PREDICTION OF EAST COAST CYCLONES BY STATISTICAL METHODS

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I. Introduction

I would like to discuss a statistical technique for the prediction of the displacement and change in intensity of wintertime east coast cyclones (Ostby and Veigas, 1960) and then go on to show how these predictions might be used to specify something about the accompanying weather over the northeastern part of the United States.

The prediction experiment is concerned with the derivation of objective techniques for predicting the behavior of winter cyclones located near the east coast of the United States. Many of these cyclones undergo intense and rapid development, leading to widespread cloudiness, low ceilings, abundant precipitation, and high winds along much of the eastern seaboard. Most of the heavy snowstorms along the east coast are a consequence of this type of development. These facts, coupled with the generally high frequency of occurrence of such cyclones, emphasize the importance of this forecast problem.

The cyclone's future position and intensity are of primary concern in the preparation of a forecast of the weather associated with an impending east coast cyclone.

This, of course, does not imply that associated weather conditions can be completely deduced from the future position and intensity of a cyclone. Nevertheless, it is generally recognized that position and intensity prognoses are basic and indispensable factors in the weather forecast. In this study, prediction equations for the 24-hour displacement and change in intensity of wintertime east coast cyclones are derived and tested.

II. Data Sources

The data for this study were acquired from two sources. Manuscript surface and 500-mb maps, prepared by the USWB at Idlewild Airport, were used for compiling the dependent data sample covering the eight-year period, 1949 - 1956. In addition, microfilm maps (surface and upper-air) for 1957 - 1958, analyzed by the National Weather Analysis Center, were used for independent data testing.

III. Selection of the Sample of Data

Cases for the dependent sample were selected from cyclone track summaries covering the months, November through March, for the years 1949 through 1956. The geographical area of concern is roughly the eastern third of the United States.

A sea-level cyclone (characterized by at least one closed isobar initially as well as 24 hours later) was selected for the sample when it first appeared in the area. If, 12 hours later, the cyclone was still situated within the defined area, it was included as another case. In order to eliminate a possible bias, any cyclone remaining in the area after two 12-hour periods was not included a third time.

Based upon these requirements, 352 cases were selected.

IV. Selection of Possible Predictors

Although statistical procedures permit examination of, and selection from a large number of possible predictors; the analysis itself is not based on knowledge of the physical processes that govern the behavior of the atmosphere. It therefore appears highly desirable to incorporate dynamic principles and synoptic experience in the selection of the initial large set of predictors. A considerable effort was made to specify a set of possible predictors containing as much predictive information as could be derived from the data available.

Grid - The type of grid used in this study was a moving grid centered over the cyclone center. Meteorological information was tabulated at locations fixed with respect to the cyclone center rather than with respect to specific geographical locations. For each cyclone case values of sea level pressure, 500-mb height, 1000-500 mb thickness, and 12-hour time changes of these variables were read at the gridpoints and tabulated. These comprised a total of about 200 possible predictors.

V. Mathematical Methods

The reduction of the number of predictors was accomplished using the screening procedure suggested by Bryan (1944), and developed and programmed for the IBM-704 by Miller (1958). The objective of the screening procedure is to select from a set of possible predictors a sub-set which contributes significantly and independently to reducing the variance of the predictand. From an array of possible predictors, that predictor which has the highest linear correlation with the predictand in question is selected. Partial correlation coefficients between the predictand and each of the remaining predictors, holding the first predictor selected constant, are then examined. The predictor associated with highest coefficient is the second one selected. Addition predictors are then chosen in a similar fashion. This procedure is repeated until a selected predictor fails to explain a significant additional percentage of the

remaining variance of the predictand.

Predictors were selected by this procedure for each of the three predictands: the 24-hour northward and eastward components of the cyclone displacement, and the 24-hour change in central pressure. Then the associated multiple linear regression equations were derived.

Forecasts were then made for 106 cases not used in the developmental sample.

VI. The Prediction Equations

The number of predictors selected for the three equations varied between 5 and 10. That is to say, that of about 200 possible predictors, there were about 10 that contained most of the predictive information.

The results of the 106 independent predictions are summarized in Table 1.

Table 1. Summary of independent predictions, with dependent predictions shown for comparative purposes. Root-mean-square errors are tabulated for predictions of N (24-hr northward displacement), E (24-hr eastward displacement), and D (24-hr change in central pressure). The "Vector" column is the root-mean-square vector error of the predicted position of the cyclone.

	Cases	$\hat{N}$ (°lat)	$\hat{E}$ (°lat)	Vector (°lat)	$\hat{D}$ (mb)
Dependent	352	2.30	2.64	3.50	7.94
Independent	106	2.59	3.06	4.01	8.70

In addition, a series of 31 operational forecasts were made during the winter of 1959 - 1960 and compared with 18-hour forecasts prepared by the National Weather Analysis Center. The root-mean square error for cyclone location was 2.25 degrees of latitude for the 24-hour statistical forecasts and 3.87 degrees of latitude for the 18-hour NWAC forecasts. Root-mean-square errors of central pressure were 8.14 mb for the statistical forecasts and 7.25 mb for the NWAC forecasts. In 24 of the 31 forecasts of cyclone locations and in 13 of the 31 forecasts of central pressure, the statistical predictions yielded smaller errors than did the NWAC predictions.

VII. Associated Weather

Now what can be said about forecasting the weather associated with these east coast cyclones? First of all, it is quite obvious to any synoptic meteorologist that if a cyclone over the southeastern states is

Table 2. Precipitation forecasts for Hartford derived from precipitation probabilities.

18-24 hr

Observed	Forecast Yes	No	Total
Yes	21	11	32
No	13	29	42
Total	34	40	74

Percent correct 68
Skill score .35

24-30 hr

Observed	Forecast Yes	No	Total
Yes	19	15	34
No	11	29	40
Total	30	44	74

Percent correct 65
Skill score .28

18-30 hr

Observed	Forecast Yes	No	Total
Yes	31	11	42
No	11	21	32
Total	42	32	74

Percent correct 70
Skill score .39

predicted to move up the Hudson Valley, it is much more likely to rain in New England rather than snow. Therefore, a method such as this one is helpful in distinguishing between certain rain vs. snow problems, where the projected path of the cyclone is the critical factor.

We know from experience that practically all heavy snowstorms in this area are caused by intensifying cyclones moving out to sea some distance south of New England. To verify this, a check of the local climatological data for Windsor Locks, Connecticut for the period from 1956 - 1961 was made. There were 22 snowstorms of 5 inches or more. In every case the cyclone passed south of Windsor Locks. In 21 of the 22 cases the minimum central pressure during the storm was 1000-mb or less. Thirteen of the 22 cases deepened to less than 990 millibars.

In order to specify something quantitatively about associated weather with east coast cyclones, a study was made to predict the probability of precipitation at Hartford based on the statistical cyclone prediction methods. This was an extension to an earlier feasibility study (Emerson and Reeves, 1961). The problem was formulated this way: Given a 24-hour cyclone prediction location, what is the probability of precipitation 18-24 hours from now and 24-30 hours? To do this, a map was plotted with cyclone locations on it, with a notation as to whether or not precipitation occurred at Hartford during the previous 6 hours. Also a map was

plotted covering the subsequent 6-hour period. In all, there were over 600 cases available for testing. Next, a percentage frequency of precipitation cases was made at a network of gridpoints by summing the number of precipitation cases in a square area surrounding a gridpoint and dividing by the total number of cases in that area. Isopleths of precipitation probability were then constructed.

By denoting a probability of greater than 0.5 to be a forecast of precipitation and less than 0.5 to be a forecast of no precipitation, a two by two contingency table was made based on 74 independent cyclone predictions (using the statistical method). Table 2 shows these results.

VIII. Summary

In conclusion, the statistical prediction method for forecasting cyclone displacement while derived on an IBM-704, is easily applied at the local weather station level with a desk calculator. A forecast can be made in about 20 minutes.

The results on independent data show it to be competitive with predictions issued at NWAC. In fact, forecasts are being made using this technique at NWAC on an experimental basis.

The precipitation probability charts are used at the Travelers Weather Service in Hartford during impending east coast cyclones. These computations are given consideration along with other methods to arrive at precipitation probabilities which are disseminated in public forecasts via radio and TV.

REFERENCES

Bryan, J. G.
1944. Special Techniques in Multiple Regression. Unpublished manuscript.

Emerson, J. E., and Reeves, R.
1961. Precipitation Probabilities Associated with East Coast Cyclones. Unpublished report, Travelers Research Center, Hartford. 10 pp.

Miller, R. G.
1958. A computer program for the screening procedure. In Studies in Statistical Weather Prediction, Final Report, Contract No. AF 19(604)-1590. Travelers Weather Research Center, 96-136.

Ostby, F. P., and Veigas, K.
1960. A Moving-Coordinate Prediction Model Applied to East Coast Cyclones, Scientific Report No. 1, Contract No. AF 19(604)-5207. Travelers Weather Research Center. 75 pp.