NOTES AND CORRESPONDENCE

A Persistence Climatology for Interior and Coastal Southern New England

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ABSTRACT

One method of evaluating forecast skill is to compare probability forecasts of temperature and precipitation to a "persistence climatology" (CLIMO) for a given location. In the absence of such data, forecasters at Central Connecticut State University have been using the CLIMO developed for Albany, New York by Bosart (1975) as the benchmark for skill in ongoing daily forecasting of minimum temperature and precipitation.

Over thirty years of local climatological data have been analyzed and a persistence climatology for both interior (Windsor Locks, Connecticut) and coastal (Bridgeport, Connecticut) regions has been developed and interpreted with respect to both synoptic and climatological situations. The probabilities of colder than normal minimum temperatures and measurable precipitation are quite similar at both locations. In addition, these probabilities are similar to those for Albany in spite of the geographic differences among the three locales.

1. Introduction

Skill levels of weather forecasters have often been measured in terms of comparison with some climatologically expected forecast (i.e., "climatology"). Forecaster skill is then measured by the degree to which the "climatology" forecast can be improved upon. This method of skill assessment has been used with success by both Sanders (1967; 1979) at the Massachusetts Institute of Technology, and Bosart (1975; 1983) at the State University of New York at Albany to determine the skill of students and faculty participating in daily forecasting competitions.

The "persistence climatology," or CLIMO, used at MIT and SUNY-Albany, consists of four whole numbers, between 0 and 10, for both temperature and precipitation, respectively. These numbers represent the probabilities (in tens of percent) that each of the next 24-h periods,

a. will have a minimum temperature below the normal minimum for the date, as determined by the most recent 30-year National Weather Service normals, and,

b. will receive measurable precipitation (i.e., 0.25 mm or more).

Each day, a CLIMO forecast is made for the next 96 h, based on the temperature and precipitation observations made during the most recent 24-h period. Usually the 1800 to 1800 UTC period is chosen, however, this can be modified to suit the forecasters.

Participants are required to make their own 96-h forecasts for temperature and precipitation each day. Their objective is to improve upon CLIMO by as large a percentage as possible. Bosart (1983) has indicated that during the period from 1977 to 1982, average reductions of 57% were achieved for minimum temperature for the first 24-h period. These skill scores dropped rapidly for days two through four. At 96 h, improvements over CLIMO averaged 14.6%. For precipitation, the average reduction was 53.4% at 24 h, dropping to only 5.3% at 96 h. Sanders (1979) reports very similar results for forecasters at MIT for the period 1966–1978.

Students at Central Connecticut State University (CCSU) have been participating in a forecasting competition similar to the SUNYA/MIT version since 1982. However, in the absence of an accurate persistence climatology for the central Connecticut area, skill scores have been based on improvement over the CLIMO developed for Albany, New York. These scores, then, could not be expected to accurately reflect the forecasters' skill, but could be used to compare relative skill among the participants.

The principal objective of the research was to analyze local climatological data over the past 30 years and develop such a persistence climatology for both central and shoreline Connecticut. Comparisons of the results were expected to point out the climatological differences between these locations. In fact, the data did point out some differences, as well as some surprising similarities.

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2. Data analysis method

The two geographical locations chosen for analysis were Windsor Locks, Connecticut (Station BDL—41°56′N. Latitude, 72°41′W. Longitude), a station some 80 km inland from the Long Island Sound, and Bridgeport, Connecticut (Station BDR—41°10′N. Latitude, 71°08′W. Longitude), a station directly on the shoreline. Local climatological data were obtained from the National Climatic Data Center for the period January 1955 to December 1986. Normal minimum temperatures for each location are the 1951–1980 normals reported in the Climatography of the United States. Fig. 1 shows the normal monthly minimum temperature for each location. Fig. 2 shows the normal monthly precipitation.

Each day on which the observed minimum temperature was below the normal minimum was considered COLD (i.e., observed probability = 10). Each day on which the observed minimum was equal to or higher than the normal minimum was considered WARM (i.e., observed probability = 0). Likewise, days on which measurable precipitation was recorded were considered WET, and days with a trace or less of precipitation were considered DRY.

The day on which a forecast is made is referred to as DAY 0. A simple computer counting routine was used to determine how many of the four days (referred to as DAY 1, DAY 2, DAY 3, and DAY 4) subsequent to each DAY 0 were COLD in each of the twelve months. Data were entered in binary form (i.e., if a day was COLD, it was entered as a 1, if it was WARM, it was entered as a 0). In this manner, the frequency of COLD weather for each of the four days following a COLD day was determined for each month by dividing the number of COLD DAYS 1, 2, 3, and 4, respectively, by the number of COLD DAYS 0. Likewise, the number of COLD days for the subsequent four 24-h periods following a WARM day were

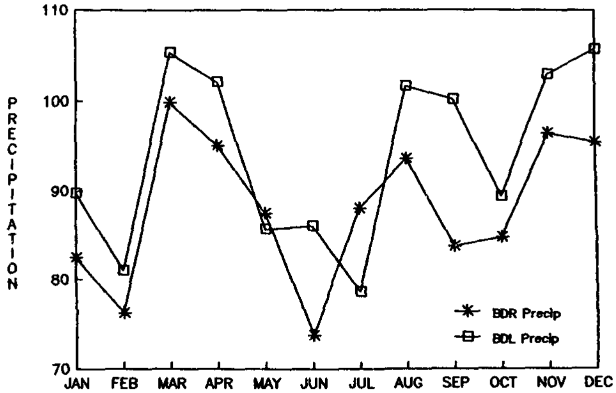

FIG.2. Normal monthly precipitation for Windsor Locks, Connecticut (BDL) and Bridgeport, Connecticut (BDR) for the period 1951–1980. Precipitation in mm.

counted, and the frequency of COLD days following a WARM day was determined.

The same routine was used to count WET days and determine the frequency of their occurrence following WET and DRY days. The data were broken down by month to see if there were any significant seasonal variations in these frequencies.

The resulting frequencies of occurrence of COLD days are shown in Figs. 3 and 4. The frequencies of occurrence of WET days are shown in Figs. 5 and 6. Note that these are all, in effect, conditional probabilities (i.e., if DAY 0 is cold, these are probabilities that DAYS 1–4 will be cold, and so on).

3. Results

a. Temperature

Figs. 3a and 3b show that both interior and coastal Connecticut exhibit about a 70% probability that a

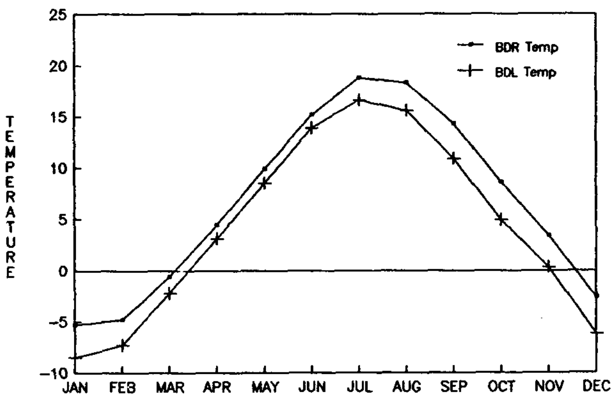

FIG. 1. Normal monthly minimum temperature for Windsor Locks, Connecticut (BDL) and Bridgeport, Connecticut (BDR) for the period 1951–1980. Temperatures in deg. C.

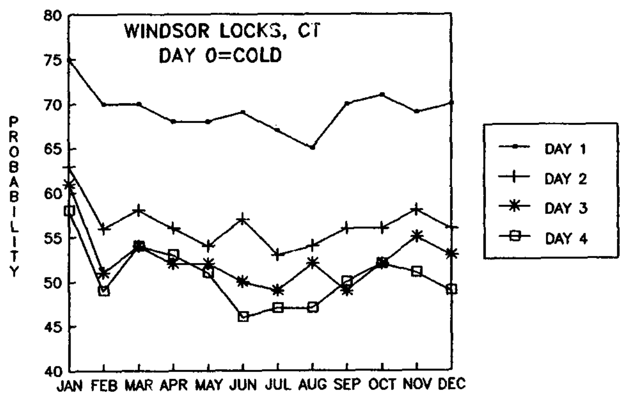

FIG. 3a. Probability of subsequent COLD days following a COLD day at Windsor Locks, Connecticut (BDL) for the period 1955–1986. Probability in percent.

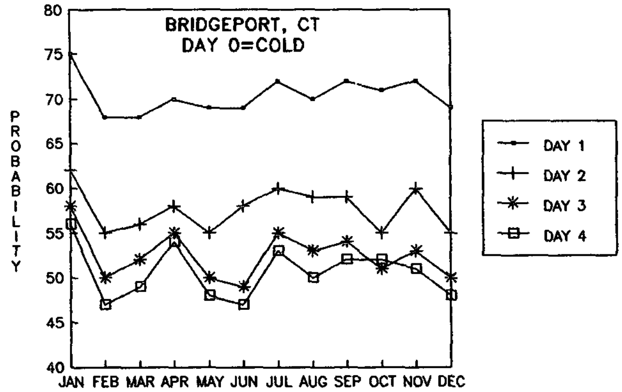

FIG. 3b. Probability of subsequent COLD days following a COLD day at Bridgeport, Connecticut (BDR) for the period 1955–1986. Probability in percent.

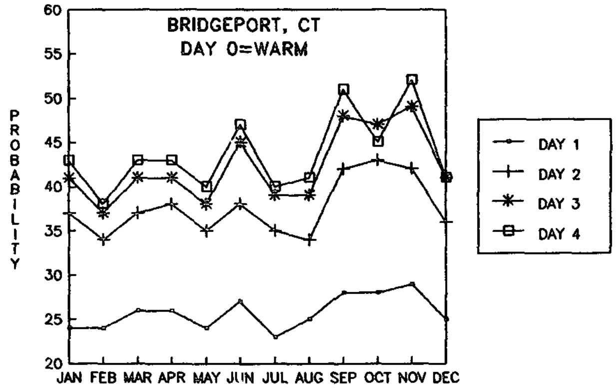

FIG. 4b. Probability of subsequent COLD days following a WARM day at Bridgeport, Connecticut (BDR) for the period 1955–1986. Probability in percent.

COLD day will be followed by another COLD day (i.e., DAY 1 will be COLD). This percentage is highest in the month of January, reaching 75% for both locations. The persistence of cold weather in January may be the result of a combination of both synoptic and short-term climatological events.

On the synoptic scale, winter storms off the New England coast which deposit snow on both interior and coastal sections are often followed by strong northwesterly flow over Southern New England associated with rapid intensification of these storms in the Gulf of Maine. This results in strong cold advection into the region as high pressure builds in from the northwest. Even as the storm moves out to sea, and winds diminish, the next one or two nights often feature clear skies, which, in combination with the fresh snowcover, will lead to strong radiational cooling and large negative temperature anomalies. Brumbach (1965) has indicated that the month of January has the second highest mean number of clear days—nine—at Windsor Locks, exceeded only during the month of October.

Climatologically, the period over which the data were analyzed (1955–1986) has been marked by a number of unusually cold winters. Diaz and Quayle (1980) have observed that the 5-year period from 1975 to 1979, inclusive, featured three of the coldest and wettest winters on record in the northeast United States. Average temperatures were some two standard deviations below normal, while average precipitation was near three standard deviations above normal. This 5-year period represents more than 15% of the analysis period, and would almost certainly affect the averages over the 32 years of data being analyzed.

There seems to be little seasonal variation in the probability of COLD weather on DAY 1. It remains at around 70% for Bridgeport throughout the year, showing a slight increase during the summer months. The lower daily maxima at the shoreline, due to the frequent summertime sea breezes, make it easier for overnight lows to drop below normal. The southerly wind and sea breeze conditions which result in persistent cool weather along the shoreline would, however,

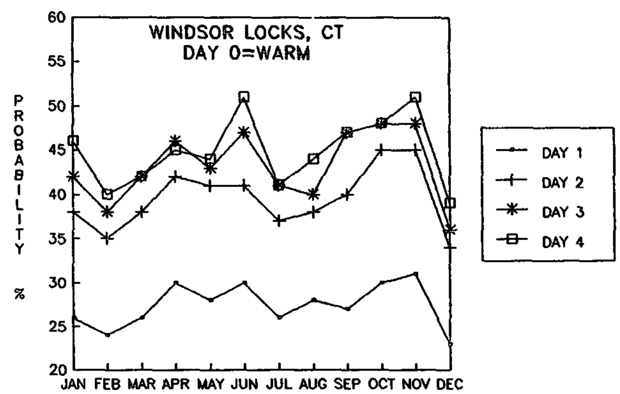

FIG. 4a. Probability of subsequent COLD days following a WARM day at Windsor Locks, Connecticut (BDL) for the period 1955–1986. Probability in percent.

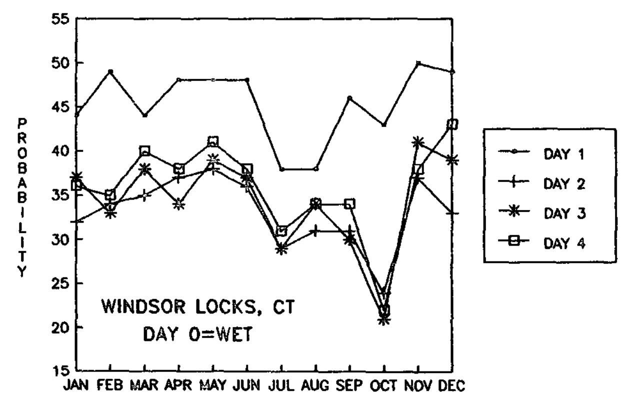

FIG. 5a. Probability of subsequent WET days following a WET day at Windsor Locks, Connecticut (BDL) for the period 1955–1986. Probability in percent.

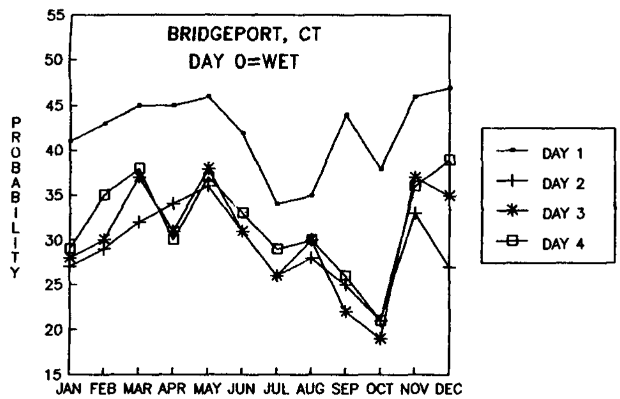

FIG. 5b. Probability of subsequent WET days following a WET day at Bridgeport, Connecticut (BDR) for the period 1955–1986. Probability in percent.

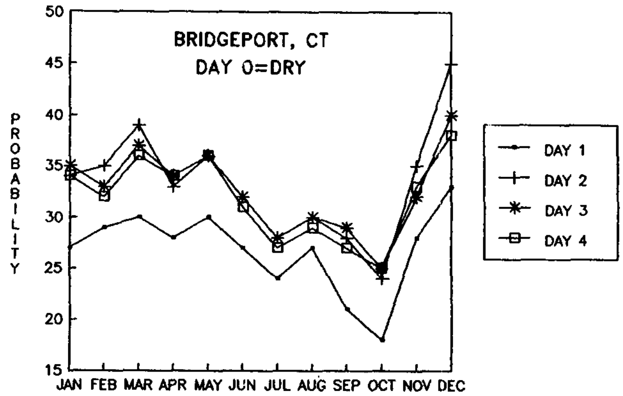

FIG. 6b. Probability of subsequent WET days following a DRY day at Bridgeport, Connecticut (BDR) for the period 1955–1986. Probability in percent.

result in mild interior conditions, where the cooling effects of the sea breeze would be lost. Thus persistent cold is a much shorter lived phenomenon in summer at Windsor Locks. The probability of DAY 1 being cold at BDL reaches a minimum of 65% during the month of August, during which time the Bermuda high pressure tends to be most well established. DAY 2 shows an average probability of 55–57% for both locations; however, it is interesting to note that DAY 2 COLD probabilities rise during the summer months along the shoreline, while they fall in the interior. Once again, the persistent summertime sea breeze is partially responsible. In addition, high pressure systems which often build across the region in summer will initially bring cool, northwesterly winds to both locations. As the high drifts off the eastern seaboard, the return southwesterly flow will bring milder conditions to the interior, while enhancing the onshore cooling effect at the shoreline. In fact, the probability that Bridgeport will experience four consecutive days of below normal minimum temperatures following a COLD day in July is 12.6%, compared to only an 8.5% chance of such an occurrence at Windsor Locks during the same month. In January, however, the chance of four consecutive COLD days following a COLD day at each location is similar (15% at Bridgeport vs. 17% at Windsor Locks). These probabilities were computed by multiplying each of the probabilities of DAYS 1 through 4 being COLD, given DAY 0 was COLD. This is similar to forecasting (prior to the first toss) the probability that any number of consecutive coin flips will come up heads.

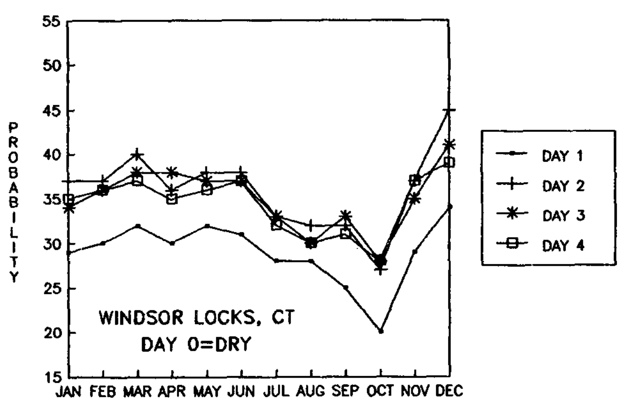

FIG. 6a. Probability of subsequent WET days following a DRY day at Windsor Locks, Connecticut (BDL) for the period 1955–1986. Probability in percent.

Warm spells also seem to persist for more than one day. Station BDL averages only a 25–30% chance of a COLD day following a WARM one (Fig. 4a), while Station BDR averages closer to 25% for DAY 1 (Fig. 4b). Again, there are no significant seasonal variations in these probabilities.

DAYS 2, 3, and 4 are very similar at both stations, but they show some interesting variability. Both locations exhibit a sharp drop (as compared to other winter months) of subsequent COLD days after a WARM day in December. Winter warm days are usually associated with intense lows that develop and track over the Great Lakes, placing southern New England in a persistent warm southwesterly flow. Both locations also show an increase in the probability of COLD days during March and April, and again during September, October, and November. These increased chances of COLD nights can most probably be attributed to the frequent occurrence of radiational cooling, which is quite common during the spring and fall in southern New England.

b. Precipitation

Precipitation shows a distinct seasonal variability which was temporally similar for both locations, but different in terms of frequency. Figs. 5a and 5b show the probability of WET days following a WET day.

From June through October at BDL, DAY 1 probabilities average 40–45%. It is unlikely that WET weather will persist for more than two days at any time during the year (i.e., the atmosphere tends to return rather quickly to the climatological mean POP of 30–35%). Frequencies for DAYS 2, 3, and 4 average around 35% for the "wet" season and 30% for the "dry" season.

At Bridgeport, June through October probabilities average 35% on the first day after a WET day, and only 25–30% on DAYS 2, 3, and 4. Much of the difference between shoreline and interior probabilities in this category can be attributed to summertime thunderstorm activity, which, according to Brumbach (1965), is more common in interior sections than along the coast.

Chances for a WET day following a DRY day are only 25–30% at both locations (Fig. 6). October is the month least likely to have a WET day at both stations. Again, this would seem to be associated with radiational cooling and the increased incidence of clear skies and persistent high pressure in the fall. In fact, Brumbach (1965) shows that October generally produces the greatest mean number of clear days at both interior and shoreline locations. October is also the month with the fewest mean number of days with precipitation of 0.25 mm or more at both interior and shoreline locations, according to Brumbach (1965). The sharp drop in the probability of WET days in October is also more sharply noted in contrast with September, which has often been affected by tropical cyclone induced rainfall during the data sample period.

Based on the monthly data for Bridgeport, Connecticut and Windsor Locks, Connecticut, a persistence climatology (CLIMO) has been developed for each location. Table 1 summarizes temperature CLIMO for the two stations. The figures represent the probability, in tens of percent, that the temperature will be below normal for each of the four 24-h periods following either a COLD or a WARM day. Precipitation CLIMO figures, shown in Table 2, represent the probability, in tens of percent, that measurable precipitation will fall during each of the next four 24-h periods following a WET or DRY day. Note that some of the more subtle frequency differences between the stations are lost due to the rounding of probabilities to the nearest ten percent.

The results of the analysis show a remarkable similarity to the CLIMO figures for Albany, New York developed by Bosart (1975), and shown in Table 3, especially in temperature climatology. All three locations show identical temperature probabilities following a COLD day. Windsor Locks climatology is also identical to Albany's following a WARM day. Bridgeport, however, shows a slightly higher chance of COLD weather on DAYS 3 and 4 after a WARM day in the fall. Again, this is likely due to the influence of high pressure during the autumn months on overnight radiational cooling.

The greatest differences among the stations are in the precipitation climatologies. Shoreline probabilities on DAYS 2 and 3 are lower than interior probabilities during the stormy November–May period. Part of the reason for this difference lies in the number of days with light snow flurry or rain shower activity in interior Connecticut. The relatively hilly terrain in the interior triggers numerous upslope effects, which do not occur as frequently near the shoreline. Landin and Bosart (1985) suggest that cold air draining into the Connecticut River valley in the wake of intense coastal storms may provide sufficient convergence to generate clouds and precipitation, given favorable synoptic conditions and a moist boundary layer. Brumbach (1965) has found that during the period from 1949–1963, Windsor Locks averaged 128 days of measurable precipitation per year, while Bridgeport averaged only 118 such days. In addition, Windsor Locks averaged 15 days per year with 2.5 cm or more of snow, while Bridgeport averaged only six such days during the period from 1949–1963. Dry season climatology numbers for both the interior and the shoreline are essentially similar, except for a slightly lower chance of precipitation along the coast on the first day after a DRY day. The coastal dry season climatology is identical to that of Albany.

TABLE 1a. Temperature CLIMO for Windsor Locks, Connecticut (BDL), in tens of percent.

	Year round	
DAY 0	COLD	WARM
DAY 1	7	3
DAY 2	6	4
DAY 3	5	4
DAY 4	5	4

TABLE 1b. Temperature CLIMO for Bridgeport, Connecticut (BDR), in tens of percent.

	Sept–Nov		Dec–Aug	
DAY 0	COLD	WARM	COLD	WARM
DAY 1	7	3	7	3
DAY 2	6	4	6	4
DAY 3	5	5	5	4
DAY 4	5	5	5	4

TABLE 2a. Precipitation CLIMO for Windsor Locks, Connecticut (BDL), in tens of percent.

	Wet season (Nov–May)		Dry season (Jun–Oct)	
DAY 0	WET	DRY	WET	DRY
DAY 1	5	3	4	3
DAY 2	4	4	3	3
DAY 3	4	4	3	3
DAY 4	4	4	3	3

Table 2b. Precipitation CLIMO for Bridgeport, Connecticut (BDR), in tens of percent.

	Wet season (Nov–May)		Dry season (Jun–Oct)	
DAY 0	WET	DRY	WET	DRY
DAY 1	5	3	4	2
DAY 2	3	4	3	3
DAY 3	3	4	3	3
DAY 4	4	4	3	3

TABLE 3b. Precipitation CLIMO for Albany, New York, in tens of percent (after Bosart 1975).

	Winter (Nov–Apr)		Summer (May–Oct)	
DAY 0	WET	DRY	WET	DRY
DAY 1	5	3	4	2
DAY 2	3	4	3	3
DAY 3	4	4	3	3
DAY 4	4	4	3	3

4. Conclusions

Analysis of over thirty years of daily weather data for Windsor Locks, Connecticut and Bridgeport, Connecticut has yielded a temperature and precipitation persistence climatology (or CLIMO) for interior and coastal southern New England. While there certainly are differences in average temperature and precipitation between the two stations, the chances that a given WARM, COLD, WET, or DRY day will be followed by subsequent COLD or WET days are essentially similar for both locations. These probabilities also show little difference from those developed by Bosart (1975) for Albany, New York, a station somewhat farther to the northwest, in the foothills of the Adirondack Mountains.

The numbers also seem to support a three-day cycle of temperature in the northeastern United States. Cold spells generally last two to three days, while warm weather shows a similar 3-day periodicity.

There is less of a cyclical pattern to precipitation. Daily probabilities average between 30 and 40 percent. There is a 40–50 percent chance that precipitation will persist for more than one day in winter, but only a 20–30 percent probability that a DRY day will be followed by a WET one.

Clearly, there is a need for further studies of this type. The emphasis on improvement in skill of extended forecasts requires that such forecasts represent a significant improvement over persistence climatology. It would be most helpful to the forecaster to know what such a persistence climatology would look like for different regions of the United States. Significant forecast deviations from normal in both temperature and precipitation should then be expressed as probabilities which differ significantly from the climatological expectation. I would expect improvement in skill scores at 96 h and beyond as forecasters recognize that a degree of uncertainty should be expressed as a forecast consistent with the persistence climatology, rather than yield to the tendency to forecast a 50% chance of the occurrence of a given event. Such a tendency would lead to overforecasting the probability of the event if the climatological frequency of occurrence is under 50%.

TABLE 3a. Temperature CLIMO for Albany, New York, in tens of percent (after Bosart 1975).

	Year round	
DAY 0	COLD	WARM
DAY 1	7	3
DAY 2	6	4
DAY 3	5	4
DAY 4	5	4

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