Experimental determination of effective refractive indices of aerosols emitted from high-moisture-content biomass combustion

Rajan K. Chakrabarty, Hans Moosmüller and Lung-Wen Antony Chen,Desert Research Institute, Reno, NV.

Claudio Mazzoleni, Petr Chylek and Manvendra Dubey, Los Alamos National Laboratory,NM.

W.Patrick Arnott and Kristin Lewis, University of Nevada Reno, Reno, NV.

Wei Min Hao, USFS Fire Sciences Laboratory, Missoula, MT.

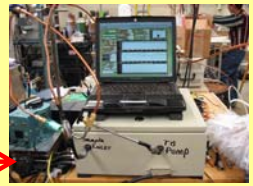
Introduction:

- Emissions from biomass combustion are a major source of fine and ultra fine particles in the troposphere
- It has been recently observed that low temperature, smoldering combustion, of high-moisture-content biomass fuels produce near-spherical particles in shape (tar balls).
- These spherical-shaped particles have a high OC content, high albedo, and therefore predominantly scatter visible light.
- No study has been done so far for determining the effective refractive indices of these aerosol particles, the knowledge of which will immensely benefit satellite retrieval algorithms and the global climate models.
- A suite of experiments were conducted during May-June 2006 at USFS Fire Sciences Laboratory, MT, USA for studying the optical, chemical, and physical properties of aerosols from laboratory combusted wild-land fuels .
- Both dry and high-moisture-content wildland fuels were combusted in a closed chamber, from where aerosols were sampled into various instruments for measurements.
- This poster presents the preliminary results of a refractive index retrieval study of particles emitted from the combustion of two high-moisture content fuels, namely ponderosa pine duff and Alaskan tundra duff, using both experimental data and theoretical calculations.

Experimental & Analytical Method:

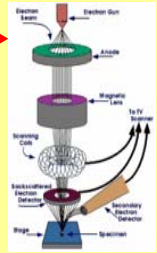
A Flow Diagram of the Analytical Procedure

Integrating Photoacoustic/Nephelometer



Fire Chamber

Scanning Electron Microscopy



Electrical Low Pressure Impactor (ELPI)

Calculation of Effective Refractive Index:

- The scattering and absorption cross sections of a sphere are given as:

$$\sigma_{scat} = \frac{2\pi}{k^2}\sum_{n=1}^{\infty}(2n+1)(|a_n|^2+|b_n|^2)$$

$$\sigma_{abs} = k\varepsilon'' \int_V |E_1|^2 dV$$

where σ_{scat} and σ_{abs} are scattering and absorption cross sections respectively, k is the wave number, a_n and b_n are the Mie coefficients involving complex index of refraction ε+ε",and E1 is the internal field of a sphere.

- The scattering coefficient (Bscat) and the absorption coefficient (Babs) are then calculated as:

$$B_{scat} = \int dN(D)\sigma_{sca}(D)dD$$

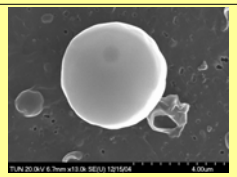
$$B_{abs} = \int dN(D)\sigma_{abs}(D)dD$$

where dN(D)dD is the number size distribution function (usually lognormal in the case of aerosols).

- The number size distribution function is obtained experimentally from the ELPI (Dekati Inc.).
- Using the number size distribution from the ELPI, B_{scat} and B_{abs} are theoretically calculated by assuming an arbitrary complex index of refraction.
- The value of the complex index of refraction is then tuned with the help of a 'Brute Force Local Search algortihm' inorder to match the calculated B_{scat} and B_{abs} values to the experimental values of B_{scat} and B_{abs} obtained from the integrating Photoacoustic/Nephelometer instrument.

Results:

Alaskan Tundra Duff

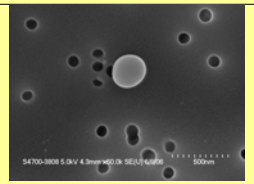


Averaged Data over 2 minutes (2:22 – 2:24 p.m.)

6/6/06

λ	B_{sca}	B_{abs}	Refractive index	
			Real	Imag
405	1134	51.6	1.176	2e-3
532	893	9.25	1.210	5e-4
870	876.5	3.5	1.385	3e-4

Ponderosa Pine Duff

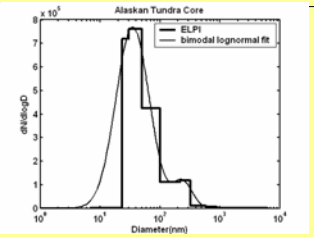


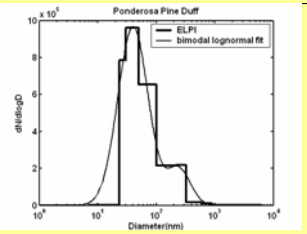
Averaged Data over 2 minutes (11:16 – 11:18 a.m.)

6/6/06

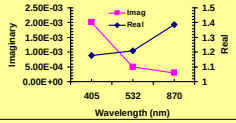
λ	B_{sca}	B_{abs}	Refractive index	
			Real	Imag
405	1921	141.6	1.125	2.2e-3
532	1544	43.5	1.149	9e-4
870	1641	15.85	1.275	5e-4

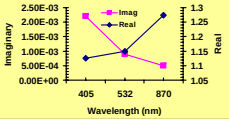
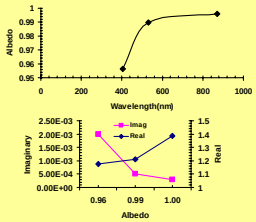
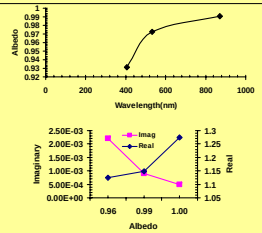
Number Size Distribution





Refractive Index (Real,Imag) vs. Wavelength





Albedo vs. Wavelength/Refractive Index (Real,Imag)