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Investigating the impact of different drought-heat signatures on carbon dynamics using a dynamic global vegetation model

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Background: the terrestrial carbon cycle

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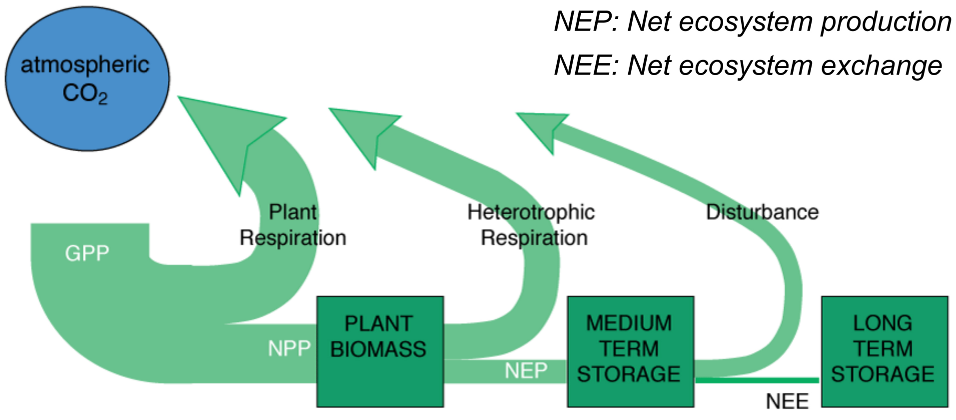
- The land biosphere has about 5 times more carbon stored than the modern atmosphere and about 10 times less than the ocean
- Changes in the terrestrial carbon storage directly and quickly affect the atmospheric CO_2 concentration
- The terrestrial biological productivity is limited by:
  - Water availability
  - Temperature conditions
  - Light conditions
  - Availability of nutrients
  - CO_2 concentrations

GPP: Gross primary production
NPP: Net primary production
NEP: Net ecosystem production
NEE: Net ecosystem exchange



$NPP = GPP - R_a$

$NEP = NPP - R_h$

$NEE = NEP - disturbance = NPP - R_h - disturbance$

credits to Nicolas Gruber

Background: drought, heat and the carbon cycle

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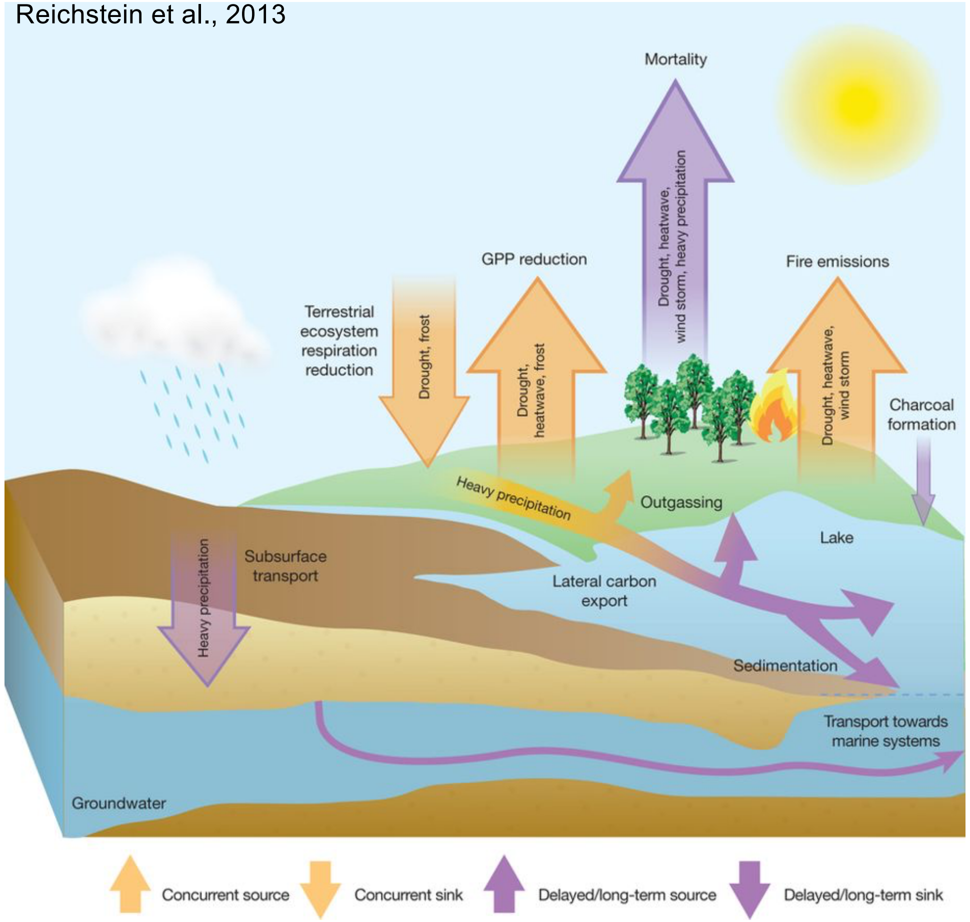
- Droughts and heat waves can have fundamental and long-lasting impacts on carbon dynamics
- Studying differential impacts (impacts of single extremes vs compound[1] extremes) and lagged impacts require a controlled environment an are difficult to study in the field
- Vegetation models offer excellent tools to explore different hypotheses

Reichstein et al., 2013



1 „the combination of multiple drivers and/or hazards that contributes to societal or environmental risk“ Zscheischler et al, 2018

Research questions

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- What is the impact of compound drought and heat compared to drought and heat alone on carbon dynamics (fluxes, variability) and carbon pools?
- Can frequent drought and heat waves trigger shifts in vegetation?
- What is the difference in the response between biomes (e.g. grasslands and forests) to different drought-heat signatures (forcing scenarios)?
- Can the clustered occurrence of droughts and heat waves push an ecosystem from carbon sink to carbon source on the long run?

Data and Method

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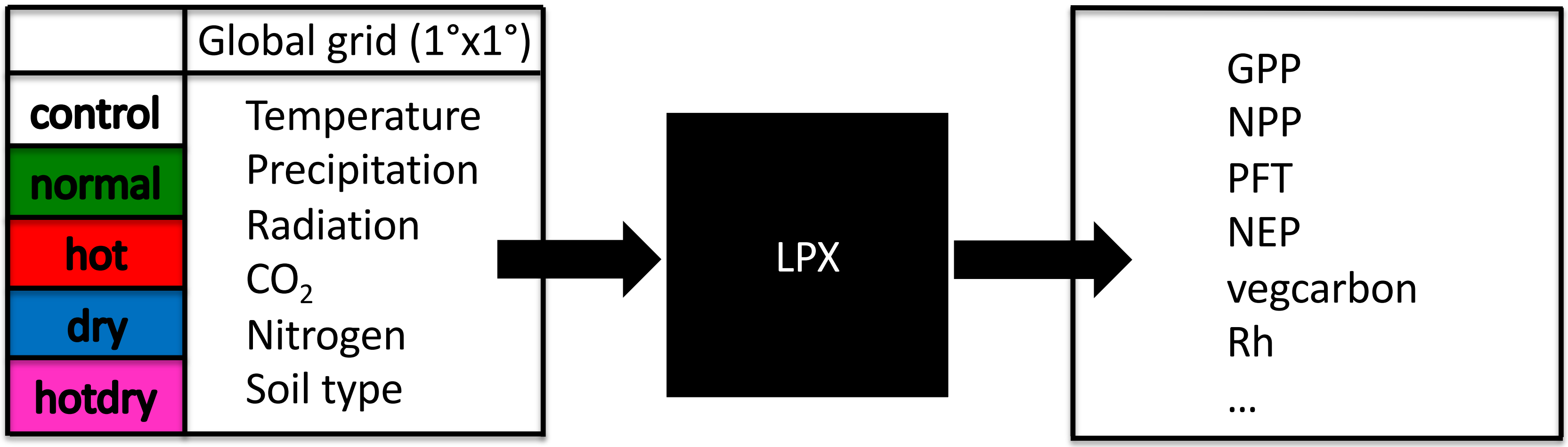
- 2000 years of present day (2011-2015) climate from EC-Earth (Hazeleger et al., 2012) to sample scenarios from
- For each grid cell, 5 forcing scenarios with different drought-heat signatures (each 100 years long, 50 extreme and 50 rest years)
- Run scenarios with the dynamic global vegetation model LPX-Bern (v1.4)
- LPX-Bern has 10 Plant Functional Types (PFTs)



Method: scenario sampling (illustrated for one grid point)

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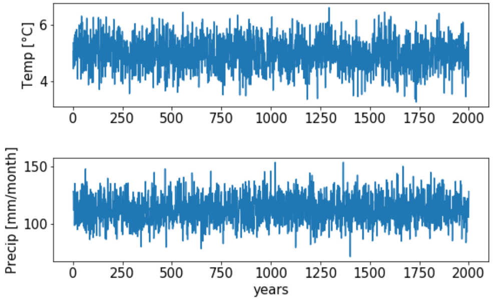
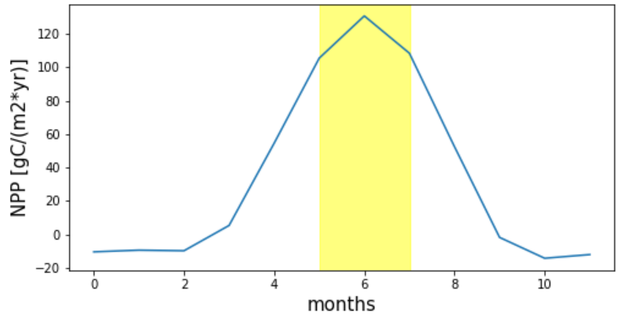
1)



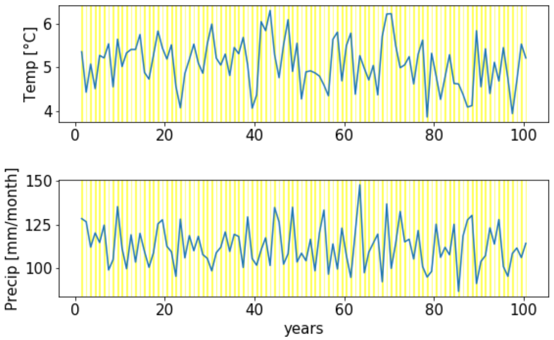
2000 years of daily temperature and precipitation

2)



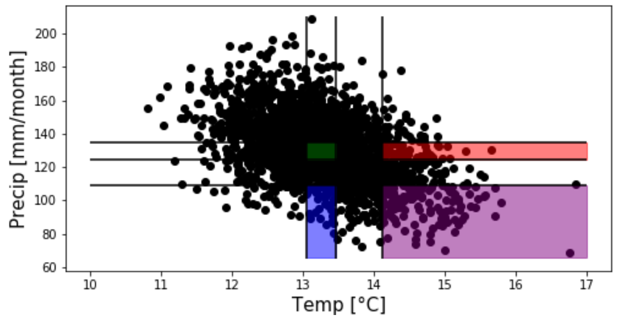
From the mean seasonal cycle of NPP, choose the most productive months

3)



Take the mean over these three months for temperature and precipitation

4)



Choose years with 3-months mean temperature and precipitation in quantile corresponding to scenario

Method: scenario sampling (illustrated for one grid point)

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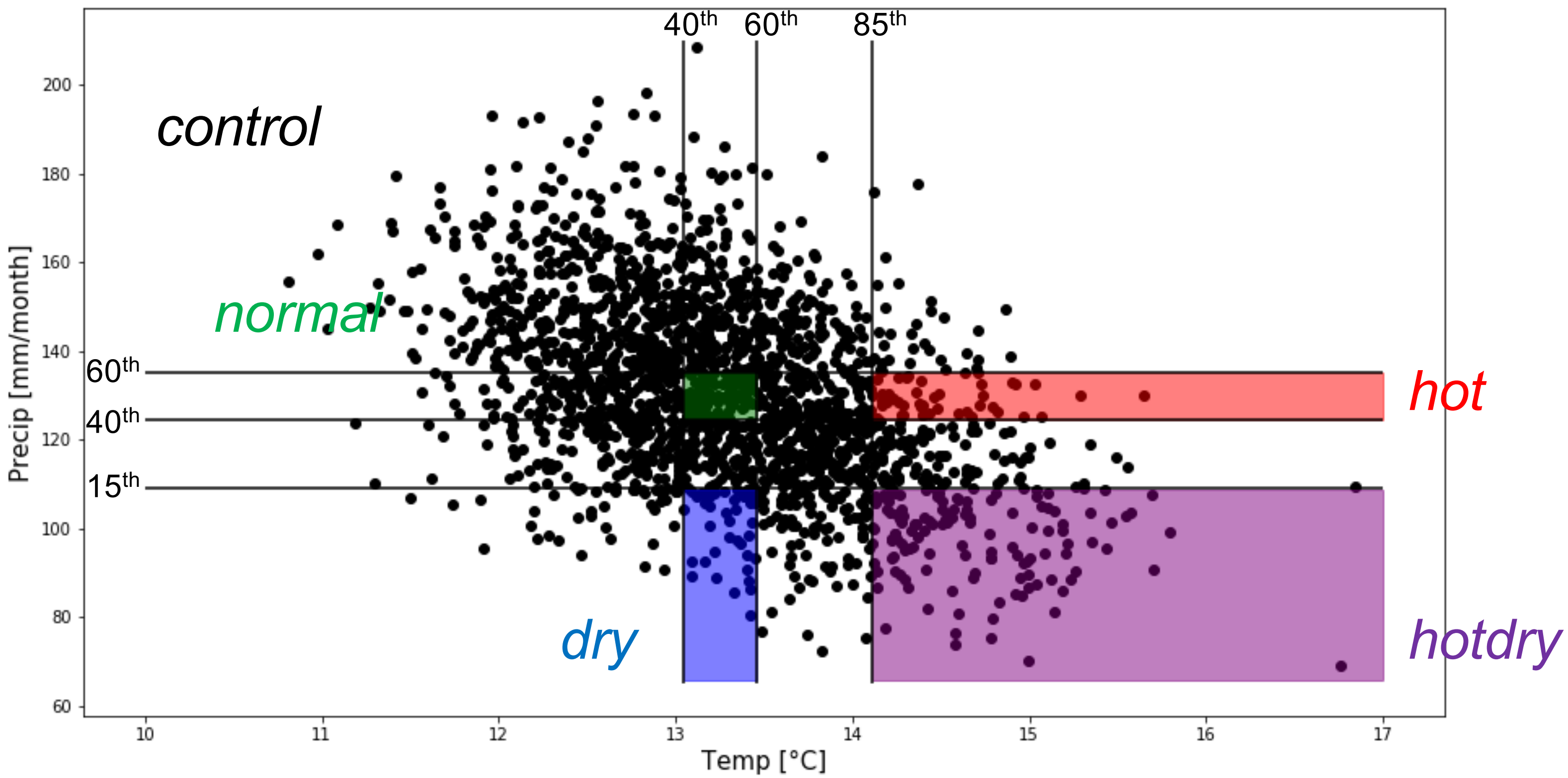

For each scenario, 50 years were sampled from the respective quandrant and 50 years from the rest. Only for *normal* (no extremes) were all 100 years sampled from the normal quadrant.

Results: global mean overview of scenarios

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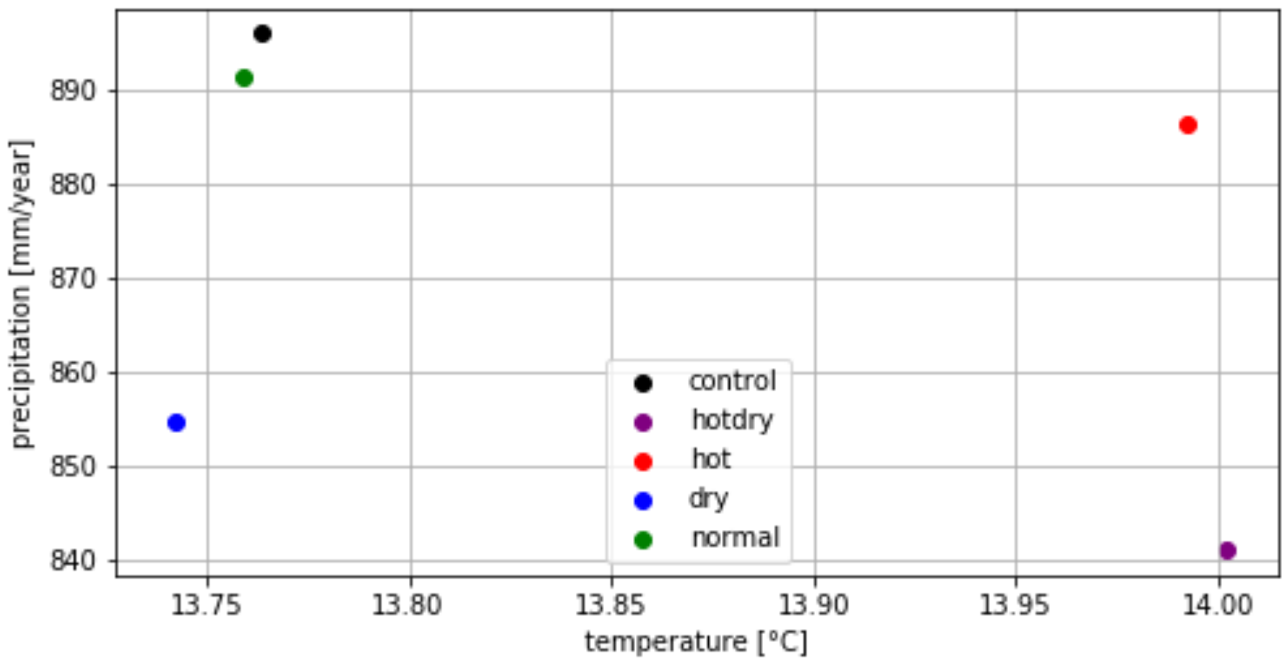
- Differences in temperature are around 0.3° C
- Differences in precipitation are around 4mm/month



Global averages of precipitation and temperature for all scenarios and the control run.

Results: effects on PFTs

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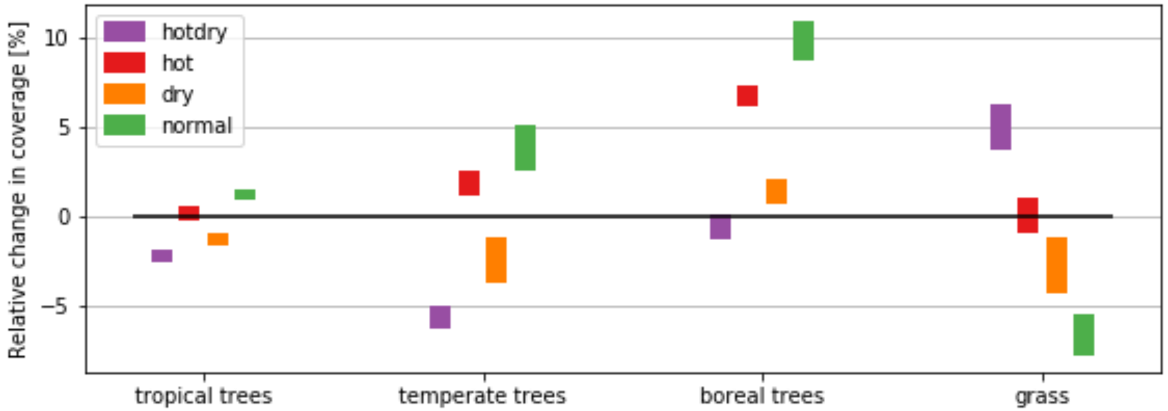
> Compared to the control
  — *Hotdry* reduces all trees and promotes grasslands
  — *Hot* favours trees while grass stays the same
  — *Dry* leads to a shift from tropical/temperate to boreal trees and reduces grasslands
  — *Normal* (no extremes) favours trees over grasslands

> Trees prefer a climate without any extremes

> All trees dislike combined hot and dry extremes

Global mean bars showing the range of PFT fractions over 100 years for each scenario – control.



Results: global PFT shifts

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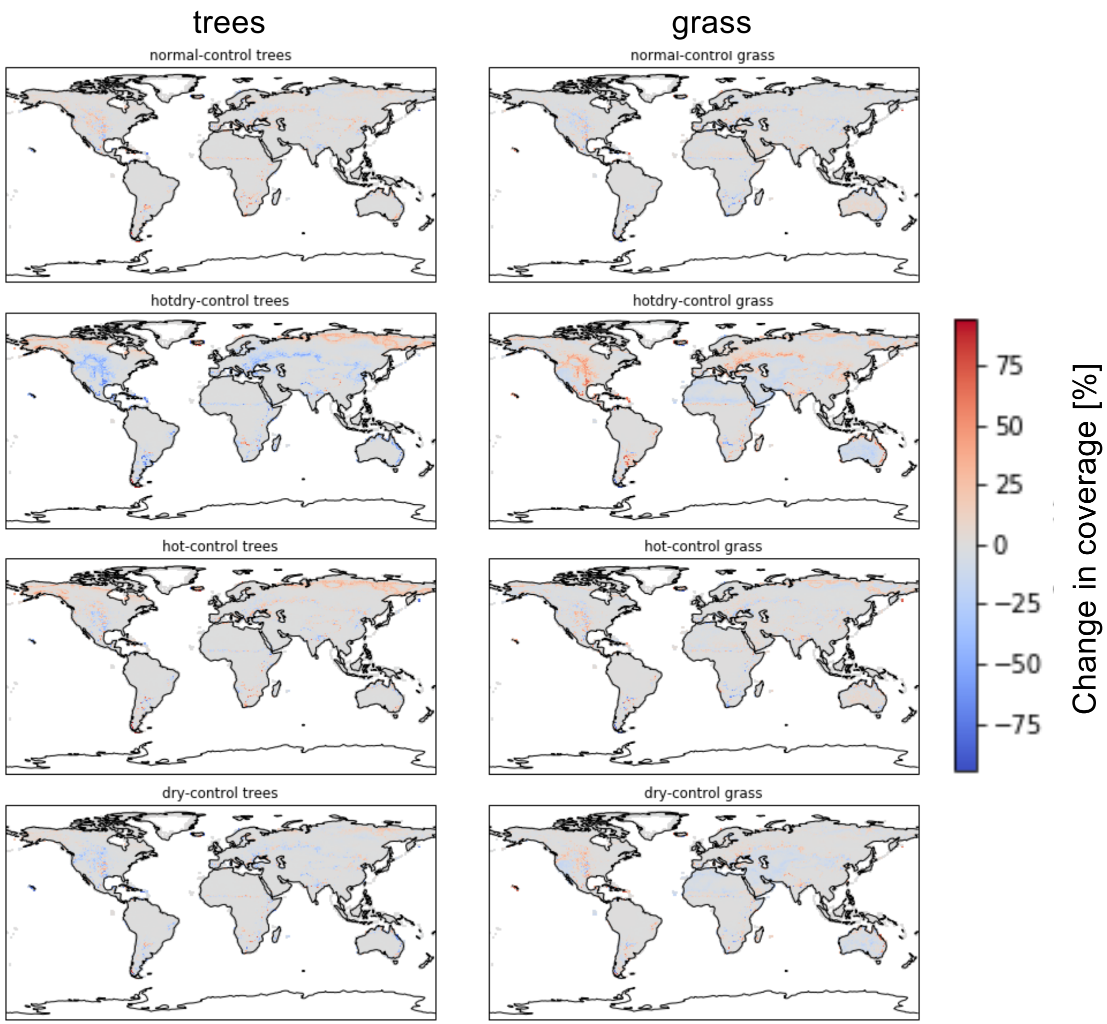
- The influence of *hotdry* is larger than both *hot* and *dry* for midlatitudes
- Trees in high latitudes grow better in hotter climate



Maps showing mean differences between the scenarios and the control for tree and grass PFTs.

Conclusions

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- The setup and sampling of the scenarios seem to make sense
- The mean climate differences between the scenarios are small, which allows us to investigate the effects of climate extremes on vegetation structure and carbon dynamics
- The different scenarios have, even in the global mean, an effect on the PFT distribution

Outlook

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> Quantify the climate extremes in the scenarios

> Study carbon pool and flux responses in the scenarios

> Compare results with multiple vegetation models

References

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