Effect of Scale Coupling Frequency on Simulated Climatology in the Uncoupled SPCAM3.0

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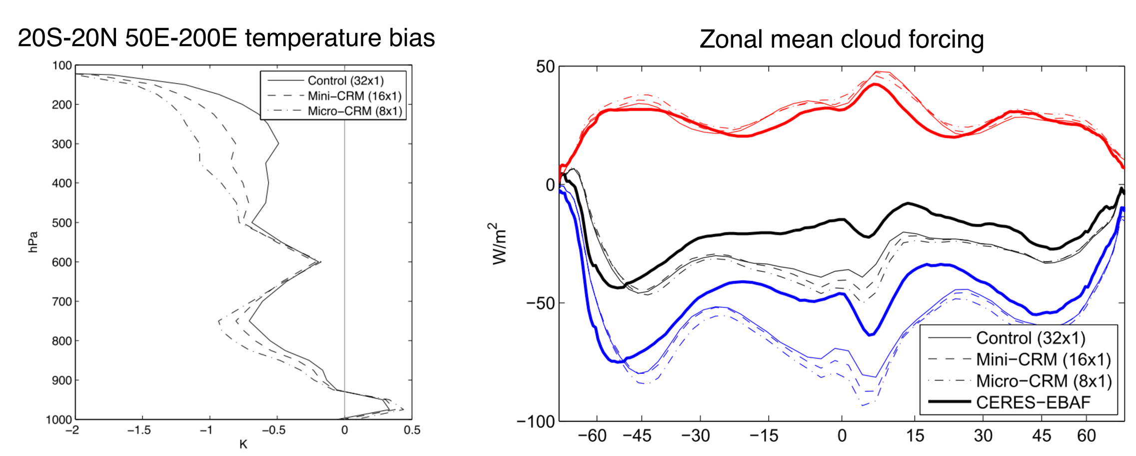
FINDINGS

1. **Scale coupling frequency (f_{scale}), at which GCM and CRM exchange information, is a useful tuning parameter.** SWCF and LWCF biases decreases with a higher f_{scale} including the Great Red Spot.
2. **The hypothesis that increased f_{scale} can compensate for throttled mixing efficiency by small CRM domains is hard to fully test due to an obscuring surface flux response.**

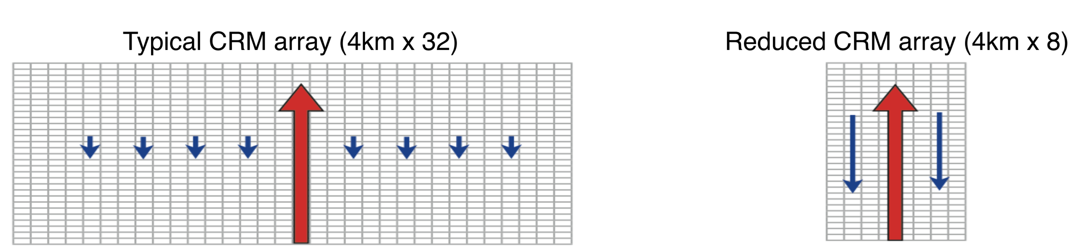
MOTIVATION

The effect of coupling frequency, f_{scale}, of SPCAM hasn't been explored yet.

Pritchard et al. (2014)* showed reduced CRM domains can desirably accelerate cloud superparameterization but at the cost of amplifying some mean state biases (e.g. cold upper troposphere, too bright liquid clouds).



The proposed mechanism was that small CRM domains artificially throttle deep convection by trapped subsidence.



Although this schematic envisions a closed CRM system, that is not true beyond the timescale of GCM-CRM coupling.

Questions:

1. Can increased scale coupling frequency (f_{scale}) mitigate small CRM climate biases by compensating for locally trapped subsidence?**
2. What are the general effects of f_{scale} on SPCAM climatology?

*: Pritchard, M. S., C. S. Bretherton, and C. A. DeMott (2014), Restricting 32- to 128-km horizontal scales hardly affects the MJO in the Superparameterized Community Atmosphere Model v.3.0, but the number of cloud-resolving grid columns constrains vertical mixing. *Journal of Advances in Modeling Earth Systems*, in press.

**: The insightful question is originally suggested by Brian Mapes.

METHOD

SPCAM Version: 3.0
CRM setup: micro-CRM (4km x 8)
Control simulation: dtime (GCM timestep, ~ 1/f_{scale}) = 1800 [s]
Experiment simulation: dtime = 600, 900, 3600 [s]
Simulation length: 10 years with 4 months of spin-up
Boundary conditions: prescribed monthly SST

LWCF, SWCF, Precipitation bias improvement

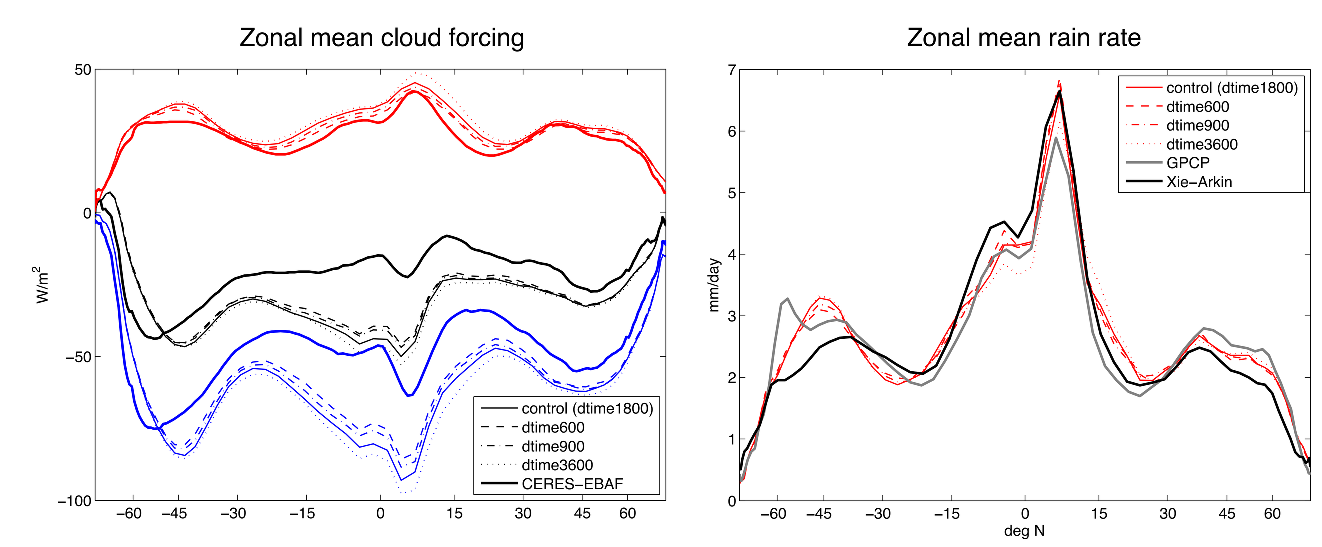
Both LWCF and LWCF biases improve with higher f_{scale}.

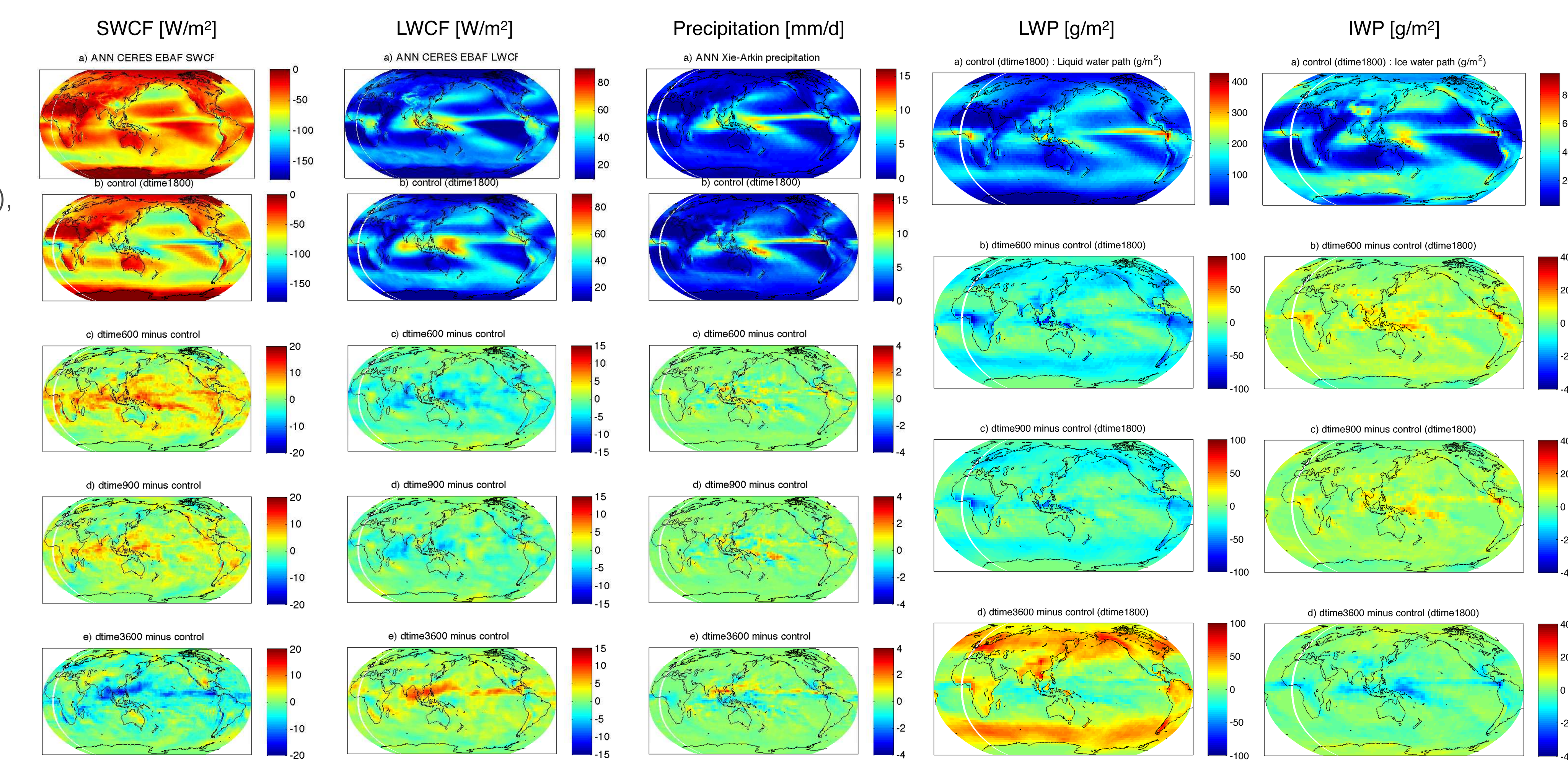
— The SWCF bias reduction is consistent with the LWP reduction.

— HOWEVER, The LWCF bias reduction is surprisingly inconsistent with IWP.

Lower f_{scale} deteriorates precipitation (e.g. amplification of the Great Red Spot), but higher f_{scale} seems to slightly improve precipitation.

The quasi-linear liquid water path reduction with f_{scale} is consistent with a positive answer to Question 1.

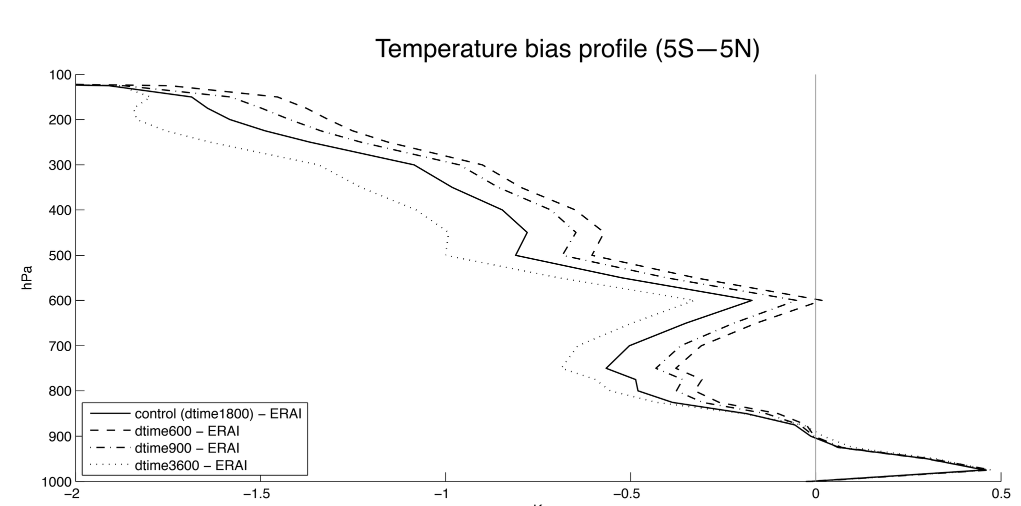


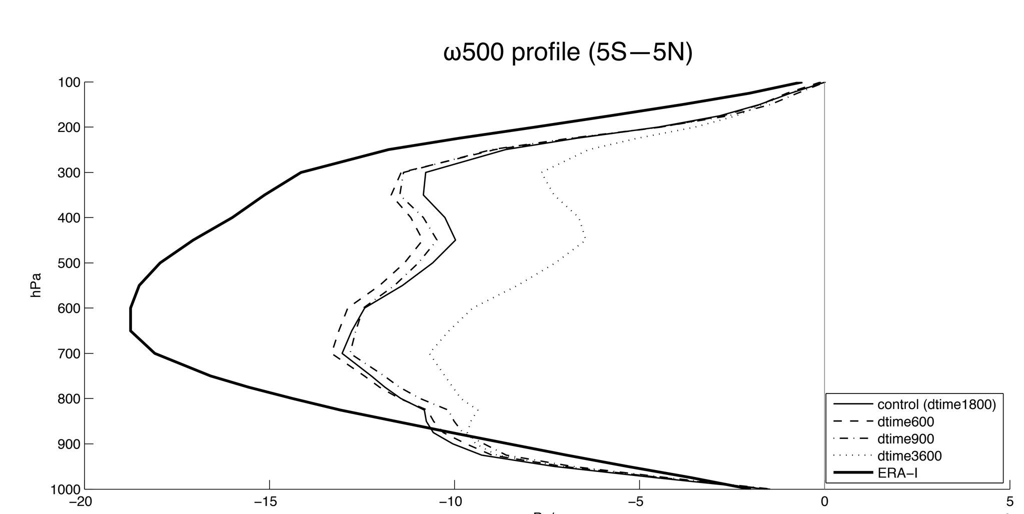


Systematic quasi-linear mid-troposphere warming

Both mid-troposphere temperature and vertical velocity increase, a slight bias reduction.

The quasi-linear warming with f_{scale} is consistent with a positive answer to Question 1.





Confounding surface heat flux responses

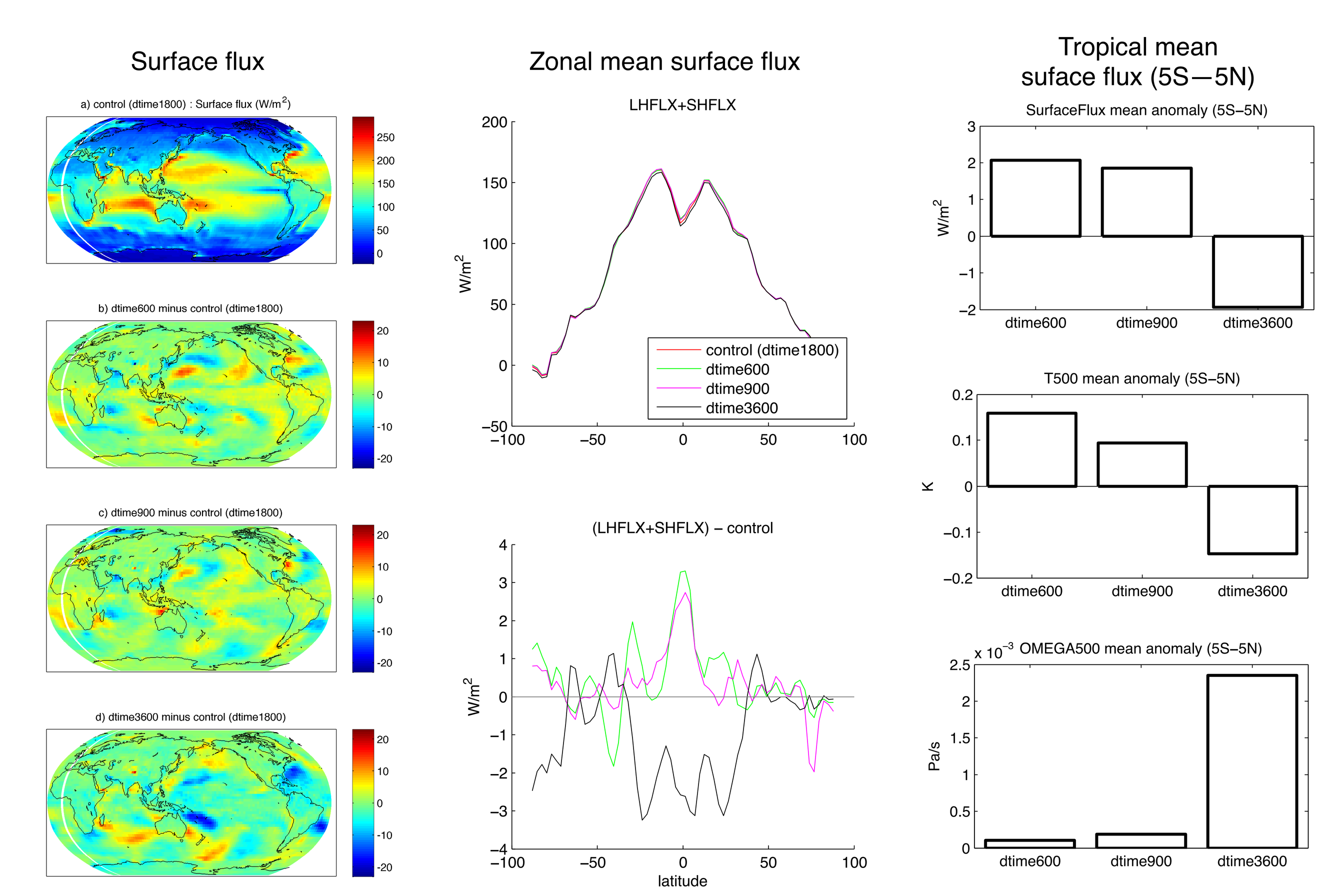
Unexpected surface flux response was observed.

Both mid-troposphere air temperature (e.g. T500) and surface flux increase with higher f_{scale} in tropics.

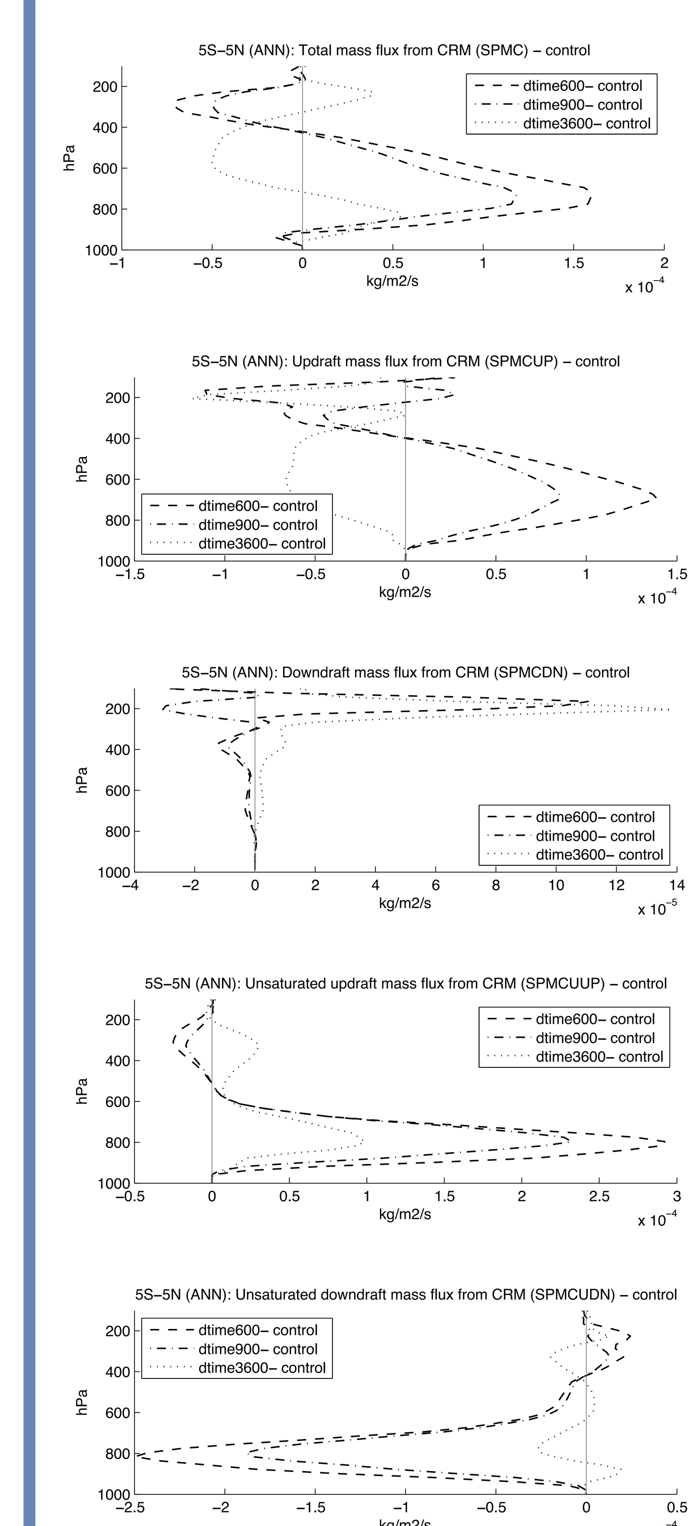
The correlation between mid-trop temperature and surface flux suggest an alternative hypothesis to explain the mid-troposphere temperature increase:

"f_{scale} compensates for throttled convective mixing"
—VS.—
"f_{scale} produces unintended surface flux feedbacks"

The alternative hypothesis seems hard to rule out. New experiments using controlled surface fluxes may be needed.



CRM Mass Flux



<Glossary> CRM: cloud resolving model GCM: general circulation model IWP: ice water path LWP: liquid water path LWCF: long wave cloud forcing ω500: vertical velocity at 500 hPa Superparameterization: a technique to improve subgrid cloud processes by replacing statistical cloud parameterization with high-resolution CRMs in GCMs
SPCAM: Superparameterized Community Atmosphere Model SST: sea surface temperature SWCF: short wave cloud forcing T500: temperature at 500 hPa