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COUPLED OCEAN-ATMOSPHERE VARIABILITY OF THE SOUTH AMERICAN MONSOON SYSTEM

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1. INTRODUCTION

Climate variability over South America is strongly linked to SST over the tropical and South Atlantic Ocean. Two phenomena that cause large rainfall interannual variability over South America, and that have apparent links with SST anomalies over the tropical Atlantic are the Intertropical Convergence Zone (ITCZ) and the South Atlantic Convergence Zone (SACZ). Yet, the linkages of such convergence zones with SSTA are quite diverse, as the former seems to be strongly modulated by interhemispheric gradients of SSTA and the latter shows negative correlations with SSTA locally. Such are the conclusions of two-tiered approaches to simulate rainfall variability using AGCMs forced by prescribed SST fields globally.

An alternative to the two-tier approach is the use of coupled ocean-atmosphere models (CGCM), which account for nonlinear effects of surface fluxes of momentum and heat on the determination of SST. Results of ongoing predictability experiments conducted at CPTEC using a global CGCM with eddy resolving ocean model over the tropical Atlantic indicates a gain of predictive skill over the area of the SACZ relative to AGCM skill measures over the same area. Yet, warm SST bias over eastern equatorial Atlantic in the CGCM forecasts remains an unsolved problem, which may be contributing to an apparent degradation of CGCM predictive skill of ITCZ related rainfall over the equatorial Atlantic and Pacific Oceans.

2. METHODOLOGY

The two general circulation models used are the CPTEC spectral AGCM with RAS deep cumulus parameterization and triangular truncation at wave number 62 and 28 levels (T062L28) and CPTEC's CGCM, which uses CPTEC's AGCM T062L28 as the atmospheric component model and GFDL's MOM_3 oceanic component model with ¼ x ¼ degree lat lon in the deep tropics of the Atlantic Ocean and 20 levels. Background viscosity and horizontal mixing coefficients were adjusted to generated best simulations in a forced run (e.g. (Giarolla, Nobre et al.). The CGCM is fully coupled (wind stress, SST, net heat and precipitation minus evaporation) with daily coupling interval. The numerical experiments consisted of integrating an ensemble of ten members for both CGCM and AGCM starting from initial conditions taken one day apart during October, November and December for seven consecutive months for the twenty years period from 1982 to 2001. Monthly climatological mean fields were then computed for each forecast month and for each set of IC starting from each month (Oct, Nov, Dec). Anomalies were then computed as the simple arithmetic difference between the ten member ensemble mean for a particular month and that month's ensemble mean climatology. No previous information is given to both models during the forecast period. Prescribed SSTs for the AGCM forced runs are computed as the SST monthly climatologies added to the month of the IC SST's anomalies (often called persisted anomaly SST forecast). The SST fields used to generate the AGCM SST forcing fields and verification of the CGCM SST forecasts are OISST from NCEP. Atmospheric IC are NCEP reanalysis; oceanic IC are taken from an OGCM forced run like in Giarolla et al. (2005). Rainfall data used for precipitation forecast skill are from the Global Precipitation Climatology Project (GPCP) for the period 1979-2001.

3. RESULTS

DJF SSTA forecast skill (as measured by the anomaly correlations between forecast and observed DJF SSTA) for initial conditions from October, November and December are shown in Figure 1. As it is apparent in Figure 1, the coupled model forecasts are remarkably skillful over the equatorial Pacific region, with anomaly correlations reaching 0.9 over the Niño 3 area (0° N, 120°W). Over the tropical Atlantic, on the other hand, the CGCM SSTA forecast skill is less in magnitude and more variable spatially then over the Pacific, depending on the initial conditions. Yet, anomaly correlations reach values higher than 0.7 over small regions over the central equatorial region (Fig. 1a,c). Such high correlations are in contrast with the strong systematic errors of the coupled forecasts, principally over the eastern equatorial Atlantic (figure not show). The reasons for the systematic errors over the eastern equatorial Atlantic are a consequence of both OGCM (e.g., erroneous eastward heat advection by the model's equatorial under current (Giarolla et al. 2005)), and AGCM deficiencies (e.g., the excess

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shortwave reaching the ocean due to the atmospheric model low stratus cloud deck formation deficiencies).

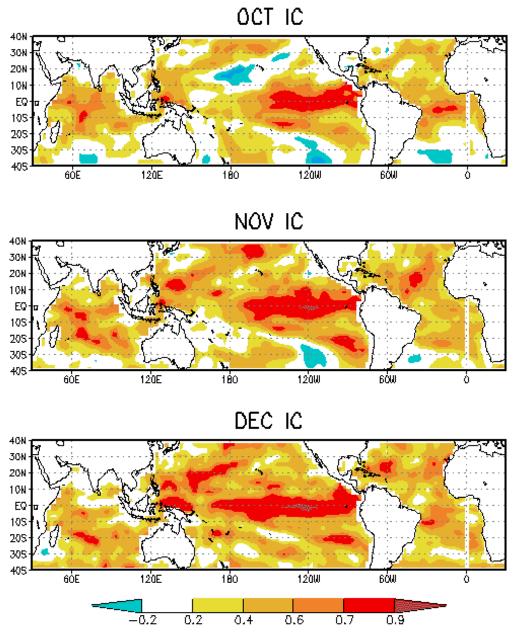

Figure 1 – SST anomaly correlations between CPTEC CGCM ensemble forecasts for DJF from October (upper panel), November (middle panel) and December (lower panel) initial conditions for the period 1981-2000 and observed OISST anomalies.

The comparison of CGCM and AGCM precipitation anomaly forecast skill over the globe for DJF are shown in Figure 2. The top panels on Fig. 2 are the difference between CGCM and AGCM anomaly correlations; the middle panels are CGCM anomaly correlations; and the lower panels are AGCM anomaly correlations for each experiment initiating in October (leftmost column); November (center column); and December (rightmost column). Although the AGCM forecast skill are generally larger than the CGCM (predominantly over the eastern equatorial Pacific and Atlantic), it is notable that the CGCM still captures the central Pacific rainfall variability quite well, indicating a coherent pattern with SSTAs locally. This is an indication, as already indicated in previous works, that rainfall and SST variability are strongly linked over the equatorial oceans.

Concerning summer precipitation over South America, two aspects come to light in Fig. 2; one is the degraded CGCM forecast skill associated with both Pacific and Atlantic ITCZ (shown by blue shades in the top panels of Fig. 2); and the other is the marginally higher CGCM forecast skill over the SACZ continental and oceanic areas, compared with the AGCM's skill (shown in red-orange shades in the top panels of Fig. 2). The reasoning for the degradation of CGCM's ITCZ forecast are seen as the effect of the CGCM strong SST systematic errors over the eastern equatorial oceans, which quickly departs from observed SST climatology and, particularly over the equatorial eastern ocean where SSTs are generally cold and the oceanic thermocline shallow, the CGCM SST bias have a deep impact on atmospheric convection. As for the improvement of the CGCM rainfall forecast over the SACZ, relative to the AGCM's forecast skill; it may be an indication that SACZ variability is not totally controlled by SSTA variability. There might be ocean-atmosphere coupled interactions locally that result in SSTA variability not accounted for by SST forced AGCM experiments. Chaves and Nobre (2004) presented similar results, speculating the importance of solar radiation-clouds-SSTA negative feedback interactions to explain the predominantly cold SSTA under SACZ formations (Robertson and Mechoso 2000).

4. CONCLUSIONS

In this work, the forecast skill of DJF seasonal rainfall anomalies has been investigated using one-tier and two-tier approaches of ensemble seasonal forecast. The one-tier approach used CPTEC's Ocean-Atmosphere coupled GCM and the two-tier approach used CPTEC's atmospheric GCM forced with persisted global SSTs. On both cases, the atmospheric GCM was identical. The results shown suggest that while the CGCM's SST systematic errors may be related to the low skill of CGCM seasonal rainfall forecasts associated with ITCZ modulations, coupled ocean-atmosphere variability possibly captured by the CGCM over the SACZ area might be among the principal reasons for the modest positive gain in DJF seasonal rainfall predictability over the SACZ area over South America and adjoining southwestern tropical Atlantic Ocean relative to the two-tier approach. Further research on this subject is being sought at CPTEC, both to diagnose and minimize OGCM systematic biases (e.g., related to erroneous zonal advection of heat by the Atlantic EUC), and AGCM radiation processes over the eastern equatorial oceans.

ACKNOWLEDGEMENTS:

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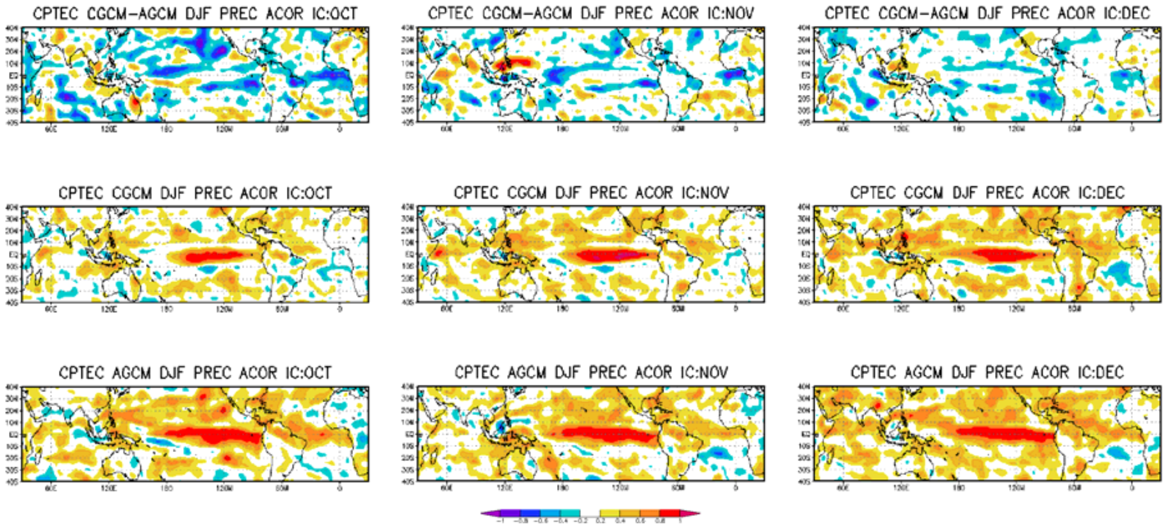

Figure 2 - CGCM minus AGCM anomaly correlations (top panels), CGCM anomaly correlations (middle panels) and AGCM anomaly correlations (lower panels) for each experiment initiating in October (leftmost column), November (center column) and December (rightmost column). On the top panel, shades of blue (red-orange) indicate that the AGCM skill is larger (smaller) than the CGCM.

5. REFERENCES

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