Geophysical Research Abstracts
Vol. 14, EGU2012-908, 2012
EGU General Assembly 2012

Does more intense burning in warmer, drier boreal forest create more stable black carbon in soils?

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Over the past four decades, arctic and boreal regions of the Northern Hemisphere have undergone a higher degree of warming than any other region on earth, and as one result, the frequency of fire in the North American boreal forest region has more than doubled within this timeframe. Many boreal forests contain deep organic layers that are a significant reservoir of terrestrial carbon and their burning in wildfires not only releases trace gasses to the atmosphere but also regulates long-term carbon storage. On the other hand, the formation of pyrogenic C (charcoal and black carbon (BC)) during wildfires may act as a long-term SOC sink. However, recent publications have shown that pyrogenic C in soils may not be as stable as conventionally thought, and in fact, the size of the C sink generated by pyrogenic C in boreal forest soils continues to be an issue of debate. We suggest that burning conditions largely determine the susceptibility of char to microbial attack in the decades to centuries following fire. Our previous work has shown that warmer, south facing sites accumulated more BC in surface mineral soil horizons than did colder sites with greater permafrost extent. We have used quantitative nuclear magnetic resonance to measure the degree of aromatic ring condensation in charcoal structure and have shown that the number of condensed aromatic carbons increases exponentially with fire temperature. We hypothesize that the stability of BC in the soil system is largely controlled by the interactivity of changes in burn condition and landscape position. We expect there to be more stable BC (higher degree of aromatic ring condensation) generated in very hot fires occurring on warmer, drier, south-facing aspects, which typically lack permafrost.

In our initial analysis of macroscopic charcoal found in surface mineral soils (A horizons) across climate gradients in interior Alaska, radiocarbon ages are highly variable within and across landscape positions. In fact, we observed macroscopic charcoal pieces that were relatively modern in age occurring in close association (same soil horizon of same site) with charcoal pieces that were thousands of years old. These data suggest that charcoal pieces that appear similar, even within a common horizon, are compositionally unique and likely reflect changes in burn conditions over time; this highlights the need for true replication in paleo-ecological studies utilizing charcoal fragments in soil profiles or sediments. In the next phases of this research, we will directly couple quantitative nuclear magnetic resonance analyses to these AMS analyses, to ascertain exactly how changes in burn condition affect the character and stability of BC in different landscape positions.