Opportunities for advancing aerosol predictability in Earth system models using ARM aerosol measurements

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Evaluation: E3SM_diags and ARM Diagnostics

E3SM_diags

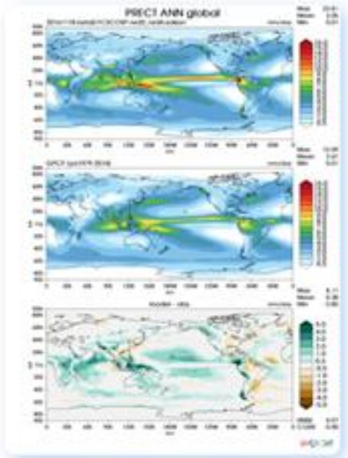
Diagnostic Plot Types and Currently Available Analysis Datasets

The software provides support for diagnostics based on seasonal or annual climatology data, including:

- Latitude-Longitude contour maps
- Polar contour maps
- Zonal mean line plots
- Pressure-Latitude zonal mean contour
- CloudTopHeight-Tau joint histograms
- Tables summarizing metrics
- Taylor Diagrams for spatial variability

A basic set of analysis datasets are established for earth system fields:

- GPCP for Precipitation
- CERES_EBAF for radiation
- Hadley Center data for sea surface temperature
- WHOI-OAFlux for ocean surface latent and sensible heat fluxes
- ERA-Interim and MERRA2 for reanalysis datasets
- ISCCP, MISR and MODIS for Satellite simulator datasets



An example of the lat-lon contour plots for global precipitation

More datasets and variables can be easily extended based on scientists' requests.

- Zhang et al (2022), GMD
- Incorporating ARM Diagnostics
    - Zhang et al (2020), BAMS
    - Mostly on cloud, precipitation, radiation
    - SGP AOD is included

ARM Diagnostics

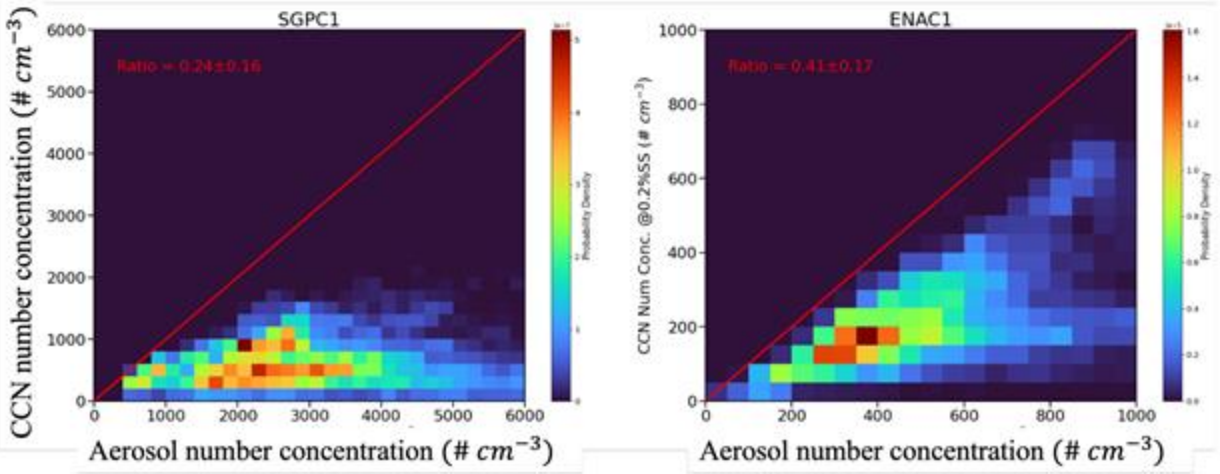
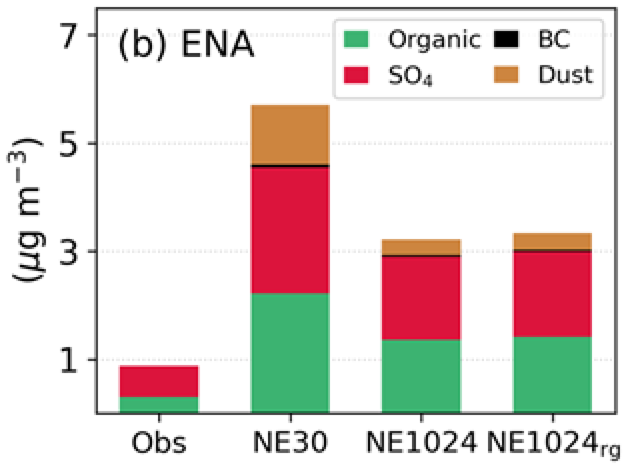
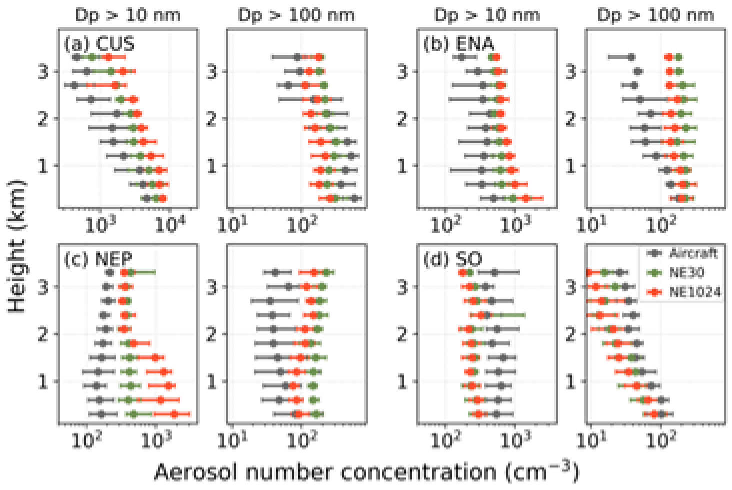


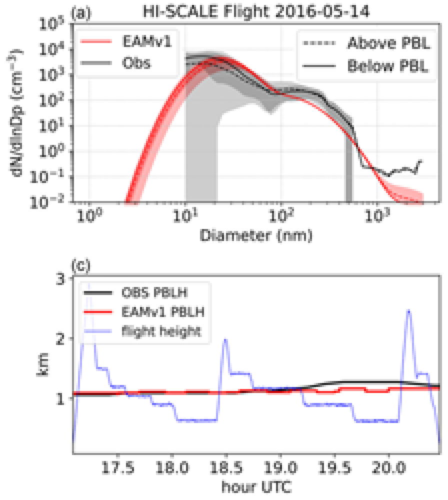
Figure 5. Probability density plots for aerosol number concentration (x-axis) versus CCN number concentration (y-axis) at 0.2% supersaturation level at the ARM SGP (left) and ENA site (right).

- Updates to the ARM Diagnostics (Zheng et al, 2022, DOE Tech Report)
- Aerosol physical/chemical properties and CCN datasets measured at SGP and ENA have been quality controlled and processed.
- The statistics metrics on the aerosol physicochemical properties and CCN number concentrations annual cycles
- The process-oriented diagnostics metrics on the aerosol-to-CCN activation assessments at different supersaturation levels.

Evaluation: EAGLES Diagnostics







- Tang et al (2022, 2023), GMD; Christensen et al (2022), ACP; Varble et al (2023), ACP, Huang et al, TBS
- Aerosol **state** (composition, distribution, time series, size distribution)

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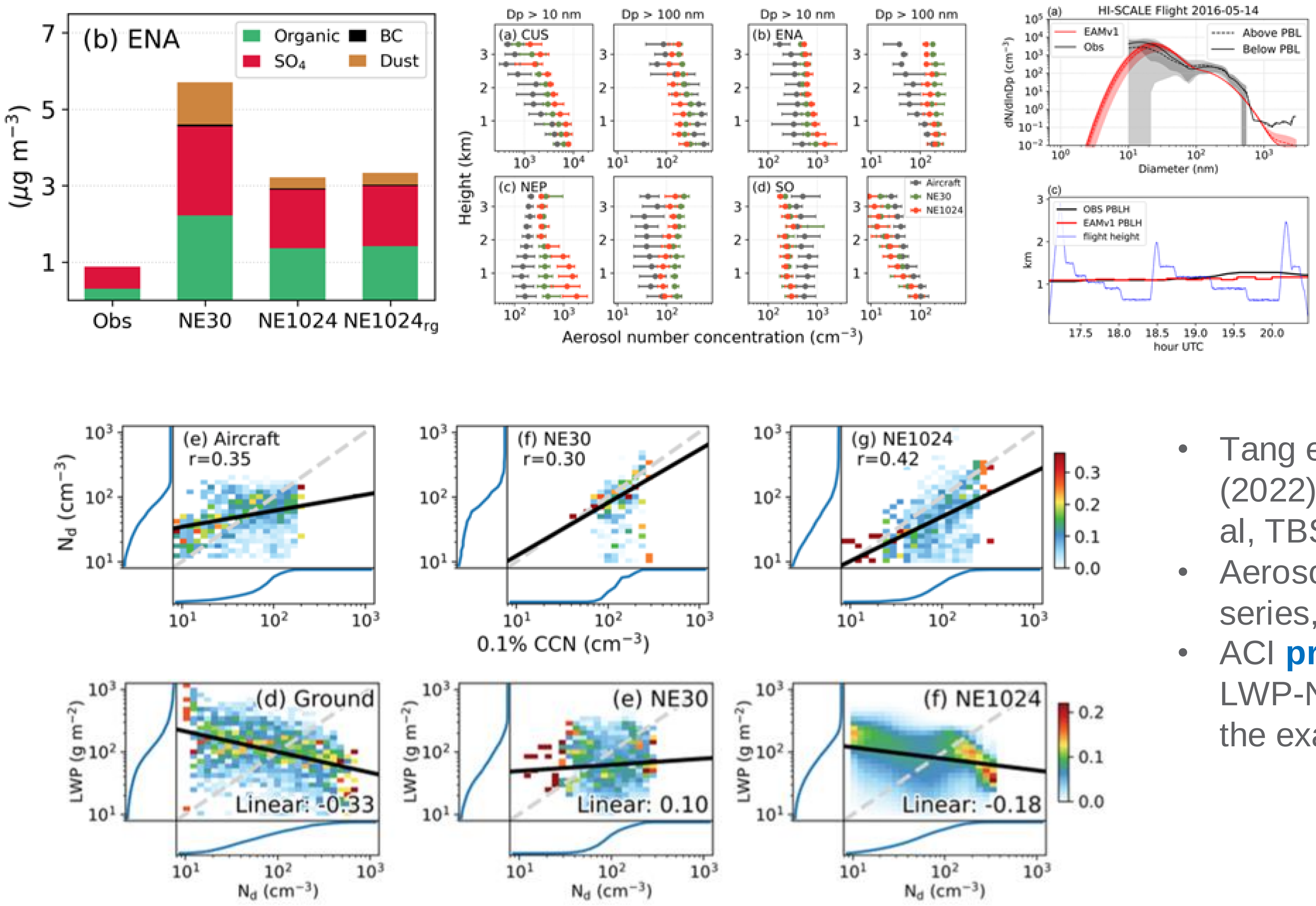

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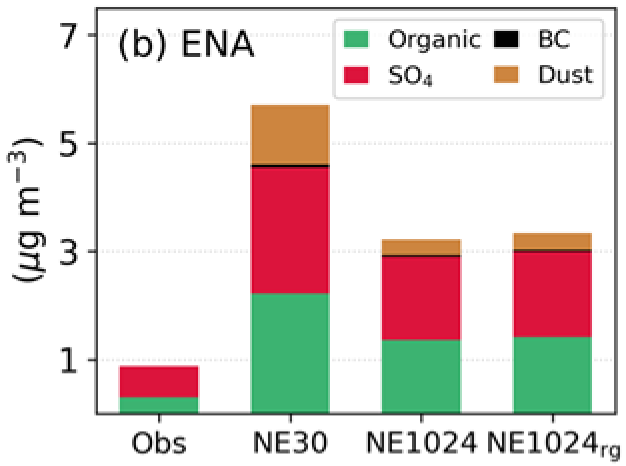

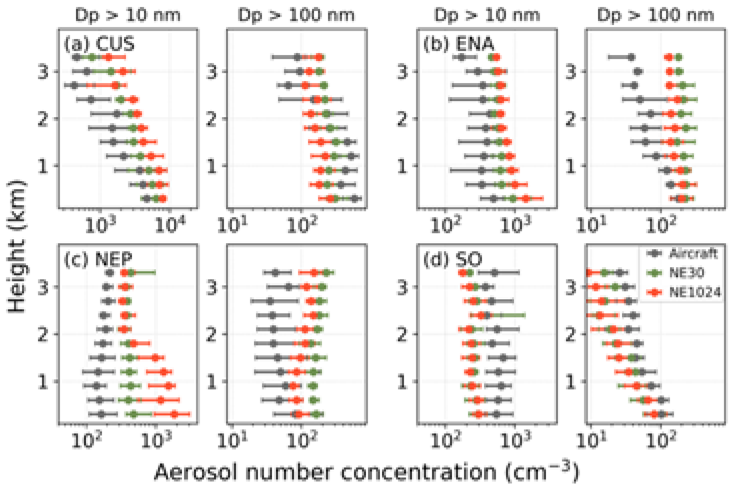

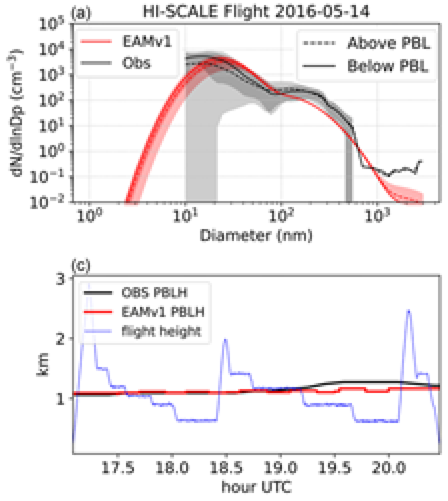

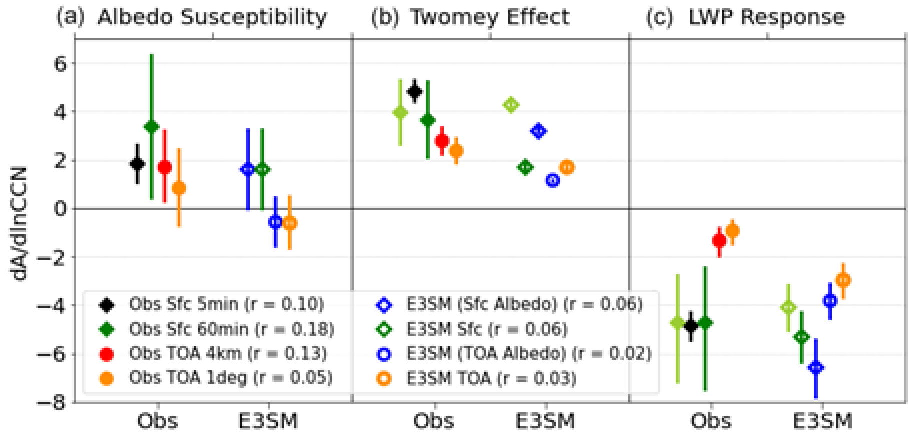

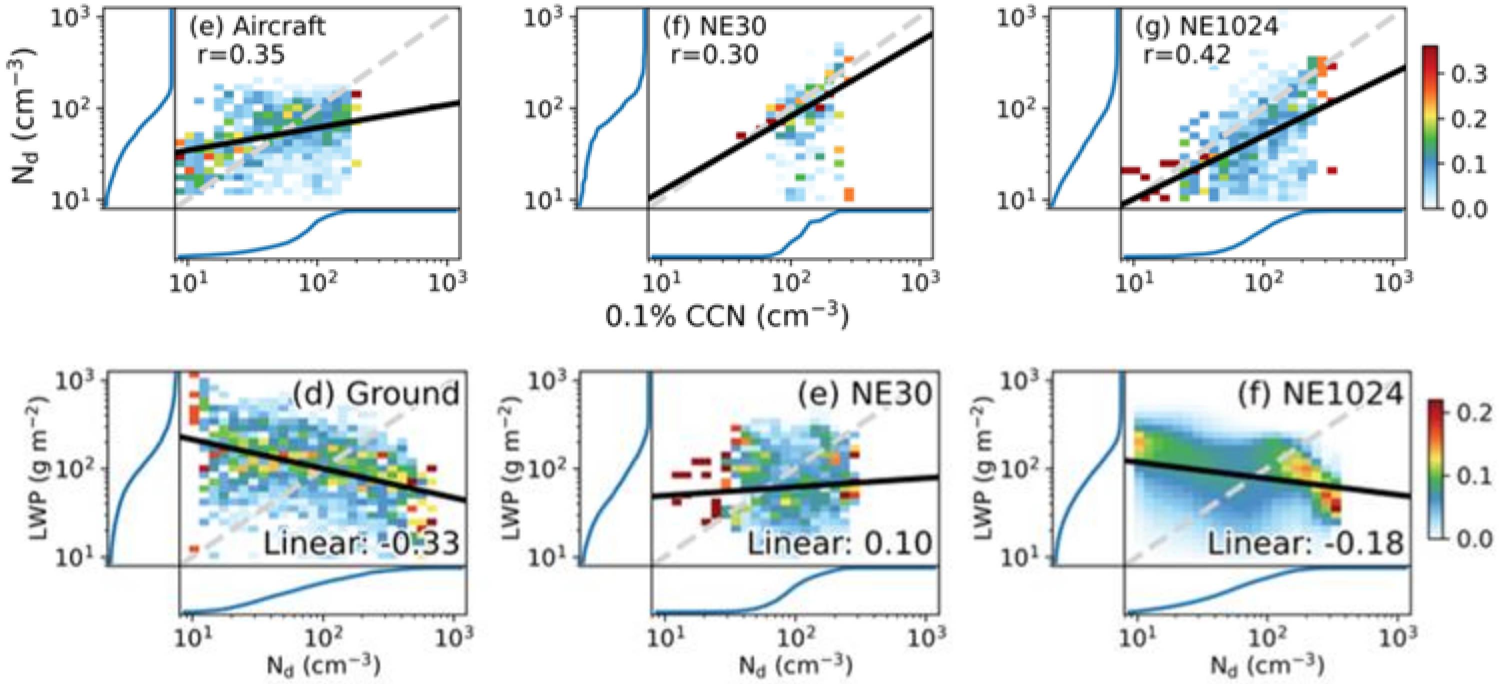

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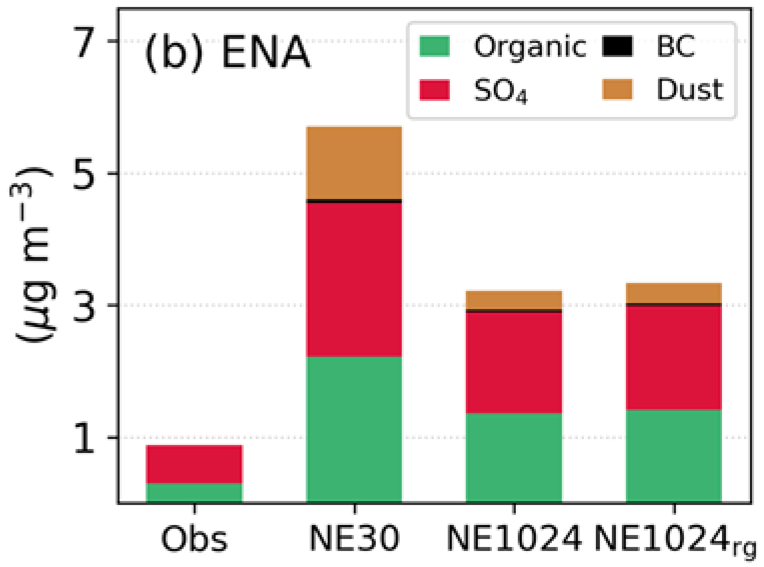
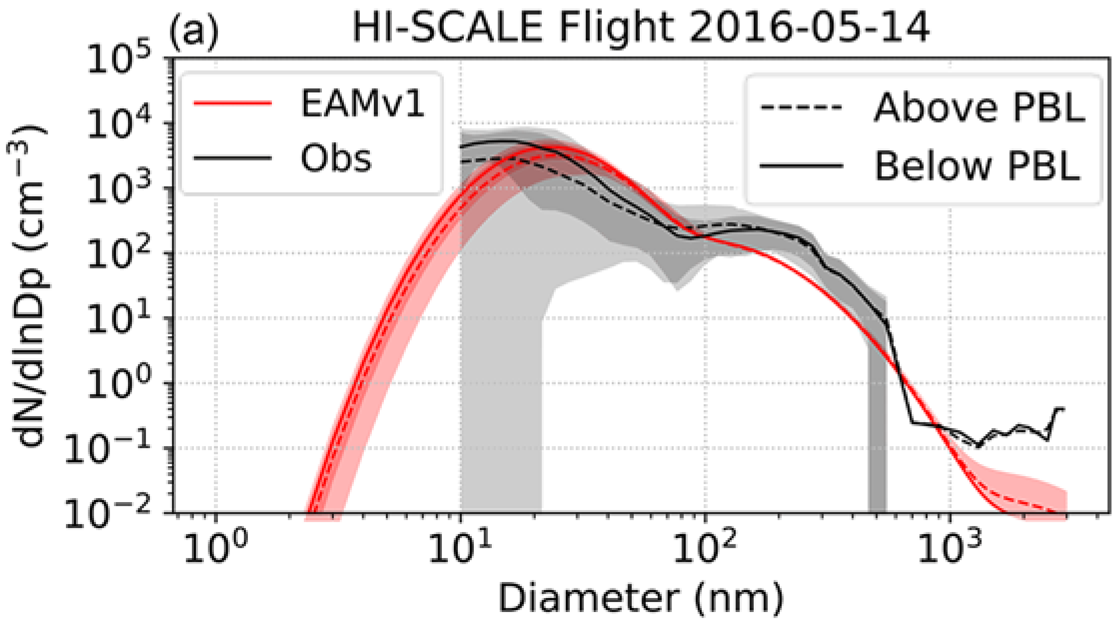
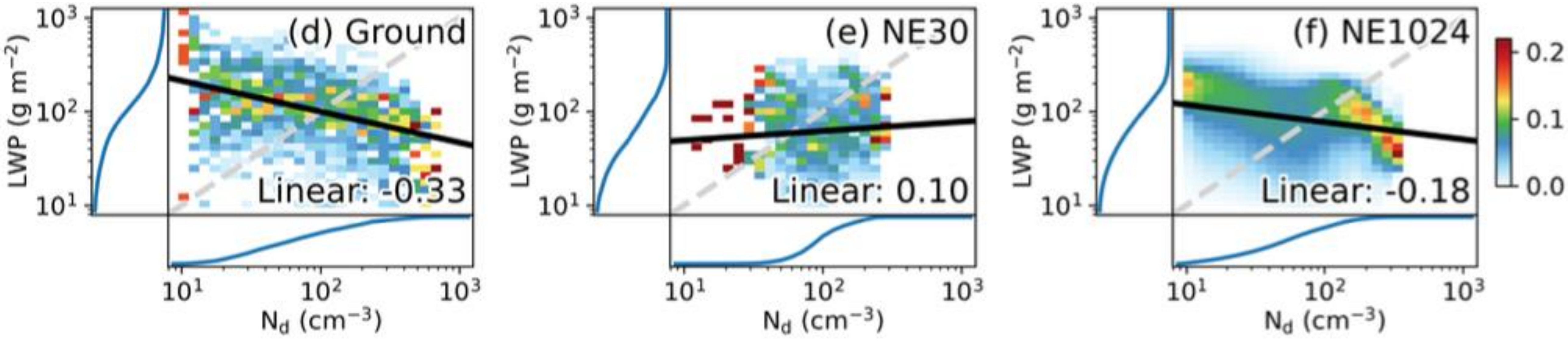
- Aerosol **state** (composition, distribution, time series, size distribution)
- ACI **process-oriented** diagnostics (Nd-CCN, LWP-Nd), but more research is needed to pinpoint the exact process(es).
- **Reconcile differences** between satellite and ARM estimates of ACI

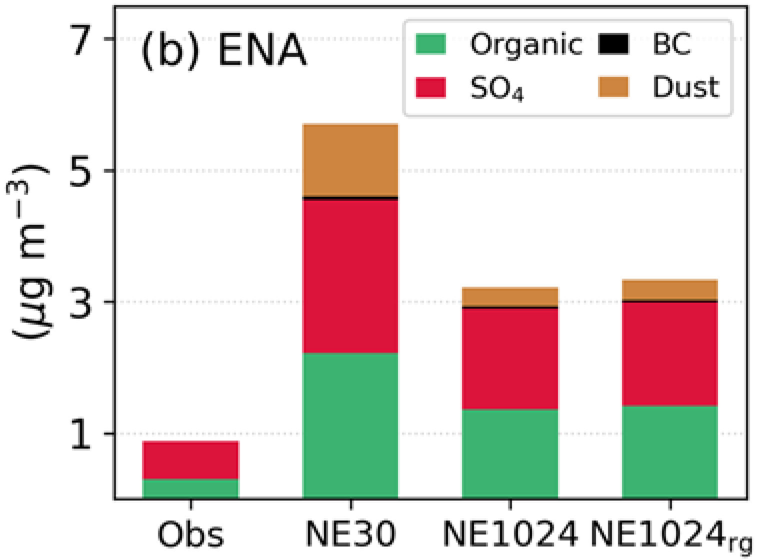
What do these diagnostics tell us?







Identify critical deficiencies in ESMs and motivate innovation



- Model produces too much aerosol

Kang et al, to be submitted

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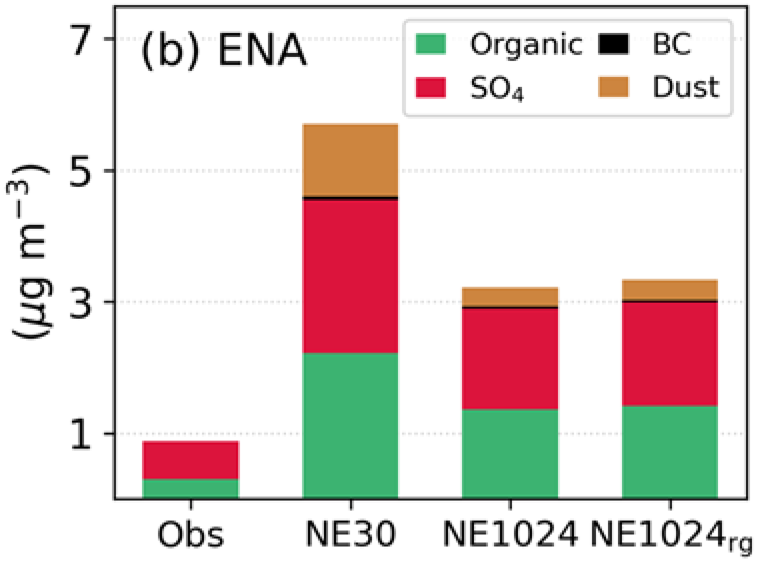

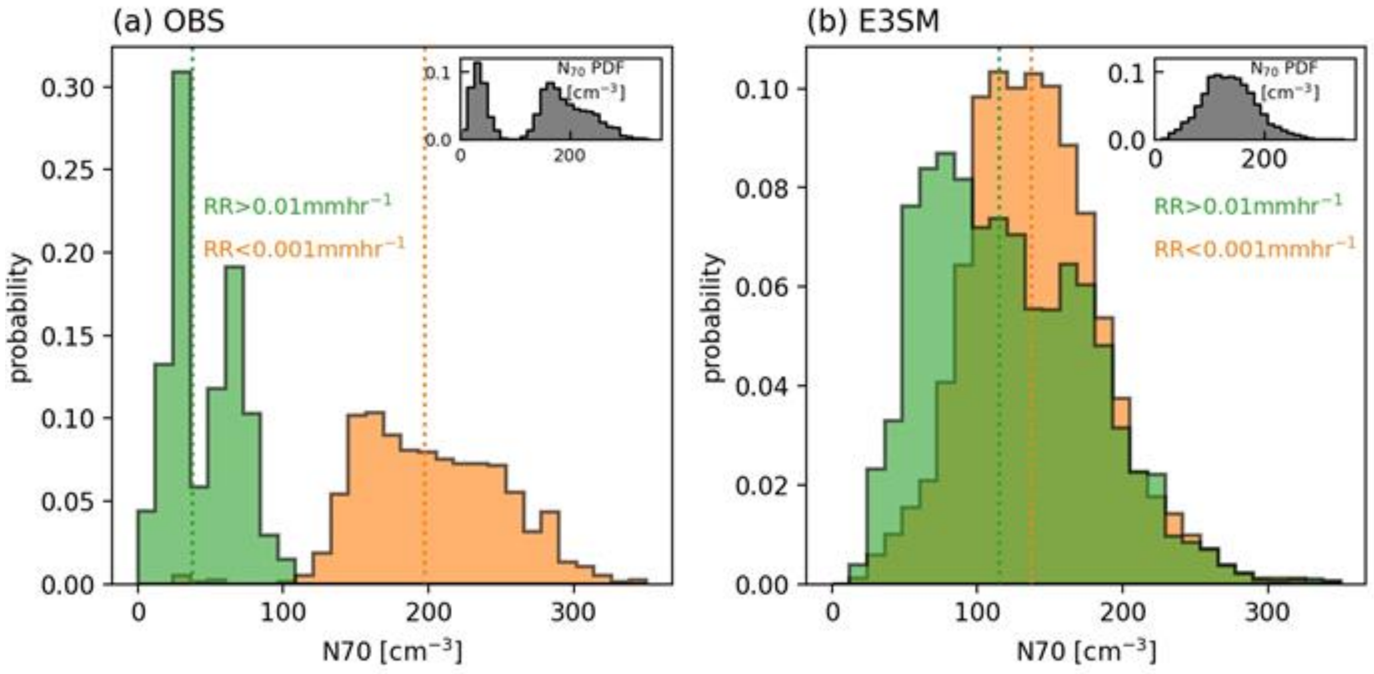

- Model produces too much aerosol
- Seems to be related to overly weak below-cloud scavenging

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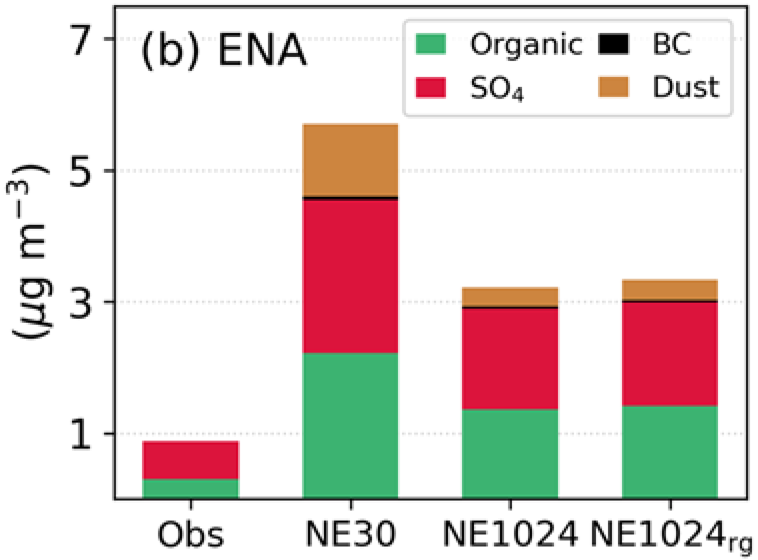

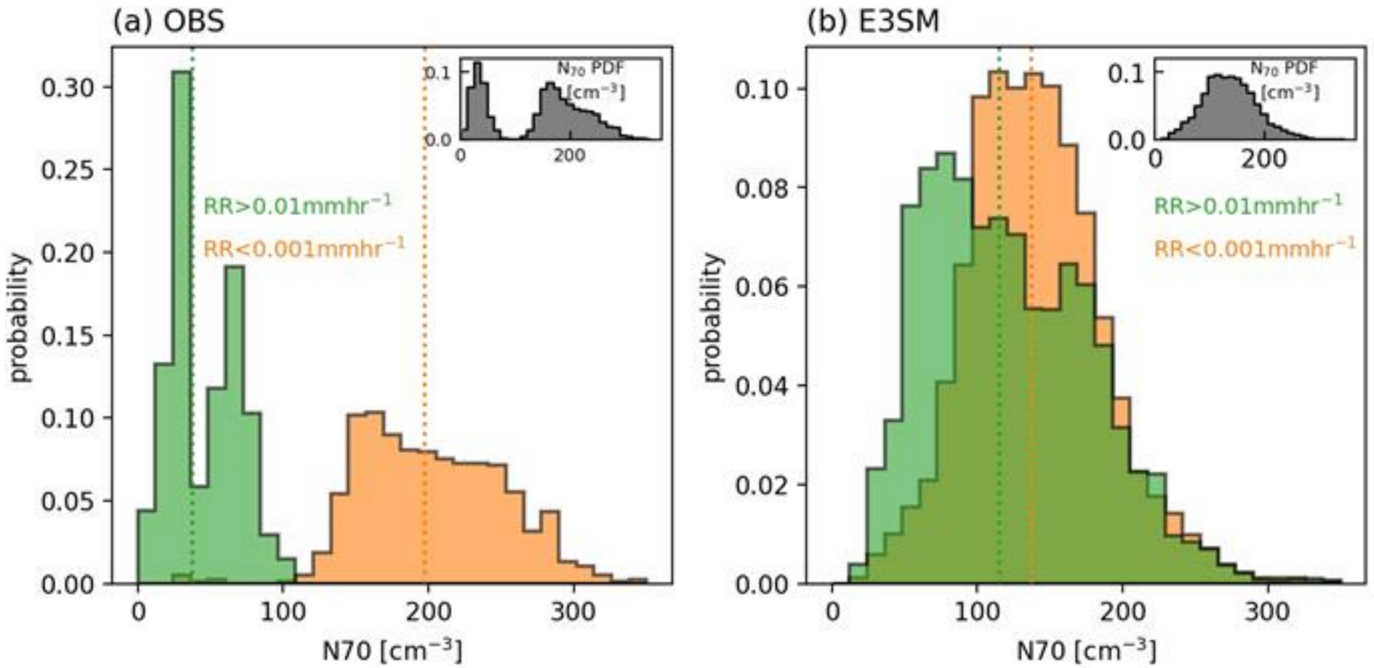

BNWL-SA-5080
Conf-741003--8

WASHOUT COEFFICIENTS FOR POLYDISPERSE AEROSOLS

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NOTICE

MASTER

Work performed by Battelle, Pacific Northwest Laboratories, Richland, Washington for the U. S. Atomic Energy Commission under Contract AT(45-1)-1830.

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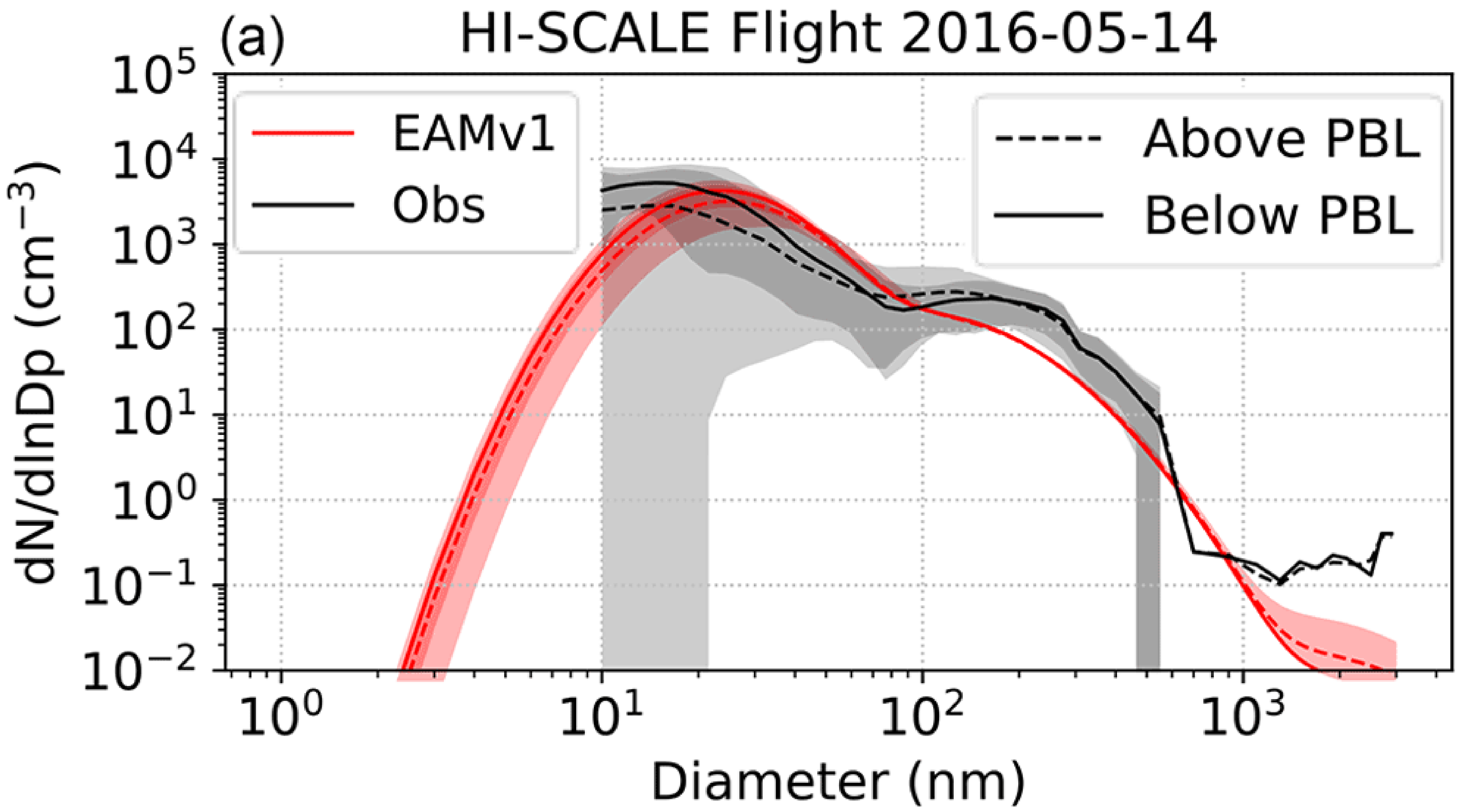
- Model produces too much aerosol
- Seems to be related to overly weak below-cloud scavenging
- Current parameterization was developed in 1974.
- It has been reported that the scavenging computed by this parameterization is 2-3 orders of magnitude lower than observations.

Kang et al, to be submitted

Size distribution



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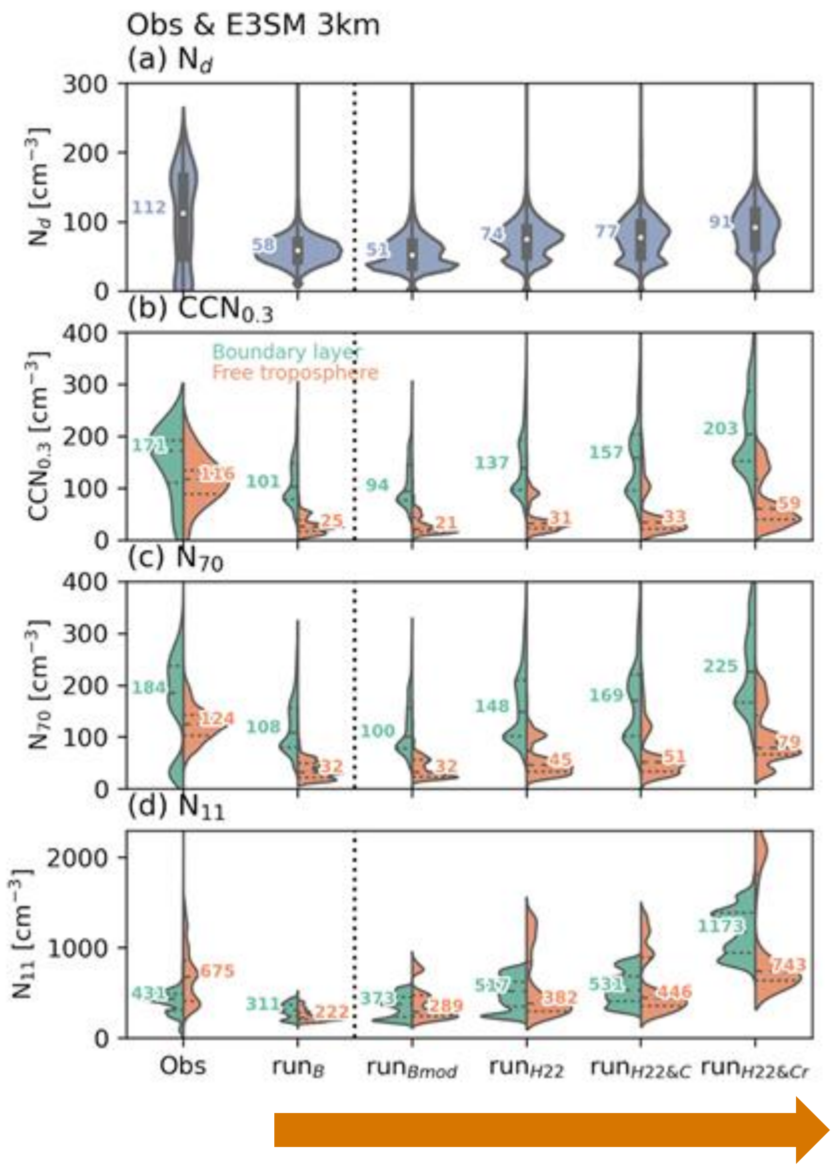
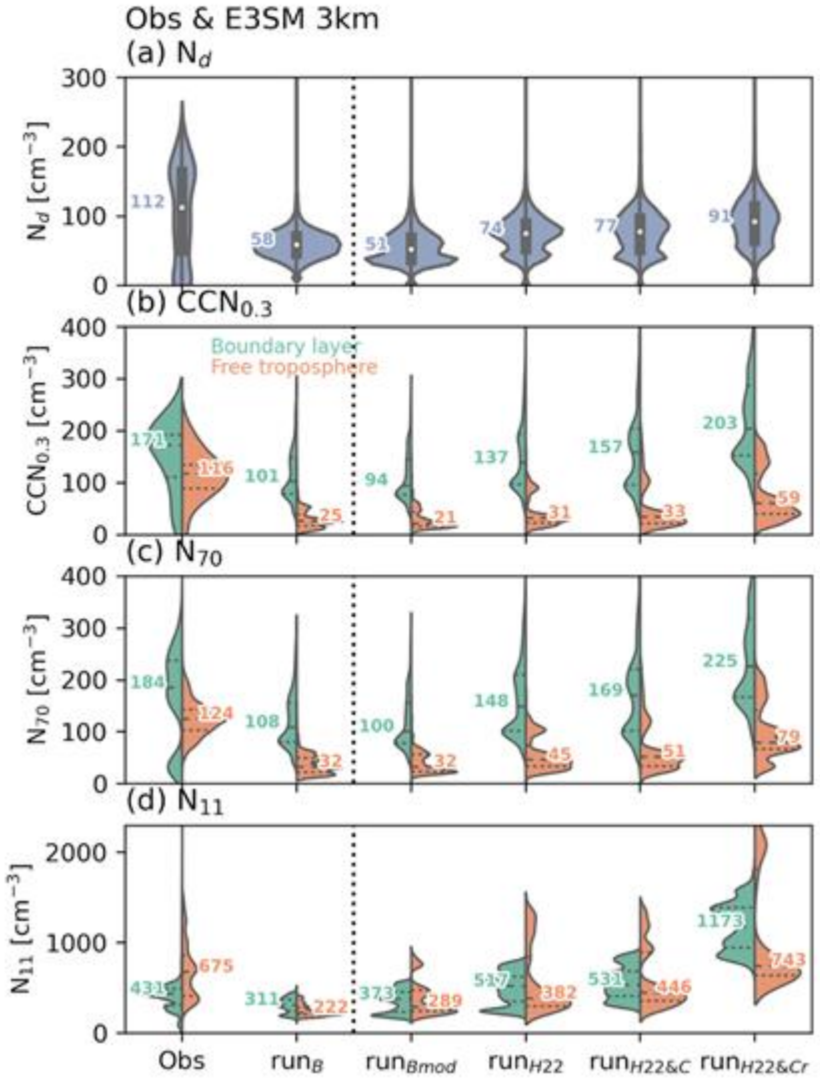


Improve DMS chemistry

Identify critical deficiencies in ESMs and motivate innovation



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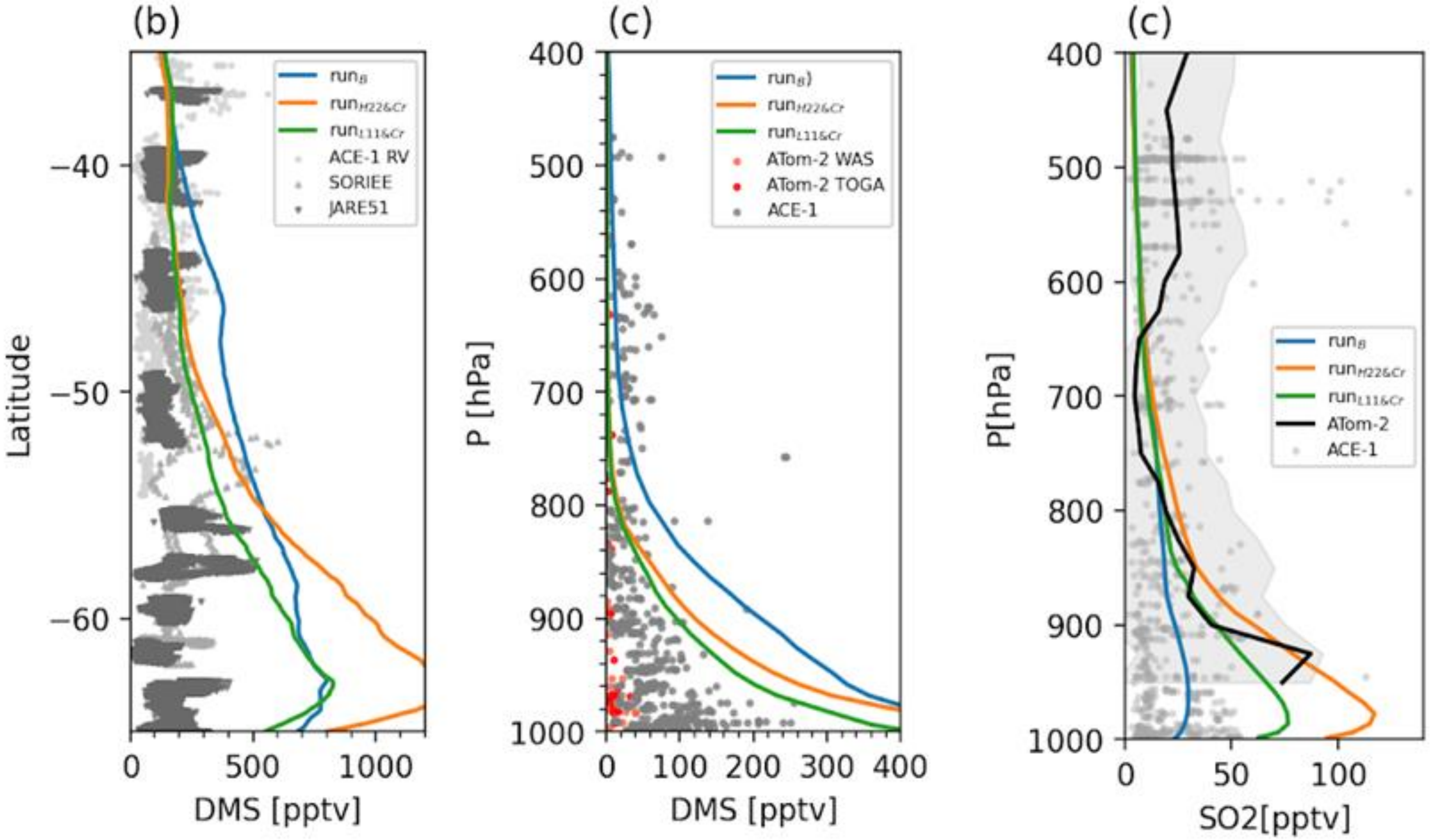


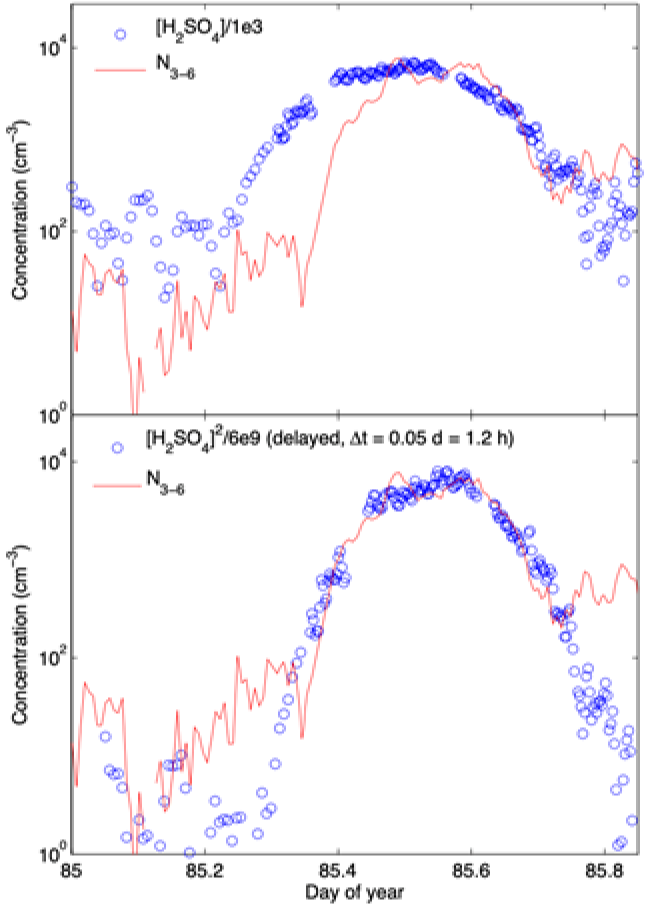
DMS and SO2 biases increase

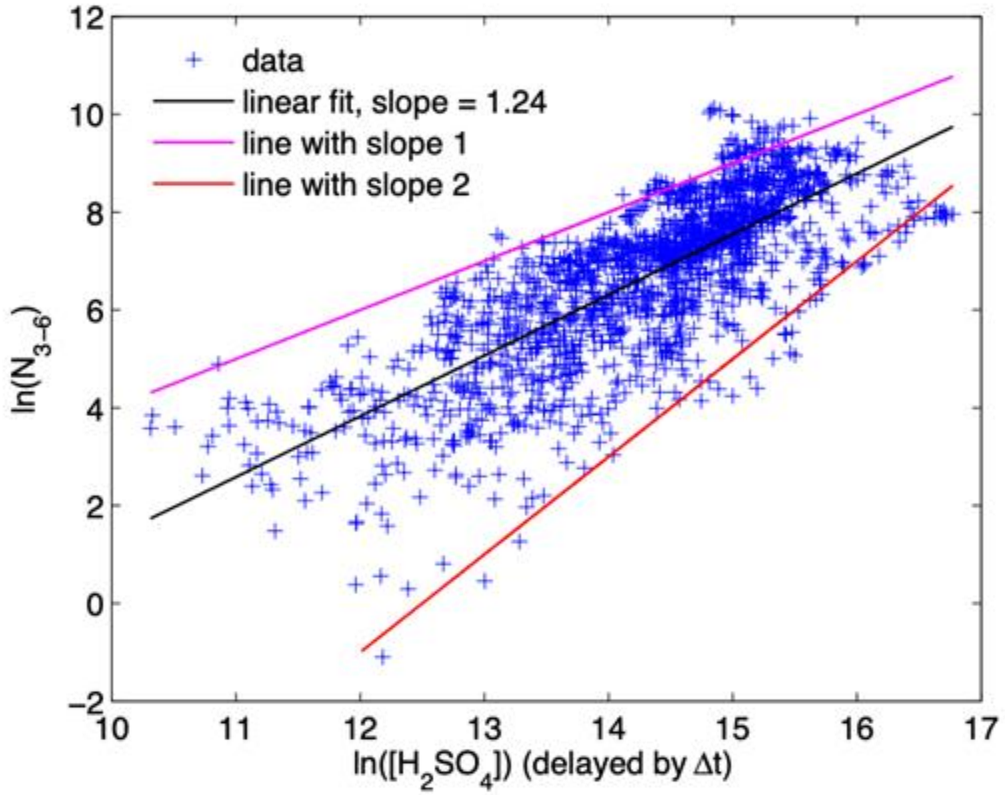
Kang et al, to be submitted

Identify critical deficiencies in ESMs and motivate innovation

We utilized the data set of QUEST 2 (Quantification of Aerosol Nucleation in the European Boundary Layer) campaign that was held at the SMEAR II station in Hyytiälä, Finland, in March–April 2003. The QUEST 2 data set is quite unique in the sense that during the campaign a large number of events was observed: of the total of 23 measurement days (from 18 March to 9 April 2003) 20 were new particle formation days. During QUEST 2 campaign a large number of different quantities were measured; here we describe only the measurements relevant to this study.

The measurement station SMEAR II (Station for Measuring Forest Ecosystem – Atmosphere Relations) is located in Southern Finland (61°51′ N, 24°17′ E, 181 m a.s.l.) in a rural region with large areas of forested land. The conditions at the station are most of the time relatively clean, even though polluted continental air arrives occasionally from the south-east to south-west directions. Also the nearest city, Tampere, located 60 km south-west from the station, can influence the local air quality. More information about the station and the measurement equipment can be found in Hari and Kulmala (2005) and at http://www.atm.helsinki.fi/SMEAR/.

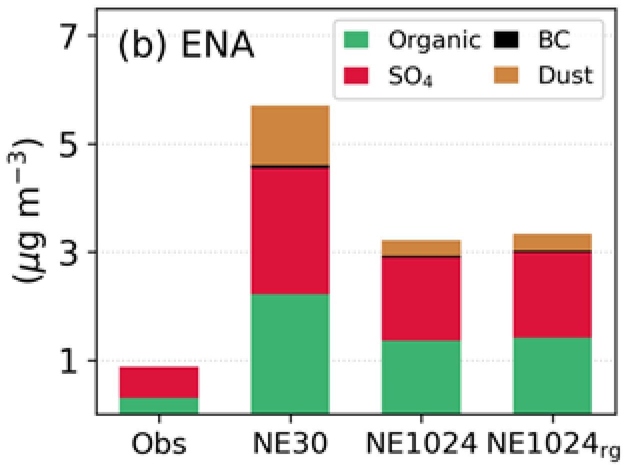




Sihto et al (2006)

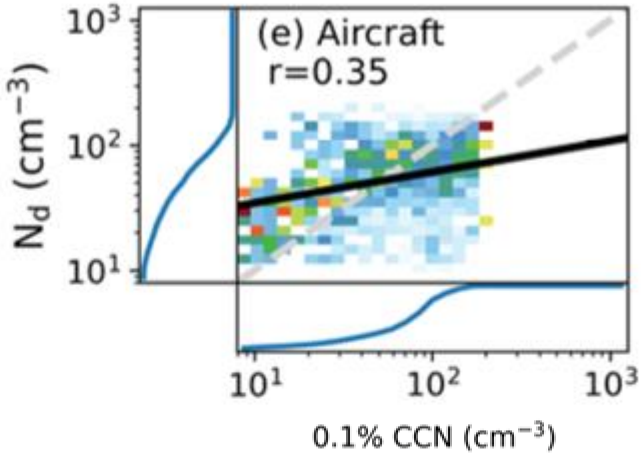
From model evaluation to model improvement

Evaluation of state



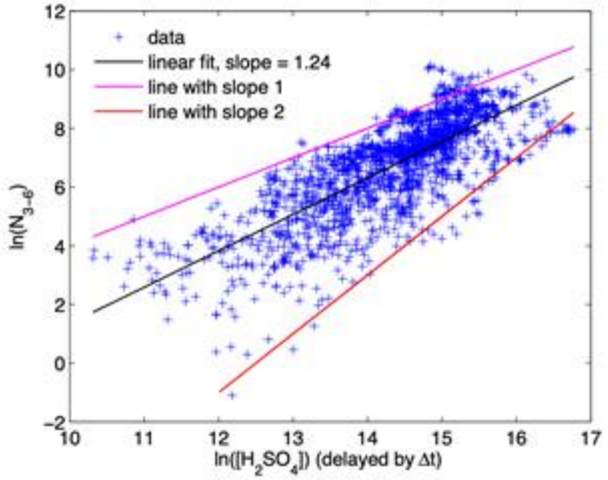
- Providing critical information regarding **aerosol state**, including
  - Mass
  - Number
  - Composition
  - Size distribution
  - Spatial distribution
  - Time evolution
  - CCN at different SS

Evaluation of processes



- Bridging knowledge gaps with **process-oriented** diagnostics, including
  - CCN-Nd joint histogram
  - Nd-LWP joint histogram
  - GCCN effects
  - BC aging and absorption
  - Aerosol water uptake
  - Wet scavenging
  - Inferred ERFaci

Improvement of understanding & predictability



- **New/more observations** needed for developing better process representations