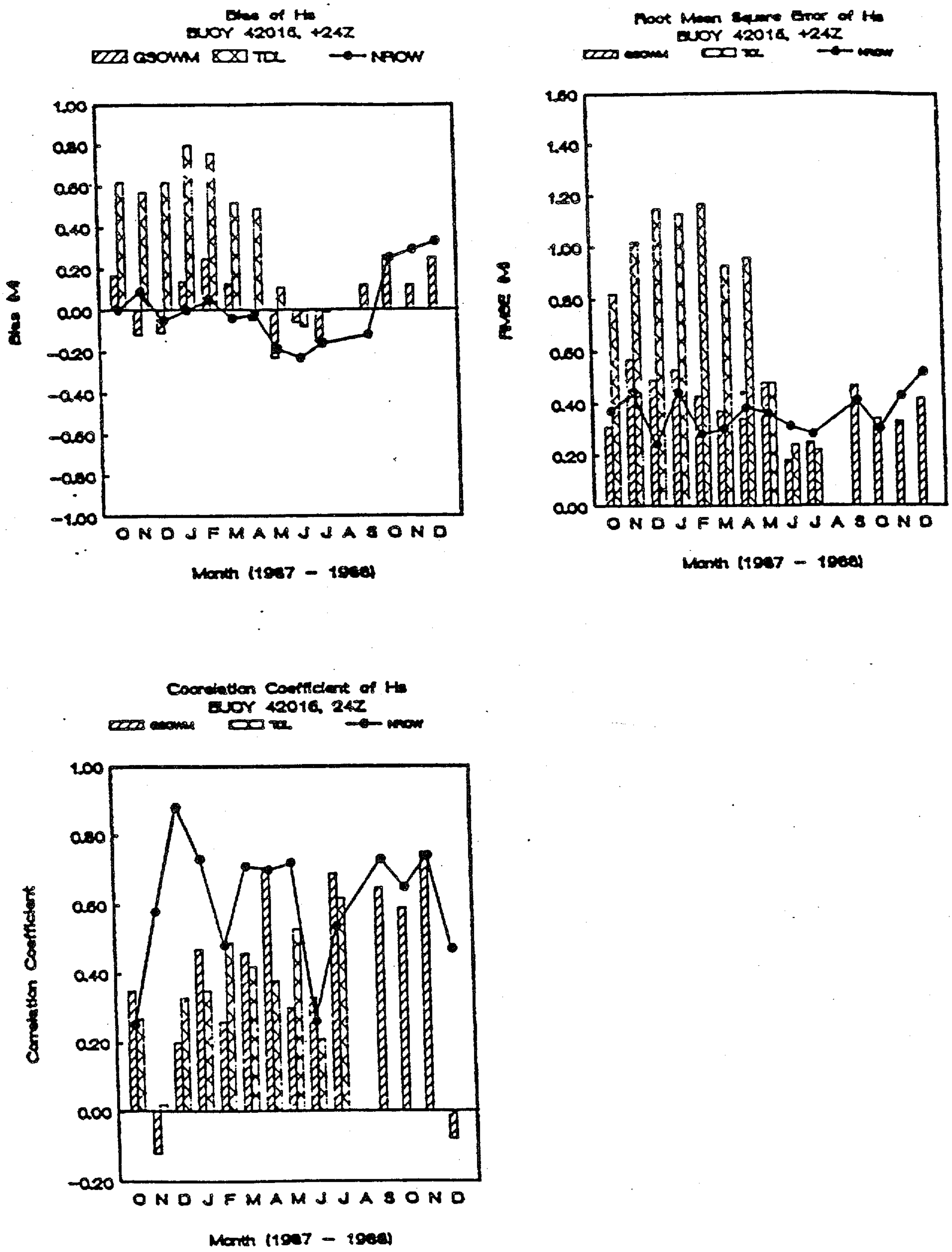

Figure 8: Same as Fig. 7 except at buoy 42015.

These observations were then compared to operational model (OPNL) forecasts. The operational model uses output from the Aviation Model on a 2.5 by 2.5 degree grid. A comparison was also made with forecasts from the NGM. The NGM has a much smaller grid spacing (about 84 km) than the OPNL. Because of this, the NGM output should produce better icing forecasts close to the shore. These runs are labelled TEST when compared with the OPNL.

The ship observations of ice accretion were compared to the OPNL and TEST forecasts interpolated to the position of the observations (see Table 1). The forecasts are valid at 0000 UTC. Where data were missing no statistics were computed.

The scores used for the ice accretion analysis are related to a 2 by 2 contingency table in which the catagories are yes and no for forecasts and observations. The main indicator used was the Gringorten skill score (Gringorten, 1965 and Daan, 1981). This score has the advantage that it varies between 0 and 1 when compared to climatology, *i.e.* in order to score one must better climatology. In this case the climatology is taken from the sample of observations. Other scores generated were the bias (the extent to which an event is over- or under-forecast), the prefigurence (the extent to which a forecast gives advanced notice of the event - power of detection), the post-agreement (the extent to which subsequent observations confirm the predictions), and the threat score (a useful indication for comparisons of relatively rare events) (Panofsky and Brier, 1963).

The statistical comparisons are shown in Table 1. Even though there appears to be no significant difference in the skill score, the TEST appears to give a better bias. This comparison will be examined further.

CASE STUDIES

While statistical analyses show how a product performs in general, they cannot show how a product will perform on any given day or in any given situation. Case studies on the other hand provide insight on product performance in specific situations. Two case studies from the Monthly Product Reviews are summarized here. The studies include wind and wave performance before and after the major changes in the wind and wave guidance took place. Neither study is exhaustive, but they are illustrative.

Pacific Storm of 13 - 17 April, 1988

This system was an explosive deepening storm which started as an ephemeral low to the north and west of Hawaii in the Central Pacific, moved rapidly to the northeast, and retrograded to the west over southwestern Alaska. Figure 9 shows the path of the storm and the sea level pressure (SLP) pattern at its deepest (937 mb). Figure 10a shows wind, wave, motion, and pressure pattern of the storm as it moved. Speeds are in knots; pressure is SLP - 1000 mb; wave heights are in feet. The lowest pressure occurred on the 15th at 0000 UTC. The highest waves measured by a ship or buoy occurred at the same time (46 ft). Figure 10b shows forecast winds interpolated to the position of the highest observed wind speed (kt). Note that at the time of greatest intensity all the forecast winds were 15 to 30 kt lower than the observed wind. Figure 10c shows the same sort of comparison except for wave heights in feet. Again at the time of greatest intensity the forecasts were all about 20 ft under the observed. By the 16th the 24-h and 48-h forecasts seem the have caught up with the observed. This is somewhat dependent on the Aviation Model's forecast of the storm.

Figures 11, 12, and 13 show the 72-h, 48-h, and 24-h forecasts valid at 0000 UTC April 15, 1988 respectively for boundary layer wind in knots (barbs) and wave height in feet (number at point of barbs). The heavier barbs and numbers are ship observations. Several points are apparent. The 72-h forecast placed the storm further east than was

Table 1: Comparison of statistics for the OPNL and TEST ice accretion models. Results are for the 24-h forecast valid at 0000 UTC. N is the sample size; SS is skill score; PF is prefigurence; PA is post-agreement, and TS is threat score.

Model	N	SS	Bias	PF	PA	TS
OPNL	138	0.57	5.92	1.00	0.17	0.17
TEST	138	0.60	5.58	1.00	0.18	0.18

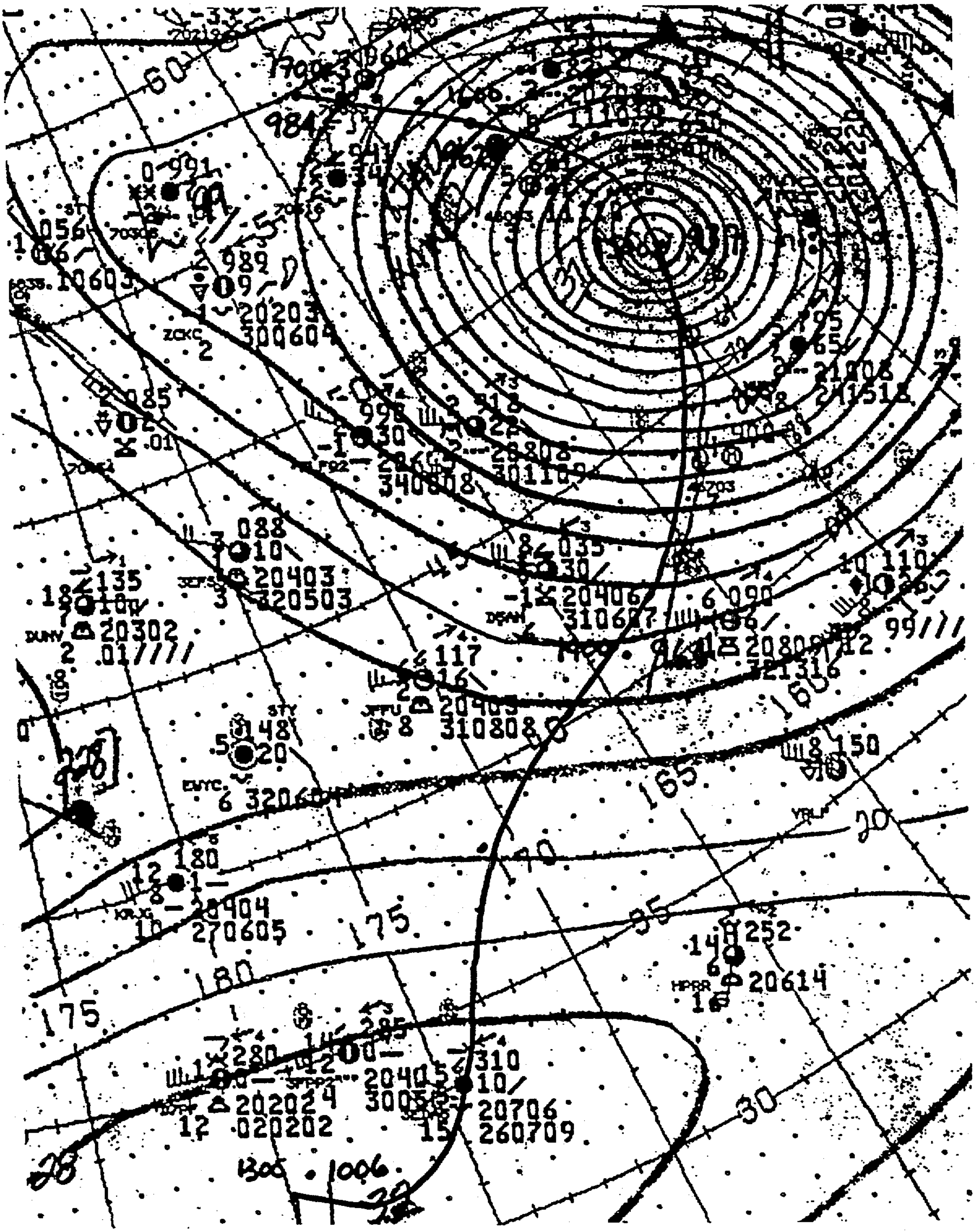

Figure 9: Pressure pattern for the storm of 13 - 17 April at its most intense (937 mb). The line through the center of the storm is its path from 13 - 17 April.

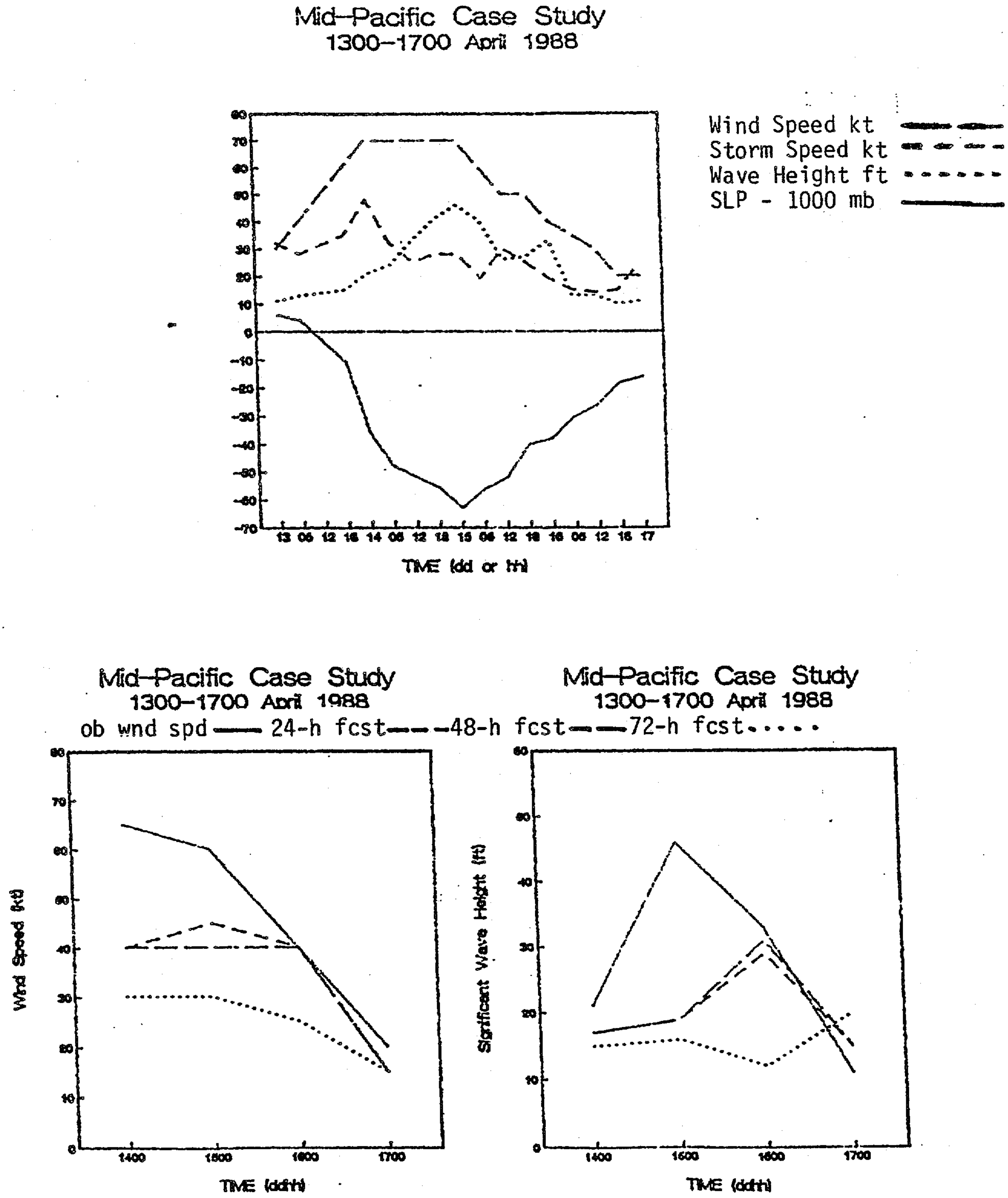

Figure 10: Storm statistics. (a) Central pressure - 1000 mb, highest wind speed (kt), speed of storm (kt), and highest wave (ft) during the life of the storm. (b) Interpolated wind forecast at location of highest observed wind speed (kt) at each forecast period, and (c) same as (b) except significant wave height (ft)

observed; the wind speeds are substantially lower than observed; the wind directions are reasonable except to the north of the storm, and the wave heights are all low because the wind speeds are low. The 48-h forecast is somewhat better in that the wind speeds are more realistic, but still somewhat low particularly to the west of the storm center. The wave heights remain low particulary to the east of the storm. By the 24-h forecast the wind speeds are almost correct, and the wind directions are very good. The wave heights remained low to the east of the storm, however. The position of the low has been moved two far west, so that the forecast low is west of the observed low. The position of the low is determined by the Aviation Model.

Atlantic Storm of 13 - 16 December 1988

On 13 December an weak low came offshore near Charleston, NC. A second low formed off Cape Hatteras on the 14th at 0000 UTC. These lows merged into one center on the 14th at 0600 UTC and explosively deepened. A mere 12-h later the low had deepened 20 mb to its greatest intensity (964 mb). After that the low began to slowly fill. Figure 14 shows the path of the storm from its formation on the 13th through the 16th. Figures 15-17 show the 72-,48-,and 24-h forecasts of wind speed and direction and wave height respectively for the 15th at 0000 UTC. Forecast and observed winds and wave heights are depicted in the same way as the preceding case study. These forecasts were selected to be shown because they are closest to the time of greatest intensity for the storm.

The forecast wind at each projection is very close to the observed wind. Forecast speeds are within 10 kt and the directions are off only because the Aviation Model didn't forecast the storm center perfectly. Figure 18 shows wave heights derived from GEOSAT data. The wave heights are a little low at each forecast period, but are much better than the forecasts for the Pacific case. The improvement is attributable, at least in part, to the changes made in the wind and wave models.

ACKNOWLEDGMENTS

All of the OPC staff have helped with this report to one degree or other. In

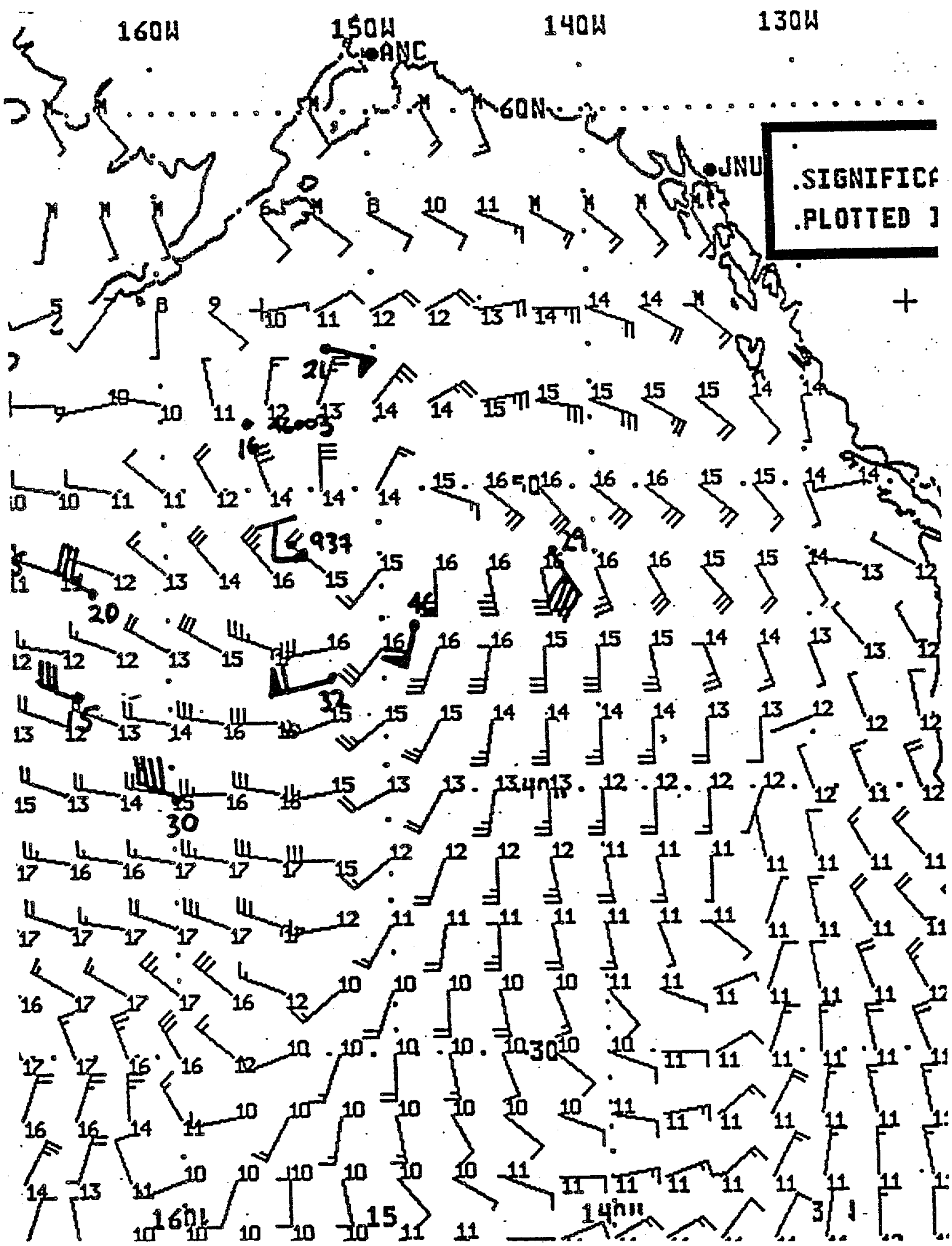

Figure 11: 72-h forecast of wind at gridpoints depicted by wind barbs. Wind speed is in knots. The wave height (ft) is given at the point of each wind barb. The heavier wind barbs and numbers are the observed values. The forecasts are valid for April 15, 1988 at 0000 UTC.

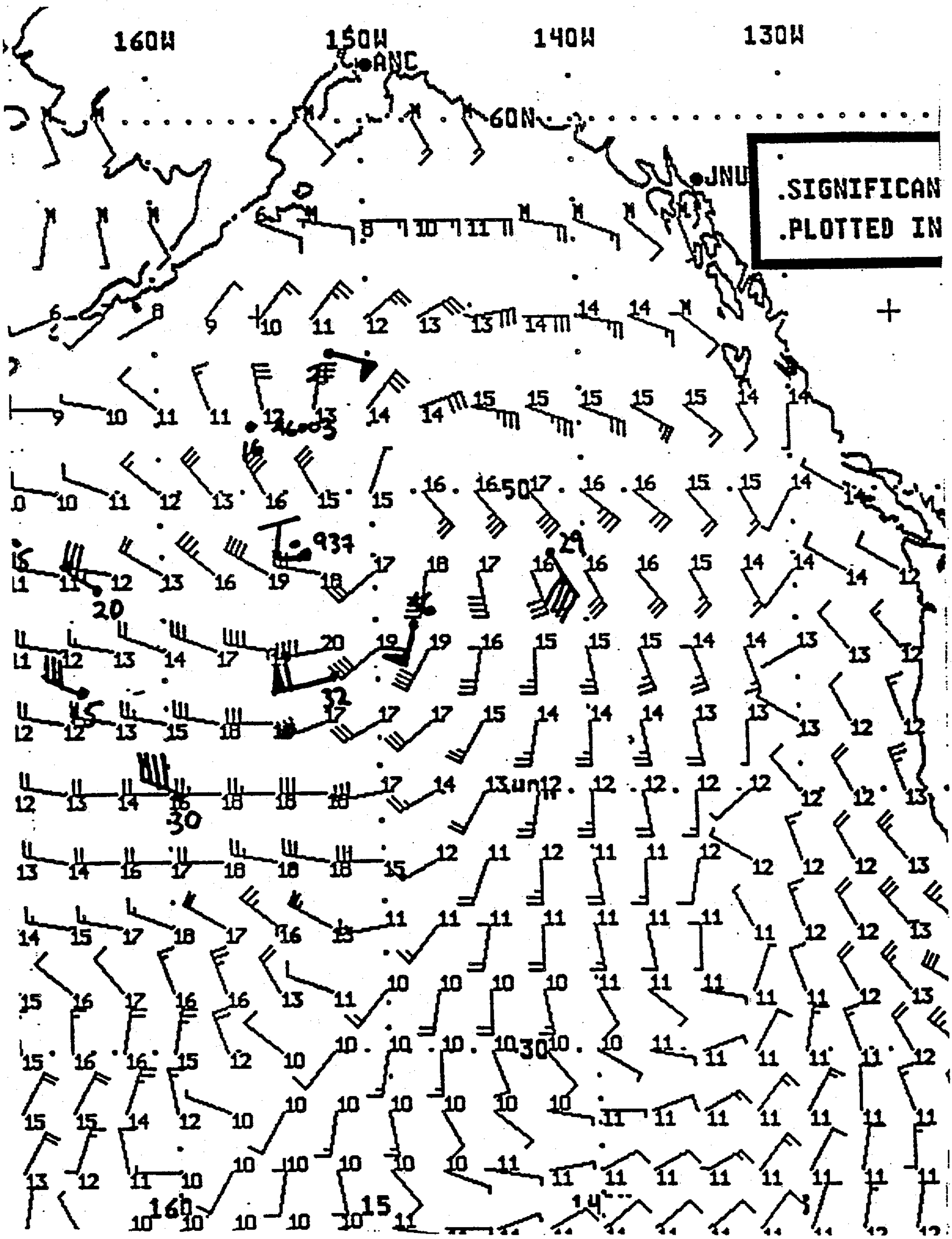

Figure 12: Same as Fig. 11 except 48-h forecasts.

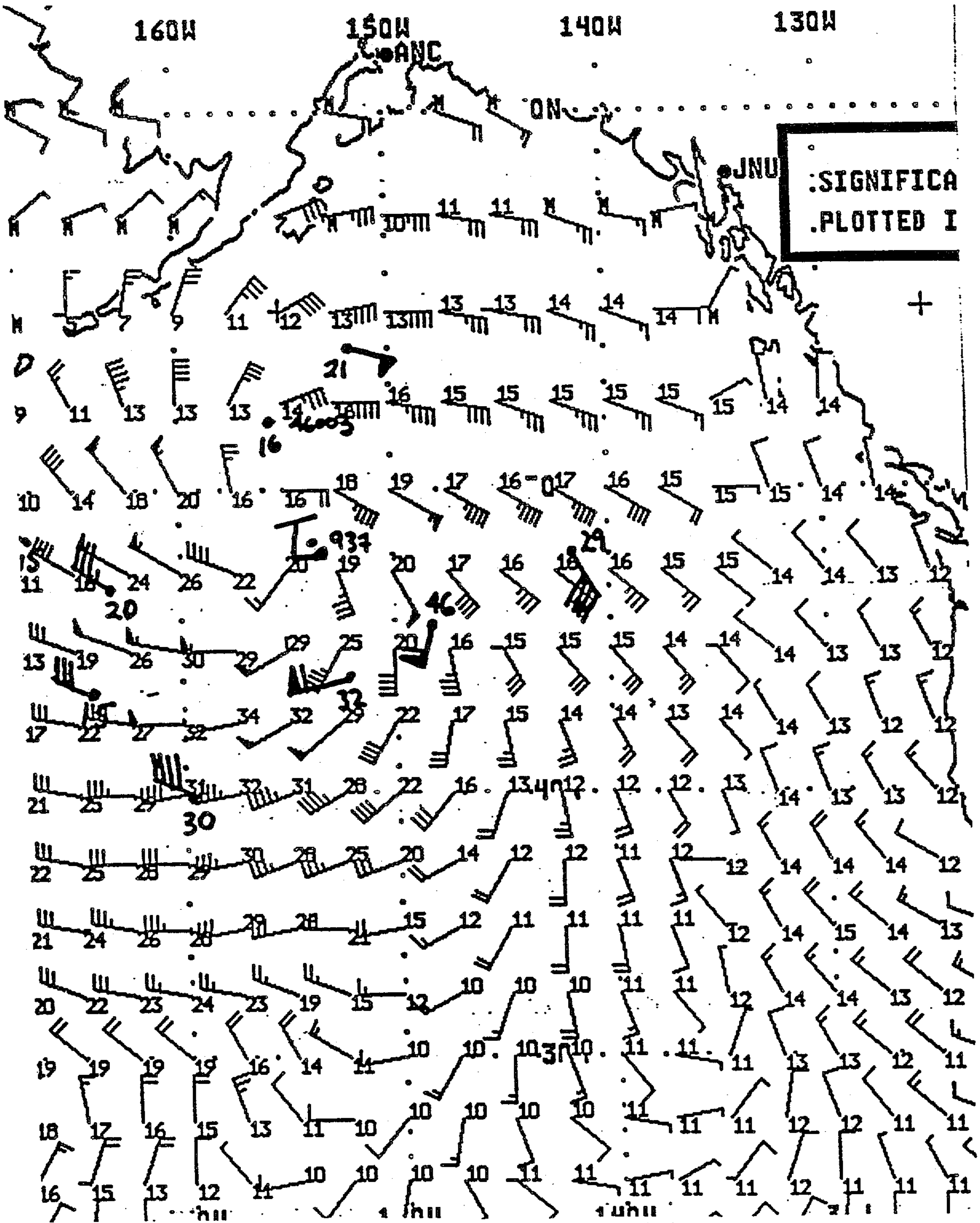

Figure 13: Same as Fig. 11 except 24-h forecasts.

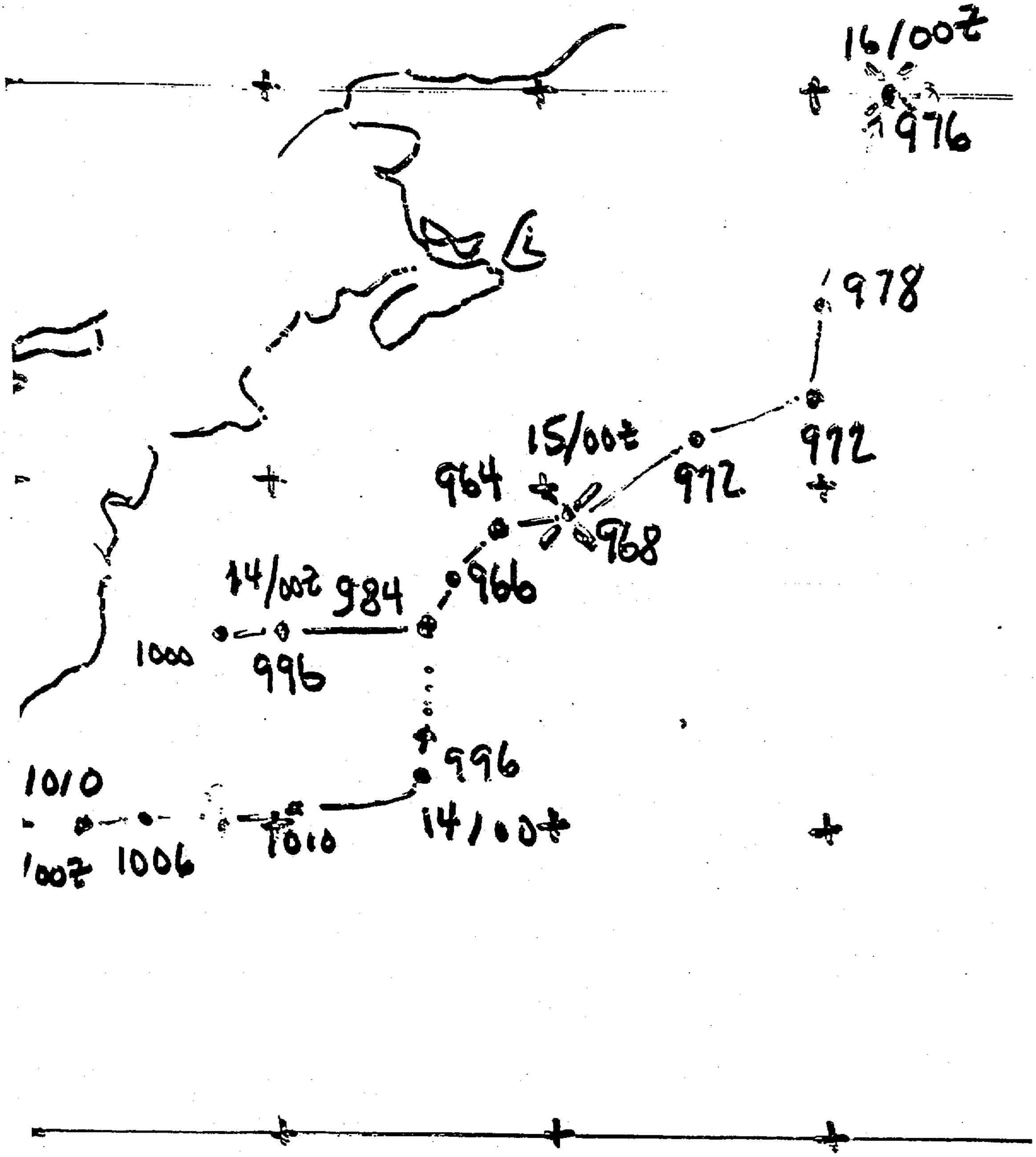

Figure 14: Path of Storm from 13 - 16 December,1988. Dots indicate 6-h positions of the storm. Pressures are shown in mb.

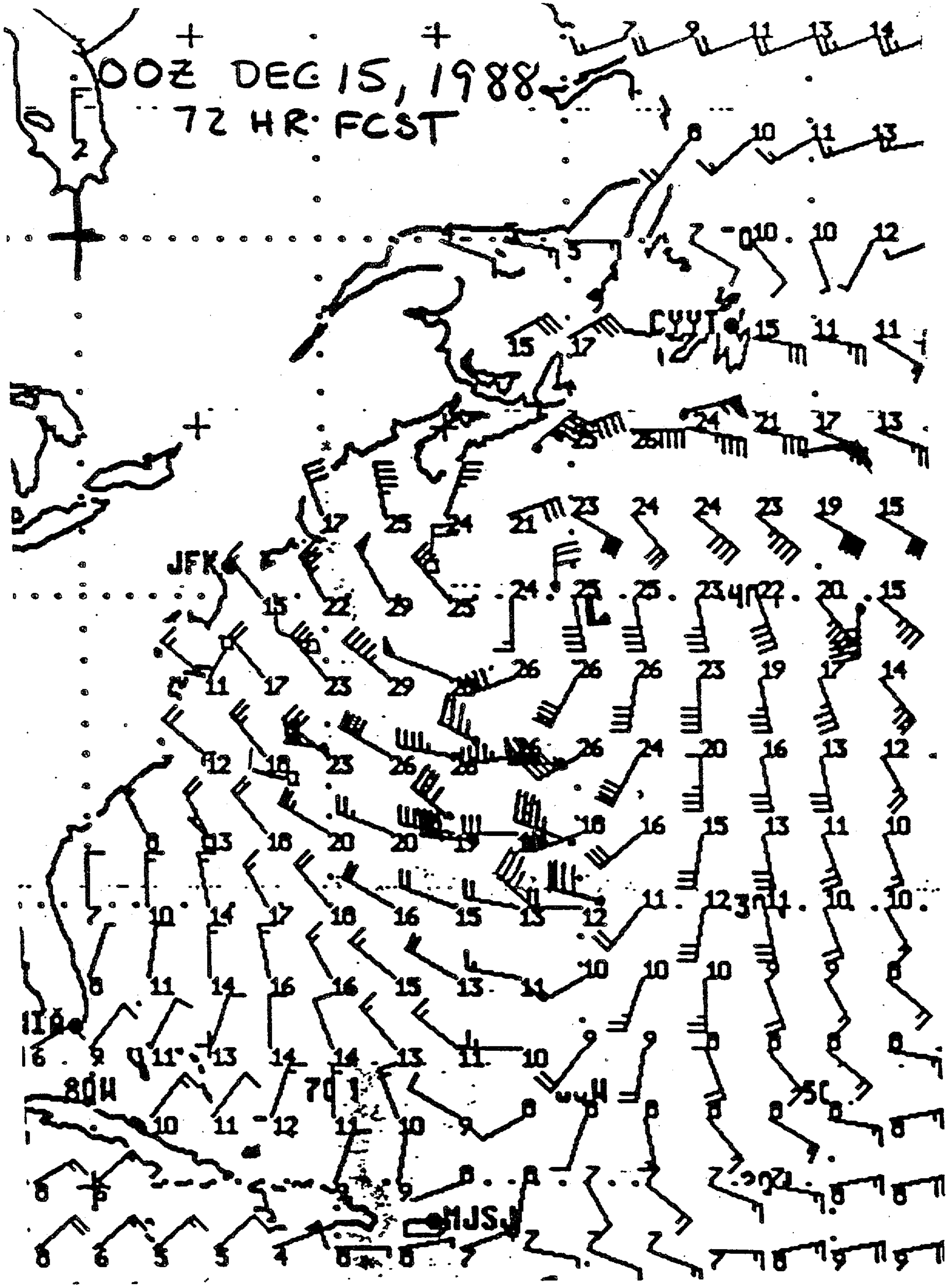

Figure 15: 72-h forecasts of wind (kt) and wave heights (ft). Barbs depict wind direction and speed. Numbers at the point of the barb are the wave heights. Heavier barbs show observed data. Forecasts are valid for December 15, 1988 at 0000 UTC.

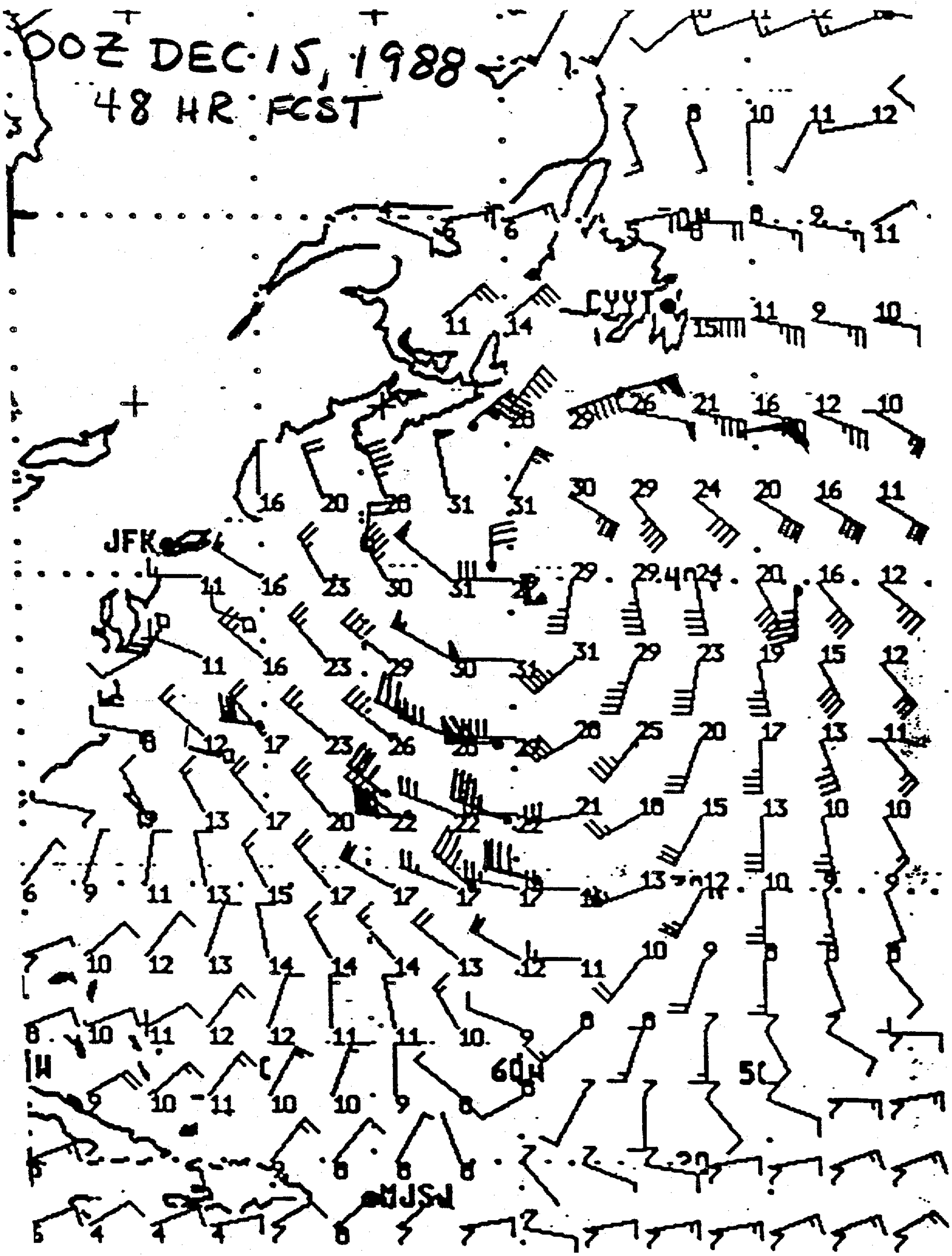

Figure 16: Same as Fig. 14 except 48-h forecasts.

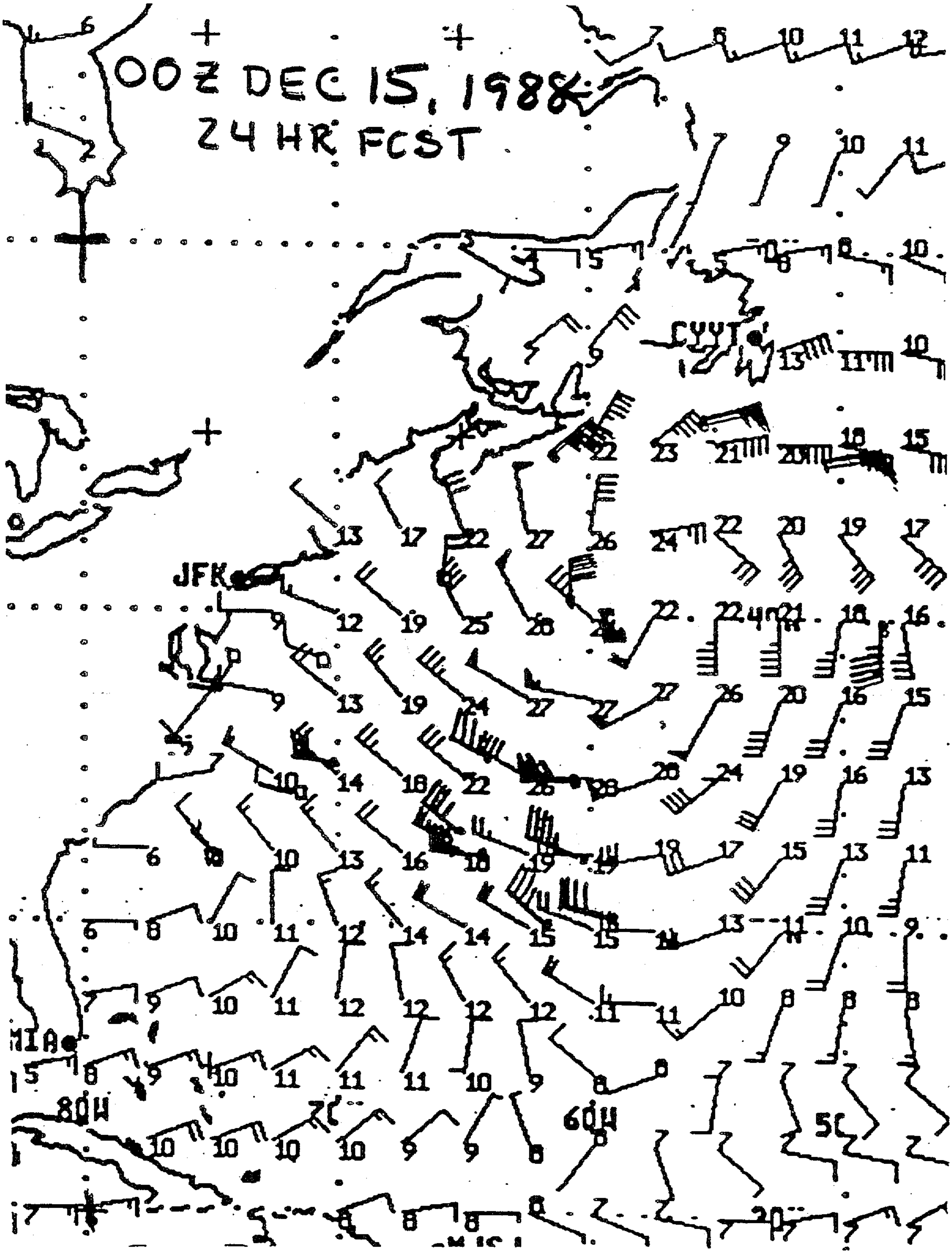

Figure 17: Same as Fig. 14 except 24-h forecasts.

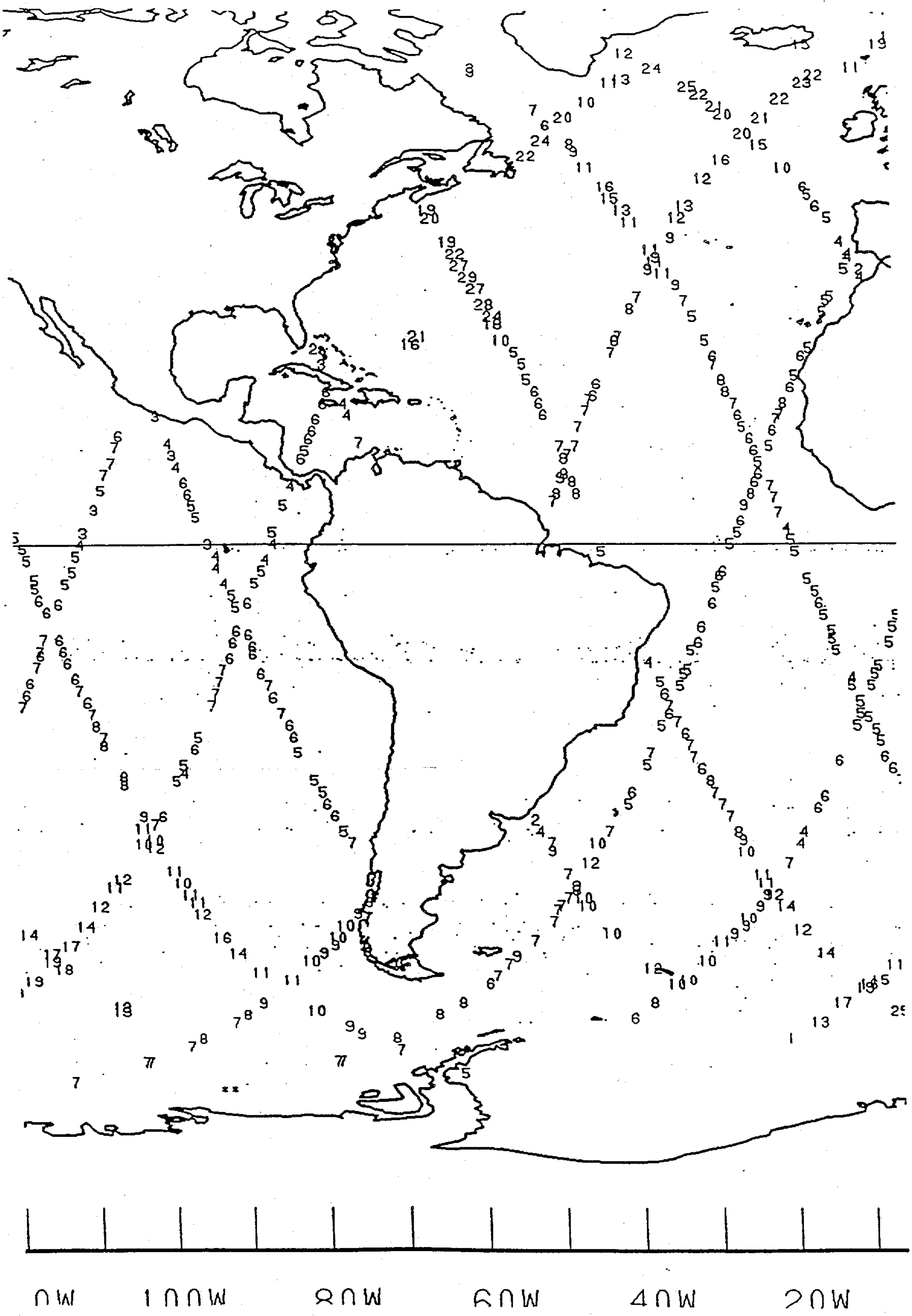

Figure 18: Wave heights in feet from GEOSAT for December 15, 1988.

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