AMAZALERT

A research project on impacts of climate change and land use change in Amazonia

Factsheet

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New multi-model projections of climate in Amazonia

AMAZALERT reports on the projections of climate change in the Amazon basin from the latest climate and Earth system models. Simulations of climate up to 2100 have been carried out according to different scenarios of greenhouse gas (GHG) concentrations, and include land use change consistent with development pathway and policy decisions. In this way, the potential implications of these changes on Amazonia can be explored.

AT A GLANCE

- New multi-model projections of change in Amazonia are presented.
- Temperature is projected to increase across South America, with greatest regional warming occurring over Amazonia.
- Changes in rainfall projected by the models are mixed and vary by season, although there is more agreement for drying in the eastern basin in Jun-Nov
- The land use changes implemented under the RCPs would benefit from improved region-specific scenarios

AMAZALERT takes advantage of state-of-the-art climate modelling to provide projections of change in Amazonia. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5), published in four parts between 2013-2014, will assess simulations that have been carried out through the Coupled Model Intercomparison Project phase 5 (CMIP5). It presents an update to the last major phase (CMIP3) model experiments that were reported in the IPCC AR4 (IPCC 2007).

Addressing uncertainties in climate model projections

Scientific uncertainties are inherent in any projections of climate, and these are derived from several sources. An important way to explore the implications of uncertainties on the projections of change is to use a group of models, or 'ensemble'. Take, for example, the uncertainty in the evolution of greenhouse gas concentrations: running a climate model under a range of concentration pathways demonstrates the simulated effects of different forcing according to differently evolving greenhouse gases. Even given the same forcing, between-model differences can be significant, particularly at the regional scale, and particularly for important variables such as the components of the water cycle. One method for characterising this type of modelling uncertainty in projections of future change is to assess those changes in a number of different models. By conducting the same experiment with an ensemble of different models, the range in model response can be explored.

Using the latest models and greenhouse gas concentration scenarios

CMIP5 comprises a coordinated suite of experiments run by climate modelling groups around the world. These experiments have been designed to address a number of research priorities towards improving understanding of past and future climate change, comparing and assessing model behaviour and exploring model capabilities (Taylor et al. 2012).

The CMIP5 modelling framework considers a number of scenarios describing the evolution of anthropogenic drivers of climate, such as fossil fuel emissions and land use change (Moss et al. 2010), which are further used to force the climate or Earth system models. The Representative Concentration Pathways (RCPs) were developed by interdisciplinary modelling frameworks to characterise a range of potential scenarios of human activities and development, and in contrast to other sets of scenarios (e.g. SRES, used to drive the CMIP3 projections of change) they account for climate mitigation policies. These RCPs describe pathways of radiative forcing and equivalent GHGs, in addition to land-use change (van Vuuren et al. 2011). In this fact sheet, we focus on RCP8.5 as representative of a high-end, 'business as usual'-type scenario, RCP4.5 as a mid-range scenario in terms of radiative forcing but with very different land-use change, and RCP2.6 as a mitigation scenario.

Model representation of the climate of Amazonia

Comparing, where possible, the model climate with observations, is an important step in demonstrating some of the model biases. It gives pointers towards areas where the model performs well or badly in the simulation of important processes, and it informs the interpretation of the future projections.

These models simulate reasonably well some aspects of the current climate of Amazonia and the wider region, such as the timing of the transitions in the seasonal cycle (Fig. 1), and the mean temperatures in the region. Many of the models capture some characteristics of the important observed relationships between rainfall and SST anomalies including being able to simulate the correct sign of the relationships between wet season rainfall and the tropical Pacific and dry season rainfall and the tropical Atlantic. However, as a whole, the ensemble

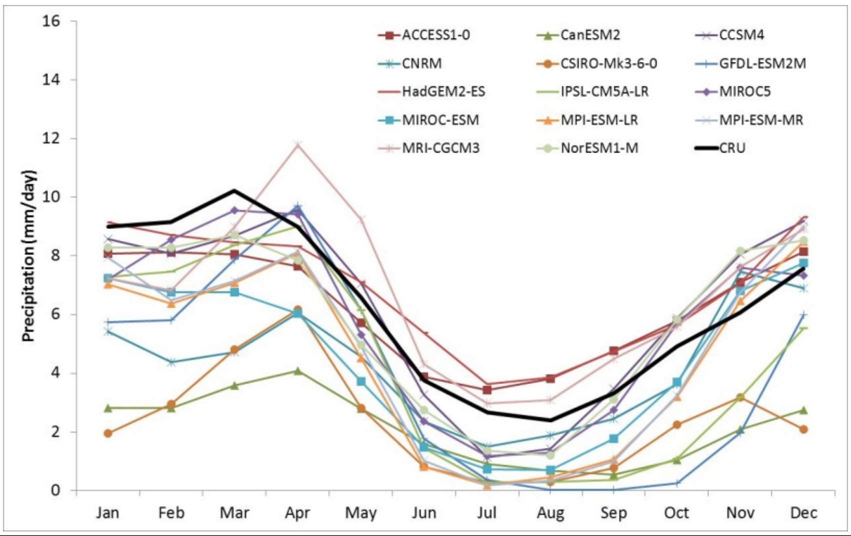


Figure 1 (right): Climatological seasonal cycle of precipitation over the Amazon region in the late 20th century: CMIP5 simulations (coloured lines) and CRU observations (black line).

simulates conditions that are too dry in the Amazon basin throughout the year, and in many models substantially so.

This poses a challenge for interpreting changes in indicators of drought or other climate measures related to forest health, particularly where absolute values are thought to be important. It also has implications for the use of model output to drive impacts models. However, if used in an informed manner, the simulations present an extraordinary opportunity to examine and understand better the potential changes driven by human activity.

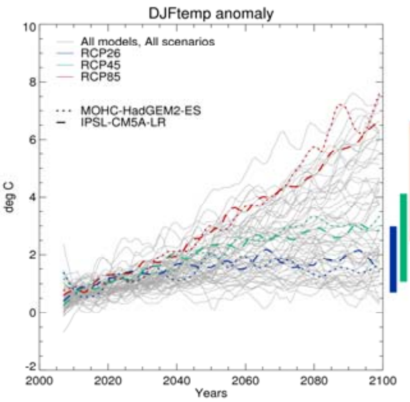


Figure 2 (top right) Temperature change (°C) over the Amazon basin relative to the baseline in left: Dec-Jan-Feb (DJF); right: Jun-Jul-Aug (JJA). Grey lines show the evolution of temperature in all models for all scenarios. Projections given by HadGEM2-ES (dotted) and IPSL-CM5A-LR (dashed) are overlaid in colour: RCP2.6 (blue); RCP4.5 (green), RCP8.5 (red). Bars indicate the range in projections according to RCP for the 30-year period 2071-2100 relative to the baseline.

Projections of climate change

The broad patterns of climate change projected by the CMIP5 ensemble are similar to those of CMIP3, and show that impacts increase under higher concentration scenarios. Temperature is projected to increase across South America, with greatest regional warming over Amazonia (Fig. 2). Increasing temperature, considered in isolation from other changes, has a detrimental effect on vegetation in Amazonia (Huntingford et al. 2013). Therefore, temperature must always be considered a potentially important stressor on the forest.

The availability of moisture is recognised to be of central importance for Amazon ecosystem health (e.g. Malhi et al. 2009), and a range of ecosystem services (e.g. Marengo et al. 2011). The changes in rainfall projected by the ensemble are mixed over the Amazon basin, and vary by season. However, there is generally more agreement on drying in the eastern basin, particularly in the June to November period, with wetter conditions projected by the majority of models in the western basin particularly in December to May (Fig. 3).

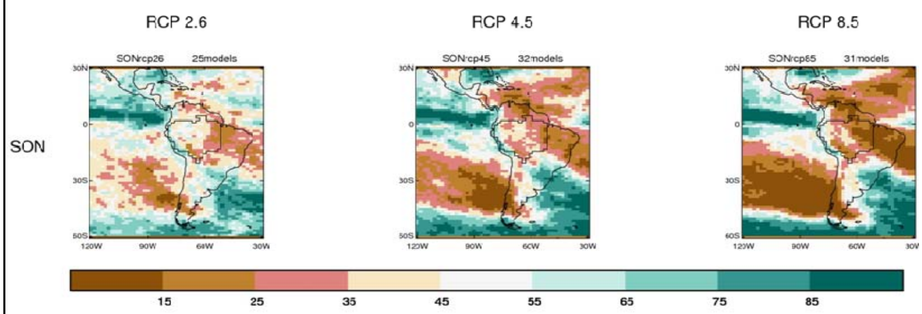


Figure 3 (down right) Indicator of CMIP5 model consensus in precipitation changes. Percentage of models that show an increase in precipitation in Sep-Oct-Nov (SON). Number of models available for each scenario varies according to RCP and is marked above each plot. The Amazon Basin is overlaid. Brown colours indicate model agreement for a drying signal and greens for a wetting signal.

However, there is a spread in the model projections that spans zero, and over the Amazon basin itself, there is no clear scenario dependency apart from an increase in spread in RCP8.5 over 4.5 and 2.6.

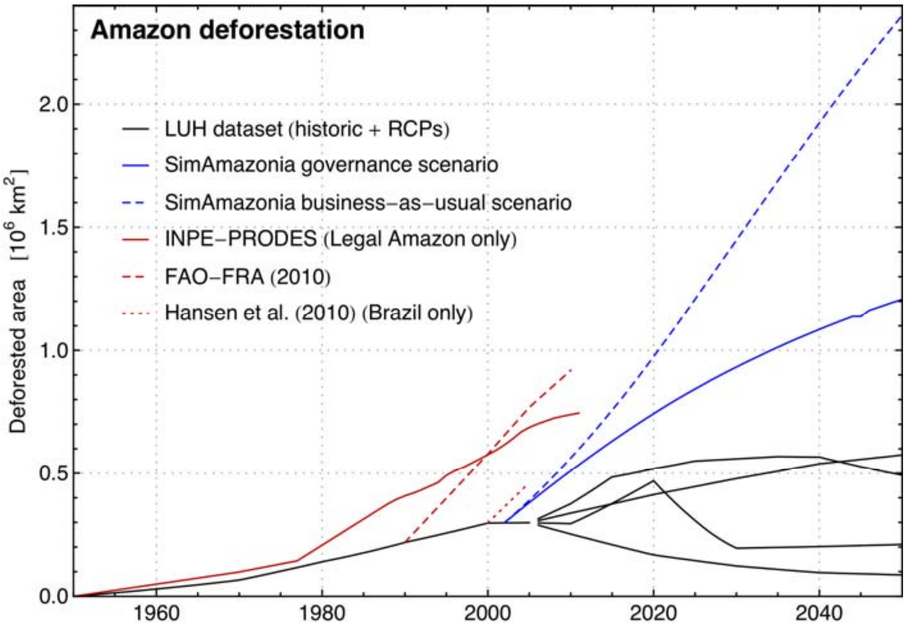
Most models projections suggest the correlation between Amazon basin precipitation and tropical Pacific SSTs in Dec-Jan-Feb will remain unchanged. In the tropical Atlantic there is little consensus on the evolution of precipitation/SST correlations in Jun-Jul-Aug, and hence it may be practical to consider only the effect of SST changes rather than changes in the precipitation/SST relationship. In most models, projections are for increased warming in the northern relative to the southern tropical Atlantic corresponding to a reduction in dry season precipitation.

Role of land use change

Experiments complementary to the CMIP5 centennial RCP simulations were carried out in order to isolate the impacts of land use change from the other drivers of change. Land use change in Amazonia over the 21st century is small, and does not have a discernable effect on climate. A comparison between observation-based estimates of historical deforestation rates and those in the RCP with largest change (RCP2.6) reveals that the RCP rates are substantially lower (Fig. 4). Furthermore, they are optimistic in comparison with some previously developed region-specific scenarios. It is suggested the historical land cover is not sufficiently accurate at the regional scale and also that RCP land use scenarios are unlikely to realistically represent changes at regional scales.

Figure 4 (right):

Total area deforested within the Amazon basin prescribed in the ORCHIDEE Land surface model (IPSL) based on CMIP5 data ('LUH'; black lines indicate the historical data and the four RCP scenarios) and based on SimAmazonia (blue; solid and dashed line indicate the governance and non-policy scenarios). Solid, dashed and dotted red lines indicate estimations of forest cover loss from different sources. For clarity of display, the SimAmazonia and the observation-based deforestation time-series are shifted so that the first year of each matches the LUH curve.



Summary

The CMIP5 multi-model ensemble provides projections of climate change that sample modelling and scenario uncertainty, and results in a range of responses in Amazonia. This allows the projections to be expressed in a way that quantifies some of the uncertainties inherent in these projections. There is strong motivation to combine the results of model runs within a multi-model ensemble, but there are many challenges associated with doing this. One way to inform the process is through validation with observations where possible. The known biases present in the CMIP5 ensemble for Amazonia should be taken into account in the interpretation of the projections of climate change, the development of Amazon ecosystem-relevant climate indicators, and in using model output to run offline impacts models.

The land use changes implemented under the RCPs would benefit from improved region-specific scenarios. The new scenarios of land use change being developed by INPE through AMAZALERT will help to address this requirement.

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