Downscaling Global Warming with a Regional Ocean-Atmosphere Model over the Tropical Atlantic

Role of equatorial ocean dynamics:
equatorial upwelling and ocean mesoscale variability

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Also thanks to
Raghu Murtugudde, Markus Jochum,
and Art Miller
Introduction:
Weakening of Walker circulation and ocean heat transport

Vecchi and Soden 2007
Introduction:
Weakening of Walker circulation and ocean heat transport

Multi-model ensemble change
(A1B-20C) in ω(500hPa)

Vecchi and Soden 2007

Change in ocean heat transport

GFDL CM2.1 10-member ensemble
(2046-2050) - (1996-2000)
• **Tropical Instability Waves (TIWs)** are the undulations of equatorial SST front in the Pacific and Atlantic.
• Generated by **oceanic intrinsic instability**.
• Primarily sub-seasonal, but important for low-frequency tropical climate.
• Not well-resolved in the IPCC-AR4 models. So we need to **downscale**.
Model and Experiments

**Scripps Coupled Ocean-Atmosphere Regional Model***
Atmosphere: Regional Spectral Model (Scripps RSM)
Ocean: Regional Ocean Modeling System (ROMS)

- **CTL**: RSM (NCEP2 6hrly) + ROMS (SODA monthly)
- 25 km ROMS + 50 km RSM
- Daily coupling

*Seo, Miller and Roads, 2007*: The Scripps Coupled Ocean-Atmosphere Regional (SCOAR) model, with applications in the eastern Pacific sector. *Journal of Climate*
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**GW:** RSM (NCEP2 6-hrly + $\delta$) + ROMS (SODA monthly + $\delta$)

- $\delta$=GFDL CM2.1 monthly difference:

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Simulation of present-day climate and global warming response: 

*Annual mean SST, surface winds, and precip.*
Simulation of present-day climate

- Zonal SST gradient and equatorial cold tongue in SCOAR
Simulation of present-day climate

- Zonal SST gradient and equatorial cold tongue in SCOAR
- Reduced warming in the equator
- Intensified cross-equatorial meridional winds
Change in equatorial zonal currents and equatorial instability

- EUC is more realistic (stronger) in SCOAR.
- Stronger cross-equatorial wind
  - Stronger EUC (Philander and Delecluse, 1983)
  - Enhanced Barotropic and baroclinic instability
  - Stronger TIWs

SCOAR CTL Mean U

SCOAR δU

GFDL 20C Mean U

GFDL δU
Strengthening of TIWs (20-40 day band-pass filtered EKE and SST variance)

- EKE and TIW-SST variance all become stronger during the cold season.
• Equatorial upwelling (cooling) increases
  • Increased $w'$ acting on climatological $dT/dz$ $>>$
    Climatological $\langle w \rangle$ acting on $dT'/dz$ due to radiative forcing.
• Net eddy heat flux (warming) increases, damping the effect of upwelling.
Conclusion and Discussion

- Downscaling is also important for study of oceanic role in weather and climate.
- Advantages: Better capture equatorial currents and mesoscale variabilities
- *Exploratory* research: Coupled downscaling of the IPCC climate change scenarios
- Upwelling increases. TIWs increase. Impact the mean state.
- Need to monitor TIW heat flux (zonal) for detection of warming signal.
- Need to resolve high-freq. processes in the model for global warming research.
Thanks!