Observed Scaling in Clouds and Precipitation and Scale Incognizance in Regional to Global Atmospheric Models

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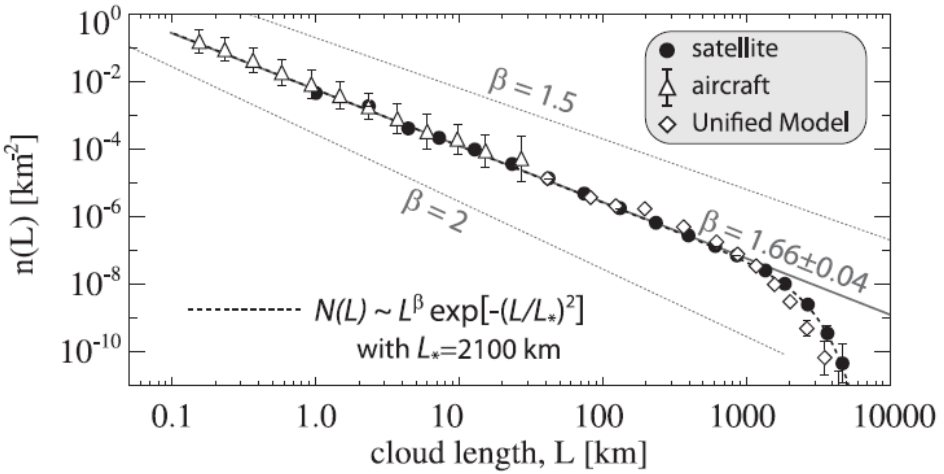
Introduction—Observations of scaling

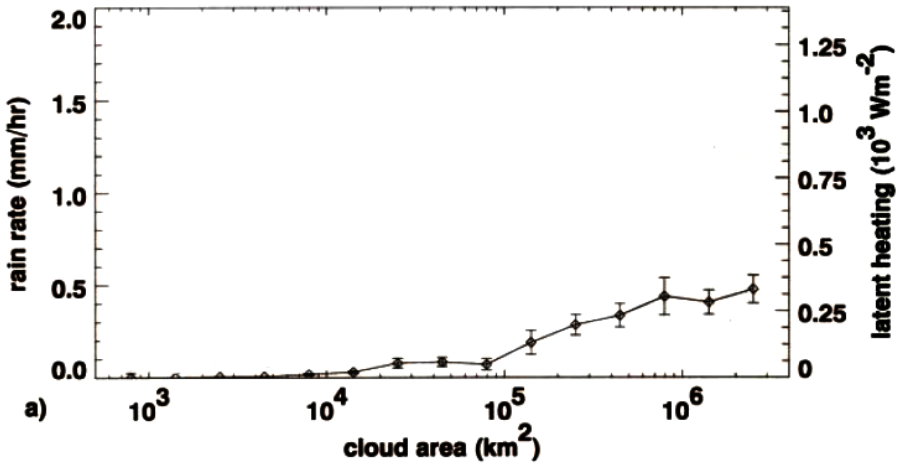


From Wood and Field (2012)

Log-linear (~ -5/3) decrease in cloud number concentration as cloud size increases.

Scale-break for clouds larger than ~1000—2000 km

Precipitation increases with increasing cloud size; rain tends to fall harder from larger cloud systems

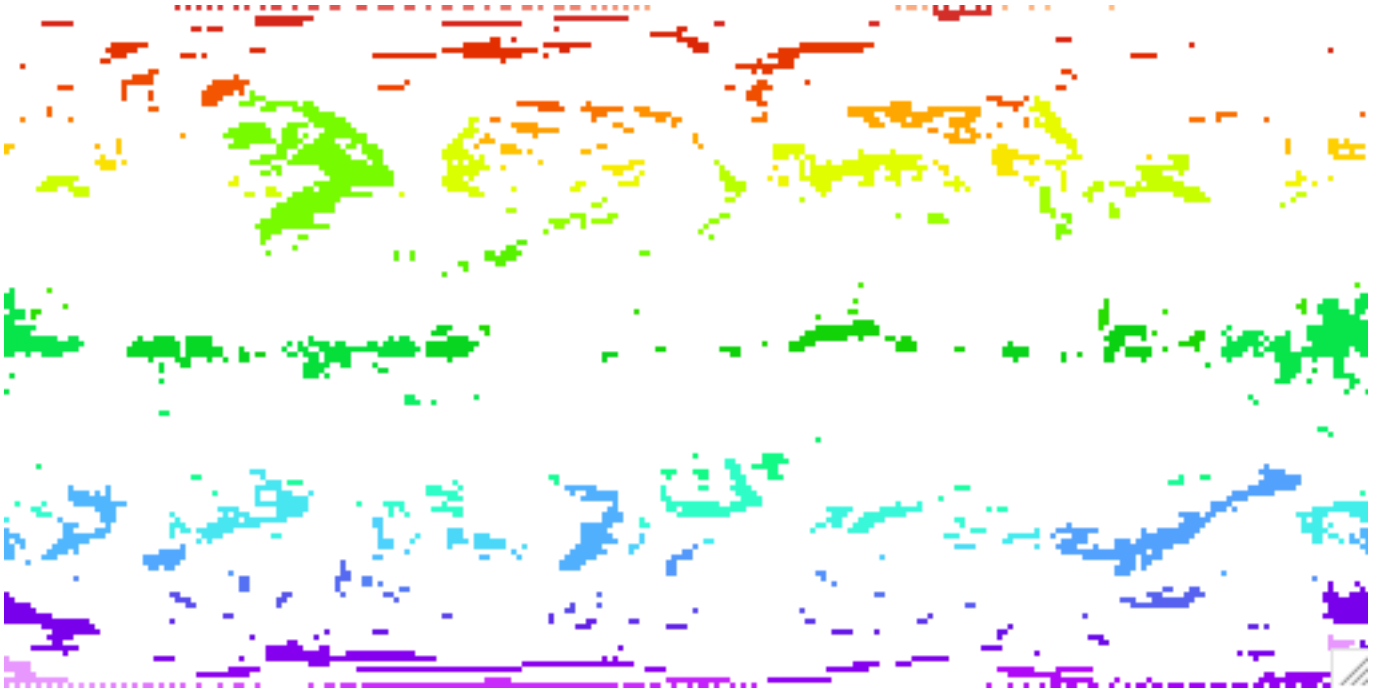


From Wilcox and Ramanathan (2012)

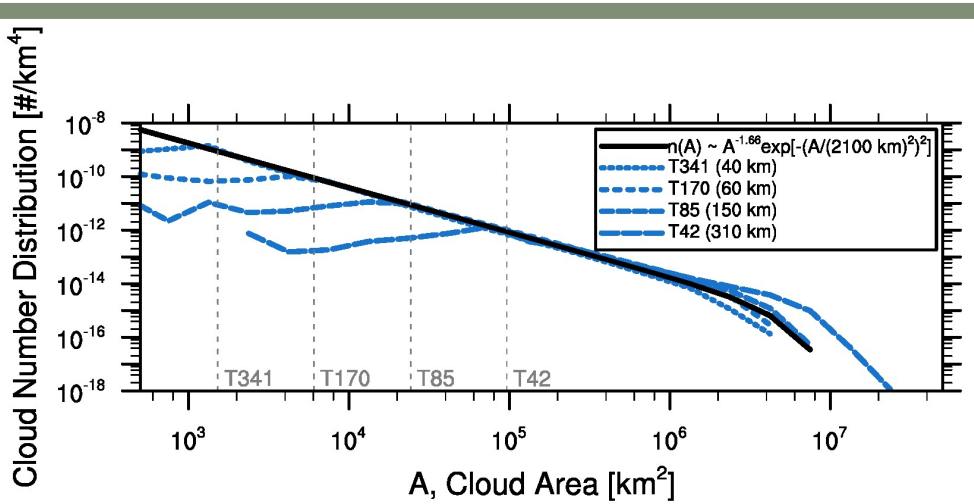
Introduction—Aquaplanet experiments

- No land
- Specified SSTs
- Zonally and hemi-spherically symmetric
- Identical physics timestep
- Multiple resolutions
- Spectral-Eulerian dynamical core

Cloud detection



Log-linear scaling in CAM



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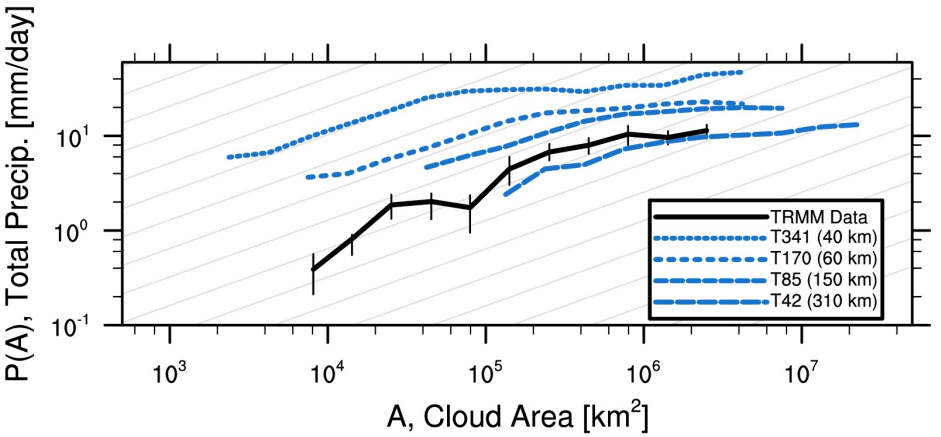
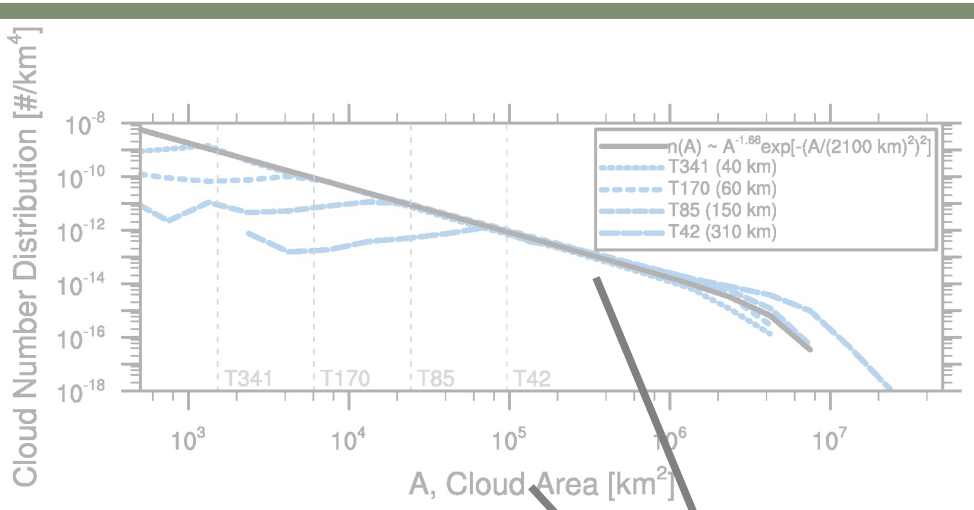
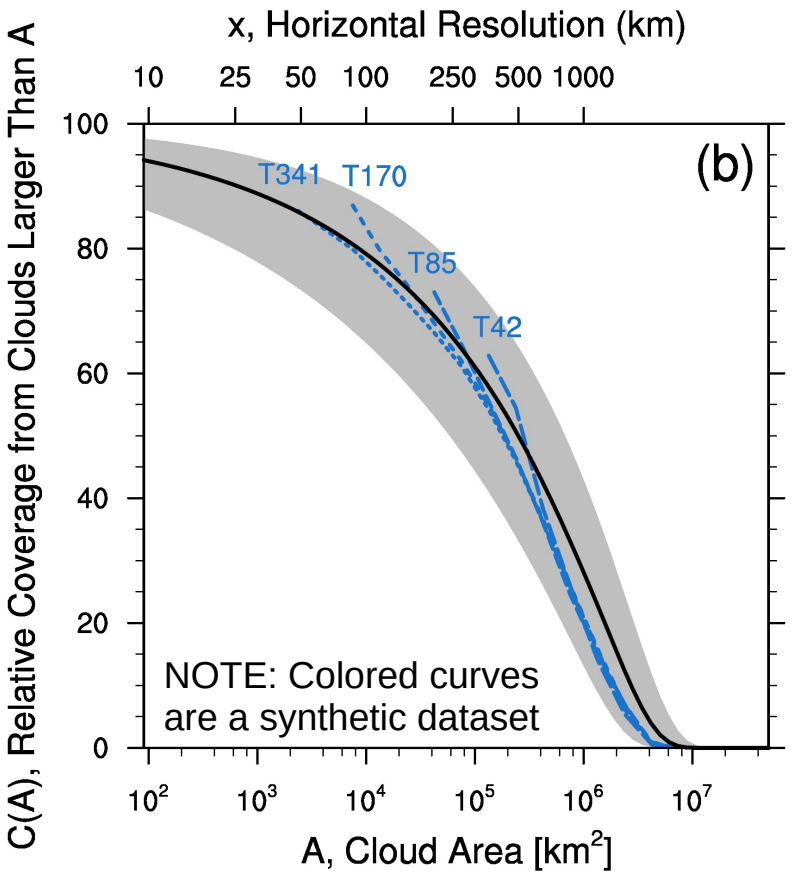


Cloud Resolution Dependence

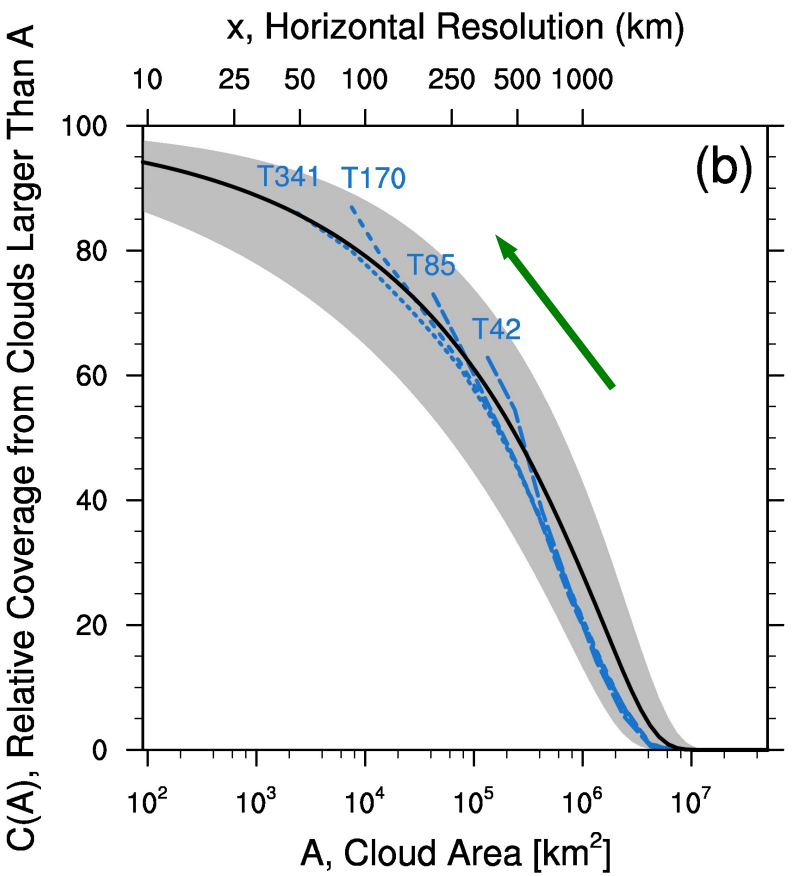


$$f_c(A > A_x) = \int_{A_x}^{A_\infty} A \cdot n(A)\, dA$$

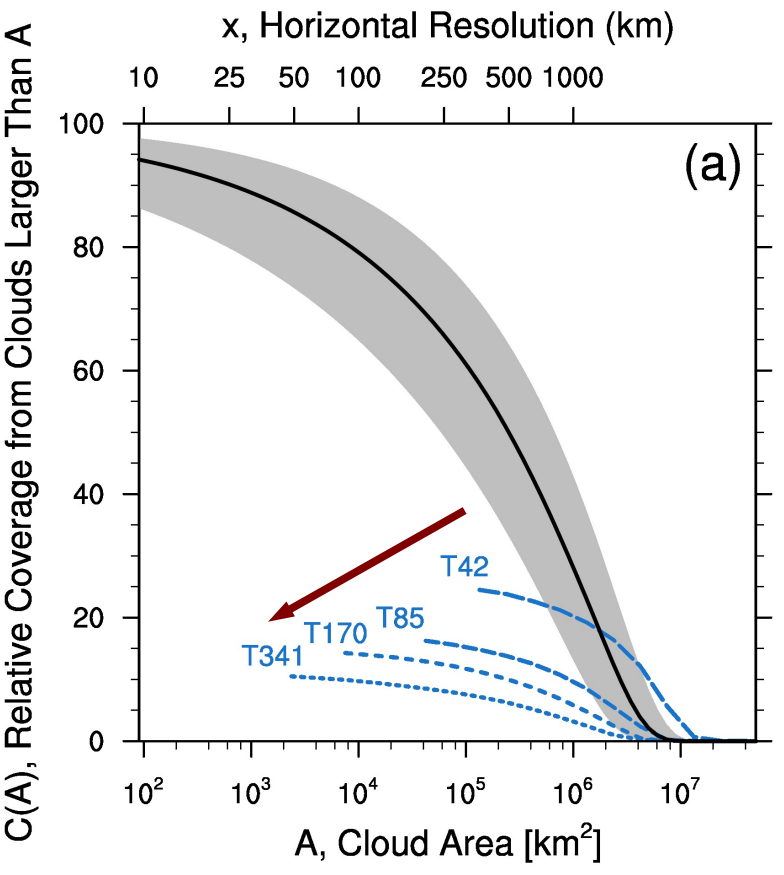
$$C(A_x) = \frac{\bar{f}_c(A > A_x)}{\bar{f}_c(A < A_\infty)}$$



Reverse Res. Dependence in CAM

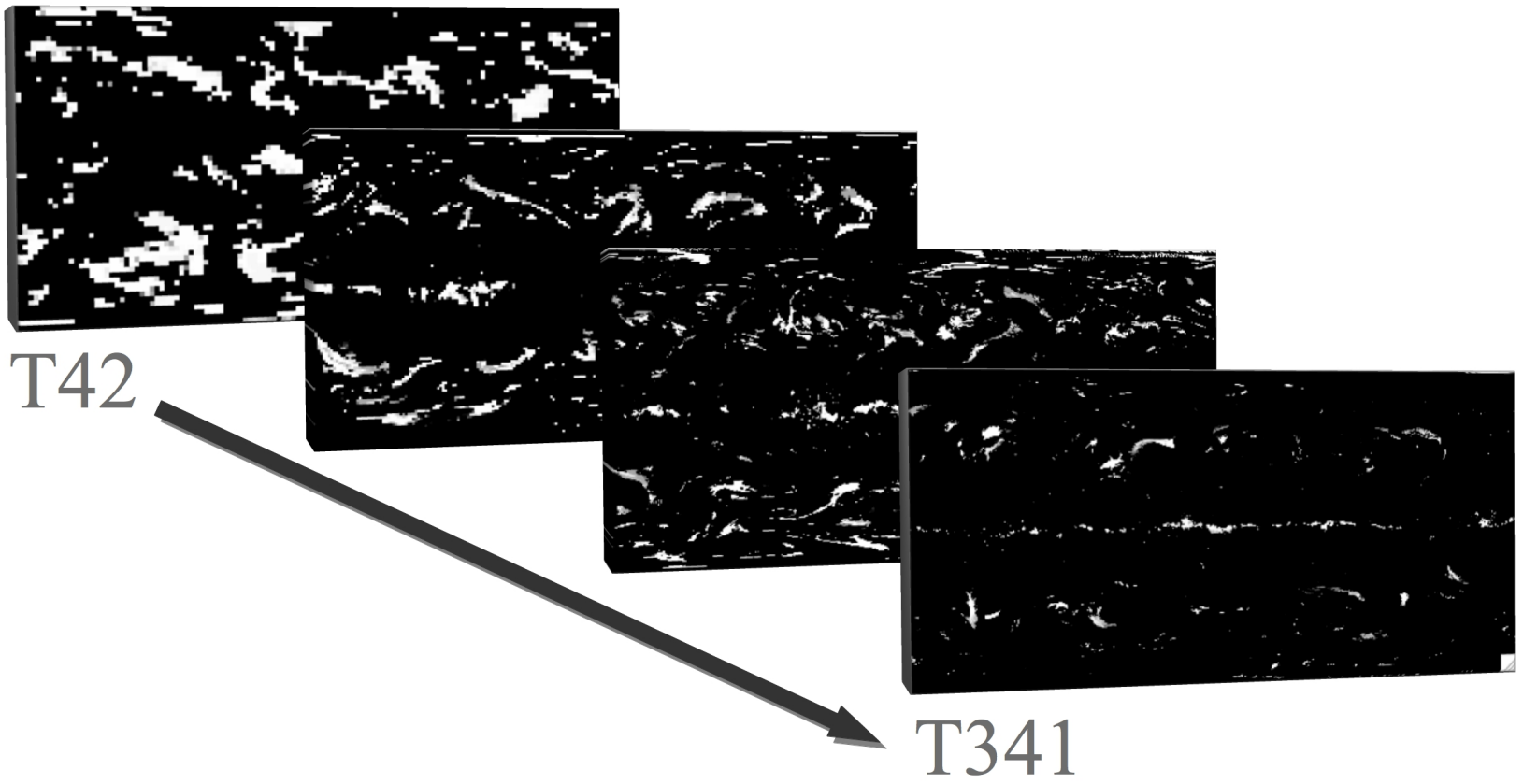


Expected Resolution Dependence

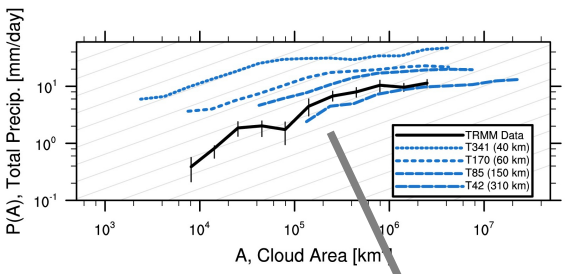


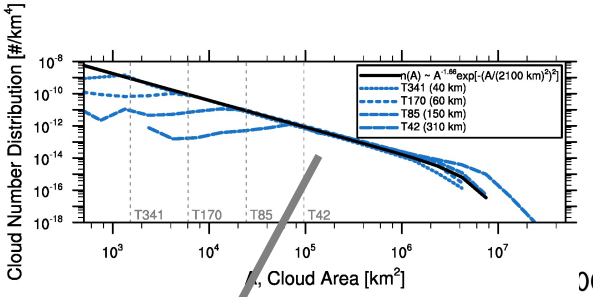
Actual Resolution Dependence

Loss of Resolved Clouds



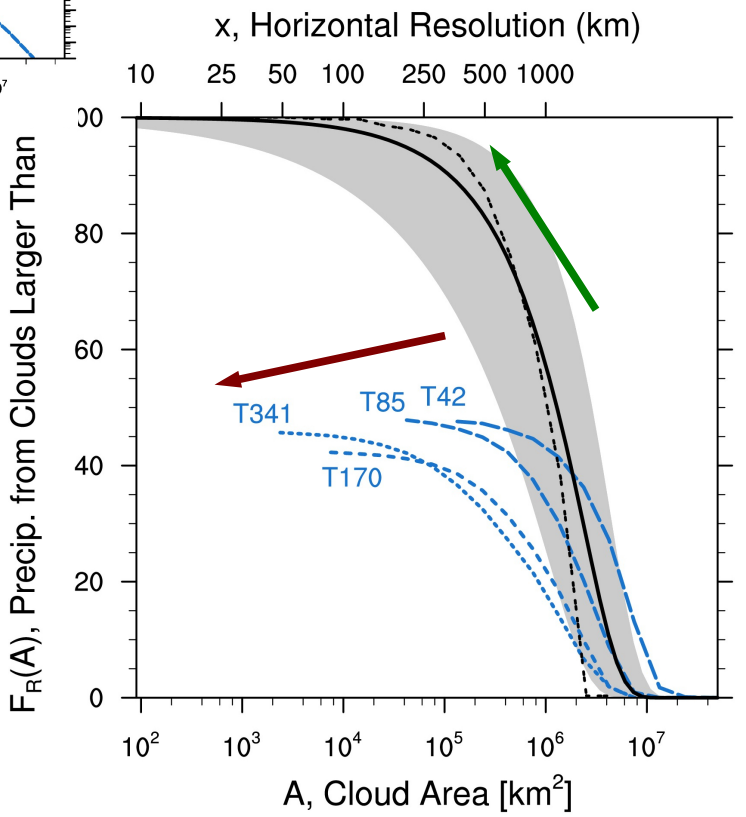
Precip. Resolution Dependence



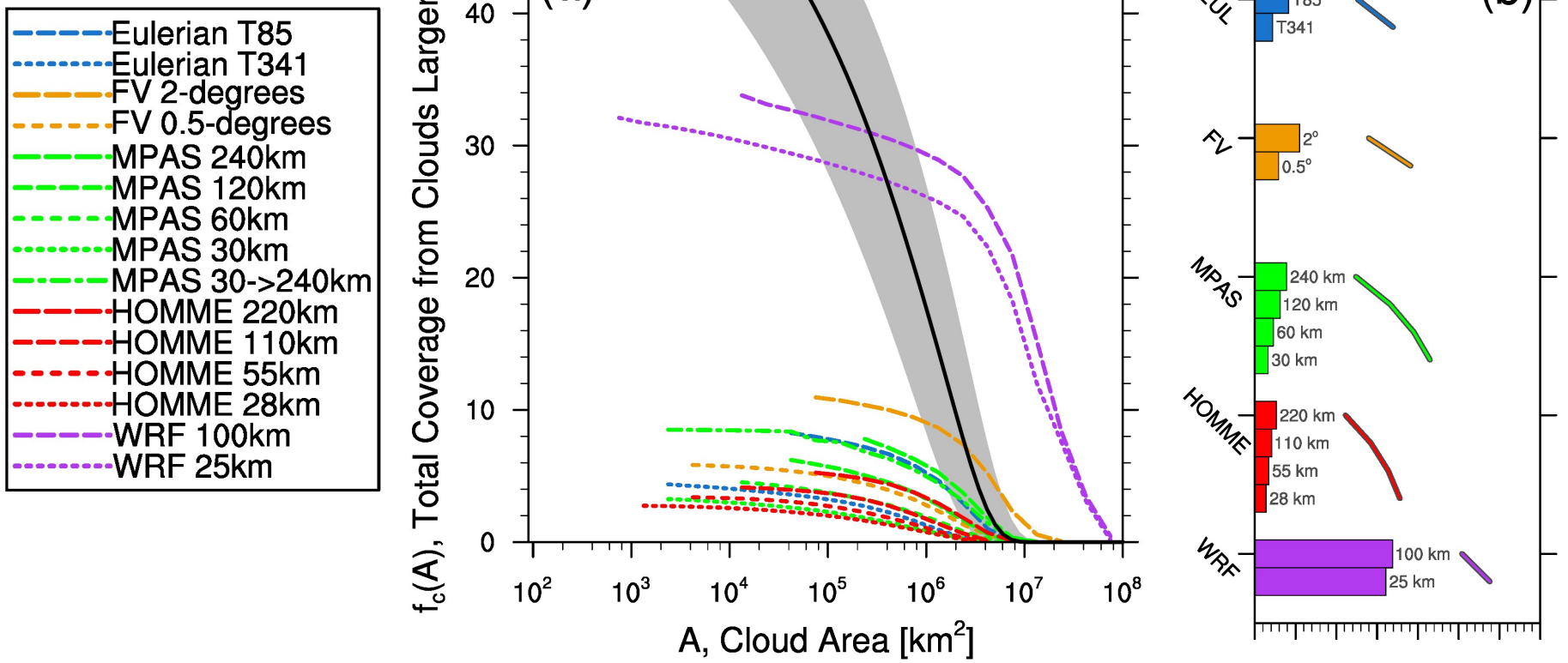


$$\bar{P}(A > A_x) = \int_{A_x}^{A_\infty} P(A) \cdot A \cdot n(A)\, dA$$

$$F_R(A_x) = \frac{\bar{P}(A > A_x)}{\bar{P}(A < A_\infty)}$$



Scale-incognizance in all dycores



Scale-incognizance summary

- CAM exhibits cloud/precip scaling similar to observations
- CAM resolves fewer clouds as resolution increases; this is wrong
- CAM resolves less precipitation as resolution increases; this is wrong

What is the cause of this behavior???

Constraints on Precip. Budget

~20 % of total. Occurs at scales ~10 km; should not change with resolution

$$P_T = P_C' + P_S$$

3 mm/day: constrained by radiative-convective equilibrium

Constrained to not change if P_T and P_C don't change

Constraints on Precip. Budget

~20 % of total. Occurs at scales ~10 km; should not change with resolution

$$P_T = P_C + P_S$$

$$= P_S^R + P_S^U$$

3 mm/day: constrained by radiative-convective equilibrium

Constrained to not change if P_T and P_C don't change

Actual resolution dependence

~Constant with res.

Increases with increasing res.

$$P'_T = P_C + P'^{U}_S + P^{R}_S$$

Decreases with increasing res.

Decreases with increasing res.

CAM Precip. Parameterizations

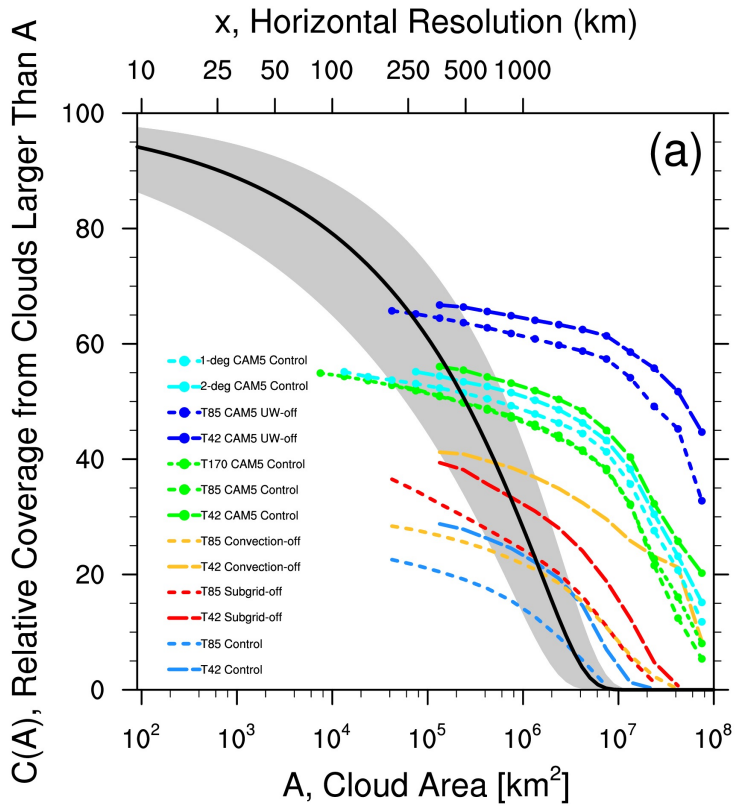
Zhang-McFarlane deep convection
&
Hack shallow convection

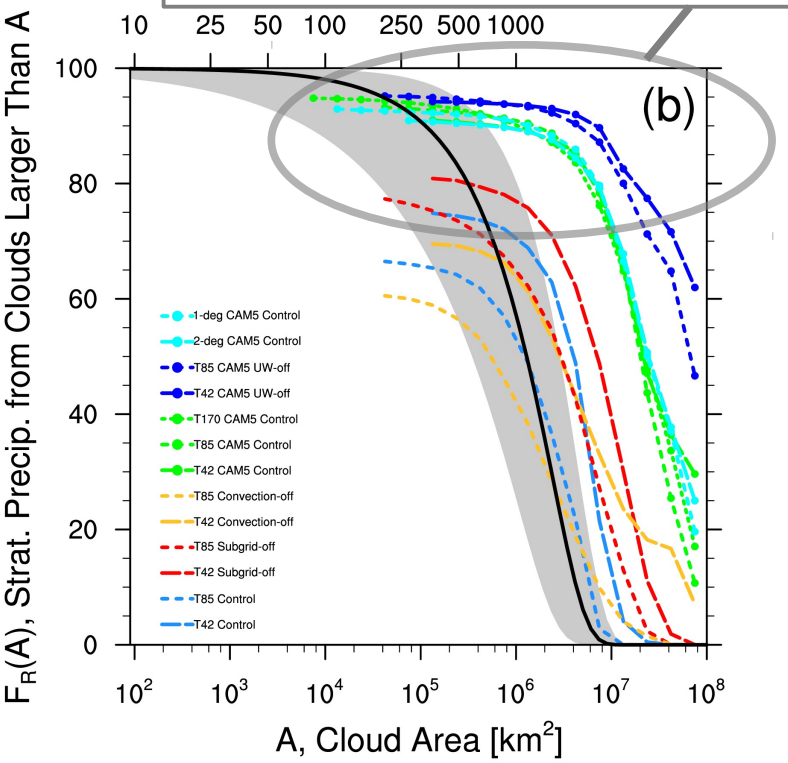
Rasch-Kristjansson microphysics

$$P_T = P_C + P_S^U + P_S^R$$

Slingo cloud fraction

Microphysics is a Cause





Summary

- Scaling of precipitation and clouds that matches observations
- Loss of large clouds with increasing resolution
- Loss of large clouds drives scale-incognizance of cloud and precipitation
- The loss of large clouds is caused by the CAM4 microphysics parameterization

This work is described in:
O'Brien et al. (2013), *J. Climate* (In Review)

Future Work

- Why does the RK microphysics cause this behavior?
- What causes the repartitioning of convection?
- Does CAM5 work better than CAM4 on a variable resolution mesh?

Acknowledgements

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