Project: 759

Project title: **Development and implementation of a hierarchical model chain for modelling** regional climate variability and climate change over southern Amazonia

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Introduction

The project was a subproject of the BMBF funded project 'Carbon sequestration, biodiversity and social structures in Southern Amazonia: models and implementation of carbon-optimized land management strategies' (CarBioCial; FKZ: 01 LL 0902 J) and covered the climate modelling part. Overreaching objective of our subproject was to analyze and model present and future spatiotemporal climate variations in southern Amazonia under different climate and land use scenarios. In addition the project provided climatological information for various impact studies in the Carbiocial framework. At DKRZ high performance computer our model activities comprised the dynamical downscaling of global data sets representing the present day climate or/and potential future conditions. The non-hydrostatic Weather Research & Forecasting Model (WRF) was used. Starting 2012 the modelling activities involved the implementation of WRF for the domain of interest (Southern Amazonia), the downscaling of the present day climate (ERA-Interim 1981-2013), the response to potential future changes in greenhouse gas concentration (ECHAM5/MPI_OM; SRES A1B), and the impact of land use changes on the potential future (hydro)-climate variability in Southern Amazonia.

Model and Methodology

The Weather Research & Forecast Model (WRF) was implemented on the DKRZ (Deutsches Klimarechenzentrum) computer architecture. Using one-way nesting a local multi domain setup for South America with special focus on the target region was defined with a final resolution of 30x30km. Short (24h) hindcast simulations with a 12h spin up time for present day data (ERA-Interim forcing) and climatological runs for greenhouse gas and land use scenarios were chosen.

The climate projections and land use scenarios were selected in accordance with the project partners. The focus of the studies was on A1B scenario on a medium time scale (until about 2040). Data from the ECHAM5/MPI-OM simulations were used to force the WRF model. Land use changes were prescribed from results of the LandSHIFT (Land Simulation to Harmonize and Integrate Freshwater Availability and the Terrestrial Environment) model with UNEP GEO4 scenario "market first". The WRF output was further refined using statistical downscaling (down to 900x900m), validated against station observations, and compared to results from the Statistical Regional Model STARS.

Results

To assess the quality of the WRF present day simulations the output was evaluated against station observations. For the period 2001-2010 a total of 25 stations in Amazonia with almost complete time series have been selected to compute long-term mean residuals. WRF reproduces the station data reasonable well. The mean wind speed shows a very small bias (< 0.1m/s for the annual mean). For the mean temperature a small cold bias is found (-1.4K for the annual mean) with larger bias in winter. The minimum and maximum temperatures are also captured with smaller differences for the minimum, presumably due to the overall cold bias. However, precipitation is clearly overestimated by WRF (678.8mm for the annual sum accumulated over all stations) valid for all seasons.

Potential climate changes (2m temperature and precipitation) in the target region simulated by ECHAM5/MPI-OM, WRF and STARS are shown in Figure 1 (IPCC S-RES A1B, 2036-40 minus 2001-05). All model realizations suggest significant near future changes of the energy and water

cycle. However, there are some notable differences in the modelling results. While temperature increases in the whole region in all simulations, STARS suggests the strongest warming signal with values up to about +3K. In WRF and STARS the maximum temperature response is located in the south-east of the target region the maximum in ECHAM is shifted to the north-west. As for temperature the strongest response for precipitation is simulated by STARS (up to 60% decrease). While STARS predicts a reduction of precipitation for the whole region ECHAM and WRF show a decrease for the centre only while an increase is suggested for the southern and northern part of the modelling domain. Small scale features are most pronounced in the WRF results which can be attributed to the sensitivity to surface boundary conditions (orography, land use, etc.). Overall, the results of all three models imply a significant impact on the local ecology and economy (agriculture) in this region.

In view of the distinctly differing precipitation projections it should be noted, that STARS generally tends to project strong (unrealistically overestimated) drying trends in a warming climate. Since the conditioning of the STARS resampling procedure by a prescribed transient temperature increase translates short term interannual co-variations of temperature and precipitation into long-term precipitation changes, STARS projections are of limited physical consistency and diverge from the forcing GCM projections. However, since STARS offers the advantage to generate ensembles of climate projections at low computational requirements, its application supports initial sensitivity studies, supplementing computational expensive dynamical climate projections.

WRF scenario simulations including land use changes predicted by the LandSHIFT model driven by UNEP GEO4 scenario 'market first' indicate a modification of the greenhouse only response of the energy and water cycle in the target region. The changes due to increased greenhouse gases can be increased or weakened depending on the respective region and the assigned land use change. However, the modification due to land use changes is in general much smaller than the greenhouse gas induced signal. A regional and land use related attribution and a thorough analysis of the underlying physical mechanisms is focus of current work.



Figure 1: Annual mean change (2036-40 vs. 2001-05) of near surface (2m) temperature (K; shaded) and precipitation (%; contours) for ECHAM5/MPI-OM (left), WRF (middle) and STARS (right).