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GROUND CONDENSATION GUIDANCE FOR INDIANA AND MICHIGAN

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1. INTRODUCTION

The Techniques Development Laboratory (TDL) has developed dew and frost guidance for 27 agricultural locations in Michigan and 19 locations in Indiana (see Fig. 1). The guidance for both states consists of probabilistic forecasts of light, moderate, and heavy ground condensation (either dew or frost). In addition, the guidance for Michigan includes forecasts of the conditional probability of frost, given that ground condensation occurs.

Dew and frost forecasts are now part of a specialized package that includes objective forecasts of several other agricultural weather elements (see Jensenius et al., 1978). The guidance is valid from April through October for Michigan, and from April through November for Indiana.

2. METHOD

Both the probability of ground condensation (POGC) and conditional probability of frost (COF) equations were developed with use of the Model Output Statistics (MOS) technique (Glahn and Lowry, 1972). This technique consists of determining statistical relationships between local weather observations (predictands) and the output of numerical models (predictors). A forward stepwise selection procedure was used to derive the POGC and COF prediction equations.

We used 0000 GMT cycle output from the six-layer Primitive Equation (PE) model to develop the prediction equations. Some of the PE forecast fields were space smoothed over 5 and 9 grid points in order to reduce the amount of small scale noise inherent in numerical output. The PE forecasts were then interpolated from the grid points to the location of each of the stations. The variables available to the regression program as potential predictors of POGC and COF included 1000-, 850-, and 500-mb temperatures; 1000-, 850-, and 500-mb heights; boundary layer, 850-, and 500-mb winds; boundary layer, 850- and 700-mb vertical velocities; 1000-850 mb and 1000-500 mb thicknesses; several low and middle level mean relative humidities; surface pressure; boundary layer potential temperature; precipitable water; and boundary layer moisture divergence. Many of these predictors were screened in both binary and continuous forms. We also screened several trigonometric functions of the day of the year, the maximum possible number of hours of sunshine per day, and the daily insolation at the top of the atmosphere. Two of these climatological predictors, the cosine of the day of the year and the maximum possible number of hours of sunshine per day, were eventually forced into the POGC forecast equations. We did this after initial screening showed that by forcing these predictors we improved our results.

The predictands for POGC were the occurrences of at least light, moderate, and heavy ground condensation at approximately 7 AM local time. In Michigan, ground condensation is subjectively observed as being either light, moderate, or heavy. For Indiana, very light and very heavy ground condensation intensities also are observed, although we included these intensities in the light and heavy categories, respectively. The criteria used in taking observations of dew in Indiana are listed in Table 1.

The predictand for COF was the occurrence of frost at approximately 7 AM local time, given that ground condensation was observed. This predictand was assigned a value of one for observations of frost and zero for observations of dew. If no ground condensation was observed, the report was not included in the developmental sample.

We developed both POGC and COF equations for approximate projections of 36, 60, and 84 hours from 0000 GMT. In order to obtain larger developmental data bases, we combined the data for each state before deriving the equations. This technique is often used when the amount of data from one station will not support the development of a stable equation.

We derived the POGC equations for all ground condensation categories of a given projection simultaneously. Thus, the resulting equations for a particular projection contain the same predictors. Of course, the coefficients of these predictors differ for each ground condensation category. By deriving equations in this manner, we minimize the chances of inconsistent forecast probabilities between categories.

We also developed climatic POGC and COF forecast equations. In these, only the sine and cosine of the day of the year were used as predictors. Thus, the forecasts from the equations give the climatic POGC and COF for each day of the year.

3. EQUATION CHARACTERISTICS

Initially, we developed Michigan's equations from observations taken during October of 1972 and April to October of 1973-75. Indiana's developmental sample included observations taken during November, in addition to those months listed for Michigan. These months correspond to the approximate growing seasons for the states. We then tested all the equations on a single growing season of independent data (April to October, 1976). We compared the MOS forecasts with the forecasts from the climatic equations.

Table 2 shows Brier scores--defined to be one half the score proposed by Brier (1950)--for MOS forecasts of POGC and COF, and also for forecasts based on climatology. In all cases the Brier scores for the MOS forecasts were better than (less than) the Brier scores for the climatological forecasts.

We also examined the overall reliability of these forecasts. A sample reliability diagram for the 36-h probability of moderate ground condensation for Indiana is shown in Fig. 2. In general, the MOS equations tended to overforecast ground condensation during the test period; however, this was probably due to abnormally dry conditions which existed during the latter part of the growing season. Fig. 3 is a sample diagram showing the reliability of 36-h COF forecasts for Michigan. In this case, there was a slight tendency to underforecast the COF, probably because the test autumn was abnormally cool.

We then rederived the equations and included the test year in the developmental sample. Table 3 lists the reductions of variance we obtained for each of the new equations. For Indiana, the reductions of variance for the POGC equations ranged from .16 for the 36-h forecasts of at least moderate ground condensations to .09 for the 84-h forecasts of at least light ground condensation. Michigan's reductions of variance for POGC ranged from .21 for the 36-h forecasts of at least light ground condensation to .08 for the 84-h forecasts of at least heavy ground condensation. The reductions of variance for the COF equations ranged from .58 for the 36-h projection to .46 for the 84-h projection.

The most important predictors for forecasting POGC were found to be the low and middle level relative humidity and wind speed, thicknesses, and several climatological factors. A sample POGC equation for the 36-h forecast of the probability of at least moderate ground condensation for Indiana is given in Table 4. For the COF forecasts, low and middle level temperatures, thicknesses, relative humidities, and climatological factors were important.

4. MESSAGES AND SCHEDULES

Agricultural weather guidance for Indiana and Michigan is transmitted daily to the Central Region at approximately 0900 GMT on the overlay circuit. The guidance is divided into two teletype bulletins--AXUS50 for Indiana and AXUS51 for Michigan. Sample portions of both bulletins are shown in Fig. 4. Table 5 lists the station abbreviations used in these bulletins.

Values of POGC in the messages are in tens of percent with the numbers from left to right in the bulletin being the probabilities of at least light, moderate, and heavy ground condensation. For Michigan, the POGC forecast is followed by a slash and the COF forecast. Values of COF are also in tens of percent.

Both the POGC and COF forecasts are valid at approximately 7 AM local time. Dates and times given in the heading of each bulletin should be used to identify the valid time for each of the forecasts.

5. OPERATIONAL CONSIDERATIONS

All the agricultural forecast equations have been developed from output of the six-layer PE model and its barotropic extension. The equations, however, are being applied to output of the seven-layer PE model and the barotropic mesh extension. As a result, the equations may not account for the characteristic differences between old and new versions of these models.

Both the POGC and COF forecasts are made from generalized-operator equations and are, therefore, not tailored to the specific characteristics of each of the stations. Because of this, it may be necessary for field forecasters to modify the guidance to incorporate local effects, such as terrain. For example, if two nearby stations were located at different relative elevations (i.e., one on a well exposed hill and the other in a frost pocket) the forecaster may wish to lower the conditional probability of frost on the hill and raise the probability in the frost pocket.

Also, the field forecaster may wish to modify the POGC guidance by considering soil moisture. If the soil moisture is high, the forecast probabilities are likely to be low, and should be raised. In contrast, if the soil is abnormally dry, the forecast probabilities are likely to be too high, and should be lowered.

6. ACKNOWLEDGMENTS

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We would also like to acknowledge the overall support and guidance provided by Mr. Harold Scott, Agricultural Weather Services Branch, Office of Meteorology and Oceanography.

7. REFERENCES

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Glahn. H. R., and D. A. Lowry, 1972: The use of Model Output Statistics (MOS) in objective weather forecasting. J. Appl. Meteor., 11, 1203-1211.

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Table 1. Dew measurement for the Indiana Agricultural Weather Observation Network

Intensity	Visual Indications
None	None
Very Light	Slight dampness on shoes and objects.
Moderate	Numerous small droplets; some medium and large. Shoes get wet.
Heavy	Many medium and large size droplets; droplets on fences and other objects.
Very Heavy	Numerous large droplets visible on vegetation and also all objects. Shoes and trouser legs get very wet (ground fog often accompanies).

Table 2. Brier scores for MOS and climatological forecasts of POGC and COF when tested on a single growing season (1976) of independent data.

Type of Equation	Approximate Forecast Projection (hours from 0000 GMT)					
	36		60		84	
	MOS	Clim.	MOS	Clim.	MOS	Clim.
INDIANA						
Probability of ≥ light	.148	.163	.161	.163	.161	.163
Probability of ≥ moderate	.215	.251	.229	.251	.241	.251
Probability of ≥ heavy	.223	.251	.233	.251	.244	.251
MICHIGAN						
Probability of ≥ light	.176	.209	.192	.209	.199	.209
Probability of ≥ moderate	.239	.273	.248	.273	.262	.273
Probability of ≥ heavy	.222	.245	.227	.245	.240	.245
Conditional probability of frost	.063	.099	.063	.099	.071	.099

Table 3. Developmental reductions of variance for the POGC and COF equations.

Type of Equation	Approximate Forecast Projection (hours from 0000 GMT)		
	36	60	84
INDIANA			
Probability of ≥ light	.1511	.1054	.0903
Probability of ≥ moderate	.1631	.1273	.1024
Probability of ≥ heavy	.1395	.1138	.0955
MICHIGAN			
Probability of ≥ light	.2111	.1435	.1367
Probability of ≥ moderate	.1675	.1224	.1016
Probability of ≥ heavy	.1280	.0963	.0794
Conditional probability of frost	.5751	.5206	.4600

Table 4. Sample equation for the 36-h probability of at least moderate ground condensation for Indiana.

Predictor	Units	Binary Limit	Smoothing (Points)	Forecast Projection (Hours)	Cumulative Reduction Of Variance	Coefficient
Regression Constant	--	--	--	--	--	3.509
1. Cosine of the Day of Year	--	continuous	--	--	.0163	-0.8060
2. Hours of Sunshine	h	continuous	--	--	.0657	-0.2513
3. PE 850-mb Wind Speed	m/s	continuous	5	36	.0981	-0.009679
4. PE Boundary Layer Relative Humidity	%	continuous	5	24	.1223	0.002126
5. PE Layer 2 Relative Humidity	%	continuous	5	36	.1441	-0.002787
6. PE Layer 1 Relative Humidity	%	30	5	36	.1514	0.1352
7. PE 850-mb Wind Speed	m/s	12	5	36	.1529	0.08235
8. PE Precipitation Amount	m	continuous	5	24	.1562	11.87
9. PE Boundary Layer Wind Speed	m/s	continuous	5	36	.1601	-0.01829
10. PE 500-1000 mb Thickness	m	continuous	5	24	.1603	0.0009294
11. PE 850-mb Temperature	^{o}K	continuous	5	24	.1615	-0.01791
12. PE Layer 1 Relative Humidity	%	continuous	5	24	.1631	0.001899

Multiple Correlation Coefficient	.4038
Brier Score	.1932

Table 5. The four-letter abbreviations used for agricultural stations in Indiana and Michigan.

	Michigan		Indiana
LELA	Lake Leelanau	PRHI	Prarie Heights
WADN	Kewadin	WMIL	Waterford Mills
MAPL	Mapleton	WSAN	Wanatah Sand
EMPR	Empire	WMUK	Wanatah Muck
BULA	Arcadia (Beulah)	CLMB	Columbia City
BEAR	Onekama (Bear Lake)	ENTL	Kentland
LKCT	Lake City	BLFN	Bluffton
LUDI	Ludington	OKMO	Kokomo
MEAR	Mears	WLAF	West Lafayette
FREM	Fremont	WLEB	West Lebanon
GRAN	Grant	LIND	Linden
EDMR	Edmore	TIPT	Tipton
ENTC	Kent City	FARM	Farmland
NUNI	Nunica	TERE	Terre Haute
PEAC	Peach Ridge	VERS	Versailles
BELD	Belding	BDFD	Bedford
GRAM	Grahm	VINC	Vincennes
HOLL	Holland	DUBS	Dubois
HUDS	Hudsonville	JOHN	Johnson
FENN	Fennville		
GJCT	Grand Junction		
PAWP	Paw Paw		
VLET	Watervliet		
SODU	Sodus		
GLEN	Glendora		
COLD	Coldwater		
MSUH	MSU Hort. Farm		

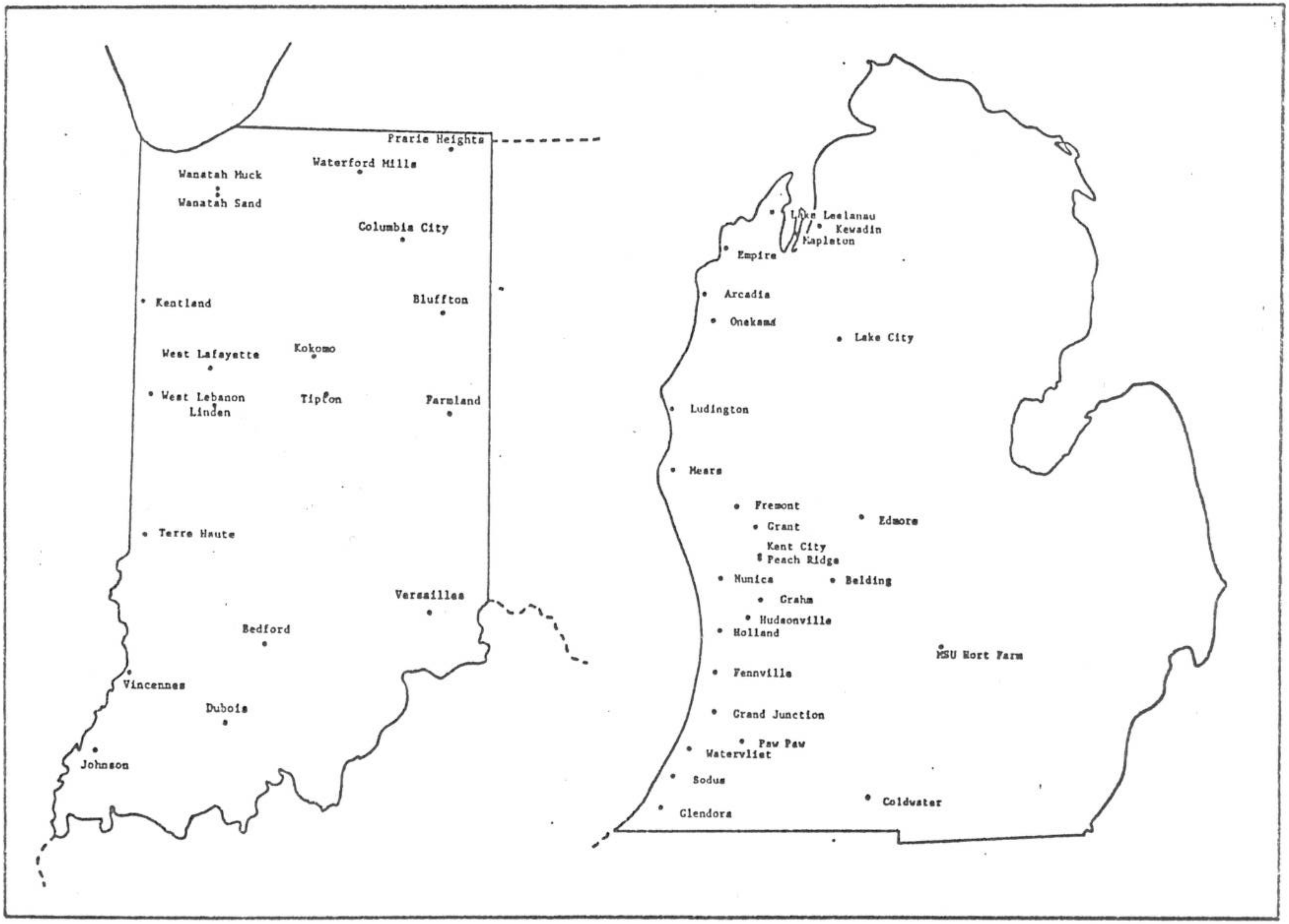

Figure 1. The 19 agricultural stations in Indiana and 27 agricultural stations in Michigan for which specialized weather guidance is available.

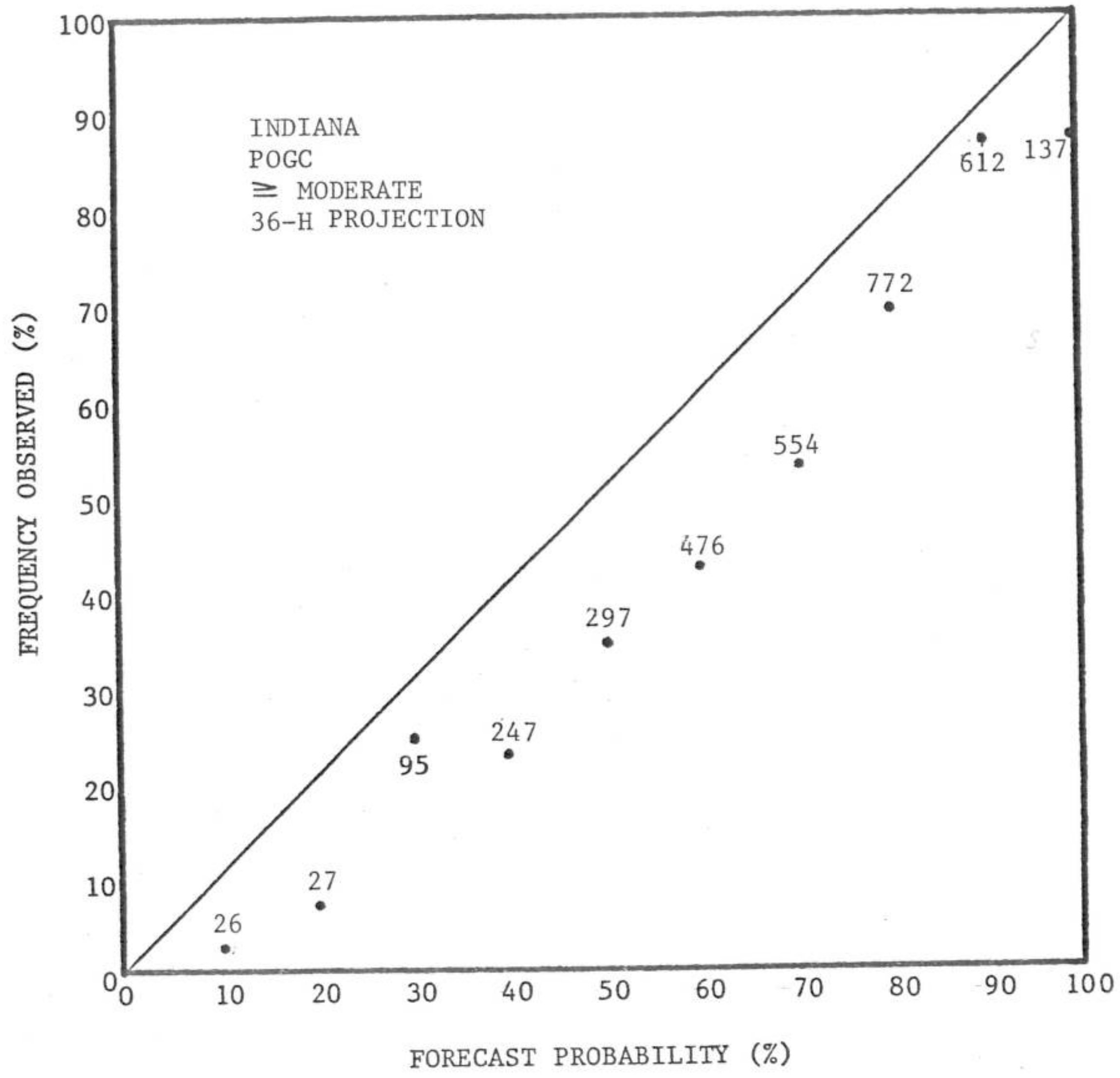

Figure 2. Sample reliability diagram for the 36-h probability of at least moderate ground condensation for Indiana. The numbers plotted on the diagram are the number of forecasts of each probability during the independent test period (April-October, 1976).

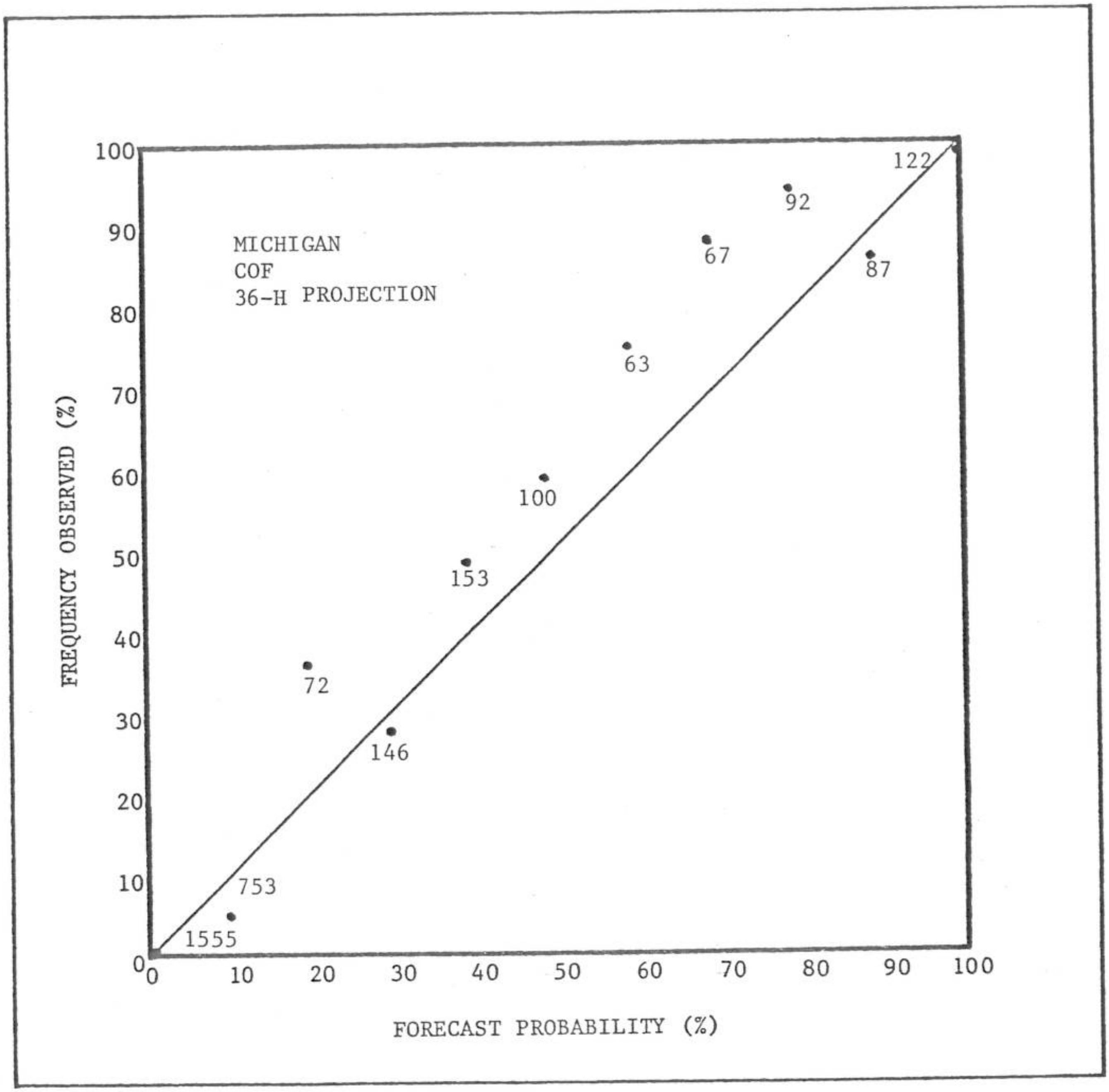

Figure 3. Sample reliability diagram for the 36-h COF forecasts for Michigan. The numbers plotted on the diagram are the number of forecasts of each probability during the independent test period (April-October, 1976).

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AXUS50 KWBC 120000
 AG WEATHER GUIDANCE /MOS/ 09/12/78  0000 GMT   INDIANA
           DATE  13   13   14   14   15   15   16   16   17   17
            GMT  00   12   00   12   00   12   00   12   00   12

PRHI AIR    MX/MN 74   55   70   54   67   53   66   49   68   48
     BARE   MX/MN 72   65   70   61   68   60   68   56   64   55
     GRASS  MX/MN 72   69   69   66   68   64   68   65   69   63
     RH      MN   68        73        72
     POPA/24 HR/    99852     87631     64321
     POGC             986       986       988

WMIL AIR    MX/MN 75   51   70   55   69   49   69   46   71   43
     BARE   MX/MN 70   65   71   62   67   60   68   57   67   56
     GRASS  MX/MN 70   67   68   64   66   63   64   62   65   62
     RH      MN   81        79        78
     POPA/24 HR/    99852     87631     64321
     POGC             987       987       988



AXUS51 KWBC 120000
 AG WEATHER GUIDANCE /MOS  / 09/12/78  0000 GMT  MICHIGAN
           DATE  13   13   14   14   15   15   16   16   17   17
            GMT  00   12   00   12   00   12   00   12   00   12

LELA AIR    MX/MN 67   46   67   52   70   50   70   47   70   51
     POPA/24 HR/    44321     33210     65421
     POGC/COF       643/1     742/0     754/1

WADN AIR    MX/MN 64   48   65   53   69   51   69   49   69   51
     POPA/24 HR/    44321     33210     65421
     POGC/COF       643/1     742/0     754/1
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Figure 4. Sample portions of the AXUS50 and AXUS51 teletype bulletins with probability of ground condensation (POGC) and conditional probability of frost (COF) guidance included.