Dirty Snow Causes Early Runoff in Cascades, Rockies

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RICHLAND, Wash. -- Soot from pollution causes winter snowpacks to warm, shrink and warm some more. This continuous cycle sends snowmelt streaming down mountains as much as a month early, a new study finds. How pollution affects a mountain range's natural water reservoirs is important for water resource managers in the western United States and Canada who plan for hydroelectricity generation, fisheries and farming.

Scientists at the Department of Energy's Pacific Northwest National Laboratory conducted the first-ever study of soot on snow in the western states at a scale that predicted impacts along mountain ranges. They found that soot warms up the snow and the air above it by up to 1.2 degrees Fahrenheit, causing snow to melt.

"If we can project the future -- how much water we'll be getting from the rivers and when -- then we can better plan for its many uses," said atmospheric scientist Yun Qian. "Snowmelt can be up to 75 percent of the water supply, in some regions. These changes can affect the water supply, as well as aggravate winter flooding and summer droughts."

The soot-snow cycle starts when soot, a byproduct of burning fossil fuels, darkens snow it lands upon, which then absorbs more of the sun's energy than clean white snow. The resulting thinner snowpack reflects less sunlight back into the atmosphere and further warms the area, continuing the snowmelt cycle.

This study revealed regional changes to the snowpack caused by soot, whereas other studies looked at the uniform changes brought by higher air temperatures due to greenhouse gases.

Previous studies have examined the effect of airborne or snowbound soot on global climate and temperatures. Qian and his colleagues at PNNL used a climate computer model to zoom in on the Rocky Mountain, Cascade, and other western United States mountain ranges. They modeled how soot from diesel engines, power plants and other sources affected snowpacks it landed on.

They found that changes to snow's brightness results in its melting weeks earlier in spring than with pristine snow. In addition, less mountain snow going into late spring means reduced runoff in late spring and summer. They will report their findings in an upcoming issue of the *Journal of Geophysical Research -- Atmospheres*.

Making Snowhills from Mountains

Researchers know that soot settles on snow. And like an asphalt street compared to a concrete sidewalk, dirty snow retains more heat from the sun than bright white snow. Qian and colleagues wanted to determine to what degree dark snow contributes to the declining snowpack.

To get the kind of detail from their computer model that they needed, the PNNL team used a regional model called the Weather Research and Forecasting model -- or WRF, developed in part at the National Center for Atmospheric Research in Boulder, Colo. Compared to planet-scale models that can distinguish land features 200 kilometers [124 miles] apart, this computer model zooms in on the landscape, increasing resolution to 15 kilometers [9.3 miles]. At 15 kilometers, features such as mountain ranges and soot deposition are better defined.

Recently, PNNL researchers added a software component to WRF that models the chemistry of tiny atmospheric particles called aerosols and their interaction with clouds and sunlight. Using the WRF-chem model, the team first examined how much soot in the form of so-called black carbon would land on snow in the Sierra Nevada, Cascade and Rocky Mountains.

Then the team simulated how that soot would affect the snow's brightness throughout the year. Finally, they translated the brightness into snow accumulation and melting over time.

Gray Outlook

"Earlier studies didn't talk about snowpack changes due to soot for two reasons," said atmospheric scientist and co-author William Gustafson. "Soot hasn't been widely measured in snowpack, and it's hard to accurately simulate snowpack in global models. The Cascades have lost 60 percent of their snowpack since the 1950s, most of that due to rising temperatures. We wanted to see if we could quantify the impact of soot."

Their simulations compared well to data collected on snowpack distribution and water runoff. But their first experiment did not include all sources of soot, so they modeled what would happen if enough soot landed on snow to double the loss of brightness. In this computer simulation, the regional climate and snowpack changed significantly, and not in a simply predictable way.

Overall, doubling the dimming of the snow did not lead to twice as high temperature changes -- it led to an approximate 50 percent increase in the snow surface temperature. The drop in snow accumulation, however, more than doubled in some areas. Snowpack over the central Rockies and southern Alberta, for example, dropped two to 50 millimeters [2 inches] over the mountains during late spring and early winter. The most drastic changes occurred in March, the model showed.

The team also found that soot decreased snow's brightness in two ways. About half of soot's effect came from its dark color. The other half came indirectly from reducing the size of the snowpack, exposing the underlying darker earth.

Studies like this one start to unmask pollution's role in the changing climate. While greenhouse gases work unseen, soot bares its dark nature, with a cloak that slowly steals summertime's snow.

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Contact:

Mary Beckman
DOE/Pacific Northwest National Laboratory
509-375-3688
mary.beckman@pnl.gov

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