Controlling Climate Model Tropical Bias Through Tropical Diabatic Heating

David M. Straus and Youkyoung Jang

George Mason University, Fairfax, VA and Center for Ocean-Land-Atmosphere Studies

Motivation: Improved simulation of stationary waves in climate models provides an important basis for enhancing the predictability of atmospheric teleconnections. Stationary waves and many teleconnections are forced by tropical diabatic heating, which is mis-represented in most models, (e.g., poor simulation of the inter-tropical convergence zone or ITCZ).

Goals of this research

✓ Apply a technique to reduce the tropical bias in monthly mean diabatic heating in simulations with the Community Earth System Model (CESM)

✓ Verify that some aspects of the mid-latitude bias in stationary waves are reduced

Method

✓ Zeroth Order "Correction" Technique

- Subtract model bias in monthly mean climatological tropical diabatic heating
- 3-dimensional model bias in monthly diabatic heating is estimated from:
  a) 50 Oct-March simulations with CESM 1.05 (CCSM4 0.9º x 1.25º)
  b) Estimates of observed diabatic heating from Chan and Nigam (2009)
- The correction term (= minus the model bias) is added directly to all the temperature tendency terms in the coupled model
- The model moist and radiative parameterizations are still fully operative, thus can react to the added heating
- All the coupled model feedbacks are retained

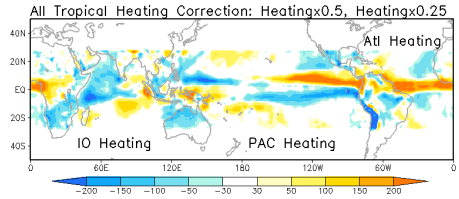
✓ First Order "Correction" needed:

- Model heating reacts so as to magnify correction and thereby lead to over-correcting so higher order correction is needed.
- Simple fix is to multiply the heating correction by 0.5 and 0.25.

✓ Higher Order "Correction" will be needed:

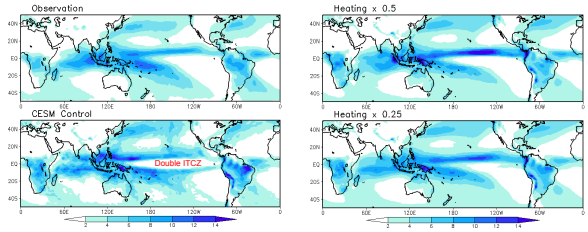
- Iterate this technique to provide an additive correction term that will reduce the climatological model tropical diabatic heating error to near zero (on a monthly basis)A

First Order Correction Experiments



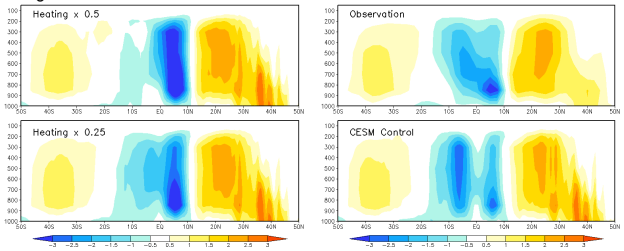
Precipitation

: The CESM Control mean precipitation shows the double ITCZ in the Pacific. The double ITCZ disappears in the two heating correction experiments. However, the tropical Pacific still has overly strong precipitation in the forced experiments.



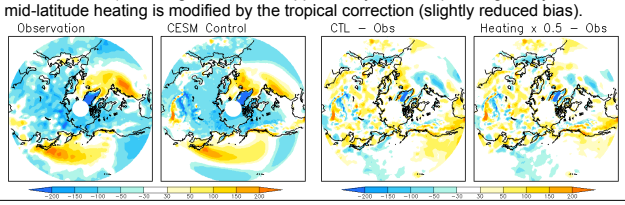
Zonal mean Omega

: In the CESM Control, erroneous strong ascending motion near 5S reflects the presence of the double ITCZ. This improved in two heating experiments. Oueslati and Bellon (2013) also showed the relationship between the double ITCZ and errors in the omega.



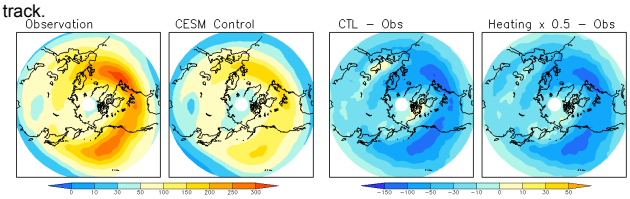
Diabatic Heating

: Vertically integrated diabatic heating rates consists of the sum of heating rates due to moist processes (convection and resolved condensation) and radiation (longwave and short wave). Heating correction is applied only in the tropical regions, yet the mid-latitude heating is modified by the tropical correction (slightly reduced bias).



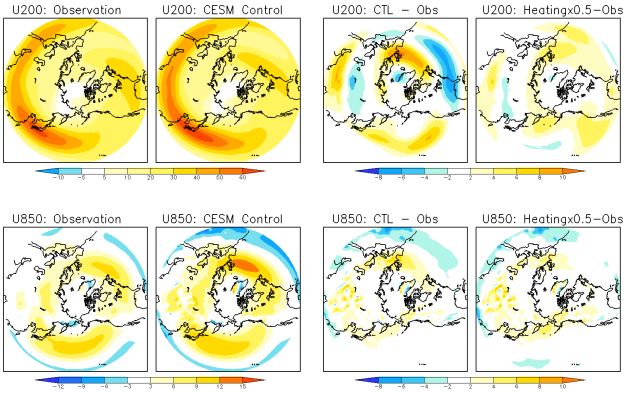
Transients (v' x v' at 300hPa)

: Storm tracks in all experiments are too weak and this problem may come from weak upper level zonal wind or incorrect stationary waves. Low resolution in conjunction with parameterizations does not resolve cyclone structure and heating well enough – weaker heating leads to less reinforcement of the storm track.



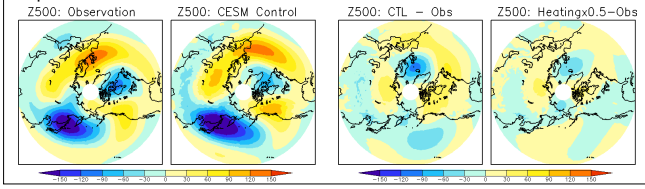
Zonal wind at 200hPa and 850hPa

: Over North America weak zonal wind at 200 hPa is simulated in the control run and this error becomes small in the heating experiment.



Geopotential Height Eddies at 500

: the bias over the North Pacific and Atlantic Ocean becomes weak in the heating experiment.



Reference

Chan, S. C. and S. Nigam, 2009: Residual diagnosis of diabatic heating from ERA-40 and NCEP reanalyses: Intercomparisons with TRMM. *J. Climate,* **22,** 414-428

Oueslati B, Bellon G (2013) Convective entrainment and large-scale organization of tropical precipitation: sensitivity of the CNRM-CM5 hierarchy of models. *J. Climate,* **26**, 2931–2946

Conclusions

✓ Tropical diabatic heating bias correction in CESM leads to the disappearance of the double ITCZ, as seen in precipitation, diabatic heating and vertical motion.

✓ CESM bias in mid-latitude stationary waves & mean zonal wind is reduced.

✓ The bias in storm tracks & mid-latitude heating has NOT been reduced. (Why?)

✓ Future Work: Further refine heating corrections; Study predictability of seasonal means.