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Land use change over Amazon Forest and its impact on the local climate

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Abstract: This study describes the physical processes associated with the impact of the Amazon (AMZ) deforestation on the climate in the north-northwest sector of South America (SA). Two simulations with RegCM4, from 1979 to 2009, were carried out: one using a default land cover map (CTRL) and other one using deforestation scenario (LUC), i.e., all broadleaf evergreen trees tropical were changed by C3 grass. RegCM4 was integrated with a horizontal grid spacing of about 50 km and considering 18 sigma-pressure vertical levels for SA CORDEX domain. The lateral and boundary conditions for driving the model were obtained from the ERA-Interim reanalysis. The climate change signal due to AMZ deforestation was evaluated by comparing the climatology of the CTRL with the LUC experiment. AMZ deforestation causes a dipolar response in the precipitation consisting of reduced (increased) precipitation over western (eastern) side of the basin. Concerning the temperature, there is a warmer anomaly over the deforested areas, and it contributes to decrease the surface pressure. The higher air temperature is associated with an increase of the sensible heat flux and a decrease of the latent heat flux over the deforested areas.

Keywords: land use, Amazon Forest, energy balance, precipitation recycling

1. Introduction

The Amazon (AMZ) forest is the largest tropical rainforest on Earth [1]. It covers approximately 5,5 million km^2, with an area of 60% located in Brazil [2]. Some problems in this region are associated with the deforestation (such as biomass burning and forest fragmentation) and the land use change (LUC) and their impacts on the climate. The Instituto de Pesquisas Espaciais do Brasil [3] indicated that the rate of Brazilian Amazon deforestation between 2000 and 2009 was one of the fastest in the world, averaging 17,486 km^2 per year. In a more recent study to the southern AMZ, [4] inferred, for the period 1970-2012, which the change in land cover was 191,319 km^2.

Deforested areas present higher surface albedo compared with that without changes [5,6]. Moreover, in these areas the moisture storage capacity decreases affecting both sensible and latent heat fluxes, i.e., the sensible heating increases while the latent heting decreases [7]. Deforestation/land use change aslo contributes as a source of greenhouse gas emissions into the atmosphere [8]. Wood is a sink or storage place for carbon, but with burned, carbon dioxide (CO_2) is release into the atmposphere. In general, the natural vegetation areas are degraded with burned in order to be used as farms or cattle ranches, and the animals produce methane that will storage in the atmosphere.

Concerning the hydrological cycle, the total amount of water that precipitates on large continental regions is supplied by two mechanisms [9]: 1) advection from the surrounding areas external to the region and 2) evaporation and transpiration from the land surface within the region. The hydroclimatic regime variability of the AMZ is affected by local climate feedbacks, i.e., the evapotranspiration (ET) plays an important role in the precipitation, and it is affected, as well, for large scale climate patterns, as for example Sea Surface Temperatures (SST) anomalies [10,11,12]. According to [12], the tropical Atlantic is a remote source of humidity for AMZ basin with the northern tropical Atlantic contributing mainly during the austral summer.

The purpose of this work is to describe the physical processes that occur when the broadleaf evergreen trees tropical are changed by C3 grass over AMZ basin. For this reason, we will analyse the energy balance and the precipitation recycling. We will also show the changes obtained in precipitation, air temperature and atmospheric circulation over AMZ and South America.

2. Material and Methods

2.1 RegCM4 configurations and experiment design

The latest version of theAbdus Salam International Centre for Theoretical Physics (ICTP) regional climate model, RegCM4 [13], was used in this work. We conduced two simulations with this model covering the period 1979-2009. One simulation was without implementation of LUC, i.e. by assuming the default land cover map of the model, the control experiment (CTRL), and in the other one we used an idealized LUC over the AMZ basin, i.e. we changed all broadleaf evergreen trees tropical (tropical rain forest) to C3 grass in order to assess the impact of these features in the present day climate and investigate underlying physical processes. The green colour in the Figure 1b represents the broadleaf evergreen tropical trees that were replaced for C3 grass in LUC experiment, the horizontal black bars indicate the cross section (5°S-5°N) selected for more detailed analysis.

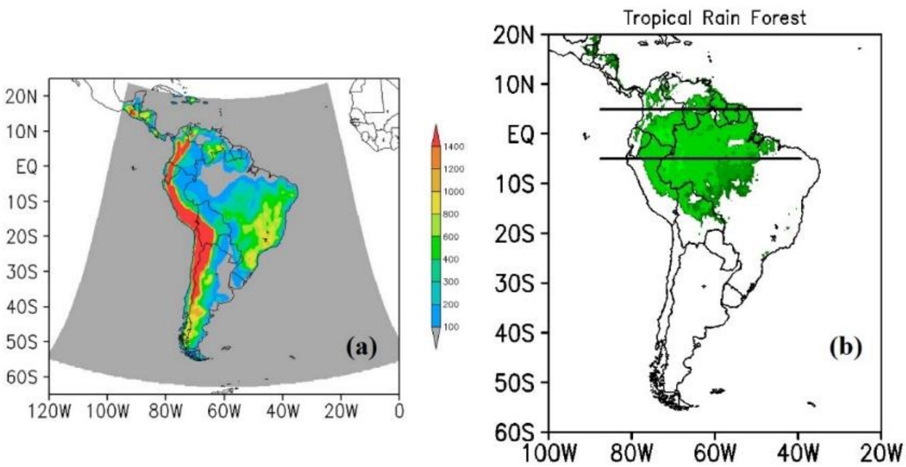

Figure 1. (a) South America CORDEX domain and topography (m); (b) Green colour represents the tropical rain forest that was replaced for grass in LUC simulation and the two horizontal lines represent the cross section (5S-5N) selected for deeper analysis.

3. Results

3.1 Effects of deforestation

In this section, we show the results obtained with LUC minus CTRL experiment. LUC implies in higher annual mean of air temperature over north-west SA (Figure 2a). The warmer contribues to decrease the surface pressure and, as a consequence, a thermal low may be formed (Figure 2b). This signal was also found by other deforestation studies over AMZ, such as: [14] and [15].

The air temperature and albedo (Figure 3a-b) increase from 0 to 2.5 °C and from 0 to 0.1 (~10%), respectively, over all the deforested cross section showed in Figure 1b. For the albedo this increase is due to the replace of the forest to grass, and this increase is more accentuated between the longitude 60°-50°W. Moreover, [6] mentioned that the net surface radiation (Rn) over cleared areas is less than that over no deforested areas. In Figura 3a, LUC has lower Rn compared with CTRL in the western sector of AMZ basin.

The physical mechanism associated with the increase of the air temperature is the increase of the sensible heat flux (green line, Figure 3c) and the decrease of the latent heat flux (blue line, Figure 3c). Changes in the vegetation modify the photosyntesis process and it impacts on the vegetation transpiration. Grass vegetation has less transpiration than the tropical forest, and it changes the energy budget at surface, i.e, less energy is used to evaporate the vegetation transpiration (decrease in the latent heat flux) and more energy is used to warm the atmosphere above the surface (increase in the sensible heat flux).The warmer in LUC experiment is also reflected by the geopotential height (Figure 3d). Over the western side of the study domain, Figure 1b (where the precipitation is reduced in LUC – Figure 4) shows that the difference in geopotential height for positive values occurs in lower levels of the atmosphere than in the eastern side in the LUC (positive values indicate surface pressure more vertically spaced due to the atmosphere warming). However, it is important to highlight that the higher positive values near 700 hPa over the western side may be associated with adiabatic heating by subsidence.

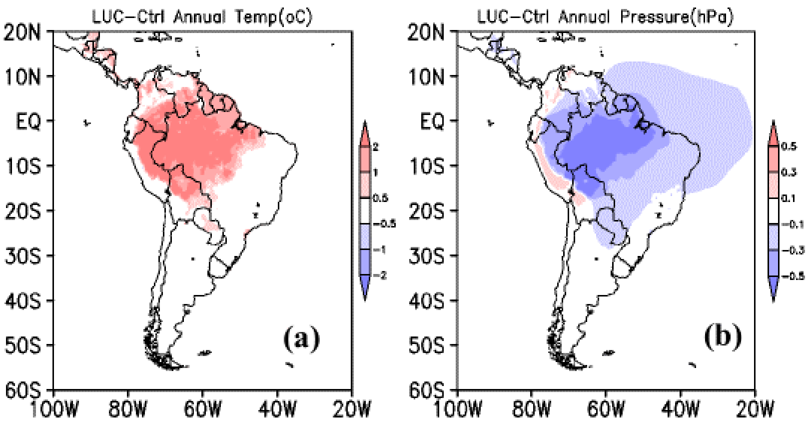

Figure 2. (a) Air temperature change in °C (LUC minus CTRL simulation) and **(b)** Surface pressure change in hPa (LUC minus CTRL simulation).

Total precipitation (Figure 4a) shows a dipole response consisting of reduced precipitation over western AMZ and an increase over eastern AMZ. Over the AMZ, the total precipitation is mainly formed from the convective process as we can see in Figure 4b, which represents only the convective part of the precipitation. In the complete paper we will discuss the reasons of the dipole pattern in the precipitation.

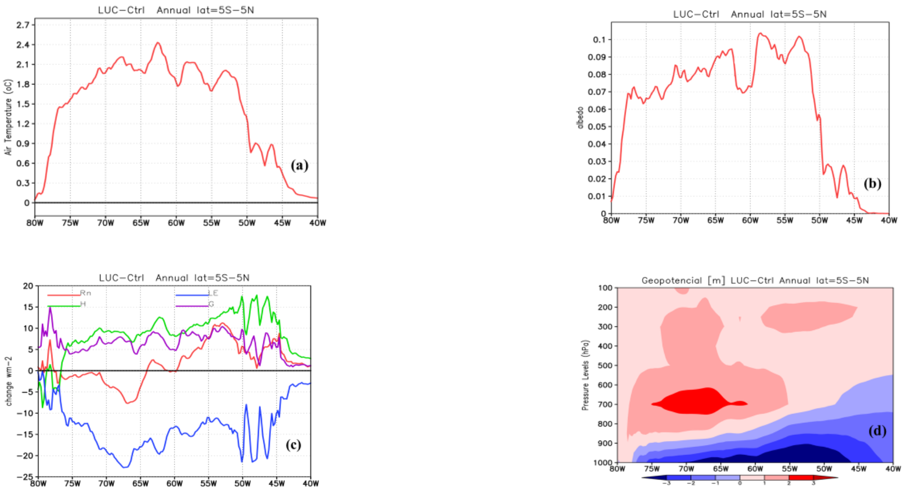

Figure 3. For the cross section (5ºS – 5ºN) over land: **(a)** air temperature change in ºC; **(b)** changes in albedo; **(c)** changes in the energy balance components (w/m²) being net radiation (red line), sensible heat flux (green line), latent heat flux (blue line) and soil heat flux (purple line) and **(d)** geopotential height (m).

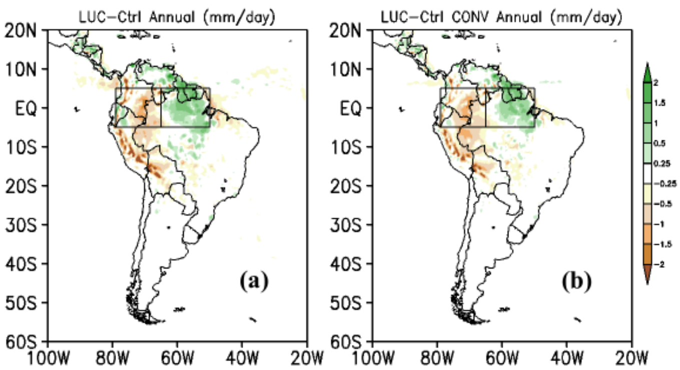

Figure 4. Precipitation change (LUC minus CTRL simulation) in mm/day for **(a)** total precipitation **(b)** convective precipitation.

4. Conclusions

We perfomed two simulations, from 1979 to 2009, with RegCM4 to study the impact of change all broadleaf evergreen trees tropical by C3 grass over AMZ basin. The climate change signal due to AMZ deforestation was evaluated by comparing the climatology of the CTRL with the LUC (land use change) experiment. AMZ deforestation is associated with an increase of air temperature, ground heat and sensible heat fluxes and a decrease in the latent heat flux, and a precipitation dipole pattern over the AMZ basin.

Changing forest by grass, the transpiration is reduced and hence it would be expected less rainfall over all AMZ. However, LUC experiment showed dry conditions in the western AMZ and wet conditions in the eastern side. The physical explanation is associated primarily with the warmer air temperature in the LUC. The higher temperatures in the LUC contribute to develop a low surface pressure over the AMZ basin. It creates a horizontal pressure gradient intensifying the winds from the tropical North Atlantic Ocean to the continent. These winds transport humidy that converges over the eastern AMZ favouring the rainfall. So, we can say that the precipitation over the AMZ basin, under the deforestations scenario, presents a dipole pattern, which is driven by local (evapotranspiration) in the west and remote feedback (convergence of moisture flux) in the east side of the basin.

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Author Contributions: Marta Llopart carried out the simulations; Diego Souza performed the precipitation recycling analysis; and Marta Llopart, Michelle Reboita and Rosmeri da Rocha analysed the results and wrote the paper.

Conflicts of Interest: "The authors declare no conflict of interest."

Abbreviations

The following abbreviations are used in this manuscript:

AMZ	Amazon
CONV	convergence of the moisture flux
CTRL	simulation with Amazon forest
ET	evapotranspiration
G	soil heat fluxes
H	sensible heat
LE	latent heat
LUC	simulation change the Amazon forest by grass
P	precipitation
Rn	net surface radiation

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