Shifts in the mean and extreme precipitation at the end-of-century in the South American Monsoon as projected by the CESM Large Ensemble

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Abstract

Similar to many areas of the globe, South America is under a monsoon regime. The Amazon rain-forest is one of the regions critical for this regime, known as the South American Monsoon System (SAMS). Besides being crucial to the Earth's carbon budget, the Amazon is also important for SAMS development. During SAMS onset, the trade winds intensify and a northwesterly low-level jet, known as the South American Low Level Jet (SALLJ), is formed east of the Andes. Moisture originating in the Atlantic Ocean is recycled and reinvigorated over the Amazon and carried by the SALLJ to continental and subtropical South America. In this project, we analyze the projected changes in precipitation and extreme events of rainfall over South America by the end of the 21st century using the CESM Large Ensemble Project (LENS). LENS is able to reproduce the important elements of the SAMS. We find that wet season rainfall is projected to increase over the east coast and central South America. The SALLJ is projected to become stronger, especially during late wet season, and carry more moisture to subtropical South America. As a result, moisture convergence between the SALLJ and the South Atlantic Subtropical High increases, creating the conditions to rainfall over Central and Southeastern South America. Meanwhile, Amazon is projected to become dryer during both dry and wet seasons. As a result, rain-forest productivity is reduced during late dry season in Southern Amazon. As vegetation struggles to save water, evapotranspiration, and consequently surface latent heat flux are reduced. These factors have been suggested as crucial to SAMS initiation and their reduction is responsible for a delay in SAMS onset by the end of the century. Extreme wet events are projected to become more frequent, especially over Northeastern Brazil, Southern Brazil and Uruguay. As dry season rainfall is reduced in all of the regions analyzed, drought events are projected to become more frequent and longer over both the wettest (Northern Amazon) and the driest (Northeastern Brazil) regions analyzed.

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Projected changes in the South American Monsoon in Large Ensemble Simulations

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Background

- During the South American Monsoon System (SAMS) onset, the trade winds intensify and a northwesterly low-level jet, known as the South American Low-Level Jet (SALLJ), forms east of the Andes.
- Moisture originating over the Atlantic Ocean is recycled and reinvigorated over the Amazon and carried by the SALLJ to continental and subtropical South America.

Scientific Question:

- How is rainfall over South America projected to change by the end of the 21st century in multiple realizations of the same global climate model?
- Isolate the anthropogenic signal from internal variability

Methods

South American Monsoon onset date:

- First day with rainfall above 4 mm/day over Amazon and westerly winds over Central Brazil, with those conditions persisting for at least 70% of the next 40 days.

The CESM Large Ensemble:

- 40 runs of the same climate model (CESM1.1)
- 1º spatial resolution

Present: 1970-2000 (historical)
Future: 2070-2100 (RCP 8.5)

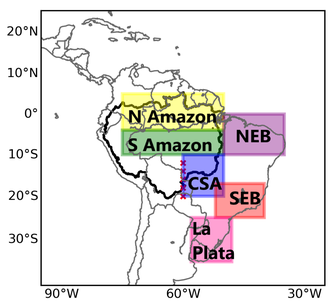


Figure 1: Spatial domain covered by each of the areas: Northern Amazon (N Amazon), Southern Amazon (S Amazon), Northeastern Brazil (Nordeste), Central South America (CSA), Southeastern Brazil (SEB), and La Plata Basin (La Plata). The cross-section of central South America where the wind is used to calculate SAMS onset date is also shown (red x), as well as the Amazon (black heavy contour).

Results

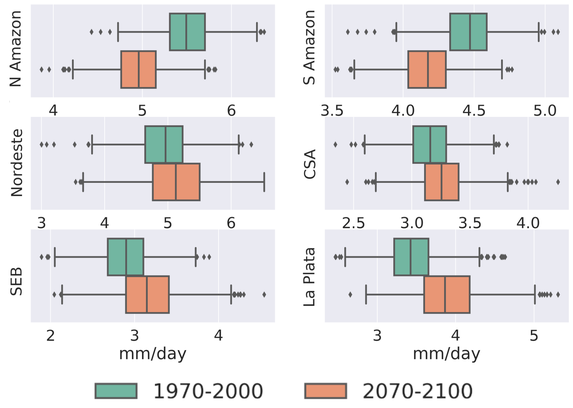
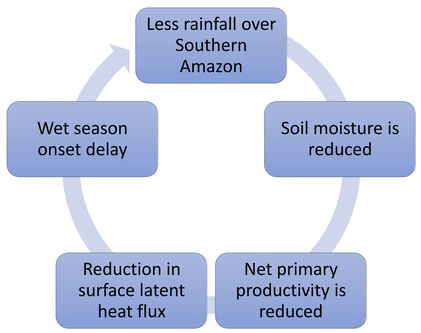


Figure 2: Distribution of the present (in green) and future (in orange) mean annual precipitation in LENS. The distributions shown in each of the panels in this figure are significantly different according to the KS-test.



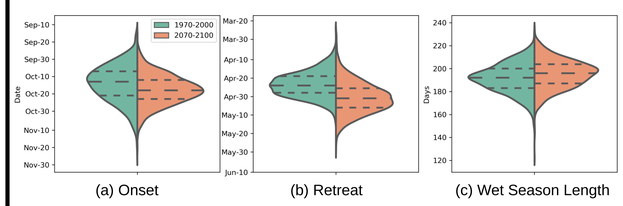


Figure 3: Distribution of (a) SAMS onset date, (b) retreat date and (c) wet season length in present (left) and future (right) climate, in LENS.

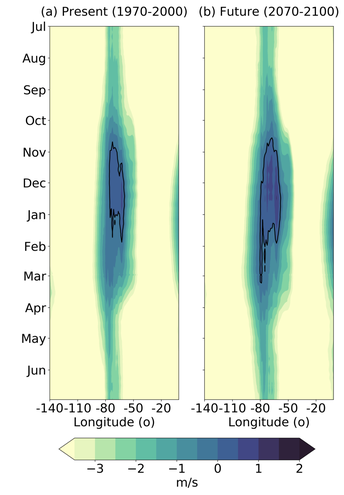


Figure 4: Time evolution of ensemble mean of the zonal wind at 850 hPa averaged between 20ºS and 5ºS for longitudes 20ºW-140ºW in the present (a) and future (b) climate. The zero-line is marked in black.

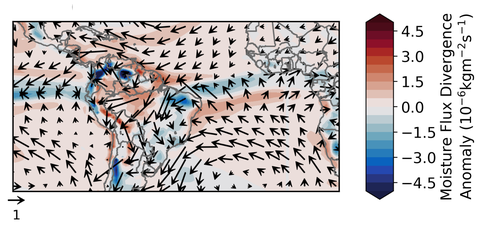


Figure 5: Difference between the ensemble mean of the vertically integrated moisture flux (arrow) and its divergence (in colors) in future and present climate averaged over January to March

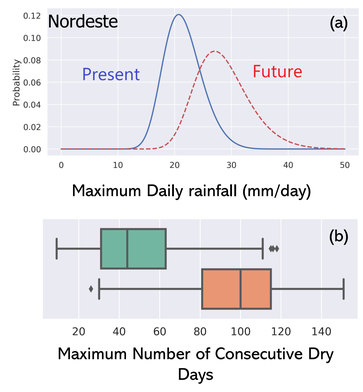


Figure 6: (a) Generalized extreme value distribution of the maximum daily precipitation in the present and future climate for Nordeste. (b) Distribution of the annual maximum number of consecutive dry days in Nordeste for the present (in green) and future (in orange) climate.

Conclusions

- Amazon is projected to get drier, negatively affecting rainforest productivity and reducing surface latent heat flux, contributing to a delay in wet season onset.
- The South American Low-Level Jet becomes stronger and persists later in the wet season, delaying the wet season retreat.
- During the wet season, moisture convergence between a stronger SALLJ and a weaker South Atlantic Subtropical High create the conditions for increased rainfall over Central and Southeastern Brazil.
- The frequency and intensity of extreme precipitation events increases in all areas, especially Northeastern Brazil and La Plata Basin.
- Dry season becomes drier in all areas analyzed, and the maximum number of consecutive dry days increases over CSA, SEB, Northeastern Brazil and Northern Amazon.

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