CMMAP Winter 2016 Team Meeting

More Frequent GCM–CRM Coupling Leads to More Bottom-Heavy Convection

Sungduk Yu (sungduk@uci.edu) and Mike Pritchard

Department of Earth System Science, UC Irvine

(Special thanks to Chris Bretherton, Stefan Tulich, Brian Mapes, and David Randall)

Going back to 2015 winter team meeting

SPCAM3.0 with prescribed SST

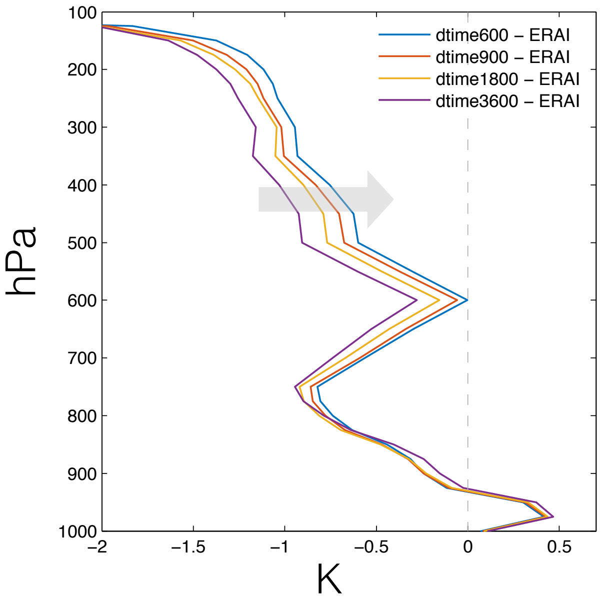
Simulation	dtime600	dtime900	dtime1800	dtime3600
Time step (s)	600	900	1800	3600
f_{scale} (1/h)	6	4	2	1

Higher “scale coupling frequency (f_{scale})”

Striking quasi-linear thermal and SWCF responses to increased scale coupling frequency

[Yu and Pritchard (2015)]

Temperature bias profile

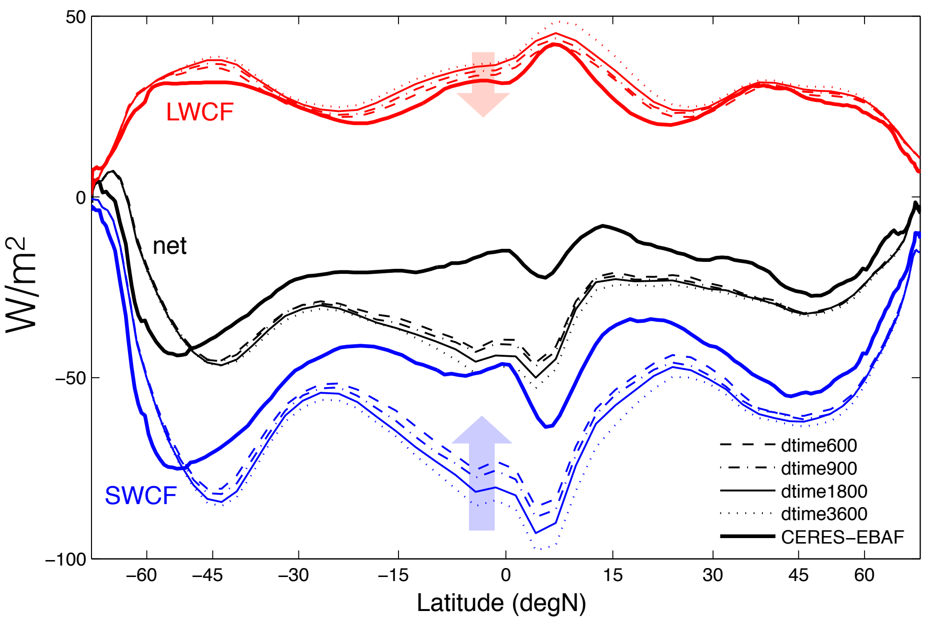


Mid-troposphere warming

low f_{scale} (dtime3600)

high f_{scale} (dtime600)

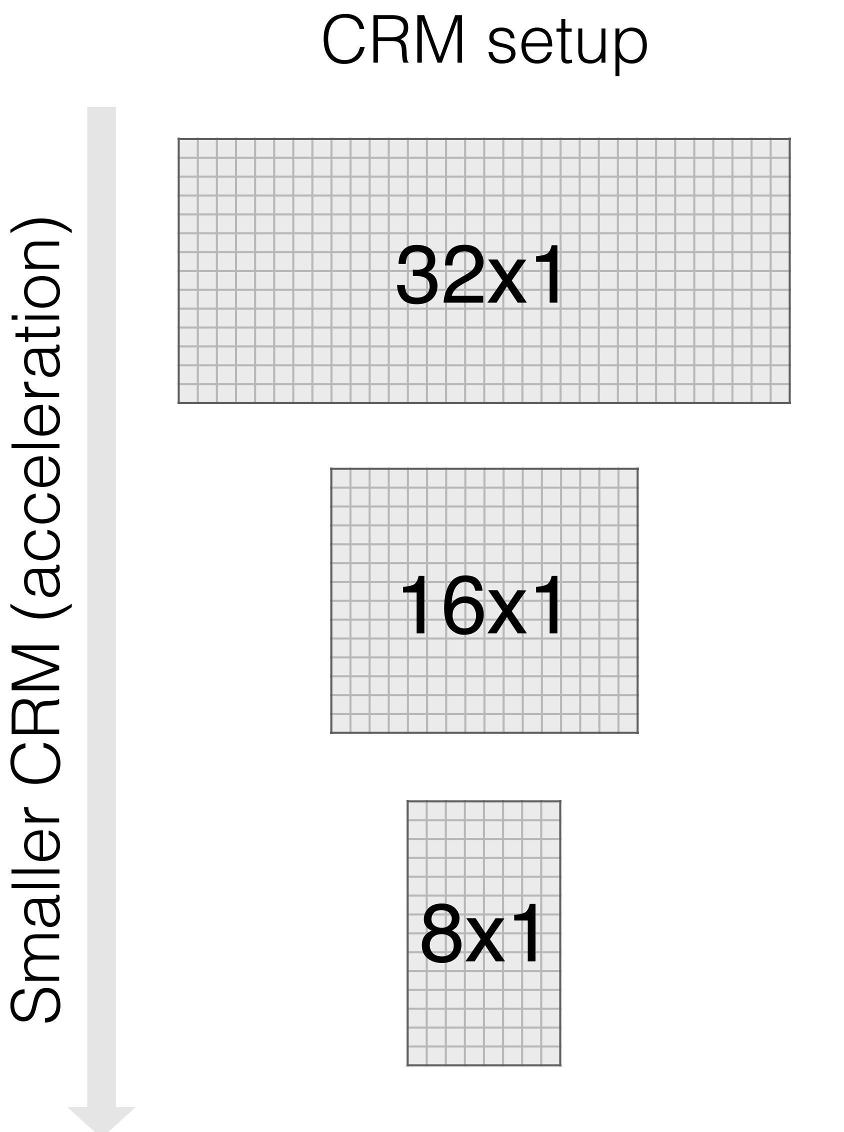
Zonal mean cloud forcing

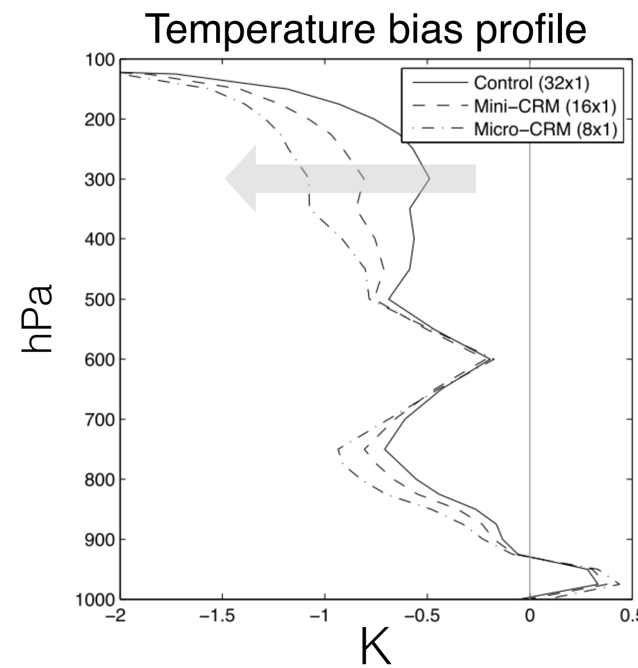


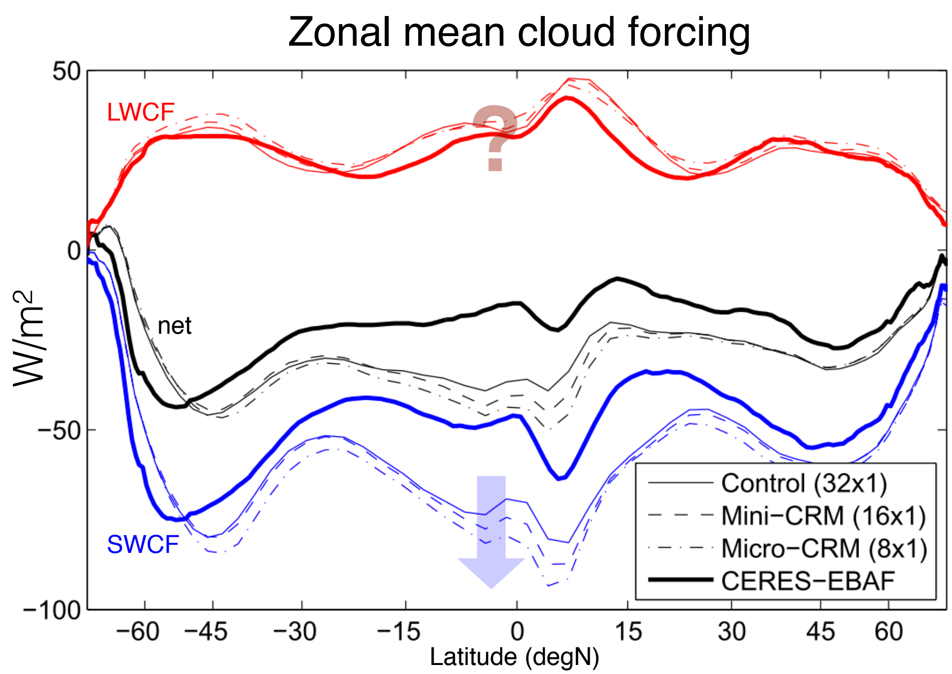
SWCF weakening

LWCF weakening

Reversing key biases introduced by reduced CRM domain





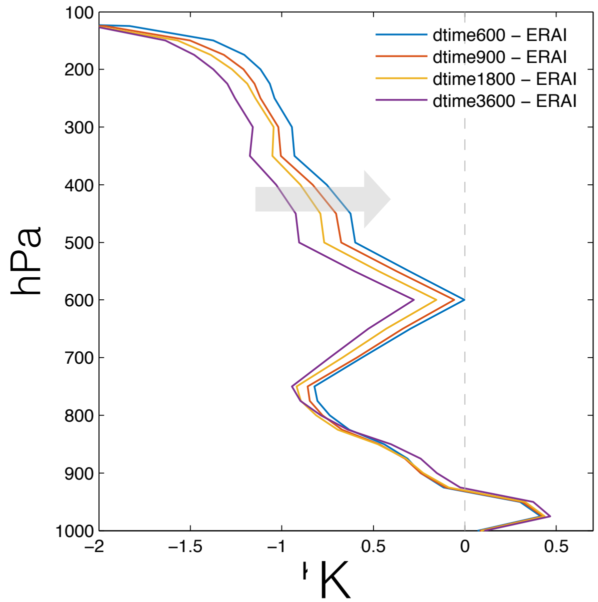


[Pritchard, Bretherton, and DeMott (2014)]

Reversing key biases introduced by reduced CRM domain

[Yu and Pritchard (2015)]

Temperature profile



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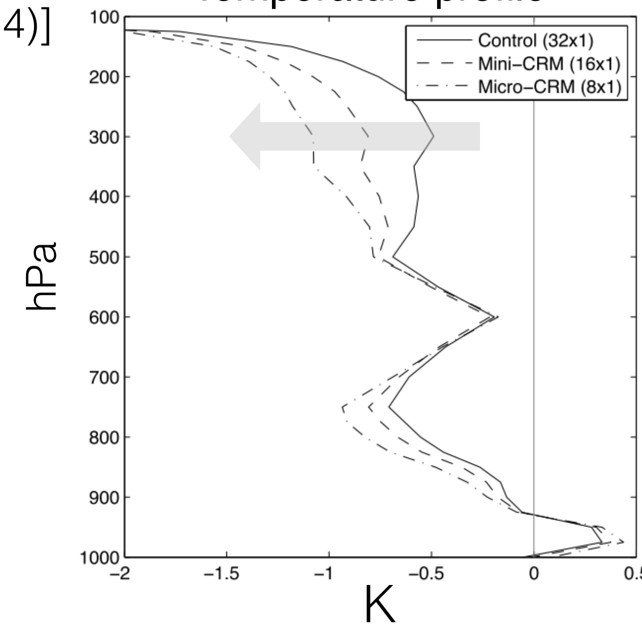
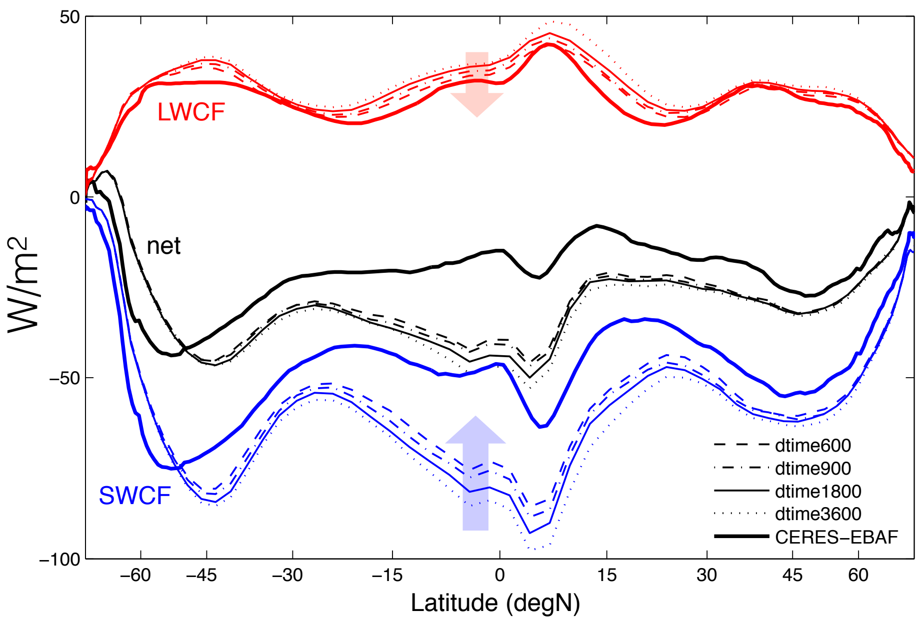
Temperature profile



Zonal mean cloud forcing



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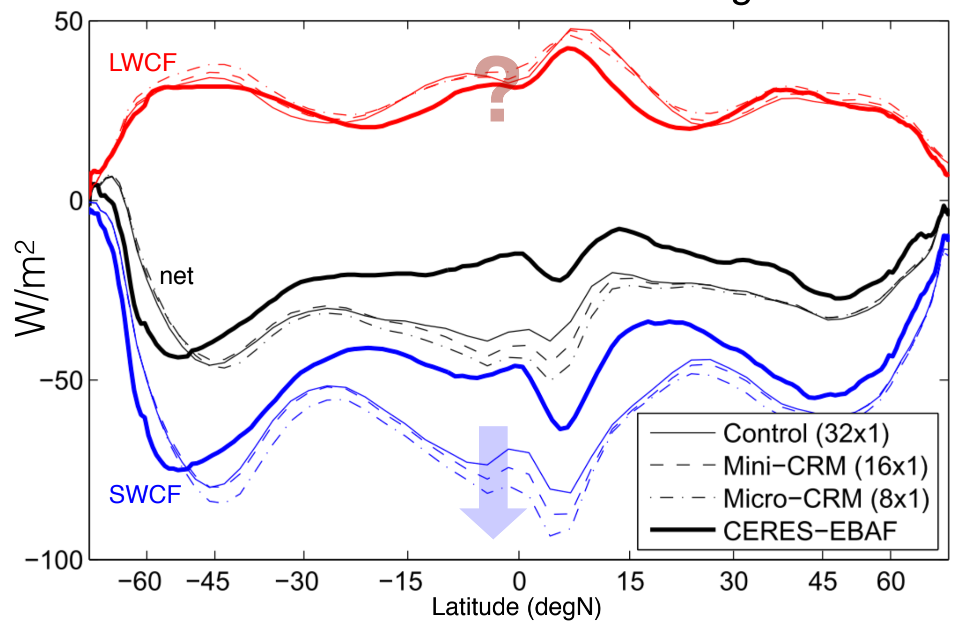
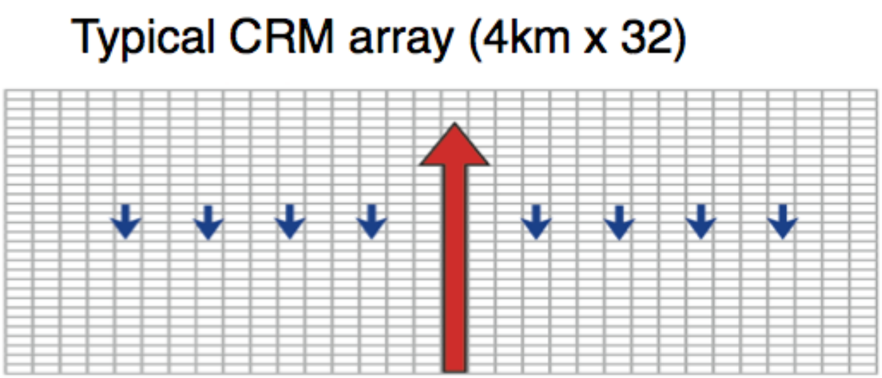
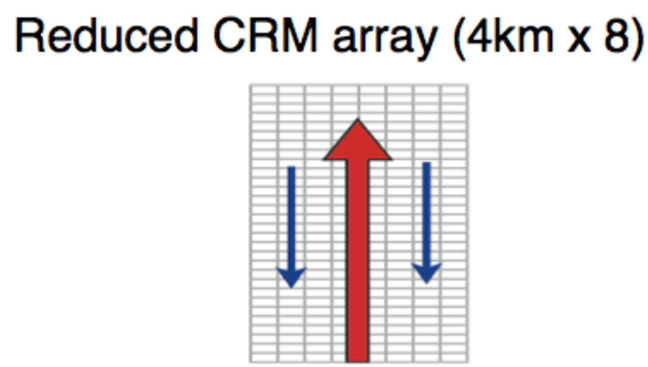


CRM throttling is only an artifact within a single time step

Pritchard, Bretherton, and DeMott (2014)'s hypothesis:

Artificially throttled deep convection by trapped subsidence





Reduced CRM domain
-> stronger subsidence
-> preventing ventilation
-> too much liquid cloud
-> too strong SWCF

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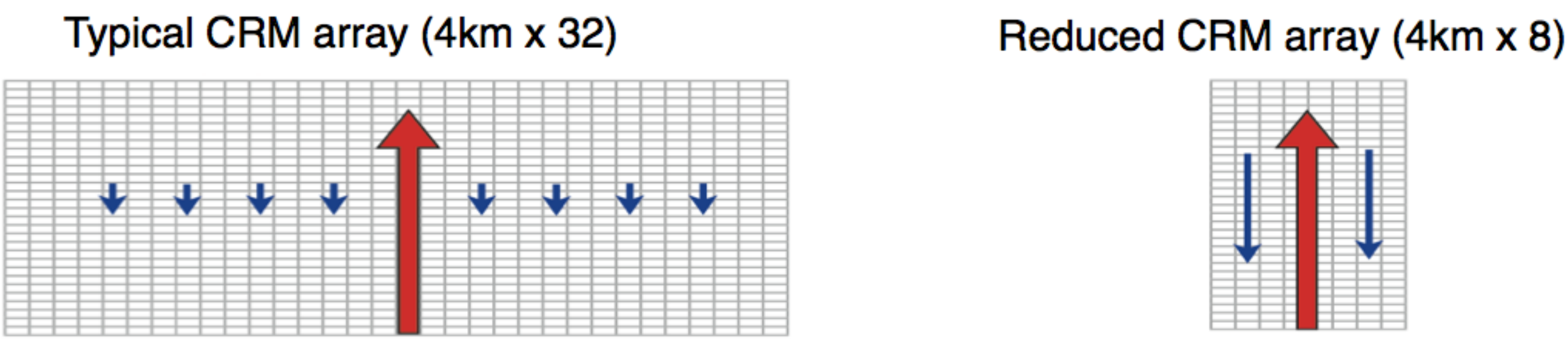


CRM is not a closed system

This artifact is corrected by GCM's large scale dynamics

More frequent scale coupling → more ventilation → less liquid cloud

Our very first hypothesis:
high f_{scale} —> unwinding convective throttling

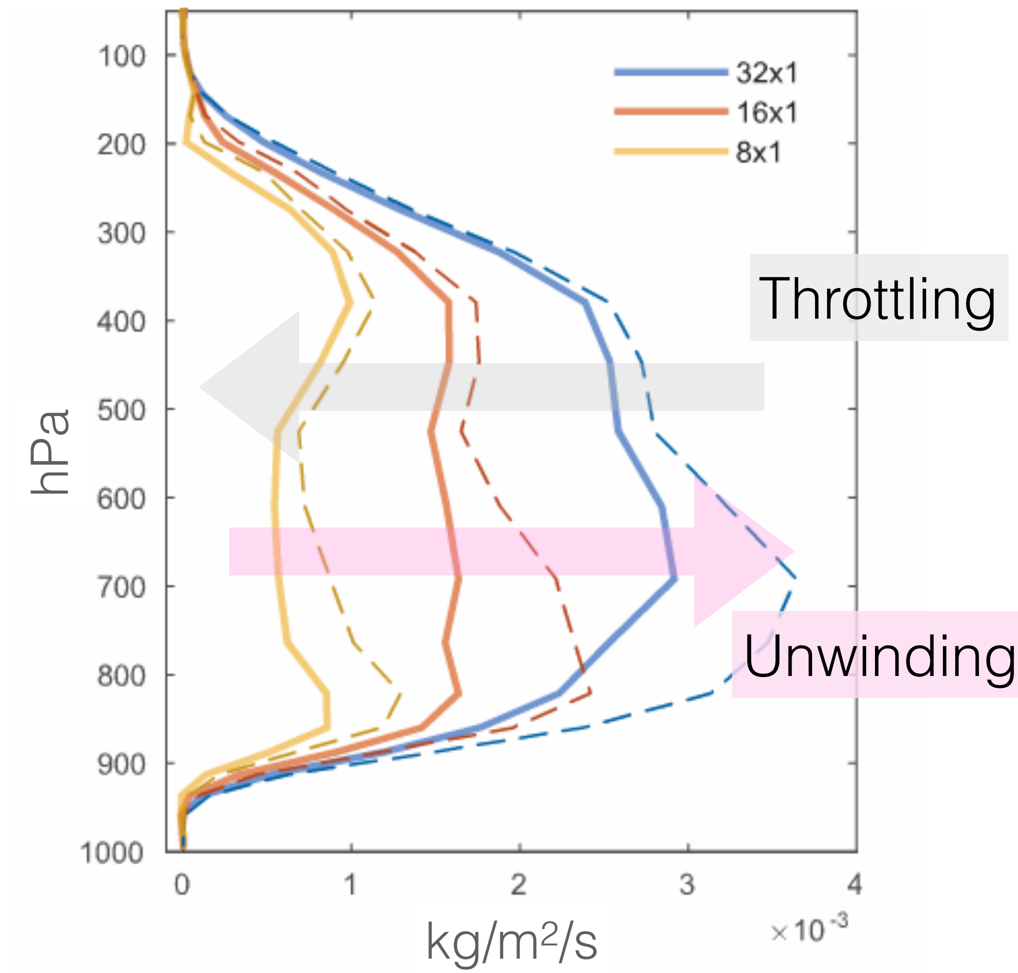
Now, we doubt our previous hypothesis.

Inconsistent response (1): updraft mass flux

Expectation from the convective throttling hypothesis (f_{scale}↑):

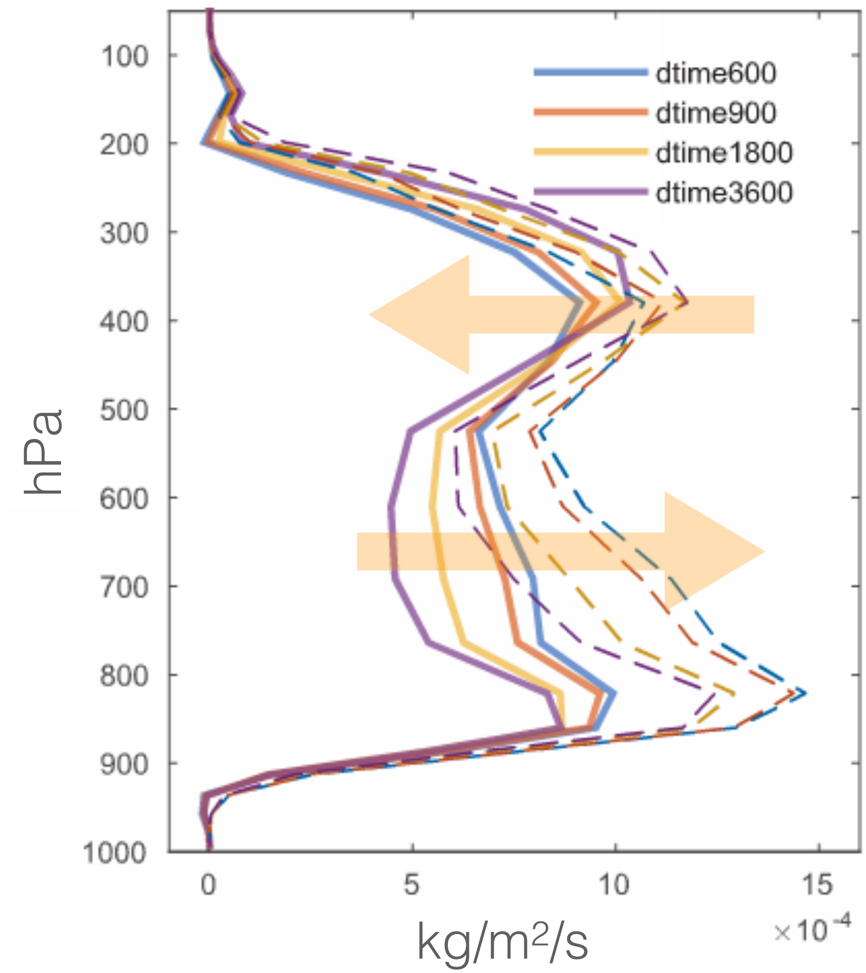
Boosting mass flux at all levels

[Pritchard, Bretherton, and DeMott (2014)]



Inconsistent response in updraft mass flux

[Yu and Pritchard (2015)]



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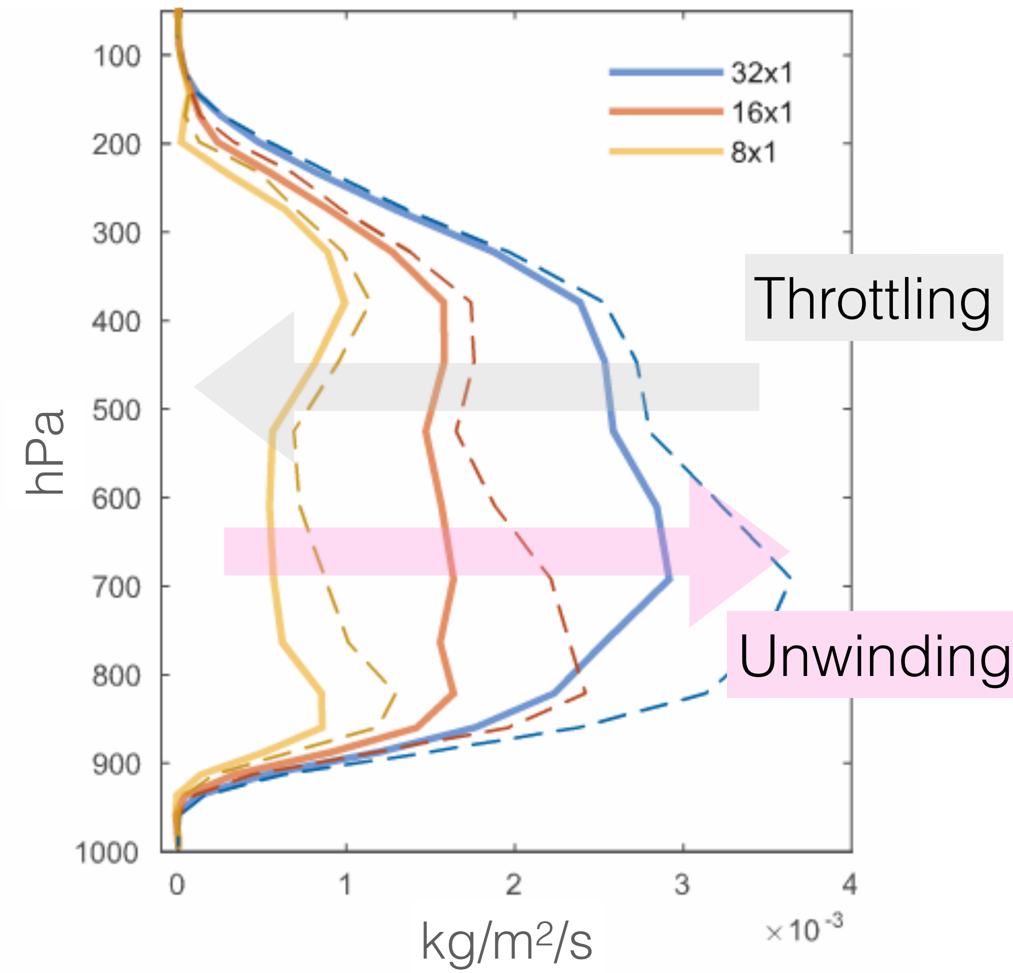
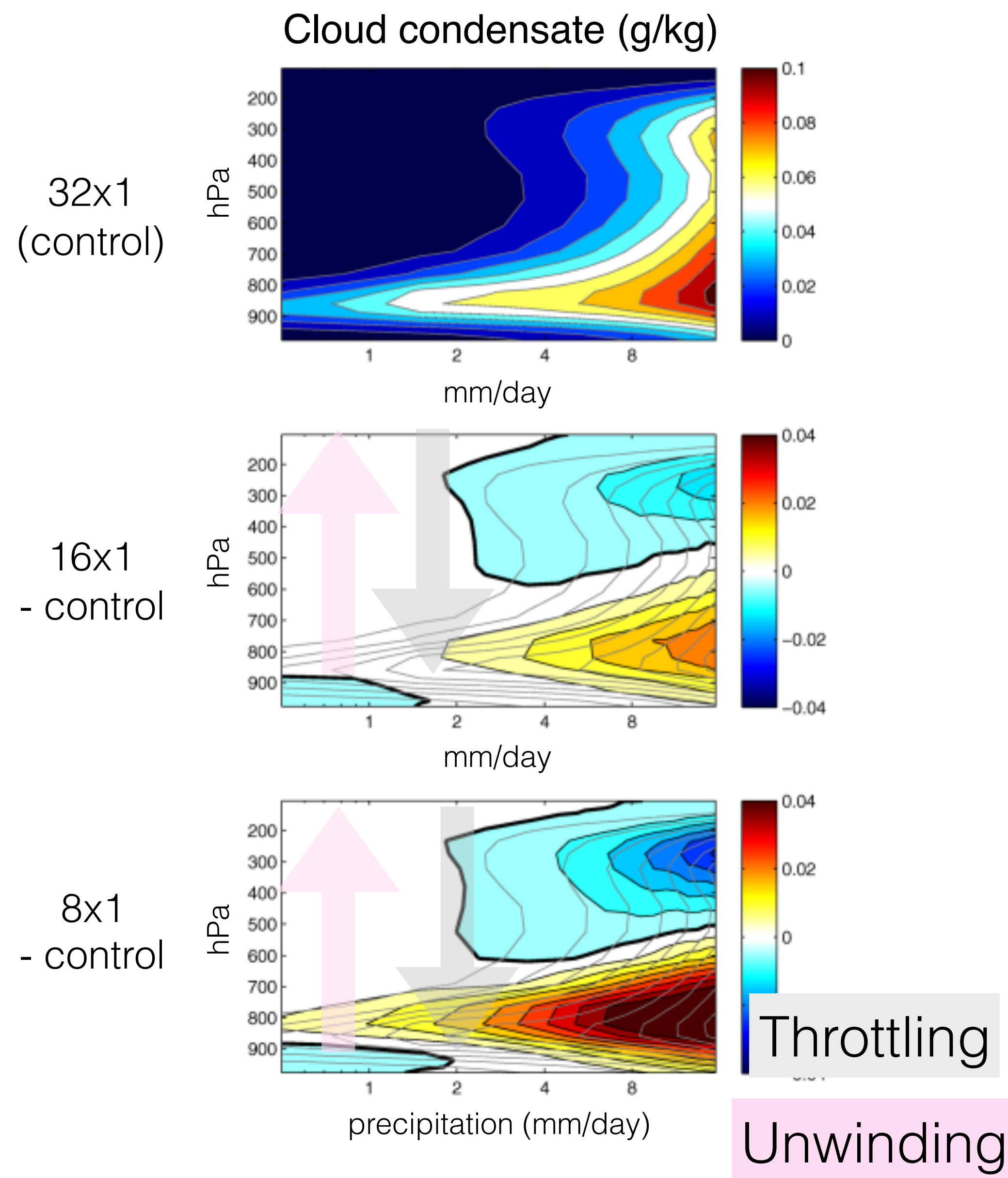


Convection becomes bottom-heavy

Inconsistent response (2): cloud water profile

Expectation from the convective throttling hypothesis ($f_{\text{scale}}\uparrow$):

Shift of cloud water towards upper troposphere



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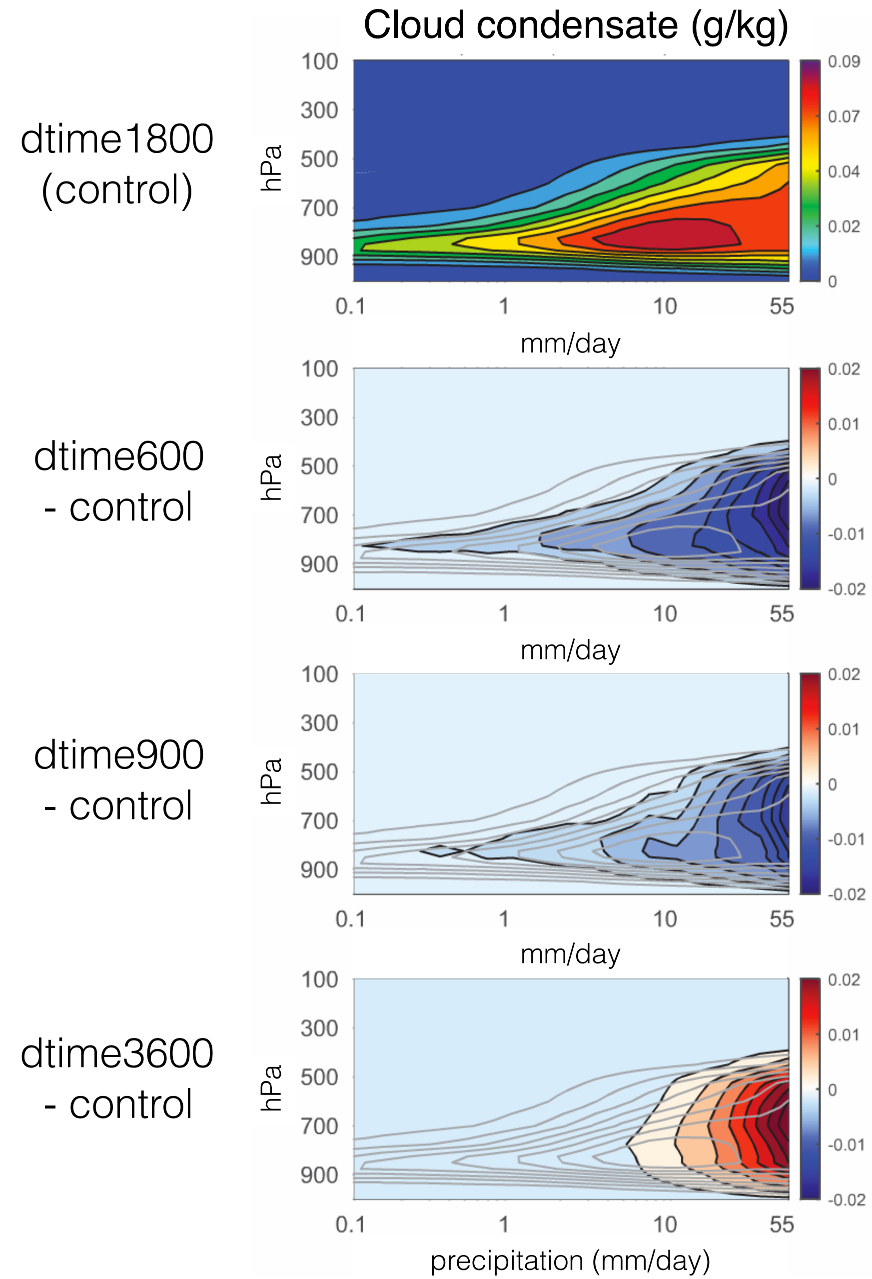

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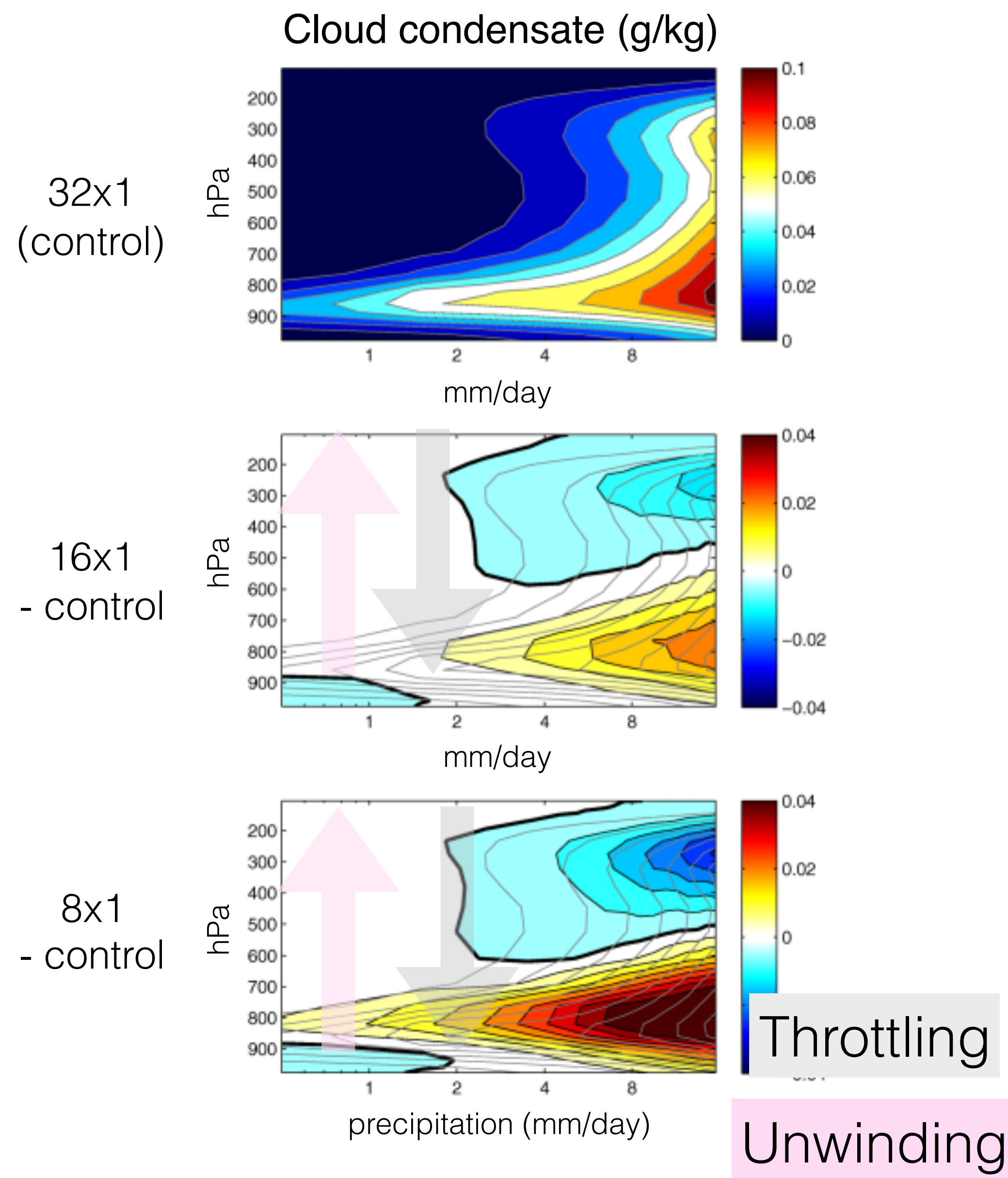

Inconsistent response (3): precipitation tail

Expectation from the convective throttling hypothesis (f_{scale}↑):

Reduced extreme precipitation tail

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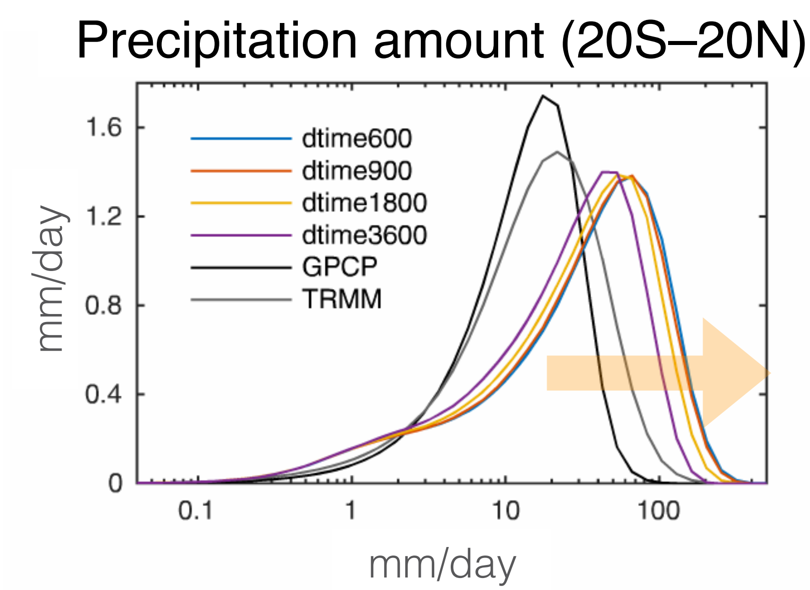

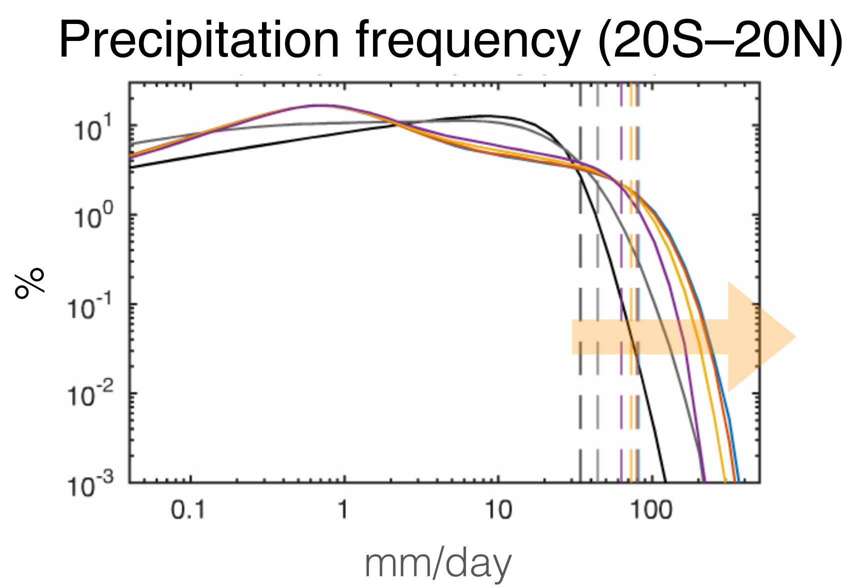

Why does faster scale coupling make convection more bottom-heavy?

Convection – Large scale wave interaction?

The Wavelength Dependence of the Gross Moist Stability and the Scale Selection in the Instability of Column-Integrated Moist Static Energy

ZHIMING KUANG

[2011]

Large-scale gravity wave with a single zonal wavenumber

$$\{\varepsilon[\overline{\rho}w'(x_0, z, t)]_z\}_z = -k^2\frac{\overline{\rho}g}{\overline{T}}T'(x_0, z, t).$$

CSRM (at $x=x_0$)

$$T'_t + w'\left(\frac{d\overline{T}}{dz} + \frac{g}{c_p}\right) = S'_T$$

$$q'_t + w'\frac{d\overline{q}}{dz} = S'_q$$

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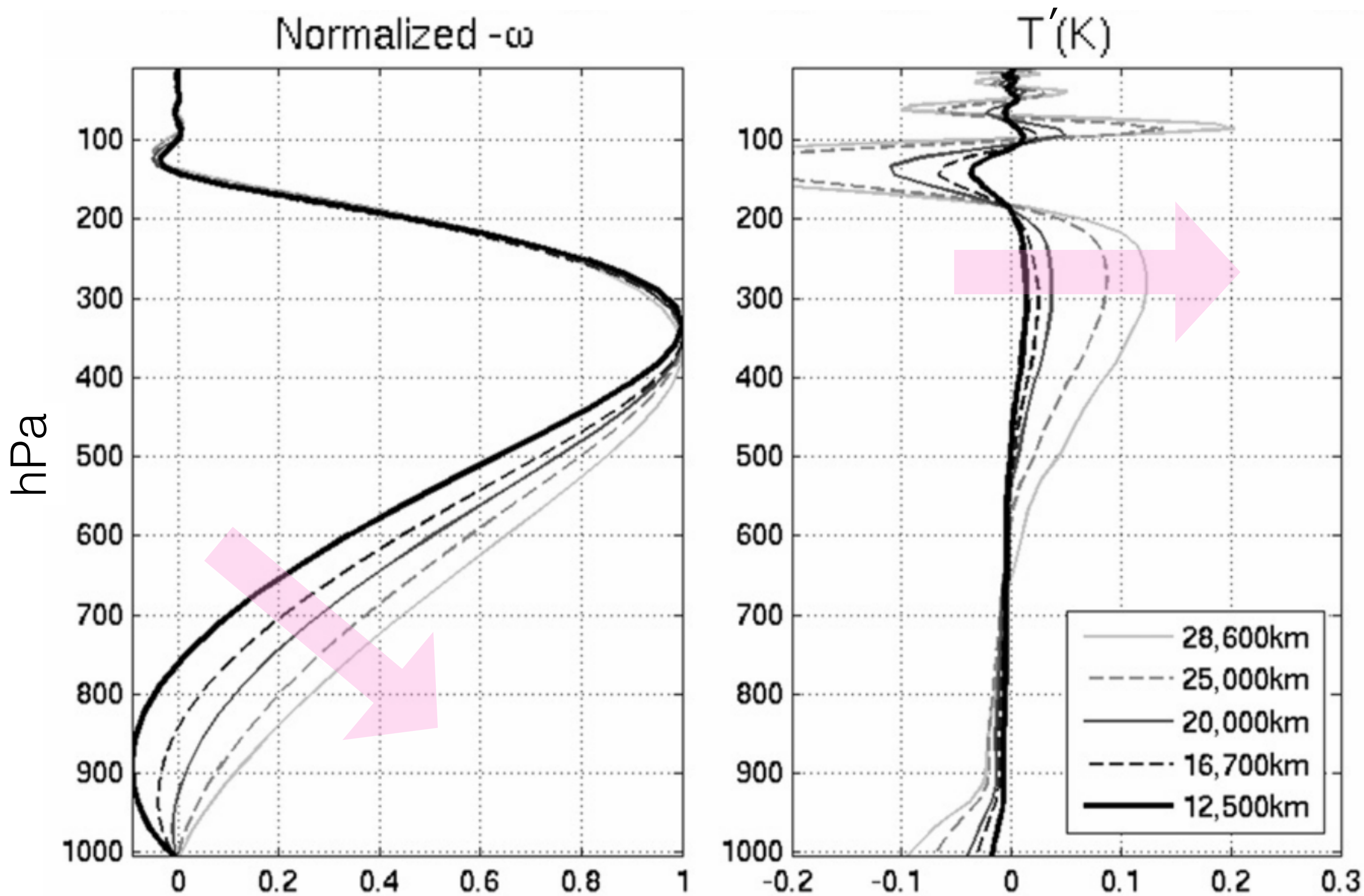
“ At long wavelengths, the required temperature anomalies become sufficiently strong to affect the shape of convective heating.” [Kuang, 11]

$$\{\varepsilon[\bar{\rho} w'(x_0, z, t)]_z\}_z = -k^2 \frac{\bar{\rho} g}{\bar{T}} T'(x_0, z, t).$$

$$k \uparrow \implies T' \downarrow$$

$$k \downarrow \implies T' \uparrow$$



Initially, we wondered about K11-like behavior at high f_{scale}

	[Kuang (2011)]	[Yu and Pritchard (2015)]
CRM	3D SAM (Δx=2km)	2D SAM (Δx=4km)
L.S. model	a single wave with a fixed k	GCM
L.S.–CRM Coupling	instantaneous	limited by f_{scale}

Initially, we expected K11-like behavior at high f_{scale}

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With more frequent scale coupling,
SPGCM may behave like K11 ??

e.g. Higher f_{scale} → Bottom-heavy convection

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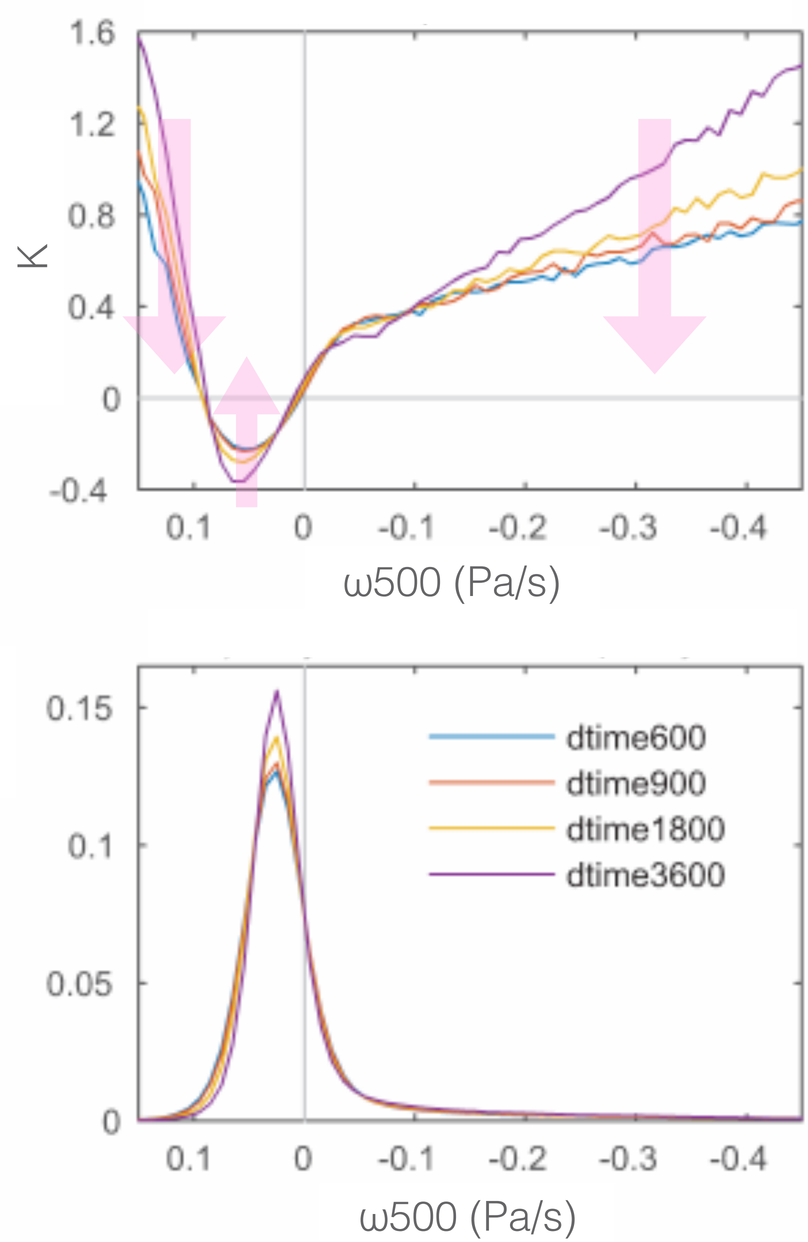
How to test?

Larger T anomalies with a higher f_{scale}? But…

Opposite sensitivity: better WTG with high f_{scale}

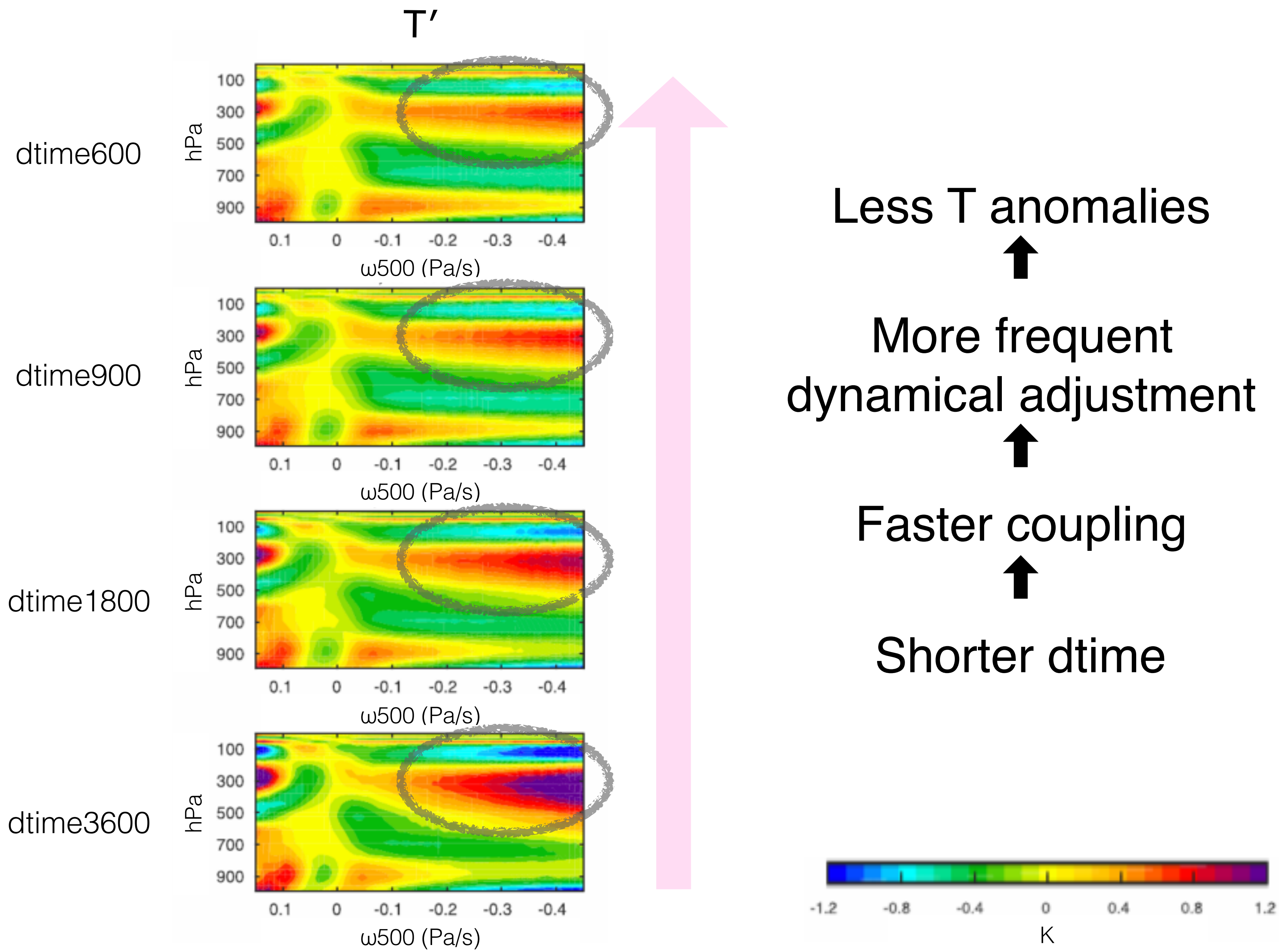
T300′

Daily ω500
relative frequency



$T'\omega < 0$

WTG conformity seems from dynamical adjustment



Less T anomalies

⬆

More frequent dynamical adjustment

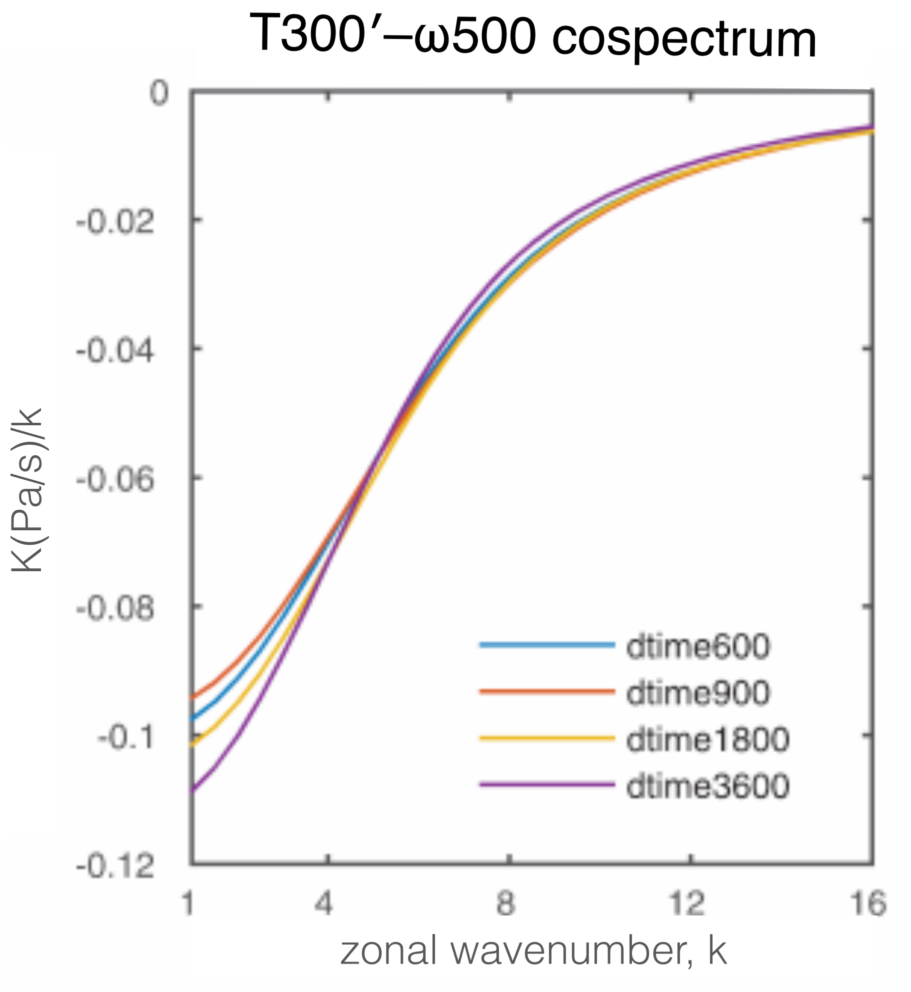
⬆

Faster coupling

⬆

Shorter dtime

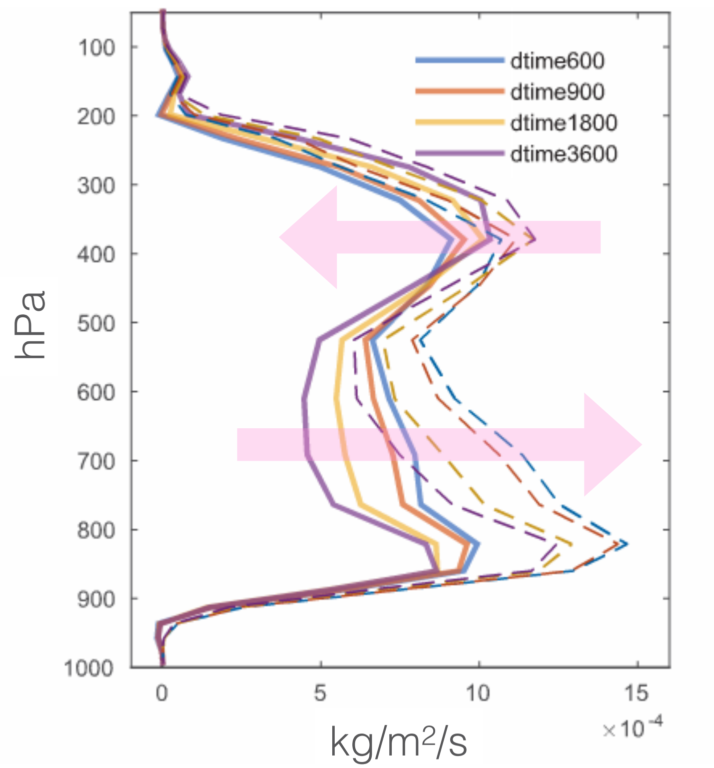
Large-scale waves are still relevant



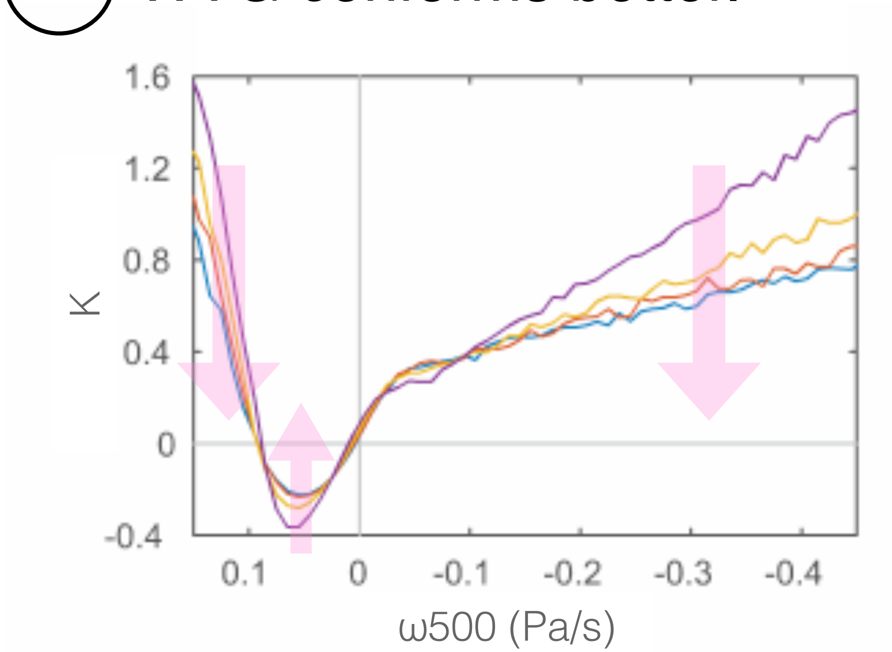
Scale coupling frequency changes the character of convective organization, but we still don't know why

With faster coupling between GCM and CRM,

1 Convection becomes more bottom-heavy.



2 WTG conforms better.



3 Cloud forcing biases decrease.

4 Precipitation tail amplifies.

For further details, see
Yu and Pritchard, *JAMES*, 2015.

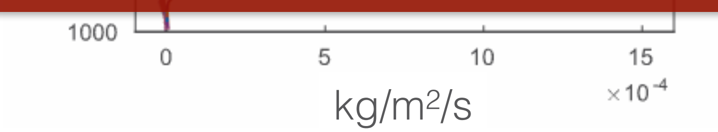
Scale coupling frequency changes the character of convective organization, but we still don't know why

With faster coupling between GCM and CRM,

1. Convection becomes more bottom-heavy.
2. WTG conforms better.

- **Something artificial (scale coupling frequency or time step) influence something really important in tropical dynamics (vertical structures)**

- **Maybe, 'scale coupling frequency' can be used to design experiments to see the effect of altering convective organization to planetary scale phenomena**



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