biodefense labs because she opposes their planned expansion. Any expansion, she has argued, just adds to the pool of scientists with the means to pull off another bioweapons attack.

Both admirers and detractors agree that she has pushed the FBI forward. "Without question, she's influenced this investigation," says Block, who also strongly suspects that the culprit, if not a U.S. citizen himself, has ties to the U.S. bioweapons program. Privately, scientists who support Rosenberg praise her for taking on what they call a thankless job.

Rosenberg, whom the conservative *Weekly Standard* ridiculed as "the Miss Marple of SUNY/Purchase" in a recent article, maintains that the importance of finding out who sent the anthrax-tainted letters demanded her involvement and that her celebrity is purely accidental. Mark Wheelis, a microbiologist at the University of California, Davis, and a member of the FAS working group that Rosenberg runs, agrees that she generally shuns the limelight. But her determination, he notes, serves her well here: "The toughness is not part of her normal manner; it's a reserve she can draw on when it's called for."

And what if she's wrong? Rosenberg concedes that interrogating Hatfill might not help the FBI crack the case. But she quickly reverts to character. Even if that's true, she says, "the broad principles and the things I've said, I stand behind."

–JENNIFER COUZIN

CLIMATE FORECASTING

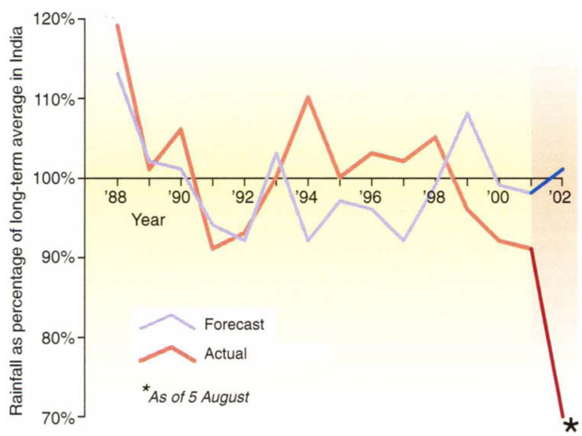
Drought Exposes Cracks in India's Monsoon Model

The annual summer monsoon rains are vital to India's economy. But a drought this summer suggests that a homegrown prediction model might be all wet

NEW DELHI—India's first serious drought in 15 years is doing more than parching the soil and threatening the country's food supply. It has also stirred up a debate over the robustness of a homegrown climate forecasting model that badly missed predicting this summer's sharp decline in life-sustaining rains over much of the country.

The summertime monsoon across India is among the toughest climatic phenomena to understand and predict because of the complex atmospheric conditions in the tropics. But its importance to the economy—the June-to-September monsoon typically delivers more than 80% of the country's 88 cm of annual precipitation—led scientists at the India Meteorological Department (IMD) in the 1980s to create a statistical model that could anticipate the timing and extent of the monsoon. The model incorporates data from 16 meteorological events believed to affect the monsoon, including winter snow cover in the Eurasian mountains and springtime atmospheric pressure over Argentina. Factoring in all these elements, IMD predicted in May that India would experience a normal monsoon.

But this summer has been anything but normal. Although the first monsoon rains arrived on schedule in early June, they soon petered out. By early August the cumulative rainfall for the country stood at 30% below average, with a particularly heavy impact on the country's grain belt in western India. That's an enormous variation for a weather system in which a 10% variation from the long-term average rainfall gets classified as an extreme event. By that definition, the last drought occurred in 1987, with the most recent serious monsoon-caused floods coming in 1994. At the same time, this month has also seen deadly flooding in the northeast.



Coming up dry. The continuing drought in western India highlights flaws in the country's monsoon prediction model.

Scientists don't really know why this year's forecast was off by so much. The model also failed badly in predicting the 1994 floods. "Monsoon prediction is at best a statistical gamble whose reliability is marginally above the throwing of the dice," says Dev Raj Sikka, the man who co-invented the model and who is now chair of the Indian Climate Research Program. Because the model has never really been operationally applied to a drought year, he adds, its "robustness to predict extreme events is questionable." But S. R. Kalsi, deputy director at IMD in New Delhi, believes that an off year is not surprising. "You cannot order the environment to behave itself," he says, adding that dry spells "are a normal part of the rich diversity in behavior of the monsoon."

Some scientists believe that a string of normal monsoons has made the model seem more reliable than it really is. In a paper due out in the December issue of the *Journal of Climate*, climatologists Tim DelSole and Jagadish Shukla of George Mason University in Fairfax, Virginia, write that "1989–2000 happens to be a rare period in which predictions based on the climatology of the prior 25 years are unusually good. This reflects the fact that the monsoon rainfall has been near normal every year during this period. Consequently, any forecast model that predicts near-normal rainfall during this period will have a relatively small mean square error."

This year's atypical monsoon highlighted the model's shortcomings. It marks the seventh consecutive year in which the gap between predicted and observed rainfall is larger than the model's margin of error (see graph). Curiously, however, none of the predictions has been wrong according to IMD's metric, in which a forecast is correct if both the actual rainfall and the prediction fall within 10 percentage points of the long-term average. Many scientists also are unhappy that they cannot judge the model's performance independently because IMD doesn't make public the values of the 16 predictors or disclose details of how the forecast is developed.

Shukla, head of the independent Center for Ocean-Land-Atmosphere Studies in Calverton, Maryland, and a frequent visitor to India, speculates that "artificial skill" might

CREDITS: (TOP TO BOTTOM) SOURCE: INDIAN METEOROLOGICAL DEPARTMENT; P. BAGLA play a role. "We are somewhat baffled why the regression model used by India has not produced a forecast in the past 13 years that is very different from normal," he says. The final product is vetted by the prime minister's office because of the monsoon's tremendous impact on the Indian economy, which has prompted whispers that the forecast could be manipulated for political reasons. But Kalsi vehemently denies that speculation.

The IMD model isn't the only one that has trouble foretelling complex phenomena, says Muthuvel Chelliah of the U.S. Climate Prediction Center in Camp Springs, Maryland. "The farther ahead in time one wants to forecast the weather in a particular place, the more one needs to know, at the present time, about a larger and larger region surrounding that place," he explains. No country, including the United States, has the capability to make monsoon predictions accurately, Chelliah adds.

Knowing which data to collect is a major challenge. The more parameters, say scientists, the more likely they will cancel each other out. "IMD uses too many parameters in their statistical model," says Chelliah, and Shukla says that "no more than three predictors should be used," although he admits that nobody really knows which ones are most appropriate.

The IMD model also depends heavily on data gathered over land. But most scientists believe that the use of general circulation models that couple constantly changing ocean and atmospheric conditions with terrestrial events are essential for understanding large-scale phenomena such as the monsoon. "Prediction of the monsoon will remain a challenging task unless atmospheric data over the oceanic regions surrounding the Indian subcontinent is collected and analyzed," says Shukla.

More extensive field observations might help. Such observations began with the Monsoon Trough Boundary Layer Experiment in 1990 and continued with the Bay of Bengal Monsoon Experiment in 1999 and the Arabian Sea Monsoon Experiment in 2002. "The analysis of data from such experiments will ultimately lead to an improvement in the long-range forecast of the monsoon," says Jayaraman Srinivasan, chair of the Indian Institute of Science's Center for Atmospheric and Oceanic Sciences in Bangalore.

There's also the need to put what is now being collected to better use. "It is almost a national tragedy that the INSAT [India's national weather satellite] data, collected at such huge cost, is underutilized," says Shukla. Officials defend their restrictive policies on the grounds of national security and the need to assist scientists who lack the computational facilities to handle large amounts of raw data.

Despite their disappointment that this year's prediction was wide of the mark, Indian officials say they don't know where else to turn. "I would be willing to prostrate myself in front" of anyone who can do better than IMD has done, says Valangiman Subramanian Ramamurthy, secretary of the Department of Science and Technology, which oversees IMD. Even better models won't help farmers, adds India's minister of agriculture, Ajit Singh: "All the supercomputers and satellites now in use are no substitute for the rain god."

–PALLAVA BAGLA

PLANT GENETICS

Surviving the Long Nights: How Plants Keep Their Cool

Researchers are exploring plants' hidden strategies for surviving the cold months—such as the Douglas fir that remains green but stops photosynthesis

When winter creeps in, casting a mottled sky and raw wind, most of Earth's residents take cover. But plants are stuck outside. With nowhere to turn, the plant kingdom has developed its own strategies for surviving—and even using—the cruel cold season. At the recent American Society of Plant Biologists (ASPB) meeting in Denver, scientists reported new research showing just how complex those strategies can be.

"What happens when plants acclimate to winter?" asked University of Colorado (UC), Boulder, ecophysiologist Barbara Demmig-Adams at the meeting. Her answer: It depends on the plant. Demmig-Adams described a new study in which she, fellow UC Boulder ecophysiologist and husband William Adams, and their colleagues compared winter survival strategies among more than a dozen plant species growing in Colorado's Flatiron Mountains.

The changes induced by cold ranged from slight to severe. During the study, for instance, the researchers documented a montane Douglas fir and a weed, *Malva*, growing side by side and sharing the same frigid days—but reacting in very different ways. Despite being an evergreen, or a plant that keeps sunlight-absorbing green chlorophyll year-round, the Douglas fir actually shut down photosynthesis during winter to stop growing. At the same time, the fir up-

CREDIT: DAVID MUENCH/CORBIS

Under the weather. With nowhere to go, plants have evolved creative ways to survive winter.

regulated carotenoid pigments—such as zeaxanthin and lutein—to help shed any absorbed sunlight as heat. By contrast, the scrappy *Malva* kept right on growing through winter, using every above-freezing chance to photosynthesize at full blast.

The fir's radical strategy is an adaptation to lower temperatures, which impede normal metabolic processes. "Shutting down seems to be the way to go to preserve green leaves in the most extreme winter conditions," remarks William Adams. Whereas short-lived plants such as *Malva* and winter cereals can survive at intermediate elevations during winter, only conifers succeed at higher altitudes. By revving up a photoprotective system, the trees avoid accumulating radical oxygen compounds that could build up in winter and damage them.

In fact, entire evergreen forests appear to wait out winter. This hunkering down is reflected in the rate of CO_2 uptake and release, shown in a study of subalpine forest in the Rockies, published this spring in *Global Change Biology* by UC Boulder ecologist Russell Monson and his colleagues.

Over 2 years, Monson's group found that CO_2 uptake by the forest plummeted as winter set in. "Even on days when it was quite warm, with the temperature approaching 15° to 20°C, the forest stayed locked down," Monson says. But as soon as spring hit in late April or early May, the forest jumped to life almost overnight, becoming a huge carbon sponge. "I think this is the true advan-