Evaluation and improvement of cloud microphysics in the Conformal Cubic Atmospheric Model

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Clouds are an essential part of the climate system that interact with various elements of the atmosphere and hydrological cycles over a range of spatial and temporal scales. Although clouds have a considerable impact on the energy balance of the atmosphere, the physical processes of clouds remain poorly understood. Therefore, the projected changes in precipitation under global warming scenarios are subject to large uncertainties.

Objectives

In this research, we investigate the difference between the single (Rotstayn, 1997) and double-moment (Zhao et al., 2022) cloud microphysics schemes in the global stretched grid Conformal Cubic Atmospheric Model (CCAM).

Model and Data

CCAM is a variable-resolution global grid, non-hydrostatic developed at CSIRO (McGregor and Dix, 2008)

- 100 km horizontal resolution and 54 vertical levels (20 m – 45 km), and run for 10 years (2006-2016)
- Spectral nudging of air temperature and wind at 3000 km length scales (no nudging of moisture)

We used the Global Climate Model (GCM)-Oriented CALIPSO Cloud Product (CALIPSO-GOCCP) (Chepfer et al., 2010) to evaluate the simulated clouds.

We integrated the Cloud Feedback Model Intercomparison Project (CFMIP) Observational Simulator Package (COSP, version 2) (Bodas-Salcedo et al., 2011), which is commonly used to evaluate the simulated clouds in the General Circulation Model (GCM), into CCAM.

Global evaluation of clouds in CCAM

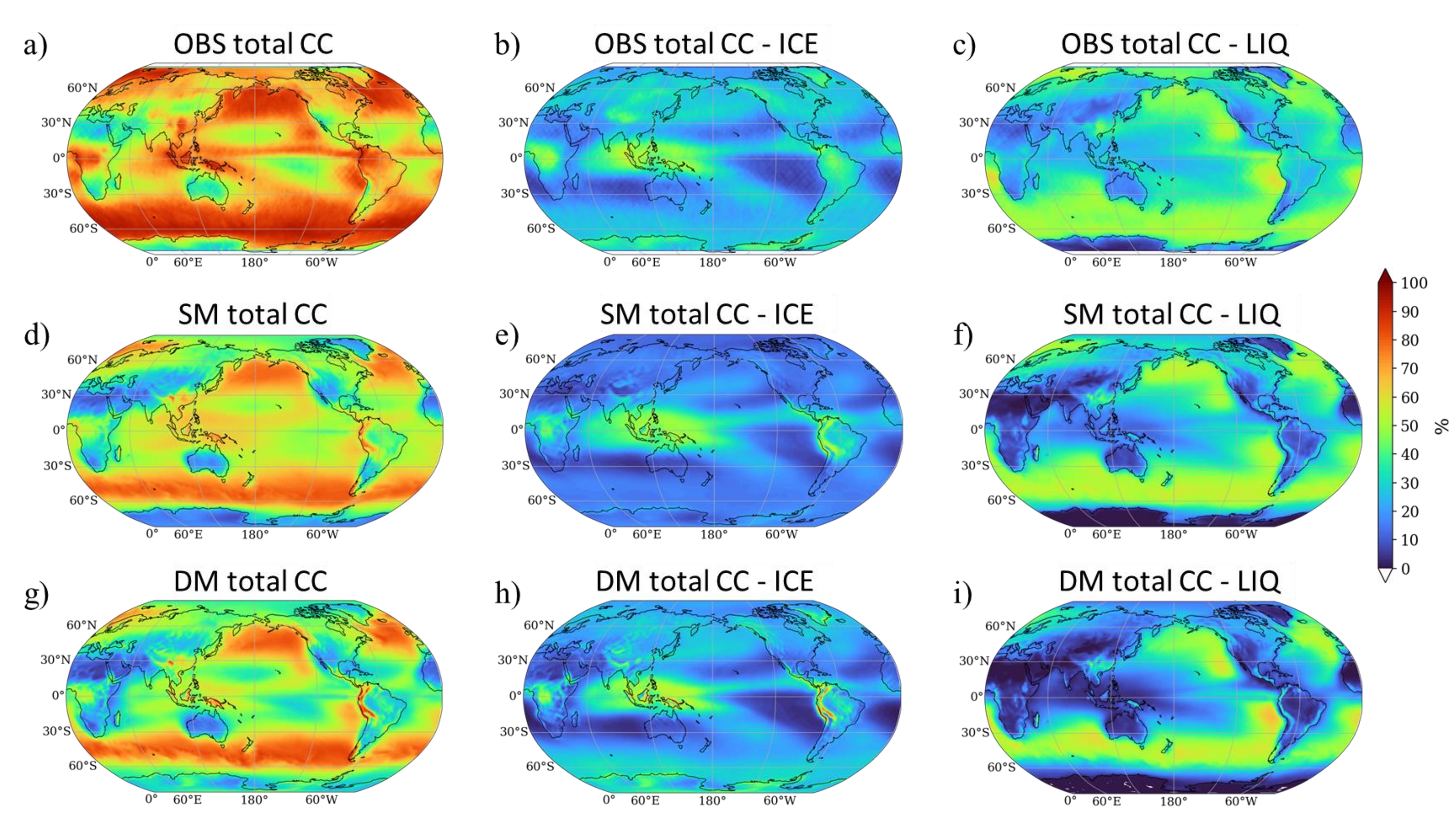
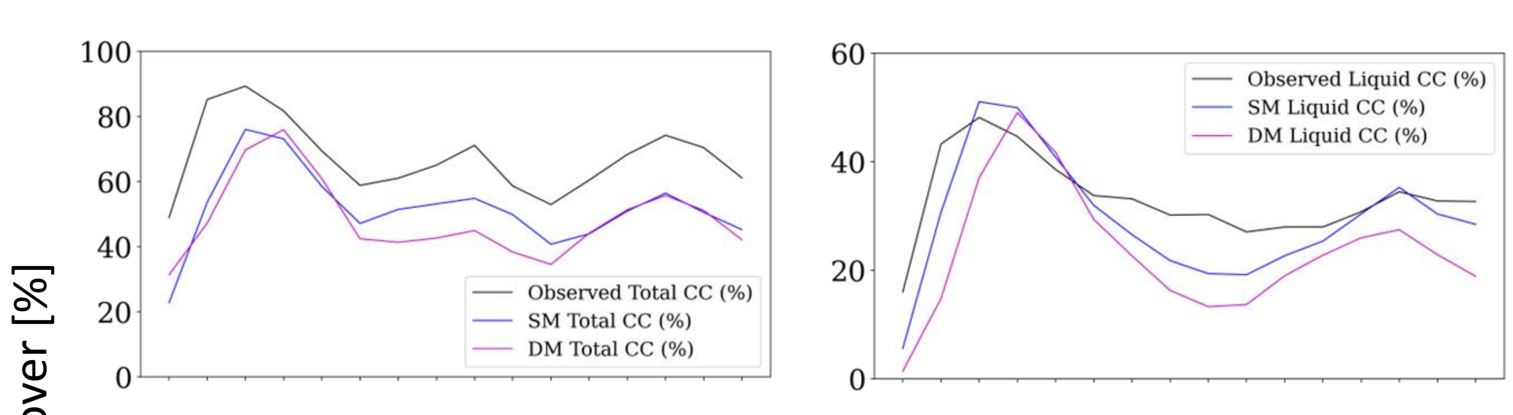
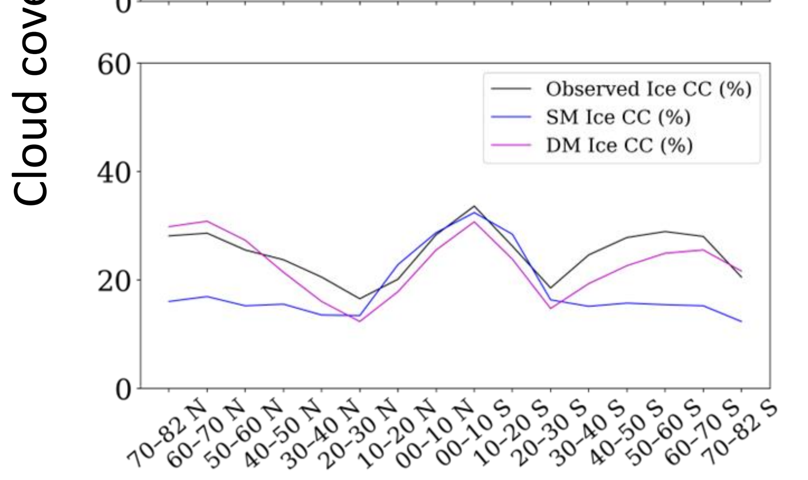


Figure 1: Global map of cloud cover of (%): CALIPSO-GOCCP observed (a) total, (b) ice, (c) liquid for the years 2006-2016. (d-f) and (g-i) same as in (a-c) but for CCAM-SM and -DM, respectively.

- DM-CCAM reproduced more low-level cloud than SM-CCAM and both SM and DM-CCAM has less mid- and high-level cloud (over ITCZ)





- Total CC underestimates by 5-25%
- Largest over the tropic due to liquid CC
- SM-CCAM has large bias in cloud ice

Figure 2: Zonal Annual Mean Total, Liquid, and Ice Cloud Cover (CC) in Units of Percent for the years 2006-2016 from CALIPSO Observations, CCAM-SM and CCAM-DM.

Regional evaluation of clouds in CCAM

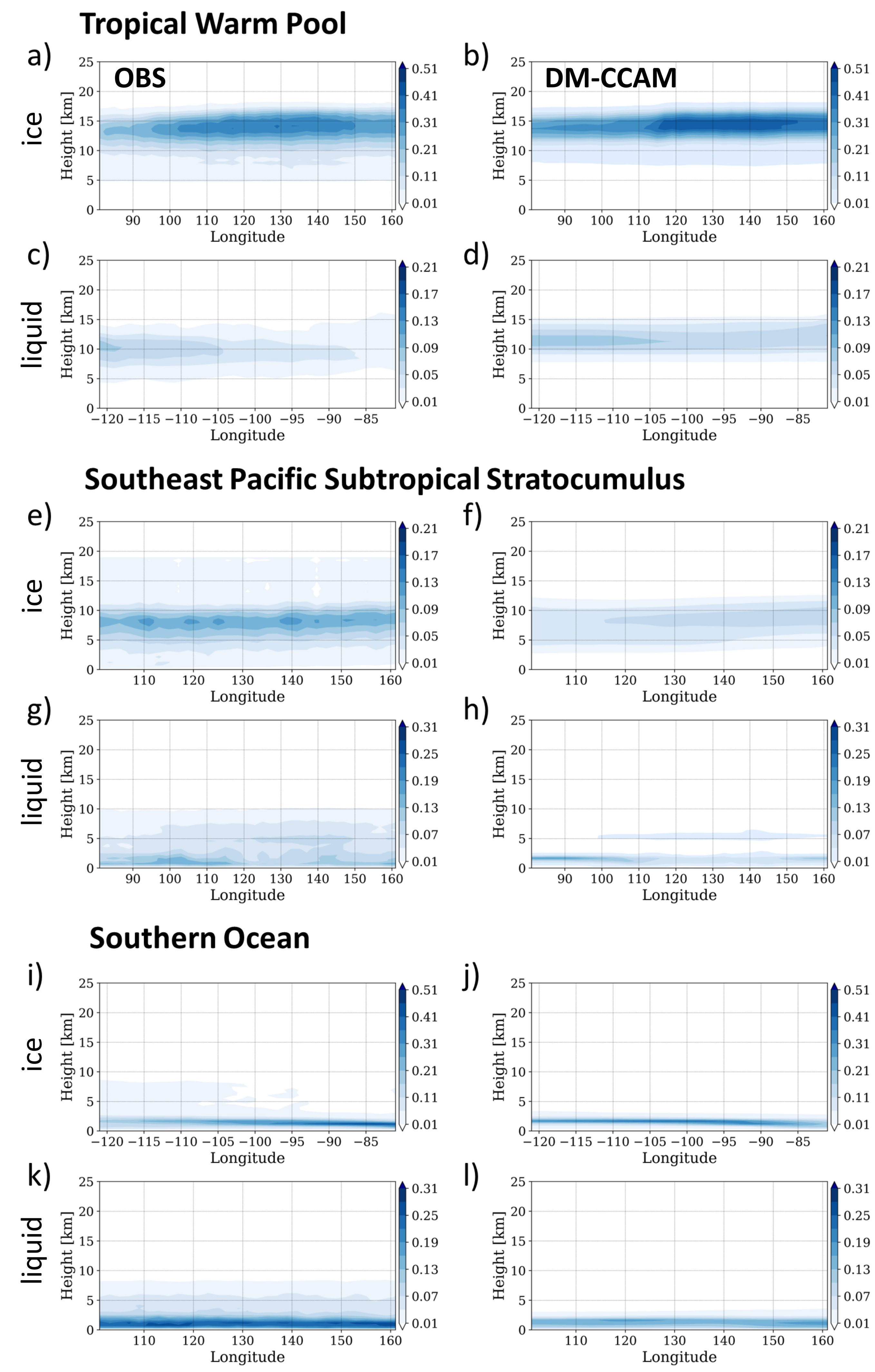


Figure 3: Vertical averaged cross section of observed (left) and modelled (right) ice and liquid clouds for Tropical Warm Pool region (10°S-10°N, 80°E-160°E), Southeast Pacific Subtropical Stratocumulus (30°S-0°S, 80°W-120°W) and Southern Ocean (40°S-60°S, 100°E-160°E) for the DJF, JJA, and DJF seasonal average during 2006-2016, respectively.

- DM-CCAM reproduced a comparable ice cloud top height; however, its low-level liquid cloud is much shallower than the CALIPSO observation.

Conclusion

We implemented the Cloud Feedback Model Intercomparison Project (CFMIP) Observational Simulator Package (COSP) to evaluate clouds at the global scale.

We found comparable cloud ice cover between OBS and both CCAM simulations but underestimated liquid cloud cover, which contributes to the bias in total cloud cover.

The double-moment cloud microphysics scheme, at least in the CCAM case, indicates a more realistic representation of large-scale meteorology than the single-moment cloud microphysics scheme.

In future works, we will further validate the modelled cloud and its cloud radiative effect in a CCAM-sketched grid over the Coordinated Regional Downscaling Experiment (CORDEX) Australasia region.

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FOR FURTHER INFORMATION

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