WEATHER MODIFICATION

Salted Clouds Pour More Rain on Mexico

Water-attracting salt grains wring more water from reluctant rain clouds in Mexican experiment, boosting the beleaguered science of rainmaking

Skies have been looking bleak for nearly 2 decades for the science of rainmaking—or weather modification, as it's more properly called. That wasn't always the case. In the late 1940s, the young science shook off 100 years of charlatanism, and pioneering researchers tried everything from seeding Missouri clouds to taming hurricanes. By the 1970s, federal funding for weather modification was running upward of $20 million per year. Then the scientific winds shifted. Practically nothing was working in experiments intended to increase precipitation, and scientists didn't understand what was happening in the little work that showed any promise (*Science*, 6 August 1982, p. 519). Research funding in the United States completely dried up. And, although professional rainmakers still plied their trade—today a dozen programs seek to bring some relief to 18 million hectares of drought-stricken Texas—the science of weather modification has been moribund ever since. Now, a glimmer of hope out of South Africa by way of Mexico has researchers guardedly upbeat again.

At the 13th International Conference on Clouds and Precipitation held last month in Reno, Nevada, cloud physicist Roelof Bruintjes and his colleagues at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, reported that their 3-year cloud-seeding experiment in drought-prone northern Mexico provides strong support for a new approach pioneered in South Africa in the mid-1990s that apparently wrings more moisture out of continental storm clouds. The method depends on dispersing tiny water-loving salt particles into developing clouds in order to grow raindrops faster and more efficiently. "I'm very impressed," says cloud physicist Johannes Verlinde of Pennsylvania State University, University Park. "I think it's really promising. The results show pretty conclusively that the seeded storms are producing more rain." Obstacles remain, notes weather modification researcher Daniel Rosenfeld of The Hebrew University of Jerusalem, including understanding all the effects of seeding, but the Mexican experiment is "an important first step toward getting a powerful cloud-seeding method."

The good news on weather modification got its start serendipitously, when a highly instrumented Learjet came upon some "huge" water drops as it flew through the flanks of a large thunderstorm over South Africa. Measuring 4 to 6 millimeters in diameter, such big drops shouldn't have been there, according to all that scientists knew about clouds. On further investigation, South African weather modification researcher Graeme Mather (who died in 1997) realized that the storm was developing over a large paper mill belching tons of particles into clouds overhead. These presumably organic particles turned out to be hygroscopic, able to attract water in vapor form the way salt in a shaker gets damp on a humid day.

Prompted by this finding, Mather, Deon Terblanche of the South African Weather Bureau in Bethlehem, and their colleagues fashioned a 5-year randomized cloud-seeding experiment. They designed a flare, based on a U.S. Navy fog-producing flare, that would yield hygroscopic salt particles (mostly potassium chloride) averaging about 0.5 micrometer in diameter. That was 1/20 the size of any hygroscopic cloud-seeding agent used previously. Mounting 24 flares on the wing of a plane, they flew just beneath puffy, developing clouds whose updrafts would draw the particles up through the cloud's base. Earlier projects had targeted higher, colder parts of clouds with the intent of forming more ice particles.

If the flare particles worked the way the pollutant particles seemed to, Mather reasoned, they would increase the efficiency with which a cloud converted water vapor into raindrops. In untreated summer clouds over eastern South Africa where the experiment was conducted, the abundant but non-hygroscopic particles typical of continental air would form the cores of water droplets once the air rose and cooled enough to saturate it with water. But the available water would be spread over a large number of uniformly small droplets that would all fall at about the same pace. As a result, collisions would be infrequent, and few droplets would coalesce into large enough drops to fall as rain before the updraft flushed all the moisture out the top of the cloud.

Hygroscopic particles, according to theory, would get more rain to form sooner. They would draw water to them, starting droplet formation earlier, and produce a range of droplet sizes, allowing larger, faster falling drops to collide with and coalesce with smaller, slower falling drops. The result would be more raindrops sooner in the half-hour life of a rainy South African cloud and thus more rain on the ground.

Squeezing a cloud. Particles from burning flares beneath a Mexican cloud *(left)* can extract more rain as the cloud grows *(above)*.

Mather's randomized trial of such hygroscopic cloud-seeding produced positive results, as he and his colleagues reported in 1997, but critical statisticians and weather modification's bleak track record required more evidence. So Bruintjes and his colleagues set out to test whether the same method in different hands and applied in a different place would work as well. It did. In Mexico, for example, among the largest quarter of storm clouds, those randomly chosen for seeding were producing 45% more rain as determined by radar than were nonseeded clouds 30 minutes after seeding

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Neighbor effect? A seeded cloud may make adjacent clouds rain more, too.

began. That difference was statistically significant at the 95% confidence level. "They are exciting results," says Daniel Breed of the NCAR group. "There's obviously something going on." Terblanche takes the Mexican results "as a verification of the South African results in a different part of the world. It's confirmation."

Cloud physicists in and out of the weather modification community are also encouraged, but they and the experimenters themselves still have reservations. For one, the Mexican results may be statistically significant, but funding—all of which had come from the state of Coahuila bordering central Texas—dried up once the northern Mexico drought eased. The funding loss prevented a fourth season of operations that should have strengthened the results. And neither the Mexican nor the South African experimenters measured actual rainfall on the ground, only the strength of the radar reflection from raindrops. Because radar is far more sensitive to the size of raindrops than to their number, a few very large drops could have made it appear that seeding triggered more rain than actually reached the ground. In his own computer modeling of hygroscopic seeding, "we definitely see an increase [of rainfall] on the ground," says Zev Levin of Tel Aviv University, "but it's not as much as the radar shows. You still need to do measurements on the ground."

Especially worrisome is that researchers don't fully understand how this seeding works. Although rainfall is enhanced in the 20 to 30 minutes after seeding starts, as the coalescence hypothesis predicts, the most dramatic increases come more than 30 minutes after seeding, and seeded storms rain 30 minutes or more longer than unseeded storms. "It points out there are many things we don't understand about clouds," says Verlinde. Such mechanistic "black boxes" in earlier weather-modification experiments helped trigger implosion of the field in the 1980s. More field studies and more modeling will be required to sort out the possibilities. They include precipitation-enhanced downdrafts that feed back into updrafts. But whatever the explanation, the current results are bringing researchers the first few drops of hope after a long, dry spell in their field.

–RICHARD A. KERR

MARINE MAMMALOGY

Japan's Whaling Program Carries Heavy Baggage

The Institute of Cetacean Research in Tokyo is the scientific arm of Japan's controversial whaling research program. What has it contributed to the field?

TOKYO—Science is supposed to be an international enterprise, but when it comes to research that requires killing whales, Japan is pretty much on its own.

Japan's recent decision to add two species to its scientific haul—which until now has targeted minke whales—has revived the question of whether the real purpose of the program is research, as Japan claims, or keeping the country's whaling industry alive. And although the political and ethical aspects of the debate tend to overwhelm any discussion of the science, the answer seems fairly clear: Although researchers agree that the work is scientifically rigorous, its focus on providing data for managing whales as a sustainable marine resource has generated data of marginal interest to the mainstream marine mammal community. "I think that they are contributing to a large, existing body of knowledge," says ecologist Randall Davis of Texas A&M University in Galveston. "But it's not startling new information."

The basis for Japan's whaling program is a clause in the 1946 International Whaling Convention that allows taking whales for scientific research. Japan has used the clause, which effectively provides a loophole through the 1983 global moratorium on commercial whaling, to allow its scientists to catch and analyze hundreds of minke whales each year as part of an ongoing study of whale stocks. Its efforts generated a political storm that had stalled over the years—until Japan announced this spring that it planned to extend the hunt to a small number of Bryde's and sperm whales. In July, the International Whaling Commission (IWC) registered its unhappiness, saying that the new plan was seriously flawed.

However, Japan pushed ahead, and last week President Clinton responded by banning Japanese whaling ships from U.S. waters, a largely symbolic act that nonetheless underscores U.S. concerns about Japan's research program. "We think that they are abusing the rights afforded them under the convention, and we certainly see no good reason to expand the research to Bryde's and sperm whales," says Mike Tillman, science director at the U.S. government's Southwest Fisheries Science Center in La Jolla, Cali-

There's a catch. Scientists from the Institute of Cetacean Research prepare to analyze a sperm whale caught this month during Japan's expanded harvest.

CREDITS: (TOP TO BOTTOM) NCAR; THE INSTITUTE OF CETACEAN RESEARCH/AP PHOTO