The influence of Atlantic and Pacific climate oscillations on Amazon carbon cycling

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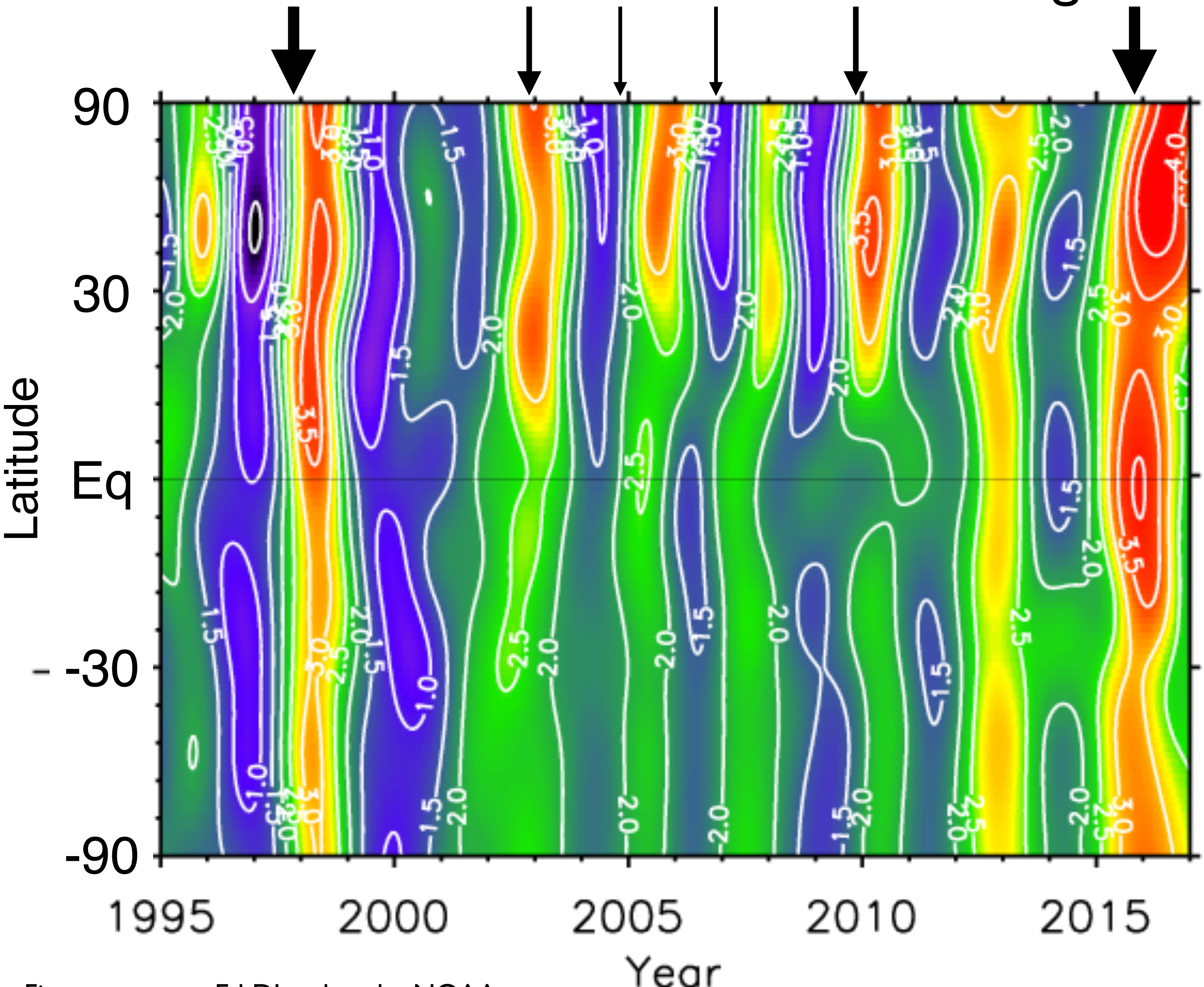
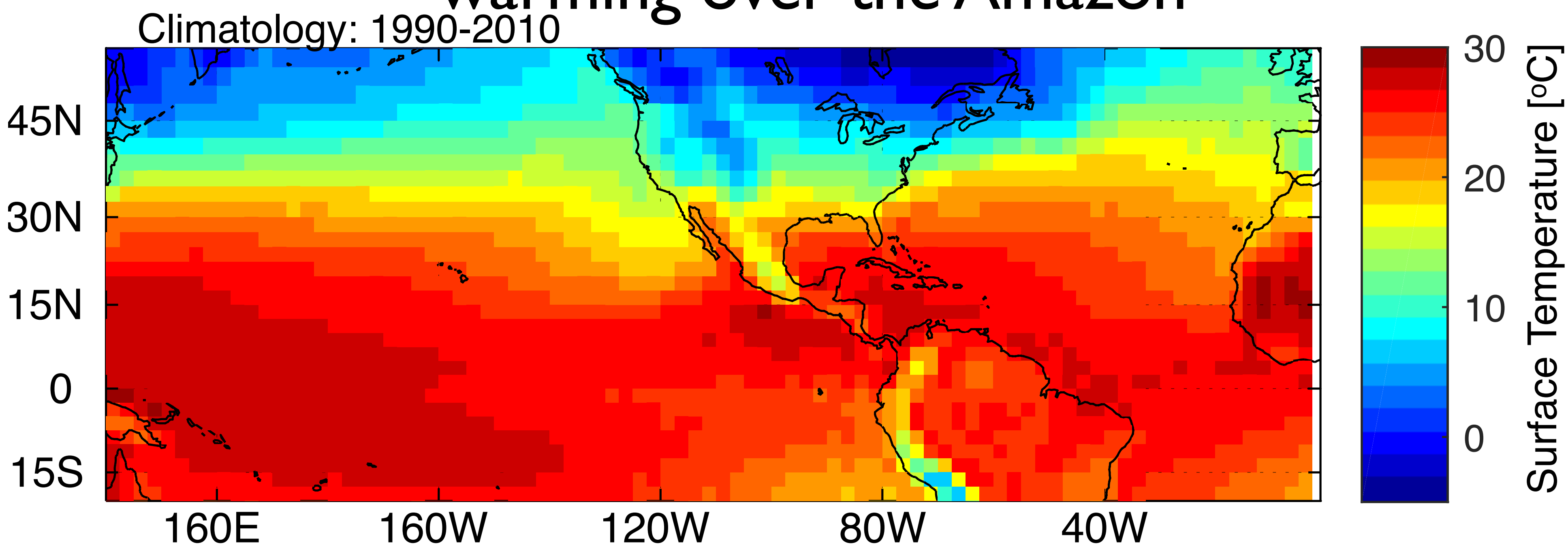
El Nino conditions modulate the CO_2 growth rate

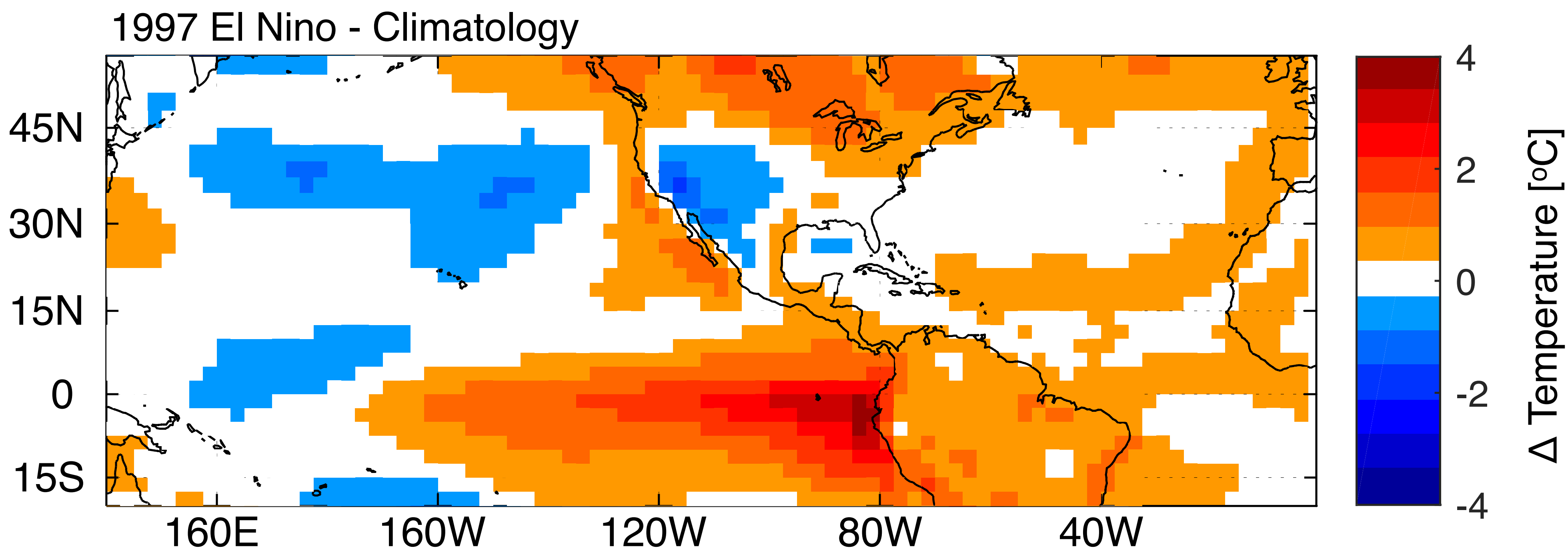


Contour units [ppm y^{-1}]

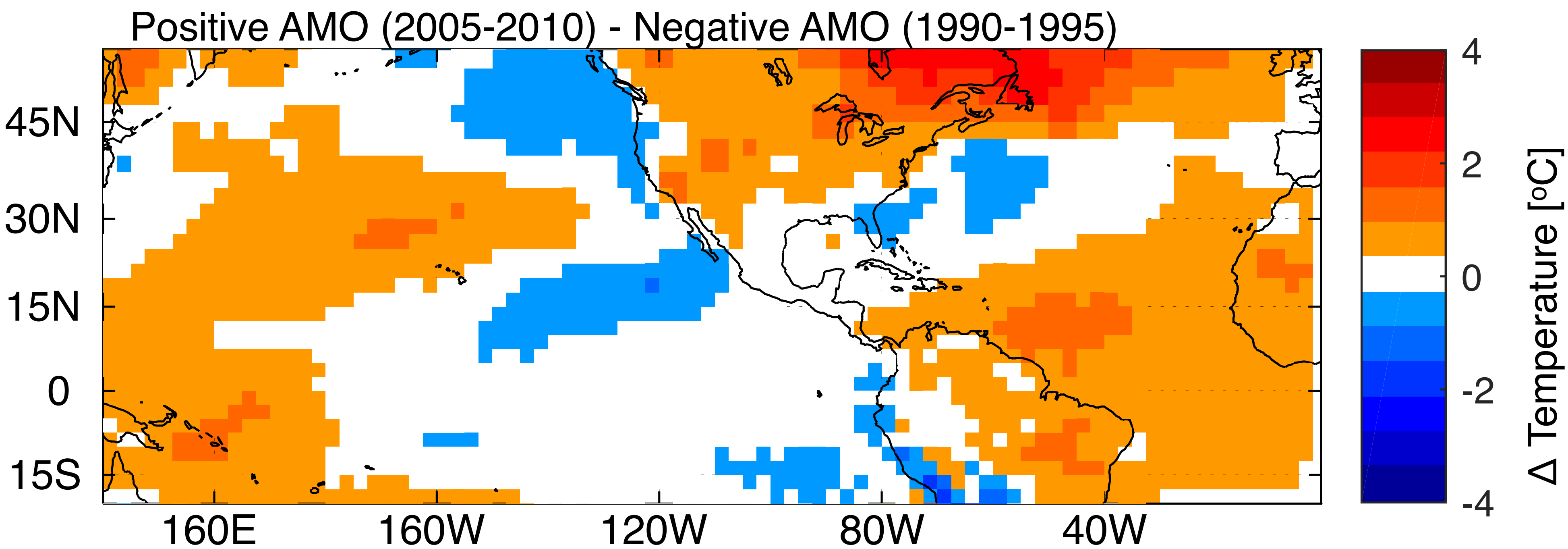
Figure courtesy Ed Dlugokencky, NOAA

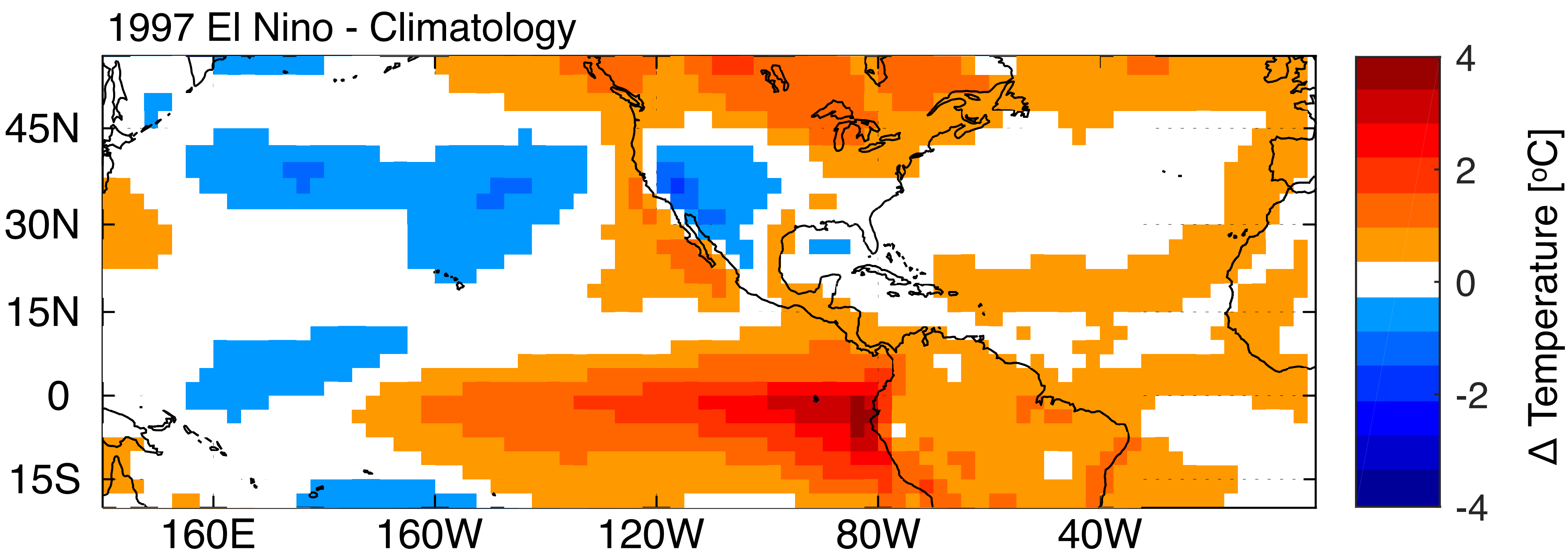
El Nino modulates global surface temperature, with warming over the Amazon



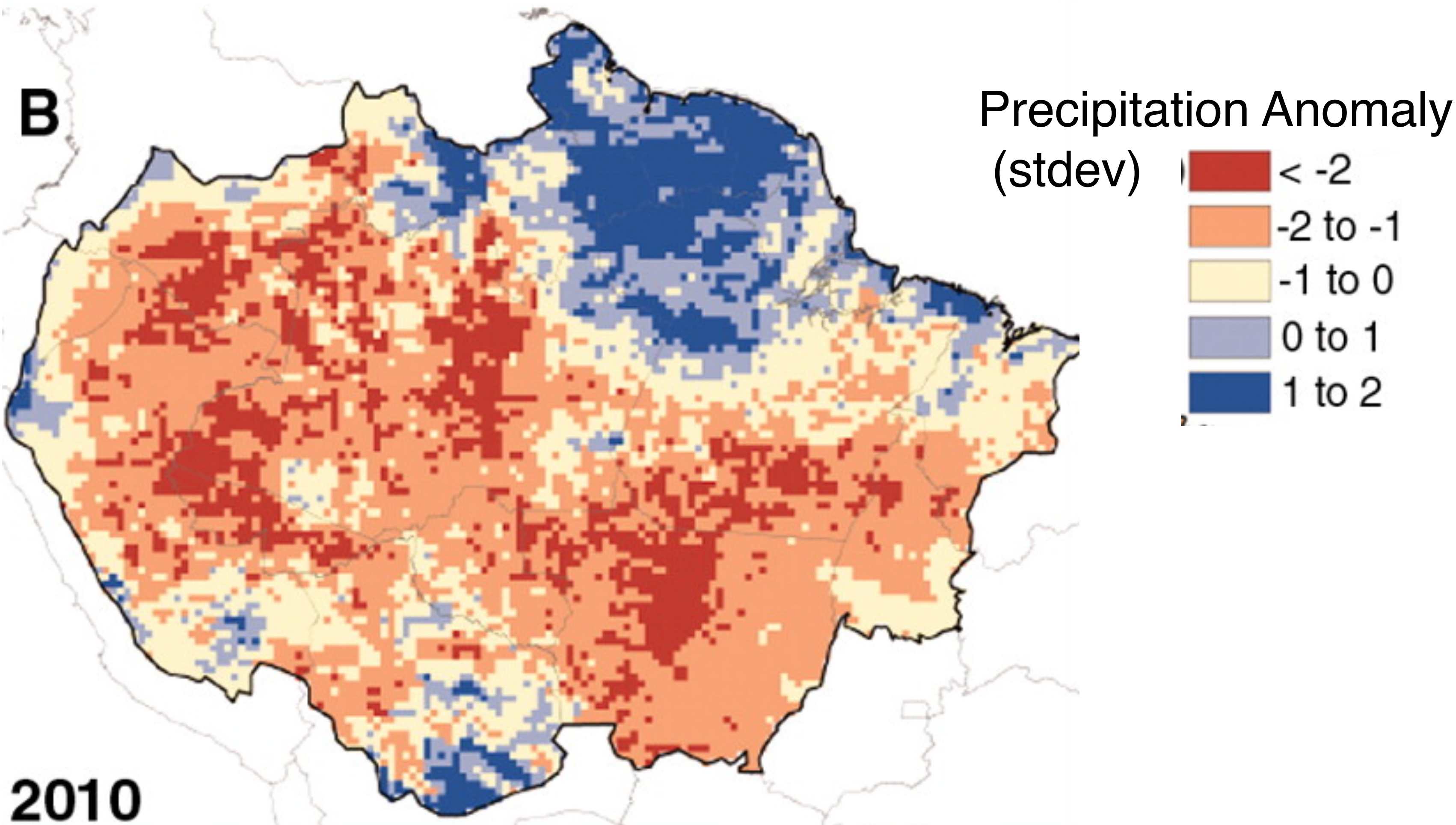


Atlantic Multidecadal Oscillation affects land climate





AMO+ northward ITCZ shift reduces Amazon rainfall



Estimated tree mortality associated with the 2010 drought was between 1.2 and 3.4 Pg C

Lewis et al., 2011

Simulation with CESM to simulate impact of climate oscillations

CO_2 radiative forcing held fixed

CAM5
Atmospheric Model

CO_2

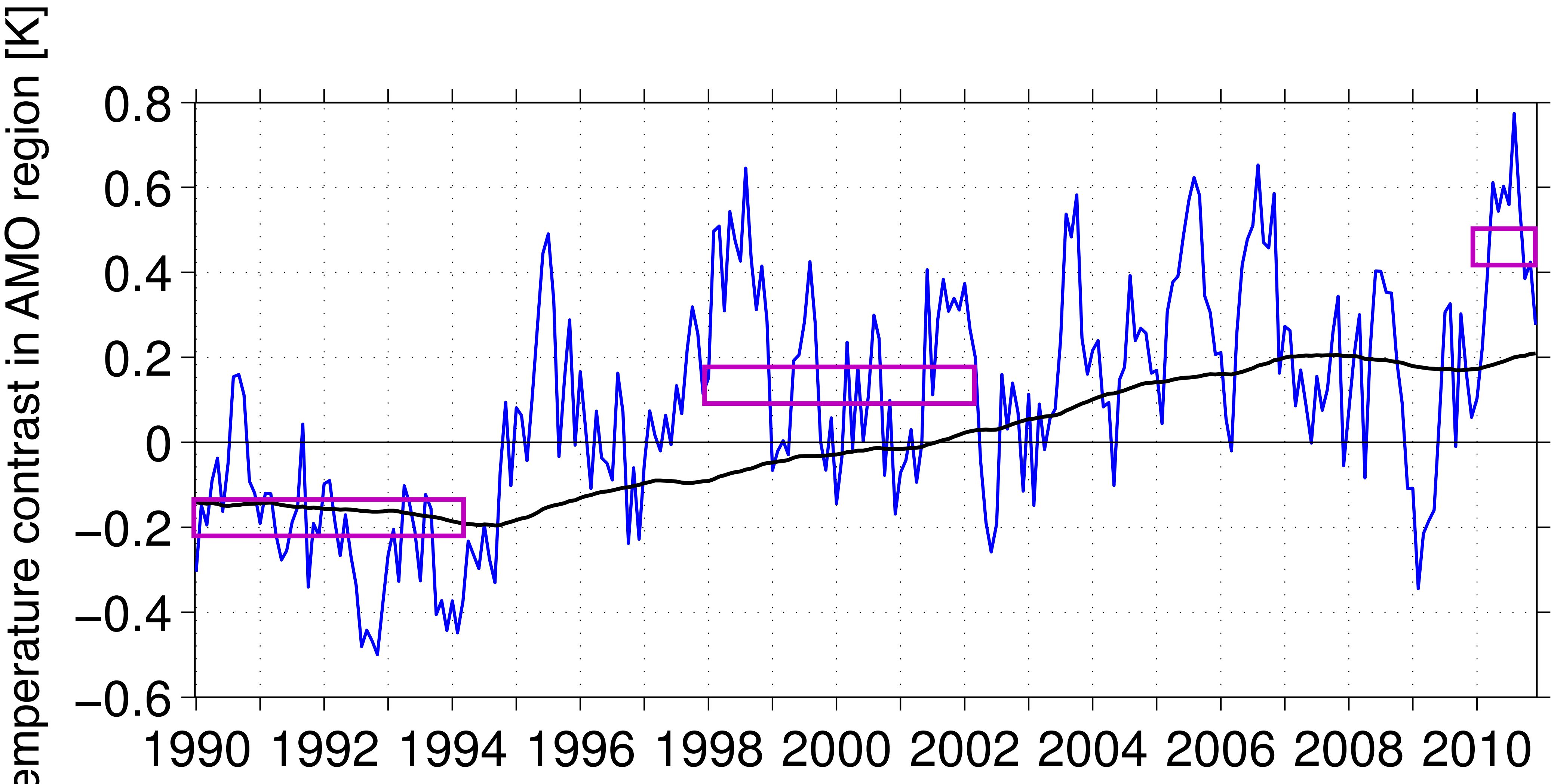
CLM4.5
Land Model

Fixed Ocean SSTs ⟷ Coupler ⟷ Land Model

Had OI boundary conditions

Simulations:
Dr. Jessica Liptak

We ran three experiments with different Atlantic SSTs



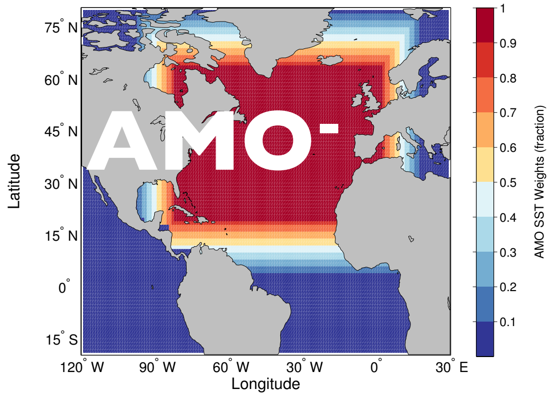
AMO- **-0.16°C**

AMO+ **0.15°C**

AMO2010+ **0.45°C**

Atlantic BCs

Pacific BCs



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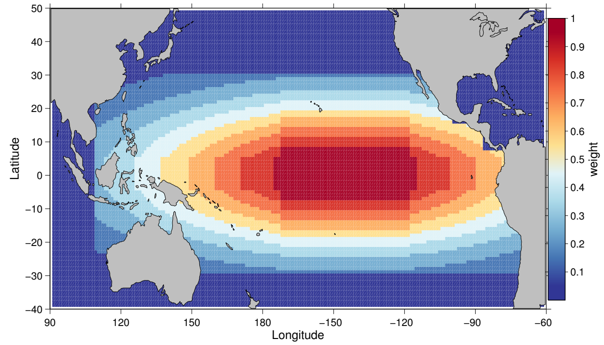

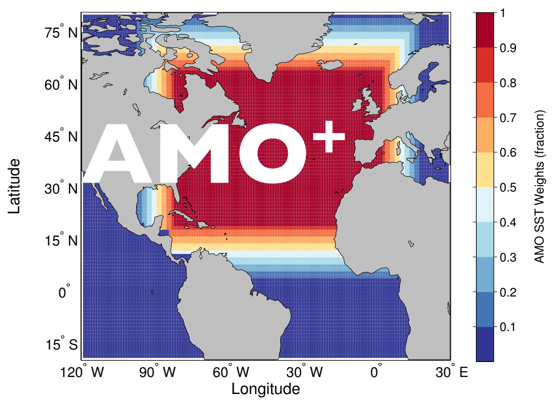

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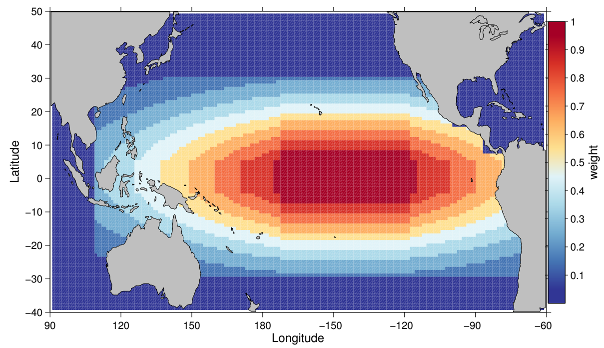

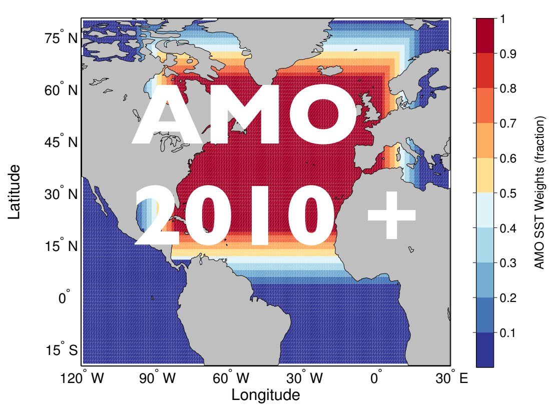

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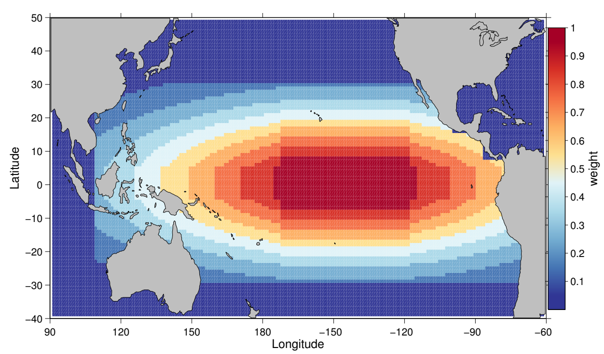
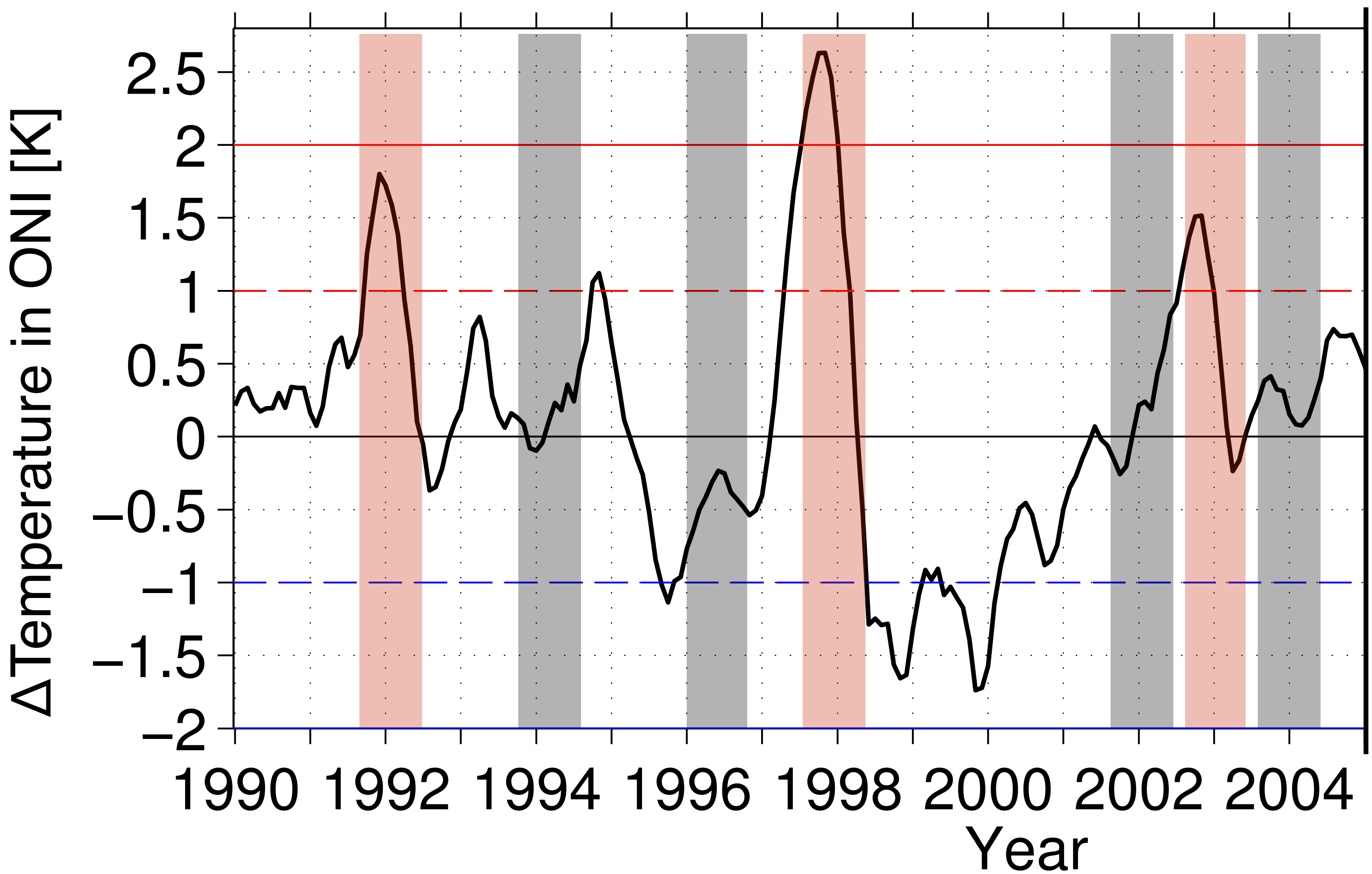
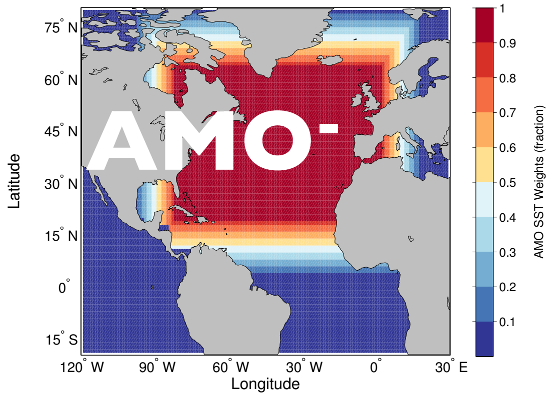


We ran each AMO experiment for 16 years, replacing SSTs in the Pacific ONI region with time-varying conditions to represent ENSO variations



Atlantic BCs | Pacific BCs | Ensemble Members



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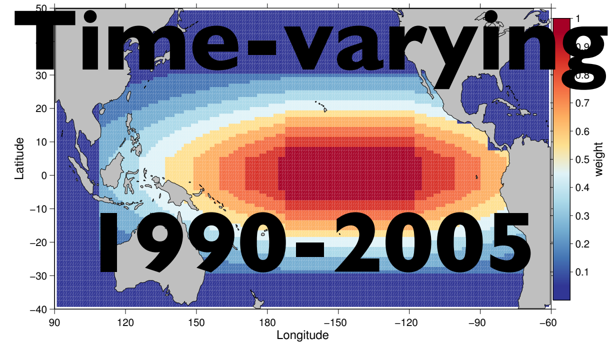
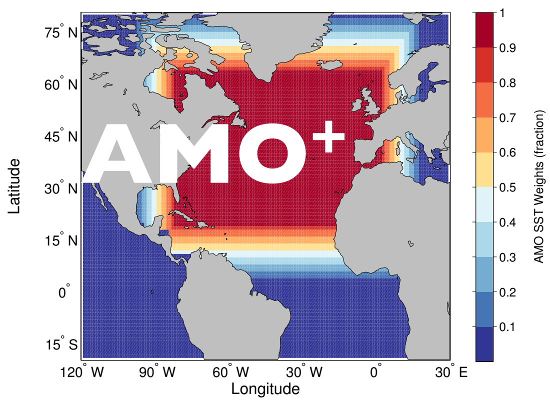


→ **6**



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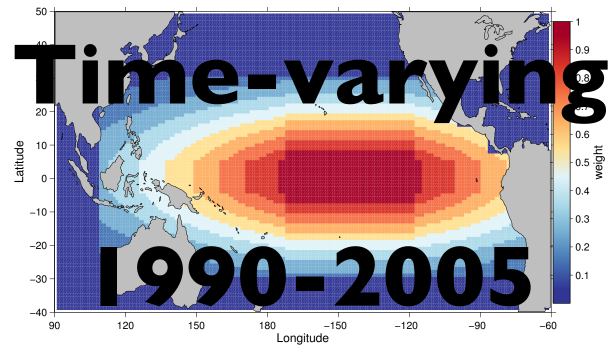
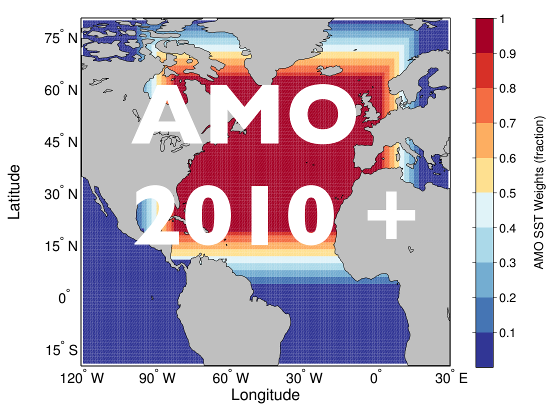


→ **6**



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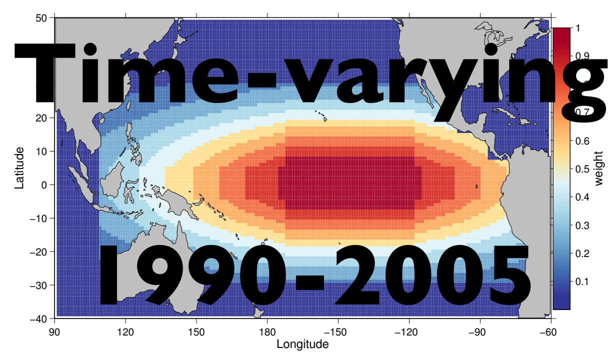
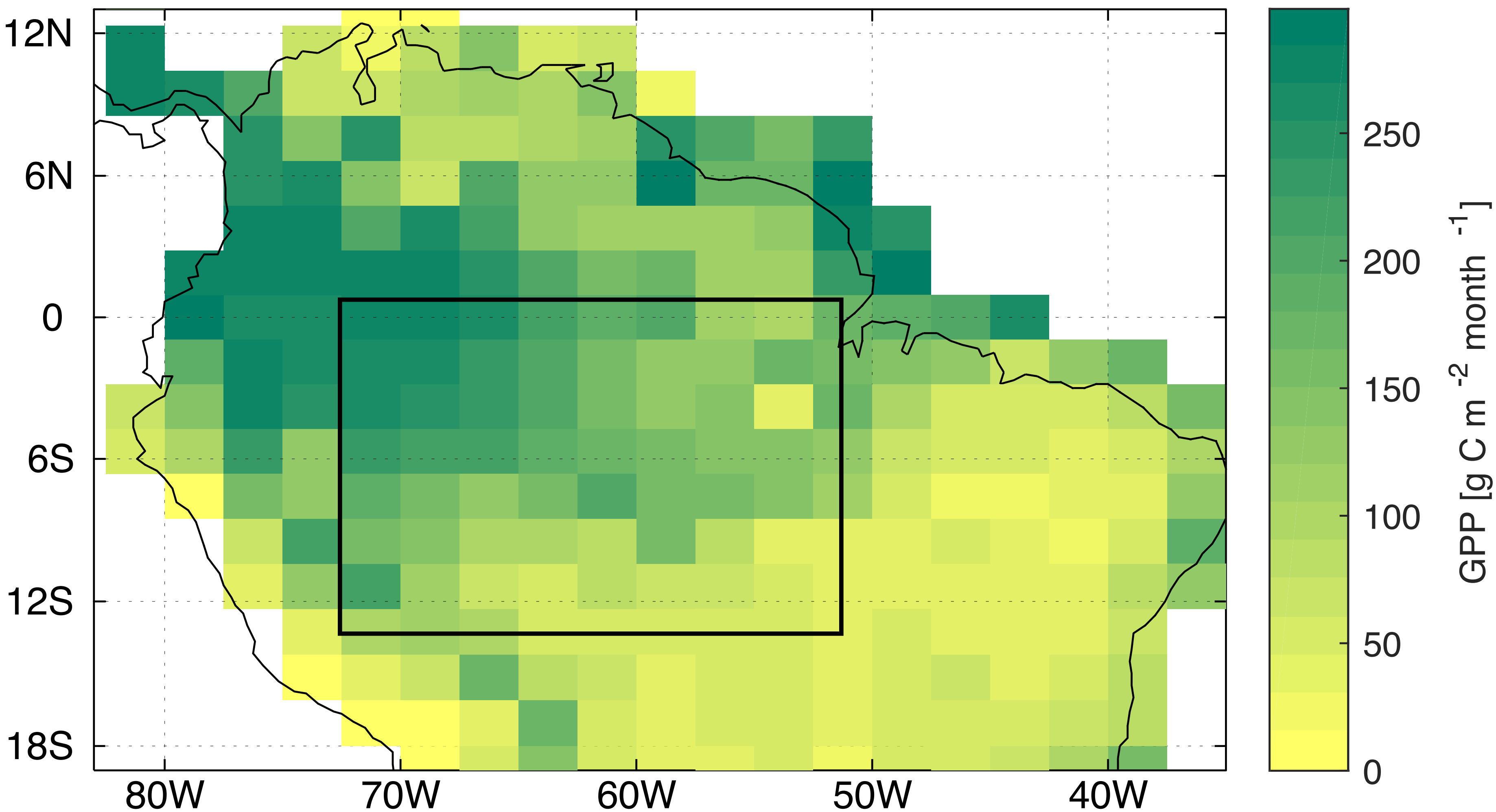
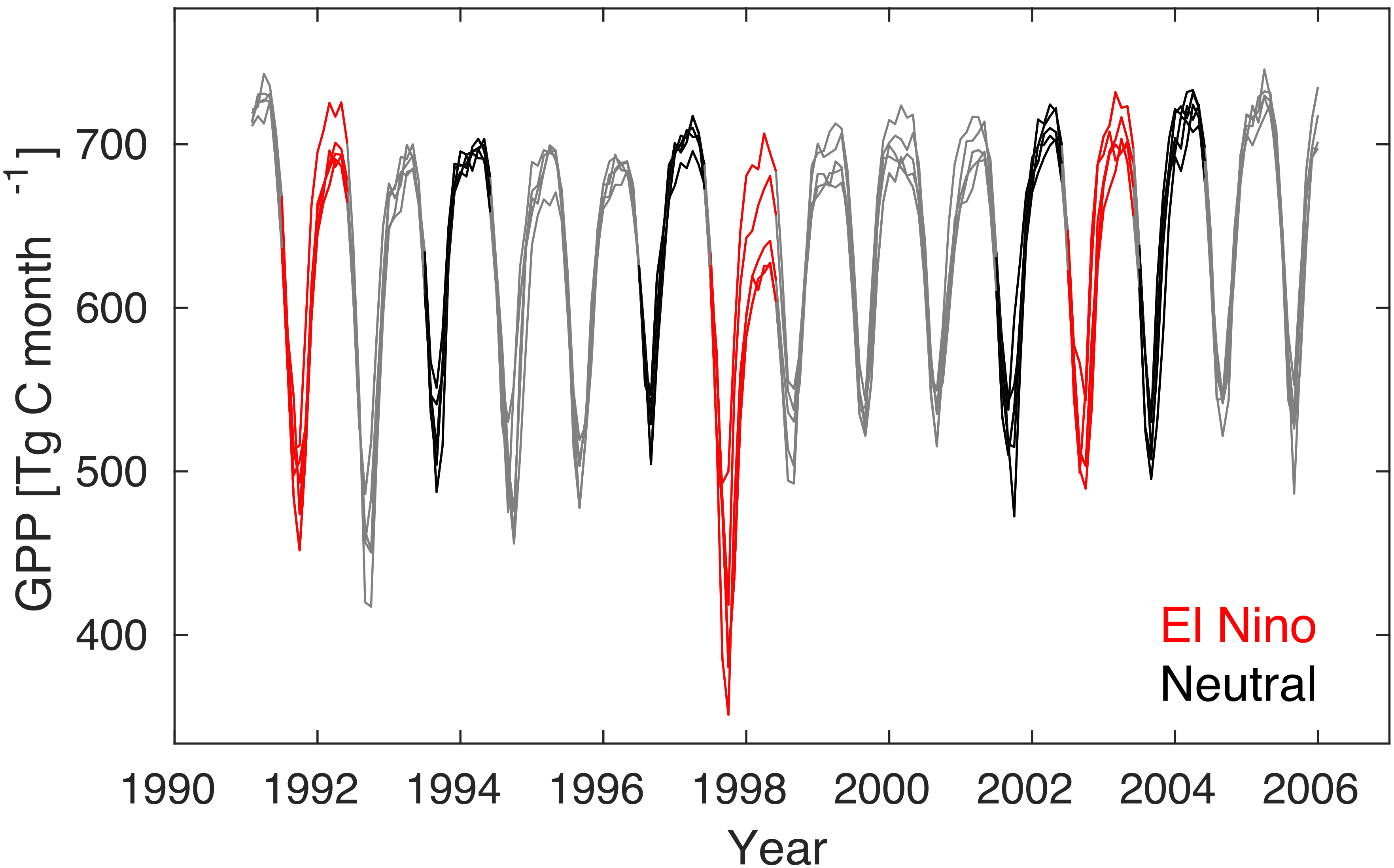


→ **5**

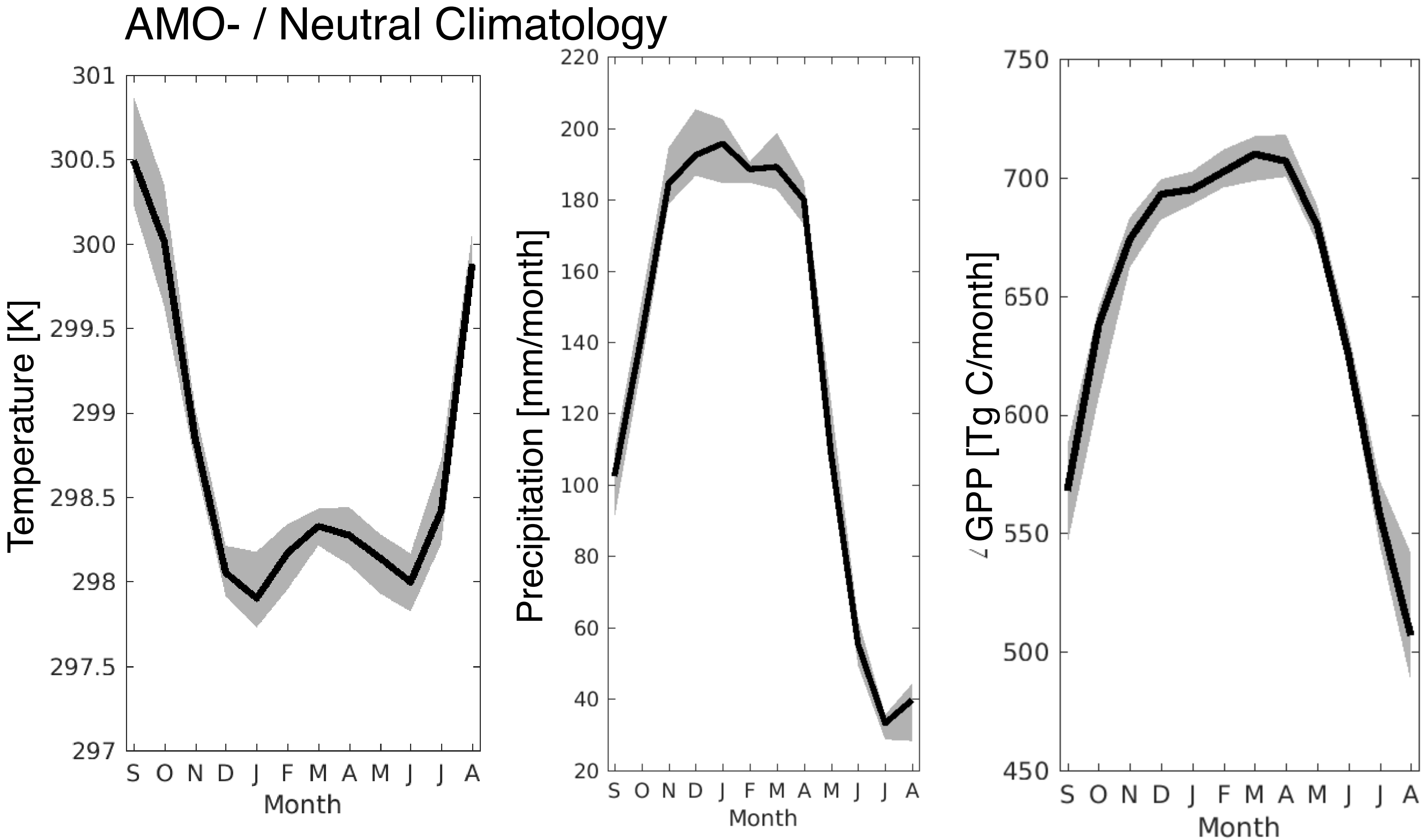
The Amazon rainforest has high GPP, and therefore has a large lever arm on carbon-climate interactions



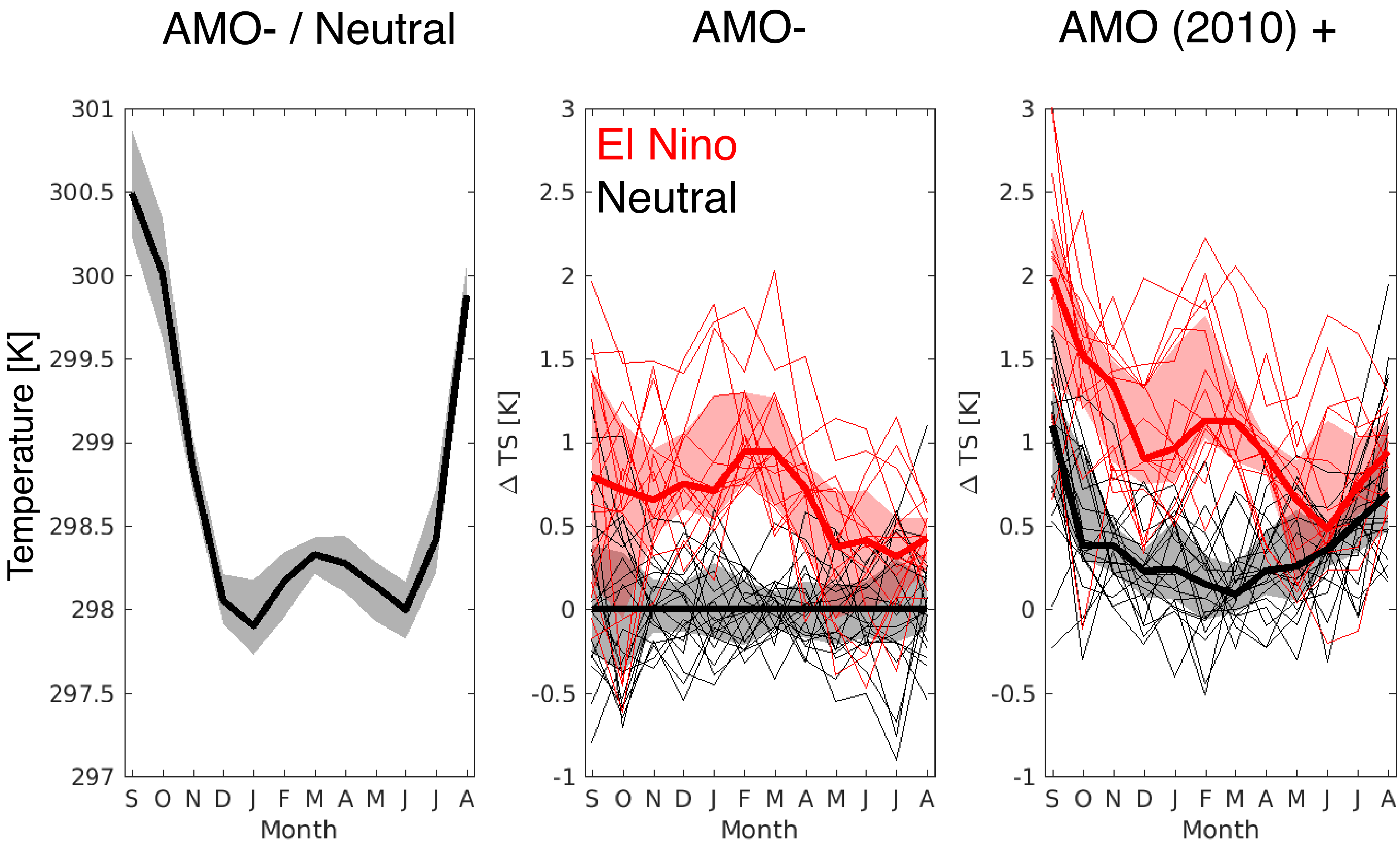
Small ensemble shows the imprint of Neutral and El Nino Pacific SST conditions on Amazon GPP



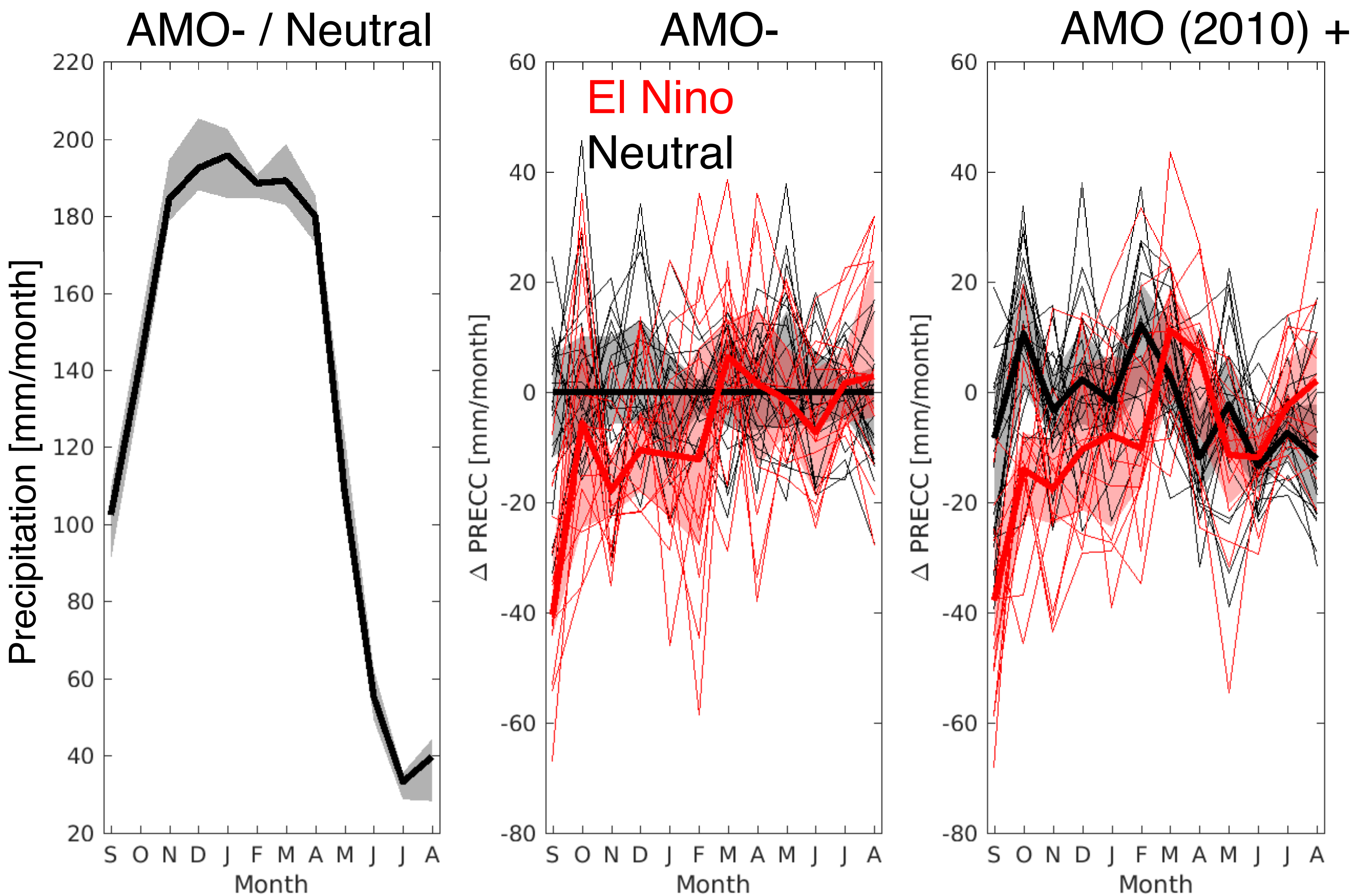
The annual cycles in Temperature, Precipitation, and GPP covary in the Amazon



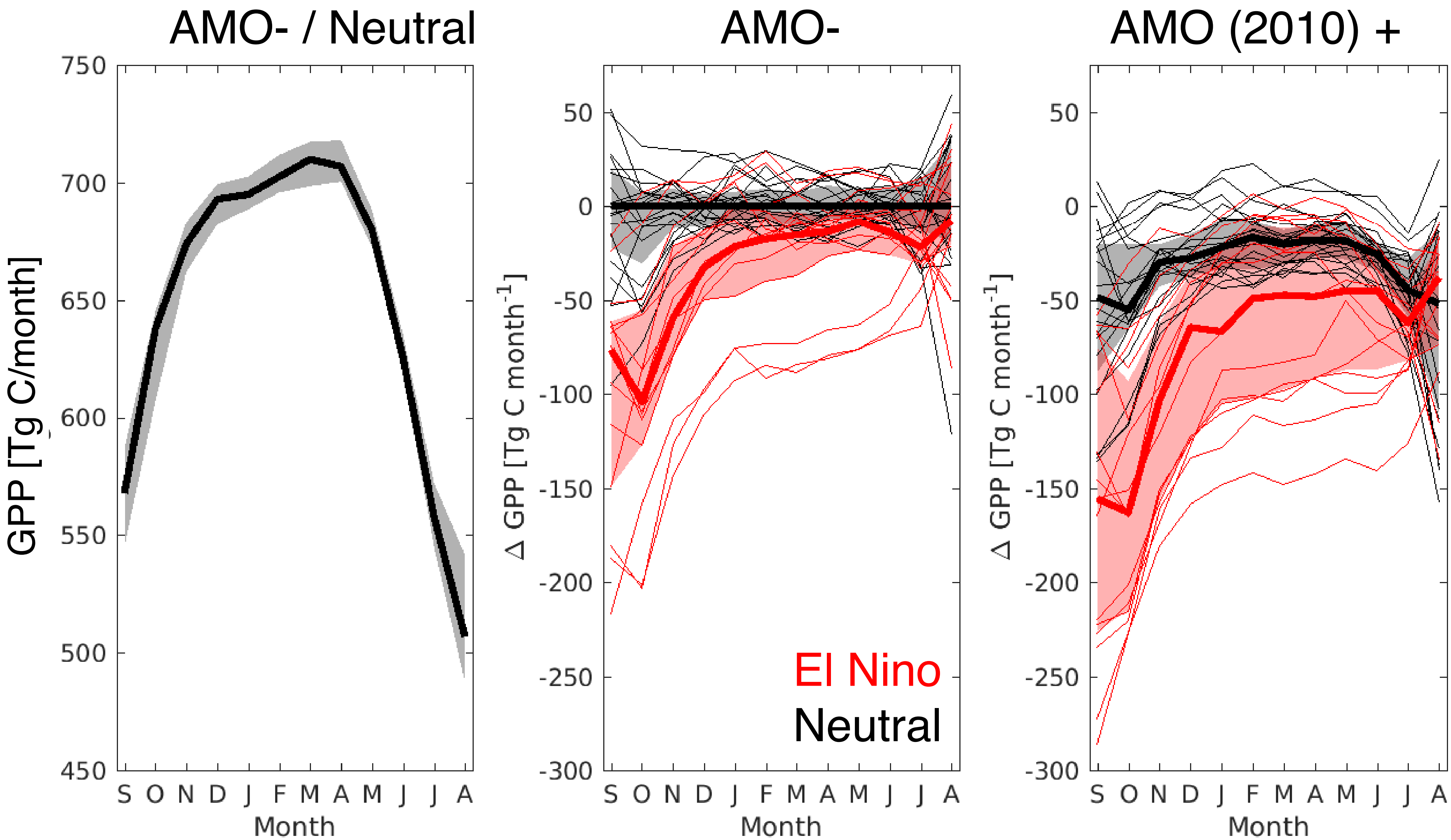
Temperature generally increases in El Nino or AMO+ conditions, with large internal variability

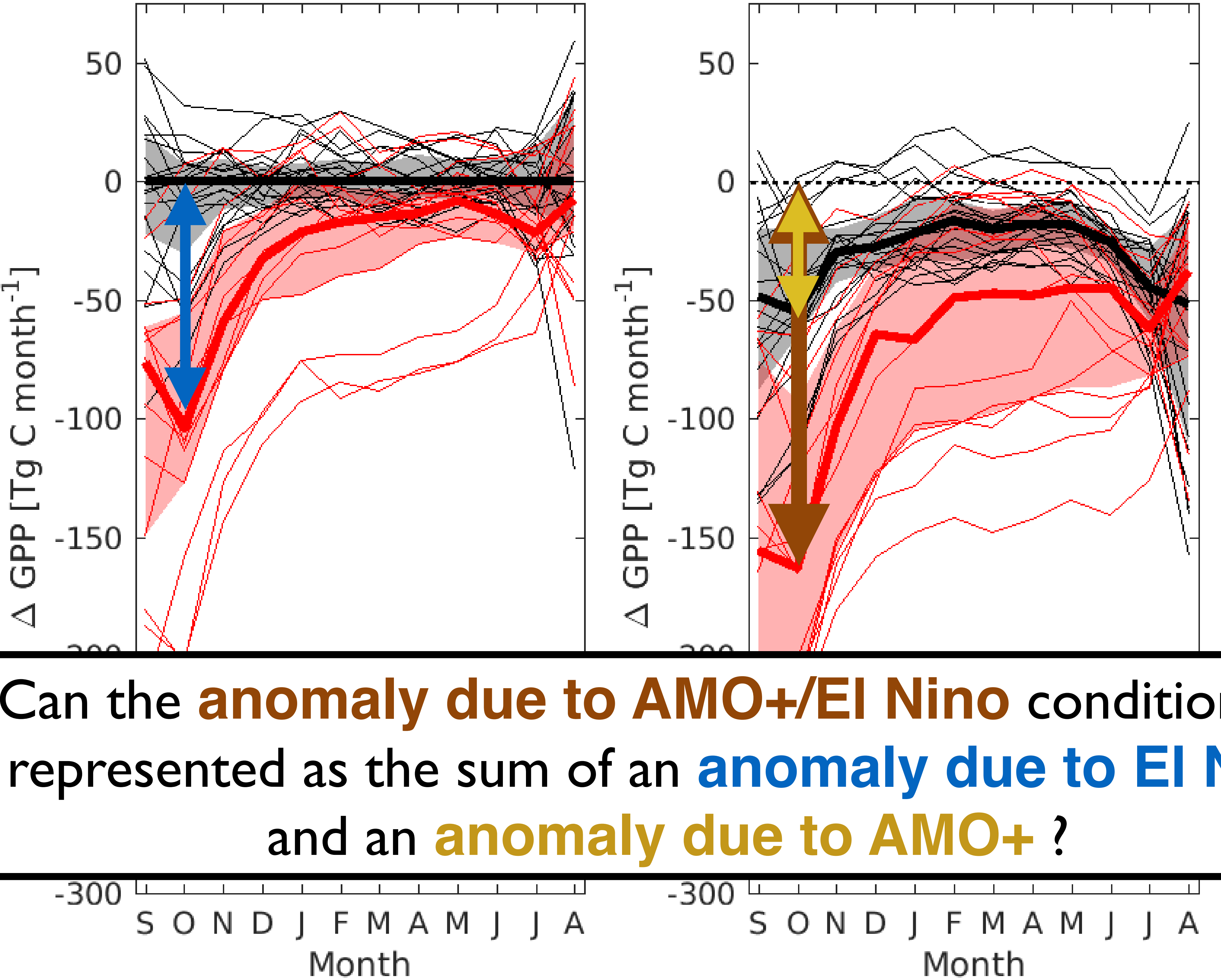


Precipitation decreases with peak El Nino conditions



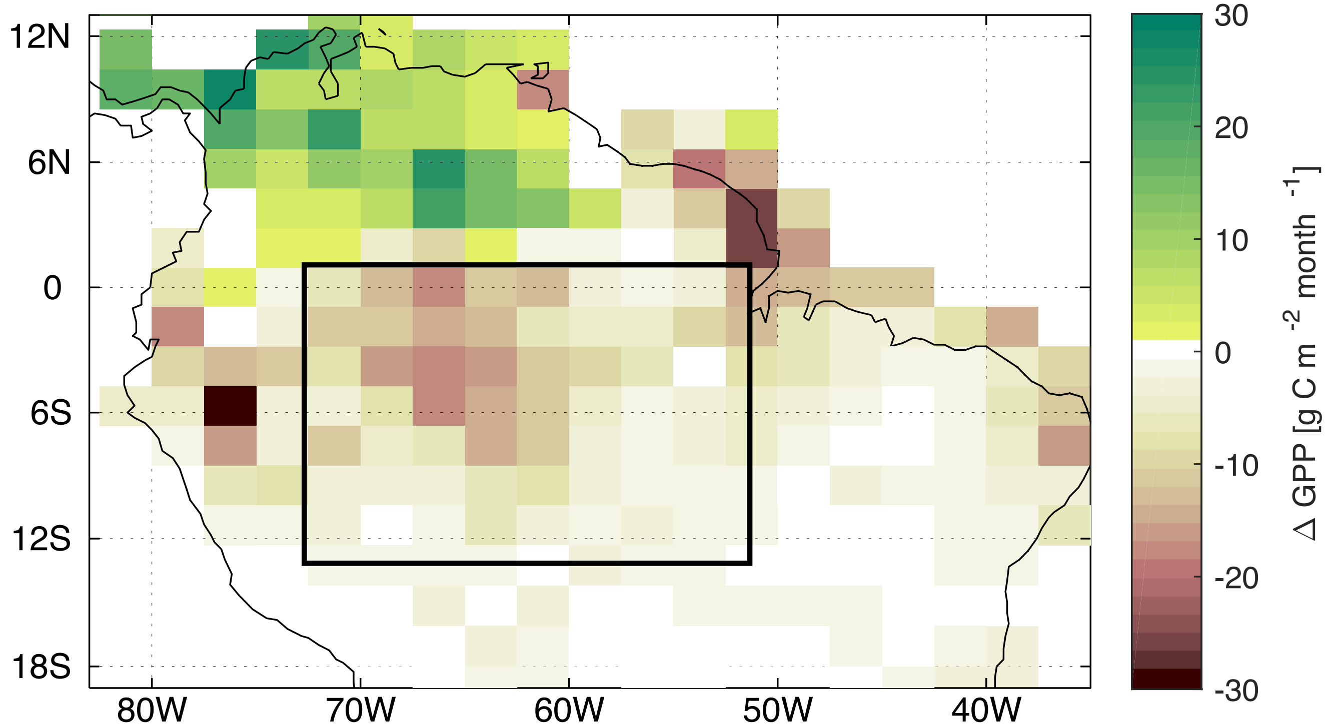
Both AMO+ and El Nino reduce GPP across an annual cycle, with largest difference at onset of wet season





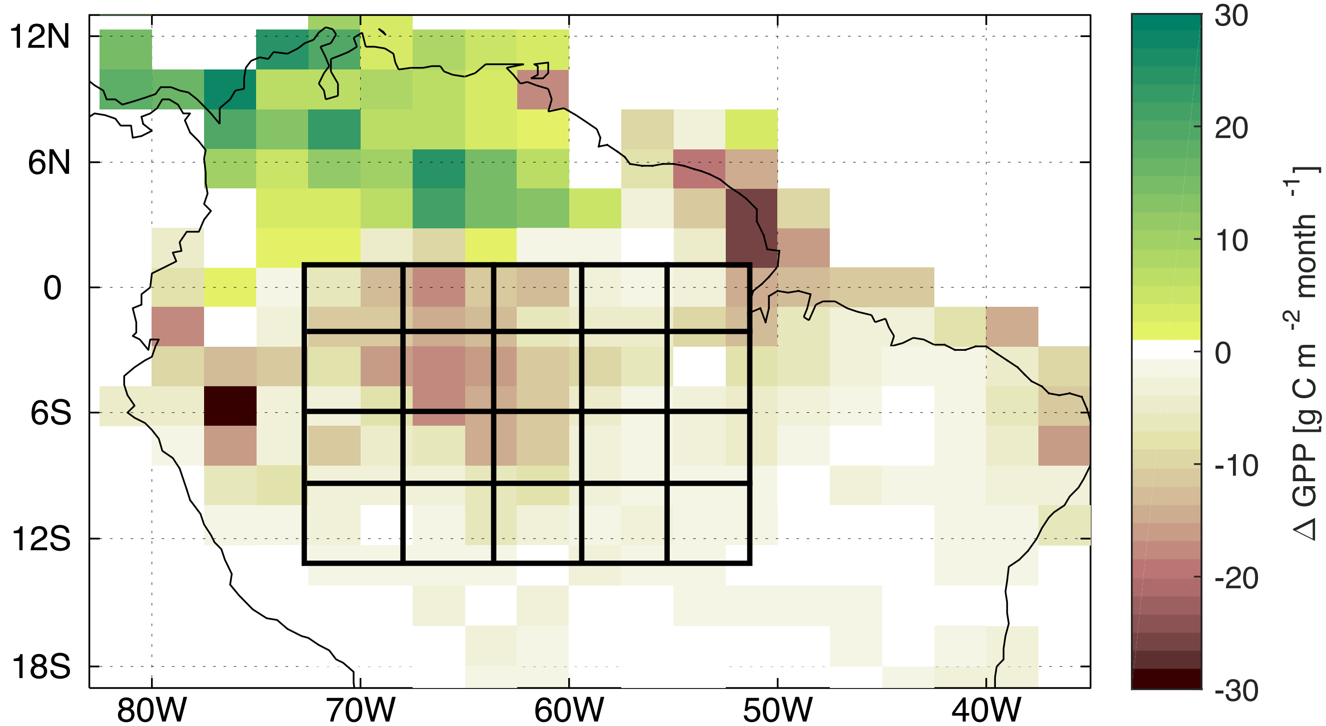
Can the **anomaly due to AMO+/El Nino** conditions be represented as the sum of an **anomaly due to El Nino** and an **anomaly due to AMO+** ?

We generate synthetic data to emulate the influence of Atlantic and Pacific SST on Amazon climate



We consider six climate states, combining AMO$^{-/+/2010+}$ and neutral/El Nino conditions

We generate synthetic data to emulate the influence of Atlantic and Pacific SST on Amazon climate



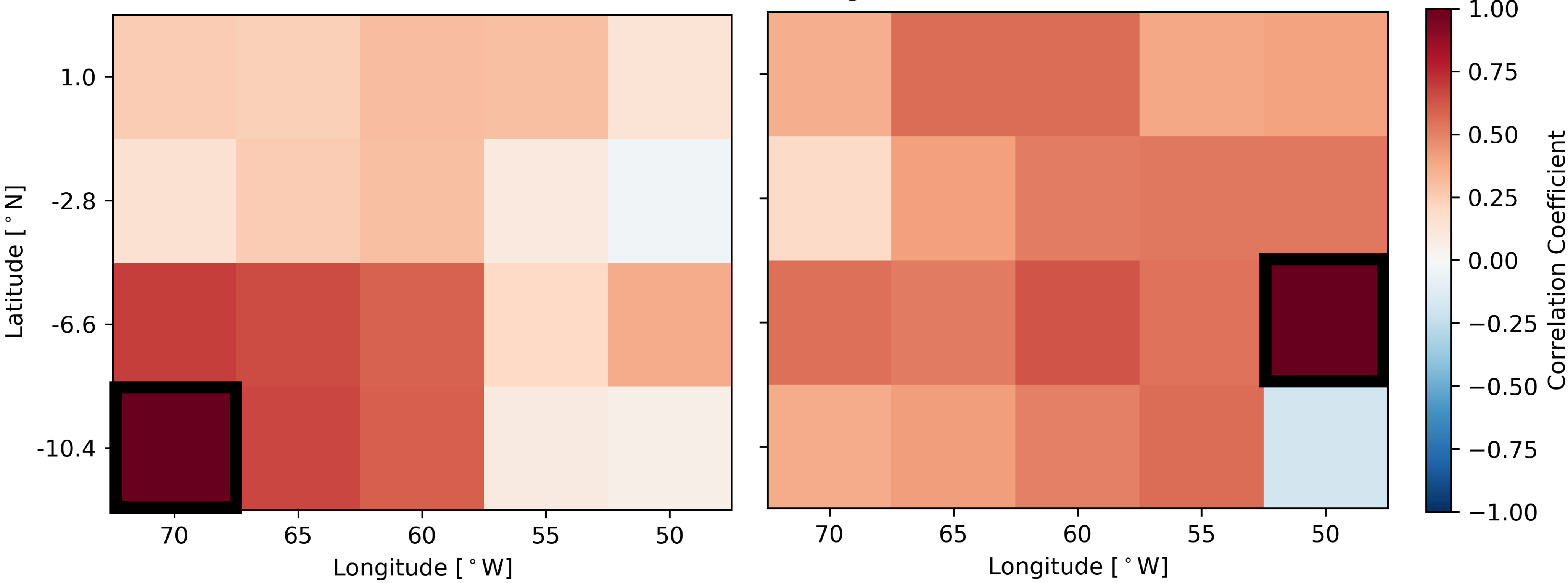
We consider six climate states, combining AMO$^{-/+/2010+}$ and neutral/El Nino conditions

We bin grid cells into 4x5 deg supercells (20 total)

For each supercell, we have **4 x Nens x $N_{(neutral/El Nino)}$** data points per month

We use relationships among the interannual variability for each supercell to calculate a spatial covariance matrix for each month

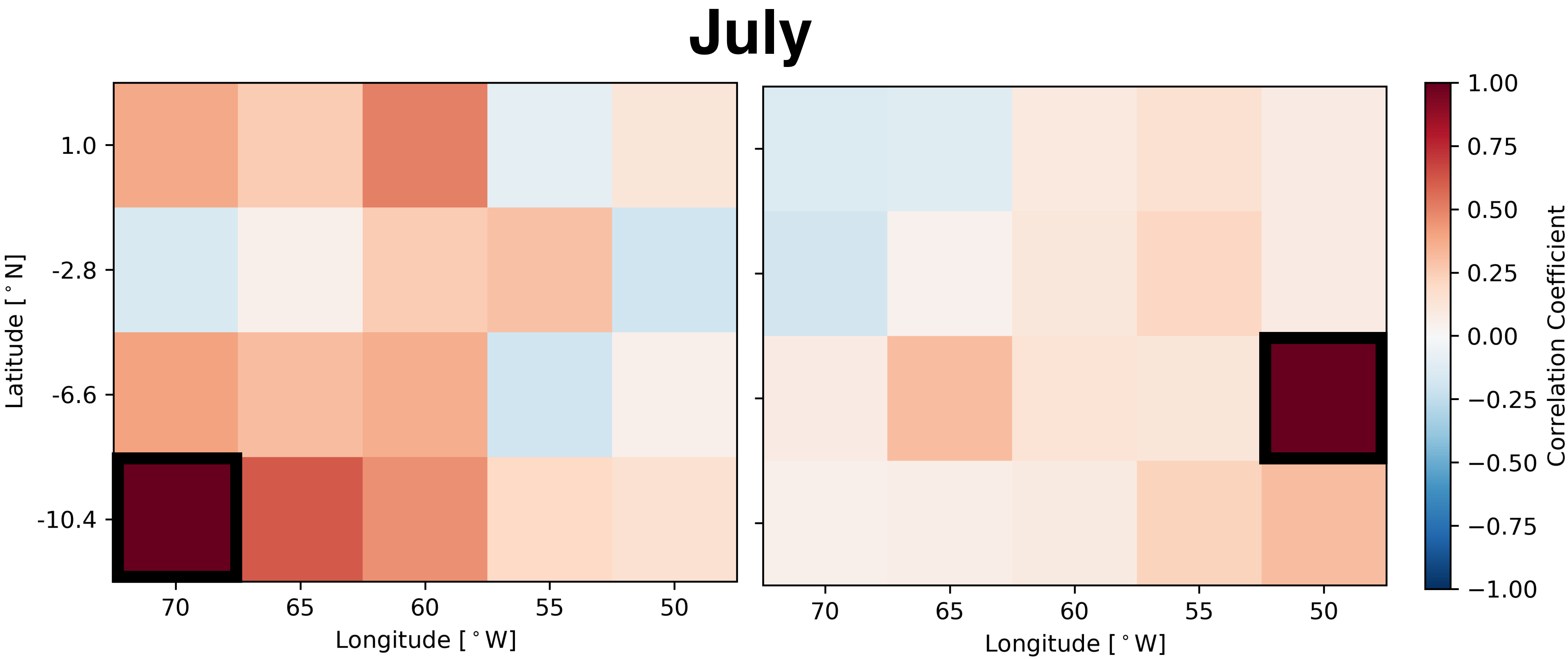
January



Southwest supercell is correlated with other supercells in the ***southwest quadrant*** of the domain

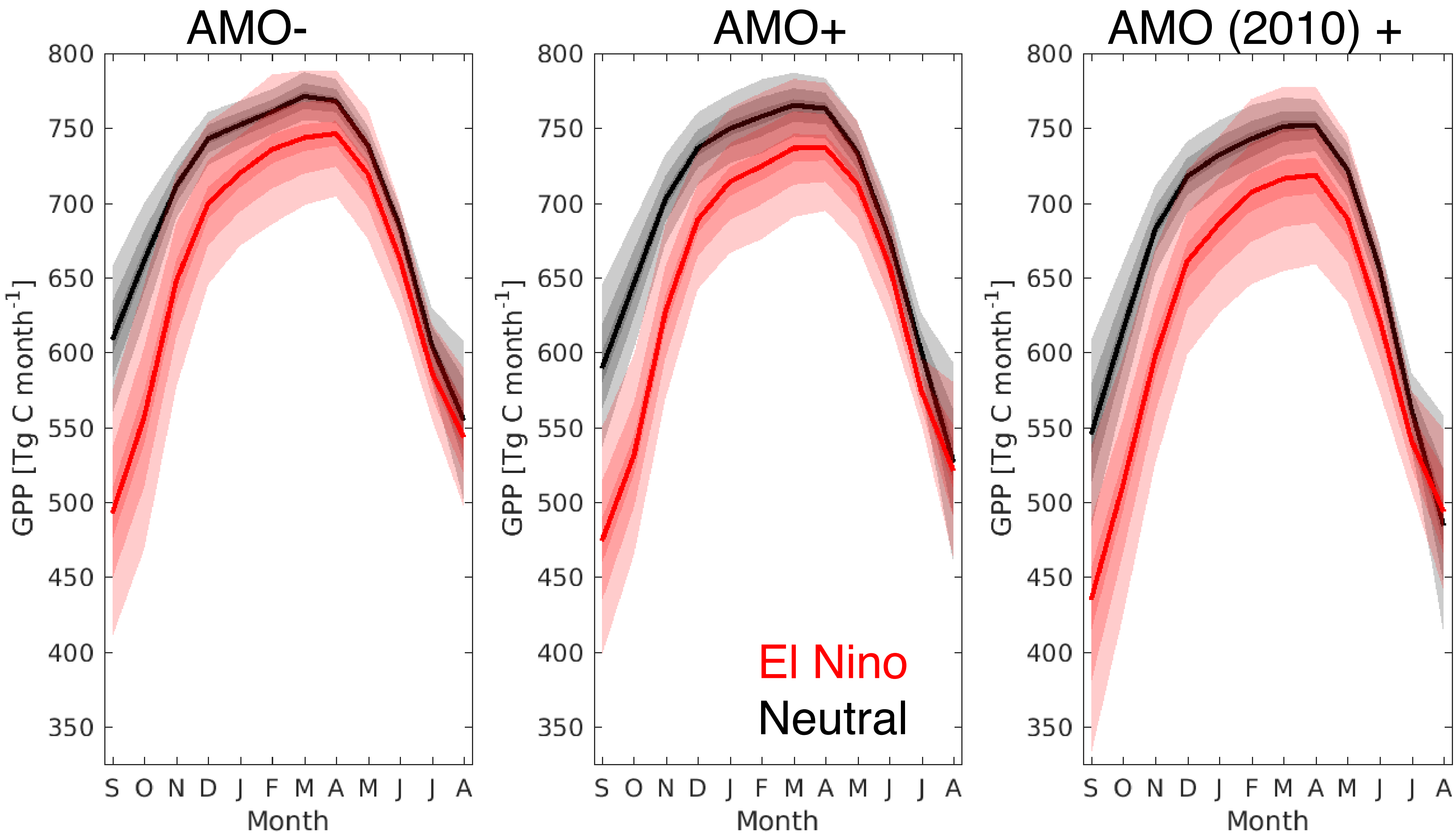
Southeast supercell is ***correlated with most of the domain***

We use relationships among the interannual variability for each supercell to calculate a spatial covariance matrix for each month

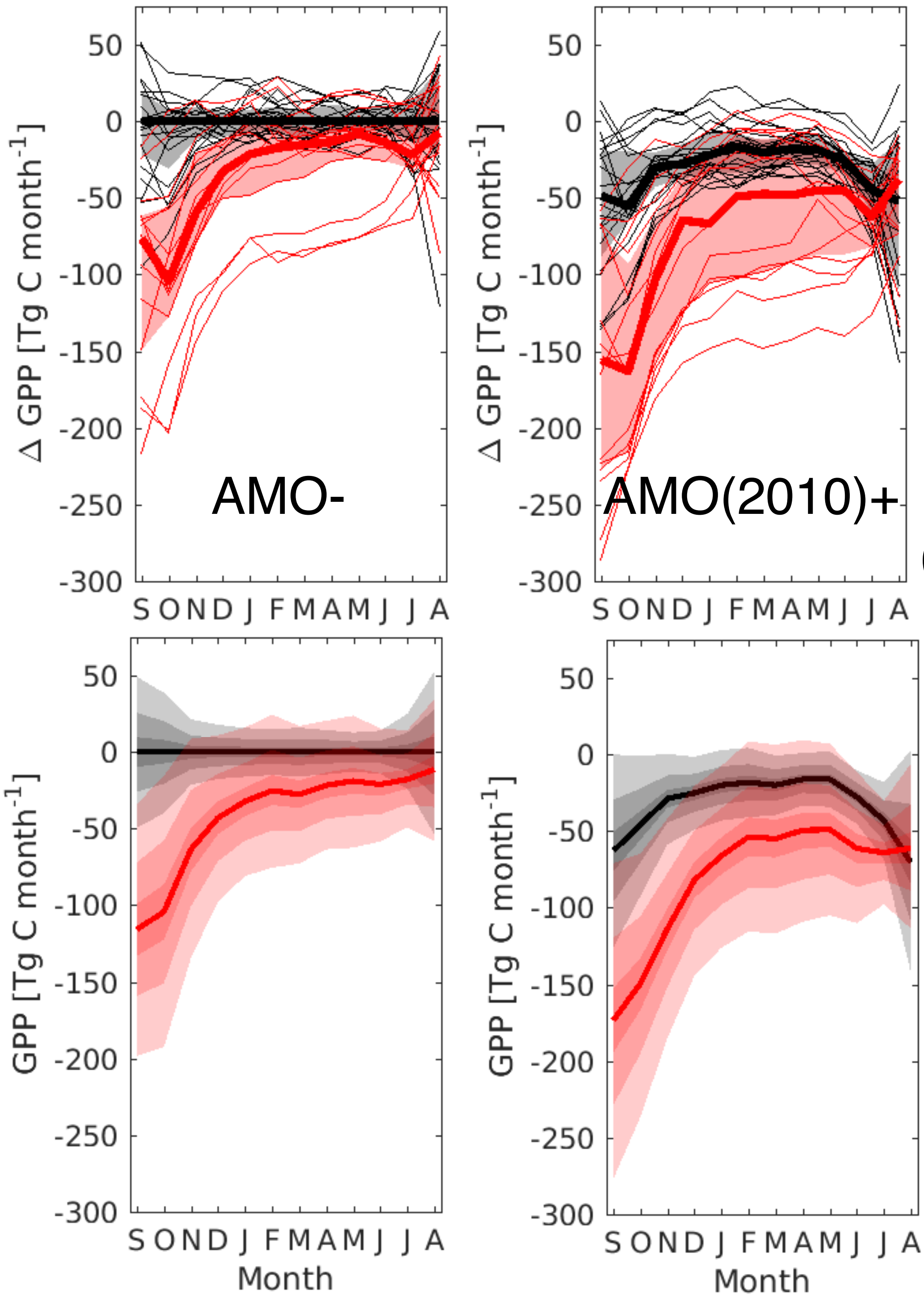


Southeast supercell is ***uncorrelated*** with most of the domain

We sample from monthly covariance matrices 10,000 times to emulate the six climate states



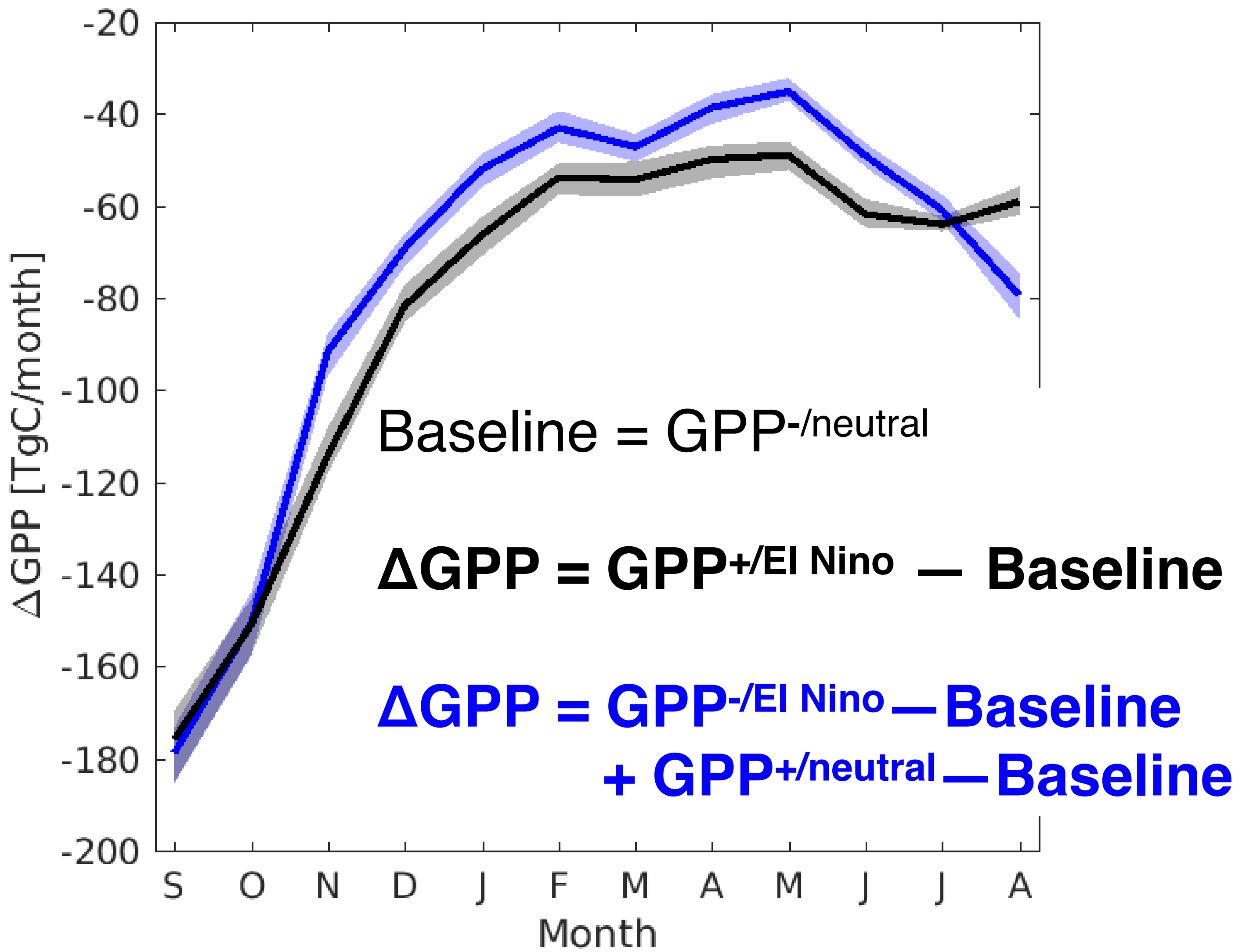
Synthetic data show similar mean and variance patterns to CESM simulations



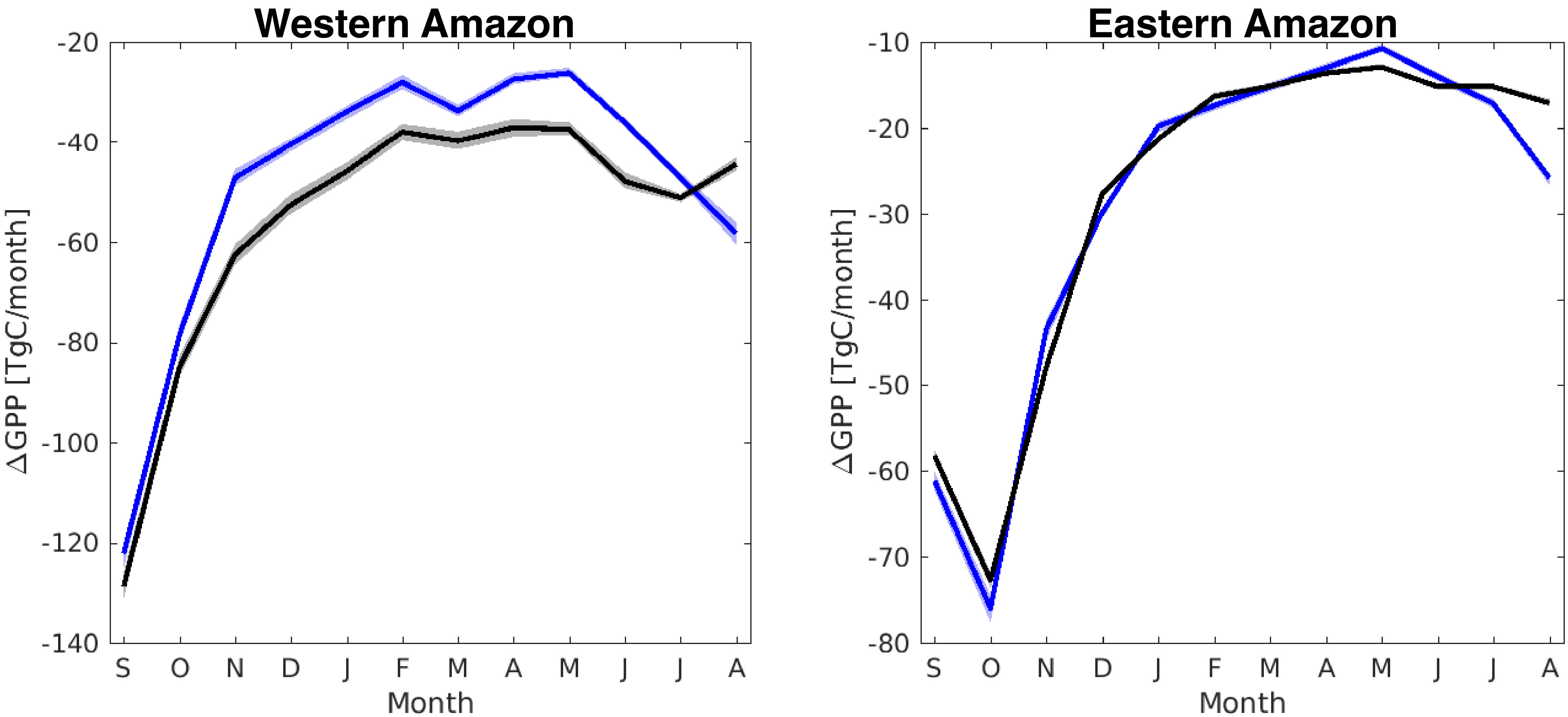
CESM Simulations

Synthetic Data

Synthetic GPP data show a systematic positive bias when we assume that the influences of El Nino and AMO+ conditions are additive



This nonlinearity is found primarily in western half of the domain

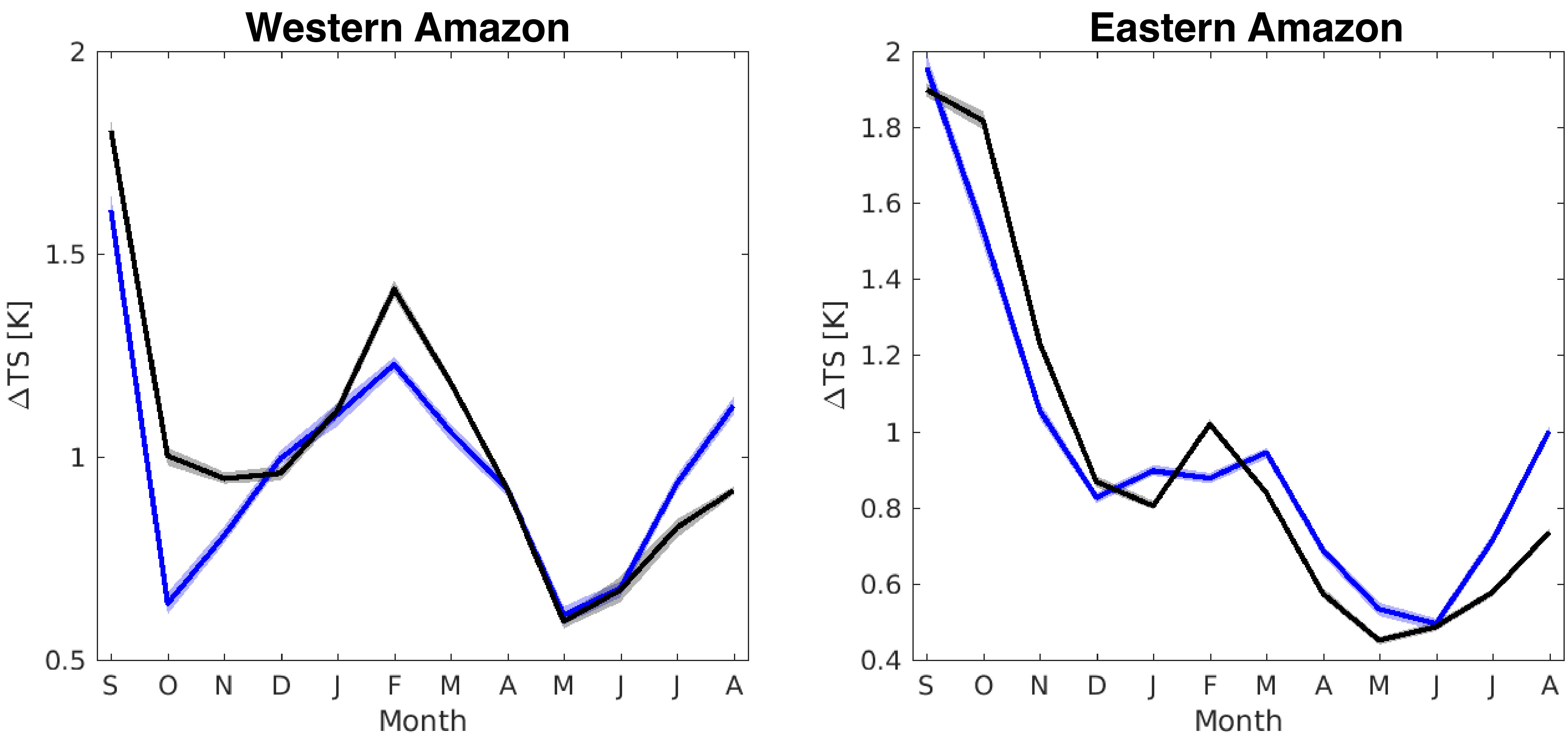


Baseline = GPP$^{-/neutral}$

ΔGPP = GPP$^{+/El\ Nino}$ — Baseline

ΔGPP = GPP$^{-/El\ Nino}$ — Baseline
+ GPP$^{+/neutral}$ — Baseline

Temperature is higher at start of hydrologic year, but similar the rest of the year

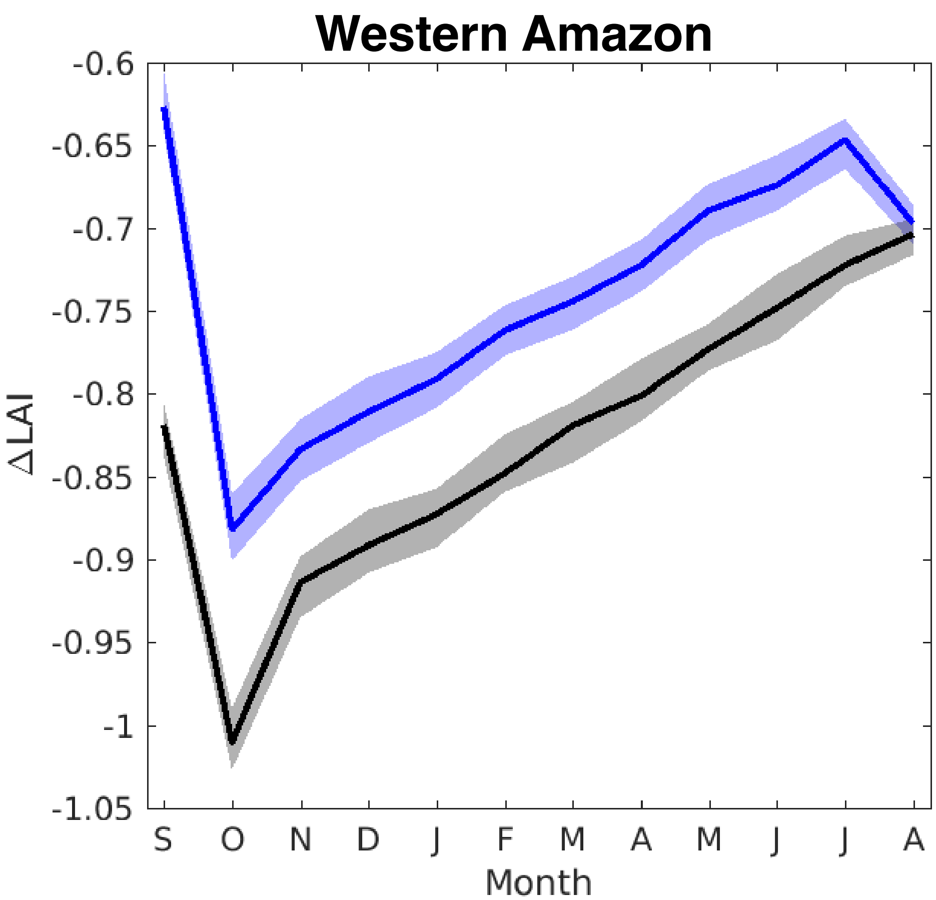


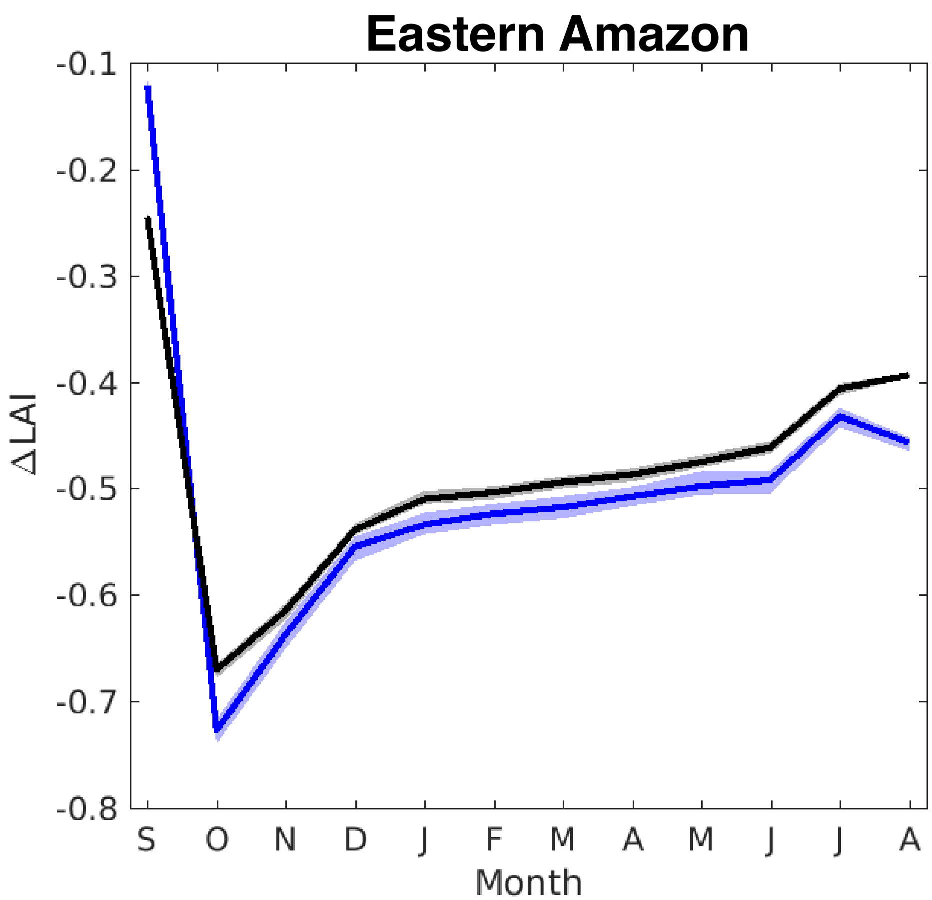
Baseline = GPP$^{-/\text{neutral}}$

ΔTS = TS$^{+/\text{El Nino}}$ — Baseline

ΔTS = TS$^{-/\text{El Nino}}$ — Baseline
+ TS$^{+/\text{neutral}}$ — Baseline

Leaf Area Index is substantially reduced at start of hydrologic year in the western Amazon due to higher



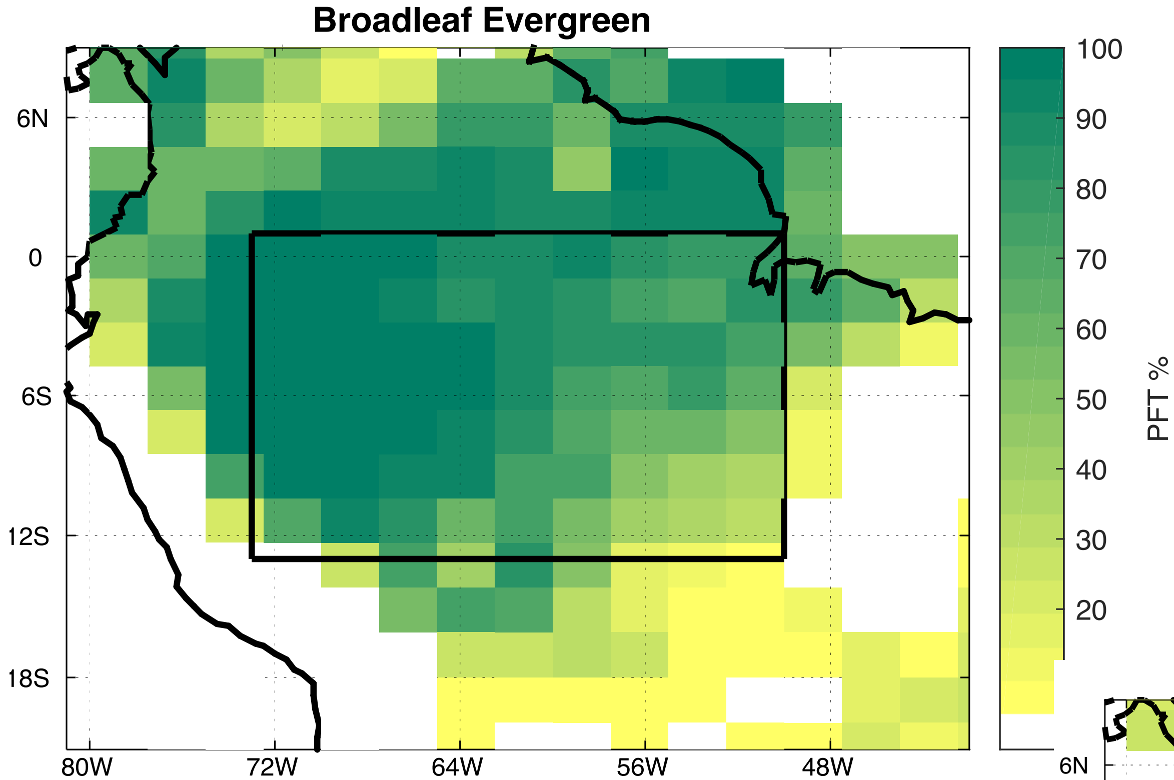


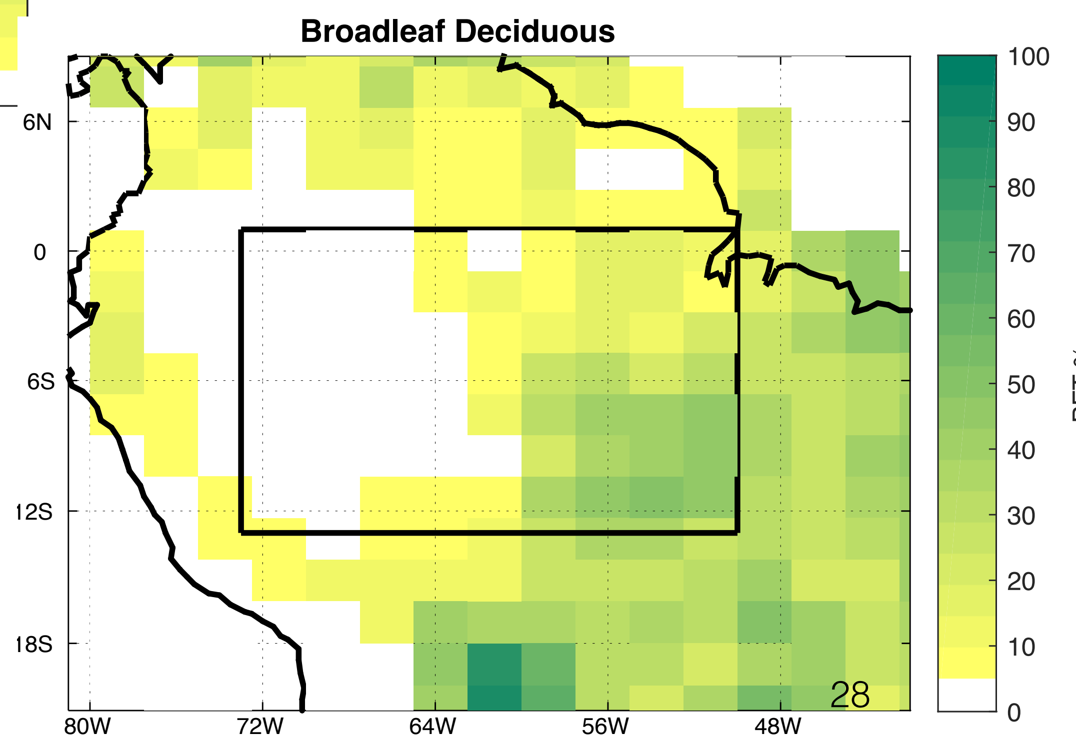
Baseline = $GPP^{-/neutral}$

ΔTS = $TS^{+/El\ Nino}$ — Baseline

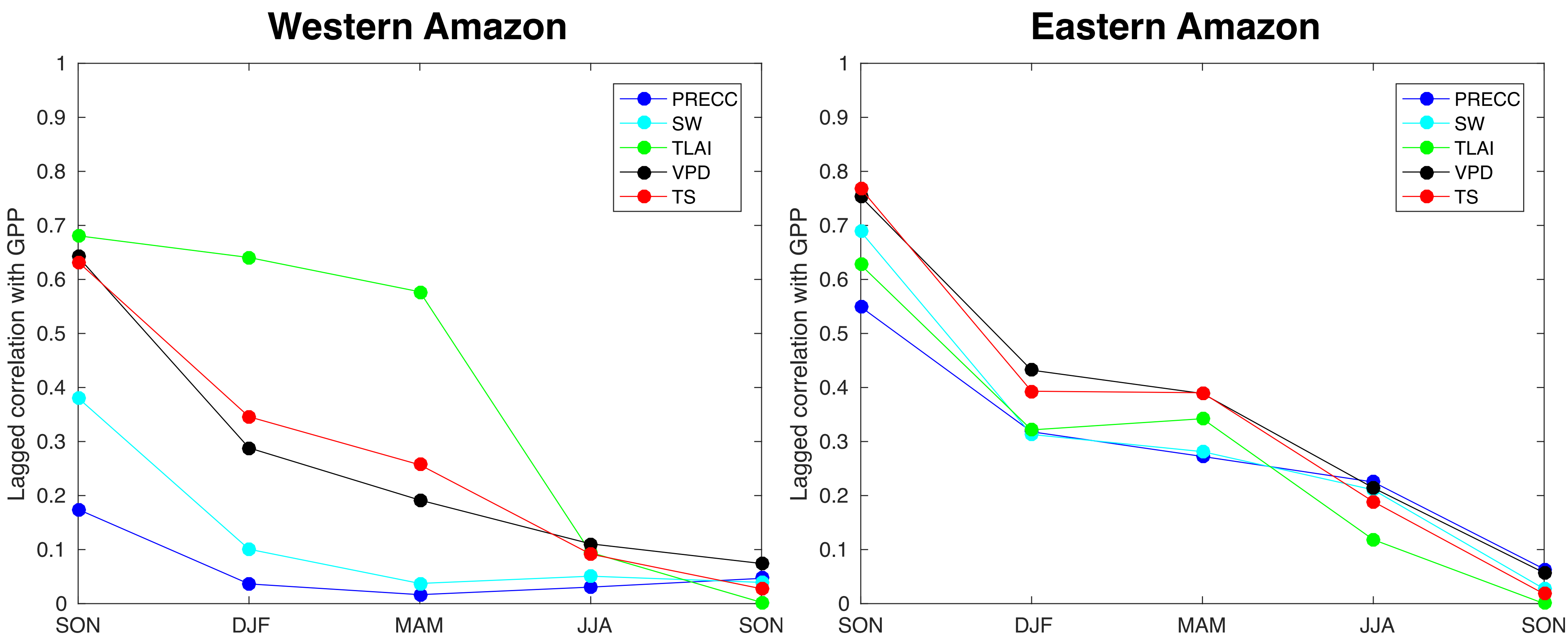
ΔTS = $TS^{-/El\ Nino}$ — Baseline
+ $TS^{+/neutral}$ — Baseline

Persistent LAI for broadleaf evergreen in western Amazon

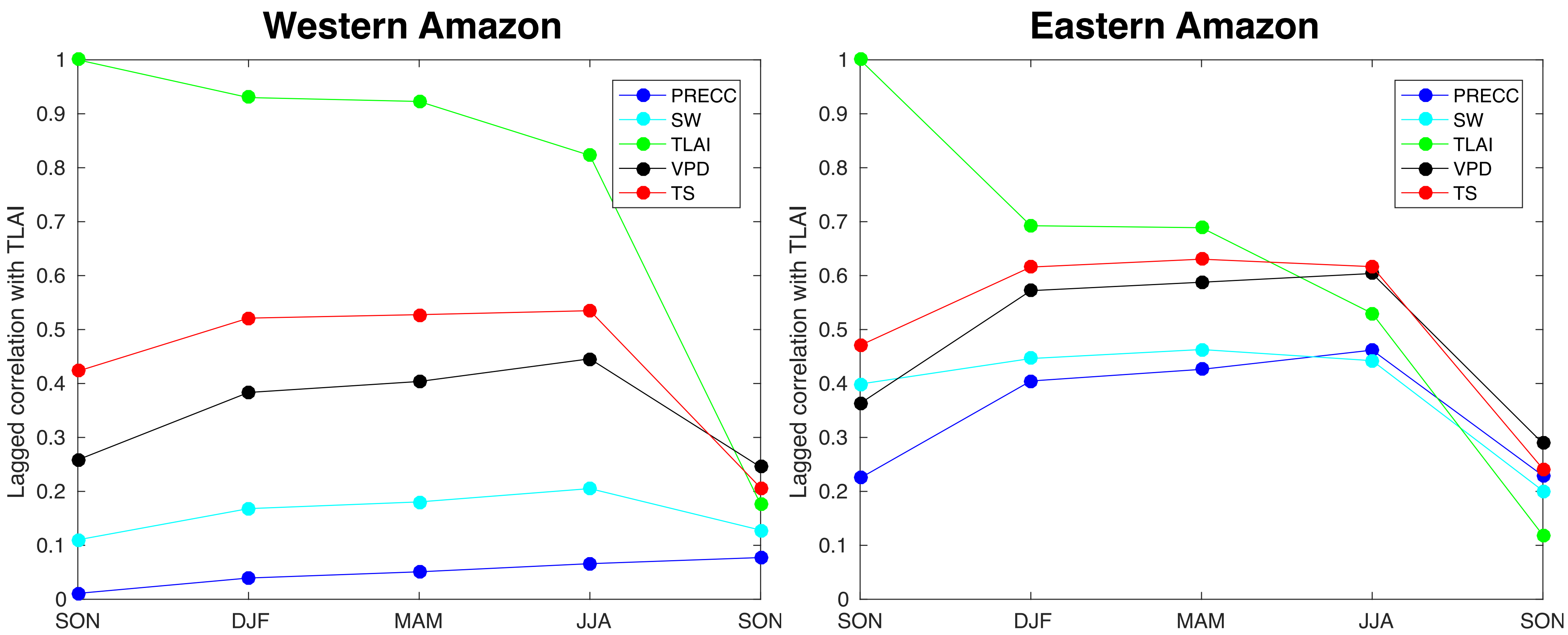




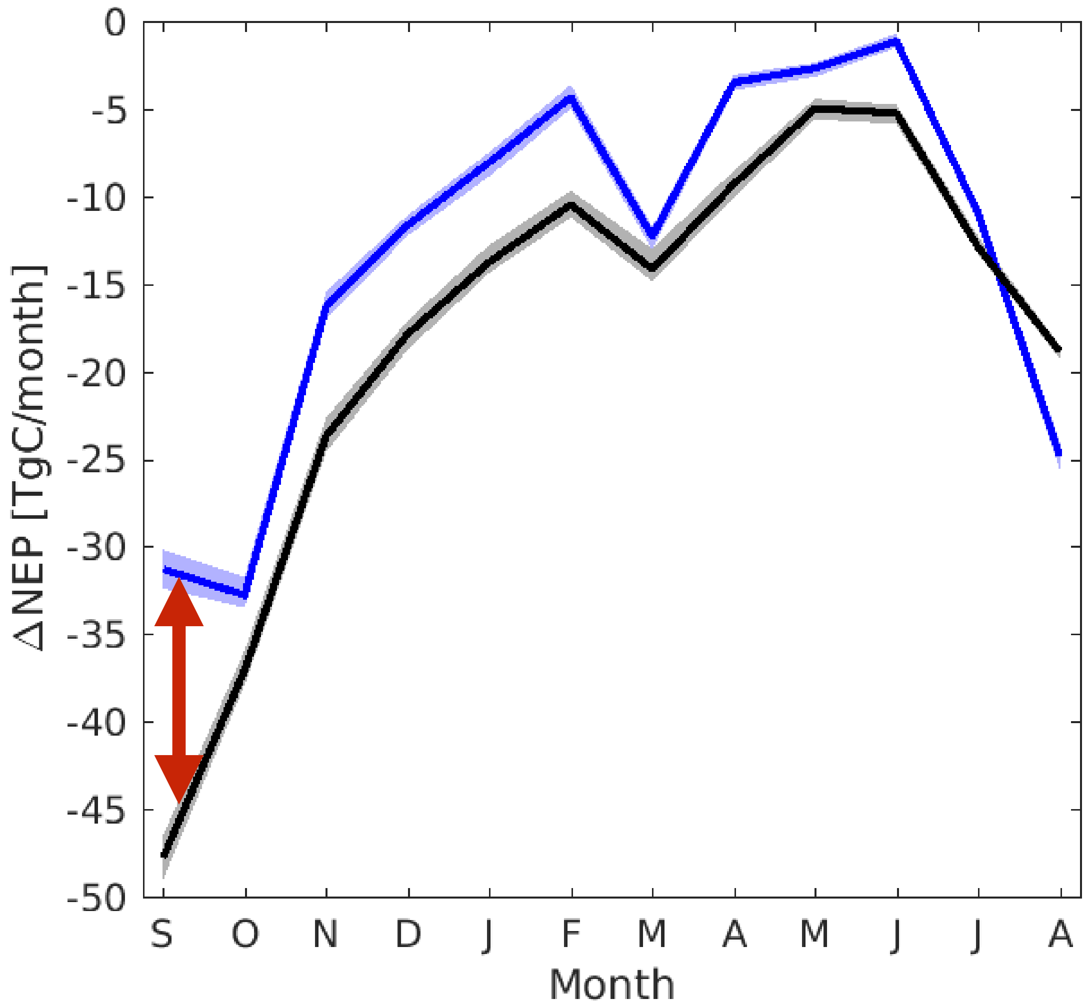
High autocorrelation for leaf area index and GPP drives nonlinear response to El Nino and AMO+ conditions



LAI for evergreen broadleaf in western half of domain shows strong memory effect



Together, AMO+ and El Nino conditions reduce NEP by 300 Tg over an annual cycle compared to AMO-/Neutral conditions



This value is 20% higher than if Atlantic and Pacific boundary conditions had independent, additive impacts

Atlantic and Pacific climate conditions drive variability in Amazon carbon cycling, with reduced gross and net uptake when oscillations are in their positive mode

The reduction in carbon uptake is larger than expected if climate oscillations have independent influence on land climate

The nonlinear reduction in carbon cycling can be traced to memory provided by LAI in broadleaf evergreen forests

These results are based on simulations, but could potentially be assessed in observations from satellite