Novel smog chamber studies of wood burning emissions at low temperatures

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Complete aerosol characterization is critical to understand aerosol influences on climate, air quality and health. Domestic wood burning is a significant source of atmospheric aerosols (Lanz et al., 2010), particularly in the winter, as it is a common heating method. Nevertheless, uncertainties remain in the magnitude and characteristics of wood burning emissions, including their chemical composition and optical properties.

In addition to directly emitted primary emissions, previous laboratory experiments have shown that oxidation of gas phase biomass emissions produces compounds with sufficiently low volatility to readily partition to the particles to form secondary organic aerosol (SOA). However, the total organic aerosol mass (OM) formed relative to black carbon (BC) tends to be lower than that observed in the atmosphere from biomass burning (Grieshop et al., 2009a,b; Heringa et al., 2011). This may be because previous laboratory studies were conducted at higher-than-ambient winter temperatures. This may affect both burner operation and gas/particle partitioning of semi-volatile organic aerosol, both of which may affect aerosol composition and loading.

We report results from experiments characterizing primary and secondary wood burning emissions performed at representative winter temperatures for the first time using a newly designed smog chamber capable of conducting photochemical experiments at low temperatures. Primary wood burning emissions were diluted to atmospherically-relevant concentrations (~5-120 μg/m^3) and injected into the chamber (7 m^3) using a heated inlet system. Formation and aging of secondary products was initiated by OH photochemistry. The effects of temperature and humidity were studied by performing experiments at 263 K and 288 K and at 50% and 90% relative humidity. The effect of wood loading in the stove was also studied.

Chemical composition and quantification of the non-refractory aerosol fraction was determined by high resolution aerosol mass spectrometry. Aethalometers were utilized with and without a thermal desorber to quantify BC and to examine the effects of organic coatings on BC optical properties. Measurements of gas phase species were made with a suite of instruments, including a proton transfer reaction mass spectrometer, to gain insight into the partitioning of compounds between the gas phase and particles with aging.

Conducting experiments at 263 K resulted in higher OM/BC ratios for the primary emissions (1.5-14) compared to experiments at 288 K (0.3-0.8) and better agreement with ambient measurements (OM/BC~7-19). (Szidat et al., 2006 and references within; Gianini et al., 2012). Also, lower temperatures enhanced the SOA/BC ratios. (Figure 1)

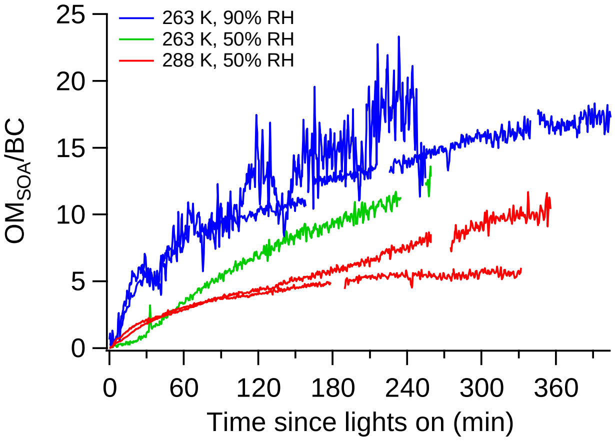

Figure 1. The ratio of SOA to BC during aging as a function of temperature and relative humidity.

These results are important in reconciling discrepancies between field and laboratory measurements. Total hydrocarbon and OH exposure will allow for consistent comparisons between experiments.

High fuel loading was found to generate significantly more polycyclic aromatic hydrocarbon (PAH) compared to average loadings and to produce considerable amounts of SOA after oxidative aging. As PAHs and their oxidation products are known to have deleterious effects on health, this is a significant finding to aid in the mitigation of negative wood burning impacts by improving burner operation protocols.

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