Communicating uncertainty in weather forecasts: Results from a survey of the U.S. public

Rebecca E. Morss
Jeffrey Lazo, Julie Demuth

National Center for Atmospheric Research
(Societal Impacts Program)
Overview of talk

- Motivation, approach
- Nationwide survey to assess the public’s views on
  - everyday weather forecasts
    (Lazo et al., BAMS, in preparation)
  - weather forecast uncertainty
  - weather forecast uncertainty information
    (Morss et al., Weather and Forecasting, in press)
- Ongoing and future work
- Discussion
Motivation

- Weather forecasting community wants to *provide useful weather forecasts* and *communicate forecast information* effectively.
- Doing so requires *understanding users’ forecast information needs, perceptions, interpretations, preferences, and uses*.
- In context of NWS mission → audience for NWS forecasts includes intermediaries, specific user groups, and *public*. 
Motivation: Communicating uncertainty

- Weather forecasts are inherently uncertain …
  And many users realize forecasts are imperfect …
  But most current weather forecast information provided to the public is deterministic

- Interest in providing uncertainty information …
  But it is challenging to do so effectively

- Community and NWS attention, e.g.:
  - National Research Council study (2006)
  - AMS Ad Hoc Committee on Uncertainty Forecasts
  - NOAA/NWS Forecast Uncertainty Steering Team
(Winter weather – December 2007)
Gaps between forecasts generated and those received and used ⇒

• Why don’t people understand forecasts?

• Why don’t people use forecasts?
Gaps between forecasts generated and those received and used ⇒

- Why don’t people understand forecasts (the way we think they should)?
- Why don’t people use forecasts (the way we think they should)?
Gaps between forecasts generated and those received and used ⇒

- How do people perceive and interpret forecasts?
- How do people use forecasts?
- How can we improve and communicate forecasts in ways that benefit interpretation and use?

*Use social science / interdisciplinary research techniques*

*Frame from societal / use perspective*
Study objectives

• To help the meteorological community in effectively providing weather forecast information, including uncertainty
  – by building empirical knowledge about what people think, want, use, etc.
  – starting with fundamental questions, “everyday” weather

• This understanding can help guide future work, aid user-oriented product development efforts
Study design and data

- Nationwide survey of U.S. households, implemented on Internet in November 2006
- Controlled-access, web-based implementation, with respondents provided by survey sampling company
- Analysis based on N=1465 respondents
- Respondent population is geographically diverse and similar to U.S. public, but somewhat older, wealthier, more educated
Survey questions

- Survey questions: some based on previous research, some to explore unaddressed aspects of forecast uncertainty communication
- Survey developed iteratively, pre-tested
- Survey questions on people’s
  - sources, perceptions, uses, and value of weather forecast information
  - perceptions of, interpretations of, and preferences for weather forecast uncertainty information
  - use of weather forecast uncertainty information
  - “weather salience” (A. Stewart)
  - demographics
<table>
<thead>
<tr>
<th>Source</th>
<th>Rarely or never</th>
<th>Once or more a month</th>
<th>Once a week</th>
<th>Two or more times a week</th>
<th>Once a day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial or public radio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telephone (dial-in) weather information source</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newspapers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cable TV stations (e.g., CNN, The Weather Channel)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local TV stations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Friends, family, co-workers, etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cell phone, personal desk assistant (PDA), pager, or other electronic device</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other webpages</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National Weather Service (NWS) webpages</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOAA Weather Radio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
How often do you get weather forecasts from the sources listed below?

- Local TV: 30 times per month
- Cable TV: 28 times per month
- Commercial or public radio: 18 times per month
- Other webpages: 14 times per month
- Newspapers: 11 times per month
- NWS webpages: 5 times per month
- Friends, family, co-workers, etc.: 5 times per month
- NOAA Weather Radio: 5 times per month
- Telephone weather info source: 1 time per month
- Cell phone, PDA, pager, etc.: 1 time per month

Average person gets weather forecasts 115 times per month.

With over 226 million U.S. adults, this totals to over 300 Billion forecasts accessed a year.
How important is it to you to have this information as part of a weather forecast?

**Most important**

– *Precipitation: When, where, type, chance (PoP)*
  ~70% of responses: very or extremely important
– *High temperature*
– *Amount of precipitation*
– *Low temperature*
– Wind speed
– Humidity
– Cloudiness
– Wind direction

**Least important**
Uncertainty research questions

- Do people infer uncertainty into deterministic forecasts? If so, how much? **PERCEPTIONS**
- How much confidence do people have in different types of weather forecasts?
- How do people interpret a type of uncertainty forecast that is already commonly available: Probability of Precipitation (PoP) forecasts? **INTERPRETATIONS**
- To what extent do people prefer to receive deterministic forecasts vs. those that express uncertainty?
- In what formats do people prefer to receive forecast uncertainty information? **PREFERENCES**
Suppose the forecast high temperature for tomorrow for your area is 75°F.

What do you think the actual high temperature will be?

<table>
<thead>
<tr>
<th>Temperatures</th>
<th>Percent of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>75°F</td>
<td>4.5%</td>
</tr>
<tr>
<td>74-76°F (± 1°F)</td>
<td>23%</td>
</tr>
<tr>
<td>73-77°F (± 2°F)</td>
<td>41%</td>
</tr>
<tr>
<td>70-80°F (± 5°F)</td>
<td>22%</td>
</tr>
<tr>
<td>65-85°F (± 10°F)</td>
<td>5%</td>
</tr>
<tr>
<td>Other</td>
<td>2%</td>
</tr>
</tbody>
</table>
How much confidence do you have in forecasts …?

Confidence: Very low Low Medium High Very high
How much confidence do you have in forecasts … ?

- 1-day temperature
- 1-day chance of precip
- 1-day amount of precip

Percent of Respondents
Interpretation of PoP

- Builds on previous related work by Murphy et al. (1980), Gigerenzer et al. (2005), others
- Asked all respondents about 2 PoP forecasts:
  - “There is a 60% chance of rain tomorrow”
  - “Rain likely tomorrow”
- Two versions of each question:
  - Closed-ended: ~90% of respondents
  - Open-ended: ~10% of respondents ("Explain in your own words")
Suppose the forecast is “There is a 60% chance of rain tomorrow”. Which of the options do you think best describes what the forecast means?

<table>
<thead>
<tr>
<th>Response option (N=1330)</th>
<th>Percent of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>It will rain tomorrow in 60% of the region.</td>
<td>16%</td>
</tr>
<tr>
<td>It will rain tomorrow for 60% of the time.</td>
<td>10%</td>
</tr>
<tr>
<td>It will rain on 60% of the days like tomorrow.*</td>
<td>19%</td>
</tr>
<tr>
<td>60% of weather forecasters believe that it will rain tomorrow.</td>
<td>23%</td>
</tr>
<tr>
<td>I don’t know.</td>
<td>9%</td>
</tr>
<tr>
<td>Other (please explain)</td>
<td>24%</td>
</tr>
</tbody>
</table>

* Technically correct interpretation, according to how PoP forecasts are verified (Gigerenzer et al. 2005)
PoP: Open-ended interpretations

- Many responses repeat PoP, without clarification
- Few offered options from multiple choice version
- Variety of other responses, some from “personal” or “use” perspective
- Most people don’t know technically correct definition of PoP — 60% chance of what?
  - But asking about PoP from a meteorological perspective may have limited relevance …
  People must infer what the forecast means for their interests
Uncertainty research questions

- Do people infer uncertainty into deterministic forecasts? If so, how much? *PERCEPTIONS*
- How much confidence do people have in different types of weather forecasts? *INTERPRETATIONS*
- How do people interpret a type of uncertainty forecast that is already commonly available: Probability of Precipitation (PoP) forecasts? *INTERPRETATIONS*
- To what extent do people prefer to receive deterministic forecasts vs. those that express uncertainty? *PREFERENCES*
- In what formats do people prefer to receive forecast uncertainty information? *PREFERENCES*
Suppose you are watching the local evening news

- Channel A: high temperature will be 76°F tomorrow
- Channel B: high temperature will be between 74°F and 78°F tomorrow.

<table>
<thead>
<tr>
<th>Preference</th>
<th>Percent of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prefer Channel A (deterministic)</td>
<td>22%</td>
</tr>
<tr>
<td>Prefer Channel B (uncertainty)</td>
<td>45%</td>
</tr>
<tr>
<td>Like both channels</td>
<td>27%</td>
</tr>
<tr>
<td>Like neither channel</td>
<td>2%</td>
</tr>
<tr>
<td>I don't know</td>
<td>4%</td>
</tr>
</tbody>
</table>
Suppose the high temperature tomorrow will probably be 85°F. However, a cold front may move through, in which case the high would only be 70°F.

Would you like the forecast given this way?

The high temperature tomorrow...

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>...will be 85°F <em>(deterministic)</em></td>
<td></td>
</tr>
<tr>
<td>...will most likely be 85°F, but it may be 70°F <em>(WITHOUT explanation)</em></td>
<td></td>
</tr>
<tr>
<td>...will most likely be 85°F, but it may be 70°F, because a cold front may move through <em>(WITH explanation)</em></td>
<td></td>
</tr>
<tr>
<td>...will be between 70°F and 85°F</td>
<td></td>
</tr>
<tr>
<td>...will be between 70°F and 85°F, because a cold front may move through</td>
<td>80% chance it will be 85°F, 20% chance it will be 70°F</td>
</tr>
<tr>
<td>80% chance it will be 85°F, 20% chance it will be 70°F, because a cold front may move through</td>
<td></td>
</tr>
</tbody>
</table>
Percent of Respondents Who Like Format

- Will be 85°F: ~35%
- Deterministic only ~7%
- Most likely 85°F but may be 70°F: >90%
- Between 70-85°F: 80% chance 85°F, 20% chance 70°F: ~63%

Legend:
- Without cold front explanation
- With cold front explanation
All the choices below are the same as a probability of precipitation of 20%.

Do you like the information given this way?

- Chance of precipitation is 20% ➔ Percent
- There is a 1 in 5 chance of precipitation ➔ Frequency
- The odds are 1 to 4 that it will rain ➔ Odds
- There is a slight chance of rain tomorrow ➔ Text

*Asked this question 3 ways --
using PoPs of 20%, 50%, and 80%*
*with corresponding text descriptions from NWS*
Summary of results

- Most people think weather forecasts are uncertain
- Most people have some understanding of relative uncertainty in forecasts
- Most people don’t know the technical definition of Probability of Precipitation – but …
  - PoP is important to many people
  - People have built sufficient understanding of PoP through experience?
- Majority of people like uncertainty forecast information, and many prefer it
- Need to understand people’s communication preferences
Implications for communication

• Explicit communication of everyday weather forecast uncertainty
  – may not reduce forecasters’ credibility
  – is desired by some and acceptable to many
  – may augment people’s general notions of forecast uncertainty with situation-specific information

• Ask not whether people understand uncertainty forecast information precisely, but whether they can interpret it well enough to find it useful?

• Key: developing “effective” communication formats
Future work

- Further analysis of data from this survey (including geospatial analysis)
- Further interdisciplinary research on
  - Interpretations of and preferences for various communication formats (including graphics), for different weather types (including high-impact)
  - People’s use of uncertainty information in decisions
- Integrate results with meteorological knowledge to improve forecast communication ⇒
  Iterative, dynamic process that connects learning from forecast users with product development
Questions?

Contact
Rebecca Morss (morss@ucar.edu)
Julie Demuth (jdemuth@ucar.edu)
Jeff Lazo (lazo@ucar.edu)