Man and Machine Forecast Big Snow

This winter's East Coast snowstorms tested weather forecasting's delicate interplay between human knowledge and intuition and computer model forecasting; the snow won a few

DAVID Olson's brother-in-law was due to fly into Washington, DC, from California on Thursday, 22 January. On the Tuesday before, Olson told his wife to call her brother and tell him to cancel his flight. Even if his plane managed to land, Olson figured, the Olsons would not be able to pick him up at the airport. Snow would foul their plans in any case.

Olson's fears were well founded, despite some contrary forecasts. Thursday morning's paper called for only a few centimeters of snow before it changed to rain—hardly much of a threat to business as usual, even in Washington. The early morning official Weather Service forecast was more threatening—5 to 10 centimeters of snow that might slow the morning rush hour and would be a problem for commuters that evening. But that did not seem too threatening to the federal Office of Personnel Management, which sent more than 300,000 federal workers into a storm that badly snarled the morning rush hour and forced a disastrous retreat from the city by midmorning. The forecasted 5 to 8 centimeters became 28 centimeters by nightfall.

Olson had not been guessing or consulting *The Farmer's Almanac*. He heads the Forecast Branch of the U.S. Weather Service's National Meteorological Center (NMC) located in the World Weather Building in Camp Springs, Maryland, just outside Washington's beltway. On the fourth floor, branch specialists in the forecasting of heavy precipitation follow the development of storms wherever they form in the country. These forecasters combine their meteorological expertise, their experience, and the forecasts of computer models to predict when and where heavy precipitation—13 to 25 centimeters or more of snow, for example—will fall.

Every on-duty meteorologist, private and public, with responsibilities for a Washington forecast was looking at the same observations and the same computer model results and considering the same question: where would the seemingly inevitable heavy precipitation fall mostly as harmless rain and where as debilitating snow? The NMC forecasters went with all snow in Washington, but the answer varied, depending in large part on how seriously a forecaster took the results from the computer models.

At the time, of course, no forecaster could tell how accurately the Nested Grid Model, created in 1984 by NMC's Development Division, was simulating the coming storm of 22 January, but it certainly was being consistent about it. Forty-eight hours ahead it was calling for 2.5 centimeters of water to fall and for the air to be always at least a few degrees centigrade below zero. That meant about 25 centimeters of snow. Fed the latest weather observations every 12 hours, this mathematical model of the atmosphere continued to churn out strikingly similar forecasts of heavy snow, including one made late on the evening of 21 January for 20 centimeters of snow, beginning before 7 a.m. the next morning. The Limited-area Fine-mesh Model, the model being supplanted by the Nested Grid Model, indicated a 75% chance that the precipitation would be snow.

Sharon Kuck, Prince George's Journal

A white January.

Back-to-back snow storms blanketed Washington, DC, in January, and another in February caused major blackouts, but computer forecasting models did surprisingly well. Human forecasters had a mixed record.

But who can trust a machine? These models are staggering simplifications of the real atmosphere. It was only late last winter that researchers allowed simulated precipitation in the Nested Grid Model to evaporate on its fall toward the ground and last summer that they added nighttime cooling and daytime heating. Averaged across the country and over many forecasts, the model's 48-hour forecasts are too cold by 1.5°C.

In their simplicity, such models are often wrong. No model warned of the infamous Presidents' Day storm of February 1979 that dumped 50 centimeters of snow on Washington instead of the expected several centimeters. Given such a record and the disruption of recent model changes, how could one trust a model on such a sensitive question as where it will rain and where it will snow? A typical coastal storm's snow-laden western half will bring nothing but snow to Frederick, Maryland, while only rain falls on Salisbury, Maryland, less than 200 kilometers to the southeast. Washington lies nearly in the middle.

"There's a big difference in Washington, DC, between an inch of rain and a foot of snow," says Ross La Porte, Meteorologist-in-Charge at the U.S. Weather Service Forecast Office for the mid-Atlantic region, by coincidence located on the third floor of the World Weather Building. "There's no magic way of forecasting which it will be," he says. "You have to go by the seat of your pants. That's where experience comes in. No model can do that." By the early 1970s models could on average predict highs, lows, and fronts better than human forecasters, notes Harlan Saylor, deputy director of NMC and an East Coast forecaster since 1946. "The question for human forecasters now," he says, "is whether there will be precipitation, how much there will be, and what form it will be in."

In order to pin down the storm's rain/snow line with respect to Washington, forecasters looked at a variety of indicators. To what extent was cold air that was being pumped in by a high over Maine piling up on the eastern side of the Appalachian Mountains? Was the air in the lower atmosphere cold enough to produce snow and

Lon Slepicka, Prince Georges Journal

A big, heavy snow.

Ten inches of wet snow fell on Washington on 22 and 23 February, damaging trees, and the houses, cars, and power lines that they fell on.

keep it from melting into rain? If not, would evaporating snow or rain cool the lower atmosphere enough to prevent melting?

On the night before the storm hit, Olson's heavy precipitation group saw all indicators pointing toward heavy snow. The models had been consistently calling for it—consistency over several model runs being a crucial indicator—and their own subjective analysis concurred. At 9:39 p.m. they predicted 20 centimeters or more of snow—no rain—in the Washington area.

Bob Ryan, a local weatherman with WRC-TV, was reaching the same conclusion for much the same reasons. Both models had been moving the rain/snow line toward the east from run to run, and this latest run continued that trend. Ryan predicted heavy snow starting by 6 a.m. and accumulating up to 25 centimeters before it ended.

There was another school of thought. At the Washington Weather Service Forecast Office forecasters were not giving the models much weight in their consideration of the rain/snow question. The evening before the storm their subjective evaluation leaned toward 5 to 10 centimeters of snow before changing to rain in the afternoon. By early morning, when federal and school go/no-go decisions were being made, the amount was up to 10 centimeters, but sleet and freezing rain were still included. Accu-Weather, a private weather service based in State College, Pennsylvania, likewise was calling for 10 centimeters before the rain would set in. By early morning its predicted snowfall was up to 15 centimeters, but Accu-Weather did not drop the turn toward rain until 9 a.m. A forecast of 10 centimeters of snow alerts most Washingtonians to likely trouble, but not the way one of 20 centimeters or more would have. The result was havoc.

The impressive performance of the Nested Grid Model in forecasting the 22 January storm must have had some element of luck in it, everyone agrees, but the model has done reasonably well with subsequent storms too. A day in advance it correctly forecast the beginning of the next storm on 25 January, although that run predicted twice as much snow as actually fell. The next run, the night before the storm, brought the total snow near the actual amount. The 26 centimeters of wet, dense snow that brought down limbs, whole trees, and power lines on 22 and 23 February appeared on time in the model with temperatures only slightly on the snow side of the freezing point, but the forecast amount never reached half the actual amount. Still, that is rather good. "I've been looking at these East Coast storms since 1946," says Saylor, "and to have the Nested Grid Model do that well with three 1-foot snow storms was really something."

"I've been impressed," says Ryan. "The NGM's [Nested Grid Model] had a good track record. But it was fortunate that we still had the LFM [Limited-area Fine-mesh Model] with its long track record. Of course, next winter it could all fall apart."

This winter at least, the combination of computer forecasts and subjective evaluation as practiced in Weather Service forecast offices along the East Coast has yielded an encouraging overall improvement. During the winter of 1985–86, the probability that the Weather Service would issue a timely winter storm warning when it was warranted was 77%. This winter that probability rose to 86%. The false alarm rate dropped from 34 to 17% since last year. The track record of the models in forecasting heavy precipitation has improved dramatically over previous years.

Perhaps the forecasters and their models in particular owe their recent success to chance. Some storms are easier to predict than others, and some winters have more of those well-behaved storms. Such variability in the atmosphere contributes to the considerable variability of forecasting skill scores. Time will tell whether this winter's improvement was luck or an early sign that computer models are improving in another aspect of forecasting. ■ RICHARD A. KERR

Supernova Neutrinos at IMB

Members of the 14-institution IMB collaboration, which operates a giant proton-decay detector in a salt mine near Cleveland, announced on 10 March that their apparatus experienced a burst of neutrinos at the time of the explosion of Supernova 1987A. Moreover, their events come at precisely the same time as the neutrino burst seen in Japan's Kamiokande II detector. Taken together, these two results thus represent the first clear-cut detection of neutrinos from beyond the earth.

Says IMB principal investigator Lawrence R. Sulak of Boston University, "The age of neutrino astronomy is upon us."

The first of IMB's eight events came on 23 February at 7:35:41.37 universal time, says Sulak, or about 18 hours before the supernova was discovered optically. (The detector, a water Čerenkov counter with an effective mass of 5000 metric tons, has a time resolution of 50 milliseconds.) The next three neutrino interactions followed within the first 1.5 seconds of the burst, while the remainder were scattered over the next 4 seconds. This is just what one would expect, says Sulak, since supernova models predict a very strong initial pulse of neutrinos followed by a more gradual trailing off.

Because of the detector's threshold, he adds, IMB neutrinos represent only the high-energy tail of the supernova's full neutrino output. However, a model recently developed by theorist John Bahcall of the Institute for Advanced Studies in Princeton suggests that the IMB distribution could be explained if the supernova had a thermal energy of 5 million electron volts at the center; thus, the observation can be seen as the first direct measurement of a supernova's core temperature.

Further analysis of the events may well shed light on such matters as neutrino mass, neutrino oscillations, and the interactions of neutrinos with matter, says Sulak. Moreover, if supernova shock waves are responsible for accelerating particles to cosmic ray energies, as many theorists now believe, then fresh bursts of cosmic rays from Supernova 1987A will begin arriving at the earth within the next few months. Underground detectors such as IMB and Kamiokande II will then begin to see neutrinos at energies of 100s of billions of electron volts, while air shower arrays on the surface will begin to see similarly energetic gamma-ray events in the atmosphere. Indeed, says Sulak, "the full implications of this discovery are yet to come." ■ M. MITCHELL WALDROP