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A FORECAST AID FOR EXTRATROPICAL STORM SURGES AT MINNESOTT BEACH, NORTH CAROLINA

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INTRODUCTION

The Weather Service Office at Wilmington, N.C., through the National Weather Service Eastern Region, has requested Techniques Development Laboratory to develop storm surge forecast equations for several locations within Pamlico Sound. Critical points within the sound were specified as Stumpy Point, Belhaven, Washington, Hobucken, Minnesott Beach, Cedar Island, Ocracoke, Hatteras, and Rodanthe. An orientation map, provided by WSO Wilmington, is reproduced as figure 1.

Storm surge at most locations is determined by subtracting the normal astronomical tide from the observed tide. Within Pamlico Sound the astronomical tide has a range of less than one-half foot, except near the inlets, and therefore can essentially be neglected.

WSO, Wilmington has access to the Corps of Engineers tide data for the Pamlico Sound area. Techniques Development Laboratory selected dates of storms that had caused surge conditions at Norfolk and Charleston, and asked WSO, Wilmington to obtain the available tide observations for these dates.

As a first approach to the storm surge forecast problem within Pamlico Sound, it was decided to statistically relate the tide height to a surface wind component.

Minnesott Beach was the location selected for first consideration because there was a considerable amount of tide data available for that location. The Cape Hatteras wind was selected to be representative of the wind over Pamlico Sound.

MINNESOTT BEACH TIDE DATA

Minnesott Beach tide data are available for several storm periods. The data used in this study are for the periods listed below:

1300 EST Jan. 29 thru 1300 EST Feb. 2, 1960
0100 EST Feb. 13 thru 1900 EST Feb. 14, 1960

0100 EST Mar. 6 thru 2200 EST Mar. 9, 1962
1900 EST Nov. 9 thru 0100 EST Nov. 11, 1962
0100 EST Jan. 22 thru 1900 EST Jan. 23, 1966
1300 EST Jan. 25 thru 0100 EST Jan. 28, 1966
0700 EST Feb. 29 thru 2200 EST Mar. 1, 1968
1300 EST Nov. 11 thru 2200 EST Nov. 12, 1968
0100 EST Feb. 9 thru 1300 EST Feb. 12, 1973

Graphs showing the tide elevations for these time periods at Minnesott Beach are shown in figures 2a and 2b.

THE WIND DATA

Subjectively it was decided that the component of the wind along the axis of Pamlico Sound should be a good predictor of the tide level in the southwest part of the sound. Wind observations at 3-hour intervals were obtained from the Environmetal Data Service's publication Local Climatological Data. The Cape Hatteras wind component from 060° was chosen to represent the wind along the axis of the sound. This component is shown graphically in figure 3 and is calculated as: $U = S \sin(\alpha + 30°)$, where S is the wind speed and α is the wind direction. For convenience the multiplication factors for determining the component (U) at 10° intervals are shown in table 1.

PROCESSING OF THE DATA

Values of the tide level and the U wind component at 3-hour intervals were punched on cards and processed by a correlation-regression program. Several runs with these data were made as follows:

1. Tide height dependent on U component with zero lag.
2. Tide height dependent on U component with lag of 3 hours.
3. Tide height dependent on U component with lag of 6 hours.
4. Tide height dependent on U component with lags of 0, 3, and 6 hours.

The four resulting regression equations with tide height expressed in feet and U expressed in knots are:

1. $\text{Tide} = 1.10 + 0.08\, U_{(0)};\ r = .80$
2. $\text{Tide} = 1.09 + 0.09\, U_{(-3\ \text{hr})};\ r = .87$
3. $\text{Tide} = 1.10 + 0.09\, U_{(-6\ \text{hr})};\ r = .84$
4. $\text{Tide} = 1.105 + 0.039\, U_{(-3\ \text{hr})} + 0.035\, U_{(-6\ \text{hr})} + 0.024\, U_{(0\ \text{hr})};\ r = .89$

The first three equations are quite similar, with the one using the wind component with a lag of three hours having a slightly higher correlation coefficient. The fourth equation using wind components with three different lag times has only a slightly higher correlation than the second equation. At this time equation 2 seems preferable for use, as it has a high correlation, uses only one predictor, and the predictor is lagged.

Figure 4 is a scatter diagram of the tide against the U component with a lag of three hours. The straight line equation 2 is also shown here. The scatter of the points is relatively small.

Figures 5a and 5b shows the storm surge calculation, using equation 2, and the observed storm surges for the nine storms considered. Of course these cases are not independent cases, but since each case only contributed about 11% of the total dependent data, they might be thought of as "somewhat independent." In any case, they are the available data until data from future storms become available. The agreement of these calculations with observations is not bad, considering that only one predictor term is used. The agreement in trend of the observed tide curves and the calculated curves is good.

PROCEDURE FOR EXPERIMENTAL USE OF METHOD FOR FORECASTING

For experimental use in the forecasting of the Minnesott Beach tide level, the following steps can be taken:

1. Determine the Cape Hatteras wind forecast by any available means.
2. Calculate the 060° wind component (U) as $S \times \sin(\alpha + 30°)$ or use multiplication factor from table 1.
3. Calculate storm surge with a three-hour lag from wind time as $1.09 + 0.09\ U_{(-3\ hr)}$ or determine surge forecast from graph of figure 4.

SUMMARY AND FUTURE PLANS

It appears that the 060° wind component at Cape Hatteras with a 3-hour lag can be used as a predictor of the storm surge at Minnesott Beach. Our future plans are to develop similar techniques for other locations within the Pamlico Sound area.

ACKNOWLEDGEMENTS

Appreciation is expressed to the Weather Service Office at Wilmington, N.C. for making the tide data available to Techniques Development Laboratory. Appreciation is also expressed to Mr. Herman Perrotti for drafting the figures and to Mrs. Audrey Johnson for typing the manuscript.

Table 1. Multiplication factors to determine the U component (060° component) over Pamlico Sound. The factor is equal to sin (α + 30°), where α is the wind direction.

Wind Direction	Factor	Wind Direction	Factor
0°	.500	180°	-.500
10	.643	190	-.643
20	.766	200	-.766
30	.866	210	-.866
40	.940	220	-.940
50	.985	230	-.985
60	1.000	240	-1.000
70	.985	250	-.985
80	.940	260	-.940
90	.866	270	-.866
100	.766	280	-.766
110	.643	290	-.643
120	.500	300	-.500
130	.342	310	-.342
140	.174	320	-.174
150	0.000	330	0.000
160	-.174	340	.174
170	-.342	350	.342

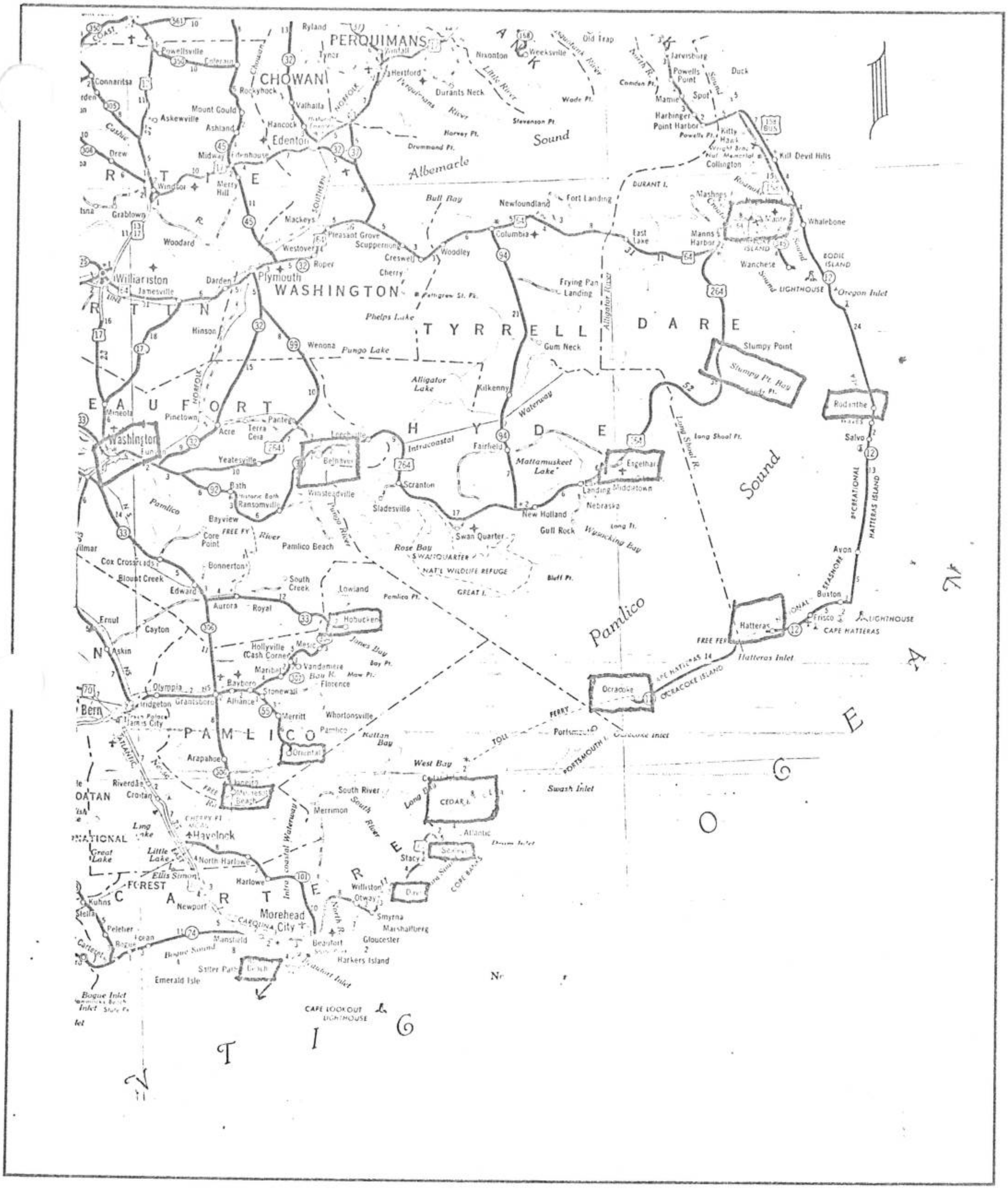

Figure 1. Map of Pamlico Sound showing some critical storm surge locations.

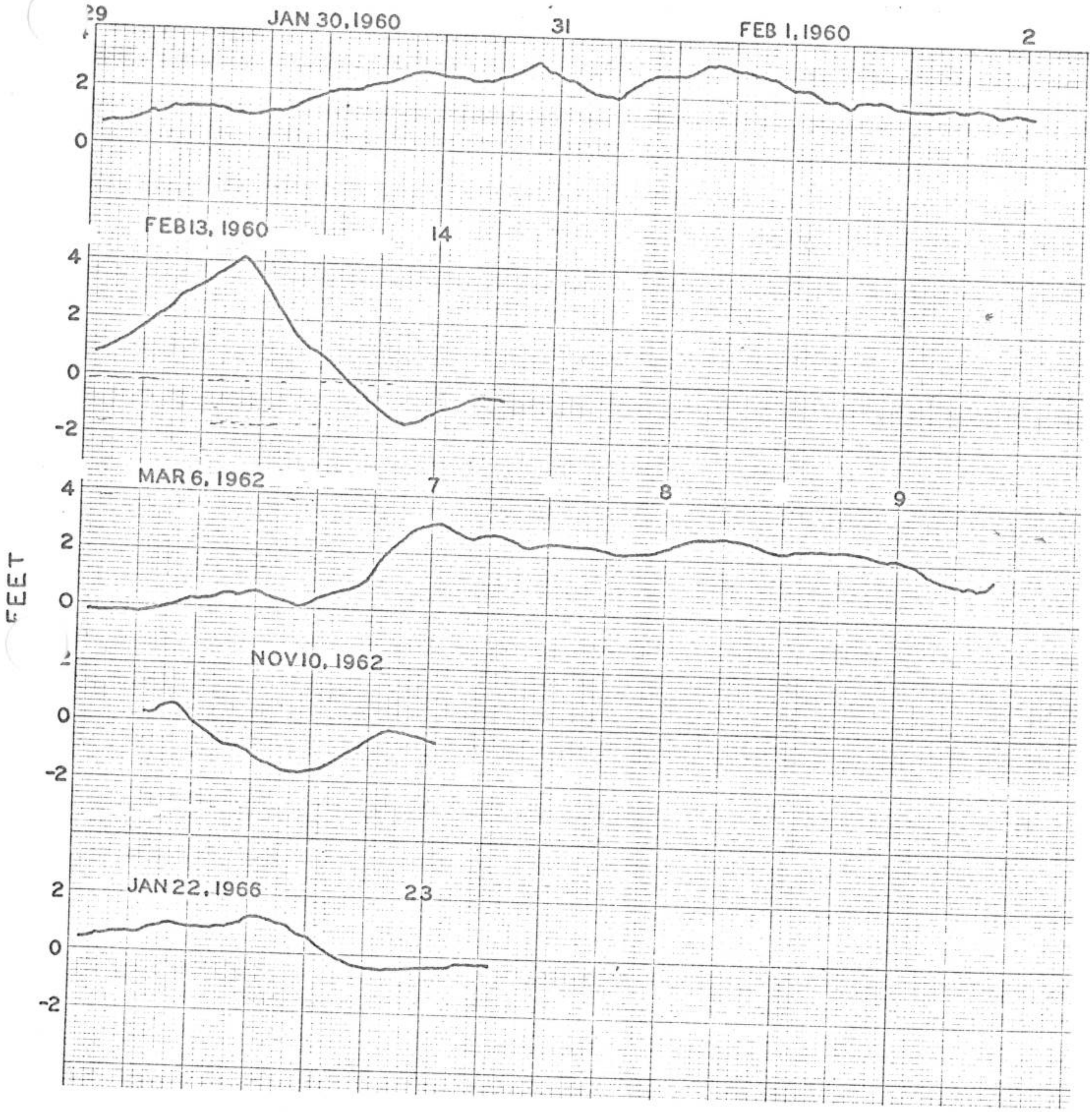

Figure 2a. Tide heights observed at Minnesott Beach during several recent storms. The curves are based on hourly values. The dates are shown at the 1200 EST positions.

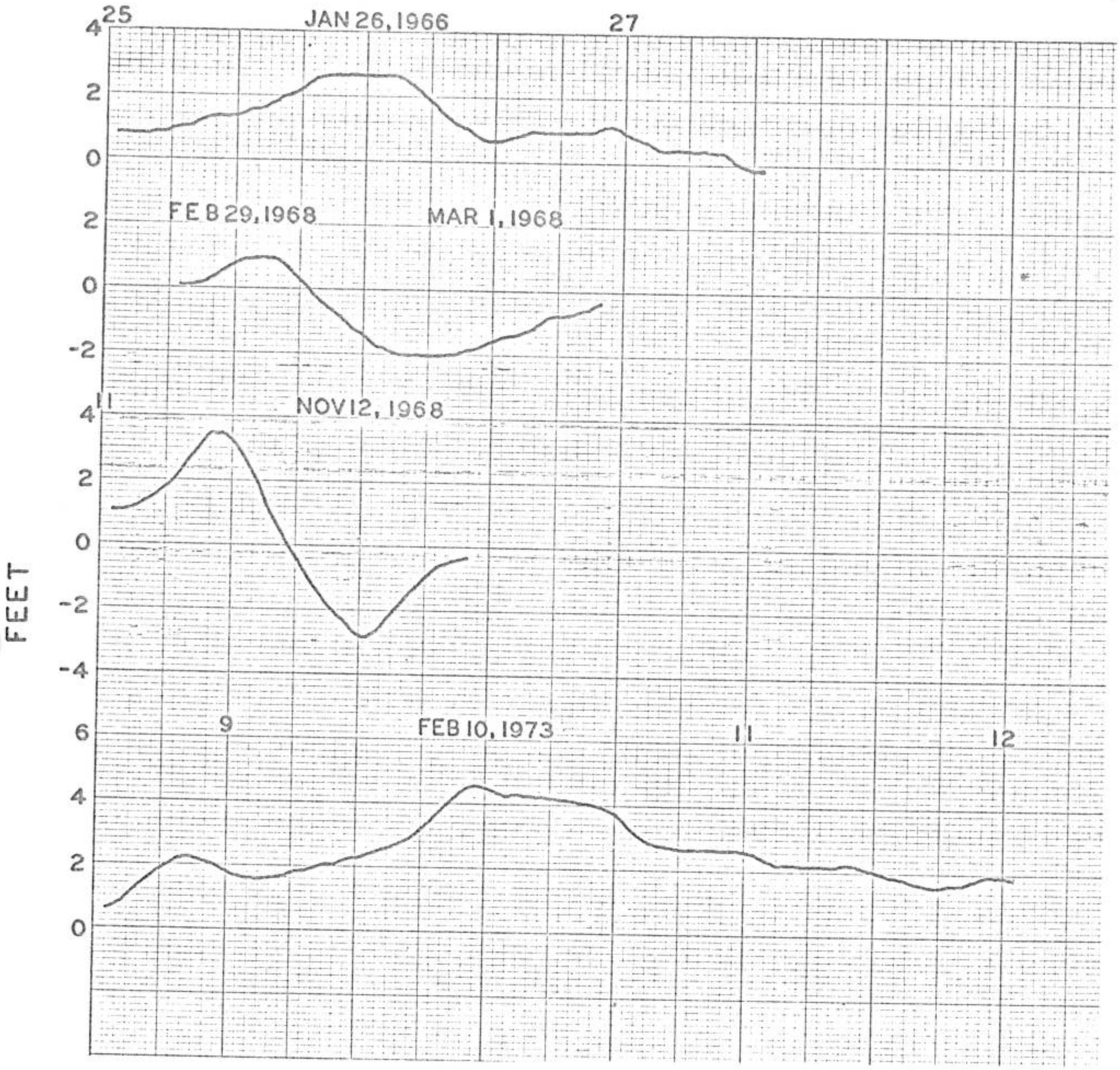

Figure 2b. Tide heights observed at Minnesott Beach during several recent storms. The curves are based on hourly values. The dates are shown at the 1200 EST positions.

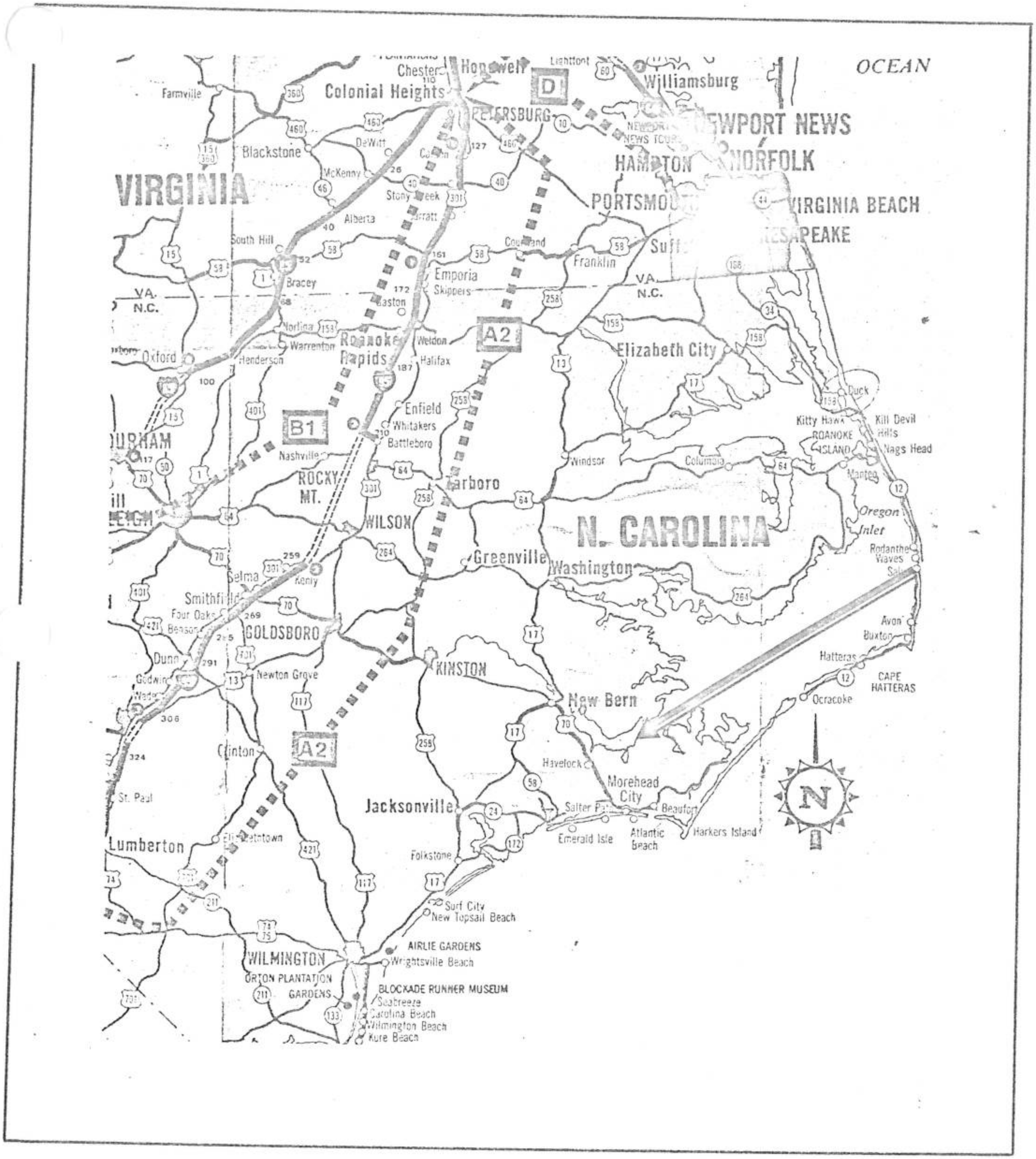

Figure 3. The U component(060° component) over Pamlico Sound.

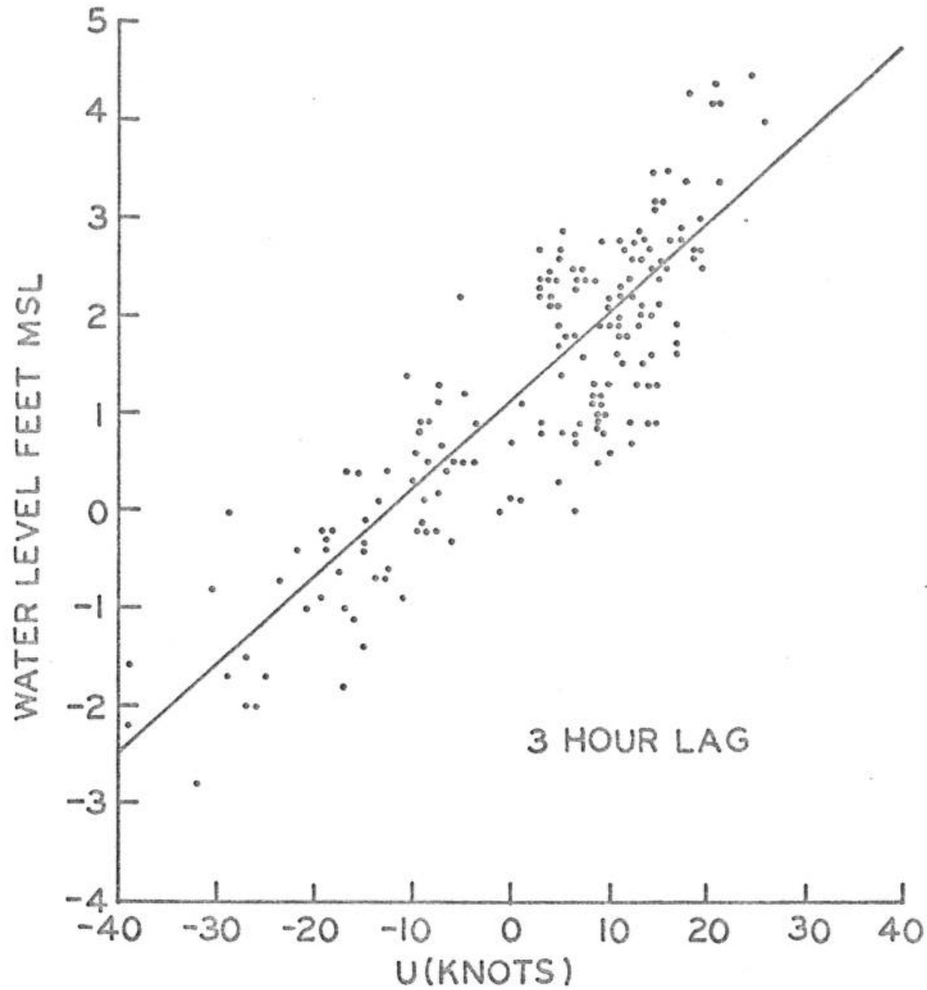

Figure 4. Scatter diagram showing tide heights at Minnesott Beach against the U component with a lag of 3 hours. The straight line shows the regression equation between these variables.

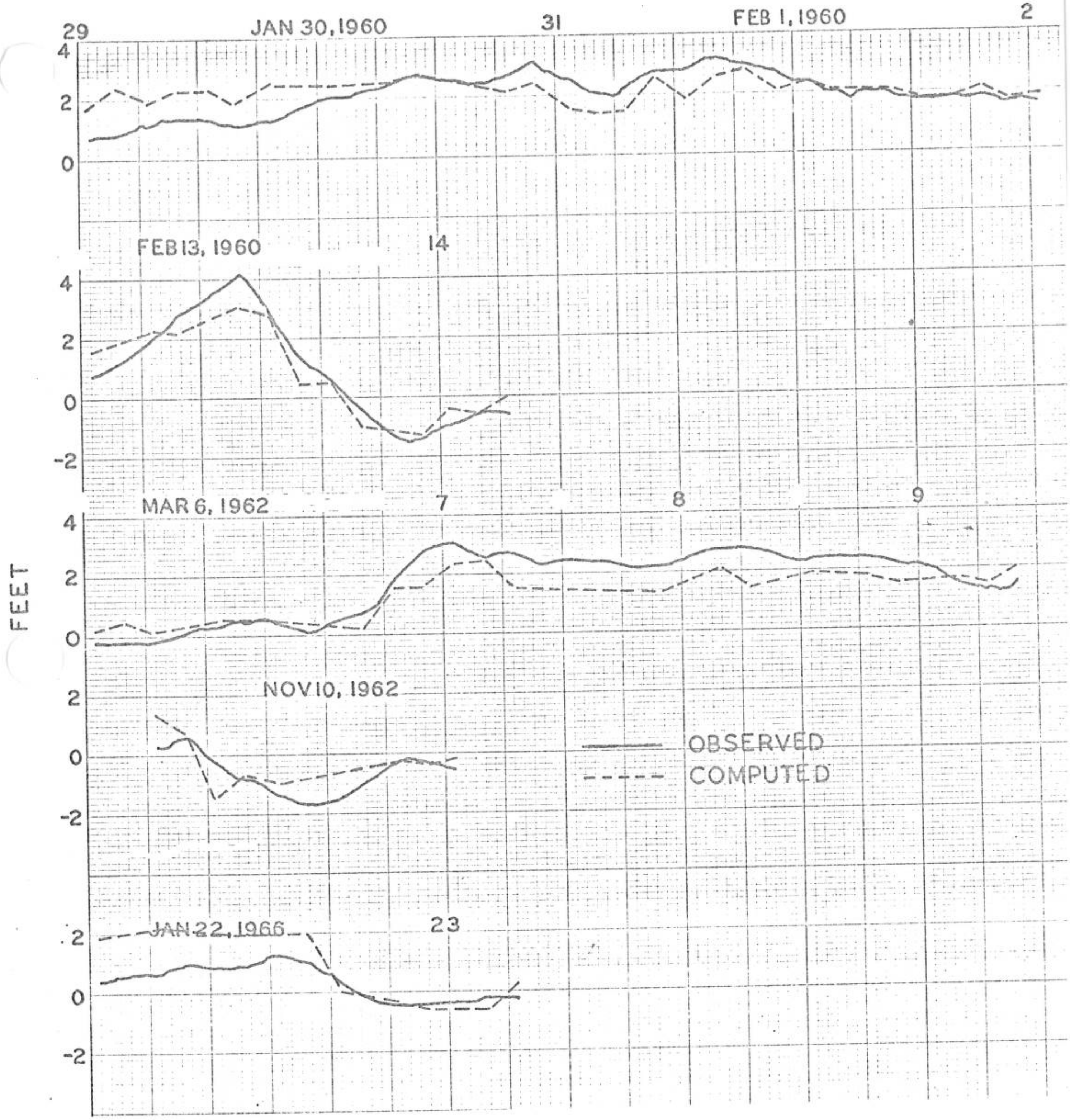

Figure 5a. Observed tide heights and computed tide heights for several storms affecting Minnesott Beach. Curves of computed heights are based on 3-hourly values.

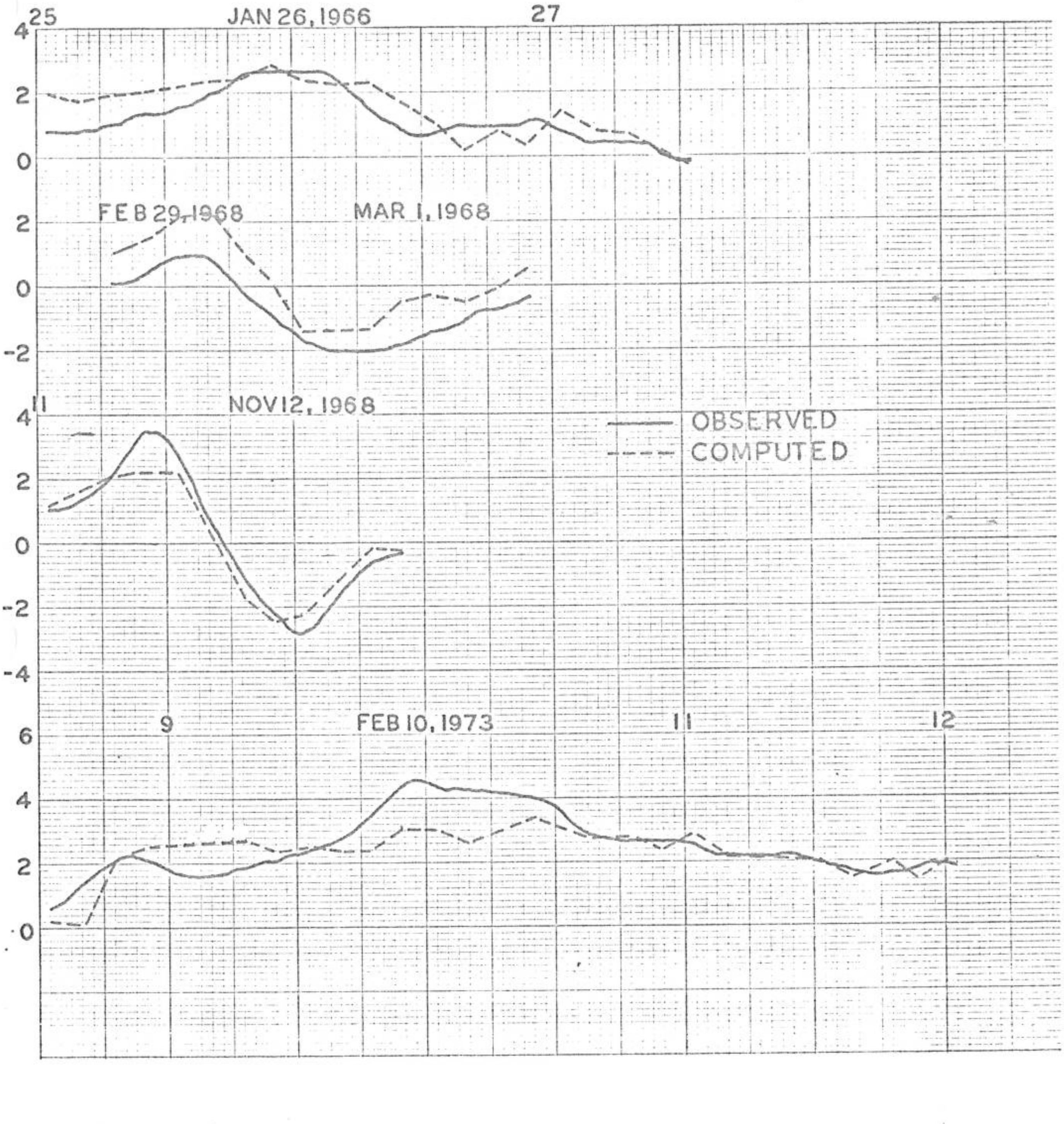

Figure 5b. Observed tide heights and computed tide heights for several storm affecting Minnesott Beach. Curves of computed heights are based on 3-hourly values.