STORM PEAK LABORATORY INVESTIGATES AIR QUALITY FROM REGIONAL AND LONG RANGE SOURCES 2.18

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INTRODUCTION

The Desert Research Institute's Storm Peak Laboratory (SPL) 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 3250 m AMSL. This site has been used in atmospheric studies for more than 20 years (Hindman et al., 1994) and a considerable depth of knowledge has been acquired on trace gases, aerosols and interaction of aerosols with clouds (Borys and Wetzel, 1997). 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. Aerosol concentrations at SPL vary by two orders of magnitude through the diurnal cycle (Lowenthal et al., 2002). 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. Under such conditions, we expect the air mass to be highly aged, with characteristically different chemistry than fresher boundary layer sources. For example in April 2007, air masses characterized by increased mercury levels were traced to Asian long range transport events (Obrist et al., 2008). Additionally, in April and May 2004, the NOAA Particle Analysis by Laser Mass Spectrometry (PALMS) instrument was deployed at SPL to study the relationship between aerosol concentration and ice nucleation. The PALMS measurements indicated that a significant fraction (~15%) of the aerosol in the free troposphere was enriched in potassium ion (K^+) (Cziczo et al, 2006). Potassium ion is a marker for biomass burning emissions which have been shown to be a significant component of tropospheric aerosols (Hudson et al, 2004).

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SPL has the unique advantage of frequently residing in the free troposphere, especially at night when condensation nucleus concentrations less than 100 cm^{-3} may occur (Lowenthal et al., 2002). The Storm Peak facility includes an office-type laboratory module for computer and instrumentation set up with outside air ports and cable access to the roof deck, a cold room for precipitation and cloud rime ice sample handling, a 150 m^2 roof deck area for outside sampling equipment, a full kitchen and overnight living accommodations. The laboratory has been equipped recently with a state-of-the art broadband high speed internet connection with a wireless network for visiting computers including network printers, and three workstations for common use. SPL is also part of several climate observational networks including the Western Regional Climate Center, the Regional Atmospheric Continuous CO_2 Network in the Rocky Mountains, and the U.S. Department of Agriculture Ultraviolet-B (USDA UV-B) monitoring and research center.

Instruments permanently deployed at SPL include the following: 1) TSI Scanning Mobility Particle Sizer (SMPS) (model 3936) coupled with a TSI model 3022A condensation particle counter (CPC); 2) stand-alone TSI model 3010 CPC for particles with diameters larger than 10 nm; 3) stand-alone TSI model 3025 CPC for particles with diameters larger than 3 nm; 4) TSI model 3321 Aerodynamic Particle Sizer (APS) for particles with diameters larger than 540 nm; 5) Droplet Measurement Technologies, Inc. (DMT) CCN-100 counter; and 6) Yankee Visible and UV Multi-Filter Rotating Shadowband Radiometer, 7) trace gases including Ozone, Carbon Dioxide, Carbon Monoxide, Elemental Gaseous Phase Mercury, 8) complete meteorological station, including temperature, pressure, wind speed and direction, and relative humidity with Campbell Scientific, Inc. (CSI), Met One and Vaisala sensors interfaced to a CSI CR10 data logger. Instruments are controlled by PC computers linked in a secure intranet with broad-band communication to DRI and the outside world. Most instrumentation can be monitored remotely via the Storm Peak web-site.

Storm Peak Laboratory also works with the Steamboat Ski Corp. to maintain six meteorological stations across the mountain. These stations measure temperature, dew point temperature, wind speed, and wind direction along an altitude gradient from the valley (i.e., the town of Steamboat Springs, elevation 2100 m AMSL) to the Storm Peak Laboratory (3210 m AMSL). These stations thus provide a vertical profile of meteorological conditions which compared well with those measured with radiosondes launched by the National Center for Atmospheric Research in 2002 (Wetzel and Borys, 2004). These data allow investigators to identify periods when the laboratory is within the surface inversion or in the free troposphere.

LONG RANGE TRANSPORT STUDY

The goal of a recent study was to test if Asian long-range transport (ALRT) of pollutants leads to enhanced levels of atmospheric mercury at Storm Peak Laboratory. The high-elevation mountaintop research facility (3200m asl) in the Rocky Mountains is located 1500 km inland from the Pacific where near-coastal stations previously measured significant atmospheric mercury enhancements due to ALRT.

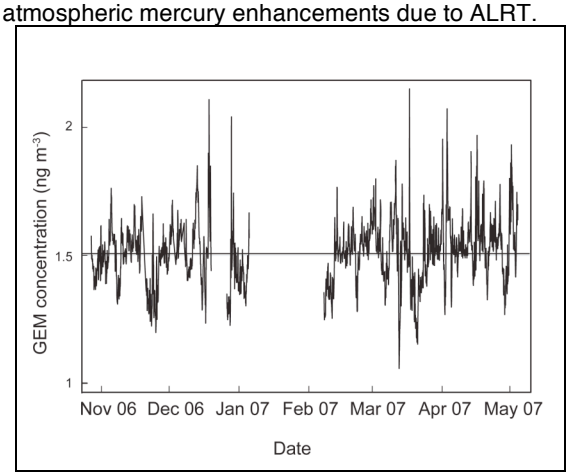

Figure 1: GEM Concentrations from study.

Measurements of gaseous elemental mercury (GEM) from October 2006 to May 2007 averaged 1.51±0.12 ng m-3 with minimum and maximum concentrations of 1.06 ng m-3 and 2.15 ng m-3, respectively (Figure 1).

GEM showed pronounced diurnal patterns with peak concentrations during daytime and lowest concentrations during late night and early morning hours (Figure 2). In fall and winter, these patterns closely followed diurnal fluctuations of water vapor, aerosol number concentration, and ozone, and are hence attributed to almost daily transitions of boundary layer and regionally influenced air masses due to daytime surface heating causing boundary layer air masses enhanced with air pollutants to rise from the valley floor to the laboratory.

In spring, diurnal patterns of GEM and carbon monoxide (CO) occurred time-shifted in respect to water vapor, aerosol number, and ozone concentrations, indicating additional or different sources or sinks (Figure 2). CO concentrations were

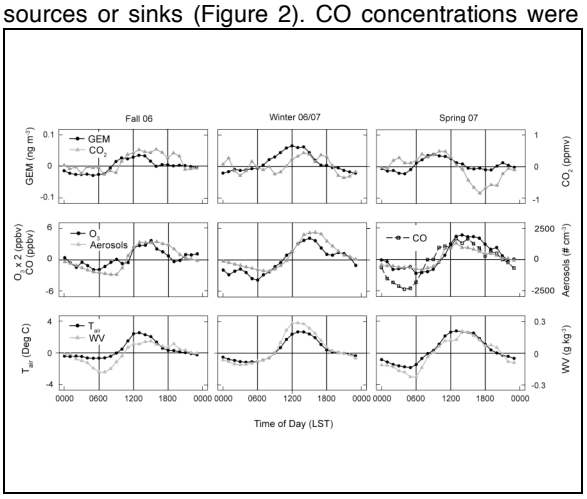

Figure 2: Diurnal plots of GEM, CO, WV, O_3, & Aerosols

measured using an isothermal gas chromatograph (Peak Laboratories Model 1 RCP, Mountain View, CA) configured with a reduction gas detector.A large GEM enhancement (2.15 ng m-3) was observed in early April and was associated with a pressure increase of almost 10 hPa and a decrease in water vapor concentration. CO levels increased correspondingly (213 ppbv) resulting in a GEM/CO enhancement ratio of 0.0061 ng GEM m-3/ppbv CO, which is in the range of previously observed ALRT. These patterns, along with 10-day HYSPLIT air mass trajectories and increased levels of coarse aerosols (i.e., 3-4 µm) typical of Asian dust events indicate the presence of Asian air masses at the laboratory. NOAA Hybrid Single-Particle Lagrangian integrated trajectories (HYSPLIT, Draxler and Rolph, 2003, Rolph 2003) were calculated for specific dates to determine the origin of air masses measured at SPL. Further, springtime concentrations showed pronounced late morning and early afternoon decreases of GEM along with decreases of CO2 typical during the onset of photosynthetic activity of plants. CO2 concentrations were measured using an Autonomous Inexpensive Robust CO2 Analyzer (AIRCOA; Stephens et al., 2006). We attribute GEM afternoon declines in spring to possible plant uptake of atmospheric mercury. We conclude that in spring, ALRT can be detected in the Rocky Mountains against local and regional patterns caused by slope flow and boundary layer upward mixing, and that plant activity may affect daytime GEM levels

RECENT AEROSOL AND CLOUD STUDY

Storm Peak Aerosol and Cloud Characterization Study (SPACCS 2008) occurred March 24 – April 14, 2008. It was funded from NSF BEACHON, NSF Biogenic SOA Nordic Program, and the Desert Research Institute Division of Atmospheric Science.

The scientific questions of this study were: What is the composition of aerosols at this site (both organic composition and biological particles)? What are the sources of the aerosols at this site? Do these particles act as CCN or IN? What organics and biological components are observed in the clouds? Snow? Can observations be used to parameterize cloud-aerosol models? How important are biological particles to impacting cloud characteristics?

To answer the above questions the following measurements, collected at SPL during the study, are currently being analyzed by groups from DRI, NCAR, University of Colorado, Los Alamos National Lab, University of Aarhus, and Louisiana State University. SPL standard meteorology data of wind speed/direction, temperature, potential temperature, relative humidity, and vertical profile of T/RH across the mountain, which is always collected, is being used. Facility instruments collected gas-phase concentrations of ozone, carbon monoxide, and carbon dioxide. In addition for this campaign SPL had installed a cavity ring down spectrometer for measuring carbon dioxide isotopes (C_{12} and C_{12}) and water vapor, which was run from March – June 2008. Aerosol facility instruments were measuring aerosol concentration (TSI CPC), size distribution (TSI SMPS and APS), and CCN size and number concentration (DMT CCN Counter). For this study aerosol absorption and scattering were being measured with a photo acoustic spectrometer (DMT PAS), which was setup from March through July 2008. Elemental carbon and organic carbon were measured using both a PM 2.5 and PM 10 cutoff (Sunset Labs EC/OC). High volume filter samplers with PM2.5 and PM10 cutoffs were setup and the filters are being analyzed with High Performance Liquid Chromatography and Mass Spectroscopy for characterizing the organic aerosols. A low-pressure impactor was setup, and the single particles are being analyzed with a raman microscope. Cloud water was collected when SPL was in cloud, and the biological particles and organic matter are being examined. The biological particles from both cloud water and snow samples are being analyzed for bacteria counts, DNA sequencing, and ice nuclei assays. Results will be presented in the upcoming year at both conferences and in publications.

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