Glaciers: Fossil fuel signature found in Alaskan ice

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New clues as to how the Earth's remote ecosystems have been influenced by the industrial revolution are locked, frozen in the ice of glaciers. That is the finding of a group of scientists, including Robert Spencer of the Woods Hole Research Center. The research will be published in the March 2012 issue of *Nature Geoscience*.

Globally, glacier ice loss is accelerating, driven in part by the deposition of carbon in the form of soot or "black carbon," which darkens glacier surfaces and increases their absorption of light and heat. The burning of biomass – trees, leaves and other vegetation around the globe, often in

fires associated with deforestation – and fossil fuel combustion, are the major sources of black carbon.

Spencer and his fellow scientists have conducted much of their research at the Mendenhall Glacier near Juneau, Alaska. Mendenhall and other glaciers that end their journey in the Gulf of Alaska receive a high rate of precipitation, which exacerbates the deposition of soot, but also makes for a good research site.

Ice wall in Mendenhall Glacier, Alaska, contains frozen clues to environmental change. Credit: Aron Stubbins, Skidaway Institute of Oceanography

"We are finding this human derived signature in a corner of the U.S. that is traditionally viewed as being exceptionally pristine," Spencer notes. "The burning of biomass and fossil fuels has an impact we can witness in these glacier systems although they are distant from industrial centers, and it highlights that the surface biogeochemical cycles of today are universally post-industrial in a way we do not fully appreciate."

The key to the process is carbon-containing dissolved organic matter (DOM) in the glacial ice. Glaciers provide a great deal of carbon to downstream ecosystems. Many scientists believe the source of this

carbon is the ancient forests and peatlands overrun by the glaciers. However, thanks to new evidence from radiocarbon dating and ultra-high resolution mass spectrometry, Spencer and his colleagues believe that the carbon comes mainly from the burning of fossil fuels and contemporary biomass. Once the organic matter that contains black carbon is deposited on the glacier surface by snow and rain, the resultant DOM moves with the glacier and is eventually delivered downstream in meltwaters where it provides food for microorganisms at the base of the aquatic food web.

"In frigid glacier environments any input stands out, making glaciers ideal sentinel ecosystems for the detection and study of anthropogenic perturbation," said Spencer referring to the reason why glaciers record the impact of human emissions. "However, the deposition of this organic material happens everywhere and in vibrant ecosystems such as those found in temperate or tropical regions, once this organic material makes landfall it is quickly consumed in the general milieu of life." The Mendenhall glacier research site therefore allows a unique perspective for studies such as this one.

Glaciers and ice sheets together represent the second largest reservoir of water on the planet, and glacier ecosystems cover ten percent of the Earth, yet the carbon dynamics underpinning those ecosystems remain poorly understood. "Improving our understanding of glacier biogeochemistry is of great urgency, as glacier environments are among the most sensitive to climate change and the effects of industrial pollution," emphasizes Spencer.

The researchers' findings also reveal how the ocean may have changed over past centuries. The microbes that form the very bottom of the food web are particularly sensitive to changes in the quantity and quality of the carbon entering the marine system. Since the study found that the organic matter in glacier outflows stems largely from human activities, it

means that the supply of glacier carbon to the coastal waters of the Gulf of Alaska is a modern, post-industrial phenomenon. "When we look at the marine food webs today, we may be seeing a picture that is significantly different from what existed before the late-18th century," said Aron Stubbins a collaborator from the Skidaway Institute of Oceanography. "It is unknown how this manmade carbon has influenced the coastal food webs of Alaska and the fisheries they support."

A warming climate will increase the outflow of the glaciers and the accompanying input of dissolved organic material into the coastal ocean. This will be most keenly felt in glacially dominated coastal regions, such as those off of the Gulf of Alaska, Greenland and Patagonia. These are the areas that are experiencing the highest levels of glacier ice loss.

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