Measurements of Trace Gases and Particles in Fresh and Aged Smoke from a Chaparral Fire in California

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On November 17th 2009 we used a Twin Otter aircraft outfitted with an airborne Fourier transform infrared spectrometer (AFTIR), aerosol mass spectrometer (AMS), single particle soot photometer (SP2), nephelometer, Licor CO2 analyzer, and a chemiluminescence ozone instrument to measure the initial emissions from a 100 hectare prescribed fire in chaparral fuels on the central coast of California, U.S.A. We also measured the post emission chemical changes in the isolated downwind plume for a distance corresponding to about 4.5 hours of smoke aging. The light scattering to CO2 ratio increased by a factor of ~2.7 over 4 hours: similar to observations in a biomass burning plume in Mexico where significant secondary formation of organic aerosol (OA) was confirmed by AMS. However, in the California plume, a decrease in OA was observed by AMS along with a concurrent increase in the fraction of thickly coated particles as measured by the SP2. Decreasing OA accompanied by increased scattering/coating may be explained by a combination of coagulation and evaporation processes. The latter may have been promoted in the California plume because it diluted in a “clean,” low relative humidity (11-26%) environment compared to the Mexican plume. AFTIR measured significant changes in gas phase constituents. The molar ratio of O3 to CO increased from approximately zero to 0.102 in 4.5 hours. Large growth factors for organic acids were also observed over the same aging period: acetic acid and formic acid increased by factors of 1.68 and 7.13, respectively. Inorganic species measured by the AMS also increased with plume aging. While the mass ratio of NH4+ to CO2 increased by ~2.3 x 10-4 in about 4 hours, the NH3/CO2 decreased by ~4.1 x 10-4, with ammonium accounting for ~55% of the gaseous ammonia lost (by mass). Conversion of NOx to PAN was observed coincident with formation of particle nitrate. A rapid decay in C2H4 was consistent with an in-plume average OH of ~5.40 x 106 molecules/cm3, providing further evidence that significant OH concentrations can occur in biomass burning plumes. A detailed photochemical model simulated many of the trace gas observations well when it included a heterogeneous HONO source. These results are compared with other plume aging studies conducted in Africa and Mexico and they confirm the rapid post-emission plume chemistry that can occur on time scales of just minutes to hours. Understanding the evolution of biomass burning smoke is a critical step towards improving the accuracy of chemical transport models.

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