Supplementary material for: A possible deforestation-induced synoptic-scale circulation that delays the rainy season onset in Amazonia

This PDF file includes:

Supplementary method

Study region

The southern Amazon (SA) is a transition region between humid tropical forest and Cerrado with a strong agricultural presence, and it covers 30 to 40% of the Amazon biome (Wright *et al* 2017). In recent decades, SA's dry season has lengthened (Fu *et al* 2013), which may be related to deforestation impacting the rainy season (Wright *et al* 2017, Leite-Filho *et al* 2020). Our study defines SA as ranging from 5° S to 15° S latitude and from 66° W to 51° W longitude; we also include the state of Mato Grosso due to the possible implications of climate change and the delayed onset of rainfall for agriculture in the state, where a substantial fraction of Brazil's soybean, maize and cotton production is located (Abrahão and Costa 2018, Brumatti *et al* 2020).

Plant Functional Types (PFTs)

Table S1 - CESM Plant Functional Types (PFT) adapted from land use classes in Rochedo *et al* (2018). We used a combination of PFTs with the same fraction as those in Ramankutty and Foley (1999, RF99) primary vegetation maps.

Rochedo et al. (2018) land use class	CESM PFT
Water	Ignored
Urban	Ignored
Pasture	C4 grasses (PFT 14)
Pasture in protected area	C4 grasses (PFT 14)
Savanna	Primary vegetation (RF99)
Savanna in protected area	Primary vegetation (RF99)
Forest	Primary vegetation (RF99)
Forest in protected area	Primary vegetation (RF99)
Soy	Crops (PFT 15)
Sugarcane	Crops (PFT 15)
Maize	Crops (PFT 15)
Cotton	Crops (PFT 15)
Rice	Crops (PFT 15)
Wheat	Crops (PFT 15)
Dry beans	Crops (PFT 15)
Coffee (Arabica)	Crops (PFT 15)
Coffee (Robusta)	Crops (PFT 15)
Oranges	Crops (PFT 15)
Cassava	Crops (PFT 15)
Bananas	Crops (PFT 15)
Cocoa	Crops (PFT 15)
Tobacco	Crops (PFT 15)
Maize (2nd season)	Crops (PFT 15)
Dry beans (2nd season)	Crops (PFT 15)
Planted forest	Broadleaf evergreen trees (PFT 5)
Soy-Maize	Crops (PFT 15)
Soy-Wheat	Crops (PFT 15)
Maize-Wheat	Crops (PFT 15)
Soy-Dry beans	Crops (PFT 15)
Maize-Dry beans	Crops (PFT 15)
Dry beans-Dry beans	Crops (PFT 15)

Observed rainfall products

Precipitation retrievals consist 1990-2005 period in a daily timestep for three observation products to describe the regional rainfall behavior: i) The Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks—Climate Data Record (PERSIANN-CDR) uses artificial neural networks to estimate precipitation based on infrared and images from satellites (Nguyen *et al* 2019); ii) The Climate Hazards Group Infrared Precipitation (CHIRPS) consists of a rainfall station and satellite data along with cold cloud duration retrievals to estimate precipitation (Funk *et al* 2015); iii) The Global Precipitation Climatology Centre (GPCC) gauge-based product interpolates station observed data to a regular grid (Schamm *et al* 2014). We used these datasets to calculate an average observed precipitation for September and October to validate the model's monthly mean precipitation.

Rainy season onset

We used a modified anomalous accumulation method (Arvor *et al* 2014, Abrahão and Costa 2018) to calculate the onset of the rainy season (Eq. 1). This method considers a relation between the daily rainfall (R_n) and a reference value (R_{ref}).

$$AA\ (day) = \sum_{n=1}^{dia} R_n - R_{ref} \quad (1)$$

We used 2.5 mm day^{-1} as R_{ref}, representative of water needs for soybean seedlings. This method has already been used in several studies in SA and Mato Grosso(Pires *et al* 2016, Abrahão and Costa 2018, Leite-Filho *et al* 2020). Onset values obtained using this method and this R_{ref} value were well correlated with soybean planting dates in the region (Zhang *et al* 2021).

We obtained the rainy season onset for all four scenarios. Then, we calculated the anomalies between the environmental governance scenarios (WEG − SEG) for the averages over the decade 2040–2050.

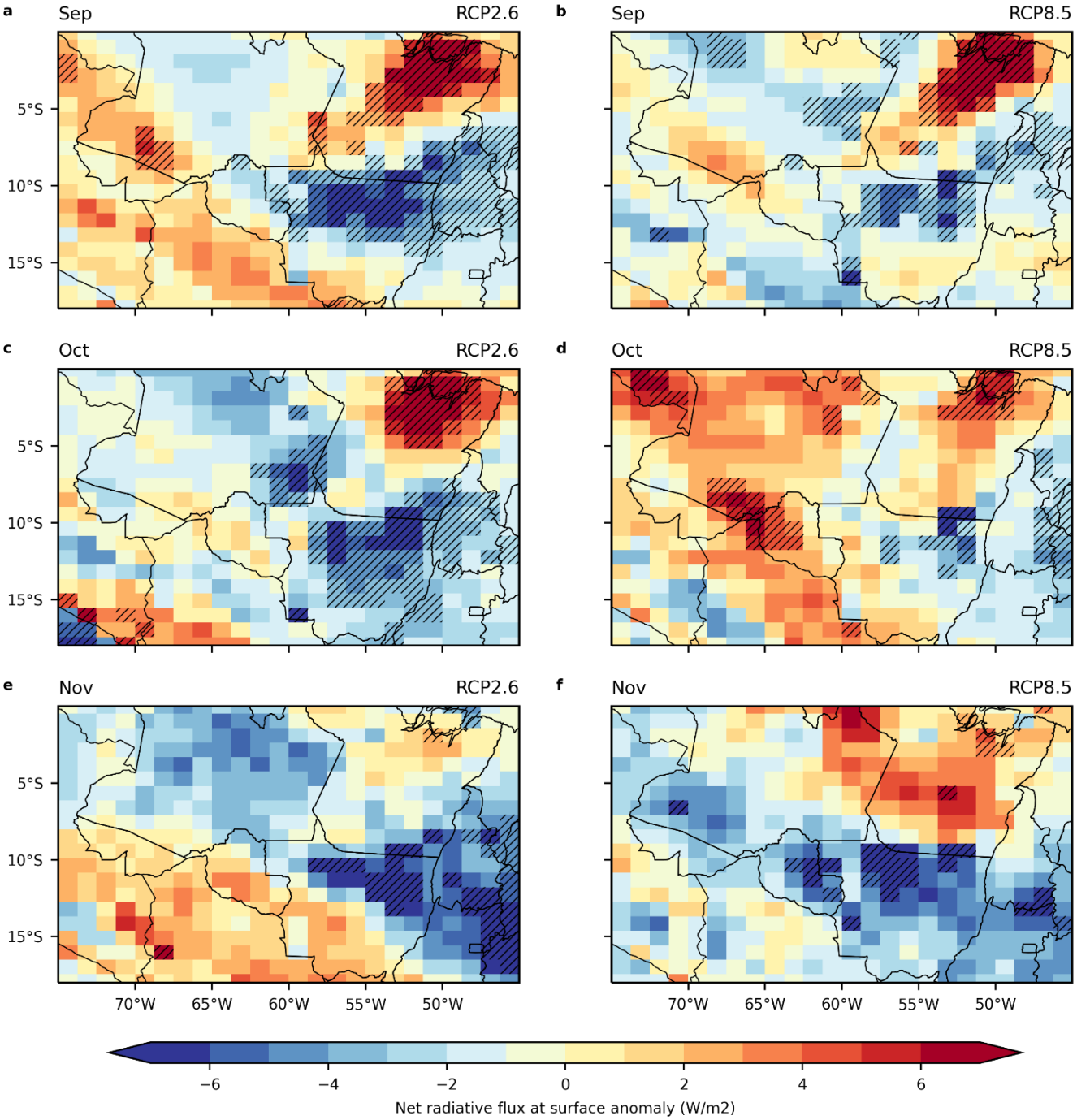

Figure S1. Net radiative flux at surface anomalies were calculated as WEG − SEG for RCP2.6 (a, c, e) and RCP8.5 (b, d, f). Shaded areas indicate results significant at α = 0.05.

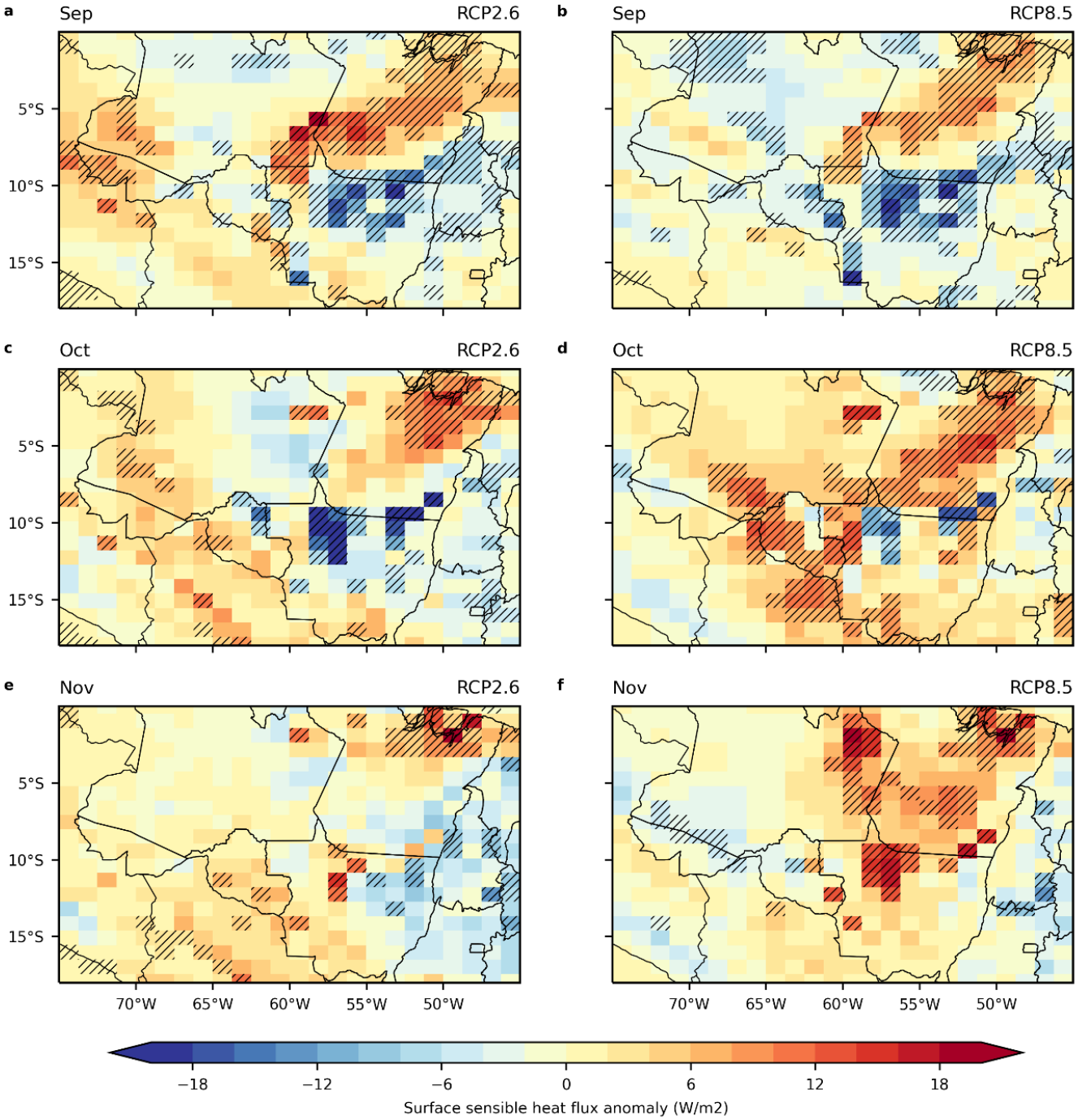

Figure S2. Surface sensible heat flux at surface anomalies were calculated as WEG − SEG for RCP2.6 (a, c, e) and RCP8.5 (b, d, f). Shaded areas indicate results significant at α = 0.05.

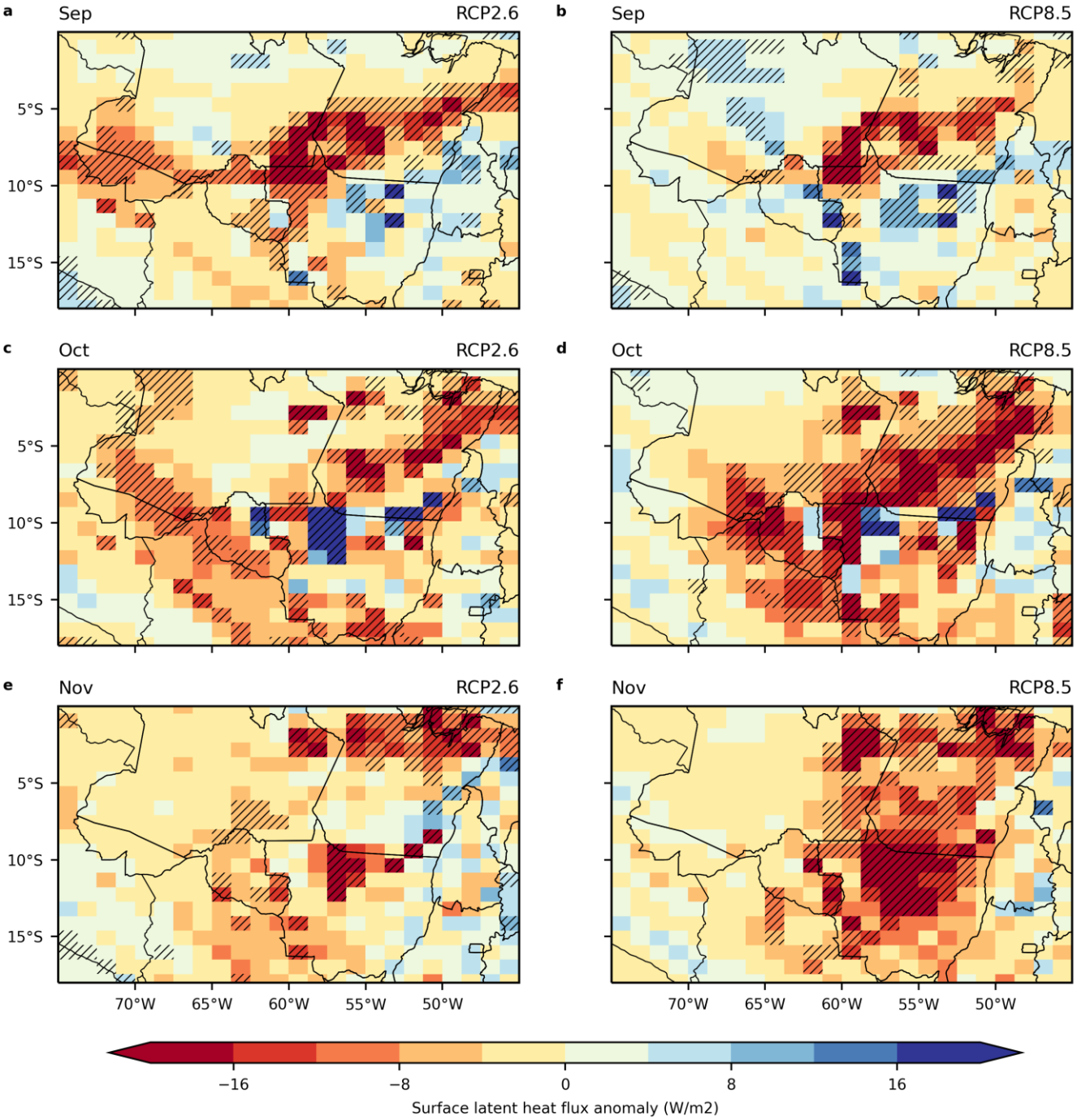

Figure S3. Surface latent heat flux at surface anomalies were calculated as WEG − SEG for RCP2.6 (a, c, e) and RCP8.5 (b, d, f). Shaded areas indicate results significant at $\alpha = 0.05$.

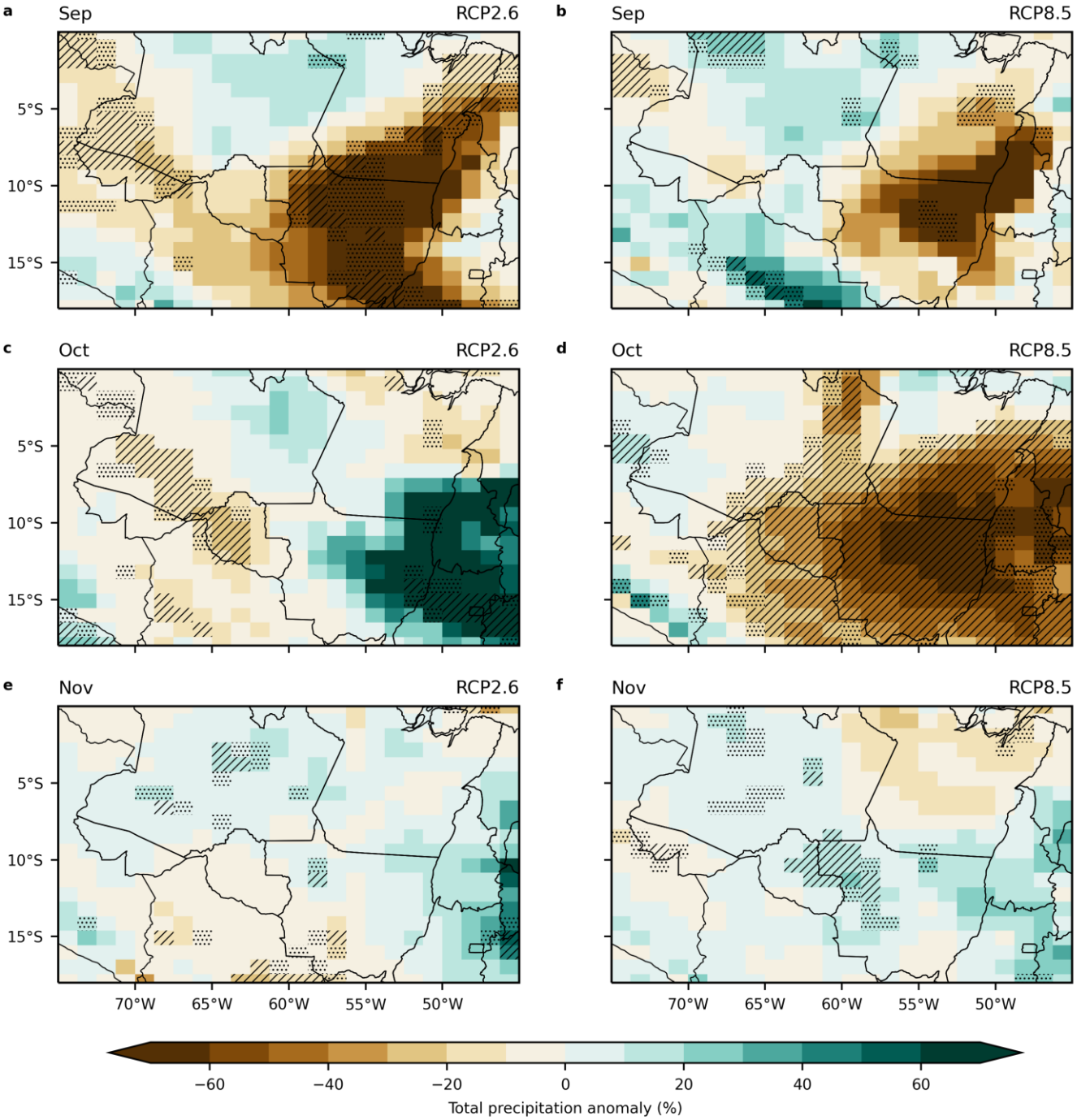

Figure S4. Total precipitation changes calculated as WEG − SEG for RCP2.6 (a, c, e) and RCP8.5 (b, d, f). Dotted and hatched areas indicate results significant at α = 0.10 and 0.05, respectively.

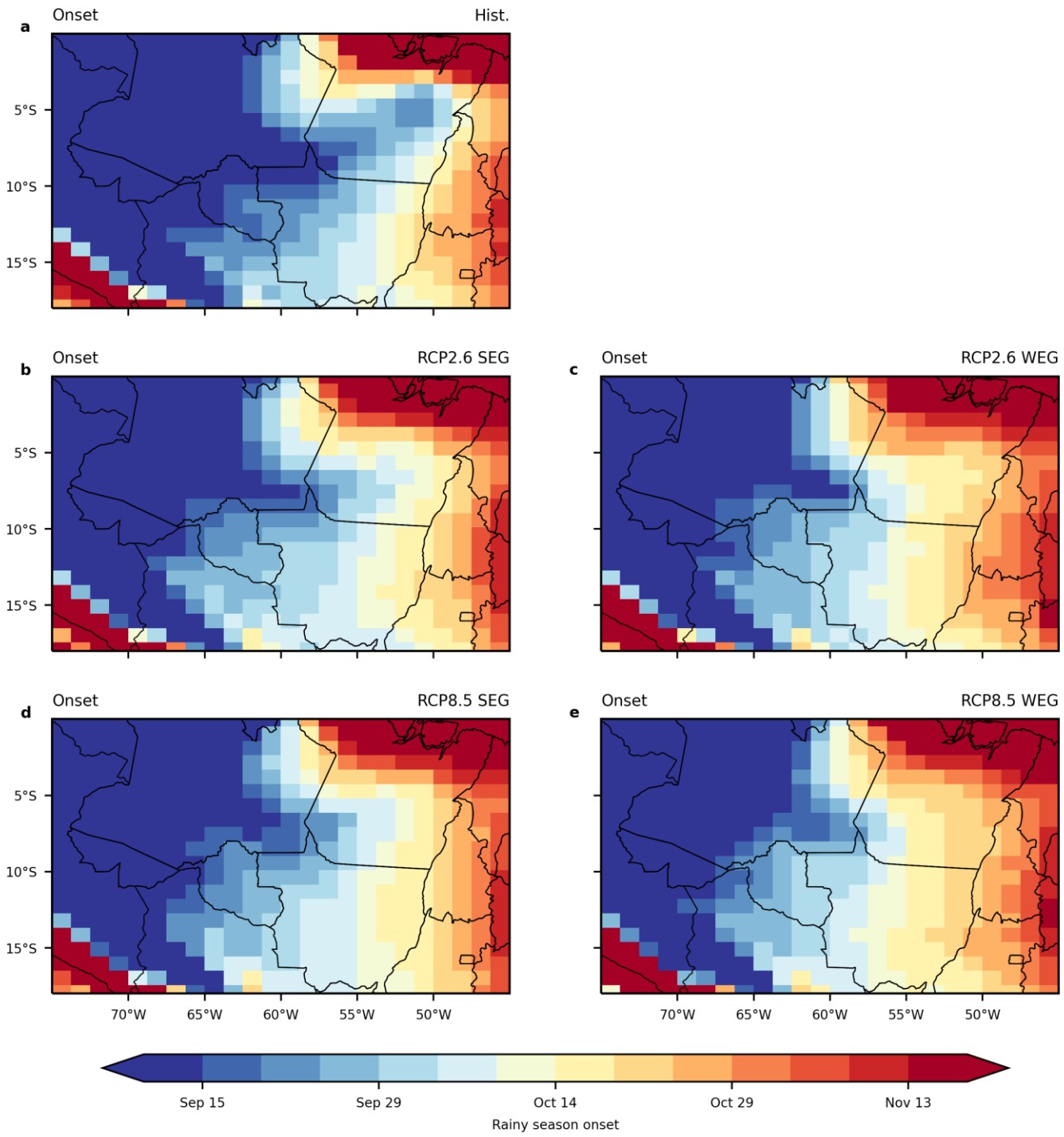

Figure S5. Mean rainy season onset for the historical period (1990–2005) (a); the average of the decade 2040–2050 for four combinations of climate pathways and deforestation scenarios: RCP2.6 and SEG (b), RCP2.6 and WEG (c), RCP8.5 and SEG (d), RCP8.5 and WEG (e).

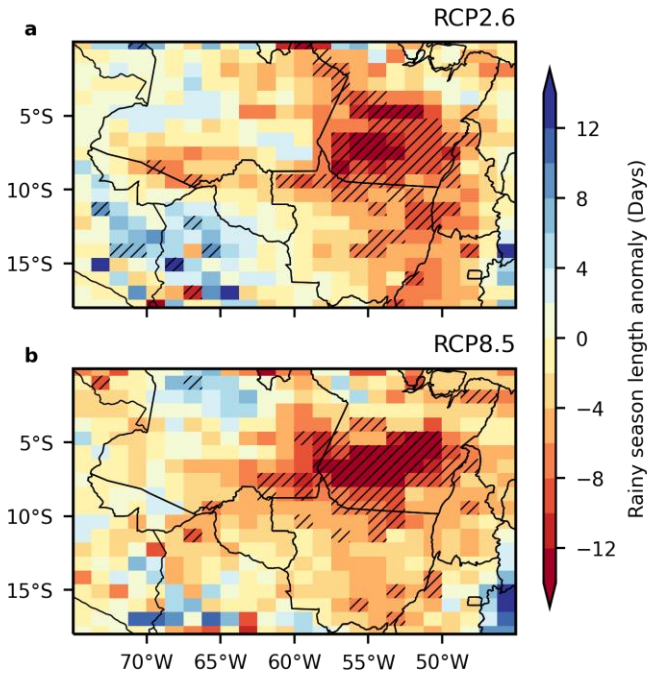

Figure S6. Rainy season length anomalies were calculated as WEG − SEG for RCP2.6 (a) and RCP8.5 (b). Shaded areas indicate results significant at a = 0.05.

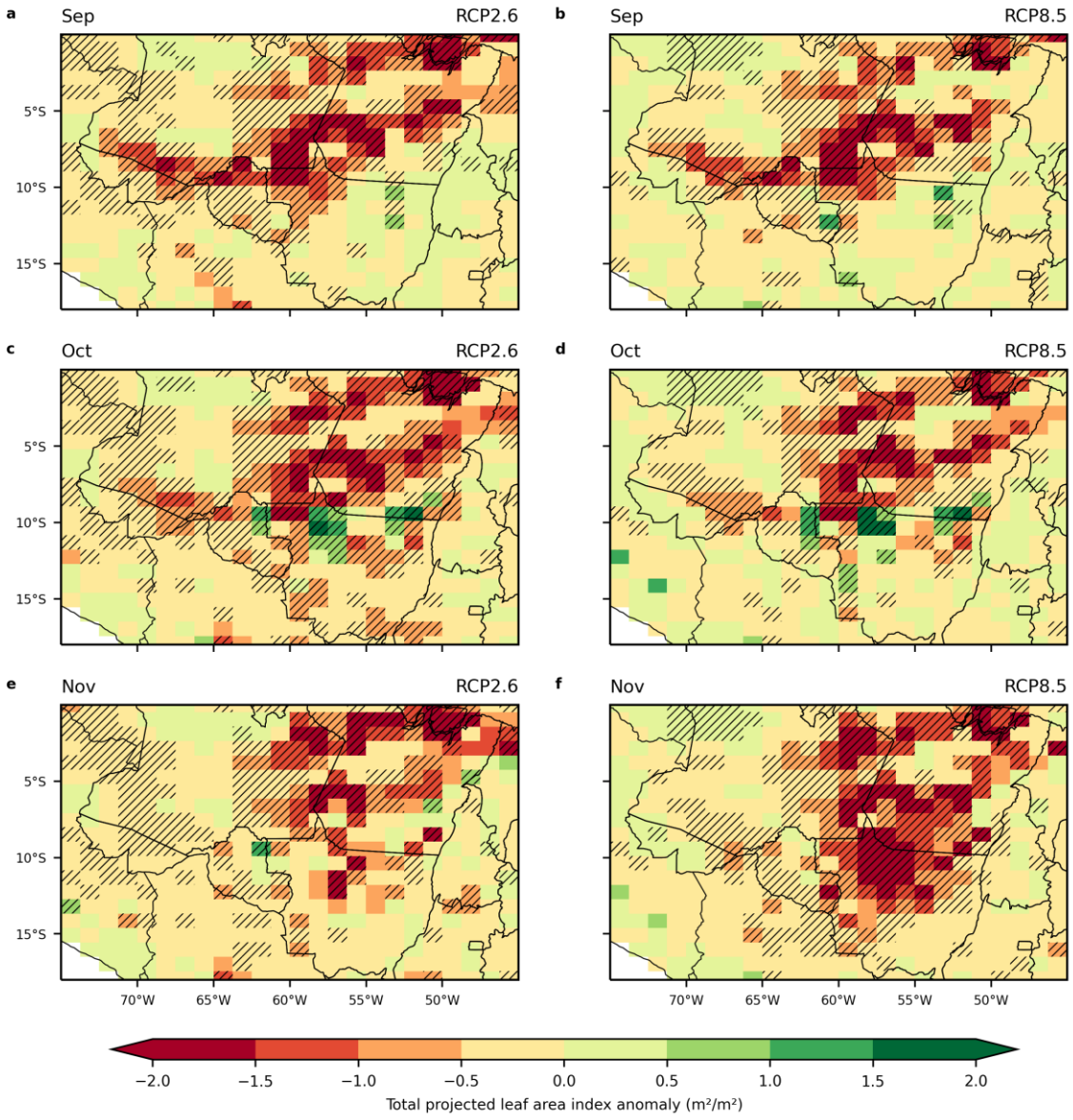

Figure S7. Total projected leaf area index (LAI) anomalies were calculated as WEG − SEG for RCP2.6 (a, c, e) and RCP8.5 (b, d, f). Shaded areas indicate results significant at 0.05.

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