

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

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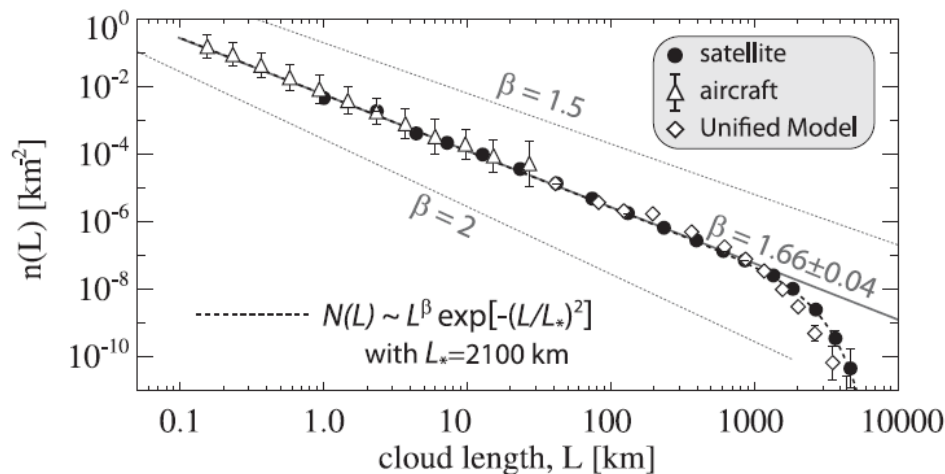
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Introduction — Observations of scaling

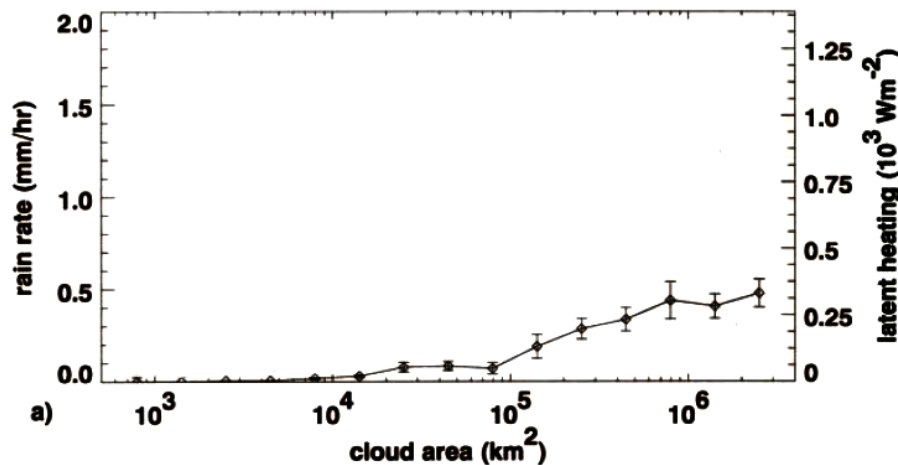


From Wood and Field (2012)

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

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

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



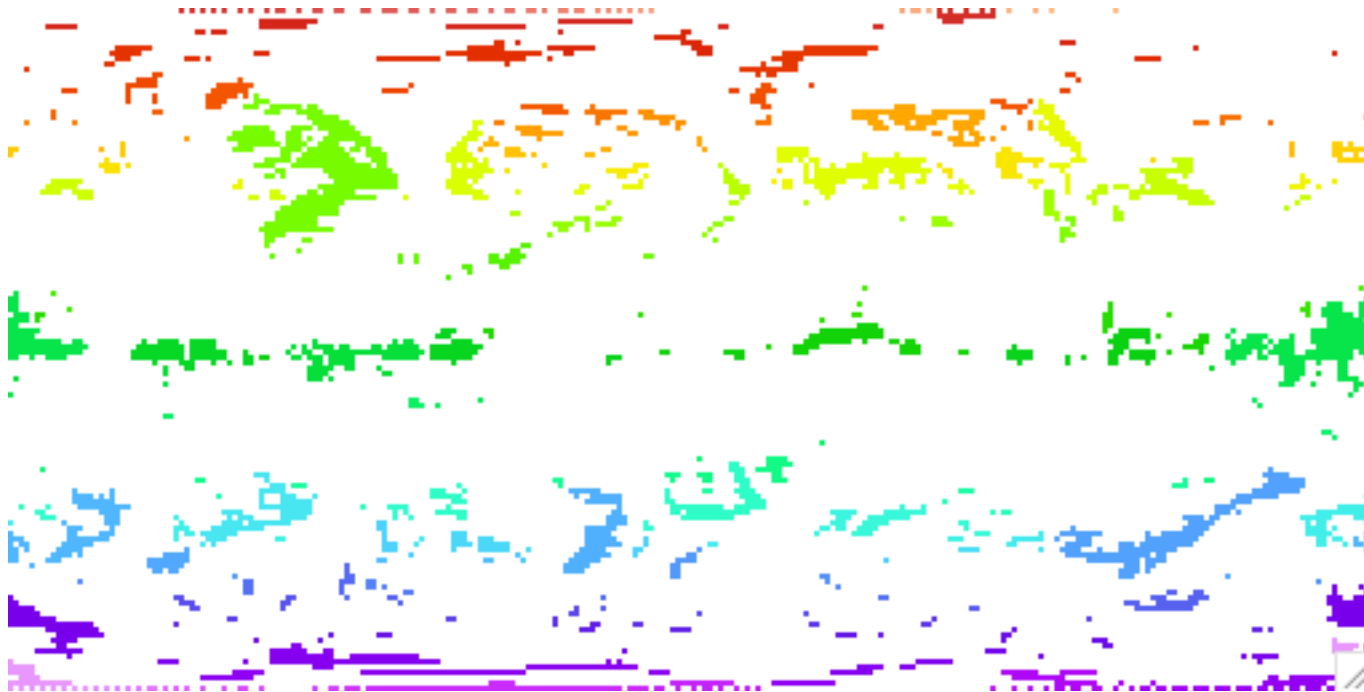
From Wilcox and Ramanathan (2012)

Introduction — Aquaplanet experiments

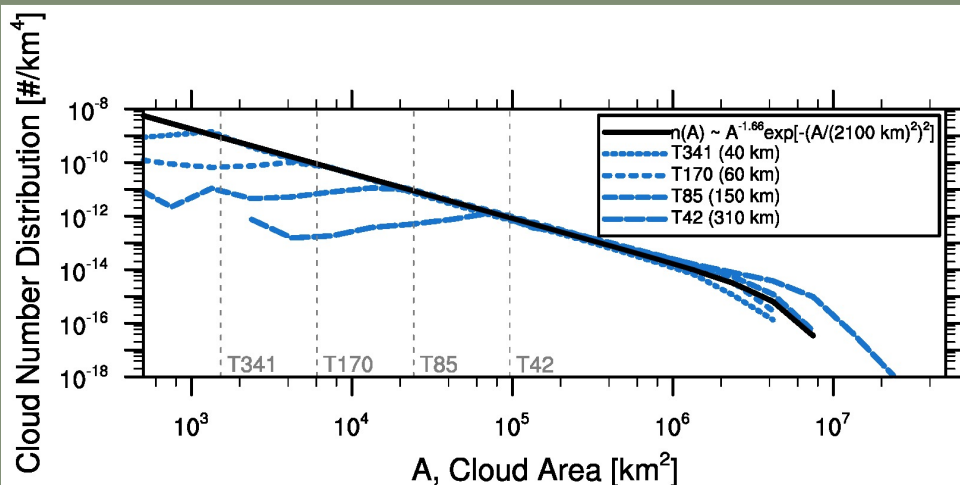


- No land
- Specified SSTs
- Zonally and hemispherically symmetric
- Identical physics timestep
- Multiple resolutions
- Spectral-Eulerian dynamical core

Cloud detection



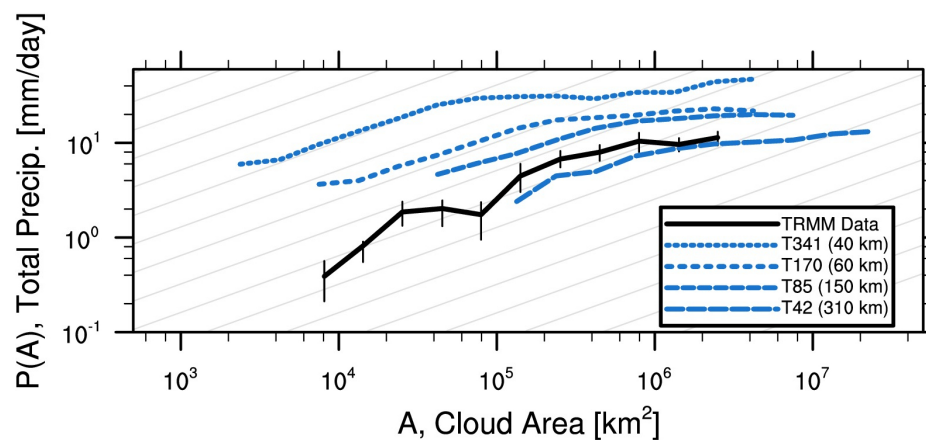
Log-linear scaling in CAM



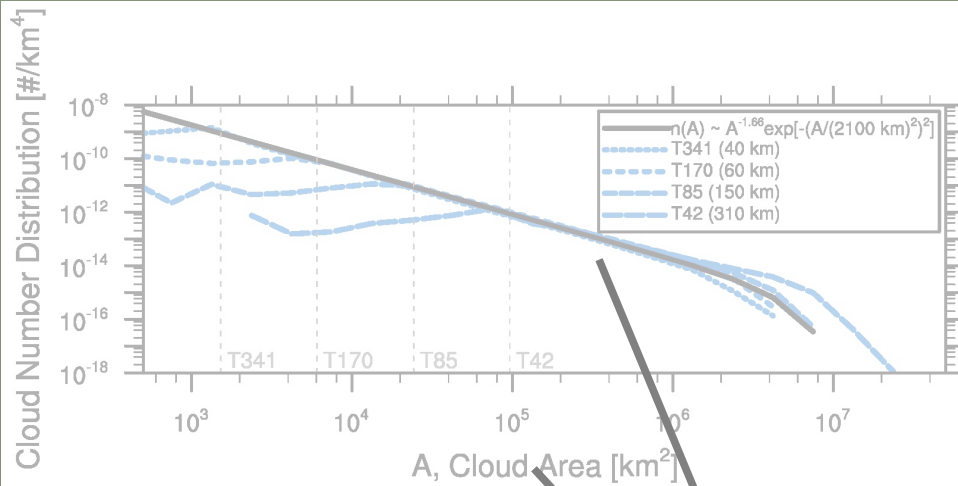
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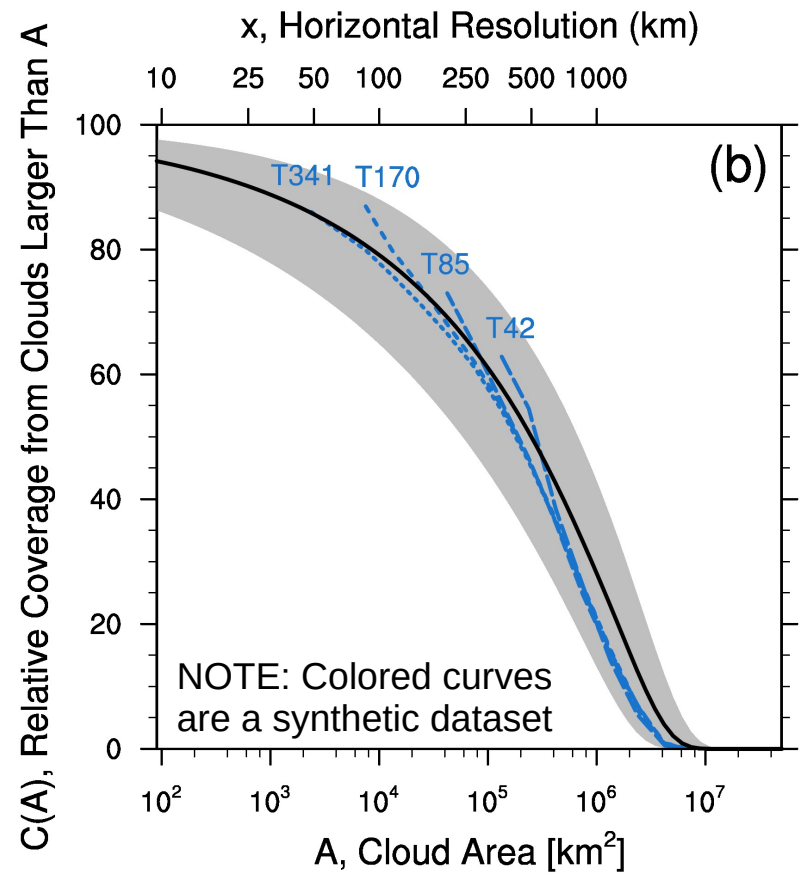
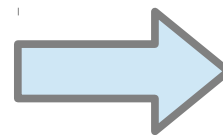


Cloud Resolution Dependence

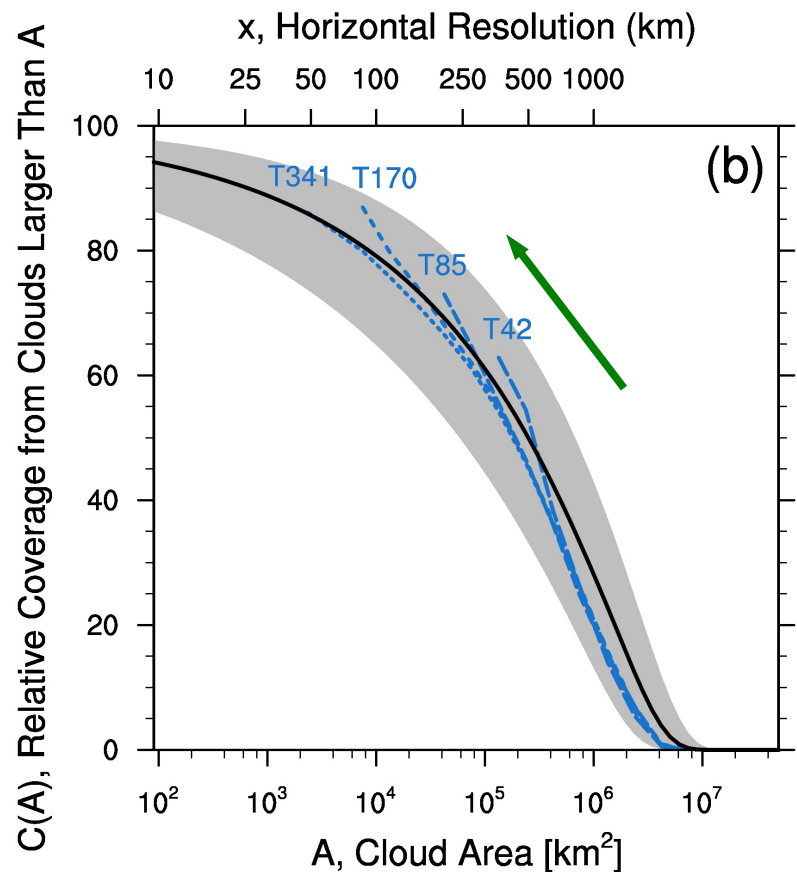


$$f_c(A > A_x) = \int_{A_x}^{A_\infty} A \cdot n(A) dA$$

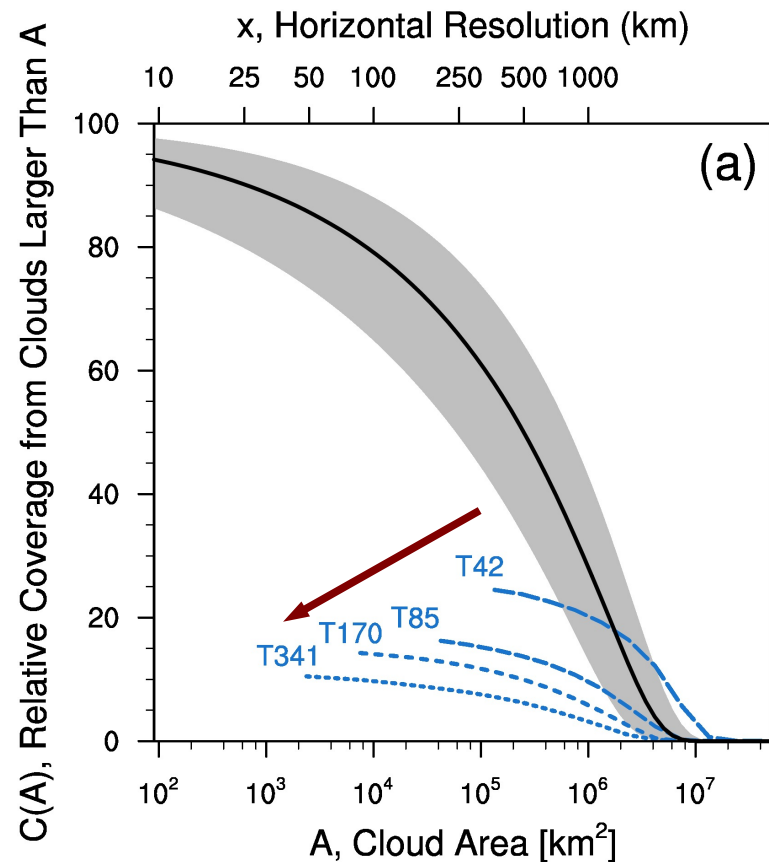
$$C(A_x) = \frac{\bar{f}_c(A > A_x)}{\bar{f}_c(A < A_\infty)}$$



Reverse Res. Dependence in CAM

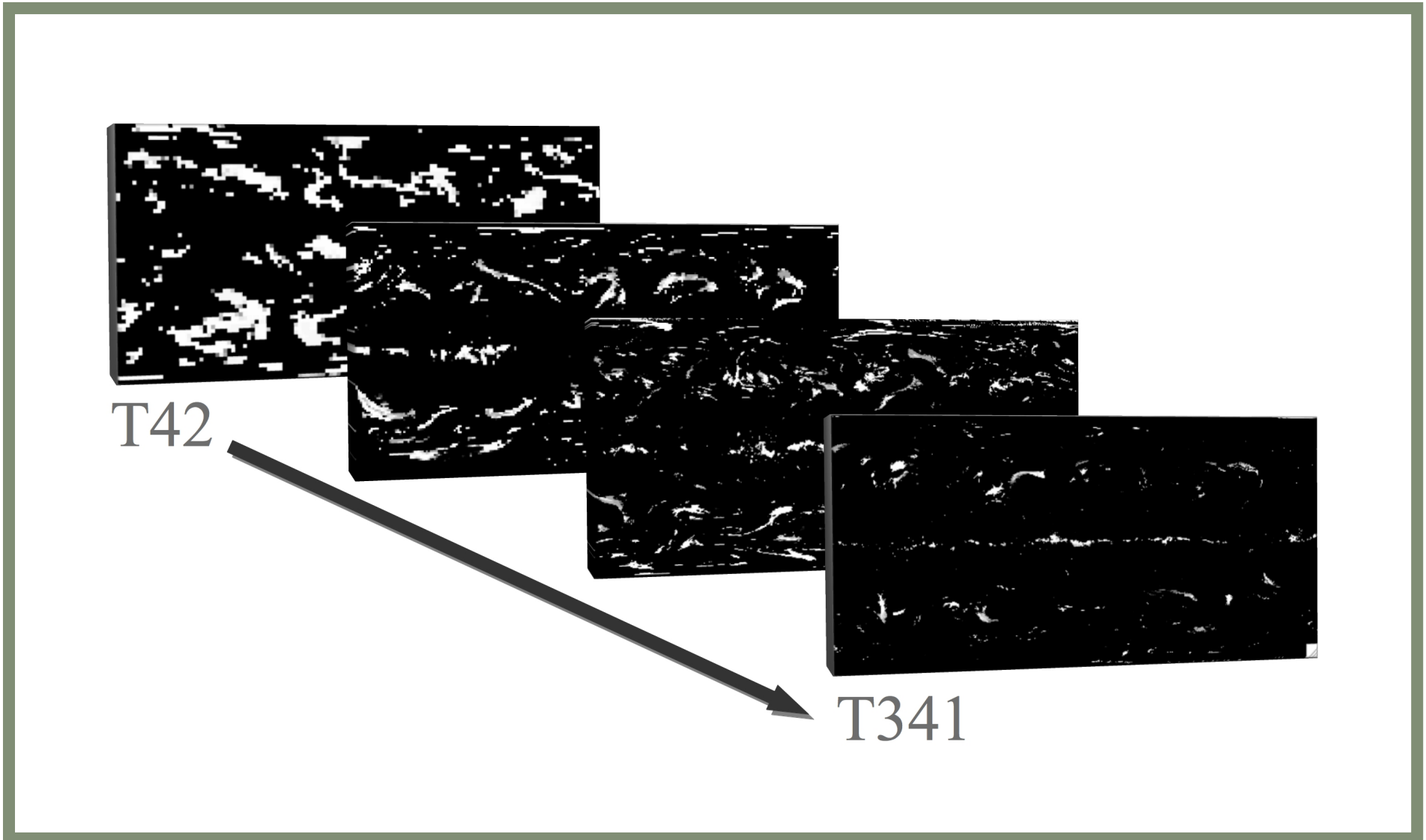


Expected Resolution Dependence

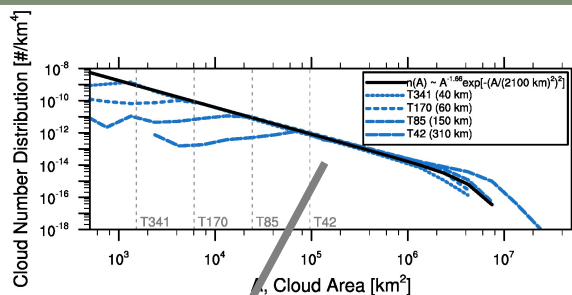
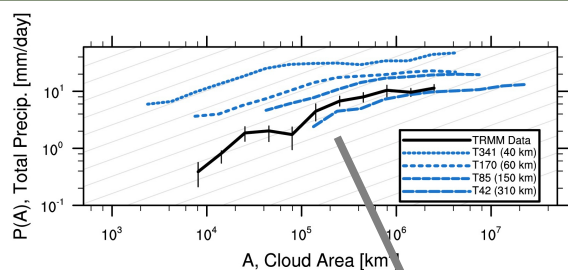


Actual Resolution Dependence

Loss of Resolved Clouds

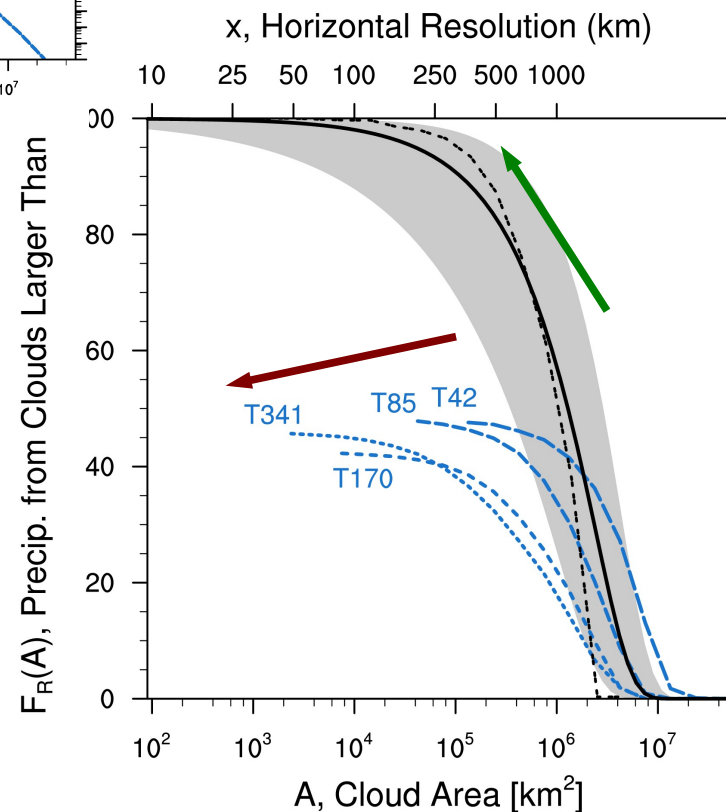
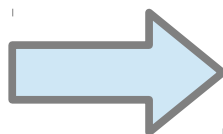


Precip. Resolution Dependence

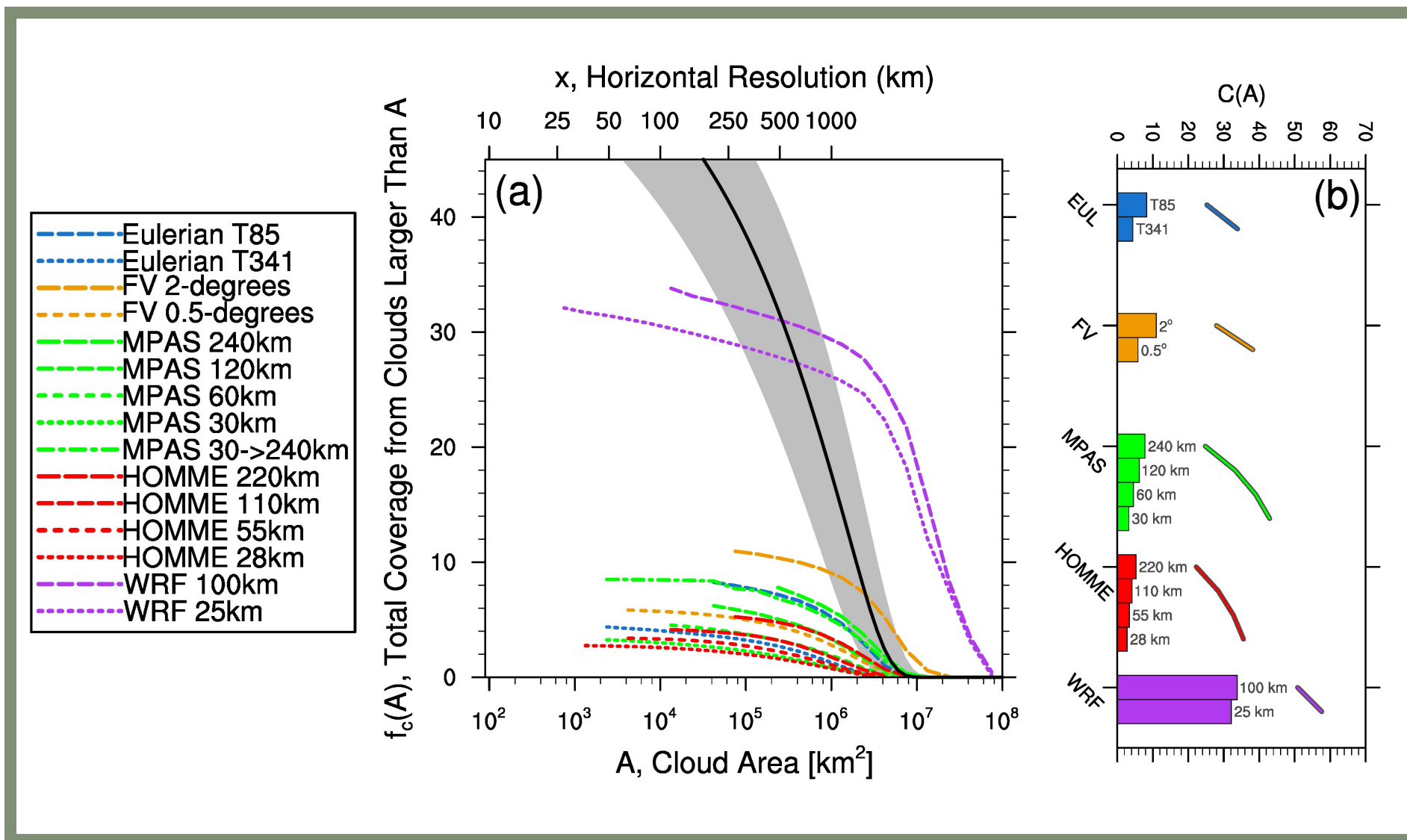


$$\bar{P}(A > A_x) = \int_{A_x}^{A_\infty} P(A) \cdot A \cdot n(A) dA$$

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



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

$$P_T = P_C + P_S$$

3 mm/day: constrained by radiative-convective equilibrium

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

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

Actual resolution dependence

~Constant with res.

Increases with increasing res.

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

Decreases with increasing res.

Decreases with increasing res.

CAM Precip. Parameterizations

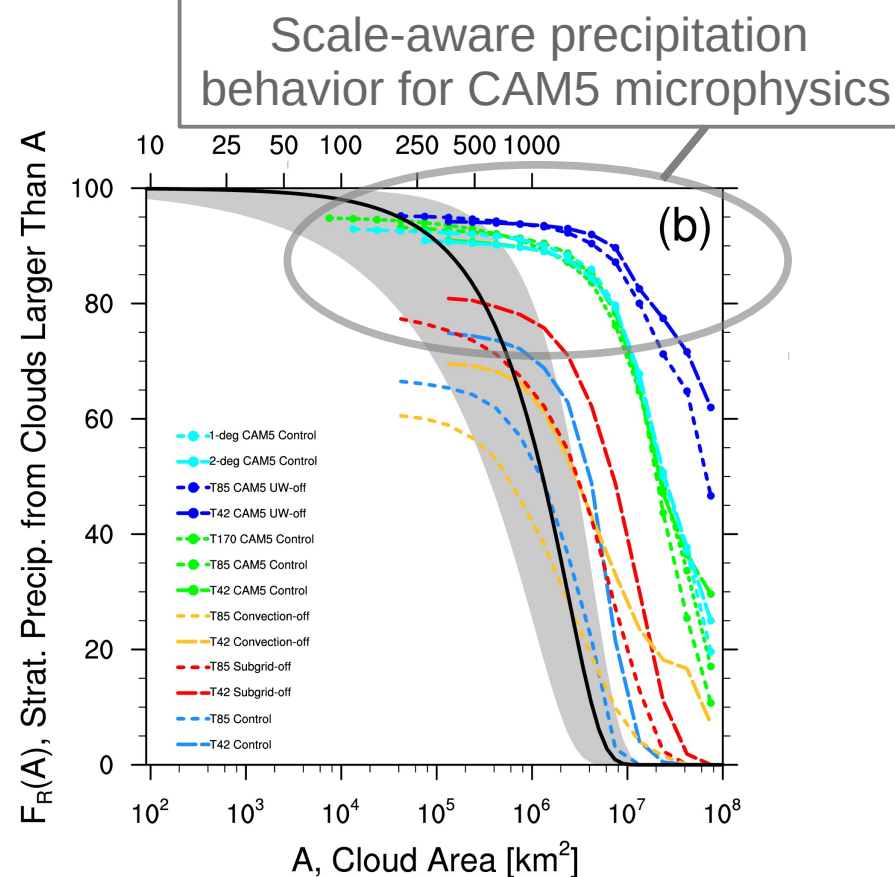
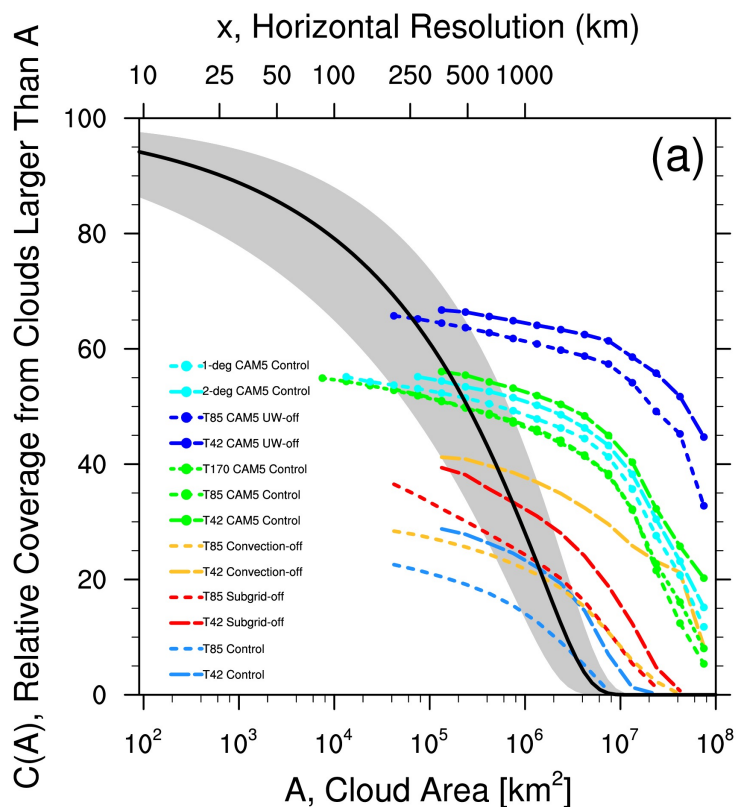
Zhang-McFarlane deep convection
&
Hack shallow convection

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

This research was supported by the Director, Office of Science, Office of Biological and Environmental Research of the U.S. Department of Energy Regional and Global Climate Modeling Program (RGCM) and used resources of the National Energy Research Scientific Computing Center (NERSC), also supported by the Office of Science of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.