A sectional cloud microphysical model (CARMA Cloud) in CESM2

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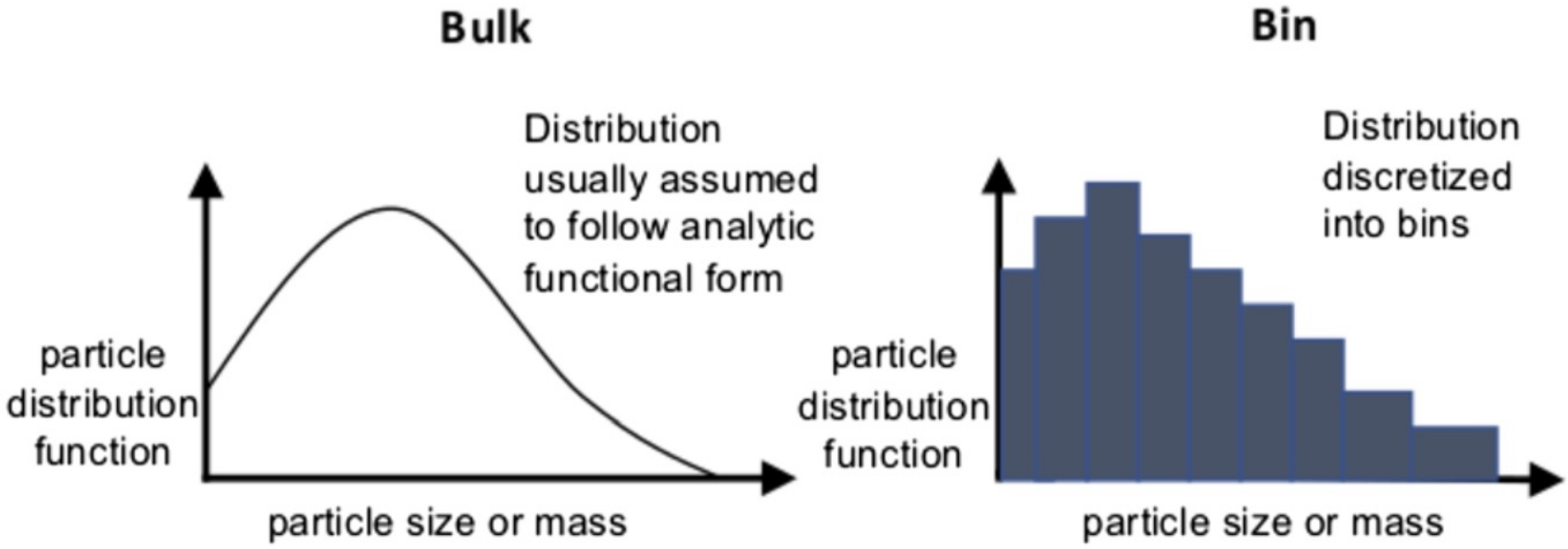
Introduction

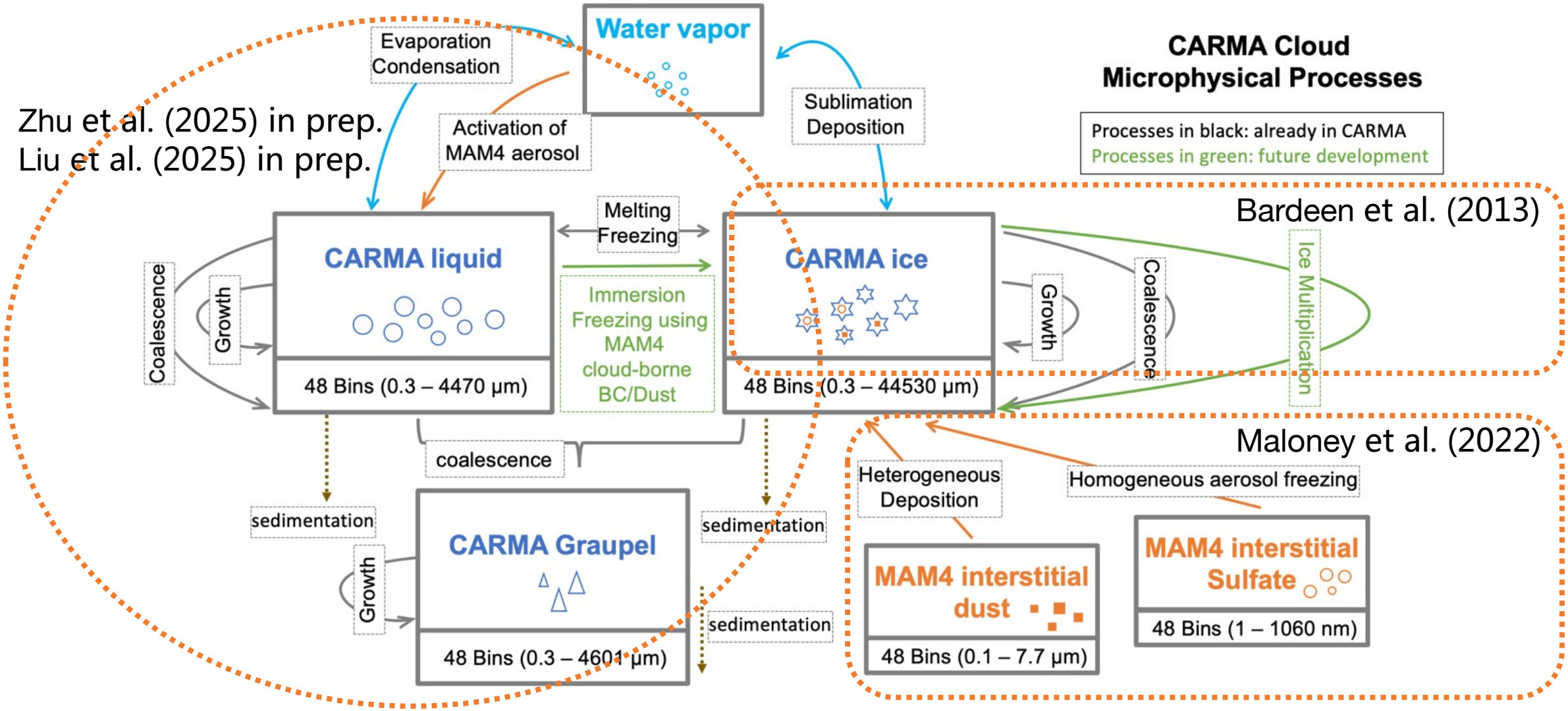
- Clouds are critical to climate systems but remain highly uncertain in climate models.



Morrison et al. (2020)

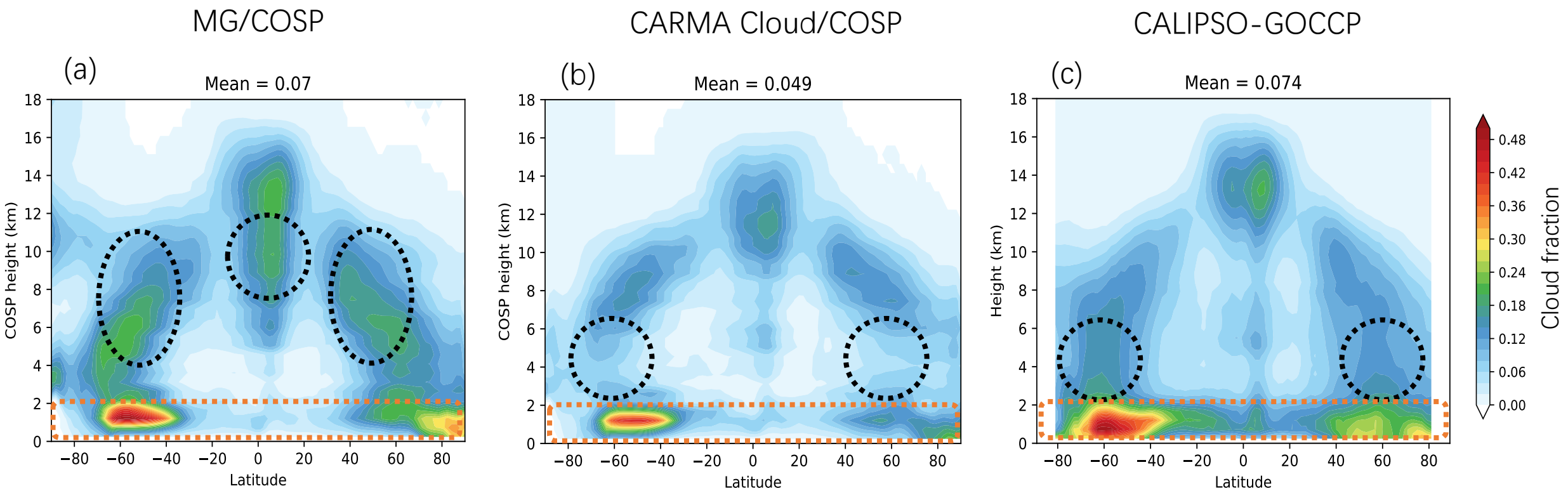
CESM2/CARMA Cloud

Zhu et al. (2025) in prep.
Liu et al. (2025) in prep.



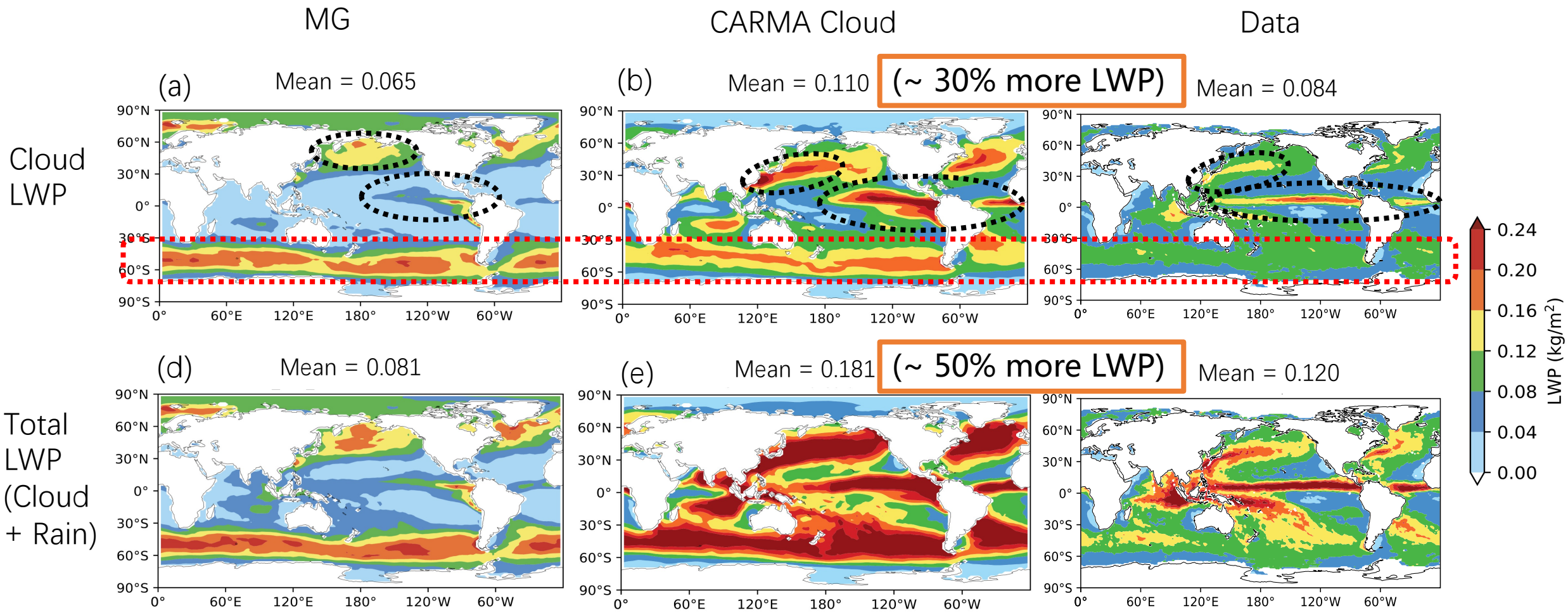
Zhu et al. (2025) in prep.

CAM6/CLUBB cloud fraction is comparable to satellite observation. We need to adjust macrophysics.



Liu et al. (2025) in prep.

CARMA Cloud captures patterns for liquid water path (LWP) but has ~ 30%-50% more LWP

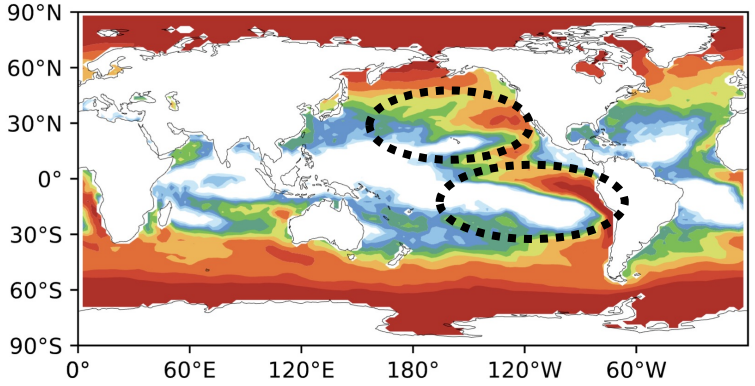


Liu et al. (2025) in prep.

CARMA Cloud captures patterns for LWP Ratio (cloud/total LWP)

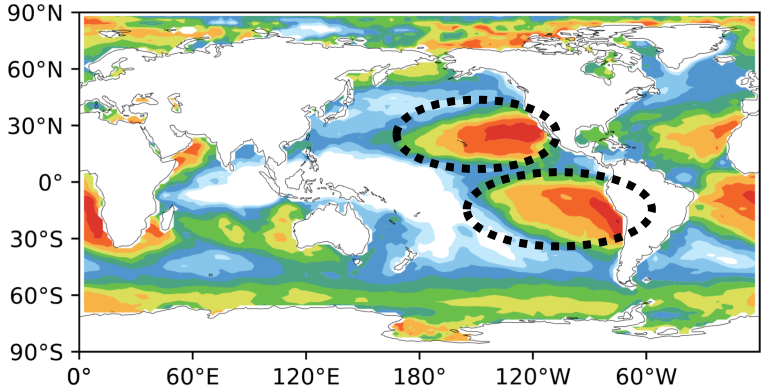
MG

(a) Mean = 0.71



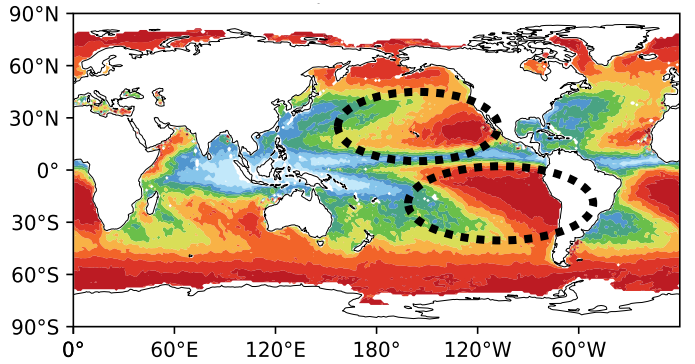
CARMA Cloud (< 30 μm)

(b) Mean = 0.66



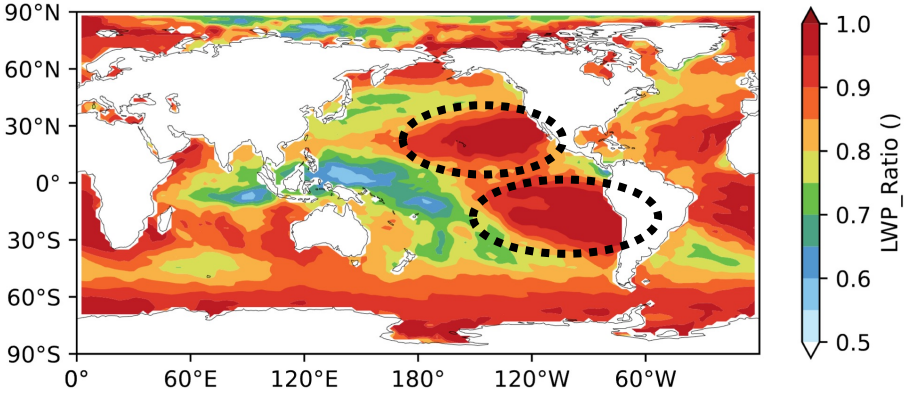
Data

(c) Mean = 0.79



CARMA Cloud (< 50 μm)

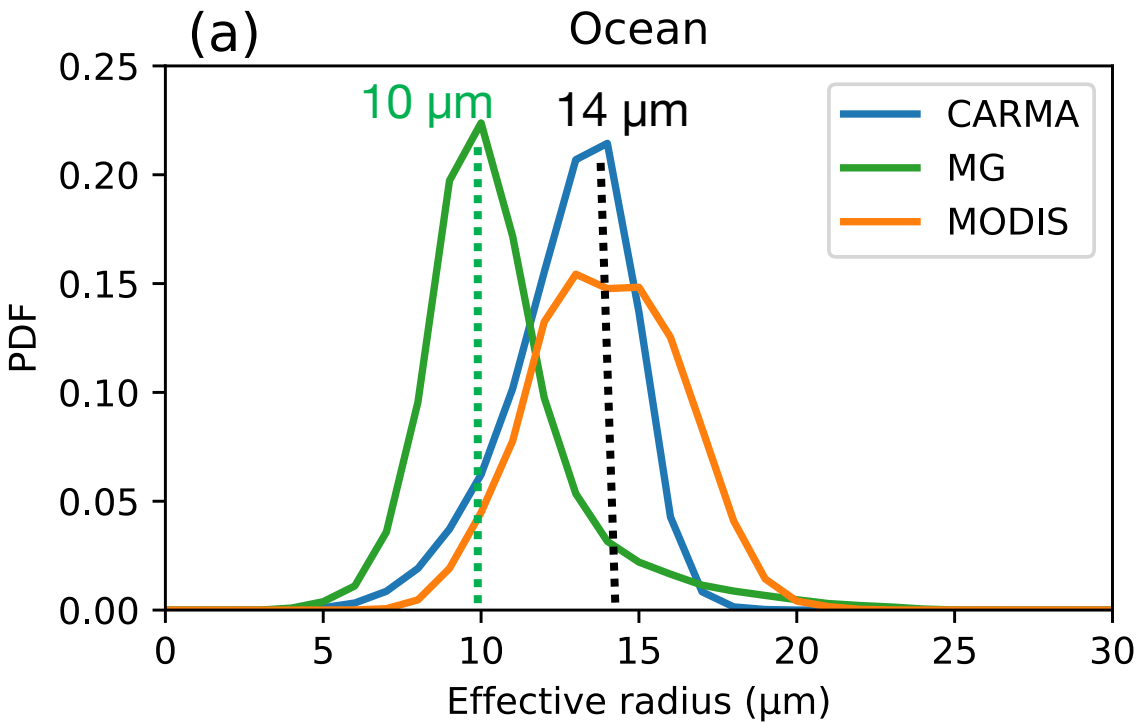
(d) Mean = 0.85

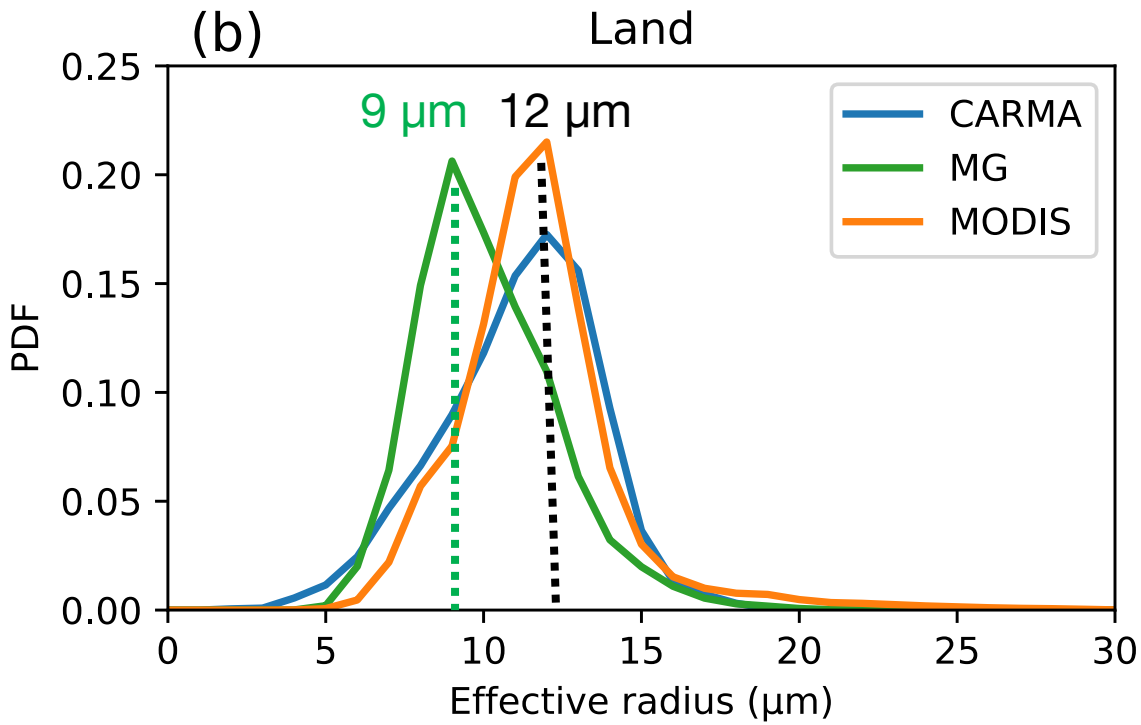


LWP Ratio is sensitive to the size cutoff in CARMA Cloud

Liu et al. (2025) in prep.

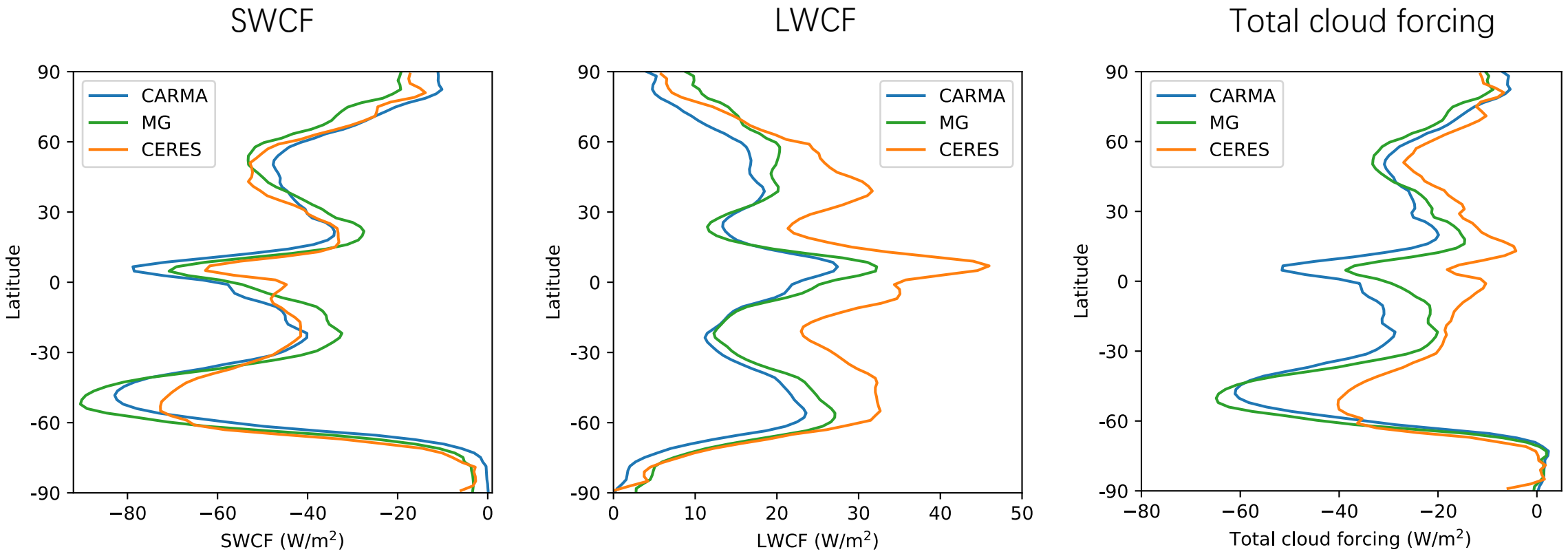
CARMA Cloud is close to the observed effective radius of liquid cloud





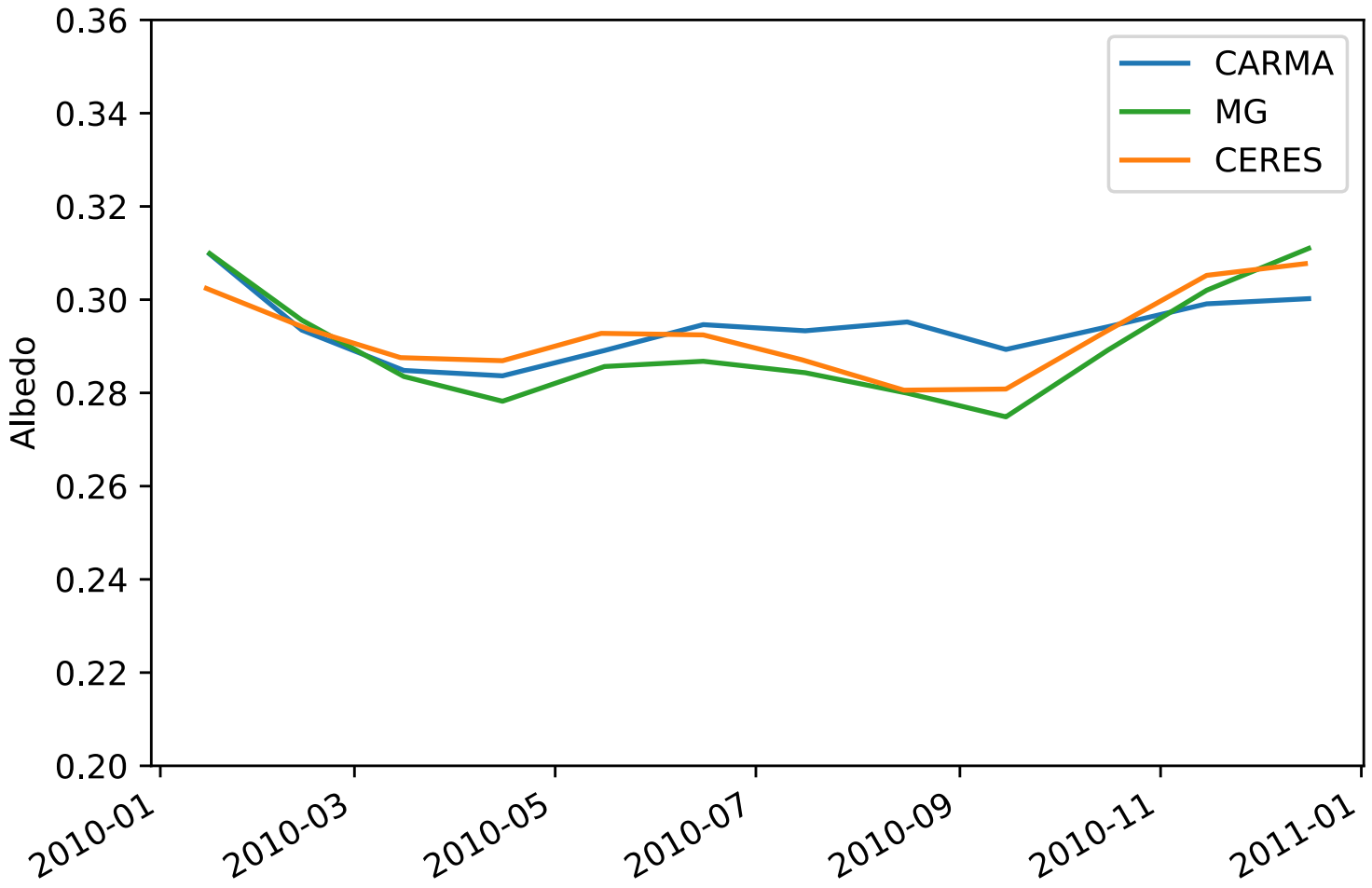
Liu et al. (2025) in prep.

Simulated SWCF is comparable to data (biases < 5% on global average), while simulated LWCF is ~ 40% lower than data



Liu et al. (2025) in prep.

Simulated albedo is comparable to CERES



Albedo	(Relative errors)
0.2939	(+ 0.48 %)
0.2901	(- 0.82 %)
0.2925	

Liu et al. (2025) in prep.

Key Points

- Global climate model with sectional cloud microphysics.
- CARMA Cloud captures patterns for liquid water path (LWP) but has ~ 30%-50% more LWP.
- CARMA Cloud is close to the observed effective radius of liquid cloud, revealing reasonable simulations of aerosol-cloud interactions.
- Both models are good for SWCF (<5% error) and albedo (<1% error). LWCF and total cloud forcing have some biases compared to data.

Future improvements

- Adjust macrophysics for cloud fraction
- Add interactive aerosols for liquid clouds by putting aerosols in the liquid-cloud particles
- Add ice multiplication
- Add immersion freezing
- Improve computational efficiency without sacrificing microphysics (e.g. coagulation)