CAM-CLUBB-SILHS-MG2: Sensitivity to horizontal grid spacing

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CAM5 is only moderately sensitive to grid spacing and time step, but a few sensitivities do exist:

For example, the balance between deep convection and large scale precipitation changes with time step and convective time scale, dt/tau (Williamson 2013, Gustafson et al. 2014).

The convective time scale, tau, is the time over which convection consumes CAPE.

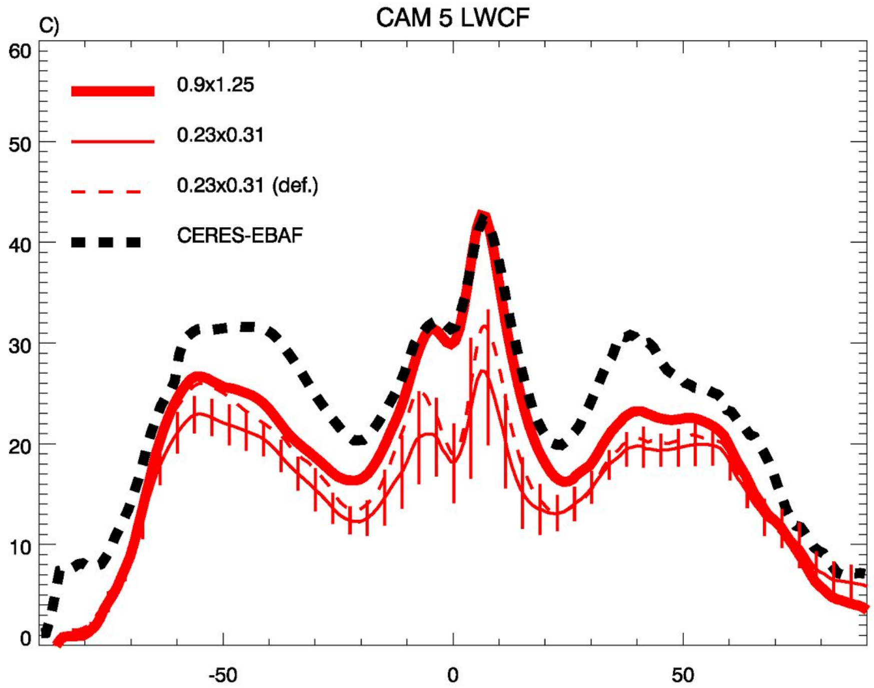
At small tau, the convection is strong but responds too quickly to buoyant instability. At large tau, the timing is delayed and more realistic, but the overall precipitation is weak (Gustafson et al. 2014).

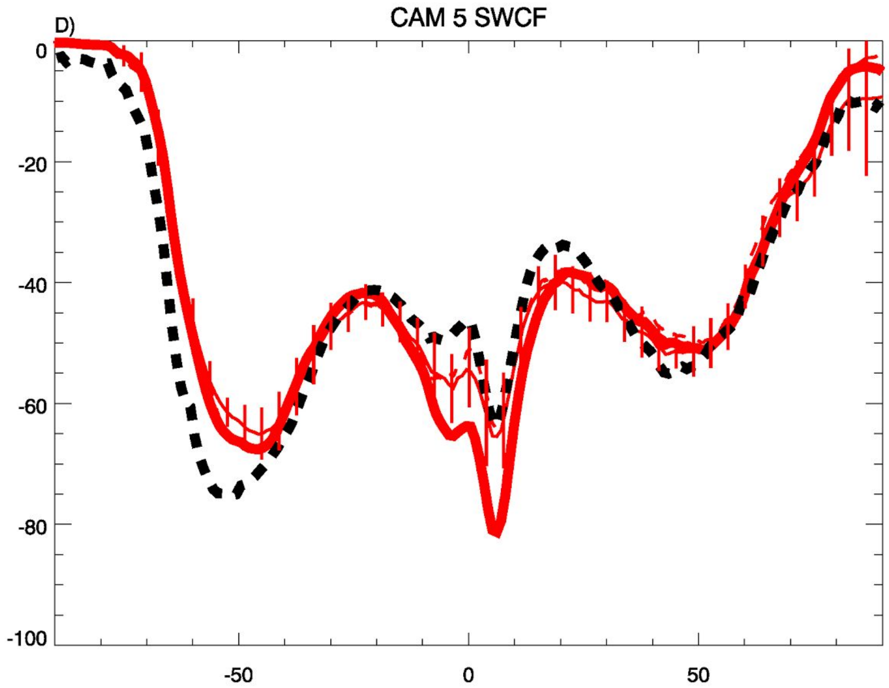
The sensitivity of ZM to dt/tau may or may not be related to other sensitivities in CAM5:

For example,

- LWCF decreases at quarter-degree resolution (Bacmeister et al. 2014).
- A double ITCZ forms at quarter-degree resolution (Bacmeister et al. 2014).

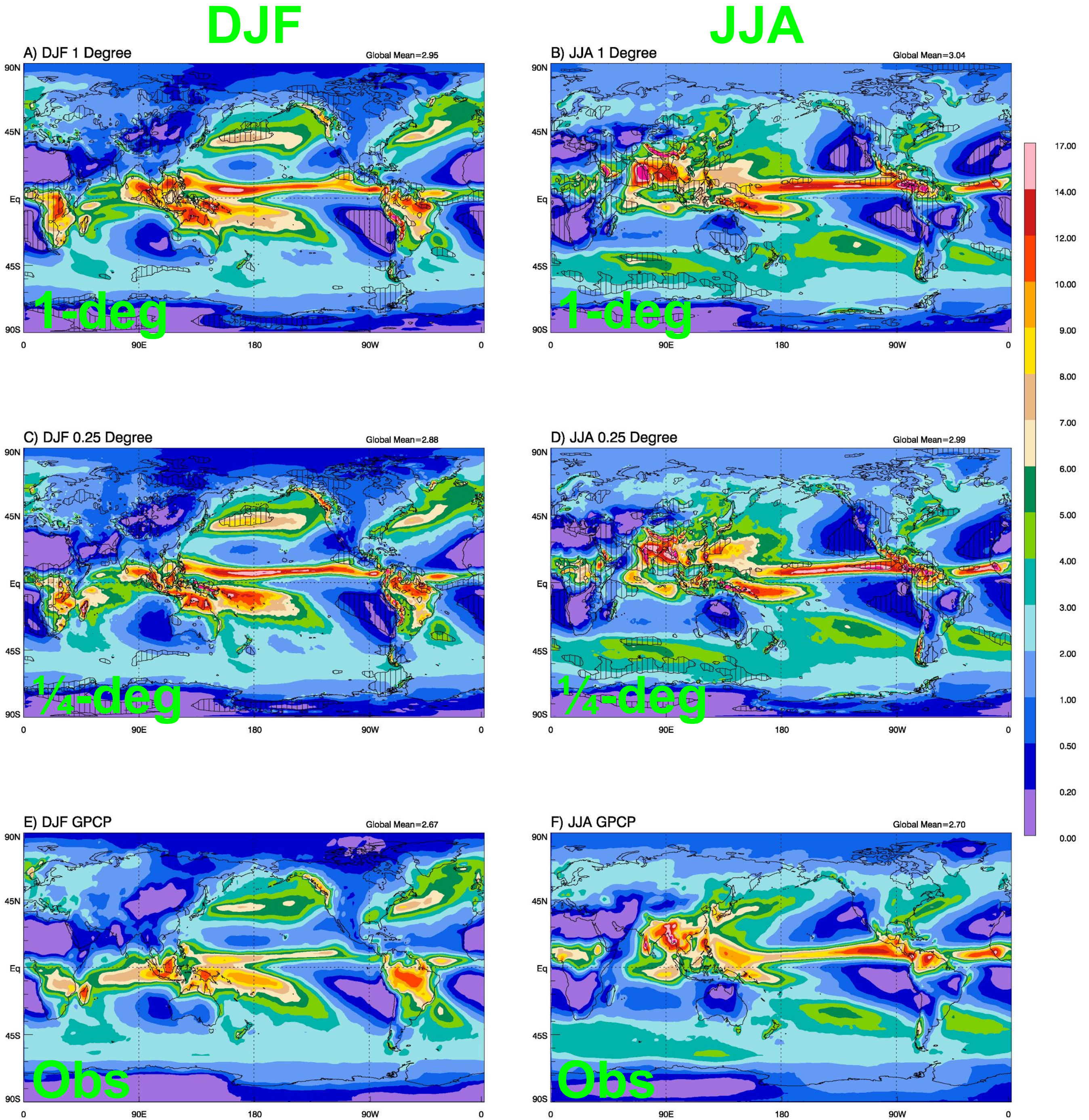
In CAM5, LWCF and SWCF are moderately sensitive to grid spacing:





Bacmeister et al. (2014)

In CAM5, a double ITCZ forms at high resolution (and short time step):



Bacmeister et al. (2014)

Can any of these sensitivities be reduced by removing the ZM mass-flux deep convective scheme?

To test this hypothesis, we run 1- and 1/4-deg simulations using a version of CAM without the ZM scheme (CAM-CLUBB-SILHS-MG2).

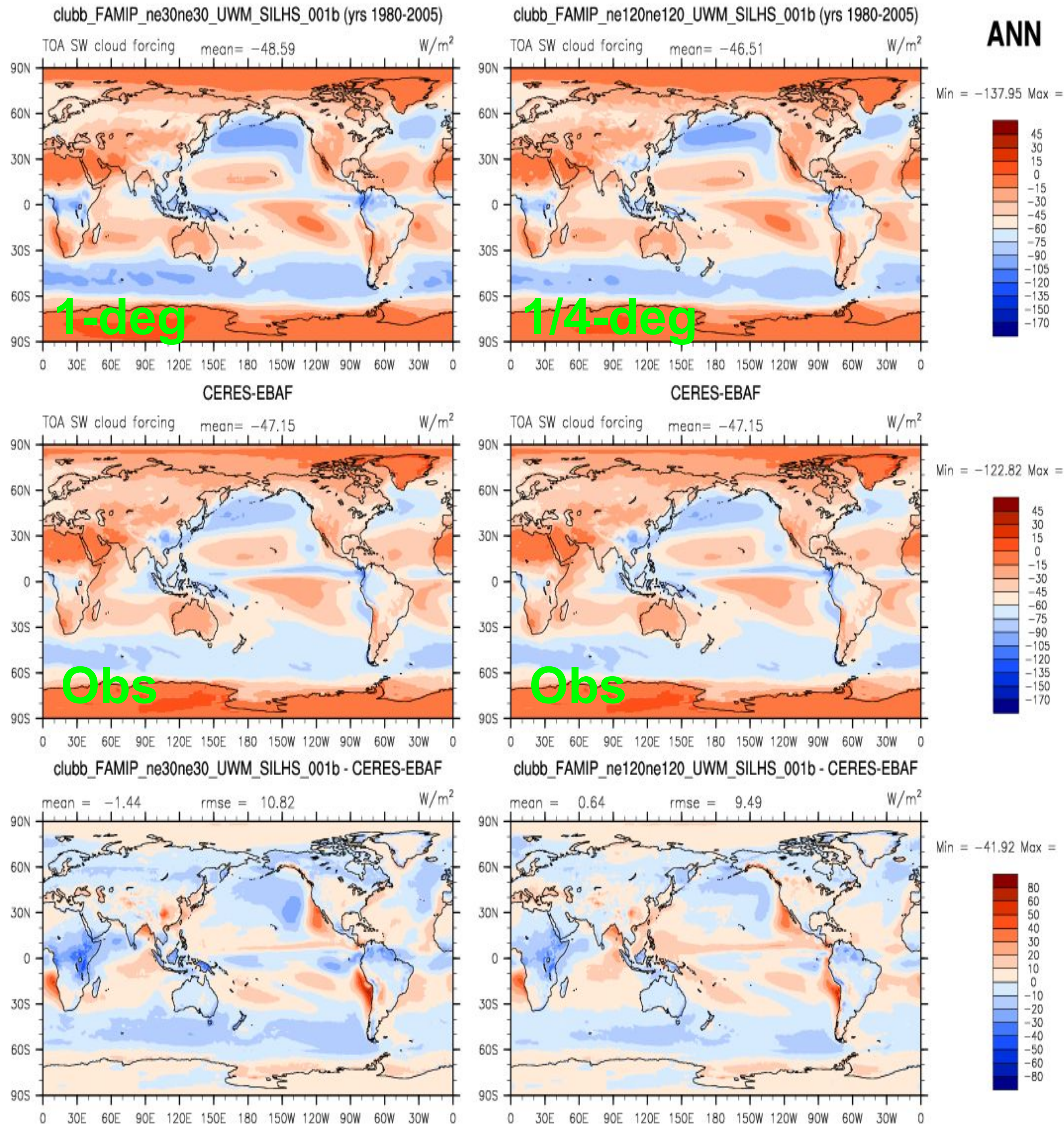
Then there is no assumption that convection is diagnostic, no explicit convective time scale (tau), and no assumption that convection covers a small fraction of the grid box.

Model configuration of our CAM-CLUBB-SILHS-MG2 simulations:

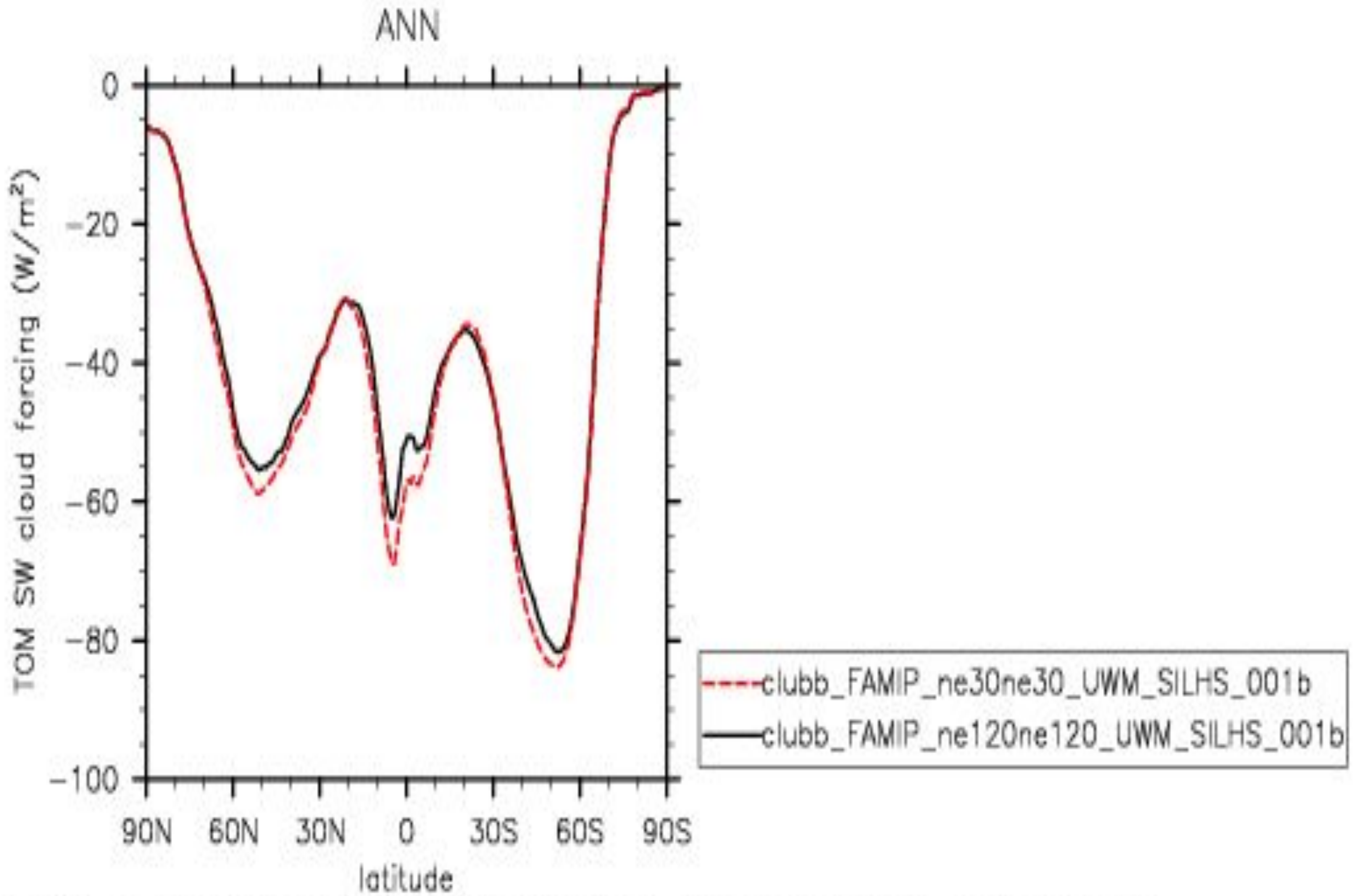
Cloud parameterization	CLUBB (ZM is disabled)
Microphysics	MG2
Interface between clouds and microphysics	SILHS
Resolution	Uniform 1 degree (“lo res”) or quarter-degree (“hi res”)
Physics (aerosol and radiation) time step	30 min (1 degree) or 15 min (¼ degree)
CLUBB and MG2 time step	5 min for both resolutions
Ocean boundary condition	AMIP (prescribed, time-varying SST)

SWCF changes by 2 W/m2 when res changes

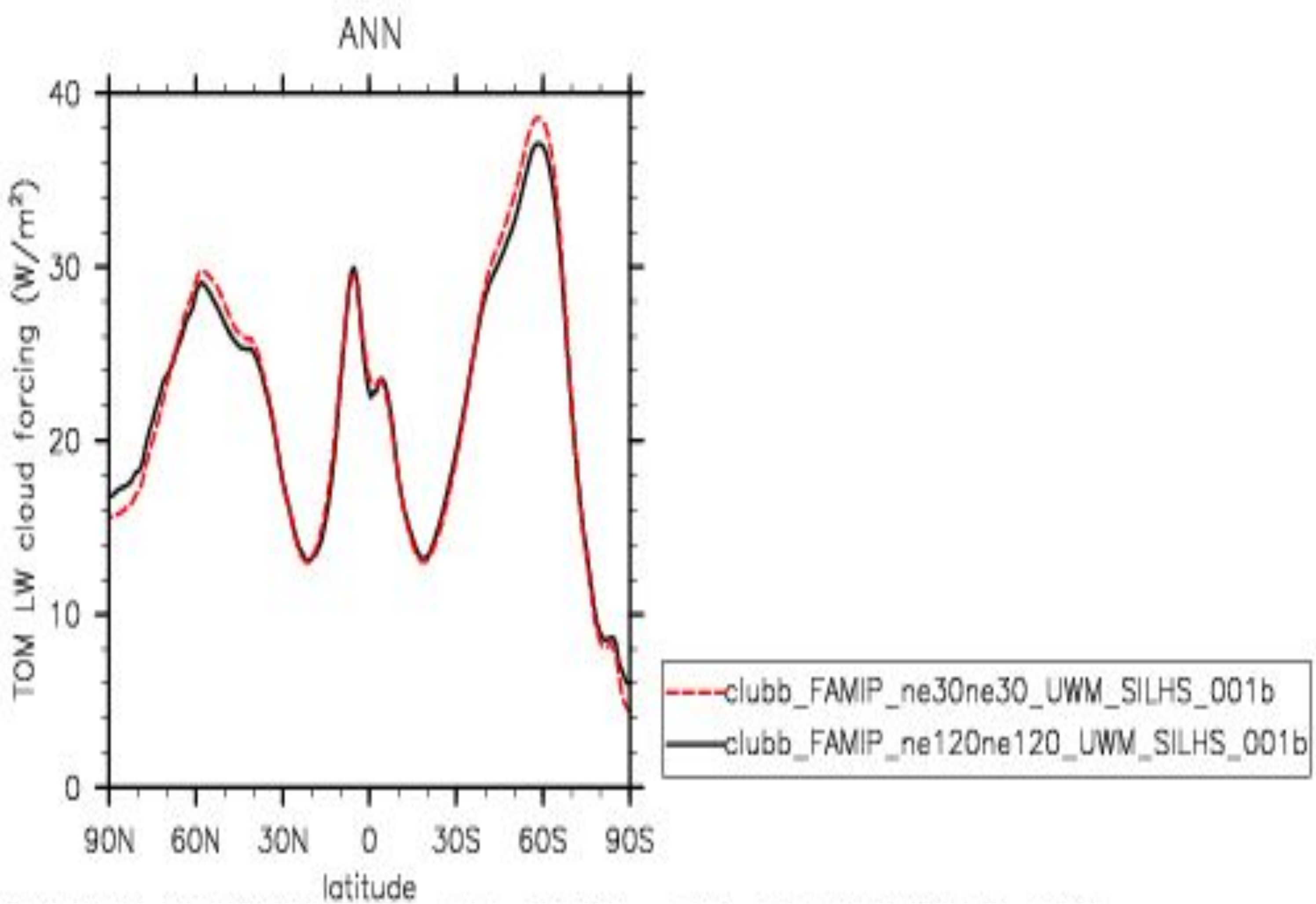
AODVIS is reduced by 28% at hi res. Are these two changes related?



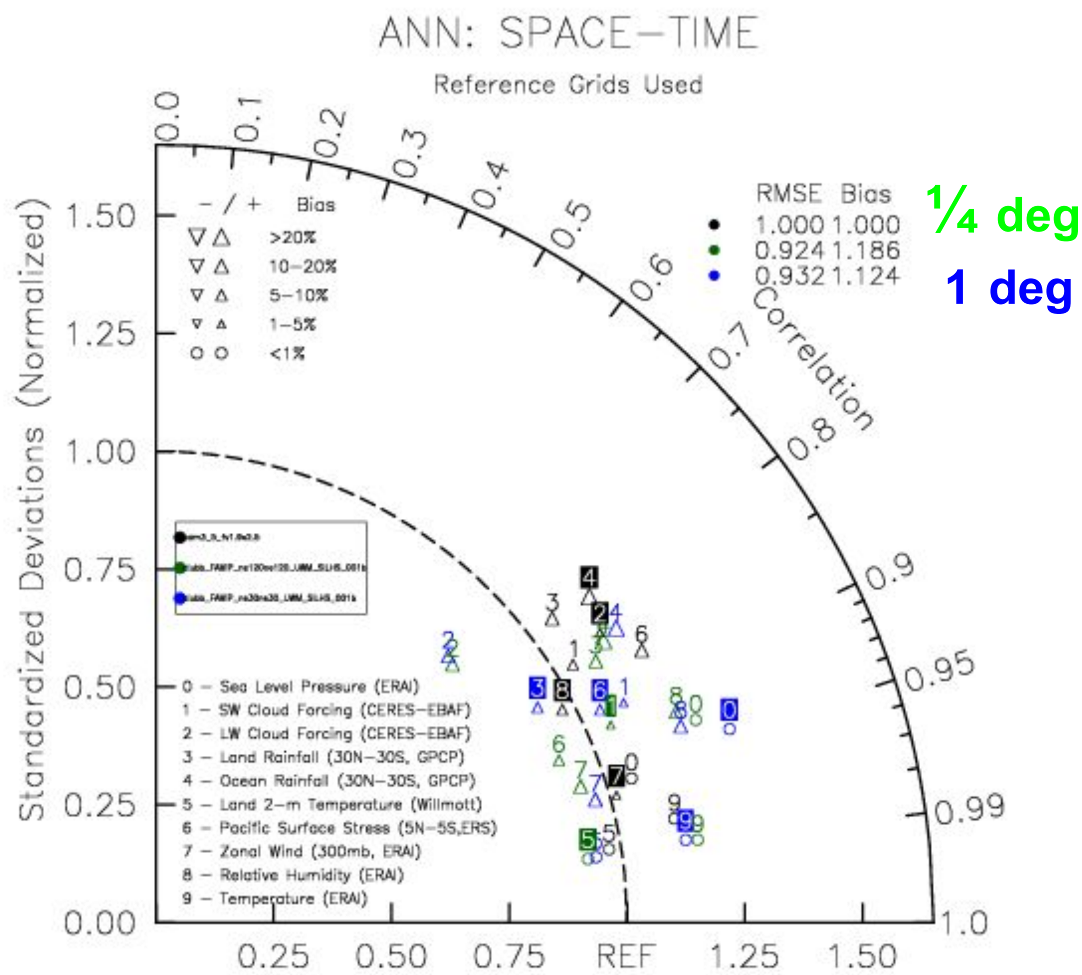
Zonal avg SWCF changes less w/ res (7 W/m2 peak) than CAM5 (15 W/m2) peak



LWCF is largely insensitive to grid spacing



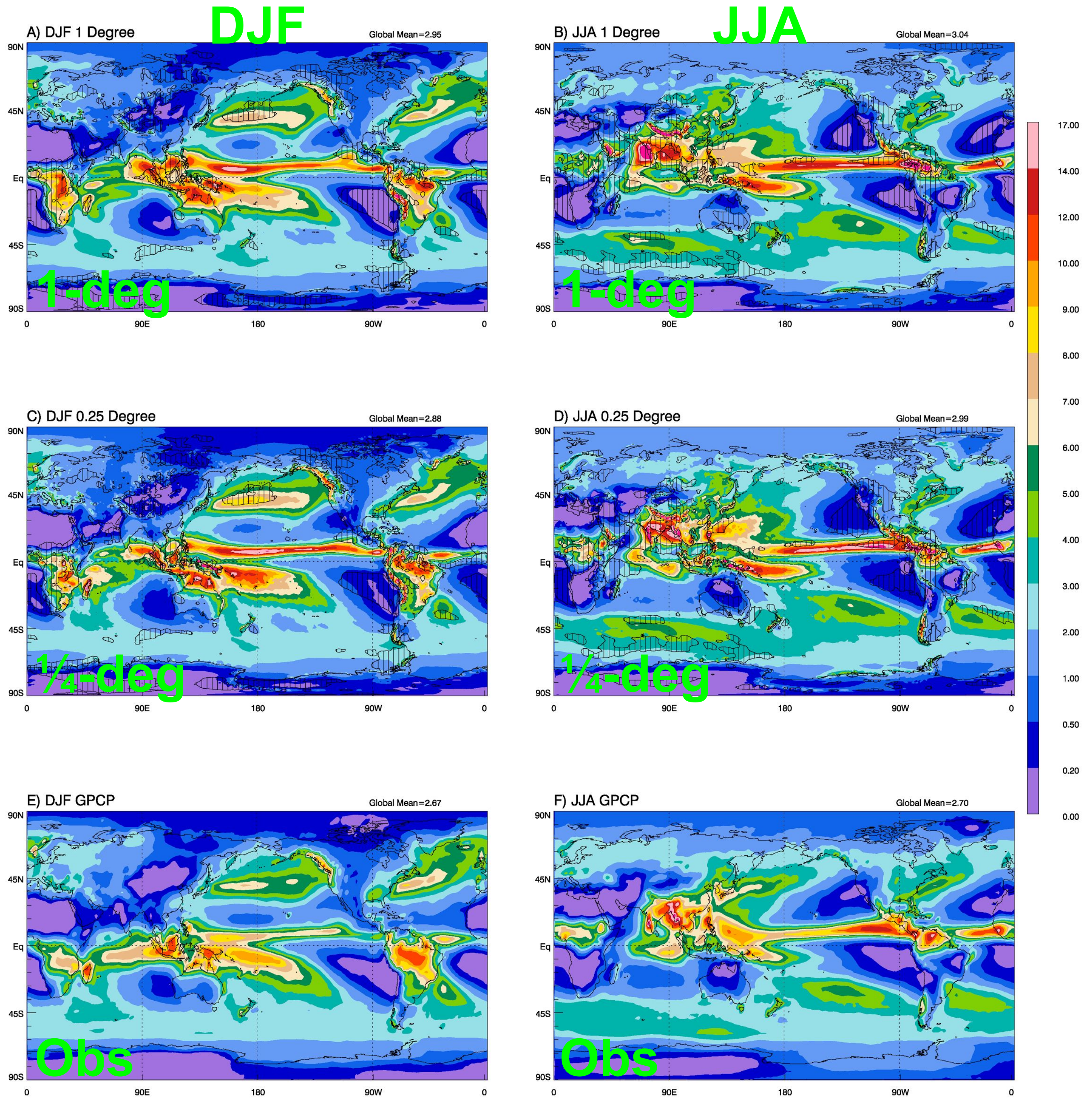
Taylor diagram remains similar at lo and hi res



Pressure, surface stress, SWCF, ocean rain are slightly improved at hi res; temperature, 300mb wind, and land rainfall are slightly worse.

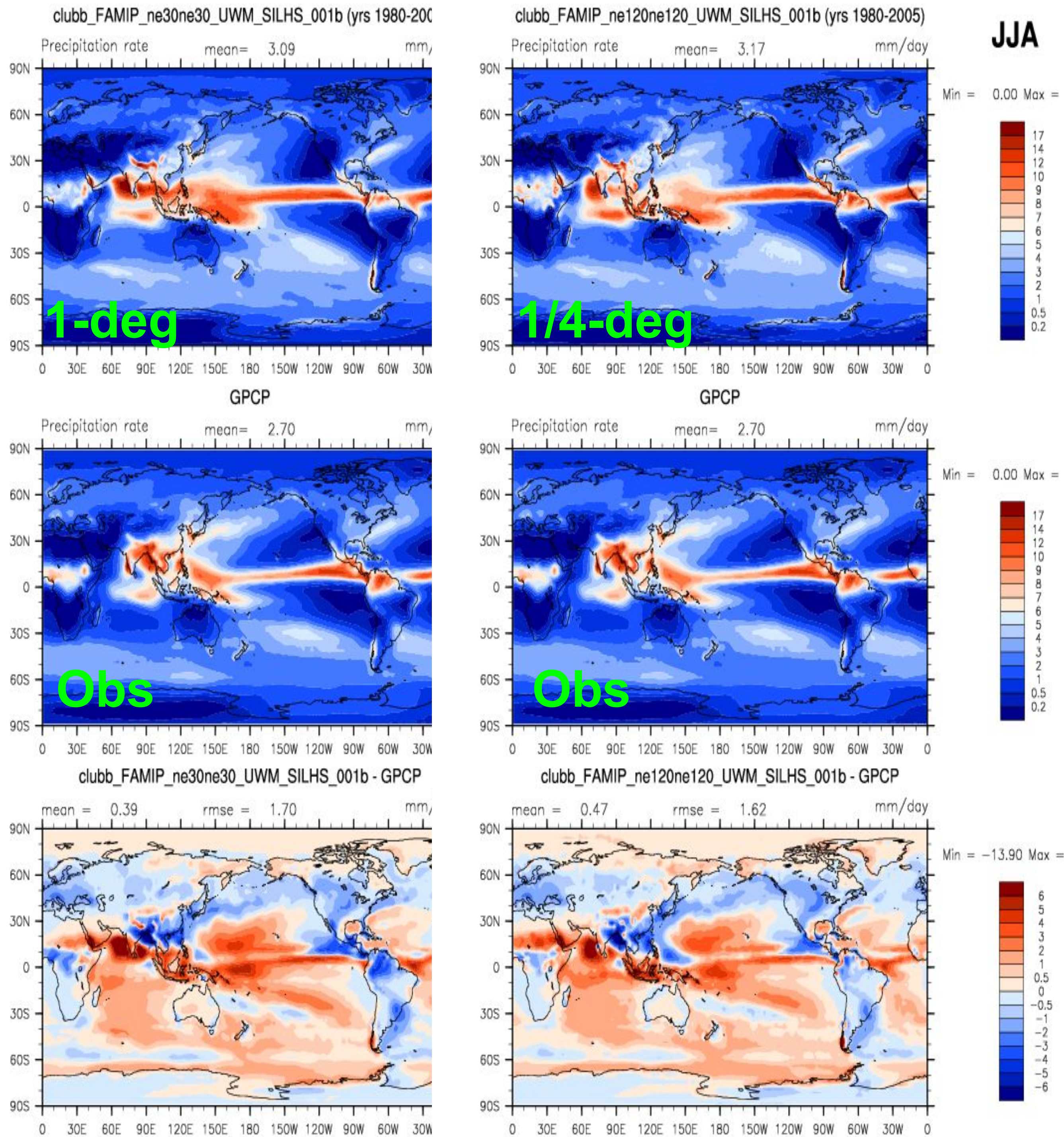
Recall CAM5: a double ITCZ forms at high resolution (and short time step):

Bacmeister et al. (2014)



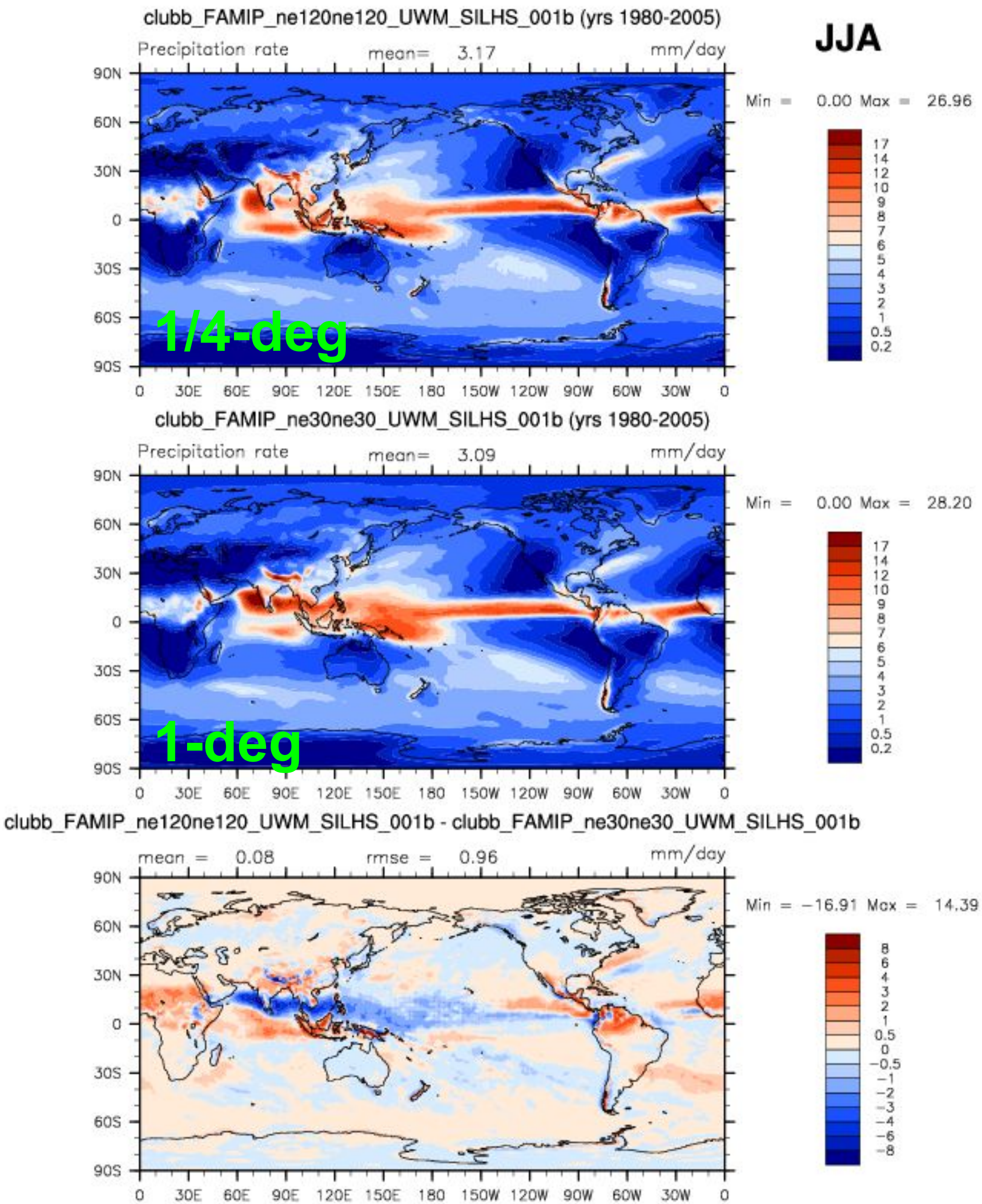
Back to CAM-CLUBB-SILHS-MG2:

JJA precip: The double ITCZ does not worsen at hi res. Amazon rain improves.

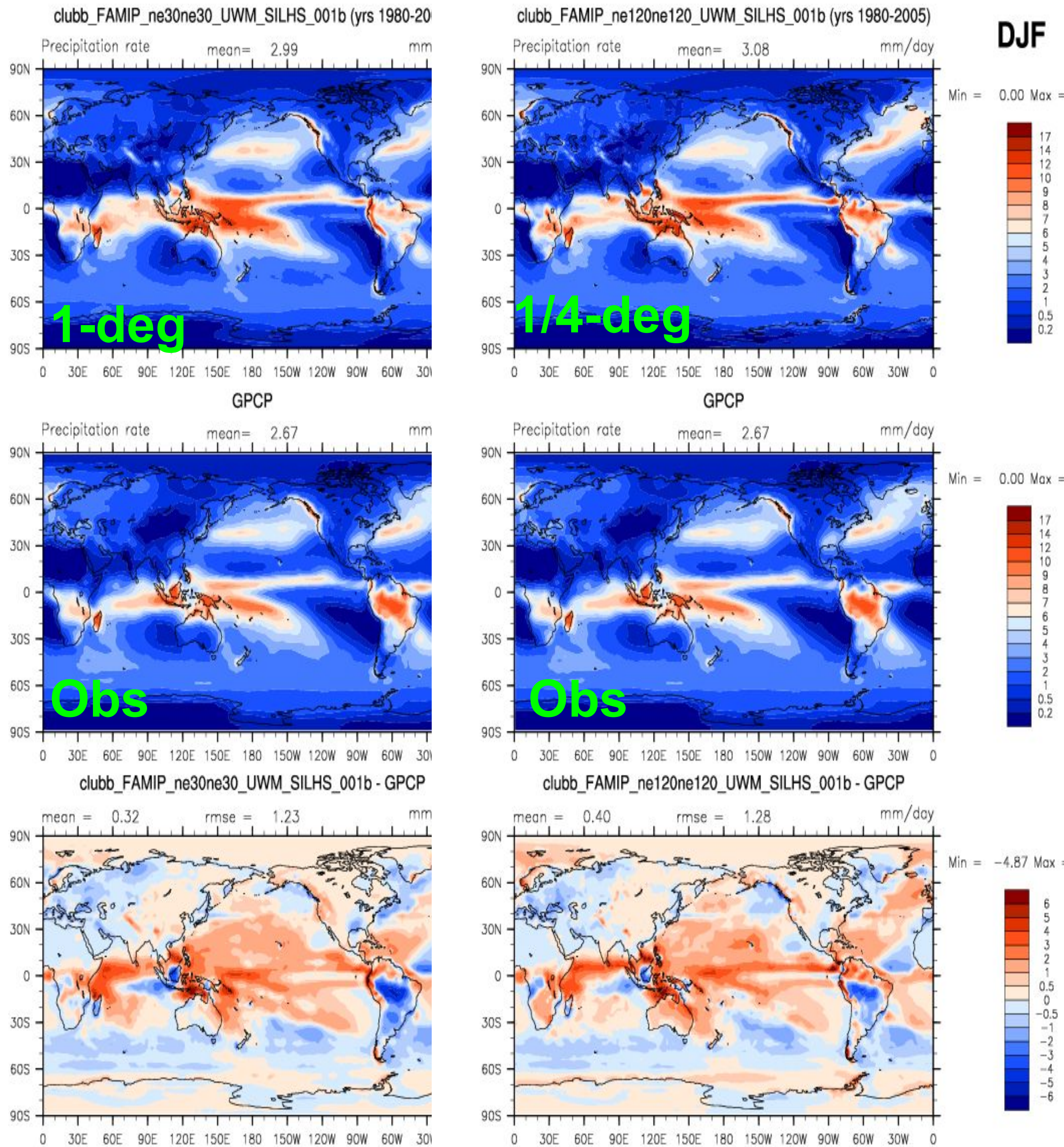


The excessive rain in the northern Indian ocean is reduced at hi res.

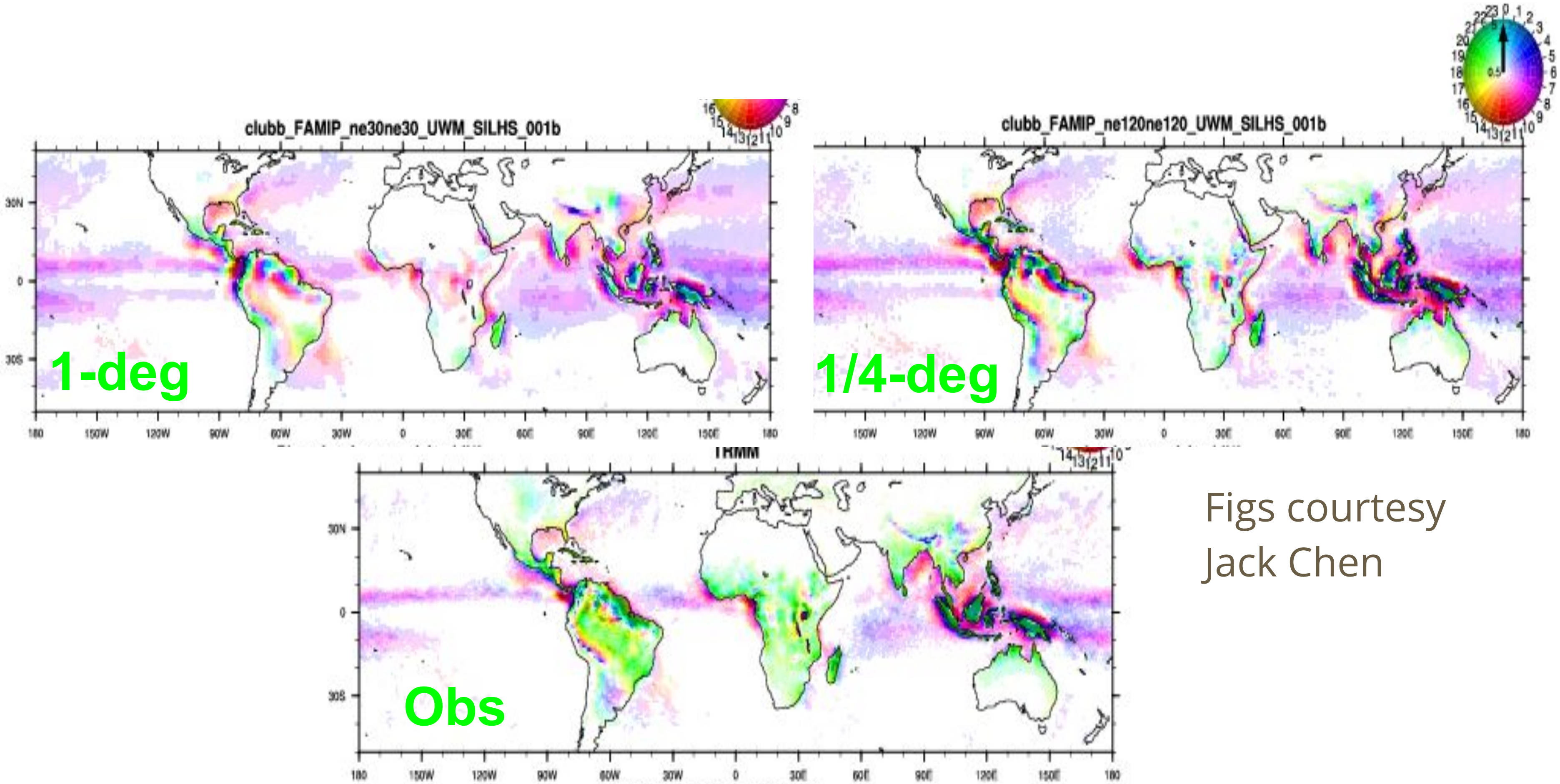
The Indian Monsoon precipitation improves.



DJF precip: Again, the double ITCZ does not worsen at hi res. Again Amazon rain improves.

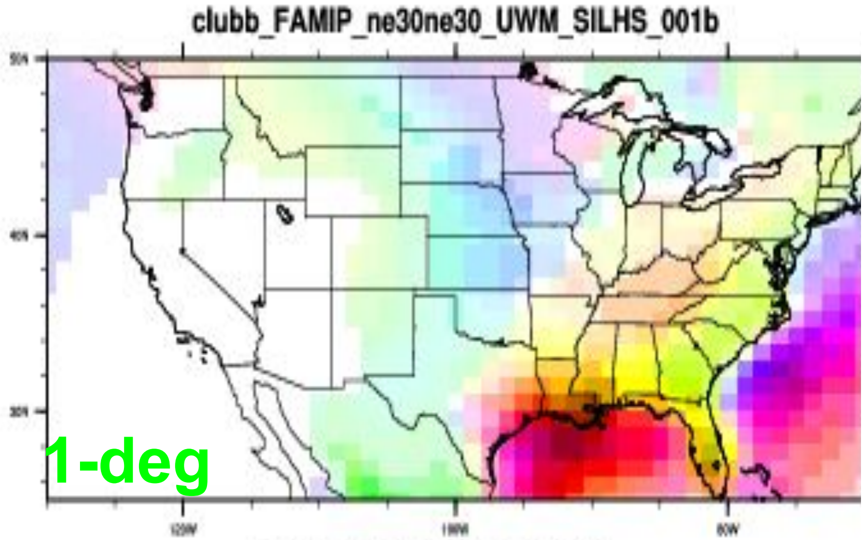


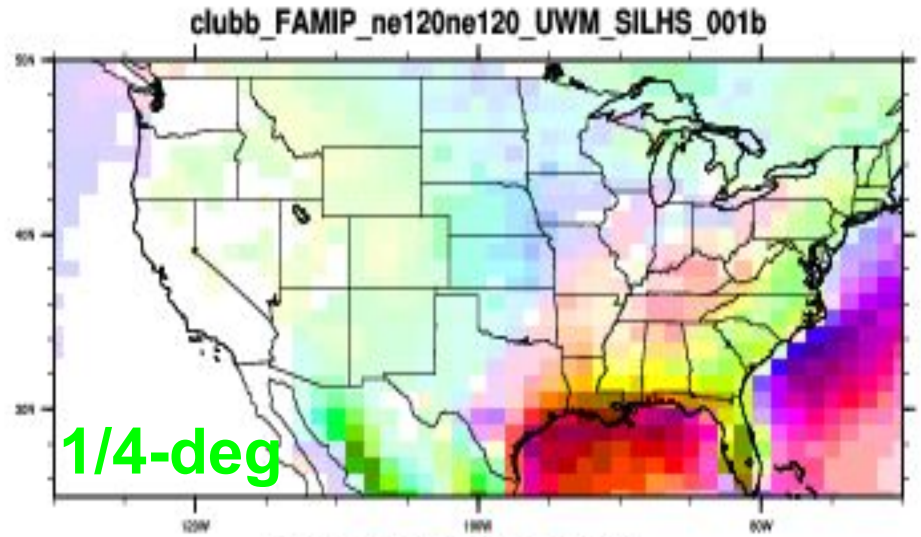
Diurnal cycle is improved slightly at hi res, especially near coasts



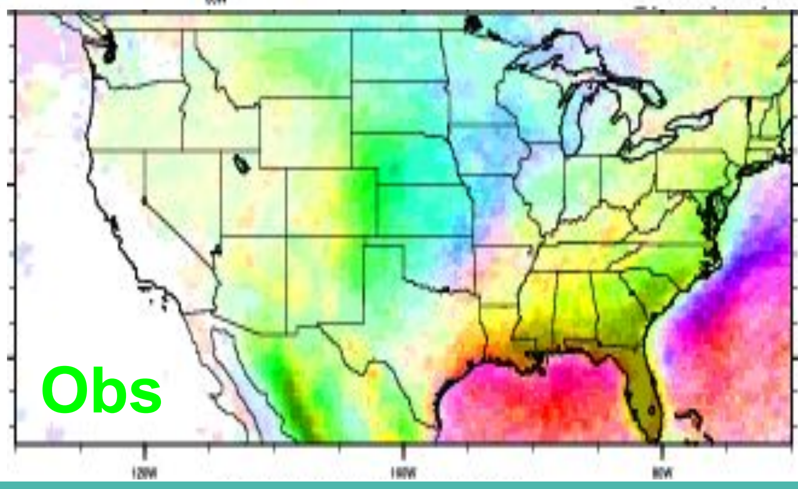
Figs courtesy Jack Chen

Diurnal cycle of rain in JJA is improved slightly at hi res over FL, the East Coast, Mexico, MN.





Precip shows nighttime max over central US



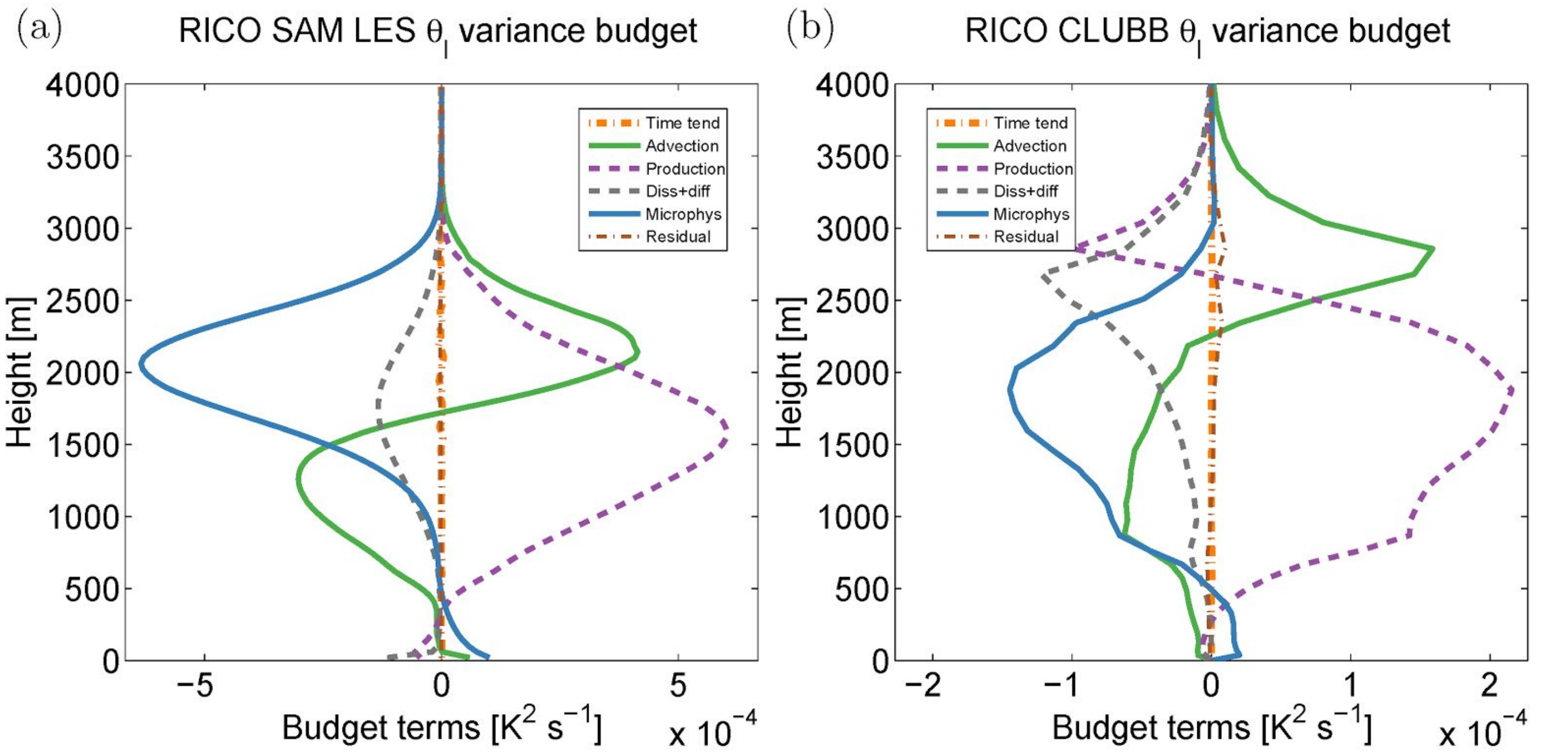
What could improve the diurnal cycle in the future? Perhaps a modification of microphysical effects on variances:

$$\frac{\partial \overline{\theta_1'^2}}{\partial t} = \underbrace{-\frac{1}{\rho_s}\frac{\partial \rho_s \overline{w}\,\overline{\theta_1'^2}}{\partial z} - \frac{1}{\rho_s}\frac{\partial \rho_s \overline{w'\theta_1'^2}}{\partial z}}_{\text{advection}} \underbrace{-2\,\overline{w'\theta_1'}\,\frac{\partial \overline{\theta_1}}{\partial z}}_{\text{production}}$$

$$\underbrace{+\varepsilon_{\theta_1\theta_1}}_{\text{diss+diff}} \underbrace{+2\,\overline{\theta_1' \left.\frac{\partial \theta_1}{\partial t}\right|_{\text{mc}}'}}_{\text{microphysics}}, \text{ and}$$

Griffin and Larson (2016)

With the right correlations, evaporation can increase temperature variance, i.e. cold pools:



Griffin and Larson (2016)

Conclusions

CAM-CLUBB-SILHS-MG2 simulations show relatively little sensitivity to horizontal resolution. In going from 1 degree to quarter degree,

- AOD does show sensivity to grid spacing;

- SWCF changes only moderately, and LWCF looks similar;

- The double ITCZ does not worsen, and rain improves over the Amazon; and

- The diurnal cycle improves slightly, especially near coastlines.