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

Po-Lun Ma

Atmospheric Sciences and Global Change
Pacific Northwest National Laboratory

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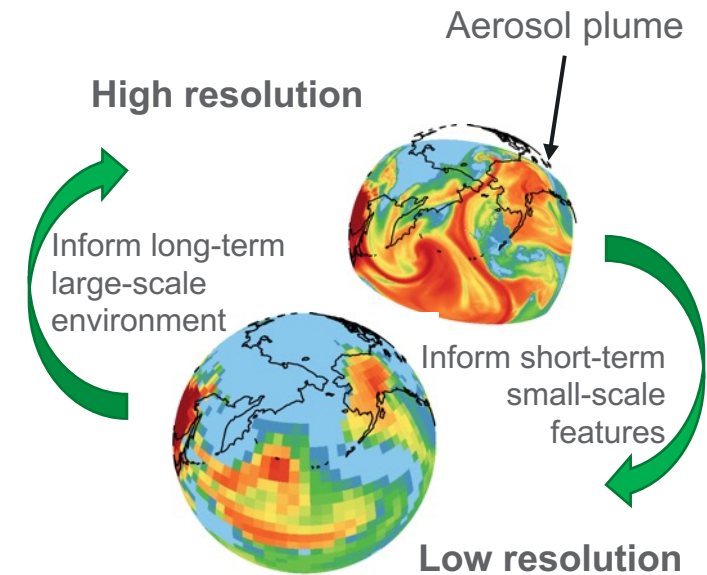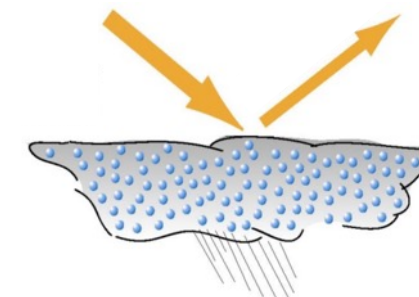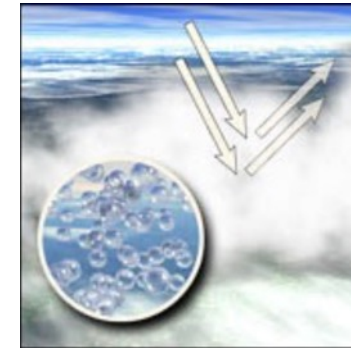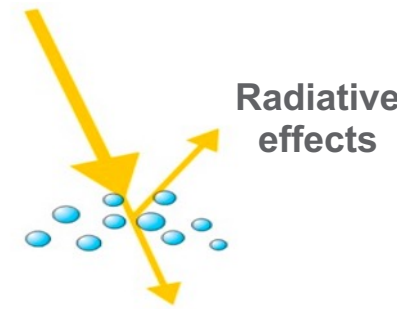
Improve the representations of aerosols and ACl in E3SM

Emission, transport, chemical/physical processes predicting aerosol properties, lifecycle, and distribution →

Aerosol-radiation-cloud-precipitation interactions →

Modern software for exascale computation →

Sea spray aerosols

Mineral dust

Wildfire aerosols

Biogenic SOA

Anthropogenic carbonaceous & sulfate aerosols

Dust

Sea salt

Sulfate

Carbonaceous

Composition, hygroscopicity

aerosol number (cm⁻³) vs Diameter (nm)

Size distribution

Radiative effects

Cloud albedo effects

Precipitation effects and cloud lifetime effects

High resolution

Aerosol plume

Inform long-term large-scale environment

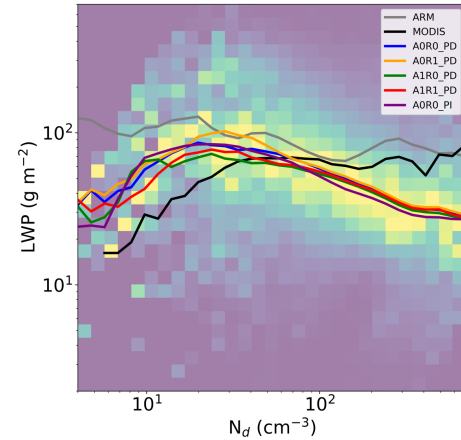Inform short-term small-scale features

Low resolution

Accurate and fast simulations at various resolutions to address science challenges

A hybrid approach that integrate data in parameterization development and evaluation

Measurements of aerosols, clouds, precipitation, and meteorology
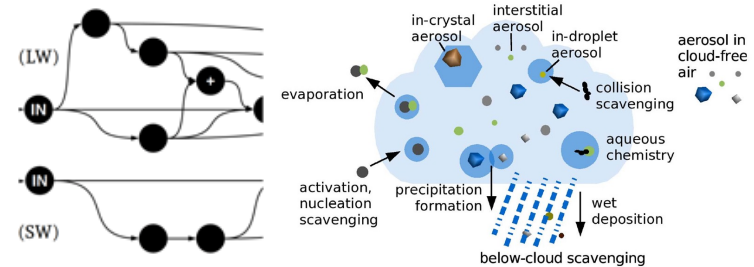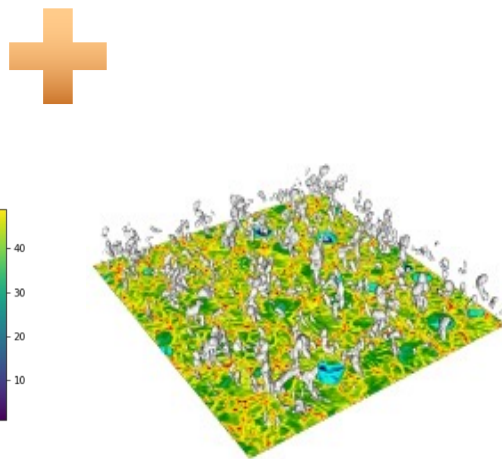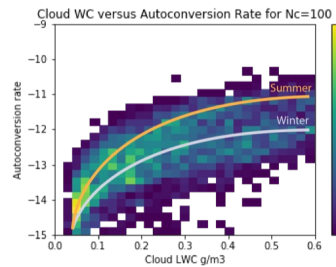
**Big data
Better physics**

Diagnostics to understand model and real-world features

C++/kokkos for km-scale simulations on GPU machines

- Christensen (2023), ACI diagnostics
- Tang (2022, 2023), Aerosol diagnostics
- Varble (2023), ACI diagnostics
- Beall, warm rain diagnostics

- Li, Resolution sensitivity
- Huang, Kilometer-scale RRM
- Fast, MAMxx
- Ma, EAGLES

Process models and LES provides information on aerosols, clouds, precipitation, and meteorology

- Shpund, Aerosol warm rain effects
- Fierce, Aerosol size distribution
- Kaul, LES library for ACI
- Pressel, PINACLES

Better data-driven or physically based parameterization

- Silva (2021), ML aerosol activation
- Geiss (2023), ML aerosol optics
- Yu, ML aerosol activation
- Zhang, Nucleation mode/NPF
- Lu, Wildfire aerosol

- Hassan, Emission
- Zhao, NPF/SOA
- Yao, Giant CCN
- Shi, Dust
- Zaveri, Aged carbon

Liquid cloud testbed that utilizes E3SM-RRM, LES, and observations for parameterization development and evaluation for kilometer-scale E3SM
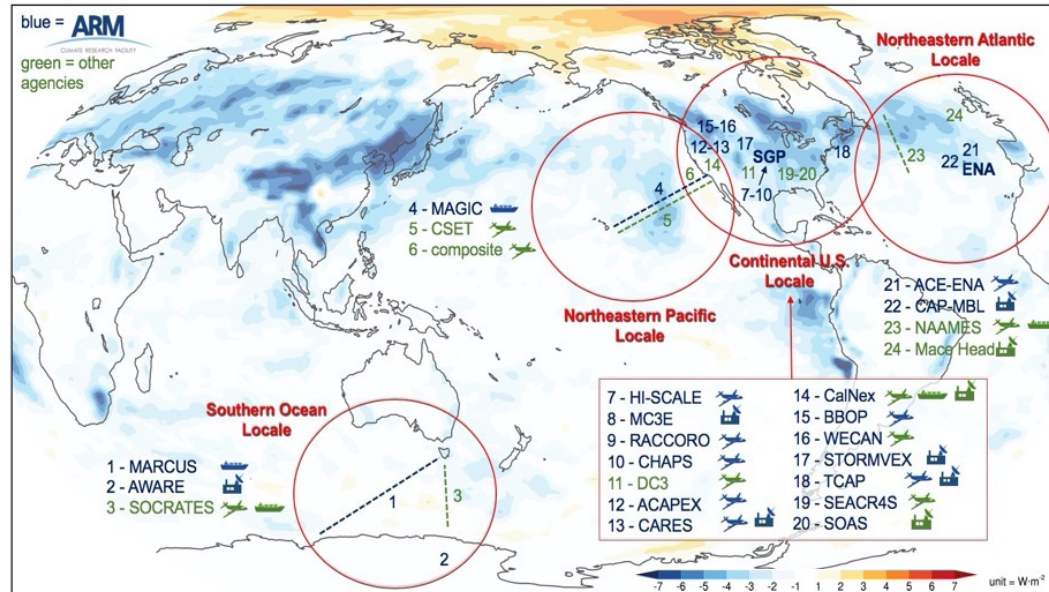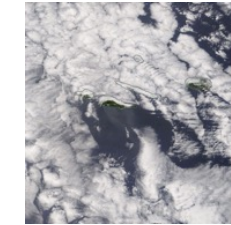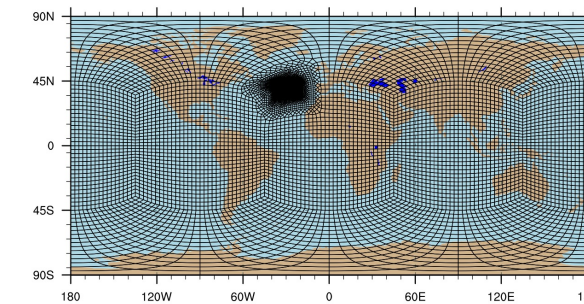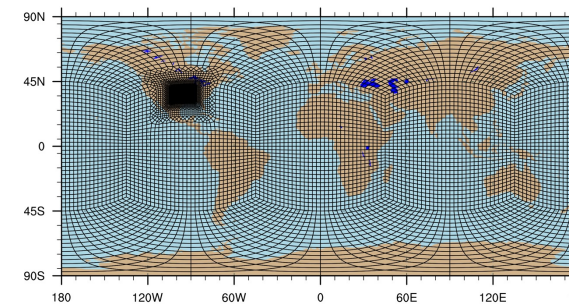

Central U.S.

Continental convective clouds with high aerosol concentration

N.E. Atlantic

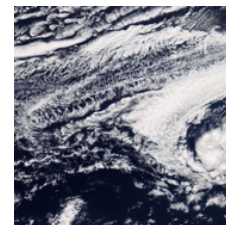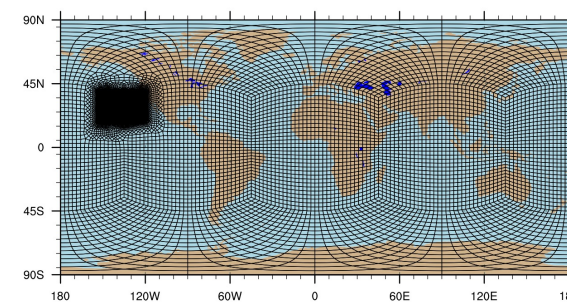Diverse subtropical clouds susceptible to aerosols

Southern Ocean

Marine clouds with low aerosol concentrations

N.E. Pacific

Transition in stratocumulus to trade cumulus

- 4 RRMs are set up
- RRMs can use both EAMv2 and SCREAM physics
- The NEP RRM can be used to study ACI and evaluated against EPCAPE data
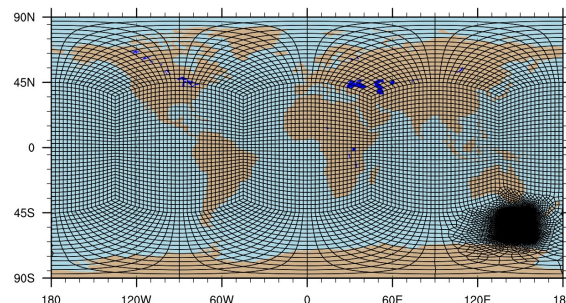
Kilometer-scale regional refinement

Kilometer-scale simulations exhibit very different ACI than the typical 1-deg model simulations

- especially for broken cells as **aerosol and clouds become segregated**, which reduces ACI
- **aerosol-turbulence feedbacks** are resolved, which weakens ACI
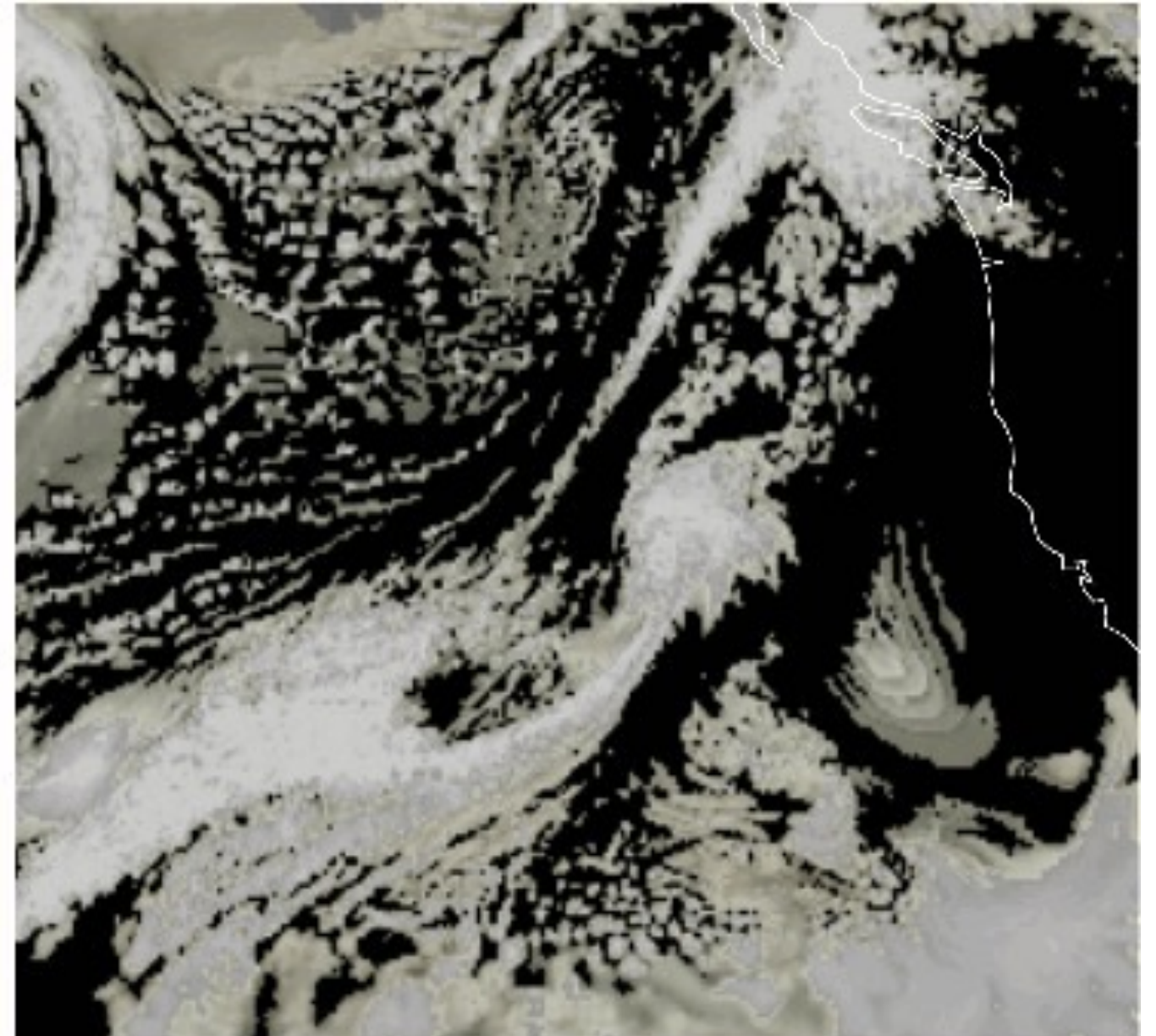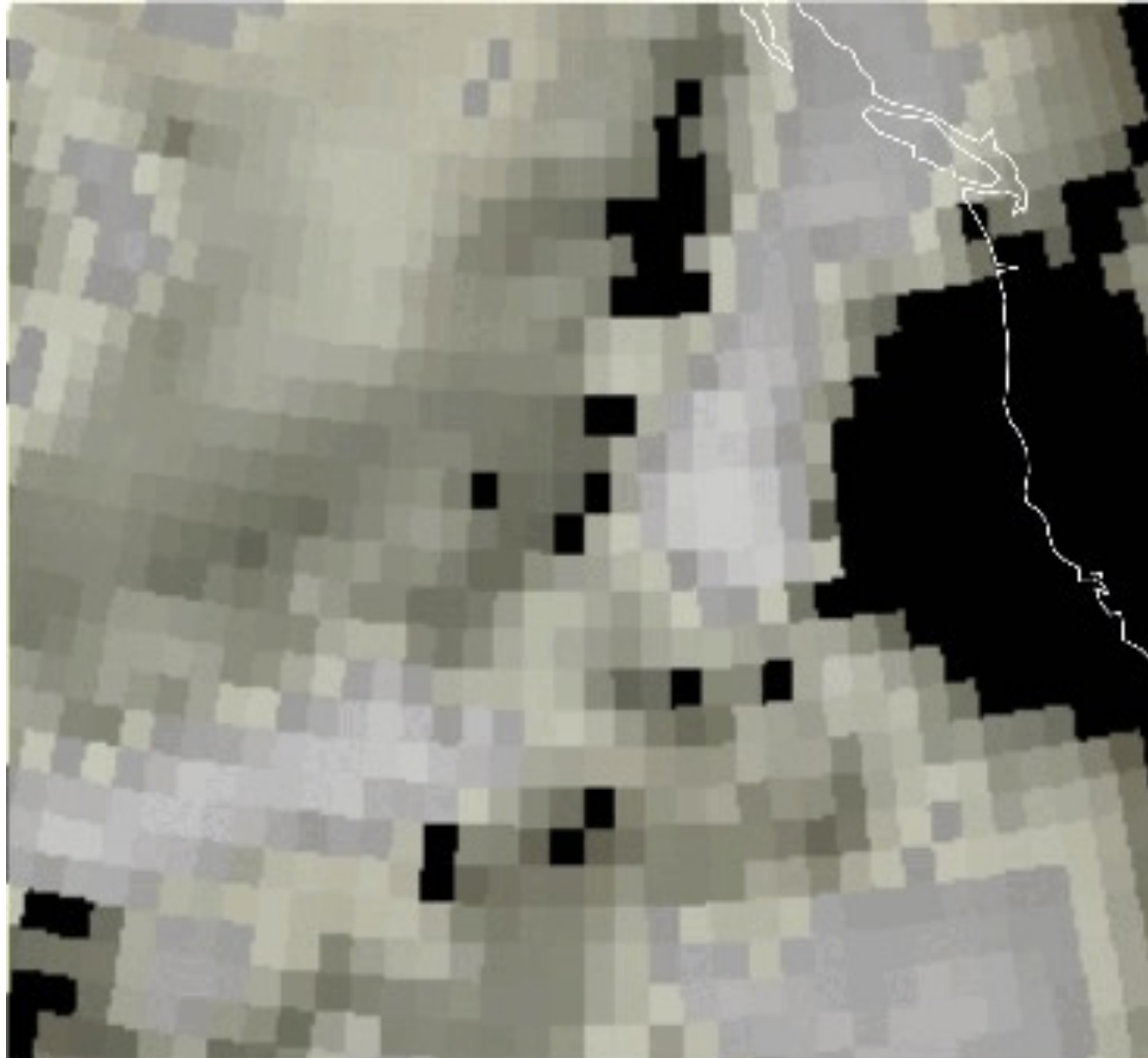
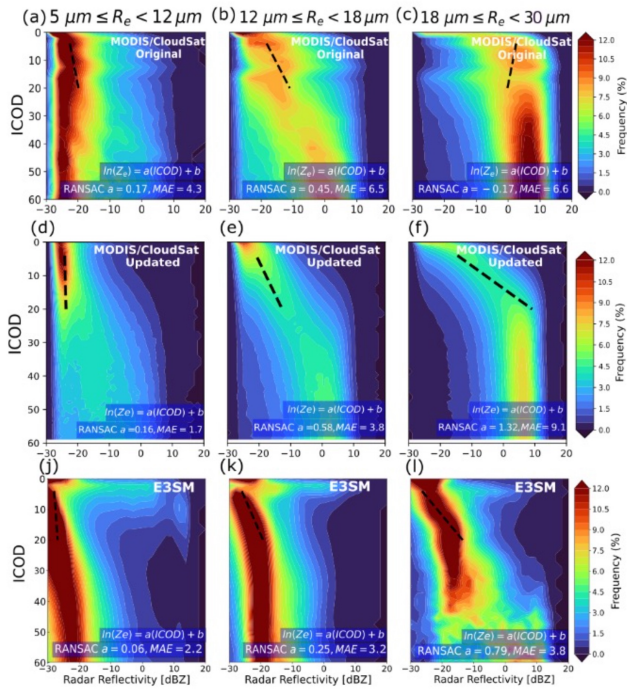# Diagnostics tools to assess state and processes of aerosol, cloud, and ACI can be easily extended to EPCAPE

Beall et al: Warm rain diagnostics

Hassan et al: Aerosol diagnostics

	Control Case	Test Case	difference	rel diff (%)
Burden (Tg)	0.196	0.206	0.0093	4.764
Sfc Conc. (ug/m3)	8e+13	6e+13	-2e+13	-25.497
Sources (Tg/yr)	9.341	9.341	-5e-05	-0.00054
surface emission	7.594	7.594	0e+00	0e+00
elevated emission	1.747	1.747	-5e-05	-0.0029
Sinks (Tg/yr)	-9.390	-9.360	0.029	0.310
Dry deposition	-4.0058	-4.530	-0.524	-13.100
gravitational	-0.201	-0.282	-0.081	-40.723
turbulent	-3.804	-4.247	-0.442	-11.640
Wet deposition	-5.384	-4.830	0.553	10.287
incloud, stratiform	-3.226	-2.220	1.0052	31.158
incloud, convective	-2.541	-3.501	-0.960	-37.792
belowcloud, strat.	-0.053	-0.021	0.032	59.680
belowcloud, convec.	-0.023	-0.043	-0.019	-83.927
rain evap, strat.	0.308	0.867	0.559	181.204
rain evap, convec.	0.151	0.089	-0.062	-40.990
Lifetime (days)	7.653	8.042	0.389	5.090
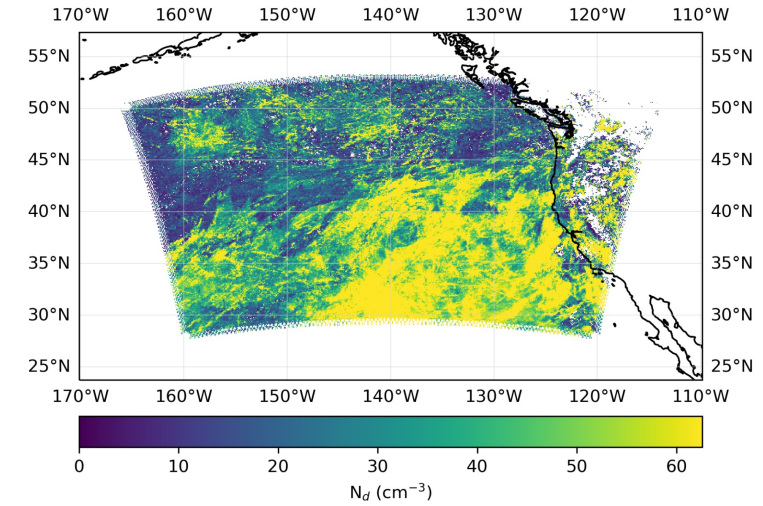
Christensen et al, Kilometer-scale ACI diagnostics
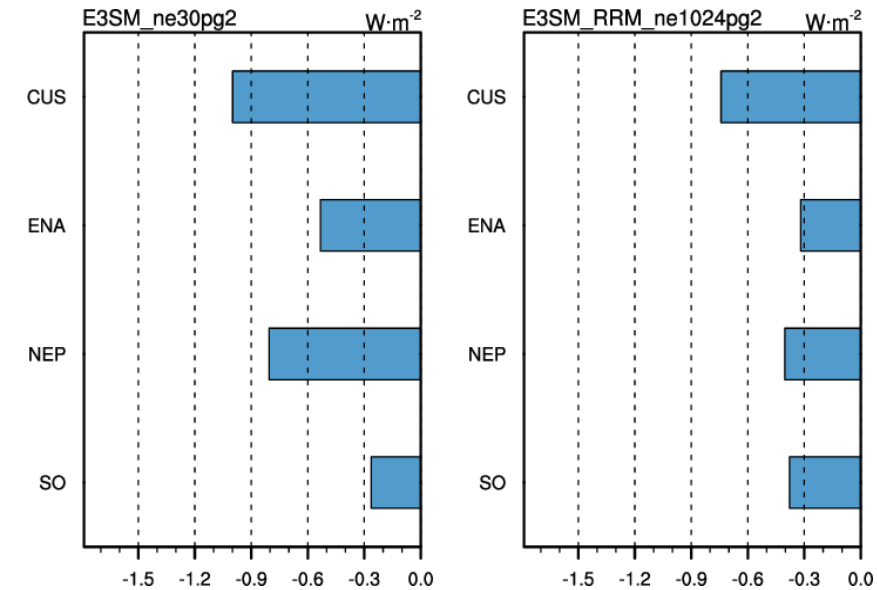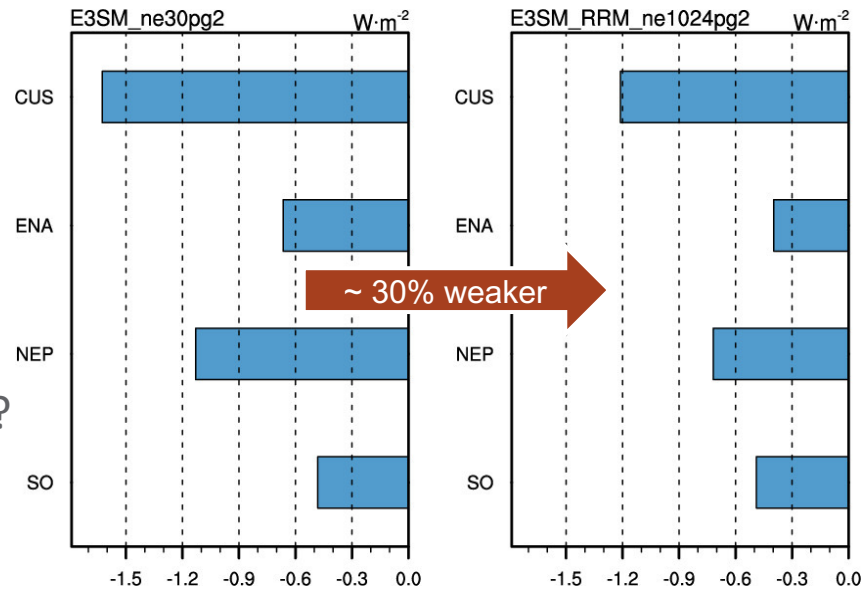
Varble et al: ACI diagnostics
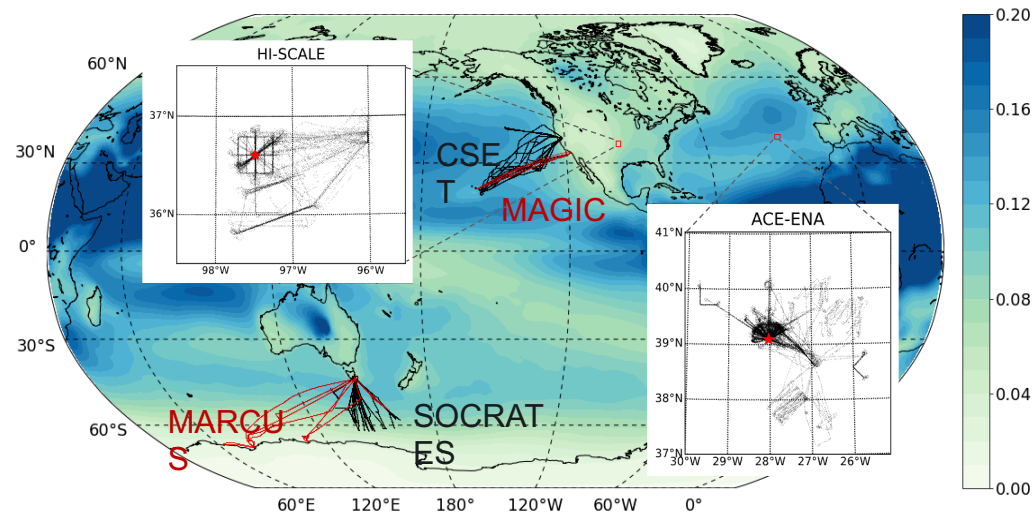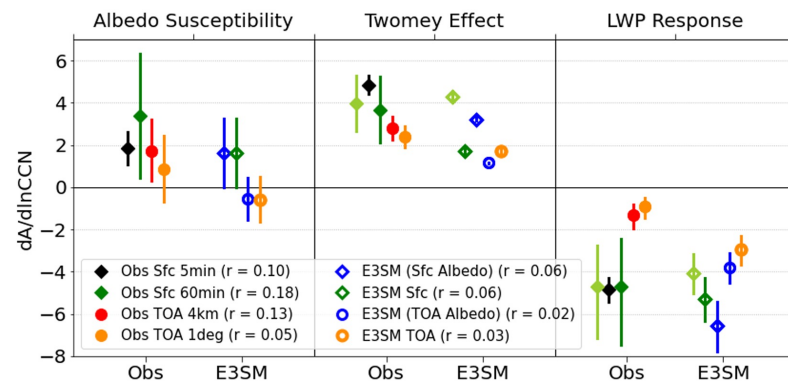
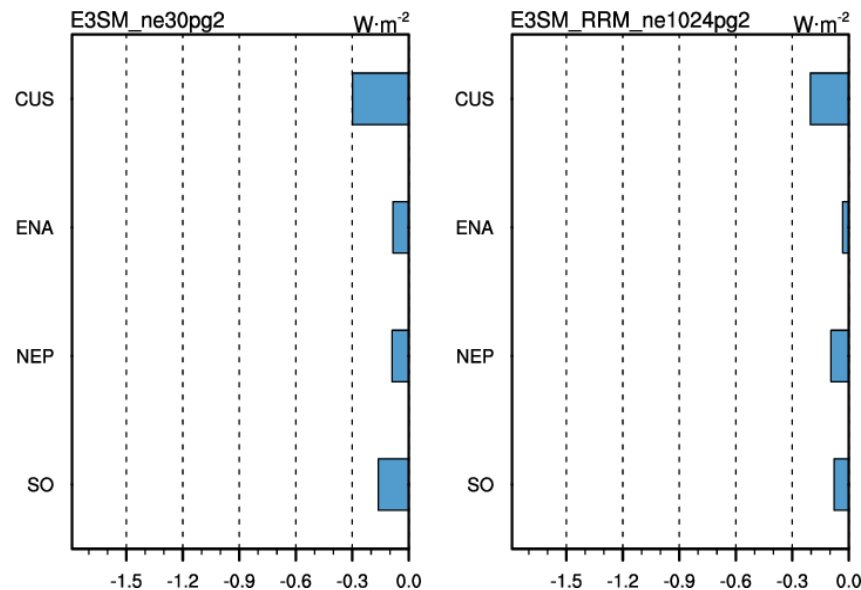Tang et al, 2022, 2023: Aerosol and ACI diagnostics

Decomposition analysis shows weaker ERFaci, Twomey effect, LWP adjustment, and cloud fraction adjustment with increasing resolution

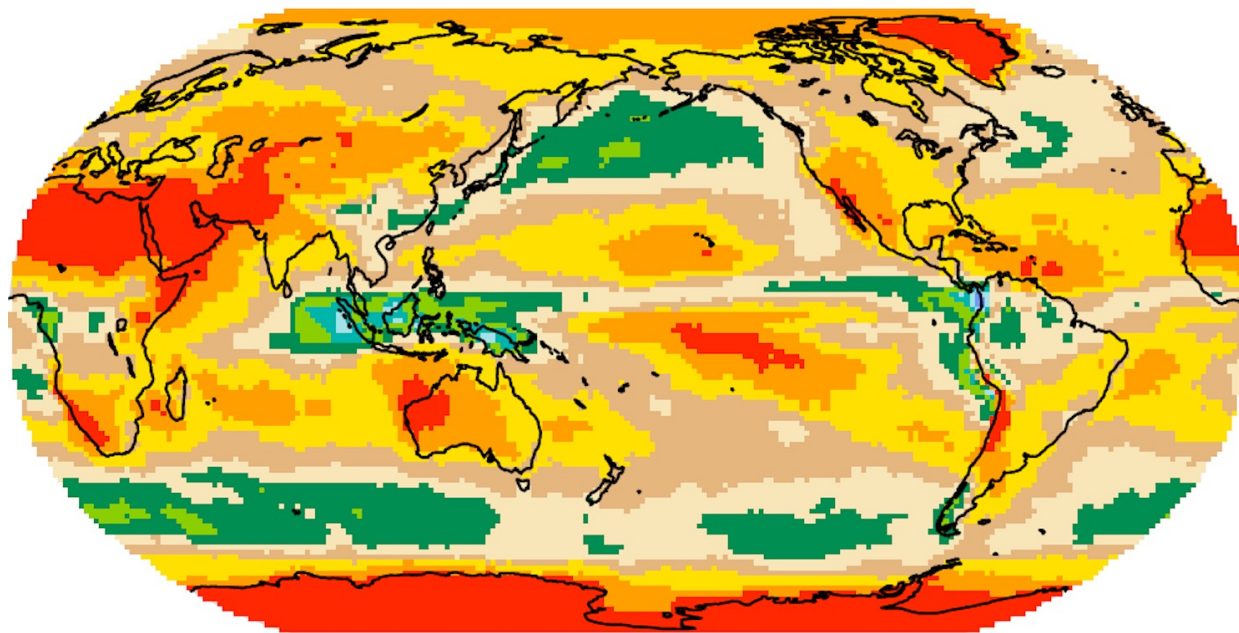**ERFaci**

AR6: -1.0 ± 0.7

E3SM: $-1.35 \rightarrow$ -1.0?

~ 30% weaker

Twomey effect

AR6: -0.7 ± 0.5

LWP adjustment

AR6: $+0.2 \pm 0.2$

Cloud fraction adjustment

AR6: -0.5 ± 0.4

Decomposition analysis performed by J. Muelmenstaedt, based on Gryspeerdt et al (2020). This is preliminary and has large uncertainty due to using just 1-month data.
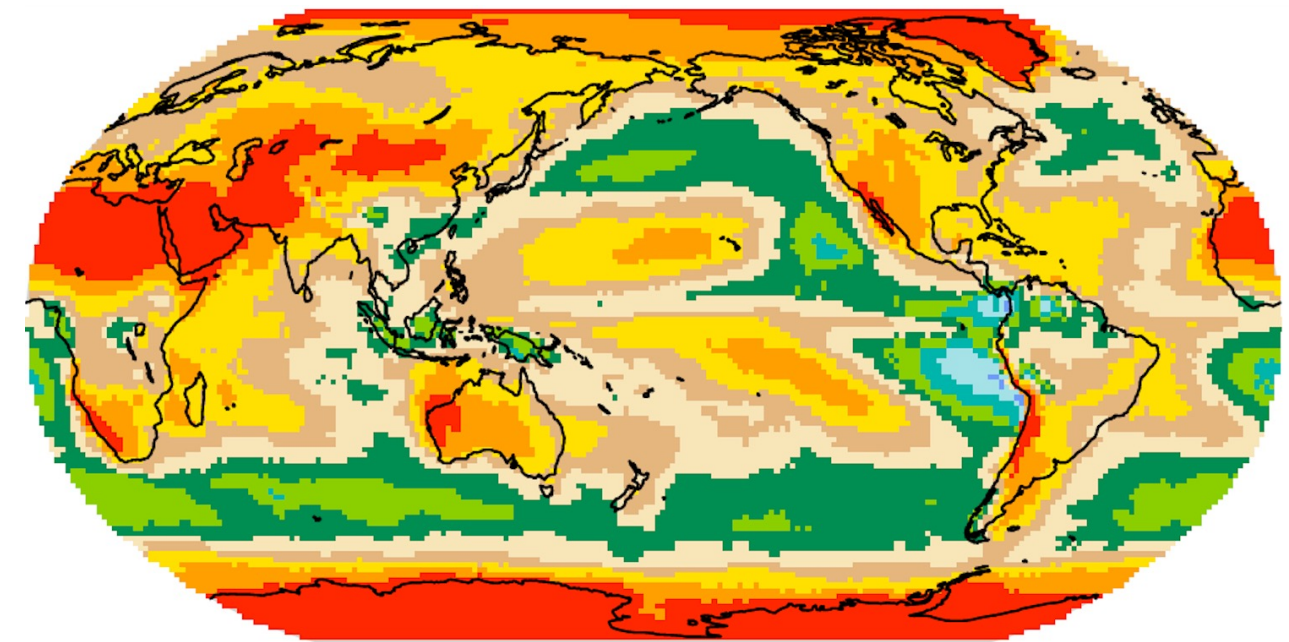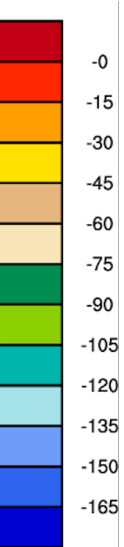
Same aerosol (MAM4); different cloud/turbulence

EAMv2: MG2, CLUBB

SCREAMv0: P3, SHOC
(EAMv3 also uses P3 and SHOC)

Summary

- E3SM RRM are useful for parameterization development and evaluation at kilometer scale.

- Diagnostics tools provides insights into model process-level deficiencies

- EPCAPE data provides important information regarding aerosol, cloud, precipitation, and their interactions in the northeast Pacific. Current diagnostics tools can be extended to include EPCAPE