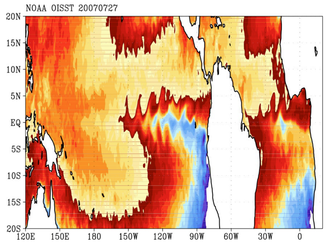
Regional Coupled Downscaling of Global Warming in the Tropical Atlantic: Response in Equatorial Upwelling and Tropical Instability Waves

Hyodae Seo (hyodae@hawaii.edu) and Shang-Ping Xie
International Pacific Research Center, University of Hawaii, Manoa

1. Summary

The Scripps Coupled Ocean-Atmosphere Regional (SCOAR) model is used for a coupled dynamic downscaling over the tropical Atlantic based on an ensemble global warming simulation carried out with the Geophysical Fluid Dynamics Laboratory (GFDL) CM2.1 to highlight a role played by ocean dynamical processes in shaping regional warming pattern under global warming.

Motivation: Equatorial currents and mesoscale variability such as tropical instability waves (TIWs) are not adequately represented in IPCC AR4 CGCMs. Downscaling allows to assess their impact on mean state changes under global warming by explicitly resolving them in a higher-resolution model grid.



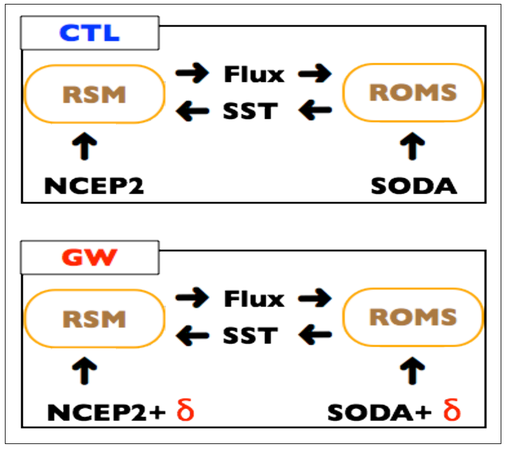
Simulation of mean state: SCOAR reproduces important aspects of the present-day mean state. Under global warming, equatorial cold tongue exhibits a reduced response in SST due to enhanced upwelling. The cross-equatorial southerly winds intensify, accelerating Equatorial Undercurrent and South Equatorial Current.

Response in equatorial upwelling: Upwelling increases due to the anomalous vertical velocities forced by the cross-equatorial winds and stronger surface divergence at the surface.

Response in TIW variability: Equatorial ocean becomes more barotropically and baroclinically unstable, strengthening TIW variability.

Impact on heat balance: The increased TIW variability significantly damps the effect by enhanced upwelling via eddy temperature advection.

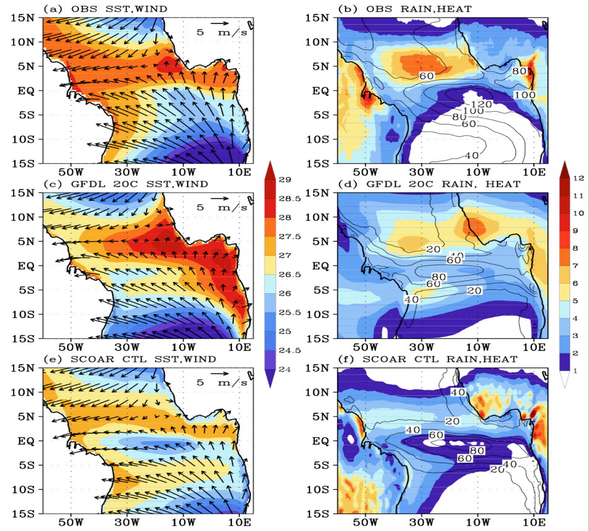
2. Scripps Coupled Ocean-Atmosphere Regional (SCOAR) model



- δ=GFDL CM2.1 10-member ensemble (2045-2050)-(1996-2000)
- 25 km ROMS + 50 km RSM
- Daily coupling
- 1980-2007

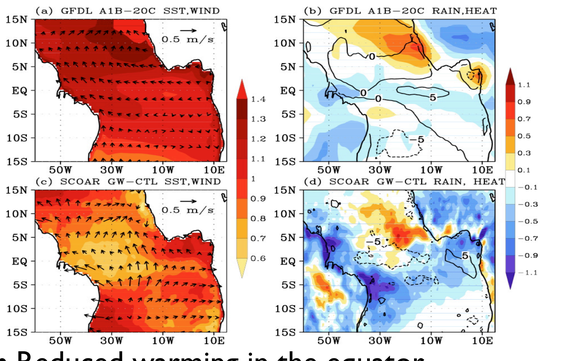
SCOAR: Seo, Miller, and Roads, *Journal of Climate*, 2007

3. Simulation of present-day climate



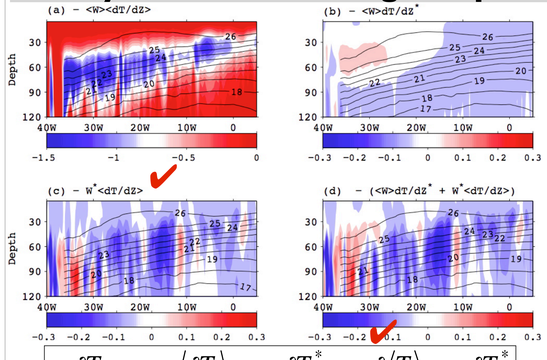
- Equatorial upwelling and zonal gradient in SST are somewhat more realistic in SCOAR.
- But note that many GCM biases still present in SCOAR.
- Stronger and consistent large-scale nudging technique is necessary.

4. Global Warming response



- Reduced warming in the equator
- Intensified cross-equatorial meridional winds

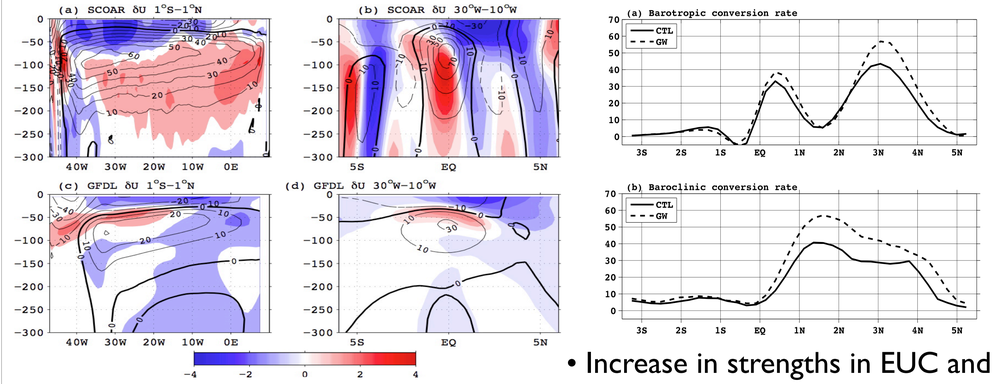
5. Why reduced warming in equator?



$$-w\frac{\partial T}{\partial z} = -\langle w\rangle\left\langle\frac{\partial T}{\partial z}\right\rangle - \langle w\rangle\frac{\partial T^*}{\partial z} - w^*\frac{\partial\langle T\rangle}{\partial z} - w^*\frac{\partial T^*}{\partial z}$$

- Increased upwelling is associated with increase in vertical velocities (w*) by surface divergence.

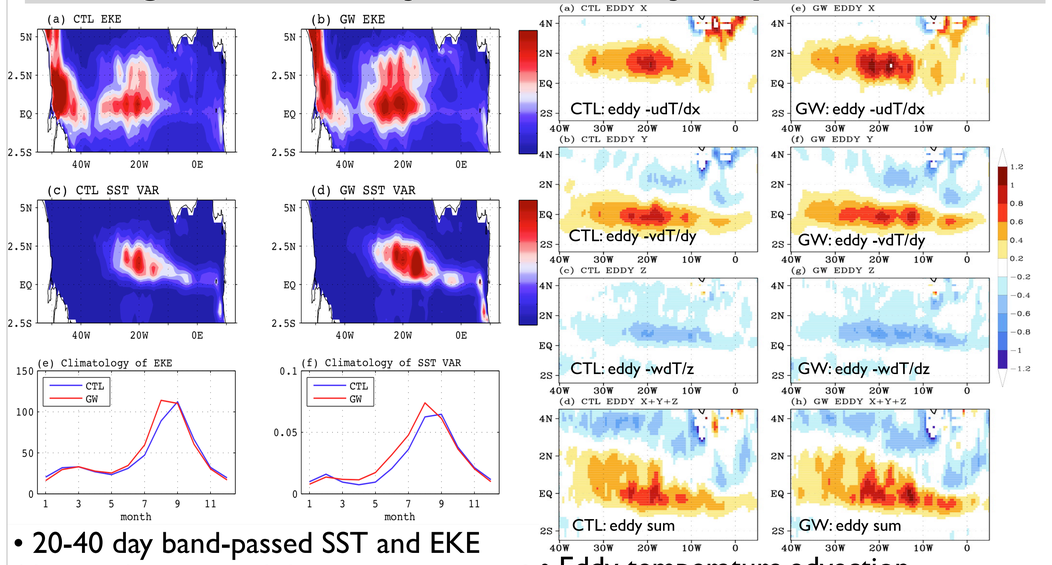
6. Change in Equatorial Undercurrent and dynamic instability



- EUC is more realistic in SCOAR in CTL.
- Zonal currents intensify in GW

- Increase in strengths in EUC and fronts leads to more barotropically and baroclinically unstable equatorial cold tongue.

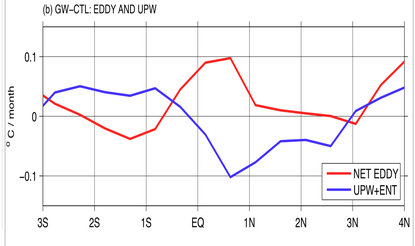
7. Strengthened variability of TIWs and eddy temperature advection



- 20-40 day band-passed SST and EKE (thermodynamic and dynamic measure of TIWs) are both intensified (~30%) in GW.

- Eddy temperature advection correspondingly increases. Note that increase in zonal advection is largest, but is offset by eddy vertical advection.

8. Impact on mean state through eddy heat flux



- Net warming by eddies substantially damps cooling associated with increased upwelling.

9. Implications of this study

- This is the first coupled downscaling experiment of the global warming simulation.
- Downscaling improves the equatorial simulation with realistic EUC and TIWs, not realistically resolved in IPCC AR4 models; a useful tool for assessment of regional projection of climate change and variability.
- Need to improve the downscaling technique, especially to reduce a drift in mean state simulation in a long-term coupled simulation.
- This exploratory research suggests that high-frequency climatic processes such as TIWs should be included in the ongoing discussion of tropical ocean response to global warming.