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Forecasting

FORECASTING THE PREDOMINANCE OF FROZEN PRECIPITATION: AN ALTERNATIVE FOR THE CLASSIFICATION OF MIXED PRECIPITATION EVENTS AND THE VERIFICATION OF PRECIPITATION TYPE

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1. INTRODUCTION

Given the event of precipitation, what is the probability that frozen precipitation (snow and/or sleet) will predominate? Defining predominance as it was used in this study, that is to say, what is the probability that the precipitation event will consist of the frozen type only, or in the event of mixed precipitation (frozen and unfrozen) that measurable frozen precipitation will occur?

The prediction of measurable frozen precipitation from mixed precipitation events becomes especially important for areas where measurable frozen precipitation is relatively infrequent, where a significant percentage of its occurrences are produced by mixed precipitation events, where facilities for its removal are limited, and where small amounts are often disruptive to the community. For such areas, frozen precipitation makes a significant impact upon the community and is perceived as predominating a mixed precipitation event whenever a measurable amount of frozen precipitation occurs.

Charlotte, North Carolina, as well as much of the Piedmont Crescent of the Carolinas, is an example of such an area. At Charlotte, from December 1970 through March 1977, there were 23 cases of measurable frozen precipitation, and 52 percent of these occurred from mixed precipitation events. Based on a 100-year period of record, Charlotte's mean annual snowfall is 6 inches. Because of the relatively infrequent occurrence of frozen precipitation, the facilities for its removal are limited. And even small amounts often result in temporary hardships such as disruption of traffic and the alteration of business and school schedules.

While the amounts of frozen precipitation occurring from mixed precipitation events will generally be small, such events do present a significant forecast problem to those areas whose conditions are similar to those described for Charlotte. But does the objective precipitation type forecast schemes (PoPT on early guidance, PoFP on final guidance(3)) used operationally by the National Weather Service adequately address this forecast problem?

The PoPT scheme classifies all mixed precipitation events as liquid (rain and/or drizzle (4,6)), while the PoFP scheme classifies all such events as unfrozen (rain and/or freezing rain and/or drizzle (5)). In the case of Charlotte, it was noted that a significant percentage of the occurrences of measurable frozen precipitation were produced by mixed precipitation events. To classify this percentage as liquid or unfrozen could bias a prediction equation to forecast lower probabilities of frozen precipitation for many cases where measurable amounts occurred.

Both the PoPT and PoFP schemes for the 12-h forecast predict precipitation type for the 12th hour (4,5,6). But for areas similar to Charlotte where small amounts of measurable frozen precipitation are often significant and the occurrence of frozen precipitation often comes from mixed precipitation events, the critical question for the forecaster is not so much what the precipitation type will be on the 12th hour as much as which precipitation type predominates during the 12 hour forecast period.

Moreover, verifying precipitation types on the hour rather than for the forecast period and classifying all mixed precipitation events as unfrozen or liquid creates a distinct possibility that measurable frozen precipitation events could be classified as unfrozen or liquid, of perhaps not to be included in the verification statistics. As an example, the winter of 1978-79 produced 4

cases of measurable frozen precipitation at Charlotte. Verification statistics for the PoPT forecast scheme showed 1 case of frozen precipitation (7).

This paper describes a forecast scheme which uses radiosonde (RAOB) data to predict the predominance of frozen precipitation at Charlotte, NC over the 12-h period between RAOB reports. It offers an alternative to the rationale being used by the PoPT and PoFP schemes for the classification of mixed precipitation events and the verification of precipitation type; an alternative which is thought to be more realistic for those areas where measurable frozen precipitation often occurs from mixed precipitation events, and where small amounts of frozen precipitation often constitute significant weather events.

2. DEFINITION OF PREDICTAND

Frozen precipitation was defined as a form of snow and/or sleet. Unfrozen precipitation consisted of any combination of rain, freezing rain, or drizzle. Mixed precipitation was a combination of frozen and unfrozen.

For this study's purposes, mixed cases were classified as frozen, provided a measurable amount of frozen precipitation occurred during the 12-h forecast period. Otherwise, mixed cases were classified as unfrozen. While trace amounts of mixed precipitation were not included in the data, trace amounts of frozen and unfrozen were included for the purpose of increasing sample size and hence improving the reliability of the data.

3. CHOICE OF PREDICTORS

The predictors of precipitation type were chosen to be the 1000-700mb thickness:

$$\Delta Z^{1000/700}$$

and the 850-mb temperature (T_{850}) as measured at the Greensboro, NC radiosonde station.

A study by Wagner (8) predicted precipitation type as a function of the 1000-500mb thickness. However, Wagner argued that the 1000-700mb thickness is theoretically a better predictor of precipitation type, as the temperature at altitudes above 10,000 ft is rarely above freezing for the majority of winter precipitation events. Hence the 1000-700mb thickness was chosen as the first predictor.

Among the predictors used in the development of the PoFP forecast scheme, T_{850} was reported as the best of any single predictor (5) and was used as the second predictor.

4. SELECTION OF DATA AND DEVELOPMENT OF PREDICTION EQUATIONS

Observations of precipitation type over the 12-h period between RAOB reports were made at the Charlotte National Weather Service Office.

Using the Greensboro, NC RAOB, the most recent values of $\Delta Z^{1000/700}$ and T_{850}, prior to the beginning of a precipitation event, were collected for the winters (Nov.-Mar.) 1970-71 through 1976-77. For each of 295 precipitation events which occurred during the period, the precipitation types, amounts, date, and time of onset were recorded.

Linear multiple regression was used to develop the prediction equation. Of the total 295 precipitation events comprising the dependent data, 220 were not used to develop the prediction equation as their values of $\Delta Z^{1000/700}$ and/or T_{850} were so high or low that invariably the precipitation type could never be in doubt. Therefore, the regression line obtained from the inclusion of these 220 cases would differ significantly from a regression line obtained otherwise. Such a regression line would not produce the most accurate forecasts for the range of $\Delta Z^{1000/700}$ and T_{850} values where precipitation type was in question and the element of prediction did in fact exist.

The values of the predictors associated with the certainty of precipitation type resulted from adjusting the highest (lowest) observed values for frozen (unfrozen) precipitation to the error of measurement of RAOB data and the class interval size of the predictors. As a result of the adjustments, 75 precipitation events were used to develop the prediction equation whose values for $\Delta Z^{1000/700}$ ranged between 2779 and 2888 meters and for T_{850} between -6.1C and 3.0C.

The resulting prediction equation for the conditional probability of the predominance of frozen precipitation (CPPFP) was:

$$CPPFP = 26.14568 + (-0.00908)(\Delta Z^{1000/700}) + (-0.07042)(T_{850})$$

5. VERIFICATION

Probability and categorical verification scores were calculated for both the dependent (D) (winters 1970-71 through 1976-77) and independent (I) (winters 1977-78 through 1979-80) data.

Table 1. Probability verification scores (P-score) for the dependent (D) and independent (I) data.

	Dependent	Independent
P-Score	.05	.08
Number of Cases	288	185

Table 2. Categorical verification scores for the dependent (D) and independent (I) data.

	Unfrozen		Frozen	
	D	I	D	I
Bias	1.00	0.93	1.00	1.12
Post-Agreement	0.98	0.99	0.84	0.81
Prefigurance	0.98	0.92	0.84	0.94
Critical Success Index	--	--	0.73	0.77
Number of Cases	256	149	32	36

Table 1 shows the probability verification scores calculated for frozen precipitation. The P-scores were calculated as shown by Panofsky and Brier (9). For those precipitation events where the prediction equation yields probabilities greater than 100 percent or less than 0 percent, the probabilities used in the calculation of the P-scores were set equal to 100 percent and 0 percent.

P-score values may range from 0 to 2. A score of 0 represents totally accurate forecasting, while a score of 2 indicates totally inaccurate forecasting. There was little difference in the P-scores between the dependent (.05) and the independent (.08) data.

Table 2 shows the categorical verification scores where the frozen category was defined as the best category whenever the predicted probabilities were equal to or greater than 50 percent.

The bias = B/C, post-agreement = A/B, and prefigurance = A/C, where A is the number of correct forecasts of the event, B is the total number of forecasts of the event, and C is the number of observations of the event (4,6).

The bias indicates that the frozen and unfrozen categories were forecast to occur as often as they did, although in the independent sample, the frozen category was slightly over-forecasted and the unfrozen category was slightly under-forecasted.

The post-agreement shows that when frozen was forecast, it was correct 84 percent (D) and 81 percent (I) of the time. The percent correct for unfrozen was 98 (D) and 99 (I).

The prefigurance shows that when frozen occurred it was correctly forecasted 84 percent (D) and 94 percent (I) of the time. The percent correct for unfrozen was 98 (D) and 92 (I).

Score differences between the dependent and independent samples may in part be due to the considerably drier winters which comprised the dependent sample, relative to the wetter winters comprising the independent sample.

Score differences between the frozen and unfrozen categories reflect that the typical Charlotte winter has a large number of unfrozen precipitation events whereas frozen precipitation is a relatively rare event, and hence more difficult to forecast. It also suggests the need for additional predictors.

The last verification score used was the critical success index (CSI). For the prediction of frozen precipitation, the CSI takes into account both types of prediction errors, failure to predict the frozen event, and the erroneous prediction of frozen (false alarms).

The CSI represents the ratio of successful predictions of frozen precipitation to the sum of these successful predictions to both types of prediction errors, and may vary from 0, complete failure, to 1 for perfection (10).

The CSI scores for frozen precipitation were quite good with little difference between the dependent (0.73) and independent (0.77) data.

6. SUMMARY AND CONCLUSIONS

Using multiple regression and six winters of RAOB data, a forecast scheme predicting the conditional probability of the predominance of frozen precipitation over the 12-h period between RAOBs was developed for Charlotte, NC.

Frozen precipitation was defined to predominate a mixed precipitation event if measurable frozen precipitation occurred during the forecast period.

The question of predominance was thought to be especially important for those areas where frozen precipitation is relatively infrequent, where small amounts are often disruptive, where facilities for its removal are limited, and where a significant percentage of its occurrences is produced from mixed precipitation events.

For such areas, this forecast scheme deals more realistically with the problems of classifying mixed precipitation events and verifying precipitation type than what is offered by the PoFP and PoPT forecast schemes used operationally by the National Weather Service.

Verification scores showed that forecast accuracy was very high for unfrozen precipitation. The somewhat lower scores for frozen reflect the more difficult task of forecasting the relatively rare event of frozen precipitation and the need for additional predictors.

For the future, the prediction equation will be revised using the observed surface temperature, the observed surface wet-bulb temperature, and the 12 hour forecast of

$$\Delta Z^{1000/700}$$

from the Limited Area Fine Mesh (LFM) Model as additional predictors.

Verification scores further suggest this forecast scheme may be used to supplement the PoPT and PoFP guidance (i.e., central guidance), especially in those situations where the forecaster suspects mixed precipitation. Specifically, its purpose is to supplement central guidance for the short range forecast (less than 12 hours). Operationally, its use is best suited for the 10:30 and 21:30 (local time) forecast updates.

Concluding, the addition of the AFOS minicomputer will hopefully enable the field forecaster to develop locally generated numerical forecast tools which address the more localized forecast problems such as the one discussed in this paper.

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REFERENCES AND FOOTNOTES

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3. PoPT = Probability of Precipitation Type; PoFP = Probability of Frozen Precipitation.

4. Bocchieri, J.R., 1979: A new operational system for forecasting precipitation type. Mon. Wea. Rev., 107, pp. 637-649.

5. Glahn, H.R. and J.R. Bocchieri, 1975: Objective estimation of the conditional probability of frozen precipitation. Mon. Wea. Rev., 103, pp. 3-15.

6. Bocchieri, J.R., 1979: Studies in the specification of precipitation type from observed upper air soundings. TDL Office Note 79-12, National Weather Service, NOAA, U.S. Department of Commerce, 19pp.

7. Zurndorfer, E.A., 1980: personal communication, Techniques Development Laboratory, NOAA, Silver Spring, MD 20910.

8. J.A. Wagner, 1957: Mean temperature from 1000 mb to 500 mb as a predictor of precipitation type. Bull. Amer. Met. Soc., 38, pp. 584-590.

9. Panofsky, H.A. and G.W. Brier, 1958: Some Applications of Statistics to Meteorology. Penn State University Press.

10. Donaldson, R.J., Jr., R.M. Dyer and M.J. Kraus, 1975: An objective evaluation of techniques for predicting severe weather events. Preprints 9th Conference on Severe Local Storms, October 1975, Norman, Oklahoma, American Meteorological Society, pp. 321-326.

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