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CLIMATE CHANGE RESEARCH

The effect of differing drought-heat signatures on terrestrial carbon dynamics and vegetation composition

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vEGU21, 28th of April 2021

Introduction: drought, heat and the carbon cycle

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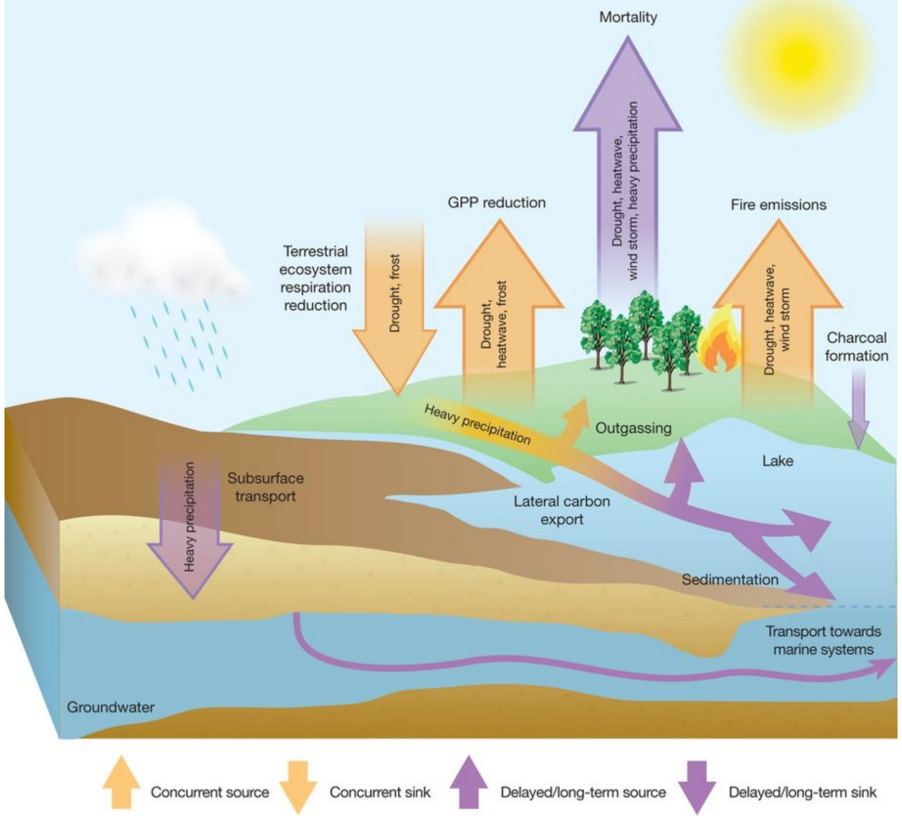
- Droughts and heat waves can have fundamental and long-lasting impacts on carbon dynamics

- Studying differential impacts (impacts of single extremes vs compound[1] extremes) and lagged impacts require a controlled environment and 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

- 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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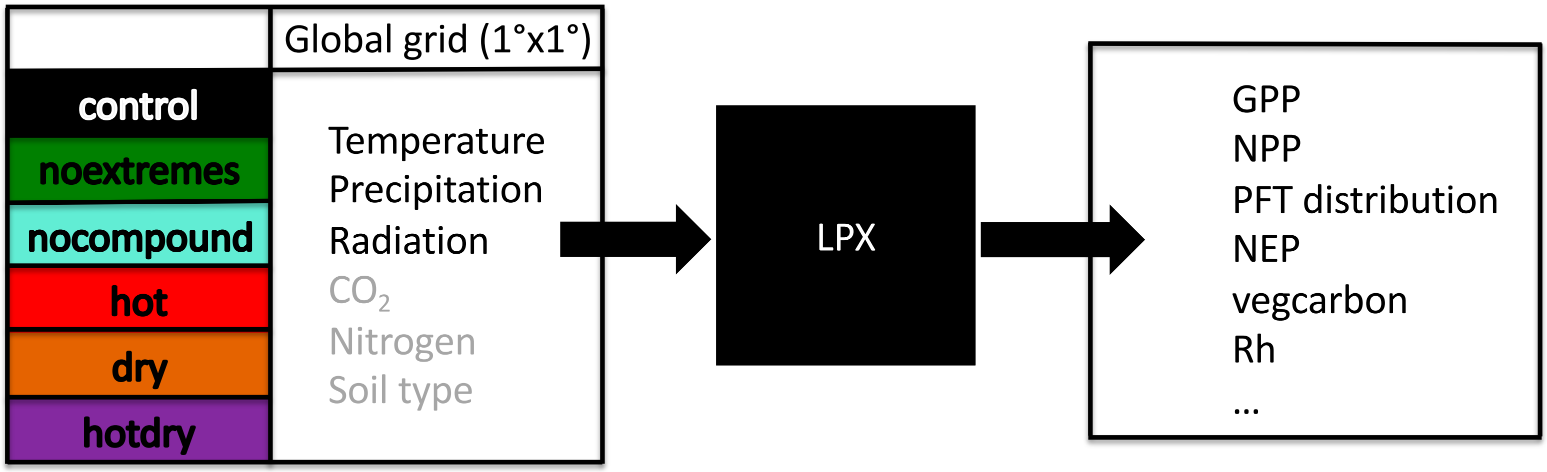
- Input data sampled from 2000 years of present day (2011-2015) climate from EC-Earth (Hazeleger et al., 2012)
- Sample 6 forcing scenarios with different drought-heat signatures (each 100 years long)
- Run the dynamic global vegetation model LPX-Bern (v1.4) with the scenarios



Method: scenario sampling (illustrated for one grid point)

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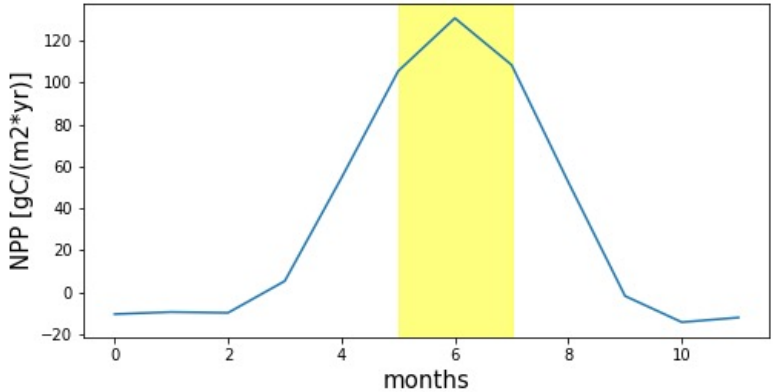
1) Run LPX with 2000 years of quasi-stationary daily temperature, precipitation and radiation (EC-Earth)

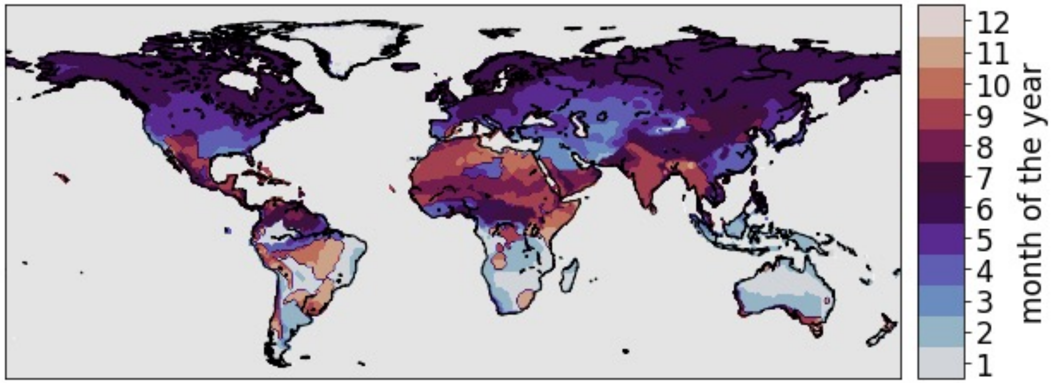
2) From the mean seasonal cycle of NPP, choose the most productive month (map on the right)

3) Take the mean temperature and precipitation over the three months centred on the most productive one

Mean seasonal cycle of NPP



Month of the year where NPP is at its maximum



Method: scenario sampling (illustrated for one grid point)

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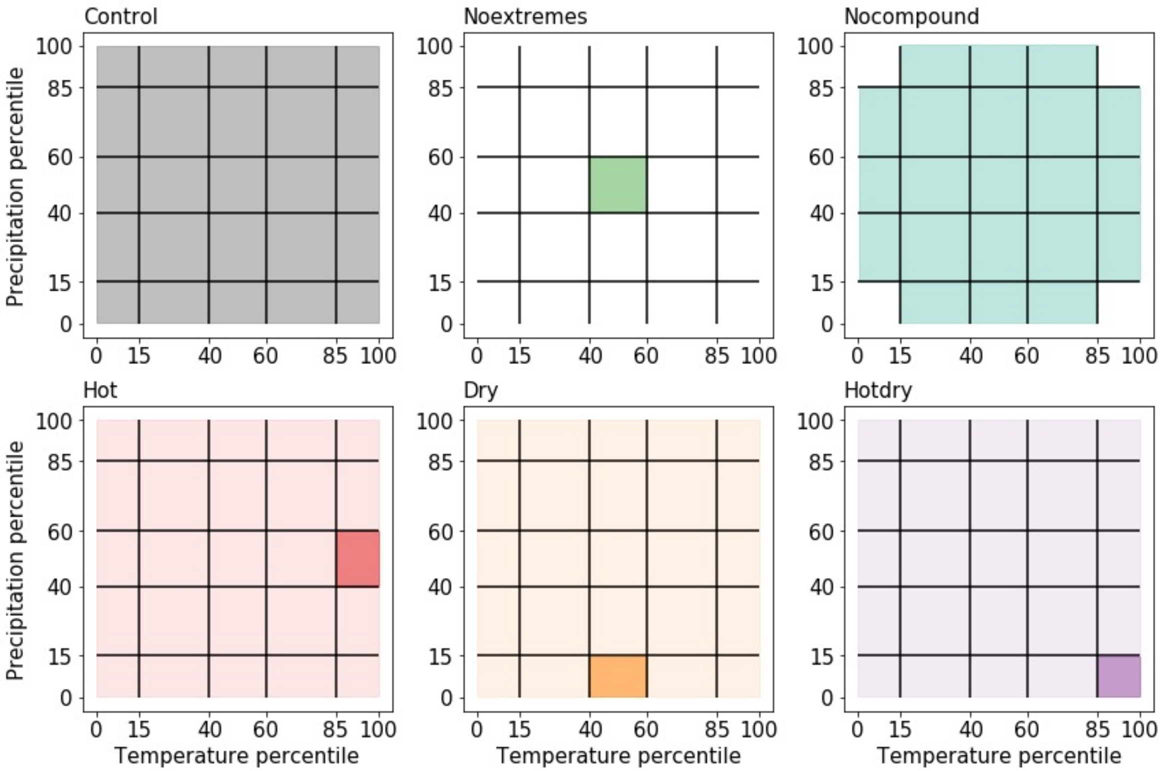
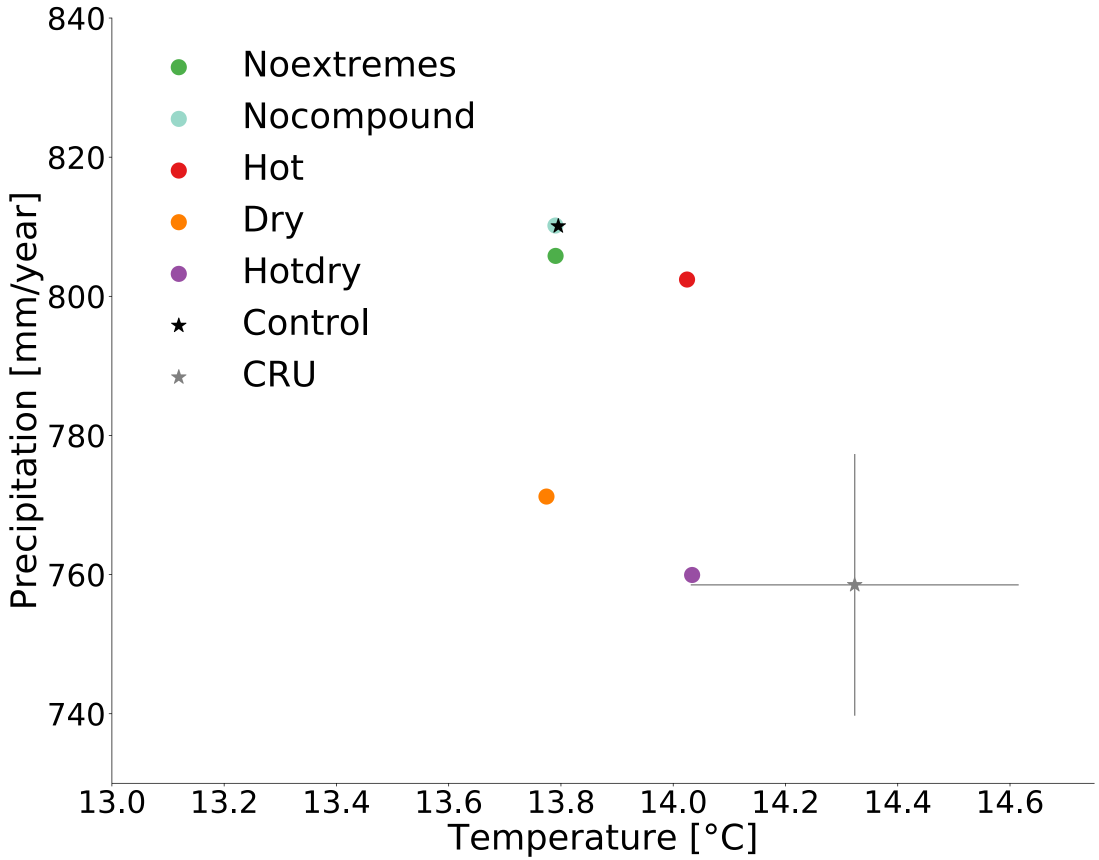
4) Choose years with 3-months mean temperature and precipitation in quantile corresponding to scenario
5) The 100 years were sampled from the colored area for each scenario. If there are two shades, 50 years were sampled form each

- This sampling process was repeated for each grid point, therefore the climate in one grid point is independent form the climate in neighbouring grid points



Data: global mean overview of scenarios

- Global and temporal mean of temperature and precipitation for all scenarios, as well as for CRU (as a reference)
- Differences in temperature between the scenarios are around 0.3°C
- Differences in precipitation between the scenarios are around 6%



Data: compound extremes

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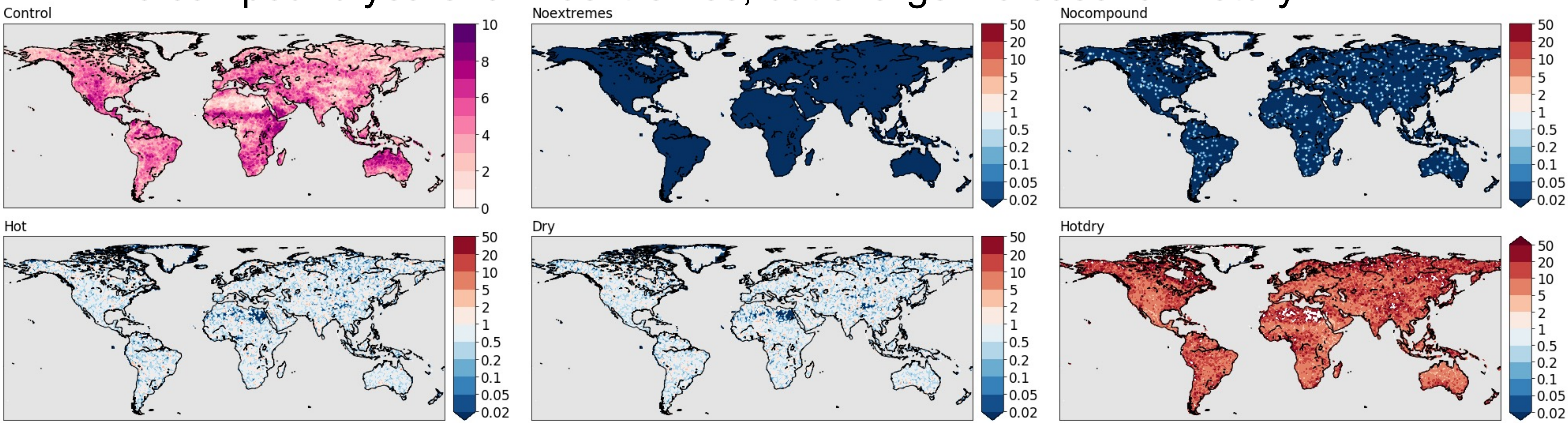
- Number of years with temperature above the 90th percentile AND precipitation below the 10th percentile (topleft panel) and probability ratios for the scenarios to the control (other panels)
- No compound years for Noextremes, but a large increase for Hotdry



Methods: PFT classes

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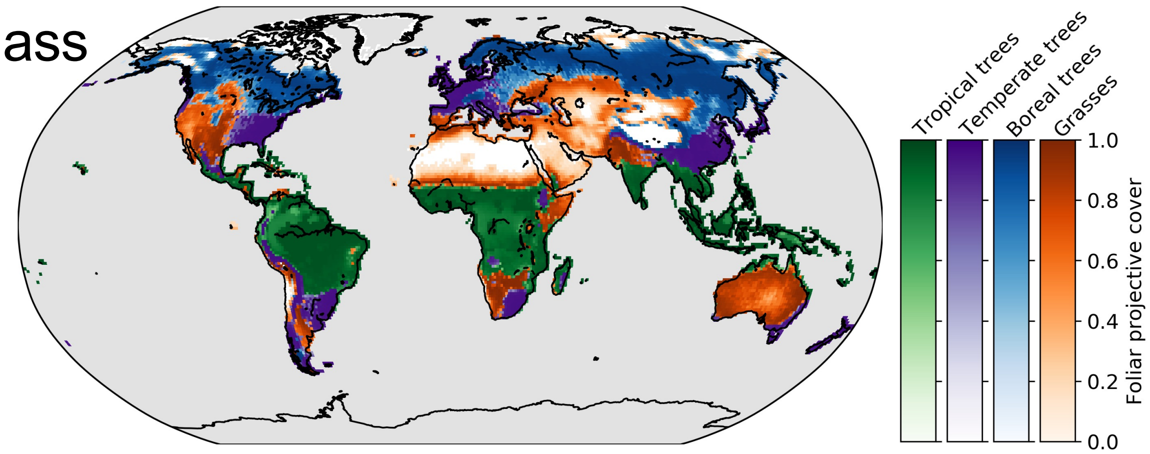
- LPX's 10 natural plant functional types (PFTs) are summed up in four classes for this study
  - Tropical trees: broad evergreen, broad raingreen
  - Temperate trees: needle evergreen, broad evergreen, broad summergreen
  - Boreal trees: needle evergreen, needle summergreen, broad summergreen
  - Grasses: temperate and tropical herbaceous
- The map shows the dominant PFT class at each grid point for the Control (mean over time). The colorbars indicate the fraction of the grid point covered by the indicated PFT class



Methods: constant and changing runs with LPX

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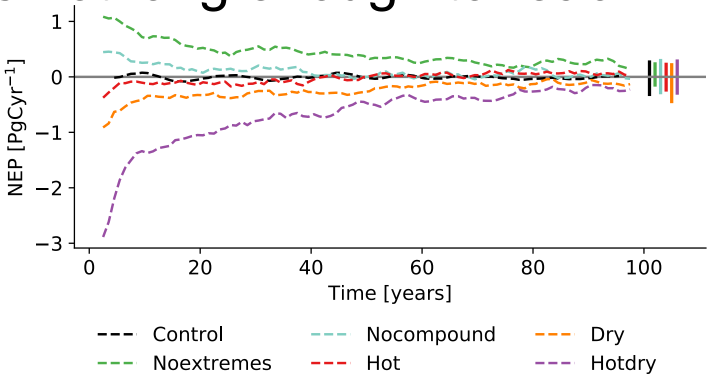
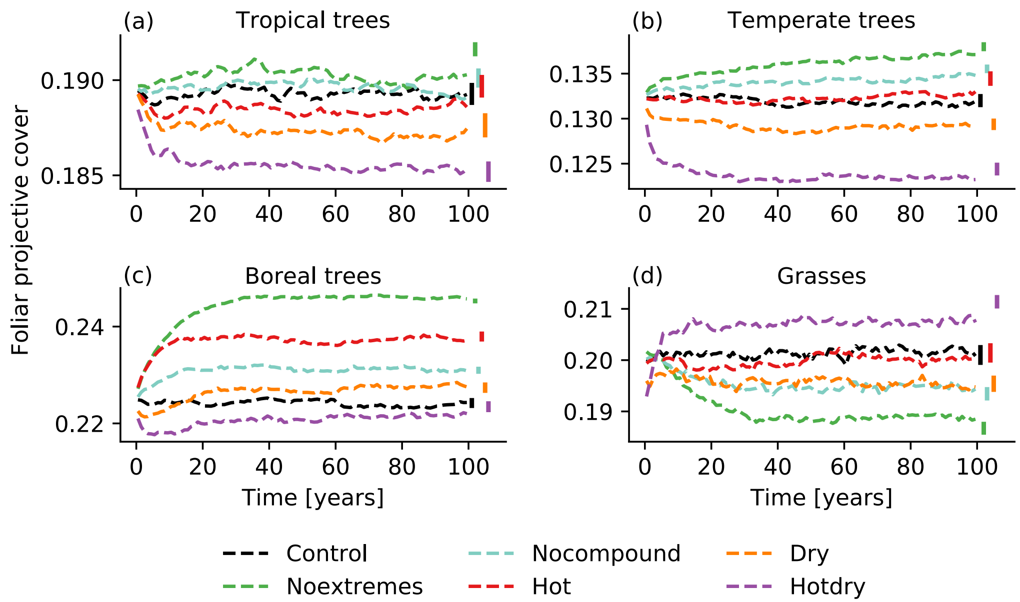
- Two different spin-ups were used
  - Constant: using the scenarios own data for the spin-up (minimum to maximum range over time is shown as bars on the right in the plots below)
  - Changing: always using the Control spin-up (shown as time series in the plots here)
- 100 years is not long enough to reach equilibrium (NEP not quite zero)





Results: relative difference in coverage and NPP

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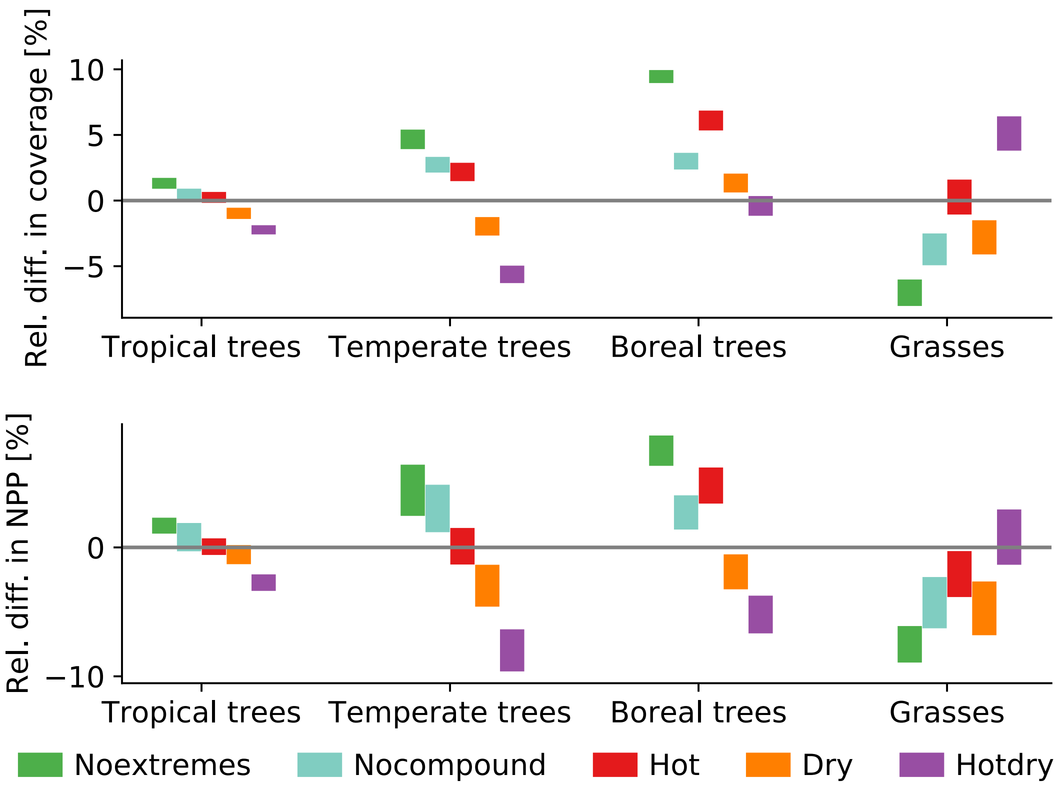
- Trees benefit from no extremes or slightly warmer climate (especially in higher latitudes, most likely due to an increase in growing season length)
- They dislike dry and hotdry weather
- Grasses mostly compensate the changes in tree coverage
- Changes in NPP follow the changes in coverage



Results: differences in coverage shown in maps

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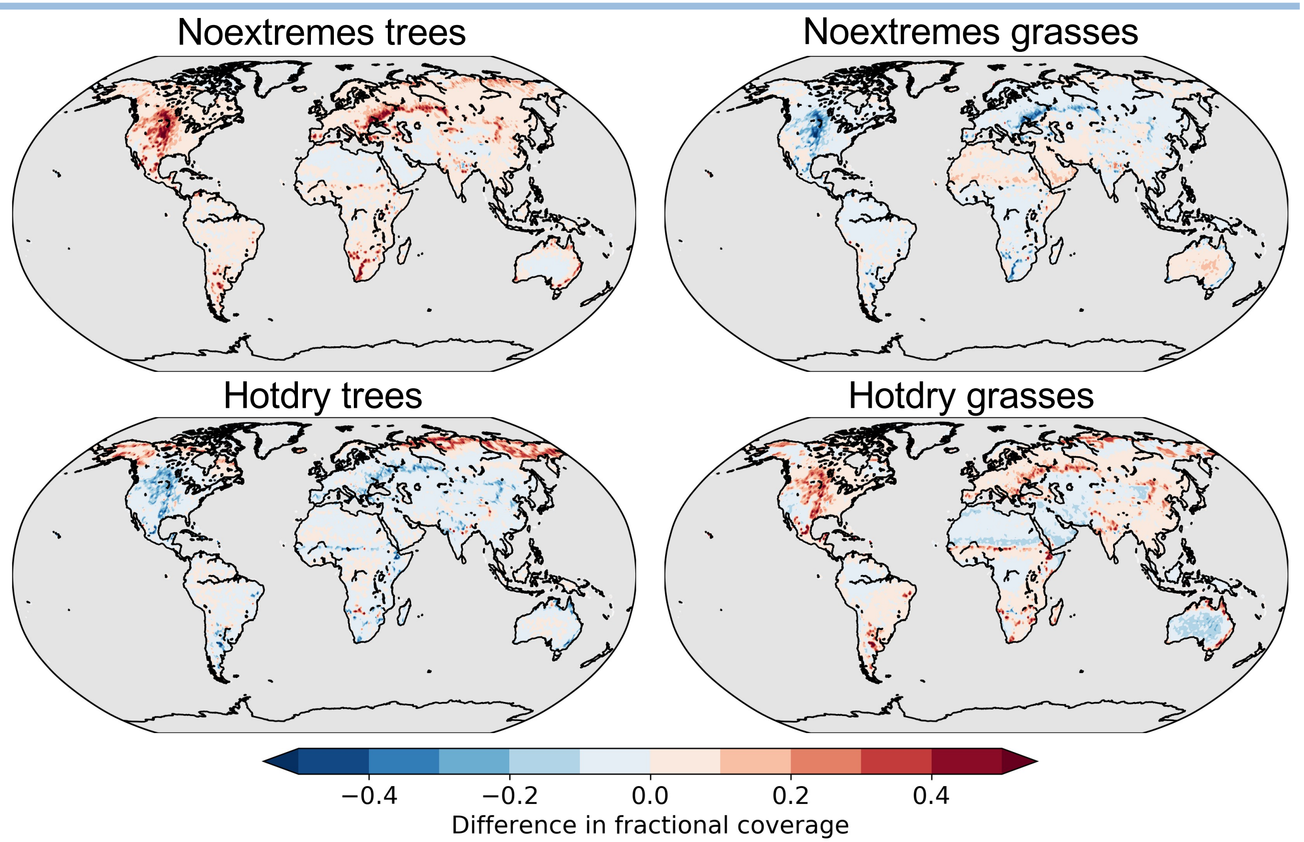
- Noextremes trees increase in coverage, while grasses decrease (except in very dry regions where they increase, probably because it gets slightly less extreme)
- Hotdry tree coverage decreases except in very high latitudes, while grasses increase except in dry regions (where they decrease because it gets even drier)



Results: relative difference in C fluxes and pools

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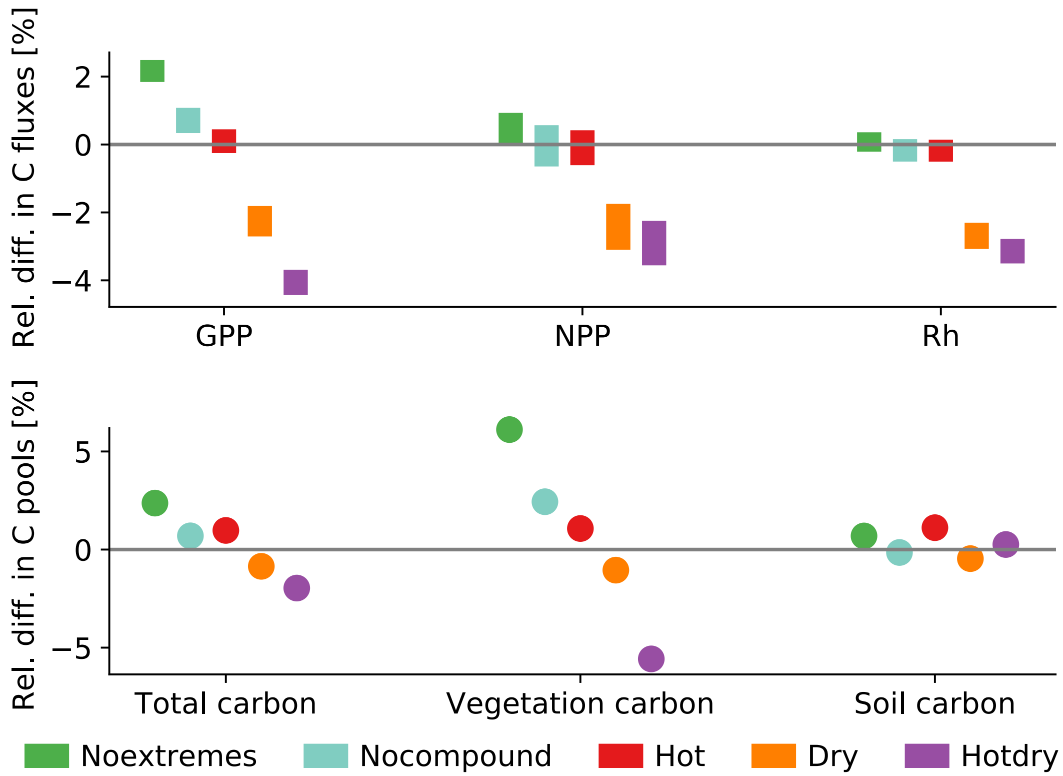
- Relative differences of global carbon fluxes and pools show patterns similar to the relative differences in coverage



Results: differences in NPP shown in maps

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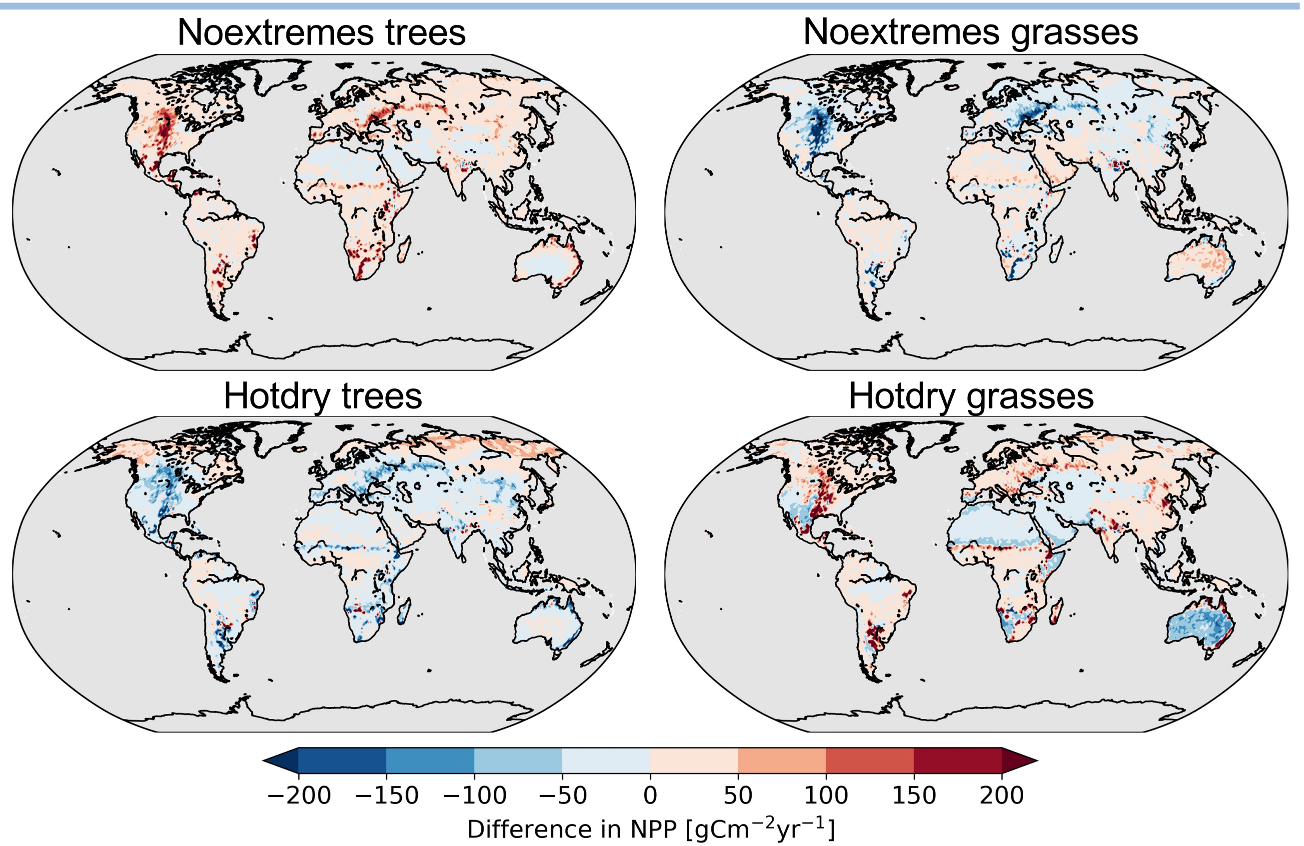
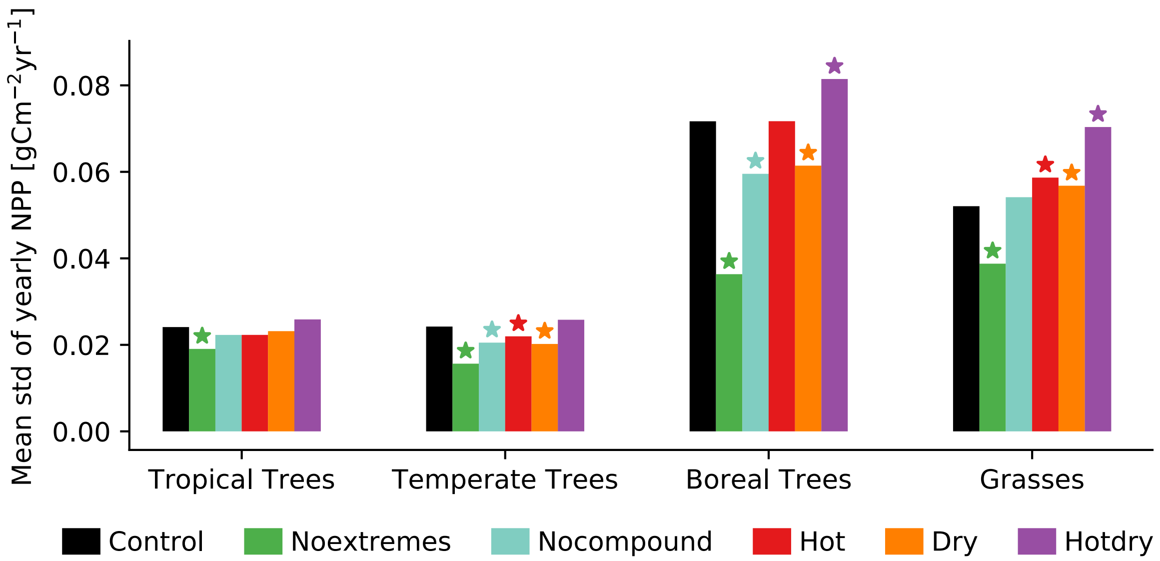
- These maps here showing the difference in NPP between the scenarios and the control display a very similar pattern to the maps showing differences in coverage (slide 11)



Results: variability

- Variability is larger for Boreal trees and Grasses than it is for Tropical and Temperate trees
- Noextremes shows the smallest variability for all PFT classes, while Hotdry shows the largest variability



Conclusions

- Even though the difference in mean climate between the scenarios is small, the different extremes frequencies lead to a noticable shift in vegetation coverage
- The changes in carbon pools and fluxes are directly linked to the changes in vegetation coverage
- The extreme scenarios have an overall negative effect on vegetation
- The impacts of compound hot and dry extremes are not simply a linear combination of the univariate hot and dry extremes impacts

Outlook

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- Using our scenarios, we plan a **model intercomparison project**, which will help us understand model uncertainties and dynamics with respect to vegetation and carbon
- So far we have seven participating models (in addition to LPX):
  - OCN (Ana Bastos)
  - ORCHIDEE (Ana Bastos)
  - CLM5 (Wim Thiery)
  - LPJ-GUESS (Anja Rammig)
  - CABLE (Anna Ukkola)
  - JULES (Karina Williams)
  - JSBACH (Julia Pongratz)
- If you are interested in participating as well, feel free to contact me! (elisabeth.tschumi@climate.unibe.ch)

References

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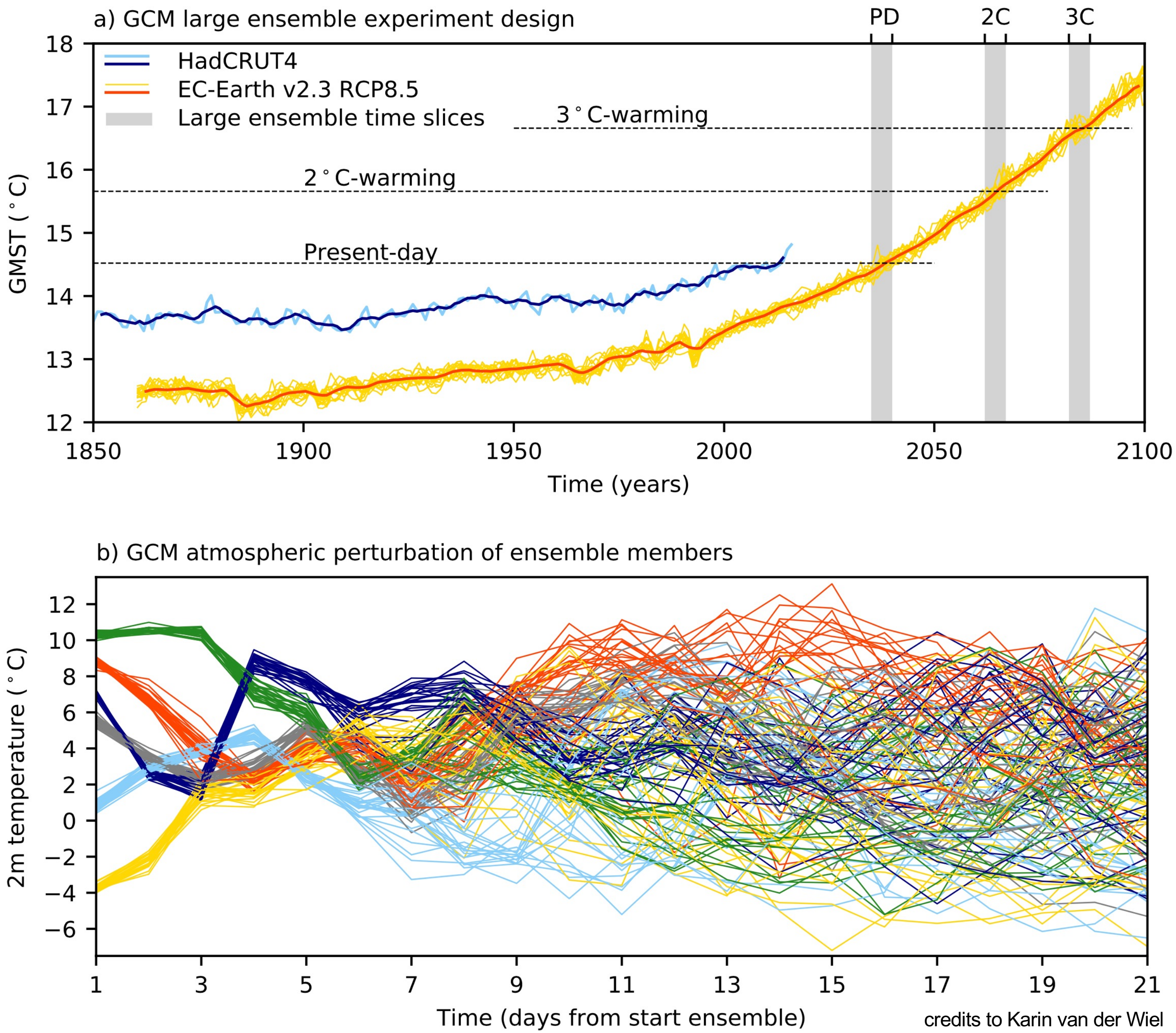
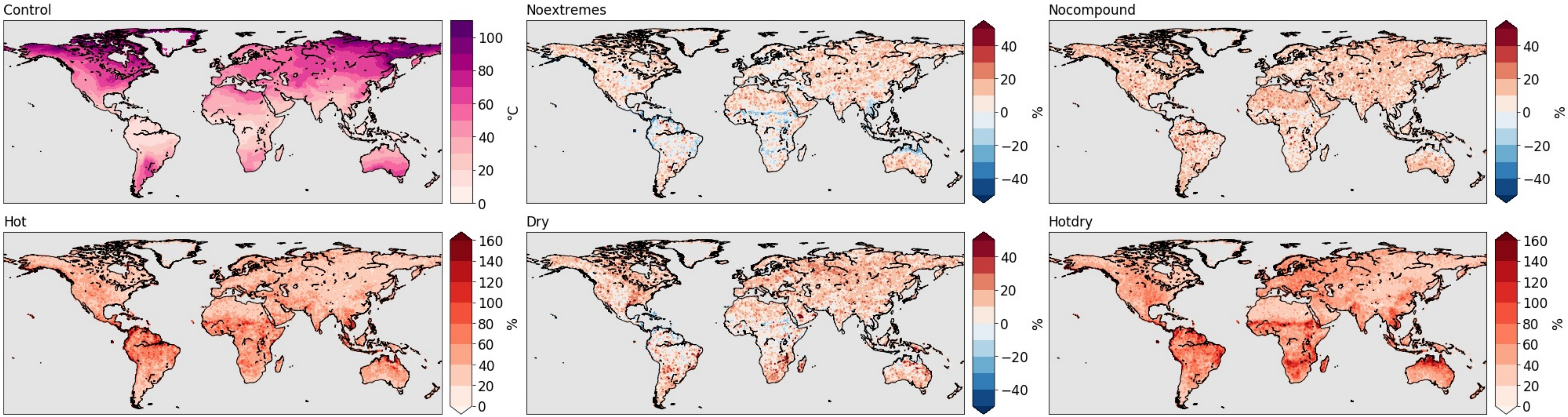
Backup: EC-Earth data

(a) GMST time series from the transient spin-up experiment (individual ensemble members in yellow; ensemble and 5 year running mean in red) and HadCRUT4 observed data (in light blue; 5 year running mean in darker blue). Grey shading shows the selected 5 year time slices for the three large ensembles. **(b)** Time series of 2 m temperature for a random land point. Lines show individual ensemble members, coloured by initial condition from the transient spin-up experiment, for clarity only 6 out of 16 initial conditions are shown.



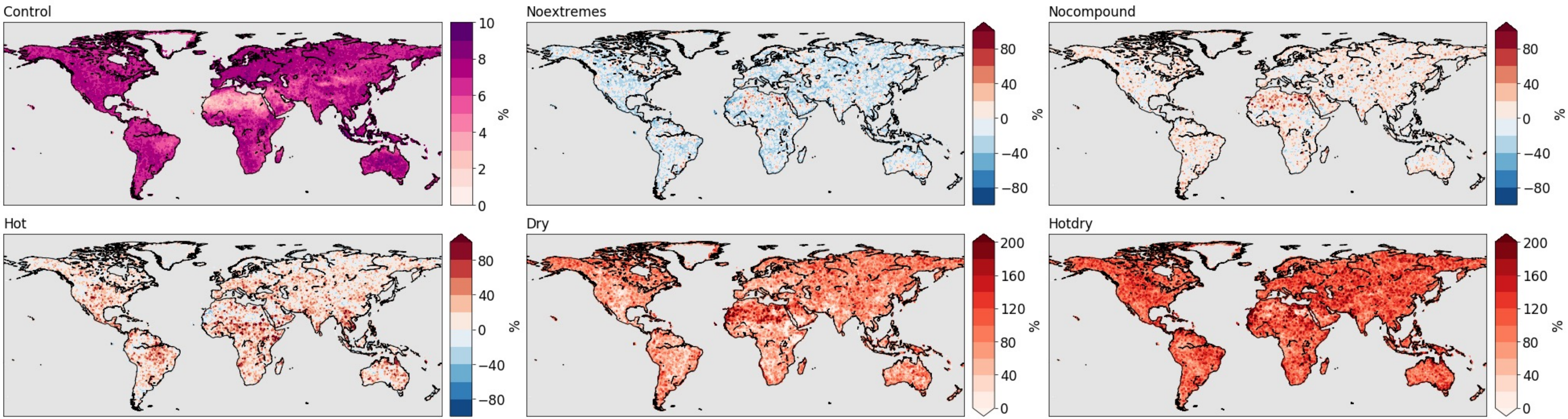
Backup: extreme heat

- Cooling degree days: sum(T-T_90) for T>T_90 (topleft panel) and changes in the scenarios relative to the control (other panels)



Backup: extreme droughts

- Percentage of SPI < -1.5 (topleft panel) and changes in the scenarios relative to the control (other panels)



Backup: dependence

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- Correlation between annual three-month mean temperature and precipitation