Inferring Aerosol Properties Using Airborne HSRL Data

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Motivation

Because anthropogenic aerosols are predominantly submicrometer, fine mode fraction (FMF) retrievals from satellite sensors have been used as a tool for deriving anthropogenic aerosols. (FMF is the fraction of aerosol optical depth associated with the fine aerosol mode.) Although satellite data are being used to derive column-averaged FMF over the ocean, satellite retrievals of FMF profiles have only been performed on a limited basis over the ocean and have not been demonstrated over land.

Recent studies have shown correlations between average satellite-derived column aerosol optical thickness (AOT) and in situ measured cloud condensation nuclei (CCN); however, the vertical variability of the aerosol distribution and the presence of coarse mode aerosols such as dust introduce large uncertainties in such relations.

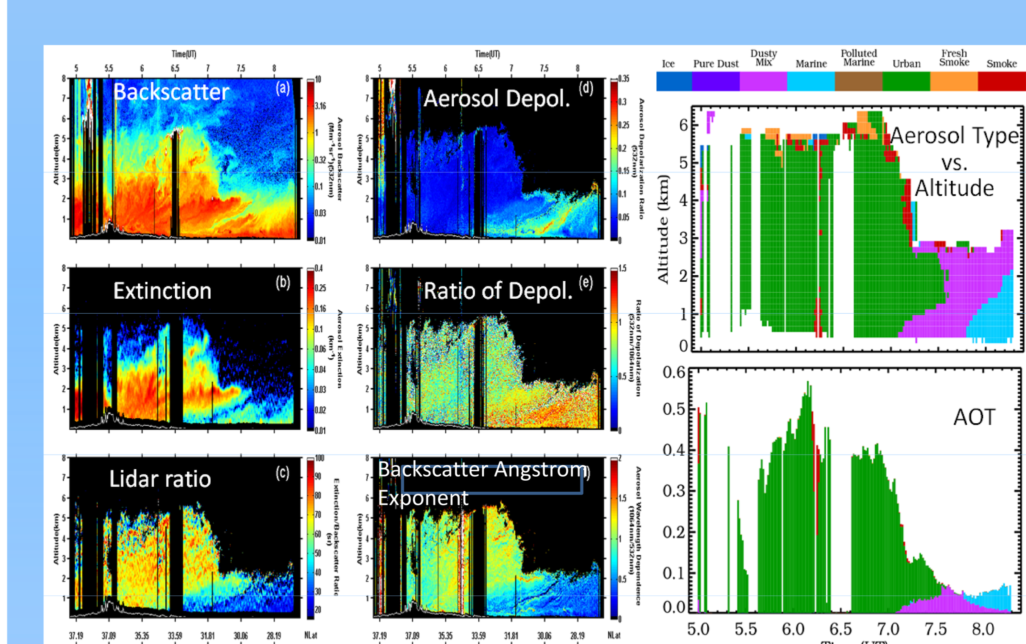
Objectives

We examine the feasibility of using airborne lidar data to: 1) infer profiles of **submicrometer fraction (SMF)** over land (which is the fraction of aerosols with diameters less than 1 micrometer and is closely related to FMF) and 2) provide a proxy for **CCN**. If these initial feasibility studies prove successful, we will then apply these methodologies in subsequent studies to examine the feasibility of using CALIPSO data in a similar manner.

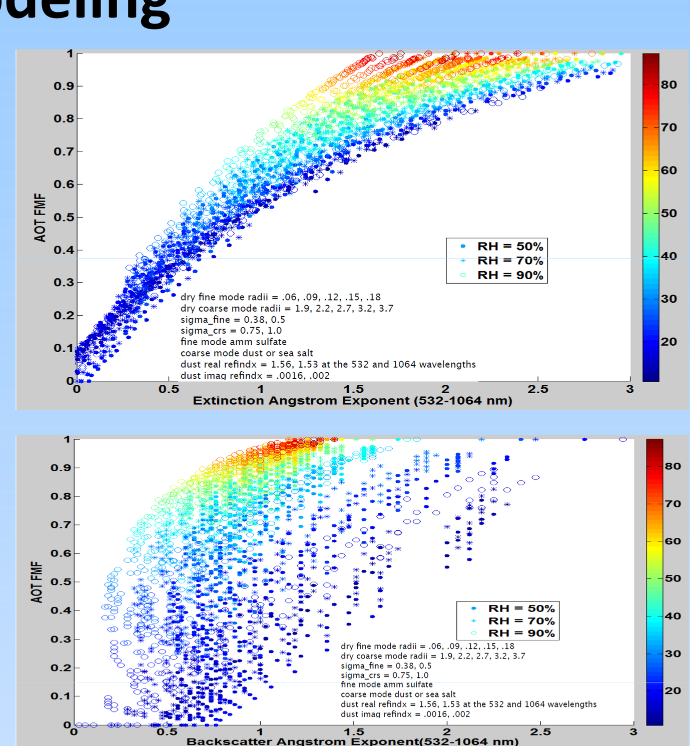
Methodology

We use data acquired by the NASA Langley Research Center airborne High Spectral Resolution Lidar (HSRL) during several recent field missions conducted by NASA, the Department of Energy, and NOAA. The airborne HSRL, which has acquired over 300 hours of data coincident with CALIPSO overpasses, measures aerosol extinction (532 nm), backscatter (532 and 1064 nm), and depolarization (532 and 1064 nm) profiles and thereby provides a dataset directly applicable to the CALIPSO measurements. During several of these field campaigns, airborne in situ measurements were acquired simultaneously within the HSRL "curtains" thereby facilitating direct correlations of the lidar observables to in situ measurements of particle size and composition, including SMF and CCN concentration. Previous studies have used simultaneous in situ measurements of SMF and Angström exponents derived from in situ scattering (Anderson et al., 2005) and remote sensing extinction (Redemann et al. 2009) measurements to build empirical relationships between these parameters. We adopt a similar approach and investigate relationships between the lidar observables, such as backscatter and extinction Angström exponents, with the coincident airborne in situ measurements of SMF and CCN concentration.

HSRL Data Products



Modeling



We used Mie theory to explore the relationships between Extinction and Backscatter Angstrom exponents and FMF. The relationships between FMF and these exponents are shown for various combinations of fine and coarse mode aerosols. Fine mode aerosols were modeled as ammonium sulfate and coarse mode as sea salt. The relationship between extinction Angstrom exponent and FMF (top) has smaller variability than the relationship between backscatter Angstrom exponent and FMF (bottom).

References

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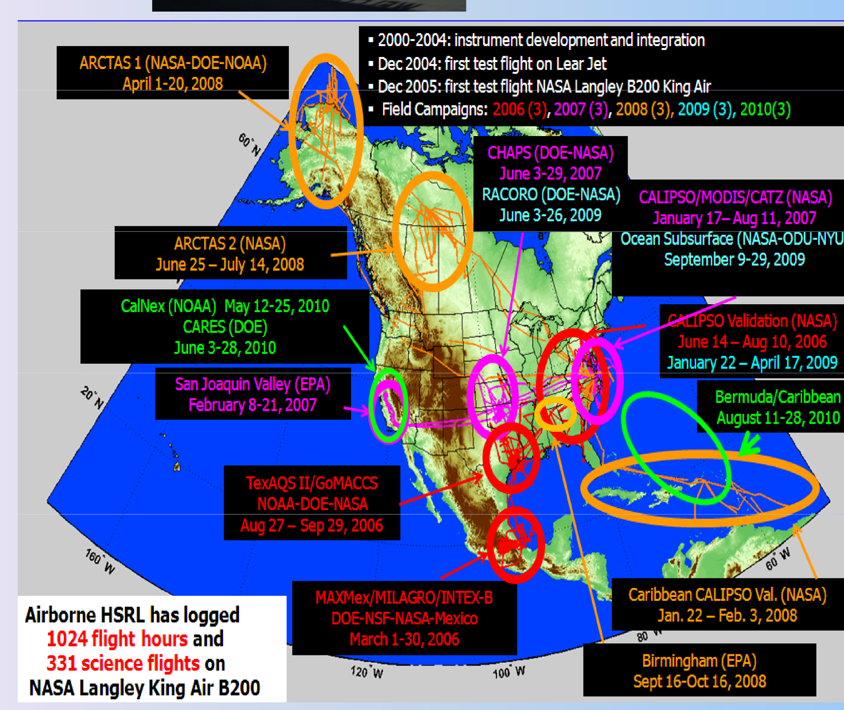
Kapustin, V.N., A.D. Clarke, Y. Shinozuka, S. Howell, V. Brekhovskikh, T. Nakajima, and A. Higurashi, On the determination of a cloud condensation nuclei from satellite: Challenges and possibilities. *Journal of Geophysical Research,*111, D04202, doi:10.1029/2004JD005527, 2006.

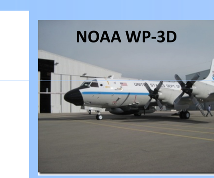
Redemann, J., Zhang, Q., Livingston, J., Russell, P., Shinozuka, Y., Clarke, A., Johnson, R., and Levy, R.: Testing aerosol properties in MODIS Collection 4 and 5 using airborne sunphotometer observations in INTEX-B/MILAGRO, Atmos. Chem. Phys., 9, 8159-8172, 2009

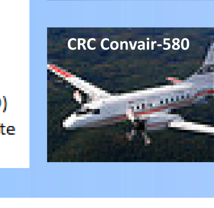
Airborne HSRL Field Experiments



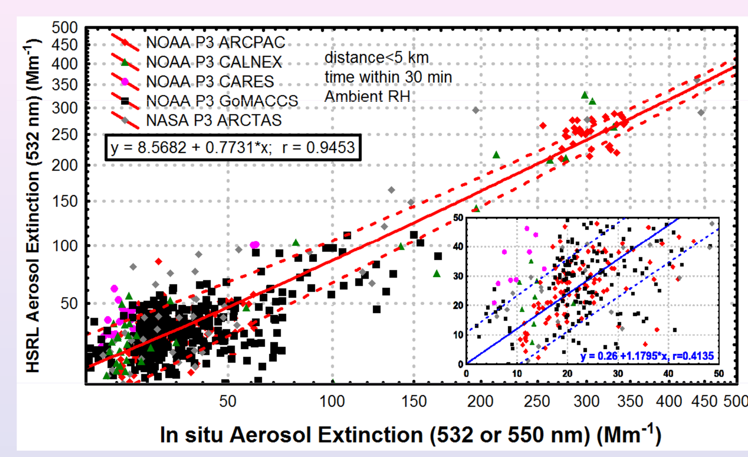
Field Mission	Location	Period	Measurements Coincident with Airborne HSRL	
			Aircraft In Situ	CALIPSO
MILAGRO[1]	Mexico City	March 2006	NSF C130, DOE G1	
CALIPSO Validation	Eastern USA	Summer 2006		X
TexAQS/GoMACCS[2]	Texas	Aug-Sep 2006	NOAA P3, CTO[3]	X
San Joaquin Valley	California	Feb 2007		
CHAPS/CLASIC[4]	Oklahoma	Jun 2007	DOE G1, CTO[3]	X
CATZ[5]	Eastern US	Aug 2007		X
CALIPSO Validation	Caribbean	Feb 2008		X
ARCTAS[6] Spring	Alaska	Apr 2008	Convair 580, NASA P3, NOAA P3, NASA DC8	X
ARCTAS[6] Summer	Canada	Jun-Jul 2008	NASA P3, NASA DC8	X
RACORO[7]	Oklahoma	Jun 2009	CTO[3]	X
CARES/CALNEX[8]	California	Jun 2010	DOE G1, NOAA P3	X

[1] Megacity Initiative: Local and Global Research Observations (MILAGRO)
[2] Texas Air Quality Study (TexAQS) - Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS)
[3] Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) Twin Otter
[4] Cumulus Humilis Aerosol Processing Study (CHAPS)/ Cloud and Land Surface Interaction Campaign (CLASIC)
[5] CALIPSO and Twilight Zone 2007 (CATZ)
[6] Arctic Research of the Composition of the Troposphere (ARCTAS)
[7] Routine ARM Aerial Facility Clouds with Low Optical Water Depths Optical Radiative Observations (RACORO)
[8] Carbonaceous Aerosols and Radiative Effects Study (CARES)/ Research at the Nexus of Air Quality and Climate Change (CALNEX)



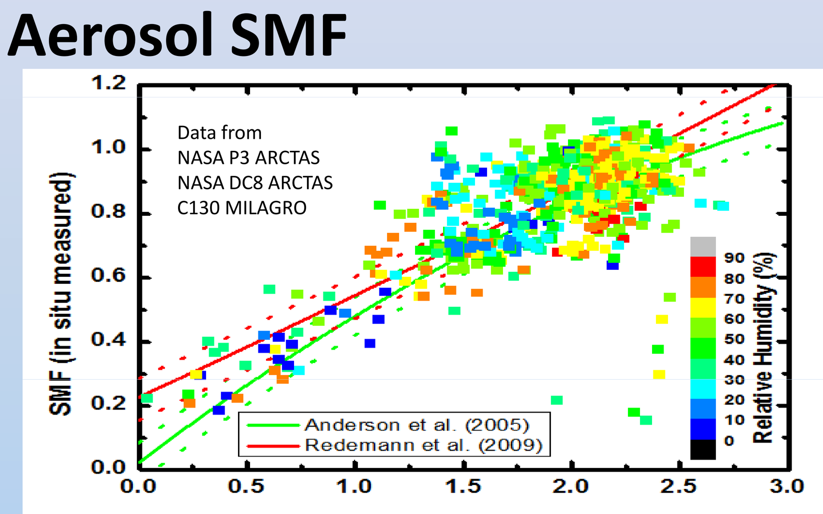


Aerosol Extinction

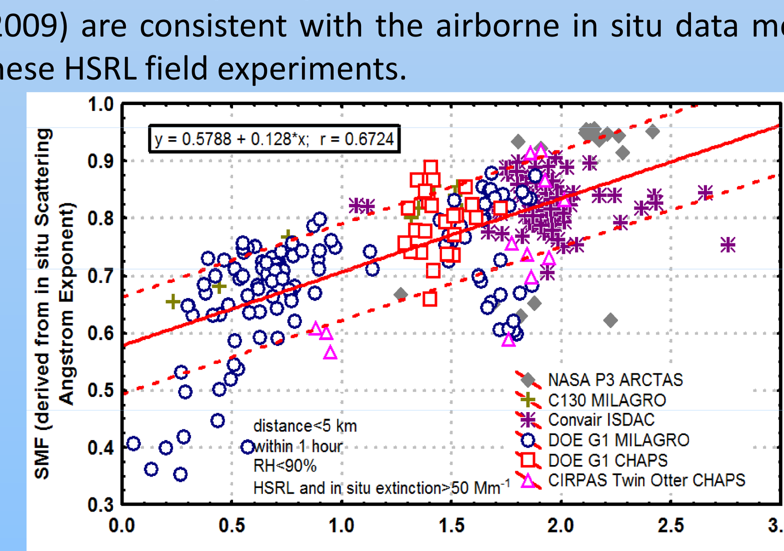


HSRL aerosol extinction measurements are well correlated to the airborne in situ measurements of aerosol extinction derived from cavity ring-down (CRD) and scattering (nephelometer)+absorption (PASP) measurements. The airborne in situ measurements have been adjusted to ambient RH. The inset graph shows a separate regression for values below 50 Mm^{-1}.

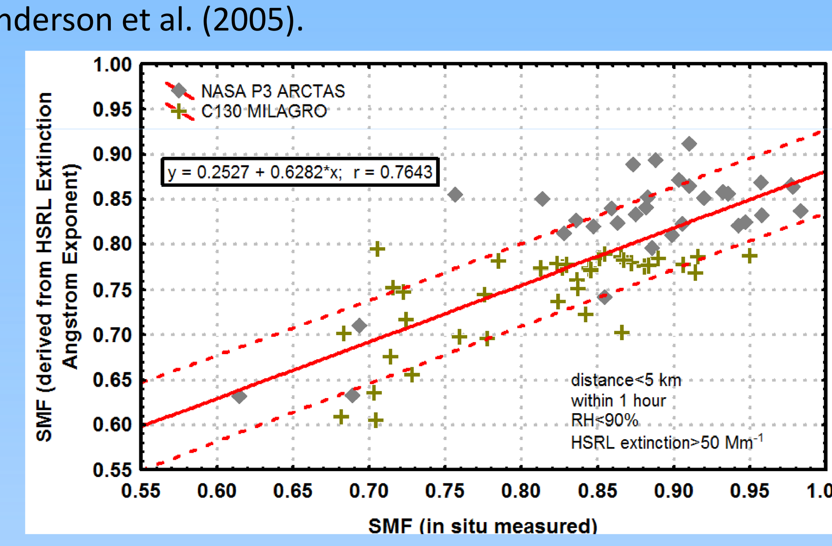
Aerosol SMF



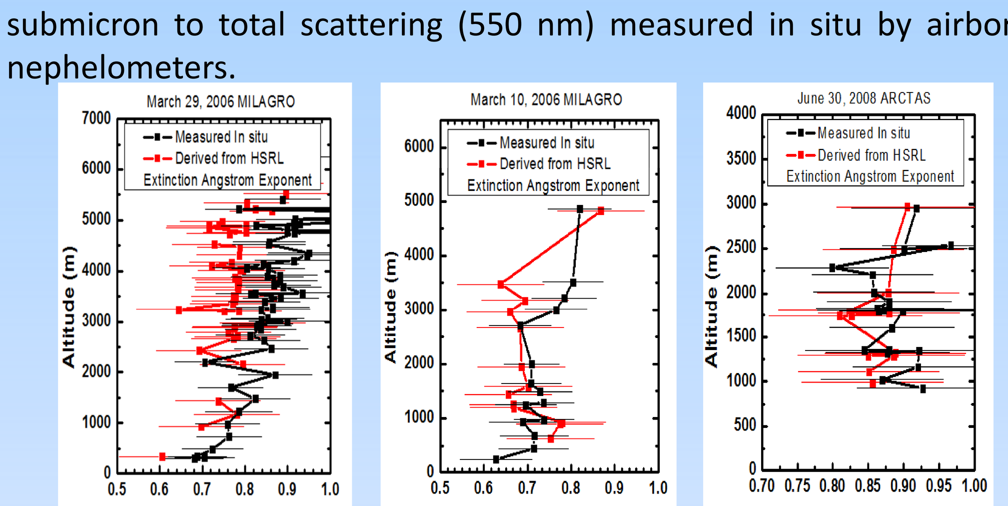
The relationships between airborne in situ and remote sensing measurements of scattering and extinction Angstrom exponent (450-700 nm) developed by Anderson et al. (2005) and Redemann et al. (2009) are consistent with the airborne in situ data measured during these HSRL field experiments.



The HSRL measurements of Extinction Angstrom Exponent are correlated to the SMF derived from the airborne in situ measurements of scattering Angstrom exponent (450-700 nm) using the relationship of Anderson et al. (2005).

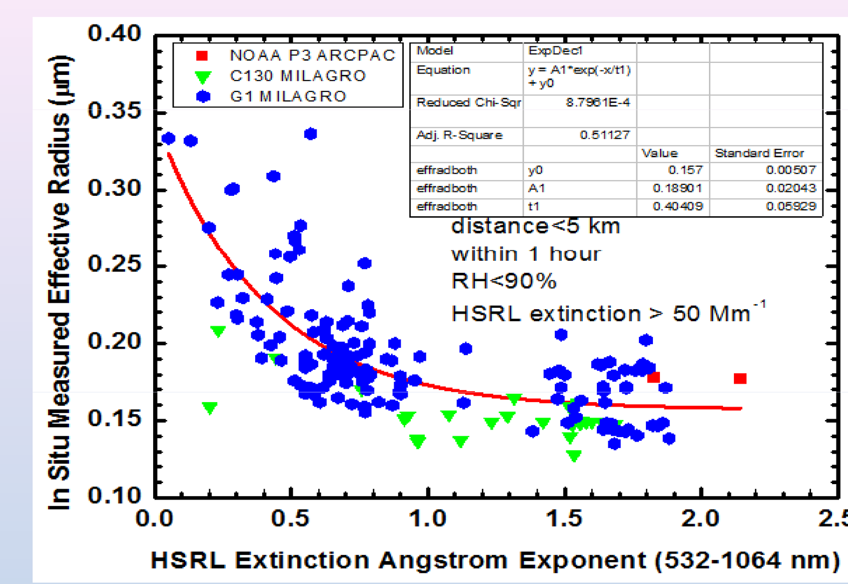


SMF inferred from the HSRL measurements of Extinction Angstrom Exponent using the relationship displayed in the previous graph are in reasonable agreement with the SMF derived from the ratio of submicron to total scattering (550 nm) measured in situ by airborne nephelometers.



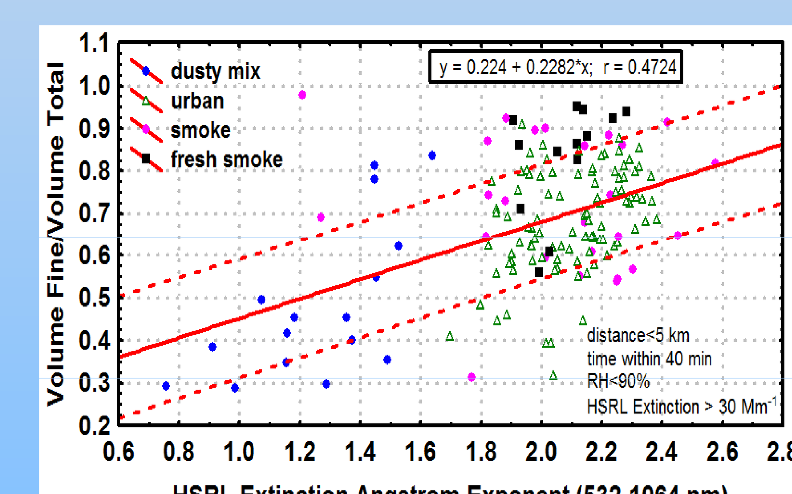
Comparisons of SMF profiles derived from the ratio of submicron to total scattering (550 nm) measured in situ by airborne nephelometers and from HSRL measurements of Extinction Angstrom Exponents.

Aerosol Effective Radius



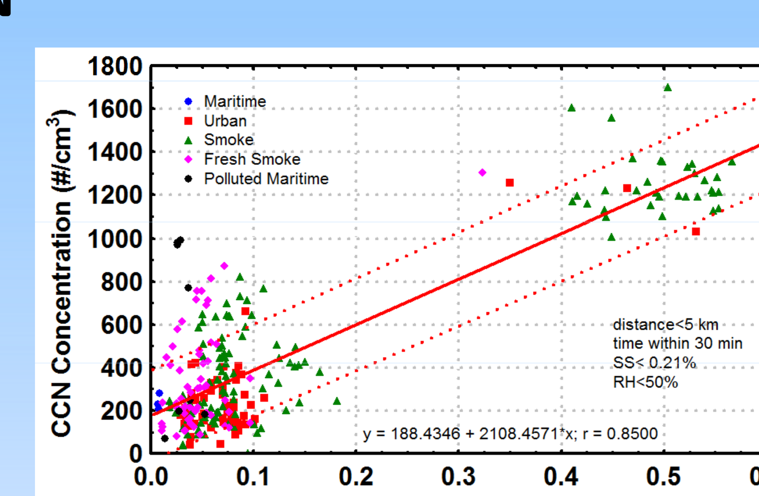
The HSRL Extinction Angstrom Exponent is also somehat correlated to the aerosol effective radius (fine+coarse) derived from airborne in situ OPC and PCASP measurements of particle size. This result suggests that these HSRL measurements may also be used in some cases to infer effective radius.

Aerosol Fine Mode Volume Fraction



The HSRL Extinction Angstrom Exponent is also somewhat correlated to the aerosol fine mode volume fraction derived from airborne in situ OPC and PCASP measurements of particle size.

CCN



The HSRL Aerosol Index, which is the product of aerosol extinction and Extinction Angstrom Exponent, is correlated to airborne in situ measurements of CCN concentration. Following the recommendations of Kasputin et al. (2006), the data are filtered by relative humidity, supersaturation, and aerosol type to examine this correlation.

Summary and Future Work

Coincident airborne HSRL and in situ aerosol measurements acquired during several field experiments show:

- **HSRL measurements of aerosol Extinction Angstrom Exponent (532-1064 nm) may be used in many cases to infer aerosol Submicrometer Fraction (SMF), effective radius, and fine mode volume fraction**
- **When filtered by relative humidity, supersaturation, and aerosol type, HSRL measurements of the Aerosol Index are correlated to CCN concentration**

Future studies will examine:

- **The sensitivities of these correlations to uncertainties in the lidar aerosol measurements**
- **The extent to which CALIPSO measurements can be used to infer these aerosol properties**

Acknowledgements

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