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Controlling the Weather

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In 1997, Midwest tornadoes and flooding caused $1 billion worth of damage and took 67 lives. Hurricane Andrew in 1992 killed 61, and reached a damage tally of $26.5 billion (nearly $33 billion adjusted to 1999 dollars). The drought and heat wave of 1988 dried up $56 billion in losses. An estimated 5,000 to 10,000 people died.

Extreme weather can be devastating and that, at least in part, is the reason why controlling the weather is a challenge scientists have accepted.

Aside from easing human suffering, weather modification potentially has other benefits. Increasing crop yields and even military applications have served as motivations.

Power Over Precipitation

Modern-day weather modification began in 1946 when General Electric discovered cloud seeding in its research laboratory.

Since then, the practice of controlling the weather has developed into more than just theory. A scientific process is used to enhance both rain and snowfall and to reduce the size of hail. It works by sending tiny particles of silver iodide, or other substances such as dry ice or liquid propane, into rain-bearing clouds via aircraft or ground-based stations. These substances serve as *ice nuclei*. Water droplets inside the clouds freeze onto the ice nuclei. Once enough of the droplets grab hold, the fattened particles are heavy enough to fall to the ground.

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Senior Meteorologist Colin Marquis of The Weather Channel explained that ice nuclei are the keys to cloud seeding.

"For freezing to occur, there needs to be ice nuclei present. On the surface of the earth, that's no problem. Different substances can serve as ice nuclei, including ice, certain clays, and other things. They're microscopic and they serve to initiate freezing. The concentration of these particles in the atmosphere is much smaller than on the earth's surface," he said.

Marquis added that it is common in the atmosphere for water to remain in its liquid state below the temperature of 32 degrees Fahrenheit. The phenomenon is referred to as *supercooled water*, and it exists because of the relative scarcity of ice nuclei within clouds.

Dr. Michael R. Hoffmann, James Irvine professor and executive officer for Environmental Engineering Science at California Institute of Technology, maintains that one gram of silver iodide can result in as many as one quadrillion nucleating particles. That number again - 1,000,000,000,000,000.

With all those particles, it seems cloud seeding might produce catastrophic weather events. However, estimates only show a precipitation increase on the order of 5 to 15 percent.

If cloud seeding can manipulate precipitation and has been explored since the 1940s, why isn't it a routine process? Many meteorologists say that's because it has yet to prove its effectiveness.

"It's difficult to prove the consequences of seeding efforts because it's hard to be sure that a cloud you seeded wouldn't have produced [precipitation] naturally, even without the modification. Still, the atmospheric science community has reached a consensus that the seeding of cold clouds (below 32 degrees Fahrenheit) in wintertime can increase precipitation in mountainous areas by about ten percent," said Severe Weather Expert Dr. Greg Forbes of The Weather Channel.

Many disregard the procedure's unproven status. California has jumped on the bandwagon as have many other states. One group of Texas counties spent close to $500,000 in the second year of its rainfall enhancement program. The covered area included 10,000,000 acres and translated to about 5Â¢ an acre.

"Municipalities, agricultural groups, hydroelectric power companies, irrigation districts," Tom Henderson, owner of Atmospherics, Inc., said when asked who hires cloud-seeding companies like his own. "Hydroelectric power companies are very interested in this because water is so valuable to them. Of course to the agricultural community it's valuable as well."

But is it environmentally safe?

According to Hoffmann, there has been no documentation of the effects from silver iodide - the substance most commonly used in seeding - in rainwater. He says that fact can be attributed to the low concentration of the substance in resulting rainwater - 0.1 parts per billion. The limit accepted by the Public Health Service is 50 parts per billion.

"As you may know, silver can be very toxic to aquatic life under the right circumstances," said William A. Stubblefield, Ph.D., Technical Director of ENSR Corporation's Environmental Toxicology and Risk Assessment Group. "However, I don't think that appreciable risk exists because of the very low exposures....They use very low concentrations of silver iodide during seeding operations."

Cloud-seeding advocates are quick to point out that the iodine concentration in resulting rainwater is far below that of table salt. These groups maintain that no significant environmental impacts have been observed thus far, including projects that have been around 30 years or more.

Those in the business of cloud seeding not only defend its negligible harmful effects, but say its benefits are obvious. Many farmers agree with these estimates, claiming that they benefit from cloud seeding. However, if the advantages are so great, why have farmers suffered so from drought?

The two-year drought across the South that began in 1998 has seen disaster declarations in several states. With Congress doling out emergency funds to bail out those whose livelihoods depend on the land, it seems cloud seeding could be a solution.

Unfortunately, for the practice to work, rain clouds must be present. During a drought, rain-producing clouds are scarce.

"By the very nature of drought, which is below-average precipitation over an extended period of time, the resulting factors are large both in scale and duration," said Marquis. "Cloud seeding is possible over a limited area, but the factors and weather patterns that define drought cover such a huge area and last such a long period of time, that it would never work."

Humbling Hurricanes

The energy of a Category 5 hurricane is about the same as all the world's power plants combined. It's no wonder that when one of these beasts makes landfall, billions of dollars in damage can result.

Now scientists are researching a way of taming these wild cyclones with *vegetable oil.*

Researchers at the Massachusetts Institute of Technology are experimenting with cooking oil by coming up with a procedure that would use airplanes to spread a thin layer on the surface of the ocean. The idea is to cut off the hurricane's energy source.

"Hurricanes are beautiful natural examples of what we call heat engines," said Professor Kerry Emanuel of the Massachusetts Institute of Technology. "They take heat energy and turn it into the energy of the wind. The heat that they use to do this comes from the ocean. And the stronger the winds at the center of the hurricane, the more evaporation occurs, the more heat is added to the hurricane, which makes the winds stronger. So it's kind of a positive feedback cycle."

But why vegetable oil?

"[It has] to be biodegradable, not in any sense environmentally harmful. Because we don't want to cause as much damage in one sense as we reduce in another," said Emanuel.

The challenge is to create a layer of the stuff that will endure hurricane-force winds, thereby reducing evaporation from the ocean surface, the fuel for hurricanes.

"There's no doubt the slick would break up. The question is whether enough of it remains to have a significant effect, whether the spray droplets remain coated," said Emanuel.

By distributing a one-molecule-thick cover of vegetable oil on the ocean's surface, scientists hope to starve the hurricane, or weaken it to a less-damaging prospect.

"We don't really know what to expect," said Emanuel. "So we have built this experimental apparatus, called a wind-wave tank, in which we will test various different compounds to determine what they do to the rates of evaporation under very high wind speed conditions."

But what are the chances this experiment will succeed?

Dr. Steve Lyons, Hurricane Expert at The Weather Channel, says there are a number of factors that could be prohibitive barriers. "You'd need to put down a coat of oil across a very large area, especially given the movement of tropical cyclones, and moist air coming in from outside the treated area would keep the tropical cyclone environment very moist and continue to supply energy. Also, you can't truly simulate a hurricane in a wave tank; very large breaking waves in an actual hurricane would disperse the oil and moisten the air," he said.

Even if the odds are extremely small, "the consequences of being successful are so great for mankind that we feel we ought to give it a shot," said Emanuel.

Taming Tornadoes

Bernard Eastlund, founder of Eastlund Scientific Enterprises, is trying his luck at taking on tornadoes.

"Within about two months of moving to Houston, Texas, my house was hit by a tornado and, when I woke up in the morning, four of my beautiful pine trees were laying in neighbors' yards," said Eastlund. "In that storm where we lost a few trees, twelve people died within a half-mile of my house. We had something like twenty-five tornadoes hit that area that night."

His company is trying to stop tornadoes before they form by using solar power-generating satellites in space.

No one truly knows how a tornado forms, but the predominant theory has to do with the winds inside a severe thunderstorm. Warm, moist air circulates in an upward motion, known as an *updraft*. This flow builds a cloud until it explodes with rain. Some of the energy trapped in the cloud finds an alternate route of escape by sinking to the ground in the form of cool air, known as a *downdraft*. The latest theories about tornado formation suggest that thunderstorm downdrafts play an important role. Scientists believe that the interaction between the cool downdraft and a warm, moist rotating updraft of a thunderstorm is crucial to the development of a tornado.

In theory, when a thunderstorm looks favorable for producing tornadoes, Eastlund thinks a satellite directing a beam of microwaves at the downdraft of the storm would dissipate the tornado. By heating the downdraft, thereby weakening it, there would be less interaction between it and the rotating updraft, and the tornado wouldn't form.

"My reasoning was, it's got to be pretty hard to form a tornado. Not every storm makes them," said Eastlund. "And maybe there's something about the fine structure of the boundaries between the cold air and the others you could affect with heating. And I identified, with the help of some people at the University of Oklahoma, the cold rainy downdraft."

This proposition could be a tricky one. Dr. Greg Forbes, severe weather expert at The Weather Channel, says the process could prove to be more complicated

in practice.

"While, in principle, steering the beam to the correct spot is technologically feasible, it's not simple. The geostationary satellites tend to wobble a little bit in their orbits, so that would have to be very accurately corrected for in the aiming software. Otherwise, it would be easy to be off by a mile. Second, there could be atmospheric effects that might bend the beam a bit which would vary with the meteorological situation. The beam would be coming down through the stratosphere at an angle, so it could be bent a bit by the strong inversion there, or by other inversions related to the storm or intervening clouds," he said.

Forbes points out that good intentions might result in harmful consequences.

"The device can be programmed to avoid hitting aircraft, but many small aircraft don't file flight plans when they're flying VFR [Visual Flight Rules - which applies to pilots and what they are licensed for in relation to using instruments to fly in bad weather]. And even flights on flight plans can deviate on short notice to the air traffic controllers to vector around thunderstorms. They could very well be in the slant path of the beam in such situations," said Forbes. "Then there is the whole difficulty of proving that you prevented a tornado, when in reality most supercell storms don't produce a tornado anyway."

Guiding Lightning

At any given time, 2,000 thunderstorms around the globe hurl 100 bolts of lightning toward the earth every second. In the U.S. alone, 15 to 20 million strikes hit the ground each year.

Lightning is one of the deadliest types of weather, causing millions of dollars worth of damage annually.

One Canadian company is taking a proactive approach to the problem by developing a lightning-steering machine.

While not yet perfected, the titanium-sapphire laser gun was created to shepherd lightning toward a predetermined terminal. The goal is to keep the mammoth surge of electricity from striking vulnerable power lines and buildings. It works by firing a laser beam into a cloud. The beam charges the air molecules it comes in contact with as it travels.

"When the lightning bolt is starting from the thundercloud, it can follow that path instead of trying to feel its own way toward the ground," explained Bruno La Fontaine, lead scientist on the project.

Once the lightning is set on a direct path, its charge can be neutralized.

Sound too good to be true? Scientists say this technique could be a reality in as few as ten years, but it may not provide a complete solution, according to Dr. Greg Forbes, severe weather expert at The Weather Channel.

"The technique might, in principle, be able to reduce the probability of a lightning strike of some key facility, but not make it completely lightning-proof," said Forbes. "The laser beam would just go along one straight-line path to the cloud, whereas the lightning strike can take a circuitous, forked path from cloud to ground. Lightning doesn't always take the most obvious path, even when you put the protective device very near the target."

How Uncle Sam Employs Mother Nature

While citizens who try to control Mother Nature are often motivated by promoting human safety, the U.S. military has been known to modify the weather for tactical purposes.

Cloud seeding was used in the Vietnam War under code-name *Popeye*.

"Project *Popeye* was intended to reduce the mobility on the Ho Chi Minh Trail on the west side of the Anateak mountains in Vietnam, Laos, and Cambodia by making it rain...so it would impede mobilization," said Geophysicist Pierre Saint-Amand, employed by the Navy at the time. "This program was classified top secret."

The Ho Chi Minh trail was the main supply line through the jungle to the Viet Cong. In 1966, American forces began to seed the clouds across the route, hoping to flood rivers and make them impassable.

"At the end of the first week of systematic seeding, you couldn't get across the fords anymore. You could look down and see these guys driving up by the river and stopping, and pretty soon, you'd see trucks in the river with water over the roof," said Saint-Amand.

The first successful project began with the U.S. Navy's seeding of Hurricane Esther in 1961. Project *Stormfury* was only one in a series of attempts to dissipate the strength of tropical cyclones.

"The hypotheses upon which *Stormfury* was based was that if you seeded the right, forward quadrant of the storm, that you could cause it to dissipate its energy faster and wear it down," said Saint-Amand. "This was the theory concocted by the people in the Weather Bureau."

However, the experiments were short-lived.

"Everybody was afraid that if they seeded a hurricane and the thing came across Cuba, we would never be permitted to hear the end of it," said Saint-Amand. "And if it came across the eastern United States, that the lawyers would have a feeding frenzy. And that's exactly what would have happened. So they decided to let it go. It was just too dangerous from a standpoint of liability."

So what does Uncle Sam have in the works for Mother Nature today? It happens that weather modification is now a taboo for the military. A 1978 United Nations agreement banned use of the tactic.

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