Size-resolved, Subsatuated, Aerosol Hygroscopicity During the SEAC4RS Field Campaign

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The DASH-SP on the NASA DC-8

Aerosol particles can scatter and absorb solar radiation and serve as cloud condensation nuclei (CCN), thereby influencing cloud properties and precipitation. The radiative and CCN-relevant properties of particles depend on their hygroscopicity. As particles are exposed to changing relative humidity (RH), they undergo a change in their size owing to hygroscopic growth (via water-uptake) with the magnitude of this growth dependent on their chemical composition.

The Differential Aerosol Sizing and Hygroscopicity - Spectrometer Probe (DASH-SP, Brechtel Mfg., Inc., Soroschny et al., 2008) is capable of rapidly measuring size-resolved hygroscopic growth factors (GFs) of ambient aerosol particles. GF values are defined as the ratio of a particle’s diameter when exposed to elevated RH values (typically ~70-95 %) vs the particle’s diameter when dried to <15 % RH. The polydisperse aerosol sampling stream is first size selected using a Scanning Electrical Mobility and Sizer (SEMS) to create a monodisperse aerosol flow at a single diameter between 175 - 350 nm. A flow splitter separates the monodisperse aerosol sample into two paths with equivalent total residence times through the “dry” and “wet” optical particle counters (OPCs). The humidifier has the ability to quickly equilibrate the sample flow to the desired RH before reaching the OPC without diluting the sample with dry/filtered air.

The DASH-SP measurement has much faster time resolution than widely used alternative hygroscopicity measurement techniques, including the HTMOA. Single scans can be acquired in as little as 1 s. The average uncertainty associated with DASH-SP GF measurements is ± 4.3 %. A range of scans covering Dp,dry sizes 175 - 350 nm at a single RH can be completed in under 5 minutes with the majority of the time being required by the SEMS between size changes. Performing replicate scans at each dry size before switching greatly increases the number of scans collected in a given time.

Emission Source Impacts on Water Uptake

In the area near Yuma, Az., the hygroscopic growth was relatively high compared to other areas. Much higher hygroscopic growth was seen in the Palmdale, Ca., area with kappa values between 0.6 and 0.8 relative to background samples. The effects of aging on biomass burning aerosols can be easily identified in the plot (orange-red; RF-03, -08, -11, -12). In contrast, sampling of urban areas frequently contains a higher concentration of inorganic material and tends to yield more hygroscopic growth (blue colors in plot, RF-04, -15, -16, -19, -20). In between these two extremes, BVOC-rich emission sources had only moderate decreases in average GF - at lower RH. The refractive index of the dried aerosols is organic material is a useful marker in aiding to distinguish size-resolved changes in an air mass over time.

Key Research Interests

1) Composite and investigate subsaturated aerosol average growth factors in specific emission source air masses for all flights during SEAC4RS.
2) Explore effects of cloud processing on aerosol hygroscopicity of advected air masses and its impacts on water uptake properties from increased/ increased size-resolved photo-oxidation rates in the presence of cloud layers.
3) Investigate the effects of aging on biomass burning hygroscopicity and validate sub-1.0 growth factors observed in air masses containing freshly-emitted biomass burning aerosols.
4) Analyze agreement between the sub- and supersaturated derived kappa values with an emphasis on biomass burning emissions. Examine compatibility between size-resolved and bulk, subsaturated hygroscopic measurements.
5) Determine applicability of using simple mixing rules in subsaturated aerosol growth estimates using size-resolved aerosol chemistry data.

Case Study: Boundary Layer Transect Through the LA Basin

A long, low-level (< 500 m AGL) transect from Yuma, Az., through Banning Pass and the LA Basin, over the San Gabriel Mountains, and finishing in Palmdale, Ca., was completed at the end of RF23.

In the area near Yuma, Az., the hygroscopic growth was relatively high compared to background samples (kappa between 0.5 and 0.6) and organic mass fractions of ~50%. Agricultural use lands in the El Centro, Ca., area and up through Banning Pass had moderate growth, with kappa values between 0.25 and 0.50, similar to background samples, with total aerosol mass concentrations of less than 4.0 μg m⁻³.

Entering into the LA Basin, the wind direction changed from out of the East to out of the West and the total aerosol mass concentration spiked to 10.6 μg m⁻³. The organic mass fraction which has increased from 0.35 μg m⁻³ decreased to below 0.1 μg m⁻³. The total mass steadily increased through the basin up to 19.5 μg m⁻³ before going over the San Gabriel Mountains and down into Palmdale, Ca., where the total mass concentrations reached below 4.0 μg m⁻³ and the organic mass fraction decreased to below 0.1 μg m⁻³. Much higher hygroscopic growth was seen in the Palmdale, Ca., area with kappa values between 0.6 and 0.8 relative to background samples.

Similar measurements were collected in 2010 during CalNex by Hersey, et al. (2013); however, they report seeing the opposite trends in organic mass fractions and hygroscopic growth. Traveling west to east from the LA Basin, Banning Pass, and out into the Imperial Valley, organic fractions increased, and hygroscopicity decreased slightly. While their measurement averaged over 17 flights compared to the single transect performed here, the complete switch in results is of interest and will be investigated further using sub-1.0 growth factor composition data to aid in analyzing the hygroscopic response observed during RF23.

The flight path for the RF23 transect through the LA Basin is plotted over Google Earth and color coded with the hygroscopicity parameter “kappa” (Petters and Kreidenweis, 2007), where a value of zero indicates non-hygroscopic material and increases with increasing hygroscopicity. Aerosol mass composition from the AMS is depicted with pie charts. See inset (b) for composition details. Numbers adjacent to the flight track indicate the time (UTC) in seconds past midnight at that point of the flight. Inset (a) indicates the aerosol GF vs RH response for RF23, color coded by the region of the transect. Inset (b) is a copy of Figure 7 from Hersey, et al. (2013), where similar measurements were made during the CalNex field campaign.

References


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