CMMAP Winter 2015 Team Meeting

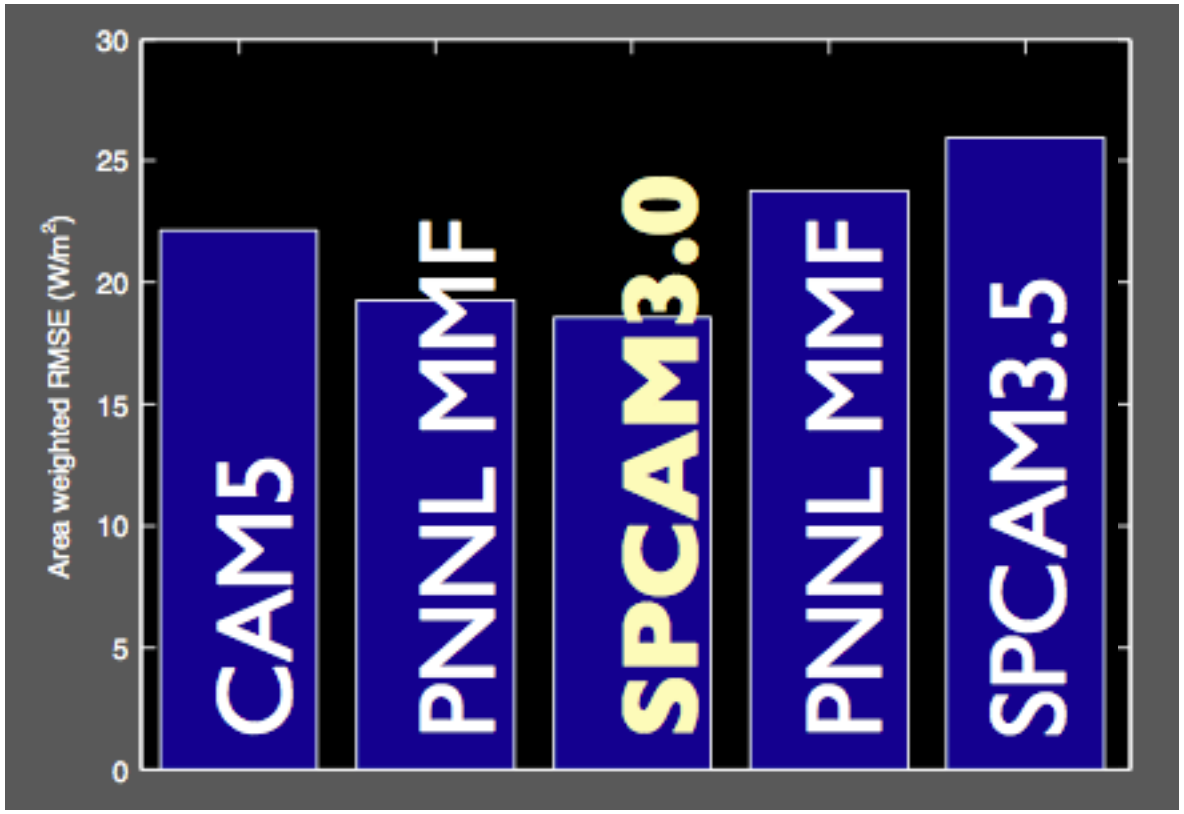
# Effect of Scale Coupling Frequency on Simulated Climatology in the Uncoupled SPCAM 3.0

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

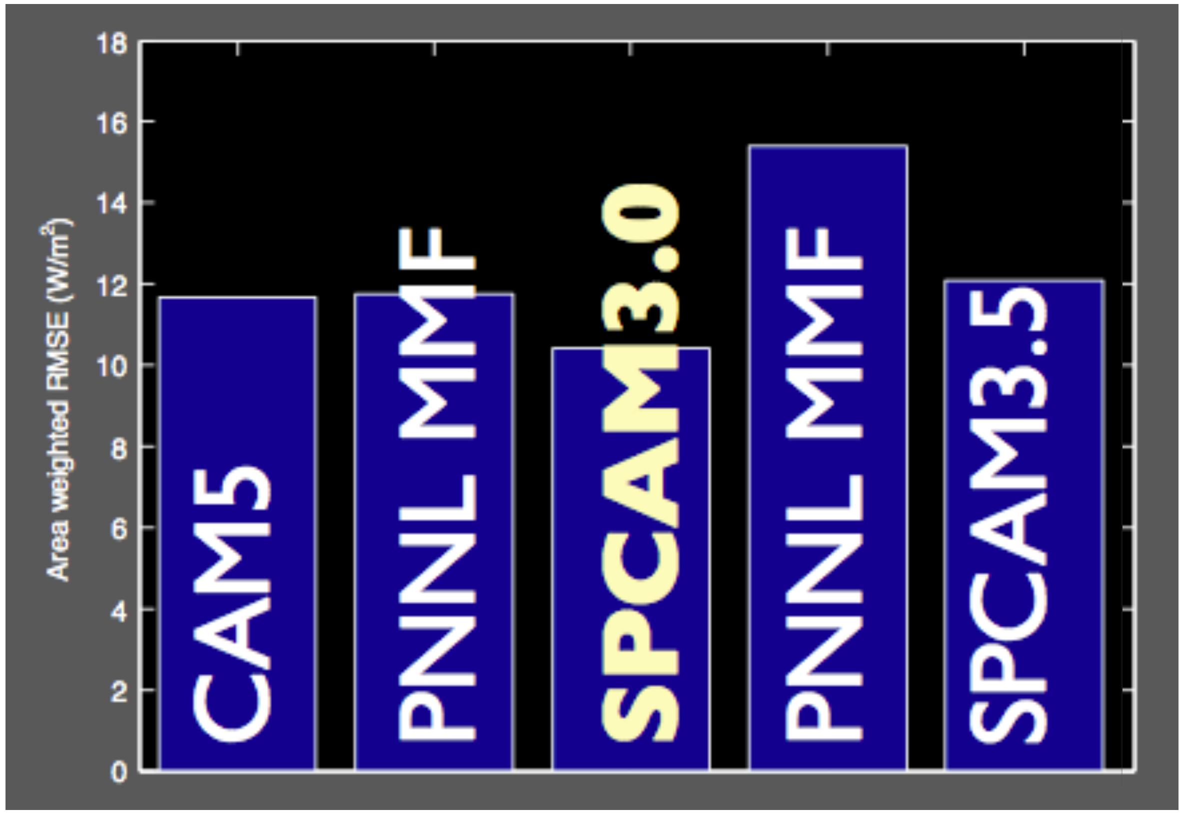
(Special thanks to Gabe Kooperman and Brian Mapes)

# Most versions of SP models have not been optimally tuned

DJF SWCF RMSE



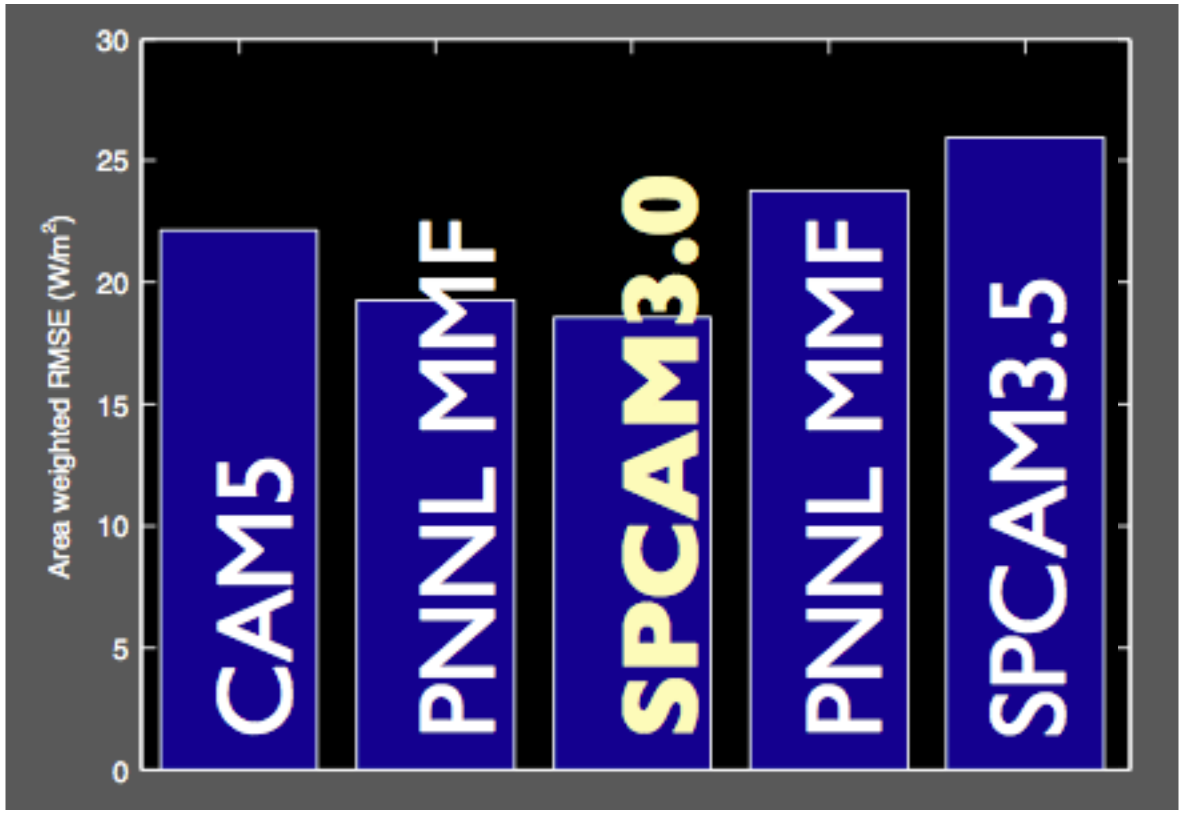

DJF LWCF RMSE



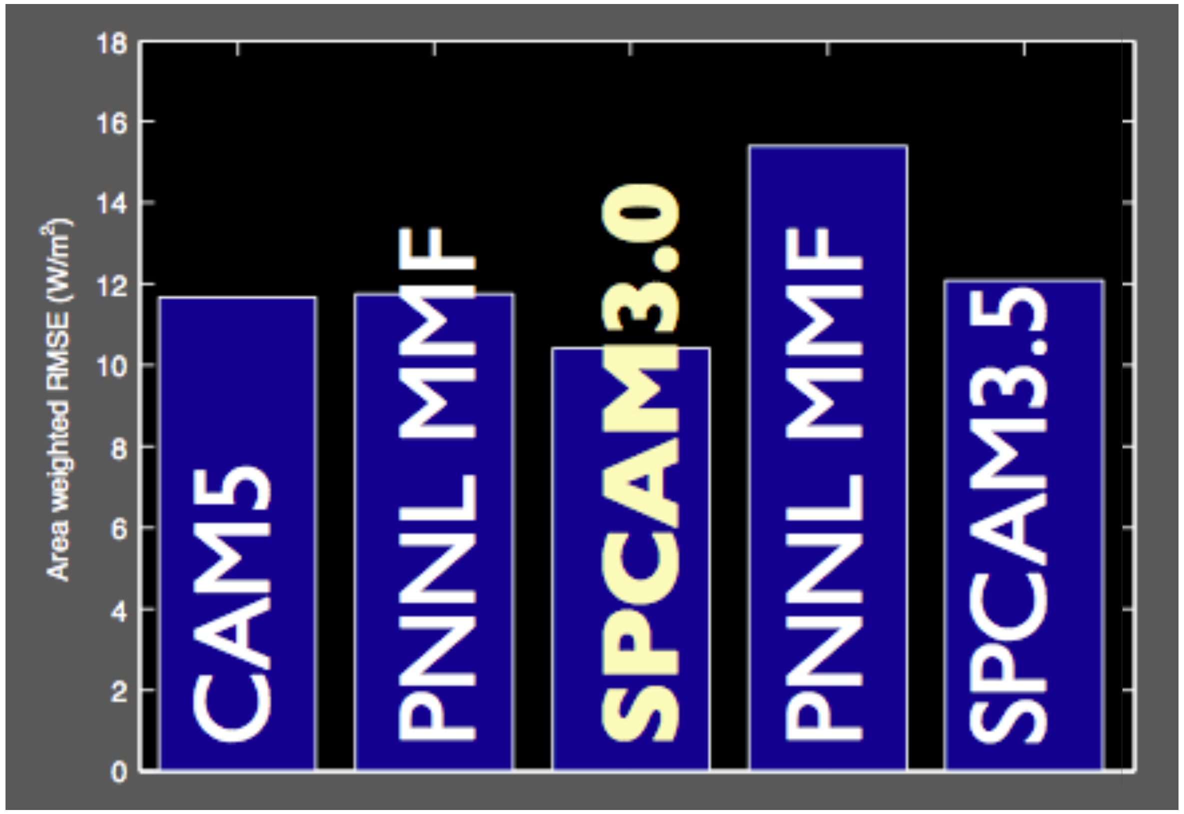

(Pritchard, CMMAP Team Meeting, 2012 August)

# Most versions of SP models have not been optimally tuned

DJF SWCF RMSE




DJF LWCF RMSE




(Pritchard, CMMAP Team Meeting, 2012 August)

SPCAM3.0 is surprisingly well-tuned

A newer model ≠ a better tuned model

# Tuning is increasingly important for existing and emerging SP models

**SP models are getting more useable**:

- several promising versions already exist
- computational resources keep expanding
- acceleration techniques are being suggested

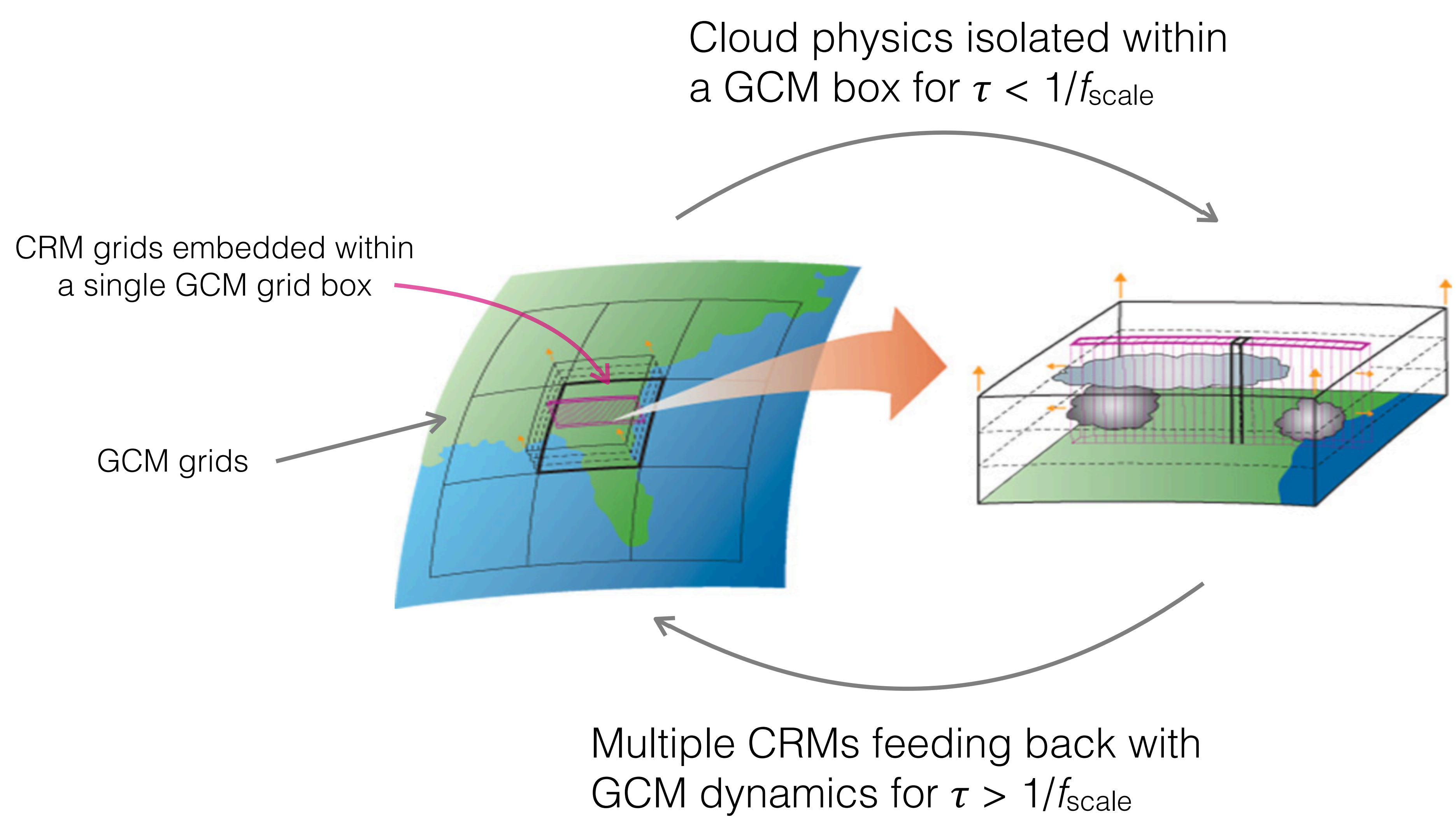
  e.g. reduced CRM set up (Pritchard, Bretherton, and DeMott, 2014)
  time scale separation (Jones, Bretherton, and Pritchard, 2014)

- UP (ultra-parameterization) models are under development

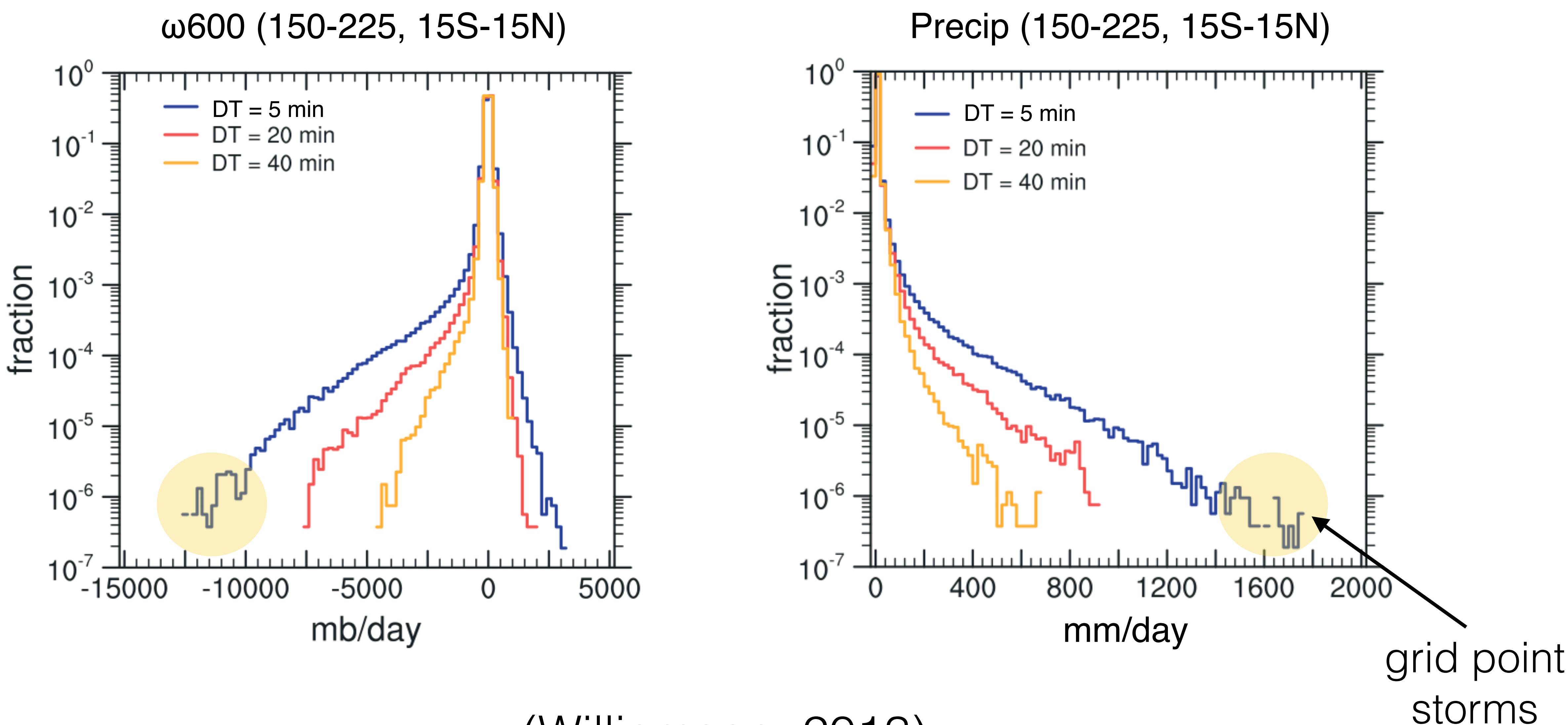
**It's unclear what are tuning knobs in SP models**

# Scale coupling frequency as a tuning parameter in SP models?

Scale coupling frequency ($f_{\text{scale}}$) ~ 1/(timestep of GCM)



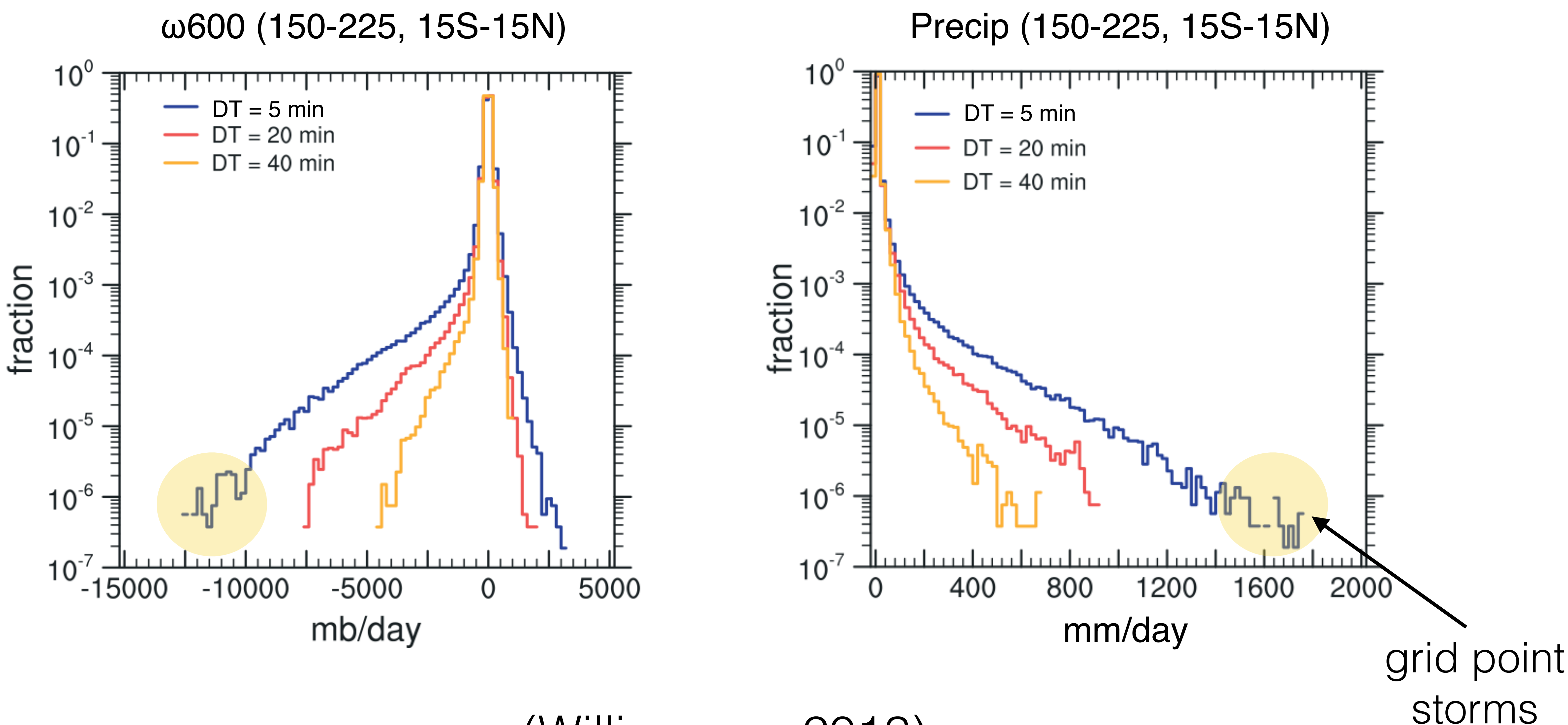
# Model timestep known to be important in GCMs




(Williamson, 2013)

CAM4
T340 resolution
dtime: 5, 20, 40 min

# Model timestep known to be important in GCMs

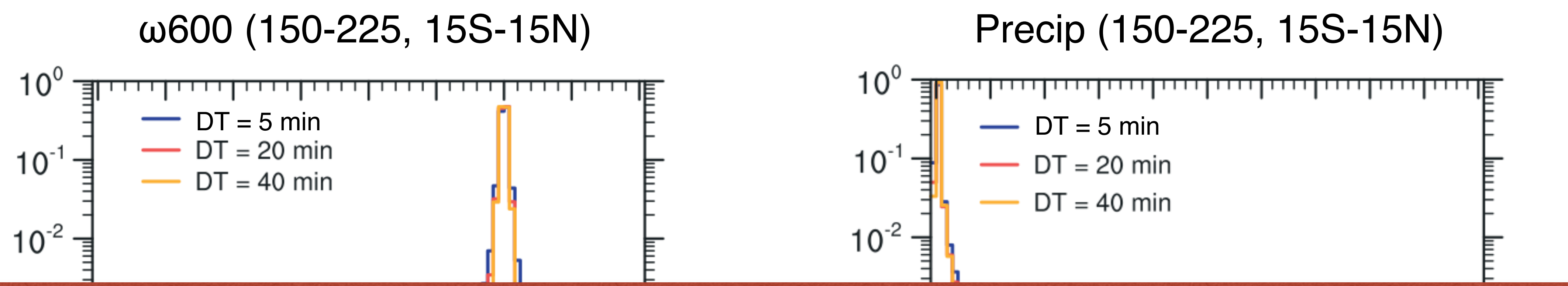



(Williamson, 2013)

GCM Δt >> $\tau$ of deep/shallow convective parameterizations
(5min) (60min and 30min)

==> excessive precipitation (e.g. grid point storms)

# Model timestep known to be important in GCMs




What about in SP models?

grid point storms

(Williamson, 2013)

GCM Δt >> $\tau$ of deep/shallow convective parameterizations
(5min) (60min and 30min)

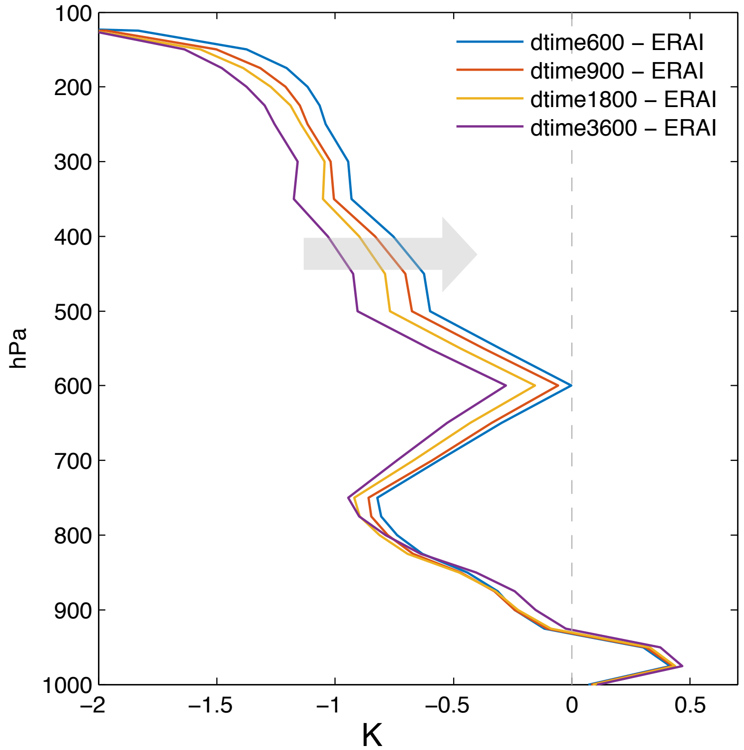
==> excessive precipitation (e.g. grid point storms)

# Simulation setup

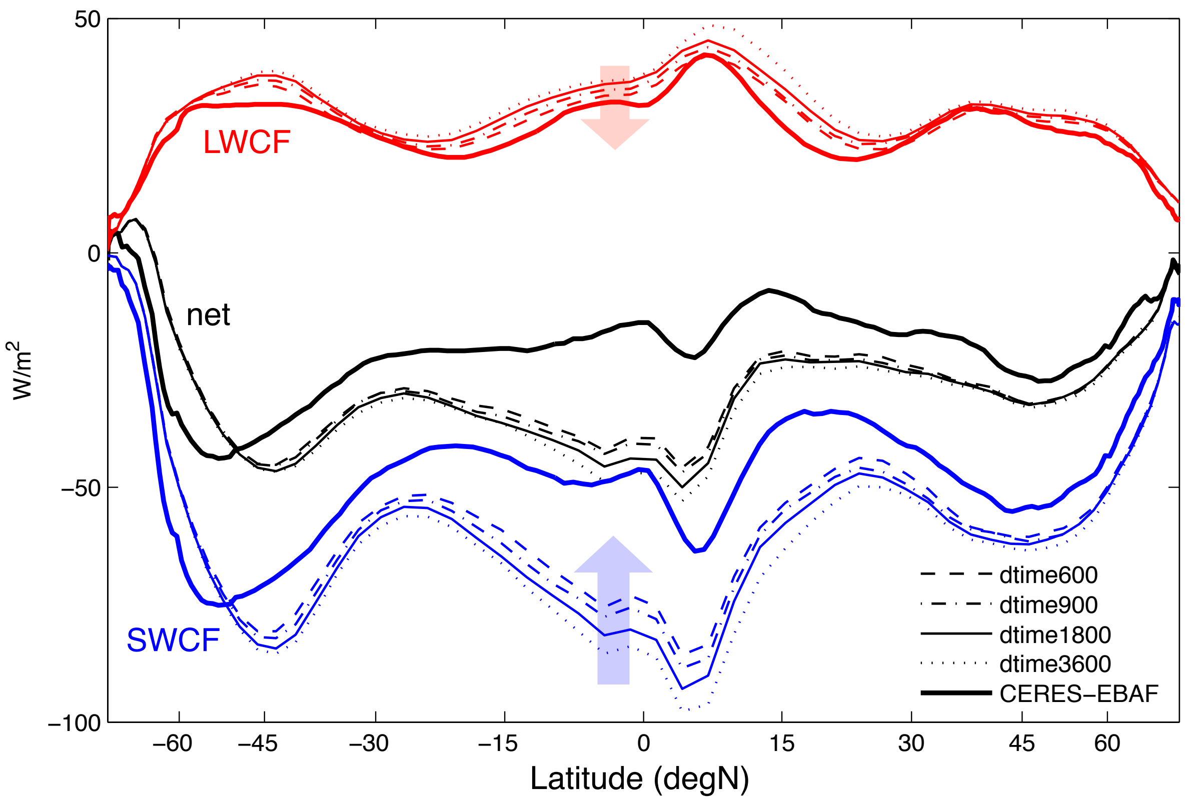
| | |
|---|---|
| Model: | SPCAM3.0 |
| CRM setup: | Micro-CRM (4km x 8) |
| | |
| Control simulation: | **dtime = 1800 [s]** |
| Experiment simulation: | **dtime = 600, 900, 3600 [s]** |
| | |
| Simulation length: | 10 years |
| SST: | prescribed |

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

20S-20N 50E-200E temperature bias




Zonal mean cloud forcing




Mid-troposphere warming

low $f_{scale}$ (dtime3600) → high $f_{scale}$ (dtime600)

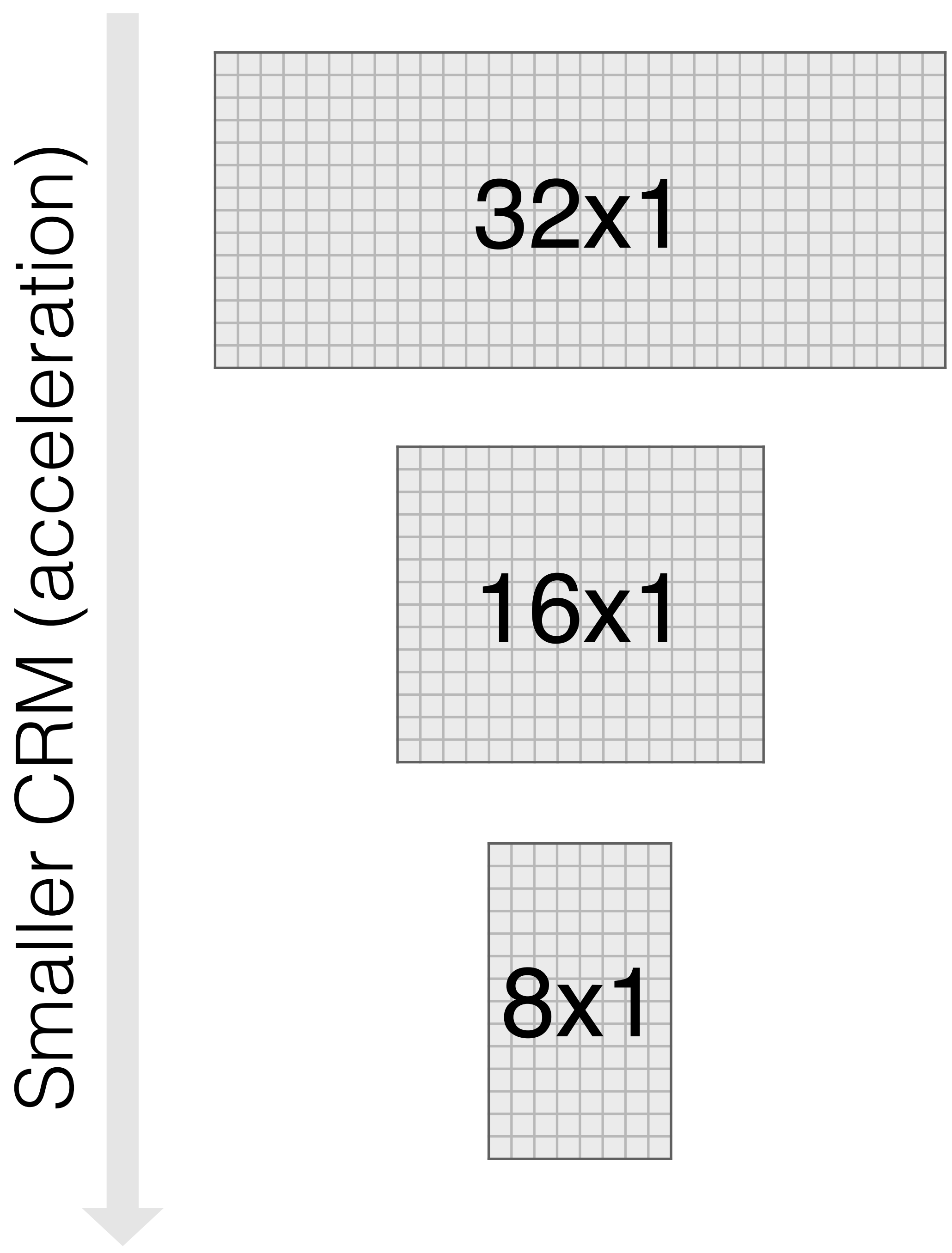
SWCF weakening

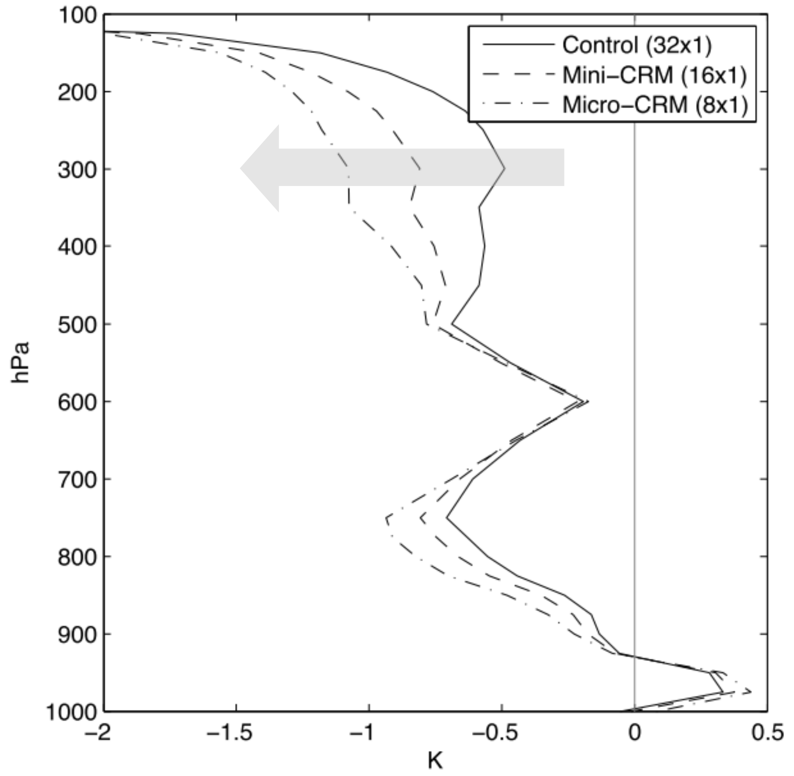
LWCF weakening

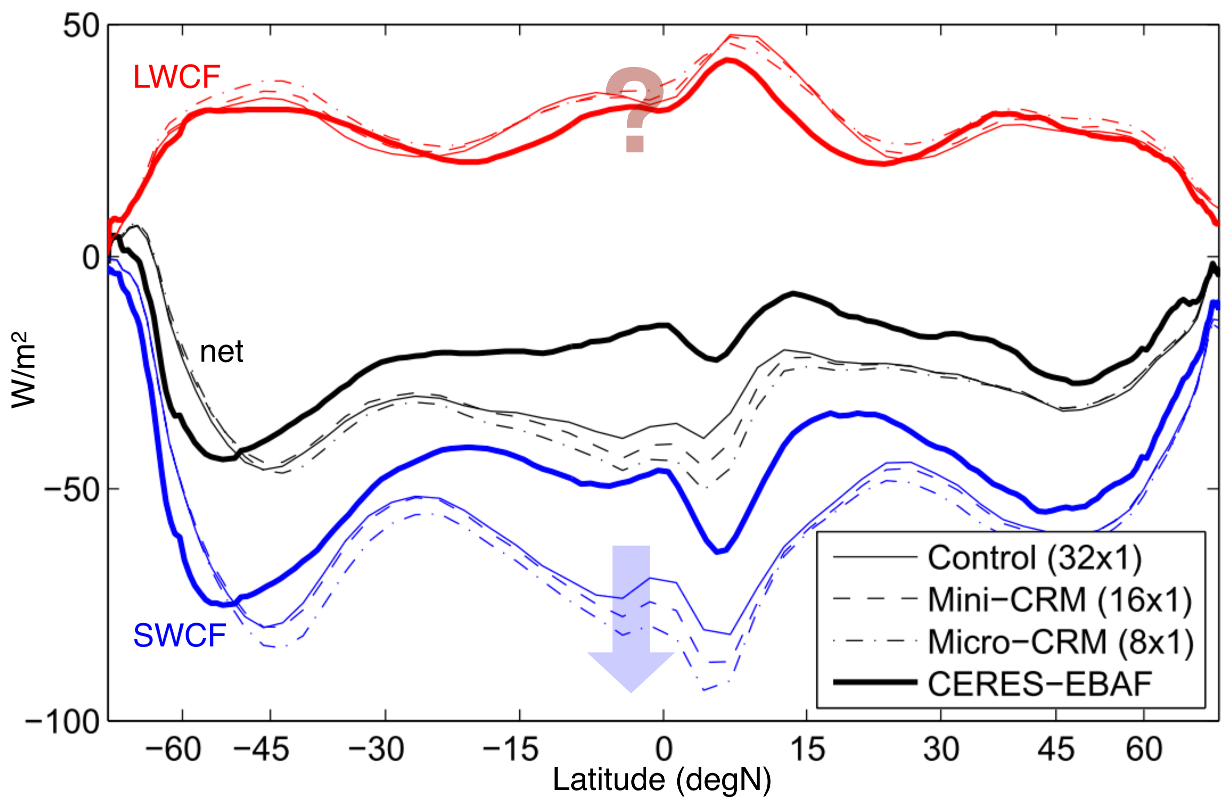
# Reversing key biases introduced by reduced CRM domain

[Pritchard, Bretherton, and DeMott (2014)]

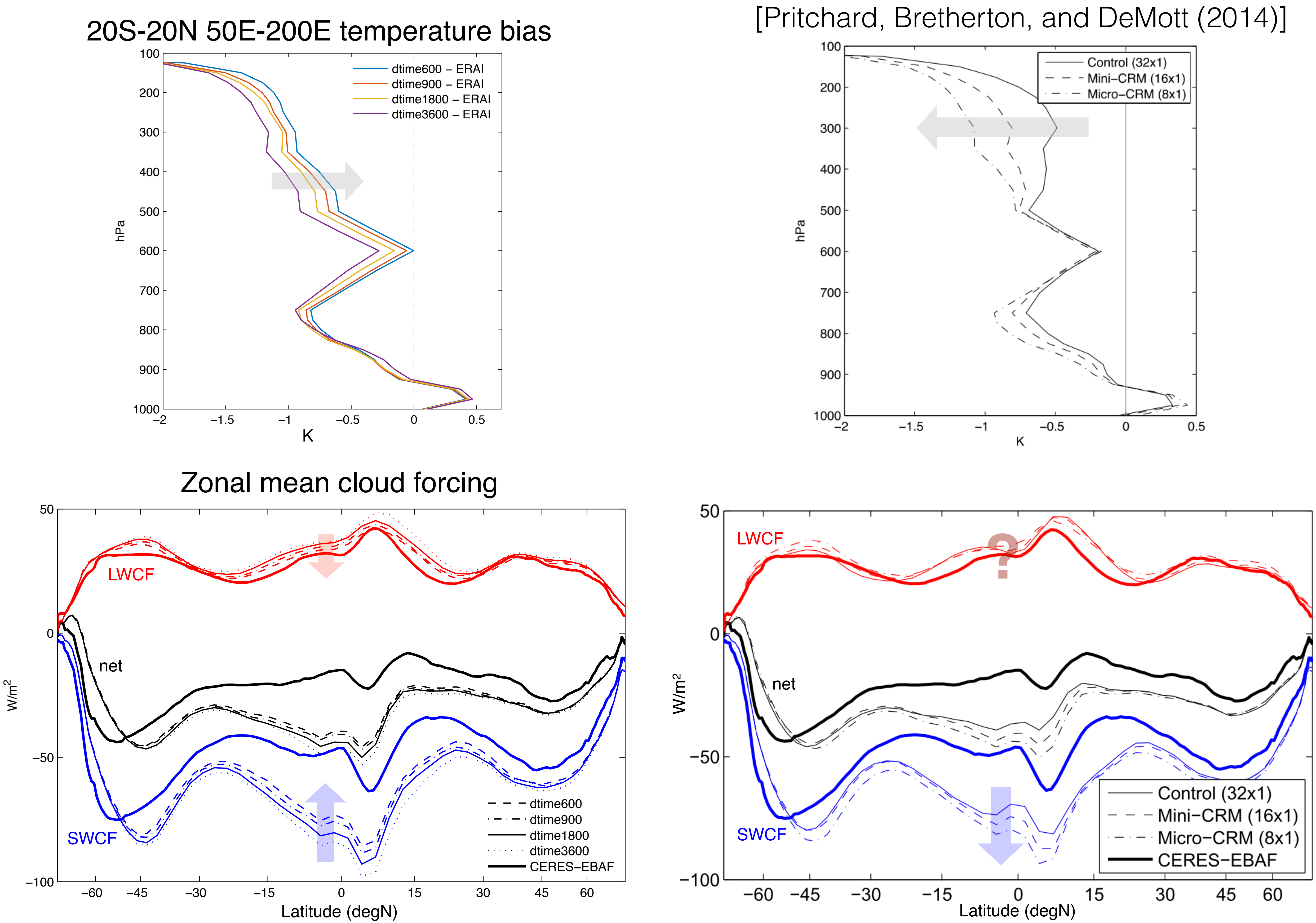
CRM setup



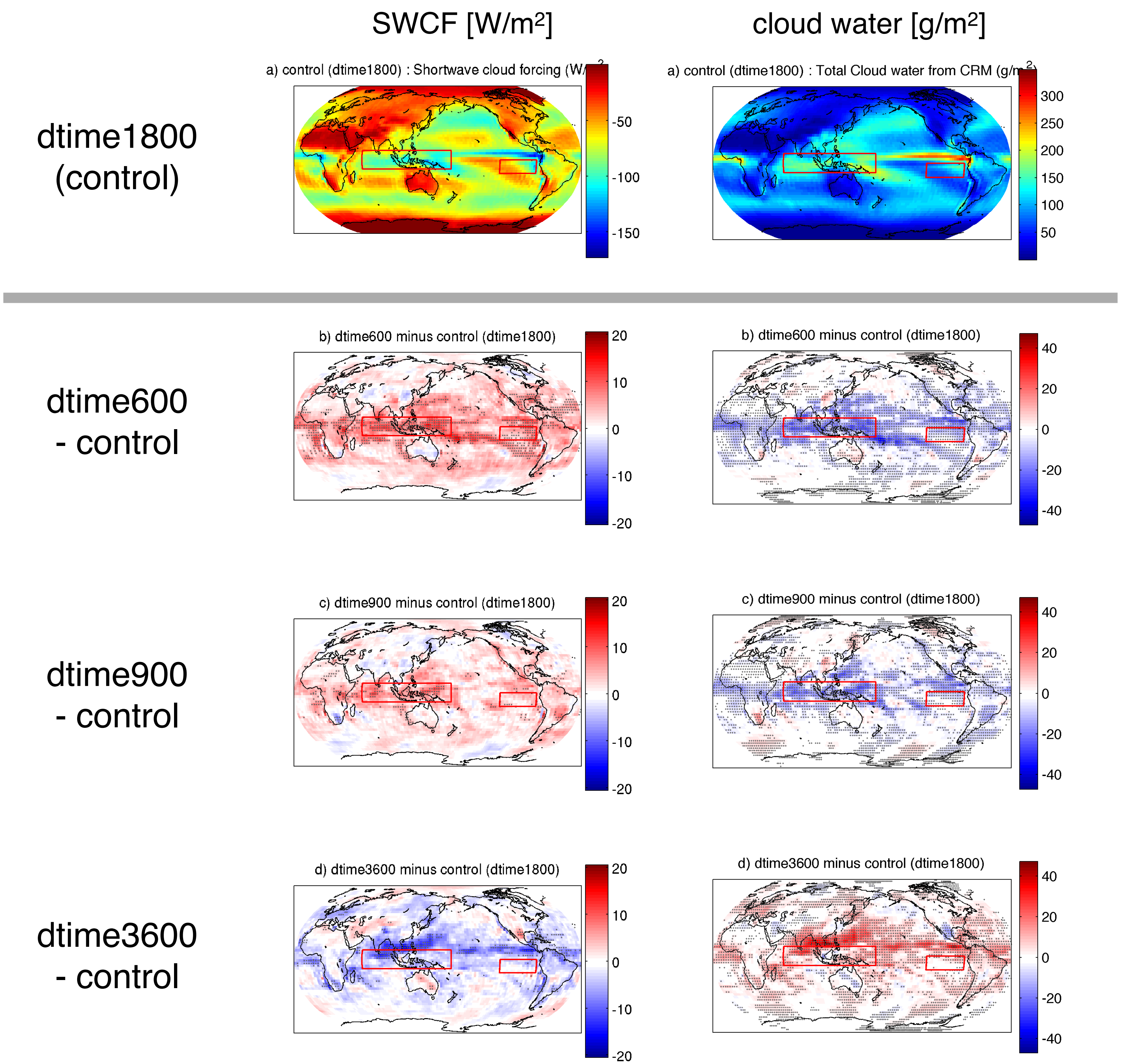



# Reversing key biases introduced by reduced CRM domain



# Liquid clouds systematically become less dense and less bright as scale coupling frequency increases



# Liquid clouds systematically become less dense and less bright as scale coupling frequency increases

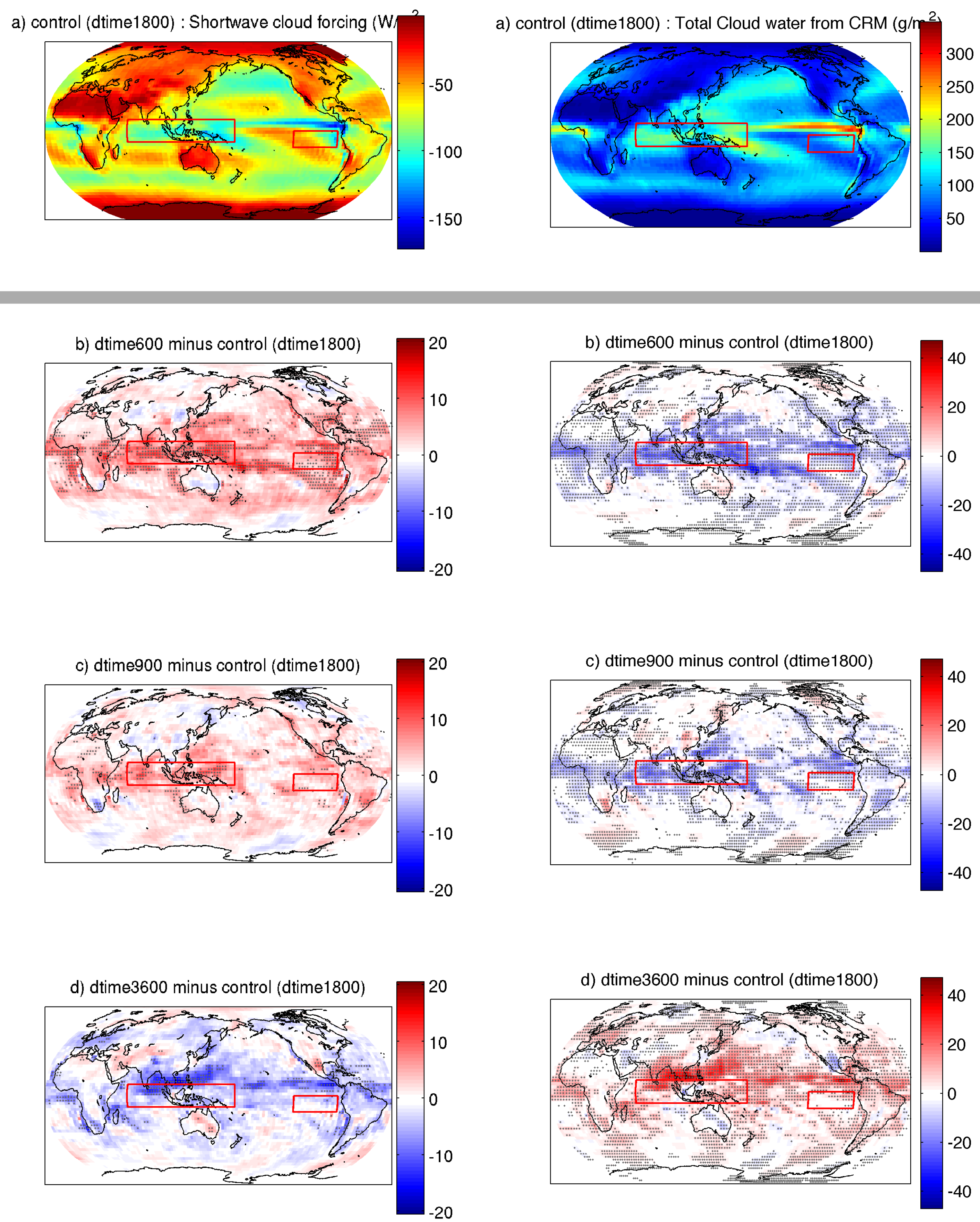
SWCF [W/m$^2$] | cloud water [g/m$^2$]

dtime1800 (control)

dtime600 - control

dtime900 - control

dtime3600 - control



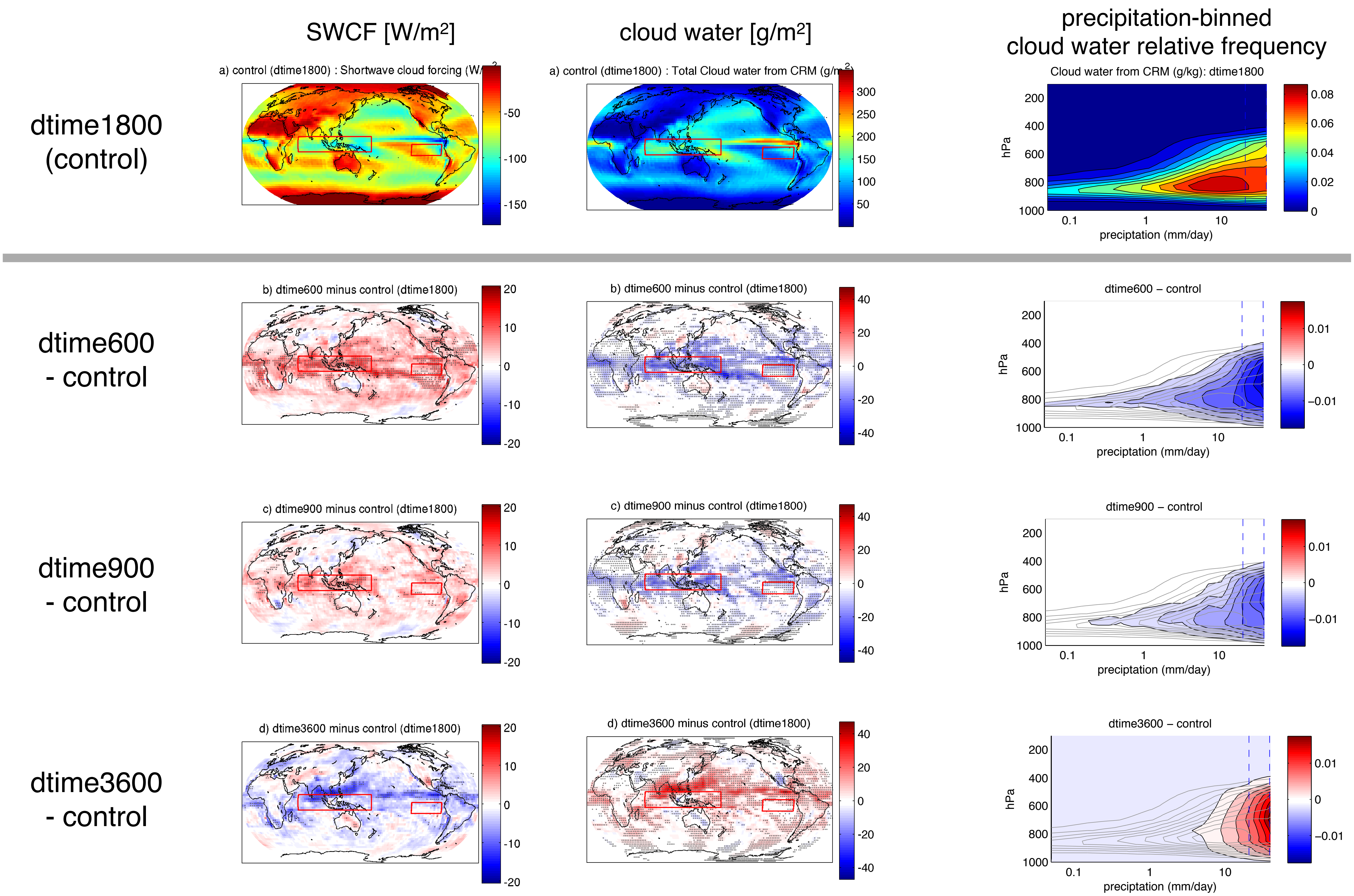

geographically robust, quasi-linear response

strong response along deep convective zones

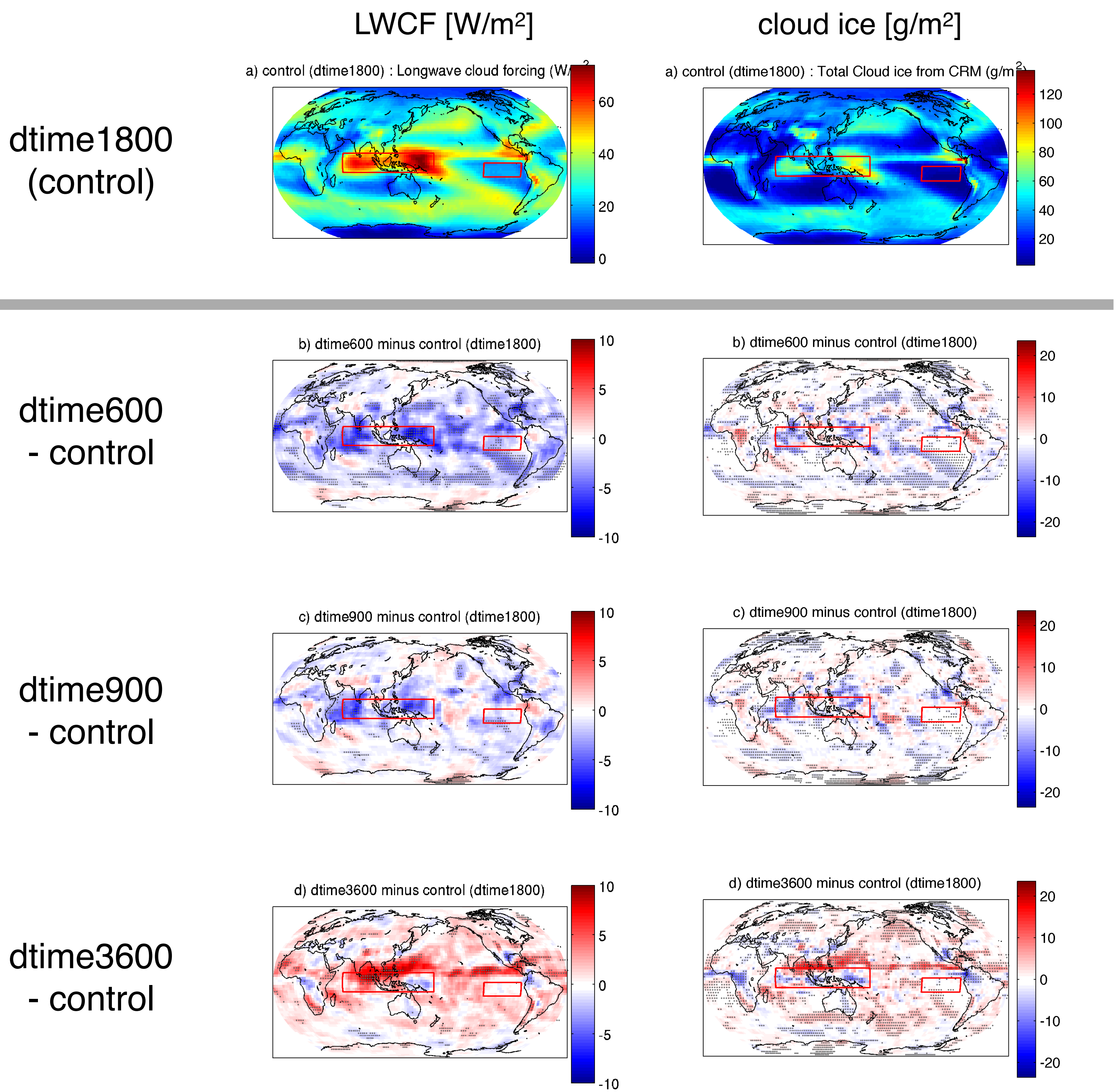
—>

convective mixing efficiency affected

# Liquid clouds systematically become less dense and less bright as scale coupling frequency increases



# High clouds reduce with scale coupling frequency but this response is weaker and more complex




systematic

more complex,
not know why yet

1/2 weaker than
SWCF response

# High clouds reduce with scale coupling frequency but this response is weaker and more complex

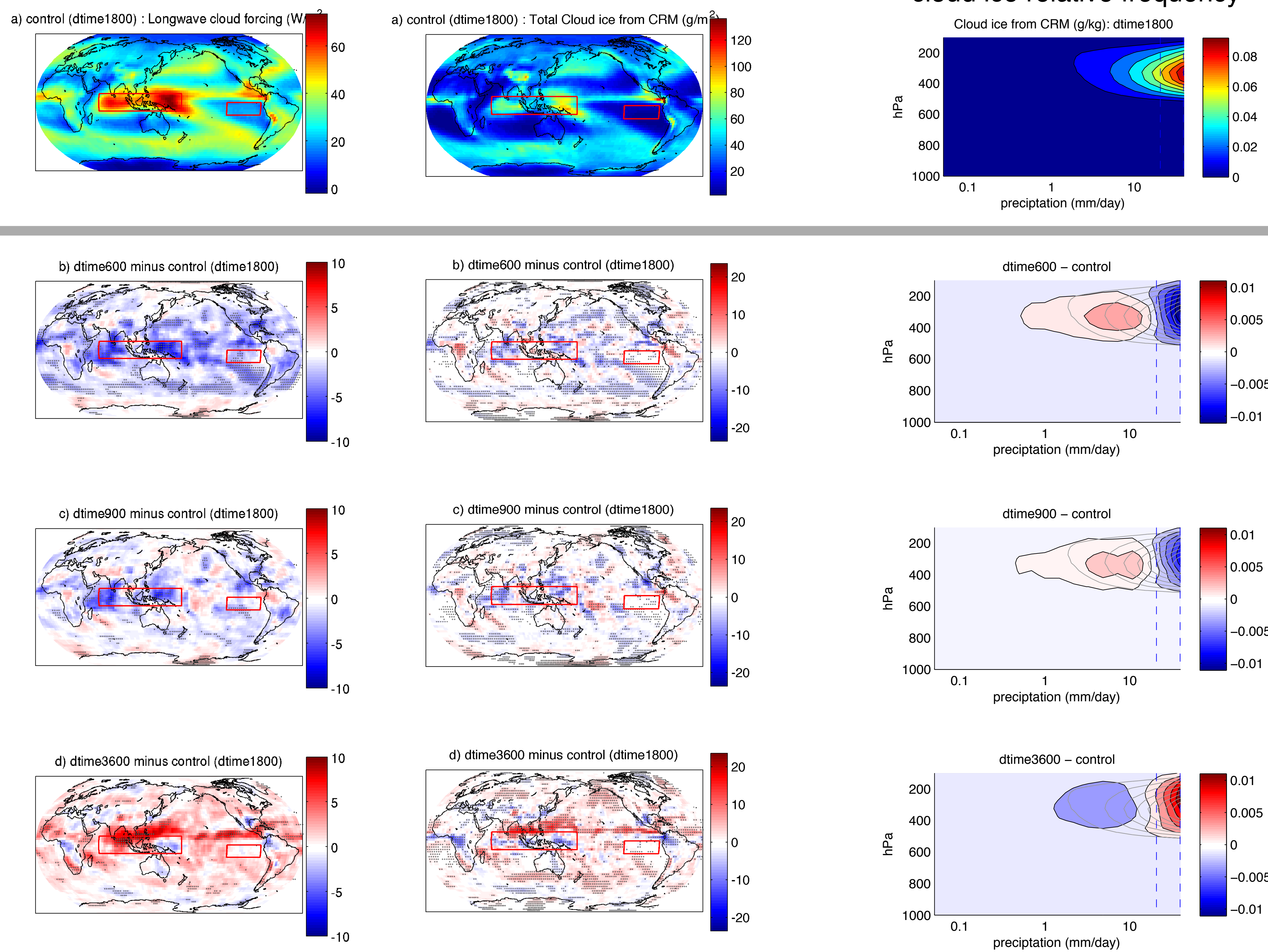
LWCF [W/m²] | cloud ice [g/m²] | precipitation-binned cloud ice relative frequency

dtime1800 (control)

dtime600 - control

dtime900 - control

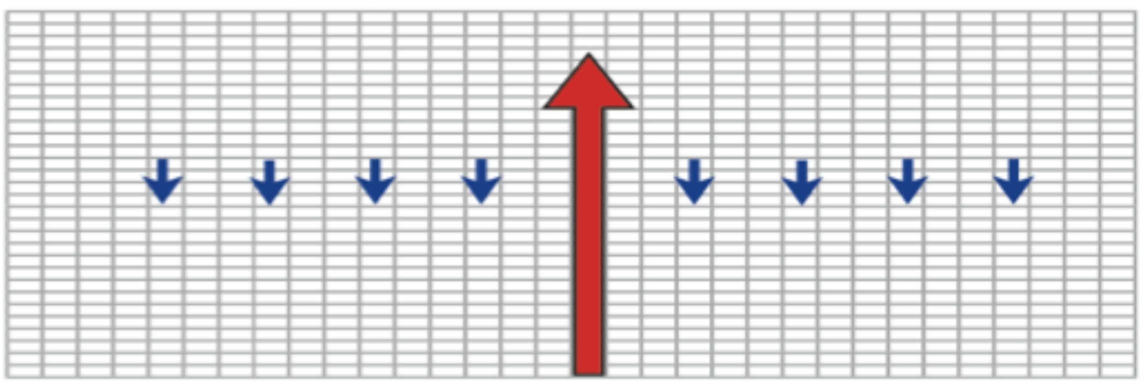
dtime3600 - control

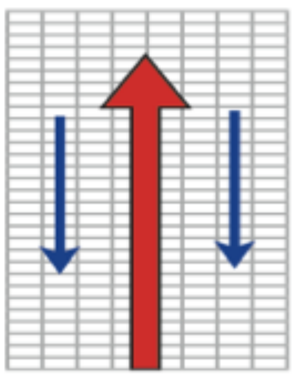


# SWCF response seems consistent with reduced CRM throttling

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

Artificially throttled deep convection by trapped subsidence



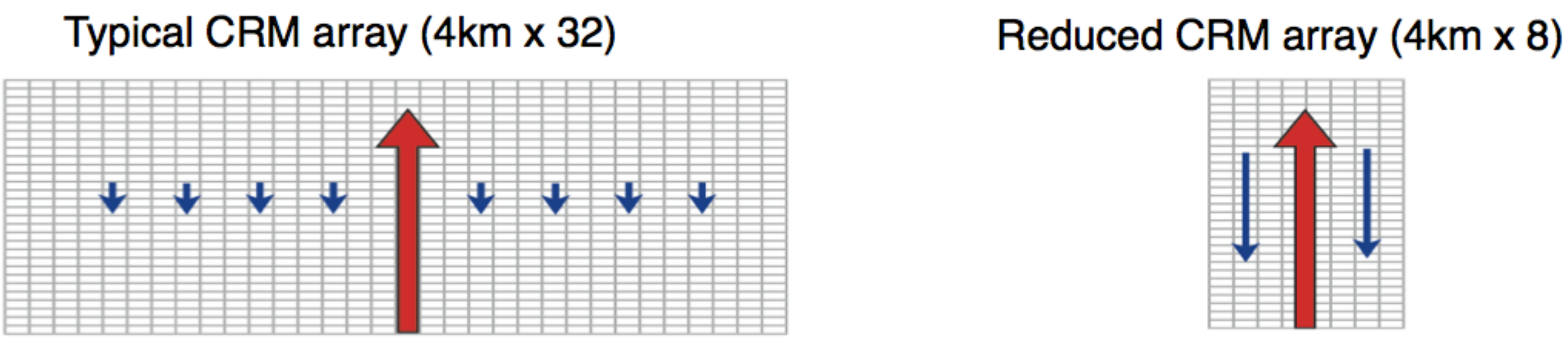




Reduced CRM domain
-> stronger subsidence
-> preventing ventilation
-> too much liquid cloud
-> too strong SWCF

# SWCF response seems consistent with reduced CRM throttling

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

Artificially throttled deep convection by trapped subsidence




CRM is not a closed system

This artifact is corrected by GCM's large scale dynamics

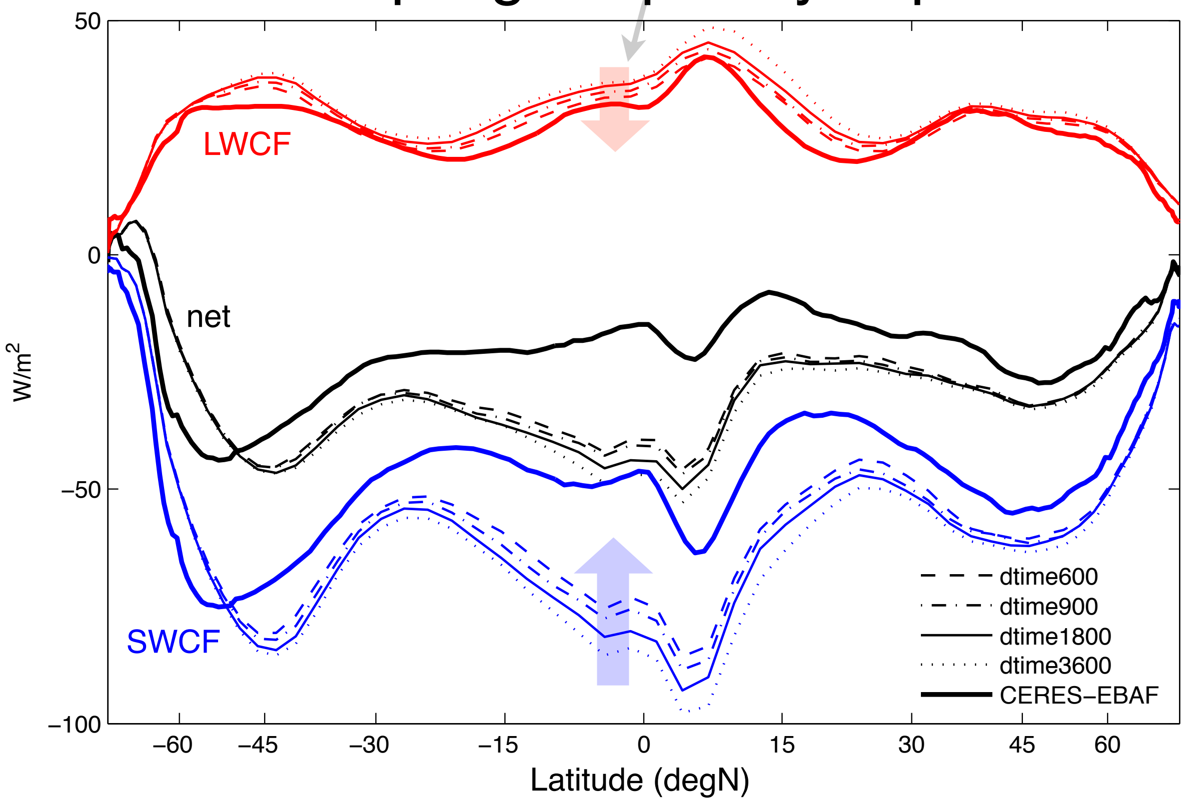
More frequent scale coupling → more ventilation → less liquid cloud

# LWCF response is new and mysterious

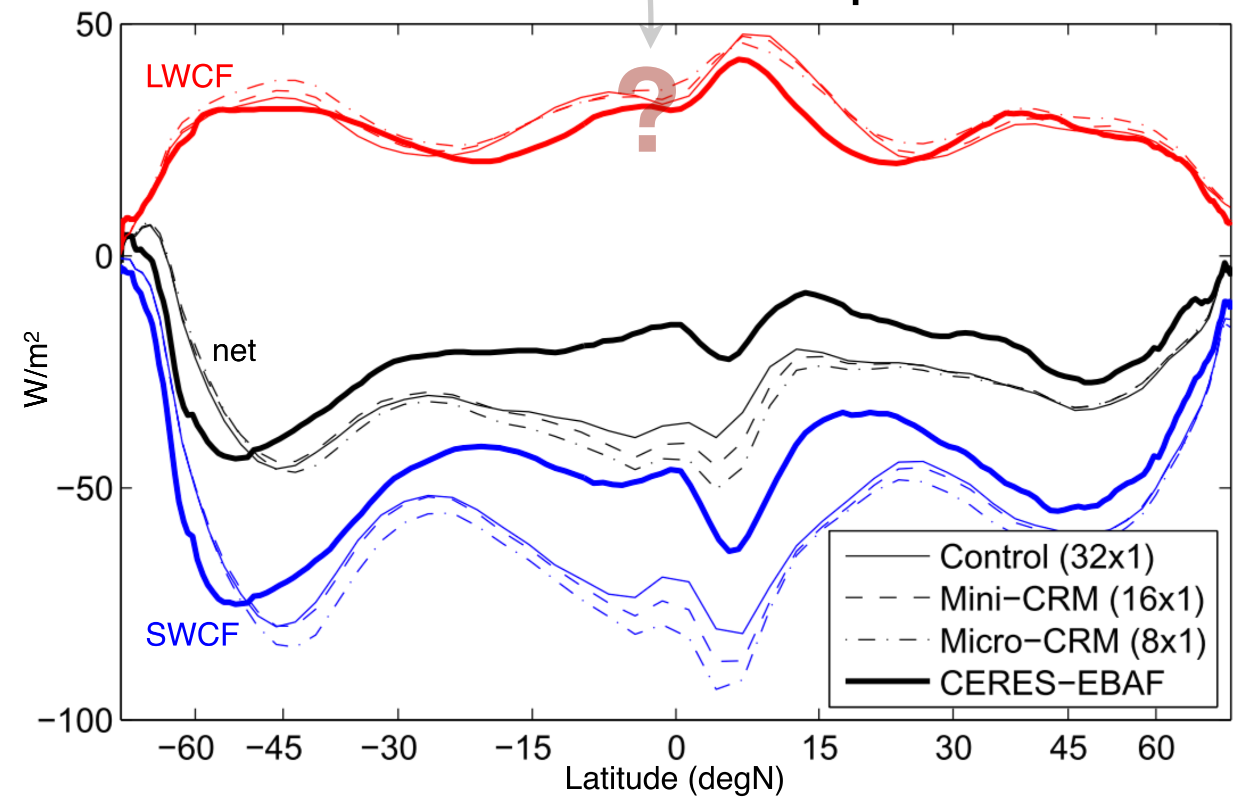
LWCF
response

<u>Zonal mean cloud forcing</u>

scale coupling frequency experiment

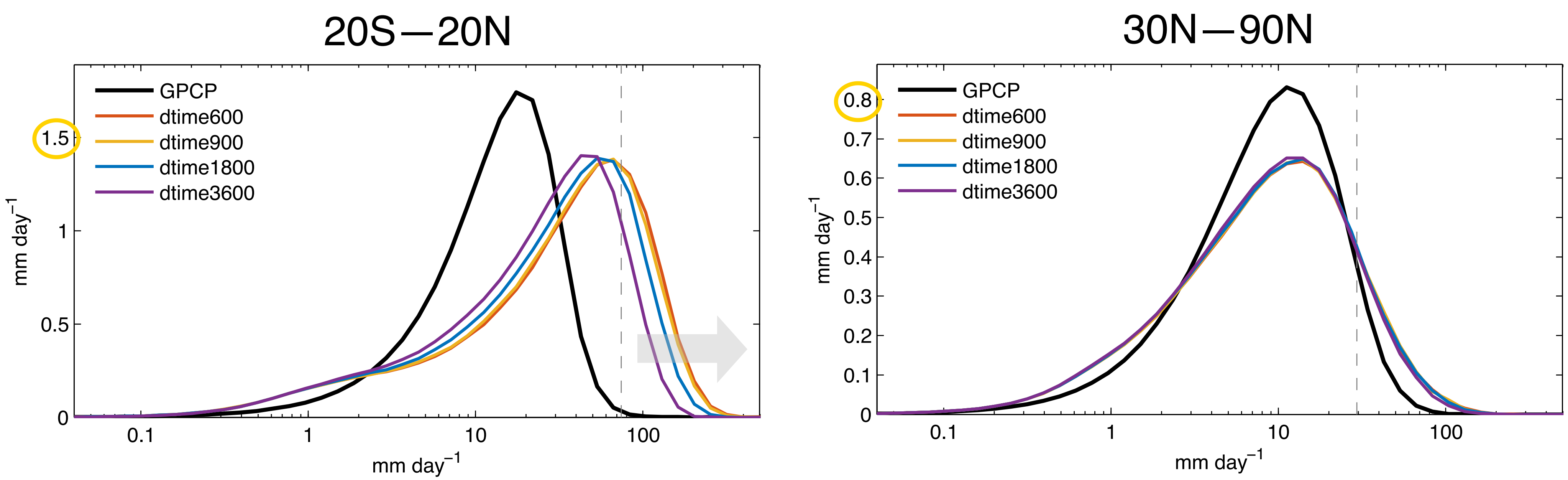



CRM domain size experiment



# Similar to GCMs, rain intensity tail amplifies

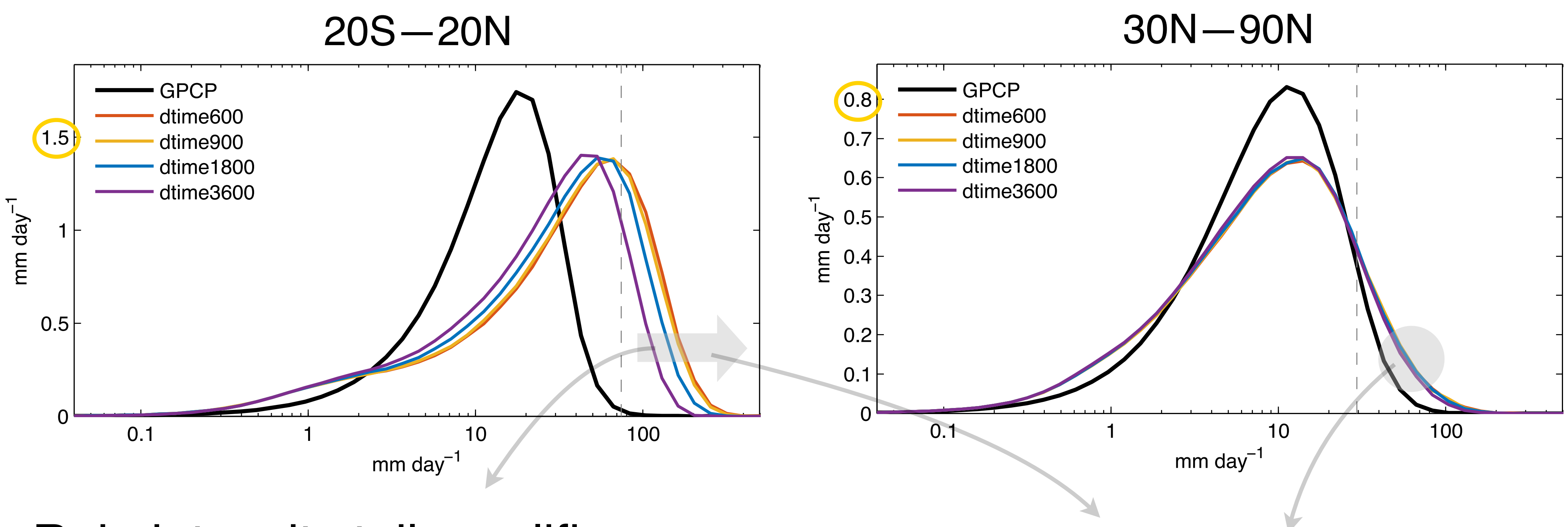
Amount distribution of precipitation




low $f_{\text{scale}}$ (dtime3600) → high $f_{\text{scale}}$ (dtime600)

# Similar to GCMs, rain intensity tail amplifies

Amount distribution of precipitation

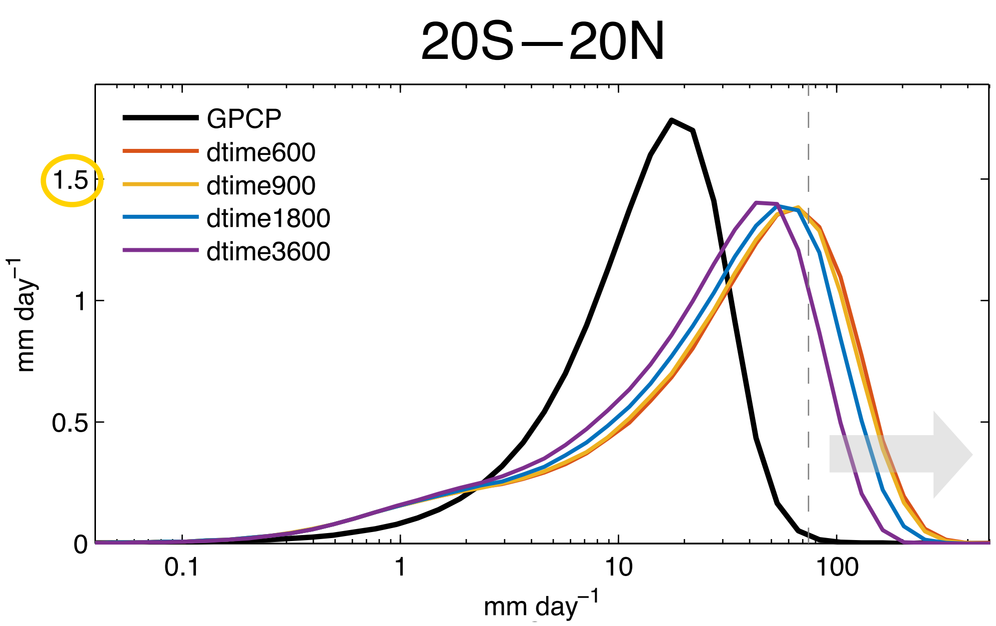



Rain intensity tail amplifies as $f_{scale}$ increases.

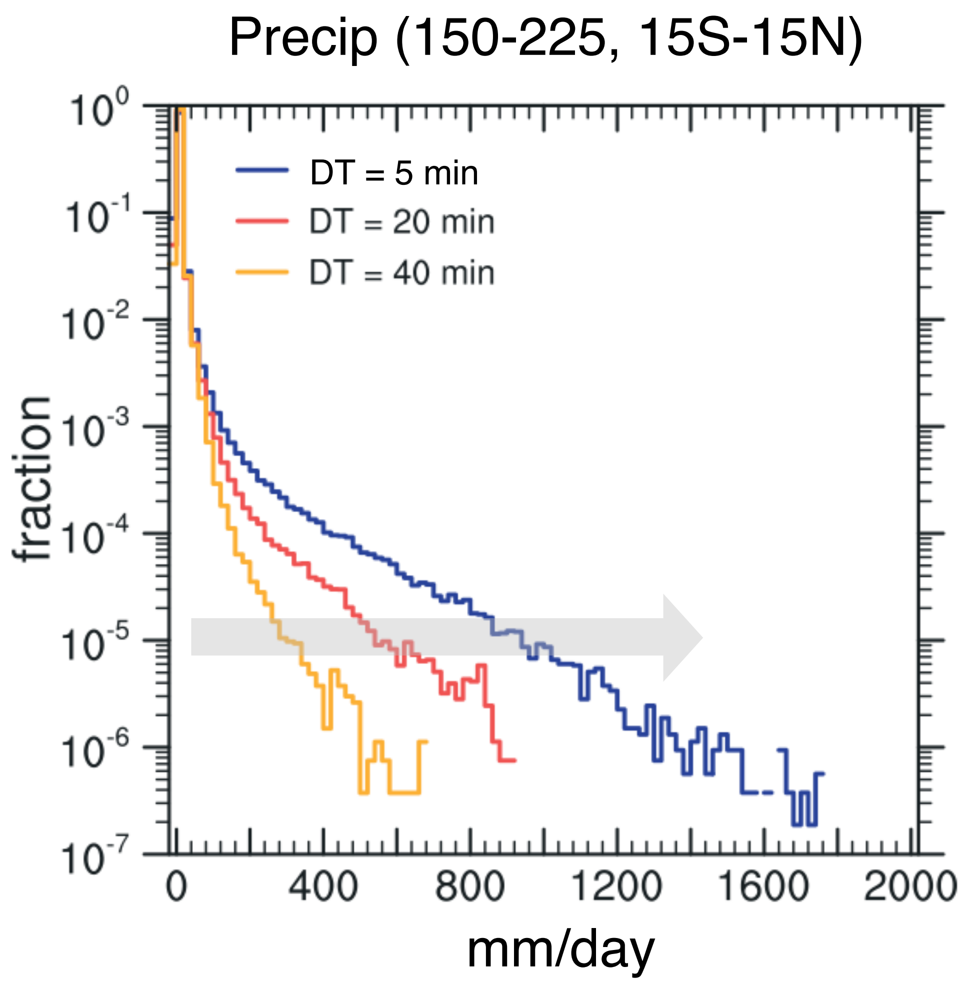
(not expected with the trapped subsidence hypothesis)

Rain intensity tail amplification is mostly from the tropics

# Similar to GCMs, rain intensity tail amplifies




SPCAM3

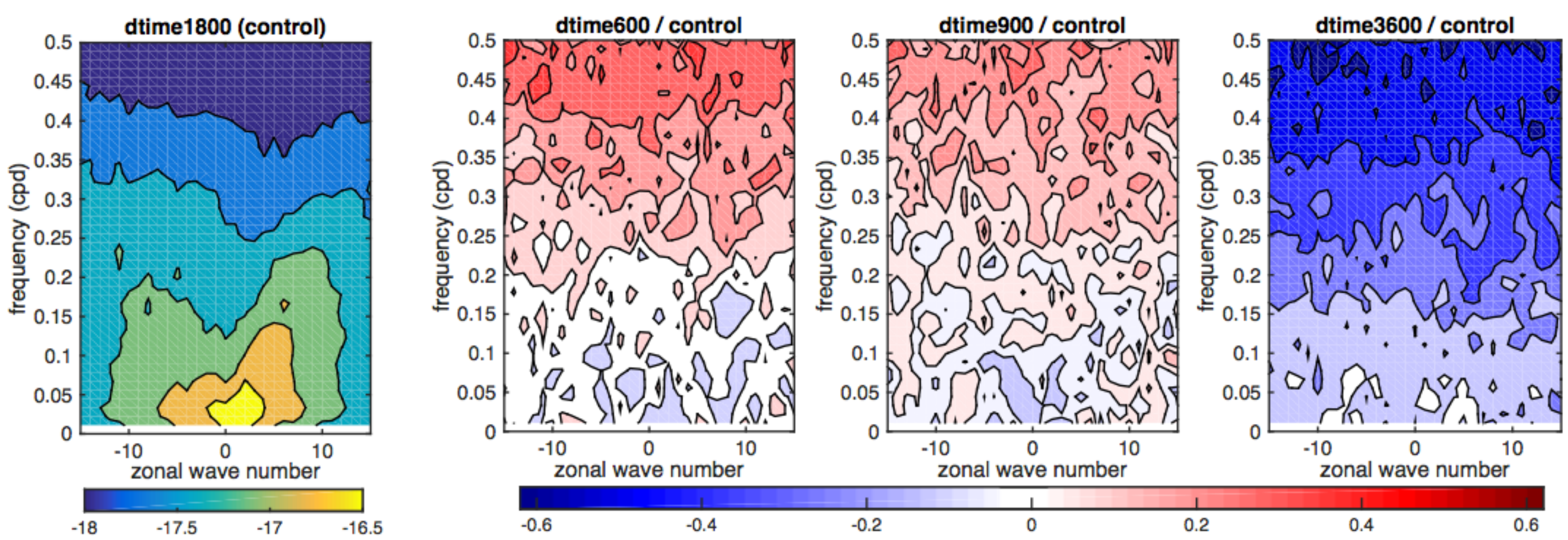



CAM4

(Williamson, 2013)

# No single mode of tropical organization dominates the rain intensity change

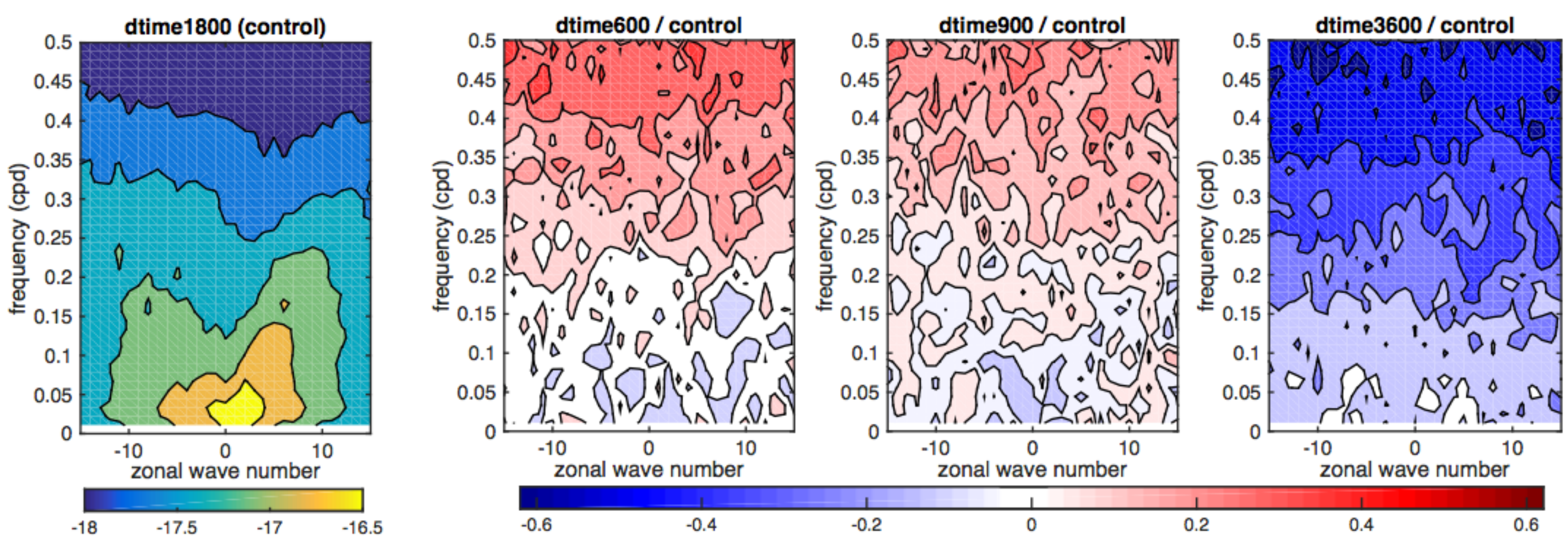
5S-5N precipitation wavenumber-frequency spectrum (symmetric)




mean power shifted to higher frequency

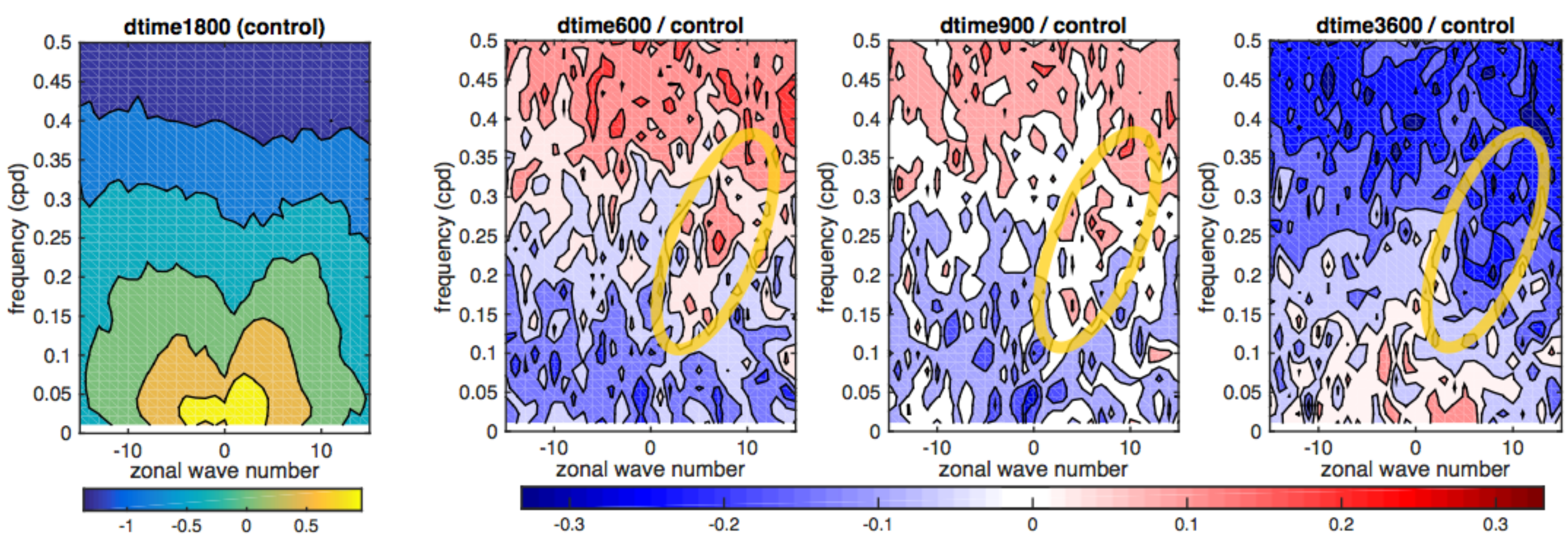
# No single mode of tropical organization dominates the rain intensity change

5S-5N precipitation wavenumber-frequency spectrum (symmetric)




mean power shifted to higher frequency

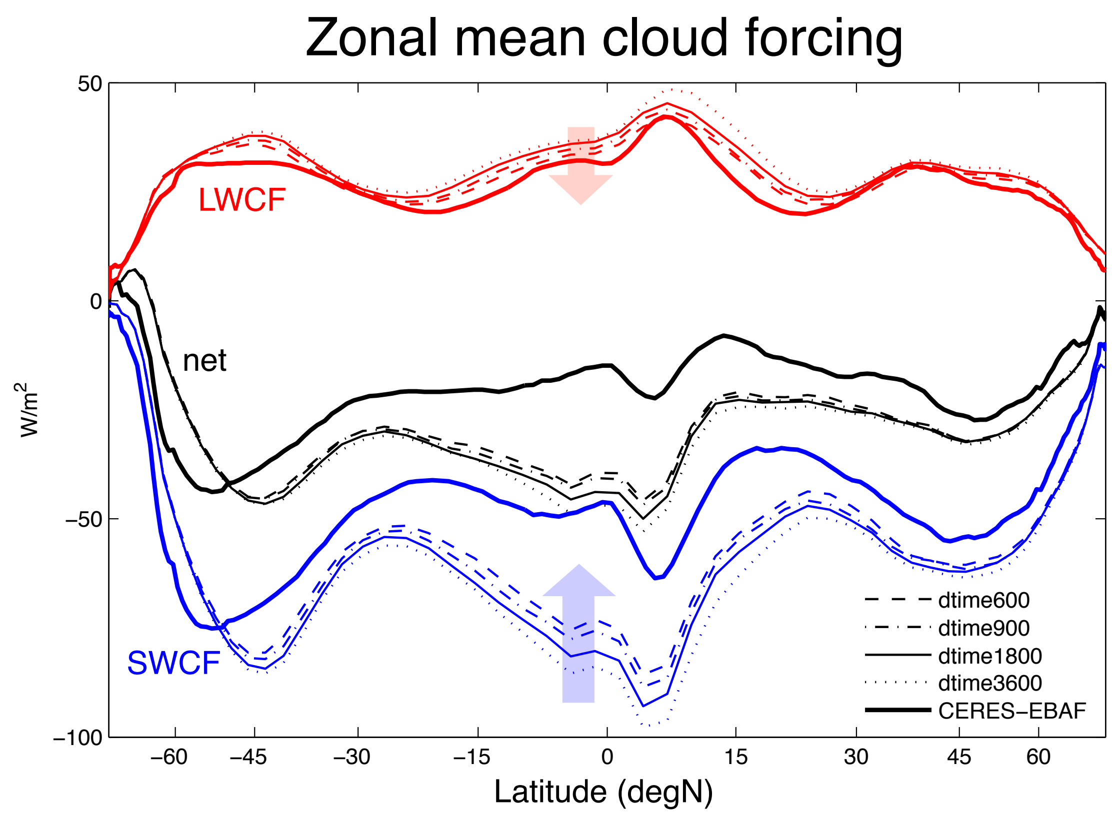
5S-5N OLR wavenumber-frequency spectrum (symmetric)



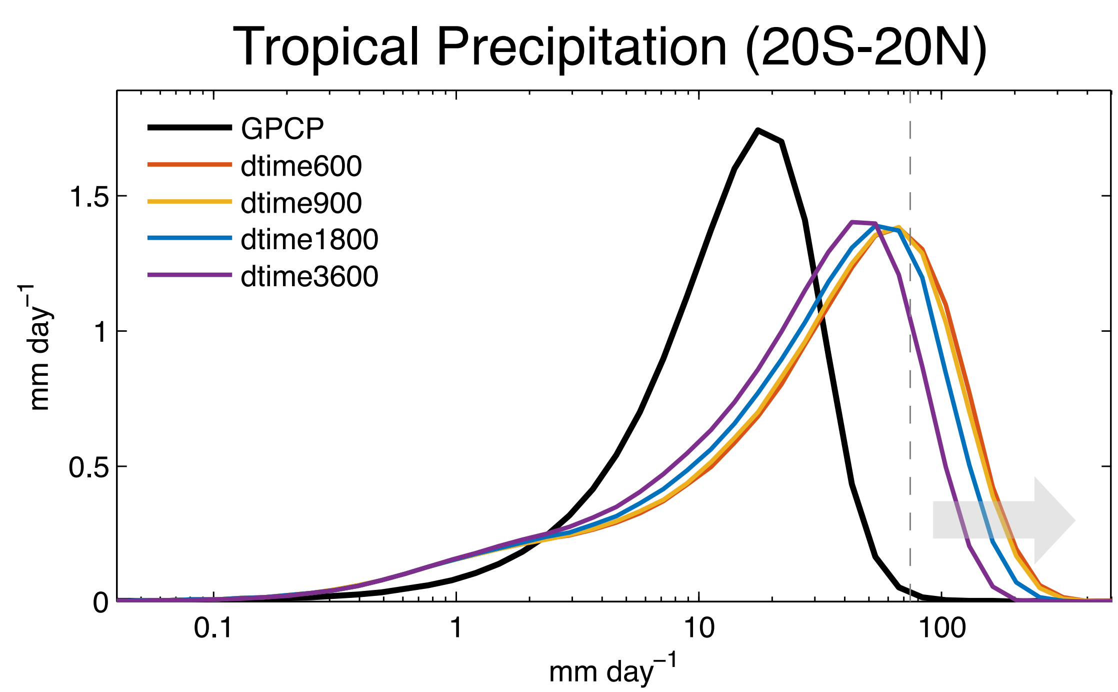

moist Kelvin wave strengthen

# Scale coupling frequency is an interesting tuning parameter for superparameterized models (with caution)

SWCF and LWCF biases decrease as $f_{\text{scale}}$ increases




Tropical precipitation tail boosts as $f_{\text{scale}}$ increase

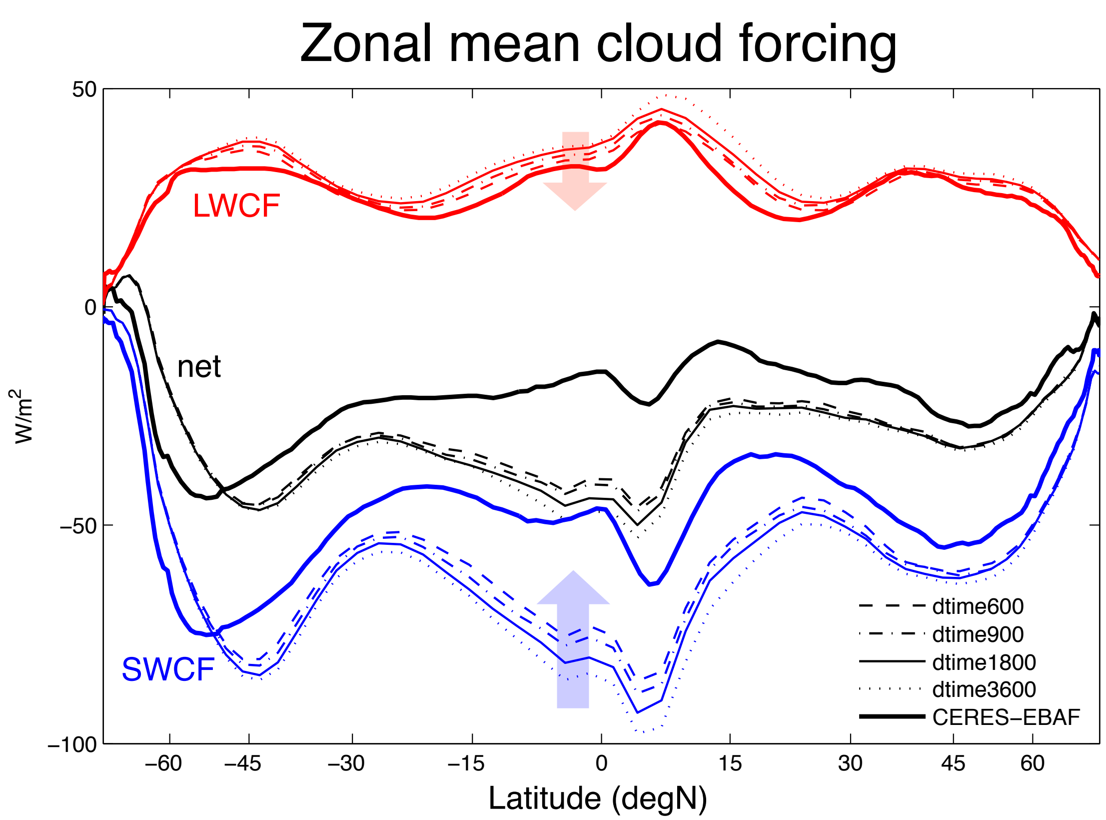


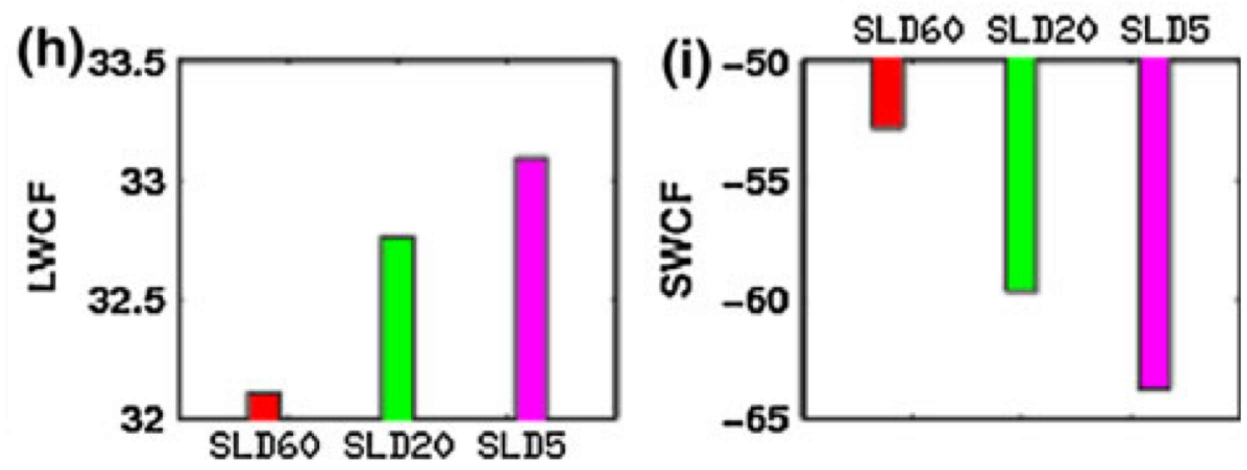
# Appendix A: SPCAM3 vs. CAM3

SPCAM3.0, T42, Δt=10, 15, 30, 60 min

CAM3, T63, Δt=60, 20, 5 min

(Mishra and Sahany, 2011)




Higher $f_{scale}$

-> weaker SWCF

-> weaker LWCF

Higher $f_{scale}$ (lower Δt)

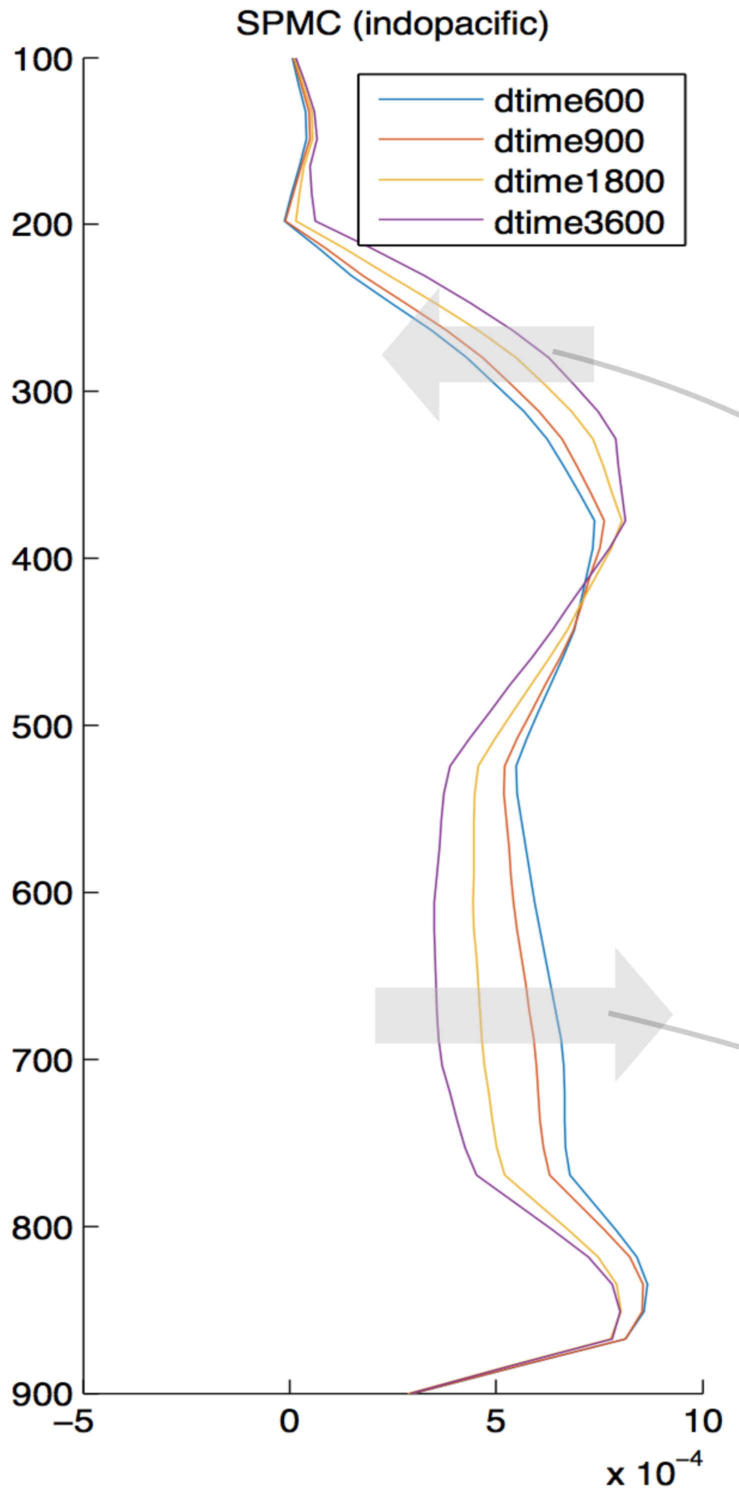
-> stronger SWCF

-> stronger SWCF

**!opposite sensitivity!**

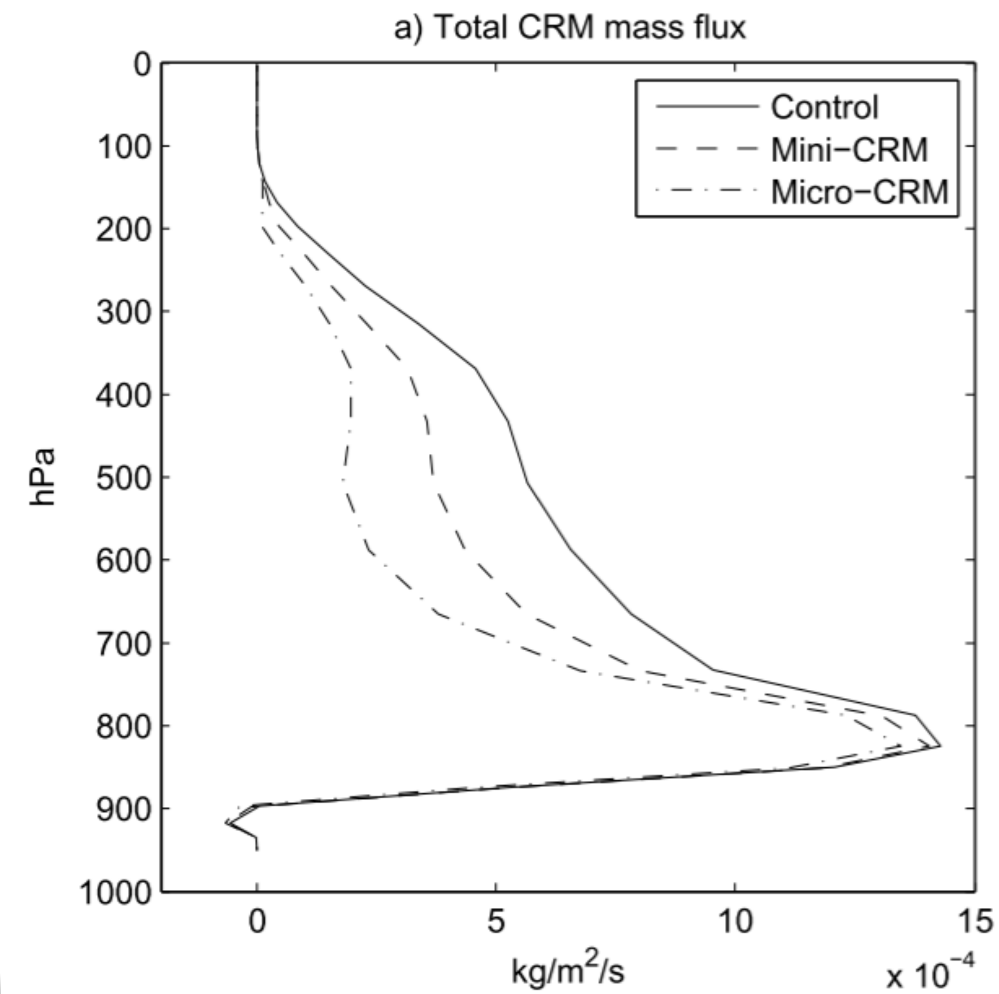
# Appendix B: CRM mass flux statistics

(Scale coupling frequency experiment)




(CRM domain experiment

by Pritchard et al, 2014)




**Something more than**

**“throttled deep convection”!**

# Appendix C: Precipitation std dev