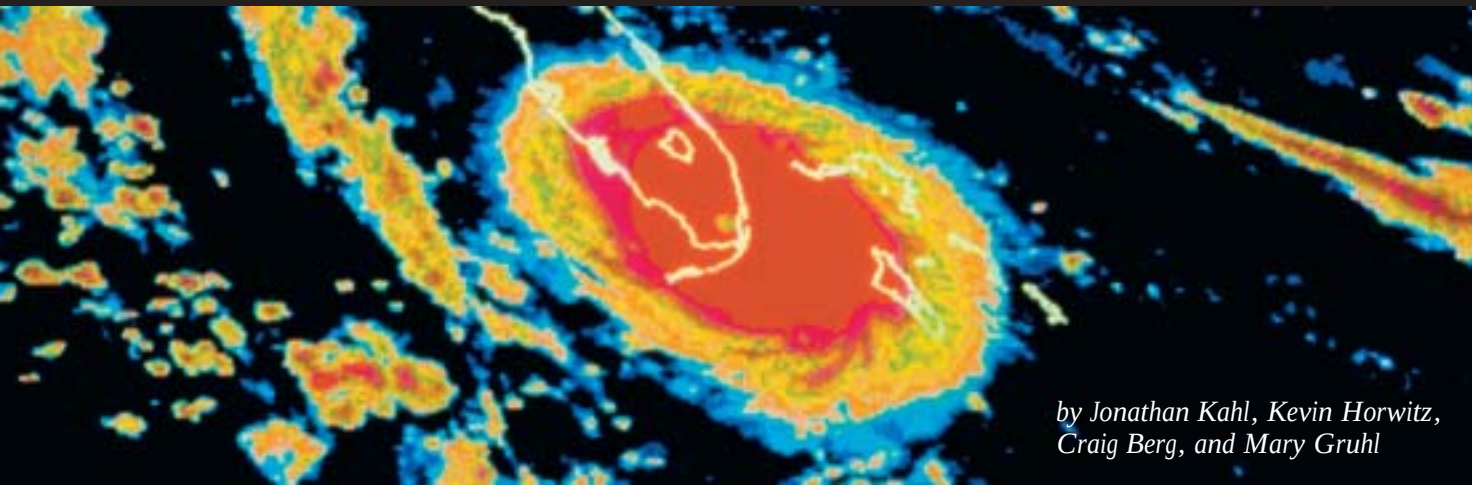
The QUEST for the *Perfect* WEATHER FORECASTER



by Jonathan Kahl, Kevin Horwitz, Craig Berg, and Mary Gruhl

It is said that meteorology is the only profession where you can be wrong half the time and still keep your job. The truth isn't quite so bleak, but we can still ask, "Just how accurate are weather forecasters, anyway?" Any meteorologist worth his or her salt knows that "Who's the best weather forecaster?" is a loaded question. Consider these hypothetical quandaries:

- Tuesday's weather featured a high temperature of 56 degrees (Fahrenheit) and 0.12 inches of rain. A day earlier, Forecaster A had predicted that Tuesday's high would be 55 degrees with no precipitation. Forecaster B predicted a high of 45 degrees with 0.10 inches of rain. Which was the better forecast?
- All week long Livonia, Michigan, had been enjoying unseasonably mild, late fall weather in the 50s and 60s (degrees Fahrenheit). An approaching cold front was expected to break the pattern sometime Saturday night, shifting the warm southwest breezes to gusty northwesterlies and dropping the temperature to the 30s. On Friday, the Channel 12 meteorologist, believing the front would arrive around 11:00 P.M. Saturday evening, predicted a Saturday low temperature of 33 degrees. (A

Jonathan Kahl *is a professor of atmospheric science in the Department of Mathematical Sciences,* ***Kevin Horwitz*** *is a former atmospheric science student,* ***Craig Berg*** *is a professor in the Department of Curriculum and Instruction, and* ***Mary Gruhl*** *is director of the Center for Science Education at the University of Wisconsin at Milwaukee.*

"Saturday low" is defined as the minimum temperature during the 24-hour period beginning at 12:00 A.M. Saturday.) In reality, the front arrived at 12:15 A.M. Sunday, and the actual low temperature was a balmy 58 degrees. The meteorologist missed the low temperature by a whopping 25 degrees! Was this a bad forecast?

- In Milwaukee, summertime lake breezes often cause afternoon temperatures near the Lake Michigan coastline to be 10–15 degrees Fahrenheit cooler than temperatures further inland. The official weather station used to verify the accuracy of weather forecasts is located at the airport, close to the lake. Suppose that on a day with a moderate lake breeze, a broadcast meteorologist predicts a high temperature of 73 degrees. The observed high temperature at the official weather station turns out to be 74 degrees, but in the majority of the city, away from the lake, temperatures were in the upper 80s. Did the meteorologist do a good job with his high temperature forecast?

Despite complications such as these, many people still claim "So-and-so forecaster at Channel 4 is much better than what's-her-name at Channel 7." While such statements generally lack a rigorous scientific foundation, people often do have strong opinions on the matter. Here are two projects for middle level students to investigate this issue in a hands-on, active-learning environment. These three-week projects take the form of webquests—inquiry-oriented exercises focusing on analysis, synthesis, and evaluation, for which the Internet is the primary information source (Dodge 1995).

The webquests

Our webquests are outgrowths of the Internet Weather Forecasting Activity (see Resources and "Meteorology Online" in the February 2001 issue of *The Science Teacher*). Originally developed for University of Wisconsin-Milwaukee introductory meteorology classes, this free, online activity is now used by over 2,000 students throughout North America and abroad. Students prepare a weather forecast for a specific city each week. Forecasts consisting of temperature readings and wind conditions are transmitted to the teacher via e-mail through the website.

The two webquests, *Weather Forecast Showdown* and *As Time Goes By in Weather Forecasting*, challenge student groups to find the best weather forecaster (or forecast source, such as a particular newspaper or television network affiliate) in their city. The challenge is met by collecting next-day high temperature forecasts made by different television stations, newspapers, and government sources. Low temperature forecasts are not used in the webquests because of a lack of uniformity in the definition of "low temperature" (Kahl and Horwitz 2003). Both webquests introduce several statistical concepts that are not traditionally part of the standard math or science curriculum. With explanations and illustrative examples (Figure 1), students are guided through the definitions of *relative errors* and *absolute errors*. Forecaster performance is evaluated in terms of both *accuracy* and *bias*. Definitions of all technical terms are included in an online glossary.

As is common in webquests (Dodge 2003), both projects include the following sections online to guide the students through the process:

- Introduction—defines the activity and sets the stage for the project
- Task—outlines the students' assignment in general terms
- Process—describes the steps and the timeline of the project
- Information resources—instructions on how to access the necessary weather forecast information from the Internet
- Guidance—detailed information on data collection and recording, computations, and report preparation
- Conclusion—postscript to the projects
- Evaluation—detailed rubric to assess student performance
- Glossary—defines all terms introduced in the projects, including those which may not be included in a typical science curriculum such as *absolute error*, *accuracy*, *bias*, *overprediction*, *relative forecast error*, *verification*, etc.
- For teachers—lists project objectives, time requirements, discussion ideas, and *National Science Education Standards* addressed by the project

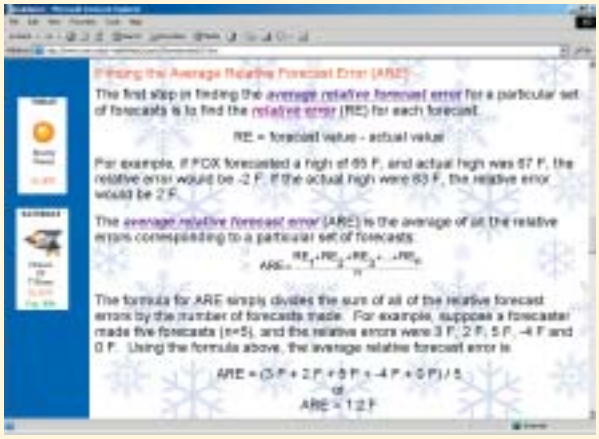
Weather Forecast Showdown—This webquest begins with a tongue-in-cheek warning of disturbing reports that some meteorologists are giving inaccurate forecasts to the public. "The Government," an ominous, pseudo-Orwellian entity, hires students to rate the weather forecasters in their town. The results of their investigation will be used to "praise the winners, admonish the losers, and improve the quality of weather forecasts."

As Time Goes By in Weather Forecasting—In this webquest, a "top-secret document" entreating students to "combat the dangers of poor weather forecasting," the task is slightly more complex and is suggested for students in grades 5–12. While investigating the deterioration of accuracy as weather forecasts are extended further and further into the future, students are "sworn to secrecy" and promised protection from the EWFO (Evil Weather Forecasters Organization).

Both webquests fit as curriculum supplements to general or Earth science classes, as well as for math classes in which statistical concepts are presented and could be introduced at any point in the class schedule. The webquests involve gathering, analyzing, and interpreting data, thinking criti-

FIGURE 1 Introducing statistical concepts

Description and example calculation of some statistical concepts introduced in *Weather Forecast Showdown*.



cally and understanding scientific inquiry, and using estimations and functional relationships. The activities in both webquests are similar, except that *As Time Goes By* evaluates the quality of both next-day and lagged (two-day, three-day, and four-day) forecasts, while *Showdown* considers only next-day forecasts.

Structure of the activities

During the first two weeks of each webquest, student groups (three to five members) collect high temperature forecast data from web sources. Sources can include forecasts made by television network affiliates (ABC, CBS, FOX, the Weather Channel, etc.), newspaper websites, and government sources (e.g., U.S. National Weather Service, Meteorological Service of Canada, etc.). Instructions and examples guide students through the processes of obtaining high temperature forecasts specific to their town, interpreting different forecast presentations (e.g., "upper 40s" is recorded as 48 degrees Fahrenheit), and recording their data on electronic forms (Figure 2). Data collection, typically a 5–10 minute daily process during the first two weeks, can be done by taking turns on a classroom computer or in a computer lab.

FIGURE 2 Data recording form

A portion of the data recording form for *Weather Forecast Showdown*, provided on the webquest site. A similar worksheet is included on the *As Time Goes By in Weather Forecasting* site. Worksheets may be downloaded and printed as ordinary images or as Excel files.

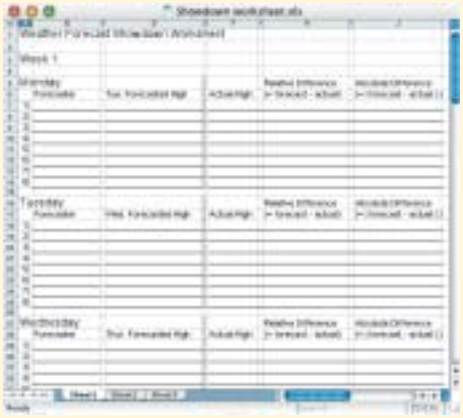


FIGURE 3 Assessement rubric

A portion of the assessment rubric from the Evaluation section of *Weather Forecast Showdown*.

In the third week, students verify the forecasts (retrieve the actual high temperatures from web sources), calculate their statistics, and prepare individual and group reports. For each forecast source, students calculate the average relative forecast error and the average absolute forecast error. This information is used to evaluate bias and accuracy. In *As Time Goes By*, students calculate these statistics for both next-day and lagged forecasts.

At the end of each three-week project, both individual and group reports are required. The individual report lists the forecast sources studied, the websites used, the average relative and absolute errors for each forecast source, the range of errors found, and a paragraph evaluating the ability of each forecast source to accurately predict high temperatures. The individual report also includes one or more graphs of the student's results. The group report, which can take the form of a presentation, poster display, or website, includes a summary table of each group member's results, a

summary graph, conclusions, and an accuracy ranking. The report should also issue awards to the best, the worst, the most biased, and the least biased forecast source. Each award citation should include a paragraph describing the reasons why the award is being given to that particular forecaster.

Additional extensions and discussion points

The results of these open-ended projects are always different, and always interesting. A rubric is provided online for their evaluations (see Figure 3), and interpreting the results provides opportunities for students to show their creativity. Results for either webquest project can be used to address questions such as:

- Do particular television stations or newspapers make consistently better high temperature forecasts than the others?
- Are forecasts for one city more accurate than forecasts for other cities?
- Are predictions made by individual forecasters biased toward underprediction or overprediction?

Additional research questions related to lagged forecasts in *As Time Goes By* could include:

- Can three- or four-day forecasts be trusted as much as one- or two-day forecasts?
- Do the forecasters who perform the best at one-day forecasts also perform well at three- or four-day forecasts?

Students' results can also serve as a gateway to a number of very interesting meteorological and mathematical (statistical) issues. For example, the following questions would make good extra credit assignments, research projects, or classroom extensions:

- Is the weather more complex (harder to forecast) at certain cities? Why?
- What weather patterns were present during the two-week data collection period? Might the forecaster rankings change if the forecast data were collected during a different two-week period?
- How might the results be different if the project was done using degrees Celsius instead of degrees Fahrenheit? (We use Fahrenheit for consistency with the units of temperature forecasts presently used in the United States.)
- Why doesn't the absolute error provide any information about bias? Why isn't just one type of mean error (relative or absolute) enough to describe the accuracy of a forecaster?
- Does an average relative error near zero necessarily indicate a good forecaster? (For example, very high overpredictions could balance out very low underpredictions and produce a very small average relative error.)
- What's a more desirable performance characteristic for a forecaster: a small average relative error or a small average absolute error?
- In *As Time Goes By*, how do the different sample sizes (more next-day forecasts than four-day forecasts) affect the results? How might the problem of different sample sizes be eliminated?

Classroom use

There are several built-in flexibilities that make the webquests readily adaptable to specific classroom needs and interests. *Weather Forecast Showdown*, which does not consider the effect of lag times on forecaster performance, may be more suitable for teachers desiring a less complex project than *As Time Goes By*. To preserve class time, the data collection portions of either project could be assigned as homework. Both projects could be shortened by eliminating the consideration of either relative or absolute errors. The role of individual group members is flexible as well. Each group member could choose a different forecaster (e.g., a particular television station) and record high temperatures forecasted for different cities. Or, each member could choose a different city and record forecasts for that city's temperatures made by several different forecast sources.

As three-week projects using only a few minutes of class time each day, the webquests fit nicely into existing curricula in science and math classes. They provide challenging, interesting, and fun opportunities for students to collect, analyze, and interpret data relevant to their everyday lives. Through a guided process of scientific inquiry, students learn that complex questions such as "Who's the best weather forecaster?" can be answered through the structured application of relevant mathematical principles.

Resources

Weather webquests—*www.uwm.edu/~kahl/WebQuests*
Internet Weather Forecasting Activity—*www.uwm.edu/~kahl/Forecast*

References

Dodge, B. 1995. "Some Thoughts About WebQuests." Available online at *edweb.sdsu.edu/courses/edtec596/about_webquests.html*.
Dodge, B. 2003. "The WebQuest Portal." Available online at *webquest.org*
Kahl, J.D.W. 2001. Meteorology online: Weather forecasting using the Internet. *The Science Teacher* 68, 22–25.
Kahl, J.D.W. and K.A. Horwitz. 2003. Daily low or overnight low? Confusion in icon-based forecasts. *Bulletin of the American Meteorological Society* 84, 155–156.
National Research Council (NRC). 1996. *National Science Education Standards*. Washington, D.C.: National Academy Press.