Present and future climate in Amazonia and its impacts

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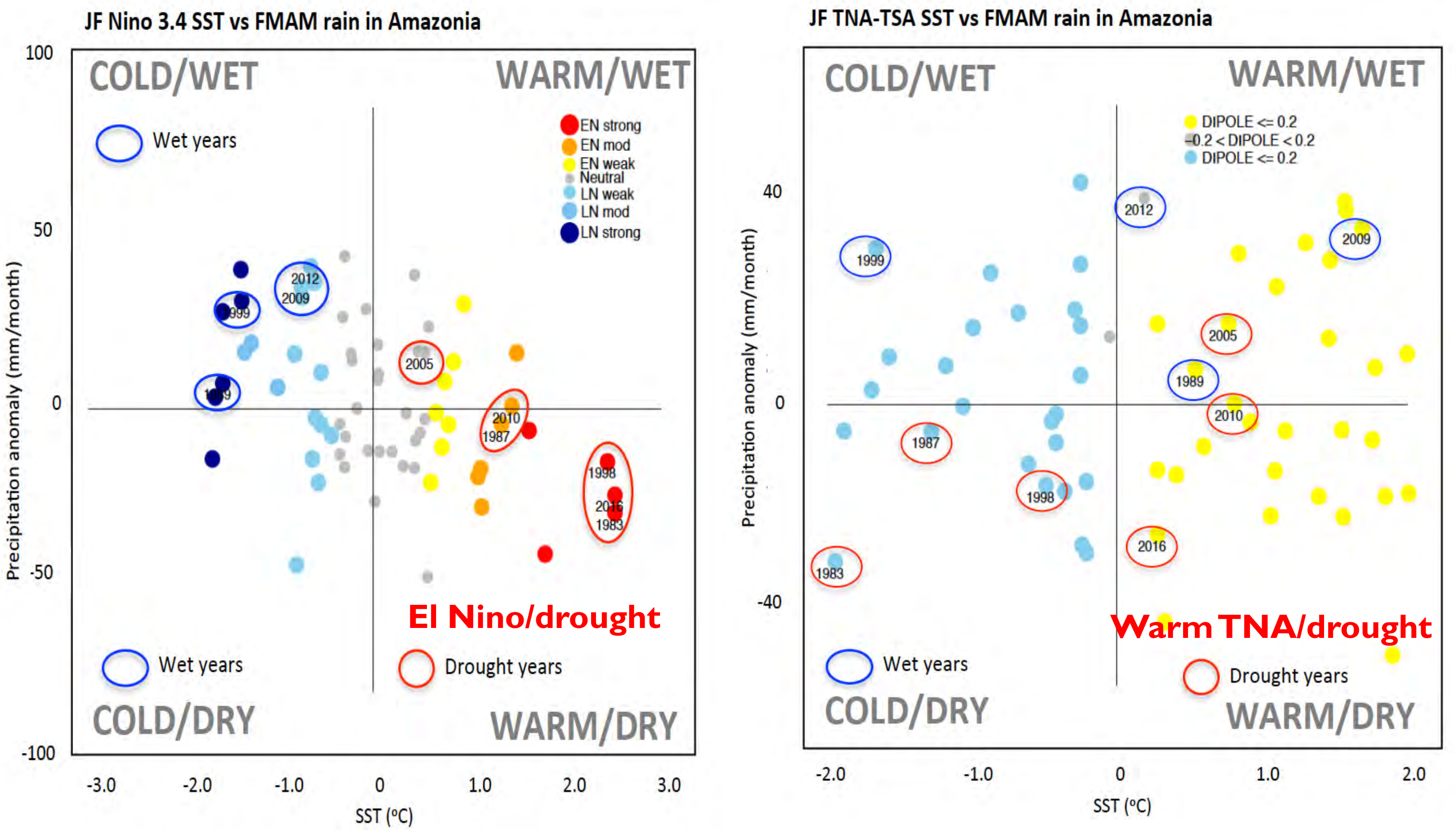
Climate trends in present and future in Amazonia

Recent extreme climatic events in the region, such as droughts and floods, changes in the rainy and dry seasons, increased fire risk with associated their impacts on climate, health and biodiversity are examples of what could happen in Amazonia as a consequence of climate change (Marengo et al 2018)

On the local and regional scales, the Amazon forest exerts control on rainfall and temperature through ET, in a process known as "moisture recycling". Several studies have quantified the water balance in the Amazon basin, and despite uncertainties, estimates of ET widely range from about 35% to over 80% of the precipitation. Furthermore, van der Ent et al. (2010) estimated that 70% of the water resources of the La Plata River basin depend on evaporation over the Amazon

An increase in annual mean temperature ranging from 0.1 to 3.8 ° C, and a reduction of 10-30% in annual precipitation, which would lead to changes in the climatic seasons both locally and regionally (Magrin et al., 2014). Spracklen *et al.* (2012) found that clearing 40% of the Amazon results in a 12% reduction in wet-season rainfall and a 21% reduction in dry-season rainfall across the Amazon basin.

El Nino and warm tropical North Atlantic during some dry and wets years in Amazonia (updated to 2017 from Marengo et al 2011)

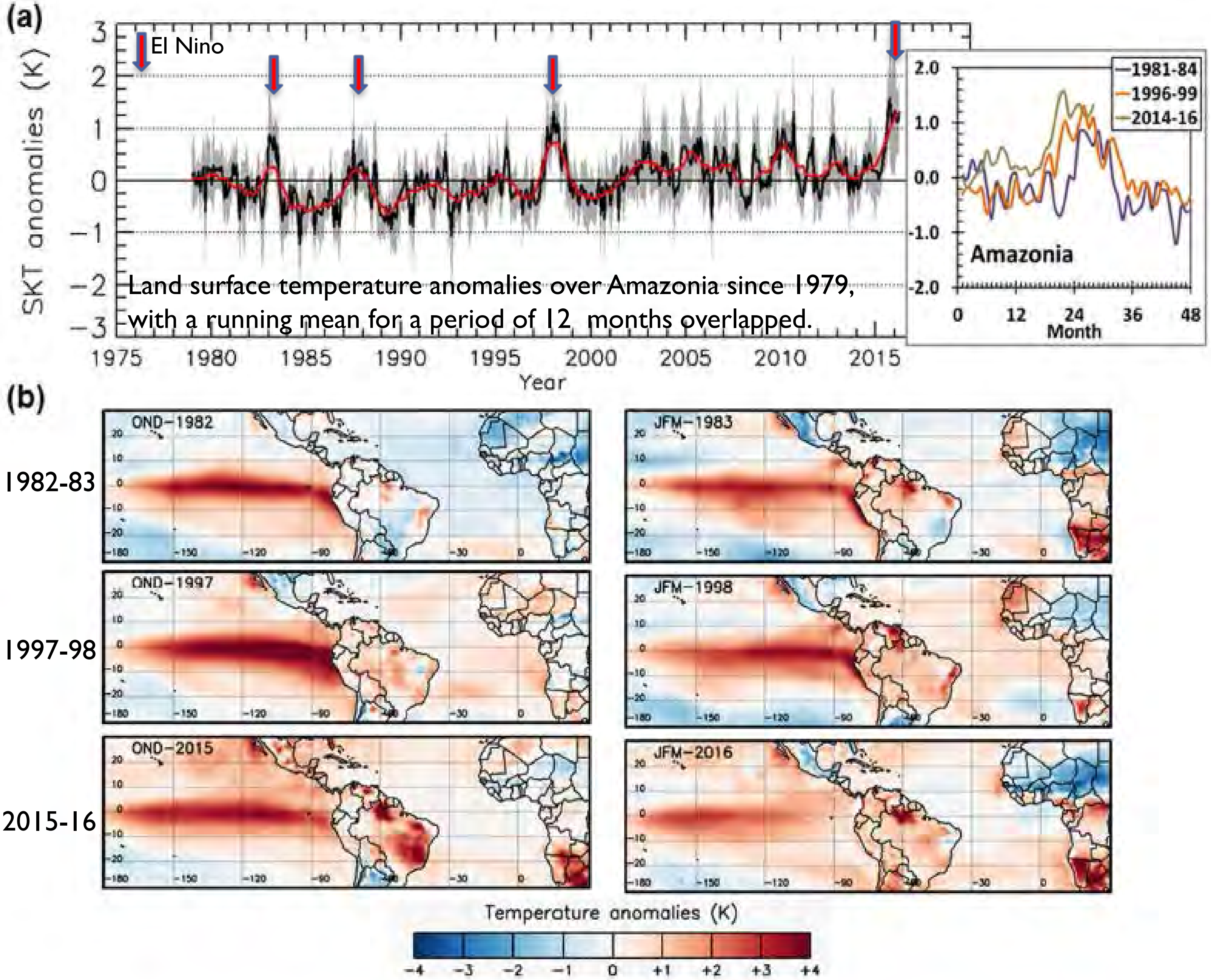


JF Nino 3.4 SST vs FMAM rain in Amazonia

JF TNA-TSA SST vs FMAM rain in Amazonia

Scatter diagrams of anomalies in the SST anomalies (°C) in the tropical Pacific (Nino 3.4) and the SST dipole in tropical Atlantic (SST tropical North Atlantic–SST tropical South Atlantic) during January–February and GPCC rainfall anomalies (mm/month) during the FMAM peak season in Amazonia. Drought and wet years in Amazonia are shown by numbers and the stronger events appear inside circles

Sea and land surface temperature (SST and LST) anomalies during the three strong Jiménez-Muñoz et al. (2016)



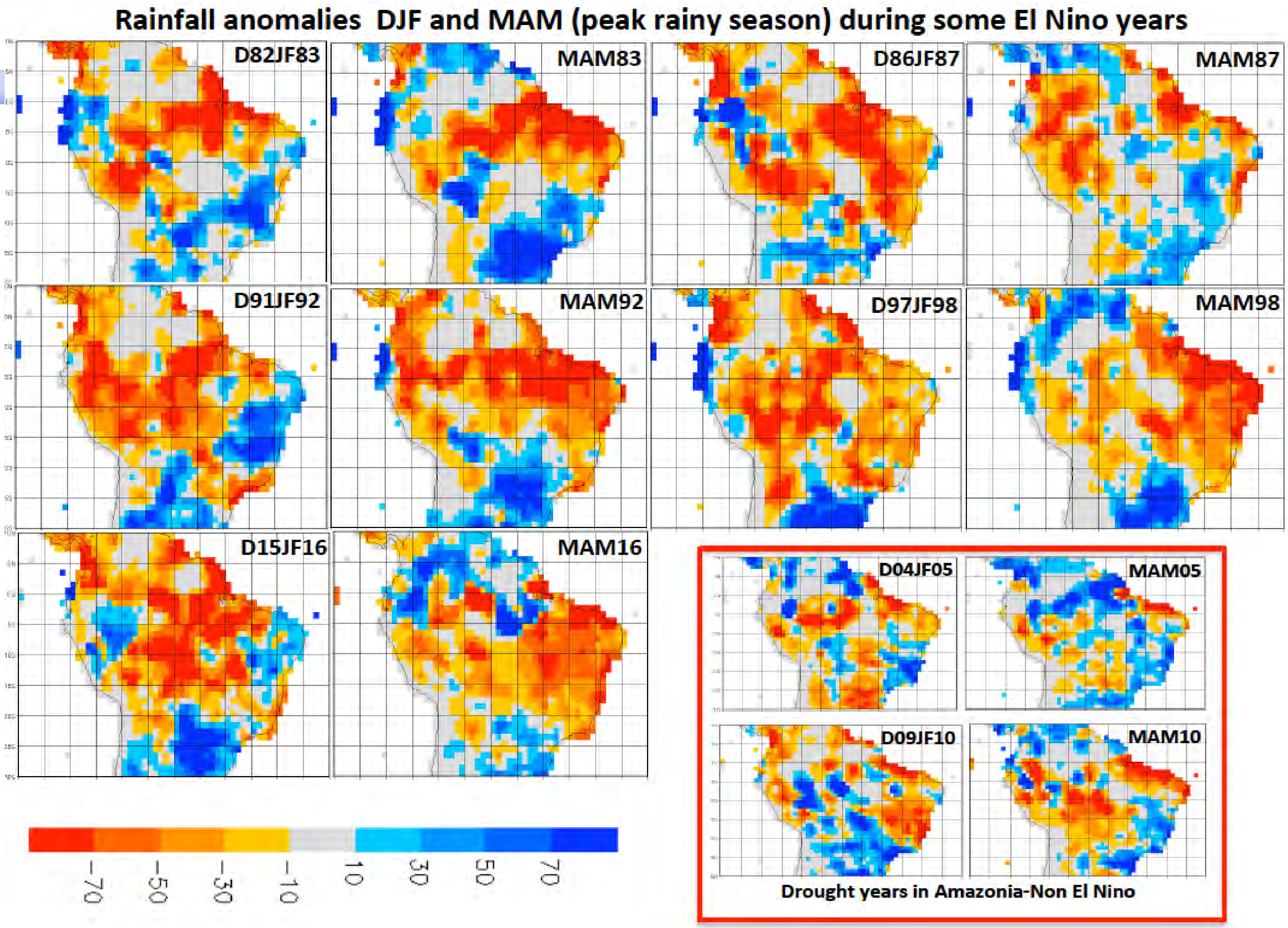
Land surface temperature anomalies over Amazonia since 1979, with a running mean for a period of 12 months overlapped.

1982-83

1997-98

2015-16

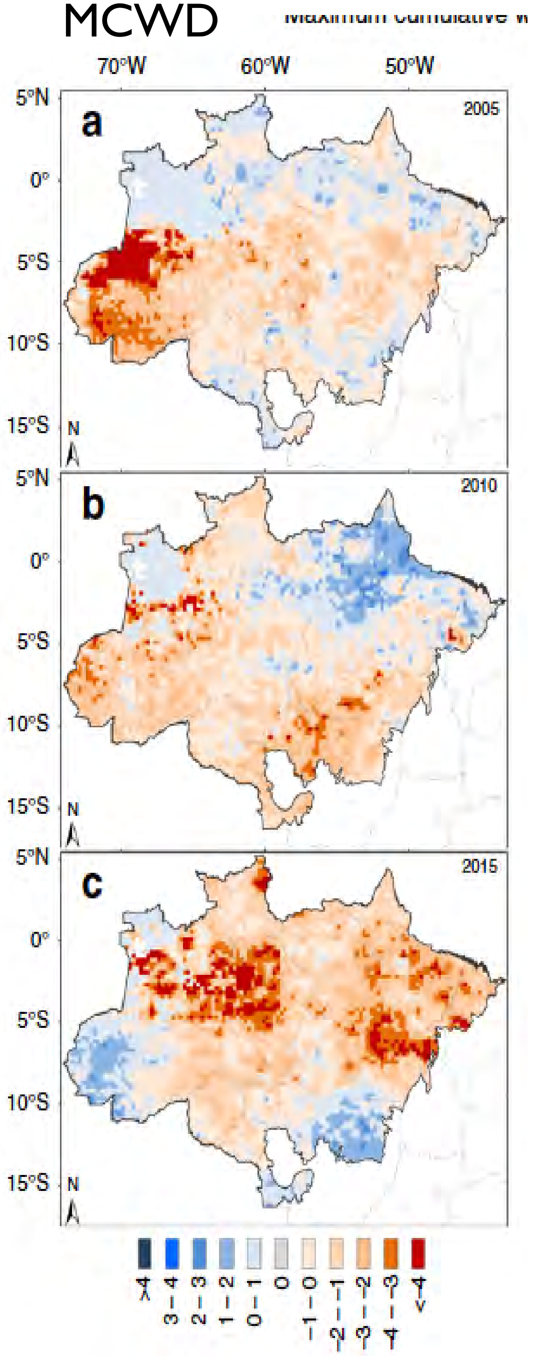
Geographical distribution of negative rainfall anomalies varies among drought years in Amazonia (Marengo et al 2018)



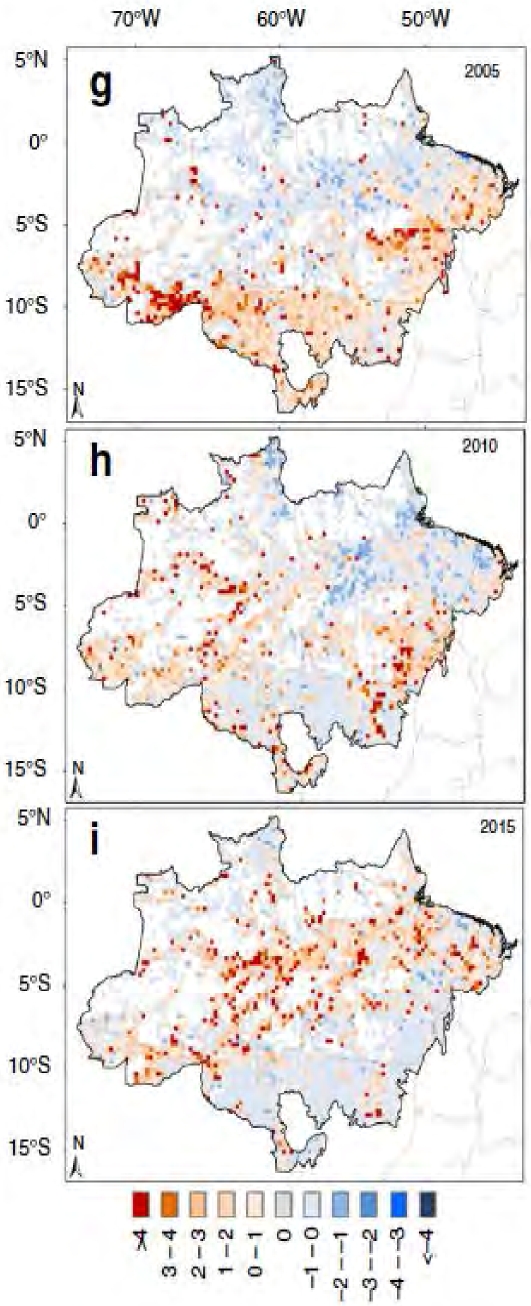
Rainfall anomalies DJF and MAM (peak rainy season) during some El Nino years

Drought years in Amazonia-Non El Nino

MCWD

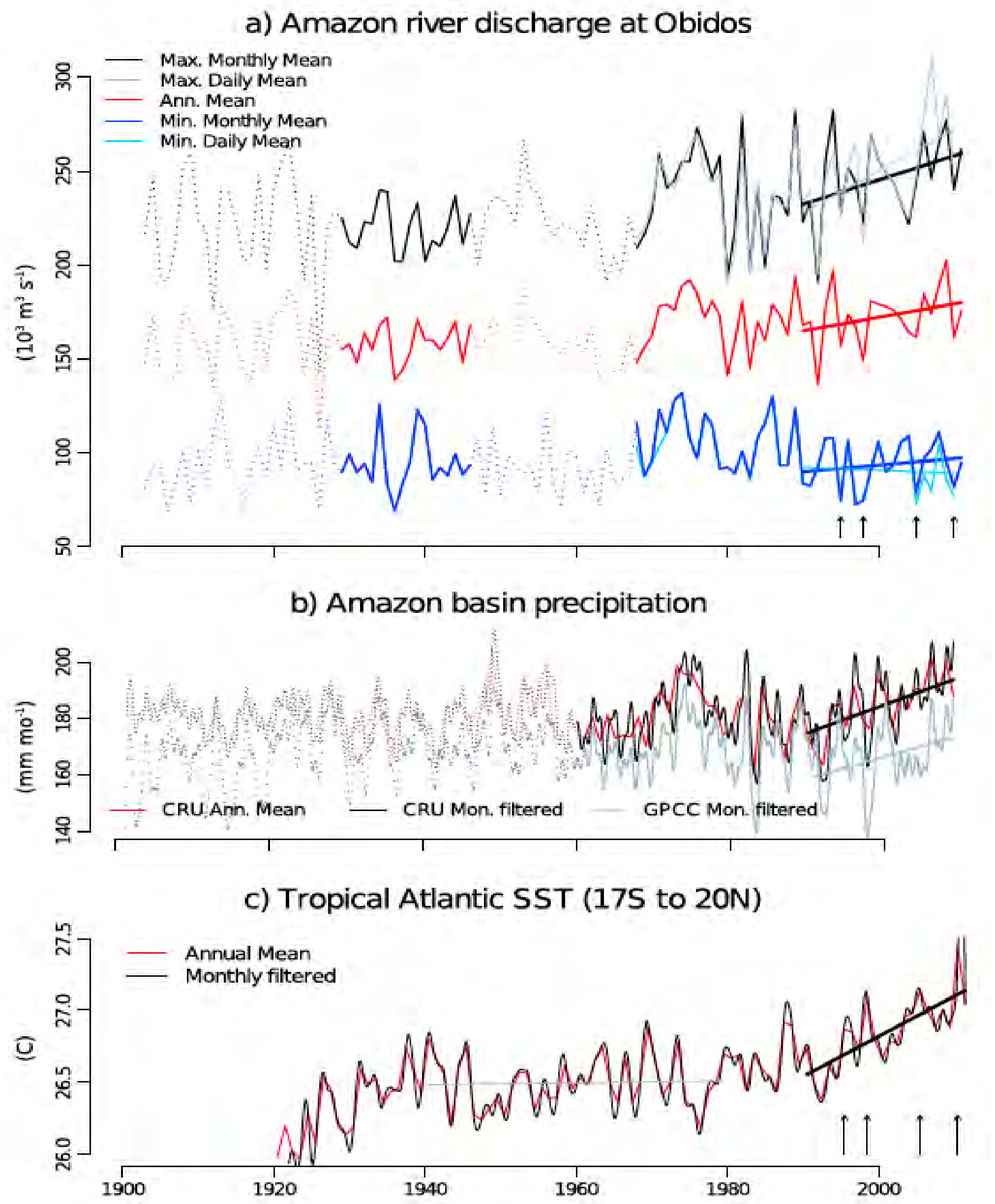


Fire anomalies



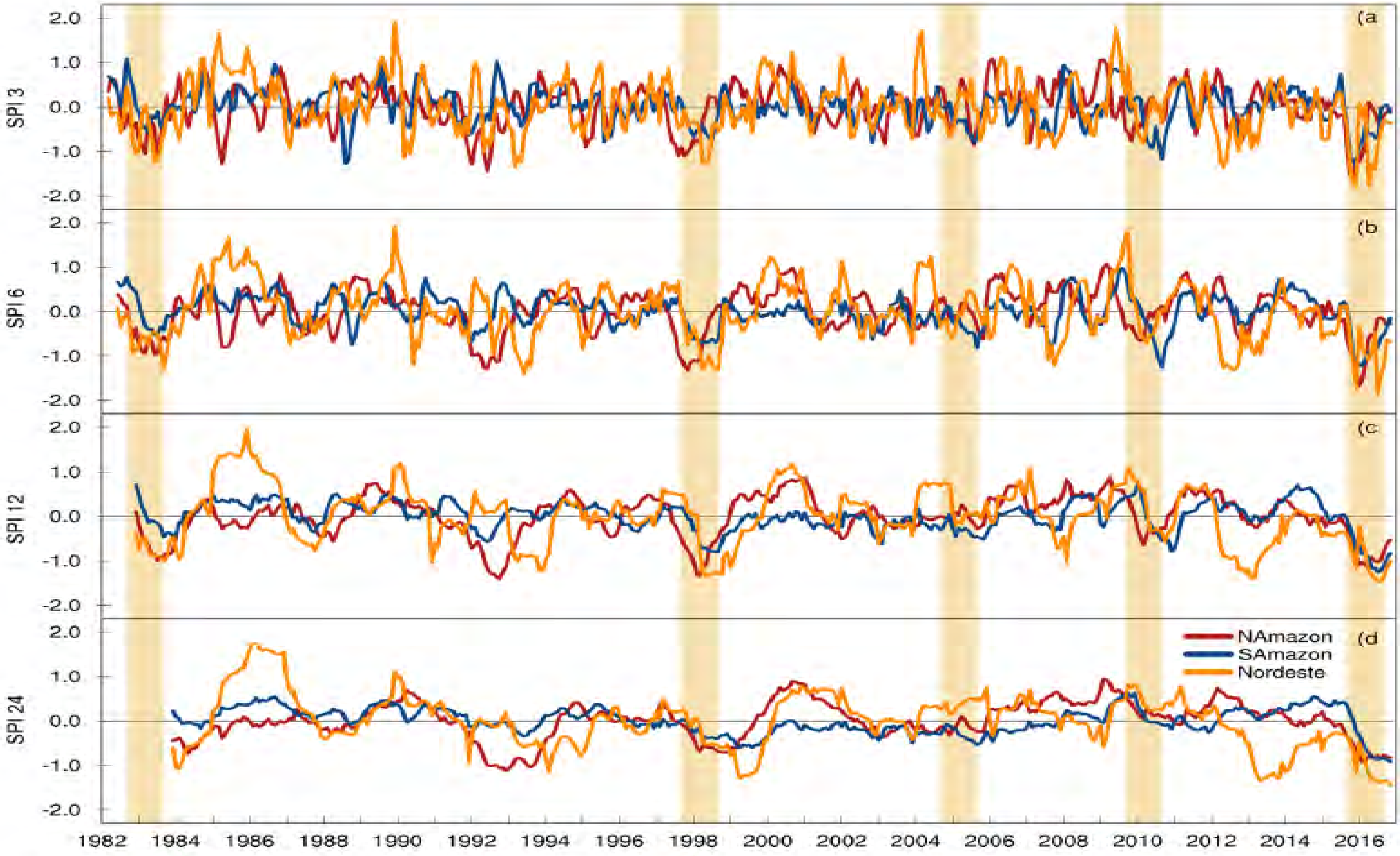
Observed Maximum Cumulative Water Deficit (MCWD) and fire anomalies for dry years 2005, 2010, and 2015; Values are standarized anomalies from 2003-2015. (Aragao et al 2018)

Intensification of the hydrological cycle in Amazonia since the middle 1990's ?, or decadal rainfall variability?



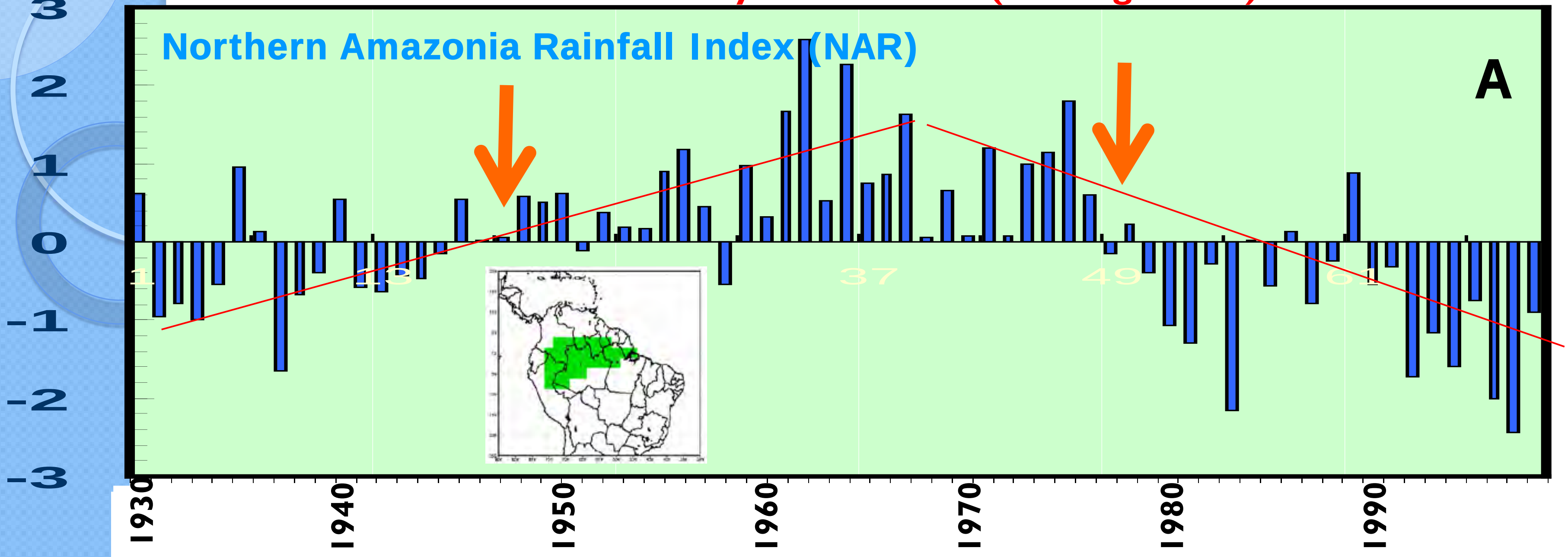
We propose that the Amazon precipitation changes since 1990 are instead related to increasing atmospheric water vapor import from the warming tropical Atlantic (Gloor et al 2013).

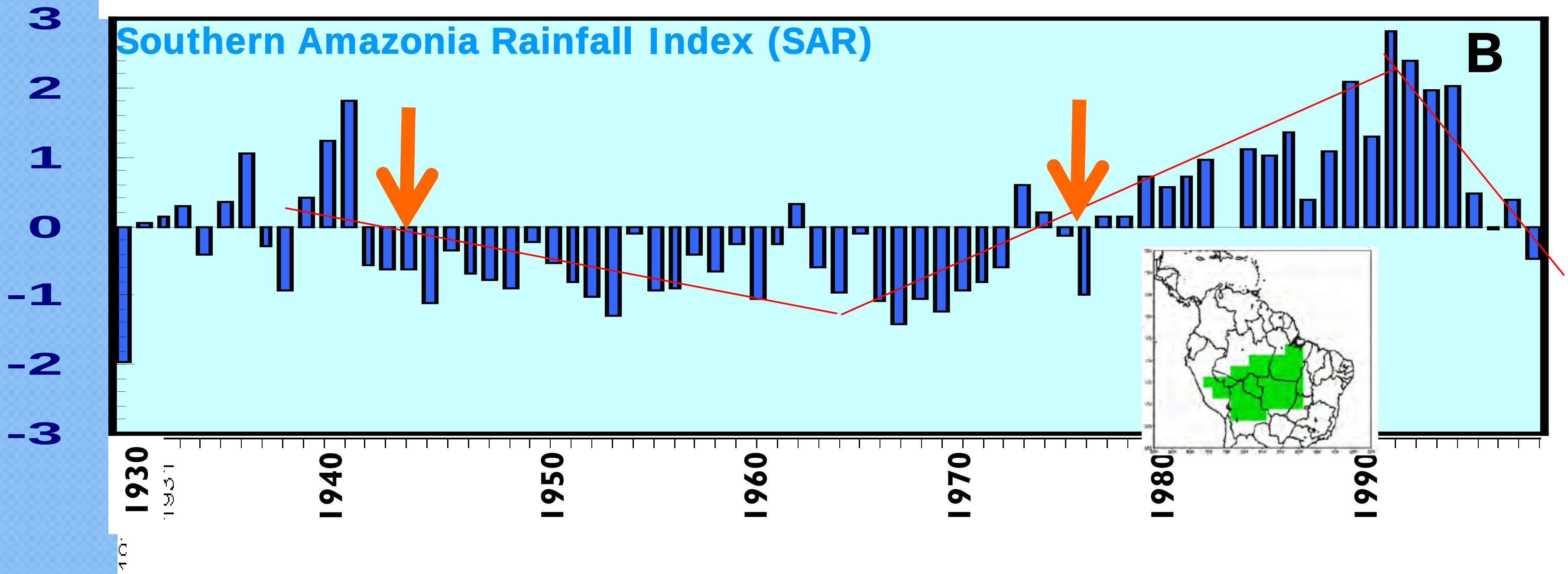
SPI time series for 3, 6, 12, and 24-month timescales averaged over the Nordeste region, North and South Amazonia (Erfanian et al 2017)



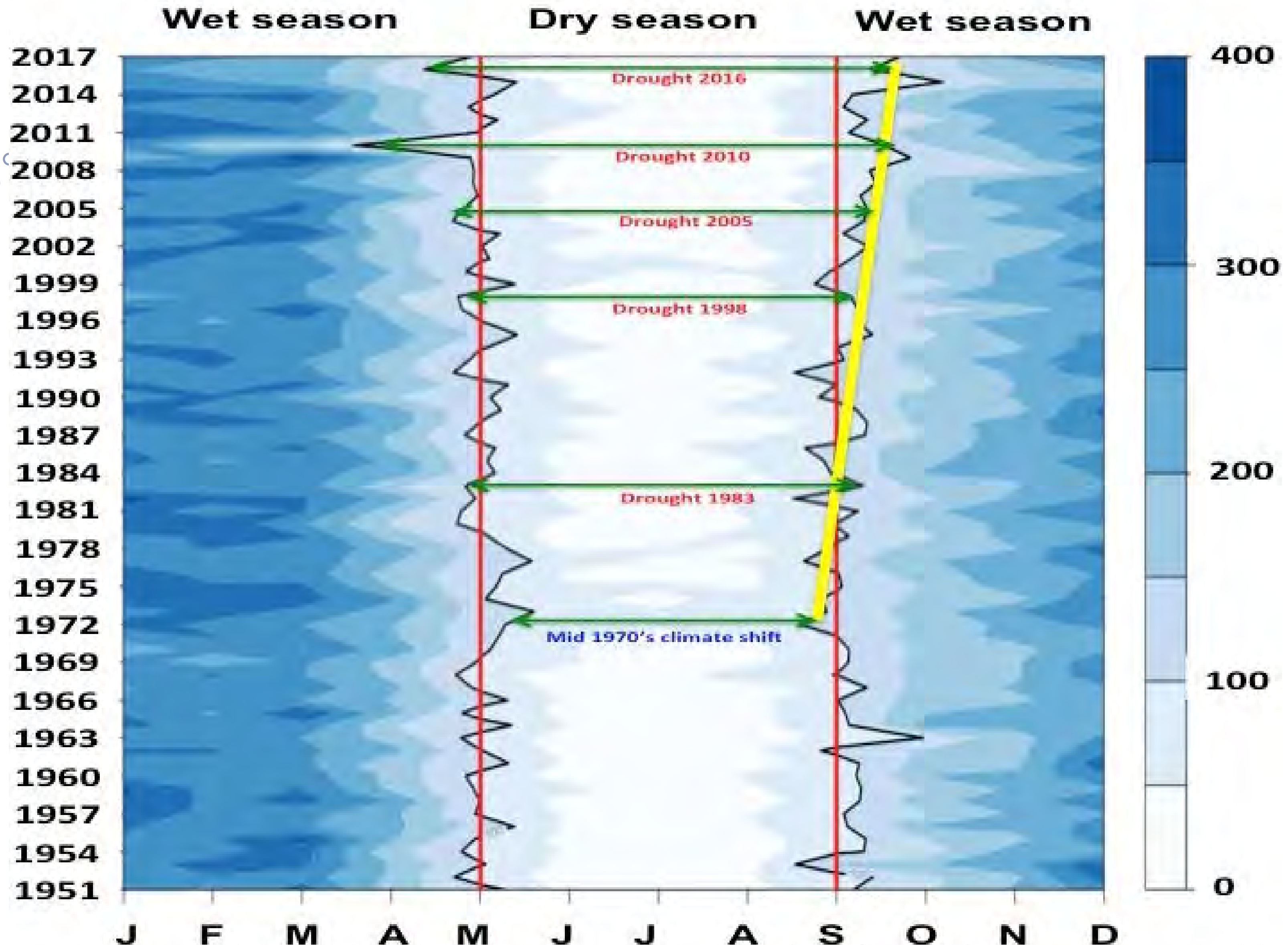
Time series of Standardized Precipitation Index (SPI). The entire Tropical/sub-Tropical South America is divided into South Amazon (SA), North Amazon (NA), and Nordeste (NORD) regions. The 3, 6, 12, and 24-month SPIs shown in (a,b,c and d) respectively were calculated using the GPCC monthly precipitation data from 1982 to 2017.

Rainfall decadal rainfall variability in Amazonia (Marengo 2004)



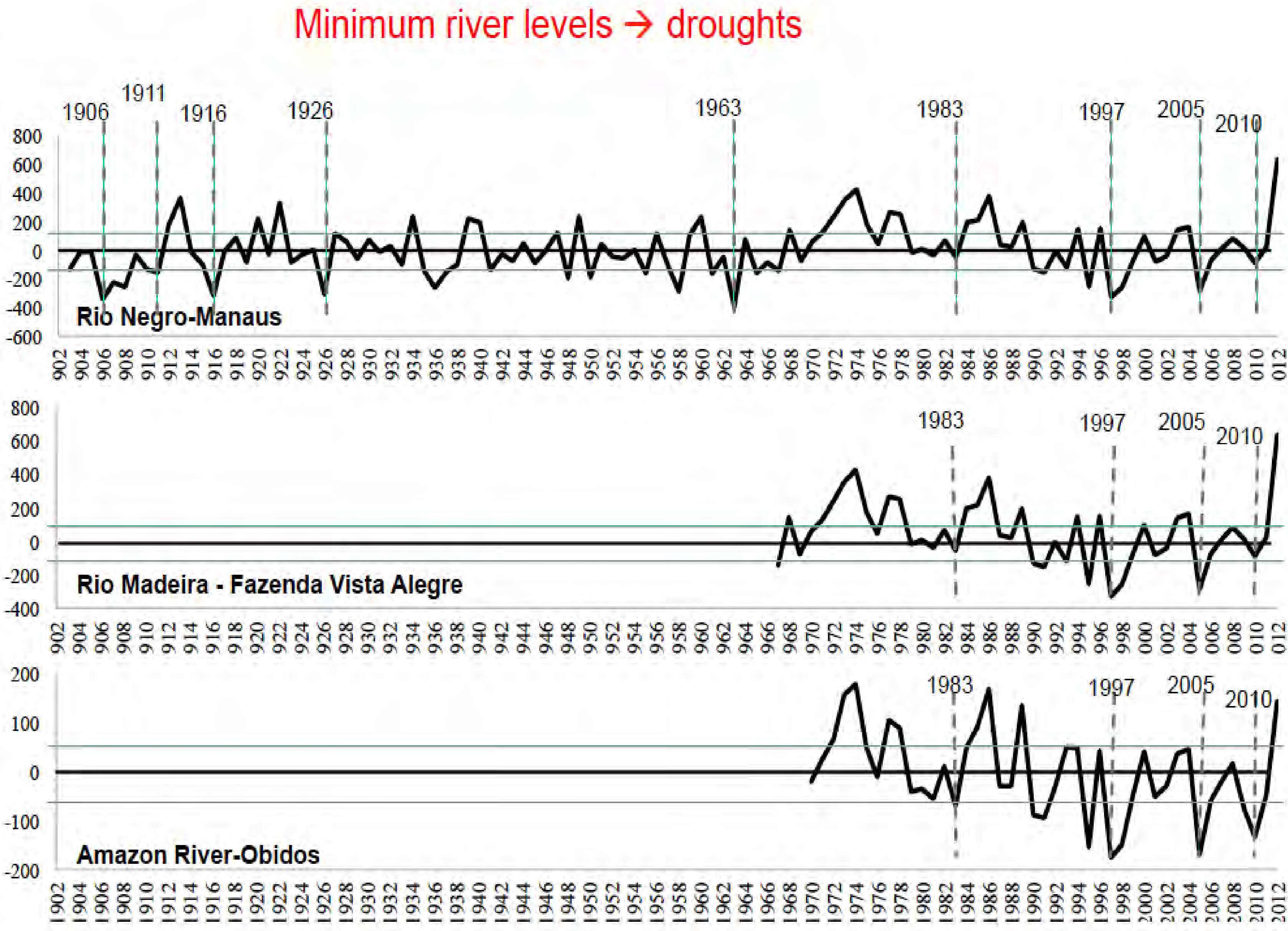


A longer dry season in S.Amazonia from 1951 to 2017 (Marengo et al 2018)



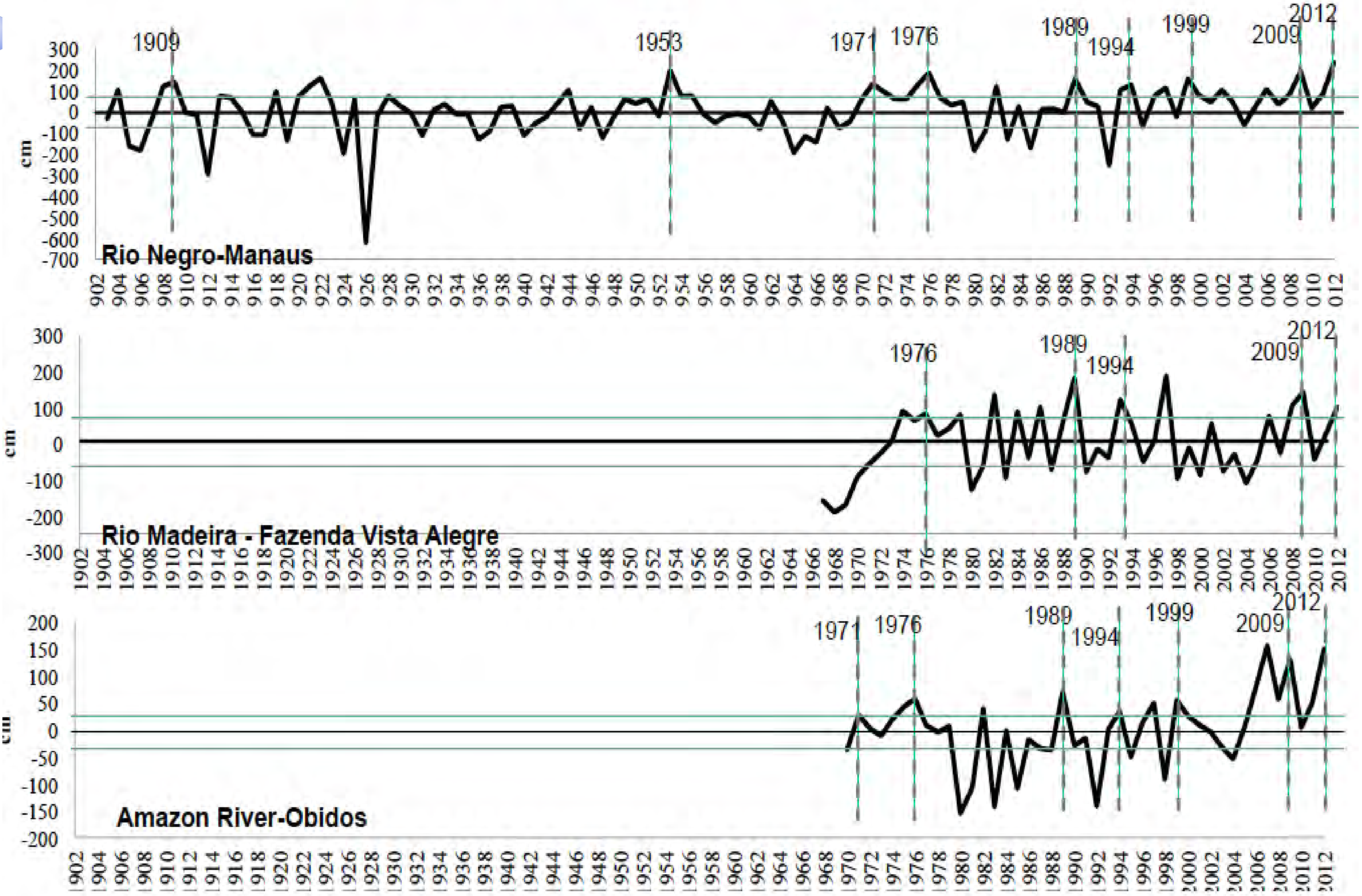
Rainfall from 1951 a 2017 for Southern Amazonia (mm/month). The isoline of 100 mm/month is an indicator of dry months in the region (Sombroek 2011). Drought years are indicated with green lines.

Annual minimum levels of some Amazon rivers during 1903-2012. Numbers indicate drought years (Marengo et al 2013)



Annual maximum levels of some Amazon rivers during 1903-2012. Numbers indicate flood years (Marengo et al 2013)

Maximum river levels → floods



Distribution of natural disasters in Brazil

- **Floods, Flash floods and landslides = 90% of occurrences in SE Brazil and 70% national**
- **Highest number of fatalities = landslides**
- **Higher mortality: SE Brazil (the most densely populated)**

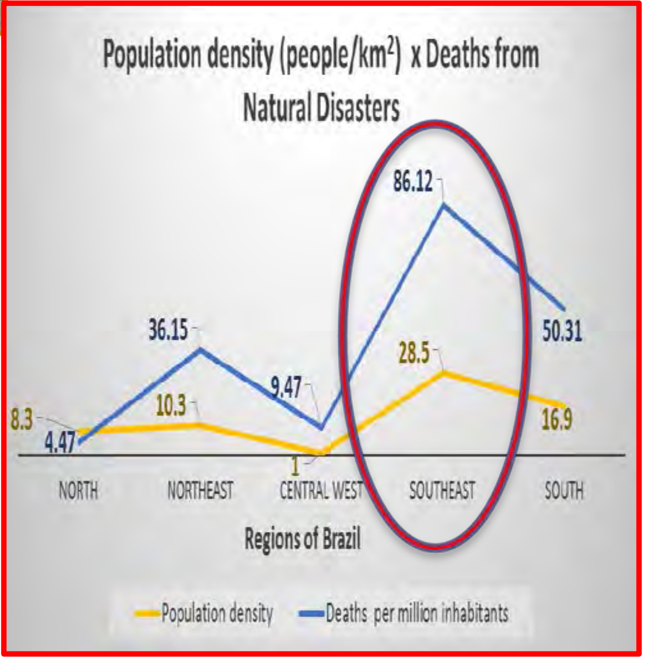
Forest fires, Floods, Droughts, Mass Movements

Droughts, Floods, Flash Floods

Wildfires, Floods, Erosions

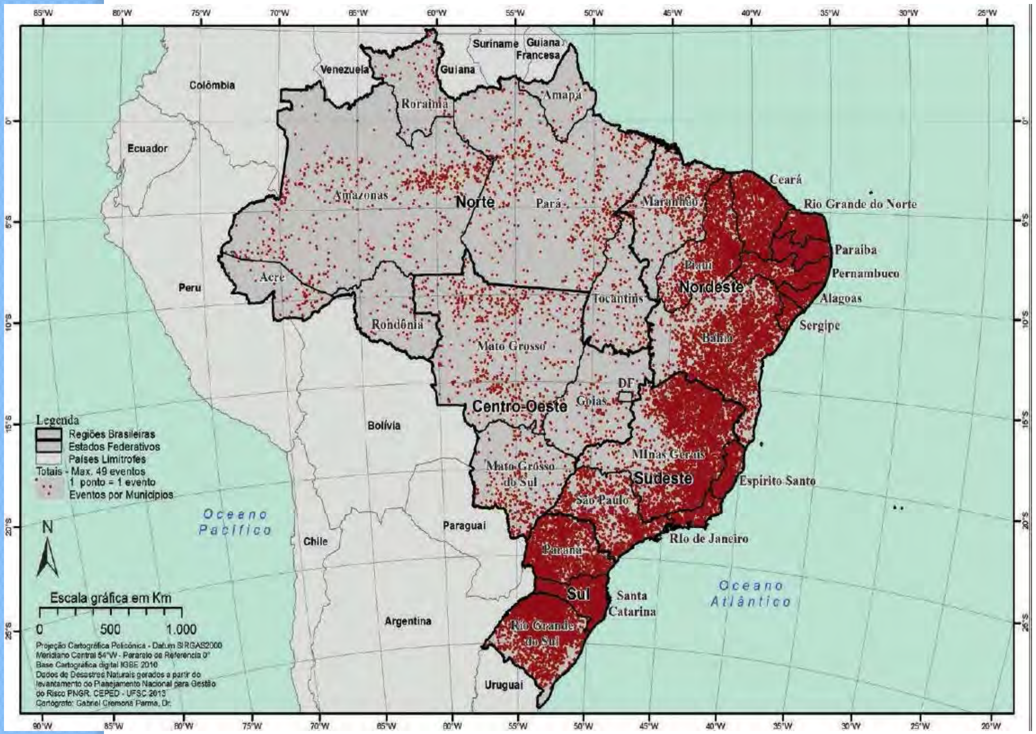
Wildfires, **Flash Floods**, Floods, Droughts, **Landslides**

Flash Floods, Wind Storms, Hail, Landslides


Population density (people/km²) x Deaths from Natural Disasters

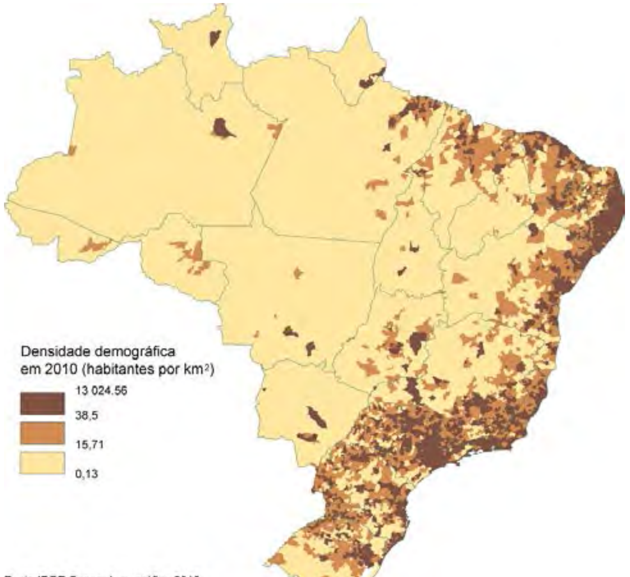
Distribution of natural disasters in Brazil

a) Distribution of natural disasters in Brazil (UFSC 2013)



Projeção Cartográfica Policônica - Datum SIRGAS2000
Meridiano Central 54°W - Paralelo de Referência 0°
Base Cartográfica digital IBGE 2010
Dados de Desastres Naturais gerados a partir do levantamento do Planejamento Nacional para Gestão do Risco PNGR, CEPED - UFSC 2013
Cartógrafo: Gabriel Cremona Parma, Dr.

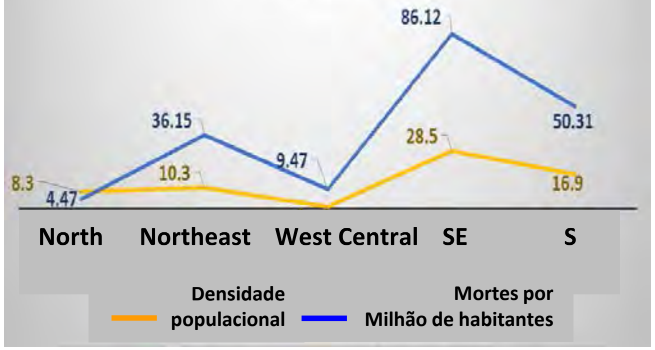
Population density (people per km^2-IBGE)



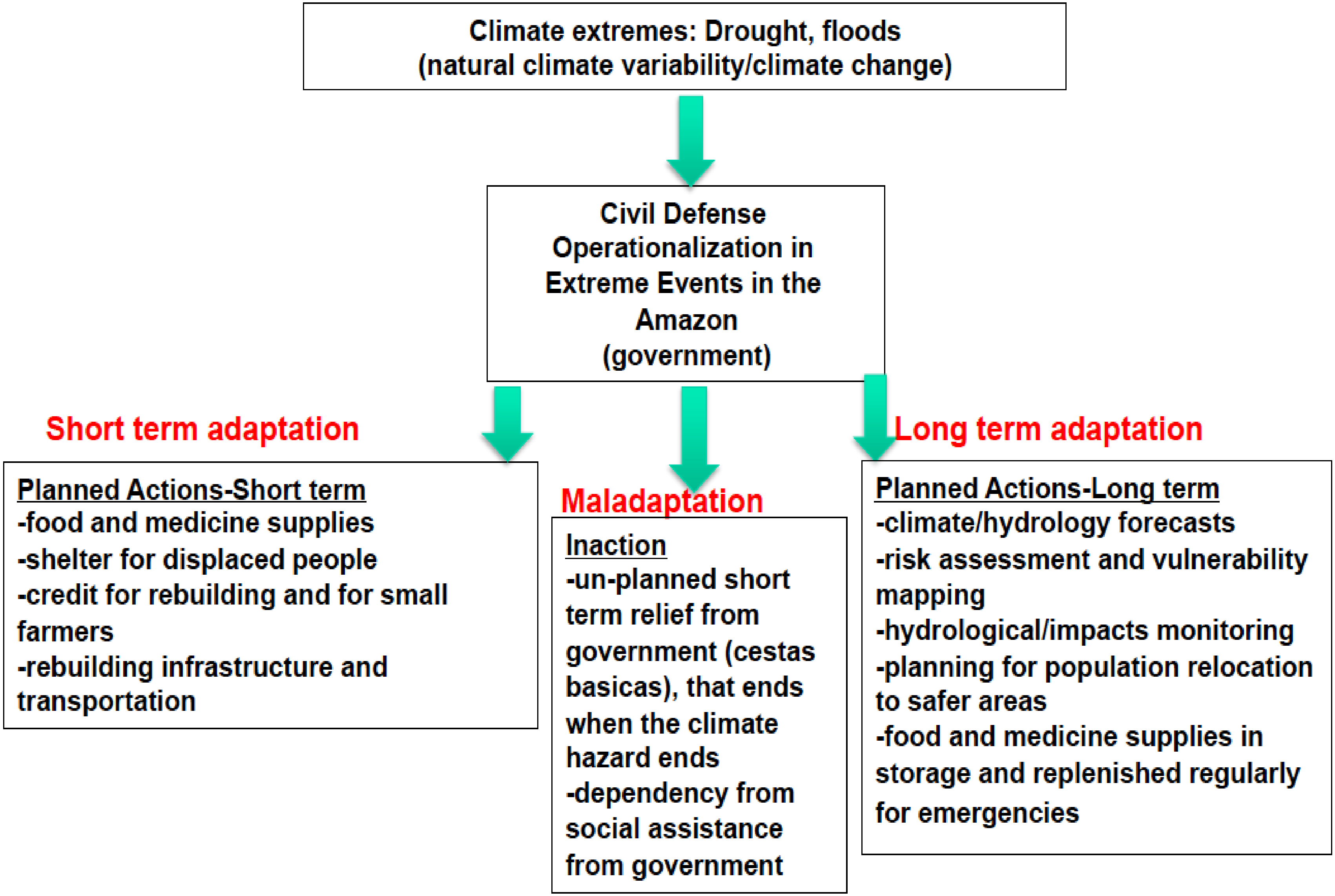
Fonte: IBGE Censo demográfico 2010
©Hervé Théry 2011
Feito com Philcarto * 28/07/2011* http://philcarto.free.

IBGE (2010)

c) Population density (people per km$^{2)}$ vs deaths (UFSC-CEPED 2013)



Conceptual model: factors affecting adaptive responses to climate variability and change in a multilevel perspective in Amazonia (Marengo et al 2013).



Climate extremes: Drought, floods
(natural climate variability/climate change)

Civil Defense
Operationalization in
Extreme Events in the
Amazon
(government)

Short term adaptation

Maladaptation

Long term adaptation

Planned Actions-Short term
- -food and medicine supplies
- -shelter for displaced people
- -credit for rebuilding and for small farmers
- -rebuilding infrastructure and transportation

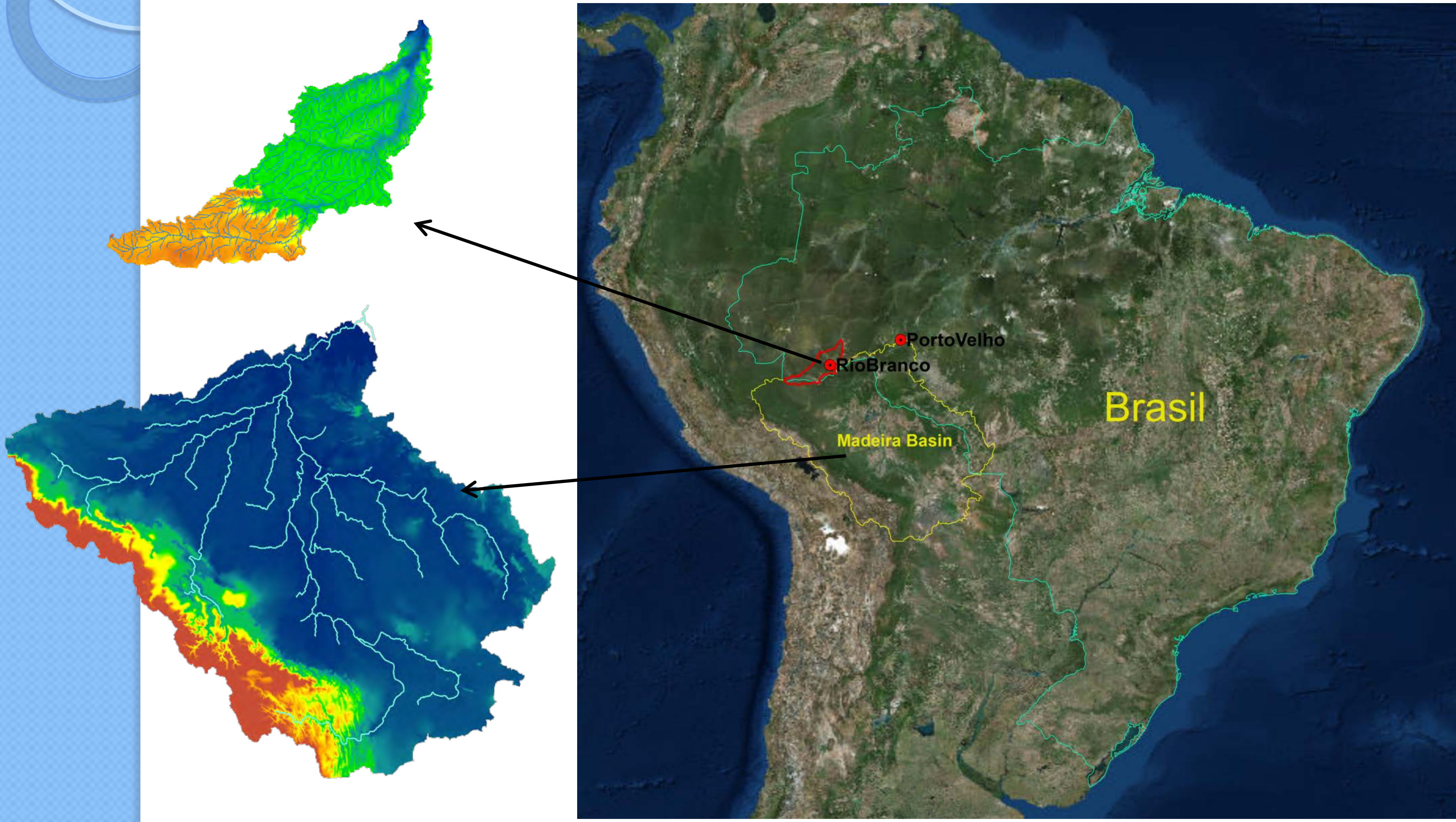
Inaction
- -un-planned short term relief from government (cestas basicas), that ends when the climate hazard ends
- -dependency from social assistance from government

Planned Actions-Long term
- -climate/hydrology forecasts
- -risk assessment and vulnerability mapping
- -hydrological/impacts monitoring
- -planning for population relocation to safer areas
- -food and medicine supplies in storage and replenished regularly for emergencies

R&D at CEMADEN

- Risks and disasters associated with hydrological events aiming to improve the understanding of hydrological processes at different temporal and spatial scales. Specific objectives are (a) to improve the ability to predict and anticipate floods and flash floods in urban areas and (b) to develop tools for quantify impacts resulting from extreme hydrological events

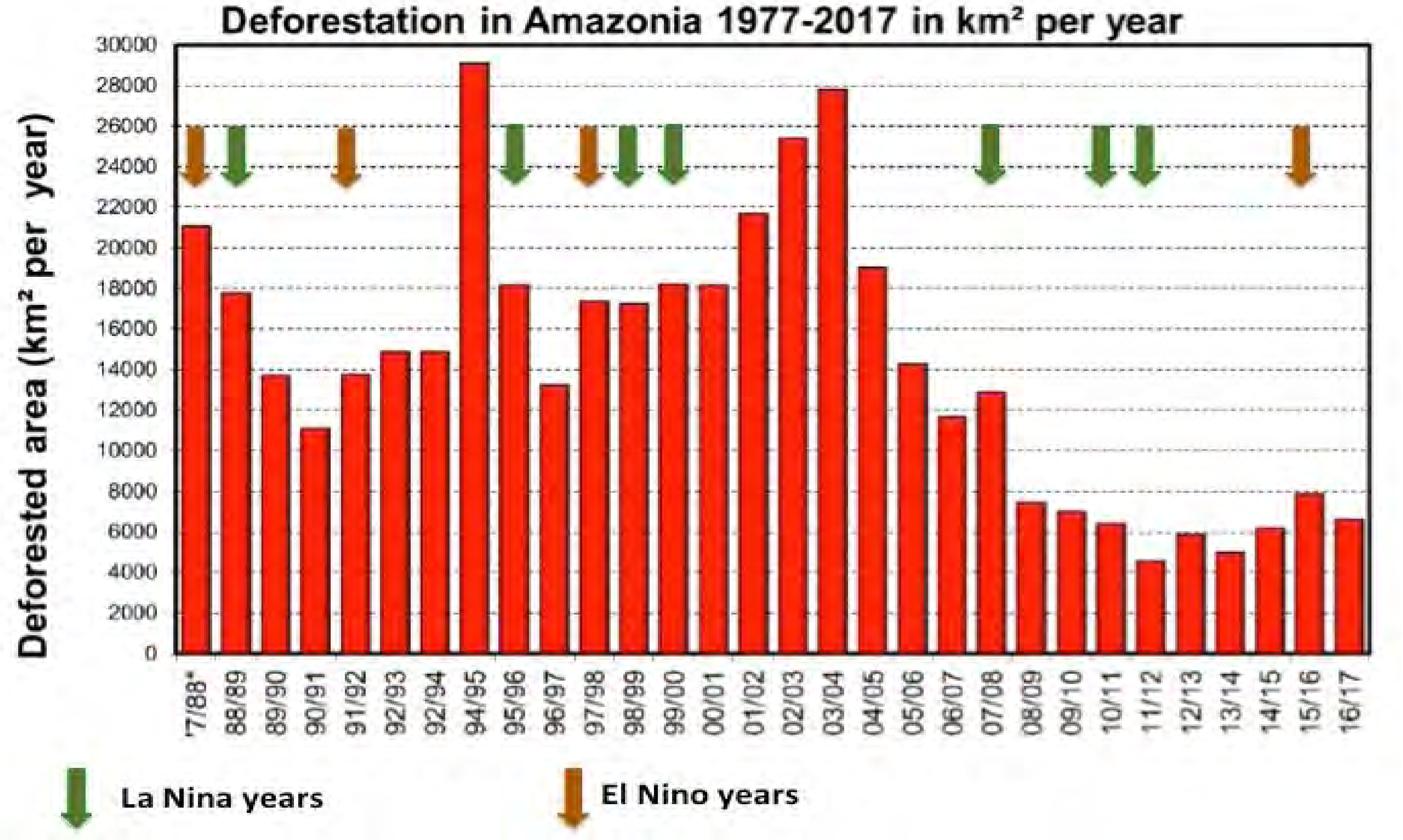
Modeling the hydrology of the Amazon rivers



Madeira River Floods - 2014

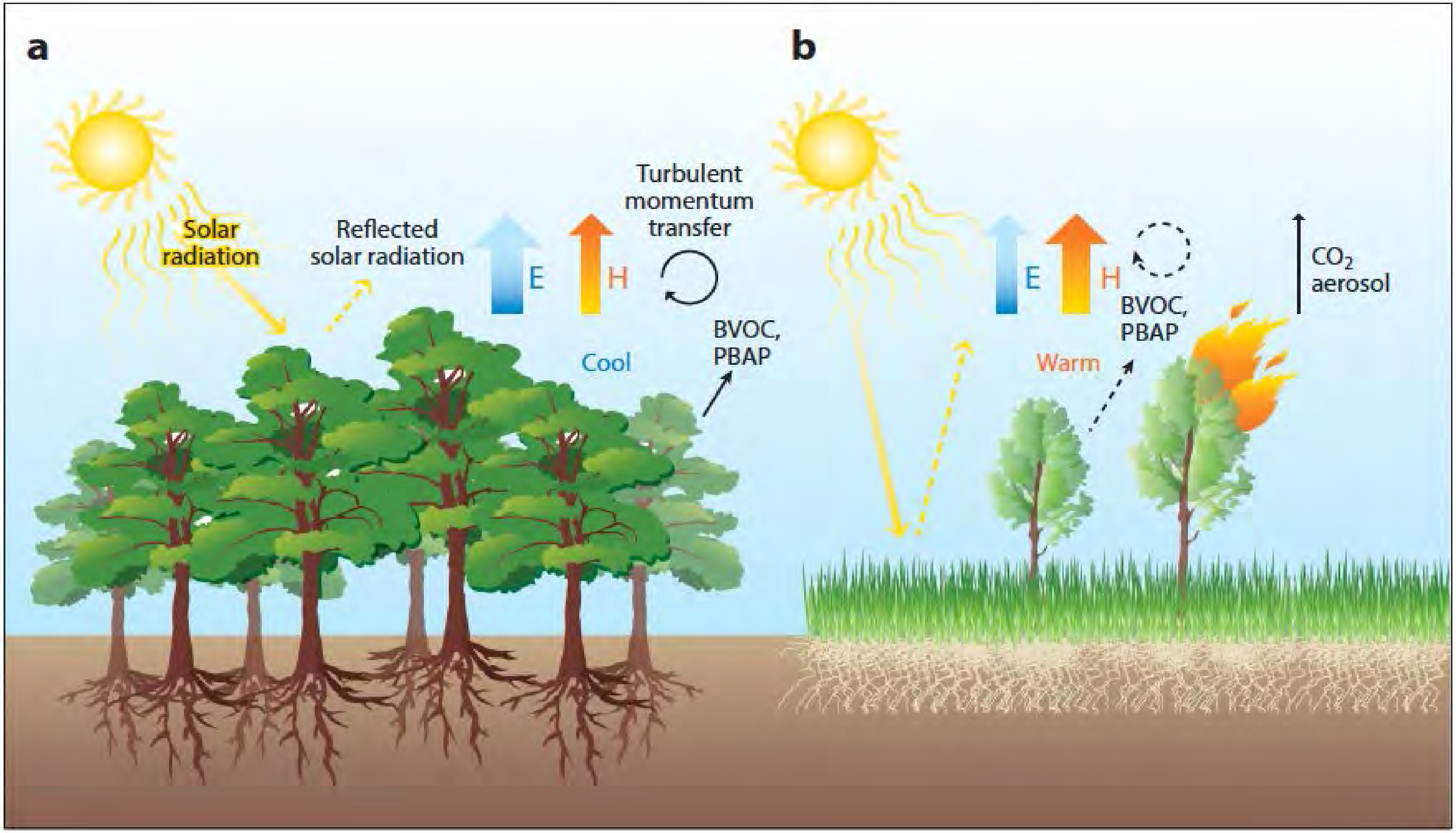
Acre River Floods - 2015

Deforestation trends in Brazilian Amazonia (INPE PRODES)



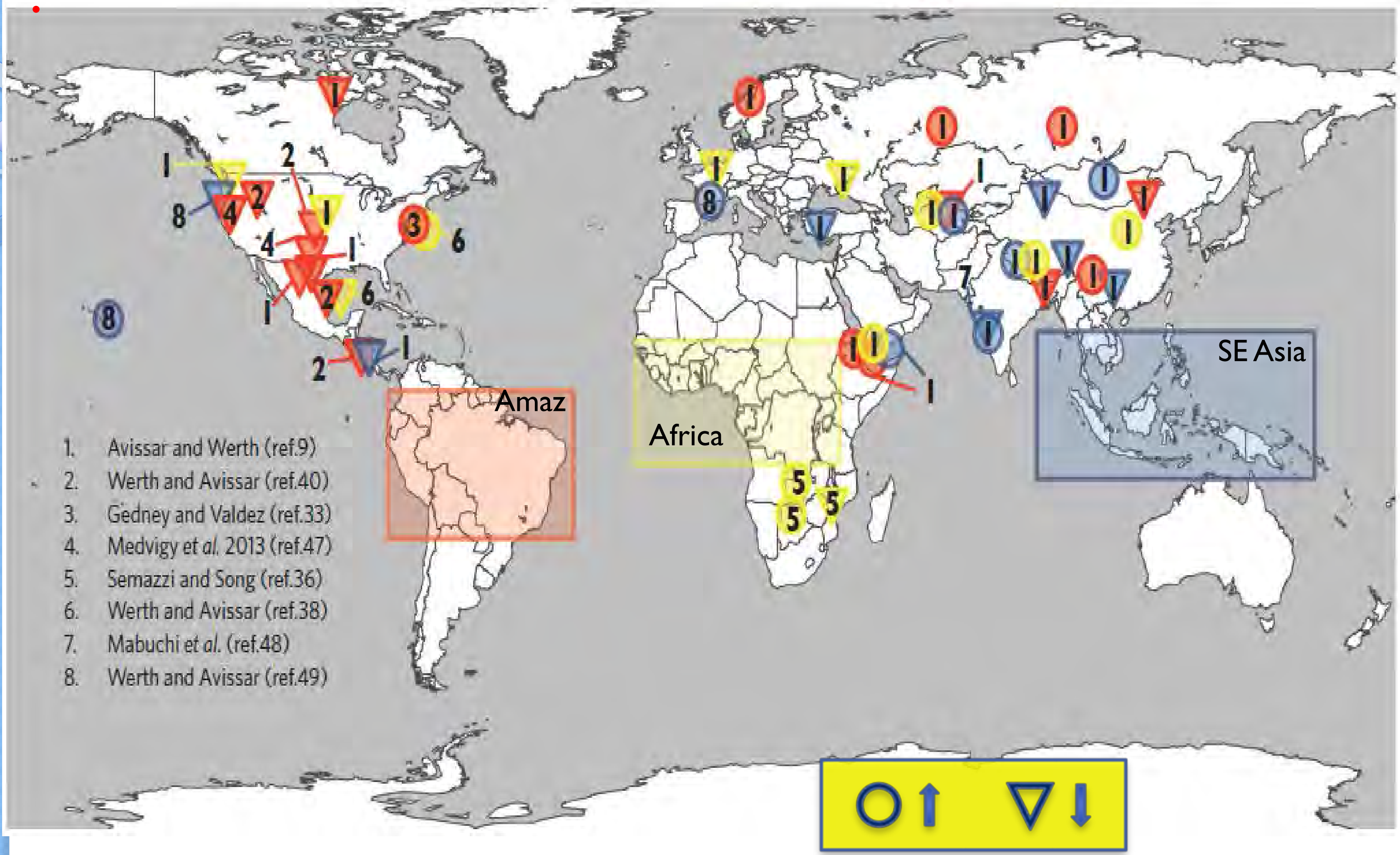
Deforestation rates in the Brazilian Amazon region from 1988 to 2017 (Source: PRODES-INPE). Years with strong and very strong El Niño and La Nina events are depicted by brown and green arrows, respectively

A tropical forest is compared to pasture (Spracklen et al 2018)



. Forests have lower albedo, greater roughness length, and greater rooting depth, resulting in higher evaporation (E) and latent heat fluxes and lower sensible heat fluxes (H). Fires associated withctropical deforestation and pasture maintenance result in greater emissions of biomass-burning aerosol

Extratropical effects on precipitation due to deforestation in each of the three major tropical regions (Lawrence and Karen Vandecar 2015)



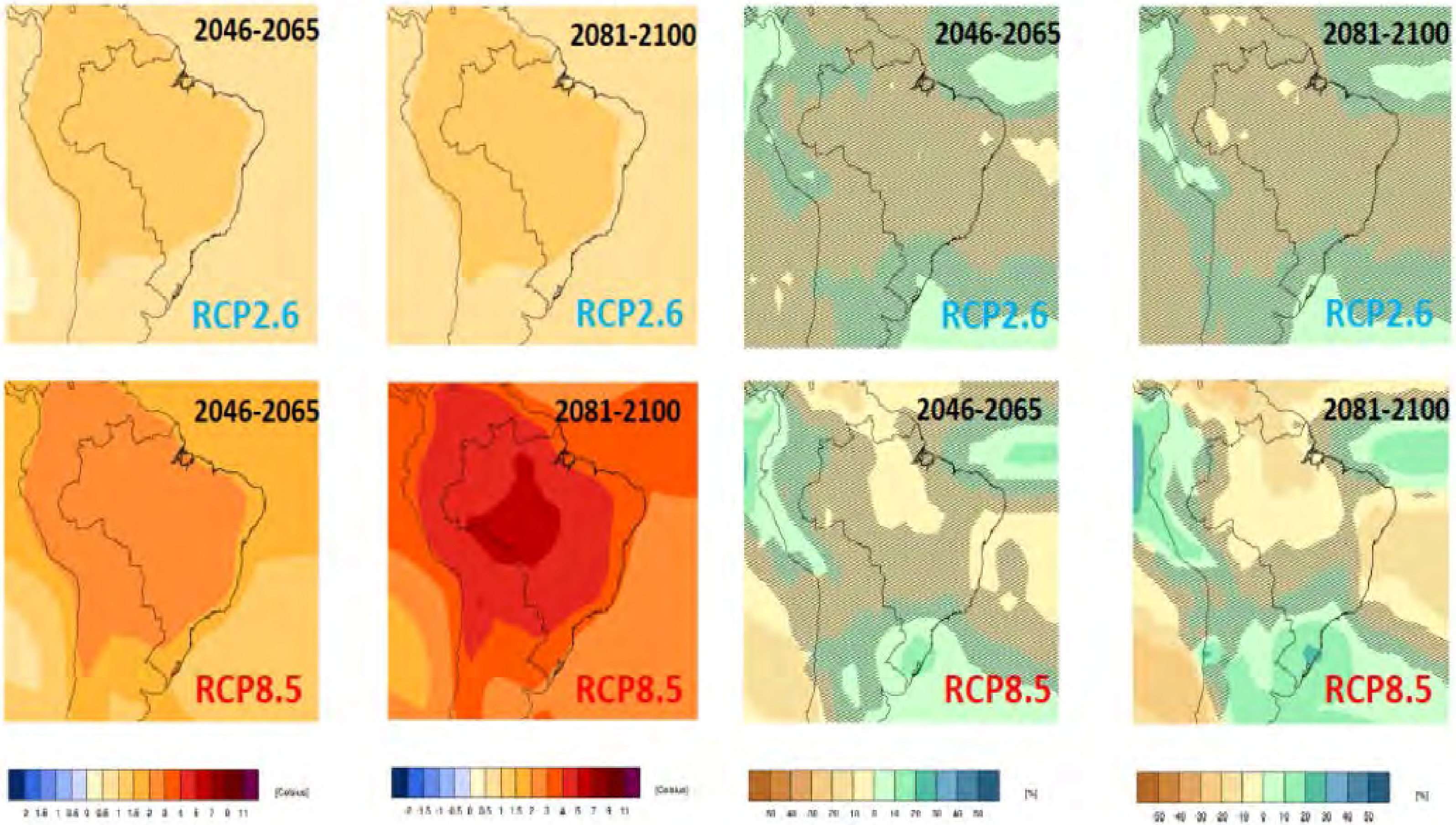
Increasing (circles) and decreasing (triangles) precipitation result from complete deforestation of either Amazonia (red), Africa (yellow), or Southeast Asia (blue). Boxes indicate the area in which tropical forest was removed in each region. Numbers refer to the study from which the data were derived.

Projected changes in annual average temperature and precipitation in Amazonia_(Magrin et al 2014).

Mean annual temperature (°C)

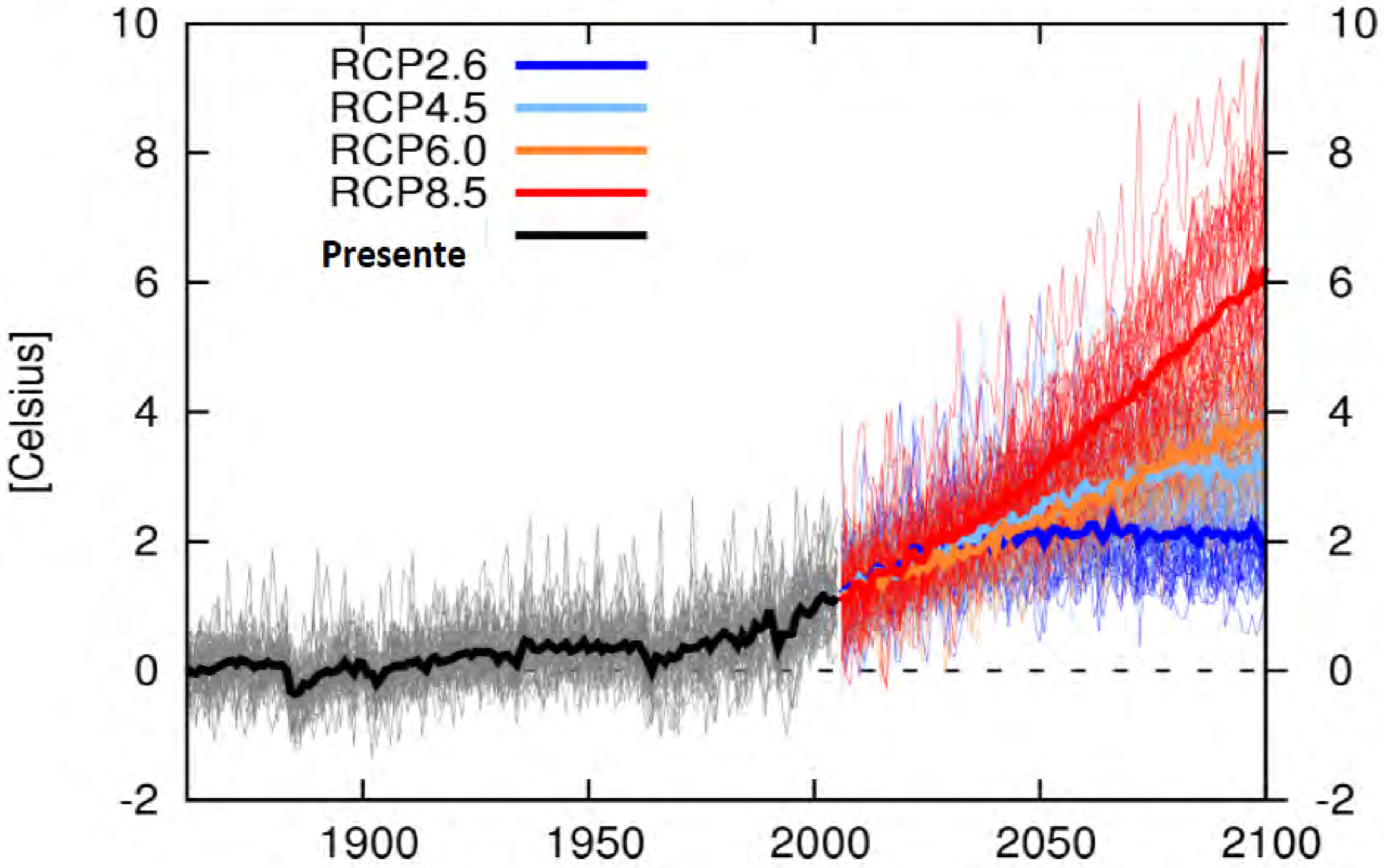
Mean annual rainfall (%)

Middle XXI century | Later XXI century | Middle XXI century | Later XXI century

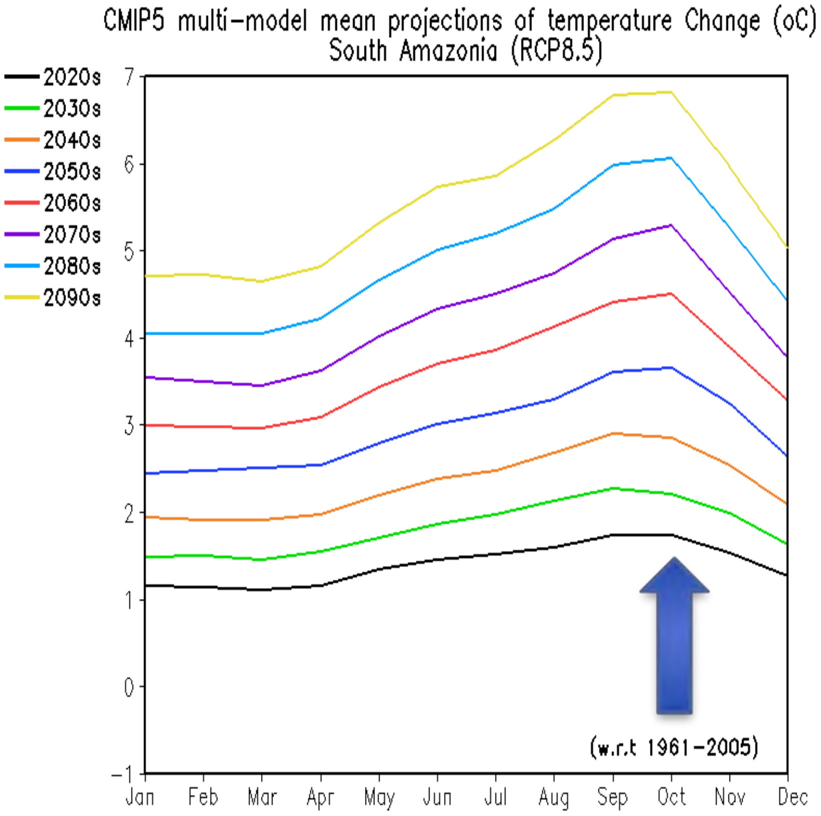


CMIP5 multi-model mean projections of annual average temperature changes (left panel) and average percent change in annual mean precipitation (right panel) for 2046-2065 and 2081-2100 under RCP2.6 and 8.5 (IPCC WG2 AR5-Magrin et al 20-14)

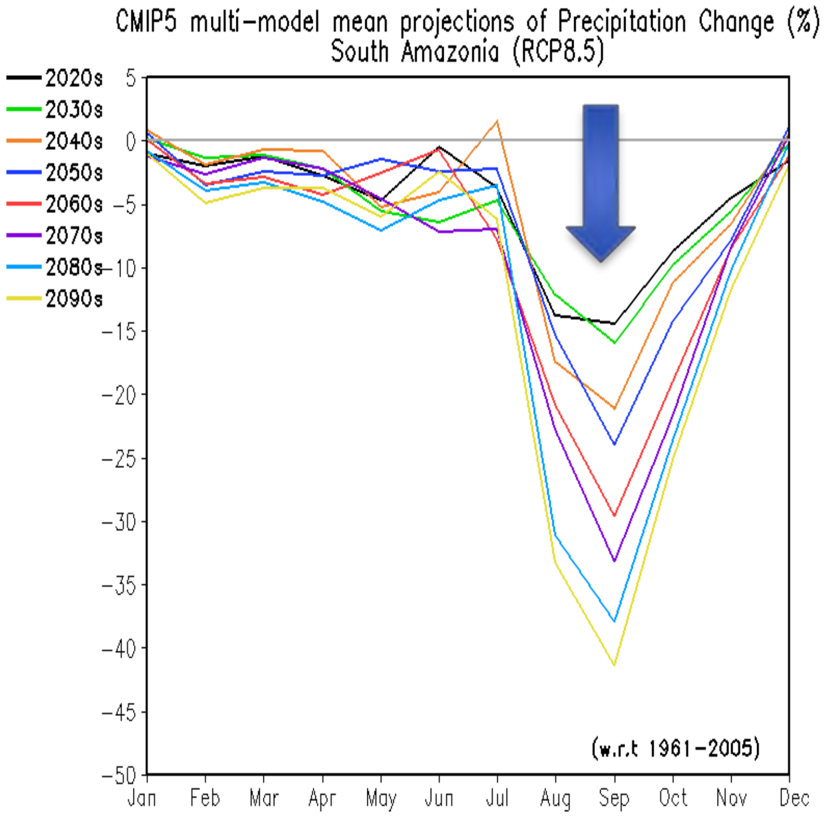
Projected changes in air temperature for Amazonia until 2100 from the mean of CMIP5 models, relative to 1961-90



Changes in temperature and rainfall in Amazonia from the mean of CMIP5 models (Sampaio et al 2018)



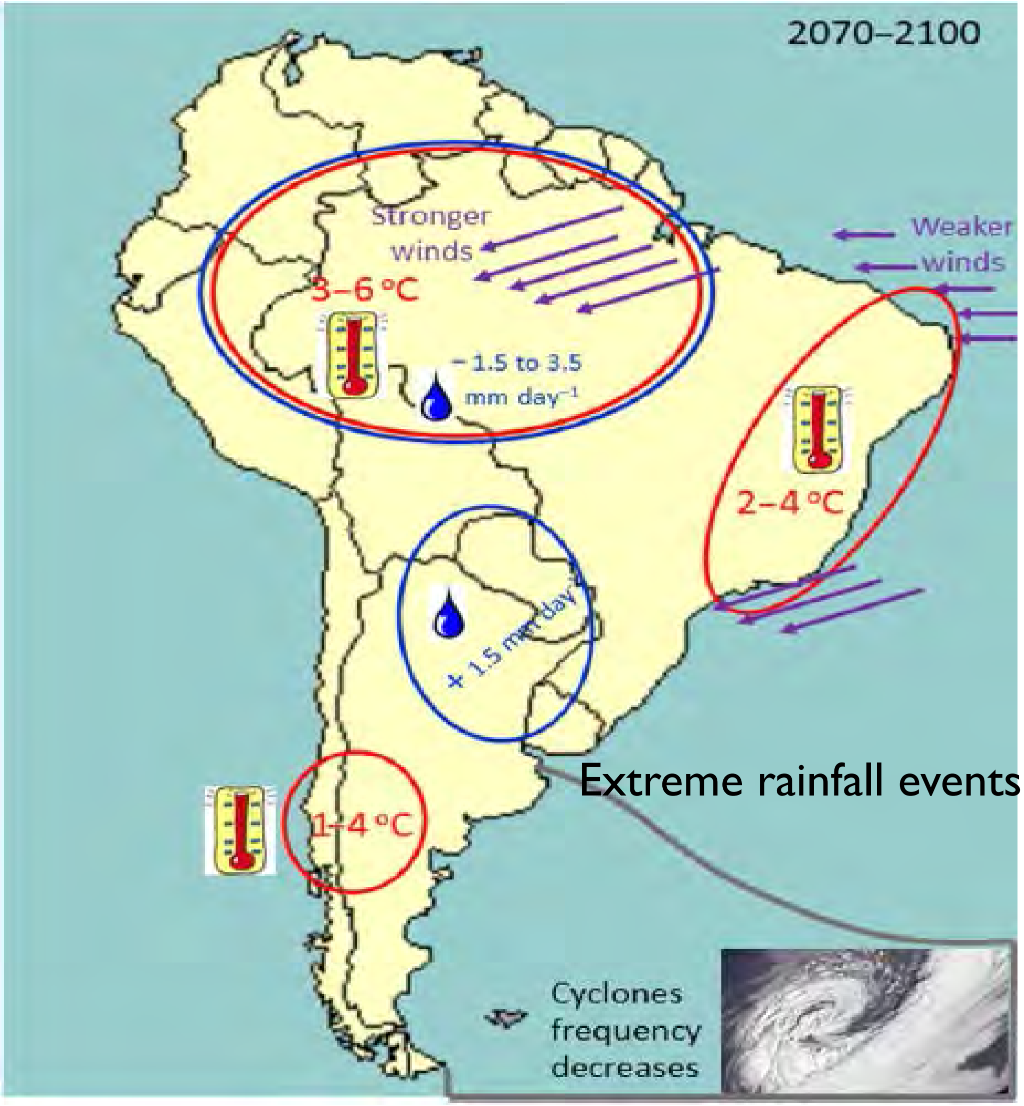
CMIP5 multi-model mean projections of temperature Change (oC)
South Amazonia (RCP8.5)



CMIP5 multi-model mean projections of Precipitation Change (%)
South Amazonia (RCP8.5)

CMIP5 multi-model ensemble projected change in air temperature (oC) and in annual cycle of precipitation (%) in southern Amazonia (70˚W - 50˚W, 12.5˚S - 5˚S) under the RCP8.5 scenario for decadal time slices for the period 2020-2100 relative to the 1961-2005 baseline (Sampaio et al 2018)

Projected changes in c;limate in South America (Magrin et al 2014).



Extreme rainfall events

Summary of the climate change projections for SA at the end of the 21st century (2070–2100). The values in the figure are based on the studies of Table 2 considering different RCMs and IPCC scenarios.(IPCC WG2 AR5-Magrin et al 2014)

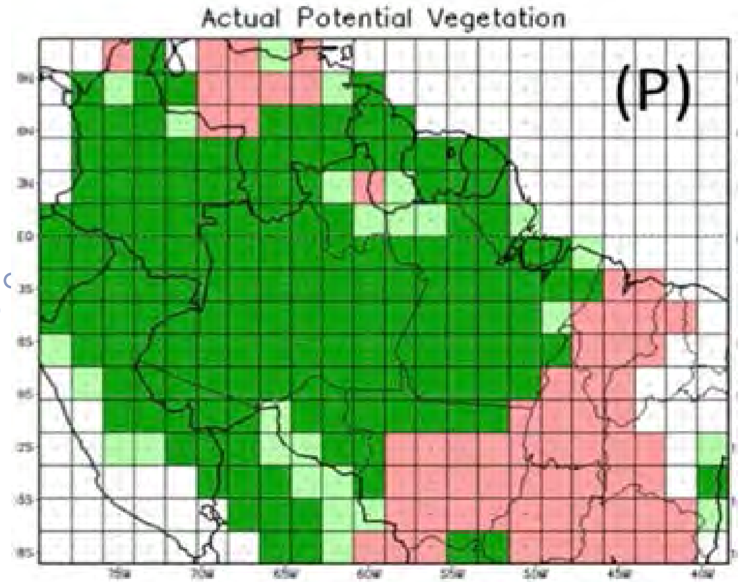
Amazon Tipping Point (Lovejoy and Nobre 2018):

Where might the tipping point be for deforestation-generated degradation of the hydrological cycle?

The very first model to examine this question (Sampaio et al 2007-CPTEC AGCM) showed that at about 40% deforestation, central, southern and eastern Amazonia would experience diminished rainfall and a lengthier dry season, predicting a shift to savanna vegetation to the east.

We believe that negative synergies between deforestation, climate change, and widespread use of fire indicate a tipping point for the Amazon system to flip to non-forest ecosystems in eastern, southern and central Amazonia at 20-25% deforestation.

The severity of the droughts of 2005, 2010 and 2015-16 could well represent the first flickers of this ecological tipping point. These events, together with the severe floods of 2009, 2012 (and 2014 over SW Amazonia), suggest that the whole system is oscillating.

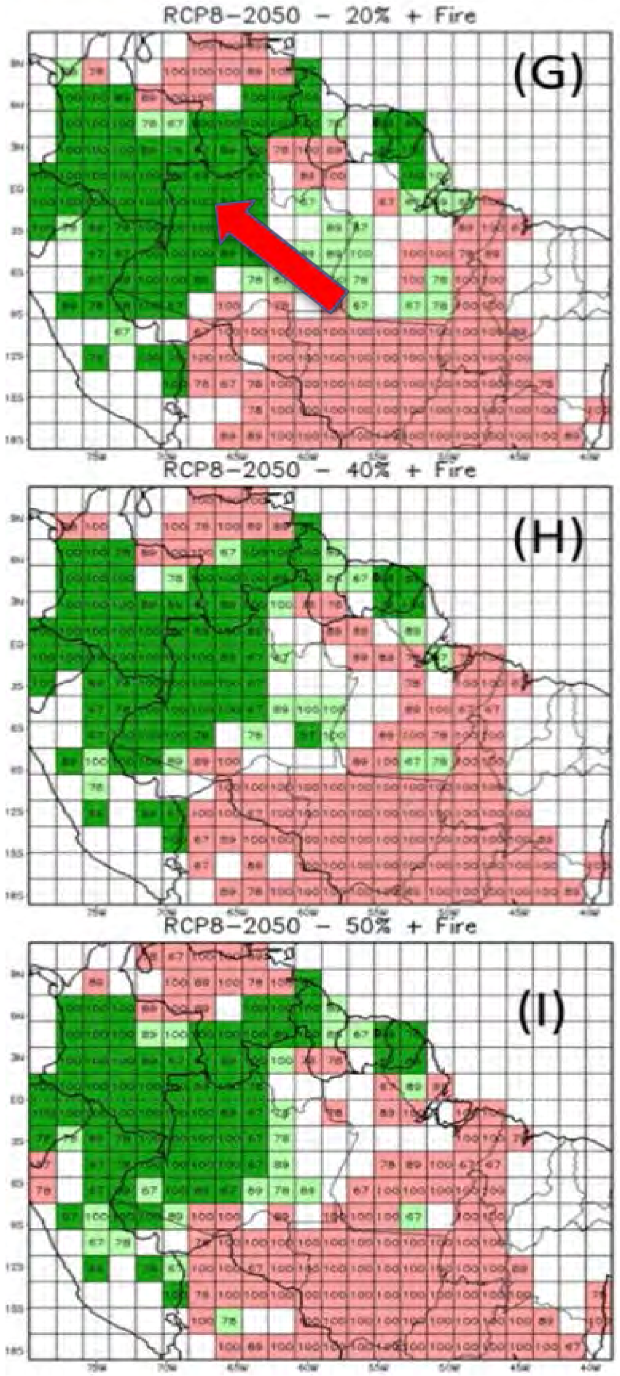


Projected distribution of natural biomes in South America

🟩 Tropical Seasonal Forest

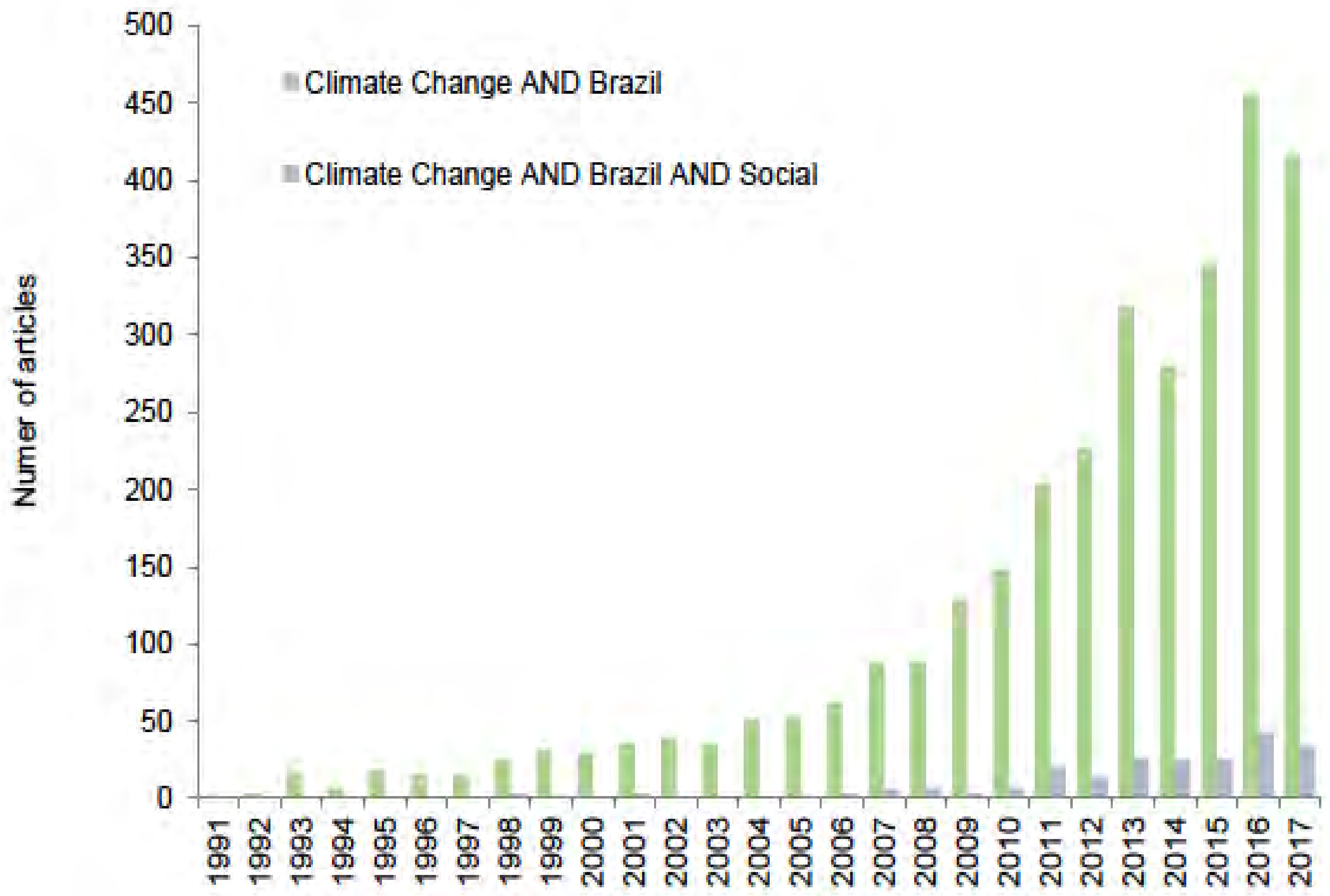
🟥 Savanna

🟩 Tropical Evergreen Forest



Projected distribution of natural biomes in South America where more than 66.7 % of 9 CMIP5 models used coincide in changes for 2050 for the RCP8.5 emission scenario. PVM2 CPTEC vegetation model; Deforestation: Reduction of forest area of 20%, 40% and 50% plus fire effect (Nobre et al 2016)

Evolution of climate change science knowledge in Brazil based on published literature considering climate change and social impacts (Pinho et al 2018)



Final thoughts

The Amazonian tropical forests have been disappearing at a fast rate in the last 50 years due to deforestation to open areas for agriculture and cattle ranching, posing high risks of irreversible changes to biodiversity and ecosystems.

Rainforest transpiration during the late dry season plays a central role in initiating the dry-to-wet season transition over the southern Amazon. Dry seasons getting longer

Climate change poses additional risks to the stability of the forests. Studies suggest "tipping points" not to be transgressed: 4° C of global warming or 40% of total deforested area. (die back of the Amazon forest-uncertainties?)

The regional development debate has focused on attempting to reconcile maximizing conservation with intensification of traditional agriculture.

Large reductions of deforestation in the last decade open up opportunities for an alternative model based on seeing the Amazon as a global public good of biological assets for the creation of high-value products and ecosystem services.