Cinnamon Snow: Flecks of Dust Alter Western Water Supplies

By Zack Guido

Fierce winds whipped across the Colorado Plateau on March 18, raking plumes of dust into the air. Hundreds of miles to the northeast, the winds scoured the San Juan Mountains at 60 miles per hour, scattering flecks of red and brown earth across the white snow. Farther north, in Boulder, Colo., air quality plummeted.

Figure 1. Fierce winds on May 11, 2009, painted the Upper Colorado River Basin, including the Elk Mountains near Aspen, Colo., with brown dust. Photo credit: Jack Brauer, WideRange Photo LLC

Walls of dust unleashed by such blustery spring conditions can sling sand and silt from the Four Corners region hundreds of miles, ultimately sprinkling snow in the Upper Colorado River Basin with a cinnamon-colored coat that soaks up sun rays. These dirty snowpacks can significantly affect water resources in the Southwest; they often cause earlier snowmelt that hastens the timing of peak streamflows and can send gushing torrents down alpine creeks. Moreover, recent research suggests that dust layers reduce the amount of water available to about 30 million people in the U.S. and Mexico who rely on the Colorado River.

With the likely specter of increasing temperatures and fewer winter storms, dust events may become more common in the future and stress the region's already limited water supply. But there is also a silver lining: minimizing dust mobility may help put water back into the river.

Albedo

The sun incessantly beats down on the Southwest. About 1,100 watts of energy hit the landscape at midday in southern Colorado every second, for example, creating enough energy, if it accumulated over three hours, to power the average U.S. house for an entire year. A fraction of this energy is absorbed by earthen materials that, in turn, give off heat. Part of the energy, however, is also reflected back to space. The reflectivity of an object is known as albedo; the higher the albedo, the more reflectance.

Darker objects have lower albedos. Deserts reflect about 30 percent, forests 20 percent, and asphalt only about 10 percent. Because cities are laced with low-albedo materials like asphalt, they tend to be warmer than pristine spaces, creating what is known as the urban heat island effect.

On average, Earth's albedo is about 0.3, reflecting 30 percent of the incoming solar radiation back to space, but the amount differs considerably across landscapes. The highest albedo of any naturally occurring surface is clean snow. The glistening surface reflects about three-quarters of the solar radiation that hits it. Snow mottled in dust reduces the albedo of fresh snow to about 45 percent, turning a highly reflective surface into a landscape that absorbs 30–70 watts more energy. Dust is like sprinkling small heat rods into the snowpack.

"Dust is a massive conduit of energy into snowpack," said Thomas Painter, a research scientist at the California Institute of Technology's Jet Propulsion Laboratory. "For clean snow to absorb the same amount of energy as dirty snow, the earth would have to be closer to the sun than Venus."

Increased energy not only melts the snow, but it also enlarges individual snow crystals. Larger crystals allow sunlight to penetrate further into the snowpack, increasing its chances of eventually striking dust and further warming the snowpack. The presence of dust often increases the temperature of snowpacks by 3–7 degrees Celsius (roughly 5–13 degrees Fahrenheit).

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Cinnamon Snow, continued

Dust Events

Since 2003, researchers have monitored the number of times visible dust layers have been deposited in southern Colorado's San Juan Mountains. In the last 10 years, the mountains have been coated with dust about eight times per year, on average. In 2009, a record 12 dust layers accumulated. Most layers are deposited in April and May, when persistent winds in the Southwest sweep across many sparsely vegetated areas.

"There are hundreds, even thousands of dust sources, and much of it comes from northeast Arizona and northwest New Mexico," said Richard Reynolds, a research scientist at the U.S. Geological Survey in Denver. "Many settings in the Little Colorado River drainage basin, but not the river bottom itself, and in Chuska Valley are particularly important source areas."

These regions become even more prone to exporting dust when dry times reign and vegetation cover wanes. Dry weather has been the norm so far in 2012, and most of the Four Corners region has received less than 50 percent of average rain and snow since January 1. As of April 16, eight dust events have occurred, and the withering landscape is primed to give up more dust.

"It's been a very dry year," Painter said. "We are on par with 2009, which was a huge year for dust-on-snow events."

The Four Corners region is aptly suited as a dust source because it is sparsely vegetated and sits in the path of spring storms. It also happens to be situated upwind of many high Rocky Mountain peaks, including the San Juan Mountains, that can act like windbreaks and cause millions of wafting particles to settle.

Dust events have occurred in the region for thousands of years.

"There are aeolian [wind transported] deposits that predate human settlement," Reynolds said. "It's been dry and windy for a long time."

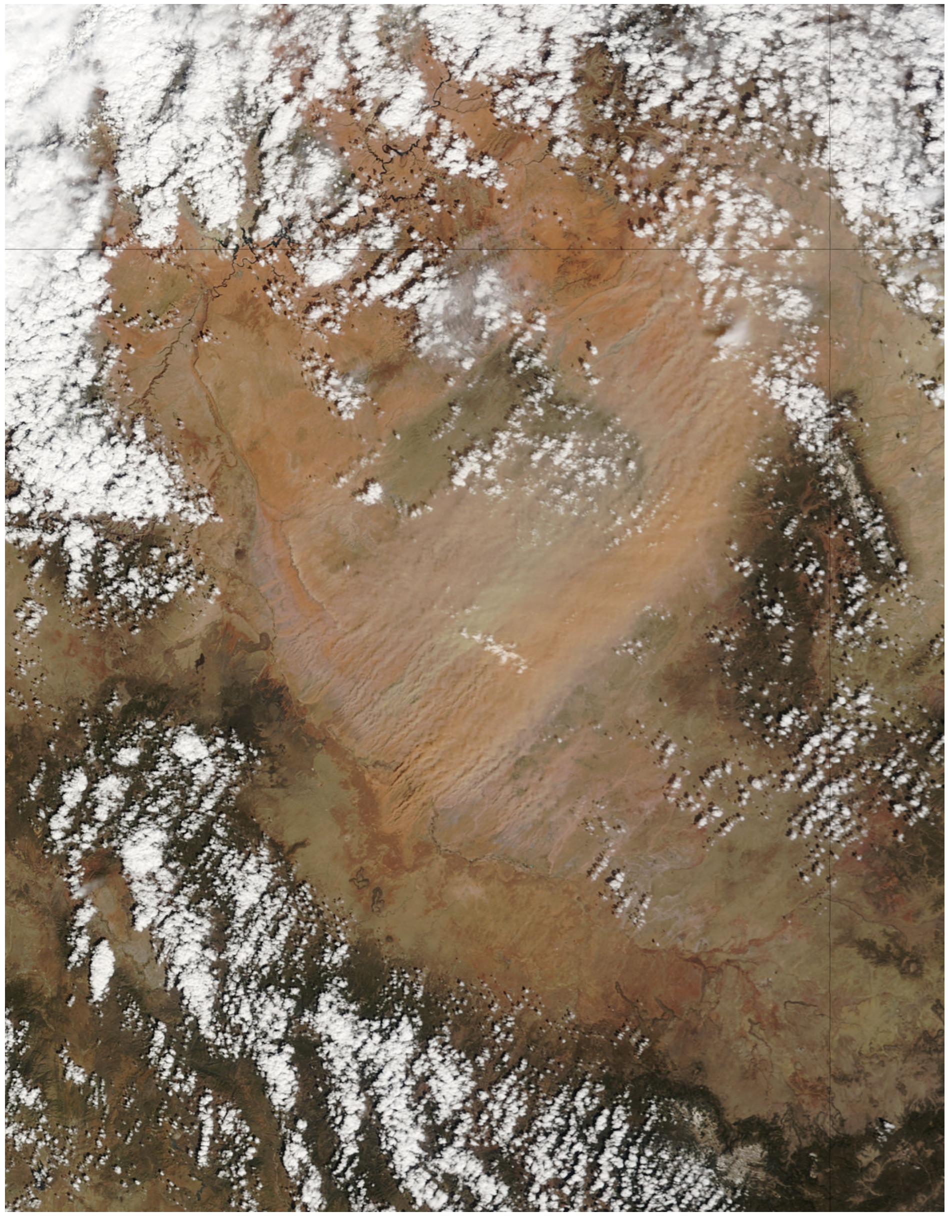

Figure 2. Winds topping 90 miles per hour hurtled across the Four Corners region on April 3, 2009, whipping plumes of dust from Arizona's Painted Desert (shown in the image) to the snow-clad Rocky Mountains. The satellite image was taken by NASA's Terra satellite. Image courtesy of NASA's Earth Observatory

Western settlement, however, has played a recent role in the dust accumulations. Research documents that as population growth accelerated around 1850, grazing, agriculture, and resource exploration that accompanied development disturbed soil surfaces in the Colorado Plateau. Records from lake cores indicate dust accumulation in the Upper Colorado River Basin increased by about 600 percent in the early 20th century, and it remains well above presettlement values today.

The larger dust accumulations and the added heat the layers absorb have altered western water resources in significant ways.

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Impacts on Water Resources

About 7.5 million acre-feet (MAF) of water in the Colorado River flows through Wyoming, Colorado, Utah, and New Mexico every year. Another 7.5 MAF provides much needed water to Arizona, Nevada, and California. Mexico's cut is 1.5 MAF. Added up, the river's current allocation is 12 percent more than the amount that historically flows in the river. Dust, as it turns out, is substantially helping to push the Colorado balance sheet into the red.

"There's a loss of about 5 percent of total runoff in the Colorado River," Painter said, referencing a recent study he co-authored that compared the effects of dust on streamflows before and after land use changes increased dust emissions from the Colorado Plateau.

A runoff reduction of 5 percent is equivalent to twice the annual consumption of Las Vegas, about 18 months of supply to Los Angeles, or about half a year's allocation to Mexico. Painter's research quantified the range of annual streamflow reductions attributed to dust to be between 2.3 and 7.6 percent.

Elevated temperatures in snowpacks are the root cause for lower flows. Higher snowpack temperatures enable more snow to directly evaporate—a process known as sublimation—which then enables winds to ferry that vapor outside the Colorado River Basin.

Dust also helps hasten spring melt, causing the duration of snow cover to shorten by four to five weeks, compared to dust concentrations prior to 1850. In turn, this enables plants to soak up soil moisture sooner and increases evaporation, both of which sap additional water from the system that would otherwise be stored in Lakes Mead and Powell, the two largest reservoirs on the Colorado River. The earlier snowmelt also lengthens the fire season by helping to dry out fire fuels, and it precipitates stream and river torrents, presenting challenges to water managers.

"We live in a more tense world for water management," Painter said. If managers store too much water, they might not be able to release it fast enough during accelerated snowmelt, which would potentially cause flooding.

Since dust emissions skyrocketed before monitoring the Colorado River began in the late 1800s, dust events of recent years likely do not alter the historical average flow. If the number of events rises, however, less water will likely be available for future use.

In a Changing Climate…

Temperatures have risen across the West in recent decades, causing an earlier onset of snowmelt in many western mountains. Numerous studies have linked higher temperatures to increasing aridity, citing the enhanced ability of warmer air to draw moisture from the landscape. Climate projections are unanimous that temperatures will continue to rise, likely resulting in decreased soil moisture and plant cover in many dust-source regions. Drier conditions are also expected to increase fire potential, which would leave soils more exposed to wind erosion. At first glance, the frequency and magnitude of dust events are set to increase.

"A lot of climate models anticipate drying in the Southwest," Reynolds said. "Given this, and the continued disturbance of landscapes, we can probably expect more dust-on-snow events in the future."

More research is needed to confirm the impact dust on snow has on snowpacks and streamflow demonstrated by Painter's research. If results stand the test of time, a reduction of dust loading on mountain snow would then become an attractive strategy to prolong snow cover, reduce runoff rates, and possibly increase total runoff in the Colorado River Basin and beyond.

"If we can anticipate droughts, we can perhaps anticipate how much dust and from where, and better manage our water resources," Reynolds said.

This issue is not just a concern for the Colorado River Basin. The Sierra Nevada in California and the Big Horn range in Wyoming also are drizzled in dust.

The lofty Himalayan peaks, which provide water to hundreds of millions of people, have experienced a 250–400 percent increase in dust compared to before the 1850s. The Aral Sea, which began to dry up in the 1960s after river water was diverted for agricultural purposes, has also become a source of dust for the Hindu Kush, the mountain range stretching between central Afghanistan and northern Pakistan.

The rugged, remote locations of many of these regions, and the costs associated with observing dust events, makes monitoring challenging. However, Painter and his research team are developing methods to monitor dust from space, which will ultimately advance understanding and facilitate the provision of important information to water managers.

"We're still so limited in our knowledge. But we're working as hard as we can—nights, mornings, and weekends—to develop remote sensing technologies and in situ technologies," Painter said.