Characterization of emissions from the laboratory combustion of wildland plant species

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The Fire Laboratory at Missoula Experiment (FLAME).
Fuels we burned during FLAME.
What we measured during FLAME...and why.

- Fire behavior
  - Fuel mass
  - Fuel moisture
  - C- and N-content
  - Fire radiance

- Fuel mass

- Fire moisture

- C- and N-content

- Fire radiance

- Aerosol emissions
  - PM2.5, PM10
  - Size distributions

- Trace gas emissions
  - CO, CO₂, CH₄, NMHC, NH₃

- Aerosol composition
  - Carbon
  - Major ions
  - Organic speciation

- Optical properties
  - Scattering
  - Absorption
  - Extinction

- Microphysical properties
  - Cloud condensation nuclei
  - Ice nuclei

- Other
  - Aerosol volatility
  - Aerosol morphology (microscopy)
  - Sp² hybridization
  - Molecular structure (H-NMR)
Aerosol composition was dominated by organic carbon.

**juniper**
- OC ~20%
- EC ~70%
- Inorganics ~10%

**chamise**
- OC ~20%
- EC ~40%
- Inorganics ~40%

> 80% OC
Combustion conditions determined emissions of elemental and organic carbon for many fuels.

\[
\text{MCE} = \frac{\Delta CO_2}{\Delta CO + \Delta CO_2}
\]
Optical properties during a ponderosa pine litter burn.

Absorption coefficient peaks during flaming phase.

Low SSA during flaming phase.

Smaller particles during flaming phase, bigger particles during smoldering phase.

'Blacker' particles emitted during flaming phase compared to smoldering phase.

Scattering coefficient peaks during smoldering phase.
Combustion conditions affect Ångström exponents.

\[ y = -17.3x + 18.2 \]

\[ r^2 = 0.39 \]
Bulk aerosol Angstrom exponents are related to EC/TC.

Upper limit:
- Organic carbon Å = 4.8
- Elemental carbon Å = 0.9

Lower limit:
- Organic carbon Å = 2.0
- Elemental carbon Å = 0.6

EC is ~60 times more absorbing than OC per unit mass.
CCN activity of aerosol emitted during FLAME

single-parameter representation of hygroscopicity (Petters and Kreidenweis, 2007)

- Critical supersaturation (%)
- Dry diameter (µm)
- Hygroscopicity (κ)

- Ammonium sulfate (0.61)
- Needlegrass rush (0.5)
- Sugar cane (0.3)
- White spruce (0.2)
- Alaskan duff (0.1)

wetting by pure water (κ = 0)
Hygroscopicity parameter ranged from ~0.05–0.7

Florida marsh species, Western chaparral, Asian rice straw had high $\kappa$ and large inorganic content

Smoldering combustion produced high fraction of organic carbon in sample and low $\kappa$
Hygroscopicity depends on inorganic aerosol content. Hygroscopicity calculated from growth factor (ratio of wet-to-dry diameters) from HTMDA.
Conclusions

Fires emit aerosol with large variability in optical and hygroscopic properties.

Combustion conditions strongly influence emissions of organic and elemental carbon, but have a weak impact on inorganic emissions.

Aerosol dry optical properties were more sensitive to organic/elemental carbon emissions, so depend more strongly on combustion conditions.

Aerosol hygroscopicity was a stronger function of inorganic content, which depended more on plant species/component than on combustion conditions.
Questions?
Reconstructed versus measured kappa

\[ \kappa = 0.022 \times \text{OC} + 0 \times (\text{EC} + \text{other}) + 0.55 \times (\text{NH}_4^+ + \text{SO}_4^{2-} + \text{NO}_3^-) + 1.0 \times (\text{K}^+ + \text{Na}^+ + \text{Cl}^-) \]
Aerosol emission factors

Christian et al. (2003)
Andreae and Merlet (2001)
Ferek et al. (1998)
Ward and Hardy (1991)
Yokelson et al. (2008)
Andreae and Merlet (2001)
Christian et al. (2003)
Hygroscopicity depends on inorganic aerosol content

-Fairly correlated
-Fraction is small, slope = 0.023 $\mu g$ C/$\mu g$ C
-Average = 0.031  0.017 $\mu g$ C/$\mu g$ C
Hygroscopicity depends on inorganic aerosol content

- Pattern based on fuel component
- Suggests potential exists to create regional source profiles