A Simple Yes-No Hail Forecasting Technique

JOHN J. PAPPAS, MSGT, USAF[1]

Air Weather Service

(Manuscript received 20 October 1961, in revised form 2 March 1962)

ABSTRACT

An objective method of hail forecasting is developed, employing as predictors (1) the ratio of cloud depth below the freezing level to the cloud's estimated vertical development and (2) the height of the freezing level. Based on dependent data for Texas, Oklahoma, Kansas and Nebraska, the method showed common and Appleman skill scores of +0.65 and +0.66, respectively.

1. Introduction

During recent years, hail studies by Appleman (1958), Douglas and Hitschfeld (1959) and Donaldson (1959) have shown a relationship between hail formation or occurrences and (1) cloud depth below the freezing level, and (2) cloud height. Earlier investigations (Fawbush and Miller, 1953; Foster and Bates, 1956) have shown the relationship between instability and hail. While all of these studies have furnished useful information leading to improved hail forecasting techniques, results from the more recent papers mentioned above have not been correlated and tested as hail storm predictors for objective forecasting methods.

Seventy severe convective storms (34 hail producing and 36 non-hail producing) are examined with respect to cloud depth below the freezing level and cloud height with the purpose of developing a simple yes-no objective hail forecasting method using these parameters as predictors. The period of study was April through August 1959 and 1960.

2. Area of study and data used

The area selected for study was Texas, Oklahoma, Kansas and Nebraska. Upper air soundings from the following stations were utilized when severe thunderstorms with or without accompanying hail were reported within a 30-mi radius of the radiosonde station[2]: San Antonio, Tex.; Forth Worth, Tex.; Midland, Tex.; Amarillo, Tex.; Oklahoma City, Okla.; Topeka, Kans.; Dodge City, Kans.; Omaha, Nebr.; North Platte, Nebr.

Severe thunderstorms as used here were defined as those thunderstorms causing measurable property damage due either to strong winds, lightning or heavy rain. Severe thunderstorms with accompanying hail were defined as those thunderstorms accompanied by hail where the hail was listed as the prime cause of the property damage even though other phenomena might also have occurred. To avoid the possibility of confusing hail damage with tornado damage when the two phenomena occurred together, all tornadoes were excluded from consideration.

3. Method of analysis

Each of the 70 storms was listed by date, place, phenomenon and time of occurrence. Representative upper air soundings (0000Z and 1200Z) for each case were plotted on the skew T log P diagram. They were then analyzed for three parameters:

(1) Convective condensation level (CCL). This is determined by the intersection of the mean mixing ratio in the lower 150 mb of the sounding and the dry bulb temperature curve.

(2) Equilibrium level (EL). The EL is found at the top of the positive area on the sounding where the temperature curve and the saturation adiabat through the CCL again intersect. This gives us a measure of the extent of the clouds' vertical development and thus an estimate of its top or maximum height.

(3) Freezing level. This is defined as the height of the zero degree isotherm.

All three heights are expressed in units of millibars.

4. Selection of final predictors

After several trials with various combinations of the above parameters, it was found that the best results were obtained with (1) the ratio of the cloud depth

[1] Present Address: Scientific Services Office, 2nd Weather Group, Langley AFB, Va.

[2] Verification data were obtained from the U. S. Weather Bureau's monthly storm data publication: Volumes 1 and 2, Numbers 4 through 8, 1959, 1960.

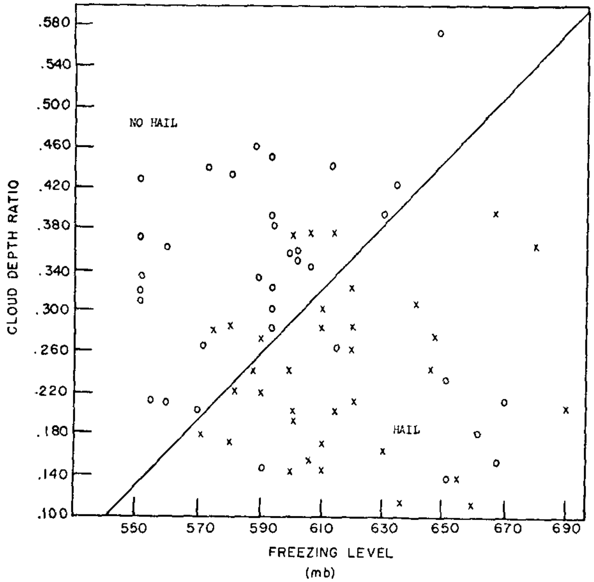

FIG. 1. Scatter diagram showing the distribution of selected hail occurrences at nine Midwestern stations during the spring and summer of 1959 and 1960. The freezing level height is plotted against the cloud depth ratio. (X=Hail reported. 0=No hail reported.)

TABLE 1. Contingency table based on Fig. 1, 70 dependent cases.

	Predicted Hail	Predicted No hail	Total
Observed			
Hail	29	5	34
No hail	7	29	36
Total	36	34	70

below the freezing level (distance from CCL to freezing level) to the cloud's estimated vertical development (distance from CCL to EL), defined as the "cloud depth ratio" and (2) the height of the freezing level as predictors. With (1) as the ordinate and (2) as the abscissa, the 70 cases were plotted on a scatter diagram. (See Fig. 1.)

5. Evaluation

Table 1 summarizes the results of this method. Using dependent data, the common and Appleman skill scores (Appleman, 1960) are +0.65 and +0.66, respectively. The per cent correct is 83. It should be noted that the frequency of incorrect cases is slightly higher when occurrences are predicted. This suggests perhaps that hail may have occurred within the area of the representative sounding but not at the observing station.

6. Summary and conclusion

This objective technique unites two related parameters, previously noted by investigators studying hail formation and severe convective activity, into a single predictor.

While the data used in this study were exlcusively from the Midwest, the application of the technique need not be confined to that area. With some modification of the scattergram, this method could serve as the basis for the development of a local forecasting tool for other areas.

REFERENCES

Appleman, H., 1958: An investigation into the formation of hail. *Nubila*, **2**, 28–37.

——, 1960: A fallacy in the use of skill scores. *Bull. Amer. meteor. Soc.*, **41**, 64–67.

Donaldson, R. J., 1959: Analysis of severe convective storms observed by radar–II. *J. Meteor.*, **16**, 281–287.

Douglas, R. H., and W. Hitschfeld, 1959: Patterns of hailstorms in Alberta. *Quart. J. R. meteor. Soc.*, **85**, 105–109.

Fawbush, E. J., and R. C. Miller, 1953: A method for forecasting hail size at the earth's surface. *Bull. Amer. meteor. Soc.*, **34**, 235–244.

Foster, D. S., and F. C. Bates, 1956: A hail size forecasting technique. *Bull. Amer. meteor. Soc.*, **37**, 135–141.