Revised (Mixed-Effects) Estimation for Forest Burning Emissions of Gases and Smoke, Fire/Emission Factor Typology, and Potential Remote Sensing Classification of Types for Ozone and Black-Carbon Simulation

We summarize recent progress (a) in correcting biomass burning emissions factors deduced from airborne sampling of forest fire plumes, (b) in understanding the variability in reactivity of the fresh plumes sampled in ARCTAS (2008), DC3 (2012), and SEAC4RS (2013) airborne missions, and (c) in a consequent search for remotely sensed quantities that help classify forest-fire plumes. Particle properties, chemical speciation, and smoke radiative properties are related and mutually informative, as pictures below suggest (slopes of lines of same color are similar).

(a) Mixed-effects (random-effects) statistical modeling provides estimates of *both* emission factors and a reasonable description of carbon-burned simultaneously. Different fire plumes will have very different contributions to volatile organic carbon reactivity; this may help explain differences of free NO_x(both gas- and particle-phase), and also of ozone production, that have been noted for forest-fire plumes in California. Our evalualations check or correct emission factors based on sequential measurements (e.g., the Normalized Ratio Enhancement and similar methods). We stress the dangers of methods relying on emission-ratios to CO.

(b) This work confirms and extends many reports of great situational variability in emissions factors. VOCs vary in OH reactivity and NOx-binding. Reasons for variability are not only fuel composition, fuel condition, etc, but are confused somewhat by rapid transformation and mixing of emissions. We use “unmixing” (distinct from mixed-effects) statistics and compare briefly to approaches like neural nets. We focus on one particularly intense fire the notorious Yosemite Rim Fire of 2013. In some samples, NO_x activity was not so surpressed by binding into nitrates as in other fires. While our fire-typing is evolving and subject to debate, the carbon-burned $\Delta(CO_2+CO)$ estimates that arise from mixed effects models, free of confusion by background-CO_2 variation, should provide a solid base for discussion.

(c) We report progress using promising links we find between emissions-related "fire types" and promising features deducible from remote observations of plumes, e.g., single scatter albedo, Ångström exponent of scattering, Ångström exponent of absorption, (CO column density)/(aerosol optical depth).