Soot packs a punch on Tibetan Plateau's climate

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New research shows that soot from industrial and agricultural pollution landing on the Tibetan Plateau (pictured here from Yushu Zangzu, Zangzu, China) is causing snow to melt earlier on the plateau. As a result, India and China are experiencing wetter winters, drier summers and stronger monsoons. Photo courtesy of Jan Reurink

(PhysOrg.com) -- In some cases, soot – the fine, black carbon silt that is released from stoves, cars and manufacturing plants – can pack more of a climatic punch than greenhouse gases, according to a paper published in the journal *Atmospheric Chemistry and Physics.*

Researchers at the Department of Energy's Pacific Northwest National Laboratory, the University of Michigan and NOAA found that soot landing on snow on the massive Tibetan Plateau can do more to alter snowmelt and monsoon weather patterns in Asia than carbon dioxide and soot in the air. Soot on snow causes the plateau's annual glacial melt to happen sooner each year, causing farmers below it to have less water for their crops in the summer. In a domino effect, the melting then prods two of the region's monsoon systems to become stronger over India and China.

"On the global scale, greenhouse gases like carbon dioxide cause the most concern related to climate change," said Yun Qian, the paper's lead author and an atmospheric scientist at PNNL. "But our research shows that in some places like the Tibetan Plateau, soot can do more damage."

Roof of the Earth

Qian and his colleagues focused their research on the Tibetan Plateau, a giant outcropping of land between China and India that's nicknamed the "Roof of the Earth." About five times the size of Texas and as much as 5 miles high in places, the Tibetan Plateau greatly influences the Asia's weather, including the annual deluge of rain and strong winds that come with monsoons. It's also home to the largest volume of ice outside of the north and south poles. Glaciers and snow on the plateau grow and melt as seasons change, providing runoff that feeds most of the region's major rivers, including the Yangtze in China and the Ganges in India.

Soot has increasingly dirtied the Tibetan Plateau's winter-white surfaces in the past two decades. A byproduct of the region's rapid growth in industry and agriculture, soot leaves smokestacks and burning fields in developing Asian countries before it floats into the sky, where winds carry it toward the plateau. Soot is dark and absorbs far more heat from sunlight than pristine white snow. Soot's ability to soak up more solar rays causes the snow it lands on to melt faster. The Tibetan Plateau also receives more direct sunlight than the distant north and south poles, meaning soot's snow-melting powers are be more pronounced on the plateau.

To find out how much soot is affecting the Tibetan Plateau's region, Qian and colleagues used a global climate computer model, the Community Atmosphere Model. The model allowed them to examine a mixture of possible scenarios, including if soot sat on the Tibetan Plateau's snow, if soot was floating in the air above the plateau and if increased carbon dioxide was in the air as a result of industrialization.

More heat, melting

The model's calculations showed that the average air temperature immediately above the plateau increased when all the scenarios were combined. Alone, both soot on snow and carbon dioxide increased temperatures about 2 degrees Fahrenheit. But while carbon dioxide increased temperatures fairly evenly throughout the region, including the ocean, soot on snow only significantly heated up the Tibetan Plateau and north Asia. Researchers concluded that soot on snow can increase the temperature differences between air over land and air over the ocean, which drive monsoons.

Soot on snow also stood out when the model investigated water runoff. Smaller changes were observed when just carbon dioxide or soot in the air were examined, but soot on snow by itself increased runoff substantially during the late winter and early spring and then decreased it during the late spring and early summer. With all three scenarios combined, the runoff increased by 0.44 millimeters (or nearly two-one hundredths of an inch) daily between February and April and then decreased by 0.57 millimeters daily between May and July. These changes provide more water in the winter, when it's not particularly useful to farmers, but less in the summer when it's needed to grow crops.

The researchers reasoned that soot on snow is more efficient in melting the plateau's snowpack because of its close proximity to the snow. Like a warm blanket covering the plateau, soot on snow can almost immediately warm and melt the snow beneath it. But carbon dioxide and soot in the atmosphere have to transfer the heat they absorb way down to the plateau below, with some heat inevitably being lost.

Nature's heat pump

Before this research, scientists knew that the Tibetan Plateau acted like a natural heat pump for the region's weather. The plateau reaches 5 miles high in some places, allowing the air above it to be warmer than other air at the same elevation. The warm air strengthens air circulation around the plateau and causes the iconic, drenching monsoons that move through the region every year.

But with soot on snow causing more snowmelt on the plateau, the plateau is increasingly bare. Less snow covering to reflect solar heat means the Tibetan Plateau is absorbing more sunlight, which the researchers hypothesized was causing the atmosphere above the plateau to warm up even more. They used climate models to find out of this affects the area's monsoons.

Stronger monsoons

The surface temperature above the plateau increased by more than 2 degrees Fahrenheit in May due to soot on snow alone. The researchers found that this warmer air above the plateau rises and air is drawn from India to replace it. In turn, moist air hanging above Arabian Sea and Indian Ocean blows in over India. Known as the South Asian Monsoon system, this southwest-northeast flow also brings in more soot from India to the Tibetan Plateau that perpetuates the cycle. As a result, the researchers found that the South Asian Monsoon system is starting earlier and bringing more rain to central and Northern India in May than it would without soot on the plateau's snow.

The soot-on-snow effect lingers throughout the summer and causes another weather shift in the East Asian Monsoon system over China. By July, much of the plateau's snow has already melted. The plateau's bare soil is warmer and further heats the plateau's air. Coupled with cool ocean air nearby, the plateau's heat strengthens the East Asian Monsoon. The models showed that rain increases 1 to 3 millimeters per day over southern China and the South China Sea. The strengthened monsoon advances to northern China, which also receives more rain than it would otherwise, while the rains mostly skip central East China, including the Yangtze River Basin.

More work needs to be done to refine these findings, however. Qian and his co-authors noted that existing global climate models don't allow for the close-up, detailed resolution needed to accurately portray the Tibetan Plateau's many varying peaks. The model's coarse resolution likely resulted in the plateaus' snowpack being overestimated, meaning the researchers' results represent the maximum amount that soot on snow could potentially impact hydrological and weather systems in the region.

Future research could also factor in dust, which blows throughout Asia with the wind. While soot is believed to have a larger impact on snowmelt than dust per unit mass, the region likely has more total dust than soot. However, dust is more challenging to represent in models, since its sources can't be as easily measured as the polluting smokestacks and burning fields that cause soot.

"The Tibetan Plateau is an amazing, dynamic place where many things come together to develop large climate systems," Qian said. "Our research indicates that soot on snow can be a large player in the region's climate, but it's not the only factor. Many other elements need to be studies before we can say for sure what is the leading cause of snowmelt – which also contributes to retreating glaciers – on the plateau."

More information: Yun Qian, Mark G. Flanner, L. Ruby Leung, Weiguo Wang. Sensitivity studies on the impacts of Tibetan Plateau snowpack pollution on the Asian hydrological cycle and monsoon climate. Atmospheric Chemistry and Physics. Published online March 2, 2010. www.atmos-chem-phys.net/11/192 … cp-11-1929-2011.html

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