Climate Change: Are Greenhouse Gas Emissions from Human Activities Contributing to a Warming of the Planet?

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Testimony Summary

The Earth system is still not understood well enough to precisely answer the question: "How do you expect future global temperatures to be affected by *greenhouse gas emissions* from human activity?" Simulations performed with state-of-the-art regional climate models add a perspective on multi-scale interactions involved in the Earth system that are not simulated in Atmosphere-Ocean General Circulation Models (AOGCMs) and, therefore, have not been accounted for in studies performed with these models. These simulations lead to significantly different results and conclusions on the behavior of the Earth system. Human activity has an impact on the Earth system that is broader than greenhouse gas emissions. For example, land-cover changes due to land use play a significant role in climate change, through feedback on ecological and hydroclimatological processes (including, among others, clouds, precipitation, fires, carbon and aerosols). Whether land use enhances or mitigates the effects of greenhouse gas emissions, and at which pace the various human activities and corresponding responses of the modified environment occur, remains to be clarified. A new generation of climate models capable of simulating such multi-scale processes and feedback is required to answer these questions more precisely. Nevertheless, there is conclusive observational evidence for global temperature and sea level rise, and ice caps and snow cover shrinkage. These phenomena are well correlated with human activity, broadly defined. Thus, the issue for scientific debate is the *relative* contribution of individual human activities, which is needed to anticipate the impact of future emissions, not their overall contribution to climate change, which according to the recent IPCC report has now been established with a high level of confidence.

Introduction:

Climate models are essential tools to study the various processes that take place in the Earth system. Yet, they are not accurate enough to precisely *assess* the impacts of greenhouse gases emissions (as a separate component of the various human activities) on our future climate. As summarized in the National Research Council report on "Radiative Forcing of Climate Change" (NRC, 2005) "…*there are major gaps in understanding of the other forcings, as well as the link between forcings and climate response. Error bars remain large for current estimates of radiative forcing by ozone, and are even larger for estimates of radiative forcing by aerosols. Nonradiative forcings are even less well understood*…"

Simulations produced with AOGCMs miss significant processes that drive the climate response in somewhat unexpected ways. As an example to demonstrate this issue, simulations of deforestation of the Amazon Basin are produced with a state-of-the-art regional climate model, namely the Regional Atmospheric Modeling System (RAMS) developed at Colorado State University. By using a much better resolution than that typically adopted in AOGCMs, land-atmosphere interactions (including clouds and precipitation) are simulated more accurately with regional models. They are compared to the simulations produced with the NASA Goddard Institute for Space Studies Model II, one of the well-accepted GCMs.

Regional *vs* Global Modeling:

Soares Filho et al. (2004)[1] have produced scenarios of land-cover change in the Amazon Basin for the next fifty years based on socio-economic development anticipated in that region. Figure 1 illustrates their predicted land-cover map for 2050.

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[1] Soares-Filho, B., A. Alencar, D. Nepstad, G. Cerqueira, M. D. V. Diaz, S. Rivero, L. Solorzano, and E. Voll, 2004. Simulating the response of land-cover changes to road paving and governance along a major Amazon highway: The Santarem-Cuiaba corridor. *Global Change Biology*, **10**, 745-764.

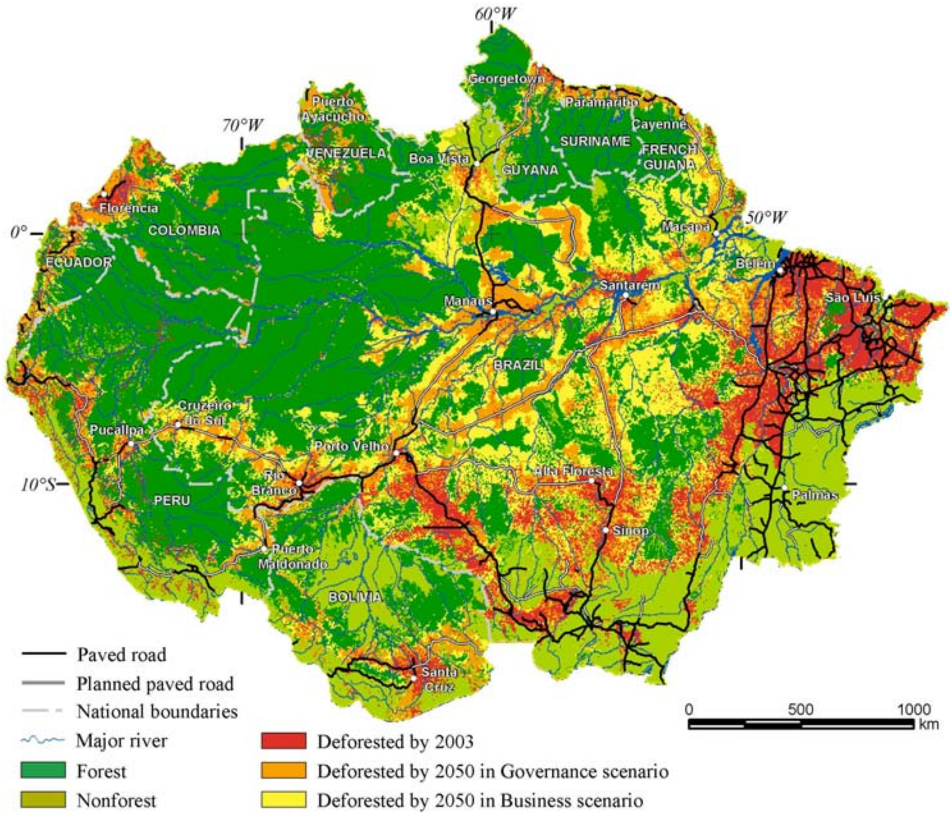

Figure 1: *Land-use map of the Amazon Basin based on socio-economic development of that region by 2050.*

Figure 2 shows the January-February mean rainfall observed in the Amazon Basin for the period 1970-2000. One can notice that year 1997 was particularly wet, 1998 (which was an El Nino year) was particularly dry, and 1999 and 2000 received an amount of rainfall similar to the 30-year average.

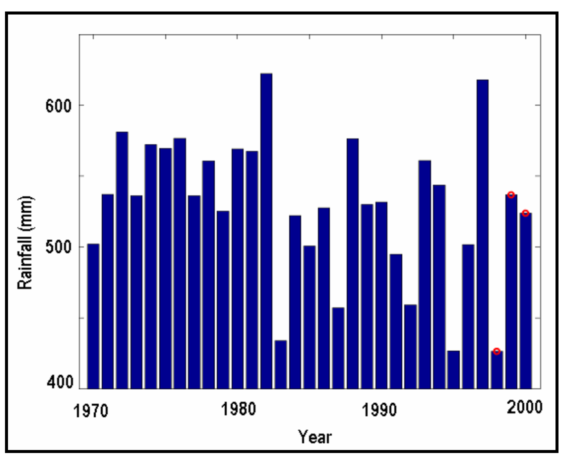

Figure 2: *January-February mean rainfall in the Amazon Basin for the period 1970-2000.*

Using the meteorological conditions of these four years as a representative sequence of weather conditions in this region, together with the scenarios of land-cover change produced by Soares Filho et al. for 2030 and 2050, we studied the hydroclimatological impacts of deforestation in the Basin with RAMS. We also produced a "control" simulation using the current land-cover map of the region, and a "total deforestation" case that could possibly happen by the end of the century at the current pace of deforestation in that region.

Figure 3 illustrates the change of precipitation obtained with RAMS for the 2050 land-cover scenario. Unlike the results obtained with a typical GCM, it is interesting to note that the heavily deforested eastern part of the basin experiences an increase while the western part of the basin sees a reduction of precipitation. This is particularly noticeable during El Nino events (not showed here). Considering the entire basin (Figure 4), the GISS GCM simulates a stronger reduction of precipitation due to heavy deforestation. During the wet year of 1997 (and to some extent in 1999 and 2000), deforestation has very little impact on precipitation. However, the *type* of precipitation changes from the "green ocean" that is obtained with current land-cover conditions to convective rainfall when the region is deforested. This significantly alters the ground radiative balance.

Comment:

The precipitation shift and cloud structure simulated with RAMS are not represented by the GCM. They have a significant impact on the radiative forcing, which is typically used as a criterion to evaluate the human impacts on climate. Furthermore, the ecosystem feedback to the climate through more frequent fires that are likely to be triggered in the western part of the basin as a result of intensified droughts produced by the precipitation shift is not represented in these models. The release of aerosols by the fires and their direct and indirect impact on the radiative forcing is not well understood. The ecosystem response under the joint influence of precipitation shift and increased carbon dioxide is not known, let alone represented in these models. Yet preliminary results indicate that increased carbon dioxide tends to intensify rainfall in that region, mitigating the effects of deforestation. Therefore, better models accounting for such processes are needed.

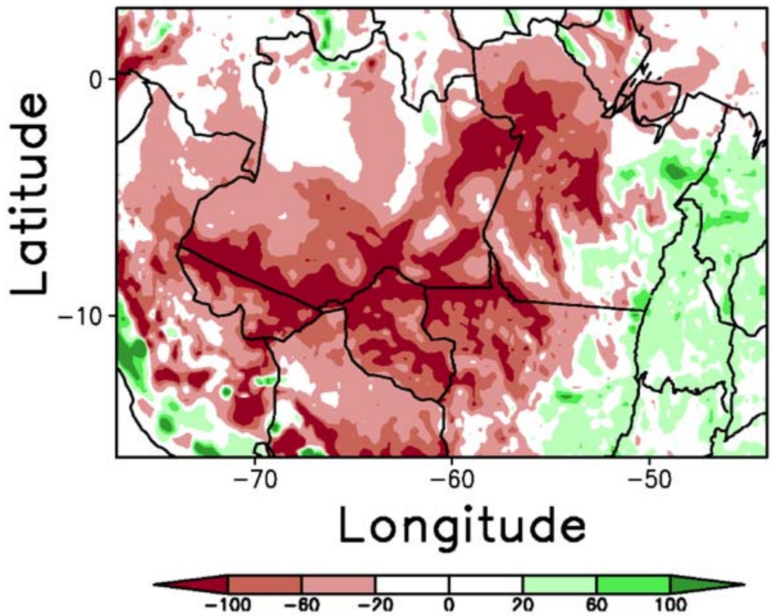

Figure 3: *Rainfall anomaly (mm) relative to the "control" simulation for the land-use scenario of 2050.*

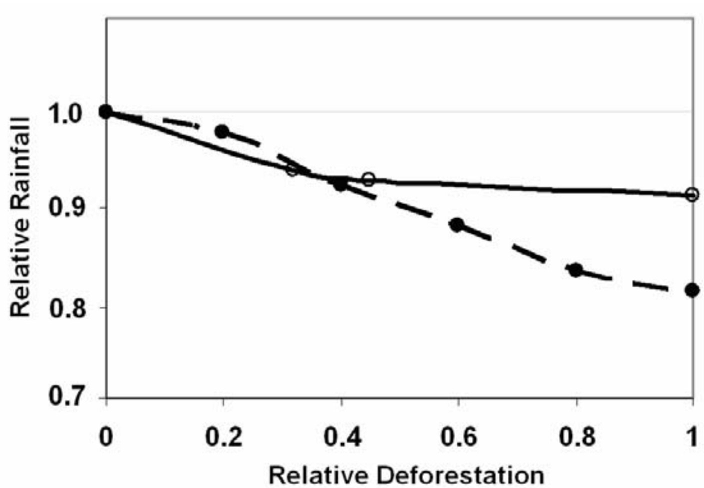

Figure 4: *Relative rainfall (compared to the "control" case) as affected by relative deforestation simulated with RAMS (solid line) and with the GISS GCM (dashed line).*