Key Factors in Simulating the Equatorial Atlantic Zonal SST Gradient in a CGCM

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1. Introduction

Modeling the mean climate state realistically is the first step toward simulating as well as predicting climate variations. However, the zonal SST gradient in the equatorial Atlantic is not well simulated in all CGCMs as the SST in the west is cooler than that in the east. The absence of a cold tongue in these models may be one of the major reason why many models fail to simulate and predict Atlantic Niño.

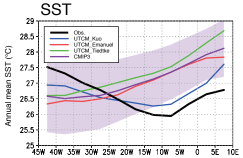
To examine the causes of the model bias, we analyze three versions of the same CGCM differing only in the cumulus convection scheme. Since one version is quite successful in simulating the zonal SST gradient, the present approach may shed new light on the causes of the equatorial Atlantic bias.

2. University of Tokyo Coupled Model (UTCM)

- Ocean model: MOM3 (0.4°-2° in horizontal, 25 vertical levels)
- Atmosphere model: T42L28 FrAM
  - Cumulus parameterization schemes
    - Kuo (1974): UTCM_Kuo
    - Emanuel (1991): UTCM_Emanuel
    - Tiedtke (1989): UTCM_Tiedtke
- Coupler: UTCM coupler, flux is exchanged daily
- Integrated for 50 years and analyzed the last 30 years

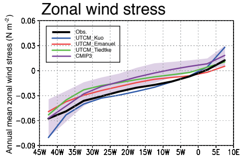
3. Mean state in the equatorial Atlantic

SST



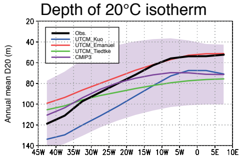
Only UTCM_Kuo is successful in reproducing the gradient of the annual mean SST along the equatorial Atlantic.

Zonal wind stress



The annual mean zonal wind stress is also best simulated by UTCM_Kuo, whereas that in others is weaker than the observation.

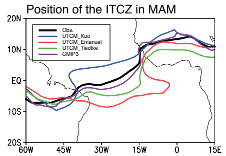
Depth of 20°C isotherm



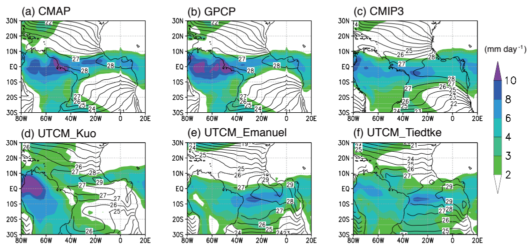
The east-west difference in the equatorial thermocline depth (depth of 20°C isotherm) in UTCM_Kuo is in good agreement with the observation.

4. Precipitation and ITCZ in boreal spring

Since the cold tongue of the equatorial Atlantic starts to develop in boreal spring, we focus on this particular season.



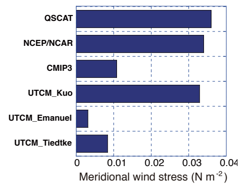
The ITCZ is located to the south of the equator in UTCM_Emanuel, UTCM_Tiedtke, and the ensemble of CMIP3 models, whereas that in the observation and UTCM_Kuo remains north of the equator.



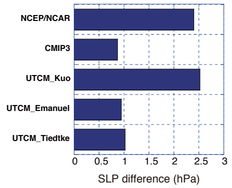
Only UTCM_Kuo is successful in simulating large precipitation over northern South America in boreal spring. This favors the easterly wind over the equatorial Atlantic that converges toward the northern South America and thus the development of the cold tongue.

5. Southerly wind along West African coast in boreal spring

The southerly wind stress in the eastern Atlantic induces coastal upwelling along the West African coast in the Southern Hemisphere, which extends westward by advection and Rossby wave propagation and generates the cold SST in the eastern equatorial region.

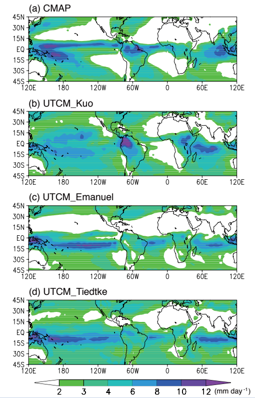


The simulated southerly wind stress in UTCM_Kuo is very close to that in QSCAT observation and NCEP/NCAR reanalysis data. In contrast, it is significantly weaker in the ensemble mean of CMIP3 models and UTCM_Emanuel and UTCM_Tiedtke.



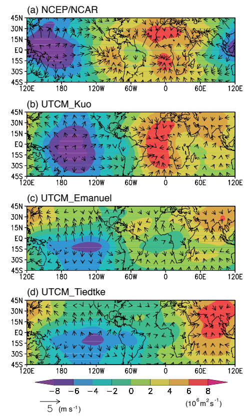
The meridional SLP difference between the western Sahel region and the southeastern tropical Atlantic in boreal spring in UTCM_Kuo is in good agreement with the observation.

6. Global precipitation in boreal spring



- The Pacific ITCZ is broad and weak in UTCM_Kuo, whereas it is very pronounced in the Southern Hemisphere in UTCM_Emanuel and UTCM_Tiedtke.
- Since the unrealistically strong precipitation in the eastern tropical Pacific along 10°S is relatively close to South America, this bias may have a strong influence on the rainfall over northern South America.

7. Global velocity potential and divergent wind at 200 hPa in boreal spring



In contrast to the observation, the divergence is centered around 160°W in UTCM_Kuo, 130°W in UTCM_Emanuel, and 120°W in UTCM_Tiedtke.

Because the divergent wind emanating from this divergence center reaches South America in UTCM_Emanuel and UTCM_Tiedtke, it may suppress convection over northern South America.

Uncoupled experiments with the atmospheric component further confirm the importance of remote influences on the development of the equatorial Atlantic bias.

8. Conclusions

The zonal SST gradient along the equatorial Atlantic is not correctly simulated by any CGCMs, but one version of our model was successful in this aspect.

Key factors to be successful are high skills in simulating:

- the meridional location of the ITCZ
- the southerly wind along the west coast of Africa associated with the West African monsoon
- the precipitation over northern South America

in boreal spring.

Model biases in the Pacific contribute to the weaker precipitation over northern South America.

For more details, please refer to Tozuka et al. (2011, JGR-Oceans).