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CONDITIONAL PROBABILITIES OF WINTER SEASON TEMPERATURE CATEGORIES FOR BOSTON, MASSACHUSETTS

Harold W. Bernard, Jr. (1)
263 Brown Bear Crossing
Nagog Woods, MA 01718

ABSTRACT

Using a lag correlation technique, conditional probabilities of winter season temperatures falling into each of five categories were developed for Boston MA. Input data to the lag correlations were the mean temperatures from two time periods: (1) the November immediately preceding the winter, and (2) the previous December through February (i.e., the prior winter.)

Results indicate some limited predictive skill that can be enhanced by using the probabilities in conjunction with the more dynamically-based temperature outlooks prepared by the National Weather Service (NWS) and other respected long-range forecasting groups or individuals.

Further, a "perfect prog" approach was used to develop a method to "guesstimate" Boston winter snowfall totals; a mean snowfall total and a standard deviation were calculated for each of the five temperature categories.

1. INTRODUCTION

The efficacy of using the mean temperatures of preceding winters and Novembers as "predictors" of the temperature regimes of immediately succeeding winter seasons was examined through development of lag correlations for Boston MA temperatures. The lag correlations were developed in the form of conditional probabilities. The technique used to develop the lag correlations, and the results and their implications, are discussed in the following sections.

2. PROCEDURE

The initial step in the development of the conditonal probabilities was to calculate a straight-line regression equation for a time series of November and winter season (December, January, February) mean temperatures for Boston MA (2). The time series extended from 1872 through 1977.

The regression line for each series (November and winter season) was then drawn on a graph as a horizontal line with a value of zero. Next, each November and winter season mean temperature was plotted -- on the appropriate graph -- as a departure from its regression value (i.e., the value the regression equation gave for that particular month or season.) Thus, the plotted distributions were normalized with respect to any long-term trends.

The normalized distributions were then divided into five equally-likely classes (i.e., classes with an equal number of values, so far as possible.) The classes so defined were labeled -- with respect to the regression equation zero-line -- as "much above normal", "above normal", "near normal", "below normal", and much below normal." The numerical range of each class was recorded.

The next step was to calculate actual 30-year means on a running 10-year basis (1881-1910, 1891-1920, etc.) for both November and winter season temperatures at Boston. The means thus calculated became the reference means for the ensuing ten years, or the "operational" period. For instance, the means calculated for the period 1941-1970 became the reference values for 1971-1980.

The numerical ranges developed for the five classes ("much above normal", "above normal", etc.) were then applied to each reference value to define the classes for the ensuing 10-year period. For example, once the bounds of the five temperature classes for the period 1941-1970 had been established, each November and winter season mean for 1971-1980 could be categorized -- based on the reference period -- as being "much above normal", "above normal", etc. Thus, using this method, the effect of trends was put back into the statistical predictors being developed. The thought here was that "contemporary" (and traditional) 30-year means could more realistically reflect trends than could long-term, straight-line regression equations.

Once the November and winter season means for each 10-year operational period were categorized, contingency tables for winter-to-winter and November-to-winter lags were developed. These are presented in the following section.

3. RESULTS

Table 1 presents the winter-to-winter (previous winter to succeeding winter) correlations, and Table 2 shows the November-to-winter (November to immediately following winter) correlations. The following abbreviations are used:

MA	much above normal
A	above normal
N	near normal
B	below normal
MB	much below normal

Raw totals for B and MB (Table 1) and for B (Table 2) do not equal 100% due to round-off error.

Examination of Table 1 reveals the following points of interest:

- There is a 72% probability an MA winter will be followed by an MA or A winter.
- An A winter is somewhat more likely to be followed by an MA or A winter (50%), than by a B or MB winter (39%)
- There is a 77% probability an N winter will be followed by an N winter, or a winter within one category of N (i.e., A or B).
- There is a 59% probability a B winter will be followed by a B or MB winter.
- There is a 58% probability an MB winter will be followed by an MA winter; only a 25% probability it will be followed by an MB winter.

A look at Table 2 shows the following significant correlations:

- There is a 77% probability that an MA November will be followed by an MA or A winter, with virtually no chance of an MB winter occurring.
- There is a 58% probability an A November will be followed by an MA or A winter.
- There is a slightly greater probability an N November will be followed by an MA or A winter (44%) than by a B or MB winter (34%).
- There is a 63% probability a B November will be followed by an N or B winter.
- There is a 72% probability an MB November will be followed by a B or MB winter.

The most significant points highlighted by the tables are these:

- MA and B winters tend to be consecutive, but MB winters tend to presage a reversal (to MA winters).
- MA and A Novembers tend to be followed by MA or A winters, and MB Novembers tend to be followed by B or MB winters.

4. DISCUSSION

The application of the contingency tables to the Boston 1982-83 winter season presented an interesting case. The winter-to-winter lags suggested the upcoming winter would be in the B category (56% probability), since the winter of 1981-82 had been below normal in the Boston area. (Note: the probabilities in the tables accompanying this text are slightly different from those referenced for predicting the winter of 1982-83, since the lag correlations for that winter have now been incorporated in the tables. Also note that by random chance each class has a 20% probability of occurring.) However, after a November averaging much warmer than normal, the winter-to-winter statistical prediction was directly challenged by the November-to-winter lags that indicated there was only about a 10% chance of a B winter occurring. Further, the November-to-winter lags seemed to lay to rest the "coldest winter of the century" outlook that had got much play in the media earlier in the autumn; the lag correlations showed a 0% probability of an MB winter coming up! (Operational forecasters never say "never", of course.)

The November-to-winter lags, in fact, supported the outlooks of the NWS and Dr. Jerome Namias. Both of those outlooks foresaw a milder-than-normal winter for the Boston area. Specifically, the November lags gave a 43% probability the up-coming winter would average in the range of 31.5° F to 33.5°F, and a 33% probability it would be milder than 33.5°F. In fact, the winter mean turned out to be 34.5°F.

Intuitively, it would seem there is a stronger argument for the November-to-winter lags to be dynamically or physically supported, than for the winter-to-winter lags to be so. The work of Dickson (3), for instance, indicates that month-to-month persistence of mean temperatures, significant at the 5% level, occurs during November-December, December-January, and January-February in the Boston area. Dickson hypothesizes that the persistence may be linked to such factors as snow cover over the northeastern U.S. and surface water temperatures of the western North Atlantic Ocean. (Namias (4) has pointed out that through the "teleconnection" mechanism, sea surface temperature anomalies in the Pacific Ocean may also play an important role in influencing wintertime temperature regimes over the eastern U.S.)

The particular succession of month-to-month temperature correlations necessary for November means to be useful predictors of following winters' temperature regimes appears to exist only in parts of southern New England (3). However, the technique described in this article could probably be effectively applied to other regions for other seasons. For example, Dickson's work (3) suggests that May mean temperatures in Nebraska might turn out to be reasonably good predictors of summertime (June, July, August) temperature regimes there. And February temperatures in Arizona might be valid predictors for mean temperatures of succeeding springs (March, April, May).

The winter-to-winter lags, especially when indicating that MA winters tend to be followed by warmer than normal winters and B winters by colder than normal winters, may be reflecting -- to some extent -- the 20-year cycling found in January mean temperatures for the eastern U.S. by Mock (5). Factors influencing the year-to-year correlations may be some of the same ones that act on the November-to-winter correlations (e.g., sea surface temperature anomalies, and hemispheric snow and ice cover.) The indluences are likely of a more complex nature however, and intertwined with other influences such as anthropogenic pollution (e.g., particulates and CO_2), and volcanic ejecta and their by-products.

5. "PREDICTING" SEASONAL SNOWFALL

As a follow-on effort to the development of the temperature contingency tables, a "perfect prog" approach to "guesstimating" winter (in this case, December, January, February, March) snowfall in Boston was examined. Specifically, mean seasonal snowfall for Boston for the period 1901-1982 was calculated for each observed winter season temperature class (as previously defined in this article; remember, the class limits are different for each decade.) The results are presented in Table 3. From a planning standpoint one of the more useful results displayed in the table related to the frequencies of seasonal snowfalls greater than or equal to 60 inches; the frequency of such a snowfall is only 19% for MA, A and N winters, and over 40% for MB winters. In general, as can be seen from the table, the colder the winter, the greater the mean snowfall. Thus, if the class of the mean wintertime temperature for Boston can be predicted correctly, a reasonably good guess regarding the amount of snow can be made. Note, however, that the standard deviation of the snowfall for several of the temperature classes approaches 17 inches.

6. SUMMARY

Using lag correlations based on Boston, Mass., November and winter mean temperatures, conditional probabilities of the following winter falling into one of five temperature categories were developed. These statistical "predictors" display limited skill that, when used in connection with dynamically-based seasonal temperature outlooks, may help to more definitively quantify such outlooks for the Boston area.

Additionally, a "perfect prog" approach, based on the five temperature classes for the winter season, was developed to assist in "guesstimating" Boston's winter season snowfall. Results indicated the major value of this approach is related to the MA and MB temperature categories and their respective frequencies of seasonal snowfalls greater than or equal to 60 inches.

For the reasons cited in the article, the lag correlation techniques developed in this study may not have universal application, but they probably can produce useful prediction tools for limited areas of the country for specific seasons.

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Table 1. Winter-to-winter lag correlations.

WINTER	SUCCEEDING WINTER MA	A	N	B	MB
MA	36%	36%	9%	5%	14%
A	28%	22%	11%	22%	17%
N	8%	23%	31%	23%	15%
B	12%	12%	18%	53%	6%
MB	58%	8%	8%	0%	25%

Table 2. November-to-winter lag correlations.

NOVEMBER	SUCCEEDING WINTER MA	A	N	B	MB
MA	36%	41%	14%	9%	0%
A	35%	23%	12%	12%	18%
N	39%	5%	22%	17%	17%
B	9%	18%	27%	36%	9%
MB	7%	14%	7%	36%	36%

Temperature Classes for Boston MA, 1981-1990

	November	Winter
MA	≥47.5°F	≥33.6°F
A	45.6-47.4	31.5-33.5
N	44.4-45.5	30.1-31.4
B	42.7-44.3	28.3-30.0
MB	≤42.6	≤28.2

Table 3. Winter temperature class vs. winter snowfall.

WINTER TEMP. CLASS	WINTER (DJFM) SNOWFALL MEAN	SD	MAX	MIN	FREQUENCY ≥60"	≤20"
MA	27.3"	8.8"	43.5"	4.6"	0%	23%
A	37.7"	16.2"	74.8"	9.7"	11%	17%
N	38.1"	16.6"	84.4"	17.4"	8%	8%
B	47.4"	11.4"	67.6"	22.3"	18%	0%
MB	54.8"	16.7"	88.1"	28.5"	42%	0%

FOOTNOTES AND REFERENCES

1. Harold Bernard is a systems analyst and meteorologist in private industry. He is also the author of two books on meteorology/climatology, and the 1983-84 president of the Eastern New England Chapter of the NWA. He has published previously in the National Weather Digest.

2. For November the regression equation was $T=.05Y+40.69$, and for the winter season $T=.03Y+28.66$, where T=the mean temperature in °F and Y=the number of the year (1872=1, 1873=2, ..., 1977=107.)

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