A Model Study of Intraseasonal Oscillations over South America

Baode Chen[1]* and Winston C. Chao[2]
[1]GEST Center, University of Maryland, Baltimore County, Baltimore,MD
[2]NASA/Goddard Flight Center, Greenbelt, MD

1. INTRODUCTION

Recent observtions have revealed that there is intraseasonal oscillation (ISO) of convection over South America. Zhou and Lau (1998) documented a coherent 30-60 day oscillation of monsoon activities during 1989/90 austral summer season. Liebmann et al. (1999) found 40-50 day oscillation in OLR (outgoing longwave radiation) over tropical South America. Using the singular spectrum analysis (SSA) technique, Paegle et al. (2000) demonstrated that a dipole convection pattern, with centers of action over the South Atlantic convergence zone (SACZ) and the subtropical plains, is modulated by modes with periods of 30-40 days and 22-28 days. In these studies, the intraseasonal oscillations over South America were attributed to the influence of MJO propagation. Recently, Zhou and Lau (2002) pointed out that, in addition to the two leading modes, which are in a close relationship with the MJO, there exists a third mode accounting for a large portion of the intraseasonal variation, and it shows a quasi-stationary feature and is independent of the MJO. They suggested that a local forcing mechanism is responsible for this independent intraseasonal mode. This mode is the principal focus of this paper.

As proposed by Hu and Randall (1994), a stationary or quasi-stationary component in the intraseasonal oscillations can be produced by nonlinear interaction among radiation, cumulus convection, and surface fluxes of sensible heat and moisture. A quasi radiative-convective equilibrium is essential to maintain the oscillation and feedback of large-scale motion on the latent heating is not required. Despite that Amazon is the most distinct tropical convection center in the western hemisphere and the fluxes from its surface of tropical rainforests are close to those from the warm tropical ocean, Hu and Randall's theory can not be directly used to interpret the oscillations, because land-atmosphere interaction and land surface hydrological cycle play key roles in forcing and maintaining convective storms locally, which are not considered in Hu and Randall's work. Unlike the sea surface temperature, ground temperature is much more sensitive to variation of the solar radiation, most convective storms are mainly forced and maintained locally due to conditional instability in the vertical distribution of atmospheric temperature, which is closely associated with surface wet-bulb temperature (Elfatih et al, 1996). Moreover, Hu and Randall did not claim that their interpretation could be used for South America. In the present study, we attempt to offer a partial explanation for the observed characteristics of intraseasonal oscillations over South America, which is based on the simulation results using the National Center for Atmosphere Research (NCAR)'s Regional Climate Model version 2 (RegCM2).

*Corresponding author address: Dr. Baode Chen, GEST, Mail Code 913, NASA/Goddard Space Fligt Center, Greenbelt, MD 20771
e-mail: bdchen@climate.gsfc.nasa.gov.

2. DATA AND METHODOLOGY

The latest version of the NCAR regional climate model version 2 (RegCM2) is used. A detail description of the RegCM2 can be found in Giorgi et al. (1993a, b) and Giorgi and Mearns (1999). The National Centers for Environmental Prediction (NCEP)/ Department of Energy (DOE) Atmospheric Model Intercomparison (AMIP-II) reanalysis is utilized to provide initial and lateral boundary conditions for the RegCM2 based upon 00Z, 06Z, 12Z and 18Z data. The sea surface temperature (SST) is taken from the extended reconstructed SST data of NOAA/National Climatic Data Center (NCDC).

The model domain and topographical field selected for the simulations are illustrated in Figure 1, which includes the whole continent of South America and extends farther east and west to cover a relatively large portion of both eastern Pacific and western Atlantic oceans. The period of simulation is the 607 days from September 1, 1996 to March 31, 1998 and the data of the last 516 days are kept to perform analysis. The choice of integration period was based on the consideration of that 1997 was a relatively "normal" year in terms of not having an active El-Nino or La-Nino event.

First we conducted a simulation using a full parameter setting and the lateral and surface boundary conditions are supplied at a 6-h interval from the NCEP R-2 and SST data. This simulation is referred to as the

Control (CNTRL) experiment. Then, a series of sensitivity experiments is designed and carried out: (1) CBC experiment, in which the lateral and surface boundary conditions are temporal means of those of the control experiment. In this experiment, the disturbances from outside of model domain are eliminated, and any temporal variation is the result of the model internal physical processes and relevant local forcing. (2) CRD experiment, the same as CBC experiment but the longwave and shortwave heat rates of the atmosphere are specified as the temporal and spatial means of the CNTRL experiment (i.e. only functions of height) but the radiation components used in the surface energy budget was calculated from the full radiation package. This setting prevents convective-radiative interaction in the atmosphere. (3) NZEN experiment, the same as CBC experiment, but the zenith angle was set to a constant which eliminates annual and daily variation in the surface radiation calculations. In this experiment, the longwave and shortwave heat rates of the atmosphere are also specified by the same way as that in the CRD experiment. The setting prevents annual and daily cycles operating in the model. (4) NDIA experiment, the same as NZEN experiment but allow the annual cycle in the surface radiation. (5) NANU experiment, the same as NZEN experiment but allow the daily cycle in the surface radiation. (6) WSFC experiment, the same as NZEN experiment but all grid point in the domain are defined as water surface with SST taken from time mean of the ground temperature of the CNTRL experiment, thus all external forcings do not vary with time, and there are no interactions between atmosphere and external forcings.

To detect and reconstruct intraseasonal signals from the simulations, the Singular Spectral Analysis (SSA) is used in the study. The SSA is a statistical technique related to EOF analysis but in the time domain (Ghil et al. 2001). Before applying SSA to a time series, the trend in the data is removed by using a time series decomposition approach STL, developed by Cleveland et al. (1990).

3. RESULTS

From the CNTRL experiment, the model captures the rainfall maxima in Amazon and the SACZ (not shown). In the present paper, we will mainly concentrate on the Amazon region which is outlined in Fig.1. Fig.2a shows time series of the mean rainfall along with seasonal trend detected by using STL approach. It can be seen that a strong seasonality exists in the simulated precipitation with maxima in the austral summers and a minimum in the austral winter. The amplitude of seasonal cycle is about 2.5 mm/day. Fluctuations with time-scales less than seasonal variation can be found to be superposed on the seasonal cycle, and are shown as the time series of precipitation anomaly in Fig. 2b by a thin line. To detect periodic oscillations, SSA is applied to the time series of anomaly in Fig. 2b. The singular spectrum is obtained as displayed in Fig. 2c. Based on significance test (same frequency and strong FFT criteria), the spectrum has three pairs of oscillatory modes, PC-1 and PC-2, PC-3 and PC-4, PC-5 and PC-6. Using these oscillatory modes, a reconstructed time series (or pre-filtered time series) can be obtained and is illustrated in Fig 2b by a thick line. To estimate the period, the MEM spectrum analysis is performed on reconstructed time series and the result is shown in Fig 2d. A clear peak at 34.8 days (0.0287 cycles/day) exists indicating there is an evident intraseasonal oscillation in the Amazon region.

Both the CBC and CRD experiments show that the intraseasonal oscillations still exist. This suggests that internal dynamics of atmosphere and localized forcing are able to excite intraseasonal oscillation modes without the MJO propagating into the model domain from remote sites and a quasi radiative-convective equilibrium. Futhermore, the NZEN, NDIA, and NANU experiments indicate that annual and diurnal cycles have no significant effects on the oscillations. The WSFC integration, in which the interaction between land surface and atmosphere is turn off, only produces irregular fluctuations with no clear spectral peaks.

On the basis of our results, we conclude that the intraseasonal oscillations over Amazon in our model essentially result from interactions among surface radiation, the surface sensible and latent heat fluxes, and cumulus convection.

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4. REFERENCES

Cleveland, R. B., W. S. Cleveland, J. E. McRae, and I. Terpenning, 1990: Stl: A seasonal-trend decomposition procedure based on loess (with discussion). *J. Official Statistics*, **6**, 3–73

Eltahir, E. A. B., and J. S. Pal, 1996: Relationship between surface conditions and subsequent rainfall in convective storms. *J. Geophys. Res.*,**101**, 26,237–26,245

Giorgi, F., M. R. Marinucci and G. T. Bates, 1993a: Development of a second generation regional climate (RegCM2): Boundary layer and radiative transfer processes. *Mon. Wea. Rev.*, **121**, 2794-2813.

Giorgi, F., M. R. Marinucci and G. T. Bates, 1993b: Development of a second generation regional climate (RegCM2): Convective processes and assimilation of lateral boundary conditions. *Mon. Wea. Rev.*, **121**, 2814-2832.

Giorgi, F. and L. O. Mearns, 1999: Introduction to special section: Regional climate modeling revisited, *J.*

Geophys. Res., **104**, 6335–6352
Hu, Q. and D. A. Randall, 1994: Low-frequency oscillations in radiative-convective systems. *J. Atmos. Sci.*, **49**, 1089–1099
Liebmann, B., G. N. Kiladis, J. A. Marengo, T. Ambrizzi, and J. D. Glick, 1999: Submonthly convective variability over South America and South Atlantic convergence zone. *J. Climate*, **12**, 1877–1891
Paegle, J. N., L. A. Byerle, and K. C. Mo, 2000: Intraseasonal modulation of South American summer precipitation. *Mon. Wea. Rev.*, **128**, 837–850
Zhou, J. and K. M. Lau, 1998: Does a monsoon climate exist over South America? *J. Climate*, **11**, 1020-1040
Zhou, J. and K. M. Lau, 2002: Summertime intraseasonal variability over South America, Reprint, *24th Annual Climate Diagnostics and Prediction Workshop*,Tucson, AZ.

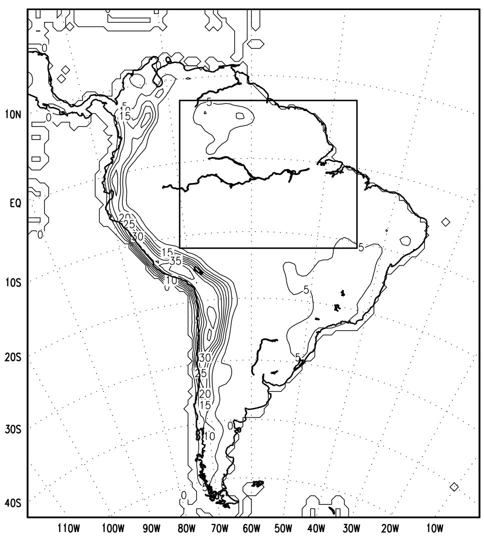

Figure 1. Model domain and topography (units are 100m). Also shown is the area selected for analysis.

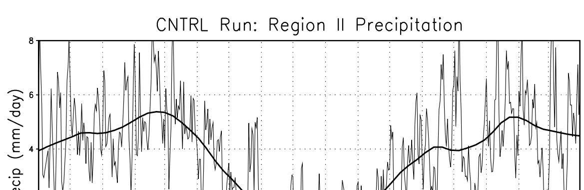

Figure 2a. Time series of mean precipitation of the CNTRL experiment (thin line) and seasonal trend (thick line).

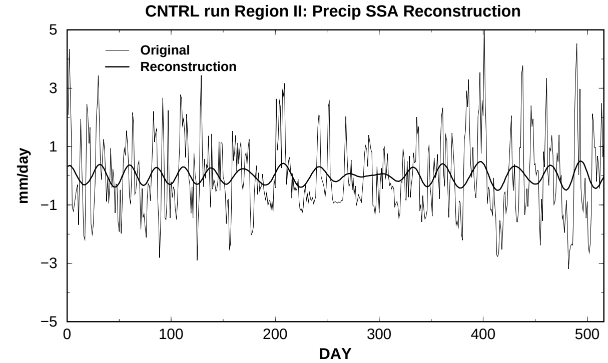

Figure 2b. Time series of precipitation anomaly and reconstructed precipitation anomaly.

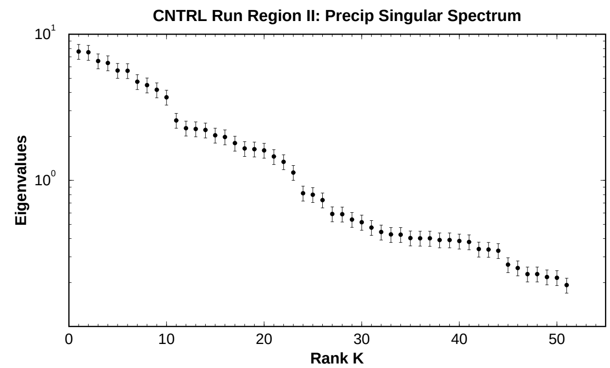

Figure 2c. Singular spectrum of precipitation anomaly.

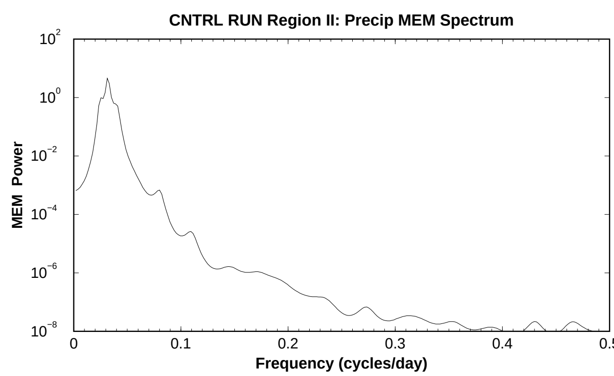

Figure 2d. MEM spectrum of reconstructed precipitation anomaly.