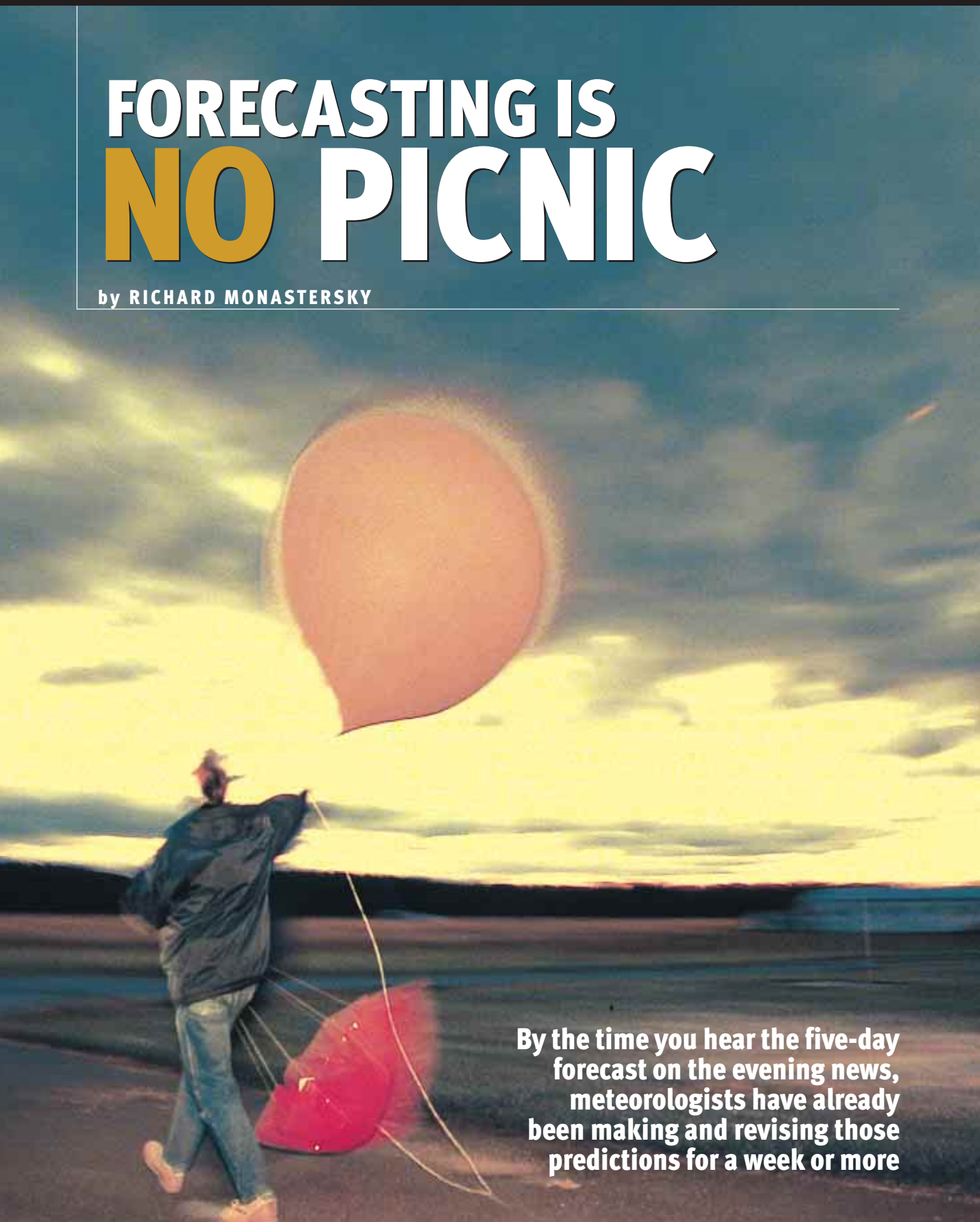
FORECASTING IS NO PICNIC

by RICHARD MONASTERSKY



By the time you hear the five-day forecast on the evening news, meteorologists have already been making and revising those predictions for a week or more

Last summer a gaggle of government dignitaries flocked to the end of Thunder Road, a quarter-mile-long strip of asphalt tucked behind Washington Dulles Airport. There, in the shadow of a giant radar dome, the bureaucrats celebrated the end of a nearly 20-year struggle to bring the National Weather Service (NWS) into the information age. This $4.5-billion modernization effort has furnished U.S. federal forecasters with sophisticated Doppler radar, a nationwide communications network, vastly improved computing power and a new suite of satellites.

KAY CHERNUSH

To test-drive the revamped system, I enlisted the full force of the weather service to answer a simple question: Will it rain on an upcoming picnic planned for my son's birthday in early October?

For a 10-day period before the event, I turned into a weather weenie, keeping in close contact with meteorologists drawing up the forecasts for Saturday, October 9. Aside from helping me plan the picnic, the exercise allowed the weather service to show off its advanced capabilities and to explain exactly how meteorologists go about predicting the weather.

Federal officials were eager to advertise the new system and its benefits. "Our three-day forecast is better than the accuracy of our one-day forecast 20 years ago," asserts John J. Kelly, Jr., director of the NWS. "We've more than doubled the lead times for tornado warnings. We've got a sevenfold increase in flash-flood warning lead times, all by this technology, this modernization."

My test revealed not only the profound improvements but also some bugs in the U.S. forecasting system. At the same time, it demonstrated just how complex a task it is to predict relatively mild conditions, let alone the blizzards, hurricanes, tornadoes and other hazards that strike disastrously from the sky.

A resident of the U.S. would have to hide in bed all day wearing earplugs to avoid hearing some sort of weather forecast. Even if one shunned every type of news media, updates about the weather would invariably slip into daily conversations. How often has a neighbor announced in passing: "They say it'll rain this weekend"?

TOP-OF-THE-LINE EQUIPMENT: The Doppler radar tower (*above*) near Washington Dulles Airport is one of the workhorses intended to increase the accuracy and timeliness of weather forecasts. The opposite page shows the early morning launch of a weather balloon.

To track down the "they" behind all these prognostications, I start off with a phone call to the World Weather Building, a boxy, brown office tower just south of Washington, D.C. The building houses the National Centers for Environmental Prediction, also known as NCEP ("encep") in the abbreviation-crazed federal government.

"Here is where it all begins," says Louis Uccellini, NCEP's head. A balding, brash meteorologist, Uccellini proudly describes how his organization drives the national forecasting effort.

The heart of the weather-prediction process rests deep within the building, where the Central Operations division oversees the computer programs that forecast the weather. More than one million meteorological observations flow into this building from around the world every day and serve as the initial seeds from which forecasts grow.

Every passenger on commercial flights unwittingly takes part in the observation process. Airplanes automatically measure air temperatures and winds and then send those data to an international information network. Weather balloons, ships, satellites, ground-based gauges and other

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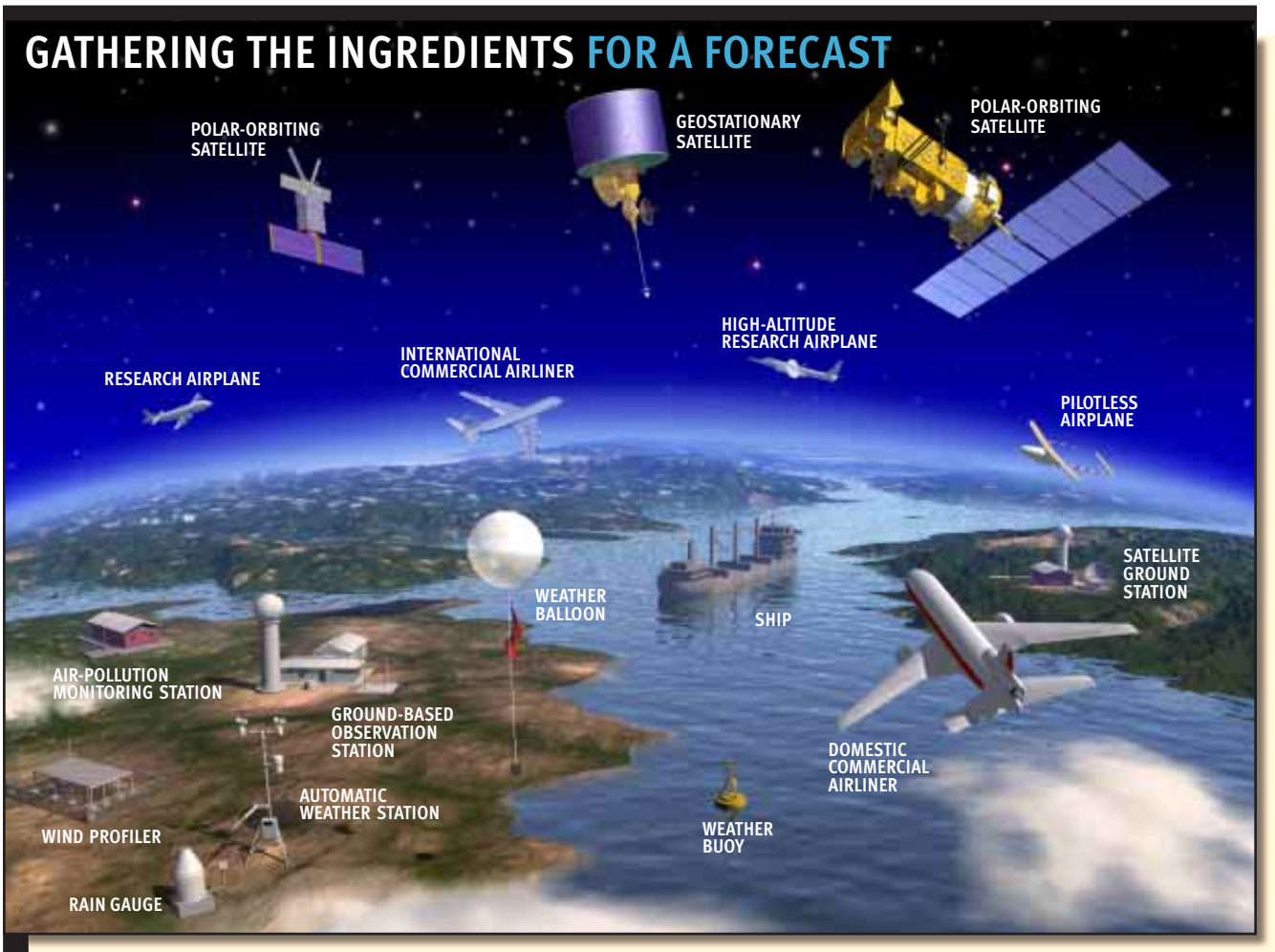


ALFRED T. KAMAJIAN, AFTER TREVOR RUTH

Computer-modeling programs that form the basis of weather forecasts must be fed meteorological data from a fleet of monitoring devices around the world. Those devices assess such factors as air temperature, moisture and pressure, and wind speed and direction.

instruments all contribute to take the atmosphere's vital signs.

The information eventually funnels into a supercomputer that runs several forecasting programs, called models. Designed to describe the atmosphere's behavior, these models are made up of mathematical formulas that predict how the sun's rays and the earth's rotation move air, heat and moisture around the planet.

The models represent the atmosphere as a spherical grid made up of dozens of vertical layers. At the start of the forecasting process, a program assembles all the meteorological observations into a complete portrait of what the weather looks like at the moment for each point on the grid. Then the models use Newton's laws of motion and other equations to determine how temperature, humidity, winds and other factors will change at every grid point.

That computer output then goes to meteorologists at NCEP, who make their forecasts by comparing the in-house models with those run by other federal agencies and foreign governments. Each model uses slightly different equations, grid spacing, starting times and initial observations. Taken together, they resemble a group of opinionated sports announcers, often producing divergent predictions of how future events will unfold.

When I began planning my son's party in late September, the weather service was using a Cray C90 computer for running its own forecasting models. At the time of its acquisition in 1994, this machine was one of the fastest supercomputers on the market, boasting a peak speed of 16 billion floating-point operations per second (16 gigaflops). Now that pace is downright poky. To build up its computational muscle, the government last year procured an IBM supercomputer that can hit 690 gigaflops. An upgrade planned for fall 2000 will boost the speed to 2.5 trillion flops.

Officials at NCEP planned to retire the Cray this year, but the supercomputer ended up quitting much earlier, and with more drama, than anyone had anticipated. Just 30 minutes after I spoke with Uccellini on Monday, September 27, a fire broke out in the Cray and destroyed the machine. Unfortunately, the IBM computer was not ready, so the weather service had to rely on its own backup systems along with those from the U.S. Air Force, Navy and other nations. For several months, the fire's legacy hobbled the computer division, forcing it to cut back on some of its forecast products.

Because of the fire, I had to wait until 10 days before the picnic to get the first inkling of what the weather would be like. This came from NCEP's Climate Prediction

Center, which is in charge of forecasts longer than a week or so in the future.

Meteorologists at this point can't hope to provide specific information that far ahead. The winds sailing around the globe are just too chaotic and the initial weather observations are too spotty for the computer models to tell whether it will rain at 4:13 P.M. two weeks hence in any particular place. Recognizing these limitations, the Climate Prediction Center staff issues only general projections beyond a week ahead. The information, however, is often accurate enough to warn forecasters that the potential for a major storm system is lurking upstream.

10 Days and Counting

When I check in with the center on September 29, the initial news is slightly sour. The forecast calls for below-normal temperatures and above-normal precipitation in the mid-Atlantic states, where I live. This assessment draws mostly on information from the European Center for Medium Range Weather Forecasts, one of the only organizations running a model out that far.

The European simulation envisions a low-pressure region sitting over the Mississippi by October 9. Called a "trough" by meteorologists, such a system deflects high-altitude winds traveling eastward across the country, forcing them to detour southward and then loop back northward around the low-pressure region. As the winds skirt the eastern edge of the trough, they push warmer, humid air northward, where it rides up and over the colder mass in front of it. The warm air cools as it rises and therefore can hold less moisture, which condenses to form clouds and rain over the Eastern states. So the presence of a trough over the Mississippi valley translates into a soggy party for my family.

Two days later the forecast looks sunnier. Doug LeComte of the Climate Prediction Center foresees normal temperatures and below-normal rainfall, a picture produced by combining the most current European model output with that from the day before. This blending helps to define the large meteorological patterns soon to be rolling across the country.

Instead of establishing a trough over the Mississippi, the most recent European model prediction shoves the system out to the northeast, putting much of the country under a high-pressure ridge eight days in the future. Like a boulder in a river, that ridge will block the atmosphere's currents and keep away storm systems, letting sun shine on my picnic, LeComte says.

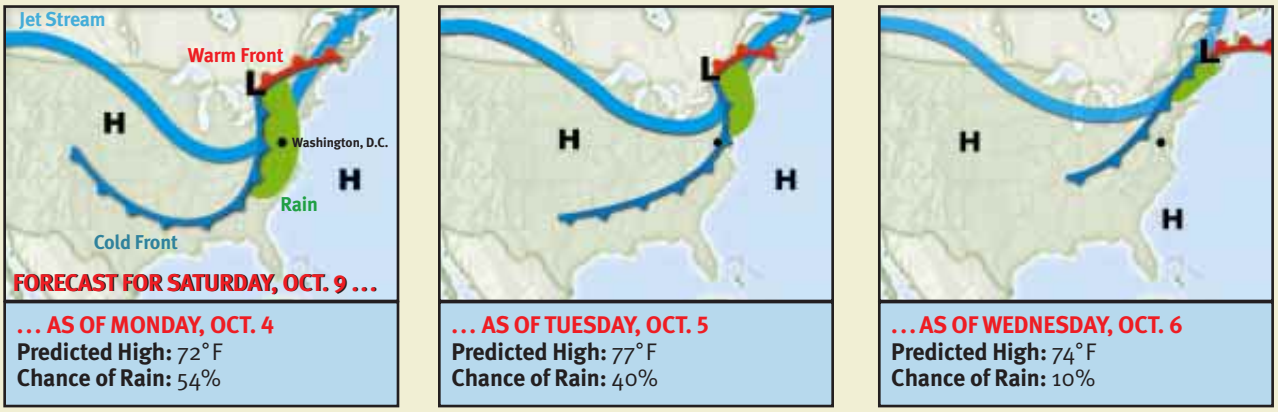
He quickly tempers my optimism, however. With the model changing its forecast so dramatically in just two days, he cautions, "anything I say will have really low confidence."

Despite the warning, I can't help putting some stock in the forecast, especially because it calls for good weather. The very existence of this information, no matter how suspect it may be, seems to give it some authority. That explains why most media outlets do not report the forecasts earlier than five days ahead. People would be tempted to place too much faith in the often inaccurate longer-range predictions.

LeComte's skepticism seems prescient the next day when I phone into the Hydrometeorological Prediction Center, the NCEP office that issues medium-range forecasts seven to two days ahead. "Right now we're looking at a cloudy day with a chance of showers and a high in the upper 60s," says Frank Rosenstein. He forecasts a 48 percent chance of precipitation at D.C.'s Reagan National Airport, the airfield nearest to my house.

The potential spoiler to my son's party is visible in the model run by NCEP. It projects that a low-pressure system will sweep across the country and reach the East by picnic day. Even worse, a couple of models show a storm brewing in the western Gulf of Mexico. The Canadian forecasting model foresees the storm growing into a hurricane and sweeping over the Gulf Coast states, where it could start to merge with the northern low-pressure system. "There is a potential for heavy rain," Rosenstein says.

His message starts to give me heartburn as I wonder how to keep several preschoolers occupied inside for two hours until it's time for cake and ice cream. Before I can get too worked up, though, Rosenstein backpedals on the forecast: "I wouldn't bet on this, especially at this time of year." Fall and springtime are no-



LAURIE GRACE; SOURCE: EDWIN DANAHER *NCEP*

WILL IT, WON'T IT? As part of making advance predictions for October 9, 1999, in the mid-Atlantic region, the National Weather Service tracked the movement of low- and high-pressure systems (*Ls* and *Hs*) across the country (*maps*). Low-pressure systems often bring rain. As the date approached, the author felt increasingly confident that no rain would mar his son's outdoor birthday party on that day. He—and the forecasts—were a bit wet.

toriously difficult seasons to predict for the models because the atmosphere is flip-flopping between a summertime mode of circulation and a wintertime pattern. What is more, the European and NCEP models do not agree on where the weather systems will be. Such discord among the computers makes forecasters' jobs more difficult because they have to figure out which model prediction to trust—a subjective process that relies in part on recalling how models have fared in similar situations before.

The following day Rosenstein and his partner Michael Schichtel have not changed the forecast appreciably. The only difference is that most of the models downplay the risk of a hurricane hitting the Gulf Coast. The NCEP medium-range model still shows a low-pressure trough moving slowly across the country and arriving on Saturday. Other models push the system along faster, which means the rain would start earlier. Either way it doesn't look good for the picnic.

After giving the forecast, Schichtel provides the by now expected caveats: "For day six and seven, we're looking at storms that haven't even developed yet." The seeds to these systems are still floating over eastern Asia as we speak. "There is a lot of room for the models to change things," he says.

The next morning—Monday—the forecasting activity begins to pick up its pace, with only five days left before the picnic. This is when the news media start to get involved, issuing their own forecasts or reporting the official predictions provided by the weather service.

The *Washington Post,* for instance, calls for a "chance of rain," on Saturday, with a high of 68 degrees Fahrenheit. This weather information comes from a commercial firm called AccuWeather in State College, Pa., which supplies the forecasts to some 660 newspapers and 250 radio stations around the country.

Bad News, Good News

I'm eager to see what the government's forecast will be, so I go to the World Weather Building. James E. Hoke, head of the Hydrometeorological Prediction Center, leads me into a long, open room filled with more than 100 monitors displaying weather maps, satellite photographs and radar images. The shades are drawn, and the hum of computers fills the air as a shift of 40 people track the nation's weather for the next week.

Hoke takes me to a work area of 10 monitors and two chairs, where a pair of meteorologists is developing the forecast. Earlier this year the scene would have been very different. "Up until April 1, we used to do all of the charts by hand with light tables and grease pencils," he says.

Now the forecasters use a network of computer workstations called the Advanced Weather Interactive Processing System, or AWIPS. Often called the central nervous system of the weather service, this system connects all the offices around the country, allowing meteorologists to display model maps and weather observations, create their forecast charts, and instantly transmit them.

The Department of Commerce began work on AWIPS back in the early 1980s, but the system's development did not progress smoothly. Its cost has reached nearly double the original budget, and the government has lagged several years

behind in completing the system, which is still not fully functioning, according to the General Accounting Office. Despite the problems, forecasters say it has revolutionized their work.

As for the picnic, the news has grown slightly worse. NCEP's medium-range model still shows the trough moving east, and it appears even stronger than in yesterday's run. The European model goes to the opposite extreme again, keeping upper-level winds blowing straight east-

. . . AS OF THURSDAY, OCT. 7
Predicted High: 76°F
Chance of Rain: 20%

. . . AS OF FRIDAY, OCT. 8
Predicted High: 74°F
Chance of Rain: 0%

ACTUAL CONDITIONS AT PICNIC
Cloudy, cool, drizzle after 3 P.M.

ward, with no deviation around a trough. The U.S. Navy, Canadian and U.K. models portray something in between these two pictures. Rosenstein takes a middle-of-the-road approach, calling for a trough to arrive farther north and weaker than the medium-range model wants it to. He gives better than even odds of a shower on Saturday.

Given the dismal prospect of drizzle, I start looking up the telephone number of a professional juggler I had met, thinking he could entertain the kids indoors. But it quickly becomes clear that our low ceilings would cramp his routine, especially the bit involving scimitars and cantaloupes.

On Tuesday morning, four days before the picnic, my mood brightens when I speak with NCEP's Steve Flood, whose name in this case is entirely inappropriate. "Today it looks pretty good that it will not rain on Saturday. We're missing some of our models, but from what we can see, the system is not coming as far south in the country. Most of the energy is staying in Canada."

The big change since yesterday is in the U.S. medium-range model, which has repositioned the trough northward, giving Washington only a slight chance of showers, Flood says. The U.S. Navy and U.K. models have remained the same since the day before, while the poor Canadian model is still on its own trying to pull the Gulf storm north toward the states.

Flood explains how he sorts out the different predictions of how weather patterns will move across the U.S.: "We start from an anchor position that all the models agree on, and then we work from there to see what happens downstream and upstream from those anchor points to try to determine what's reasonable or not."

The next day the news keeps improving. The U.S., European and U.K. models are all in agreement in calling for relatively undisturbed air over the Eastern states on Saturday. Flood and his colleagues have dropped the chance of precipitation down to 10 percent in Washington.

That matches the prediction coming out of AccuWeather. Eliot Abrams, a senior meteorologist there, gives me the news by phone: "Right now the forecast is for a fine day with mixed clouds and sun, partly sunny. High 72, low 58. It's a good day for outdoor activity, and a good breeze will be blowing."

With a penchant for puns and a sonorous voice, Abrams seems a natural for radio forecasts. His sunny disposition clouds over only when asked about the recent fire at NCEP. "It's outrageous," he says,

PHOTOGRAPHS BY KAY CHERNUSH

FORECASTERS IN ACTION: Doug LeComte (*left photograph*) of the Climate Prediction Center at the National Centers for Environmental Prediction (NCEP) constructs a long-range forecast more than a week ahead. Michael Schichtel (*at left, above*) and Frank Rosenstein confer on a medium-range forecast (seven to two days out) at NCEP's Hydrometeorological Prediction Center. At the National Weather Service office in Sterling, Va., John Billet (*right photograph*) consults depictions of winds, pressures and such to compile a short-range forecast for the D.C. area.

"that the government of the United States is so vulnerable to one computer."

Abrams's boss, Joel N. Myers, contends that the government should get out of much of the weather-forecasting business, leaving it to private companies like the one he owns: "My vision of what will happen 10 or 15 years out is that the need for the government weather services might almost disappear." The government, Myers adds, should focus on issuing severe-weather warnings and leave the routine forecasts to private companies.

Uccellini of NCEP takes issue with that forecast of the future: "Our warnings are made by the same people who issue the day-to-day forecasts." The forecasters have to stay on top of the daily weather in order to recognize when thunderstorms, tornadoes, hurricanes, floods and other threats are looming, he asserts. What is more, the forecasts put out by private companies rely heavily on information issued by the NWS. Often, he notes, meteorologists working for news outlets use the government's official forecast verbatim.

What will happen a decade hence, however, fades in importance as the picnic looms only 48 hours away. At noon on Thursday, I drive out past Dulles airport to visit the weather service office at Sterling, Va., which issues forecasts for the Washington area.

John Billet, the lead forecaster on duty, walks me through the information he uses to predict the weather for the next two days. An avuncular man with a face like a young Charles Kuralt, Billet starts off with the NWS's most sophisticated computer models. The AWIPS system lets him click quickly through 12-hour steps in the model simulations to see the virtual weather evolve.

The models show a strong low-pressure trough over New Mexico moving eastward, drawing moisture from the Gulf of Mexico into the center of the country. Another trough lurks near the Canadian border. "There's quite a bunch of moisture—80 to 90 percent—over Louisiana and all the way up into Illinois," Billet comments. "My question for Saturday is: How much of this moisture is going to get hooked up with that trough we saw coming down and make it in to here?"

The next few screens of model predictions help him answer that question. The moisture will hit us on Friday and Saturday, but there won't be any force causing that air to rise, Billet says. Without the vertical motion, the moisture won't condense to form precipitation on Saturday, he predicts. The rain will come later.

He checks out the weather satellite images and refers to the computer projections of temperature and precipitation. Then he moves to another computer to type out his forecast. The official prediction for Saturday: "Partly sunny and warmer, with highs in the mid-70s." The chance of precipitation at Reagan National Airport is 20 percent.

The following day the specter of rain disappears completely. The Sterling office predicts a 0 percent probability of precipitation at Reagan National Airport. The skies will be partly sunny with a high of 74 degrees F, says Phil Poole, the lead forecaster on Friday afternoon.

The update from AccuWeather differs only slightly from the weather service's. "More cloudiness, high of 74," says Abrams in a voice-mail message. "It will be 60 to 70 percent cloudy. A one- or two-out-of-10 chance for showers. A one-out-of-100 chance for raining more than an hour." He signs off with his trademark line: "Have the best day you've ever had."

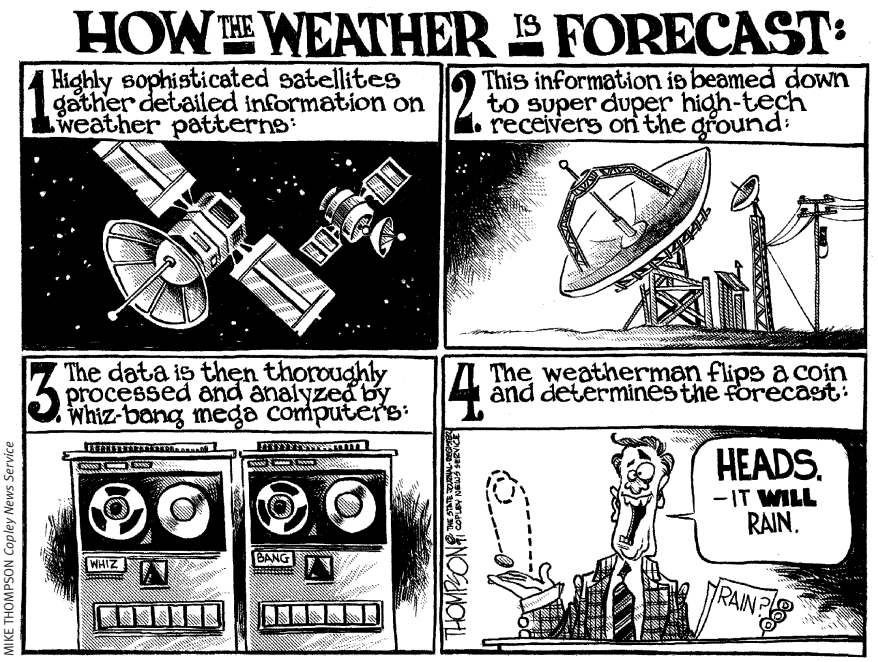
As I drift to sleep Friday night, the outdoor party seems a sure bet. The forecasts for the past five days have been getting increasingly sunnier and more consistent. Tomorrow should be warm and rain-free, with even some blue sky peeking through the clouds—perfect weather for letting the kids run around until they tire.

Flawed Forecast, Great Party

At dawn on Saturday, the forecast looks like a bull's-eye. The air feels softer than it has in days, a sign that the moisture has arrived in the region right on schedule. Fluffy white clouds stand out against a bright blue sky. I don't realize it then, but this will be the last clear sky I see all day. Within 30 minutes, a sheet of midlevel clouds moves in from the southwest to stay. As a result, the temperature never rises above 68 degrees F, making the air chillier than expected.

The party goes off well, although the clouds, mosquitoes and cool air combine to drive people indoors soon after the meal ends. That turns out to be a fortunate move. By 3 P.M. the sky darkens and a light rain starts falling, confounding the forecasts that I have heard. The morning's weather report from Sterling had said "rain likely after midnight" but did not mention precipitation during the day.

At 4:45 P.M. I call Poole and ask whether



ABLE TO TAKE IT: Showing a sense of humility, the NWS posted this cartoon on its Web site.

he would consider this a blown forecast. He sighs and takes a long pause before answering: "Let's put it this way—if I had made the forecast and called for an absence of precipitation and there was precipitation from three o'clock on, I wouldn't be very satisfied with that forecast."

At the same time, however, he notes that the rain is extremely light and has not hit all parts of the forecast area. In fact, by midnight on Saturday, Reagan National Airport will record only a trace of rain, less than $^1/_{100}$ of an inch. By the weather service's standards, any rainfall less than that amount does not officially count as precipitation, even if other parts of the forecast area measure more.

Still, the temporary drizzle is enough to keep us inside for the rest of the day. Poole feels compelled to alter his forecast for the evening. Instead of predicting that the rain would arrive after midnight, he says, "Rain likely overnight." The strong precipitation does wait for Sunday.

Several days later Jim Travers, head of the Sterling office, explains that part of the problem on Saturday came from interpreting the models: "The models in general seem to be a little slow in bringing in the precipitation, which is not unusual. They go through periods when they're too fast or too slow." The forecasters must spot these biases and make adjustments, a tough task in borderline cases such as Saturday's drizzle. "Any forecaster would tell you that the most difficult forecasts we have to make are marginal situations," Travers says. "There aren't many big events that we or the models totally don't know are coming."

As computer power improves and models can better tune into local geography, the accuracy of forecasts continues to edge upward, as it has for several decades. Yet benign conditions will continue to be the bane of meteorologists, in part because the radar, satellites, models and other tools cannot give forecasters 20/20 insight into the atmosphere's future movements. The potential for rain will always lurk in the unseen currents of air swirling over the heads of picnickers. W

RICHARD MONASTERSKY is the earth science editor for *Science News*.