A High Altitude Interdisciplinary Field Campaign - The Storm Peak Aerosol and Cloud Characterization Study (SPACCS08)

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Introduction

Bioaerosols are defined as organic aerosols that are alive, carry living organisms, or are released from living organisms. Examples of bioaerosols include bacteria, fungi, virus, pollen, cell debris, and biofilms and range in sizes between 10 nm and 100 µm (Ariya and Amyot, 2004). Current work in progress globally is investigating the role of bioaerosols as acting as ice nuclei (IN), cloud condensation nuclei (CCN), and implicating them as potentially altering of cloud coverage and thus global climate (Sun and Ariya, 2006 and references herein).

Recent studies also suggest that bioaerosols may significantly contribute to the mass of organic compounds observed in atmospheric particles (e.g. Bauer et al., 2002). This organic aerosol (OA) accounts for a large, often dominant fraction of fine particulate matter in the atmosphere. Despite significant advances in recent years, our present understanding of OA composition, physical and chemical properties, sources, and transformation processes is still limited (Fuzzi et al., 2005). OA influences physical and chemical properties of fine particulate matter and thus affects visibility, human and biosphere health, and ultimately global climate. OA originates from direct emissions (primary organic aerosol, including bioaerosols) as well as from chemical reactions and gas-to-particle conversion in the atmosphere (secondary organic aerosol, SOA). Bioaerosols are a small fraction of the total particle numbers in the atmosphere, yet their numbers are approximately the same order of magnitude as that of IN (10^3 – 10^4 per m^3), indicating their potential significant role. Due to the lack of understanding regarding bioaerosol, further study is needed (Sun and Ariya, 2006). To better constrain our understanding of OA and the role of bioaerosols in the atmosphere, Storm Peak Aerosol and Cloud Characterization Study (SPACCS08) was conducted in March 24 through April 15 2008 at the Storm Peak Laboratory (SPL; see photo in figure 1).

The Desert Research Institute's Storm Peak Laboratory

The Desert Research Institute's Storm Peak Laboratory is located on the west summit of Mt. Werner in the Park Range near the town of Steamboat Springs in northwestern Colorado at an elevation of 3210 m ASL (shown on map in figure 2). This site has been used in cloud and aerosol studies for more than 20 years and a considerable depth of knowledge has been acquired on the aerosols and interaction of aerosols with clouds (Borys and Wetzel, 1997). SPL includes a laboratory for instrumentation with access to the large roof deck, a cold room for snow and cloud rime ice handling, a full kitchen and overnight living accommodations for nine. SPL is also part of several climate networks including the Western Regional Climate Center, the Regional Atmospheric Continuous CO_2 Network in the Rocky Mountains, and the US Department of Agriculture Ultraviolet-B center. SPL is in cloud 30% of the time during winter. The ridge-top location produces almost daily transition from free-troposphere to boundary layer air which occurs near midday in both summer and winter seasons. Long-term observations at SPL document the effect of orographically-induced mixing and convection on vertical pollutant transport and dispersion. SPL experiences transport from distant continental sources including urban areas, power plants, and natural fires.

At SPL, we expect the aerosol to be highly aged, with characteristically different size distributions, chemistry, and hygroscopic properties than fresher boundary layer aerosols. SPL has a multitude of continuous measurements including meteorological parameters, atmospheric trace gases, and aerosol properties. Combining this existing equipment with measurements of bioaerosols and mercury species, SPACCS08 was able to provide new understanding from this interdisciplinary collaboration.

The Storm Peak Aerosol and Cloud Characterization Study (SPACCS08)

Participants of SPACCS08 included a multitude of universities and researchers. Atmospheric, chemical, and biological scientists involved with this campaign include: Drs. Anna Gannet Hallar, Daniel Obrist, and Xavier Faïn, Desert Research Institute; Dr. Christine Wiedinmyer, National Center for Atmospheric Research; Dr. Marianne Glasius, University of Aarhus, Denmark; Dr. Mike Hannigan, Kelly Baustian, Eszter Horayni, University of Colorado; and Dr. Lynn Mazzoleni, Michigan Technological University. The microbiologist involved in this campaign included: Dr. Noah Fierer and Robert Bower, University of Colorado; Dr. Duane Moser, Desert Research Institute; and Dr. Brent Christner, Louisiana State University.

Results from SPACCS08 produced valuable insights about biological particles (bacteria, fungal spores, and pollen) in the remote, continental atmosphere. During the two-week SPACC study, total microbial abundance, diversity and composition of airborne bacteria and fungi, and total ice nuclei measurements were performed and correlated to the meteorological conditions at the time of sampling. Results from Bowers et al. (to be submitted) show the consistency of bacteria and fungal species across all atmospheric samples. There have been few comprehensive studies using culture-independent techniques (i.e. eliminated the requirement of studying only the species that grow to need mass concentrations) to describe the diversity and temporal dynamics of airborne bacteria and fungi. During this sampling campaign, the microbial communities were surprisingly stable in terms of microbial abundance, diversity, and community composition, while the total number of ice nuclei was significantly higher during times of high relative humidity, which was used to distinguish between cloudy and clear skies (Bowers et al., to be submitted). These species distributions, although highly consistent in the atmosphere, were also significantly different from the distributions observed in snow (Bowers et al, to be submitted). Captured cloud water also demonstrated sensitivity to heat denaturation and protease digestion, indicators of IN protein (Christner et al., to be submitted). Airborne microbial life may be strongly influenced by atmospheric conditions. The number of ice nucleators within those particles identified as having intact DNA was on the order of 1 in 10,000; typical of atmospheric concentrations (Bowers et al, to be submitted). Wiedinmyer et al. (to be submitted) show that, although uncertain, the contribution of bacteria and fungal spores to particulate organic carbon in the atmosphere is substantial and warrants more detailed investigation.

As part as the SPACC campaign, continuous monitoring of gaseous elemental mercury (GEM, Hg0), reactive gaseous mercury (RGM) and particulate mercury (PM) was initiated. In the lower atmosphere, RGM and PM (the oxidized forms of mercury) represent only a few percent of the total mercury. However, we observed multi-day events of enhanced RGM at Storm Peak Laboratory, which could not be related to local pollution as no relation was found between RGM and CO, ozone or aerosol concentrations. On the contrary, RGM and GEM appeared to be anti-correlated, demonstrating in situ production of RGM. Similar to the airborne microbial life, the local meteorology is key to mercury concentrations: drops in atmospheric RGM levels were related to high humidity and air saturation. High humidity promotes RGM scavenging and consequently deposition on the snowpack (Fain et al., to be submitted).

Future Work

Several of the SPACC participants are currently continuing this work at SPL with improved methodologies, instrumentation and scientific direction. A field campaign is currently planned for January 2010, which will include an additional ice nucleation instrument.

References:

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Figure 1: Storm Peak Laboratory, January 2009. Picture taken by Patrick Joyce

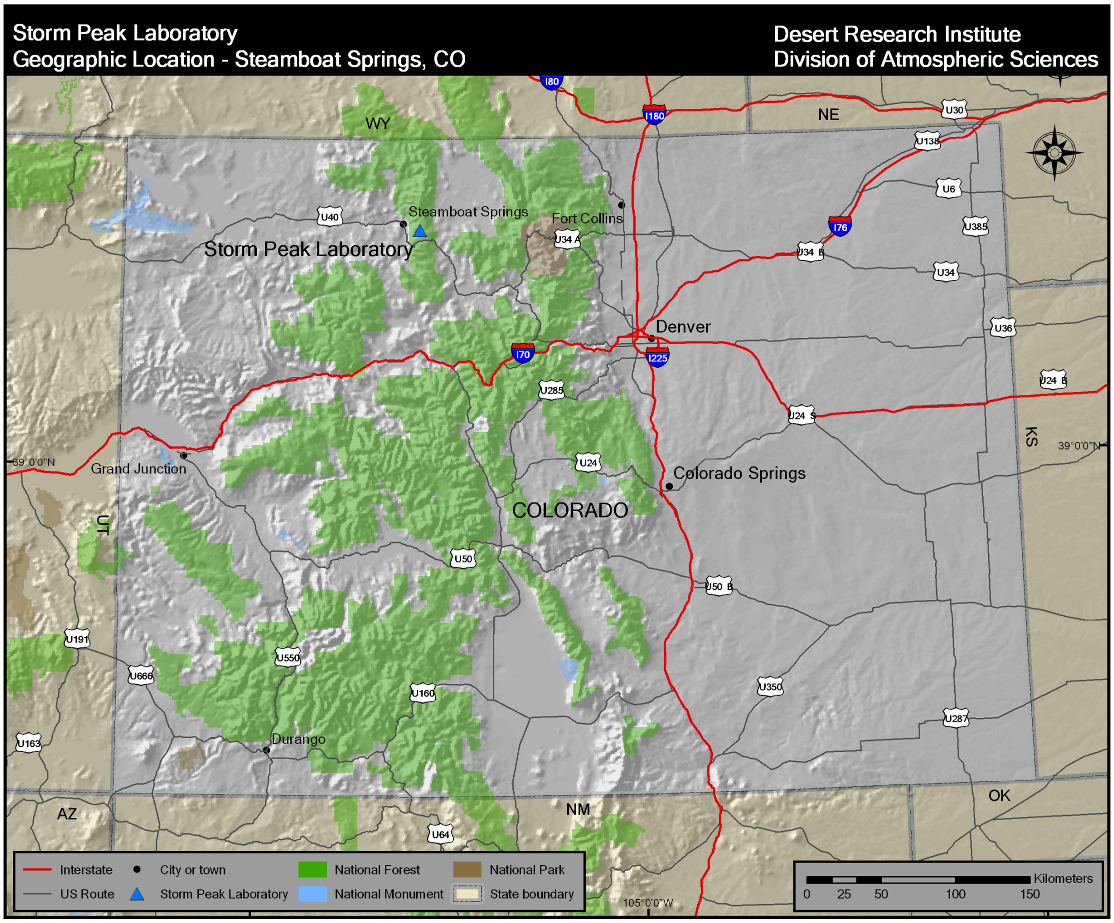

Figure 2: Map of Colorado with Storm Peak Laboratory denoted.