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Evaluating Arctic clouds across scales: a comparison of clouds in large-scale and multi-scale models with observations over the north slope of Alaska and beyond

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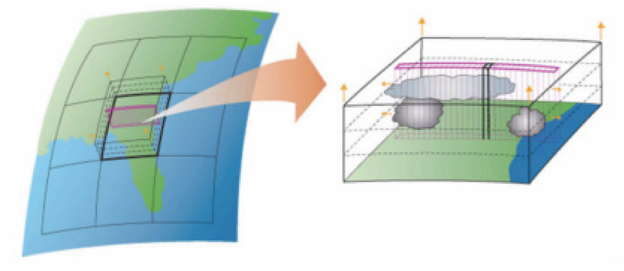
Key points

- 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-parameterization

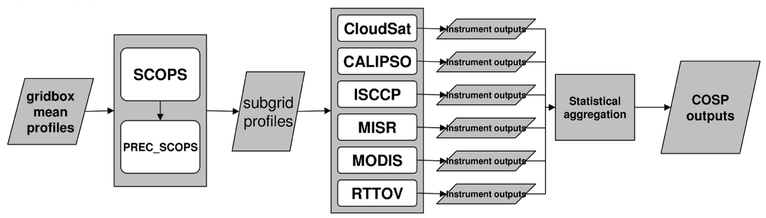
- The super-parameterization or "Multi-scale Modeling Framework" (MMF; Randall et al., 2003) embeds a coarse-resolution cloud resolving model into each grid-cell of a traditional global climate model



- The MMF has been implemented into the NCAR Community Atmosphere Model (CAM); we compare simulations from the traditionally-parameterized model (CAM5) with the super-parameterized version (SP-CAM)

Satellite simulators

- Satellite simulators enable more reliable comparisons between models and satellite retrievals by accounting for known limitations in specific retrievals.



- We have embedded the CFMIP Observation Simulator Package (COSP; Bodas-Salcedo et al., 2011) into the SP-CAM code, enabling in-line computation of simulated retrieval products from the model state

Bodas-Salcedo, A., Webb, M. J., Bony, S., Chepfer, H., Dufresne, J.-L., Klein, S. A., Zhang, Y., Marchand, R., Haynes, J. M., Pincus, R., and John, V. O. (2011). COSP: Satellite simulation software for model assessment. *Bull. Amer. Meteor. Soc.*, 92(8).

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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Biases in total cloud relative to CALIPSO

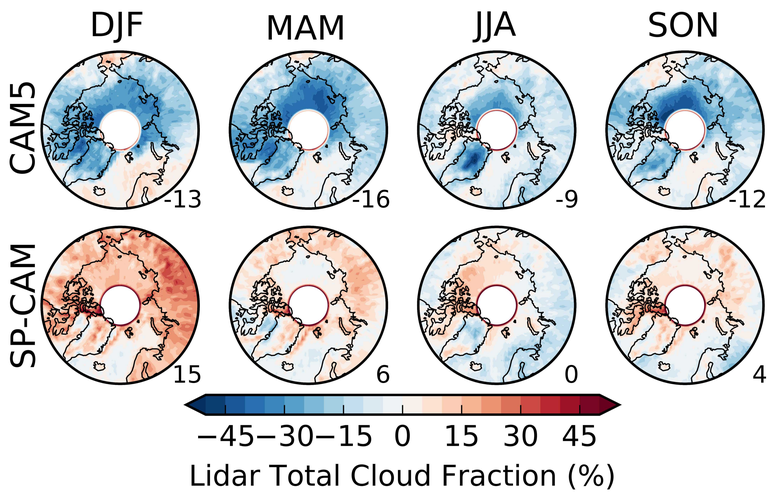

Figure 1: Total cloud fraction is underestimated throughout the Arctic in CAM5 in all seasons compared with CALIPSO retrievals. Cloud fraction is higher in SP-CAM, so much so that it is overestimated relative to CALIPSO especially in DJF and MAM. The seasonal cycle of cloud fraction is reduced is SP-CAM, leading to the large biases in DJF.

Biases in liquid cloud relative to CALIPSO

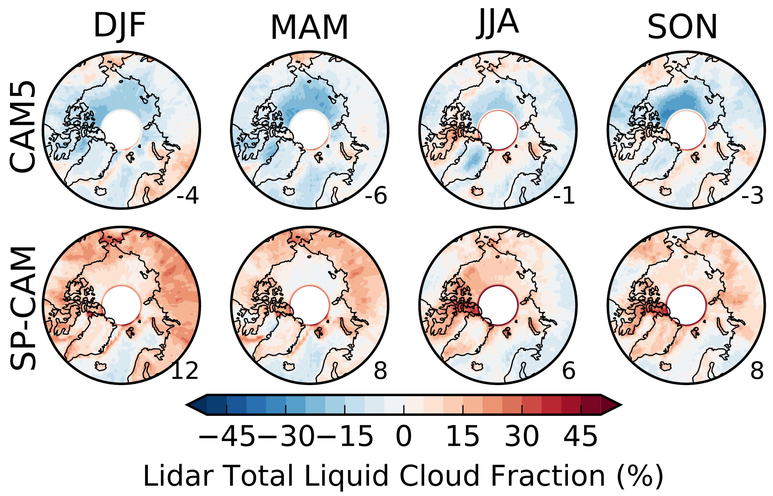

Figure 2: Liquid cloud is underestimated throughout the Arctic in CAM5, but overestimated in SP-CAM. Increase in liquid cloud is largely responsible for the overestimation of total cloud in SP-CAM, especially in DJF.

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Comparisons with ARM climatologies

- We compare climatologies of cloud properties from model simulations with ground-based retrievals at the ARM north slope of Alaska site

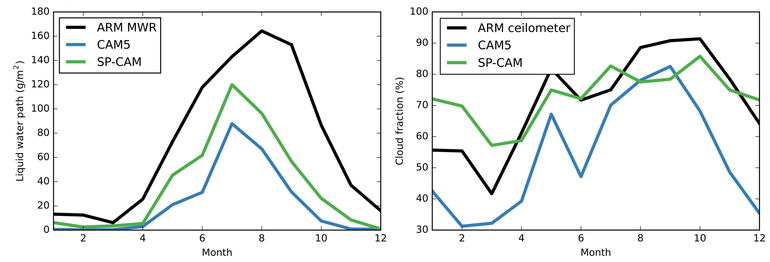

Figure 3: Liquid water path is underestimated in CAM5 (relative to ARM microwave radiometer retrievals), but improved in SP-CAM. Cloud fraction is underestimated in CAM5 (relative to ceilometer retrievals), but increased in SP-CAM and actually overestimated in the winter months.

Towards evaluation at the process-level

- Can we use high temporal resolution point observations to evaluate large-scale models at the process-level?
- We run CAM and SP-CAM simulations "nudged" to (6-hourly) atmospheric state fields from reanalysis
- Compare 3-hour means of model fields directly to ARM retrievals for a single month (October 2016 shown)

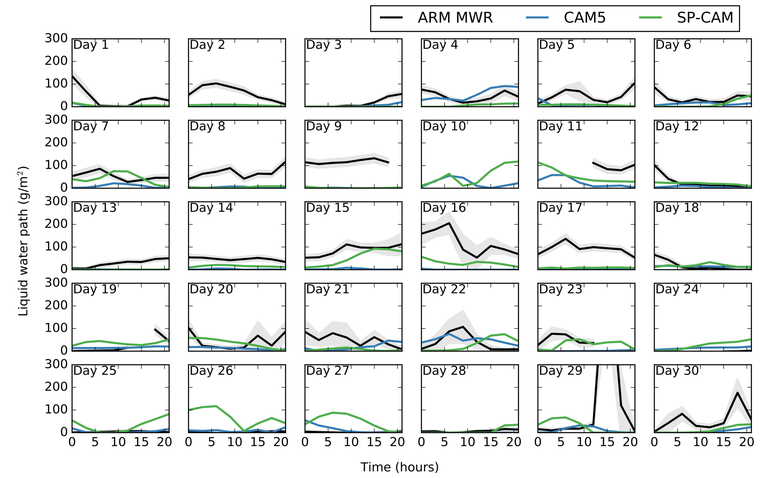

Figure 4: Comparison of 3-hourly liquid water path between ARM microwave radiometer retrievals and nudged CAM5 and SP-CAM simulations shows little to no apparent correlation.

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