Potential state shifts in terrestrial ecosystems related to changes in El Niño-Southern Oscillation dynamics

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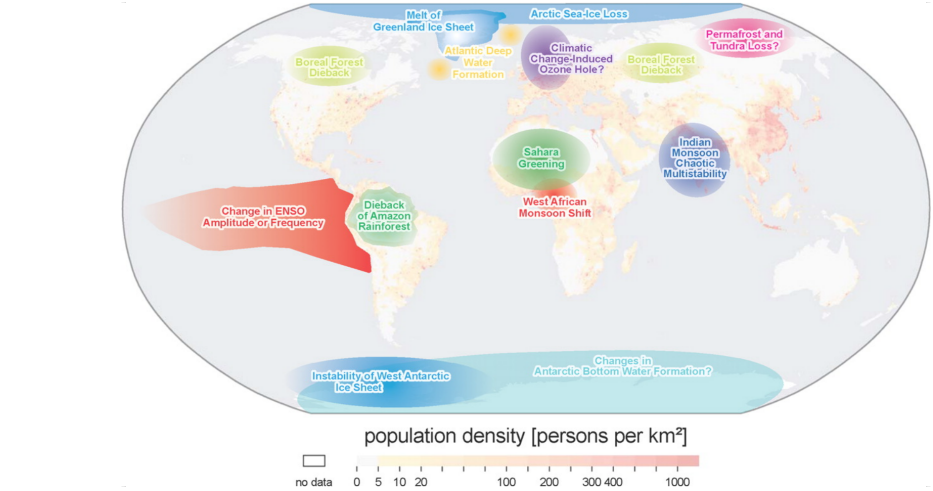
6th May 2020

Tipping elements and El Niño



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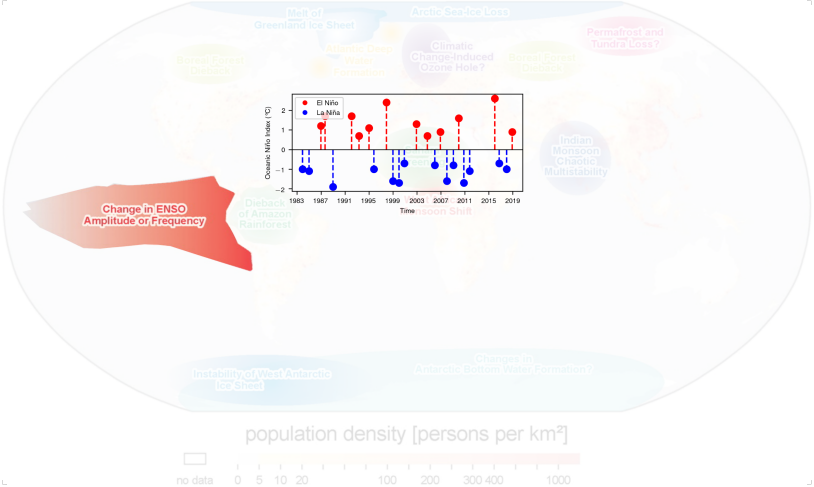

Original data from Climate Prediction Center (NOAA)

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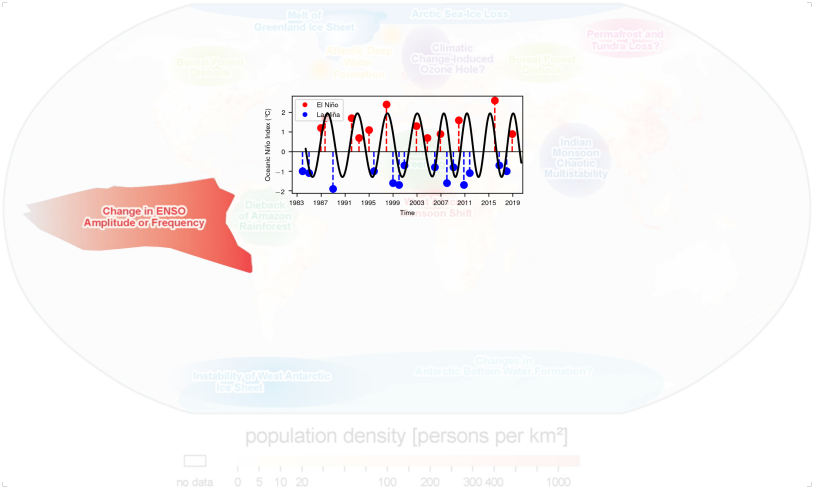

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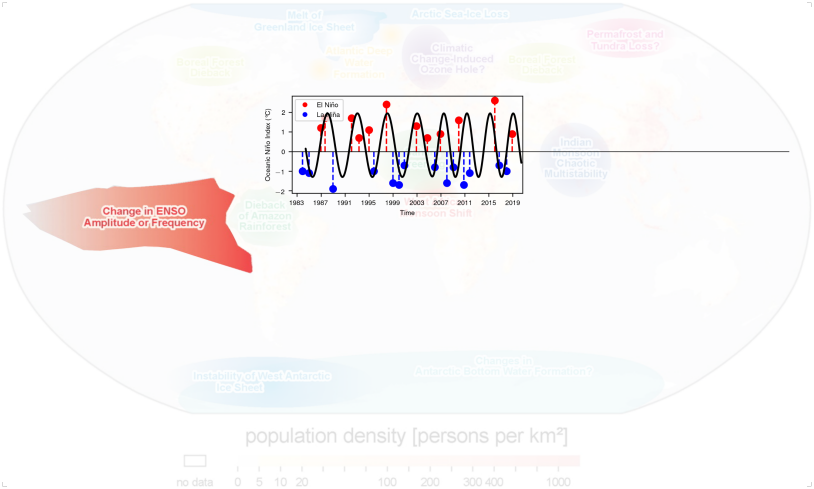

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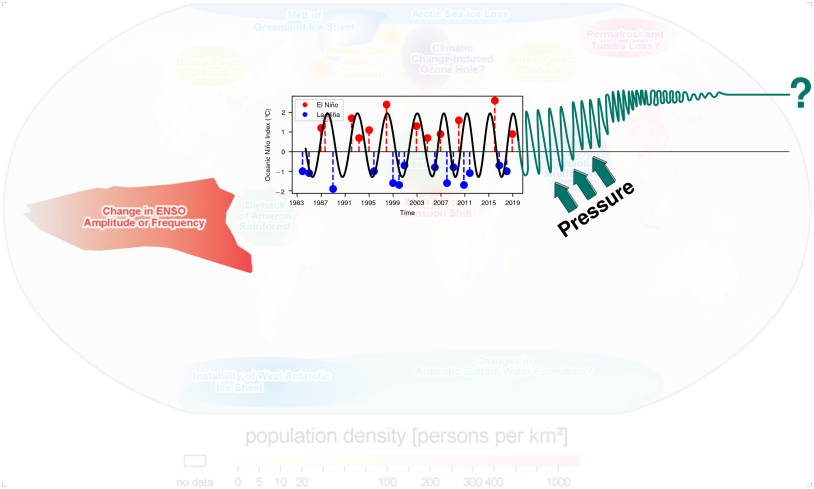

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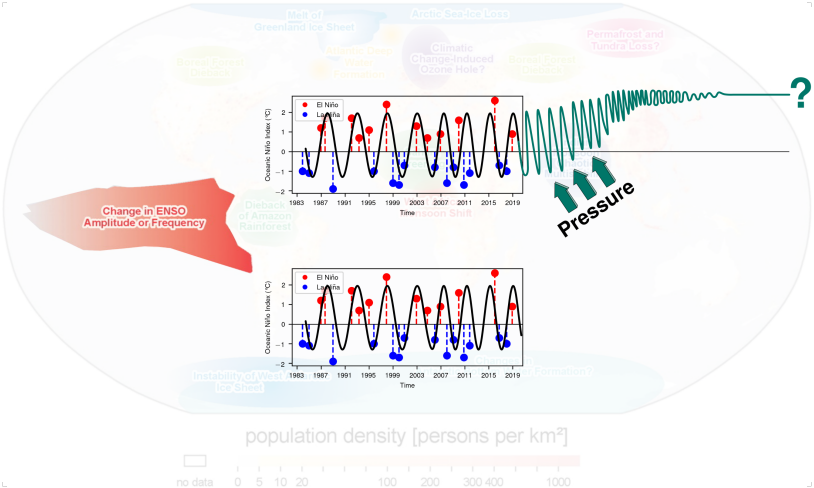

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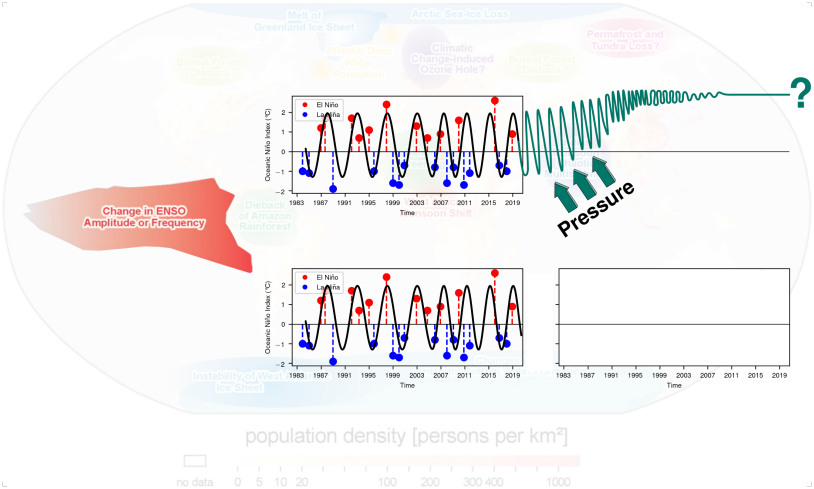

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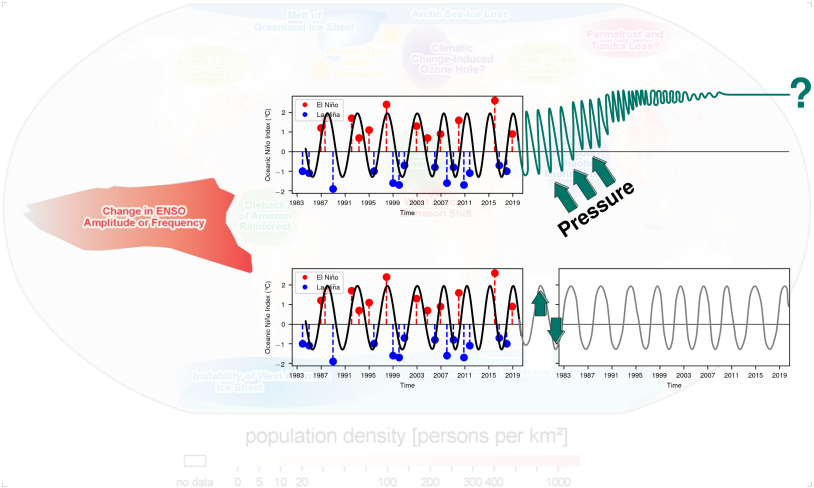

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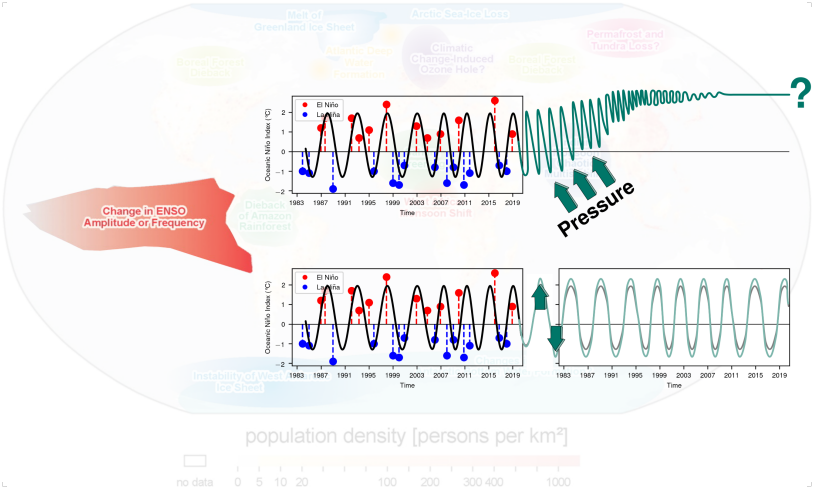

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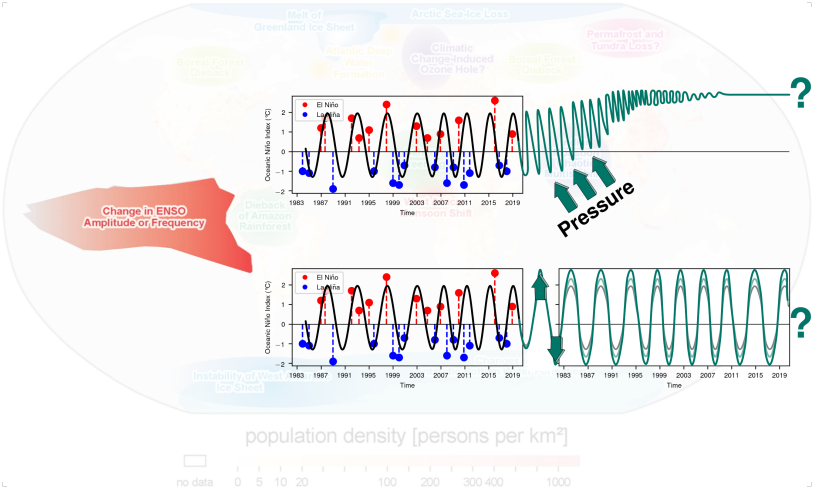

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Cai et al. (2015)

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1. What is more “increased frequency” than **permanent**?

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1. What is more "increased frequency" than **permanent**?
2. What happens when extremes become **more extreme**?

Water deficit and potential biome

- Amazon rainforest
- TRMM (1998–2005)
- Global Land Cover 2000
- Biome thresholds: savanna, seasonal forest and rainforest
- What do AR4 model projections say will happen to this pixels?
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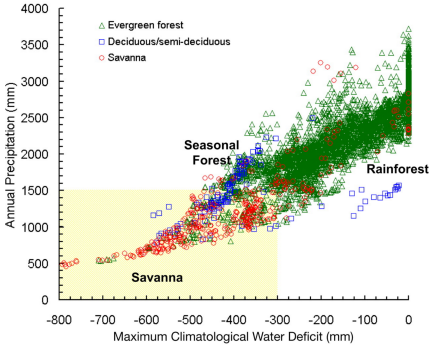

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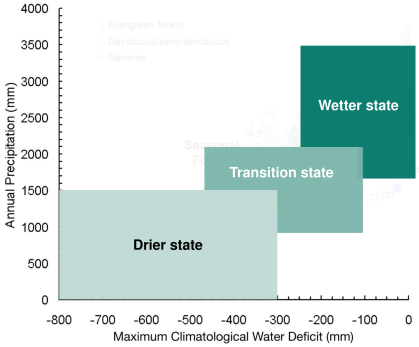

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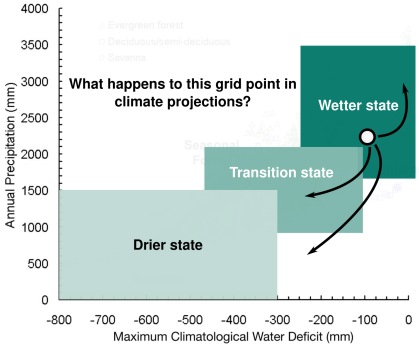

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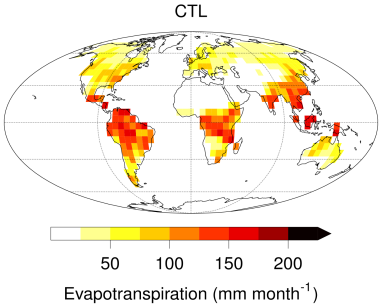

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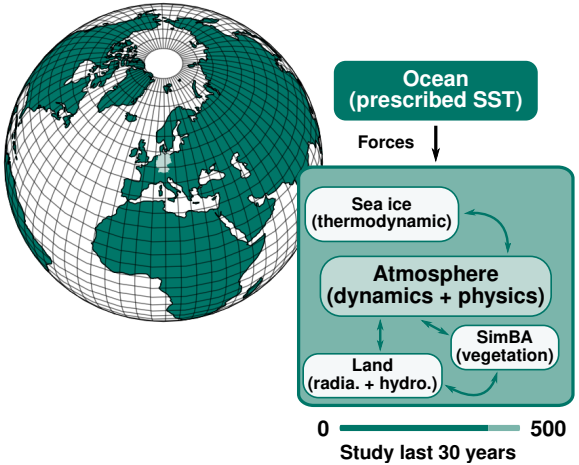
Planet Simulator (PlaSim)



See Lunkeit et al. (2011) and Fraedrich et al. (2005)

- CO_2: 415 ppm (380 ppm)
- Solar irradiance: 1365 W m^2
- Horizontal: T21 ($\approx$ 5.6)
- Vertical: 10 σ
- Present-day/default

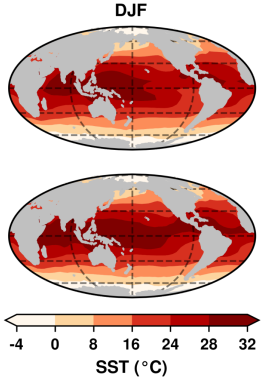
Data from observations and reanalyses

Variable	Data set	Period	Grid	Step
SST	Atmospheric Models Inter-comparison Project Phase II (AMIP-II)	1979–2016	1°	Monthly
Near surface temperature	HadCRUT4	1988–2017	5°	Monthly
Daily precipitation	Global Precipitation Climatology Project (GPCP)	1987–2016	2.5°	Monthly
Mean sea level pressure	HadSLP2	1979–2004	5°	Monthly
Gross Primary Productivity (GPP)	MODIS (MOD17A2)	2000–2015	1 km	Monthly
On pressure levels, radiative and water budgets	ERA-Interim	1987–2016	2.5°	Monthly

Simulation scenarios: frequency

ConTroL (CTL)
1979–2010

Permanent El Niño (PEN)
June 2015–May 2016



- Control and PEN scenarios
- Only difference between scenarios is SST
- Ensembles of 3 simulations for each scenario (random initial disturbance in pressure)
- Student's *t*-test with $\alpha = 0.05$
- Other signals?

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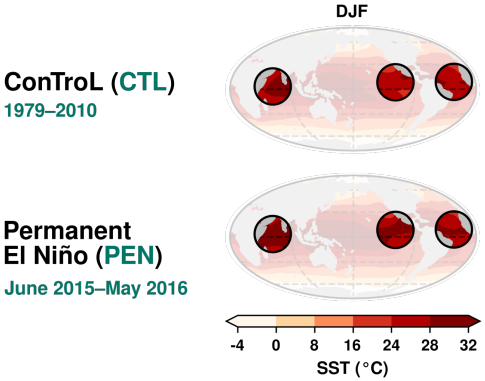

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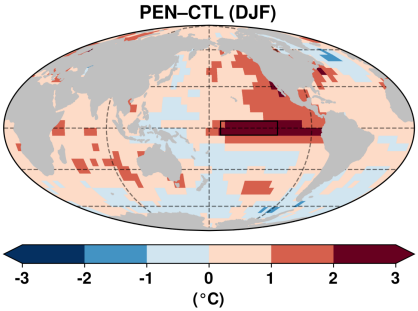

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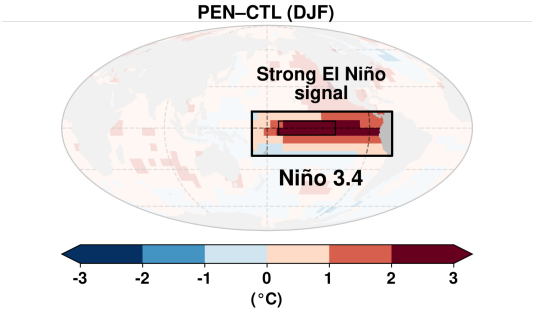

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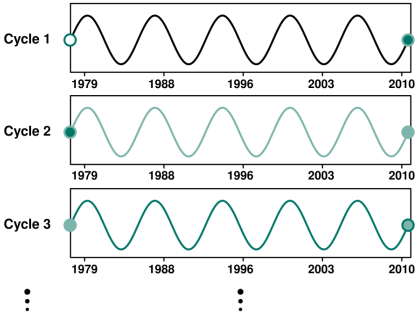
Simulation scenarios: amplitude

- Five cycles of SST 1979–2010
- A1 (control) and A2, A3, A5, A10, A12 scenarios
- Only difference between scenarios is amplified SST
- Only equatorial Pacific Ocean



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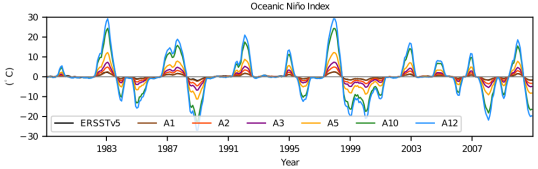

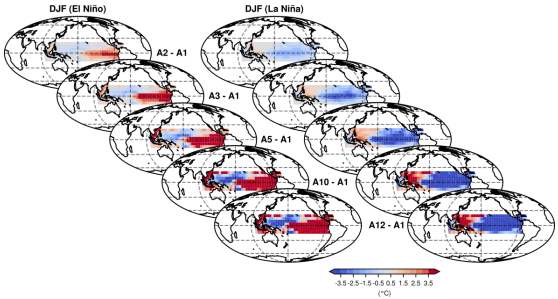

After days of CPU time and months of human time

Control climate evaluation

PlaSim used in many **sensitivity** experiments. Unfinished technical report about present-day values performance.

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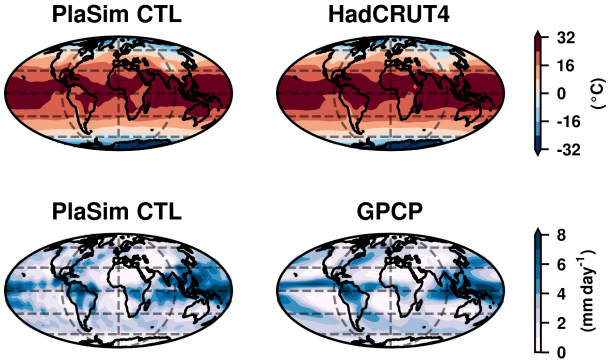
Our assessment with CTL and A1:

- Energy and water budgets fine
- Surface fields are realistic
- Vertical structure realistic
- ENSO variability is realistic



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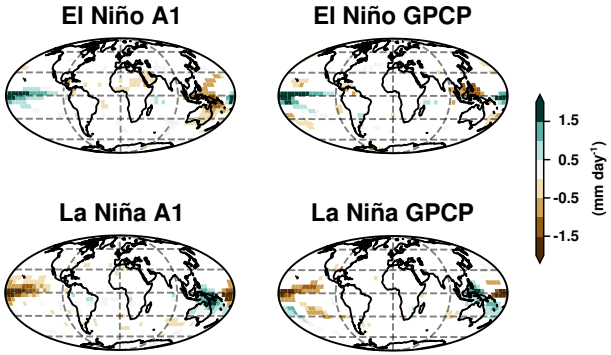
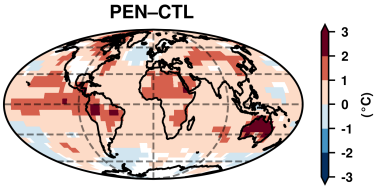
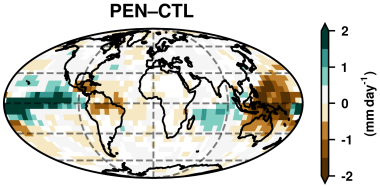


PEN climate

Near surface temperature



Total precipitation



- Warmer atmosphere
- Faster subtropical jets
- Water budget redistribution: more P over oceans
- Warmer and drier continents
- What happens to terrestrial ecosystems?

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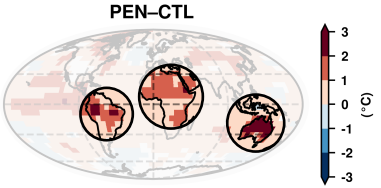

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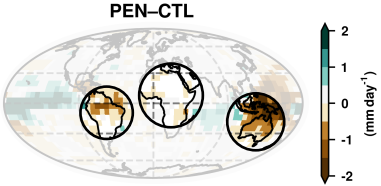

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Map and asymmetry

We **overlaid** differences maps (**PEN – CTL**) and categorized grid points with threshold **10% deviation from their value in CTL**:

Color			
MAP MCWD	much less much greater	much less greater	less much greater
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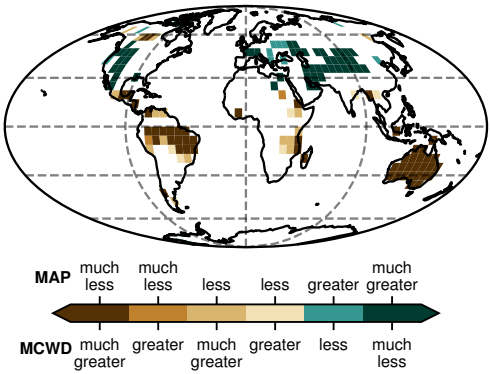

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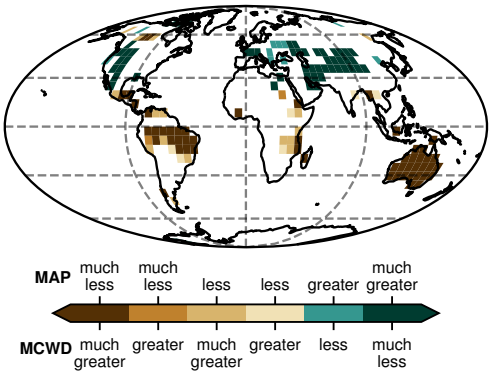
Color → **in PEN than in CTL**

MAP much less
MCWD much greater

Worst case in terms of water availability



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Best case in terms of water availability

Color	
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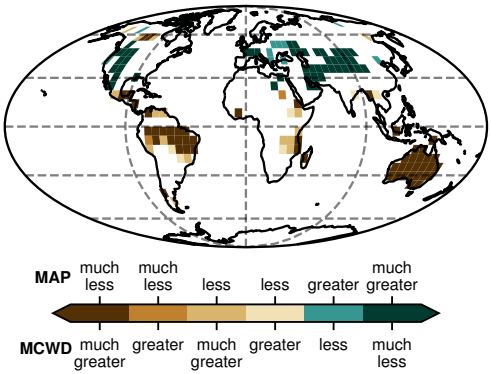
MCWD	much less



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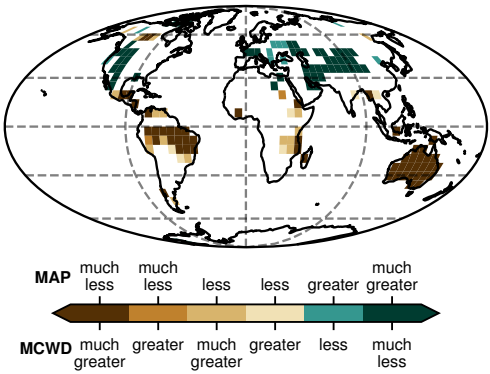

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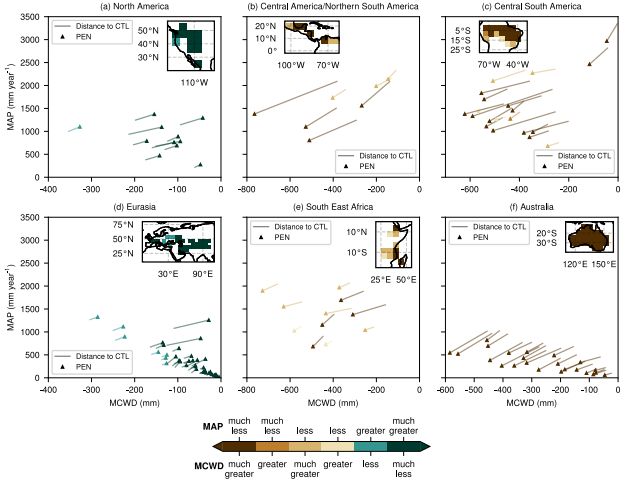
Potential biome shifts



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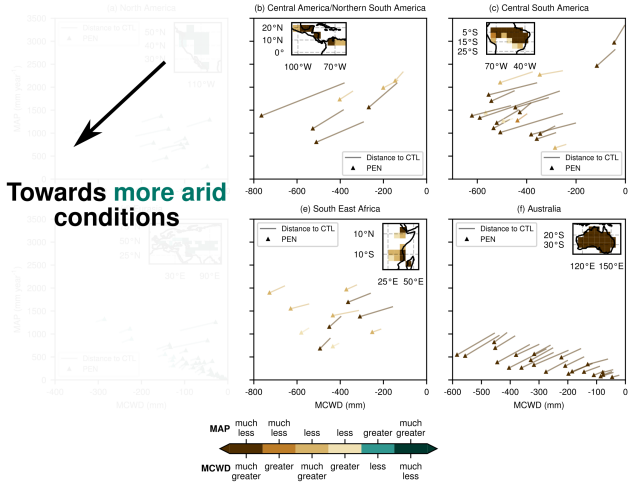

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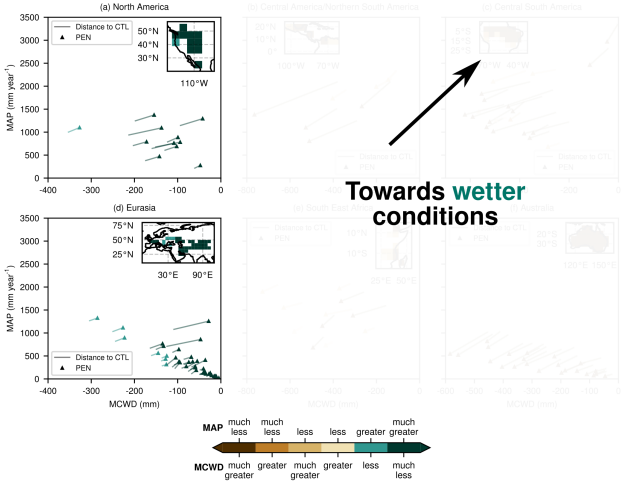

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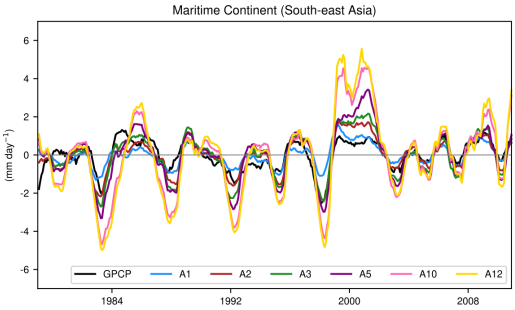
Amplified ENSO climates



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- PlaSim picked up the signals
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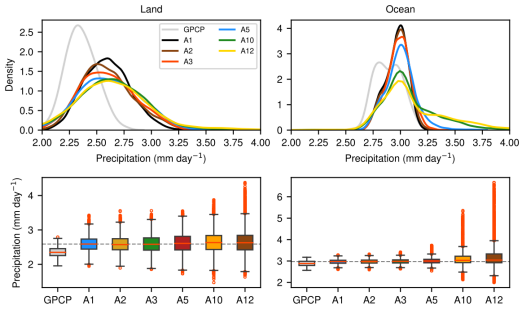

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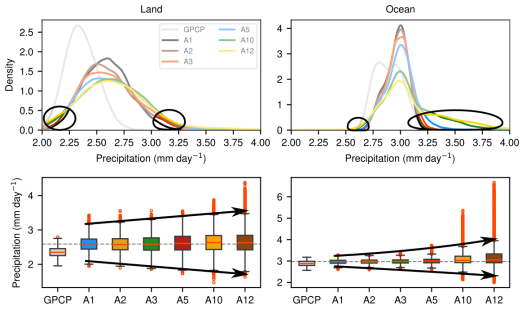
Amplified ENSO climates



- Work in progress
- PlaSim picked up the signals
- We study empirical PDF changes
- Extremes become more likely and more extreme
- Regional changes?

Final remarks

- PlaSim simulates climate well
- Global water budget changes in PEN scenario
- Asymmetric results: tropics contrasted by boreal latitudes
- PEN as a plausible mechanism for biome transitions
- With amplified ENSO, extreme values become more extreme

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