Dust and Snow

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High in the snowy San Juan Mountains, tiny particles have big implications

Tom Painter thinks a lot about dust, and it all started during a hike with his father.

Eight years ago, when the younger Painter was working on his Ph.D. in geography, he and his father spent a day hiking in the Maroon Bells near Aspen, Colo. "We were walking up the snowfields at about 5:30 in the morning, and I told my dad, 'Let's do an experiment,' " he says. "I knew there was a layer of dust on the snow, so I scraped off an area about a foot square, and showed him how clean it was underneath. "Then we climbed the peak, and when we returned in the afternoon, you could see this column of white snow just extruding out of the surface." On top of that column, about a handsbreadth high, was the small, bright square he'd exposed in the morning.

The column hadn't risen from the snowfield; the snow surrounding it had melted, because the dirty snowfield had absorbed more solar radiation than the clean square. Says Painter: "My dad started asking questions that I didn't know the answer to."

Painter, now a researcher at the National Snow and Ice Data Center in Boulder, Colo., knew that dust changed the reflectivity — or albedo — of the snow surface. White snow reflects a lot of light, so it absorbs less energy and melts relatively slowly. Dirty snow reflects less light and melts more quickly. The faster snow melts, the sooner it exposes deeper dust layers, creating a feedback loop that further accelerates the melt.

What Painter didn't know was where the dust in the Rockies came from, how often it arrived, or just how large a role it played in the melting of the snowpack. "So when I finished my dissertation a few years later, the first thing I did was to start looking at dust," Painter says. "It's turned out to be a much bigger issue than I ever expected."

From the summit of Red Mountain Pass in southwestern Colorado, on a clear day in mid-April, the snow-covered slopes of the San Juan Mountains wink back from every direction. Here, a crew of hydrologists, chemists, snow scientists, and inveterate skiers is preparing to climb into Senator Beck Basin, high above the western side of the pass, to watch snow disappear. As University of Colorado graduate student Maureen Cassidy jokes, the team will "weigh and measure and smell and taste" the snowpack, looking at the role of dust in its seasonal exit.

In 2004, when Painter first started investigating the mysteries of dust, he and his collaborators gathered some preliminary data in Senator Beck Basin, using it to construct a computer model that compared the effects of temperature and dust on snowmelt. They found that stepping up air temperatures by a whopping 6 degrees

Celsius would cause the basin's snow to disappear five days earlier.

The impacts of dust were more dramatic. "We expected a difference of maybe five or six days," between the melting of dusty and dust-free snow, says hydrologist Andrew Barrett, also with the National Snow and Ice Data Center. Instead, they found that a single dust event could cause snow to melt away 18 days earlier than it would if there were no dust at all.

In the Western mountains, which act as the region's water towers, the implications of these rough estimates are stark. If dust deposits in the mountains increase for any reason, the researchers surmise that snowmelt will both happen faster and finish sooner, leading to bigger and earlier peak flows in streams and rivers. That would cause headaches for water managers, who would need to store the rush of water, and it would perhaps result in more frequent or serious summer water shortages. The dance between dust and snow, the scientists realized, needed closer examination.

So Painter and Barnett, along with Chris Landry, the director of the Center for Snow and Avalanche Studies in Silverton, Colo., expanded their study and began gathering a suite of detailed data. Each week during the spring, Landry and others dig a series of pits in the snow — sometimes more than seven feet deep — to study how the snowpack changes as dust layers are exposed to the surface. They also download hourly measurements of snow reflectivity from a state-of-the-art meteorological station, and hourly data on streamflow from a gauge at the bottom of the basin.

During their mid-April outing, the crew digs additional snow pits, and also measures the depth of the snow throughout the basin with thin aluminum probes. With these and other datasets, the researchers plan to build a sophisticated model of dust, climate, snowmelt and runoff, one that can be adapted to other basins and ranges.

After a couple of hours of climbing on wide backcountry skis, the scientists and their assistants reach the highest point in the basin, a 13,500-foot ridge marked by a cairn. Behind lies the rugged bulk of the San Juans, and far below their ski tips is the arrow-straight main street of Telluride. Beyond are the deserts of the Colorado Plateau, spiked with the Abajos, the La Sals, and the hazy, distant outline of the Henry Mountains.

"Look at all the damn dust!" says Painter, gesturing at the slopes. To a casual observer, the snow looks white, but on closer inspection, it is covered with streaks of red and pink dust. The next question: Where is all the dust coming from?

From the top of Senator Beck Basin, we can't see Jayne Belnap, but she is less than 100 miles away on the dusty horizon, studying how soil moves around the world. Belnap, a researcher with the U.S. Geological Survey, has spent most of her career investigating the soils of the Utah deserts (HCN, 1/19/04: Getting under the desert's skin), and she has gathered several years of data on dust.

On desert grasslands that have never seen grazing, "there's barely any dust production, no matter what"; the dust traps she posts in those areas collect perhaps a tablespoon every six months. Most years, traps in formerly grazed grasslands collect about twice as much, and currently grazed lands collect even more, about nine times as much. But the most dramatic differences, says Belnap, emerge during severe drought years. While the ungrazed grasslands stay more or less the same, formerly grazed ground produces as much as 20 times the amount of dust as in wetter years. Currently grazed lands "just go bonkers," with the dust traps sometimes filling faster than Belnap and her coworkers can empty them.

Grazing, development, off-road vehicle use, and military training activity form what Belnap calls a "background signal" of dust in the Southwestern deserts.That signal seems to be strengthening. Jason Neff, a researcher at the University of Colorado at Boulder who works with both Belnap and Painter, studies historic dust in sediment cores from lakes in the Senator Beck Basin. He says most dust in the San Juans comes from northern Arizona, and that "there's a hint that things have changed in the past 100 to 150 years," with dust deposits appearing to have increased significantly.

One prime suspect is heavy grazing on the Navajo Reservation in northern Arizona and New Mexico, though road-building and other construction are clearly on the rise. "Whether it's cows, people or vehicles, we don't know, and we may never know," says Neff. "But over the last 150 years, so much of the landscape has been used. It just makes sense that there would be more dust."

The researchers hypothesize that if dust events do continue to increase, mountain snow will melt earlier in the spring, and the summer droughts that may ensue could lead to — you guessed it — more dust, further eroding the mountains' ability to store water. "I hate to use the word catastrophe, but that's probably the right word," says Belnap.

Throw climate change into the mix, and the forecast gets even more grimly interesting. So far, the effects of global warming on the higher, colder Rockies are not as marked as those in lower coastal ranges, where even a small rise in winter temperatures can turn snow into rain (HCN, 3/6/06: Save our snow). But if dust keeps crowding into the mountains, says Painter, it could amplify the effects of warmer temperatures, boding ill for high-elevation snow in the Rockies and elsewhere. "If you put dust and warming together — watch out," says Painter.

The effects of dust aren't limited to the San Juans, or the Colorado Plateau. Many major mountain ranges, in the West and beyond, are downwind from deserts, and they collect dust just as the San Juans do. And dust, of course, knows few boundaries. Every so often, Westerners are showered with tiny particles from the Gobi Desert, or from the Takla Makan Desert of far western China.

It's enough to make Painter think big. On the downhill slide to Red Mountain Pass, after a long day of discussions and data collection on the sun-crusted snow, the researcher pauses again to look at the slopes' streaks of dust, which appeared earlier than usual this year. He shakes his head at their bold appearance, and their global implications. "The next thing we need to do," he says with a grin, "is send a grad student to the Hindu Kush."

Michelle Nijhuis is *HCN*'s contributing editor. Her series on global warming in the West won the 2006 Walter Sullivan Award for Excellence in Science Journalism.

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Michelle's articles are so well crafted and have such clarity. She's the best environmental reporter I've read. Particlesin the atmosphere and airplane contrails dim the sun and reduce temperature. Yet darkened snow melts faster and snow and ice free areas absorb more solar radiation raising temperatures. The dimming of the sun moderates the rise and yet dust settling out accelerates melting. Overgrazing and oil and gas exploration and development are causing the West's basins and deserts worldwide to blow away. Evidence of human activities driving climate change is irrefutable and understanding their complex effects is difficult.

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