The Double-ITCZ Problem in IPCC AR4 Coupled GCMs: Symptoms, Physical Mechanisms, and Possible Ways to Alleviate

Jia-Lin Lin
NOAA ESRL/CIRES Climate Diagnostics Center, Boulder, CO

1. Introduction

The double-ITCZ problem is one of the major tropical biases in coupled general circulation models (GCMs). It has been persisting in the last several generations of coupled GCMs (e.g. Mechoso et al. 1995; Latif et al. 2001; Davey et al. 2002; Meehl et al. 2005). Previous GCM sensitivity experiments suggested that the problem is mainly caused by the AGCM rather than the OGCM (e.g. Schneider 2002), and increasing the AGCM resolution or modifying AGCM convection scheme can alleviate to some extent the problem (e.g. Mechoso 2006; Zhang and Wang 2006). However, as pointed out by Mechoso (2006), "a synthetic view of the double-ITCZ problem is still elusive".

2. Symptoms of the double-ITCZ problem in 22 IPCC AR4 coupled GCMs

About half of the models have significant double-ITCZ problem, which is characterized by cold SST bias over much of the tropical oceans, excessive tropical precipitation, overly strong trade winds, excessive latent heat flux, and insufficient shortwave flux.

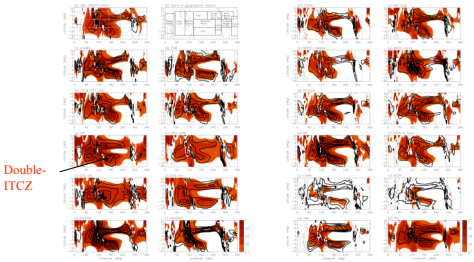

Figure 1. Annual mean SST (shading) and precipitation (contours) for observation and 22 IPCC AR4 CGCMs.

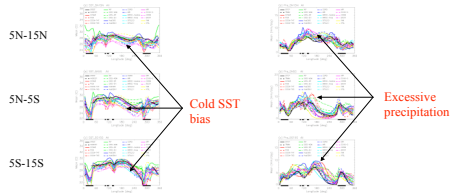

Figure 2. Zonal profiles of annual mean SST (left panels) and precipitation (right panels).

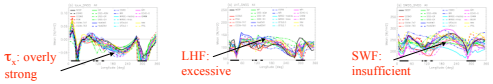

Figure 3. Zonal profiles of surface fluxes averaged between 5N-5S.

3. Physical mechanisms of the double-ITCZ problem: Three ocean-atmosphere feedbacks

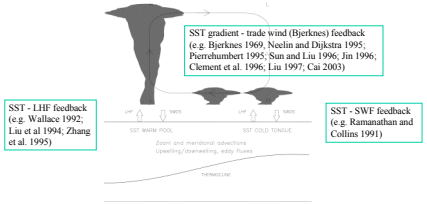

Figure 4. Schematic depiction of the ocean-atmosphere feedback mechanisms in tropical mean climate system.

Neelin and Dijkstra (1995) showed that any excessive positive feedback (or insufficient negative feedback) tends to shift the whole system westward, leading to a double-ITCZ pattern. However, few previous studies have evaluated quantitatively the feedback parameters in GCMs.

4. Quantitative evaluation of ocean-atmosphere feedback parameters in AGCMs

(1) Bjerknes feedback parameter: Overly strong in several models, which is caused by insufficient boundary layer mechanical damping.

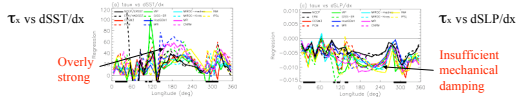

Figure 5. Linear regression between the raw monthly data of two variables related to Bjerknes feedback. Linear relationship holds well for the regressions. Using area averaged data gives similar results.

(2) SST-LHF feedback parameter: Incorrectly positive in several models, which is caused by excessive sensitivity of surface air humidity to SST.

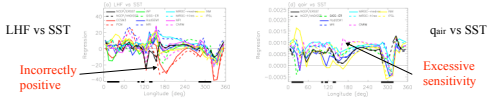

Figure 6. Same as Fig. 5 but for variables related to SST-LHF feedback.

(3) SST-SWF feedback parameter: Overly weak in several models, which is caused by insufficient sensitivity of cloud amount to precip.

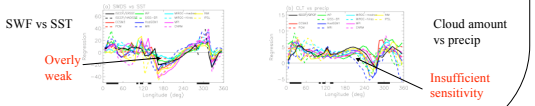

Figure 7. Same as Fig. 5 but for variables related to SST-SWF feedback.

5. Summary of the double-ITCZ problem: Symptoms, physical mechanisms, and possible ways to alleviate

Symptoms:
- Overly cold SST
- Excessive tropical precipitation
- Overly strong trade winds
- Excessive LHF
- Insufficient SWF

Most of these biases already exist in the AGCMs.

Physical mechanisms:
Incorrect ocean-atmosphere feedback parameters

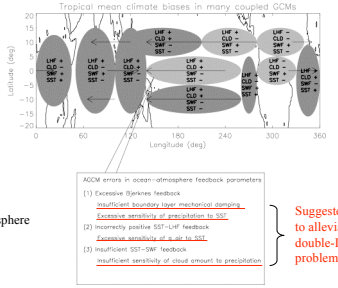

Figure 8. Schematic depiction of the tropical mean climate biases in many IPCC AR4 CGCMs. Dark shading denotes excessive precipitation, while light shading denotes insufficient precipitation. Arrows denote surface zonal wind stress bias. The biases in total cloud amount (CLD), surface downward shortwave flux (SWF), surface latent heat flux (LHF), and SST are denoted by "+" for positive bias, and "-" for negative bias.

6. Future works

(1) Apply the analysis to NCEP CFS/GFS and NASA GEOS5 models;
(2) Apply the analysis to OGCMs to assess the feedback parameters.

NCEP CFS climatology: shares the double-ITCZ problem

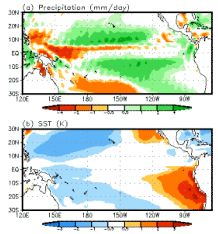

Figure 9. Annual mean climatology of NCEP CFS: (a) precipitation and (b) SST (Courtesy of Wanqiu Wang and Pingping Xie of NCEP/CPC).

REFERENCES

Lin, J. L., 2006: The double-ITCZ problem in IPCC AR4 coupled GCMs: Ocean-atmosphere feedback analysis. J. Climate, accepted with minor revisions.

Lin, J. L., B. E. Mapes, and W. Han, 2006: What are the sources of mechanical damping in Matsuno-Gill type models? J. Climate, submitted.

Lin, J. L., G. N. Kiladis, B. E. Mapes, K. M. Weickmann, K. R. Sperber, W. Y. Lin, M. C. Wheeler, S. D. Schubert, A. Del Genio, L. J. Donner, S. Emori, J.-F. Gueremy, F. Hourdin, P. J. Rasch, E. Roeckner, and J. F. Scinocca, 2006: Tropical intraseasonal variability in 14 IPCC AR4 climate models. Part I: Convective signals. J. Climate, 19, 2665-2690.

Acknowledgements: This work benefits from discussions with Chris Bretherton, Brian Mapes, Ed Schneider, Max Suarez, Julio Bacmeister and Winston Chao.