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WARM SEASON NOCTURNAL QUANTITATIVE PRECIPITATION FORECASTING FOR EASTERN KANSAS USING THE SURFACE GEOSTROPHIC WIND CHART

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ABSTRACT

The surface geostrophic wind (SGW) chart has been used to statistically derive probability of precipitation (PoP) and probability of precipitation amount (PoPA) equations for the nighttime periods for eastern Kansas and extreme western Missouri. The season of interest is May through September. The 1800 GMT SGW chart was used to obtain the predictors. The scientific basis for using this chart is that nocturnal precipitation in the forecast area is known to be related to boundary layer wind maximums.

These PoP and PoPA values were then compared for skill with Model Output Statistics (MOS) values transmitted from the National Meteorological Center. The SGW values were found to be inferior on independent data to those of MOS in all 5 scores computed; however, a consensus (average) of SGW and MOS was superior to MOS in 3 of 5 scores. Joint values were constructed and found to be superior to those of MOS in all 5 scores, but this verification of joint values was not on independent data, so further testing will have to be done.

Numerous examples with maps are given, in the belief that a dedicated forecaster could better his chances of improving upon all objective techniques by a study of these maps.

1. INTRODUCTION

The surface geostrophic wind (SGW) chart has been available to National Weather Service Forecast offices since 1974. For details concerning this chart, see Sangster (1960) and National Weather Service (NWS) Technical Procedures Bulletin (TPB) No. 111 (1974). This chart has found utility in formulating several kinds of short-term forecasts, including making subjective forecasts of nocturnal warm season precipitation in the Great Plains area.

The impetus for this present study came from an experience during the summer of 1977. I was looking at the current 1800 GMT chart on 17 June 1977 and a feature was apparent which I had seen on previous occasions and had associated with heavy nocturnal precipitation. The SGW chart for this time is shown in Fig. 1. The feature which struck my eye was the pronounced diffluence over eastern Kansas and extreme western Missouri. Note that SGW speeds decrease from over 40 kt over Texas to less than 5 kt over Nebraska. I made a mental note of the situation, and after heavy rain fell in eastern Kansas that night, I made a written note of the date.

July came and went (it was hot and dry in eastern Kansas). Again perusing the current 1800 GMT chart on 4 August 1977, I was struck with the similarity of the situation to that of 17 June 1977. I obtained the June case from the files and put the charts side by side. The similarity is obvious by comparing Fig. 2 (for 1800 GMT 4 August 1977) with Fig. 1. This time I went to the Central Region Headquarters Duty Meteorologist/Hydrologist for the week (Russ Mann) and told him of the similarity and that I thought eastern Kansas was in store for more heavy rain that night. He called the WSFO at Topeka, Kansas, and relayed my feelings about the situation. Heavy rain again fell in eastern Kansas that night.

The objective of this memorandum is to discuss the methods and results of a statistical study intended to put into numbers what has been heretofore subjective. The reason that the nighttime period (0000-1200 GMT) was used is that the area of study receives a preponderance of nocturnal rains, especially heavy ones. For example, see Vrcek and Sangster (1974). Actually 0300-1500 GMT might be better, but it does not fit the standard forecast periods.

2. THEORETICAL BASIS FOR USING THE SGW CHART

Sangster (1958) and Pitchford and London (1962) have associated nocturnal precipitation with boundary layer wind maximums (BLWMs) (Blackadar, 1957). Bonner (1968) has shown the Great Plains area to have a high frequency of BLWMs. Sangster (1967a and 1967b) has shown that there is a diurnal variation of the geostrophic wind over the plains. It appears that both the diurnal variation of the geostrophic wind and the diurnal variation of friction in the boundary layer are important factors involved in producing the BLWMs (see Bonner and Paegle, 1970 and Paegle and Rasch, 1973).

The importance of the BLWMs lies in their effect on the higher level vertical motion. It is the diurnal variation in the vertical motion at some

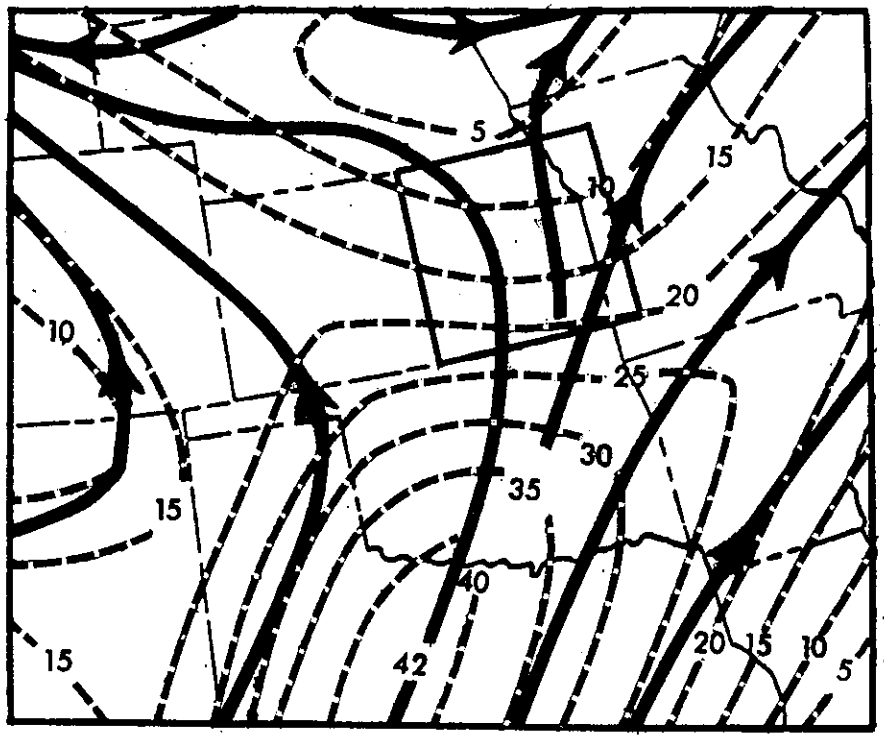

Fig. 1. SGW chart for 1800 GMT 17 June 1977. Streamlines and isotachs (knots). Area outlined is area of study.

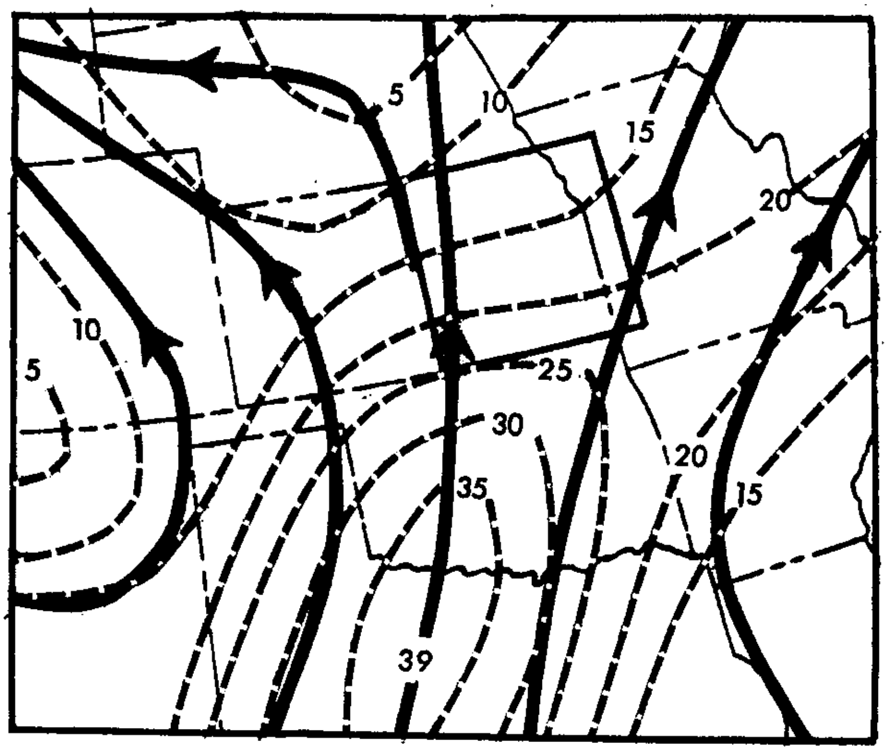

Fig. 2. SGW chart for 1800 GMT 4 August 1977.

level like 700 mb which leads to saturation and thunderstorms. The SGW has divergence, but it is not directly relatable to the vertical motion because it is geostrophic and because of the slope of the terrain. However, one can hope that the vertical motion field which will be generated, say, 12 hours after data time can be partially captured statistically if the pattern of the SGW is computer processed. Subjective forecasting experience would suggest that this is the case.

3. DATA SOURCES

SGW values at grid points were obtained from the runs made operationally at the National Severe Storms Forecast Center in Kansas City. The period of May through September of 1972 was used as the developmental data sample. The 1800 GMT chart was used, which is six hours prior to the beginning of the first forecast period.

The predictand data consisted of six- and twelve-hour totals of precipitation for the 0000 to 0600 GMT, 0600 to 1200 GMT, and 0000 to 1200 GMT periods taken from the Hourly Precipitation Data (HPD) publication. The amounts were further categorized as follows for entry into the statistical program, as shown in Table 1.

Table 1. Predictand categories

Precipitation amount (inches)	Category
0 or T	0
.01-.09	1
.10-.49	2
.50-.99	3
1.00-1.49	4
1.50-1.99	5
2.00-2.49	6
2.50-2.99	7
3.00 or more	8

Thirty-six HPD stations in an area bounded by 37° N, 40° N, 94° W, and 98° W were used. The area of concern and the stations are shown in Fig. 3.

Verification data from 1978 were taken from the Local Climatological Data (LCD) publication.

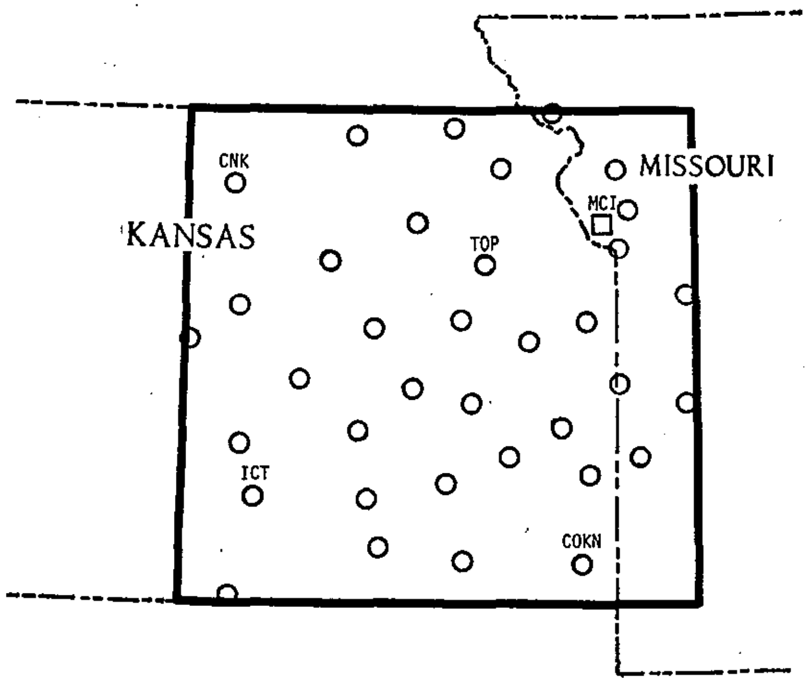

Fig. 3. Forecast area and locations of the thirty-six HPD stations. MCI was not an HPD station in 1972.

4. REGRESSION RESULTS

A forward stepwise screening program was used to process the data and select predictors. For a discussion of the screening regression procedure see Glahn and Lowry (1972).

The predictors were the u (west) and v (south) components of the SGW on a movable 1.5^{o} latitude by 2^{o} longitude grid placed with respect to each precipitation station as shown in Fig. 4. The HPD station always had the coordinates IL = 4 and JL = 6. Values for the latitude-longitude grid were interpolated from the polar stereographic grid on which the SGW was originally computed. The 36 stations were pooled in the regression computations. Due to computer core and time limitations only those 20 grid points encircled in Fig. 4 were used in the screening runs. These were selected after some experimentation, but there is no guarantee that the best 20 points were chosen. Thus, 40 predictors were input--20 u's and 20 v's. The predictand in the first step of the two-step procedure used in this study was the categorized precipitation amount from Table 1 as a continuous predictand. Three regression runs were made, one for each of the two 6-h periods and one for the 12-h period. Twelve terms were used in each case, but in the interest of simplicity the three-term equations are shown here in Tables 2, 3 and 4.

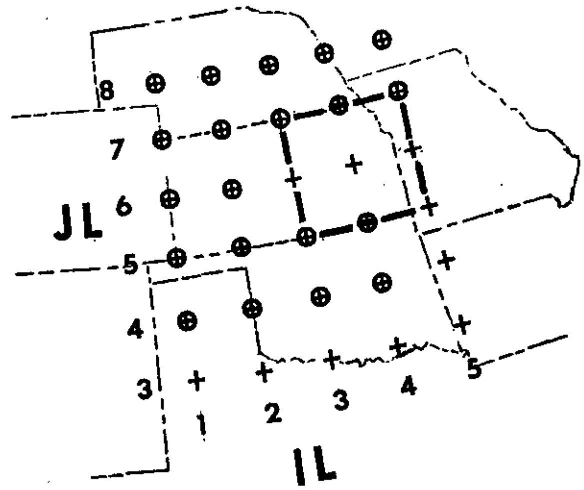

Fig. 4. Latitude-longitude grid which moves so that the HPD station is always at IL = 4 and JL = 6. The location shown is for a hypothetical HPD station located at the center of the forecast area. Encircled points are the ones actually used in the regression computations.

Table 2. Regression results for the 0000-0600 GMT period. Continuous predictors and continuous predictand. u and v are in knots.

	Coefficient	Cumulative Reduction of Variance (%)
Constant	0.2263	
1) u(1,6)	-0.01675	8.41
2) v(4,4)	0.01198	12.26
3) v(1,7)	-0.00785	14.30

Average value of predictand = .1864

Total number of cases = 4791

Reduction of variance with 12 predictors = 17.14%

Table 3. Regression results for the 0600-1200 GMT period. Continuous predictors and continuous predictand. u and v are in knots.

	Coefficient	Cumulative Reduction of Variance (%)
Constant	0.2022	
1) v(4,4)	0.01244	4.17
2) u(1,6)	-0.01193	7.58
3) v(1,8)	-0.00609	8.85

Average value of predictand = .2223

Total number of cases = 4796

Reduction of variance with 12 predictors = 11.02%

Table 4. Regression results for the 0000-1200 GMT period. Continuous predictors and continuous predictand. u and v are in knots.

	Coefficient	Cumulative Reduction of Variance (%)
Constant	0.3689	
1) u(1,6)	-0.02278	8.34
2) v(4,4)	0.02049	14.24
3) v(1,7)	-0.01137	16.44

Average value of predictand = .3450

Total number of cases = 4780

Reduction of variance with 12 predictors = 19.45%

The number one and two predictors in each of the three cases were u(1, 6) and v(4, 4) though in inverse order in one case. The ability to distinguish precipitation that falls before midnight (0600 GMT) from that which falls after midnight does not appear to be great from the SGW technique. The reduction of variance (RV) for the 0600-1200 GMT period is significantly lower than for the other two regression analyses. About 3 percent additional RV is obtained by going from 3 predictors to 12 predictors. More will be said about the number of predictors to use in a later section.

The four variables used in the three 3-term equations and their locations with respect to the HPD station are shown in Fig. 5. Note that u(1, 6) has a negative sign in each case, meaning that an east wind is to be preferred for precipitation to occur. Obviously, v(4, 4) should have and does have a positive sign, indicating the influx of moist tropical air from the south necessary for substantial precipitation to fall. Note that this combination of a negative u to the west of the station combined with a positive v to the south of the station is present in the cases shown in Figs. 1 and 2. Also this combination would be present if there is a front in the target area (the fronts in the two cases mentioned were to the north of eastern Kansas). East-west stationary fronts in the area are well known for their ability to produce precipitation.

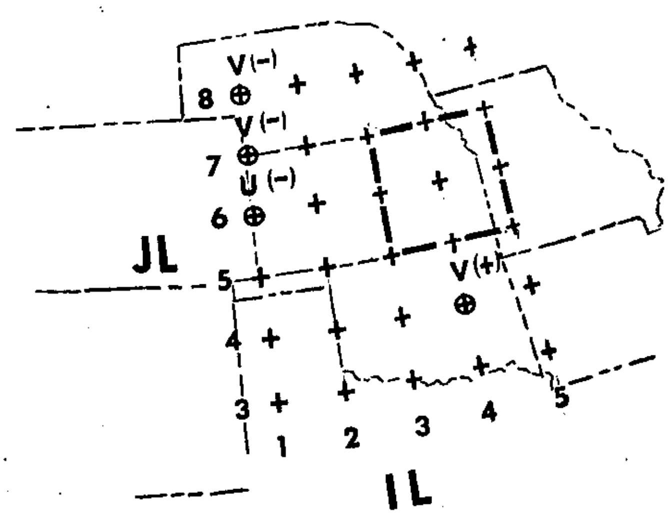

Fig. 5. Locations on latitude-longitude grid of top-selected predictors.

As mentioned previously, the statistical procedure used was a two-step one. The second step had as its objective the derivation of probability of precipitation (PoP) and probability of precipitation amount (PoPA) equations. From the previously-derived equations synthetic predictors consisting of the regression estimate of the continuous predictand were constructed for each of the three periods. These synthetic predictors were then submitted to the screening regression program using both a binary predictand and binary predictors. If the continuous predictand equalled or exceeded a certain limit, the predictand was given a value of one; otherwise, it was zero. The same was done for the predictors, using a series of evenly spaced limits. The end result is a discrete set of PoPs or PoPAs. The regression results are summarized in Table 5. The number of terms included in each equation was determined by stopping at 6 or before a negative coefficient was reached, whichever came first.

Table 5. Summary of regression results using synthetic predictors in binary form and binary predictand.

Period (GMT)	Limit (in.)	Rel. Freq. (%)	No. Cases	Red. Var. (%)	Probability set (%)						
0000-0600	.01	9.9	2280	22.92	2	7	20	29	43	71	100
0000-0600	.50	2.5	4791	20.96	0	4	12	17	36	69	
0600-1200	.01	12.5	2278	17.34	2	7	16	26	42	100	
0600-1200	.50	2.3	4796	4.62	0	3	5	10			
0000-1200	.01	16.5	2276	22.46	3	7	10	16	29	51	93
0000-1200	.50	5.0	4780	19.23	0	2	5	9	18	32	67
0000-1200	1.00	2.1	4780	10.87	0	3	5	11	38		

The number of cases for the .01 in. or more runs was about half that for the other runs because the Fischer-Porter gages, which do not measure hundredths, had to be excluded from the sample for these runs. The number of probabilities in each set is always one more than the number of binary predictors selected. Note that there is a positive correlation between the number selected and the RV. Note also that the RV for the 0600-1200 GMT period for the .50 in. limit was quite low. This agrees with forecaster experience that after-midnight heavy rains are difficult to forecast.

For measurable precipitation the equations can give high PoPs, but these high PoPs are used rather rarely. The technique is incapable of giving near zero PoPs (2 percent is the lowest for 6 hours, and 3 percent is the lowest for 12 hours), probably an indication that variables such as lower tropospheric mean relative humidity must be used in order to give a very low PoP. An unfavorable SGW configuration does not guarantee zero precipitation, because the humidity may be high. A near zero PoPA for the categories of .50 and 1.00 in. or more was attained, however.

5. A PHYSICAL EXPLANATION OF THE STATISTICAL RESULTS

That a positive v component to the south of the station is favorable for precipitation in eastern Kansas is no surprise. That is the direction from which low-level moisture arrives from the Gulf of Mexico.

The negative u component to the west of the station is subject to at least three possible interpretations. First of all a diffluent SGW wind pattern can be effectively created by having a positive v to the south and a negative u to the west. A diffluent pattern can be considered favorable from the following physical reasoning. It is reasonable to assume that the diurnal variation of the boundary layer wind is greater when the SGW speed is greater. Thus in flows such as in Figs. 1 and 2, strongly super-geostrophic winds at night in the boundary layer to the south of the area are impinging upon slower-moving air (more nearly geostrophic) in eastern Kansas, giving rise to convergence and upward vertical motion at some distance above the ground.

Secondly, this pattern is favorable for a positive relative geostrophic vorticity in the forecast area, thus giving rise to upward vertical motion due to frictional retardation (see Holton, 1972--p.89). This effect would operate day and night.

Another interpretation of the negative u component is that it is upslope motion to the west of the forecast area, which is favorable for causing the air to rise, form clouds and thunderstorms, which drift into the area of concern. This also operates day and night.

Beyond this, it would be foolish to try to explain all 12 terms in the regression equations.

6. VERIFICATION ON INDEPENDENT DATA OF SGW AND MOS POPS AND POPAS

SGW and MOS PoPs were verified on independent data for the warm season (May through September) of 1978 for four stations in the area of interest--Concordia (CNK), Wichita (ICT), and Topeka (TOP) in Kansas, and Kansas City, Missouri (MCI). This leaves the southeastern part of the area of study without a verification station, but MOS does not provide a forecast for a station in that part of the area.

For a discussion of the MOS technique applied to developing PoPs, see Glahn and Lowry (1972) and NWS TPB No. 233 (1978). The MOS approach to developing PoPA equations is discussed by Bermowitz (1975) and in NWS TPB No. 227 (1978).

The precipitation amounts were categorized according to Table 1 and the previously-derived continuous-variable regression equations for each period were tested with one through twelve predictors to determine the optimum number of predictors from the relatively small sample of independent data available. The RV as a function of the number of predictors for each of the three periods is shown in Table 6.

Table 6. Reduction of variance as a function of number of terms in regression equations. Four stations pooled--CNK, ICT, TOP, and MCI. Continuous predictors and continuous predictand.

Number of terms	Reduction of Variance (%)		
	0000-0600 GMT	0600-1200 GMT	0000-1200 GMT
1	2.19	4.90	4.40
2	6.65	10.09*	11.68
3	7.58	9.91	12.17
4	8.26	9.19	11.55
5	8.95	9.48	12.81
6	9.86	9.50	13.41
7	9.59	9.89	13.33
8	9.56	9.89	13.89
9	9.57	9.48	14.49
10	10.00	9.28	14.77
11	9.85	9.23	14.97*
12	10.17*	9.53	14.79
Asterisks indicate maximum RV.			
Average value of predictand	.2467	.2516	.4297
Number of cases	612	612	612

On this sample the optimum number of terms was 12, 2, and 11, for the three periods in the order shown. The 0600-1200 GMT period shows an anomalous behavior, with the RV maximizing at only 2 predictors; however, adding more predictors does not degrade the forecasts to any great extent. Therefore, we may say that our choice of 12 terms (made before the 1978 season began) is satisfactory, since the extra terms do no great harm and a larger sample of independent data might show more than two terms to be desirable for the 0600-1200 GMT period.

Note that the RVs for the 0000-0600 and 0000-1200 GMT periods are noticeably lower on the independent data than on the developmental data. For the 0600-1200 GMT period it is slightly higher for two terms than for two terms on the developmental data. The average value of the predictand was higher on the test data than it was on the developmental data.

The scores used in this memorandum are the percent improvement of the Brier (1950) scores of the forecasts over the Brier scores produced by forecasts of the climatic frequency. Sanders (1963) used this score. The climatic probabilities are those given by Jorgensen, Klein, and Roberts (1969). Summer season (June, July, and August) values were used for all months and interpolation to CNK and TOP from surrounding stations had to be performed since they were not given.

Scores for the warm season of 1978 are shown in Table 7. CON (Consensus) is the average of SGW and MOS. There is not complete correspondence between SGW and MOS time periods and precipitation thresholds, so not all slots are filled.

Table 7. Skill scores (percent improvement over climatology) on independent data from May-September of 1978. Consensus (CON) is an average of SGW and MOS.

Period	0000-0600 GMT				0600-1200 GMT				0000-1200 GMT		
Limit	.01"	.25"	.50"	1.00"	.01"	.25"	.50"	1.00"	.01"	.50"	1.00"
SGW	10.8		3.4		9.4		6.3		11.8	8.7	5.0
MOS	18.0	10.4	6.5	6.8	17.5	11.1	11.2	-2.1	20.5		
CON	20.9		6.5		18.3		10.4		23.4		

The number of cases for each score varied from 577 to 612.

From a comparison of SGW with MOS for the five scores for which there were both forecasts available, it is apparent that MOS has a clean sweep--it is definitely superior. Consensus (CON, average) forecasts made from SGW and MOS improved upon MOS for the .01 in. threshold. The 12-h PoP (the one we hear the most about) showed a CON score which was almost three points better than that of MOS. For the two scores for .50 in. or more for 6-h periods, CON and MOS scores were the same in one case, and CON lost slightly to MOS in the other case. Note that all SGW scores were positive, even for the 1.00-inch-or-more-in-12-hours-category. MOS had trouble with the 0600-1200 GMT 1.00 in. category--the score was negative.

It is obvious that the SGW technique cannot supplant MOS--it can only modify it. A simple consensus shows some evidence of being able to improve upon MOS. But there is a better way of combining SGW and MOS--this is the subject of the next section. It is encouraging that a method of forecasting precipitation quantitatively which does not include a moisture variable or a stability variable can come up with positive skill on independent data.

7. PROBABILITIES USING THE JOINT RELATIONSHIP BETWEEN SGW AND MOS

SGW forecasts had a maximum of 7 probabilities, and MOS PoPA forecasts can be conveniently rounded to the 13 standard NWS PoP values used for many years (they were transmitted to the nearest percent in the bulletin most often used in this study). This gives us the possibility of producing matrices of reasonable size containing the number of forecasts and the number of rain events for each combination of SGW and MOS probabilities. Relative frequencies of rain events are then a simple step. The joint SGW-MOS relative frequency and frequency of usage for each combination are shown in Tables 8 to 12.

Table 8. Relative frequency of rain event (top number--percent) and frequency of usage (bottom number) for joint SGW-MOS relationship. 0000-0600 GMT period, .01 inch or more. From May-September 1978.

	MOS Probability											
SGW Prob.	0	2	5	10	20	30	40	50	60	70	80	ALL
2	0 98	0 46	4 48	0 28	0 18	0 7	0 2	0 2	0 2	- 0	- 0	1 251
7	5 22	0 25	9 45	11 56	12 25	14 14	33 12	80 5	67 3	- 0	- 0	13 207
20	0 3	0 3	13 8	33 9	17 12	0 1	33 3	50 2	33 3	- 0	- 0	21 44
29	0 1	0 1	0 8	0 2	33 3	33 3	0 4	50 2	- 0	- 0	- 0	13 24
43	0 1	- 0	8 12	30 10	33 9	50 2	100 3	0 1	57 7	100 1	100 2	38 48
71	- 0	- 0	- 0	0 1	- 0	- 0	- 0	- 0	- 0	- 0	100 2	67 3
100	- 0	- 0	- 0	- 0	- 0	- 0	- 0	- 0	- 0	- 0	- 0	- 0
ALL	1 125	0 75	7 121	11 106	13 67	15 27	33 24	50 12	47 15	100 1	100 4	10 577

Table 9. Same as Table 8, except for 0000-0600 GMT period, .50 inch or more.

	MOS Probability						
SGW Prob.	0	2	5	10	20	30	ALL
0	0 253	2 123	1 83	10 20	- 0	- 0	2 479
4	0 13	0 11	10 30	0 17	50 2	- 0	6 73
12	50 2	0 2	0 7	17 6	0 1	0 1	11 19
17	0 1	25 4	0 12	20 5	80 5	0 2	21 29
36	- 0	- 0	- 0	0 2	0 1	- 0	0 3
69	- 0	- 0	- 0	- 0	- 0	- 0	- 0
ALL	1 269	3 140	3 132	8 50	56 9	0 3	3 603

Table 10. Same as Table 8, except for 0600-1200 GMT period, .01 inch or more.

	MOS Probability										
SGW Prob.	0	2	5	10	20	30	40	50	60	70	ALL
2	0 27	0 28	0 54	8 63	0 20	22 9	20 5	0 1	0 1	100 1	4 209
7	0 8	0 7	3 37	4 69	13 38	18 22	44 9	33 3	- 0	- 0	9 193
16	0 1	20 5	0 9	21 33	14 14	50 12	29 7	100 1	- 0	100 1	24 83
26	- 0	0 1	0 4	10 10	20 10	57 7	0 2	100 1	- 0	100 2	27 37
42	- 0	- 0	0 7	39 18	0 4	43 7	67 6	33 6	0 2	100 5	38 55
100	- 0	- 0	- 0	- 0	- 0	- 0	- 0	- 0	- 0	- 0	- 0
ALL	0 36	2 41	1 111	12 193	11 86	33 57	38 29	42 12	0 3	100 9	14 577

Table 11. Same as Table 8, except for 0600-1200 GMT period, .50 inch or more.

	MOS Probability					
SGW Prob.	0	2	5	10	20	ALL
0	0	0	2	0	-	0
	170	175	53	22	0	420
3	0	0	8	9	-	3
	15	37	25	11	0	88
5	0	0	0	14	50	5
	8	8	15	7	2	40
10	0	17	0	13	67	11
	10	12	14	16	3	55
ALL	0	1	3	7	60	2
	203	232	107	56	5	603

Table 12. Same as Table 8, except for 0000-1200 GMT period, .01 inch or more.

	MOS Probability												
SGW Prob.	0	2	5	10	20	30	40	50	60	70	80	90	ALL
3	0	0	0	7	3	0	17	25	0	0	100	-	5
	33	22	35	54	35	7	6	4	1	1	2	0	200
7	0	0	0	7	6	15	44	44	17	0	-	-	13
	3	4	16	43	16	20	9	9	6	1	0	0	127
10	0	0	0	0	0	43	25	0	50	100	-	-	20
	1	2	2	14	11	7	4	1	6	3	0	0	51
16	0	33	0	12	30	31	50	75	60	100	-	-	29
	1	3	13	25	23	13	8	4	5	4	0	0	99
29	-	-	20	17	14	38	20	67	0	50	100	-	28
	0	0	5	18	7	16	5	3	2	4	1	0	61
51	-	-	0	38	63	50	50	40	44	100	60	100	52
	0	0	1	21	8	2	10	5	9	4	5	3	68
93	-	-	-	-	0	-	-	-	-	-	-	100	67
	0	0	0	0	1	0	0	0	0	0	0	2	3
ALL	0	3	1	12	15	26	38	46	38	77	75	100	19
	38	31	72	175	101	65	42	26	29	17	8	5	609

There are many numbers in these five tables, and one could make comment on each table separately. At this point, however, we will be content to discuss Table 12 only.

Turning to the overall reliability of the SGW forecasts, we see that the relative frequencies for the 3, 7, 10, and 16 percent PoPs were considerably higher than they should have been. The 29 and 51 percent PoPs were nearly perfectly reliable, however. The overall result was that SGW forecast only 77 percent of the observed rain frequency, as an average. MOS forecasts were generally reliable except for an overforecast on the 60 percent PoP. MOS forecast 111 percent of the observed rain frequency, on the average. The underforecasting of SGW may be partially due to the fact that only one year constituted the developmental data, and it had a rain frequency of 16.5 percent, as compared with 19.4 percent for the independent data.

An interesting part of the table is the set of PoPs for SGW = 51 and MOS = 20 through 60. There were 34 such forecasts, and exactly half had rain--SGW was nearly perfectly reliable. On the other hand, MOS underforecast at the low end and overforecast at the high end of this range. Even the combination of SGW = 51 and MOS = 10 was closer to the SGW value in relative frequency. In another part of the table we see that for SGW = 3 and MOS = 20 through 80, there were 56 forecasts and only 9 percent of these had rain--lower than the lowest MOS PoP in this range.*

These two areas of Table 12 illustrate that SGW is adding independent information to the MOS forecasts. They suggest that combining SGW and MOS in a way other than simply averaging the two would pay off in better scores, at least on the developmental data. We have developed a joint (JNT) SGW-MOS probability by simply assigning, quite subjectively ("eyeballing"), each SGW-MOS combination a value based on Tables 8 through 12. These values were made the same as MOS except when SGW seemed to be saying something different. Values were assigned even to combinations which had no data. The Probability of Precipitation Type (PoPT) technique uses joint predictors and a discussion of the reasons for using them is given in NWS TPB No. 243 (1978). The subjectivity may have been large, but great care was taken not to "overfit" the data. Hopefully, then, scores on independent data would hold up to the level of those of dependent data. The JNT values were not evaluated on independent data, even though SGW and MOS were, because they were developed from the 1978 data, not the 1972 data.

Tables showing the assigned JNT values are shown as Tables 13 through 17.

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*The two (3, 80) rain events occurred on the same day and were .01 in. at MCI and .04 in. at TOP.

Table 13. Joint (JNT) PoPs from SGW and MOS. 0000-0600 GMT period, .01 inch or more. Underlined JNT PoPs are the same as for MOS.

	MOS Probability										
SGW Prob.	0	2	5	10	20	30	40	50	60	70	80
2	0	2	5	10	10	20	30	30	40	50	60
7	2	5	5	10	20	30	40	50	60	60	60
20	5	5	10	20	20	30	40	50	60	60	70
29	5	10	10	20	20	30	40	50	60	70	70
43	5	10	20	30	30	40	40	50	60	70	80
71	10	10	20	30	40	50	50	60	70	80	90
100	10	20	30	40	50	60	60	70	80	90	100

Table 14. Same as Table 13, except for 0000-0600 GMT period, .50 inch or more.

	MOS Probability					
SGW Prob.	0	2	5	10	20	30
0	0	2	5	5	10	10
4	2	5	5	5	10	10
12	2	5	10	10	20	20
17	5	10	10	20	30	30
36	5	10	10	20	30	40
69	5	10	20	30	40	50

Table 15. Same as Table 13, except for 0600-1200 GMT period, .01 inch or more.

	MOS Probability									
SGW Prob.	0	2	5	10	20	30	40	50	60	70
2	0	0	2	5	10	20	30	30	40	40
7	0	2	5	5	10	20	30	40	50	50
16	2	5	5	10	20	30	40	50	60	60
26	5	5	5	10	20	30	40	50	60	70
42	10	10	10	20	20	30	40	50	60	70
100	20	20	20	30	30	40	50	60	70	80

Table 16. Same as Table 13, except for 0600-1200 GMT period, .50 inch or more.

	MOS Probability				
SGW Prob.	0	2	5	10	20
0	0	0	2	5	5
3	2	2	5	10	10
5	2	2	5	10	30
10	2	5	10	10	30

Table 17. Same as Table 13, except for 0000-1200 GMT period, .01 inch or more.

	MOS Probability												
SGW Prob.	0	2	5	10	20	30	40	50	60	70	80	90	100
3	0	0	2	5	5	10	20	30	30	30	40	50	50
7	0	2	2	5	10	20	30	40	40	40	50	60	70
10	0	2	5	10	20	30	30	40	50	60	70	80	90
16	2	5	5	10	20	30	40	50	60	70	70	80	90
29	5	10	20	20	20	30	40	50	60	70	80	90	100
51	5	10	20	40	50	50	50	50	60	70	80	90	100
93	20	30	40	50	60	60	60	70	70	70	80	90	100

Note that in some cases the JNT value for the 6-h periods is greater than that for either SGW or MOS (this occurs when both SGW and MOS are relatively high). For example, pooling of all cases for the 0600-1200 GMT period, .50 inch or more, when MOS = 20 and SGW = 5 or 10, give a synergistic effect. There are five such cases and 3 had a rain event (.50 inch or more, that is). These combinations were conservatively placed at 30 percent, since the sample is minute. The reality of this situation cannot be proven from the data at hand. More testing on independent data is needed.

Skill scores on the developmental data were computed and are shown in Table 18.

Table 18. Skill scores on developmental data of JNT PoPs and PoPAs.

Period	0000-0600 GMT		0600-1200 GMT		0000-1200 GMT
Limit	.01"	.50"	.01"	.50"	.01"
	22.5	9.2	20.9	14.7	27.9

Note that these scores are higher than the corresponding scores for MOS and CON on Table 7. Time will tell whether they will hold up on independent data.

The reliability of the 12-h PoP from JNT is shown in Table 19. This shows the relative frequency of rain and number of forecasts for each JNT probability.

Table 19. Relative frequency (percent) of rain and number of forecasts for each JNT probability value. 12-h period, .01 inches or more.

PoP	0	2	5	10	20	30	40	50	60	70	80	90
Relative frequency of rain	0	0	6	7	18	35	38	55	50	83	68	100
Number of forecasts	59	58	150	62	91	55	53	38	20	12	6	5

Note that there were 117 zero or 2 percent forecasts without rain. In contrast with MOS alone, where more rains (21) occurred on 10 percent forecasts than on any other single value, the JNT value with the most rains (again 21) is 50 percent. The numbers of rains for JNT and MOS of 20 percent or more are 105 and 95, respectively. For values of 40 percent or more, the numbers are 70 and 63. JNT has the edge on these lower limits, but the numbers of rains for 60 percent or more are 29 and 35. This is a reversal, but is not surprising since SGW used the 93 percent value only 3 times, and the next lower value of 51 percent was used 68 times.

Making PoP forecasts of 30 percent or higher categorical "yes" forecasts, the threat scores (ratio of number of correct rain event forecasts to number of times the rain event was either forecast or observed) were .41 for JNT and .35 for MOS.

Note that SGW cannot usually help JNT get more very high PoPs. Its function is to help JNT prevent rains on low values, and no-rains on high values. Due to the local nature of thunderstorms, one can wonder whether PoPs of 60 or 70 percent or higher are very often justified in the warm season, anyway.

A breakdown of skill by stations is of interest, but because of the limited size of the verification sample, individual station scores will be shown only for the 0000-1200 GMT period, .01 in. or more. These scores represent more rain events than any other set of scores. Table 20 shows the scores for the four stations.

Table 20. Skill scores on 1978 data for the 0000-1200 GMT period, .01 in. or more. LCL is the local forecast, but GUI is the WSFO guidance forecast for the station (MOS for TOP). OPT (optimum is obtained by taking the better of SGW or MOS according to whether it rained or not).

Station	SGW	MOS	CON	JNT*	LCL	GUI	OPT
CNK	20.2	17.5	25.3	24.8*	31.7	30.8	49.2
ICT	20.6	23.6	30.9	40.1*	35.5	31.7	60.1
TOP	5.3	22.3	20.5	25.8*	24.7	22.3	47.8
MCI	3.4	19.1	18.4	22.8*	20.3	19.1	46.5
ALL	11.8	20.5	23.4	27.9*	27.6	25.6	50.5

*JNT is on developmental data.

Note that JNT, though on developmental data, scored better than MOS at all four stations, in spite of the fact that SGW alone did poorly at TOP and MCI. At the central Kansas stations SGW alone did better than MOS at CNK, and almost as well at ICT. Another season of independent data would probably help settle the question of whether SGW, CON, and JNT really do better at these stations. Physically there are reasons why the SGW technique may do better in central Kansas than in eastern Kansas. Central Kansas seems to be more in the favored region for BLWMs (the terrain slope is more) and it is on the edge of the surface moisture from the Gulf of Mexico much of the time. MOS may not handle this sharp moisture cut-off well.

JNT also scored higher than the LCL forecasts, except at CNK. OPT scores are included here for academic interest. They are naturally higher than anything else, and the high level of the scores indicates the degree to which SGW and MOS have "minds of their own."

8. SOME EXAMPLES OF SGW CHARTS FOR VARIOUS SITUATIONS

a. The Quantitative Precipitation Forecast Index

Before proceeding to a discussion of various cases we will introduce a quantity used to summarize the SGW PoP and PoPA forecasts. This will be called the Quantitative Precipitation Forecast Index (QPFI). It refers to a 12-h period and is obtained by multiplying the probability (in percent) of .01 in. or more by one, the probability of .50 in. or more by two, and the probability of 1.00 in. or more by three, and then summing the three numbers. This gives a compact idea of the precipitation threat for any period.

b. Previously-mentioned Cases from the Summer of 1977

Figs. 1 and 2 are two examples of heavy rain cases for eastern Kansas. SGW PoPs and PoPAs were computed for these cases and are shown in Table 21.

Table 21. SGW PoPs and PoPAs for 1977 cases.

	0000-0600 GMT		0600-1200 GMT		0000-1200 GMT				Precipitation Inches	
	Limit								0000-0600 GMT	0600-1200 GMT
Station	.01	.50	.01	.50	.01	.50	1.00	QPFI		
			From 1800 GMT 17 June 1977							
CNK	43	17	42	10	51	18	11	120	0	.40
ICT	43	12	42	10	51	18	5	102	0	0
TOP	43	17	42	10	51	18	11	120	.94	.56
MCI	43	17	42	10	51	18	11	120	.44	.20
COKN	29	4	42	10	51	18	5	102	0	0
			From 1800 GMT 4 August 1977							
CNK	29	4	26	5	51	18	5	102	0	.34
ICT	29	4	42	10	51	18	5	102	0	.49
TOP	29	4	26	5	51	18	5	102	1.23	1.29
MCI	20	4	26	5	29	9	5	62	0	1.26
COKN	20	4	16	3	29	5	3	48	0	0

The MOS 12-h PoP was 30 percent in each case for TOP. PoPA was not available in 1977. Note that eight of the ten 12-h PoPs were 51 percent. There was only one PoP available in the SGW system higher than this--93 percent and this was used very sparingly. In the JNT scheme we get a value close to the SGW value--50 percent. The PoPAs are away from zero, though usually not reaching the maximum values for each category. These values are illustrative of the magnitude of the probabilities on a heavy rain night. Some of the heavy rains in eastern Kansas on these days are listed in Table 22.

Table 22. Six- and 12-h amounts of precipitation (in.) on 18 June 1977 and 5 August 1977. All stations are in eastern Kansas.

Station	0000-0600 GMT	0600-1200 GMT	0000-1200 GMT
		18 June 1977	
Milford Lake	2.1	2.1	4.2
Tuttle Creek Lake	4.68	.60	5.28
Melvern Lake	0	2.69	2.69
		5 August 1977	
Easton	.16	2.74	2.90
Perry Lake	1.67	2.46	4.13
Baldwin	0	3.3	3.3
Muncie Sewage Plant	.8	2.6	3.4

Thus, 12-h rains in excess of 4 inches fell somewhere in the area of this study on both of these nights. But, of course, probably only a small percentage of the gages in the area received a large amount, indicating the difficulty of forecasting high PoPA values.

c. The September 1977 Flood in Kansas City

Another pair of dates not in either the developmental data or the test data is 11 and 12 September 1977. This corresponds to the Kansas City flood, during which rainfalls of 5 in. or more fell in the Kansas City area on two separate occasions within a 24-h period. The first burst of rain was during the 0600-1200 GMT period on 12 September, and the second was during the 0000-0600 GMT period on 13 September. The maps for this period are shown in Figs. 6 and 7.

It will be seen that on 11 September there was no diffluence over eastern Kansas--a rather uniform southerly flow prevailed. There were no easterly SGWs to the west of MCI. On 12 September a different situation was to be found, however. At a grid point near Goodland (GLD) the SGW is 070° at 8 kt., while south of MCI a south-southwesterly flow prevailed--a high PoP situation for SGW. The SGW probabilities are shown in Table 23 for this case.

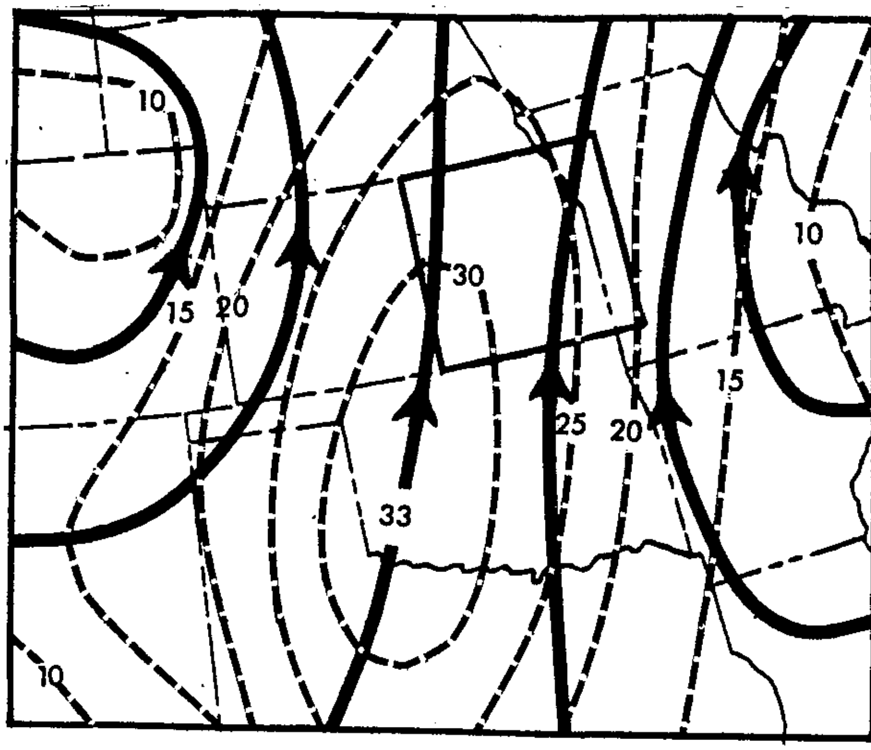

Fig. 6. SGW chart for 1800 GMT 11 September 1977.

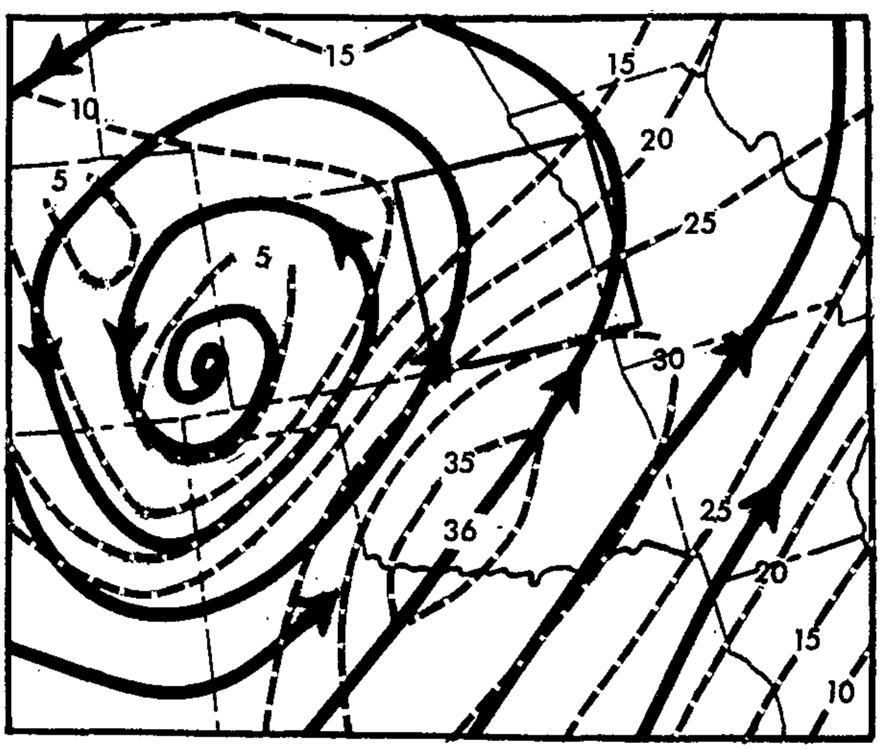

Fig. 7. SGW chart for 1800 GMT 12 September 1977.

Table 23. SGW PoPs and PoPAs for Kansas City flood of 1977

	0000-0600 GMT		0600-1200 GMT		0000-1200 GMT				Precipitation Inches	
	Limit								0000-0600 GMT	0600-1200 GMT
	.01	.50	.01	.50	.01	.50	1.00	QPFI		
Station			From 1800 GMT 11 September 1977							
CNK	7	0	16	3	29	5	3	48	.02	.44
ICT	7	0	7	0	16	5	3	35	0	0
TOP	7	0	16	3	16	2	0	20	.02	.44
MCI	7	0	7	0	16	2	0	20	.19	3.55
COKN	7	0	7	0	7	0	0	7	0	0
			From 1800 GMT 12 September 1977							
CNK	43	12	26	5	51	18	5	102	0	0
ICT	29	4	26	5	51	18	5	102	.12	.39
TOP	43	12	42	10	51	18	5	102	1.40	.05
MCI	43	12	42	10	51	18	5	102	3.75	.33
COKN	7	0	16	3	29	5	3	48	0	.73

The MOS 12-h PoP was 80 percent for MCI for the night periods on both occasions, which converts to a JNT value of 70 percent for the first night and 80 percent the second night. Clearly, SGW was dragging MOS down the first night, and going along with it on the second night. The high MOS value on the first night is probably an indication that upper-air features were dominating.

It seems, then, that on the first night the SGW chart was only saying that it could rain, not that it would. The second night the boundary-layer wind probably played a more active role than on the first night. Put another way, on the first night the boundary layer was providing only some of the moisture, and not much convergence; on the second night the boundary layer was probably providing both convergence and moisture.

d. Another Case of Locally Very Heavy Rain in 1977.

During the evening and night of 31 August-1 September 1977 an unofficial 9 inches of rain fell at Salina, about halfway between CNK and ICT. Between 2240 GMT 31 August and the morning of 1 September (around 1500 GMT) the Salina FAA station recorded 6.65 in. (HPD data were not available for Salina.) More than four inches fell at TOP during the 0000-1200 GMT period on 1 September. The 12-h MOS PoP was 50 percent for TOP. The SGW chart for this situation is shown in Fig. 8 and the PoPs and the PoPAs are shown on Table 24. It will be seen that there was a diffluent SGW pattern on this day, with modest south-southwesterly SGWs across central Oklahoma and an east SGW in northwest Kansas. The probabilities were moderate in this case--about the same as for several other heavy rain cases.

Table 24. SGW PoPs and PoPAs from 1800 GMT 31 August 1977

	0000-0600 GMT		0600-1200 GMT		0000-1200 GMT				Precipitation Inches	
	Limit								0000-0600 GMT	0600-1200 GMT
	.01	.50	.01	.50	.01	.50	1.00	QPFI		
Station										
CNK	43	12	42	10	51	18	5	102	0	.15
ICT	20	4	16	3	29	5	3	48	.14	2.22
TOP	43	12	42	10	51	18	5	102	3.83	.20
MCI	20	4	42	10	51	18	5	102	.56	.38
COKN	7	0	16	3	16	5	3	35	0	0

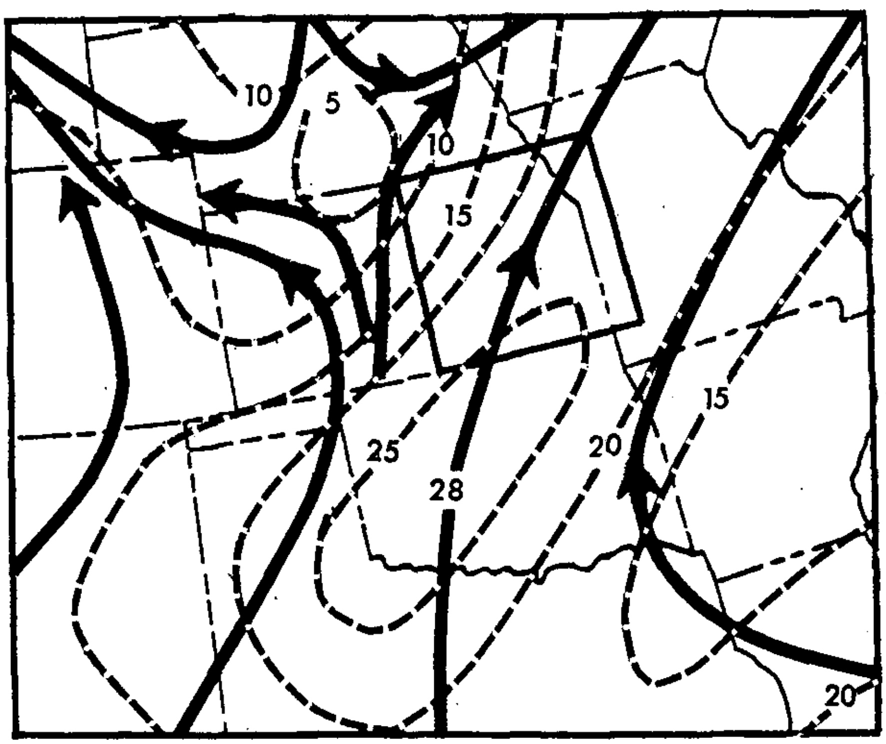

Fig. 8. SGW chart for 1800 GMT 31 August 1977.

We now proceed to an examination of some interesting cases in the 1978 sample, where both SGW and MOS values for both PoP and PoPA were available. Eight cases will be examined--this number is dictated by the number of combinations available from: (high SGW, low SGW), (high MOS, low MOS),(rain, no rain).

e. A Case of High SGW, High MOS, Rain

The heaviest 12-h nighttime rain during the warm season of 1978 at any of the four verifying stations came when both MOS and SGW had high probabilities. This was the 3.63 in. which fell at CNK during the period of 0000-1200 GMT on 22 July 1978. The chart preceding this period is shown in Fig. 9. There is a rather strong southerly SGW flow to the south of ICT and CNK, and an easterly flow over northwest Kansas and western Nebraska. The results from the SGW technique and MOS are shown in Table 25.

Since the 12-h MOS PoP for CNK for this situation was 70 percent, the JNT PoP would have stayed at 70 percent, as can be seen from Table 17. Most of the rain at CNK fell before 0600 GMT so the highest SGW PoPA for .50 in. or more--17 percent for CNK for the 0000-0600 GMT period--worked out well. Since the MOS PoPA for this period for .50 in. or more was 18 percent, we can see from Table 14 that the JNT PoPA would be 30 percent--higher than either SGW or MOS. SGW got caught on a fairly low PoP at ICT (16 percent), but the 7 percent at COKN came through with no precipitation.

Table 25. SGW and MOS PoPs and PoPas from 1800 GMT and 1200 GMT 21 July 1978.

		0000-0600 GMT		0600-1200 GMT		0000-1200 GMT				Precipitation Inches	
		Limit								0000-0600 GMT	0600-1200 GMT
		.01	.50	.01	.50	.01	.50	1.00	QPFI		
Station											
CNK	SGW	43	17	42	10	51	18	11	120	3.09	.54
	MOS	40	18	70	22	70					
ICT	SGW	7	0	7	0	16	5	3	35	0	.22
	MOS	30	13	50	12	60					
TOP	SGW	29	4	42	10	51	18	5	102	0	0
	MOS	30	13	50	15	60					
MCI	SGW	29	4	42	10	51	18	5	102	0	0
	MOS	30	9	50	9	60					
COKN	SGW	2	0	7	0	7	0	0	7	0	0

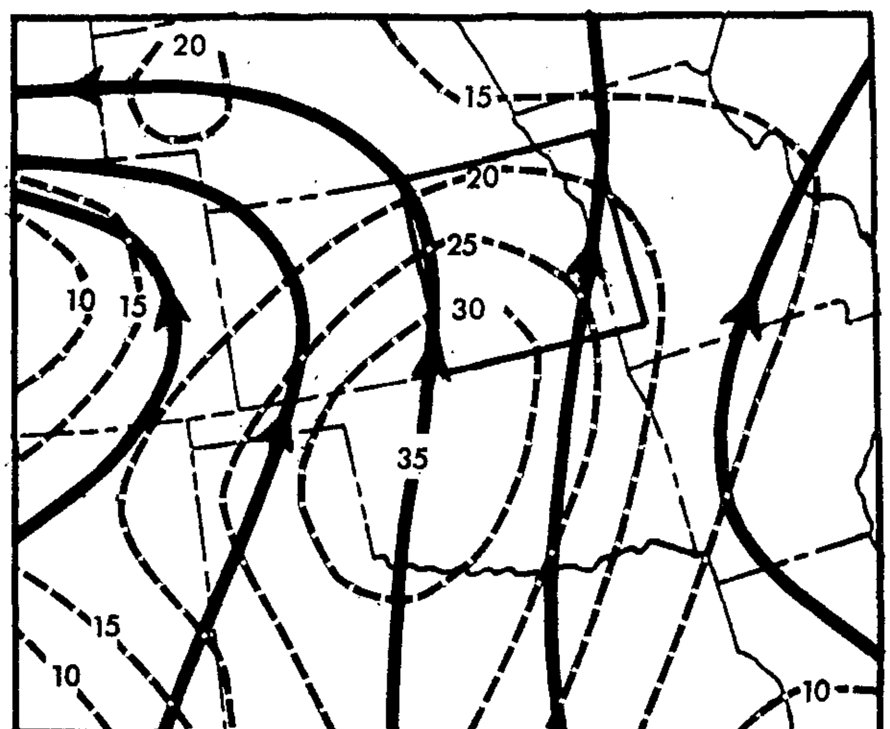

Fig. 9. SGW chart for 1800 GMT 21 July 1978.

f. A Case of High SGW, High MOS, No (?) Rain

No case could be found in the 1978 sample where SGW was 51 percent or higher and MOS was 70 percent or higher for most of the stations without rain falling that night on one or two of the stations. The closest to desired example which could be found was from 1800 GMT 6 July 1978. The SGW chart for this day is shown in Fig. 10. There are southerly winds in eastern Oklahoma and easterly winds in northwest Kansas and western Nebraska, the combination which gives high SGW PoPs. MOS was quite high, so the day had the earmarks of a big rain-producing situation for the following night. The probabilities and precipitation are shown in Table 26.

The station that got the only significant precipitation (ICT) also had lower probabilities than CNK, TOP, and MCI. However, it would not be wise to write this case off as a bad bust until the HPDs are available for this month (not received at this writing). It may have been that CNK and TOP barely missed getting precipitation. 24-h non-zero amounts were numerous for the period ending the morning of the 7th, but one cannot tell the distribution by time periods.

Table 26. SGW and MOS PoPs and PoPAs from 1800 GMT and 1200 GMT 6 July 1978.

		0000-0600 GMT		0600-1200 GMT		0000-1200 GMT				Precipitation Inches	
		Limit								0000-0600 GMT	0600-1200 GMT
		.01	.50	.01	.50	.01	.50	1.00	QPFI		
Station											
CNK	SGW	43	17	42	10	51	18	11	120	0	0
	MOS	60	10	60	4	80					
ICT	SGW	20	4	16	3	29	5	3	48	.25	0
	MOS	20	9	20	4	30					
TOP	SGW	43	12	42	10	51	18	5	102	0	0
	MOS	60	9	60	9	80					
MCI	SGW	43	12	42	10	51	18	5	102	.01	0
	MOS	40	8	50	9	70					
COKN	SGW	7	0	7	0	16	2	0	20	.32 in 24 h ending 1200 GMT 7 July	

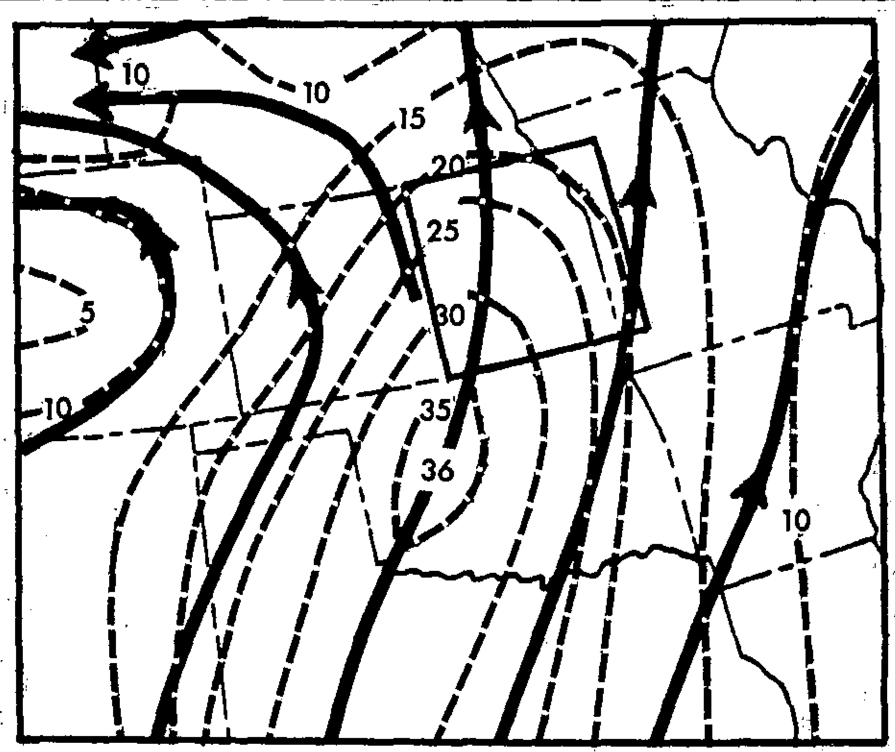

Fig. 10. SGW chart for 1800 GMT 6 July 1978.

g. A Case of High SGW, low MOS, Rain

The largest 6-h amount (2.16 in) at MCI of the season in the 0600-1200 GMT period occurred on 10 July 1978 when the 12-h MOS PoP was 10 percent and the SGW PoP was 51 percent. The SGW chart for 1800 GMT 9 July 1978 is shown in Fig. 11. There was southerly geostrophic flow to the south of MCI and rather strong easterly SGWs over northwest Kansas. This led to the PoPs and PoPAs shown in Table 27.

The western stations had lower SGW probabilities than did the eastern stations, and did not get rain.

It may have been that MOS was trying to bring in a drier air mass over MCI and TOP, whereas in actuality the cold front became quasi-stationary across northern Oklahoma, and overrunning to the north of the front set up the precipitation. This combination of SGW and MOS PoPs would give a JNT value of 40 percent, a significant improvement over the MOS PoP of 10 percent. But, of course, in this instance one would have been wise to have gone along with SGW completely (or higher) at TOP and MCI.

This is an unusual case in that the front by 0600 GMT was in Oklahoma, quite far south for precipitation to occur at MCI. It seems that quasi-stationary frontal positions all the way from Nebraska to Oklahoma can be associated with precipitation in eastern Kansas.

Table 27. SGW and MOS PoPs and PoPAs from 1800 GMT and 1200 GMT 9 July 1978

		0000-0600 GMT		0600-1200 GMT		0000-1200 GMT				Precipitation Inches	
		Limit								0000-0600 GMT	0600-1200 GMT
		.01	.50	.01	.50	.01	.50	1.00	QPFI		
Station											
CNK	SGW	29	4	16	3	29	9	5	62	0	0
	MOS	5	1	10	1	20					
ICT	SGW	20	4	16	3	29	5	3	48	0	0
	MOS	5	3	10	2	10					
TOP	SGW	43	17	42	10	51	18	5	102	0	.37
	MOS	5	3	10	1	10					
MCI	SGW	43	17	42	10	51	18	11	120	0	2.16
	MOS	5	3	10	1	10					
COKN	SGW	29	4	42	10	51	18	5	102	0	0

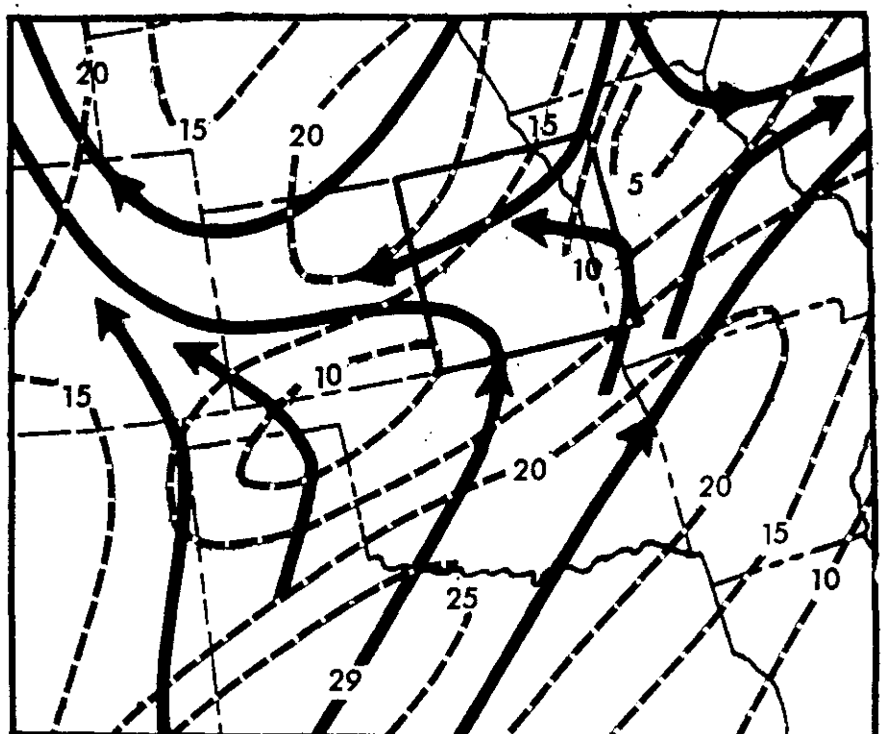

Fig. 11. SGW chart for 1800 GMT 9 July 1978.

h. A Case of High SGW, Low MOS, No Rain

At the four verification stations the 12-h SGW PoP was 93 percent only three times during the season, and two of these were when MOS had 90 percent. Both (93, 90) combinations had rain--see Table 12. The third was a (93,20) combination for MCI that did not have rain. The SGW chart for this day at 1800 GMT 18 August 1978 is shown in Fig. 12. This case had northeasterly winds on the SGW chart over northwest Kansas and southwest Nebraska, and the usual southerly winds to the south. The probabilities are given in Table 28.

The QPFI for MCI was much higher than for any case cited where heavy rain fell, but, alas, no rain fell on MCI that night.

What went wrong? An examination of Fig. 12 shows a northeast-southwest oriented front moving through eastern Kansas. By 0000 GMT it had passed MCI, and thus the only chance for precipitation would have been post-frontal. Had the front been oriented more east-west there would have been a good chance for this to develop. The implications are clear--beware of fronts which sweep on through leaving dry air behind. The best indication that the front was going to keep moving might have been in the 1800 GMT SGW chart itself. The SGWs to the northwest of the front were 040 or 050° in direction. Allowing a correction of 40 or 50 degrees would have given a surface wind of almost straight north. This would give enough component normal to the front to keep it moving.

This case was one of personal agony to the author. I was driving west on I-70 through eastern Kansas on the late afternoon of the 18th, knowing that SGW had forecast 93 percent for MCI. I could see the thunderstorms forming on the front, but not in a position to rain at MCI. I kept hoping the Royals baseball game would get rained out, but it never did.*

This is a good example of how simple classical statistical techniques can lead one astray. But an application of some weather forecasting know-how would allow one to discount the SGW technique.

- -

*The Texas Rangers beat the Kansas City Royals, 4-3, so it was a bad evening all around.

Table 28. SGW and MOS PoPs and PoPAs from 1800 GMT and 1200 GMT 18 August 1978

		0000-0600 GMT		0600-1200 GMT		0000-1200 GMT				Precipitation Inches	
		Limit								0000-0600 GMT	0600-1200 GMT
		.01	.50	.01	.50	.01	.50	1.00	QPFI		
Station											
CNK	SGW	43	17	42	10	51	18	5	102	0	0
	MOS	10	1	5	0	10					
ICT	SGW	43	17	42	10	51	18	5	102	0	0
	MOS	5	4	10	0	10					
TOP	SGW	43	17	42	10	51	32	11	148	0	0
	MOS	10	6	10	2	10					
MCI	SGW	71	36	42	10	93	67	38	341	0	0
	MOS	10	7	10	0	20					
COKN	SGW	43	17	42	10	51	18	5	102	unknown	

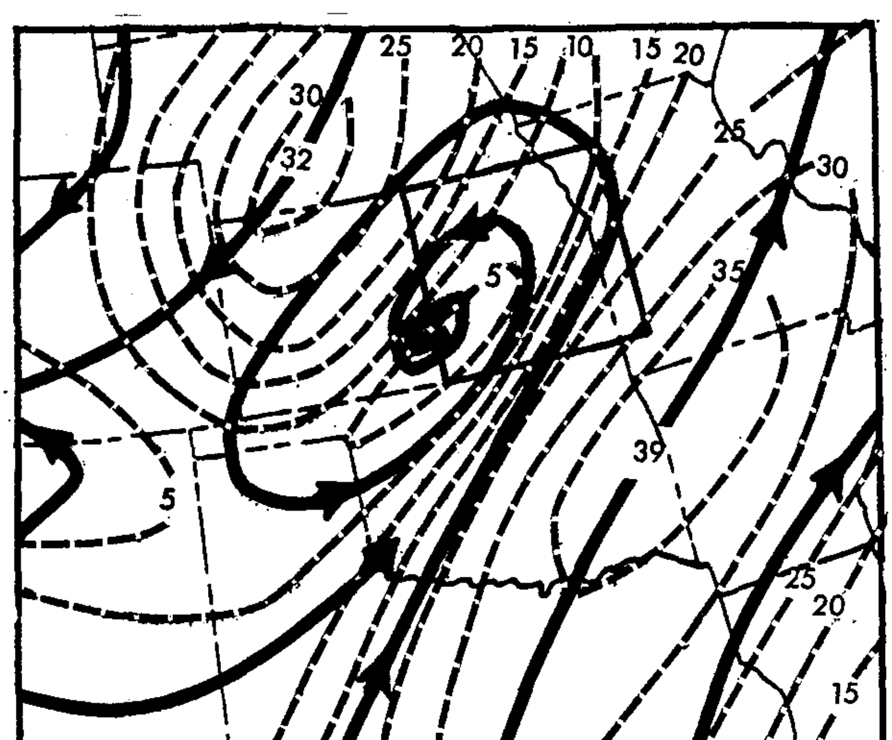

Fig. 12. SGW chart for 1800 GMT 18 August 1978.

i. A Case of Low SGW, High MOS, Rain

Choosing a case for this category was not clear-cut. One could look at all the rains on the 12-h SGW PoPs of 3 percent, and this was done. The largest amount (.19 in) came when MOS was 50 percent, but since the amount is so small we will go on to another more interesting case. Before leaving the "3 percenters," however, it is interesting to note that all of the rains on this value came at TOP and MCI--all SGW 3 percent values were without rain at CNK and ICT. Maybe this is an indication that it is easier to use low values for the western stations.

The case chosen for this category is one where SGW was relatively low (16 percent) and MOS was 70 percent for the 12-h PoPs, and TOP got 3.37 inches in 12 hours. The map for this case on 19 June 1978 is shown in Fig. 13.

There is a south-southwesterly flow all the way from Texas to Iowa on the SGW chart, but no easterly winds in western Kansas. In some respects it is similar to that on 11 September 1977 (Fig. 6). A front in western Nebraska at 1800 GMT moved across the area and had pushed through all except the southeastern part of Kansas by 1200 GMT 20 June. SGW was again saying only that it could rain, not that it would. The JNT 12-h PoP for TOP for this case would still have been 70 percent, so at least SGW did not hurt the JNT forecast. The statistics for this case are shown in Table 29.

Even the 3 percent PoP at COKN (not part of the verification sample) most likely had rain, since nearby Chanute (CNU) reported .99 in. in the 0600-1200 GMT period. However, the day was not a complete failure for SGW, since it had 51 percent for CNK. But MOS clearly stole the show. It is apparent that SGW just does not do well when the surface situation is changing and upper-air features such as warm-air advection and positive vorticity advection are the important overriding factors.

Table 29. SGW and MOS PoPs and PoPAs from 1800 GMT and 1200 GMT 19 June 1978

		0000-0600 GMT		0600-1200 GMT		0000-1200 GMT				Precipitation Inches	
		Limit								0000-0600 GMT	0600-1200 GMT
		.01	.50	.01	.50	.01	.50	1.00	QPFI		
Station											
CNK	SGW	43	12	42	10	51	18	5	102	.90	.08
	MOS	30	10	40	6	60					
ICT	SGW	7	0	7	0	10	2	0	14	0	.85
	MOS	30	5	40	5	60					
TOP	SGW	7	0	26	5	16	5	3	35	2.69	.68
	MOS	40	6	50	13	70					
MCI	SGW	7	0	16	3	16	2	0	20	.18	.47
	MOS	40	5	50	13	70					
COKN	SGW	2	0	2	0	3	0	0	3	unknown	

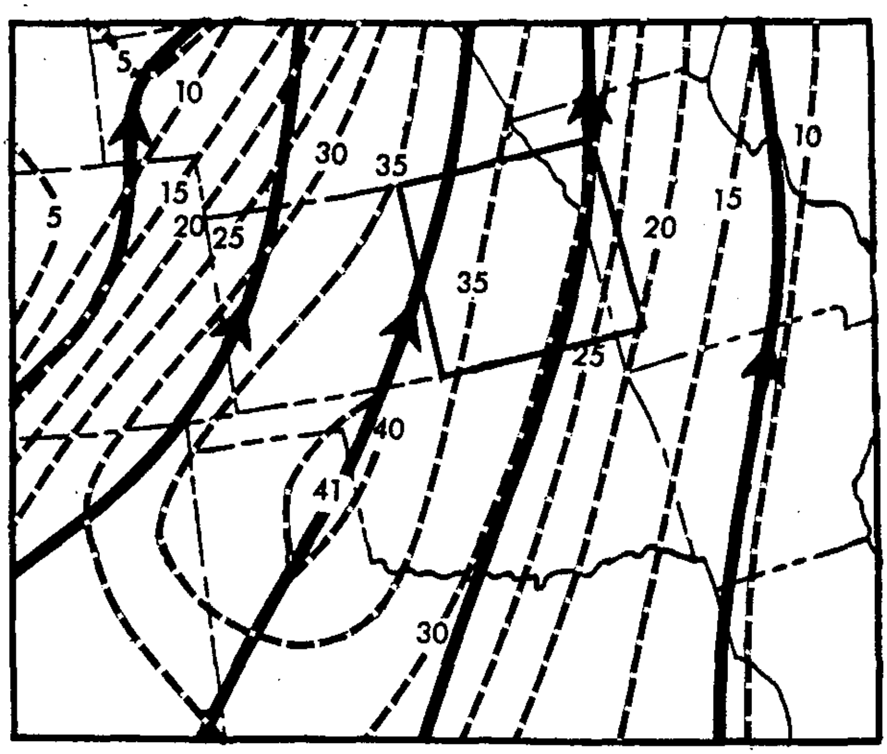

Fig. 13. SGW chart for 1800 GMT 19 June 1978.

j. A Case of Low SGW, High MOS, No Rain

For an SGW value of 3 percent for the 12-h PoP, the highest MOS PoP recorded with no rain was 70 percent. The only case occurred on 2 June 1978--the SGW chart is shown in Fig. 14. A surface anti-cyclone is located over extreme southeast Nebraska and the SGWs across Oklahoma are east-northeasterly. The SGW chart looks nothing like any of the rain cases presented previously. Probabilities are shown in Table 30.

Note that the MOS PoPAs are low, in spite of the fact that the PoPs are as high as 70 percent. Probably the only factor favorable for rain was high mean relative humidity in the lower troposphere. Certainly there was no low-level influx of moisture from the south. This was SGW's day.

Table 30. SGW and MOS PoPs and PoPAs from 1800 GMT and 1200 GMT 2 June 1978

		0000-0600 GMT		0600-1200 GMT		0000-1200 GMT				Precipitation Inches	
		Limit								0000-0600 GMT	0600-1200 GMT
		.01	.50	.01	.50	.01	.50	1.00	QPFI		
Station											
CNK	SGW	2	0	7	0	3	0	0	3	0	0
	MOS	20	0	30	0	40					
ICT	SGW	2	0	2	0	3	0	0	3	0	0
	MOS	60	0	60	10	70					
TOP	SGW	2	0	2	0	3	0	0	3	0	0
	MOS	20	0	30	0	40					
MCI	SGW	2	0	2	0	3	0	0	3	0	0
	MOS	10	0	20	0	20					
COKN	SGW	7	0	7	0	10	2	0	14	0	0

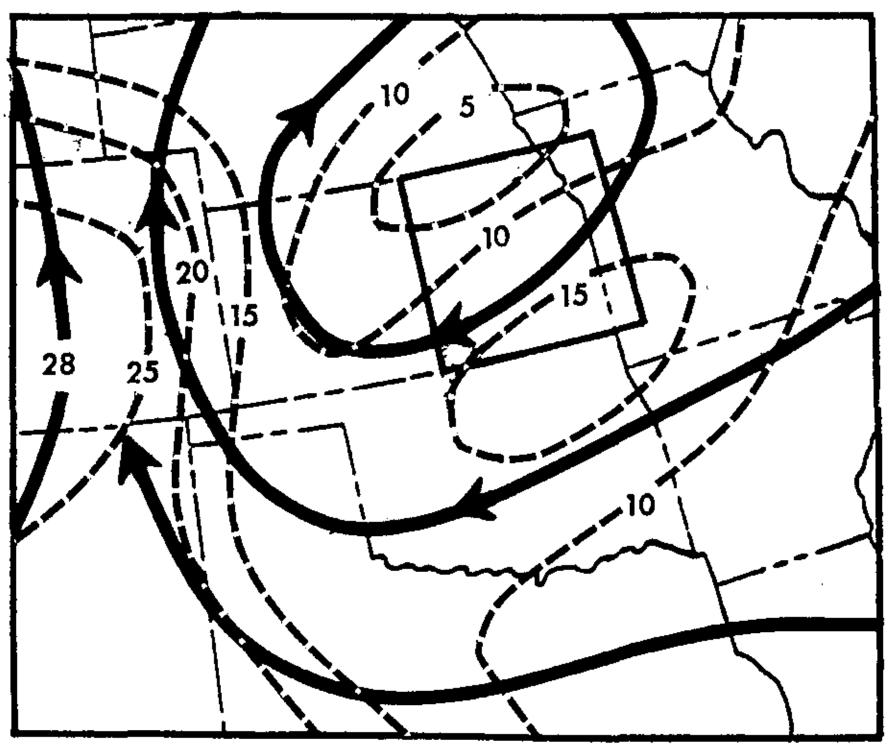

Fig. 14. SGW chart for 1800 GMT 2 June 1978.

k. A Case of Low SGW, Low MOS, Rain

There were 54 cases where the 12-h PoP from SGW was 3 percent, and 10 percent from MOS; four of these had rain. The total rain from these four events was only .33 in. and the largest value was .13 in. The SGW chart for the day on which this occurred is shown in Fig. 15. The probabilities are shown in Table 31.

There are no easterly SGWs in western Kansas and the southerly SGWs in eastern Oklahoma are rather light, which is why the PoPs were low. This is a case which illustrates that one cannot be absolutely certain that rain will not fall, as long as there is moist tropical air feeding up from the Gulf of Mexico. Note that there <u>is</u> a speed decrease to the north from the maximum in southwest Oklahoma, even though there isn't much diffluence over eastern Kansas.

Table 31. SGW and MOS PoPs and PoPAs from 1800 GMT and 1200 GMT 16 August 1978

		0000-0600 GMT		0600-1200 GMT		0000-1200 GMT				Precipitation Inches	
		Limit								0000-0600 GMT	0600-1200 GMT
		.01	.50	.01	.50	.01	.50	1.00	QPFI		
Station											
CNK	SGW	7	0	7	0	7	0	0	7	0	0
	MOS	2	0	5	0	10					
ICT	SGW	7	0	7	0	7	0	0	7	0	.04
	MOS	5	0	5	0	10					
TOP	SGW	2	0	2	0	3	0	0	3	0	.04
	MOS	5	0	10	10	10					
MCI	SGW	2	0	2	0	3	0	0	3	0	.13
	MOS	5	0	10	10	10					
COKN	SGW	2	0	2	0	3	0	0	3	0	0

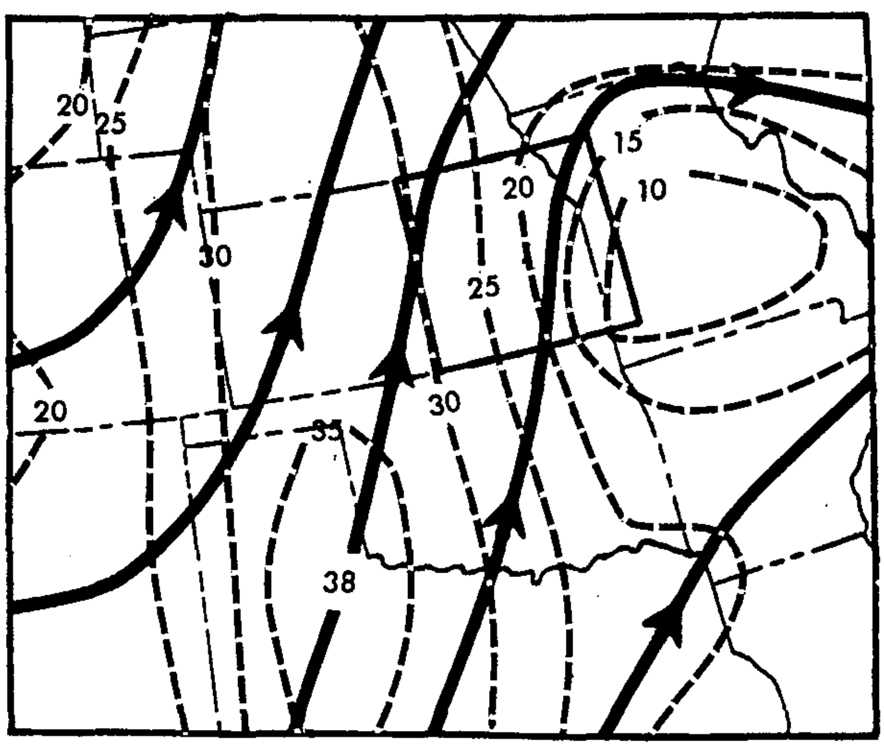

Fig. 15. SGW chart for 1800 GMT 16 August 1978.

7. A Case of Low SGW, Low MOS, No Rain

There are many potential cases to choose from in this category, and the one chosen represents a case with ample surface moisture (dew points in the upper 60's F) and southerly flow, so one might say that the possibility of thunderstorms was not obviously small. MOS came in with 10 percent, as it frequently does, and SGW values were lower for the 12-h PoPs. The chart for 29 June 1978 is shown in Fig. 16. It will be seen that the SGWs over western Kansas have a westerly component and the SGWs to the south in Oklahoma are rather light south-southwesterly. Note that the strongest SGW speeds are in northwestern Kansas and southwestern Nebraska, a location which does not at all fit the eastern Kansas rain pattern, as developed in this memorandum. The probabilities are shown in Table 32.

Table 32. SGW and MOS PoPs and PoPAs from 1800 GMT and 1200 GMT 29 June 1978.

		0000-0600 GMT		0600-1200 GMT		0000-1200 GMT				Precipitation Inches	
		Limit								0000-0600 GMT	0600-1200 GMT
		.01	.50	.01	.50	.01	.50	1.00	QPFI		
Station											
CNK	SGW	2	0	7	0	7	0	0	7	0	0
	MOS	2	0	10	1	10					
ICT	SGW	2	0	2	0	3	0	0	3	0	0
	MOS	2	0	10	1	10					
TOP	SGW	2	0	2	0	3	0	0	3	0	0
	MOS	2	1	10	1	10					
MCI	SGW	2	0	2	0	3	0	0	3	0	0
	MOS	2	1	10	2	10					
COKN	SGW	2	0	2	0	3	0	0	3	0	0

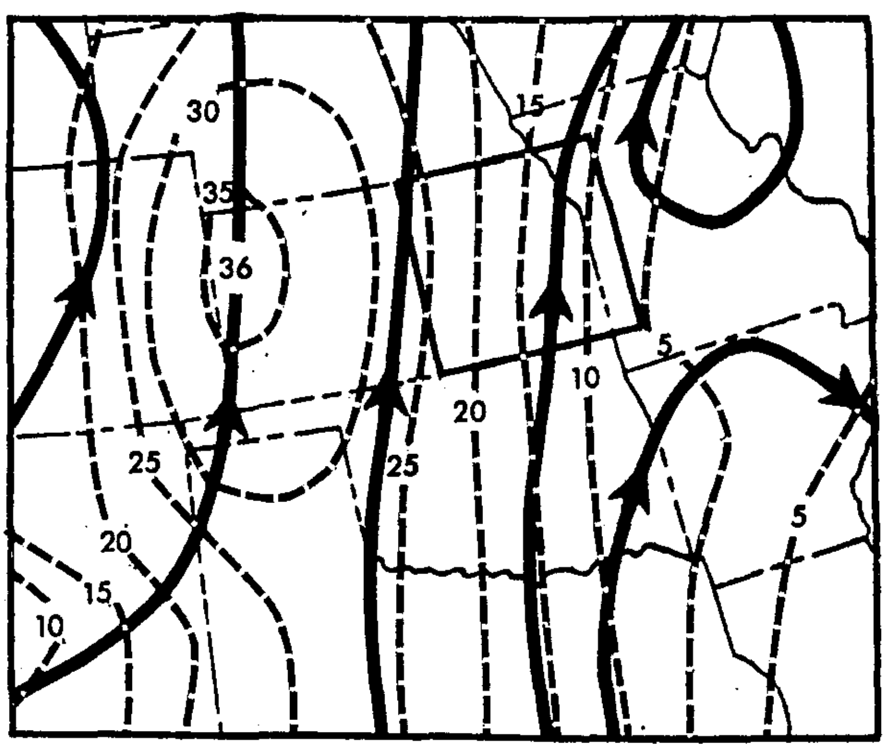

Fig. 16. SGW chart for 1800 GMT 29 June 1978.

9. CONCLUSIONS

It is to be hoped that the JNT SGW-MOS system can be proven superior to MOS probabilities alone on independent data. Hopefully a test on 1979 data will provide an answer, as well as more data from which to revise the JNT scheme. A knowledgeable forecaster should be able to improve upon all objective schemes, on the average. Streamline-isotach analysis of the SGW charts is a recommended practice for all forecasters.

It would seem that quite often the best clues as to what the forecast should be are to be found in the SGW chart. At other times other higher-level factors overshadow the low-level features in importance. Stagnant situations found in the heat of the summer may be handled better by the SGW technique.

The possibility that the SGW technique will consistently do better in central Kansas than farther east should be pursued. It is likely that the SGW technique has potential for areas farther west and north. A study of the maps shown here for eastern Kansas situations should prove useful for forecasters in other plains areas.

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