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Climate Measurements and Modeling in the Arctic

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High Resolution Atmospheric General Circulation Models with Variable Resolution and Super-Parameterization

Global earth system model development is trending toward higher resolutions. The Department of Energy's Accelerated Climate Model for Energy (ACME) uses the spectral-element dynamical core with the cubed-sphere geometry that can be refined over specific regions to gain insight into high resolution model behavior at a fraction of the computational expense. With this tool, we quantify resolution sensitivities of clouds and gain insight into the Arctic climate.

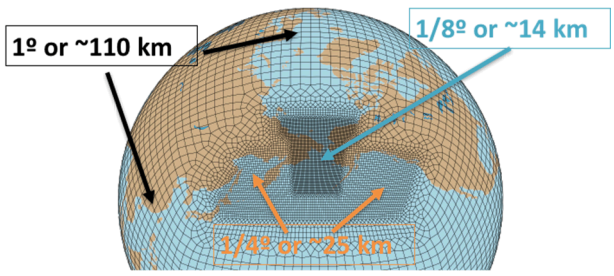


Figure: A variable resolution grid used to study extratropical cyclones.

The super-parameterization of the Community Atmospheric Model (SP-CAM) or "Multi-scale Modeling Framework" (MMF; Randall et al. 2003) embeds a coarse-resolution cloud resolving model into each grid-cell of a traditional global climate model (GCM), with the aim of improving the simulation of deep convection and cloud condensation processes by replacing the traditional physics parameterizations with explicit simulation.

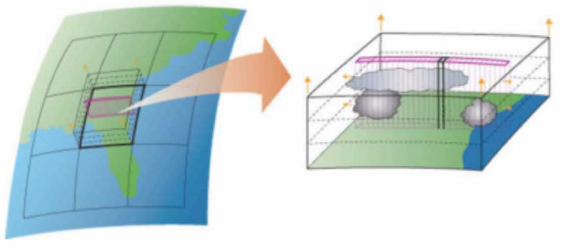
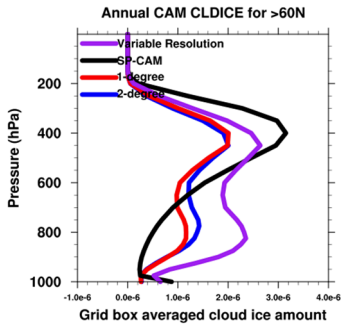


Figure: A cartoon illustration of SP-CAM showing how the embedded cloud resolving model, SAM, is placed in every grid cell of the GCM.

While certain aspects of the climate are improved with SP-CAM, unique biases in cloud liquid and ice content arise when compared with CAM simulations in the Arctic.



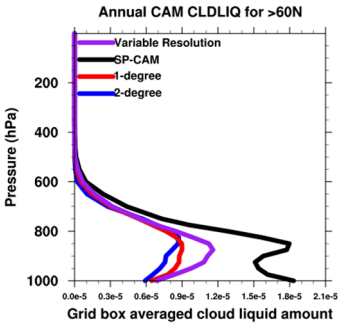


Figure: Profiles of annual means of (top) cloud ice and (bottom) cloud liquid for all latitudes greater than 60N for simulations of uniform resolution, variable resolution, and SP-CAM.

Evaluating model simulations against satellite retrievals

Spaceborne active remote sensing retrievals of cloud properties from the CALIPSO satellite platform allow us to extend our model evaluation efforts beyond the point observations available from the ARM sites. Evaluation is done using a satellite simulator tool, which simulates from the model state what a particular satellite instrument would retrieve (including known biases in the satellite retrieval).

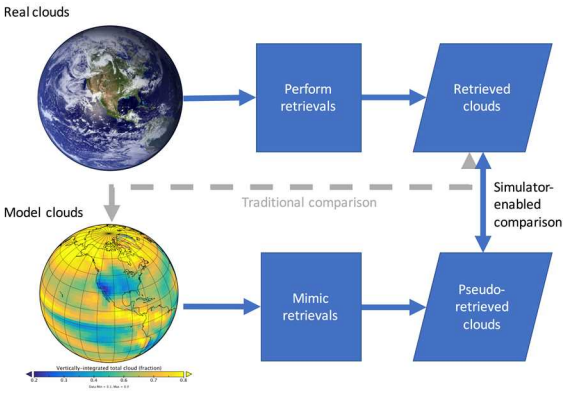


Figure: Schematic of model evaluation framework using satellite simulators to make consistent comparisons.

We find that the Community Atmosphere Model (CAM) and its super-parameterized counterpart, SP-CAM have very different biases in liquid cloud amount relative to CALIPSO retrievals (below).

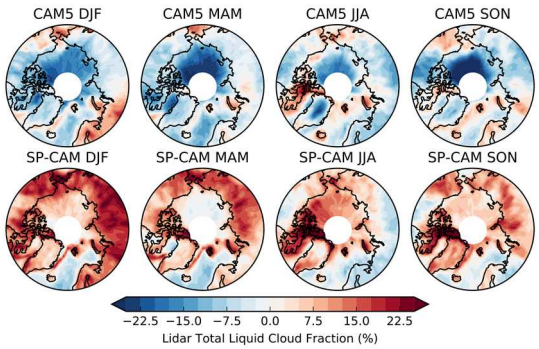
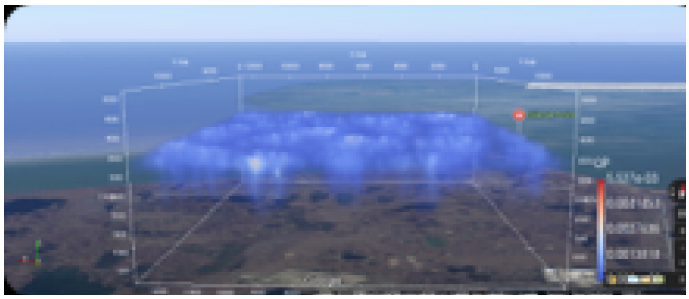


Figure: Seasonal cycle of biases in liquid cloud amount in CAM and SP-CAM relative to retrievals from CALIPSO.

High Resolution with Large Eddy Simulations and in situ Tethered Balloon Measurements

Routine high-resolution large eddy simulations (LES) are developed for the ARM sites at the North Slope of Alaska to develop a statistical understanding of the phase of the clouds. We use the System for Atmospheric Modeling (SAM) to explore LES performance of cloud amount at Oliktok Point during field campaigns. A supercooled liquid water content sensor and fiber-optic distributed temperature sensor are flown on a tethered balloon to obtain observations of supercooled liquid for evaluation of LES performance. We found the magnitude of the supercooled liquid water content in the simulations is sensitive to tuning and forcing conditions.



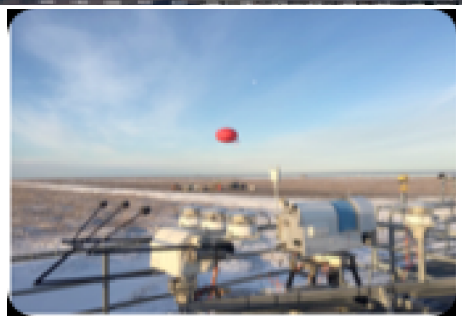


Figure: (Top) Snapshot of three-dimensional precipitation from a simulation of a cloud over Oliktok Point for day in October, 2016. (Bottom) The ascending aerostat balloon on the runway of the Long Range Radar Station in Oliktok Point, Alaska as viewed on the instrumentation deck at the ARM facility.

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