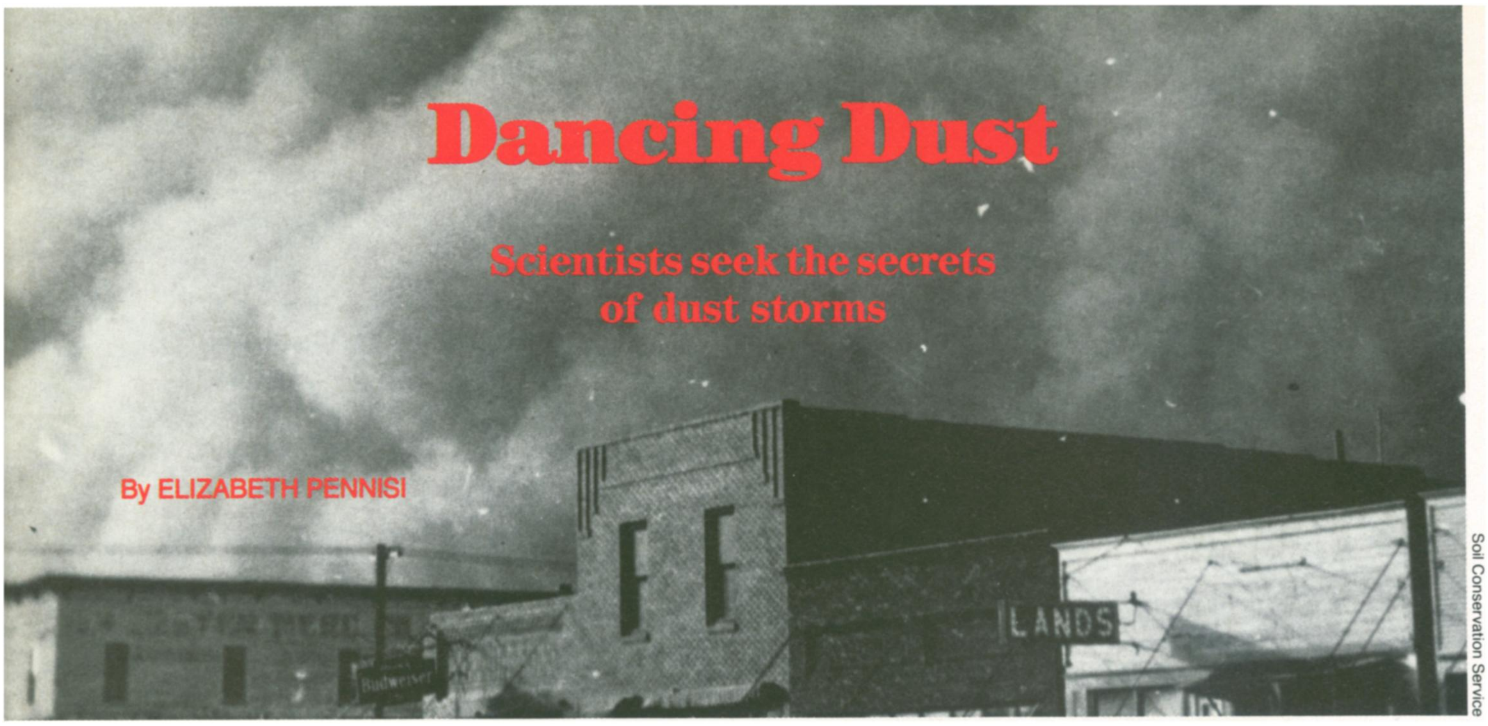
Dancing Dust

Scientists seek the secrets of dust storms

By ELIZABETH PENNISI



Soil Conservation Service

A Dust Bowl era storm blackens the sky in Morton County, Kan.

When winds race helter-skelter across the countryside, the serenity of a rural landscape can come to a dramatic end. What begins as a gentle breeze wafting across open land may end up as a violent dust storm that can cause millions of dollars in damage to crops, buildings, and roads.

First, the wind picks up imperceptibly and makes small pebbles quiver. Then some dirt starts to tumble downwind, recruiting more dirt and sand with each bounce and building to a gritty stampede. This jostling can crunch the ground's fragile crust and make soil more erodible.

Like a novice juggler, the moving air tosses the bits of dirt and sand upward, only to drop them again. As the wind intensifies, it snatches any loose soil and hurls it back at the ground. These projectiles smash into clods of earth, knocking off other small bits — further ammunition for the wind's attack.

The continuing barrage breaks down more and more clods, sending particles into the air where they rain back down again with increasing frequency. Finally, some of the dirt becomes small enough and light enough that the wind sweeps it off, sometimes carrying it long distances.

Thus, in a knee-high space, a dust storm is born.

Almost 15 years ago, a researcher watching the evening news in Washington, D.C., noticed a giant dust cloud swirling eastward across the station's satellite weather map. He quickly phoned Carol S. Breed and her colleagues at the U.S. Geological Survey (USGS) in Arizona. The next day, the USGS scientists borrowed a plane to chase the storm.

Two plumes of dust had converged to create this particular cloud. Covering 1 million square kilometers, it remains the largest dust storm the Geostationary Operational Environmental Satellites (GOES) have ever tracked, says Breed. From its origin in eastern New Mexico and Colorado, it swept across the southern United States in less than four days, finally dying out over the Atlantic Ocean.

In some fields, the storm's winds gouged a meter deep into the soil; downwind, the storm erected equally high sand piles that blocked roads and buried fences in parts of the West. Gusts scoured the fields, killing crops and eroding topsoil. Winds blew down fences and damaged roofs. Pilots in Texas complained about dusty haze 4,000 and 5,000 meters above the Earth's surface. "It was very dramatic," recalls Breed. And for farmers in the storm's path, "it was a big disaster."

The magnitude of this storm, which arose because of a convergence of unusual environmental conditions, made scientists like Breed take notice. Dust can be a symptom of an unhealthy soil surface, Breed says, and she wants to get to the underlying causes.

"What we're trying to do is get a lot better at predicting the conditions under which a dust storm might develop," says Milan J. Pavich, a geologist with the USGS in Reston, Va. The Dust Bowl years exacted a heavy toll, but a repeat of those conditions today could be even more devastating. "For much of the West, there's more of a technologically based infrastructure that is much more sensitive to dust," Pavich says.

Researchers have begun to document how erosion occurs and the role airborne soils play in geological and atmospheric processes. Dale A. Gillette, an atmospheric scientist with the National Oceanic and Atmospheric Administration's Air Resources Laboratory in Boulder, Colo., calculates that wind erodes about 20 million tons of U.S. soil a year. That's enough dust to fill four baseball stadiums to the top row of seats, says Gillette, who will describe dust sources in an upcoming Global Biogeochemical Cycles.

Gillette classifies dust by its origin: human-made or natural. Wind whipping across farm fields kicks dirt into the air, but so do cars driving down unpaved roads, his research shows. Wind also erodes nonagricultural areas, sometimes creating storms of the magnitude recorded in 1977. But even without a steady breeze, dust can storm, especially in hot weather, he adds.

As air warms, it rises not as a mass, but in narrow vortices that spiral upward, explains Donald W. Fryrear, an agricultural engineer with the U.S. Department of Agriculture (USDA) office in Big Spring, Texas. If the soil can erode, then the spiral whips up a dust devil. And while Fryrear contends dust devils contribute little dust to the air, Gillette argues that these swirls can add amounts comparable to that generated by wind alone.

Once airborne, particles can travel quite far. "Some of that soil will actually circle the globe," says Fryrear.

Often, the chemical makeup of dust gives its geographic origins away. Chemical analyses have proved, for example, that Texas dirt can be found in every eastern state and parts of Europe.

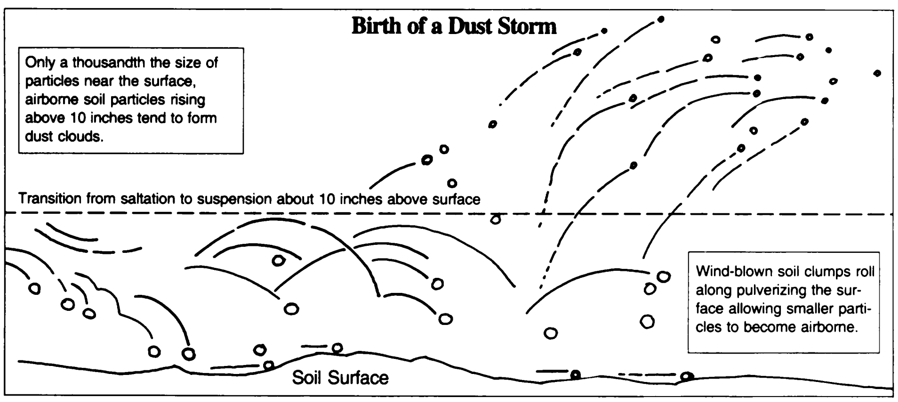
Wherever it winds up, that dust exerts profound effects on air, soil, and ocean chemistries. "If you look at all the particles in the air, a lot is dust," says Gillette. "There can be a lot of chemical reactions in the air, and a lot of them can be influenced by dust." For example, much dust, especially that derived from unpaved roads, consists of calcium, which can help neutralize acid rain, he says.

Terrestrial dust probably supplies the ocean with much of its iron, a nutrient thought by some scientists to limit the productivity of deep-sea algae, says H. Brad Musick, an arid lands ecologist from the University of New Mexico in Albuquerque.

Dust may also build up soils. "For the western U.S., one of the things we're learning is there may be more of a dust contribution to soil than was expected," Pavich says. Other research indicates that airborne dust may help build soils in West Africa and Australia as well, and at least one study has hinted that most of the inorganic nutrients found in the Amazon rain forests blew in from the Sahara.

Also, if predictions about global warming prove true, increased dryness in semi-arid regions could lead to more frequent dust storms, intensifying their influence on the delicate chemical balance of the air and oceans, and even on the world's soils.

Dust scientists argue, therefore, that researchers concerned about global change need to pay more attention to dust. "The global change community is mostly driven by the concerns of atmospheric scientists, who are focusing on gas composition," Musick says. "They are not used to dealing with dust. But we think there's at least a possibility that dust could be producing a secondary effect."



AGRICULTURAL RESEARCH

Fryrear has long appreciated the significant – and pervasive – nature of dust storms. While growing up in eastern Colorado, he was fascinated by the dark dust clouds and by tales about the devastation of the Dust Bowl years. When he went to work for the USDA in Big Spring during the 1960s, local farmers commonly bought enough seed to plant their fields twice each season. About 80 percent of the time, dust storms would wipe out the first planting, he says.

These days, fewer than 20 percent of those first plantings fail, thanks to a better understanding of the mechanisms and causes of wind erosion and some preventive actions, he adds.

"We can show that we have reduced by at least 50 percent, or perhaps even 75 percent, the number of erosion events," says Fryrear. "We are not doing anything about the wind, but we can change the erodibility of the soil."

Cotton farmers in the region know just when the soil is wet enough to till without leaving the dirt susceptible to wind. They keep dead crops in the fields to cut down the wind's power and access to soil surfaces. And they know not to wait until a field starts to erode to till it and not to think that rain will solve the problem.

"If they use an implement to roughen the soil up, the big clods formed are very stable," Fryrear says. "It cuts down on the magnitude of erosion."

Dry soil tends to clump, forming pieces too heavy for all but the strongest winds to break up. But just a quarter inch of rain primes that soil for wind erosion. "It will tend to melt [clods] down into a smooth, flat surface," Fryrear explains. "On the top there will be a layer of sand grains that are not attached."

Even a soaking rain can leave a soil vulnerable. When wet particles clump to form bouncing, marble-sized projectiles, "they become the groundbreaking sledgehammers that make the whole thing happen," says Fryrear. "I've seen soils eroding that were too wet for a farmer to get in and work."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The 1936 Dust Bowl days in Cimarron County, Okla.

Only in the past decade have Fryrear and others begun to clear the air on how dust storms begin.

First he needed techniques and equipment for sampling airborne dust. He finally came up with a sturdy device that could withstand pelting by sand and would not clog when bombarded by windblown particles. These devices also sample particles at different heights – upwards of 100 feet at times – and work no matter what the wind direction.

The samplers handle high winds well but are no match for cattle scratching their backs by rubbing up against the poles on which the devices are mounted. "And birds like to roost on top of them," Fryrear complains.

Since 1989, his devices have collected 15,000 samples during 180 "erosion events" in Colorado, Nebraska, Montana, and Texas. Researchers are setting up samplers in Minnesota, Missouri, Kansas, Washington, and Utah to study how freezing and thawing affect erosion.

At each location, the scientists are installing the equipment for the duration of the erosion season – late fall through early spring, says Fryrear. Typically, the research team sets up its sampling poles in a barren field. Each pole holds five samplers at different heights; the researchers empty the samplers after each wind storm. Another device enables the researchers to trap particles too heavy for the wind to lift.


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Dust-covered fields.

The samplers don't pick up much material – often less than a thimbleful per storm. But this research has helped clarify mechanisms of wind propulsion.

The field experiments revealed that the size of the particles undergoes a marked decrease as height above ground increases, says Fryrear. Along the ground, particles ranging from 2 to 4 millimeters in diameter roll along in what Fryrear calls the "creep zone." Inches higher, slightly smaller, saltating particles – those that are lifted up and then thrown back down again – fill the air. Three feet above that, the airborne particles are only one-thousandth the size of those racing along the surface. Particle size drops most dramatically in the first 10 inches above the ground, says Fryrear.

Thus, 10 inches or so marks an important boundary: the transition from saltation to suspension (TSS). A particle lifted above the boundary becomes suspended indefinitely, Fryrear explains. However, the height of this boundary varies, he notes. The stronger the wind, the lower the TSS zone. Soil type also affects the height of the boundary.

Fryrear thinks that changes in the amount of dust above and below the TSS boundary may help predict dust storms. For example, a sudden increase in the number of particles below the boundary might have warned officials about the dust storm that last year blinded drivers on Interstate 5 in California's Central Valley. "Maybe we could have prevented the terrible pile-up and wreckage and loss of life," he says.

For USGS' Breed, the 1977 dust blizzard drove home the need to understand the forces that lead to wind erosion, not just on agricultural land, but also on natural landscapes. She helped set up the USGS Desert Winds project, now in its 12th year. For Desert Winds, five monitoring stations – one for each desert type in the Southwest – gather both meteorological and geological information. "[Each] collects round-the-clock data on critical conditions that control the capability of wind to erode, transport, and deposit particles of sand and dust," Breed explains.

Every hour, the solar-powered devices relay wind speed and direction, precipitation, air and soil temperatures, humidity, and pressure from these "geomet" towers back to computers, where the data are stored. Four of the five stations also monitor solar radiation, contain special sensors to detect grains of sand hitting them, and hold three of Fryrear's samplers for collecting windblown sediment. In addition, the researchers periodically photograph specific spots to record changes in the landscape. Thus they know the wind's speed at the moment sand becomes airborne, and they can track the amount of soil picked up.

"By comparing the different types [of deserts], we can see some of the major influences on the size and mass of sediment moved," Pavich says.

Desert Winds researchers hope to establish the extent of normal variability in weather, wind, and soils. "The geomet stations are going to provide us with a baseline about climatic conditions and current ground conditions over a period of time," says Breed. These detailed wind and dust data will help scientists develop more accurate models of wind erosion and will act as checks for observations made via aircraft and satellite sensing, she adds.

So far, three years of drought at the geomet station in Yuma, Ariz., have taken their toll, USGS geologist Paula J. Helm reported at the December 1991 meeting of the American Geological Union. From 1988 to 1990, the wind speed required to initiate dust movement decreased dramatically, and the amount of dust carried per storm increased, she says.

Plant cover plays a key role in wind erosion. At the geomet site in Yuma and at a field site north of Las Cruces, N.M., Musick has begun studying long-term vegetation changes. He has assessed the role of plants in wind tunnel experiments as well as in field studies, using inch-high cylindrical blocks to stand in for plants. Perennial plants – trees, cacti, bushes – influence erodibility, but so do more ephemeral flowers: A little rain causes tiny annual plants to sprout, greatly reducing the ground's susceptibility to wind, Musick says. Eventually he hopes to be able to predict the amount and distribution of plants needed to minimize wind erosion in these arid regions.

In general, the geomet data show that as smaller soil particles blow away as dust, the ground grows coarser over time. "You see very dramatic changes in the land surface characteristics," says Breed. The sand that remains tends to roll, creep, or bounce with the wind until it meets some obstacle. Then it settles and can build into a dune.

"This may all seem very obvious, but it has not been documented on natural surfaces," she adds.

One of the most recently established geomet stations monitors conditions at Owens Lake in southern California east of the Sierra Nevada. Once fed by Owens River, the lake dried up in 1926 after engineers diverted the river 400 kilometers to provide water to Los Angeles. Now the lake site, with about 100 square miles of exposed, barren lake bed that erodes easily in the region's frequent high winds, represents what Gillette calls "the greatest natural [dust] laboratory in the United States." In addition to measuring natural storms, Gillette has also used a 6-foot-long wind tunnel on this lake bed to simulate wind storms.

"In a wind tunnel you can control [conditions] better," he explains. "So if you are looking at subtleties, you can find them. Also, a wind tunnel gives you the opportunity to repeat the experiment as often as you need."

At this natural laboratory, Gillette has studied dust storm dynamics. Like avalanches, dust storms build up as they travel, he says. At first he thought that the energetics of the wind might cause it to pick up increasing amounts of dust as it moves along. But his research, like Fryrear's, shows that soil plays a big part in generating ever more dust.

When wind first hits the dry lake bottom, many particles that it tries to lift weigh too much. But when these heavy bits fall back to the ground slightly downwind, they may split into smaller pieces. The wind picks these smaller pieces up and carries them a little farther before discarding them and splitting them into even tinier pieces.

Thus, as the wind zips down the lake, it needs less and less strength to make these ever smaller particles airborne. Farther along, "the soils are more beat up," Gillette explains. As a result, the so-called threshold velocity – the minimum wind speed needed to initiate erosion – decreases. Gillette hopes next to couple his studies with geomet data.

Slowly these results help build a sense of what dust storms are really all about – and how they can eventually alter the landscape. "What we're trying to do is come up with information that will help us advise countries about their land-use policies," Pavich says. These efforts need to spur an appreciation for the role dust can play in global change, he adds. Otherwise, like a powerful dust storm that seems to appear out of nowhere, dust may one day sneak up on global change experts with an unexpected, dramatic effect. □

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Dust devil or "windwhirl" in Minidoka National Forest, Utah.