Heating in the Tropical Atmosphere

What level of detail is critical for accurate MJO simulations in GCMs?

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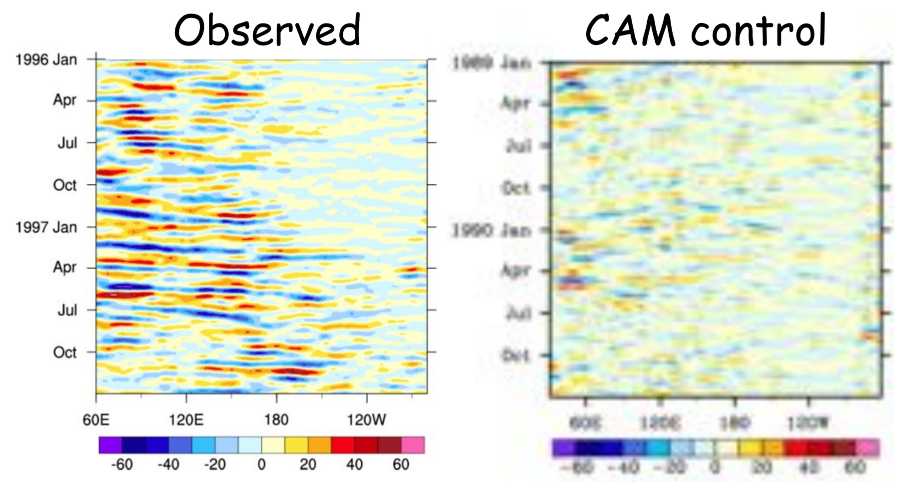
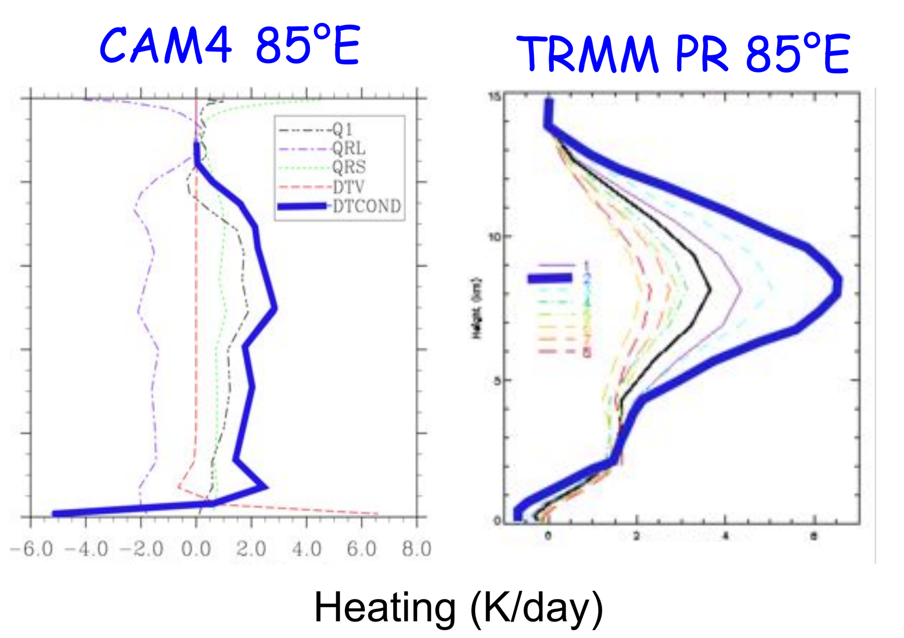
1. Motivating question

If GCMs were perfect at simulating the vertical and horizontal heating distributions in the tropics, would the Madden-Julian Oscillation (MJO) be accurately described?

Most GCMs struggle simulating the MJO. CAM4 Hövmoller OLR anomaly plots show negligible sign of the MJO.

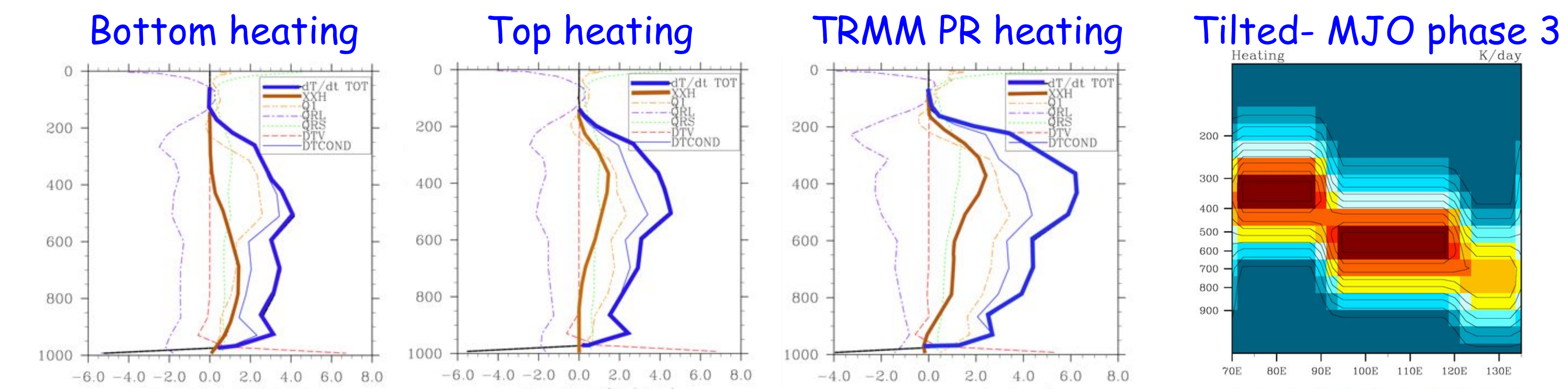




One glaring deficiency of the CAM4 run is the heating profiles. They are too weak and distributed incorrectly both in the vertical and horizontal.

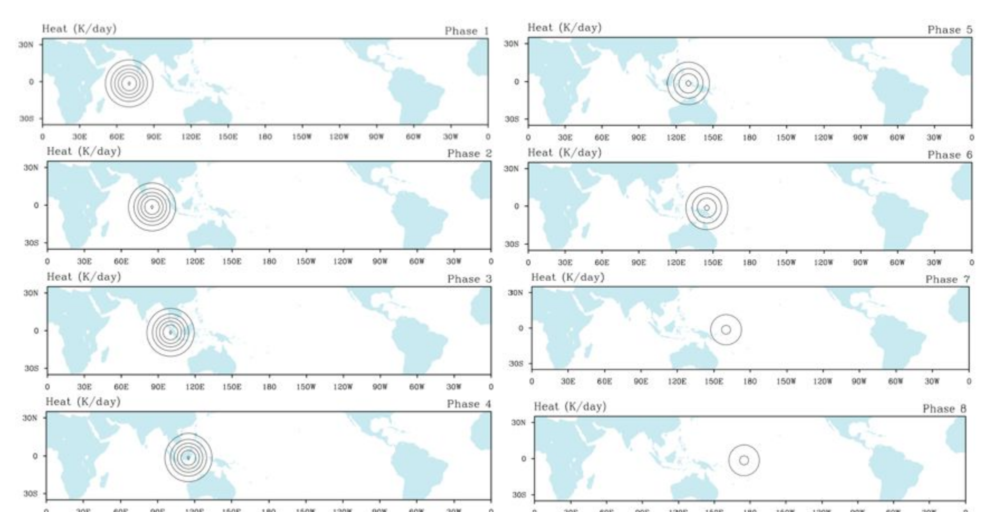
2. CAM4 heating modifications

We developed a technique in which heating is added to CAM4 in three ways. The 1st method uses idealized bottom- and top-heavy profiles. The 2nd method uses 3-D values of TRMM PR latent heating for strong MJOs. The 3rd method combines the 1st method in a way that generates idealized *tilted* heating distributions.

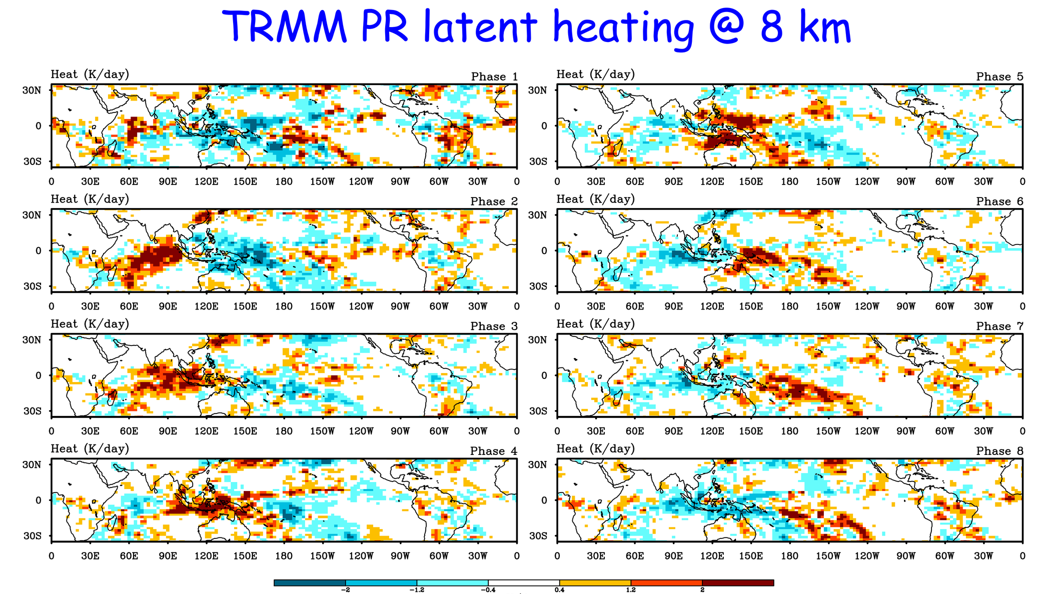


Brown lines are the added heating. Blue lines are the total heating (K/day).

The center of the heating for *all* cases except TRMM PR is placed at the location of the maximum heating *for each phase* of the MJO. The heat decreases in a Gaussian manner in the horizontal.

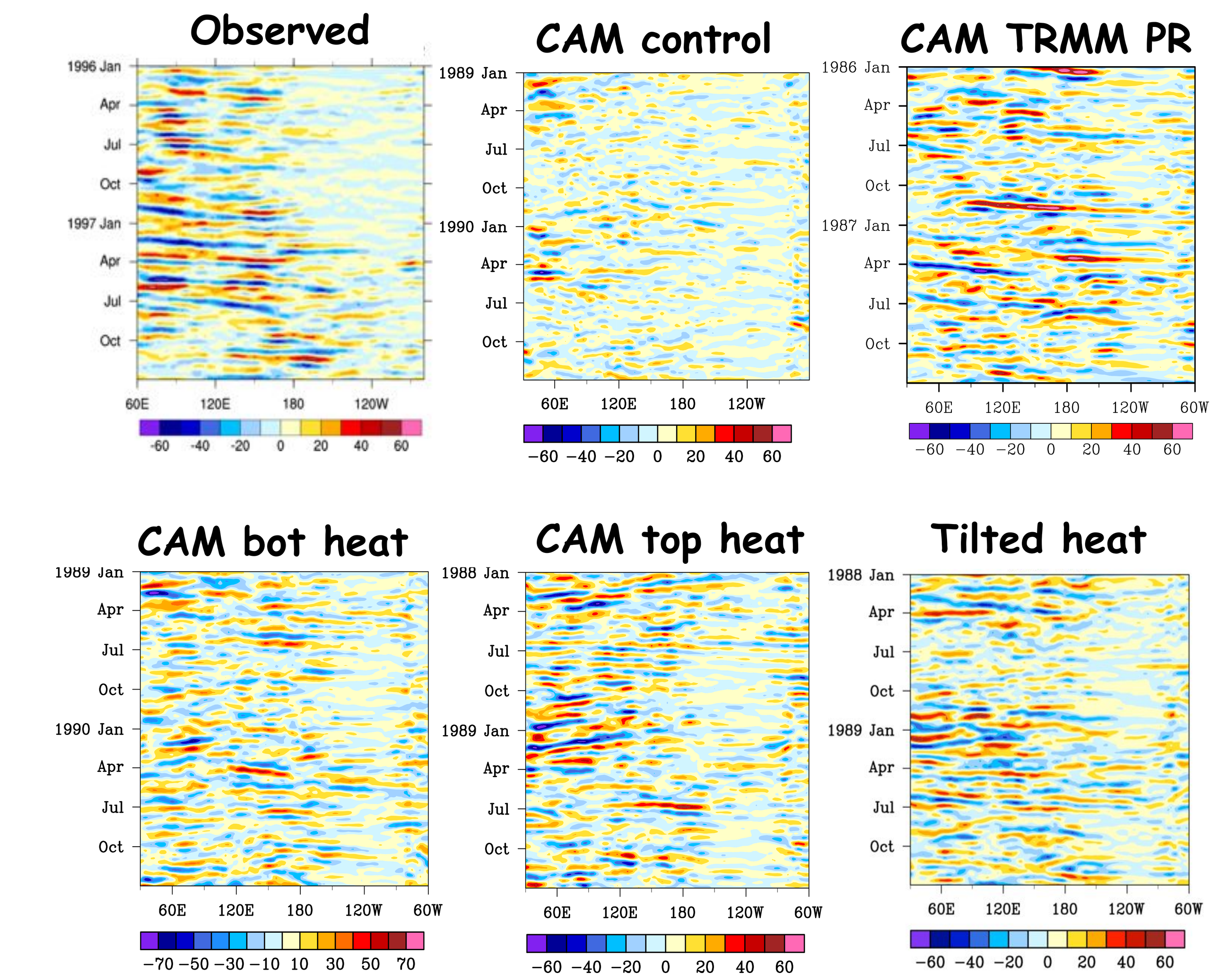


TRMM PR latent heating @ 8 km



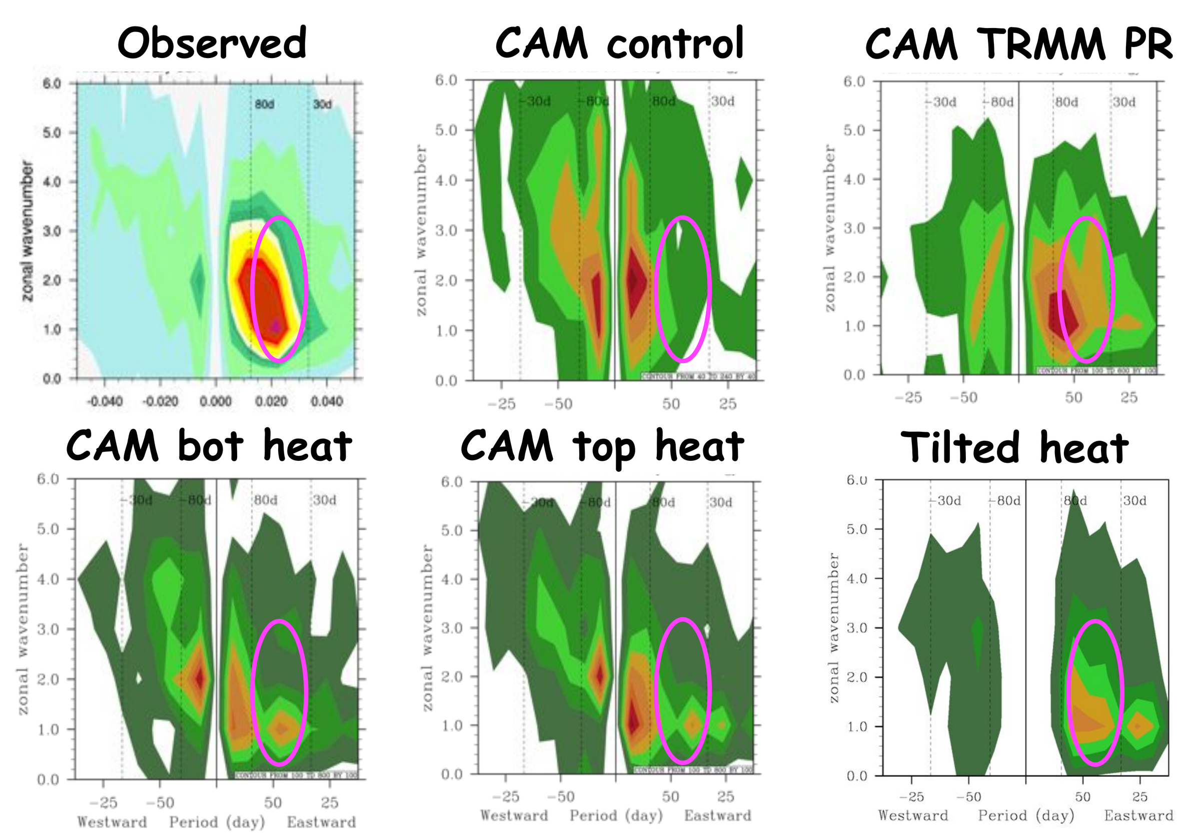
TRMM PR latent heating varies more, both in the horizontal and vertical.

3. Hövmoller plots of OLR



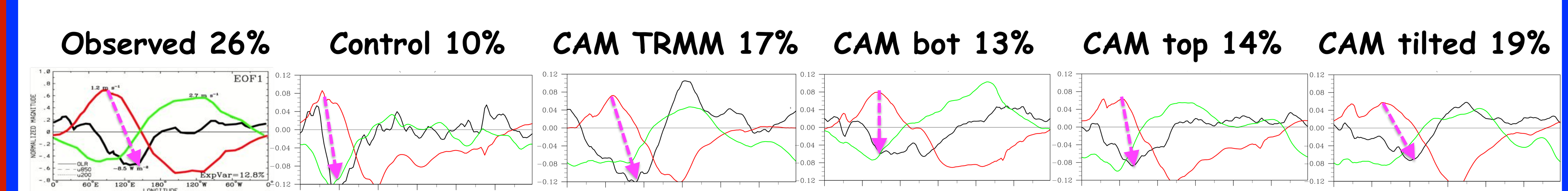
All runs show some improvement over the control. Only CAM4 forced with either TRMM PR or tilted heating shows eastward propagation at the correct phase speed. Only the tilted heating run shows strong initiation in the Indian Ocean and a weaker signal in the central and eastern Pacific (similar to observed).

4. Wave number-frequency plots



Observations of DJF OLR show eastward propagation at wave numbers 1-3 with a period between 30 and 80 days typical of the MJO. When idealized top and bottom heating is added to CAM4, there is little energy in this MJO domain. In the runs forced with TRMM PR and idealized tilted heating, we see the eastward propagation of MJO energy. However, only the TRMM PR run show this signal through wave number 3.

5. Multivariate EOF 1



We expect to see 850 hPa winds and 200 hPa winds 180 degrees out of phase, and the peak in low level westerlies (positive red) to precede the peak in negative **OLR** (negative black). The 850 hPa winds and **OLR** offset is most evident in the CAM run with TRMM PR and idealized tilted heating. The highest explained variance for EOF 1 is found for the CAM run with the idealized tilted heating.

6. Discussion

All tests done with CAM4 show an improvement in the representation of the MJO when heating is added in any form. The most realistic MJO is simulated when either (a) horizontally and vertically varying heating from the TRMM PR or (b) an idealized tilted heating profile is used to force CAM4. This highlights the fact that both the horizontal and vertical distribution of heating are critical for accurate MJO simulation.

Tests were performed varying the angle of tilt in the tilted heating runs from 0.2° to 0.7°. The MJO signal was most robust at a tilt of 0.3° (2500km horizontally and 12km vertically). The signal was further enhanced when the tilt between the middle and upper heating was smaller (0.2°) than that between the middle and lower heating (0.5°). If CAM4 could produce accurate *tilted* heating profiles, its MJO would improve dramatically.