The role of Tilted Heating in the Initiation and Maintenance of the MJO

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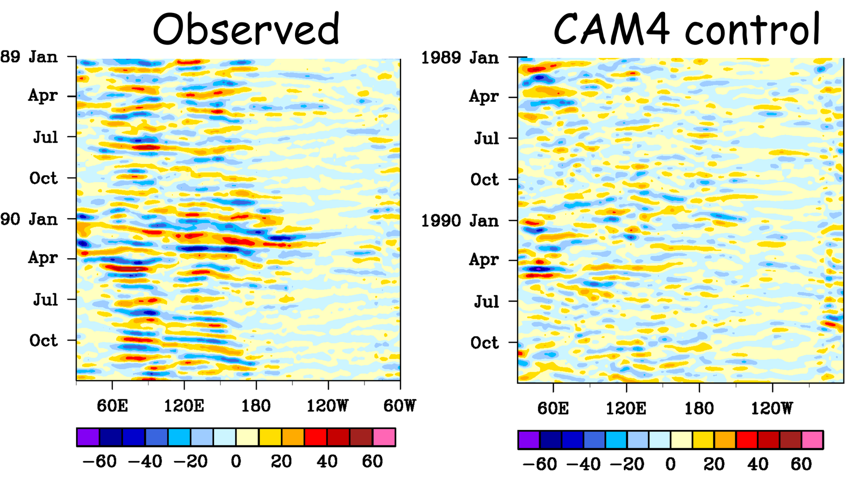
1. Background

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



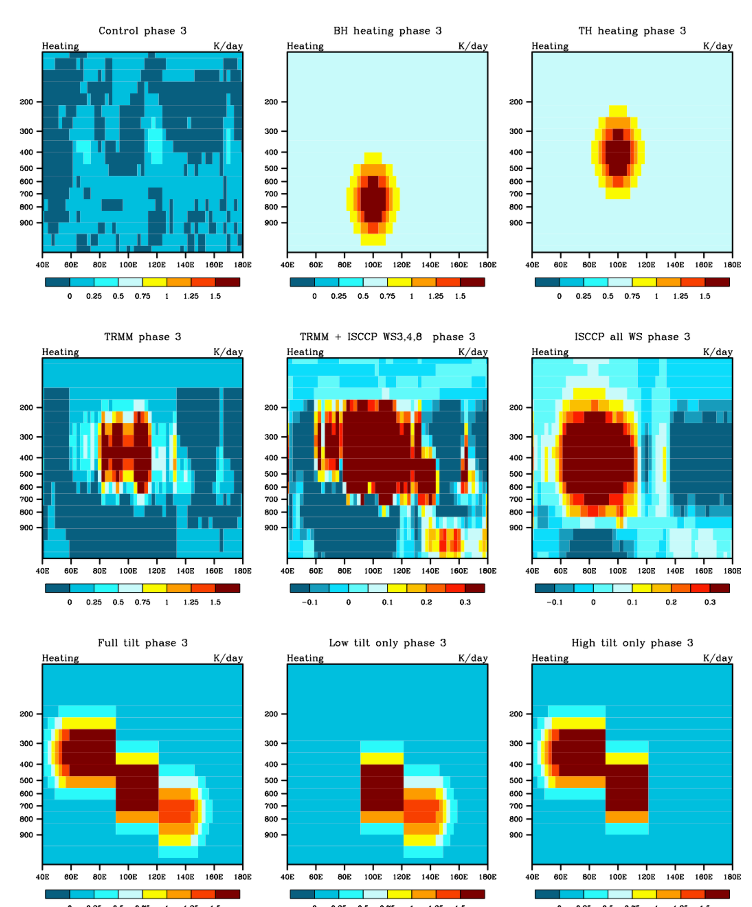
Heating in CAM4 is too weak and incorrectly distributed. Previous work (Lappen and Schumacher, 2012) show that a correct horizontal distribution of heating can greatly improve the simulation of the MJO. One theory suggests that this distribution needs to be tilted westward with height. In this theory, low-level heating ahead (east) of the MJO preconditions the air with the moisture needed to initiate and maintain the MJO in its early phases. Upper-level heating behind (west) of the MJO is theorized to help maintain the deep convection (through the moisture-stratiform instability; Mapes, 2000) in the later stages of the MJO.

How important really is a low-level or upper-level tilt in heating in simulating the MJO in GCMs?

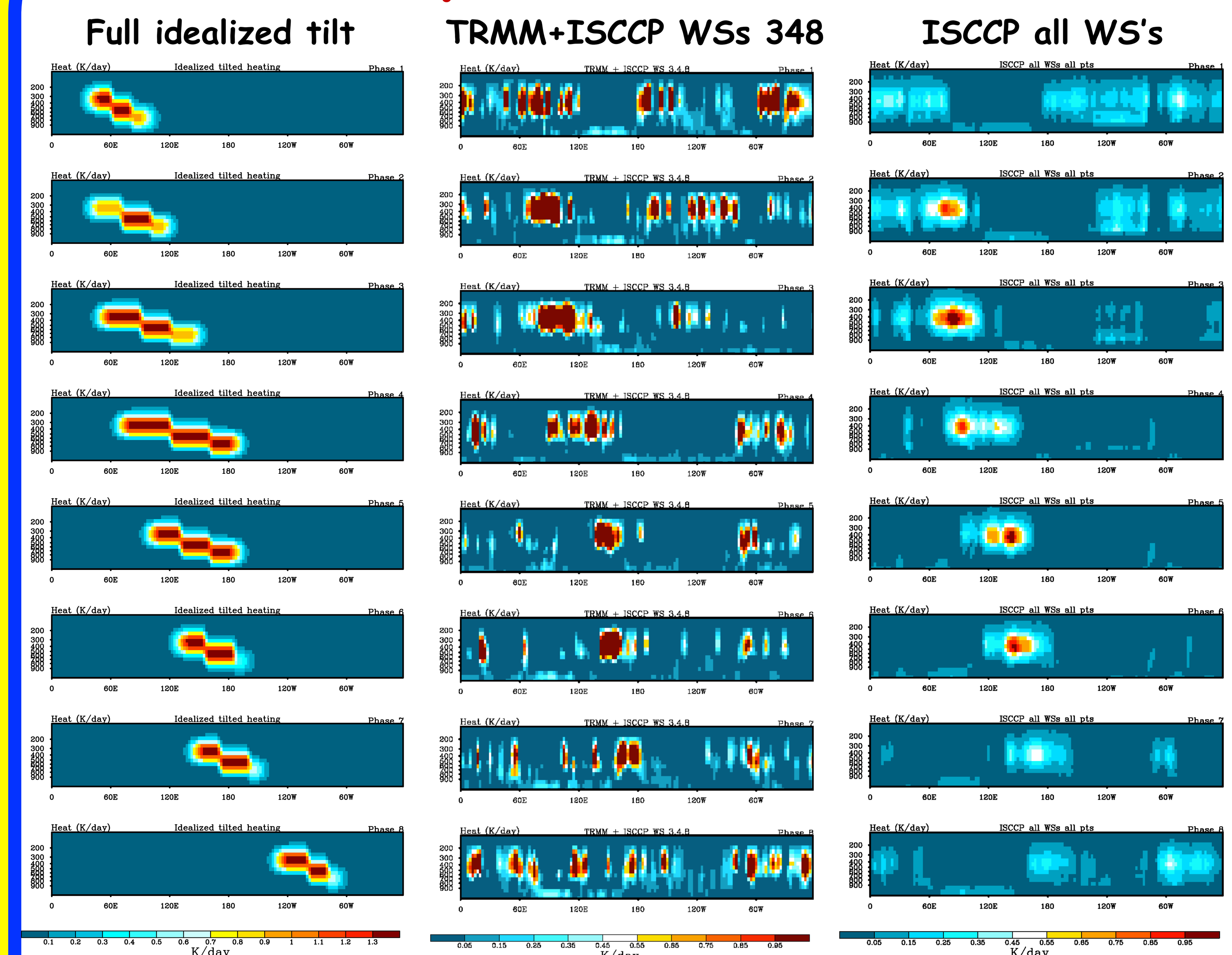
2. Technique and Simulations 1

To test the theory about tilted heating in the MJO, we created 8 different cases. In each case, we add heating distributions to CAM4 to try and trigger an MJO. CAM4 retains fully interactive physics for all cases. In the first two cases, we insert blobs of (untilted) heat at lower or upper levels (upper row). In the next three cases, we use observed distributions of heat from TRMM, ISCCP, and a combination of the two designed to produce a tilted structure (middle row). In the final three cases, we use idealized tilted heating profiles to force CAM4 (upper, lower, and full tropospheric tilt; bottom row). . In each of the idealized cases, the heat is added at the location of the maximum heating for each MJO phase.

CASE	Description	Interactive with model physics?	Tilt?
Control	ccsm4 run with no modifications	Yes	No
TH	Top heavy heating blobs added as a function of MJO phase	Yes	No
BH	Bottom heavy heating blobs added as a function of MJO phase	Yes	No
TRMM	TRMM derived latent heating	Yes	No
TRMM+ISCCP	TRMM added to ISCCP weather states 3,4, and 8	Yes	Yes
ISCCP	ISCCP all weather states	Yes	No
Full tilt	lower and upper level tilted heating added as a function of MJO phase	Yes	Yes
Low Tilt	Lower level tilted heating added as a function of MJO phase	Yes	Yes
High tilt	Upper level tilted heating added as a function of MJO phase	Yes	Yes

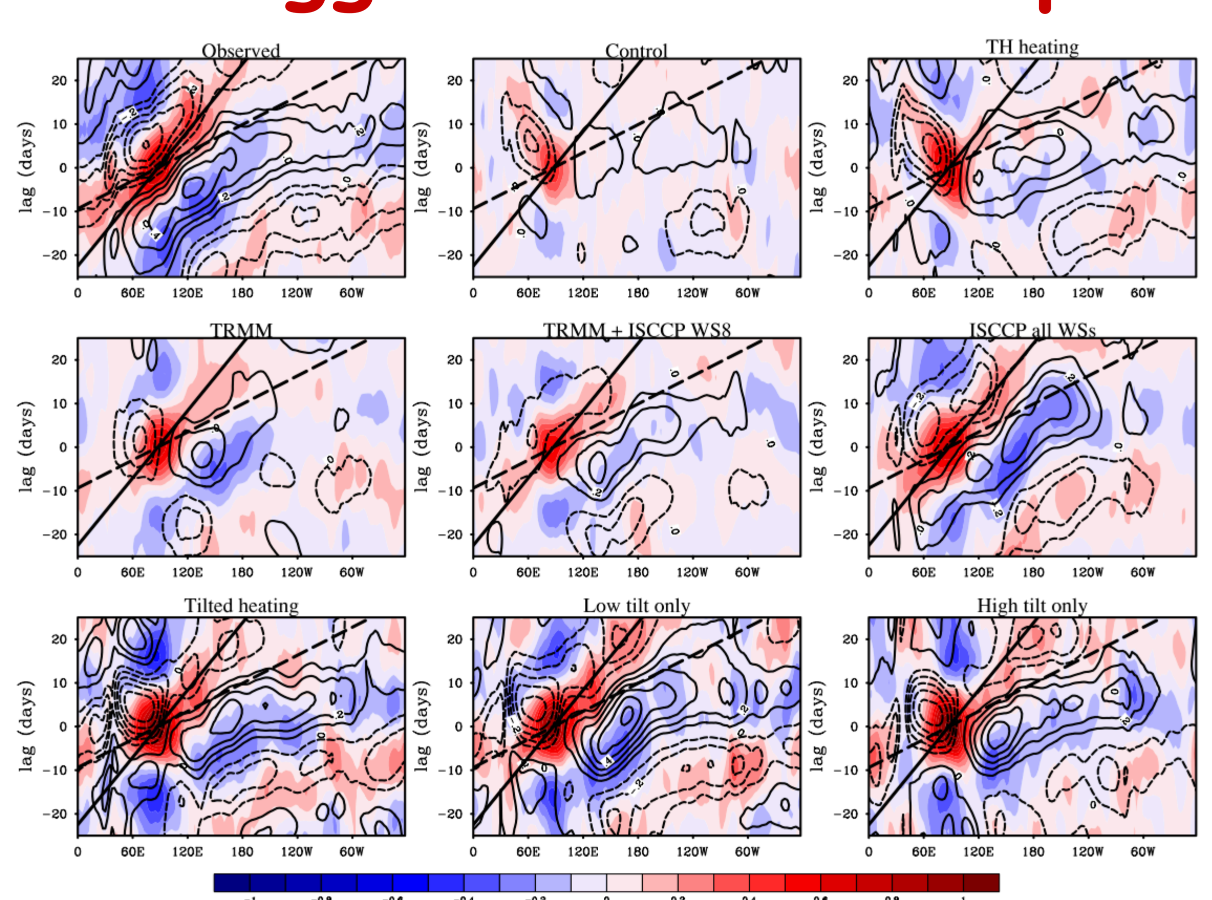


3. Technique and Simulations 2



Heating is added by MJO phase. In all 3 *tilt* cases, heat is added at the same locations. In TRMM + ISCCP WS348, there is low level tilt during the early MJO phases. For ISCCP all WSs, the low-level heating is more of a shelf out in front of (but not tilted with) the main convection.

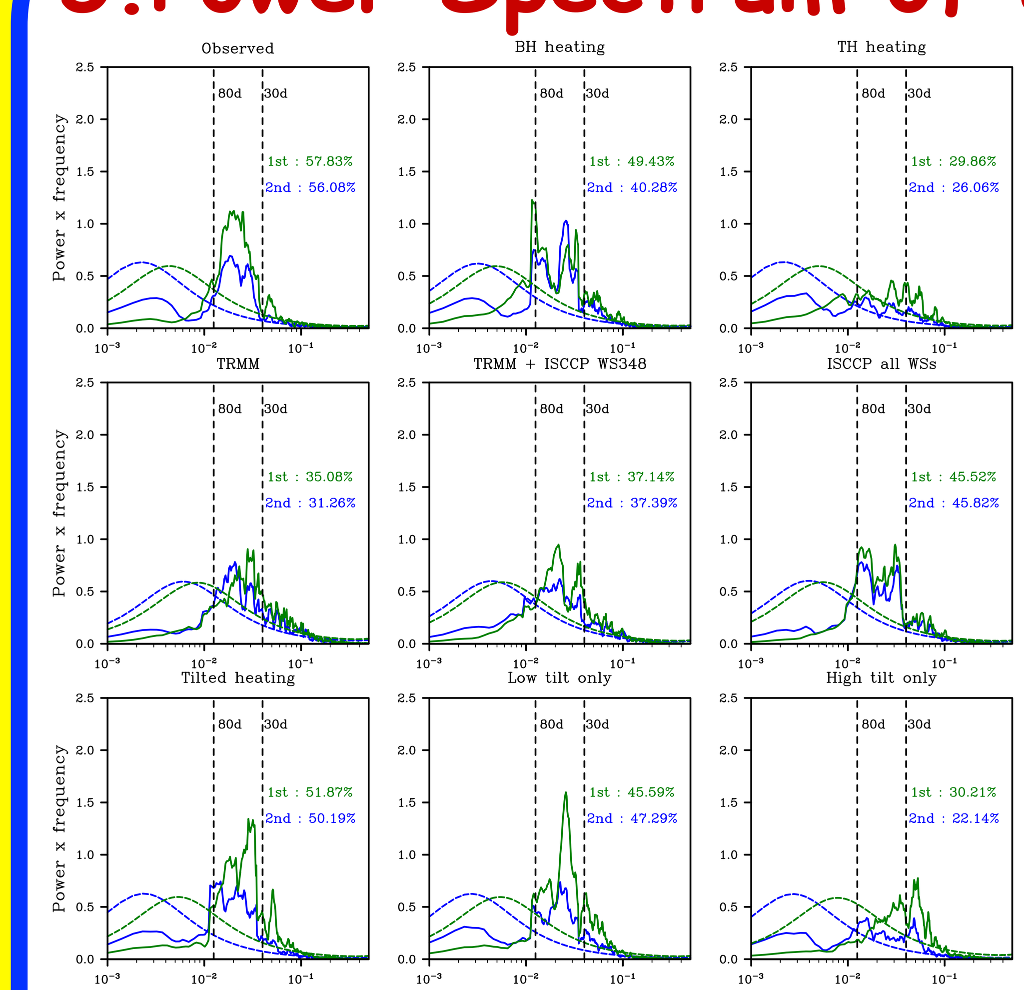
4.Lagged Correlation plots of OLR



The reference point is the Indian Ocean and the equator. Solid line: typical MJO. Dashed line: typical Kelvin wave. Blue (neg. OLR) is convective regions.

Obs. show MJO propagation out of the IO, transitioning to a Kelvin wave mode in the central Pacific. ISCCP all WSs and low tilt show the best MJO. Runs with upper-level heating added (TH and high tilt) show some westward Rossby wave propagation, and Kelvin wave activity, but little MJO. Hovmoller plots confirm this. Adding low-level heating from ISCCP WSs 3,4,8 did not produce as strong of an MJO as having a shelf of heating in front of the main heating (ISCCP all WSs, see panel 3)

5.Power Spectrum of unfiltered PCs



Multivariate EOF analysis (not shown) showed that adding heat at any level created MJO-like modes. The power spectrum to the left show that not all these modes are significant. The dashed lines show the red noise spectrum for the first two EOFs

Runs that only have upper level heat added (tilted or not) do not show significance above a red noise spectrum in the 30-80 day MJO band. Adding tilted *low*-level heating to TRMM (middle) increases the significance of the EOF modes, but not as much as putting un-tilted heating ahead of convection (middle right). Any form of low-level heating shows significance over a red noise spectrum, including an untilted blob of heat inserted at low levels (BH; top middle)

6. Discussion/Conclusions

- Low-level heating ahead of the MJO convective center is critical for the initial strengthening and later maintenance of the MJO. It does not appear that this heating needs to be tilted with the deeper convection. i.e., low-tilt is sufficient but not necessary.
- Upper-level heating, whether tilted or not, appears to degrade the MJO signal. When upper level heating is added in addition to low-level heating, the MJO mode is not as strong as when the upper-level heating is not there.
- Westward propagating Rossby modes occur when upper-level heat is added in any form to CAM4. These do not show up in runs with only low-level heating. This is confirmed with wave-number frequency analyses and Hovmoller diagrams (not shown).
- Kelvin wave activity is evident over the central Pacific but not noticeable over the IO when MJO mode is strong.
- The implications for GCMs is that accurate shallow-convective parameterizations may be more important than the deep convective parameterizations in maintaining an MJO mode that vigorously propagates eastward