U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
SYSTEMS DEVELOPMENT OFFICE
TECHNIQUES DEVELOPMENT LABORATORY

TDL Office Note 74-9

A FORECAST AID FOR EXTRATROPICAL STORM SURGES AT WASHINGTON, NORTH CAROLINA

N. Arthur Pore

July 1974

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INTRODUCTION

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WASHINGTON STORM SURGE DATA

Storm Surge data for Washington are recorded by the U.S. Army Corps of Engineers. Data for several storm periods were extracted and tabulated by WSO, Wilmington for this study. The dates of these storm periods are:

1300 EST Jan. 29 thru 1300 EST Feb. 2, 1960
1300 EST Feb. 12 thru 0700 EST Feb. 15, 1960
1300 EST March 5 thru 2200 EST March 10, 1962
0100 EST Nov. 9 thru 0400 EST Nov. 11, 1962
0100 EST Jan. 22 thru 0700 EST Jan. 24, 1966
1300 EST Jan. 25 thru 1600 EST Jan. 27, 1966
0700 EST Jan. 28 thru 1000 EST Jan. 31, 1966
0100 EST Feb. 29 thru 2200 EST March 1, 1968
0400 EST Nov. 9 thru 1000 EST Nov. 10, 1968
1300 EST Nov. 11 thru 2200 EST Nov. 12, 1968
0100 EST Feb. 9 thru 1300 EST Feb. 12, 1973

These are the same storm periods used in the Minnesott Beach Study with the addition of two periods. Graphs of storm surge elevations for these time periods are shown in figures 2a and 2b.

WIND DATA

Cape Hatteras wind observations at 3-hourly intervals were obtained from the Environmental Data Service publication, Local Climatological Data. Components of the wind were chosen as possible predictors of the storm surge at Washington. One component considered was the U component which was used as a predictor of the Minnesott Beach storm surge. This is the component from 060^{0} and is calculated as: $U = S \sin(\alpha + 30^{\circ})$, where S

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Another component considered as a tentative predictor of the Washington storm surge was the component from 105^0. This is the component (PR) along the axis of the Pamlico River which leads from Pamlico Sound to Washington and is calculated as: $PR = S \sin(\alpha - 15°)$. For convenience the multiplication factors for determining the component (PR) at 10^0 intervals are shown in Table 1. The U and PR components are shown in figure 3.

PROCESSING OF THE DATA

Values of storm surge, the 060° component[U], the 105° component (PR), the square of the 105° component (PR^2), and the 105° component of the square of the wind speed were punched on cards and processed by a correlation-regression program. Several runs with these data were made and these resulted in many possible forecast equations using various combinations of wind components with several lag times as predictors.

The five regression equations with surge expressed in feet and wind components expressed in knots, which were considered in detail as possible forecast equations are:

1. $Surge=0.667+0.070\ U_{(-3\ hr)}$; $r=0.69$

2. $Surge=1.137+0.091\ PR_{(-3\ hr)}$; $r=0.76$

3. $Surge=1.046+0.061\ PR_{(-3\ hr)}+0.002\ U_{(0\ hr)}+0.019\ U_{(-3\ hr)}+0.014\ PR_{(0\ hr)}$; $r=0.78$

4. $Surge=1.147+0.004(\text{PR Component of Speed Square})_{(-3\ hr)}$; $r=0.75$

5. $Surge=1.184\pm 0.005\ (PR)^2_{(-3\ hr)}$; $r=0.80$

   (The sign used for the $(PR)^2$ term is the sign of the PR Component)

These equations have somewhat lower correlation coefficients (r) than those obtained for Minnesott Beach. For example, the forecast equation for tide at Minnesott Beach with the 3-hour lagged U component as the predictor has a coefficient of 0.87.

Because we have no truly independent storm cases on which to test the above regression equations, they were applied to the 11 dependent storm cases and the results were subjectively compared. These 11 cases are thought of as "somewhat independent", as each storm on the average made up less than 10% of the total data.

The U component (from 060^{0}) is not as good as the PR component (from 105^{0}) for predicting the storm surge at Washington. Equation 3 yields slightly better results than equations 1 or 2, because it contains the predictors of both equations 1 and 2. Equation 5, which has the square of the PR component as the predictor has a high correlation, but when it was applied to the 11 storm cases the resulting calculations were too irregular. A problem with predictor terms which are the square of wind components is the fact that the relative error in wind observations and forecasts are approximately twice as great for squared wind values as for linear wind values.

Subjective consideration of the application of the regression equations to the 11 storm cases has led to the decision that equation 2 is preferable for experimental use. This equation has a physically meaningful predictor which is lagged, has only one independent variable, and has a fairly high correlation coefficient. A scatter diagram showing the PR component plotted against storm surge is shown in figure 4. Also the line representing the forecast equation 2 is shown.

Figures 5a and 5b show the tide calculations, using equation 2, and the observed storm surges for the 11 storms considered. The agreement of these calculations with the observations is quite reasonable, considering the simplicity of the forecast equation. The greatest departures of the calculations from the observations were when the water level was much below normal (negative storm surges) following a high water occurrence. Such cases occurred on January 30, 1966 and March 1, 1968. The calculation of these extreme low waters may not be as important as high water calculations.

PROCEDURE FOR EXPERIMENTAL USE OF METHOD FOR FORECASTING

The following steps are suggested for experimental use in forecasting the Washington, N.C. storm surge during extratropical storms:

1. Determine the Cape Hatteras wind forecast by any available means.

2. Calculate the 105^{0} wind component (PR) as $S \times \sin(\alpha - 15^{\circ})$ or use the multiplication factor from table 1.

3. Calculate storm surge with a three-hour lag from wind forecast valid time as $1.137 + 0.091\ PR_{(-3\ hr)}$ or determine surge forecast from graph of figure 4.

SUMMARY

It appears that the 105^{0} wind component at Cape Hatteras with a three-hour lag can be used as a predictor of the storm surge at Washington, North Carolina.

ACKNOWLEDGEMENTS

Appreciation is expressed to the Weather Service Office at Wilmington, N. Carolina for making the storm surge data available to Techniques Development Laboratory. Appreciation is also expressed to Mr. Herman Perrotti for drafting the figures and to Mary-Blue Battle for typing the manuscript.

Table 1. Multiplication factors to determine the PR component (105° component) over Pamlico Sound. The factor is equal to $\sin(\alpha - 15^{\circ})$, where α is the wind direction.

Wind Direction	Factor	Wind Direction	Factor
0°	-.259	180°	.259
10	-.087	190	.087
20	.087	200	-.087
30	.259	210	-.259
40	.423	220	-.423
50	.574	230	-.574
60	.707	240	-.707
70	.819	250	-.819
80	.906	260	-.906
90	.966	270	-.966
100	.996	280	-.996
110	.996	290	-.996
120	.966	300	-.966
130	.906	310	-.906
140	.819	320	-.819
150	.707	330	-.707
160	.574	340	-.574
170	.423	350	-.423

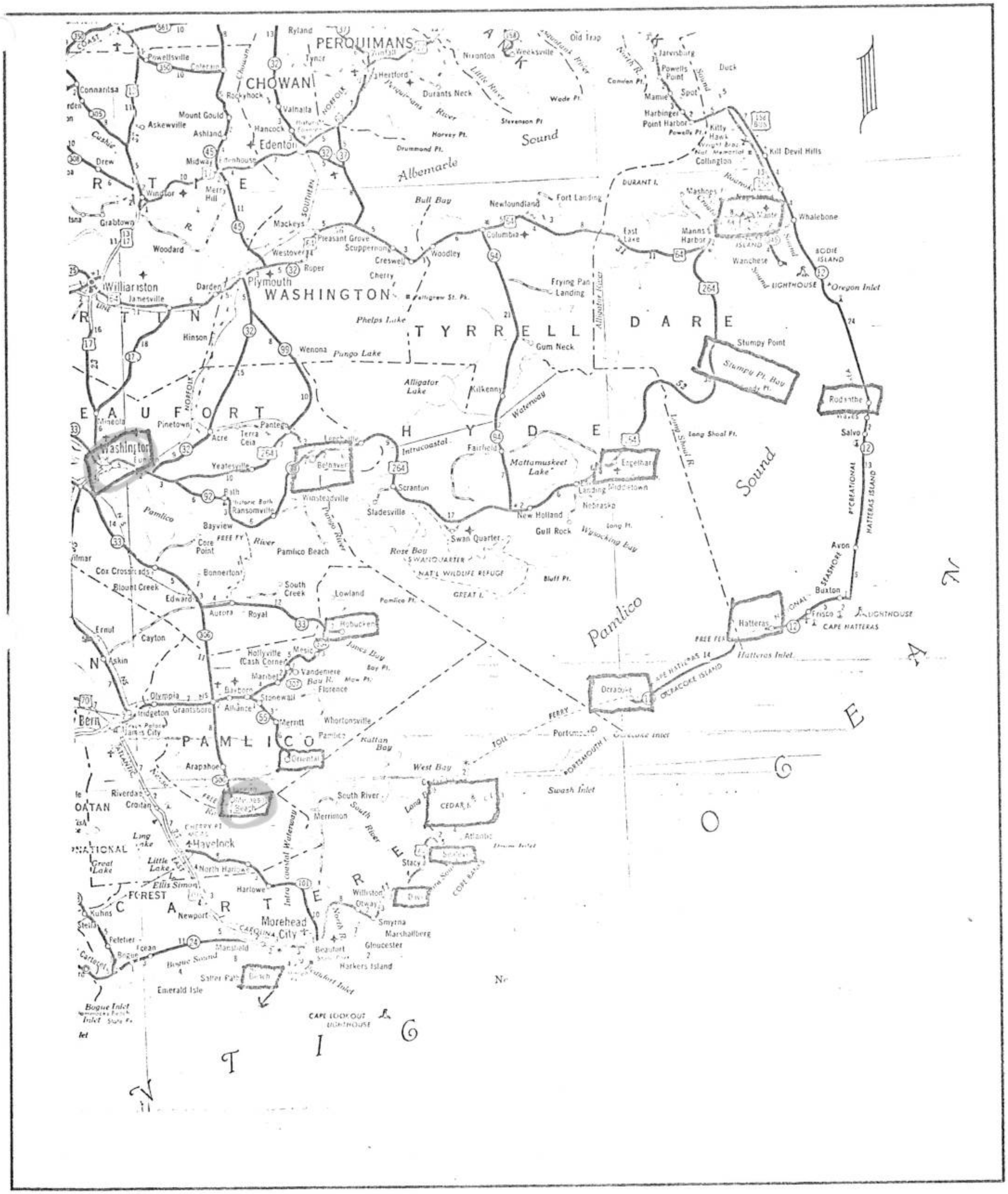

Figure 1. Map of Pamlico Sound showing some critical storm surge locations.

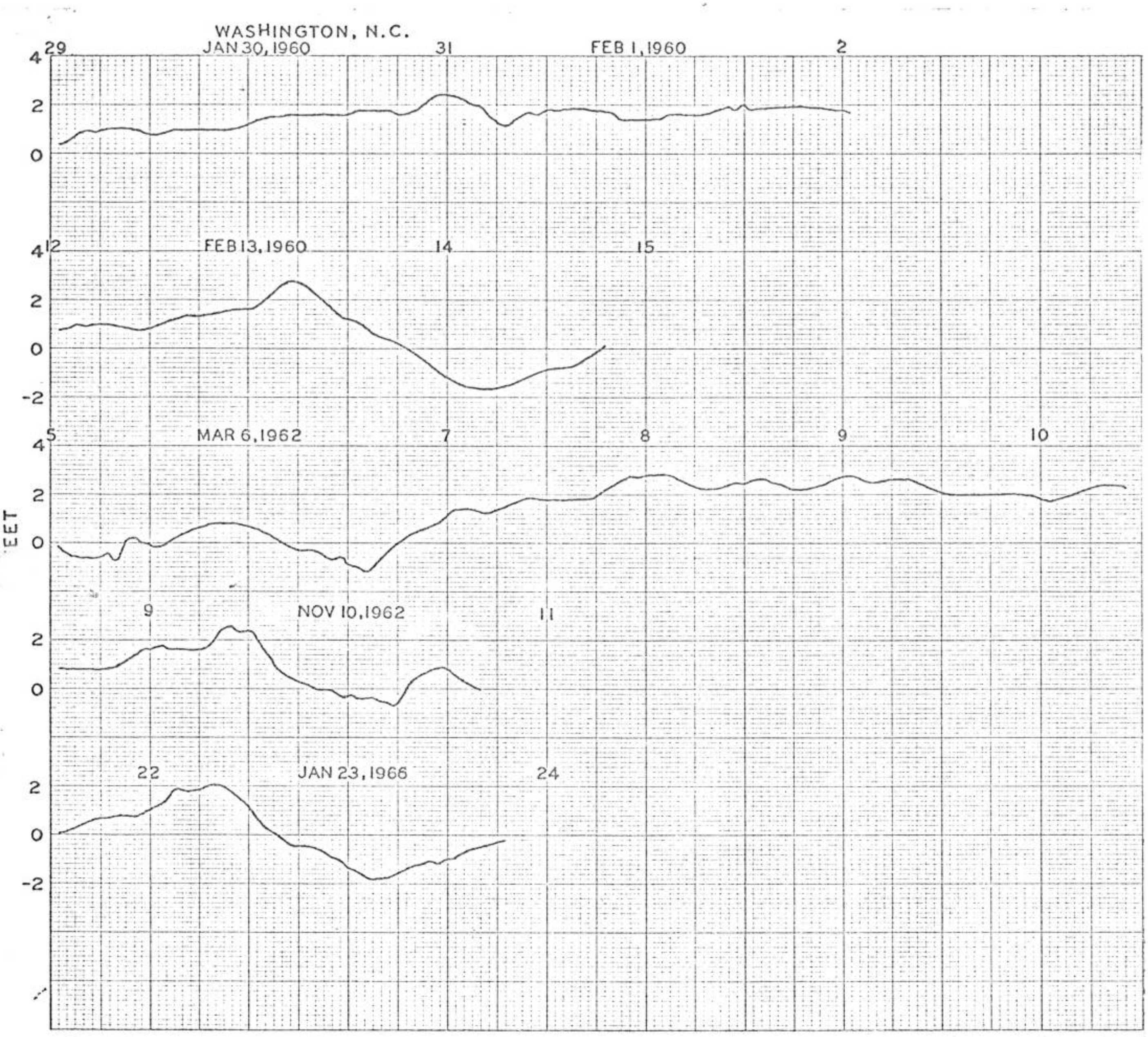

Figure 2a. Storm surges observed at Washington, North Carolina during several recent storms. The curves are based on hourly values. The dates are shown at the 1200 EST positions.

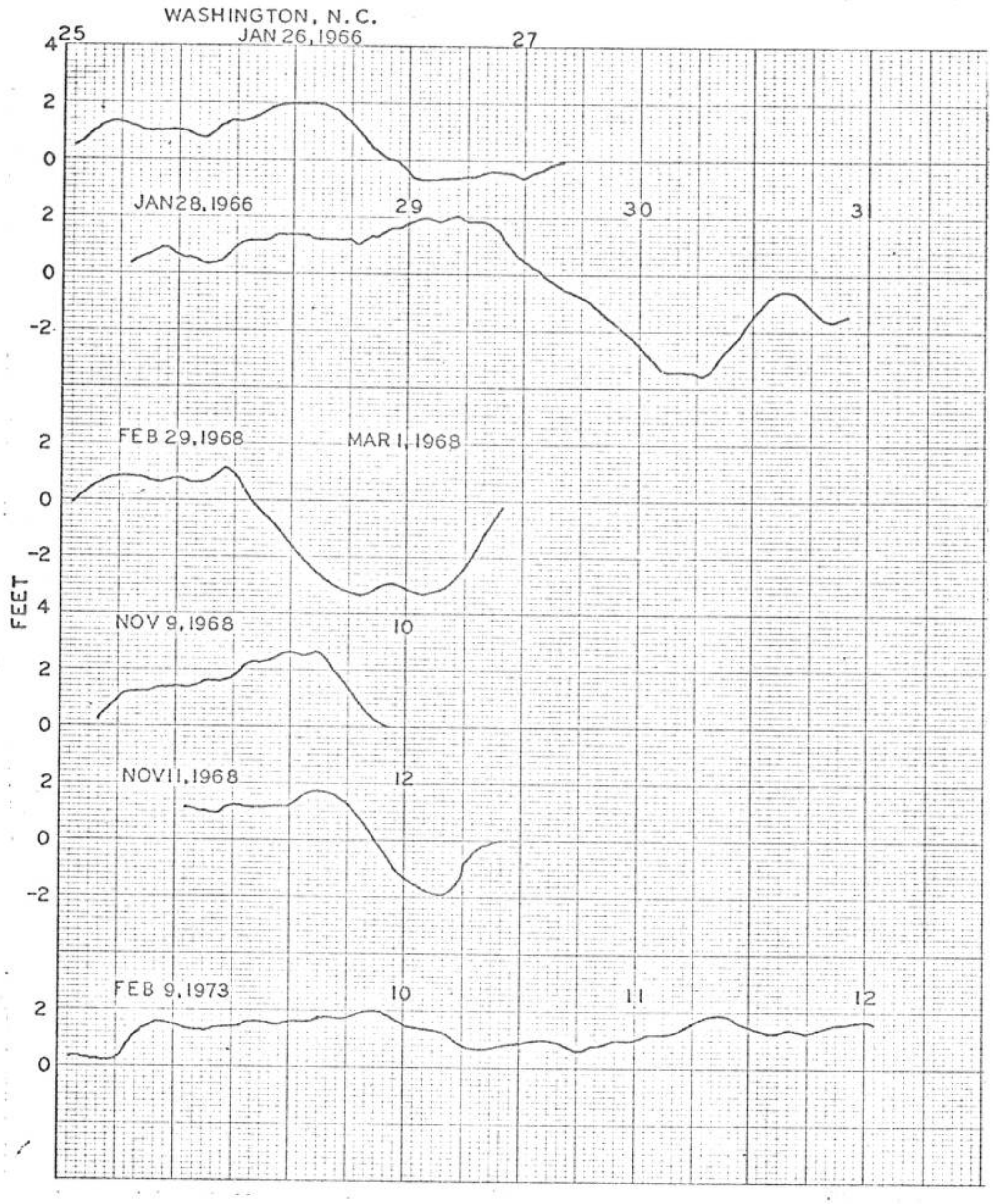

Figure 2b. Storm surges observed at Washington, North Carolina during several recent storms. The curves are based on hourly values. The dates are shown at the 1200 EST positions.

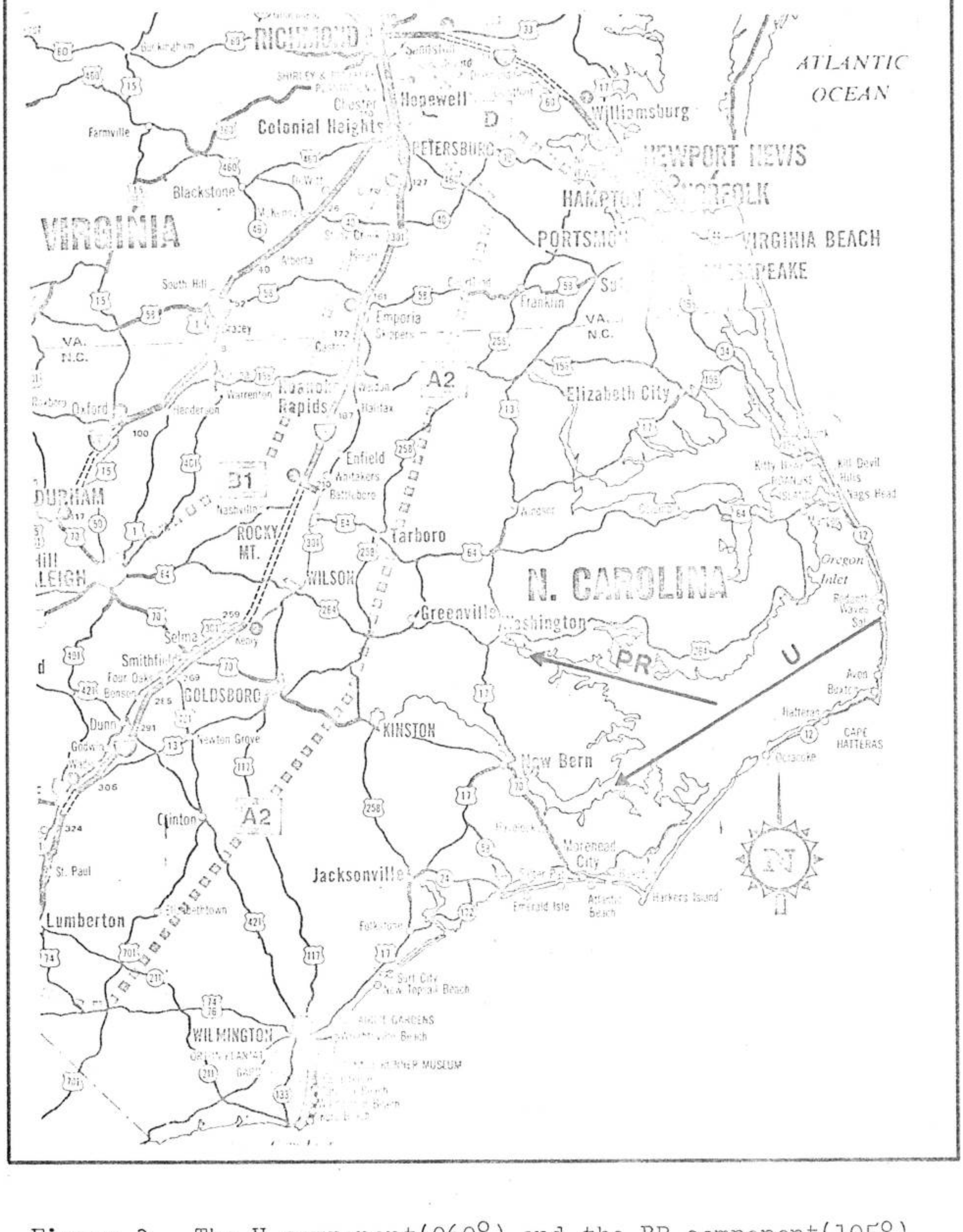

Figure 3. The U component(060°) and the PR component(105°) over Pamlico Sound.

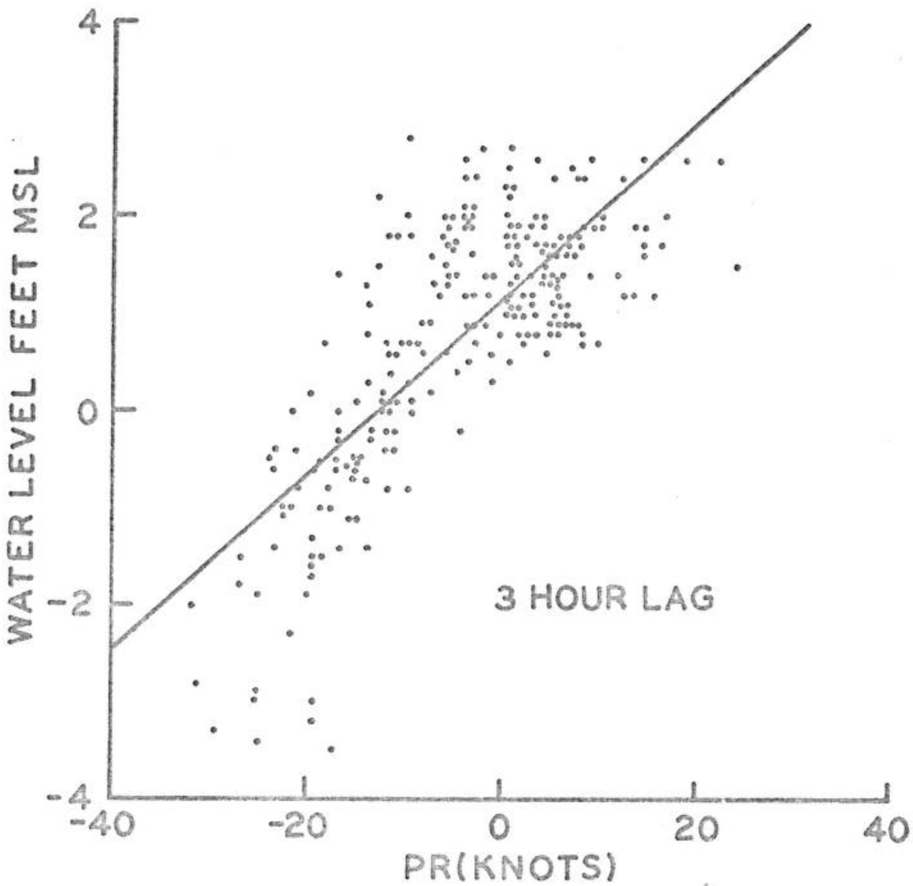

Figure 4. Scatter diagram showing storm surge heights at Washington, North Carolina against the PR component with a lag of 3 hours. The straight line shows the regression equation between these variables.

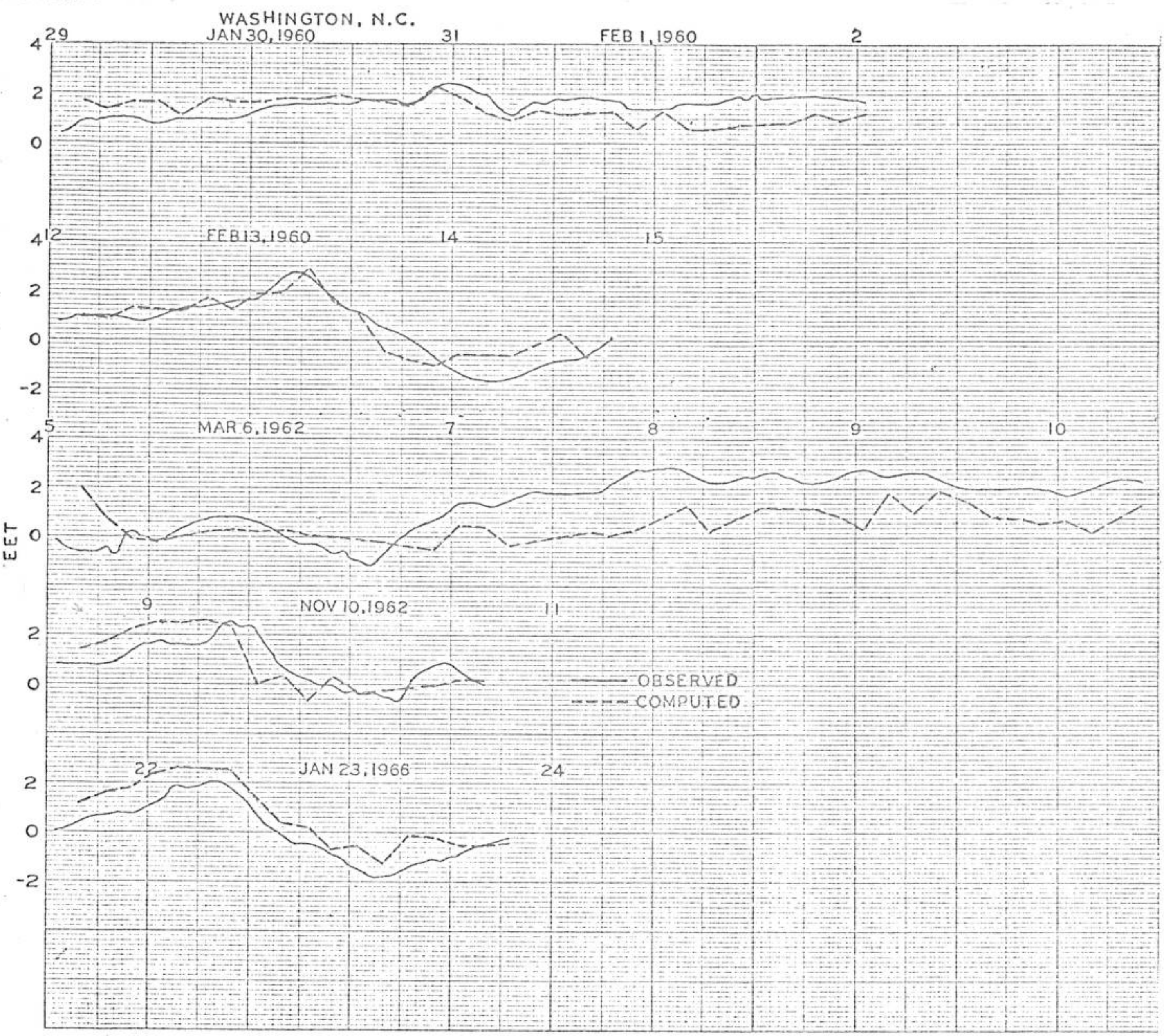

Figure 5a. Observed and computed storm surges for several storms affecting Washington, North Carolina. Curves of computed heights are based on 3-hourly values.

Figure 5b. Observed and computed storm surges for several storms affecting Washington, North Carolina. Curves of computed heights are based on 3-hourly values.