LARGE-SCALE CHANGES IN PRECIPITATION AND TEMPERATURE IN SOUTH AMERICA UNDER CLIMATE CHANGE - ENSEMBLE CLIMATE MODEL PROJECTIONS AND UNCERTAINTY ASSESSMENTS

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1. INTRODUCTION

Following the extensive conclusions from the IPCC (Intergovernmental Panel on Climate Change) Fourth Assessment Report and other reports (including INPE's report 2007 - www.cptec.inpe.br/mudancas_climaticas) we have credible evidence that the climate is changing across the world. But it is important to note that while the current versions of atmosphere–ocean general circulation models (AOGCMs) have the ability to simulate well the state of the global climate at the large and continental scales, there are significant variations between these models in future climate projections of precipitation and temperature changes at the regional scale, including those for South America.

One of the top priorities for narrowing gaps between current knowledge and policymaking needs is the quantitative assessment of the sensitivity, adaptive capacity and vulnerability of human and natural systems to climate change. Vital for such assessments are reliable estimates of current and future climate variability at the regional scale which can be readily used to assess the sensitivity of these systems to climate change. Often an important requirement for these assessments is for the climate data to be provided at high spatial and temporal resolution, and the main method for providing these data regionally is dynamical downscaling, i.e. output from global climate models is used to drive a high resolution regional climate model.

Regional models provide improved spatial detail, but in order to improve reliability of projections, it is essential to run multiple realizations, to take uncertainties into account. There has been much effort to quantify the range of uncertainties that are known to exist in global climate model projections and dynamical downscaling allows a detailed exploration of these. Important for the interpretation of any downscaled projections is to assess the regional-scale climate and climate changes in the global projections. This can guide the selection of suitable global models for driving the regional model where the quality of global model control simulations and the identification of global model large-scale projected changes which are considered reliable would be relevant information. As a starting point for this, in the present paper, we present the results of an ensemble simulation of the HadCM3 climate model, where each ensemble member incorporates different but plausible versions of the parameterizations of important physical processes. This is used to assess the potential impacts of climate change on precipitation and temperature over South America and explore the range in projections obtained via the modifications to the model parameterizations.

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2. DATA AND ANALYSIS

The Global Climate Model HadCM3: The Perturbed Physics Ensemble

At the Met Office Hadley Centre, the first perturbed physics ensembles (PPEs) examined uncertainty in the atmospheric physics, and in a few land surface and sea ice parameters. A total of 29 parameters were considered. A large sample was taken from the space of all possible versions of the model, in an ensemble of over 300 members. Initially, the atmosphere was coupled to a simplified ocean in equilibrium (doubled CO2) experiments. However, for the simulation of a transient response, fully coupled model experiments are required. From the 300+ member ensemble, 17 models were selected on the basis of sampling the parameter space as fully as possible while still capturing twentieth century climate adequately. These 17 models were run in fully coupled mode under the SRES A1B greenhouse gas emissions scenario. More details about the values used in these model versions are given in Collins et al. (2006).

3. RESULTS

Regional patterns of change and the effects of parameter uncertainty in these can be assessed by examining the perturbed physics ensemble of 21st century changes in seasonal mean precipitation and surface air temperature (Figure 1, 2). As Figures 1 and 2 demonstrate, different members of the PPE exhibit different patterns of change, in both temperature and precipitation with a greater variety in the latter. Significant changes among the members at all latitudes are evident.

Figure 1 shows that in summer, the projections exhibit a region of substantially reduced precipitation in the vicinity of the Amazon basin and South America Summer Monsoon. It is noted that in regions such as Northern Peru-Ecuador, western Amazonia, southern Brazil-Uruguay-Northern Argentina and southern Chile most of the members show precipitation increases under the A1B scenario, while negative rainfall anomalies are detected in Northeast Brazil and Amazonia. This would suggest that for rainfall projections in the future, while uncertainties in the simulated monsoon strength are large they are relatively smaller in north-eastern and southern South America perhaps suggesting a robust signal. Changes in rainfall for the future somewhat resemble the pattern of observed rainfall anomalies typical of an El Niño-like signal, which has also been seen in other climate models (Collins et al., 2005). It is critical to note that model versions with similar sensitivities often show differences in such regional details. The impact of uncertainties in rainfall change over Amazonia on the probability of forest die-back will be a key application of this ensemble (Cox et al., 2004).

Figure 2 shows that all 17 models have the familiar increased warming over land areas in comparison to ocean areas. In both seasons, the ensemble spread of the uncertainty the warming in certain regions of South America is substantial, exceeding 3°C in Amazonia and across a great part of central Brazil. All of the models display a warming tendency, with enhanced warming over the land.

Figure 3 illustrates the annual cycle of the precipitation change (%) over selected land areas in South America simulated in the PPE under A1B scenario forcing. It shows a decrease in most of the tropical region (Amazonia and Northeast Brazil) and southern Brazil-Uruguay in spring (August to November) while increases are indicated in autumn and winter in northwest Peru-Ecuador and Northeast Brazil. It is clear that inter-model differences over Northeast Brazil and Peru-Ecuador are most pronounced in winter. The variations between the models are modest in Amazonia and Southern Brazil-Uruguay in comparison with the other two regions.

Figure 4 illustrates the annual cycle of the temperature response (°C) over the same regions. There is qualitative agreement among the simulations, e.g., temperature anomalies exceeding 3°C is a relatively consistent response in all of the regions. The largest temperature response in southern Brazil-Uruguay is projected to occur in March to June while in the Amazonia region, a large response is evident in the models throughout the year. In general, the spread among the projections over Amazonia is largest compared to the other regions.

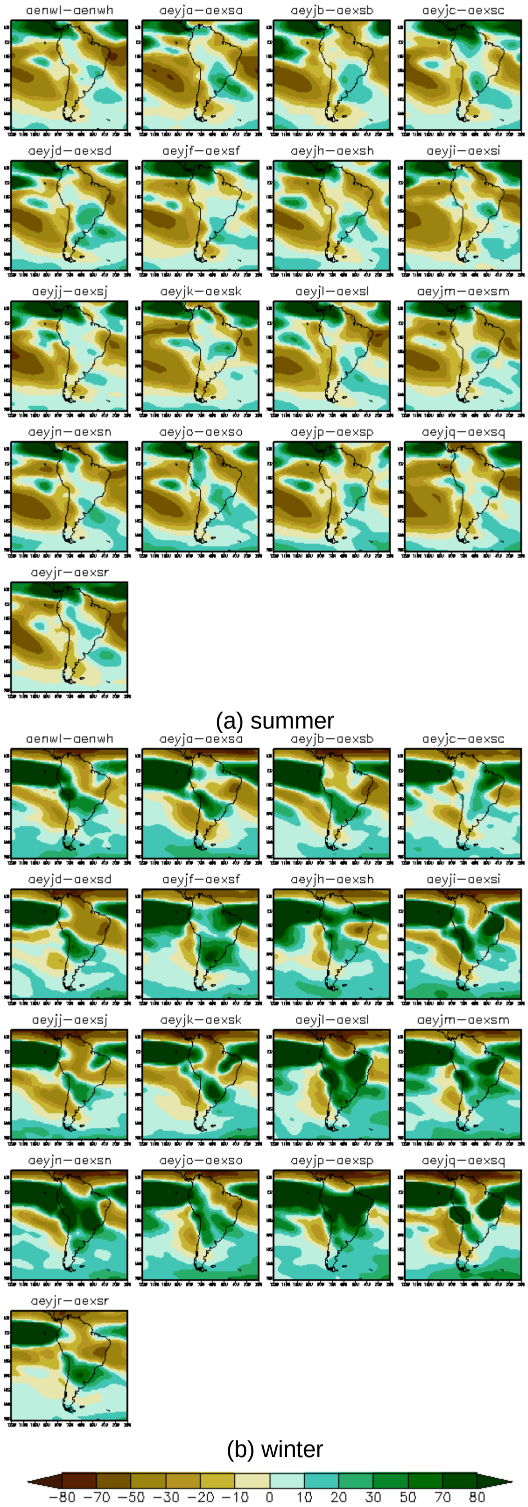

Figure 1 - Precipitation change (%) for 2071-2099 relative to 1961-1989 over South America from the PPE (SRES A1B scenario) for (a) December to February and (b) June to August

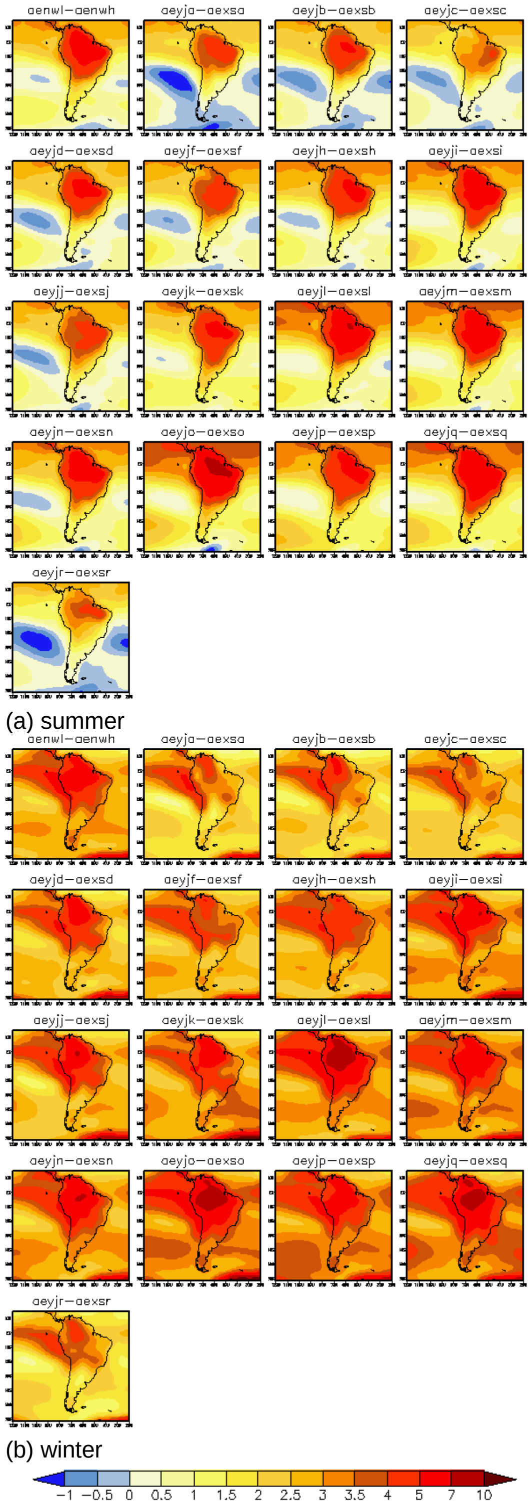

Figure 2 - Temperature change (°C) for 2071-2099 relative to 1961-1989 over South America from PPE (SRES A1B scenario) for (a) December to February and (b) June to August

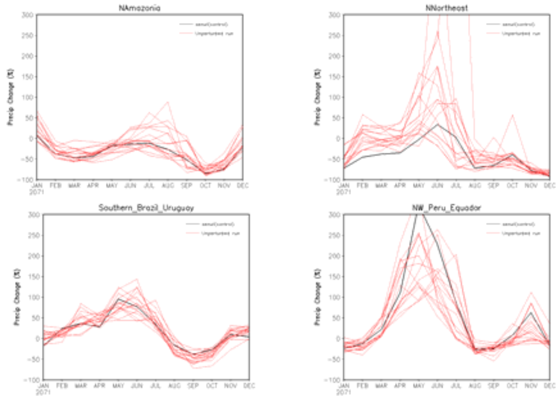

Figure 3 – Annual cycle of precipitation change (%) for 2071 to 2099 relative to 1961 to 1989 from the PPE (SRES A1B scenario) for selected land regions over South America: (a) Northern Amazonia, (b) Northeast Brazil, (c) Southern Brazil-Uruguay and (d) NW Peru-Ecuador

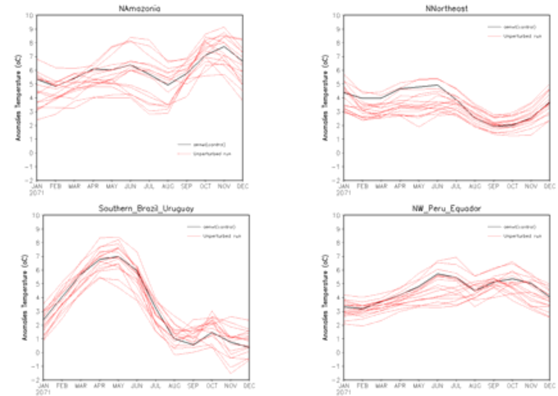

Figure 4 – Annual cycle of temperature anomalies (^{o}C) from the PPE (SRES A1B scenario) for selected land regions over South America: (a) Northern Amazonia, (b) Northeast Brazil, (c) Southern Brazil-Uruguay and (d) NW Peru-Ecuador

4. FINAL REMARKS

This study synthesizes projections of 21st century climate change over South America from a 'perturbed physics ensemble', which enables the uncertainties derived from model representation of processes, and potential effects on climate, to be quantified. Our primary conclusions can be summarized as follows: The ensemble members share to a greater or lesser extent the tendency towards an enhanced El Niño-like state in the future (hence wet season reduction of rainfall in the Amazon region and Northeast of Brazil). This precipitation response pattern, as well as a tendency towards wetter conditions displayed by the ensemble in the southern Brazil-Uruguay-Northern Argentina, is consistent with the patterns of change simulated by the IPCC AR4 multi-model ensemble (Christensen et al., 2007), although large biases in modeled regional precipitation must be acknowledged.

In all of the PPE members, in common with the results reported in the IPCC AR4 (Christensen et al., 2007), warming is projected over the 21st century, with enhanced warming over land. However, in both seasons, the ensemble spread of the uncertainty in the warming in the tropics is substantial, exceeding 3°C in Amazonia and across a great part of central Brazil.

The work presented here demonstrates that, at the global model resolution, there can be large differences between the PPE members in the projections of future climates over Brazil. These uncertainties in projections can be explored in finer detail using dynamical downscaling, and to this end, a small group of the PPE members was selected for driving regional model Eta. The atmospheric PPE data were archived at 6-hourly resolution and are available to CPTEC as lateral boundary conditions for the regional model. The selection process entailed the satisfaction of certain criteria. It was important that these models should span the range of possible warming in the PPE, displaying high or low climate sensitivity compared with the ensemble, but could also reproduce important patterns of regional mean climate and climate variability, including the simulation of ENSO and ENSO teleconnections with the South American continent.

Currently, Brazil is working on the Second National Communication of for Climate Change aimed at advancing the climate impacts research and vulnerability assessments in Brazil, directed toward impacts analyses and the design of adaptation measures. In this context, climate change simulations of southern South America climate are being performed using the Eta-CPTEC regional climate model (with horizontal resolution of 40 km) nested on the HadCM3 global model, for 4 of the 17 available PPE members. These projections will be available for the period 2010-2100. At the regional scale there remains an urgent need for relevant, targeted projections of climate change. Furthermore, adaptation is inherently a local and regional scale issue, and limited by the measure of confidence in the projected changes at these scales. Without appropriate regional projections of climate change, it is arguable whether regional adaptation strategies can be developed or implemented.

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