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Observations of Clouds at McMurdo Station, Antarctica and Evaluation of a Global Climate Model

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Abstract

A comparative analysis between McMurdo Station, Antarctica observational data and global climate model simulation is performed with respect to cloud microphysical and macrophysical properties. Evidence suggests that when the presented nudged CAM6 simulation underestimates or overestimates cloud fraction, model thermodynamic profile also exhibits large deviations from observed conditions. This illustrates a need to improve model physics to more accurately estimate atmospheric conditions.

Findings

- Cloud fraction (CF) bias is observed in CAM6 at the study site (Research Question 1, CAM6 is not accurately estimating clouds)
- RH bias is observed in CAM6, RH has a strong influence on cloud fraction, RH bias is seen in same regions as CF bias
- RH bias is decomposed into contributing parts (Figure 3, dRH_T, dRH_{rv})
- RH bias is influenced primarily by dRH_{rv} based on linear regression and correlation of decomposed variables (A = 0.97; r^2 = 0.66) (Research Question 2, the thermodynamic biases influence CAM6's misrepresentation of clouds)

Observation Site: McMurdo Station, Ross Island

Below: Main AWARE ARM Mobile Facility, located at McMurdo Station, Ross Island, Antarctica; courtesy DOE ARM

Above: HSRL beam at McMurdo Station AMF; Images, Courtesy Earth Observing Laboratory and Scripps UCSD)

Observed and Simulated Cloud Fraction Case

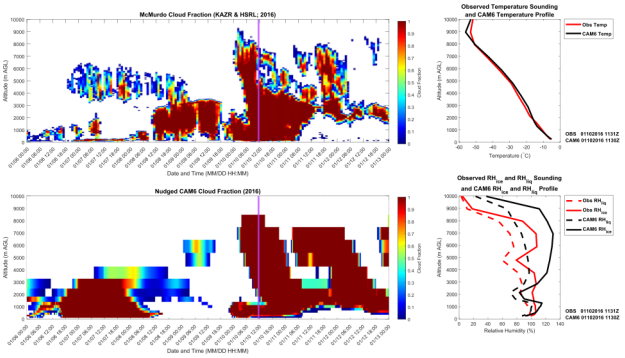

Figure 1: Visual comparison of observed (top left panel) and simulated clouds (bottom left panel), note that CAM6 estimates more cloud than observed and RH is higher than observed here as well.

Can CAM6 estimate cloud fraction accurately at McMurdo?

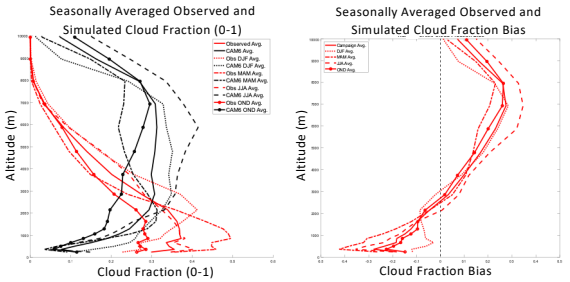

Figure 2: (Left) Seasonal and campaign average profiles of observed and simulated cloud fraction. (Right) Cloud fraction bias of simulated cloud fraction with observed cloud fraction subtracted. Note Strong positive bias above 3km altitude and strong negative bias below 3km altitude.

Are the thermodynamic conditions responsible for the observed biases?

$$de = (e_m - e_o) \quad ; \quad d\left(\frac{1}{e_s}\right) = \frac{1}{e_{s,m}} - \frac{1}{e_{s,o}}$$

$$dRH = RH_{model} - RH_{obs} = de * \frac{1}{e_{s,o}} + e_o * d\left(\frac{1}{e_s}\right) + de * d\left(\frac{1}{e_s}\right)$$

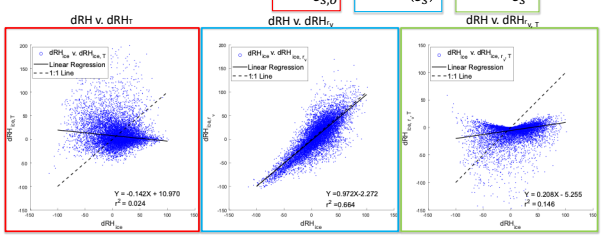

Figure 3: dRH bias contributions, each component of dRH (dRHT (red), dRHrv (blue), and dRHrv,T (green)) plotted against dRH (RHmodel – RHobs), note nearly 1:1 regression and strong r^2 of dRHrv v. dRH

Discussion and Future Work

Further study is required to identify the primary model parameterizations responsible for these biases in simulated thermodynamic conditions. Previous research suggests inaccurate representation of low-level dynamics and precipitation processes. To this effect, it has been shown that higher resolution mesoscale atmospheric models struggle to represent katabatic winds at the surface, which have a significant effect on surface horizontal moisture and heat transport. Furthermore, these models poorly estimate the precipitation processes in higher altitude clouds, where accuracy is both difficult to attain and imperative to realistically represent vertical moisture transport in the model atmosphere.

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