A Central Texas Synoptic Climatology and its Use as a Precipitation Forecast Tool

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ABSTRACT

A synoptic precipitation climatology was derived for central Texas centering on Austin. Characteristics of the 500 mb wind field were combined with a surface wind parameter to "type" the 1200 GMT circulation pattern for 2327 days of study. The relative frequency of precipitation was computed for three consecutive 12 h periods following 1200 GMT for each circulation type. Use of the derived precipitation frequencies as a first estimate of the probability of precipitation, given a predicted circulation pattern, was evaluated for its effectiveness as a forecast tool. Results indicated that for the first 12 h period, use of the synoptic climatology provided guidance inferior to that currently available to forecasters in the field. However, for the second and the third 12 h periods, the synoptic climatology provided guidance better than that available to meteorologists over teletype and the weather facsimile network.

1. Introduction

First instituted on a trial basis in San Francisco in 1956 (Root, 1962), a statement of expected probability of precipitation has since become a regular part of the public weather forecasts issued by the National Weather Service. A probability statement, although useful in many ways, introduces problems of interpretation to the user of a forecast as well as to the meteorologist who prepares the forecast. To the forecaster, once an interpretation of the synoptic situation has been established, there remains the task of deriving some number to use as a statement of precipitation probability. It is with the latter problem that this study is concerned. In particular, an attempt is made to develop an objective forecast tool to aid the local forecaster in formulating a probability statement.

Subjective forecasts are generally derived by following some assessment process that considers a variety of current and forecast parameters obtained through the use of numerical aids, forecast rules, experience, and theoretical concepts. Experience undoubtedly plays a major role in every forecaster's assessment process. One essentially develops an individual "synoptic climatology" based upon the meteorological situations with which he has dealt. This memory file of past synoptic situations and accompanying weather phenomena becomes a significant factor in a forecaster's formulation of a probability statement.

Unfortunately, individuals tend to be poor processors of information (Peterson and Beach, 1967). Laboratory experiments have shown that, when given samples of binary data and asked to make statistical inferences about parent populations, individuals are consistently conservative in their estimates. If this conservatism holds true in a meteorological context, then one's memory of past synoptic situations and his judgment of associated precipitation frequencies may be unreliable. The development of a local synoptic climatology could not only help the forecaster to approach objectively the problem of deriving a probability statement, but could also aid in eliminating a possible systematic error introduced by one's dependence upon his past experience. The foregoing premise was the basis for selecting a synoptic climatology as the mode for developing the proposed forecast tool.

The development of such a climatology was accomplished by "typing" the various recurring weather patterns that affect the central Texas area and computing the associated precipitation frequencies. The derived frequencies could then be used as a first estimate of the probability of precipitation, given an expected synoptic situation from numerical prognoses of circulation patterns routinely available over the weather facsimile network.

Bocchieri (1974) notes that "the generalized operator technique (several stations within a "homogeneous" region) is better than the single station technique" (abstract). With a larger dependent data sample, however, he states that "the single station system should prove to be superior" (p. 17). The dependent data sample used in this paper is large (13 years). Beyond that, however, the case for "generalized operators" should not exclude techniques of the kind described in

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this paper. The objective of any forecast technique is to improve local forecaster performance, using all available guidance.

2. Development of the synoptic climatology

a. *Approach*

It was intended that the scheme used in this study make use of data routinely utilized by field forecasters in making their local forecasts. In addition, the parameters used were expected to stratify differing weather situations into a spectrum of precipitation frequency categories. A simple and objective classification procedure was sought to facilitate the use of the resultant forecast aid in the field.

The scheme finally settled upon makes use of 500 mb wind flow characteristics in combination with surface wind direction in the central Texas area centering on Austin. The technique could be applied to any other location by preparing a new set of data. Both 500 mb and surface maps are routinely used by forecasters in their assessment process and are available in current data and forecast form over the National Weather Service (NWS) facsimile circuit. Wind direction and flow curvature at the 500 mb level, along with wind direction at the surface, define each type; thus, objectivity in the classification procedure is achieved in a simple manner.

b. *The scheme*

Four basic categories of 500 mb wind direction were utilized as determining parameters in the scheme: northeast (ne), southeast (se), southwest (sw), and northwest (nw). Quadrants represented 360–080°, 090–170°, 180–260°, and 270–350° true for the directions northeast through northwest respectively. The same categories were used to describe surface parameters. A combination of these four upper level and surface wind categories yields 16 possible circulation types. The notation used throughout this paper places the 500 mb wind direction first, followed by the surface wind parameter. For example, *sw-se* represents a condition in which the upper level wind is blowing from the southwest quadrant, while at the surface the wind is from the southeast quadrant.

In addition to the above categories, two sub-types were used to account for streamflow curvature at the 500 mb level. Thus, when curvature was evident, a cyclonic prefix, *cy*, or an anticyclonic prefix, *a*, was added to the basic type notation. Cyclonic curvature would indicate a potential for upward vertical motion, while anticyclonic curvature might be indicative of subsiding air. It was felt that this consideration might provide an additional means of separating low precipitation frequency situations from the higher frequency cases. These additions tripled the number of possible circulation types.

Two additional categories were included to describe cases in which no organized surface wind flow pattern was evident. These categories occurred when light winds (5 kt or less) were predominant over the central Texas area. Notation for these two categories were *r* and *col*. The *r* classification represented cases in which winds were light due to an overlying ridge of high pressure. *Col*, a misnomer, was used to describe all other cases of weak pressure gradient or unorganized, light flow. With the addition of these two surface categories, the possible number of circulation types rose to 72.

c. *Data*

Synoptic maps used in determining wind flow at both the 500 mb level and the surface were taken from two sources: 1) the *Daily Series Synoptic Weather Maps* for the period 1 November 1958 through 30 April 1967; and 2) the *Daily Weather Maps, Weekly Series*, from 15 April 1968 through 31 December 1971. Map time for both series was 1200 GMT or 0600 CST. Missing data included April 1960 from the Daily Series and 22 December through 28 December 1971 from the Weekly Series.

A preliminary study indicated that 500 mb wind speeds were often light during the warmer months of the year, making a representative wind direction over central Texas difficult to ascertain. Thus, the study was restricted to a six month "winter" period (November through April) for the 13 years, making 2327 days of data available for use in the synoptic typing scheme.

Precipitation data were taken from *Local Climatological Data* sheets for the NWS airport station at Austin, Texas. These data were in the form of hourly precipitation amounts and were available for each of the 2327 days.

d. *Procedure*

A streamline was drawn roughly over Austin on each day's surface and 500 mb maps. At the upper level the appropriate classification representative of wind direction and flow characteristic was determined. Similarly, one of the six categories of surface wind was selected. The two were then combined to denote the 1200 GMT local "circulation type." This simple procedure was used to determine a circulation type for each day of the study period.

Objectivity in type determination was one of the features sought in the development of this local synoptic climatology. The procedure described above is largely objective. There were, however, minor subjective judgments involved: 1) curved latitude lines on the polar stereographic projection used on the synoptic maps made it difficult in cases of near-zonal flow to determine whether streamline curvature was significant. Generally, when a question arose, the straight flow category was chosen, but subjectivity was involved; 2) in some instances light winds were evident over the local area although a significant pressure gradient was present on the surface map. In such cases it was felt that the pressure gradient was more indicative of the synoptic situation than were either of the light wind categories; therefore, a wind direction indicated by the pressure gradient was chosen as the surface contribution to the type determination; 3) cases in which streamlines at the surface were curved and fell between two quadrants. In such cases the final choice was made by choosing the quadrant best represented by the air stream's trajectory. These judgments were not often required; thus, the typing procedure may be considered basically objective.

Precipitation data were extracted from the *Local Climatological Data* sheets in 12 h increments. This was done in order to establish compatibility with the forecasting procedure followed by NWS. A typical forecast contains three periods of 12 h duration.[2] Thus, a precipitation total for each of the three consecutive 12 h periods following map time (1200 GMT) was computed for each day of the study and was recorded along with the day's circulation type. The number of precipitation occurrences for each type was then divided by the number of cases to obtain the relative frequency of precipitation associated with each circulation type for each of the three 12 h periods following map time.

TABLE 1. The derived synoptic climatology.

Circulation type	Number of cases	Number of precipitation cases and frequency of occurrence					
		1st period		2nd period		3rd period	
		No.	%	No.	%	No.	%
Straight flow							
sw-ne	167	85	51	64	38	56	34
sw-se	320	95	30	105	33	83	26
sw-sw	40	1	3	3	8	4	10
sw-nw	105	23	22	9	9	9	9
sw-r	156	24	15	24	15	44	28
sw-col	73	14	19	17	23	11	15
nw-ne	47	2	4	4	9	5	11
nw-se	42	1	2	1	2	5	12
nw-sw	38	0	0	1	3	0	0
nw-nw	64	0	0	2	3	4	6
nw-r	285	1	0	8	3	25	9
nw-col	35	1	3	2	6	3	9
Curved flow							
Cyclonic							
cy-sw-ne	34	16	47	10	29	4	12
cy-sw-se	52	21	40	13	25	12	23
cy-sw-sw	22	1	5	0	0	0	0
cy-sw-nw	71	17	24	2	3	1	1
cy-sw-r	56	7	13	4	7	5	9
cy-sw-col	29	2	7	0	0	0	0
cy-nw-e*	36	8	22	2	6	3	8
cy-nw-w*	95	0	0	0	0	1	1
cy-nw-r	90	0	0	0	0	0	0
cy-nw-col	28	2	7	0	0	1	4
Anticyclonic							
a-sw-ne	25	8	32	10	40	9	36
a-sw-se	88	17	19	22	25	22	25
a-sw-lt.*	89	13	15	16	18	28	31
a-nw-e*	50	3	6	7	14	7	14
a-nw-r	96	1	1	10	10	21	22
a-w-w*	31	0	0	1	3	1	3
other a	35	0	0	0	0	1	3
	2299	367	16	340	15	366	16
Undefined	28						
Total cases	2327						

* Combined categories to bring number of cases to 20 or larger. See text.

The precipitation frequencies computed for the types with a small number of occurrences may not be reliable, while the more frequently occurring categories can be expected to have more reliable precipitation frequencies. A determination of reliability versus sample size is a problem very difficult to resolve (Panofsky and Brier, 1958). In practice, the minimum sample size is determined by the accuracy desired in computation (Langley, 1971). For the purpose of this investigation, an accuracy in computation to the nearest 5% is sufficient. Thus, 20 is the minimum sample size required. Note should be taken that the establishment of this criterion does not insure a certain statistical significance, or reliability, in the derived precipitation frequencies. Rather, a minimum limit to computational accuracy is fixed. It will be assumed that sample sizes greater than 20 will provide adequate reliability for the derived frequencies.

In order to meet the established criterion, circulation types that occurred less than 20 times were combined with another type or types of similar characteristics to form new, more general types. For example, a type reasonably expected to have a low precipitation frequency (such as one with surface winds from the southwest) was combined with one or more other types with the same low precipitation frequency characteristics.[3]

3. The derived synoptic climatology

In its final form, the derived synoptic climatology (Table 1) included 2299 days on which the 1200 GMT circulation pattern was typed. Of these, precipitation occurred on 367 occasions during the first period for a frequency of 16%. Similarly, the second and third periods were accompanied by precipitation 15% and

[2] A forecast for "today" represents the period from 6 a.m. to 6 p.m. L.S.T. Similarly, "tonight" and "tomorrow" indicate the periods 6 p.m. to 6 a.m. and 6 a.m. to 6 p.m. of the following day, respectively.

[3] Combinations included the incorporation of *a-sw-sw*, *a-sw-nw*, *a-nw-sw*, and *a-nw-nw* into a new *a-w-w* category, and *a-sw-r* and *a-sw-col* into a new *a-sw-lt.* category. In addition, *cy-nw-ne* and *cy-nw-se* were combined to form *cy-nw-e*, and *cy-nw-sw* and *cy-nw-nw* were combined to form *cy-nw-w*. There were several cases of cyclonic and anticyclonic upper level winds with northeasterly or southeasterly components. The cyclonic cases were placed in an undefined status. The anticyclonic cases were added to an *other a* category; i.e., each anticyclonic type is unlikely to produce precipitation.

16% of the time, respectively. These values can be considered the basic climatological frequency of precipitation occurrence for Austin and are used as such later in the paper. These computations are in agreement with those derived by Jorgensen (1967) over a 15-year period of study.

Some interesting points become apparent upon inspection of Table 1. The most frequent precipitation-producing circulation type is *sw-ne*. This is representative of an overrunning situation in central Texas and is expected to have a high incidence of precipitation occurrence. On the other hand, *cy-nw-r* appears to be the "driest" type. There were no cases of precipitation in any period following the 90 occurrences of this type.

As expected, most of the 500 mb southwesterly flow types have the highest frequency of precipitation occurrence while the northwesterly types are basically dry. Note, too, that the southwesterly upper level flow types far outnumber the northwesterly types even though the study was conducted for the cooler months of the year. At the surface, however, those flows indicative of the presence or advection of cold air exceed the warm air flow types.

There are also points of interest concerning surface winds noted in the synoptic climatology: 1) Those types with southwesterly flow are marked with near-zero precipitation frequencies during the first and second periods, with 10% or less in the third period; this reflects the dry characteristics of the flow trajectory. 2) The northwesterly surface flow types, although also indicative of the influx of dry air, show precipitation frequencies near 20% during the first period when accompanied by southwesterly flow at the 500 mb level. Under such circumstances, a cold front oftentimes had just passed the Austin area in advance of the upper level trough; thus, the occurrence of frontal precipitation is reflected in the first period frequencies. 3) Circulation types with easterly component surface winds have higher precipitation frequencies than do the other wind flow types of the same upper level classification, indicating an available moisture source with that flow, or reflecting the presence of a lifting mechanism (i.e., overrunning).

There are weaknesses in the typing scheme used to derive the synoptic climatology. Although stratification of types into a range of precipitation frequencies was achieved, it was not to the extent hoped for. Frequencies ranged from 0% for a number of types to a maximum of 51% for the first period *sw-ne* case. This constraint is probably due to the neglect of parameters important to the precipitation process (e.g., available moisture, frontal position). Although reflected somewhat by 500 mb and surface wind characteristics, certainly enough variability exists in the neglected parameters to limit the degree of stratification possible in the typing scheme.

A strength of the scheme is that it does label almost every weather pattern that occurs in nature on the synoptic scale in the central Texas area. Of the 2327 cases classified, only 28 remained undefined. These few undefined cases represent slightly more than one percent of the cases analyzed, pointing favorably to the utility of the scheme.

4. Use of the synoptic climatology as a forecast tool

a. Interpretation of probability

Use of the derived frequencies as a statement of the probability of precipitation requires that an interpretation of probability be established. Although forecasters ascribe various meanings to the probability statement (Murphy and Winkler, 1971), a direct use of the synoptic climatology developed here is restricted to a single meaning as dictated by the derivation of the precipitation frequencies. The derived frequencies were computed from point rainfall measurement, i.e., the raingage at Austin's municipal airport. The frequencies were also computed on the basis of a 12 h period. Thus, proper use requires that the resultant probability statement refer to a point (Austin) for a 12 h time period.

The results are generally applicable to a larger area as long as there are no orographic or other features that could affect precipitation patterns within the area. The synoptic climatology presented herein is assumed to be valid for Austin and its nearby communities with the possible exceptions of the hilly areas to the west and northwest of the city. Precipitation data from those localities would be necessary to compute applicable frequencies.

b. Methods

It is suggested that the synoptic climatology developed in this study be used as a forecast tool in either of two ways. The first method involves the application of the derived values in the same manner in which they were computed. Upon receipt of both 500 mb and surface maps, a type determination is made. The frequencies for the first, second and third periods for that type are then used as a first estimate of the precipitation probability for each of the three consecutive 12 h periods following map time. This procedure will be referred to as the SC-method (synoptic climatology) henceforth.

The second method makes use of numerical prognoses received over the facsimile network. First period frequencies are used as the 12 h precipitation probability following the verification time of the prognosis. The preferred numerical product for use with this method is the National Meteorological Center's (NMC) six-level, baroclinic, primitive equation, 500 mb prognosis.[4] Issued twice daily, the product is a four-panel chart

[4] NMC's primitive equation model is preferred simply because it currently provides the best predictions of future circulation patterns. Should better models become available, they would become preferable for use with this scheme.

showing 500 mb contours and vorticity patterns for an initial time (0000 or 1200 GMT) and three subsequent verifying times at 12 h intervals. The 500 mb contribution to type determination can be taken from this chart and combined with an appropriate forecast surface wind classification to obtain a predicted weather type. Objective surface wind forecasts are routinely available to field forecasters (Carter, 1973). Alternatively, a locally produced surface wind forecast may be used.

Once predicted types are established, the frequency indicated by the initial-time circulation type is used as the first 12 h probability, the first-period frequency that corresponds to the 12 h predicted type is used for the second 12 h period, and the first-period frequency for the 24 h predicted type is used for the third 12 h period. This procedure will be referred to as the FSC-method (forecast synoptic climatology) in subsequent sections.

Two discrepancies arise upon application of the two forecast methods described above. First, receipt of both 500 mb and surface synoptic maps over the facsimile network is not completed until about $2\frac{1}{2}$ h after map time. Thus, a first-period forecast can be made at best for a $9\frac{1}{2}$ h period. The derived precipitation frequencies, however, were based upon a 12 h period; therefore, their use for the shorter period is not completely valid. The derived frequencies are to be used only as a first estimate of the probability of precipitation; hence no serious errors should result with their use for the shorter period. This is especially true if the forecaster is aware of the discrepancy and makes any necessary adjustments.

Second, since 1200 GMT was the base from which precipitation frequencies were derived, will the synoptic climatology be applicable to 0000 GMT initial data? If the synoptic weather pattern has some diurnal dependence, then any diurnal variation in precipitation occurrence should be manifest in a difference in climatological frequencies during the "nighttime" and "daytime" periods. The climatological frequency of precipitation was found to have a diurnal variation of only 1% (Table 1). This is further supported by Jorgenson (1967), who reported that the only significant diurnal variation in precipitation occurrence for this region occurs during the summer months. There is no reason to believe that there is any significant diurnal variation in synoptic scale weather patterns. Therefore, it is concluded that application of the synoptic climatology to 0000 GMT as an initial time is valid.

The FSC-method is preferred over the SC-application of the synoptic climatology. Its advantages are obvious. Circulation type changes can be accounted for with FSC, whereas changes are reflected with use of SC only to the extent that some circulation types probably follow a sequential development. With the forecast synoptic climatology, a definite type is indicated at the beginning of each 12 h period. This, in turn, makes use of first period derived frequencies for precipitation probabilities. First-period frequencies exhibit a larger range of values than do the second- and third-period frequencies; therefore, a greater stratification is achieved.

5. Independent data study

a. *Objectives*

An independent data study was conducted to establish some estimate of the usefulness of the derived synoptic climatology as a forecast tool. Obviously, such an estimate is difficult. Since the scheme is to be used as an aid, an evaluation of its direct application cannot determine its utility precisely. And, an evaluation of its influence upon a forecaster's judgment is highly complex and beyond the scope of this paper. However, by comparing verification scores produced by the use of this scheme with those produced by other forecast methods, its relative validity is examined.

Comparisons were made of the scores produced by the SC- and FSC-methods with the scores produced by climatology, by NMC's field guidance, and by the local forecasts issued by Austin's NWS office. Data available precluded a direct comparison of all the methods for the same period of study; therefore, three separate comparative evaluations were made.

b. *Comparison of SC and no-skill probabilities*

The first comparative evaluation involved "blind" application of the SC-method over a 14-month period. Type determinations were made as in the development of the synoptic climatology. Data used consisted of the *Weekly Series* 500 mb and surface charts and Austin's *Local Climatological Data* sheets. The "winter" months (January, February, March, April, November, and December) of 1972 and 1973 along with January and February of 1974 were utilized. Of the 420 days in the period, 417 types were identified, while 3 remained undefined. Probability forecasts were made using the derived SC frequencies for each of the three 12 h periods following map time. It is standard practice to express probability forecasts in 10% increments ranging from zero to 100%. Thus, the derived frequencies were rounded to the nearest 10%.

The probability score (PS) used to evaluate the forecast methods was one-half the value of the Brier score (Brier, 1950). The probability score is expressed by

$$PS=(1/n)\sum_{i=1}^{n}(F_i-O_i)^2,$$

where n is the number of forecasts, F is the forecast probability, and O, the observed occurrence of precipitation, is given the value *one* if precipitation occurs and *zero* if it does not. A score of zero represents perfect forecasting; one, the worst possible. Murphy and Epstein (1967) suggest that the probability score is a satisfactory means of comparing forecast methods.

A monthly probability score was computed for each of the three forecast periods. In addition, a score was computed using the climatological frequency. The climatological frequencies were also rounded to the nearest 10%, resulting in the use of 20% for each of the forecast periods.

Climatology is generally considered a no-skill method of forecasting. Thus, the climatological frequency is used as a base upon which a determination of the skill exhibited by other forecast methods can be examined. Clearly, any forecast method that cannot produce probability scores that surpass those of climatology is of little value. A comparison of scores is expressed mathematically as

$$S=(C-PS)/C,$$

where C is the climatic probability score and PS the probability score of the method being evaluated. Generally, S is known as the "skill score," or, when expressed as a percentage, as the "improvement over climatology." Comparisons of the SC-method and the "no-skill" method (CLI) were made for the 417 cases. Results are shown in Table 2.

Clearly, the use of SC probabilities produces better results than does the use of climatological probabilities. This is especially true for the first and second forecast periods, whereas the SC effectiveness decreases considerably for the third period. Although Table 2 lists scores for the entire period of study, monthly scores were also computed and ranged from 0.025 to 0.175 for SC and from 0.040 to 0.200 for climatology. Included in the period were months with no precipitation as well as months with as many as 10 precipitation occurrences in a single month. This variability of precipitation occurrence is good in that the forecast scheme is tested over a wide range of conditions. Also, the significance of the results is enhanced since bias due to an extended wet or dry period is excluded.

c. *Comparison of SC and NMC guidance*

Probabilities obtained by the SC-method were also compared with those probabilities issued by NMC as guidance to forecasters in the field. This guidance, known as the *P*rimitive *E*quation *a*nd *T*rajectory *M*odel *O*utput *S*tatistics (PEATMOS), is produced numerically by the use of multiple linear regression equations and is transmitted regularly over both teletype and facsimile circuits. PEATMOS data were extracted from monthly summaries on file at Austin's NWS office.

Table 2. Comparison of SC-method and climatology.

Period	*PS* SC	*PS* CLI	Improvement over climatology	
1st	0.102	0.132	22.8%	417 cases
2nd	0.101	0.130	22.4%	
3rd	0.121	0.132	8.3%	

Table 3. Comparison of SC and NMC guidance.

Period	*PS* SC	*PS* PEATMOS	*PS* CLI	Improvement over climatology SC	Improvement over climatology PEATMOS
1st	0.102	0.088	0.130	21.6%	32.3%
2nd	0.102	0.096	0.133	23.3%	27.8%
3rd	0.117	0.126	0.131	10.7%	3.8%

276 cases

Available data included that for the months of March, April, November, and December of 1972 and all the months of 1973 for which the synoptic climatology is valid. During these months, guidance was issued on 276 days. Guidance that was available at the time the SC-method could have been employed was used to determine probability scores.[5] As in the previous evaluation, scores were computed for the SC-method but only for those days for which PEATMOS guidance was available. Table 3 shows the results of that comparison.

PEATMOS guidance yields better scores than does SC in the first period. Second period scores are relatively close, but in the third period the synoptic climatology produces better results. Monthly scores during the period of this evaluation ranged from 0.018 to 0.245 for PEATMOS and from 0.019 to 0.162 for SC. Even with the smaller number of cases, precipitation variability was large during the period, indicating significant results because of the wide range of conditions.

d. *Comparison of SC, FSC, and local forecasts*

Although only limited data were available, a third comparison was made of the SC-method, the FSC-method, and the local subjective forecasts issued by the NWS office in Austin. Data for this comparison were limited to a 4-month period, November 1973 through February 1974. Ninety-four cases were available for score computations. SC scores were computed as in the previous evaluations. Type determination for the FSC-method was made from NMC's baroclinic prognosis received over facsimile, and scores were computed from the resultant probabilities. Local forecast probabilities were obtained from the files of the Austin NWS office. The local forecast used in this comparison was that issued daily at 1120 CST. Surface wind for use in the FSC-method was also taken from the local forecast. Although the primitive equation, baroclinic prognostic chart is not available to the local forecaster at the time of issuance of the 1120 CST forecast, a barotropic chart as well as another baroclinic-model product (the limited fine-mesh model) is available for guidance. Thus, any

[5] Note that the PEATMOS forecast periods begin 12 h after initial data time, while the SC forecast period begins at initial data time. The purpose of the comparison, however, was to test the utility of the scheme against *available* guidance.

TABLE 4. Comparison of SC, FSC, and local forecasts.

Period	PS				Improvement over climatology		
	SC	FSC	LOC	CLI	SC	FSC	LOC
1st	0.083	0.083	0.068	0.110	24.6%	24.6%	38.2%
2nd	0.105	0.088	0.097	0.136	22.8%	35.3%	28.7%
3rd	0.094	0.083	0.088	0.110	14.6%	24.6%	20.0%

94 cases

advantage to the FSC-method due to availability of data is considered minimal. A tabulation of the scores computed in the evaluation is shown in Table 4.

The small number of cases involved in this comparison (less than 100) makes it difficult to draw any firm conclusions. In addition, the daytime period was marked by a low incidence of precipitation, whereas the second or nighttime period was relatively wet. In spite of this, some information can be gleaned from the results. Note that, as in the case of the two previous comparisons, SC scores deteriorate in going from the first to third period. However, the FSC score remains unchanged. This is indicative of the fact that the FSC uses first-period frequencies and allows for a type change during the forecast period. Note, too, that although the local forecast produces better results than does FSC in the first period, FSC shows improvement over the local forecast in the second and third periods. The magnitude of the second period improvement over climatology demonstrated by FSC seems large, but the fact that it is greater than that of either the SC method or the local forecast is probably significant. It is also significant that the local forecast produced much better results during the first period in comparison with climatology than either SC or FSC.

6. Conclusion

The synoptic climatology described in this paper satisfies the initial objective of developing an objective forecast tool to aid the local forecaster in formulating a probability statement of precipitation at Austin, Texas. Its degree of utility as a forecast aid is indicated by the results of the independent data study. As has been suggested, no indisputable conclusions can be drawn from these results. General indications are, however, that both SC (synoptic climatology) and FSC (forecast synoptic climatology) application of the derived synoptic climatology have merit. The SC-method shows considerable improvement over climatology in the first and second forecast periods with only slight improvement in the third period. In addition, the SC-method provides guidance roughly equivalent to the PEATMOS guidance in the second period, provides superior guidance in the third period, but is not competitive in the first period.

The FSC-method is equivalent to the SC-method in the first period. Second period FSC scores indicate an improvement over SC and superiority to the local subjective forecast. Third period scores show the FSC-method to be better than all the other forecast methods with which it was compared. These results suggest that use of the derived synoptic climatology may not be significantly helpful during the first period. However, for second and third period use, its guidance may be better than that available to the forecaster in the field at the present time. As a guide in making a first estimate of the probability of precipitation, the scheme devised is considered quite satisfactory.

The use of a synoptic climatology as a forecast aid has been shown to be relatively successful. The tool developed within this study considered 500 mb and surface wind characteristics only. In spite of the limited range of precipitation frequencies, good probability and skill scores were obtained. Further refinements to the scheme described here could result in the development of a synoptic climatology capable of providing excellent precipitation forecast guidance. The inclusion of a moisture parameter alone could conceivably produce such results.

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