A POSSIBLE SINGULARITY IN THE JANUARY MINIMUM TEMPERATURE AT PHOENIX, ARIZONA

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ABSTRACT

Daily minimum temperature averages for the Phoenix City Office based on 61 years of record show a definite rise in the period January 9–17, with relatively lower values in the 9-day periods preceding and following. This rise is investigated statistically and shown to be greater than chance would allow if random effects alone are responsible for the phenomenon. The possibility of a relationship between the Phoenix singularity and those demonstrated by Wahl [1] for stations in the eastern United States is discussed briefly.

1. INTRODUCTION

Evidence presented by Wahl [1] indicates the strong possibility that a period of warming has occurred between the 20th and 23d of January at stations along the northeastern coast of the United States over a period of about 75 years ending in 1952. Using unsmoothed daily mean temperature records for Washington, D. C., New York City, Boston, Mass., and Blue Hill Observatory, Mass., Wahl showed that a slight rise in temperature occurred during the period January 20–23 at all four stations. Columbia, Mo., farther to the west, also showed a rise but some days earlier (January 17–21). An inspection of the records for Phoenix, Ariz. indicates that a similar phenomenon has occurred here, but somewhat earlier in the month than at Columbia, Mo.

The phenomenon first became evident in the Phoenix records in a table designed to show the climatological expectancy that "severe freezing conditions" will persist for a given number of hours during each week of the winter season in the Salt River Valley—a question of considerable interest to Valley citrus growers. Table 1 shows the total number of hourly observations which reported "severe freezing conditions" and which were followed by at least N more consecutive hourly observations with "severe freezing conditions" during each week in December, January, and February. The following criteria for temperature T establish the definition of "severe freezing conditions" that was used:

$$\text{1948–1955 (Airport record):} \quad T \lesssim 28° \text{ F.}$$
$$\text{1916–1947 (City Office record):} \quad T \lesssim 30° \text{ F.}$$

A temperature of 28° or less was used as a criterion at the Airport because minimum temperatures at other Valley stations average as much as 10° lower than airport temperatures, giving severe freezing conditions in important agricultural areas when temperatures are only a few degrees below freezing at the Airport. In combining the two records, 30° was used at the City Office because 3 years of overlapping record showed that very low temperatures average about 2° higher there than at the Airport during the winter months. The numerical value of the temperatures used at each location in combining the records is not extremely critical in this case because we are essentially interested in the seasonal distribution of runs of various lengths of low temperatures, and one would expect the distribution to look about the same for temperatures within a range of several degrees of any given temperature.

Table 1 shows considerably lower frequencies during the week January 12–18 than in either the preceding or following week, and indicates that very low temperatures are less frequent during that week. Accordingly, an inspection was made of daily minimum temperature averages at the City Office for the entire period of record (1895–1956) and a decided rise in mean minimum temperature was indicated during the period January 9–17 (fig. 1).

TABLE 1.—*Total number of hourly observations which had "severe freezing conditions" and which were followed by at least N more consecutive hourly observations with "severe freezing conditions." Data under column N=0 are the total number of hourly observations during the 40-year period with "severe freezing conditions." Definition of "severe freezing conditions": 1948–55 (Airport): $T \lesssim 28°$ F., 1916–47 (City Office): $T \lesssim 30°$ F.*

Week	N											
	0	1	2	3	4	5	6	7	8	9	10	11
Dec. 1–7	8	3	2	1	---	---	---	---	---	---	---	---
Dec. 8–14	62	42	28	19	12	7	3	1	---	---	---	---
Dec. 15–21	52	25	11	5	2	1	---	---	---	---	---	---
Dec. 22–28	62	31	20	12	5	2	1	---	---	---	---	---
Dec. 29–Jan. 4	86	58	39	27	20	15	10	5	2	---	---	---
Jan. 5–11	74	54	42	31	25	20	17	14	11	8	5	2
Jan. 12–18	25	11	5	3	1	---	---	---	---	---	---	---
Jan. 19–25	122	88	65	48	34	23	17	13	9	5	3	1
Jan. 26–Feb. 1	36	21	12	6	3	1	---	---	---	---	---	---
Feb. 2–8	24	12	7	4	2	1	---	---	---	---	---	---
Feb. 9–15	35	21	13	6	2	---	---	---	---	---	---	---
Feb. 16–22	5	2	1	---	---	---	---	---	---	---	---	---
Feb. 23–Mar. 1	0	---	---	---	---	---	---	---	---	---	---	---

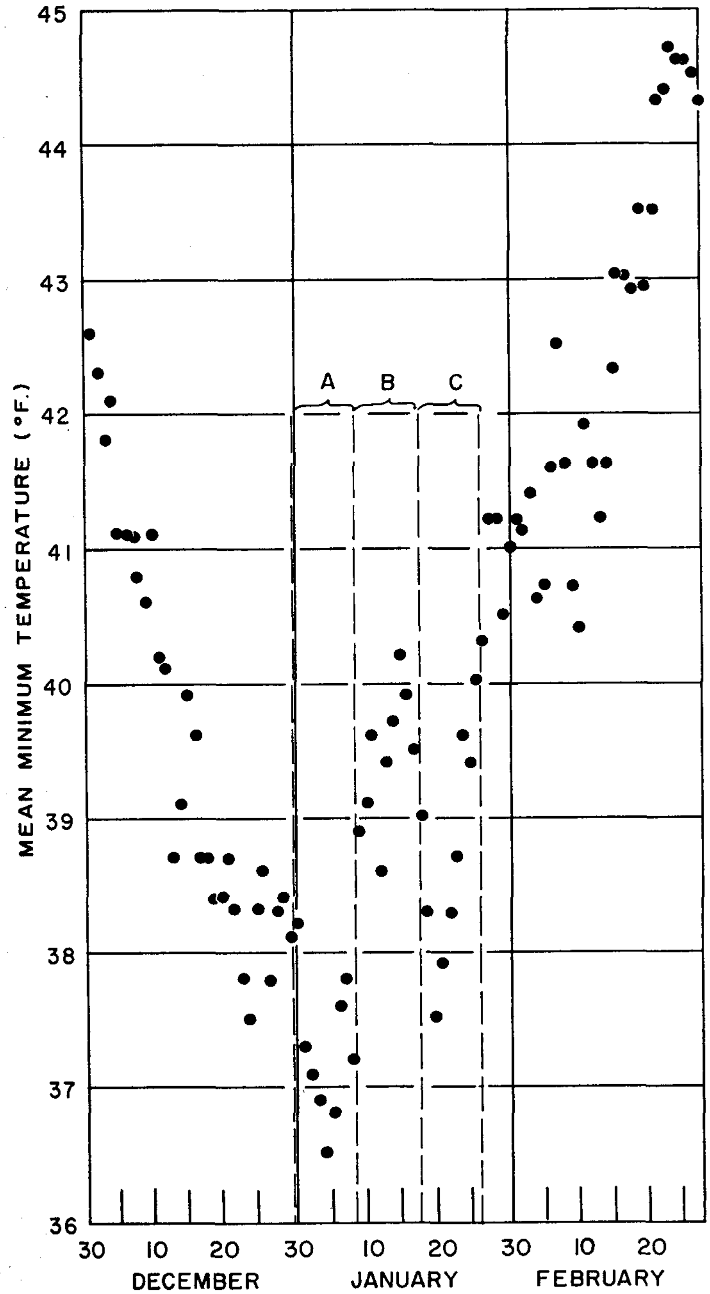

FIGURE 1.—Mean daily minimum temperature. City Office, Phoenix, Arizona (December 1895–February 1956).

2. STATISTICAL INVESTIGATION

Before we can investigate this possible singularity statistically, we must set up a working definition of a "singularity." For the purposes of this discussion we define a singularity as a period of higher or lower values of an element, that is superimposed on the seasonal trend curve of the element, and that exhibits a strong tendency to recur at about the same time each year. If we accept the official U. S. Weather Bureau normal daily minimum temperatures [2] as a "best estimate" of the smoothed seasonal trend of this element during the period of interest, we can investigate statistically the question of whether or not we have a singularity in terms of our definition.

The following procedure was used. The 9-day period in question (January 9–17) was bracketed by two other 9-day periods (December 31–January 8, and January 18–26) and average values in each year during each of these three 9-day periods were computed using daily minimum temperature data for the City Office for December 1895 through February 1956. These average values were used instead of individual daily values to minimize the effects of serial correlation in the data. One approach might be to compute the mean minimum temperatures during the three periods for the entire length of record, then compare them statistically by using Student's "t" test on the final averages. Throughout the period of record of the City Office, however, the instruments have been exposed at a number of different locations and elevations, making the entire series of observations nonhomogeneous. The instrument exposures during the three periods in *each individual year* are comparable, however, so the method of "pairing" was used. Hypotheses are harder to prove (or disprove) by this method than by averaging the whole series, because the number of degrees of freedom in the estimate of the variance is reduced by about one-half; however, the nature of the data in this problem forces us to pair the observations.

Let us call the period December 31–January 8 "period A," the period January 9–17 "period B," and the period January 18–26 "period C;" and call the *observed* average minimum temperature in the i^{th} year in periods A, B, and C, respectively, T_{ai}, T_{bi}, and T_{ci}. As a first step, averages during each year for periods A and B were paired and the algebraic difference $T_{bi}-T_{ai}$ computed, and a list of differences was made for all years. Similarly for periods B and C, differences $T_{bi}-T_{ci}$ were computed and listed for all years.

Table 2 shows the official U. S. Weather Bureau normal daily minimum temperatures at the Phoenix City Office throughout the three 9-day periods in question. Let us call $\overline{T}_a$, $\overline{T}_b$, and $\overline{T}_c$ the average of the *normal* mean minimum temperatures in periods A, B, and C, respectively. Then,

$$\overline{T}_a=38.00,\ \overline{T}_b=37.67,\ \overline{T}_c=38.33$$

and,

$$\overline{T}_b-\overline{T}_a=-0.33,\ \overline{T}_b-\overline{T}_c=-0.66$$

On the basis of these differences in the average of *normal* values, we would expect the *observed* average minimum temperatures T_{ai}, T_{bi}, and T_{ci}, in the i^{th} year in periods A, B, and C, respectively, to satisfy the following hypotheses:

$$\lim_{n\to\infty}\left[\frac{\sum_{i=1}^{n}(T_{bi}-T_{ai})}{n}\right]\to -0.33$$

$$\lim_{n\to\infty}\left[\frac{\sum_{i=1}^{n}(T_{bi}-T_{ci})}{n}\right]\to -0.66$$

These hypotheses can be tested using Student's "t" test by testing the equivalent hypotheses:

$$\frac{\sum_{i=1}^{n} T_{bi}}{n} - \frac{\sum_{i=1}^{n} T_{ai}}{n} + 0.33 = 0$$

and

$$\frac{\sum_{i=1}^{n} T_{bi}}{n} - \frac{\sum_{i=1}^{n} T_{ci}}{n} + 0.66 = 0$$

for $n=61$, allowing $n-1$ degrees of freedom. In this case, if both hypotheses are rejected, we will have good reason to believe that the average minimum temperature is higher or lower in period B than one would expect it to be due to chance variations from the smoothed seasonal trend. Choosing a 5 percent level of significance, we reject the hypotheses if $t < -2.00$ or if $t > +2.00$.

The value of t for the set of differences between B and A values is +3.45, while that for the differences betwen B and C values is +2.30, indicating a strong probability that the minimum temperature values in period B are higher than one would expect them to be due to chance variations alone.

The following points should be emphasized about the above statistical treatment:

(1) The significance test was applied after inspecting the data and this selection increases the probability of getting a high value of t.

(2) The number of degrees of freedom was determined on the assumption that the years are independent. This is not strictly true because of year-to-year persistence, which has the effect of making the number of degrees of freedom somewhat less.

(3) The test of significance used above applies only to random samples from a single, normally distributed population. Because of the nature of the meteorological problem, we cannot assume that weather phenomena behave in random fashion and that the next 61 years will belong to the same population as the past 61 years. Hence, the above test indicates only that the singularity has occurred during the past 61 years, and the question of whether or not it will occur in the future can only be answered by testing independent data; i. e., future records.

TABLE 2.—*Normal daily minimum temperature. City Office, Phoenix, Ariz.* [2]

Date	Normal minimum (° F.)	Date	Normal minimum (° F.)
Dec. 31	39	Jan. 14	38
Jan. 1	38	15	38
2	38	16	38
3	38	17	38
4	38	18	38
5	38	19	38
6	38	20	38
7	38	21	38
8	37	22	38
9	37	23	38
10	37	24	39
11	37	25	39
12	38	26	39
13	38		

3. CONCLUDING REMARKS

The possible singularity discussed above is much more evident in the minimum temperature curves than in the mean or maximum temperature curves for Phoenix. The maximum temperature curves show little evidence of it (mean temperatures are computed from the formula: mean temperature$=\left(\frac{\text{max. temp.}+\text{min. temp.}}{2}\right)$. This is probably due to the fact that solar heating during the middle of the day plays a major role in determining the maximum temperature at this station and tends to make day-to-day maximum temperature changes less responsive to the subtle changes in the general circulation which Wahl showed accompanied the singularities at east coast stations. The Phoenix singularity has occurred roughly 4 days earlier than the one at Columbia, Mo., and about 7 days earlier than the east coast singularity [1]. One must be careful in concluding that the eastward propagation of some large-scale feature of the atmosphere is involved, but the possibility seems interesting enough to warrant further study.

REFERENCES

1. E. W. Wahl, "The January Thaw in New England (An Example of a Weather Singularity)", *Bulletin of the American Meteorological Society*, vol. 33, No. 9, Nov. 1952, pp. 380–386.
2. U. S. Weather Bureau, *Daily Temperature, Degree Day, and Precipitation Normals, Phoenix, Arizona CO*, (Based on, or adjusted to, the 1921–1950 period), Washington, D. C.