Forecast Terminology: Composition and Interpretation of Public Weather Forecasts^{2,3}

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Abstract

Worded forecasts, which generally consist of both verbal and numerical expressions, play an important role in the communication of weather information to the general public. However, relatively few studies of the composition and interpretation of such forecasts have been conducted. Moreover, the studies that have been undertaken to date indicate that many expressions currently used in public forecasts are subject to wide ranges of interpretation (and to misinterpretation) and that the ability of individuals to recall the content of worded forecasts is quite limited. This paper focuses on forecast terminology and the understanding of such terminology in the context of short-range public weather forecasts.

The results of previous studies of forecast terminology (and related issues) are summarized with respect to six basic aspects or facets of worded forecasts. These facets include: 1) events (the values of the meteorological variables); 2) terminology (the words used to describe the events); 3) words versus numbers (the use of verbal and/or numerical expressions); 4) uncertainty (the mode of expression of uncertainty); 5) amount of information (the number of items of information); and 6) content and format (the selection of items of information and their placement). In addition, some related topics are treated briefly, including the impact of verification systems, the role of computer-worded forecasts, the implications of new modes of communication, and the use of weather forecasts.

Some conclusions and inferences that can be drawn from this review of previous work are discussed briefly, and a set of recommendations are presented regarding steps that should be taken to raise the level of understanding and enhance the usefulness of worded forecasts. These recommendations are organized under four head-

ings: 1) studies of public understanding, interpretation, and use; 2) management practices; 3) forecaster training and education; and 4) public education.

1. Introduction

Weather forecasts frequently are presented in the form of worded messages. Such messages, which usually consist of both verbal and numerical expressions, play an important role in the communication of weather information to the general public. Therefore, it is surprising to discover that relatively few studies of the composition and interpretation of worded forecasts have been conducted. Moreover, the studies that have been undertaken to date indicate that many expressions used in weather forecasts are subject to wide ranges of interpretation (and to misinterpretation) and that the ability of individuals to accurately recall the content of worded forecasts is quite limited. Evidently, then, the utility of the information provided by the forecasting system is reduced significantly during the processes of communicating and assimilating this information. In order to minimize the loss of information and to provide worded forecasts that contain understandable and useful information, it is necessary to study the composition of such forecasts and their interpretation from the viewpoint of both the forecaster and the general public.

Many types of weather forecasts can be identified, including 1) short-range forecasts for the general public; 2) short-range forecasts for specific user groups (e.g., for users in the agricultural, aviation, or maritime communities); 3) extended-range or long-range forecasts (i.e., forecasts or outlooks for periods of 5–10 days, a month, or a season in advance); and 4) watches and warnings related to severe weather events (e.g., hurricanes, tornadoes, winter storms). Since different types of forecasts require different “vocabularies,” a comprehensive discussion of forecast terminology and related issues with respect to all these (and other) types of forecasts is clearly beyond the scope of this paper. Here we

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focus primarily on forecast terminology and the understanding of this terminology in the context of *short-range public weather forecasts*. (By short-range forecasts, we mean forecasts that contain information concerning day-to-day weather conditions.) Nevertheless, it is believed that this treatment of forecast terminology also may have some implications for forecasts other than short-range public forecasts.

In considering the nature and content of worded forecasts, a number of basic facets, or aspects, of such forecasts can be identified. For the purposes of this paper, we consider the following facets: 1) events (the values or sets of values of the meteorological variables with which the forecasts are concerned); 2) terminology (the words used to describe the events, including their spatial and temporal variability and their intensity); 3) words versus numbers (the use of verbal and/or numerical expressions to convey information); 4) uncertainty (the mode of expression of uncertainty in forecasts); 5) amount of information (the number of items of information in forecast messages); and 6) content and format (the choice of items of information to include in forecasts and their arrangement or placement).

The results of previous studies related to these six aspects of public weather forecasts are described briefly in Sections 2 through 7. Brief treatments of several other topics related to forecast terminology are contained in Section 8, including the impact of verification systems on worded forecasts, the role of computer-worded forecasts, the implications of new modes of communication of weather information for forecast composition and interpretation, and the use of weather forecasts by the general public. Section 9 consists of a summary and a short discussion of some inferences and conclusions that the authors (and others) have drawn from the previous work in this area. In Section 10 we present a set of recommendations regarding steps that should be taken to enhance the understanding and usefulness of worded forecasts.

2. Events

A weather forecast expressed in the form of a worded message generally contains several segments, each of which relates to a specific meteorological variable or element (e.g., temperature, precipitation, wind, sky cover). In essence, such a segment consists of a statement that specifies the value or values that a variable is expected to assume (in the case of a numerical probability statement, the likelihood of occurrence of the possible values is specified (see Section 5)). We shall refer to these values as "events." Among the factors that a forecaster should consider in defining the events for a particular variable are the underlying nature of the variable itself (e.g., continuous/discrete, bounded/unbounded), its spatial and temporal variability and predictability, and the specific needs of actual and potential users for forecasts of the variable. Failure to take these considerations into account frequently has created problems for both forecasters and users of weather forecasts.

As indicated previously, events are defined first in terms of the values of a meteorological variable. Such a variable may be continuous or discrete and its values may be bounded or unbounded. It is important to consider these factors in defin-

ing the events for which forecasts will be formulated. The events may represent individual values or ranges of values of the variable, as in the cases of temperature and wind speed; or categories or classes of values, as in the cases of sky cover and type of precipitation. The situation in which only two categories of a variable are permitted (e.g., rain/no rain, fog/no fog) is frequently of special interest.

Several other dimensions of events, including their spatial and temporal domains, also must be considered. In the case of spatial domain, it is important to specify whether the events are defined for a point or an area. For example, the probability of precipitation (PoP) statements included in public weather forecasts in the United States (e.g., see Hughes, 1980) are point forecasts; that is, a PoP forecast represents the probability that measurable precipitation will occur at a particular point in the forecast area (generally, the official rain gage). However, surveys of the general public (see Section 5) indicate that the PoP forecasts frequently are interpreted as area probability forecasts (i.e., the probability that measurable precipitation will occur at one or more points in the area).

With regard to temporal domain, it is important to specify whether the events refer to instantaneous values of the variable, time averages, or simply the occurrence or nonoccurrence of certain values in an interval of time. Moreover, it should be recognized that a change in the temporal domain generally defines a new event. Failure to recognize this fact can lead to problems for both forecasters and users. For example, Hughes (1980) found that forecasters who usually make PoP forecasts for 12 h periods have a tendency to overforecast when asked to make similar forecasts for 6 h periods (i.e., they do not properly take into account the reduction in the length of the forecast period when formulating their forecasts). Moreover, users of such forecasts should be aware of the fact that PoP forecasts for a 24 h period (say) cannot be inferred from PoP forecasts for two consecutive 12 h periods without obtaining some additional information or without making some simplifying (and possibly inappropriate) assumptions.

Predictability is another factor that should be considered in defining the events. If forecasters are unable to discriminate between certain events, then these events should be combined into a single event. Such considerations suggest that the results of forecast verification studies have an important role to play in the process of event definition. In this regard, advances in the state of the art of weather forecasting should be reflected, *inter alia*, in the further refinement of such definitions.

Clearly, the "sensitivity" of users of forecasts to specific values of a variable should be an important determinant in defining the events. That is, the "scale" used to define the events should discriminate between values of the variable that have appreciably different impacts on important segments of the public. On the other hand, it is not necessary (or even desirable in view of the constraints imposed on the length of worded forecasts) to include further refinements in the events' scale beyond this minimally sufficient level. Thus, the choice of an appropriate set of events depends on the uses to which the forecasts are put, and this fact emphasizes the need for forecasters to become more familiar with the activities of the users of public weather forecasts.

3. Terminology

Weather forecast terminology consists of systems of generic terms, such as “sunny,” “cloudy,” and “rain,” and systems of spatial, temporal, and intensity modifiers, including such words as “scattered,” “frequent,” and “light,” respectively. Generic terms are used to specify a wide range of weather conditions, whereas the modifiers attached to these terms provide a means of describing such conditions more precisely and/or completely. Several questions can be posed regarding the use of these systems of terms in public weather forecasts: 1) How well are commonly used terms understood by forecasters and the general public? 2) What types of scales or other guidelines are required to ensure appropriate and consistent usage of forecast terminology? 3) How well is the terminology used in hazardous weather forecasts understood? 4) How should any differences between forecaster usage and public interpretation of forecast terms be resolved? 5) Do regional differences in the interpretation of forecast terminology exist and, if so, how should such differences influence the forecaster’s choice of terms? Some insight into the issues raised by these questions is provided by examining the results of recent investigations of forecast terminology.

Studies related to the understanding of worded forecasts indicate that most generic terms are fairly well understood (Abrams, 1971, 1980; Freitas and Wells, 1982; Maunder, 1969; McBoyle, 1974; Riebsame, 1978; Yacowar, 1979). For example, words such as “clear,” “sunny,” “overcast,” “a shower,” and “a thunderstorm” are most often interpreted correctly. On the other hand, terms such as “cloudy” and “fair” are subject to misinterpretation more frequently. Moreover, it should be noted that the level of understanding of many generic terms, including words such as “rain,” “calm,” and “windy,” has not been investigated.

Some modified expressions (i.e., generic terms plus modifiers) apparently are well understood. However, the evidence currently available suggests that the interpretation of such expressions is generally more variable than that of the generic terms themselves. In fact, many modified expressions (e.g., “partly cloudy,” “occasional rain,” “moderate winds”) are poorly understood (Abrams, 1971, 1980; Freitas and Wells, 1982; Maunder, 1969; McBoyle, 1974; Riebsame, 1978; Rogell, 1972; Stutchbury and Lapczak, 1979; Yacowar, 1979).

The difficulties associated with the interpretation of modified forecast terms may be due in part to the lack of suitable numerical scales to ensure consistent usage of terminology by forecasters. For example, Riebsame (1978) suggests that the overlap in the definitions of cloud cover terms (e.g., a forecast of five-tenths cloud cover could be described using the terms “sunny,” “partly cloudy,” or “considerable cloudiness”) contributes to the misinterpretation of state-of-the-sky (SOS) expressions. Instead of providing more specific descriptions of forecast conditions, the use of modified terms defined on overlapping scales may make these descriptions more ambiguous. The study by Riebsame and studies by several other investigators (e.g., Abrams, 1971; Landsberg, 1940; Yacowar, 1979) indicate the need for carefully constructed and well-defined scales that prescribe the conditions under which each forecast term should be used.

The understanding and interpretation of the terminology

used in severe weather forecasts are of special importance due to the threat to life and property that is implicit in any misinterpretation of such messages. Pifer and Mogil (1978) describe National Weather Service (NWS) hazardous weather terminology and discuss the results of several studies concerning the interpretation of the words “watch” and “warning.” These results indicate that between 70 and 90% of the general public can define these terms adequately. However, in a recent study of public responses to natural hazard warnings (Leik *et al.*, 1981), it was found that “hazard warning messages are generally not formulated in a manner which motivates optimal response” (p. 183). Apparently, the wording and interpretation of warning messages require further investigation.

The resolution of differences between the official definitions of forecast terms employed by forecasters and the “operational” definitions of such terms adopted by the general public is another issue of considerable importance. A study by Abrams (1971) reveals that forecaster and public interpretations of terminology used in precipitation forecasts frequently are divergent. These results (and others discussed earlier in this section) indicate that, in many cases, the two “communities” define forecast terms differently. Such differences in interpretation of terminology must be recognized and some compromises reached and/or educational programs initiated in order to ensure that the terms employed in public weather forecasts have a mutually agreeable and understandable set of meanings.

Another issue that requires consideration in the selection of terms to be used in worded forecasts is the possibility that terminology may be interpreted differently in different regions. Such differences were noted by Yacowar (1979), who suggested that they may arise from climatological variations between regions. That is, a day with five-tenths cloud cover (on the average) might be considered to be a “cloudy” day by an individual from a climatologically sunny region, whereas it might be considered to be a “sunny” day by an individual from a climatologically cloudy region. The existence of such differences in interpretation indicates that it is important for the terminology used in local forecasts to be consistent with regional interpretations (see McBoyle, 1974; Shak *et al.*, 1966).

4. Words versus numbers

Since specific segments of worded forecasts frequently are (or can be) expressed either in verbal or in numerical form, the question arises as to which of the two forms provides the most precise and useful information. With regard to precision, it is clear that numbers are more precise than words. Of course, it should be kept in mind that the use of numbers, in some instances, may imply an unwarranted degree of precision (i.e., false precision) in view of the current state of the art of weather forecasting.

With regard to the relative usefulness of verbal and numerical expressions, the primary issue is the ability of members of the general public to properly interpret and make use of the information contained in such phrases. The evidence cur-

rently available indicates that verbal expressions frequently are subject to very wide ranges of interpretation or even to misinterpretation. For example, Abrams (1971, 1980) discovered that words that are used to describe time periods in forecasts, such as "evening," are interpreted differently by various individuals (e.g., the starting time for this period, according to the participants in the survey, ranged from approximately 3 pm to 9 pm).

Studies of the interpretation of SOS forecasts (e.g., Riebsame, 1978; Yacowar, 1979) reveal that a considerable degree of ambiguity exists in current forecast terminology for such events. Moreover, Riebsame indicates that the use of terms describing both cloudiness and sunshine in a single vocabulary tends to increase this ambiguity and to detract from the usefulness of the various phrases. These authors suggest that expressing SOS forecasts in numerical form would increase both the amount of information that could be communicated and its usefulness.

A general issue that has arisen recently is the extent to which it is possible and/or desirable to introduce quantitative, or numerical, expressions into forecasts. Evidence available from several studies (e.g., Riebsame, 1978) indicates that the public is able to interpret numerical information in forecasts quite successfully, which suggests that the introduction of quantitative expressions into worded messages certainly is feasible. With regard to the desirability of utilizing such expressions, some authors (e.g., Murphy, 1978b; Pielke, 1977) have argued that increased quantification will yield more precise forecasts and forecasts that are less subject to misinterpretation. On the contrary, others (e.g., Maunder, 1970; Smith, 1978) have voiced some reservations about greater use of numerical expressions in worded forecasts. Obviously, a worded forecast cannot consist entirely of numerical expressions; it should represent a proper, balanced mixture of words and numbers. Moreover, it should be kept in mind that segments of forecasts can be expressed in *both* verbal and numerical forms; PoP forecasts provide an example of a forecast segment that currently is expressed in terms of both words *and* numbers (see Section 5).

5. Uncertainty

Uncertainty is inherent in all weather forecasts. When forecasts are presented in the form of written messages, this uncertainty can be treated in three ways: 1) it can be ignored; 2) it can be expressed qualitatively in terms of verbal modifiers; or 3) it can be described quantitatively by means of numerical expressions. When uncertainty is ignored, forecasts are necessarily expressed in categorical (i.e., definite) terms, and such forecasts suffer from serious deficiencies (e.g., see Murphy, 1977a, 1978a). Thus, it is assumed here that the uncertainty in weather forecasts is described in all worded messages. The issue, then, is whether it should be expressed in qualitative or quantitative terms. This issue could be viewed as another example of the words versus numbers facet that was discussed in Section 4. We prefer to treat uncertainty as a separate facet because of its pervasive nature, its fundamental importance to users of forecasts, and the controversy that

has surrounded efforts to "characterize" this uncertainty in worded messages.

Traditionally, when uncertainty has been described in worded forecasts, it has been expressed in the form of verbal modifiers. For example, terms such as "chance" or "likely" have been used in connection with forecasts of the occurrence of measurable precipitation and other events. In some cases, the words employed to characterize uncertainty in forecasts have been "defined" by certain ranges of probability values (e.g., see NWS Operations Manual, 1977). Such practices undoubtedly help to ensure some degree of consistency among forecasters in the use of these terms. Consistent usage of terminology in worded forecasts is a necessary, but *not* a sufficient, condition for ensuring that the general public is provided with meaningful and potentially useful information.

Are these verbal expressions of uncertainty interpreted by the public in an appropriate and consistent manner? This question has been addressed in several studies related to terminology in weather forecasts (e.g., Abrams, 1971; Bickert, 1967; McBoyle, 1974; Rogell, 1972) and in laboratory experiments conducted by behavioral psychologists (e.g., Beyth-Marom, 1982; Budescu and Wallsten, 1981; Lichtenstein and Newman, 1967). In brief, these investigations all reached the same general conclusion—a large amount of variability exists when individuals are asked to assign numerical values to such verbal expressions and the amount of overlap among terms is substantial. To eliminate this overlap, it would be necessary to limit the forecaster's vocabulary to a very small set of "distinct" words (e.g., "always," "often," "sometimes," "never"), thereby severely restricting the amount of information concerning uncertainty that could be transmitted to users. Moreover, Budescu and Wallsten (1981) make an important point that should be noted here:

... part of the motivation for using words rather than numbers as responses stems from the idea that people's opinions generally are vague or fuzzy rather than precise, and that this property of their opinion is better captured with the use of words. . . . It is clear from our results that words are more inconsistently interpreted than are numbers . . . , but to claim that therefore words provide a better representation of the underlying opinion is equivalent to suggesting that fuzzy quantities ought to be measured with blurred rulers. Clearly, one wants the ruler to be as unambiguous as possible so that all observed vagueness can be attributed to the quantity being measured and not to the instrument doing the measuring [p. 18].

They conclude that "... communication from one person to another regarding degrees of uncertainty would be degraded by the use of probabilistic phrases rather than numbers" (p. 17).

Numerical probabilities have been used from time to time to describe uncertainty in weather forecasts for many years. However, only with the advent of the NWS nationwide PoP forecasting program in 1965 have probability forecasts been disseminated to the public in the United States on a routine, operational basis. Considerable controversy has surrounded this program since its inception, and this controversy has re-

lated primarily to the understanding and use of the PoP forecasts by the general public.

Several studies have been undertaken in which selected individuals have been asked to interpret a PoP forecast such as "the probability of precipitation today is 30%" (e.g., Bickert, 1967; Rogell, 1972; Scoggins and Vaughn, 1971). These studies indicate that many (in some cases, most) individuals do not know that a PoP forecast represents the probability of measurable precipitation at a point in a specified period of time. That is, they misinterpreted the PoP forecasts. However, as Murphy (1977b) has indicated, it is important to distinguish between misinterpretation of the event (e.g., precipitation at a point versus precipitation in an area) and misinterpretation of the probability associated with the event. In a subsequent study (Murphy *et al.*, 1980), the authors discovered that misinterpretation of PoP forecasts consisted almost entirely of event misinterpretation rather than probability misinterpretation. It should be noted that this result is not inconsistent with the results of previous studies, since they were concerned exclusively with event misinterpretation. Moreover, Murphy *et al.* found that a comparable amount of event misinterpretation also existed for categorical forecasts of precipitation occurrence.

The PoP program initially encountered some resistance from both the forecasters and the public, but it is now generally agreed that these probabilities are an important and integral part of public weather forecasts in the United States (e.g., American Telephone and Telegraph Company (AT&T), 1971; Bickert, 1967). Moreover, a recent nationwide statistical survey of 1300 members of the general public revealed that 70% of the participants preferred numerical probabilities to verbal modifiers as descriptors of uncertainty in forecasts of precipitation occurrence (M.S.I. Services, Inc., 1981).

6. Amount of information

The amount of information that can be communicated effectively in any message, including a weather forecast, depends on two basic factors: 1) the amount of information that the recipient of the message wants to obtain; and 2) the amount of information that the recipient is able to absorb, process, and recall for use at a later time. Of course, other factors such as space or time constraints may place a prior limit on the length of a forecast and thus on the amount of information that it may contain. However, within the limits imposed by such constraints, the two factors just identified determine the amount of information that should be included in a weather forecast.

Several studies (e.g., AT&T, 1971; Cornog and Bickert, 1969) have investigated the preferred length of weather forecasts. In general, the results of these studies have indicated that the public prefers forecasts that contain a moderate amount of information. Specifically, a majority of the participants in a survey conducted by Cornog and Bickert preferred a short, interpretive message to a longer and more detailed forecast. Of the three messages that were presented to listeners in the AT&T study, a message of length 20 s was preferred to messages of lengths 9 and 48 s, with most partici-

pants considering the 9 s forecast to be too short and the 48 s forecast to be too long. Evidently, some information that is routinely reported in weather forecasts (e.g., barometric pressure) is considered to be superfluous by many individuals.

With regard to the second factor, studies by AT&T (1971) and Namm (1979) revealed that few participants could recall specific parts of a weather forecast that had just been presented to them. The recall of very short messages (e.g., the 9 s message in the AT&T study) was fairly good, but overall a maximum of only about 25% of the participants could recall any one particular segment of the forecast, with most percentages being much smaller than this value. Gordon and Bestwick (1969) found that immediately following the presentation of a forecast, students were able to reproduce only about one-fourth of the information in the message.

The results of three experiments by Wagenaar and Visser (1979) indicate that the amount of information that can be recalled from a weather forecast is independent of the length of the message. That is, no matter how much information is presented in a forecast, a limit appears to exist beyond which additional information cannot be processed and remembered. On the average, the subjects in these experiments were able to reproduce only seven or eight items from worded messages of varying lengths. It is of interest to note that memory research has found that the number seven (plus or minus two) characterizes the number of items that can be recalled from lists of unrelated items (Miller, 1956). This result suggests that segments of worded weather forecasts are processed in much the same manner as items of information that bear no relationship to each other.

What parts of worded messages are recalled? Wagenaar and Visser (1979) discovered that the recall of primary information is much better than the recall of secondary information. That is, subjects are more likely to remember the fact that "rain" was mentioned in the forecast than to remember expressions related to where it will rain, how much it will rain, or the likelihood of occurrence of rain. The loss of such information greatly increases the chances that a forecast will be misinterpreted or that its implications will be misunderstood.

The results of a more recent experiment (Wagenaar *et al.*, 1982) provide further insight into the ability of the public to recall the information contained in weather forecasts. First, it was found that a shortened forecast (e.g., eliminating the wind segment) did not lead to an increase in the number of items recalled, although an improvement in the recall of some details of the forecast was achieved. Second, selective listening for a particular item in the forecast seemed to improve the recall of that item to some extent, but the recall percentage was still less than 50%. Furthermore, the inclusion of an interpretive explanation of the meteorological situation did not appear to aid in the reproduction of the contents of a forecast.

Thus, in determining the amount of information to include in a weather forecast, it appears that considerations related to the second factor (the recipient's ability to absorb, process, and recall information) dominate considerations related to the first factor (the amount of information desired by the recipient). If only a limited amount of information can be assimilated and used, then the amount of information desired is largely irrelevant. Wagenaar and Visser (1979) suggest that

the way to overcome this problem may be to increase the meaningfulness of the forecast (e.g., by advantageously grouping the segments of a forecast or by utilizing existing redundancies in expressions), thereby enhancing the process of recalling the information contained in the message. If this effort is unsuccessful, then it may be necessary to accept the full implications of their results; namely, that little if anything is gained by providing more than a relatively limited amount of information in public weather forecasts.

7. Content and format

Once a decision has been made concerning the amount of information to include in a forecast, it is then necessary to decide what information should be presented and how this information should be arranged in the worded message. It seems clear that forecasts should describe, if possible, those weather events that are of the greatest significance to the general public. In this regard, several surveys have included questions that were designed to measure the relative importance of forecasts of various meteorological elements to the public. In general, temperature and precipitation forecasts (including PoP forecasts) were found to be the most important parts of such messages, with forecasts of sky condition and wind speed and direction considered to be less important (AT&T, 1971; Maunder, 1969; Namm, 1979). The study by Namm also indicated that PoP statements were recalled best, followed by temperature and wind forecasts, in that order. Thus, it appears that a modest degree of correspondence exists between the relative importance of forecast items and the ability of the public to recall them.

The evidence available from recent studies suggests that the order in which the segments of a forecast are presented has little influence on the overall level of understanding of, or the ability to recall, the forecasts. In fact, the experiments conducted by Wagenaar and Visser (1979) indicate that the recall of individual forecast items does not depend on the serial positions of the items in a message. That is, the first segments reported apparently are not remembered any more accurately than segments presented later in the forecast. The results of these experiments also reveal that the order in which the items appear in a forecast has no influence on the total amount of information that can be recalled from the forecast. On the other hand, the study by Namm (1979) suggests that when a message containing forecasts for several periods is presented in order (i.e., with the forecast for the first period appearing at the beginning of the message), recall is a decreasing function of forecast period.

The placement of significant information, such as a local forecast, within the context of a general weather message is another issue of considerable importance. Wagenaar and Visser (1979) and Gordon and Bestwick (1969) both suggest that the recall of a localized (relevant) forecast is hampered by including forecasts for other regions in the same message. Specifically, they cite psychological evidence that indicates that the inclusion of such largely irrelevant information interferes with the process of remembering the local forecast.

8. Some comments on related topics

As indicated in Section 1, this paper does not contain a comprehensive treatment of forecast terminology and related issues. Nevertheless, we now offer some brief comments on several relevant topics not addressed heretofore. These topics include the impact of verification systems, the role of computer-worded forecasts, the implications of new modes of communication of weather information, and the use of forecasts by the general public.

Verification systems (and related considerations) can have significant impacts on forecast terminology even though the scoring rules embedded in such systems have been designed carefully to avoid undue influences on the forecasters. For example, standard forecast periods are specified across the United States, with the evening/nighttime period extending from 0000 GMT to 1200 GMT. This period corresponds to 7 pm–7 am on the East Coast and to 4 pm–4 am on the West Coast. It should not be surprising, then, that a forecaster's use of the term "evening" may differ from the interpretation of this term adopted by at least some members of the general public. Obviously, it is important to minimize the impacts of such considerations on the use of forecast terminology.

It has been demonstrated that worded forecasts similar in structure and phrasing to forecaster-produced messages can be prepared entirely by computer (Glahn, 1970, 1979; Lönqvist, 1973; Smith, 1974). Such forecasts may be useful to forecasters by identifying events that should be highlighted in a forecast or by providing them with ideas concerning alternative phrasing or wording. Moreover, forecasters can easily edit and/or revise computer-worded forecasts in the context of the NWS Automation of Field Operations and Services (AFOS) system and rapidly disseminate this information to the media and other users. It should be noted, however, that these forecasts suffer from the same deficiencies *vis-à-vis* public interpretation and understanding as worded messages formulated by forecasters. In addition, when prepared centrally, computer-worded forecasts may not be sufficiently sensitive to local conditions (e.g., local climatology, recent weather events), with the result that inappropriate expressions may be employed in some cases.

New modes of communication of weather information are becoming available, and these systems can be expected to have significant impacts on the manner in which weather forecasts are disseminated and presented to the general public. Such impacts might include greater use of pictorial and graphical (as opposed to verbal) displays of weather information. In addition, systems such as teletext that provide an opportunity to "tailor" information to specific locations may allow forecasters to simplify forecasts (e.g., by decreasing the size of the area that must be covered in a single forecast), thereby reducing the amount of information that an individual must recall (or process) for later use. Nevertheless, significant amounts of weather information undoubtedly still will be expressed in the form of worded messages, and such messages necessarily will be subject to at least some of the deficiencies that currently plague public weather forecasts.

In this paper we have been concerned primarily with the composition and interpretation of worded forecasts, rather than with the use of the information contained in such forecasts. Nevertheless, it is the actual or potential use of this in-

formation by members of the general public that provides the basic motivation for preparing such forecasts in the first place and for attempting to improve the way in which they are presented. What is currently known about the use of weather forecasts by the public? The answer, unfortunately, is "very little." Some studies of the so-called requirements of the general public for short-range weather forecasts have been conducted (e.g., see Murphy and Brown, 1982), but very few investigations of the actual use of such forecasts have ever been undertaken. One exception is an interesting study of the use of weather forecasts in making New England beach trip decisions (Adams, 1973), which revealed that individuals tended to distort the meaning of the forecasts to justify their decisions. Clearly, more studies of this type—focusing on important and/or frequent weather-sensitive decisions made by significant segments of the general public—are required to provide more detailed information concerning the manner in which forecasts actually are used. This information is essential if a serious effort is to be made to enhance the level of understanding and increase the usefulness of weather forecasts in general and worded forecasts in particular.

9. Summary and discussion

To facilitate this brief summary and discussion of the topics and issues considered in the previous sections, a list of these topics and some of the principal conclusions that can be drawn from previous work in this area are presented in Table 1. It is evident from the results summarized in Sections 2 through 7 that the information contained in weather forecasts is frequently misinterpreted and/or quickly forgotten by the general public. These misinterpretations apparently are due in part to a lack of agreement among forecasters and between forecasters and the public regarding the meaning of commonly used forecast terms. Such disagreements may arise from misinterpretation of the events being forecast or may be due to overlapping or ambiguous scales defining the appropriate range of usage of each relevant term. The use of verbal expressions rather than equivalent numerical phrases also may add to the variability in the interpretation of forecast terminology.

It appears that the deficiencies in the interpretation of weather forecasts noted in the previous paragraph could be

TABLE 1. An outline of the topics discussed in Sections 2 through 8 and brief descriptions of the principal conclusions. The conclusions are underlined.

Topics and conclusions
<i>Events</i> (considerations in defining)
Nature of variables
Spatial and temporal domains
Predictability
User sensitivity
<i>Terminology</i>
Generic terms— <u>Fairly well understood</u>
Spatial, temporal, and intensity modifiers— <u>Less well understood than generic terms</u>
Numerical scales— <u>Needed to define usage of terms</u>
Forecaster vs. user interpretations— <u>Differences need to be resolved</u>
Regional differences in interpretations— <u>Forecast terminology should be consistent with local usage</u>
<i>Words versus numbers</i>
Relative precision and usefulness
Words— <u>Imprecise; frequently subject to wide ranges of interpretation</u>
Numbers— <u>Precise (possibly too precise in some cases); concise</u>
Degree of quantification of forecasts— <u>Balanced mixture of words and numbers desirable</u>
<i>Uncertainty</i>
Verbal modifiers— <u>Wide ranges of overlapping interpretations</u>
Numerical probabilities— <u>Precise; seldom misinterpreted</u>
Probability of precipitation (PoP) forecasts— <u>Precipitation event frequently misinterpreted; probabilities preferred (to verbal modifiers) by public</u>
<i>Amount of information</i>
Amount desired— <u>Moderate (not too detailed)</u>
Amount recalled— <u>Seven or eight items, regardless of forecast length</u>
<i>Content and format</i>
Content— <u>Temperature and precipitation (including PoP) forecasts most important to public</u>
Format— <u>Order of presentation doesn't affect recall of forecast</u>
<i>Related topics</i>
Severe weather terminology (see Section 3)
Impact of verification systems
Computer-worded forecasts
New modes of communication
Use of forecasts by general public

remedied at least in part by 1) clearly specifying the spatial and temporal domains of the events of interest; 2) establishing precise systems of terminology based on unambiguous scales defining the appropriate usage of terms; and 3) making use of numerical expressions as well as (or instead of) verbal statements whenever possible. The lack of adequate recall of the contents of weather forecasts, noted in Section 6, indicates that the important parts of forecasts must be given greater emphasis and that an effort must be made to increase the meaningfulness of worded messages.

With regard to uncertainty in weather forecasts, it is important to understand that an intimate relationship exists between this uncertainty and the credibility—and therefore the usefulness—of forecasts as viewed by the general public. Efforts to enhance the credibility of forecasts necessarily will require forecasters to treat uncertainty explicitly in their worded forecasts. Probability provides a precise, unambiguous language of uncertainty, and the results of a recent nationwide survey in the United States indicate that the public prefers these probabilities to verbal expressions of uncertainty in precipitation forecasts (see Section 5). Moreover, it should be noted that numerical precipitation probability statements are now included in public weather forecasts in several other countries, including Canada (P. G. Aber, personal communication) and The Netherlands (Daan and Murphy, 1982). Thus, it would seem propitious at this time to investigate, on an experimental basis, the possibility of including probabilities of other significant events in forecasts disseminated to the general public. As an example, the probability that the minimum temperature will be below 32°F could be included in public forecasts during those periods of the year that frost damage to agricultural crops and ornamental plants presents a potential hazard (e.g., see Murphy and Winkler, 1979).

In summary, the information currently available regarding the composition and interpretation of weather forecasts is incomplete, since the studies that have been undertaken concerning these topics have been limited in both number and scope. Moreover, many of these investigations have suffered from serious deficiencies. For example, most such studies have attempted to address a large range of questions and thus have succeeded, at best, in obtaining answers to only some of them. Furthermore, many experiments and surveys have not been designed adequately, with the result that they may not accurately reflect the public's understanding of forecast terminology. Thus, to fully answer some of the questions regarding the composition and interpretation of worded forecasts posed in this paper, additional studies are required. These studies should be designed and evaluated carefully and should be limited to specific and well-defined issues (see Section 10). Evidence from such studies would be invaluable in determining what changes in current practices related to forecast composition and presentation are required to increase public understanding and use of weather forecasts.

10. Recommendations

This section contains a set of recommendations regarding

steps that we believe should be taken to raise the level of understanding and enhance the usefulness of worded forecasts. These recommendations are organized under four headings: 1) studies of public understanding, interpretation, and use; 2) management practices; 3) forecaster training and education; and 4) public education.

a. Studies of public understanding, interpretation, and use

More detailed studies concerning public understanding, interpretation, and use of worded forecasts must be undertaken. It should be emphasized that the information provided by these studies is required before other appropriate actions (e.g., changes in management practices, initiation of training programs) can be taken to improve the current situation. Moreover, such investigations should be based on carefully designed studies (surveys, case studies, etc.) of representative samples of relevant segments of the general public. Specific topics that require investigation include: 1) the interpretation of terms and expressions in forecasts (including regional differences); 2) differences in interpretation between forecasters and the public; 3) preferences for verbal or numerical expressions (including expressions of uncertainty); 4) the preferred length, content, and format of forecasts; 5) the ability of recipients to process and recall expressions in worded forecasts; and 6) the actual use of information contained in such forecasts to make decisions in specific situations. Studies of the latter are needed, *inter alia*, to provide some evidence that future changes in terminology (or other aspects of the forecasts) have raised the level of public understanding and/or have been translated into tangible benefits.

b. Management practices

Perhaps the most important recommendation that can be made under this heading is to suggest that an *experimental approach* be adopted to the entire process of forecast composition and dissemination. This approach would involve the extensive use of operational trials in which new terminology, modes of expression, formats, etc., would be employed in the worded forecasts provided to selected segments of the public on an experimental basis. The feasibility of such trials should be enhanced by the existence of new modes of communication and presentation of weather information (e.g., teletext). These trials must be followed by carefully designed studies of public acceptance, understanding, and use of the experimental forecasts. Specific steps that could be taken at this time (but might require some modification after the results of surveys, operational trials, etc., become available) include the establishment of guidelines to ensure the consistent usage of spatial, temporal, and intensity modifiers among forecasters and the specification of numerical scales for all such verbal phrases. In addition, current management prescriptions should be relaxed in order to allow the investigation of other modes of expression of forecasts, including the possibility of describing uncertainty in forecasts of events other than precipitation occurrence in numerical as well as verbal terms.

c. Forecaster training and education

Forecaster training and education related to the composition

and understanding of worded forecasts should focus on several issues. Forecasters, in general, need a greater familiarity with, and appreciation of, the public's interpretation and understanding of the terminology currently employed in weather forecasts. Moreover, efforts should be made to ensure that such terminology is used in a consistent manner, both by individual forecasters over time and among different forecasters. In addition, the forecasters should understand fully and continually keep in mind the precise definitions of the relevant events during the processes of formulating the forecasts and of composing the worded messages. It might also be beneficial to formulate some guidelines and training materials related to the content, length, and format of worded forecasts. The development of such materials and their use in training sessions should be given careful consideration in any effort designed to improve current educational and training programs for forecasters (e.g., see Doswell *et al.*, 1981).

d. Public education

With regard to public education, much greater efforts must be made to enhance the public's understanding and proper interpretation of the terminology used in weather forecasts. This effort might begin with the provision, on a regular and continuing basis, of clear definitions of both the forecast terms themselves and the events to which these terms are attached. Both generic terms and verbal modifiers should be included in this program. Moreover, efforts should be made to familiarize the public with the reasons for uncertainty in weather forecasts, the need to include expressions of uncertainty in such forecasts, and the desirability and means of taking this information into account in making weather-sensitive decisions.

In conclusion, unless a genuine effort is made to enhance the understandability and usefulness of worded forecasts, this mode of communication of weather information will continue to act as a serious impediment to the provision of the relatively detailed and high quality information that the current forecasting system can provide.

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announcements (continued from page 10)

NOAA seeking user requirements for Landsat cloud data

Since 1972, National Aeronautics and Space Administration (NASA) has operated the Landsat (until 1975 called the Earth Resources Technology Satellite or ERTS) spacecraft, providing images of the earth at 80 m resolution in four spectral bands: 0.5–0.6; 0.6–0.7; 0.7–0.8; and 0.8–1.1 μm . Since the primary objective has been studying the land masses, predominately cloudy scenes and most ocean areas have been ignored. On 31 January 1983, the new Landsat 4 system will be declared operational (rather than research and development) and will be turned over to the National Oceanic and Atmospheric Administration (NOAA) for management. Data can be obtained by any user either from the archive, which is operated for NOAA by the Department of the Interior at their Earth Resources Observation Satellite (EROS) Data Center in Sioux Falls, S.D., or by special order, in which case the purchaser specifies the time and location for the coverage desired.

NOAA plans the routine collection of a "basic data set" designed to satisfy the requirements of as much of the user community as possible. The meteorological community, particularly those involved in cloud studies, has not been well served in the past because of the preoccupation with surface observations. Now, however, NOAA plans to include meteorological requirements in the basic data set as much as possible (without forgetting the land community's needs) and is soliciting comments from interested atmospheric science users on the subject. Details of requirements may be submitted to Daniel J. Cotter, Director,

User Affairs Division, NOAA/NESS/Sx32, Washington, D.C. 20233. Requirements must be as specific as possible, and should include the objectives of the investigation, the amount of data that would be useful, global areas of interest, and cloud conditions of interest, such as type and percent of coverage. A new price list is also available from Cotter.

New dumping site assessment report available

The Western Gulf of Mexico Dumping Site Assessment Report has been issued as National Oceanic and Atmospheric Administration (NOAA) Dumpsite Evaluation Report 81-2. The report examines the impact of biological sludge dumping at a deepwater site in the Gulf of Mexico. This dumping ended in late 1977. The NOAA studies consisted of chemical characterization and biological tolerance studies in the laboratory and site characterization and waste tracking studies in the field. The results indicate that the overall environmental consequences of the discharge of the biosludge were probably negligible. Copies of this report, as well as Dumpsite Evaluation Report 81-1 on the 106-Mile Site are available from: Office of Marine Pollution Assessment, NOAA/OMPA, MP2, Rockwall Bldg.—Rm. 320, Rockville, Md. 20852.

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