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NOAA Technical Memorandum NWS ER-45

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

FORECASTING TYPE OF PRECIPITATION

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ERTM 18 Procedure for Developing a Nomograph for Use in Forecasting Phenological Events from Growing Degree Days. John C. Purvis and Milton Brown. December 1966

ERTM 19 Snowfall Statistics for Williamsport, Pa. Jack Hummel. January 1967

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ERTM 21 New England Coastal Fog. Richard Fay. April 1967

ERTM 22 Rainfall Probability at Five Stations Near Pickens, South Carolina, 1957-1963. John C. Purvis. April 1967

WBTM ER 23 A Study of the Effect of Sea Surface Temperature on the Areal Distribution of Radar Detected Precipitation Over the South Carolina Coastal Waters. Edward Paquet. June 1967 (PB-180-612)

WBTM ER 24 An Example of Radar as a Tool in Forecasting Tidal Flooding. Edward P. Johnson. August 1967 (PB-180-613)

WBTM ER 25 Average Mixing Depths and Transport Wind Speeds over Eastern United States in 1965. Marvin E. Miller. August 1967 (PB-180-614)

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WBTM ER 27 A Study of Areas of Maximum Echo Tops in the Washington, D.C. Area During the Spring and Fall Months. Marie D. Fellechner. April 1968 (PB-179-339)

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WBTM ER 32 The Meteorological and Hydrological Aspects of the May 1968 New Jersey Floods. Albert S. Kachic and William Long. February 1969 (Revised July 1970) (PB-194-222)

WBTM ER 33 A Climatology of Weather that Affects Prescribed Burning Operations at Columbia, South Carolina. S. E. Wasserman and J. D. Kanupp. December 1968 (COM-71-00194)

WBTM ER 34 A Review of Use of Radar in Detection of Tornadoes and Hail. R. E. Hamilton. December 1969 (PB-188-315)

WBTM ER 35 Objective Forecasts of Precipitation Using PE Model Output. Stanley E. Wasserman. July 1970 (PB-193-378)

WBTM ER 36 Summary of Radar Echoes in 1967 Near Buffalo, N.Y. Richard K. Sheffield. September 1970 (COM-71-00310)

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NWS ER 39 A Preliminary Climatology of Air Quality in Ohio. Marvin E. Miller. January 1971 (COM-71-00204)

(Continued On Inside Rear Cover)

UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE EASTERN REGION
Garden City, New York

NOAA TECHNICAL MEMORANDUM NWS ER-45

FORECASTING TYPE OF PRECIPITATION

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Garden City, New York

SCIENTIFIC SERVICES DIVISION
Eastern Region Headquarters
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FORECASTING TYPE OF PRECIPITATION

I. INTRODUCTION

Precipitation type is determined by the temperature structure of the atmosphere from its boundary with the earth's surface to the level from which the precipitation is falling, and the temperature of the surface on which the precipitation falls. In the winter most precipitating clouds do not extend above 500 mb. A relationship can be expected to exist then, between precipitation type and the mean temperature of the atmosphere from near the surface to 500 mb., and the mean temperature of the boundary layer of the atmosphere.

The mean virtual temperature between two pressure levels is proportional to the difference in height between these levels, or thickness of the layer. Wagner, 1957, showed a relationship between the observed 1000-500 mb. thickness and precipitation type. This relationship with observed thickness is useful for short term forecasting, but for periods beyond about 12 hours, information concerning the skill of thickness predictions are required before one can determine the probability of a precipitation type using Wagner's results. Wagner did not consider the effects of the boundary layer temperature in his study. Spar, 1971, showed that a good relationship does exist between the primitive equation (PE) model predictions of the mean potential temperature of the boundary layer (PE model surface to 50 mb. above the surface) and precipitation type. Spar, however, did not consider the effects of the temperature structure of the atmosphere above the boundary layer. Younkin, 1967, considered the effects of the mean temperature in a higher and a lower atmospheric layer by relating precipitation type to the simultaneous values of the 1000-850 mb. thickness and the 850-700 mb. thickness. Younkin's results, like Wagner's, are for observed thickness and are intended for short term forecasts only, unless additional information is available concerning the skill of thickness forecasts. The Techniques Development Laboratory (TDL) of the National Weather Service, 1969, presented an objective technique that provides up to 17-hour precipitation type forecasts. TDL related 1000-500 mb. thickness and 1000 mb. temperature forecasts to precipitation type.

In this study 1000-500 mb. thickness, to the nearest decameter, and the mean boundary layer potential temperature forecasts by the PE model, available operationally in the FOUS 1/2 message transmitted on teletype Service "C", are used as predictors in an objective procedure for forecasting precipitation type out to 48 hours.

II. PROCEDURE AND RESULTS

It is recognized that a relationship between the predictors used here and precipitation type may vary with geography; however, because of a small data sample for any one location, one relationship for several locations combined is presented here. (Data for individual locations were provided to forecast offices). All Eastern Region stations which are included in the FOUS 1/2 messages plus a few stations just west of the Eastern Region were used (Table 1). In order to account for any change in forecast skill with time, separate relationships were developed for the 12-, 24-, 36-, and 48-hour forecasts. PE model forecasts generated from the 0000Z and 1200Z initial data are combined in this study. The development sample period is December 1, 1970 to March 31, 1971.

TABLE 1. *List of Stations Included in Study*

FOUS 1		FOUS 2
Buffalo	Pittsburgh	Raleigh
Charleston, WV	Albany	Cape Hatteras
Burlington	New York (JFK)	Columbia
Boston	Bangor	Knoxville
Washington	Philadelphia	Louisville
Cleveland	Indianapolis	

Precipitation data were not readily available for three stations. Therefore, data for BAL, EWR, and OLD were substituted for DCA, JFK, and BGR respectively.

Precipitation is considered to have occurred at a forecast verification time if a 3-hourly observation of precipitation, trace or greater, occurred within plus or minus three hours of the forecast verification time (viz. 0900Z, 1200Z, 1500Z observations were examined for forecasts verifying at 1200Z).

Four precipitation types are considered in this study. These precipitation types are (1) liquid, (2) frozen, (3) liquid and frozen combined, and (4) freezing. *Liquid* type referred to hereafter as *rain*, consists of rain, rain showers and drizzle, with no other precipitation types reported in the three 3-hourly observations examined for any particular forecast time. *Frozen* type, referred to hereafter as *Snow*, consists of snow, snow pellets snow showers and snow grains, with no other precipitation type reported in the three 3-hourly observations examined. The precipitation type referred to as *liquid and frozen combined* hereafter referred to as *mixed*, includes those occurrences when both liquid type and frozen type precipitation are reported in the same observation or in different 3-hourly observations applicable to a forecast time. *Freezing* type precipitation consists of freezing rain, freezing drizzle and ice pellets (sleet). Freezing precipitation takes precedence when it is reported and it is considered here as the only precipitation type that occurred, even if other types are also reported, in the observations applicable to a forecast validation time.

The results are presented in Figure 1 - 4. These figures can be used directly as a technique for forecasting precipitation type. The results presented in each of the Figures were arrived at by performing an objective stepwise analysis of data appearing on each of four scatter diagrams, a separate diagram for each forecast period. The scatter diagrams were generated by computer processing of data tapes containing FOUS 1/2 predictions and every third hour of hourly aviation surface observations (service "A"). No attempt was made to identify and exclude incorrect data, although in a few cases data which appeared unlikely were recognized. It is believed that bad data does not significantly effect the results.

The stepwise analysis procedure of the scatter diagrams was as follows:

1. Determine the lowest forecast 1000-500 mb. thickness for which the frequency of rain exceeds 80%, and the highest forecast 1000-500 mb. thickness for which the frequency of snow exceeds 80% (80% is chosen arbitrarily).

2. In the range of forecast 1000-500 mb. thickness values for which the frequency of rain and the frequency of snow is less than 80%, determine the lowest (highest) forecast mean boundary layer potential temperature for which the frequency of rain (snow) exceeds 80%.

3. From steps 1 and 2, three areas can be identified on each scatter diagram. In one area, the frequency of rain as a function of any combination of the two predictors exceeds 80%. In another area, the frequency of snow as a function of any combination of the two predictors exceeds 80%. The analysis is complete for these two areas. In the remaining area on the scatter diagram, referred to here as Area 3, the frequency of rain or snow as a function of any combination of the two predictors is less than 80%. This area incidentially, is noted to increase with increasing length of forecast time, due probably to decreasing skill with time of the predictions of 1000-500 mb. thickness and mean boundary layer potential temperature. Area 3 is analyzed further to determine sub-areas where the frequency of either rain or snow is between 50% and 80%.

4. Considering only data in Area 3, determine the lowest forecast 1000-500 mb. thickness for which the frequency of rain exceeds 50% and the highest forecast 1000-500 mb. thickness for which the frequency of snow exceeds 50%. Using these two thickness values, three sub-areas are determined within Area 3. One sub-area has a frequency of snow between 50% and 80%, another sub-area has a frequency of rain between 50% and 80%, and in the third sub-area neither rain or snow occur with a frequency greater than 50%. Each of these sub-areas, if present, are to be refined further based on information contained in the predicted value of mean boundary layer potential temperature. It is possible, however, for less than 3 sub-areas to exist. This occurs when the frequency of a precipitation type changes markedly with a one decameter change in 1000-500 mb. thickness. In the

12th hour for example (Figure 1), the frequency of snow exceeds 80% for any thickness at or below 535 decameters. The frequency of snow for any thickness above 535 decameters is less than 50%. Thus, in this case, there are no 1000-500 mb. thickness values, in decameters, for which the frequency of snow is between 50% and 80%.

5. In each sub-area of Area 3, which was determined on the basis of 1000-500 mb. thickness, it is further determined if there is a mean boundary layer potential temperature above which the frequency of rain exceeds 50% for each and all of the remaining warmer values of mean boundary layer potential temperature. It is also determined if there is a mean boundary layer potential temperature below which the frequency of snow exceeds 50% for each and all of the ramaining colder values.

6. From steps 4 and 5, sub-areas within Area 3 on the scatter diagrams are identified in which the frequency of snow as a function of the two predictors is between 50% and 80% and the frequency of rain as a function of the two predictors is between 50% and 80%. In these areas the forecast would be either rain or snow as indicated by the higher frequency. The observed frequency of occurrence of each precipitation type in these areas, to the nearest 5%, are presented in the figures as additional forecast guidance. Finally, for the remaining sub-areas within Area 3 on the scatter diagram the frequency of both rain and snow is less than 50%. For these uncertain areas, the frequencies of occurrence for each precipitation type are presented as forecast guidance.

III. CONCLUSION

An objective technique for forecasting precipitation type in the eastern United States, out to 48 hours, has been presented. PE model predictions of 1000-500 mb. thickness and mean boundary layer potential temperature, together with the procedure presented here can be used to determine if the probability of a precititation type is greater than 80%, between 50% and 80% or less than 50%. The procedure can be automated to produce precipitation type forecasts for any location as a by-product of the operational PE model. After additional data becomes available for analysis, the technique can be refined if warranted, so as to have a separate forecast procedure for each of many locations, and to present the forecast as a probability of occurrence (to the nearest 10%) of each precipitation type. Also, other predictors can be examined to determine if they contain additional useful predictive skill. Additional predictors that may be helpful include predicted boundary layer wind direction, month of the year and trends of the predictors used in this study. Month of the year and wind direction can be important at locations that are affected by maritime temperatures.

Acknowledgement

This study was made possible by the availability of data in suitable form for computer use. The data were collected by the National Severe Storms Forecast Center (NSSFC) Kansas City, Missouri. Mr. John Curran of the NSSFC prepared a computer program for the generation of the scatter diagrams referred to in the text. Mr. Curran ran the program on a NSSFC computer and provided the output.

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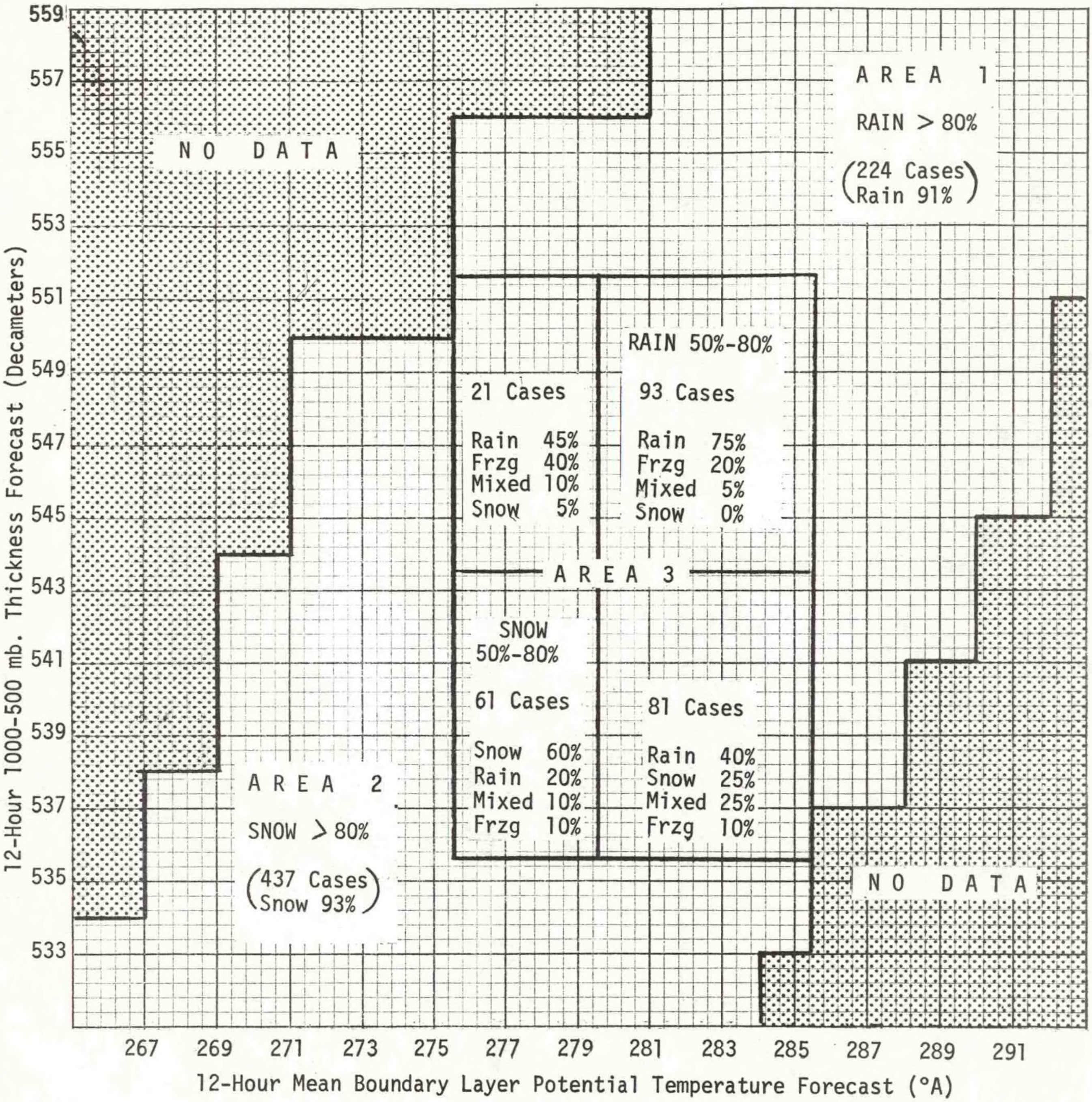

FIGURE 1. *Predominant precipitation type and its probability of occurrence as a function of PE model 12-hour predictions of 1000-500 mb. thickness and mean boundary layer potential temperature. The observed frequency of each precipitation type (to nearest 5%) and total number of cases are shown for development data in each delineated sub-area of Area 3. Also, for each Area 1 and 2 the mean observed frequency of predominant precipitation type and total number of cases are shown in parentheses.*

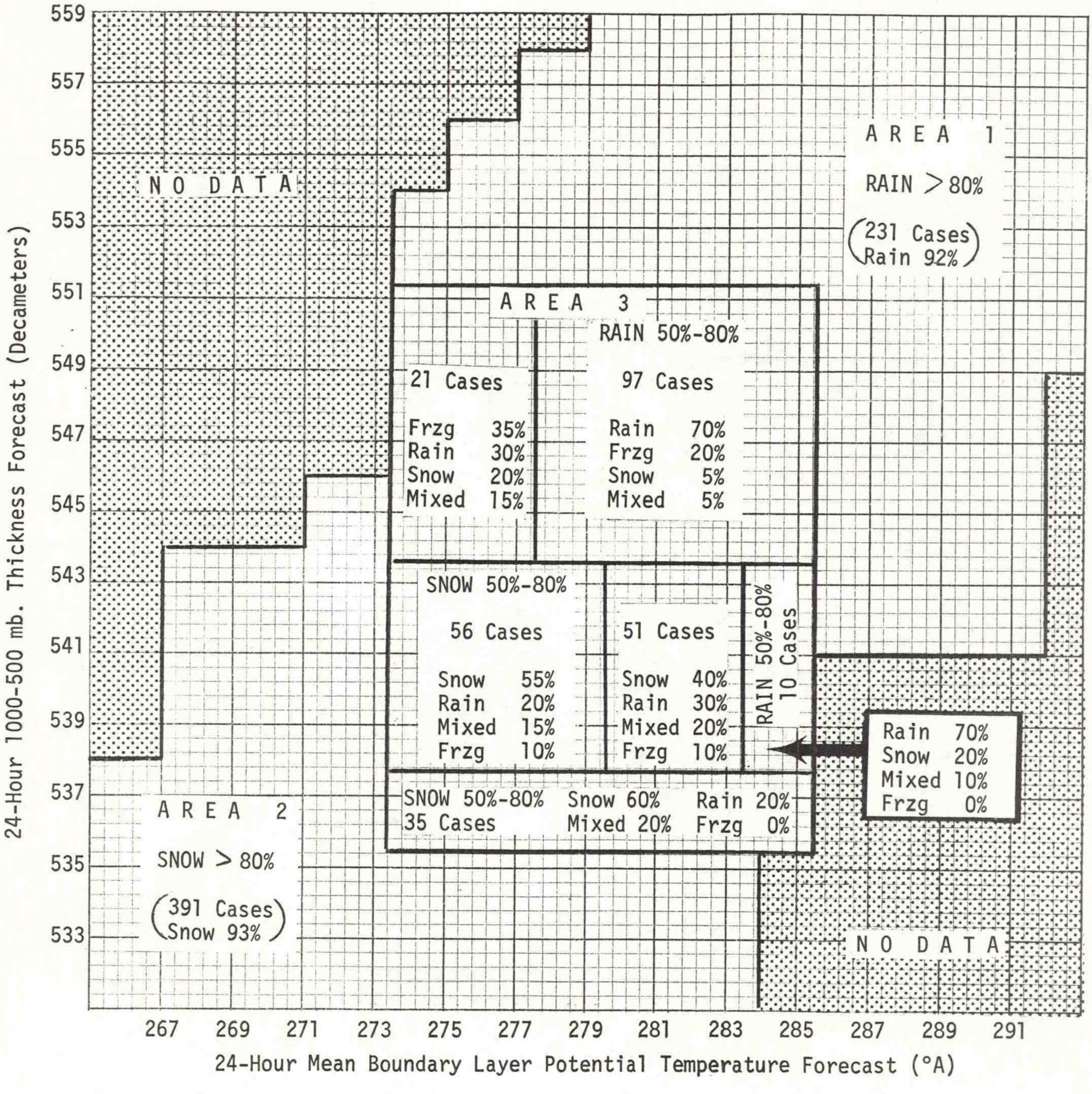

FIGURE 2. *Same as Figure 1, except for 24-hour PE model predictions.*

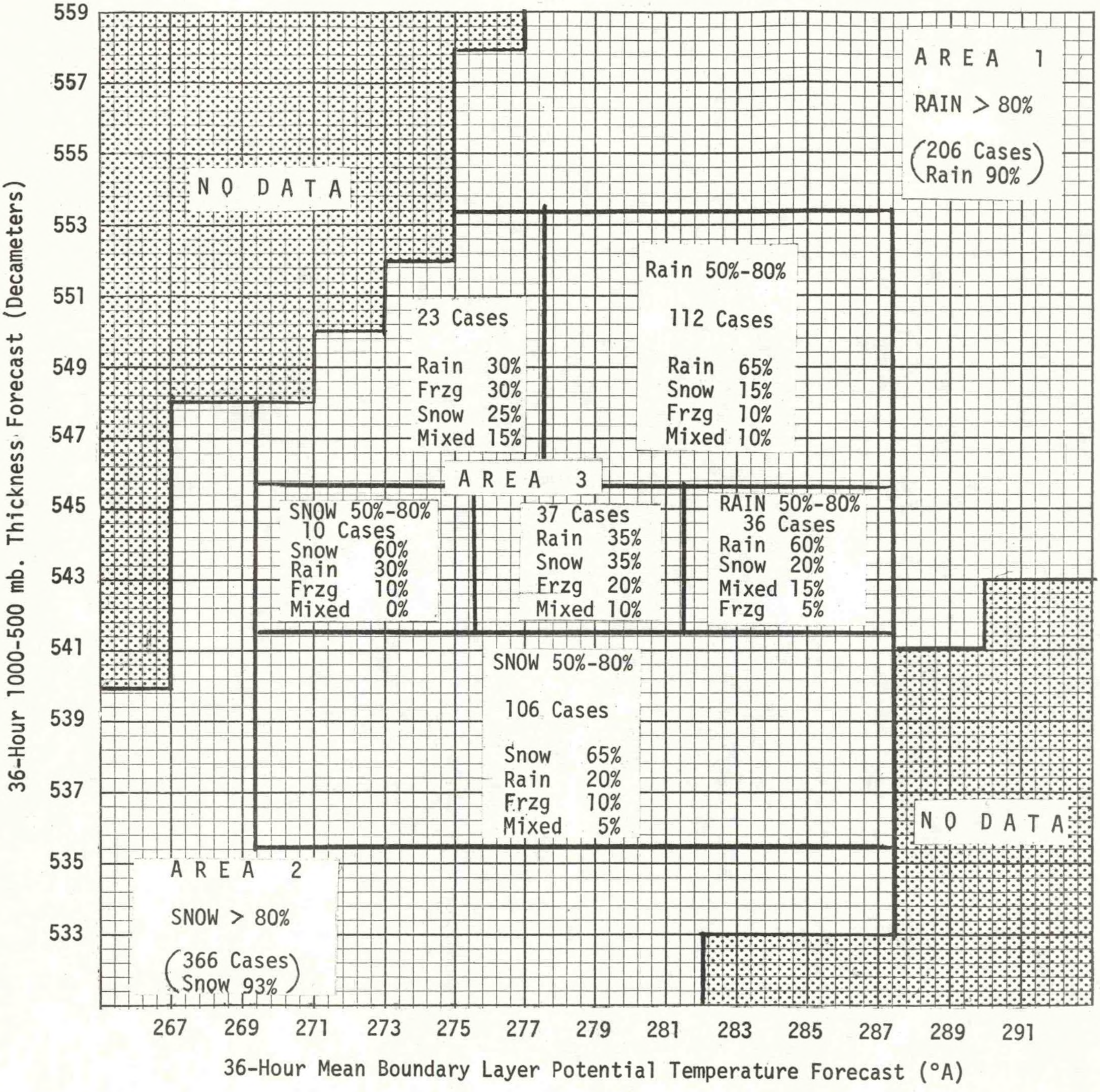

FIGURE 3. *Same as Figure 1, except for 36-hour PE model predictions.*

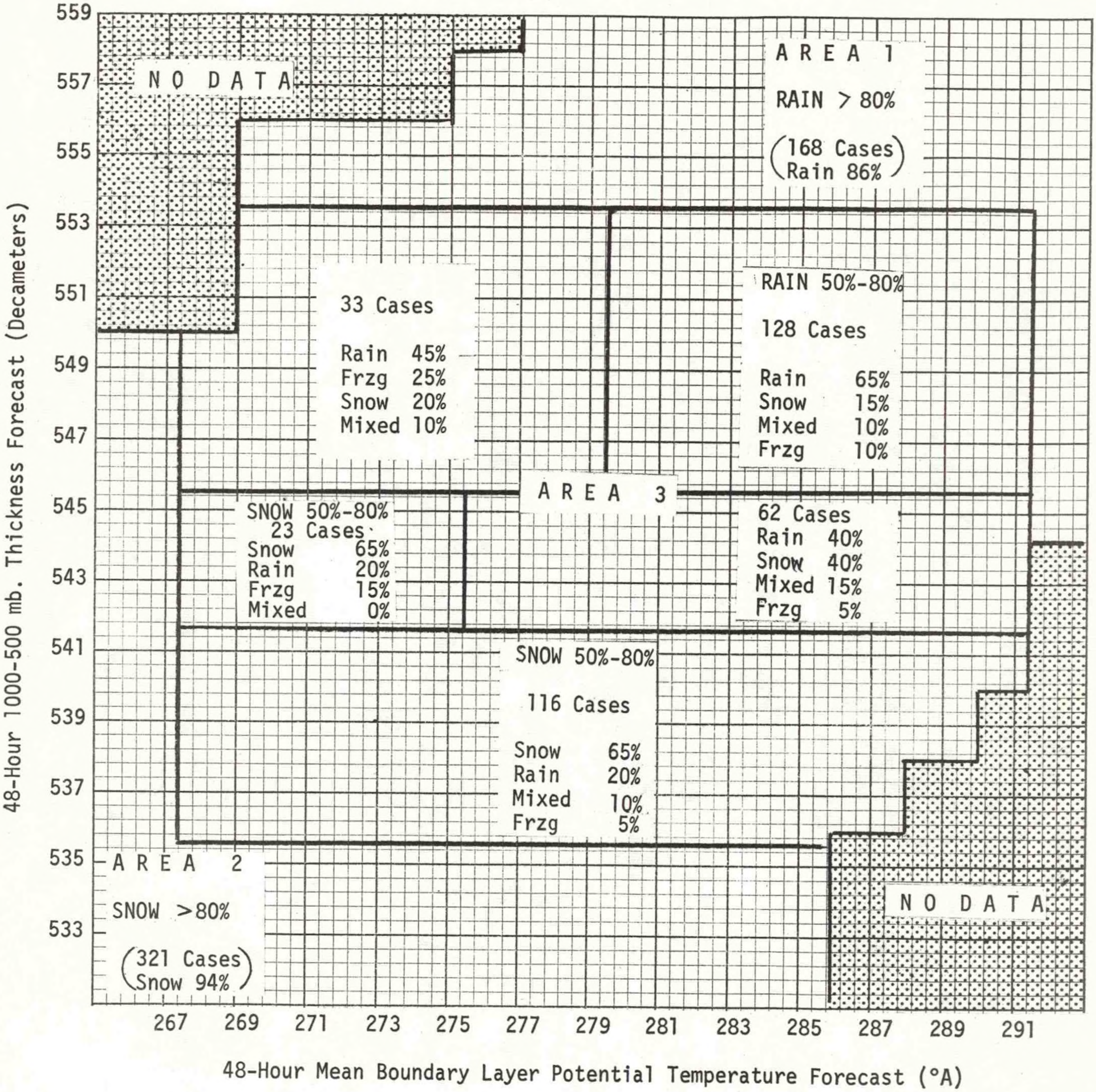

FIGURE 4. *Same as Figure 1, except for 48-hour PE model predictions.*

LIST OF EASTERN REGION TECHNICAL MEMORANDA
(continued from inside front cover)

NWS ER 40 Use of Detailed Radar Intensity Data in Mesoscale Surface Analysis. Robert E. Hamilton. March 1971 (COM-71-00573)

NWS ER 41 A Relationship Between Snow Accumulation and Snow Intensity as Determined from Visibility. Stanley E. Wasserman and Daniel J. Monte. May 1971 (COM-71-00763)

NWS ER 42 A Case Study of Radar Determined Rainfall as Compared to Rain Gage Measurements. Martin Ross. July 1971 (COM-71-00897)

NWS ER 43 Snow Squalls in the Lee of Lake Erie and Lake Ontario. Jerry D. Hill. August 1971 (COM-71-00959)

NWS ER 44 Forecasting Precipitation Type at Greer, South Carolina. John C. Purvis. December 1971.