Unraveling the surprising ecology of dust

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A dust storm approaches Phoenix. Credit: ALAN STARK/FLICKR

High in the snowfields atop the Rocky Mountains in Colorado, things are not as pristine as they used to be. Dust from the desert Southwest is sailing into the Rockies in increasing quantities and settling onto the snow that covers the peaks, often streaking the white surface with shades of red and brown.

The amount of dust that settles on snow varies from year to year. From 2005 to 2008, about five times as much dust fell on the Rockies as during the 1800s, and those years are characterized by researchers as moderately dusty, according to a recent study. In 2009 and 2010, however, the Rockies saw an extreme dust scenario, with the amount of dust blowing onto the mountains mushrooming to five times more than those moderate years. The cause, scientists say, was increasing drought—linked to a warming climate—and human development.

Because darker, dust-flecked snow absorbs more solar energy and warms faster than pure white snow, it means snow cover melts earlier—a lot earlier. "It's not subtle at all," said Jeff Deems, a research scientist with the National Snow and Ice Data Center in Boulder, Colorado. "There is 30 to 60 days difference in the melt out. Over a larger watershed, it's massive."

With the snow disappearing earlier and the growing season significantly extended, plants consume more water and transpire it into the atmosphere. That is water that would otherwise go into streams but is now lost, and Deems says this translates into 5 percent less water flowing into the Colorado River in dusty years, a significant amount. The more rapid rate of snowmelt also has a cascade of effects, with the darker, bare ground absorbing more heat and warming the atmosphere.

The same phenomenon is happening in other mountain ranges across the globe, most notably the Himalayas and the Caucasus Mountains, where grazing, desertification, and development are taking place upwind of glaciers and snow-covered terrain, increasing the deposition of dust on those surfaces.

The major impacts of a warming climate are well known: hotter temperatures, more—and more intense—storms, melting glaciers and sea ice, drier climates in many regions and wetter weather in others. But some researchers say one major element of climate change is being overlooked: dust. Dust plays a fundamental role in the world's ecological processes, and the dynamics of dust are changing as the climate changes.

Although the issue is poorly studied, it's clear that dust dynamics are shifting in two main ways. Humans are the main cause of an increasing amount of dust in the atmosphere. As farming, grazing, and other development in places such as the Horn of Africa or the U.S. Southwest spread deeper into arid regions, vegetation is destroyed, exposing the soil to wind erosion. In addition, increasing drought due to a warming climate is a major cause of the dust problem, as it kills vegetation and uncaps the soil, allowing it to become windborne.

Dust covers the snow in the San Juan Mountains in Colorado during an extreme dust year in 2009. Credit: CHRIS LANDRY/CENTER FOR SNOW AND AVALANCHE STUDIES

This has both positive and negative effects. More dust, for example, means more nutrients and minerals, such as iron, are being transported long distances, which stimulates the growth of oceanic plankton—an essential link in the marine food chain. But increasing quantities of dust could cause serious problems for parts of the world, from decreased water flow in some mountain regions to increased human exposure to dust-borne pathogens, a growing health concern.

In the United States, the 2017 National Climate Assessment found that warmer temperatures are reducing soil moisture in parts of the West, and also predicts more drought in the coming years. These factors kill vegetation that keeps soil in place and have already led to more dust storms. And winds that blow in from the Pacific Ocean are increasing as ocean temperatures heat up. That, in turn, draws in drier north winds that suck moisture out of the soil in the southwestern U.S. The frequency of dust storms there has more than doubled since the 1990s—from 20 per year to 48 in the 2000s—and will likely continue to increase, according to one study.

On the other side of the world, weather patterns in some regions have shifted in a different way. Rainfall in the Sahara has increased because of warmer ocean temperatures, which has meant less dust blowing westward across the Atlantic Ocean. Dust storms have also declined in the deserts of China and South America and are projected to be lower in the Great Plains of the U.S.—all because of an increase in precipitation that stimulates plant growth, which caps the soil.

Peripatetic dust is an ancient and vital geological phenomenon because dust carries nutrients that regulate the distribution of life across the planet. A recent study found that dust from the Gobi Desert—one of the world's two major sources of dust, along with the Sahara—has long ridden the jet stream and settled in the Sierras in California, where it provides an essential source of life-giving phosphorous for the giant sequoias and other trees in that phosphorous-limited ecosystem. The study found that dust provides even more phosphorous than the other major source—the weathering of bedrock in the mountains.

"Dust is a connector of ecosystems around the world," said Emma Aronson, a plant pathologist and microbiologist at the University of California at Riverside and a co-author of the study.

Nutrient-rich dust is critical, as well, in the oceans. "Dust depositions deliver nutrients that are in very, very scarce supply," said Jason Neff, a professor of environmental biogeochemistry at the University of Colorado. "Iron, phosphorous, nitrogen, carbon, and other micronutrients in the open ocean lead to higher marine productivity." A case in point: A massive 2009 dust storm in Australia called Red Dawn (the largest loss of soil in history there), followed by another large dust storm, caused a huge spike in the growth of phytoplankton in the Tasman Sea because of high levels of iron in the wind-blown soil. Such phytoplankton blooms can pull substantial amounts of carbon dioxide from the atmosphere as the marine algae photosynthesize.

Dust clouds and the aerosol particles they contain have major impacts on climate in other ways, such as the blocking of sunlight headed for Earth. But this field of research is young and complex, and the science is lacking, adding uncertainty to future climate models. "The way that aerosols affect climate depends on their size, their color, their height in the atmosphere, how they interact with water vapor," said Neff. "Aerosols are a tough area, because they can warm or they can cool depending on their composition and their location."

One proven impact from an increase in dust is on human health. In the U.S., an increase in dust storms is leading to many more cases of Valley fever, a fungus that lives in desert soils, becomes airborne as dust, and is then inhaled. The number of cases of Valley fever has increased dramatically in Arizona and California in recent years. In 2000, California and Arizona reported a total 2,757 cases of Valley fever. That number rose to 22,164 in 2011 following several extremely dusty years. The two states reported 11,459 Valley fever cases last year, with 57 fatalities occurring in Arizona. This sharp rise is due not only to increased wind and drought, but to increasing development, including the construction of utility-scale solar energy projects.

"At all of these solar ranches being put in out there, especially in the Mojave, there are huge areas being graded, all the vegetation is removed, and they keep it graded because they don't want the vegetation to interfere with these solar panels," said Antje Lauer, a microbial ecologist at California State University in Bakersfield who studies the disease. Changing patterns of drought and rain also favor the spores that cause Valley fever. Military training grounds in Texas and California create dust clouds so big they are visible from satellites.

In Japan, cases of Kawasaki disease—a rare malady that, among other things, causes inflammation of blood vessels, particularly coronary arteries—have been increasing. The bacteria or virus (no one is sure) can travel in events known as Yellow Dust—storms that blow in from the Gobi Desert.

Dust-filled winds that blow across a swath of central Africa during the dry season, from the Atlantic Ocean to the Red Sea, create something called the meningitis belt, so called because of the rash of outbreaks of the bacterial disease there.

In the U.S., Phoenix and Tucson, Arizona are ground zero for giant haboobs—an Arabic term for dust storms—stirred by intense winds from thunderstorms that can be a mile high and engulf entire cities. Phoenix gets an average of three per year. Haboobs are the third-most dangerous type of weather in Arizona—after extreme temperatures and flash flooding—because they rise suddenly and without warning, greatly reducing visibility and causing traffic accidents. They also carry disease, bacteria, fecal matter from stockyards, herbicides, and pesticides and other pollutants harmful to human health.

The role that dust plays in the earth's natural systems is only now coming into sharper focus as humanity's impact on the planet intensifies. As researcher Aronson's team put it in their study of Gobi Desert dust wafting over to California's Sierras, "quantifying the importance of dust … is crucial for predicting how ecosystems will respond to global warming and greater use of the land."

More information: S. McKenzie Skiles et al. Regional variability in dust-on-snow processes and impacts in the Upper Colorado River Basin, *Hydrological Processes* (2015). DOI: 10.1002/hyp.10569

Christopher M. Taylor et al. Frequency of extreme Sahelian storms tripled since 1982 in satellite observations, *Nature* (2017). DOI: 10.1038/nature22069

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