

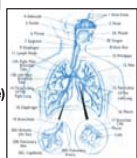
Rebecca M. Garland<sup>1,2</sup>, A.R. Ravishankara<sup>1,3</sup>, Edward R. Lovejoy<sup>3</sup>, Margaret A. Tolbert<sup>1,2</sup>, and Tahlee Baynard<sup>2,3</sup>  
<sup>1</sup> Department of Chemistry and Biochemistry, CU; <sup>2</sup> CIRES; <sup>3</sup> NOAA ESRL

## Motivation

### Effects of Atmospheric Aerosol

#### Health

- (composition, size, atmospheric lifetime)



#### Visibility

- (extinction)



#### Climate

- (optical properties, atmospheric lifetime)
- Direct and indirect effects



- These effects depend on Relative Humidity (RH)

## Introduction

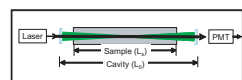
Aerosols, which are ubiquitous in the Earth's atmosphere, are comprised of a variety of inorganic and organic compounds. The composition of the organic fraction is complex and can vary by region. Organic material can dominate atmospheric aerosol composition with a substantial amount of the organic fraction being water-soluble. The uptake of water by a particle is highly dependent upon its chemical composition. Due to the variability in the chemical composition of the organic fraction for atmospheric aerosol and limited laboratory studies of complex internal mixtures, the ability to generalize the RH dependence of water uptake and optical properties is not well established.

Atmospheric aerosols scatter and absorb radiation, thereby influencing the Earth's radiative balance. Light extinction is the sum of scattering and absorption. The extinction coefficient of particles ( $\sigma_{sp}$ ) is dependent on the wavelength of light and is highly sensitive to particle size. This study addresses the impact of changing relative humidity on the light extinction of aerosols. The hygroscopic growth of particles of various chemical compositions (i.e. organic/inorganic content) was studied to probe the dependence of water uptake on the composition of the organic fraction, thereby relating aerosol light extinction, hygroscopicity, and chemical composition.

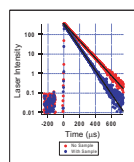
Previous laboratory studies have focused on the change in the particle diameter as a function of RH, i.e., growth factor (Gf). While Gf values are useful in determining the amount of associated water, Mie theory must be applied to determine light extinction. Direct measurement of light extinction reduces the uncertainty in the RH dependence of extinction. In this study, we probe the connection between aerosol composition, size and light extinction directly by measuring  $fRH_{ext}$ , the ratio of the extinction coefficient for humidified particles to the extinction coefficient for dry particles.

## Method

### Cavity Ring-down Aerosol Extinction Spectrometer (CRD-AES)



Sample = Particles and Gases  
 Particles → Scatter and Absorb  
 Gases → Absorb (and Rayleigh Scattering)

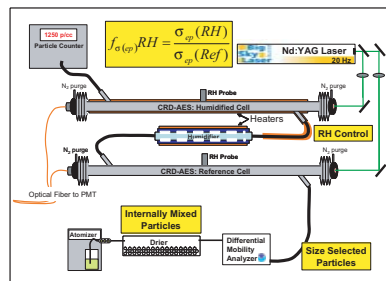


$$\sigma_{sp} = \frac{L_0}{L_s c} \left( \frac{1}{\tau} - \frac{1}{\tau_0} \right)$$

$\sigma_{sp}$  = extinction coefficient,  $\tau$  = time constant,  $c$  = speed of light

## Experimental Set-up

### Laboratory Relative Humidity Studies Cavity Ring-Down Aerosol Extinction Spectrometer (CRD-AES)

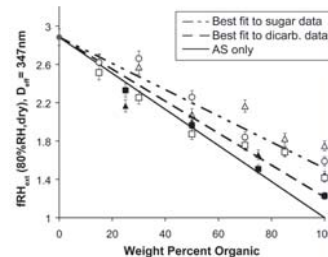


## Organics Studied with $(NH_4)_2SO_4$

| Organic Compounds Studied | Chemical Formula   | Solubility in water (wt%) | pKa <sub>1</sub> /pKa <sub>2</sub> (d) |
|---------------------------|--|---------------------------|--|
| Dicarboxylic Acids        |  |                           |  |
| Adipic Acid               | C <sub>8</sub> H <sub>16</sub> O <sub>4</sub>                | 2.5 (a,b, 24°C)           | 4.43/5.41                              |
| DL-Malic Acid             | C <sub>4</sub> H <sub>6</sub> O <sub>4</sub>                 | 72.3 (b, 24°C)            | 3.40/5.05                              |
| Succinic Acid             | C <sub>4</sub> H <sub>6</sub> O <sub>4</sub>                 | 7.68 (b, 25°C)            | 4.16/5.61                              |
| Malonic Acid              | C <sub>3</sub> H <sub>4</sub> O <sub>4</sub>                 | 61.7 (a, 25°C)            | 2.83/5.69                              |
| Maleic Acid               | C <sub>4</sub> H <sub>4</sub> O <sub>4</sub>                 | 44.6 (a, 25°C)            | 1.83/6.07                              |
| Sugars                    |  |                           |  |
| Glucose                   | C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>                | 54.4 (b, 30°C)            |  |
| Levoglucosan              | C <sub>6</sub> H <sub>10</sub> O <sub>5</sub>                | 17.8 (b, 25°C)            |  |
| Mannitol                  | C <sub>6</sub> H <sub>14</sub> O <sub>6</sub>                |                           |  |
| Amino Acids               |  |                           |  |
| Glycine                   | C <sub>2</sub> H <sub>5</sub> NO <sub>2</sub>                | 20.1 (d, 25°C)            | 2.34/9.60                              |
| Threonine                 | C <sub>4</sub> H <sub>9</sub> NO <sub>3</sub>                | 8.84 (d, 25°C)            | 2.09/9.10                              |
| Arginine                  | C <sub>6</sub> H <sub>13</sub> N <sub>3</sub> O <sub>2</sub> | 15.3 (d, 25°C)            | 2.17/9.04/12.48 (R-group)              |
| Humic Acid (Fluka)        | N/A  | N/A                       | N/A                                    |

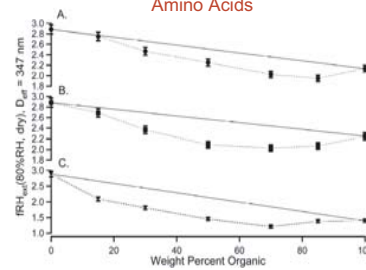
## Results

### Sugars and Dicarboxylic Acids



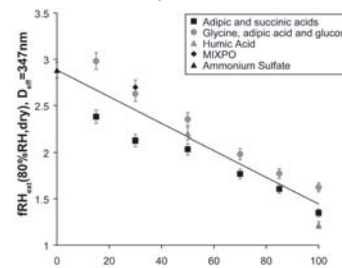
- Organics contribute to growth
- Additive uptake describes mixtures

### Amino Acids



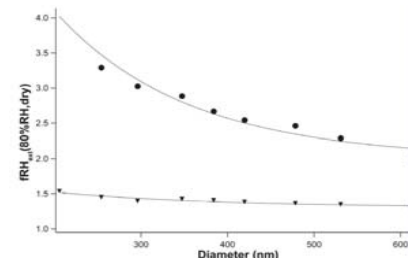
- Additive water uptake model overpredicts growth

### Complex Mixtures



- All mixtures well represented by additive water uptake

## Size Dependence of $fRH_{ext}$

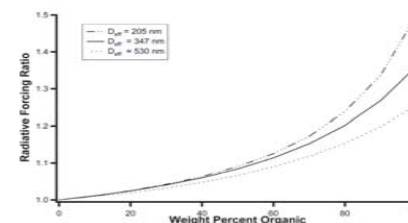


- Due to the additive nature of water uptake, knowledge of the particle size and composition allows accurate prediction of  $fRH_{ext}$

## Atmospheric Implications

$$\frac{\Delta F_{R(B)}}{\Delta F_{R(A)}} = \frac{-(\beta \tau_{wet})_B}{-(\beta \tau_{wet})_A} = \frac{-(\beta fRH_{wet})_B}{-(\beta fRH_{wet})_A}$$

$$\Delta F_R = -\frac{S_0}{4} T_{air}^2 (1-N)(1-a)^2 (2\beta \tau_{wet} - 4a\tau_{abs})$$



- Neglect of the organic fraction underpredicts cooling at the Earth's surface.

## Acknowledgements

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