Earth System Model Aerosol-Cloud Diagnostics Package (ESMAC Diags) for High-Res Modeling

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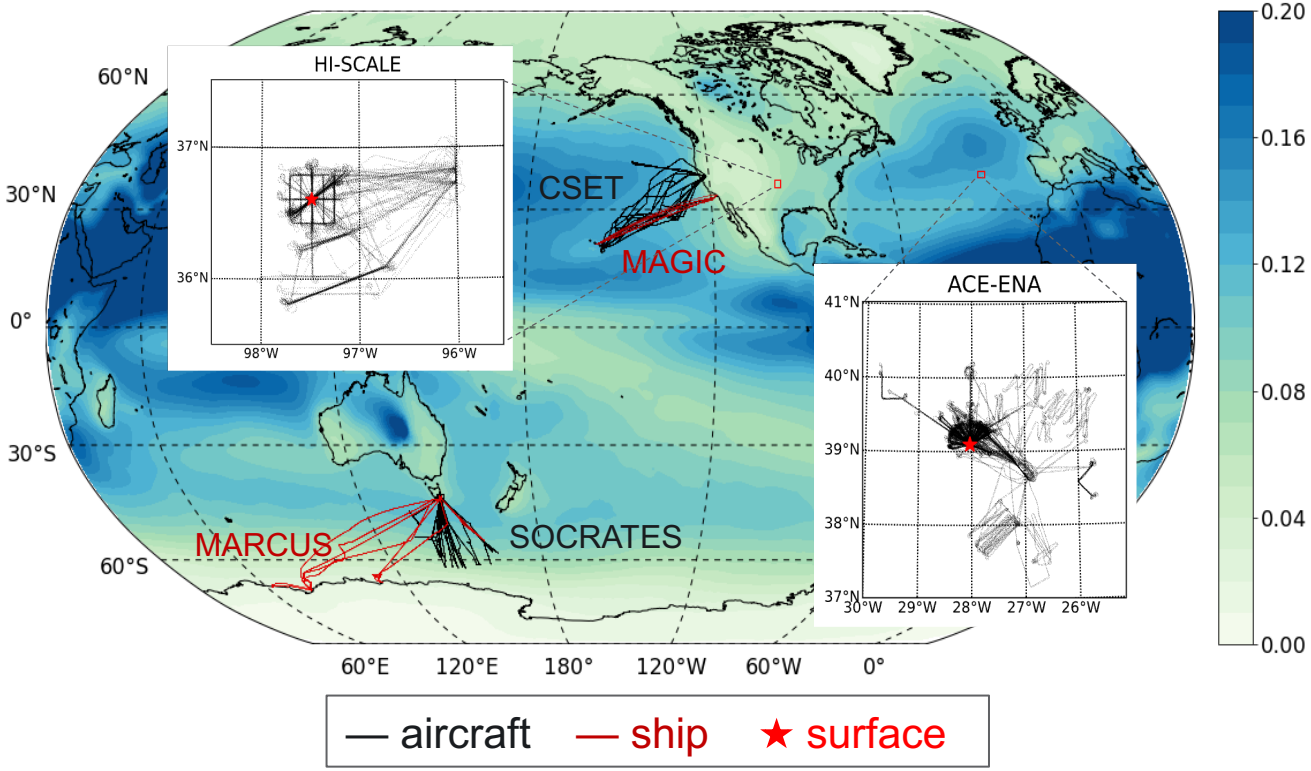
Enabling Aerosol-cloud interactions at Global **convection-permitting** scalES (EAGLES)

- **Goal**: To increase confidence in, and understanding of, the role of **aerosols and aerosol-cloud interactions** in the evolution of the Earth system in the global **convection-permitting** E3SMv4.
- **Method**: Rescale observations and model output to be comparable.
- An "**aircraft simulator**" is used to extract aerosol and meteorological model variables along flight paths (ship tracks) that vary in space and time.

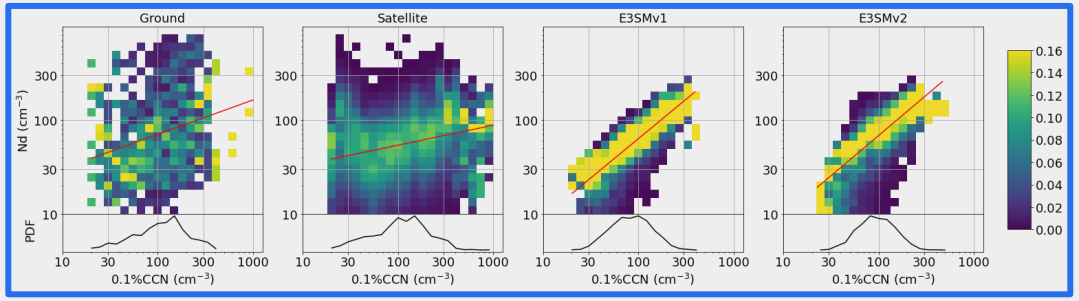
Field Campaigns Currently Included in ESMAC Diags

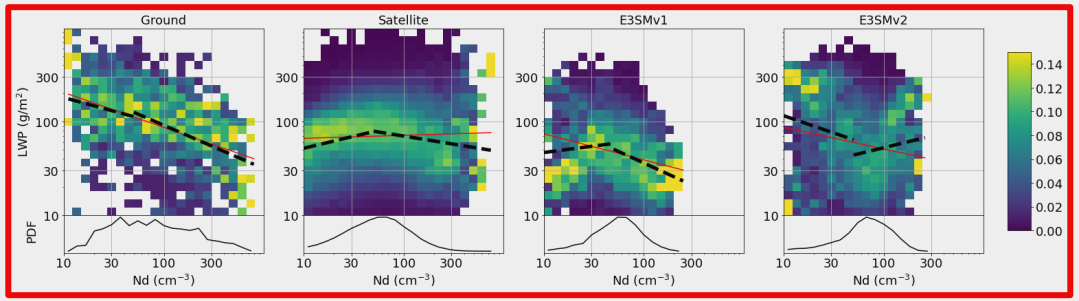


Examples

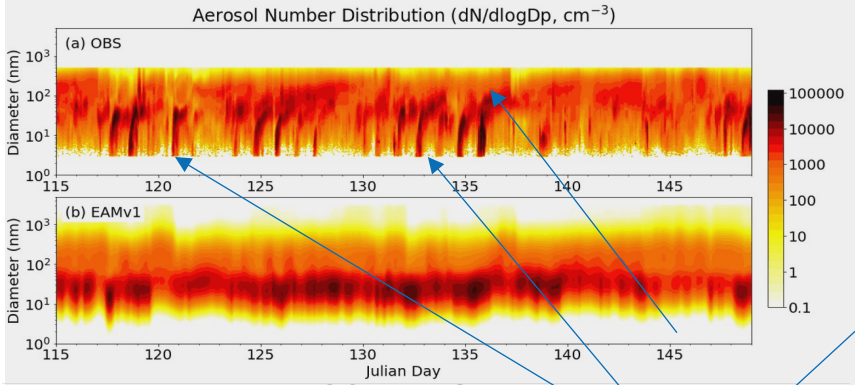
- (right) Regular single-variable diagnostics
- (down) Multi-variable relations for susceptibility processes analysis

$$\frac{dA}{dlnCCN} = \left(\frac{\partial A}{\partial lnN_d} + \frac{\partial A}{\partial lnLWP}\frac{dlnLWP}{dlnN_d}\right)\frac{dlnN_d}{dlnCCN}$$





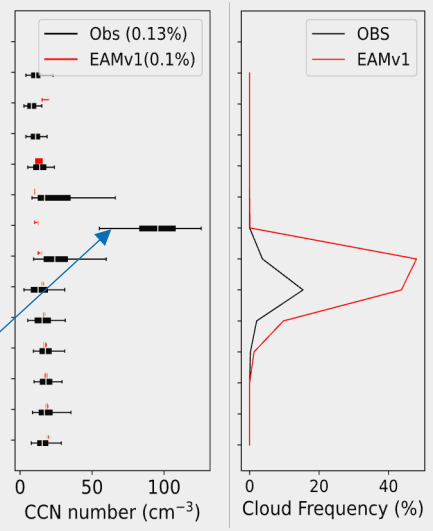
Time series



HI-SCALE IOP1

NPFs

Vertical profiles



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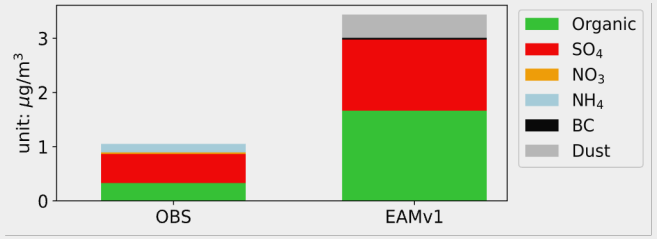
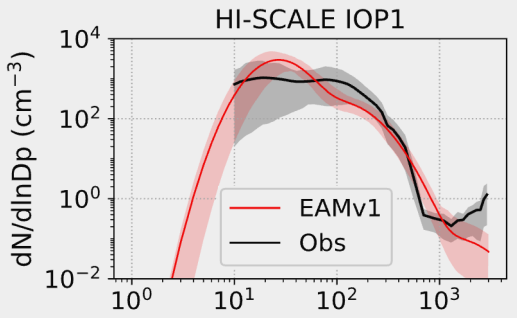
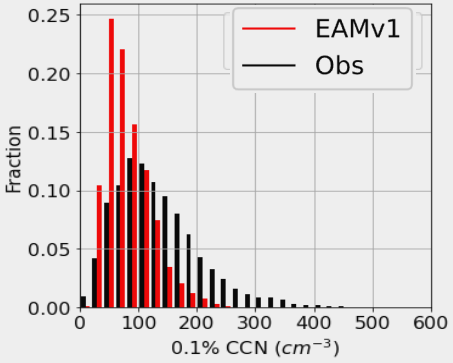
Aerosol composition



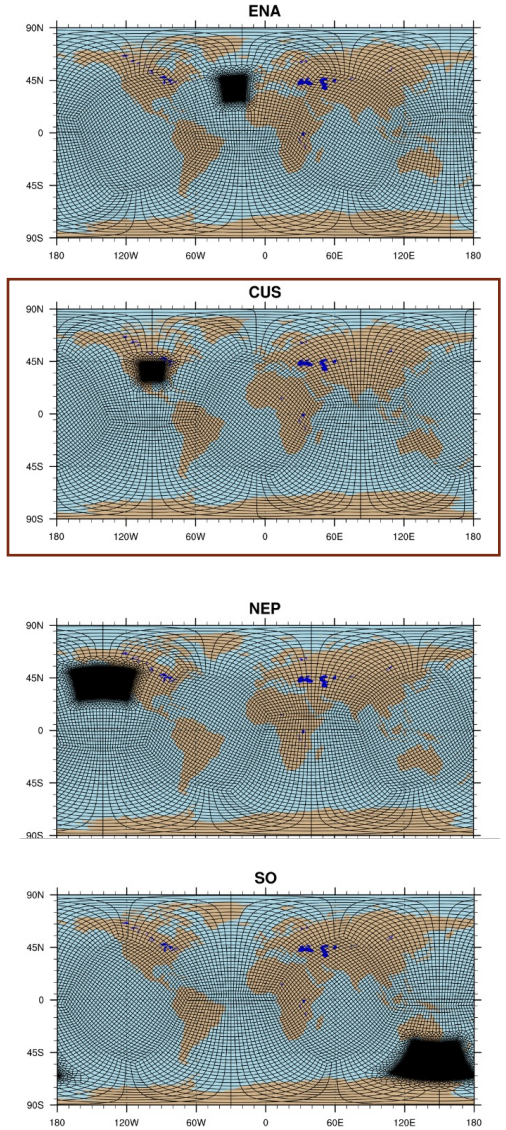
Aerosol size distribution



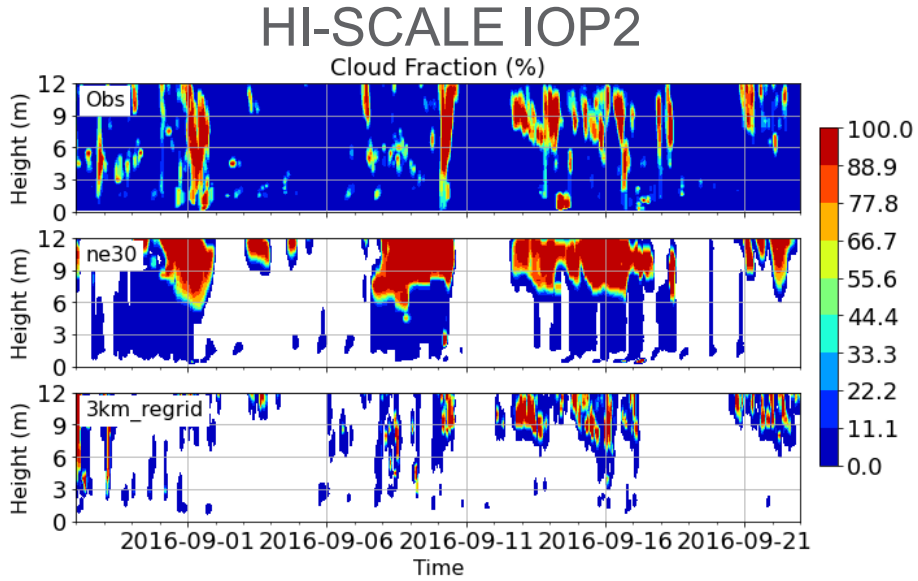
1d histogram

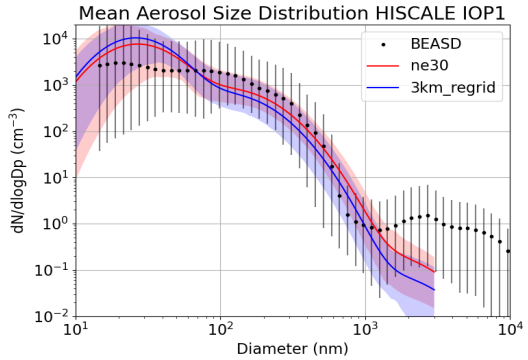


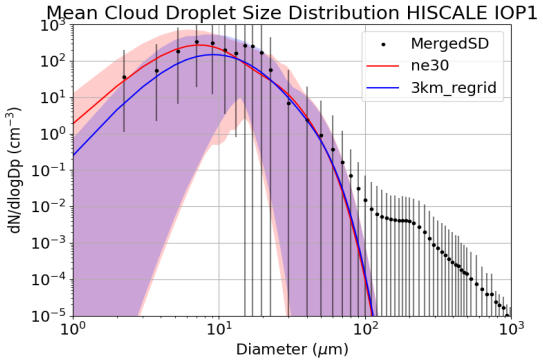
Evaluating 3km RRM

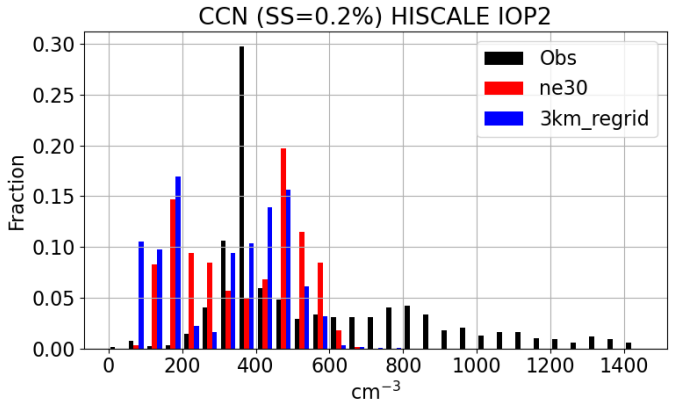


- **ne30**: default E3SMv2 (1˚x1˚)
- **3km**: RRM with 3km reso mesh
- **regrid**: average into ne30 grid









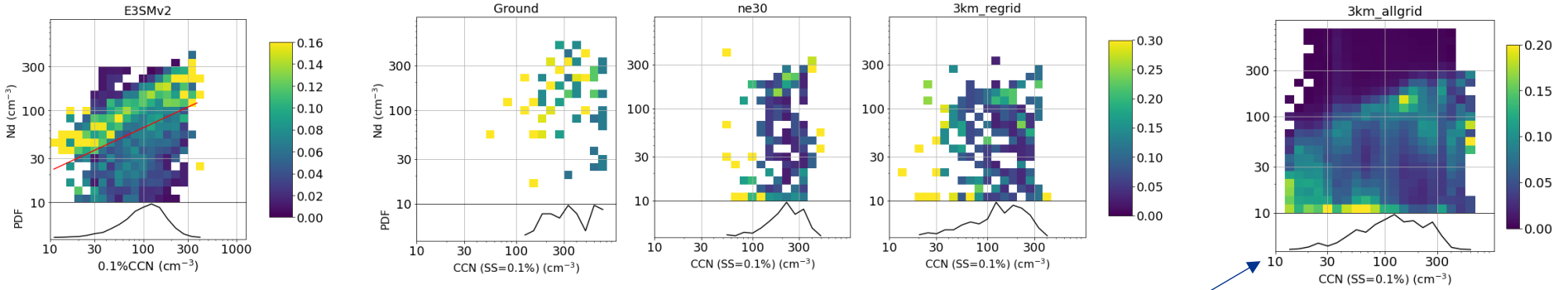
Overall, RRM produces more broken clouds than 1˚ simulation, but has similar performance on aerosols and cloud microphysics properties.

Discussions

1. High-res models only run for **short-term** field campaigns, not enough samples for robust ACI diagnostics.

Use all 3km grids within a 1x1 domain for statistics

$$\frac{dlnN_d}{dlnCCN}$$



SGP (2011-2020)

HI-SCALE IOP1

- How to address the small-sample problem?

2. 3km RRM still uses coarse-res emission data, which will degrade the aerosol spatial variation.

3. How to make a fair comparison with high-frequency aircraft measurements?
   - How high the model output frequency (vertical resolution) is needed to be comparable with aircraft measurements?
   - What statistics are independent of scale differences?