Aerosol Hygroscopicity in an Urban Environment: Airborne Observations during NASA DISCOVER-AQ

LUKE D. ZIEMBA, Andreas J. Beyersdorf, Gao Chen, Suzanne Crumeyrolle, Rich Ferrare, Charlie Hudgins, K. Lee Thorhill, Edward L. Winstead, and Bruce E. Anderson

NASA Langley Research Center

Introduction

• Aerosol hygroscopicity (the propensity of particles to uptake water) is an important factor in determining optical properties and cloud activation.

• The relationship between scattering coefficient and relative humidity (f(RH)) is integral for:
  1. understanding the role of chemical composition on optical properties,
  2. extrapolating airborne measurements to ambient conditions for evaluation of remote sensing observations, and
  3. understanding the importance of aerosol water content.

Conclusions and Future Work

• An empirical relationship is currently used to describe f(RH); validation is necessary for variable atmospheric conditions.

• Data from the DISCOVER-AQ campaign on the NASA P-3B was used to systematically explore aerosol hygroscopicity in the urban Washington, DC/Baltimore, MD area.

• f(RH) in-situ is used to relate dry observations to ambient RH conditions for comparison directly with observations together allowed a unique assessment of the f(RH) model relationship:

  • A comparison of observations with model predictions (shaded areas) reveals generally good agreement.
  • Potential bias was observed for high f(RH); aerosol, in-situ extinction systematically exceeded HSRL at RH between 50-80%.

1. Measurements on the NASA P-3B

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2. Overview of Vertical and Diurnal Variability

• The dry extinction coefficient profile shows that the majority of aerosol loading was confined to the lower 2-5 km of the atmosphere.

• f(RH) increased above this level to an average value of less than 4.7 km.

• For both the boundary layer (BL) and 2-5 km altitude bins, f(RH) decreased from 12.00 to 18:00 local time, consistent with photochemical processing yielding more hygroscopic aerosol.

• The opposite effect was observed at high altitude.

3. Hygroscopicity and Chemical Composition

• Chemical composition measurements from the PLS showed that organic compounds dominate the resolved mass.

• The distribution of resolved mass shifts from nearly 90% organic at f(RH)in-situ of 1.25 to less than 50% at 1.95, suggesting that organic compounds present are considerably less hygroscopic than the sulfate component.

• There is a strong correlation between the presence of ammonium sulfate and f(RH)in-situ.

• The sulfate aerosol observed during DISCOVER-AQ appears to be fully neutralized by ammonium.

• The presence of ammonium sulfate is consistent for both the low f(RH)in-situ and high f(RH)in-situ cases.

• On the contrary, there is a discernible trend in f(RH)in-situ suggesting that any variation in the source of organic aerosol did not affect hygroscopicity.

• Similarly, no f(RH) dependence was observed with scattering Angstrom exponent (AE, a proxy for particle size).

• Very little variability was observed in AE, consistent with a predominance of pollution aerosol, especially in the lowest 2.5 km.

• The sulfate aerosol observed during DISCOVER-AQ appears to be fully neutralized by ammonium.

Conclusions and Future Work

• An average f(RH) value of 1.6 was measured in the DC/Baltimore BL and decreased to nearly 1.2 at higher altitude.

• Hygroscopicity was found to increase throughout the day with decreasing organic content.

• Convection of dry extinction to ambient humidity resulted in good agreement with an independent, remote sensing measurement.

• Evaluation of the f(RH) model showed a minor RH-dependent bias, especially for highly hygroscopic aerosol.

• Future objectives:
  1. Focus on high humidity conditions
  2. Systematic analysis of spatial variability
  3. Evaluation of hygroscopicity for highway sampling
  4. Development of scanning-RH capability
  5. Relationship with CCN concentration

4. Ambient Extinction: Comparison with HSRL

• f(RH)in-situ is used to relate dry observations to ambient RH conditions for comparison directly with remote sensing measurements and to better understand aerosol water content.

• Ambient scattering (σscat, ambient) and extinction (σext, ambient) are calculated as follows:

  • HSRL and in-situ observations together allowed a unique assessment of the f(RH) model relationship:

  • A comparison of observations with model predictions (shaded areas) reveals generally good agreement.
  • Potential bias was observed for high f(RH) aerosol, in-situ extinction systematically exceeded HSRL at RH between 50-80%.

5. Case Study – Flight 10 – 22 July 2011

• A consistent elevated layer was observed at 3 sites by both in-situ and HSRL platforms.

• Extinction coefficient discrepancy differed between the BL and the elevated layer.

• Nitrate-enhancements seem to coincide with HSRL in-situ- difference trend in elevated layer suggesting a dependence on chemical composition.