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MISINTERPRETATIONS OF PRECIPITATION PROBABILITY FORECASTS

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EDITOR'S NOTE

I am grateful to the authors for giving me permission to publish their work before it gets into the formal literature. The subject is an important one for all NWS forecasters.

Certainly the sample of persons used in this study can be questioned as being unrepresentative, but the authors discuss this limitation.

This technical memorandum has been reviewed and is approved for publication by Scientific Services Division, Western Region.

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ABSTRACT

Previous studies have suggested that the general public misinterprets probability of precipitation (PoP) forecasts, leading some meteorologists to argue that probabilities should not be included in public weather forecasts. Upon closer examination, however, these studies prove to be ambiguous with regard to the nature of the misunderstanding. Is the public confused about the meaning of the probabilities or about the definition of the event to which the probabilities refer? If event misinterpretation is the source of the confusion, then elimination of the probabilities would not reduce the level of misunderstanding.

The present paper summarizes a study of seventy-nine residents of Eugene, Oregon who completed a questionnaire designed to investigate their understanding of an attitude toward precipitation probability forecasts. Results indicate that the event in question frequently is misunderstood, with both traditional precipitation forecasts and PoP forecasts experiencing similar levels of event misinterpretation. On the other hand, the probabilities themselves are well understood. Moreover, most respondents revealed a preference for the use of probabilities to express the uncertainty inherent in precipitation forecasts. Although the sample size was limited, the results of this study strongly support the inclusion of probabilities in public forecasts of precipitation occurrence. The paper concludes with a brief discussion of some implications of these results for operational weather forecasting.

I. INTRODUCTION

Precipitation probability forecasts offer two important advantages vis-a-vis traditional precipitation forecasts in which uncertainty is expressed in terms of verbal qualifiers such as "chance" and "likely". First, probability forecasts provide quantitative information needed by users to make rational decisions in uncertain situations, and this information can have considerable economic value. Second, probabilities express the uncertainty inherent in forecasts in a precise, unambiguous manner, whereas the crude measure of uncertainty characterized by traditional forecast terminology is subject to a wide range of misinterpretations (e.g., Bickert, 1967; Lichtenstein and Newman, 1967; Abrams, 1971; Rogell, 1972).

In 1965, these advantages prompted the National Weather Service (NWS) to initiate a nationwide program of probability of precipitation (PoP) forecasting. As a result, precipitation probabilities have been routinely appended to public weather forecasts in the U.S. for almost fifteen years.

Although the PoP forecasting program initially encountered some resistance from both forecasters and the public, it is now generally agreed that these probabilities are an important and integral part of NWS's public forecasts (e.g., Bickert, 1967; American Telephone and Telegraph Company, 1971; Murphy and Winkler, 1974).

Notwithstanding the inherent advantages of PoP forecasts, some meteorologists have argued that the general public does not understand these forecasts and that, as a result, the potential benefits of PoP forecasts are seldom realized. These arguments have led some individuals in the meteorological community to conclude that PoP forecasts should no longer be disseminated to the public. Moreover, such arguments have tended to discourage the extension of probability forecasts to other significant weather events.

To support their beliefs, critics of PoP forecasts frequently point to the results of several studies in which selected individuals were asked to interpret a PoP forecast such as "the probability of precipitation today is 30%" (e.g., see Rogell, 1972, p.128). These studies indicate that many, even most, respondents do not know that a PoP forecast represents the probability of occurrence of measurable precipitation at a point in a specified period of time. This result has been taken to mean that the general public does not understand PoP forecasts as well as it understands traditional precipitation forecasts. However, to the authors' knowledge, none of the questionnaires used in these studies investigated the respondents' understanding of traditional forecasts.

Misunderstanding of PoP forecasts could involve misinterpretation of the event (e.g., precipitation at a point versus precipitation in an area) or misinterpretation of the probability associated with the event, or both (Murphy, 1977). All studies to date have dealt exclusively with event misinterpretation. Thus, it is impossible to say whether misunderstanding of PoP forecasts is due primarily to event misinterpretation or to probability misinterpretation. Clearly, it would be inappropriate to reject PoP forecasts without determining the level of understanding for these forecasts vis-a-vis that for traditional precipitation forecasts and without identifying the primary source of any misunderstanding.

This paper describes a study designed to investigate the extent of event and probability misunderstanding of PoP forecasts among members of the general public and the amount of event misinterpretation of traditional forecasts of precipitation occurrence. Section 2 briefly discusses the nature of the study, including questionnaire design, content, and administration and the sample of subjects who participated in the study. Responses to the various questions are summarized in Section 3 and discussed in Section 4. Section 5 consists of a brief summary and conclusion, including some recommendations for future research and a discussion of the implications of the results of this study for operational procedures and practices in weather forecasting.

II. NATURE OF STUDY

The results presented in this paper are based primarily on responses to a questionnaire administered to 79 individuals in Eugene, Oregon. The questionnaire contained eleven questions (or items) concerning the interpretation and use of precipitation probability forecasts. These questions are reproduced in the Appendix. An earlier version of this questionnaire was pre-tested in several locations (Albany, NY; College Station, TX; San Jose, CA; Worcester, MA), and some results from these pre-tests also will be reported.

The first item was an open-ended question asking respondents to interpret a typical PoP forecast in their own words, and it appeared by itself on the first page of the questionnaire. The other ten items were multiple-choice questions. Two questions (5 and 6) dealt with the interpretation of probabilities, while two items (3 and 7) were concerned with the interpretation of precipitation events. The remaining questions, of lesser importance in this study, explored issues such as the perceived reason for uncertainty in precipitation forecasts, respondents' preferences for the mode of expression of precipitation forecasts, and their opinions regarding the quality of hypothetical PoP forecasts. Some questions had correct and incorrect answers, whereas other items asked for the respondents' opinions or preferences.

The participants in the study were 50 females and 29 males who responded to an advertisement placed in the University of Oregon campus newspaper. The advertisement did not mention the topic of the precipitation probability questionnaire or the subjects of several other questionnaires that the participants also completed. Although most of the respondents were college students, they should not be considered to be representative (in a statistical sense) of any particular population.

The questionnaire was administered to separate groups of about 40 individuals on each of two consecutive days in May 1979. The participants were paid $5 each for approximately 1 1/2 hours of work involving questionnaire completion. The precipitation probability questionnaire was self-paced and took about ten minutes to complete on the average. The set of instructions was very brief:

> "Numbers play a vital role in the communication of weather information to the public. For example, rain forecasts are generally expressed in terms of probabilities (e.g., the probability of precipitation today is 30%). This task relates to your interpretation and use of precipitation probability forecasts."

III. RESULTS OF STUDY

Results are reported in the order in which the questions appeared in the questionnaire, except that the responses to questions concerned with related issues are considered together.

Interpretation of Pop forecast. The first item was an "open-ended" question asking each participant to "write down what you think the forecast 'the probability of precipitation today is 30%' means." The subjects were encouraged to make their answers as specific as possible. Of the 76 respondents who answered this question, more than 80 (62) gave a numerical interpretation, including 58% (44) who simply restated the probability (e.g., "the likelihood of rain is 3 in 10") and 24% (18) who provided relative frequency interpretations (e.g., "30 out of 100 days like these, it rains"). The remaining 14 subjects (18%) gave non-numerical or verbal interpretations (e.g., "mild chance of rain foreseen").

Twelve of the 44 respondents who restated the probability numerically, as well as twelve of the 14 subjects who gave verbal interpretations, also provided supplemental information in their responses to this question. The two most frequent types of comments related to sky cover or cloudiness (e.g., "I wouldn't expect a bright, sunny day") and the frequency or duration of precipitation (e.g., "it might rain for a little while, but not all day"), in that order. Other types of supplemental responses included remarks concerning the amount of precipitation (e.g., "it might rain for a little while, but not all day"), in that order. Other types of supplemental responses included remarks concerning the amount of precipitation (e.g., "it's not likely to rain, but if so, not too much"), the areal coverage of precipitation ("it is going to rain in 30% of the area in 24 hours"), and the climatological probability of precipitation with particular reference to Oregon (e.g., "in Oregon, it will rain"). None of the 18 subjects who gave a relative frequency interpretation provided any supplemental comments. Evidently, they believed that such an answer was sufficient in itself. On the other hand, almost all (12 of 14) of the subjects who gave verbal interpretations provided additional information of the types indicated above.

Reason for inclusion of probabilities. The second question was concerned with the reason that weather forecasters use numerical probabilities in precipitation forecasts (A - because the amount of precipitation is difficult to measure, B - in order to make forecasts difficult to understand, C - so that their forecasts will never be completely wrong, D - in order to describe their uncertainty regarding the occurrence of precipitation). Of the 78 subjects who answered this question, 72% (56) selected D, the correct answer. Of the remaining 22 respondents, 15 chose A and 7 chose C. Thus, a substantial majority of the respondents understood the reason that weather forecasters use probabilities in precipitation forecasts.

Event interpretation. Items 3 and 8 asked subjects to interpret the event in a Pop forecast of 30% and in a traditional forecast of "precipitation is likely today." The four possible answers to each question defined the event as (A) the occurrence of precipitation during a portion of the forecast period, (B) the occurrence of precipitation at a particular point in the forecast area, (C) the occurrence of precipitation somewhere in the forecast area, and (D) the fraction of the forecast area expected to experience precipitation if precipitation occurs somewhere in the area. The two questions only differed in the manner in which uncertainty was expressed, numerically in Question 3 and verbally in Question 8. The correct answer in either case is B, since both PoP forecasts are defined in terms of the occurrence of measurable precipitation at a point in specified period of time.

Only 39% (31) of the 79 respondents chose the correct answer to Question 3, whereas 56% (44) selected C. Thus, a majority of the participants believed that a PoP forecast is an area forecast. The fraction of the sample correctly interpreting a traditional forecast (Question 8) was even smaller. Only 28% (22 of 78) selected B, whereas 44% (34) chose C and 14% (11) each selected A and D. Misinterpretation of traditional forecasts appears, therefore, to be at least as great as that of PoP forecasts.

Interpretation of probabilities. Questions 5 and 6 explored respondents' interpretations of the numerical probabilities in PoP forecasts. With regard to Question 5, 65% (51) of the 79 respondents chose the correct answer (B). The most popular incorrect answer ("on 10 occasions like this one, precipitation will occur exactly 2 times") was selected by 21% (17) of the sample. This response, too, would be correct if "exactly" was replaced by "approximately, since it is only in the limit that the probability and relative frequency must be equal. However, this subtle difference is undoubtedly not obvious to many members of the general public, which explains the fairly frequent selection of this alternative. The correct response to Question 6 was expressed in two equivalent forms ("80% chance of precipitation" and "20% chance of no precipitation"), and approximately one-half of the respondents received each of the two possible wordings. Overall, the responses to this question indicate that 90% (71) of the participants chose the correct response (C), with 93% (38) choosing C when the 80% expression was used and 87% (33) selecting C when the 20% definition appeared in the statement. Thus, the indirect response ("20% chance of no precipitation") did not result in a significant change in the fraction of subjects who chose the correct response.

Usefulness of alternative modes of expression of precipitation forecasts. The fourth and seventh items asked respondents about the usefulness of alternative forecast formats. Question 4 revealed considerable disagreement about the precipitation event for which subjects would like to have forecasts. Only approximately one-third of the sample preferred a point precipitation forecast, whereas slightly more than one-half of the respondents preferred either fraction-of-the-time or area precipitation forecasts.

Much more agreement existed with regard to alternative modes of expression of uncertainty. Responses to Question 7 revealed that two-thirds of the sample preferred a statement containing a numerical probability, whereas only one-fourth preferred a verbal expression of uncertainty. In Item 9, respondents indicated their degree of agreement (or disagreement) with several statements regarding preferences for modes of expression and understanding of PoP forecasts. Overall, substantial agreement (2.5 on a scale from 1, strongly agree, to 7, strongly disagree) was noted with a statement indicating a preference for having precipitation forecasts expressed in probabilistic terms.

Perceived quality of PoP forecasts. The final two questions solicited assessments of the quality of PoP forecasts in December and July, respectively, as a function of the forecast probability on a day on which precipitation actually occurred. For both months, a monotonic relationship existed between perceived forecast quality and probability of precipitation (i.e., the greater the probability, the better the forecast). A slight tendency was noted for respondents to "grade" the forecasts more extremely in winter than in summer. Specifically, high (low) probabilities on a December day with precipitation are represented to be better (worse) forecasts than the same probabilities assigned to a July day with precipitation.

IV. DISCUSSION OF RESULTS

Responses to the open-ended question about the meaning of a PoP forecast of 30% were remarkable in several respects. First, very few respondents answered this question with either "I don't know" or a response that could be considered fallacious. In fact, with the exception of three individuals who did not answer the question, all participants provided responses that could readily be classified as either numerical or verbal interpretations of the probability of precipitation. Moreover, since positive relationships generally exist between the probability of occurrence of measurable precipitation and the amount of cloudiness, the frequency or duration of precipitation, and the precipitation amount or areal coverage, the supplemental information offered by many respondents demonstrates a good understanding of the relationships between the precipitation probability and other meteorological events. In addition, these responses and supplemental comments indicated that the participants in the study provided thoughtful and careful responses to our questions.

The answers to the first question also suggest that a large majority of the sample is ready and willing to accept numerical probabilities in precipitation forecasts. The fact that less than 20% of those respondents who gave a numerical interpretation provided supplemental information indicates that most such individuals believed that a numerical interpretation is sufficient in itself. On the other hand, those respondents who recorded a verbal interpretation of the precipitation probability generally felt a need to supplement this statement, suggesting that such an interpretation is incomplete. These results provide strong evidence in support of the inclusion of a numerical description of uncertainty in forecasts of precipitation occurrence.

Responses to Questions 3 and 8 revealed that more respondents interpreted a precipitation forecast as an area forecast than as a point forecast, regardless of whether uncertainty was expressed numerically or verbally. In particular, 39% of the sample gave the correct interpretation of a PoP forecast (Question 8), and 28% of the respondents chose the correct interpretation of a traditional precipitation forecast (Question 3). The difference between these proportions (.39 and .28) is not statistically significant. Further, the answers to Questions 3 and 8 appear to be reasonably consistent. Of the 56 respondents who answered Question 8 incorrectly, 40 (71%) also gave an incorrect answer to Question 3, and of the 22 respondents who answered Question 8 correctly, 14 (64%) gave a correct answer to Question 3. Thus, those individuals who misinterpret PoP forecasts also tend to misinterpret traditional precipitation forecasts as well. The presence of a considerable amount of event misinterpretation also is supported by the results of the results of the pre-tests, which included a question similar to Question 8. Specifically, 51% (43%) of the participants in the pre-tests (n=236) chose a point (an area) interpretation of a PoP forecast. The results of the present study indicate that the amount of event misinterpretation of traditional precipitation forecasts is at least as great as that of PoP forecasts.

Two complementary explanations can be offered for such misinterpretations: (1) the respondents do not know whether official NWS forecasts, expressed either in traditional or PoP format, relate to a point or an area (or some other event); (2) the respondents do not understand the difference between a point forecast and an area forecast. Since official NWS forecasts seldom indicate the proper interpretation of the events of concern, ignorance on the part of some members of the public would hardly be surprising. Moreover, many individuals may not understand the difference between a point forecast and an area forecast. In any case, it is clear that a concerted effort is needed to educate the public concerning the proper interpretation of NWS forecasts.

Additional evidence of confusion between point and area forecasts may be found in the fact that 30% of the participants in the study indicated a preference for an area probability forecast in Question 4. Since the activities of most individuals generally take place over an area that is small relative to the size of the local forecast area, it is difficult to believe that an area forecast would actually be more useful than a point forecast. The fact that an additional one-fourth of the sample preferred a fraction-of-the-period forecast suggests that it may be desirable to supplement PoP forecasts and traditional precipitation forecasts with information concerning the character and/or duration of precipitation events.

Responses to Questions 5 and 6 indicate that probability misinterpretation is much less common than event misinterpretation. Almost two-thirds of the respondents chose the correct response to Question 5 and 90% of the sample selected the correct response to Question 6. Most incorrect responses in Question 5 involved an answer that could be considered to be correct in the limit (see Section 3). In the pre-tests, 70% and 96% of the total sample (n=235) chose the correct responses to questions similar to Questions 5 and 6, respectively. Thus, although it would be desirable to inform the public about the meaning of the probabilities in PoP forecasts, the results of this study indicate that the primary emphasis of any educational program should be to reduce the amount of event misinterpretation.

In responding to Question 7, two-thirds of the sample considered a numerical expression of uncertainty in precipitation forecasts more useful than alternative modes of expression. In fact, a majority of respondents preferred a numerical expression of uncertainty regardless of the interpretation that they gave to PoP forecasts on Question 1 (verbal, numerical/restatement, or numerical/relative frequency). Responses to Question 9 indicated substantial agreement with the statement expressing a preference for probabilistic precipitation forecasts. Specifically, more than 70% of the sample (55 out of 77) recorded responses that can be characterized as representing modest to strong agreement with this statement.

V. CONCLUSIONS AND RECOMMENDATIONS

The primary problem that members of the general public face in interpreting forecasts of precipitation occurrence is understanding the event of concern. This problem is not at all aggravated (and may be somewhat relieved) by using probabilities rather than words to express uncertainty. Specifically, we found little evidence that individuals are confused by numerical probabilities. Thus, it seems reasonable to conclude that the level of misinterpretation of precipitation forecasts will <u>not</u> be reduced by eliminating probabilities from such forecasts. In fact, this course of action could lead to a higher level of misinterpretation, especially if verbal qualifiers are used to describe the uncertainty inherent in precipitation forecasts.

A substantial majority of the participants in this study, when asked to answer an open-ended question concerning the meaning of a typical PoP forecast, responded with a numerical rather than a verbal description. When asked to select the form of a precipitation forecast that would be most useful to them, two-thirds of the sample expressed a preference for a numerical precipitation probability forecast whereas only one-fourth of the respondents indicated a preference for a verbal expression of uncertainty. In short, participants not only understood but strongly preferred forecasts of precipitation occurrence in which uncertainty is expressed in probabilistic terms.

In light of these results, we offer the following recommendations for further research:

(1) A survey of the general public addressing the present issues should be undertaken. It should involve a sufficiently large and representative sample to allow firm conclusions to be drawn for the U.S. population as a whole. The questionnaire or interview

schedule used in the survey must be clearly and carefully worded, should differentiate between event and probability misinterpretation of PoP forecasts, and must investigate event misinterpretation of traditional precipitation forecasts.

(2) The National Weather Service should initiate a program designed to inform and educate the general public about the correct meanings of the terms used in weather forecasts, with particular reference to the events to which the forecasts pertain.

Despite the limitations of the present study and the need to validate the results presented here with a larger, more representative survey of the general public, we believe that these results have important implications for operational procedures and practices in weather forecasting:

(1) The inclusion of probabilities in forecasts of precipitation occurrence provides potentially useful information to users of such forecasts. The evidence currently available does not support the contention that misinterpretations of precipitation forecasts are due to the presence of probabilities in these forecasts. Since the sample studied here not only understands but also strongly prefers the numerical expression of uncertainty in forecasts, no rational basis appears to exist for eliminating PoP statements in public weather forecasts.

(2) The results of this study, in particular respondents' preferences for probabilistic forecasts, suggest that serious consideration should be given to the inclusion of probabilities of other significant weather events in public forecasts. Initially, such forecasts could be disseminated on a trial basis, followed by a study of the public's understanding, acceptance, and use of the forecasts. In this regard, the case for an operational program of probabilistic temperature forecasting has been described recently by Murphy and Winkler (1979).

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Appendix

Questionnaire - Precipitation Probability Forecasts

1. Please write down what you think the forecast "the probability of precipitation today is 30%" means. Be as specific as you can.

On the following questions, please circle the letter corresponding to the answer you select:

2. Which one of the following answers most closely corresponds to the reason that weather forecasters use numerical probabilities in their precipitation forecasts?

   A. Because the amount of precipitation is difficult to measure

   B. In order to make the forecasts difficult to understand

   C. So that their forecasts will never be completely wrong

   D. In order to describe their uncertainty regarding the occurrence of precipitation

3. A precipitation probability forecast of 30% means that:

   A. Measurable precipitation will occur during 30% of the forecast time period, and not occur during 70% of that time.

   B. At any one particular point in the forecast area (for example, at your house) there is a 30% chance that there will be measurable precipitation and a 70% chance that there will be no measurable precipitation during the forecast period.

   C. There is a 30% chance that measurable precipitation will occur somewhere (i.e., in at least one place) in the forecast area during the forecast period, and a 70% chance that it will not occur anywhere in the area during the period.

   D. If precipitation occurs during the forecast period, 30% of the total area will experience measurable precipitation and 70% of the area will not have any measurable precipitation.

4. In making routine decisions that are influenced by the occurrence of precipitation, which of these five types of probability forecasts would be most useful to you? (Note that the first four of these alternatives correspond to the alternatives given in question 3.)

B. The probability that precipitation will occur <u>at any one particular point</u> in the forecast area during the day.

C. The probability that precipitation will occur <u>somewhere</u> in the forecast area during the day.

D. The proportion of the forecast area expected to receive precipitation, given that precipitation occurs somewhere in the area.

E. The proportion of the forecast area expected to receive some precipitation.

5. A precipitation probability forecast of 20% means that:

A. On 10 occasions like this one, precipitation will occur <u>exactly</u> 2 times.

B. The odds against precipitation are 8 to 2.

C. Precipitation will not occur.

D. The forecaster has no idea whether or not precipitation will occur.

6. A precipitation probability forecast of 80% means that:

A. The odds in favor of precipitation are 80 to 1.

B. On 100 occasions like this one, precipitation will occur 20 times.

C. There is an 80% chance of precipitation.

D. If precipitation occurs, the forecaster was right.

(<u>Note</u>: On approximately one-half of the questionnaires alternative response 6.C was expressed as "there is a 20% chance of no precipitation.")

7. Suppose that the forecaster feels that the odds in favor of precipitation are 3 to 1. Which of the following forecasts would generally be <u>most useful</u> to you?

A. The forecaster says that precipitation is likely.

B. The forecaster predicts that precipitation will occur.

C. The forecaster says that she or he is uncertain whether or not precipitation will occur.

D. The forecaster says that there is a 75% chance that precipitation will occur.

8. Suppose the precipitation forecast states that "precipitation is likely today." This forecast means that:

A. Precipitation is likely throughout the day somewhere in the forecast area.

B. Precipitation is likely to occur at any one particular point in the forecast area sometime during the day.

C. Precipitation is likely to occur somewhere in the forecast area during the day.

D. Given that precipitation occurs somewhere in the forecast area during the day, it is likely to occur over the entire area.

9. Indicate your agreement with the following statements:

	strongly agree	strongly disagree
A. I prefer to have precipitation forecasts given in probabilistic terms.		
B. A major problem with precipitation probability forecasts is that people don't understand the event that's being forecast (i.e., don't know which of the alternatives in question 3, above, the forecaster really means).		
C. A major problem with precipitation probability forecasts is that people don't understand probabilities very well.		
D. A major problem with precipitation probability forecasts is that the forecasters are wrong too often.		

10. One morning in December you hear the following forecast: "The probability of precipitation today is X%". By noon, it's raining. For each of the following values of X, rate how good the forecast was:

The the forecast was:

If the forecaster said the probability was:	very bad	adequate	very good
0%			
10%			
50%			
90%			
100%			

11. One morning in July you hear the following forecast: "The probability of precipitation today is X%". By noon, it's raining. For each of the following values of X, rate how good the forecast was:

Then the forecast was:

If the forecaster said the probability was:	very bad	adequate	very good
0%			
10%			
50%			
90%			
100%			

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