Boundary Layer Mixing State and Vertical Distribution of Aerosol at High Latitude Locations

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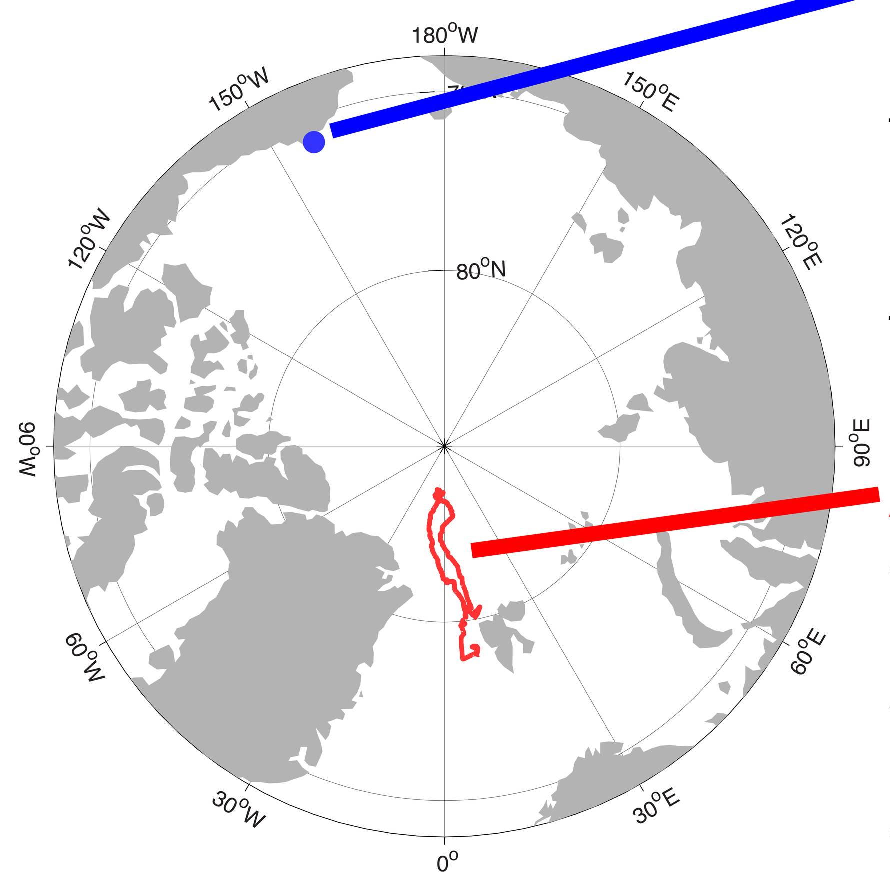
Introduction

Estimation of the relationships between aerosol properties and clouds is often done using surface-based measurements of aerosol properties. This is justified at lower latitudes by the idea that clouds are associated with well-mixed boundary layers, resulting in reduced vertical variability of atmospheric and aerosol properties. At high latitudes, however, this well-mixed assumption often breaks down, resulting in uncertainty of the meaning of using surface-based aerosol properties along with remotely senese cloud properties to derive aerosol indirect effects (AIE). Here, we look at aerosol profiles derived during two different campaigns (ASCOS and ISDAC) in order to evaluate the potential impact of vertical variability on the estimation of AIE. Additionally, we investigate the potential to use surface-based remote sensors to estimate lower atmospheric mixing state under mixed-phase cloud conditions.

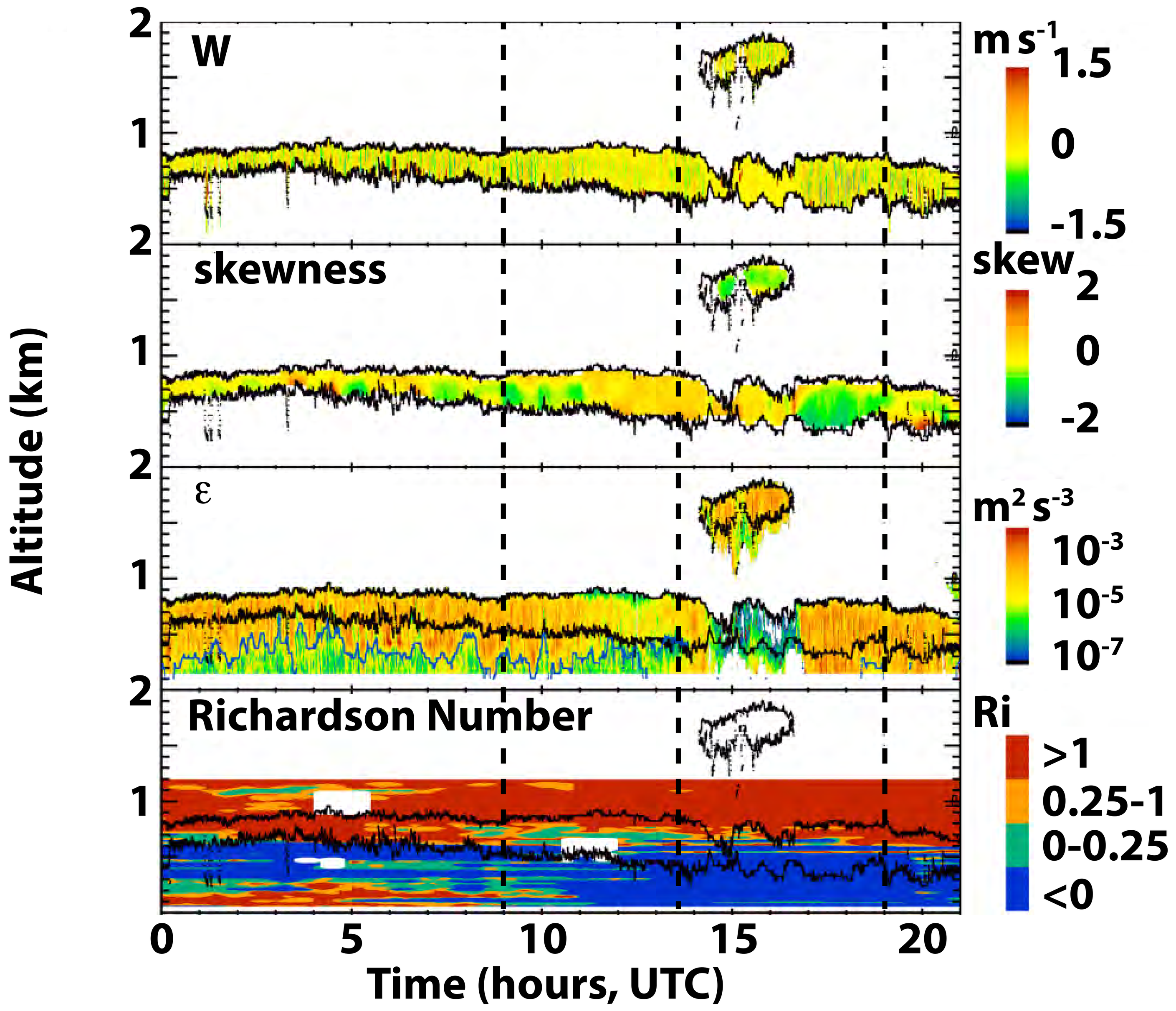
Measurement Sites

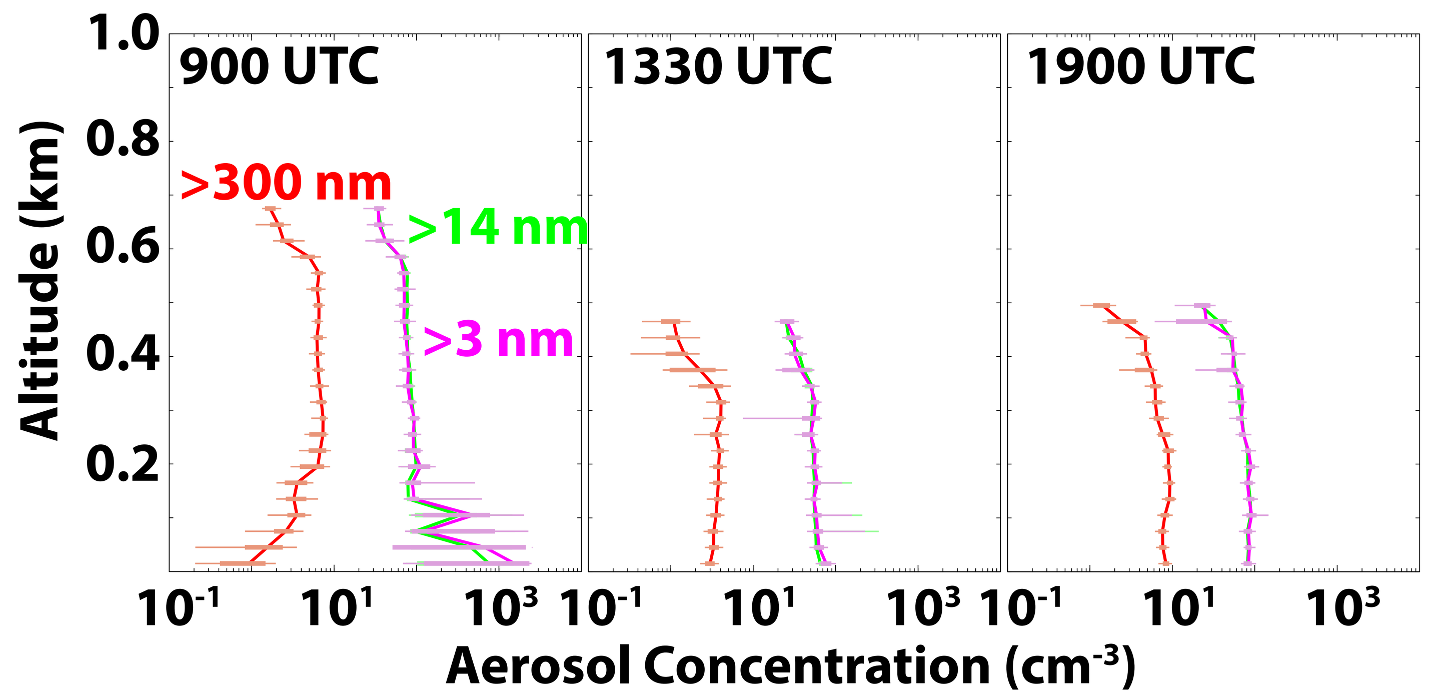


NSA: Here we use field campaign data from IOPs around the ARM NSA site. Most directly, aerosol measurements from ISDAC are used to evaluate vertical distribution of aerosol.

ASCOS: This 2008 field campaign was unique in its high-latitude offshore location, as well as it's measurements. Included are profiles of aerosol concentrations taken by helicopter.

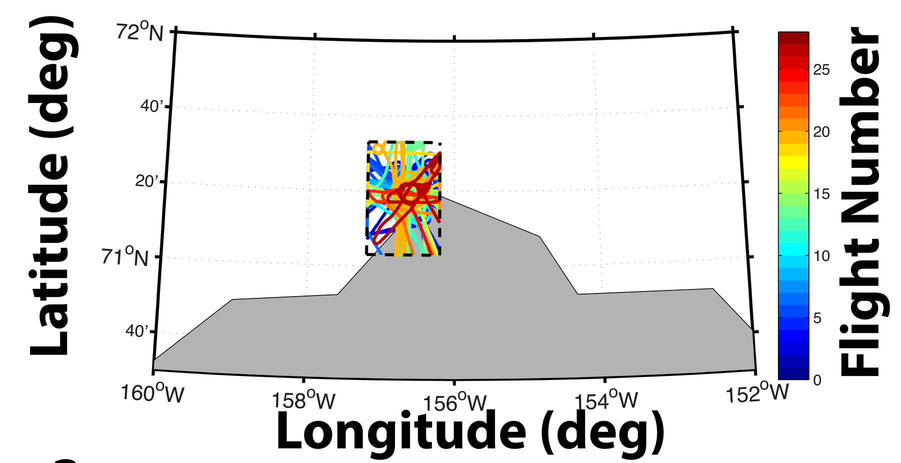
Ground-Based Mixing State Evaluation

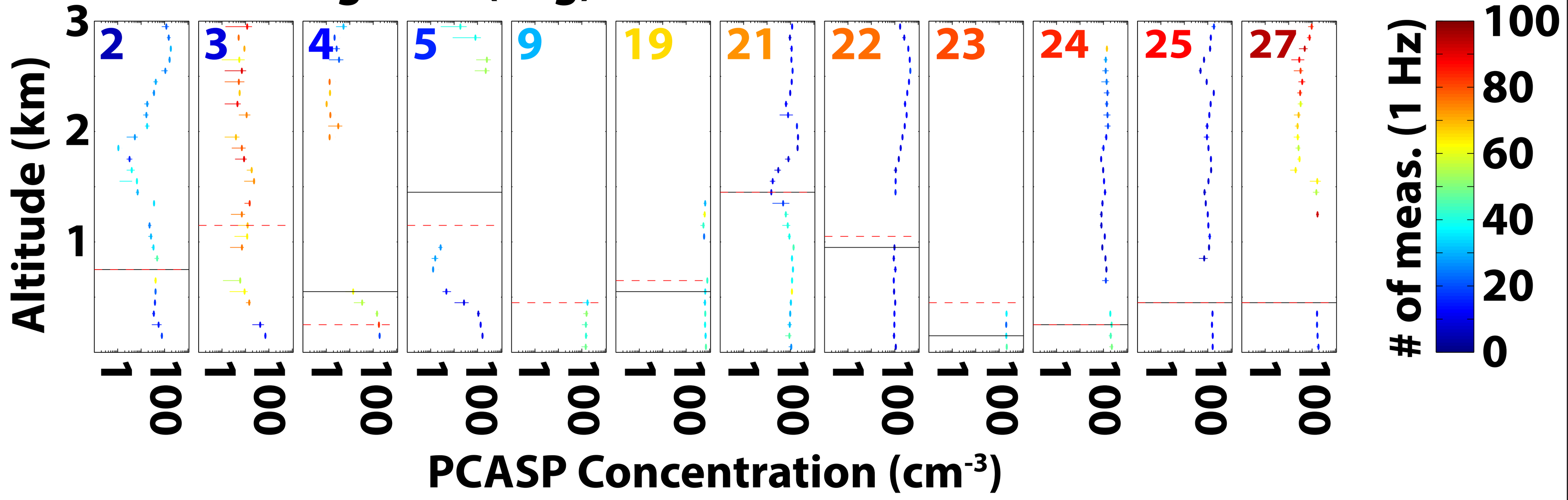




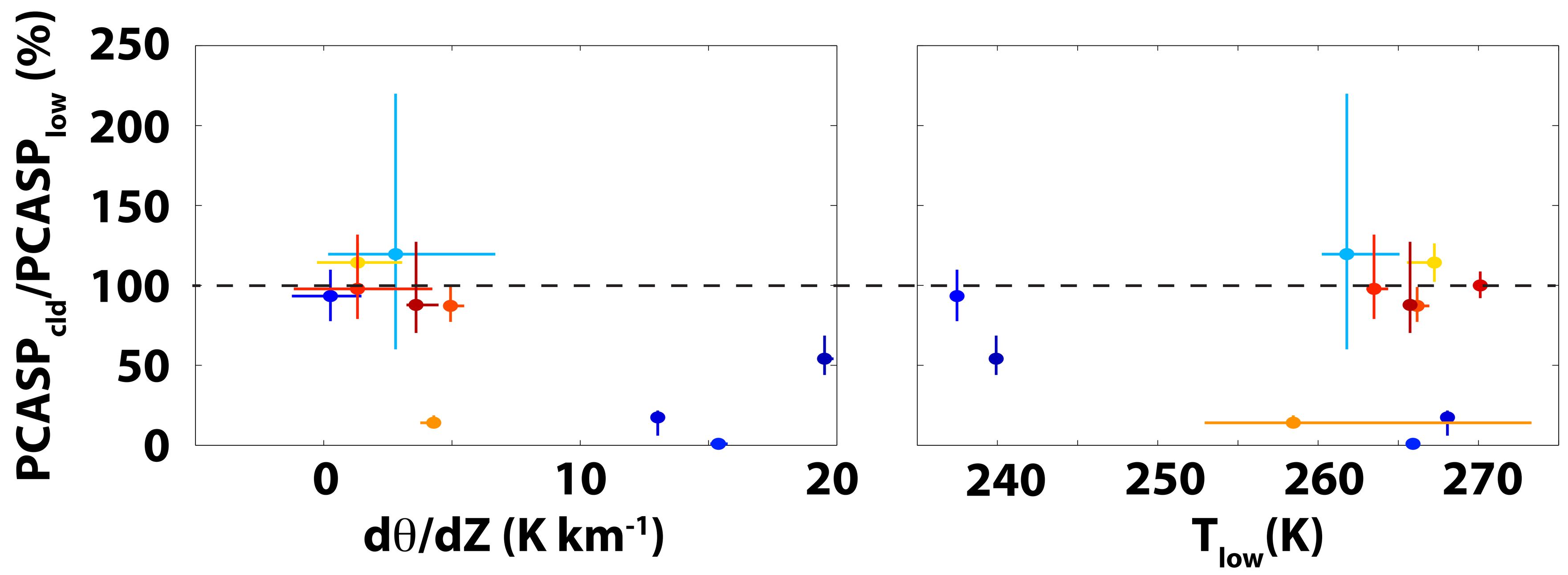
ASCOS surface-based estimates of vertical velocity, skewness, turbulent dissipation rate, and Richardson Number (top, from Shupe et al., 2013). Also plotted are helicopter derived profiles of aerosol number concentrations (bottom) for the same date.

ISDAC Aircraft Profiles



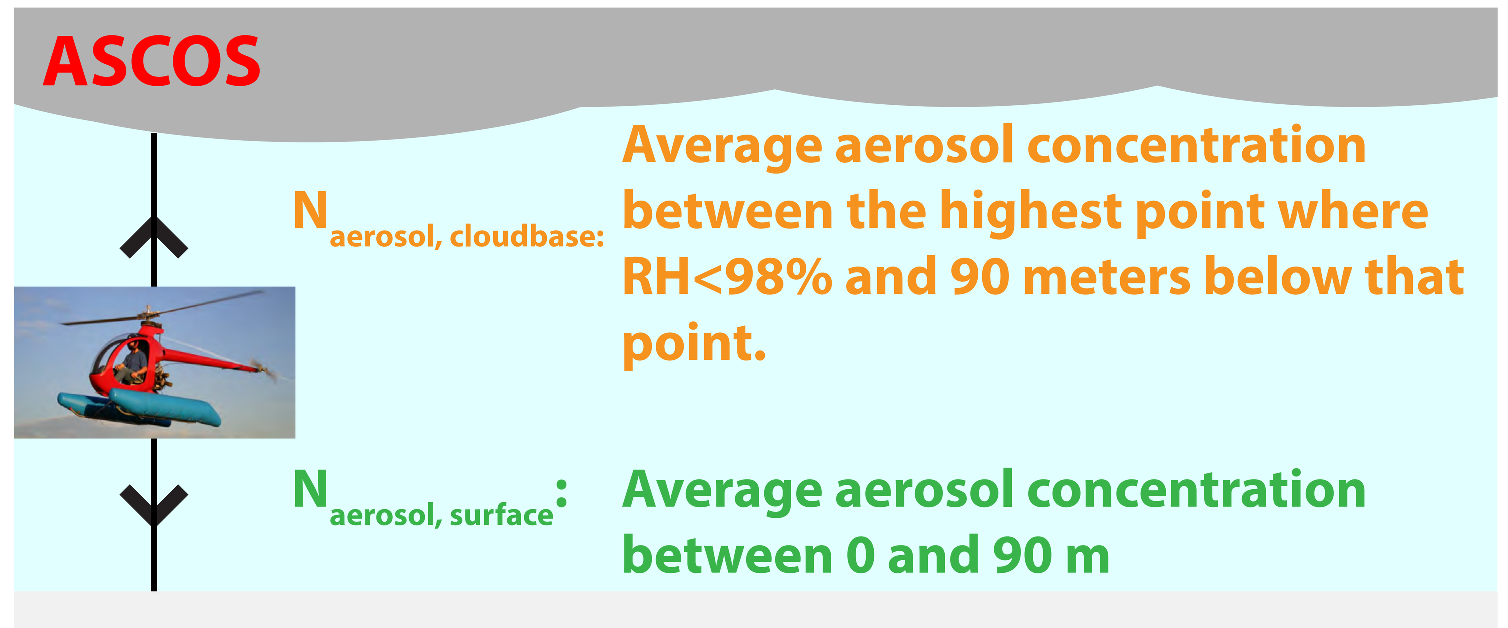


A map illustrating ISDAC flights within a 1° (lon) x 0.5° (lat) distance from Barrow (top left), and the Convair aircraft used during ISDAC (top right). The lower panel shows PCASP concentrations from all flights with liquid clouds (as indicated by dashed red line from McFarquahar ISDAC microphysics product.



PCASP concentration at cloud base divided by lower atmospheric PCASP concentration, plotted as a function of lapse rate (left) and low-level air temperature (right). Individual flights are color-coded to match the upper figures.

Relevance to Estimatation of Aerosol Indirect Effects

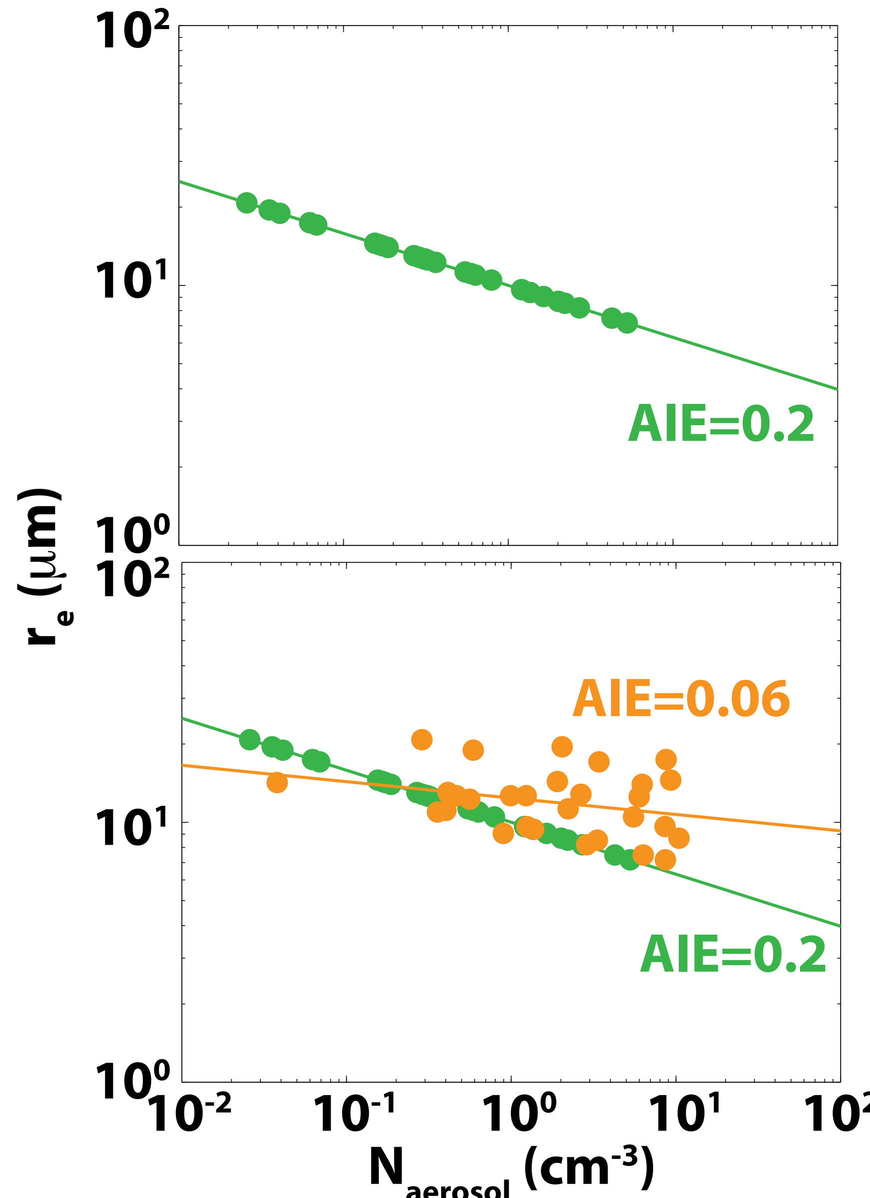


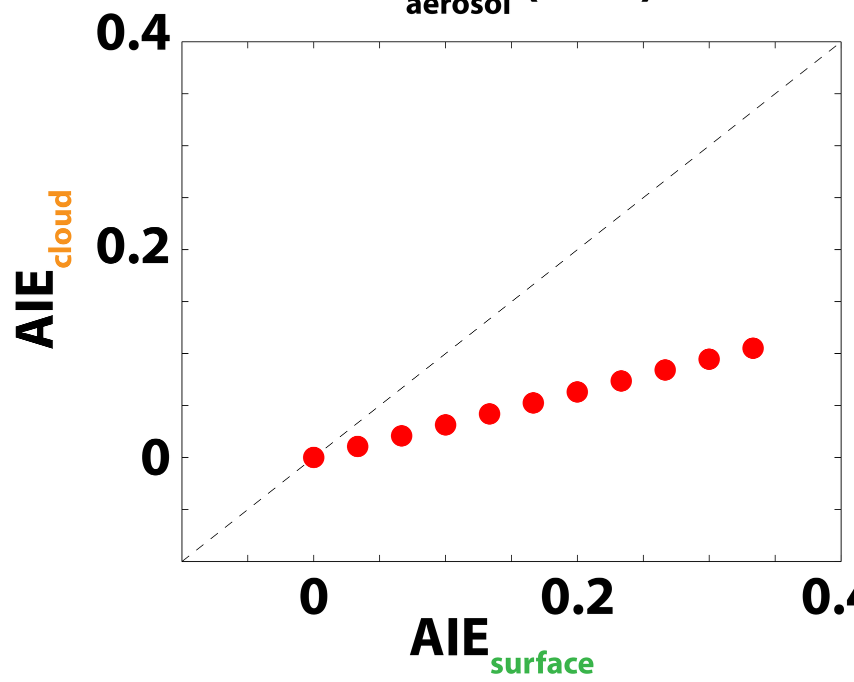
$$AIE = -\frac{\partial \ln r_e}{\partial \ln N_{aerosol}}\bigg|_{LWP}$$

Step 1: Use $N_{aerosol,surface}$ to calculate theoretical r_e, assuming a specific value for AIE and fixed LWP. This assumes a "perfect" relationship, though one could add artificial noise.

Step 2: Use calculated r_e values to determine AIE for the same cloud, but using $N_{aerosol,cloudbase}$. Note the change in relationship when using the upper level aerosol concentrations.

Step 3: Evaluate the impact of aerosol measurement location on estimation of aerosol indirect effect. For ASCOS helicopter profiles, using the near-surface aerosol concentrations results in an overestimation of AIE.





Acknowledgments

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