Probabilistic Temperature Forecasts: The Case for an Operational Program

Abstract
The case for an operational program involving the formulation and dissemination of probabilistic temperature forecasts is presented. First, the need for information concerning the uncertainty in temperature forecasts is discussed, and examples of formal and informal decision-making situations in which such information would be useful are described. The results of experiments in probabilistic temperature forecasting are then reviewed, and it is concluded that experienced weather forecasters can quantify the uncertainty inherent in temperature forecasts in a reliable and skillful manner. Finally, the essential components of an operational probabilistic temperature forecasting program are outlined, and some suggestions are made regarding specific temperature events that should receive probabilistic treatment on an operational basis.

1. Introduction
A probability of precipitation (PoP) forecast represents the probability that measurable precipitation (i.e., ≥0.01 inch) will occur during a specific period (generally 6 or 12 h) at a particular point in the area of concern. Since 1965, PoP forecasts have been formulated on an operational basis by National Weather Service (NWS) forecasters and routinely disseminated to the general public. Extensive evaluations of these forecasts have been conducted, and the results of such studies indicate that PoP forecasts are both reliable and skillful (e.g., Cummings, 1974; Hughes, 1976; Murphy, 1978; Sadowski and Cobb, 1974). Moreover, while the nationwide PoP forecasting program initially encountered some resistance on the part of both the forecasters and the public, it is now generally agreed that these probabilities are an important and integral part of the NWS's public weather forecasts (e.g., American Telephone and Telegraph Company, 1971; Bickert, 1967; Murphy and Winkler, 1974b).

Forecasts of maximum and minimum temperatures are also routinely disseminated to the general public. These forecasts are generally expressed in terms of a range of temperature values (e.g., “today’s maximum temperature will be in the mid-60s” or “today’s maximum temperature will be near 65°F”). Thus, such forecasts can be considered to be interval forecasts, although the end points of the intervals are not well defined. The use of an interval, instead of a single value (e.g., “today’s maximum temperature will be 65°F”), is intended to account for both the variability of temperature among points in the area of concern and the uncertainty inherent in the forecast for a specific point. As a result, the user of such forecasts is unable to distinguish between spatial variability and forecaster uncertainty. In any case, NWS forecasters do not attempt to quantify their uncertainty by assigning probabilities to these intervals. Nevertheless, the general public and specific users make many different decisions each day that depend at least in part on temperature forecasts, and the absence of information concerning the uncertainty in these forecasts may frequently lead to suboptimal decisions.

In recent years, a number of experiments and experimental programs involving the quantification of uncertainty in temperature forecasts have been conducted (see references cited in Section 3). The results of these studies indicate that NWS and other forecasters can formulate reliable and skillful probabilistic forecasts for a variety of temperature events. Moreover, it has been shown recently (Murphy, 1977) that the value of reliable probabilistic forecasts generally exceeds the value of traditional categorical forecasts.

The overall purpose of this paper is to present the case for an operational program involving the formulation and dissemination of probabilistic temperature forecasts. We are concerned here only with the problem of quantifying the uncertainty inherent in temperature forecasts for a specific point in the area of concern. The need for information concerning the uncertainty in temperature forecasts is discussed in Section 2, with examples of both “formal” and “informal” decision-making situations in which such information would be useful. The results of recent studies in probabilistic temperature forecasting are summarized in Section 3. The essential components of a proposed program of operational probabilistic temperature forecasting are outlined in Section 4, and some specific suggestions are made regarding temperature...
2. The need for probabilistic temperature forecasts

An examination of the weather-problem catalog compiled by Rapp and Huschke (1964), as well as other sources of information related to the societal impacts of weather and climate, reveals that many of man’s activities and operations are sensitive to temperature conditions, particularly temperature extremes. In this section, we briefly describe several activities that are temperature sensitive and for which the use of temperature forecasts has led or can lead to improved decisions (i.e., to an increase in “benefits” and/or a decrease in “expenses”). It should be mentioned that the individuals involved in the activities of concern may make their decisions after a formal analysis (e.g., by adopting a decision-analytic approach) or they may reach their decisions in an essentially intuitive manner (without any attempt at formal analysis). In order to realize the full advantage of temperature forecasts in such a situation, regardless of the nature of the activity or of the individual’s approach to decision-making, the uncertainty inherent in the forecasts must be quantified and expressed in a concise and unambiguous manner.

Perhaps the most familiar and widespread temperature-related problem is that involving the effects of frost on agricultural activities. A specific example of this type of problem is provided by the orchardist whose deciduous or citrus fruit crop may be damaged if the temperature falls below certain critical levels. In an effort to reduce damages, he must decide, on a nightly basis, whether or not to take certain protective measures (which generally involve the use of orchard heaters, wind machines, or overhead sprinklers), and temperature forecasts currently play an important role in such decisions in many of the major fruit growing regions of the United States. In this regard, the value of frost forecasts to pear growers in Jackson County, Oreg., was investigated recently in a study by Baquet et al. (1976). Such studies demonstrate that orchardists and others cannot properly evaluate and utilize temperature forecasts within the contexts of their respective decision-making situations (involving tradeoffs between costs of protection and possible losses if protective actions are not taken) unless the forecasts contain information related to their uncertainty. The need for such information is also revealed by the existence, since 1970, of a temperature forecasting program at the NWS Forecast Office in Albuquerque, N.Mex. (Gregg, 1977). This program, which was initiated in response to requests from fruit growers, involves probabilistic forecasts that are now routinely disseminated to orchardists in several areas of N.Mex. during the spring season (see Section 3).

At the other end of the scale, many operations are significantly affected by high temperatures. A good example is provided by electric utilities, whose loads can increase dramatically during the summer months when temperatures exceed approximately 80°F for several days (particularly if these temperatures are accompanied by high humidities). Electrical systems operators can use temperature forecasts to decide whether they should commit additional generating capacity that is currently on standby status, purchase supplemental power from other utilities, or rely on their existing on-line resources. Moreover, temperature forecasts are also useful in scheduling maintenance on power-producing units. Clearly, operators cannot make the best decisions in such situations unless they know the likelihood that certain critical temperature values will be exceeded during the periods of concern. Traditional categorical temperature forecasts are inferior to probabilistic temperature forecasts in these situations.

Many other activities are affected adversely by high or low temperatures. A short list of such activities includes the following temperature-related problems:

1) transportation of livestock when the temperature exceeds 90°F;  
2) outdoor painting when the temperature falls below 60°F;  
3) production of artificial snow when the temperature exceeds 20°F;  
4) work by outdoor crews when the temperature exceeds 90°F;  
5) service calls for automobiles when the temperature falls below 15°F;  
6) fruit and grape growing when a rapid rise in daytime temperatures occurs over a one- or two-day period.

Individuals involved in these and other activities require information concerning the probability of occurrence of the relevant temperature events in order to make the best possible decisions.

The examples cited above involve specific users with relatively serious decision-making problems, but probabilistic temperature forecasts can be useful to the general public as well. For example, probabilistic frost forecasts are of value not only to the orchardist concerned with protecting a fruit crop worth millions of dollars, but also to the homeowner concerned with reducing frost damage to his vegetable garden or ornamental plants. Probabilistic temperature forecasts can also be helpful in making day-to-day decisions such as setting the thermostat to regulate heating or air conditioning in the home or selecting suitable clothing to wear or carry. As indicated above, such forecasts can be useful whether the individuals receiving the forecasts reach their decisions after some formal analysis or whether they make their decisions in a completely informal or intuitive manner.

3. Probabilistic temperature forecasting: some experimental results

The first experimental results specifically concerned with the quantification of uncertainty in temperature forecasts were obtained by Williams (1951). He assigned weights, or confidence factors, to forecasts of the 24 h changes in maximum and minimum temperatures (warmer, little change, colder) at Salt Lake City, Utah, during the
The results of this experiment are summarized in Table 1. Correspondence between confidence factors and percentages of correct forecasts was actually quite close, Williams (1951, p. 281) concluded that it was feasible to use such confidence factors in connection with temperature forecasts.

Leight (1953) described the results of an experiment in five-day average temperature forecasting in which probabilities were assigned to the occurrence of five categories of temperature anomalies (much above, above, near, below, and much below normal) for 50 forecast periods. A comparison of the observed relative frequencies and forecast probabilities indicated that the reliability of these forecasts was quite good, both overall and for the individual forecasters. The forecasters did tend to be overconfident on those few occasions on which they assigned relatively high probabilities to the events of concern (i.e., their probabilities tended to exceed the relative frequencies on those occasions). The results also revealed that the experimental probability forecasts were only slightly more accurate, according to the probability score (Brier, 1950), than forecasts based upon the relevant climatological probabilities.

A set of temperature forecasts from an experiment in which forecasters assessed the probability that the minimum temperature would be ≤32°F was presented by Thompson and Brier (1955) in connection with their study of the economic value of weather forecasts. These forecasts were prepared each day during a three-month period in the winter of 1950-51. While the correspondence between forecast probabilities and observed relative frequencies was not particularly close (i.e., the forecasts were not very reliable), the relative frequency of occurrence of this event did tend to increase as the probability increased.

Probabilistic temperature forecasts have been made in connection with the synoptic laboratory program in the Department of Meteorology, Massachusetts Institute of Technology, for more than 20 years (Sanders, 1958, 1963, 1967, 1973). Most recently, these forecasts have consisted of probabilities assigned to 10 categories of departure of the minimum temperature from the climatic mean, with category limits chosen in such a way that each category occurred about 10% of the time over the year as a whole (Sanders, 1973, p. 1171). The forecasts were made each weekday during the spring, summer, and fall semesters for four consecutive 24 h periods (0-24, 24-48, 48-72, and 72-96 h). Since no individual forecaster has a complete record of forecasts, Sanders has been concerned primarily with the performance of consensus forecasts, which were defined simply as the arithmetic averages of the probabilities assessed by the participants. He compared the accuracy of these forecasts, as measured by the ranked probability score (Epstein, 1969; Murphy, 1971), with the accuracy of climatological mean forecasts and found that the subjective forecasts exhibited positive skill for all four periods. For the five-year period from 1967-72, the percentage improvement in the score for consensus over the score for climatology (skill score in percent) was approximately 54.5%, 34.5%, 20.5%, and 10.0% for the 0-24, 24-48, 48-72, and 72-96 h forecasts, respectively (Sanders, 1973, p. 1175).

A similar “game” has been conducted within the synoptic laboratory program at the Department of Atmospheric Science, State University of New York at Albany, since 1969 (Bosart, 1975). In this contest, the participants have assessed the probability that the minimum temperature will be below the climatological minimum at any time during four consecutive 24 h periods. A comparison of the probabilities for the consensus forecasts with observed relative frequencies indicated that these forecasts were quite reliable for all four periods, although the frequency of use of probability values differing appreciably from the climatological probability decreased significantly as the lead time increased. These consensus forecasts also demonstrated positive skill for all four periods, with the percentage improvement over climatology (in terms of probability score) decreasing monotonically from 48.6% for the 0-24 h forecasts to 7.2% for the 72-96 h forecasts.

In a series of recent experiments conducted in NWS forecast offices (Peterson, Snapper, and Murphy, 1972; Murphy and Winkler, 1974a; Winkler and Murphy, 1978), credible intervals have been used to express the uncertainty in forecasts of maximum and minimum temperatures. A credible interval temperature forecast is simply an interval of temperature values accompanied by a probability that expresses the forecaster’s degree of belief that the temperature of concern will fall in the interval (e.g., “the probability is 0.80 that the maximum temperature tomorrow will be between 63° and 67°F”). Thus, credible interval temperature forecasts represent a straightforward extension of the interval forecasts frequently used in current temperature forecasting practice.

The forecasters who participated in the Denver experiment (Murphy and Winkler, 1974a) and the Milwaukee experiment (Winkler and Murphy, 1978) used either variable-width credible intervals or fixed-width credible intervals to quantify the uncertainty in their temperature forecasts. In the case of the variable-width

<table>
<thead>
<tr>
<th>Confidence factor</th>
<th>Number of forecasts</th>
<th>Number of correct forecasts</th>
<th>Percentage of correct forecasts</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>181</td>
<td>101</td>
<td>55.8</td>
</tr>
<tr>
<td>8</td>
<td>230</td>
<td>176</td>
<td>76.5</td>
</tr>
<tr>
<td>10</td>
<td>186</td>
<td>163</td>
<td>87.6</td>
</tr>
<tr>
<td>Total/average</td>
<td>597</td>
<td>440</td>
<td>73.7</td>
</tr>
</tbody>
</table>

* These factors were intended to represent a 60%, 80%, and 100% chance, respectively, of the temperature forecast actually verifying (Williams, 1951, p. 279).
Table 2. Relative frequency of occurrence of observed temperatures below interval (BI), in interval (II), and above interval (AI) and average interval width for (a) variable-width interval forecasts and (b) climatological forecasts corresponding to variable-width interval forecasts.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Number of forecasts</th>
<th>Percentage of observed temperatures</th>
<th>Average width (standard deviation of width) (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>50% intervals</td>
<td>75% intervals</td>
</tr>
<tr>
<td>(a) Variable-width forecasts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denver</td>
<td>132</td>
<td>25.8</td>
<td>45.5</td>
</tr>
<tr>
<td>Milwaukee</td>
<td>432</td>
<td>18.1</td>
<td>53.9</td>
</tr>
<tr>
<td>(b) Climatology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denver</td>
<td>132</td>
<td>31.1</td>
<td>44.7</td>
</tr>
<tr>
<td>Milwaukee</td>
<td>432</td>
<td>17.8</td>
<td>56.9</td>
</tr>
</tbody>
</table>

Forecasts the probability assigned to the intervals was fixed and the width of the interval varied from occasion to occasion, while in the case of the fixed-width forecasts the opposite was true. The results for the variable-width interval forecasts prepared in the Denver and Milwaukee experiments are summarized in Table 2 (part a). These forecasts were formulated in such a way that it was possible to obtain 50% and 75% central credible intervals on each forecasting occasion (see references for additional details). If these forecasts were perfectly reliable, then 25% (12.5%) of the observed temperatures would fall below, 50% (75%) would fall in, and 25% (12.5%) would fall above the intervals in the case of the 50% (75%) intervals. A comparison of the observed relative frequencies with these theoretical (perfectly reliable) relative frequencies indicated (Table 2a) that the variable-width interval forecasts formulated at both Denver and Milwaukee were very reliable. For comparative purposes, we have also included, in Table 2b, an evaluation of interval forecasts based solely upon climatological probabilities. As expected, these climatological credible interval forecasts were also quite reliable, although a careful examination of these data (cf. Table 2a and b) indicated that the forecasters' intervals were slightly more reliable than the climatological intervals. More importantly, the forecasters' intervals were much more precise than the climatological intervals, as is indicated by a comparison of the average widths of these two types of intervals in Table 2. Specifically, the climatological intervals were almost twice as wide, on the average, as the forecasters' intervals. Thus, the variable-width interval temperature forecasts formulated during the Denver and Milwaukee experiments were both reliable and skillful in comparison with climatological intervals.

An experiment in which forecasters have assigned probabilities to the occurrence of temperatures ≤28°F has been conducted in the NWS Forecast Office in Albuquerque, N.Mex., during each spring season since 1970 (Gregg, 1977). These forecasts are now provided to orchardists in several fruit-growing areas of New Mexico. The reliability of the forecasts formulated during the seven-year period from 1970–76 is indicated in Fig. 1, in which the observed relative frequency is plotted against the forecast probability. The bars on each point in this reliability diagram represent 95% confidence intervals based upon the binomial distribution and computed using sample estimates. Note that these temperature forecasts were quite reliable, although the forecasters did tend to be somewhat overconfident for higher probability values.

Finally, Mason (1978) describes the results of an experiment conducted from March 1973 through February 1974 in which forecasters in the Regional Forecast Center in Canberra, Australia assessed probabilities related to their official maximum and minimum temperature forecasts for the following day. Five temperature ranges were identified with respect to the difference between the official forecast and the observed temperature, and the forecasters assigned probabilities to these five temperature categories on each forecasting occasion. A comparison of the observed relative frequencies and forecast probabilities for both maximum and minimum temperatures indicated that these forecasts were quite reliable, with only a slight tendency toward overconfidence for higher probability values. When these subjective probability forecasts were compared with climatological probabilities (in this case, the climatological probabilities...
actually were relative frequencies obtained from a record of the past performance of categorical forecasts), it was found that the maximum (minimum) temperature forecasts were more (less) accurate than climatological forecasts according to the probability score.

The results of these studies provide convincing evidence that weather forecasters can subjectively quantify the uncertainty inherent in forecasts of a variety of temperature events in a reliable and skillful manner. It is important to note that the forecasters who formulated these forecasts had little if any experience in probabilistic temperature forecasting and that they prepared these forecasts without the aid of objective probabilistic guidance (in contrast to the situation involving PoP forecasts). Nevertheless, the forecasts proved successful, and additional experience and the availability of probabilistic guidance information should lead to even better forecasts.

4. Operational probabilistic temperature forecasting: some proposals

The need for temperature forecasts as input into a variety of formal and informal decision-making situations was discussed in Section 2, and several examples of such situations were briefly described. It was emphasized that temperature forecasts cannot be used to the best advantage in these situations unless the uncertainty inherent in the forecasts is quantified and expressed in a concise and unambiguous manner. In Section 3, the results of a number of studies involving the subjective quantification of uncertainty in temperature forecasts were summarized. These results demonstrate that forecasters can quantify this uncertainty in a reliable and skillful manner for a variety of temperature events. Thus, both the need for probabilistic temperature forecasts and the ability of experienced forecasters to formulate such forecasts have been established. In this section we describe the components of a program leading to the preparation and dissemination of probabilistic temperature forecasts on a nationwide basis.

We believe that the program should consist of the following elements:

1) a survey of actual and potential users of temperature forecasts in order to determine their specific needs for information concerning the uncertainty inherent in such forecasts;
2) a training program for NWS forecasters related to the processes and procedures involved in the formulation and evaluation of probabilistic temperature forecasts;
3) a program designed to develop and test statistical and other procedures that will provide the basis for the preparation of objective probabilistic temperature forecasts on an operational basis;
4) operational trials in which probabilistic temperature forecasts would be prepared on a regular basis, with feedback provided to the forecasters but without general dissemination of the forecasts;
5) a program designed to inform and educate the general public and specific users concerning the meaning and use of these forecasts;
6) an operational program of probabilistic temperature forecasting implemented initially at a number of selected locations and then eventually on a nationwide basis.

These elements of the program will be described in somewhat greater detail in the paragraphs that follow.

A survey of user needs should precede any proposed operational program involving the preparation and dissemination of a new type of forecast. The responses of the users can have important implications for various components of the system that will ultimately be designed to produce the forecasts, including the events for which forecasts should be prepared, the objective and/or subjective procedures used to formulate the relevant forecasts, and the manner in which the forecasts should be expressed. Moreover, these responses can provide valuable information concerning the ways in which the forecasts would be used. In summary, information regarding the needs and preferences of potential users of such forecasts will help to ensure that the forecast system is both efficient and effective.

A training program for forecasters is also an important prerequisite for any proposed new operational forecasting program. In this case, the forecasters need to receive information concerning the procedures that can be used to assess (or estimate) the relevant probabilities as well as the methods that will be used to evaluate these forecasts. In addition, the forecasters must become familiar with the ways in which such forecasts should be interpreted. The fact that the nationwide PoP forecasting program was not preceded by a training program of this type led to numerous difficulties, some of which have yet to be overcome.

An operational objective temperature forecasting program involving the use of statistical procedures has been in existence within the NWS for more than a decade (e.g., see Hammons et al., 1976). However, the guidance forecasts currently produced by these procedures are categorical in nature, and, as a result, a supplemental program designed to provide objective probabilistic temperature forecasts should be initiated as soon as possible. While the results of the experiments presented in Section 3 indicate that forecasters can formulate reliable and skillful probabilistic forecasts on a subjective basis, objective probabilistic forecasts contain useful information that can lead to improvements in the ultimate product of the “man-machine mix.” On the other hand, it must be emphasized that NWS forecasters should not be encouraged to depend unduly on such guidance forecasts, since the best forecasts result when the forecaster makes full use of his knowledge and experience in combination with all of the available guidance information.

After these first three steps have been taken, operational trials should be designed and conducted in which NWS forecasters in many if not all locations formulate
probabilistic temperature forecasts on a regular basis. At this stage, the forecasts would not be disseminated to the general public, but they might be provided to specific users on a trial basis. An evaluation program should be initiated at this time, and the forecasters should receive timely and detailed feedback concerning their performance. It would be desirable (but not necessary) to have objective probabilistic guidance forecasts available to the forecasters during this phase of the program.

An educational program designed to provide the general public and specific users with information concerning the proper interpretation and use of the forecasts of concern is also an essential component of any new forecasting program. Such an educational program should attempt to reach the relevant individuals in a variety of ways; for example, directly, by means of brochures and pamphlets, and indirectly, through articles in newspapers, magazines, and other publications. Moreover, the program should be initiated prior to the implementation of the operational program of probabilistic temperature forecasting, and it should be conducted on a continuing basis for some period of time after the operational program has begun. The lack of any coherent program of this type in connection with the PoP forecasting program has led to numerous misunderstandings and misinterpretations of PoP forecasts on the part of the general public and others and has significantly reduced the effectiveness of this program.

The final phase of the program, of course, consists of the initiation of the operational program of probabilistic temperature forecasting in which these forecasts would be formulated and disseminated on a regular basis. It would appear to be feasible to implement such a program concurrently on a nationwide basis, particularly if all of the previous phases of the program had been completed or were well underway. In this regard, the NWS PoP forecasting program was initiated on a nationwide basis in 1965 after a series of internal trials but with very limited programs of forecaster training and user education. However, if desirable, the proposed new program could be implemented first at a number of selected locations and then gradually expanded to include all of the relevant NWS offices.

An important dimension of the proposed program has not as yet been considered; namely, for which temperature events should probabilistic forecasts be formulated? While the answer to this question ultimately depends upon the use that is to be made of the forecasts, we will offer some general comments on this topic relative to probabilistic temperature forecasts intended for specific users and for the general public. With regard to the former, many users are particularly concerned with whether or not the temperature will fall below or rise above certain critical values. Thus, we believe that major user groups should be provided with probabilistic forecasts that indicate the likelihood that the events of interest to them will occur. Presumably, these events will differ from group to group and even from location to location for some groups. It should be noted that such forecasts are similar in many respects to PoP forecasts, in that both types of forecasts involve assessing the likelihood of occurrence of a single event with reference to a specific critical value (0.01 inch of precipitation in the case of PoP forecasts).

With regard to the general public, the most appropriate forecasts of this type would appear to be variable-width credible interval forecasts of maximum and minimum temperatures. In this case, temperature is treated as a continuous variable (instead of as a dichotomous variable). While it is clearly not practical to report an entire probability distribution of temperature to the public, a credible interval temperature forecast provides a convenient summary measure of this distribution. Since the description of such an interval involves only a probability and a range of temperature values, a credible interval temperature forecast is similar to the interval forecasts generally used in current temperature forecasting practice. Of course, a credible interval forecast applies only to a single point (or possibly to an area for which the same forecast is considered to be appropriate for all points), but spatial variability of temperature could be handled by issuing different credible interval forecasts for different points (or areas).

If variable-width credible intervals are used in public forecasts, then a probability value must be chosen. While various probability values might be considered, a probability of 50% appears to offer certain advantages. First, the probability should not be too high (e.g., 90%) because the intervals that result will generally be too wide; on the other hand, it should not be too low because the intervals will seldom contain the observed temperatures. Second, the results presented in Section 3 indicated that the 50% intervals in the Denver and Milwaukee experiments were approximately 6°F wide on the average—a width that is reasonably consistent with the current practice of issuing forecasts such as “today’s maximum temperature will be in the mid-60s”. Finally, the width of a 50% central credible interval represents the interquartile range of the forecaster’s distribution, a useful statistic for characterizing the variability or spread of a probability distribution (McGill et al., 1978). Of course, intervals corresponding to probability values of 67% or 75% might be considered as reasonable alternatives to 50% intervals.

Since many members of the public will still prefer to receive a single “most likely” temperature value, it might be desirable to include such a value, the forecaster’s median, in a variable-width forecast. The inclusion of the median as well as the endpoints of the 50% central credible interval in the forecast will provide some information concerning the existence of any skewness in the forecaster’s distribution. Thus, for example, the forecast might read “today’s maximum temperature near 66°F, with a 50% probability interval extending from 63°F to 67°F”.

Fixed-width forecasts represent an obvious alternative to variable-width forecasts. The former require the
choice of a value for the width, and a width of 5°F appears to be consistent with current temperature forecasting practice (see above). The choice between these two types of credible interval forecasts, as well as the choice of a particular probability or width, should be based at least in part on the ease of dissemination to and interpretation by the general public.

As a summary measure, credible intervals may not always provide a completely satisfactory description of the forecaster's state of knowledge regarding maximum and minimum temperatures. For example, consider a situation in which the forecaster's distribution is bimodal because a frontal zone is approaching the area of concern. In this case, a credible interval forecast may be somewhat misleading in the sense that recipients of the forecast will generally assume that the forecaster's distribution is concentrated about the midpoint of the interval. However, such situations are relatively infrequent, and the uncertainty inherent in temperature forecasts on these occasions could be described in greater detail simply by adding a few words of explanation to the respective forecast texts.

Another probabilistic temperature forecast that might be disseminated to the public, at least at certain times of the year, is the frost forecast. Single-event probabilistic forecasts of this type are similar to PoP forecasts, a fact that should tend to reduce the chances that the forecasts would be misunderstood or misinterpreted. As indicated in Section 2, such forecasts would be of value to homeowners concerned with protecting their vegetable gardens and ornamental plants against frost damage, as well as to orchardists and others who make decisions of a similar nature involving very significant economic consequences.

In conclusion, we believe that an operational program of probabilistic temperature forecasting, both for major user groups and for the general public, would lead to significant increases in the value of the current NWS forecasting program. The need for such forecasts and the ability of forecasters to formulate these forecasts have been established. It has also been demonstrated recently that reliable probabilistic forecasts are of greater value than climatological and categorical forecasts for most if not all users of such forecasts. A carefully designed and conducted program—involving a survey of user needs, forecaster training, and public education—will minimize most of the difficulties encountered in connection with the nationwide PoP forecasting program.

Cooke (1906a, b) first provided the rationale for, and demonstrated the ability of, experienced forecasters to formulate, probabilistic weather forecasts almost three-quarters of a century ago. Unfortunately, 60 years elapsed before the "meteorological establishment" recognized the merits of the arguments and evidence set forth by Cooke (and others in the interim) and decided to initiate an operational program of precipitation probability forecasting. We hope that another 60 years will not pass before the meteorological and user communities realize at least some of the benefits that could be obtained from the implementation of a nationwide program of operational probabilistic temperature forecasting.


References


Peterson, C. R., K. J. Snapper, and A. H. Murphy, 1972:


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**announcements**

**Unit formed to study nitrogen**

A SCOPE/UNEP (Scientific Committee on Problems of the Environment/United Nations Environment Program) International Nitrogen Unit has been set up at the Royal Swedish Academy of Sciences in Stockholm. It is intended that the unit serve as a focal point for nitrogen cycling studies on local, regional, and global scales. The unit will also collect and critically assess data concerning the global nitrogen cycle, aiming to complete a revised model describing the circulation of nitrogen. The unit will also consider the need for monitoring of nitrogenous substances in cooperation with other appropriate bodies, such as MARC (Monitoring and Assessment Research Centre), Chelsea College, London. Further information may be obtained from: SCOPE/UNEP International Nitrogen Unit, the Royal Swedish Academy of Sciences, Fack, S-104 05 Stockholm, Sweden. Interested scientists are encouraged to visit the Nitrogen Unit or write to the Unit on any matter concerning the biogeochemical nitrogen cycle.

**Atmosphere-Ocean, new journal**

The Canadian Meteorological and Oceanographic Society, formerly the Canadian Meteorological Society, recently changed the name of its scientific journal *Atmosphere* to *Atmosphere-Ocean*. The new names are intended to show the Society's official interest in both meteorologists and oceanographers. The contents of the first issue of *Atmosphere-Ocean* were "devoted to the refereed proceedings of the first International Workshop on Hailfall Measurements held in Banff, Alberta, October 22-26, 1977. . . . The papers were selected and refereed by a group of Society members with special interests in hail studies." The journal is distributed free of charge to members of the Society. The annual Institutional subscription rate for *Atmosphere-Ocean* is $25.00. For information on Institutional subscriptions contact: University of Toronto Press, Journals Dept., 5201 Dufferin St., Downsview, Ontario, Canada M3H 5T8. Information on membership is available from: the Corresponding Secretary, Canadian Meteorological and Oceanographic Society, c/o Department of Geography, Simon Fraser University, Burnaby, B.C., Canada, V5A 1S6.

**New journal on earthquake, wind, and ocean engineering**

A new quarterly journal, *Engineering Structures, the Journal of Earthquake, Wind and Ocean Engineering*, which recently began publication, may be of interest to some *Bulletin* readers. The journal hopes "to provide a new forum for . . . an interchange of ideas between those involved with dynamic environmental loads such as winds, waves, and earthquakes. The journal will feature theoretical and applied research papers and the Editors will encourage the submission of articles on the design and construction of significant structures." Articles scheduled for early future issues of the journal include *Wind Tunnel Techniques for the Study of Wind Loads on Structures: A New Approach; Influence of Wind Profile on the Static Response of Cooling Tower Shells; and Failure of a 140 m High Steel Chimney Caused by Wind-Induced Oscillations Transverse to the Wind Direction*. The annual subscription rate for the journal is £35.00 (~$70.00), including postage by surface mail; airmail rates quoted on request. The journal is also available in microfiche. For more information contact: IPC Science and Technology Press Limited, IPC House, 32 High St., Guildford, Surrey, England GU1 3EW (Tel: 0489-71661; Telex: 859556 Scitec G).

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