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Multi-scale modeling of Arctic clouds

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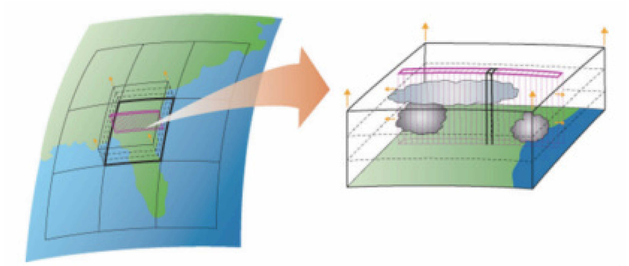
Key points

- **Question: can super-parameterization improve simulation of Arctic clouds in large-scale models?**
- Large-scale models have difficulty simulating the amount and phase of clouds in the Arctic
- Kay et al. (2016) demonstrate an improved simulation of liquid clouds in CAM5 by adjusting the convective parameterization
- We explore the simulation of Arctic clouds in "super-parameterized" simulations, in which the cloud and convective parameterizations are replaced with a 2D cloud resolving model
- Super-parameterized simulations show increased cloud amount relative to the traditionally-parameterized (CAM5) configuration, but liquid water is still underestimated relative to observations
- Simulations using the stand-alone CRM (SAM) show sensitivity in simulated cloud water path to the CRM configuration, with an increased number of columns leading to an increase in cloud water path

Super-parameterization

- The super-parameterization or "Multi-scale Modeling Framework" (MMF; Randall et al., 2003) embeds a coarse-resolution cloud resolving model (CRM) into each grid-cell of a traditional global climate model



- The MMF has been implemented into the NCAR Community Atmosphere Model (CAM), using the System for Atmospheric Modeling (SAM) for the embedded CRM; we compare simulations from the traditionally-parameterized model (CAM5) with the super-parameterized version (SP-CAM)

Comparison with microwave radiometer retrievals at the ARM NSA site

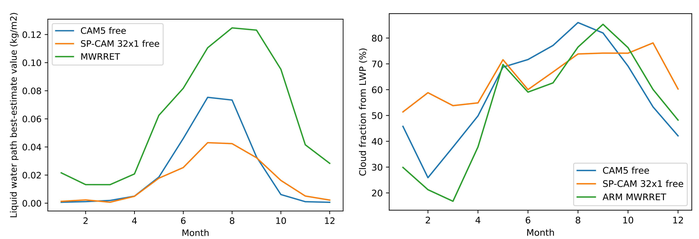


Figure 1: Comparisons of CAM and SP-CAM climatologies of liquid water path (left) and liquid cloud fraction (right) against retrievals from microwave radiometer measurements at the ARM NSA site (from the MWRRET product). Cloud fraction from ARM retrievals is calculated as the fraction of time the best-estimate liquid water path exceeds a minimum threshold of 5 g/m^2.

Biases in total cloud relative to CALIPSO

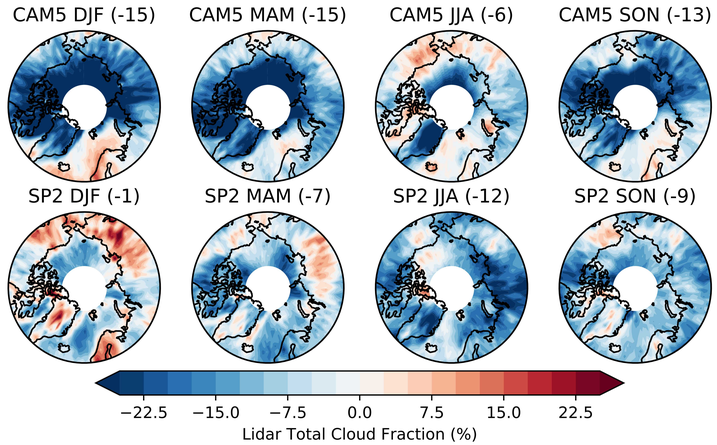


Figure 2: Total cloud cover is underestimated in all seasons in both model configurations as compared with CALIPSO retrievals, but the super-parameterized cloud cover is larger (closer to observed) in all seasons except the summer (JJA).

Biases in liquid cloud relative to CALIPSO

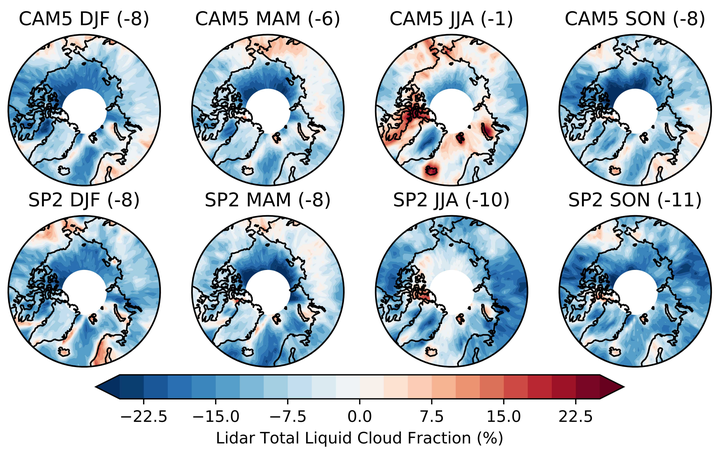


Figure 3: Liquid cloud amount is consistently underestimated in both simulations relative to CALIPSO, and accounts for the majority of the bias in total cloud cover.

References

Kay, J. E., Bourdages, L., Miller, N. B., Morrison, A., Yettella, V., Chepfer, H., and Eaton, B. (2016). Evaluating and improving cloud phase in the Community Atmosphere Model version 5 using spaceborne lidar observations. *Journal of Geophysical Research: Atmospheres*, 121(8):4162–4176.

Randall, D., Khairoutdinov, M., Arakawa, A., and Grabowski, W. (2003). Breaking the cloud parameterization deadlock. *Bull. Amer. Meteor. Soc.*, 84(11):1547–1564.

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On-going work: testing the limits of the CRM for the Arctic

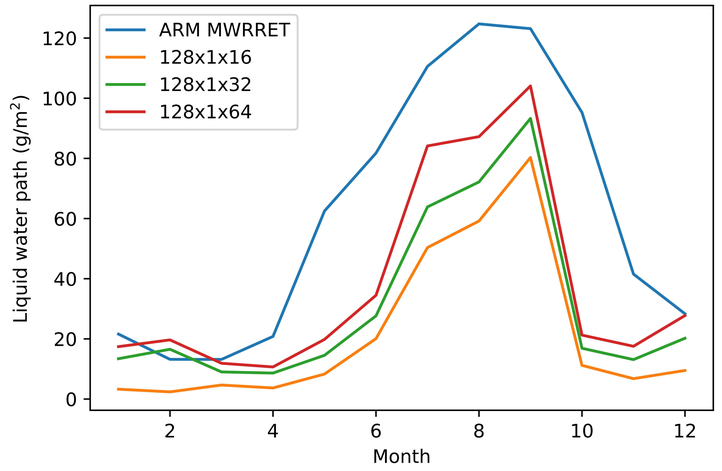

Figure 4: Sensitivity of stand-alone SAM simulations to resolution; forced by ECMWF reanalysis over the ARM NSA site for 2002. Simulations show that liquid water content is in fact sensitive to vertical resolution and horizontal extent (not shown) of the CRM. These results suggest that the small CRM domain and coarse vertical grid used in the SP-CAM may be negatively affecting simulated liquid cloud amount, and that both increasing the horizontal extent of the domain and increasing the number of vertical levels may lead to increases in simulated cloud liquid.

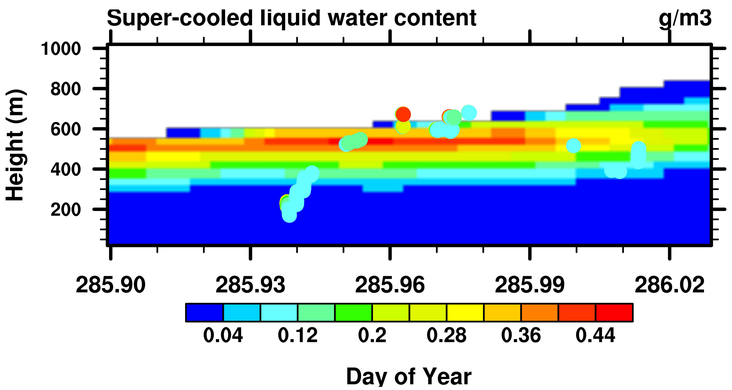

Figure 5: Comparison of LES-scale simulation with in situ supercooled liquid water measurements via tethered balloon at Oliktok. See posters by Erika Roesler and Darielle Dexheimer for more information.