EFFECTS OF ENSO-INDUCED EXTREMES ON TERRESTRIAL ECOSYSTEMS

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Objectives

- Identify ENSO-induced extremes over the Tropics
- Study impacts of climate extremes on terrestrial ecosystem and biogeochemical extremes

Model and methodology

DOE Energy Exascale Earth System Model (E3SM) model v0.3

- 1-degree (ne30np4) F-compset configuration:
  - active atmosphere model (CAM5-SE)
  - active land (ELM) with the biogeochemical model on
  - data ocean (DOCN)
  - thermodynamic sea ice (CICE)
- Data ocean reads NOAA Optimum Interpolation (OI) version 2 daily sea surface temperature (SST) (1981 to present)
- Ice fractions are also provided in the OISSTv2 data set
- Future SST projections come from 9-month seasonal forecasts of the NOAA Climate Forecast System (CFSv2)
- Beyond 9 months from present, SSTs and ice fractions are estimated from historical OISSTv2 data to complete simulations to 2020

The model spin-ups to reach the model equilibrium state

- use the land initial condition for the 20th century simulations in a 0.9x1.25 finite volume grid in the E3SM model data input directory
- remap the above initial condition to the spectral element grid (ne30np4) that we used
- recycle the 1982–1994 OISST data to drive the model till it reaches the quasi-equilibrium state
- continue the above simulation to 2020 from the quasi-equilibrium state
- getting the ensembles by running the model from different quasi-equilibrium states

Our analysis here utilized one of the ensemble results simulated from the equilibrium state at 182 model years.

Conclusions and Discussions

Drought and heat wave affect terrestrial ecosystem severely during the El Niño events.

- the losses of GPP, autotrophic and heterotrophic respirations caused by short and long-term droughts are similar
- approximately 18-43% of total GPP/respiration losses are caused by rare climate extremes
- climate extremes lead to about 20-79% of BGC extremes in Tropics

Our future plan is as follows:

- verification by the observational/remote-sensing data
- improvements on computing potential evapotranspiration
- impacts of bi-variate extremes on terrestrial ecosystem

Identification of extremes

El Niño-Southern Oscillation (ENSO) includes its warm (El Niño) and cold (La Niño) phases, can significantly alter precipitation and air temperature patterns locally and globally by teleconnections. It normally causes drought (flood) and excessively hot (cold) weather over Tropics during El Niño (La Niño), respectively. Drought is one of climate anomalies and its intensity and duration depend not only on the current weather conditions, but also on the cumulative effects of previous months. The short-term of water deficit due to lack of precipitation may not cause the plant hydraulic imbalance large enough for plants to response. In this study, we use 3-month SPI and SPEI to find short-term drought (index less than -1.5) and scPDSI (index less than -3) to find long-term droughts caused by ENSO using model results. We use 95% and 5% percentiles for monthly mean of daily maximum and minimum temperature to identify heat and cold waves respectively. All biogeochemical variables are considered as extremes if they are less than their 5% percentiles.

Results

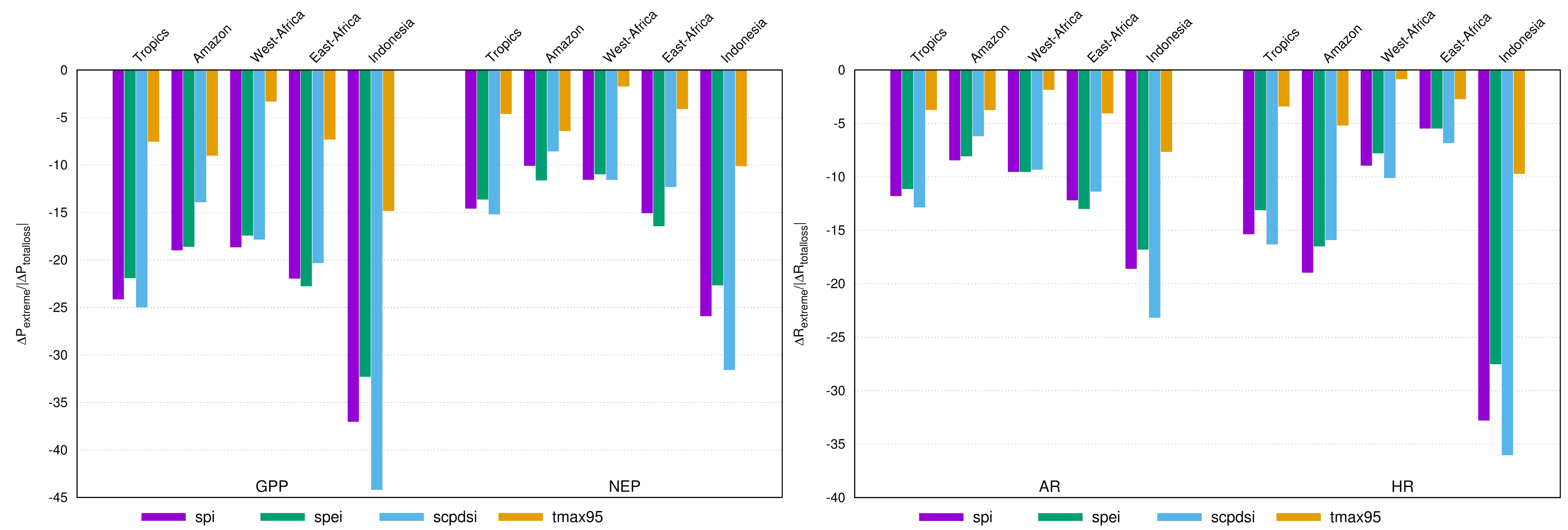

Figure: The percentages of the production (GPP&NEP) and respiration(AR&HR) losses due to extremes identified by SPI, SPEI, scPDSI and Tmax95 to the absolute values of total losses in Tropics, Amazon, West and East Africa and Indonesia respectively. The losses on ENSO sensitive grids and months are computed by subtracting their corresponding monthly climatology calculated among all neutral years.

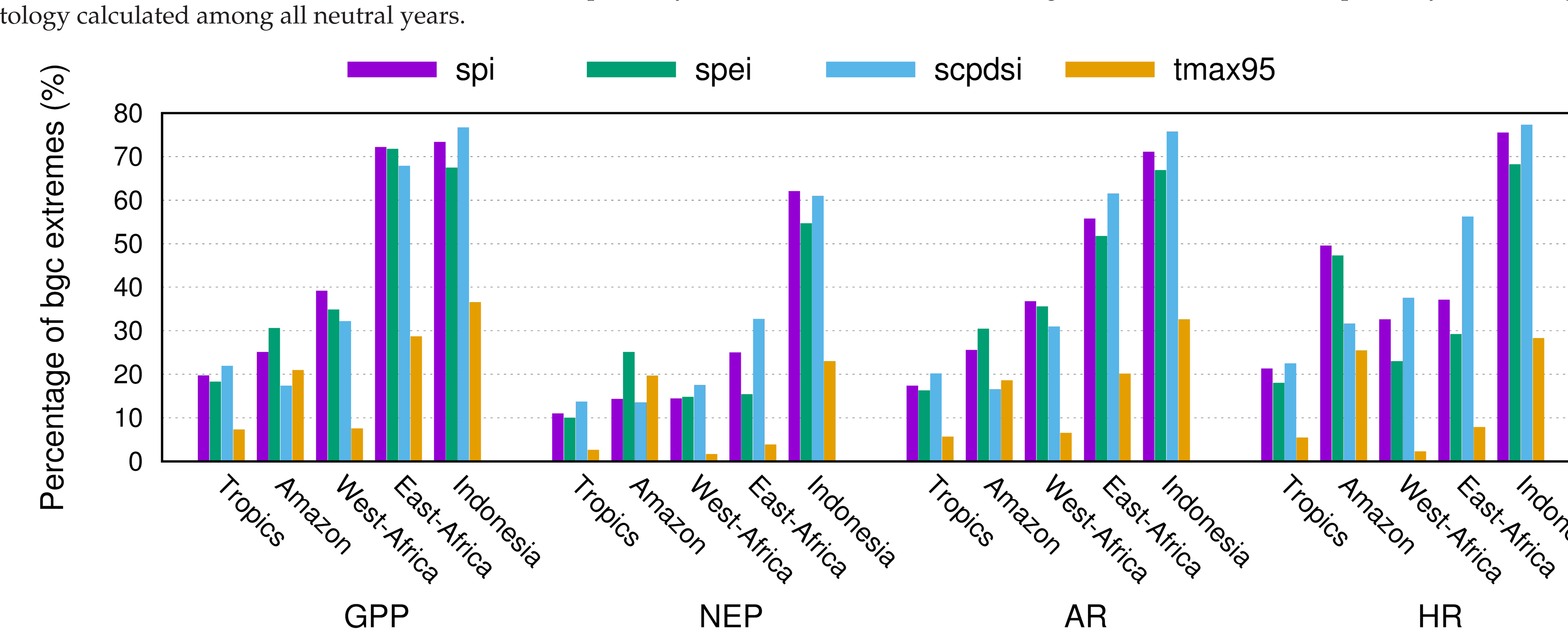

Figure: The percentages of the extremes in the biogeochemical variables (GPP, NEP, AR and HR) coincided with the climate extremes to the total BGC extremes.

Acknowledgment

This research was supported through the NGEE Tropics Project and the Reducing Uncertainties in Biogeochemical Interactions through Synthesis and Computation Scientific Focus Area (RUBISCO SFA), which are sponsored by the Climate and Environmental Sciences Division (CESD) of the Biological and Environmental Research (BER) Program in the U.S. Department of Energy Office of Science.

ENSO months and ENSO-sensitive regions

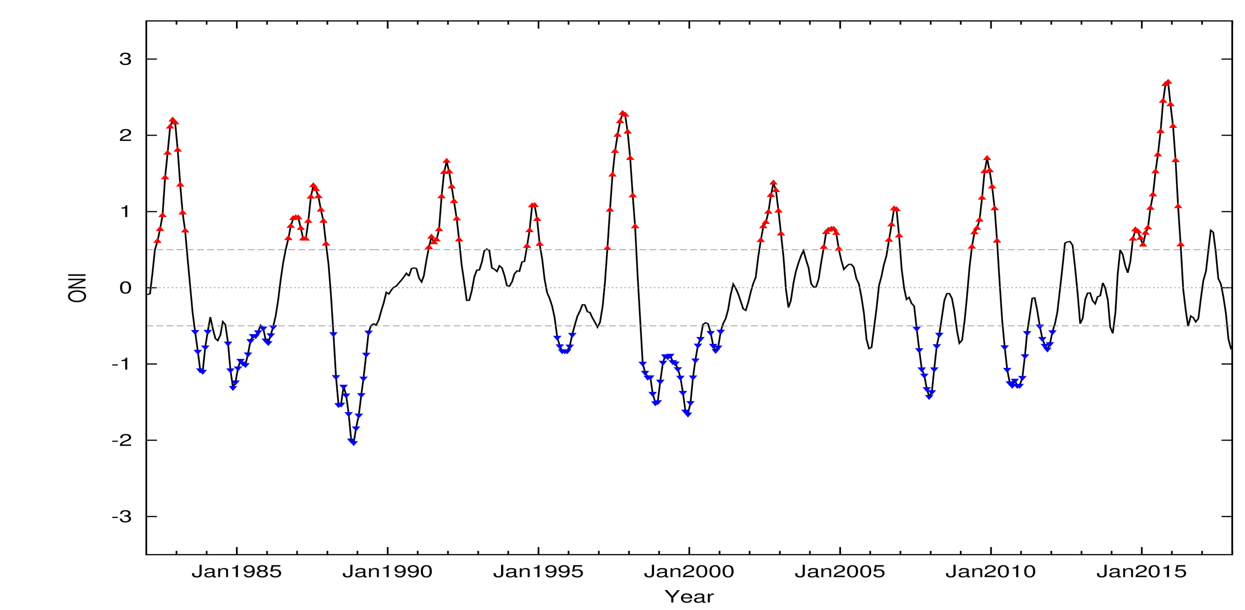

Figure: The 3-month running means of the oceanic Niño index (ONI) computed from NOAA OISSTv2, CFS 9-month forecast and reconstruct SSTs from 1982-2020. Red and blue triangles indicate the months in a El-Niño and La Niña cycles respectively.

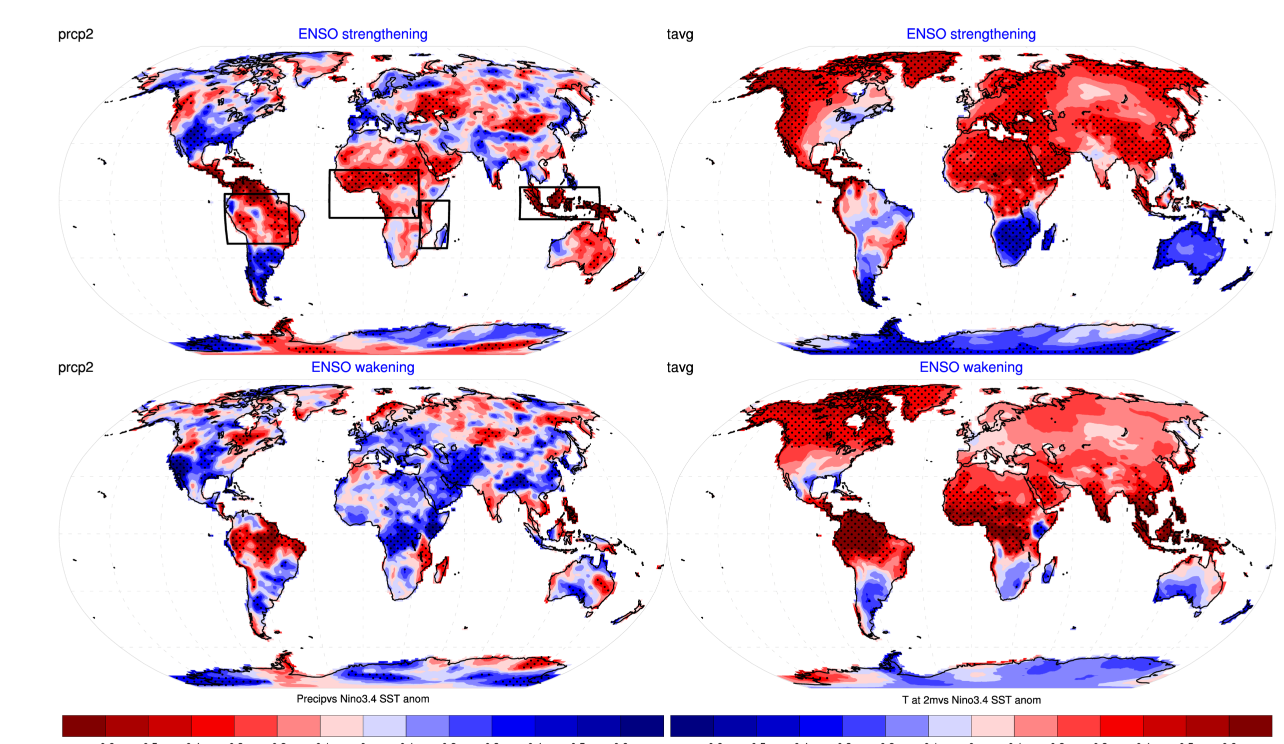

Figure: Correlations between the 5-month average (Nov-Feb) of Niño 3.4 SST anomaly and the annual total precipitation (left panel) and annual mean air temperature (right panel) at present (top panel) and next year (bottom panel). Correlations with statistical significance greater than 95% are stippled. The boxes from left to right depict Amazon, West and East Africa and Indonesia, respectively.

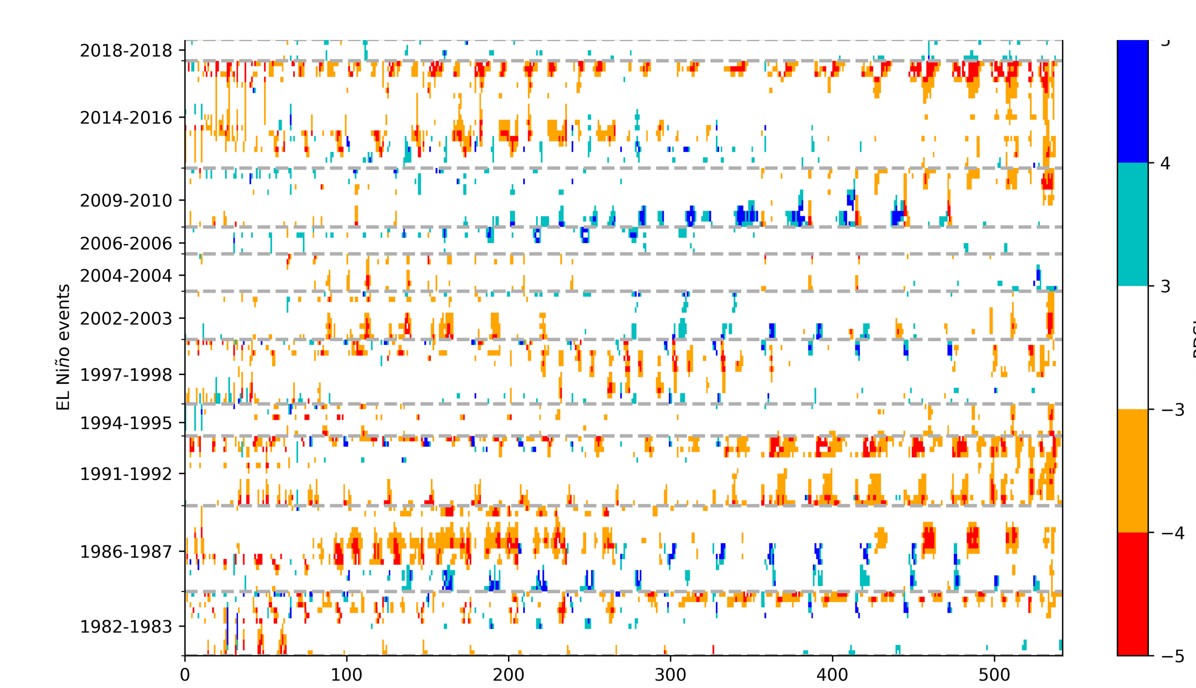

Figure: The scPDSI distributions over the ENSO-sensitive grid cells of the Amazon region (X axis) and the El Niño months from 1982 to 2020.