

ENSEMBLE SIMULATION OF INTERANNUAL CLIMATE VARIABILITY USING THE CPTEC/COLA AGCM FOR THE PERIOD 1982-1991

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ABSTRACT

The interannual climate variability of the CPTEC/COLA AGCM is assessed for several regions of the tropics and extratropics. The evaluation is made for the period 1982-91 for an ensemble of 9 members of the model forced by observed global sea surface temperature (SST) anomalies. Interannual variability of Northeast Brazil, Amazonia, southern Argentina-Uruguay and in smaller degree for Sahel and Eastern Africa rainfall are well simulated by the model. The model exhibits lower skill in reproducing interannual rainfall variability in regions such as India, the monsoon regions of the Americas, and southern Africa, indicating that simulation on interannual variations of climate in those regions still remains problematic, possibly due to the effect of land-surface moisture and snow feeds backs, that besides the SST external forcing may play a role in climate variability. Although the model represents quite well the interannual variability of rainfall in the Amazon basin, it also shows a systematic underestimation of this quantity.

INTRODUCTION

Beginning the 1960's, observational and modeling studies of the ocean and atmosphere began to make clear that certain behaviors of the coupled system might be predictable, including El Niño (see reviews in Mason et al. 1999). The seasonal mean tropical circulation may be potentially more predictable than the middle latitude circulation as the low-frequency component of the tropical variability is primarily forced by slowly varying boundary conditions, such as sea surface temperature (SST), as supported by observational and modelling work. The ability of an atmospheric model to simulate to observed climate and its variability varies with scale and variable, with the radiative effects of clouds and the land-surface and sea-air interactions remaining an area of difficulty. Given the correct SST or ice extent, most atmospheric GCMs can simulate the observed large-scale climate with better skill for some areas as compared to another, and give a useful indication of some of the observed regional and global interannual climate variations and trends. Even though the ability of a model to reproduce the observed mean interannual variability of climate is an important aspects of its performance, it comes the fact that the ability of the model to reproduce specific time sequences of interannual variability, either at regional or global scales, not always is forced (e.g. by SST), and that a part of this variability may be internal of the atmosphere and climate system themselves. Climate simulations using specified SST have an extensive history (see reviews in Brankovic and Palmer 1998), as well as a host of papers derived from the AMIP climate simulations (see reviews in Zwiers 1996 and Gates et al. 1992). The possibility that the atmosphere's internal dynamics or slowly evolving surface properties, such as soil moisture or snow cover may also generate potentially predictable interannual variability of seasonal mean climate.

The evaluations implemented in this paper include the assessment and validation of interannual variability of climate as produced by the GCM from the Center for Weather Forecasts and Climate Studies from Brazil (CPTEC/COLA GCM). A companion paper shows a comprehensive description of an ensemble of 9-member 10-years of the surface and upper-air climatology generated by this model. and this validation effort was made in order to identify climate features and possible systematic errors and biases on the modeled climate. The model was run with prescribed SST covering the period 1981-92. The study focuses on rainfall and circulation features at regional and large scales. Issues such as modeling the interannual variations of the Bolivian and Tibetan upper-troposphere anticyclones, the monsoon circulations in Asia and the Americas, and the impacts of El Niño/La Niña are discussed. A second purpose is to assess the skill of the model and the predictability at regional scale, and to identify the deficiencies and uncertainties of the model, as well as systematic errors, with a view to further model improvement.

ENSEMBLE SIMULATION OF CLIMATE VARIABILITY

Seasonal climate forecasts are based on the fact that slow variations on the boundary conditions, that include SST, sea ice, surface air temperature, albedo, soil moisture and snow can have significant impacts on the atmosphere evolution (Brankovic et al. 1994). Each simulation made with observed SST and different boundary conditions show different results, as in the climate forecast runs in discussion on this paper. Multiple realizations are necessary to firmly assess the robustness of an individual model response to SST forcing (Sperber et al. 1999). Significant reproducibility of climate anomalies among ensembles indicates potential seasonal forecasts skill, because the similar atmospheric anomalies must derived from a common response to anomalous SST forcing. Ensemble methods typically are used to indicate the range of possible climate outcomes for a given SST boundary forcing (Zwiers 1996, Mason et al. 1999). An ensemble forecast represents a collection of forecasts that all verify at the same time. These forecasts are regarded as possible scenarios given the uncertainty associated with forecasting. Due to the fact that model's internal variability can be very important, many studies use an ensemble approach to assess the atmospheric response to anomalies in SST. Li (1999) indicates that the basic idea is that climate simulation is mainly a boundary-forced problem and model internal variability can be considered as noise. Even though the causes of model internal variability are not fully known, the use of ensemble means can overcome the difficulties of the model internal variability. Lau et al. (1996) and Sperber et al. (1999), based on the AMIP results, show that a better simulation of the mean state is associated with a better simulation of the interannual variability.

CPTEC/COLA AGCM and model experiment design

The model describes realistically the global climatic features of circulation, precipitation and convection, as well as regional circulation and rainfall features, such the position and seasonal variability of the main convergence zones of the globe, the mean zonal and meridional circulation, the intensity and location of the upper-level subtropical westerly jets and upper-air anticyclones, as well as the monsoon regions of the world.

To validate the model interannual variability, monthly lower-and upper level circulation fields were derived from the NCEP/NCAR reanalysis. Global and regional rainfall was derived from the Climate Prediction Center Merged Analysis Precipitation (CMAP) data (Xie and Arkin 1996). The simulation was initiated from 11 November 1981 ECMWF operational analyses and NCEP SSTs, for the 12 UTC. The remaining 9 simulations were initiated from November 11 states with model states at 24 hour intervals. The ensemble is considered to be a collection of 9 independent simulations of the December 1982 to December 1991 climate that are physically consistent with observed SST and sea-ice extent in this period.

SOME PRELIMINARY RESULTS

In this abstract, we will discuss some issues regarding the interannual climate variability in the tropical region. The tropical region show a direct lower atmosphere response to SST anomalies, and thus showing an interannual variability associated to the extremes of the El Nino. The model's ability to mimic the observed variability associated with the extremes of ENSO in the 1982-91 period is briefly examined by showing results of the intercomparison of the interannual variability of tropical precipitation, circulation, and convection. We have constructed the Southern Oscillation Index (SOI) from the 1982-91 period using anomaly monthly sea level pressure difference between Tahiti and Darwin based on station data. The model SOI is computed from area-averaged sea level pressure at grid points closest to the two locations from the ensemble of the 9 10-year integrations. The major interannual fluctuations, including the 1982/83 and 1986/87 El Nino events, and the 1988/89 La Nina are well simulated, with the model ensemble mean variation following closely the observed. Other indices indicative of the interannual variability in the tropical regions have also been implemented, in addition to the SOI. These are the OLR index averaged over the area 5N-5S, 160E-160W, a 200-hPa zonal wind anomaly index averaged over the area 5N-5S, 165W-110W, and an index based on 550-hPa virtual temperature averaged over the latitude band 20N-20S. The observed OLR index below -1 during the El Nino episodes 1982/83 and 1986/87 indicating enhanced tropical convection across the western and central Pacific, and increased across Indonesia. Opposite pattern is deduced from the positive OLR index especially during the 1988/89 La Nina event. The CPTEC/COLA GCM depicts remarkably well this observed variability, with increased/reduced convection over western Pacific during the El Nino/La Nina events. The 200-hPa zonal wind index shows observed intense wind easterly anomalies during the El Nino 1983/83 and the large westerly anomalies during the La Ninas of 1984/85 and 1988/89, with the later showing the largest anomalies. The 200-hPa GCM-derived zonal

wind index reproduced the easterly wind anomalies during the EL Nino 1982/83, but the major shortcoming of the simulation is that CPTEC/COLA GCM 200-hPa zonal wind anomalies do not reproduce the largest westerly wind anomalies during La Nina 1988/89, and showing instead large easterly anomalies. The 500-hPa virtual temperature anomaly on the tropical region shows a much better agreement between model and observations. Large positive anomalies are observed for the 1982/83 and the 1986/87 El Nino events, and negative rainfall anomalies during 1984/85 and 1988/89 La Nina events.

In order to test the sensitivity of rainfall response to ENSO conditions and to illustrate the response of the COLA/CPTEC GCM's equatorial rainfall, convection and surface circulation prediction, we have compared the east-west migration of the equatorial band of convection and rainfall equatorial belts from model and observations. The model simulates the eastward migration of the rainfall and convection of the 1982/83 and 1986/87 El Nino events remarkably well. The model also reproduces quite well the observed double maxima of rainfall over the western Pacific and over the Indian Ocean. Even though, the model shows the observed reduced convection and rainfall in Amazonia and Northeast Brazil during the El Ninos 1982/83 and 1986/87, and the larger rainfall and convection over the same regions in 1984. Therefore, the observed and simulated SO indices show good agreement, reinforcing the view that the tropical response to SST is deterministic. The observed shifts in tropical and equatorial convection and rainfall associated with variations in the observed index of the SO are also well simulated by the CPTEC/ COLA GCM. Thus, the CPTEC/COLA GCM is very sensitive to the anomalous SST forcing during ENSO.

SUMMARY AND DISCUSSIONS

In very large drainage basin, such as the Amazon, backwater effect may affect the variations of the discharge/levels series, especially at the Solimoes basin and at the Manaus site. Thus rainfall comes as perhaps the best indicator of hydrologic trends in the region. From the analysis of trends using rainfall indices and river series, it has been shown that no trends towards drier conditions have been detected in Amazonia, as one would expect due to increased deforestation. However interdecadal variations have been observed in rainfall in both northern and southern portions of the basin: (a) northern Amazonia show some associations with the SO variations, and a 20-years time variation in rainfall, (b) southern Amazonia exhibits similar time-variation, and is independent of SO and rainfall variation in northern Amazonia.

CONCLUSIONS AND FUTURE DEVELOPMENTS

The strengths and weaknesses identified in this model should not be regarded as a permanent defects, since the model is undergoing continuous improvement. It is clear that some areas exhibit systematic biases, such as the underestimation of rainfall in Amazonia and an overestimation of rainfall in the Sahel. On the whole, the CPTEC/COLA AGCM simulates the broad aspects of the observed ENSO variations reasonably well, as may be expected since these variations are primarily driven by prescribed SST.

In general, the simulated interannual variability of the model compares well to observations. Over the tropics the model simulates a clear eastward-propagating anomaly in tropical convection and rainfall during events of anomalously warm tropical Pacific associated with El Niño events. This signal is evident in the zonal winds too. At large scale, simulated indices of the SO agree closely with the observed SO, and changes in tropical and subtropical precipitation and circulation fields related to El Niño.

Some regions, such as Northeast Brazil (both its northern and southern portions), Amazonia, southern Brazil-Uruguay exhibit better predictability due to the large skill of the CPTEC/COLA AGCM in reproducing interannual variability of climate in those regions.

For several regions of the planet, other factors beyond the external forcing provided by SST anomalies may be important in their year-to-year climate variability, suggesting limitations on predictability on regions where low skill of the CPTEC/COLA AGCM was found.

Field experiments have provided significant benefits to the modeling community, and numerical weather prediction and land surface parameterizations have been enhanced, leading to direct improvements in precipitation over continents. In the Amazon basin, satellite measurements, as field experimental data of energy and water balance measurements, as well as surface and radiosonde observations during the January-March 1999 LBA-WET Atmospheric Mesoscale Campaign (AMC) parallel with TRMM-LBA, in Rondonia, in the Brazilian southern Amazonia are allowing model validation and intercomparison tests that use this field data sets to baseline the performance of land surface process models, ground hydrology, clouds parameterizations, as well as upscaling processes and parameter sets to describe continental-scale fluxes, including the treatment of

heterogeneous land cover, vegetation, topography, soil water transport and moisture, and catchment hydrology. Ongoing experiences using river routing scheme such as the LBA-HydroNET to be incorporated in the land surface of the CPTEC/COLA AGMC will allow the determination of river discharge from the instantaneous model runoff taking into account the hydrological lags.

Future field campaigns, such the LBA-DRY AMC planned for the boreal winter of 2001, and the VAMOS (Variability of American Monsoon Systems) related ALLS (South American Low Level Jet) and LAPLASIN (La Plata River basin) [Mechoso, personal communication] will also provide field data for validation and improvement of models, not only for simulation of the basic climate, but also of the interannual and even decadal variability of climate.

This study along with its companion dealing with the simulated mean state, aims at assessing the ability of the CPTEC/COLA AGCM to simulate the observed climate and its interannual variability. Topics of ongoing research include assessment of the atmospheric and hydrologic water balance in the major basins of the world, as well as the variability of climate at several time-scales.

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