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On the "Best" Temperature and Precipitation Normals: The Illinois Situation

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ABSTRACT

Historical (1901–79) temperature and precipitation data for four Illinois stations were used to determine the frequency with which summer and winter averages for periods of various length (i.e., different climatic normals) are closest to the value for the next year, and hence its best predictor. The normal achieving the highest frequency in this regard is considered the best for characterizing the recent climate for a given point in time and assessing the abnormality of the following year.

Normals for 5, 10, 15, 20 and 25 years were investigated, along with the 30-year ones generally used. Five-year normals most frequently provided the closest estimate of the next year's value for both parameters in both seasons. Ten-year normals also have a high probability of being the best predictors, whereas 20-year normals have a particularly low probability of such success. The standard 30-year normals also perform poorly in this regard. These results contrast strongly with earlier suggestions that 15–25 year normals are "optimum" for prediction because they possess the minimum extrapolation variance when normals are employed as predictors. This difference between the two sets of results indicated that 5-year normals tend to possess larger prediction errors when they are not the best predictors, than do other normals on the greater number of occasions they are not the best predictors. The present findings were used by the Illinois Commerce Commission in evaluating weather normalization rate adjustments proposed by utility companies in 1979–80.

An investigation also is made into the nature of the climatic variation occurring when each normal is the best predictor. Five-year normals tend to attain this position for precipitation when the difference from the preceding year and the departures from longer-term averages are all moderate-to-small. When 5-year normals are the best temperature predictors, in contrast, the departures from this normal (and hence prediction errors) are very large. The frequency with which various normals were the best predictors shows no marked temporal variation during the study period.

1. Introduction

a. Background

Presently there is no firm physical basis for predicting climate. However, since economic planning and evaluation often require assumptions about future climate, alternative methods of climatic prognosis need to be investigated and the most skillful ones implemented. In this regard, there is a growing consensus that ". . . predictions of climatic variability . . . will, for the foreseeable future, be probabilistic statements based largely on the statistics of past records" (Mason 1979). For instance, research which will allow this potentially beneficial use of existing climatic information is emerging as a high priority of the U.S. National Climate Plan (National Academy of Sciences, 1980, pp. 2–3). The present study uses an interesting situation to serve as a contribution to this developing research area.

Seasonal averages of Illinois historical temperature and precipitation data are computed for moving periods of various numbers of years. These are considered to form sets of different climatic "normals" (Huschke, 1970, p. 394) that are identified by their base period length, and whose values were recomputed at yearly intervals. The basic objective is to determine the frequency with which each normal is closest to the value for the next year, and hence its best predictor. The normal achieving the highest frequency in this regard is the one most likely to minimize the departure characteristic of the year immediately following those from which it is calculated. Such a climatic normal therefore may be the most appropriate for a given point in time and the year ahead.

b. History of normals

At their introduction more than a century ago, climatic normals ". . . were considered to approximate the 'true' (stable) climate which . . . (although) . . . subject to . . . random variations from year to year . . . (was regarded as) . . . essentially invariant over the centuries" (Court, 1967–68, Part I, pp. 3–4). The longest available record was accordingly believed to provide the best normal. This principle was followed in the construction of U.S. temperature and precipitation normals until the mid-

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1950's (U.S. Weather Bureau, 1958). The first nationwide sets, issued for first-order stations in 1907, were for either 1873–1905 (temperature) or the entire record (precipitation). Their adjustment in the 1920's was largely limited to extending the base periods forward to that time. A more pronounced change occurred in the mid-1950's, with the adoption of 30-year (1921–50) temperature and precipitation normals by first-order stations (U.S. Weather Bureau, 1958) and interim 1931–55 normals by cooperative substations (U.S. Weather Bureau, 1955). The latter had previously used 1900–44 normals. Commencing in the early 1960's, the U.S. Weather Bureau adopted 30-year temperature and precipitation normals for all stations. They are computed from the data for the preceding three decades (i.e., initially 1931–60, superceded by 1941–70 in the early 1970's, and soon to be replaced by 1951–80).

This change to a moving 30-year base period conformed to a WMO recommendation aimed at reducing the influence of varying observation practices and natural climatic fluctuations on computed normals (Court, 1967–68, Part I, p. 6). It prompted Court (1967–68, Part I, pp. 5, 8) to suggest that a primary application of climatic normals now lay in the prediction of future values, and that predictive accuracy and constitutes an appropriate empirical evaluation of normals. Many users of normals treat them as the best prediction of the future, and in turn adopt them as references for the evaluation of recent weather and their pre-event decisions.

c. *Motivation for present study*

The present study is, in essence, an investigation into the predictive capability of various climatic normals. It arose from an inquiry by the Illinois Commerce Commission (ICC) about the use of normals in adjudicating rate increase applications by power companies. Decisions on rate increases are considerably affected by the degree of climatic abnormality experienced during immediately preceding years. There has been a growing tendency for Illinois utility companies to seek rate increases each year. This has increasingly necessitated an annual judgement by the ICC about the normal that best characterizes the recent climate, and hence is most appropriate for assessing the abnormality of the previous year and the preparedness of utility companies for unusual weather. This user situation reflects but one of many needs to express the climatic value most "likely" to characterize a given year.

The present research was initiated when it became apparent that the standard meteorological practice of using 30-year temperature and precipitation normals might not be the best in the foregoing contexts. Normals for 5, 10, 15, 20 and 25 years are therefore considered here, in addition to 30-year ones. This number and range of normals were believed adequate to address the broad issues identified above. Using a somewhat different criterion to that adopted in the present work, earlier studies intimated that 15–25 year normals may be better predictors for the following year than 30-year normals (e.g., Lenhard and Baum, 1954; Beaumont, 1957; Enger, 1959; Craddock and Grimmer, 1960; Court, 1967–68). Our study also examines the nature of the climatic variability occurring when each of the above normals provides the best estimate of the following season's mean value, something not previously attempted.

2. Data and methods

This study utilized data from four Illinois cooperative substations (Aurora, Urbana, Mount Vernon, Anna) aligned along a 500 km north-south axis. Their locations are depicted in Changnon (1979) and coordinates appear in Table 1. They were chosen because of their situation in each of the state's four major latitude zones, their similar elevation (~200 m), and their high-quality records (Changnon, 1979).

Basic data processing involved several steps. First, individual winter (December–February) and summer (June–August) seasonal mean temperatures and seasonal precipitation totals were computed from summer 1901 through winter 1978–79. This utilized daily maximum and minimum temperatures and daily precipitation totals. Second, the above four sets of data for individual seasons were then each converted into six time series of "running means". For an original time series of n entries X_i, running mean time series containing $(n - k + 1)$ k-year averages $\bar{X}_{k,i}$ are given by

$$\bar{X}_{k,i} = \frac{1}{k} \sum_{j=0}^{k-1} X_{i+j}. \tag{1}$$

The values of k used here were 5, 10, 15, 20, 25 and 30 years. Finally, the individual values in each running mean time series (e.g., the 1943–52 average) were then subtracted from the actual value for the year immediately following the end of their averaging period (1953 in the above example). The resulting time series of $(n - k)$ temperature or precipitation differences $\Delta X_{k,i}$, given by

$$\Delta X_{k,i} = \left[X_{i+k} - \frac{1}{k} \sum_{j=0}^{k-1} X_{i+j} \right], \tag{2}$$

provided a range of measures of the abnormality of individual seasons. They are, in effect, time series of anomalies with respect to different reference periods. Furthermore, they also constitute expressions of the accuracy attained by the various normals in predicting the next season's mean value, as is shown below. The comparative analysis of these time series for the period summer 1931 through winter 1978–79

TABLE 1. Number of times during summer 1931 through winter 1978–79 that different climatic normals were closest to the actual value for the immediately following individual season. Values include a count for more than one normal if a tie occurred.

Climatic normal (years)	Aurora (41°45'N, 88°21'W)		Urbana (40°06'N, 88°14'W)		Mt. Vernon (38°21'N, 88°52'W)		Anna (37°28'N, 89°14'W)		All-station total	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
					Mean temperature					
5	13*	19*	15*	16*	16*	16*	15*	16*	59*	67*
10	9	6	12	7	9	12	12	12	42	37
15	9	15	9	8	9	5	8	10	35	38
20	9	8	6	12	8	10	4	9	27	39
25	9	7	6	7	10	7	6	9	31	30
30	12	8	7	11	8	7	7	5	34	31
					Total precipitation					
5	10	20*	14*	11*	10	17*	11*	14*	45*	62*
10	11*	7	6	9	12*	6	8	9	37	31
15	6	4	6	10	5	3	9	8	26	25
20	8	4	9	4	7	6	4	6	28	20
25	7	7	9	7	5	4	8	3	29	21
30	7	7	6	7	9	13	8	11	30	38

* Largest value in each column.

forms the basis of this paper. Summer 1931 was the earliest season during 1901–78/79 for which averages were available for all six of the specified preceding periods.

The previous investigations of the predictive accuracy of climatic normals referred to above were based on the evaluation of the "extrapolation variance" S_k^2 (Court, 1967–68, Part I, pp. 9–10), which resulted, where

$$S_k^2 = \frac{1}{(n-k)} \sum_{i=1}^{n-k} \left[X_{i+k} - \frac{1}{k} \sum_{j=0}^{k-1} X_{i+j} \right]^2 . \qquad (3)$$

Symbols are as defined earlier. It is readily apparent that S_k is simply the average of the squares of the prediction errors specified by Eq. (2), with S_k accordingly being the "standard error of extrapolation." The "mean prediction error" (Q_k) is obtained by taking the absolute value of the difference in Eq. (3), rather than its square. Previous research concentrated on identifying the value of k for which S_k^2 (or S_k^2) or Q_k was smallest. This "implicitly . . . was assumed to indicate the optimum length of record (i.e., normal) for prediction" (Court, 1967–68, Part I, p. 10). For comparative purposes, this study also will evaluate Eq. (3) for X_{i+k} values starting with summer 1931.

3. Predictive success of different climatic normals

Table 1 documents the frequency with which different climatic normals provide the closest (or closest equal) estimate of the next year's seasonal mean temperature and total precipitation in Illinois. In the notation of Eq. (2), the normal(s) providing the closest such estimate for a particular year is/are denoted by the value of k giving the minimum $|\Delta_{k,i}|$. This information is believed to provide the best *user* indication of the predictive success of various normals in cases where annual evaluations are required, more so than the relative values of the time-averaged S_k^2, S_k and Q_k indices employed in earlier studies (see Table 2 and later discussion). The outstanding feature of Table 1 is that 5-year normals are more likely to be closest to the actual value of the next year's seasonal mean temperature than normals computed for longer preceding periods. This characterizes all four stations for both winter and summer. Furthermore, for half of the cases studied, the second-shortest normal (10 years) has the second highest probability of being closest to the next year's seasonal mean temperature (Table 1). In contrast, 20-year normals are the least likely to provide the best estimate of the average temperature of the following winter. A further conspicuous temperature result is the poor performance of the standard 30-year normals in the foregoing context, particularly for the southern stations of Mount Vernon and Anna.

The precipitation results in Table 1 are generally quite similar to those for temperature. In six of the eight cases considered, 5-year normals most frequently provided the closest estimate of the next year's total seasonal precipitation. Ten-year normals attained this position in the two remaining instances, but only by a small margin over 5-year normals. Precipitation results in Table 1 also suggest that 20-

TABLE 2. Values of the extrapolation variance, S_k^2, resulting from the use of different climatic normals as predictors of the next season's actual value. Predictions were made for the period summer *1931 through winter 1978–79.*

Climatic normal (years)	Aurora		Urbana		Mt. Vernon		Anna		All-station average	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
					Mean temperature (°C^2)					
5	4.52	0.85	4.23	1.01	4.15	0.94*	3.58	1.12	4.12	0.98
10	4.18	0.91	4.01	1.03	4.02*	1.04	3.36*	1.20	3.89	1.05
15	4.02	0.81*	4.10	1.01	4.09	1.08	3.45	1.05	3.92	0.99
20	3.85*	0.82	3.94*	0.96*	4.03	1.14	3.36*	0.95	3.80*	0.97*
25	4.08	0.82	4.08	0.99	4.14	1.15	3.41	0.94*	3.93	0.98
30	4.24	0.88	4.10	1.08	4.27	1.18	3.56	1.00	4.04	1.04
					Total precipitation (mm^2)					
5	4187	7684	6606	8000	10568	9419	14839	11619	9050	9181
10	3581	7142	5690	7355	8884	9084	13510	9903	7916	8371
15	3503	6832	5465	7116	8664	8400	13458	9994	7773	8098
20	3361	6716	5594	6942	8316	8252	12974	9284	7561	7799
25	3239*	6548*	5000*	6884*	8065*	8168	12684*	9432	7247*	7758
30	3335	6574	5135	6884*	8161	7968*	12729	9168*	7340	7649*

* Smallest values in each column.

year normals have a particularly low probability of being the best predictor of the seasonal total for the next year. The standard 30-year normals again performed poorly in this regard, though this was not as pronounced for southern Illinois as in the temperature case.

Table 2 gives the extrapolation variance S_k^2, as specified by Eq. (3), resulting from the use of each climatic normal as the predictor of the next year's seasonal mean temperature and total precipitation. As already noted, the S_k^2 statistic constituted the basis of previous investigations of the predictive accuracy of climatic normals. It therefore is evaluated here for comparative purposes. The general pattern evident in Table 2, particularly for temperature, is largely consistent with that obtained in the earlier studies. S_k^2 tends to decrease as the normal lengthens from 5 to 20 years (temperature) or 25 years (precipitation), and then increases as the normal extends to 30 years. Since the normal with the smallest S_k^2 was previously assumed to be optimum for prediction, the foregoing pattern gave rise to the earlier suggestion that 15–25 year normals may be better predictors than the standard 30-year normals. Furthermore, it evidently precluded serious consideration of the predictive utility of very short normals. Table 2 also contains pronounced spatial variations and winter–summer contrasts which illustrate some interesting dimensions of the Illinois climate. However, they are outside the scope of the present paper.

As the above discussion suggests, the results in Tables 1 and 2 possess striking contrasts. In particular, the normal most likely to provide the best prediction for an individual season (5 years) tends to be characterized by either the highest or very high S_k^2 values for the overall study period. Furthermore, 10-year normals, which Table 1 shows to also have a high probability of predictive success in many cases, likewise possess high values of S_k^2 (Table 2). The foregoing features are particularly true of precipitation. The criterion being used in the present study to determine the predictive "success" of a climatic normal (frequency of best prediction; Table 1) thus gives a very different verdict on 5- and 10-year normals to the extrapolation variance index (Table 2) employed in earlier work to identify the so-called "optimum" predictive normal. This also is characteristic of the longer normals studied. Those for 15–25 years, previously considered optimum for prediction by virtue of small S_k^2 values such as in Table 2, have a relatively low probability of being closest to the seasonal value for the next year (Table 1). A good example is the 20-year normal/winter temperature case already referred to in the consideration of Table 1. The foregoing discussion indicates that 5-year normals tend to possess larger prediction errors [see explanation of Eq. (3)] when they are not the best predictors than do other normals, particularly 20- and 25-years, when they are not the best predictors.

In view of the possibly surprising nature of the foregoing results, it appeared desirable to relate those in Table 1 to the climatic variability experienced during the study period, and also to investigate whether they contain any significant temporal variations. The results are reported in succeeding sections, and yield some further insight into the aforementioned differences between Tables 1 and 2.

TABLE 3. Average anomaly magnitude relative to each normal for the years this normal was the best predictor of the next season's value. Predictions were made for the period summer 1931 through winter 1978–79.

Climatic normal (years)	Aurora		Urbana		Mt. Vernon		Anna		All-station average	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
	Mean temperature (°C)									
5	1.55	0.52	1.33	0.75	1.18	0.65	1.16	0.83	1.31	0.69
10	0.47*	0.46	0.52*	0.31	1.05	0.41	0.77	0.27	0.70	0.36*
15	1.77	0.55	1.30	0.35	0.96	0.29	1.28	0.29	1.33	0.37
20	0.60	0.17*	0.69	0.63	0.38*	0.17*	0.52*	0.74	0.55*	0.43
25	1.27	0.29	0.66	0.22*	0.74	0.40	1.34	0.55	1.00	0.37
30	1.10	0.59	0.88	0.41	1.08	0.69	1.67	0.14*	1.18	0.46
	Total precipitation (mm)									
5	26	32	43	44	60	49	75	43*	51	42
10	15*	49	43	31*	41*	29*	85	45	46	39*
15	61	31*	28	61	44	33	14*	60	37*	46
20	31	85	27*	70	41*	60	100	97	50	78
25	49	38	54	48	78	81	55	130	58	74
30	44	62	54	65	71	67	64	47	58	60

* Smallest values in each column.

4. Climatic abnormality when each normal was best predictor (or predictive accuracy of different climatic normals)

One objective in relating the results of Table 1 to the climatic variability experienced during the study period was to determine the abnormality which tended to prevail when each normal constituted the best predictor. Since the exact quantification of climatic abnormality is dependent on the reference period used in its computation, as was noted in the discussion of Eq. (2), two sets of results were obtained here. First, for the years in which each normal was the best predictor, we calculated the mean anomaly magnitude relative to that normal (Table 3). In the notation of Eq. (2), these results were obtained by averaging, as a function of k, the set of the *smallest* value (or values if a tie occurred) of $|\Delta X_{k,i}|$ for each study year. A more general indication of anomaly size, as independent of reference period as possible, was also obtained for the years each normal constituted the best predictor. This consisted of the mean anomaly magnitude relative to all normals (not shown) or, in the terminology of Section 2, the average $|\Delta X_{k,i}|$ for *all* values of k for the years each normal was the best predictor. Although these averages were of course larger than those in Table 3, both sets of results exhibited remarkably similar general patterns. In view of this, and also because the results in Table 3 have the advantage of indicating the accuracy each normal tended to attain when it was the best predictor [see discussion of Eq. (2)], only Table 3 is presented here. It actually contains values of a variant of the mean prediction error (Q_k) defined in relation to Eq. (3)—in this case they are computed from only those years in which a normal was the best predictor.

A prominent feature of Table 3 is that large temperature anomalies tend to prevail when 5-year normals constitute the best predictors for either season, and also when 15-year normals attain the best predictor position for winter. Much smaller anomalies generally characterize seasons whose mean temperatures are estimated closest by 10- and 20-year normals (winter) and 10–25 year normals (summer). Thirty-year normals tend to be the best predictors when the temperature departures are of intermediate size. Table 3 thus shows that when the best temperature prediction is provided by the normal which does this most frequently (five years, Table 1), the difference between the actual value and that predicted by the normal (i.e., the prediction error) tends to be very large. In contrast, smaller mean errors (Table 3) generally characterize the cases when the best temperature predictions are by the normals which provide this information less frequently. This is particularly true of 20-year normals. Further insight is therefore provided into why the "optimum" predictive normals for temperature suggested by Table 2 and earlier work differ from the most "successful" one identified by Table 1. The foregoing situation also suggests that the present utilization of the "statistics of past records" (Mason, 1979; see Introduction) for seasonal temperature forecasting, the simple form of which was dictated by the particular applied problem at hand, has inherent limitations. These are more pronounced for winter, when the departures are largest, than for summer when temperatures are less anomalous (Table 3).

TABLE 4. Average difference from preceding year for occasions each normal was the best predictor of the next season's value. Predictions were made for the period summer 1931 through winter 1978–79.

Climatic normal (years)	Aurora		Urbana		Mt. Vernon		Anna		All-station average	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
	Mean temperature (°C)									
5	1.94	0.76	1.76	0.92	1.41	0.80	1.64	1.13	1.69	0.90
10	1.66	0.95	1.55	0.73*	2.12	1.11	1.71	1.16	1.76	0.99
15	1.81	0.91	1.80	0.93	1.46	0.64	1.69	0.62*	1.69	0.78*
20	1.02*	0.72*	1.14	0.74	0.95*	0.95	1.43*	0.88	1.14*	0.82
25	1.64	0.82	1.05*	0.96	1.68	0.60*	1.63	1.01	1.50	0.85
30	1.88	1.36	1.46	1.06	1.83	1.21	2.01	0.64	1.80	1.07
	Total precipitation (mm)									
5	50	64*	59*	96	64*	111	85*	73*	65*	86
10	33*	90	77	90	98	49*	149	82	89	78*
15	89	74	72	99	127	96	91	84	95	88
20	54	233	100	106	71	99	187	173	103	153
25	52	88	69	61*	101	195	113	232	84	144
30	85	144	83	145	91	133	86	111	86	133

* Smallest values in each column.

Interestingly, the precipitation results in Table 3 are in considerable contrast to those for temperature. Moderate-to-small precipitation anomalies, and hence prediction errors, tend to occur when the best prediction is provided by the normals which do this most frequently (5 and 10 years, Table 1). This is especially true of summer. In contrast, large anomalies (prediction errors) generally characterize the less frequent seasons whose total precipitation is estimated closest by 20–30 year normals (Table 1). Temperature and precipitation results in Table 3 for 20-year normals are thus in particular contrast. These circumstances suggest that the prediction of Illinois seasonal precipitation using climatic normals may not have the inherent limitations apparent for temperature.

5. Difference from preceding year when each normal was best predictor

The attempt to set the results in Table 1 in the context of the climatic variability experienced during the study period also included relating them to interannual fluctuations. Results are summarized in Table 4, which gives the average difference from the preceding year for the occasions each normal was the best predictor. The general pattern of the precipitation results in Table 4 is very similar to that just described for the anomalies in Table 3. Small changes from the previous year tend to occur when the best prediction is provided by the normals which do this most frequently (5 and 10 years, Table 1). On the other hand, large differences from the preceding year generally prevail on the fewer occasions when seasonal precipitation is estimated closest by 20–30 year normals (Table 1).

Unlike the foregoing precipitation results, those for temperature in Table 4 have a slightly different general pattern to the anomalies in Table 3. The largest changes from the previous year tend to occur when the best temperature predictions are provided by 30-year normals, whereas Table 3 showed such relatively infrequent occasions (Table 1) to be characterized by only intermediate-sized anomalies. In addition, more normals attain the position of best temperature predictor when large interannual changes occur (Table 4) than when large anomalies occur (Table 3). Tables 3 and 4, however, do show that 20-year normals (winter) and 15–25 year normals (summer) are the best temperature predictors when the year-to-year changes and the anomalies are both small.

6. Temporal variation of predictive success of different normals

An investigation also was conducted into whether there was any marked temporal variation during the study period of the frequency with which individual normals provided the best predictor of the following season's value. Since no pronounced trends emerged, the results are not documented here. The occasions when 5-year normals constituted the best predictors were well-distributed across the decades studied, and not excessively concentrated in the 1970's. The frequency with which 30-year normals were the best predictors was highest in the 1950's (precipitation) and 1940's and 1970's (temperature).

7. Applications

Many users of climatic normals do so with the expectation that the published values, now having a

30-year base, provide the best prediction of the next year's conditions. Furthermore, many of these users subsequently evaluate their decision, and the ensuing economic outcomes determined by the actual weather of a given year, against the normal that was built into the decision. A typical comment might be, "last year we assumed the available 30-year normal was the best predictor of this winter. But because the winter was very extreme in comparison with the 30-year normal, we were hurt severely. . . ." Such uses of climatic normals as the best estimator of the next year's seasonal value, and in turn as the evaluator of the annual outcomes in some socioeconomic or environmental context, motivated this investigation of the predictive capability of 5-, 10-, 15-, 20-, 25- and 30-year seasonal temperature and precipitation normals for Illinois.

The present findings are now part of the evidence used by the ICC in evaluating weather normalization rate adjustments proposed by Illinois utility companies.[1] For instance, in late 1979 they were "specifically . . . used to question the value of the National Weather Service's "30-year normal" as a predictive tool for near-future weather when new rates would go into effect," in relation to adjustments proposed by three Northern Illinois utility companies.[1] These proposed adjustments, which ". . . effected revenues by a total of $153 million . . . ," were denied by the ICC.[1] This particular case was prompted by the severe 1978–79 winter, which had the lowest mean temperature this century at Aurora, the second lowest at Urbana and Anna, and the third lowest at Mount Vernon. Table 5 shows that 5-year normals provided the best prediction of this severe event; they were 1–2°C closer to the actual winter mean than the 30-year normal. The abnormality of the 1978–79 winter is thus minimized by reference to the 5-year normal. Since the beginning of 1980, our results have also ". . . been referred to (by the ICC) in rate cases involving utilities in central and southern Illinois."[1]

8. Summary and conclusions

This paper has analyzed Illinois historical temperature and precipitation data to determine the frequency with which different climatic normals are closest to the seasonal value for the next year, and hence its best predictor. The normal achieving the highest frequency in this regard also was considered the best for characterizing the recent climate for a given point in time and assessing the abnormality of the next year. Our investigation arose from an inquiry by the Illinois Commerce Commission (ICC) about the use of climatic normals in adjudicating annual rate increase applications by utility companies. It was initiated when it became apparent that the standard meteorological practice of using 30-year normals may not be appropriate in the foregoing context.

TABLE 5. Temperature departure (°C) of 1978–79 winter from various normals.

Climatic normal (years)	Aurora	Urbana	Mt. Vernon	Anna
5	−3.78	−3.33	−3.28	−3.17
10	−4.56	−3.94	−4.11	−3.44
15	−4.39	−4.06	−4.39	−3.44
20	−4.22	−3.94	−4.44	−3.50
25	−4.56	−4.33	−4.72	−3.83
30	−4.78	−4.61	−5.06	−4.22
Difference (5 years vs 30 years)	1.00	1.28	1.78	1.05

Normals for 5, 10, 15, 20 and 25 years were considered here, in addition to 30-year ones. Five-year normals were found to most frequently provide the closest estimate of the next year's summer and winter mean temperature and total precipitation. Future research into the predictive utility of climatic normals should therefore ascertain whether 3-, 4-, 6- or 7-year normals perform better in this regard than 5-year ones. This is distinctly possible, and its investigation will require the computation of normals at one-year intervals. Ten-year normals were also found to have a high probability of being the best predictors of the parameters in question, whereas 20-year normals have a particularly low probability of such success. The standard 30-year normals were likewise found to perform poorly in this regard. These results contrast strongly with earlier suggestions that 15–25 year normals are "optimum" for prediction because they possess the minimum extrapolation variance when normals are employed as predictors. This difference between the two sets of results indicated that 5-year normals tend to possess larger prediction errors when they are not the best predictors, than do other normals on the greater number of occasions they are not the best predictors.

An investigation was made into the nature of the climatic variation occurring when each normal is the best predictor. Five-year normals were found to attain this position for precipitation when the difference from the preceding year and the departures from longer-term averages all tended to be moderate-to-small. When 5-year normals are the best temperature predictors, in contrast, the departures from this normal (*and hence prediction errors*) are larger than the prediction errors on the less frequent occasions the longer normals are the best predictors. This suggests that the present utilization of the "statistics of past records" (Mason, 1979; see Introduction) for seasonal temperature forecasting has inherent limi-

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[1] T. L. Griffin, personal communication, 1980.

tations. Since such statistical procedures are now viewed to constitute the only viable immediate basis for the development of climate forecasting schemes, there is an obvious need for long-term physically based research into the predictability of climate. Finally, the frequency with which various normals were the best predictors was found to show no marked temporal variation during the study period.

The general similarity of the results obtained along the entire 500 km north–south Illinois transect suggests that they should be reasonably transferable to other parts of the central United States.

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