Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Regional climate sensitivity and its modulation by land surface processes

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Workshop «The Future of Earth System Modelling: Biosphere and Land Surface»

California Institute of Technology/JPL, 27.3.2018

Outline

- Relating changes in global temperature to regional extremes and impacts
- Role of soil moisture feedbacks for temperature projections: Global vs regional climate sensitivity
- Regional land-climate interactions in low-emissions scenarios
- Soil moisture and the carbon cycle
- Conclusions

2015 Paris agreement: 1.5C vs 2C

United Nations — FCCC/CP/2015/L.9

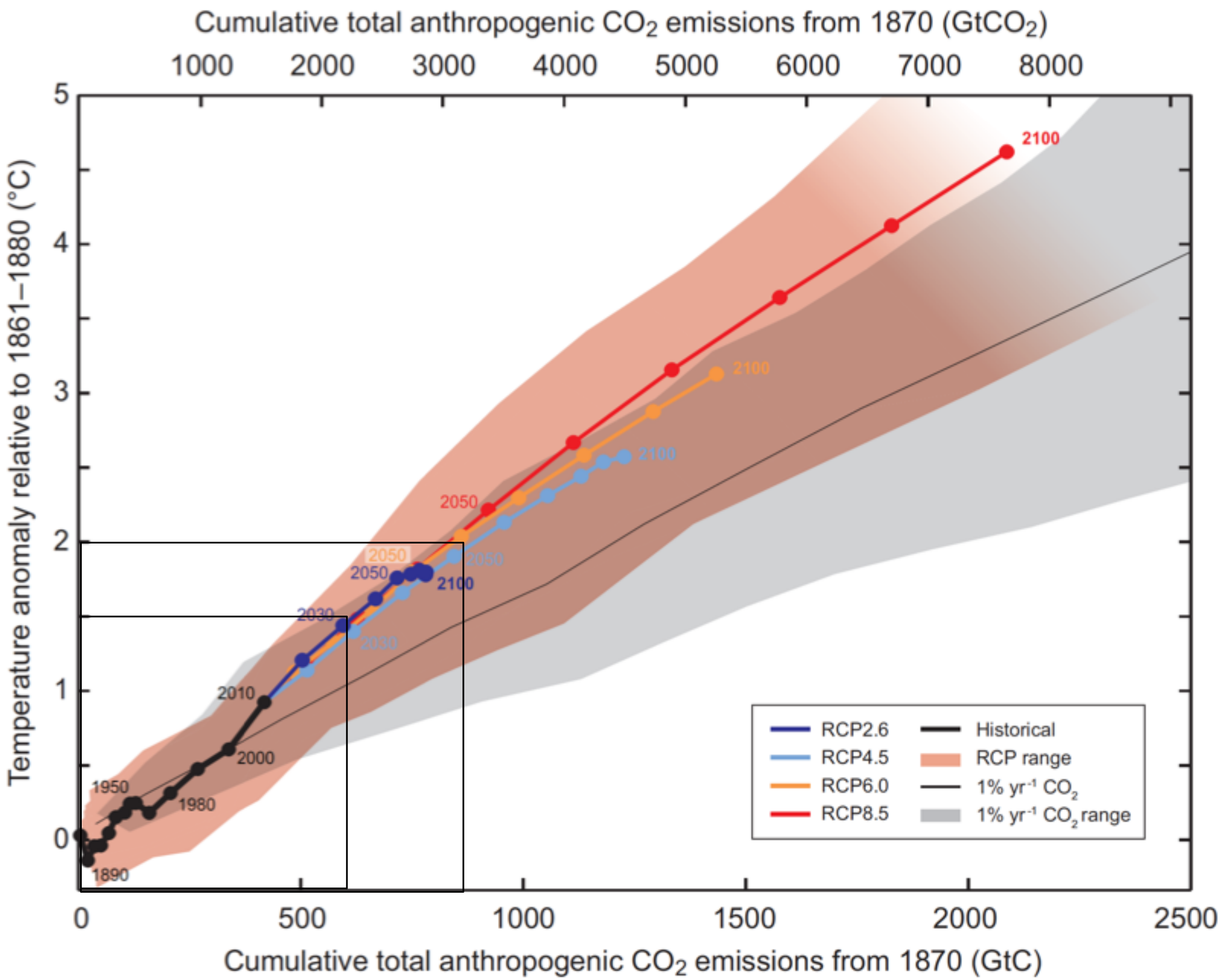
Framework Convention on Climate Change

Distr.: Limited
12 December 2015

1. This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

(a) Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

Link between cumulative CO_2 emissions and global T°

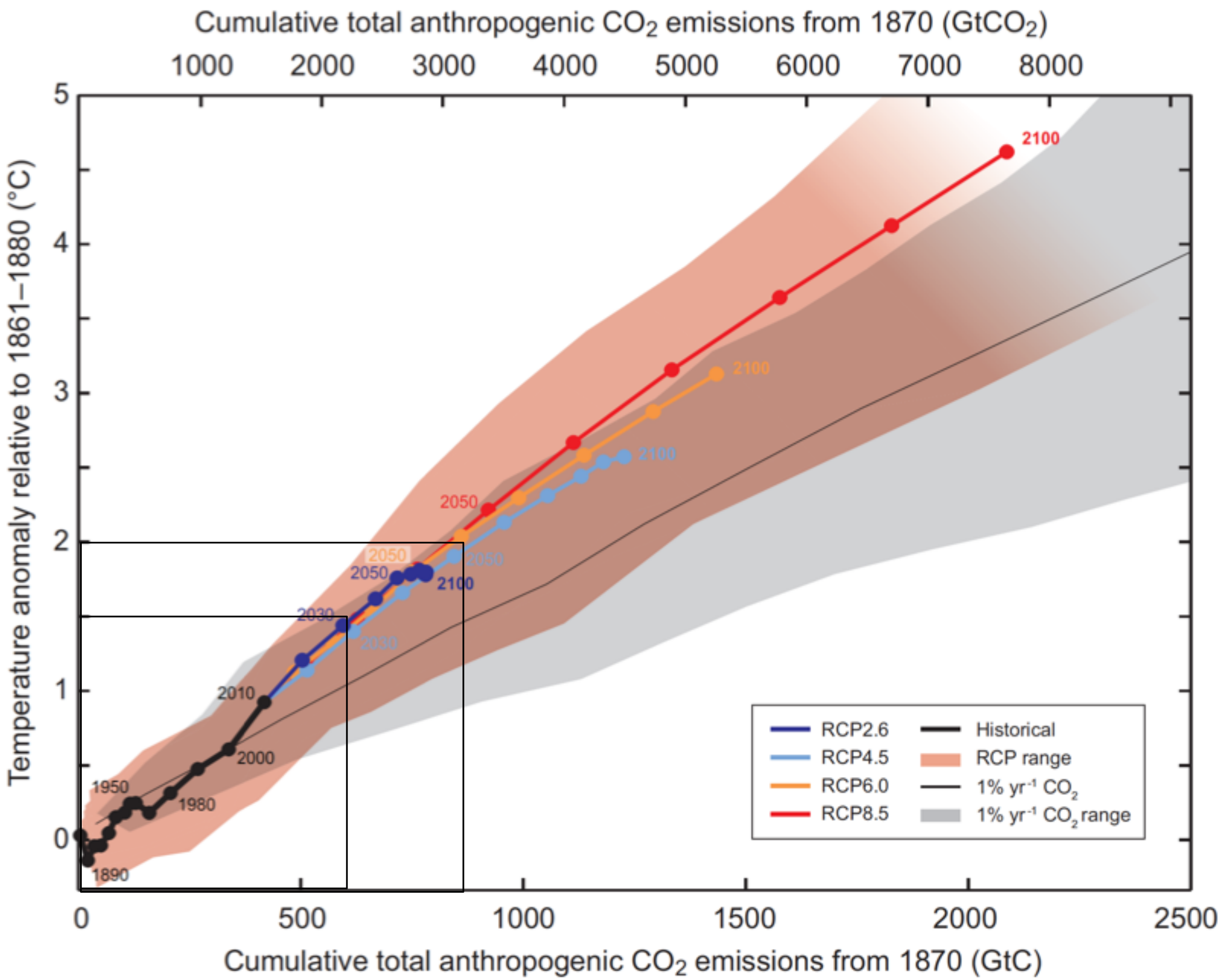


Direct link between cumulative CO_2 emissions and climate response

A global T° target can be linked to cumulative emissions target

(IPCC 2013)

Link between cumulative CO_2 emissions and global T°



Direct link between cumulative CO_2 emissions and climate response

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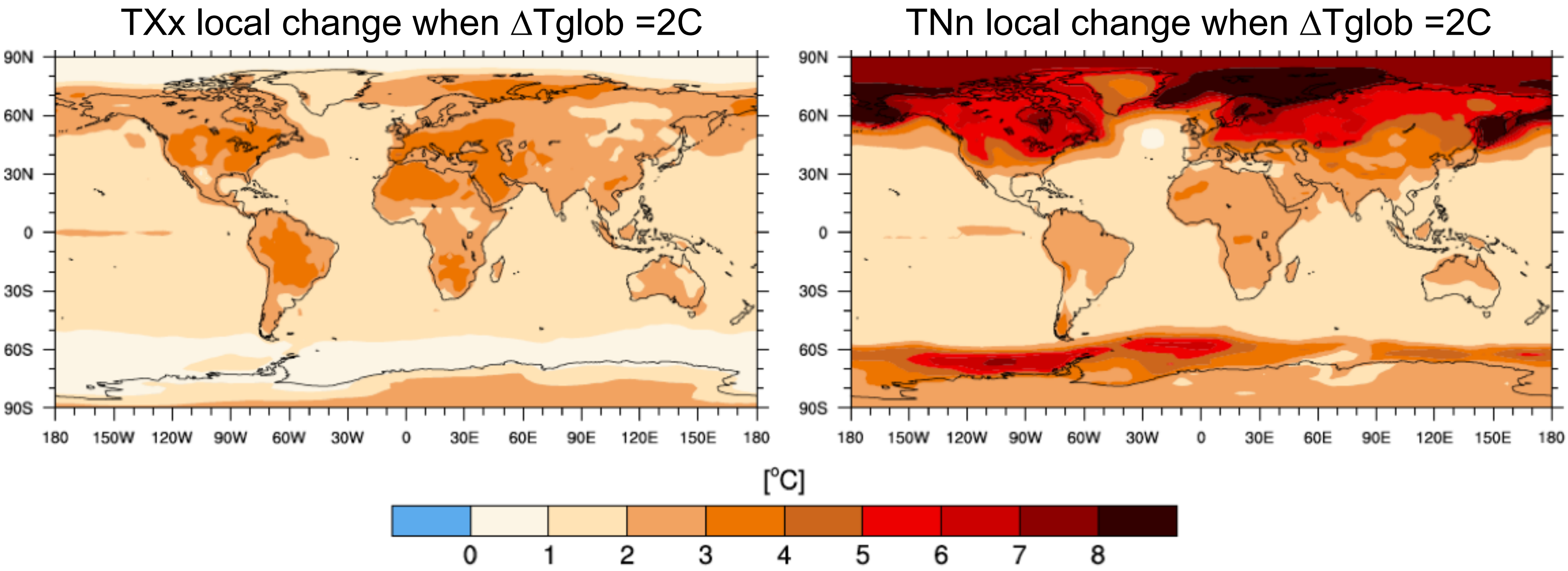
What are the implications for regional extremes?

(IPCC 2013)

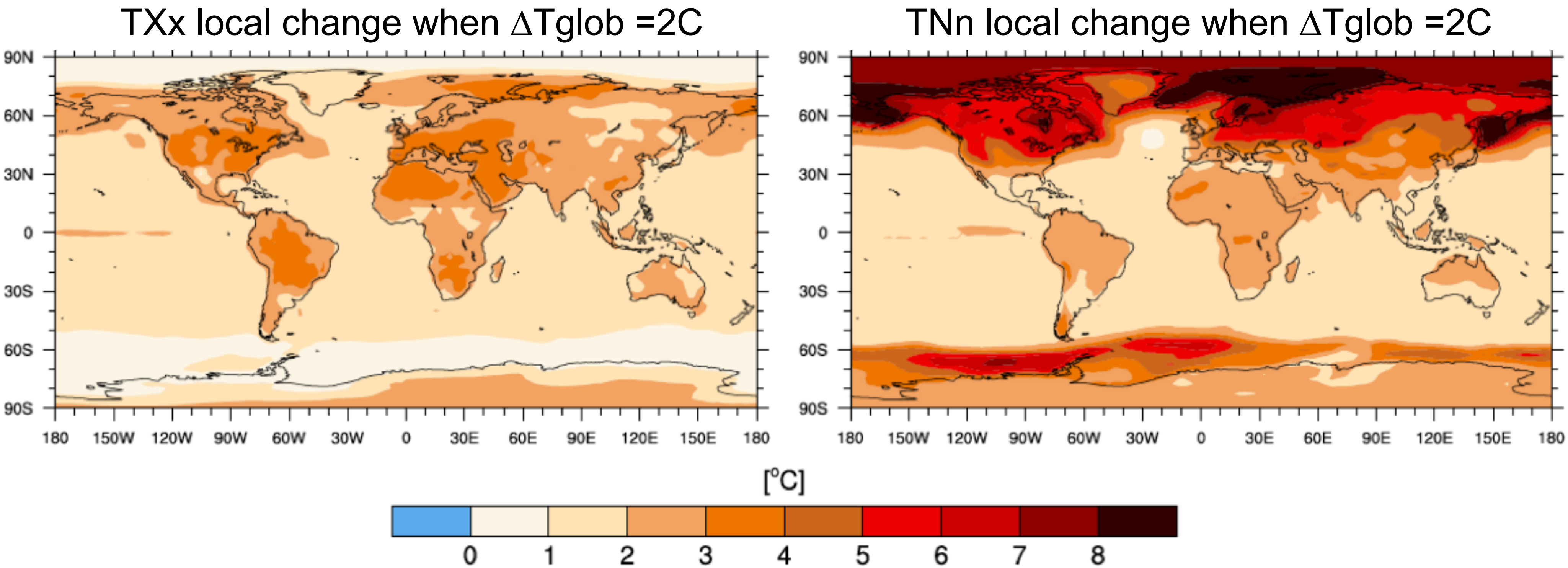
Scaling relationships for regional extremes



Does a 2C global warming target implies a 2C warming everywhere and all the time?

(Seneviratne et al. 2016, Nature)

Scaling relationships for regional extremes

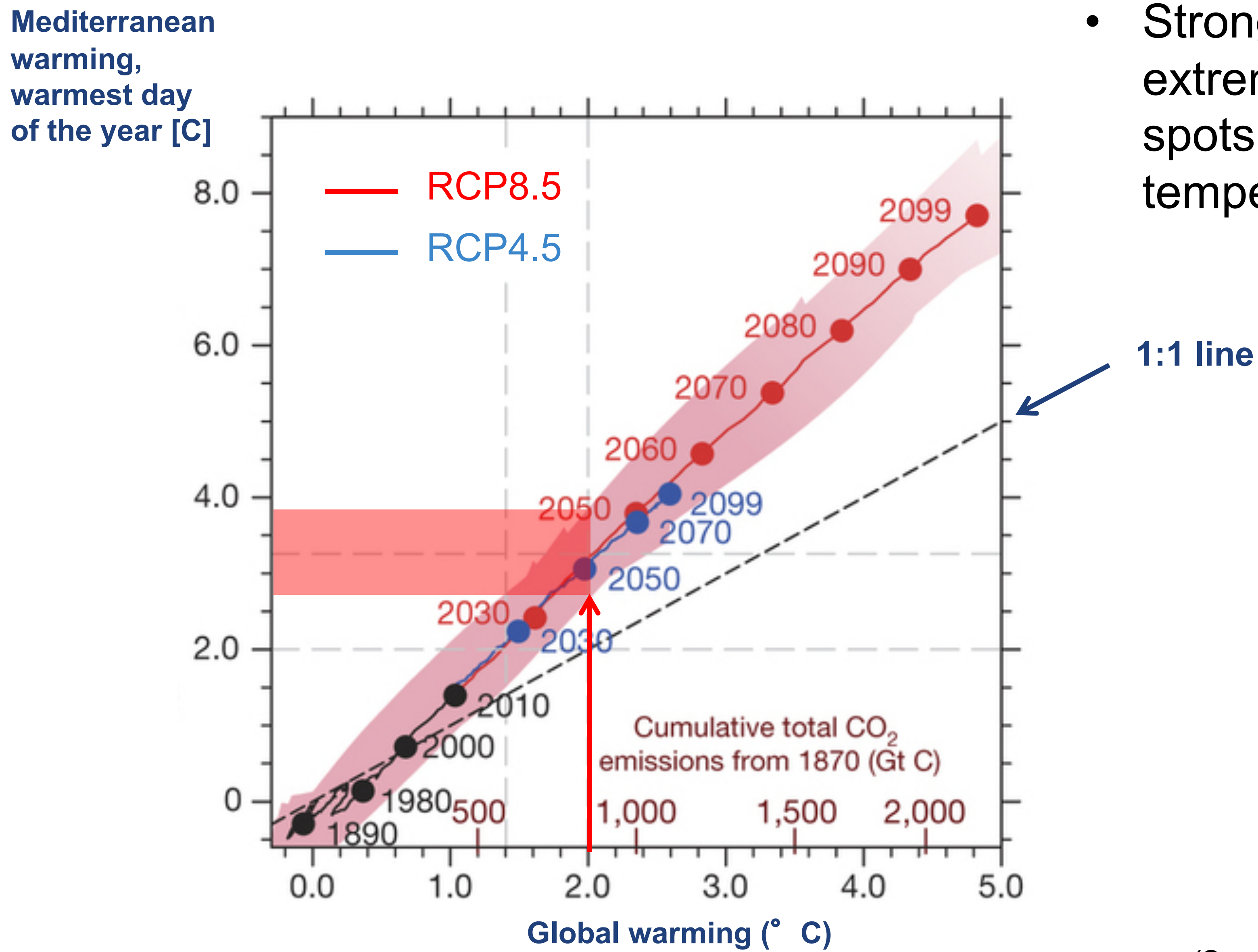


Does a 2C global warming target implies a 2C warming everywhere and all the time?

No! Stronger warming of land extremes compared to global temperature. Why?

(Seneviratne et al. 2016, Nature)

Regional extremes vs global climate change



- Stronger warming of extremes in land hot spots vs global temperature

(Seneviratne et al. 2016, Nature)

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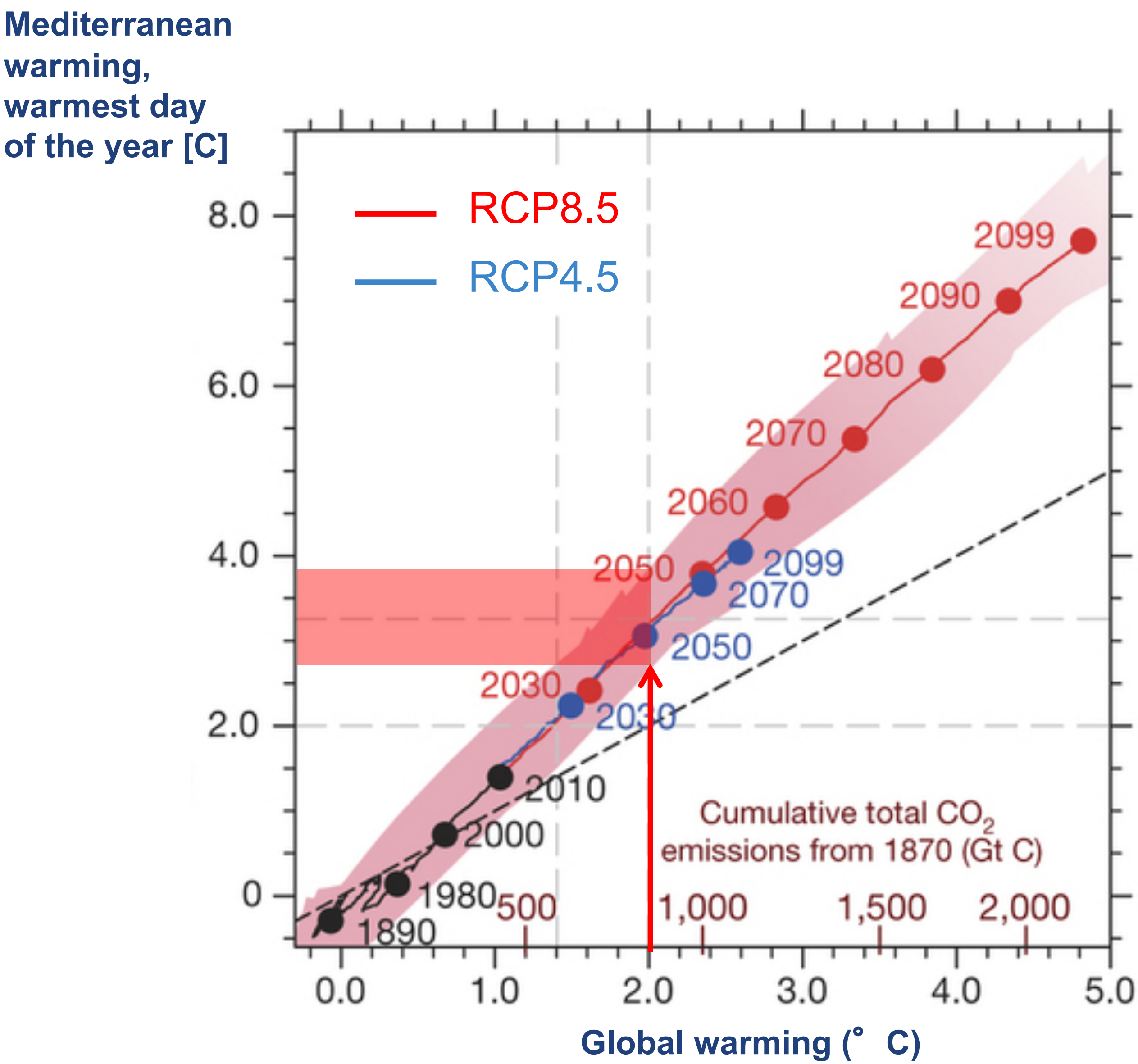
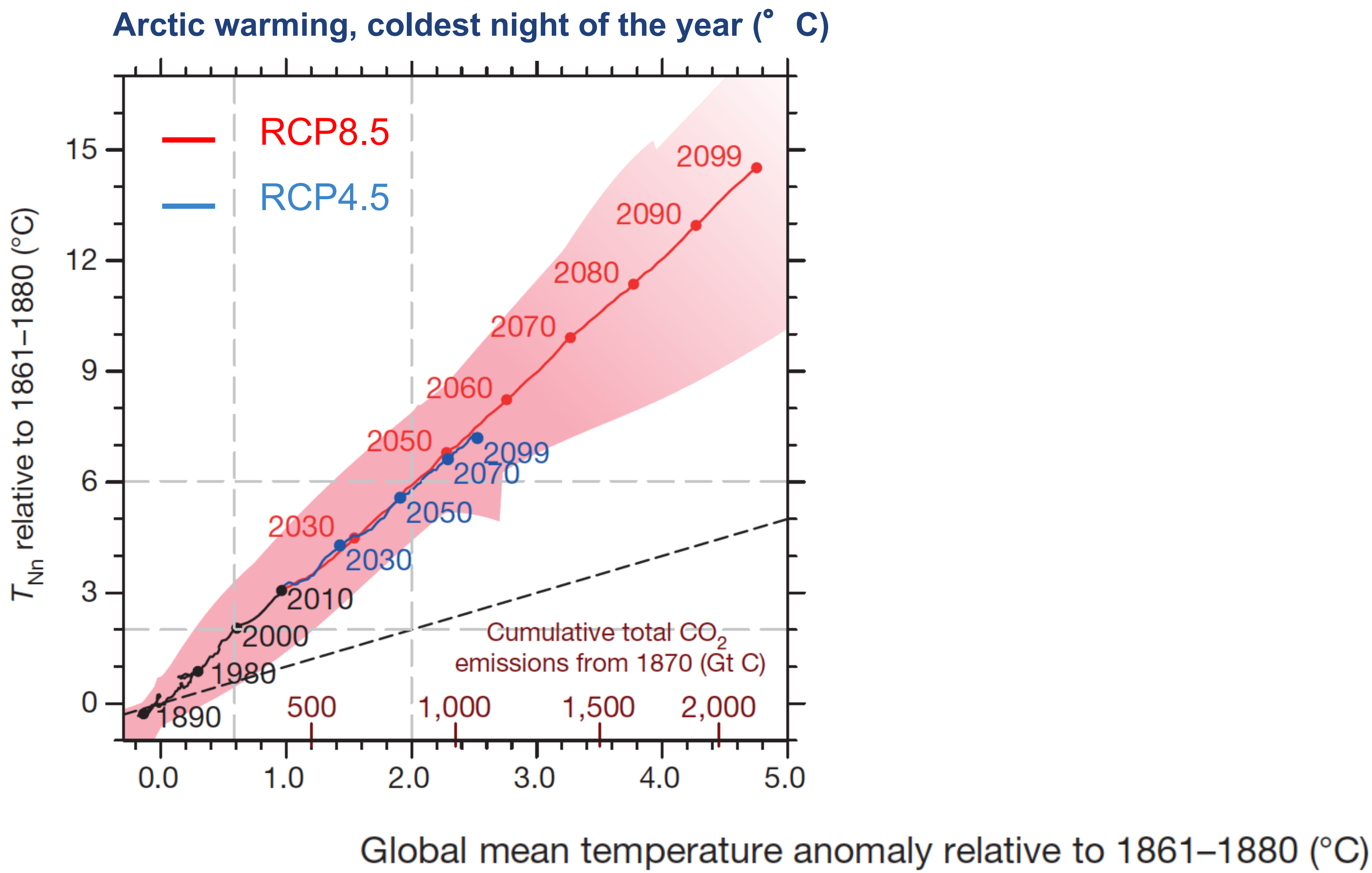


- Stronger warming of extremes in land hot spots vs global temperature
- Robust and almost linear scaling, mostly independent of emissions scenario! *(see also Wartenburger et al. 2017, GMD)*

(Seneviratne et al. 2016, Nature)

Also scaling found for warming of minimum temperatures and changes in heavy precipitation



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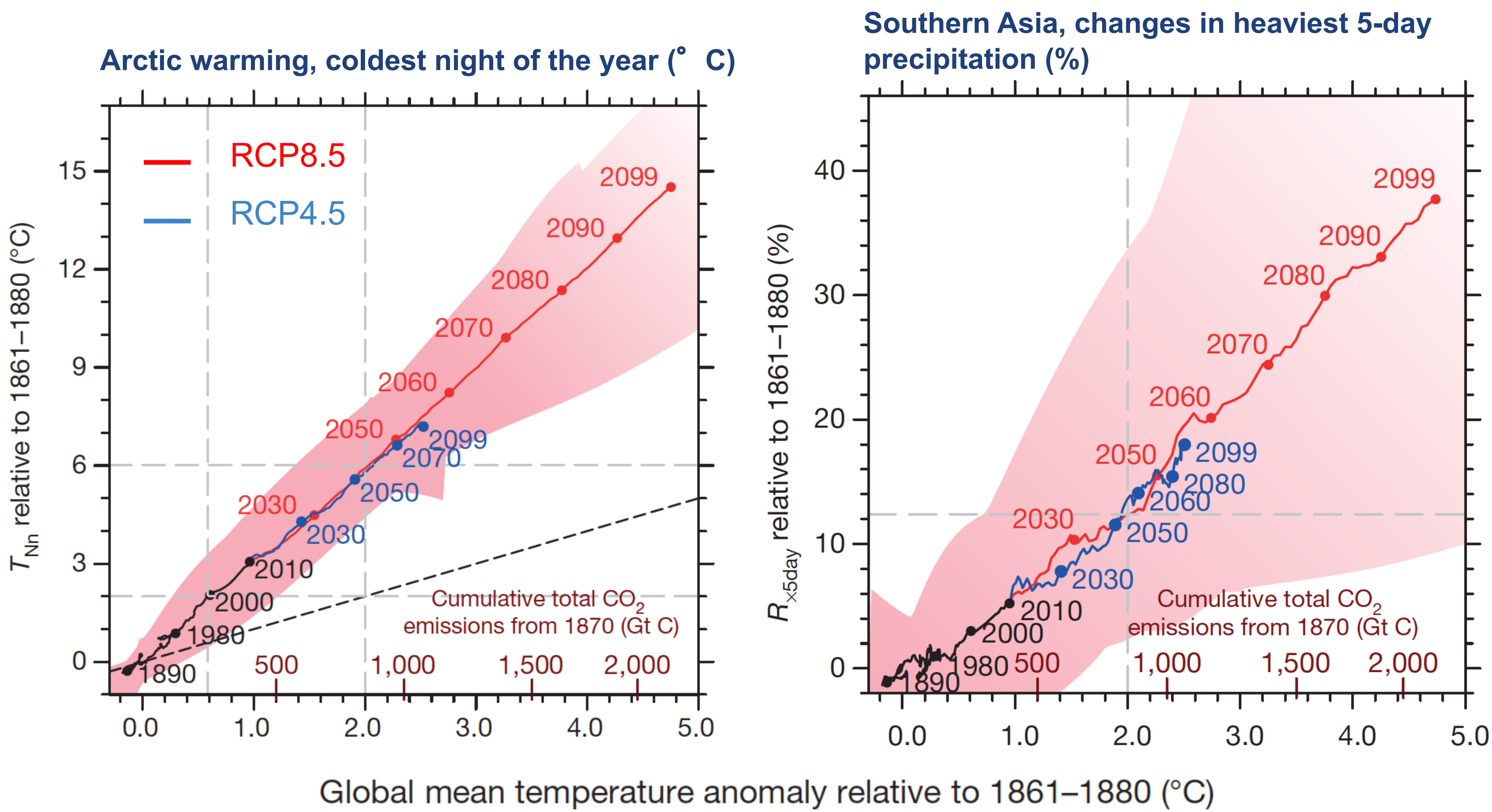

Regional extremes vs global climate change

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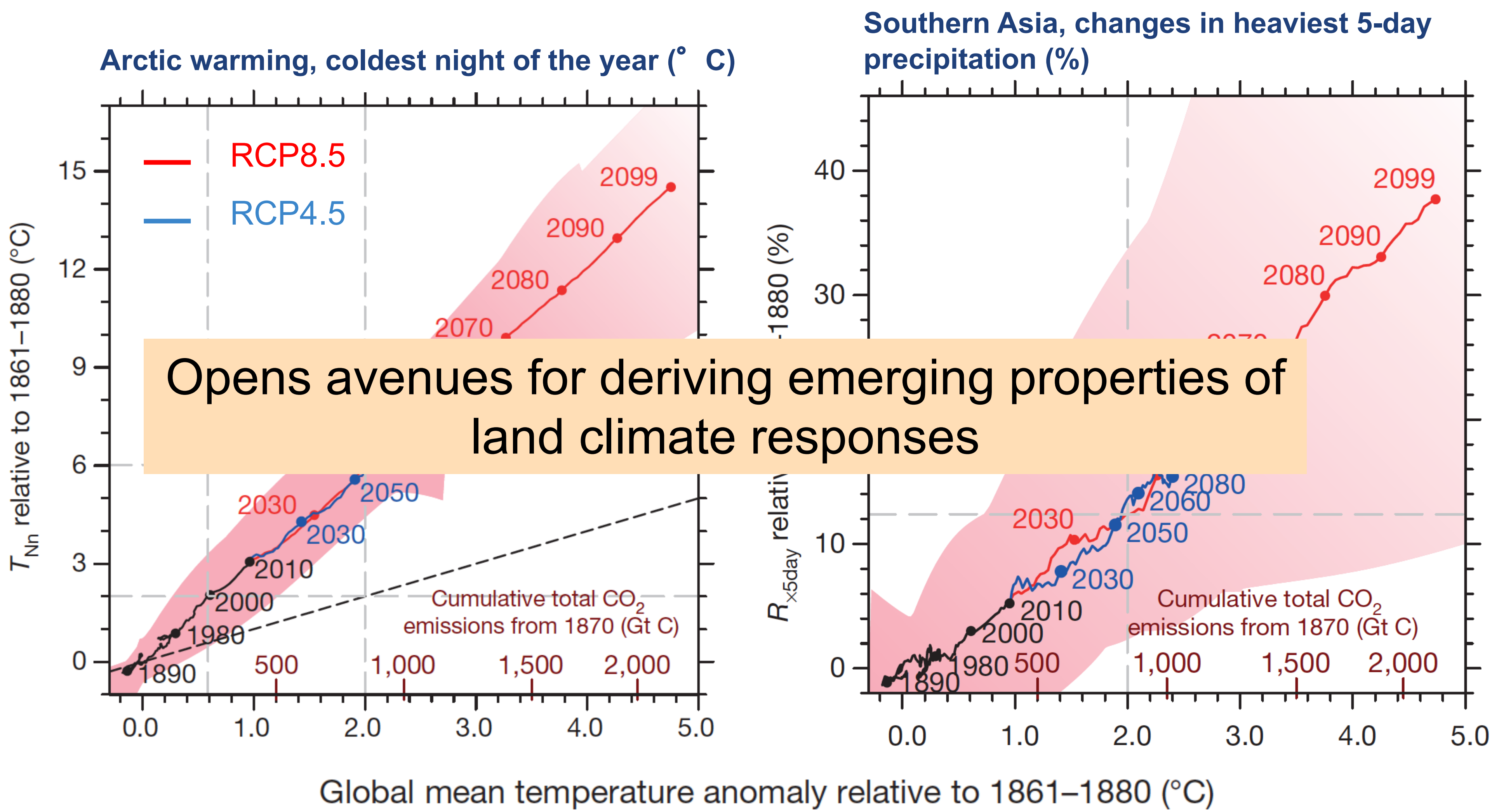
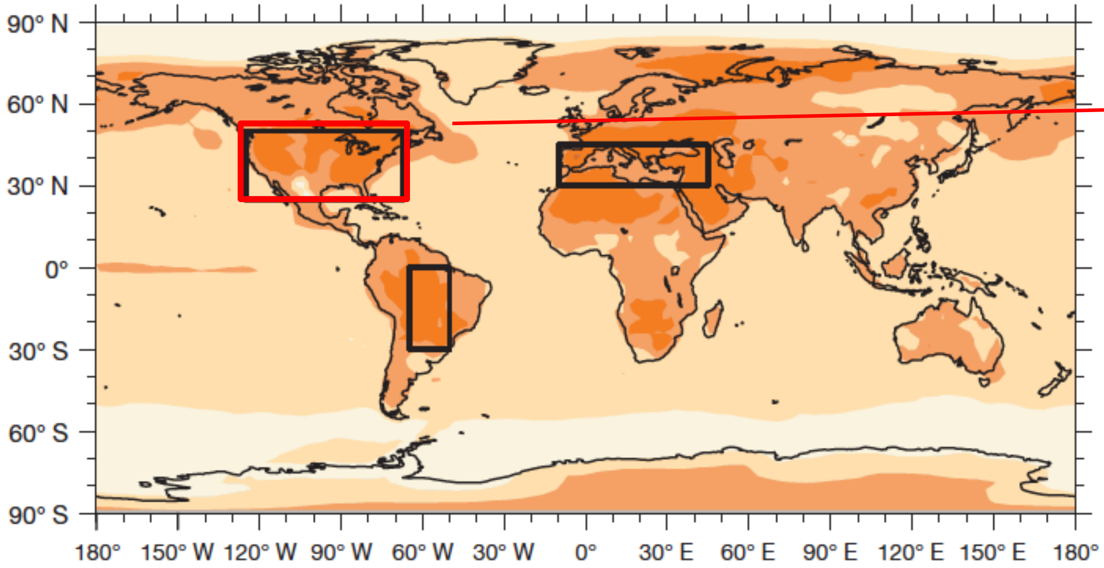
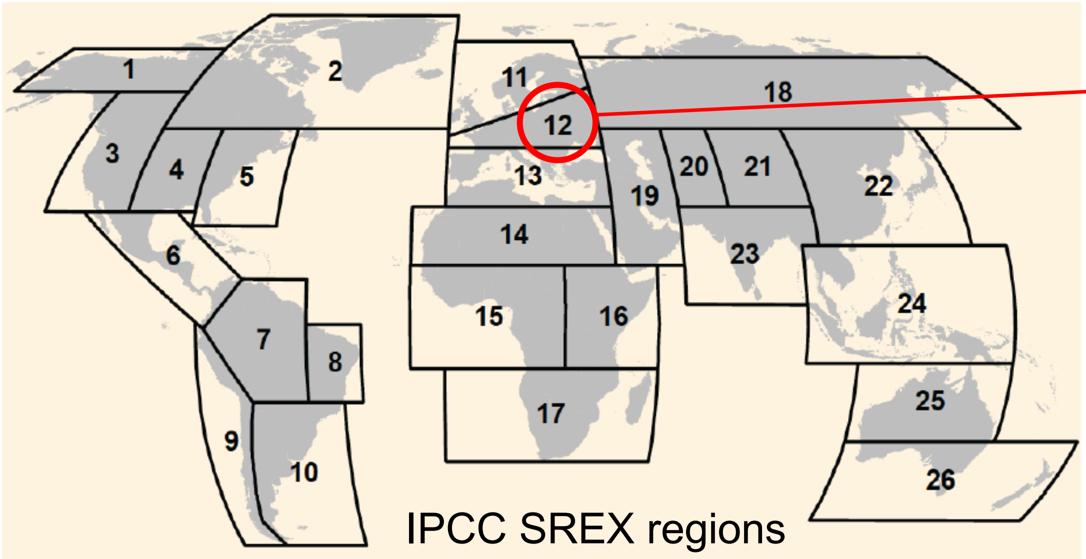


Opens avenues for deriving emerging properties of land climate responses

Complex regional scaling: Example from 2 regions

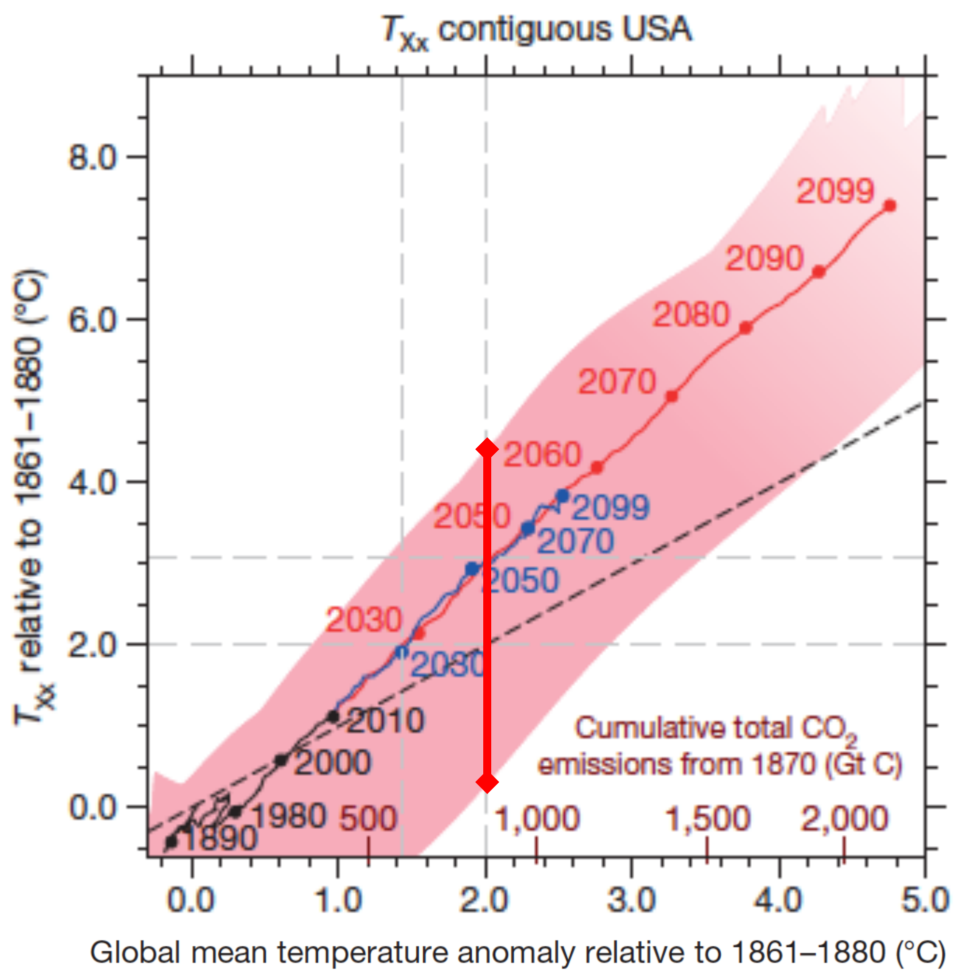


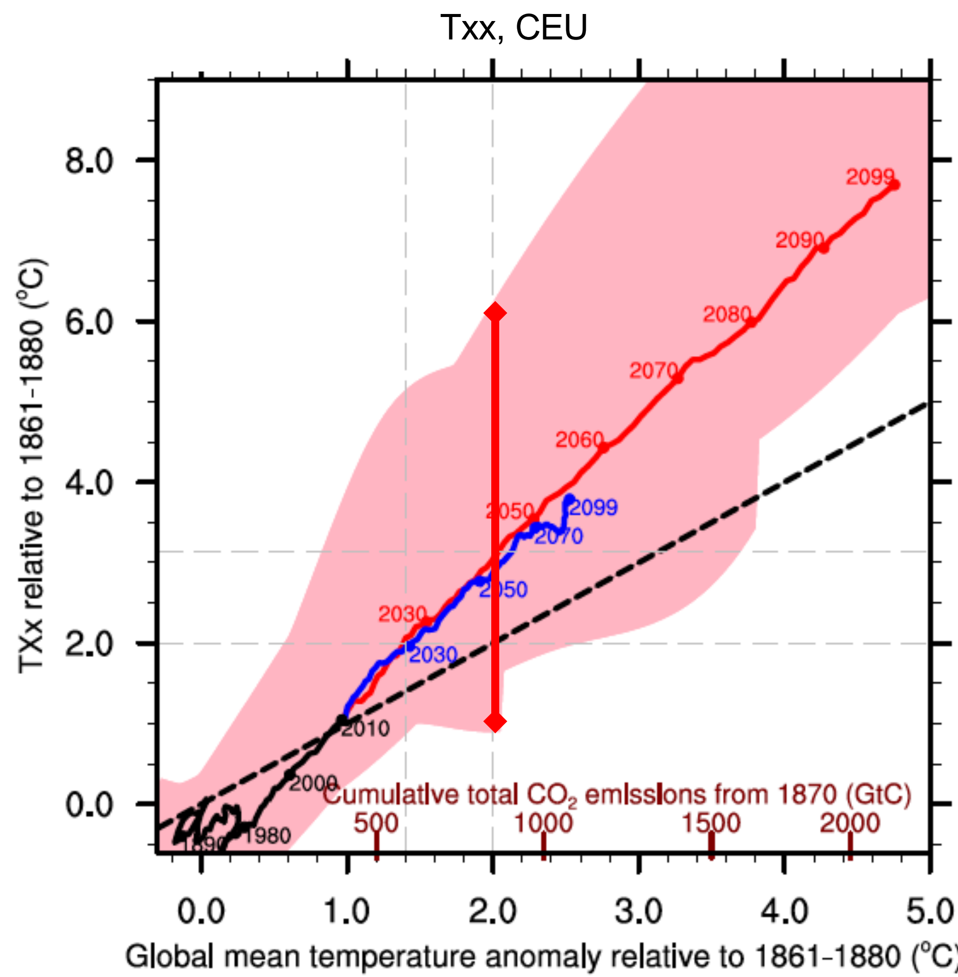
Contiguous US



Central Europe

Complex regional scaling: Example from 2 regions





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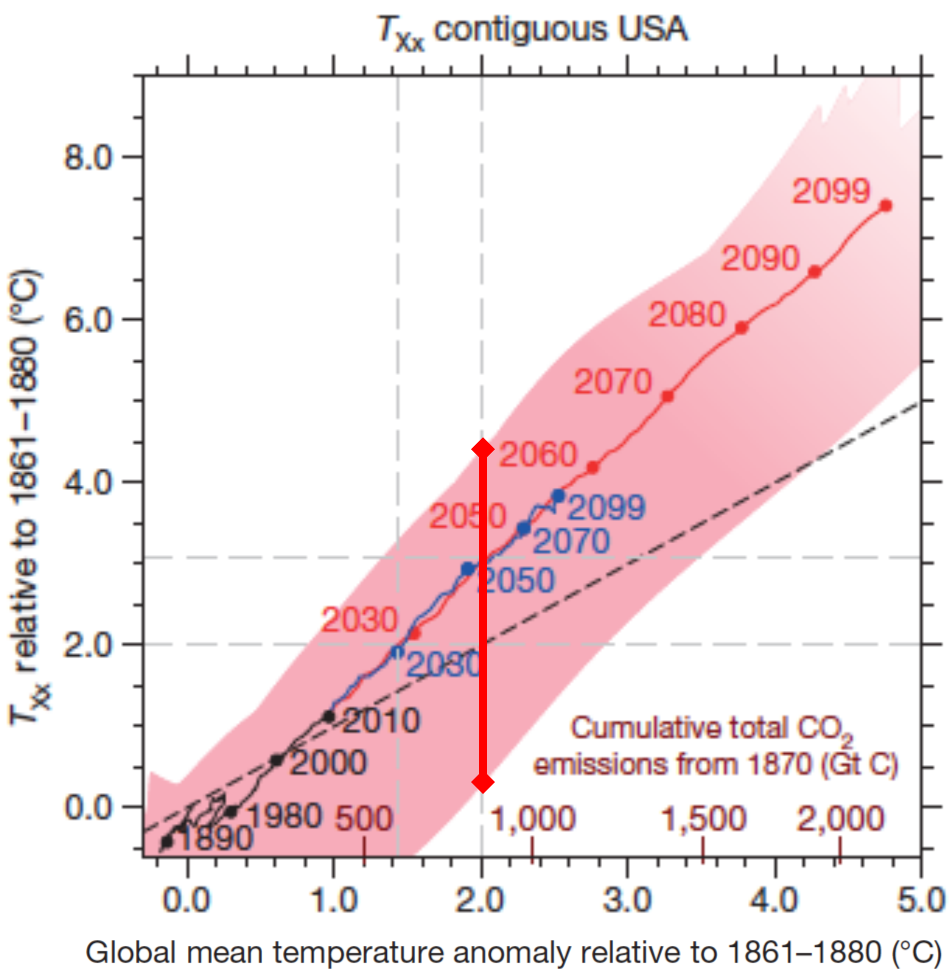

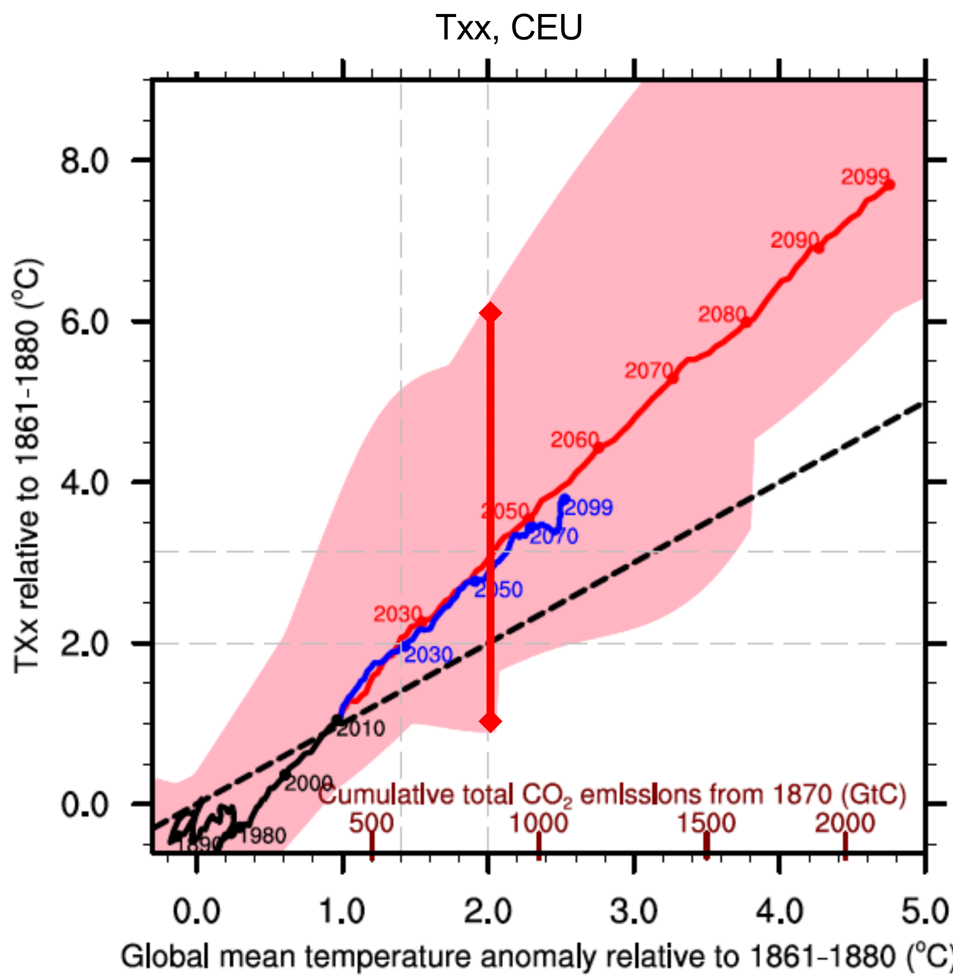

NB: Regions with large spread in regional responses are found in locations of known large soil moisture-temperature feedbacks *(e.g. Mueller and Seneviratne 2012, PNAS; Seneviratne et al. 2013, GRL)*

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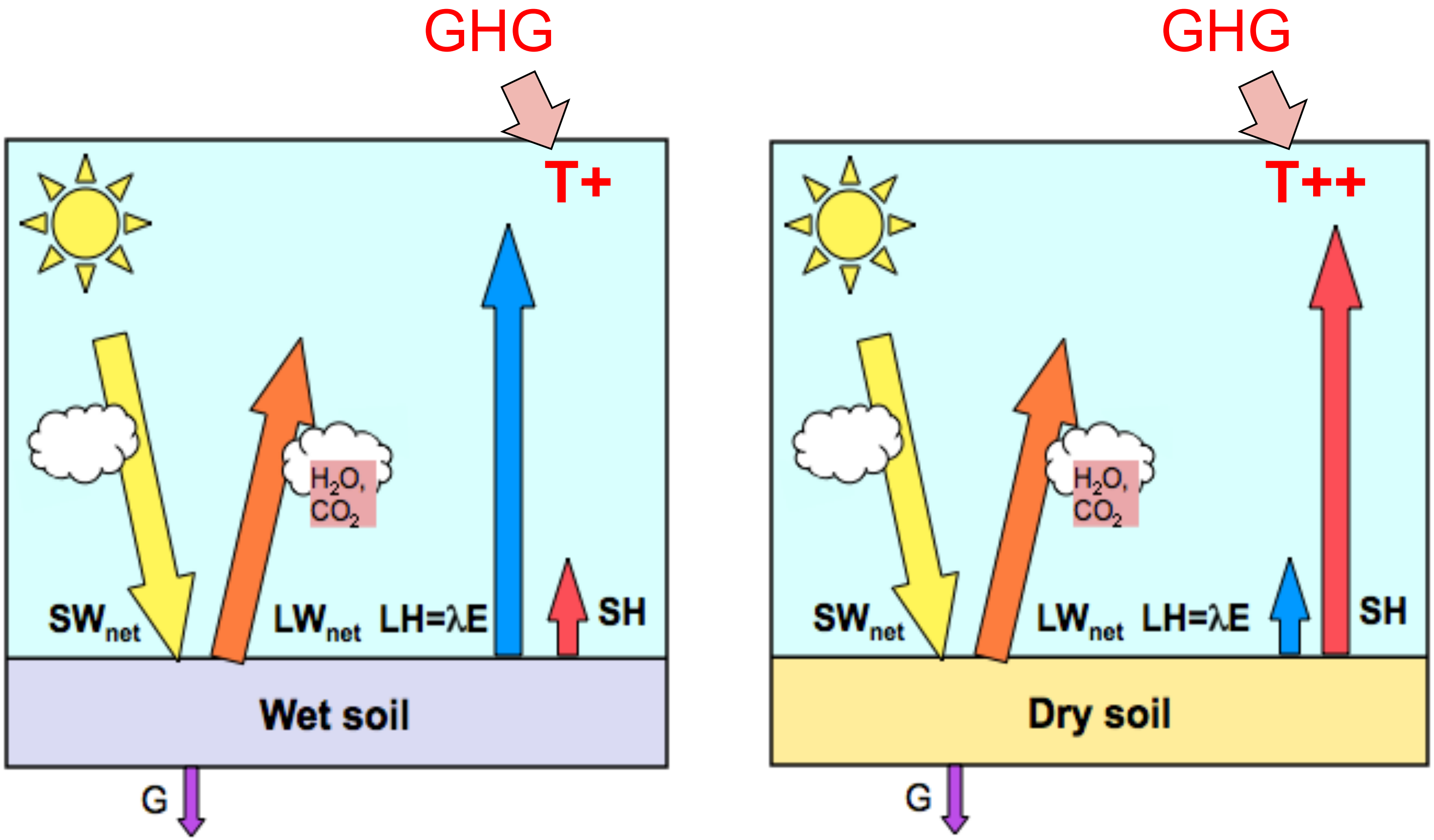
Possible role of soil moisture – temperature feedbacks



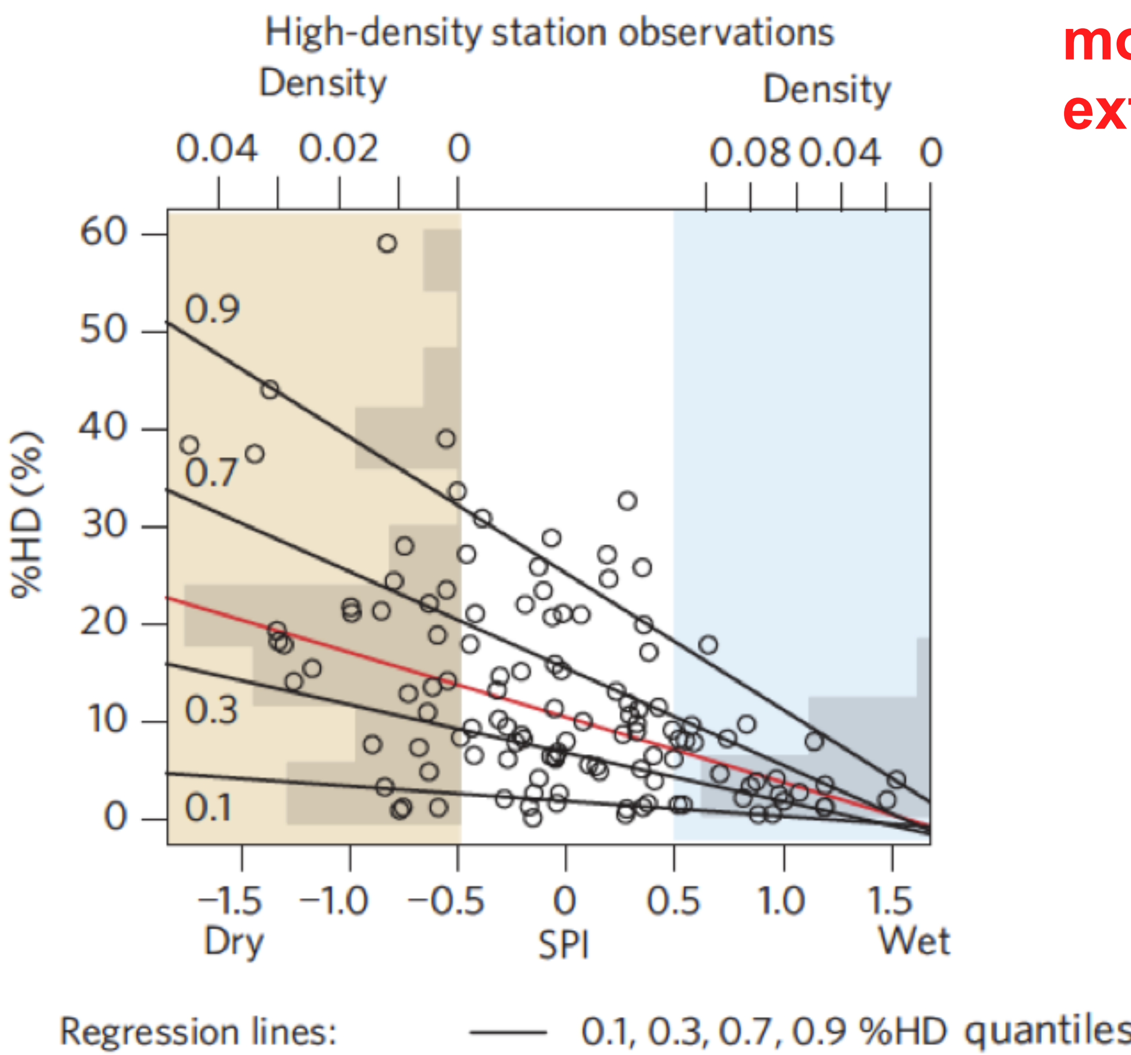
➔ *evidence in projections: Seneviratne et al. 2006, Nature; Diffenbaugh et al. 2007, GRL; Seneviratne et al. 2013, GRL*

➔ *observational evidence: Hirschi et al. 2011, Nature Geoscience; Quesada et al. 2012, Nature Climate Change; Mueller and Seneviratne 2012, PNAS; Miralles et al. 2014, Nature Geoscience*

Soil moisture – temperature feedbacks: Observations

Analysis for Southeastern Europe

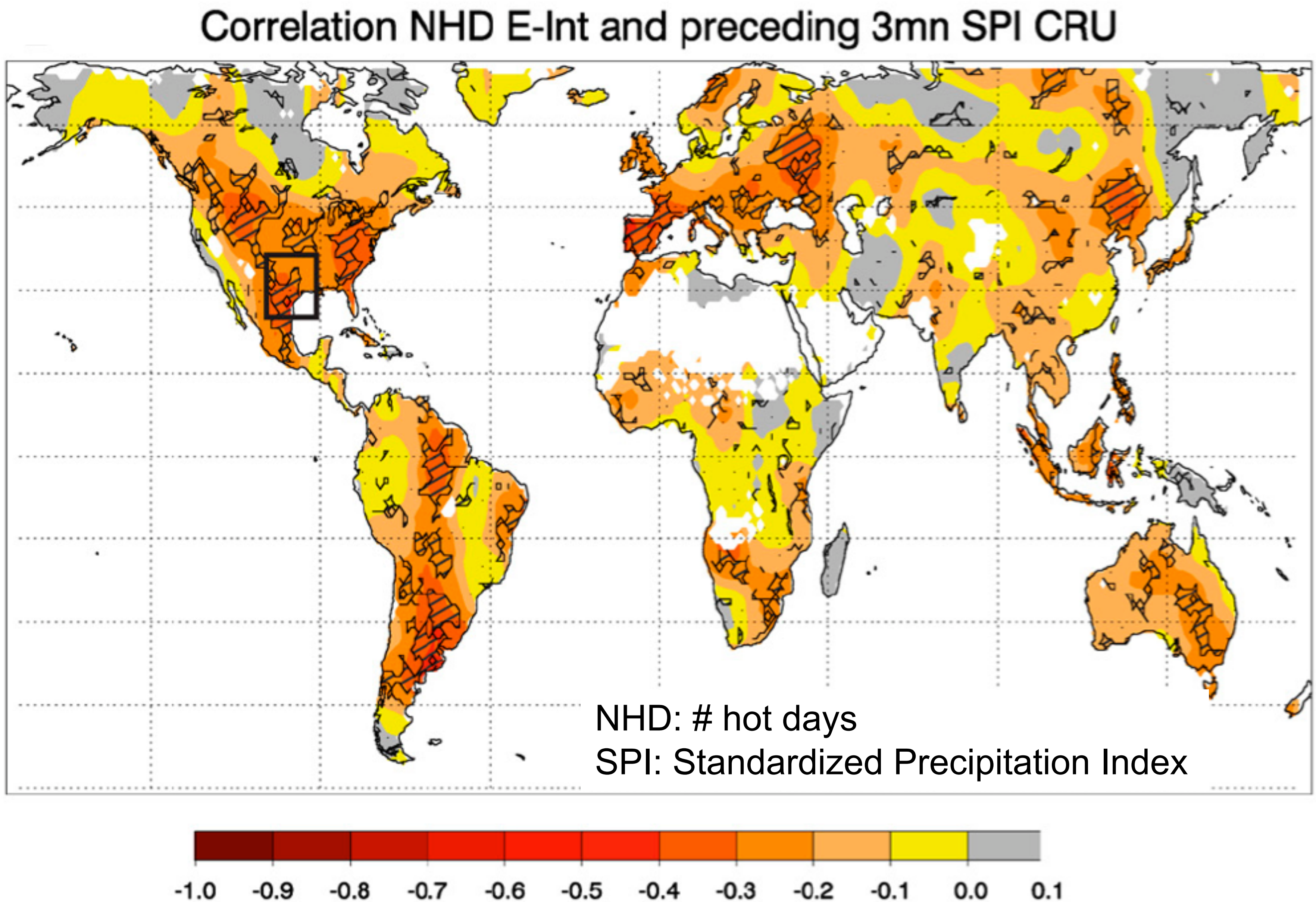
Quantile regression of %HD with 6-month SPI



Impact of soil moisture on hot extremes

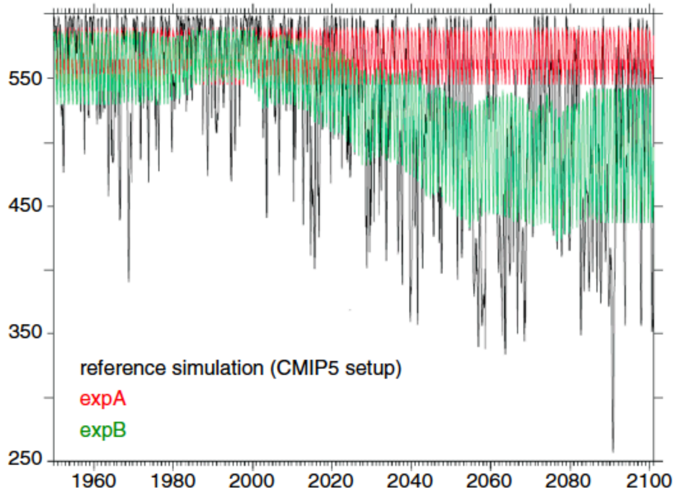
(Hirschi et al. 2011, Nature Geoscience)

Soil moisture – temperature feedbacks: Observations



(Mueller and Seneviratne 2012, PNAS)

Soil moisture – temperature feedbacks: Projections



SM20C

SMtrend

CTL

GLACE-CMIP5 experiments:

(Seneviratne et al. 2013, GRL)

Prescribed soil moisture to present-day levels in projections to assess impact of soil moisture changes for projections

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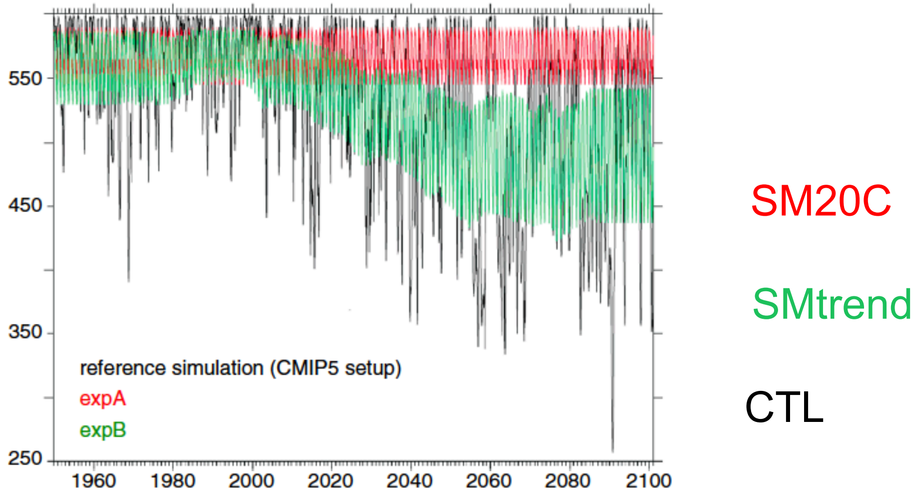

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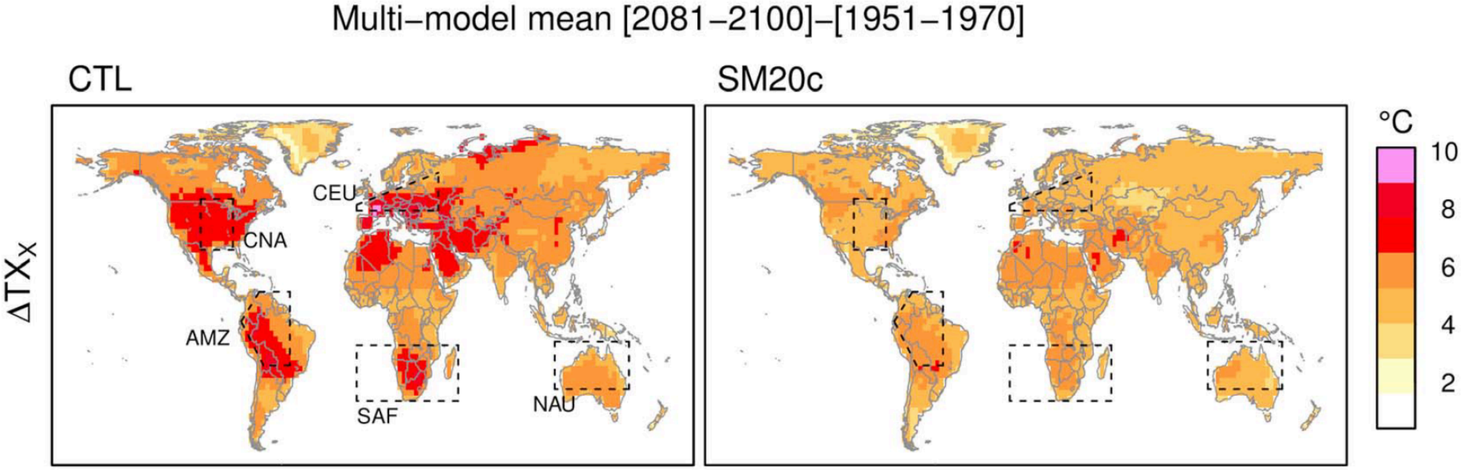
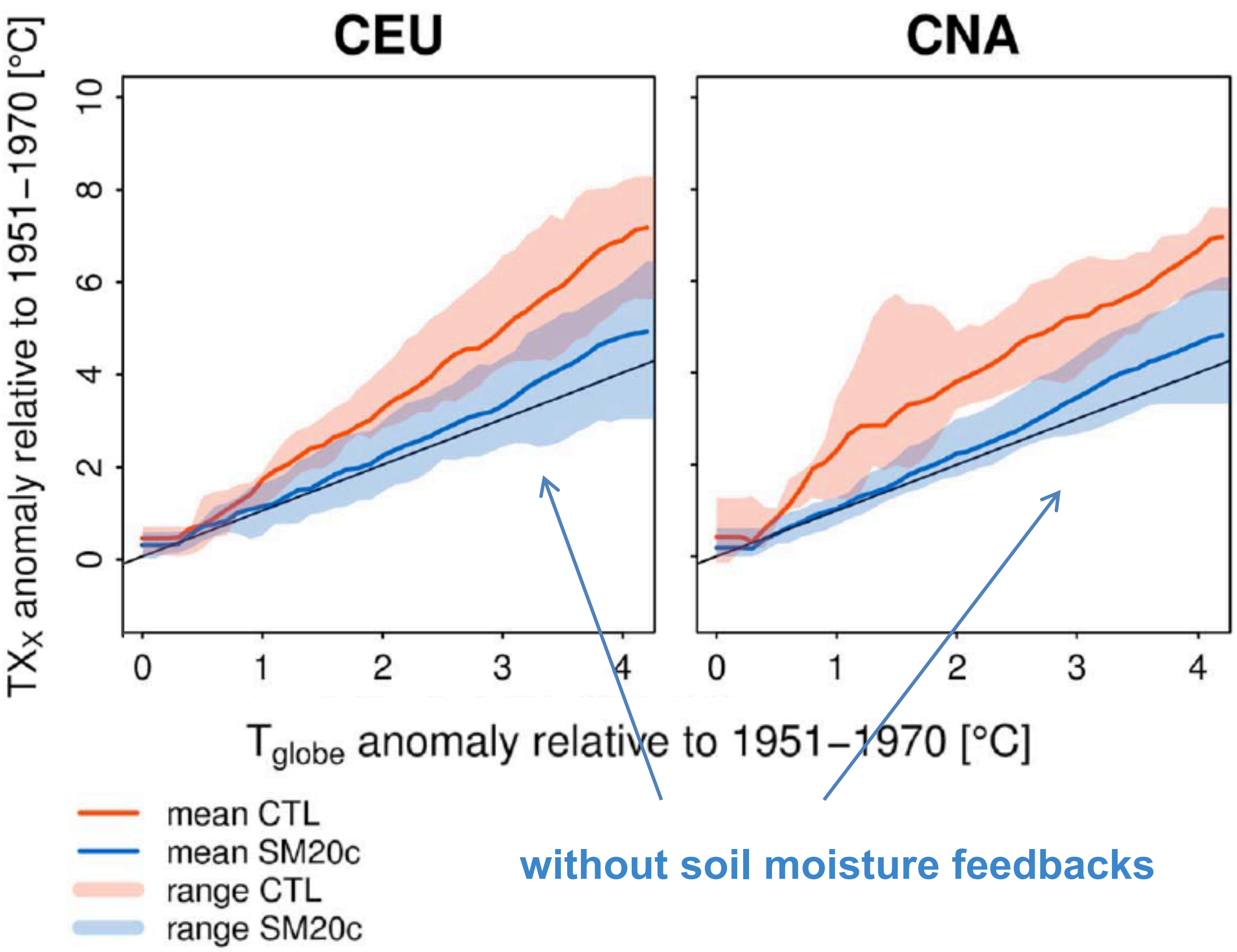


Mean drying of the soil is explaining added warming in extremes in several land regions

(Vogel et al. 2017, GRL)

Soil moisture – temperature feedbacks: Projections

Scaling for GLACE-CMIP5 experiments



Soil moisture-temperature feedbacks are the main driver for the projected temperature extremes amplification in mid-latitudes!

(Vogel et al. 2017, GRL)

Soil moisture – temperature feedbacks: Projections

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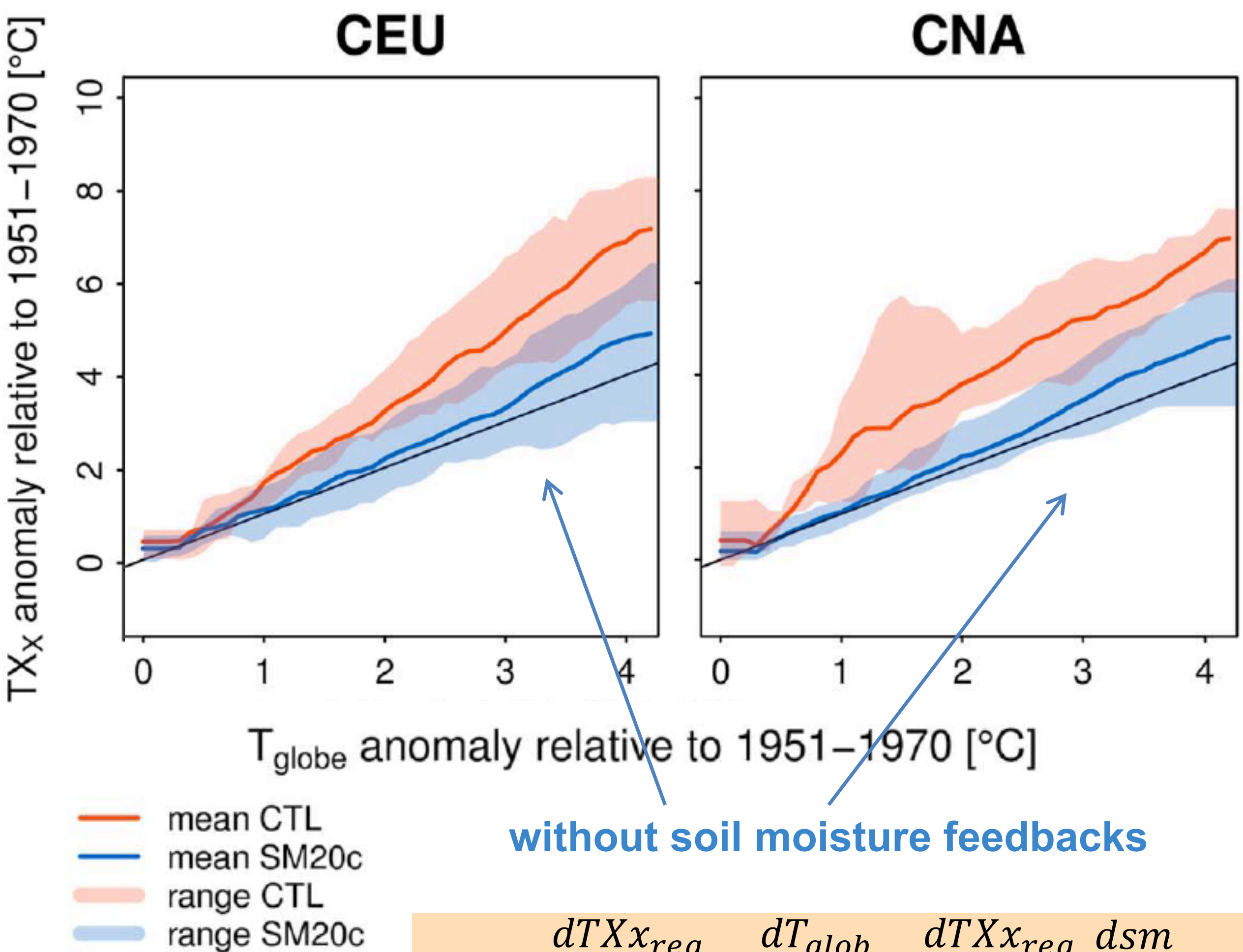

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$$\frac{dTXx_{reg}}{dCO2} = \frac{dT_{glob}}{dCO2} + \frac{dTXx_{reg}}{dsm}\frac{dsm}{dCO2}$$

Soil moisture – temperature feedbacks: Projections

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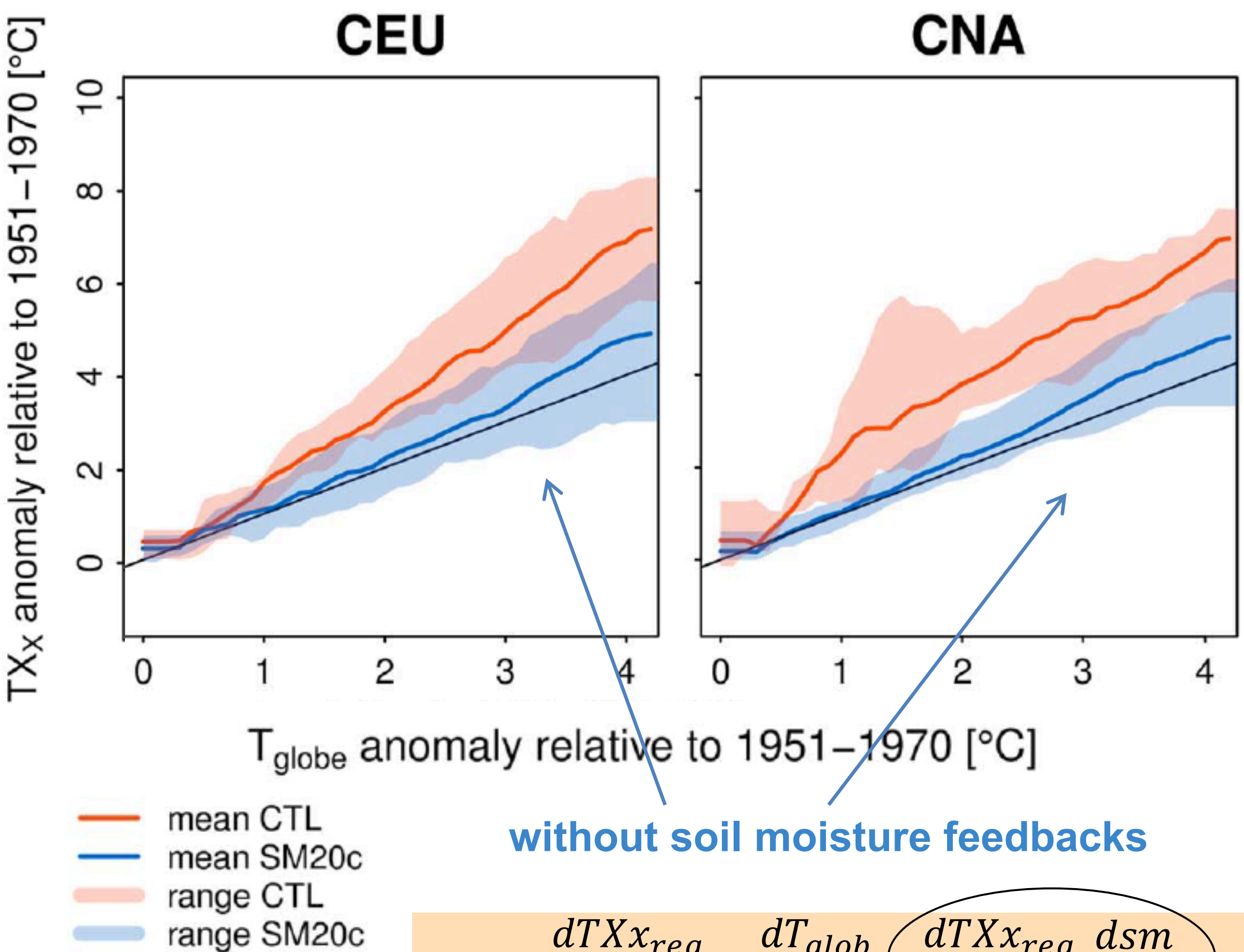

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Regional climate sensitivity as additional controlling factor beside global climate sensitivity!

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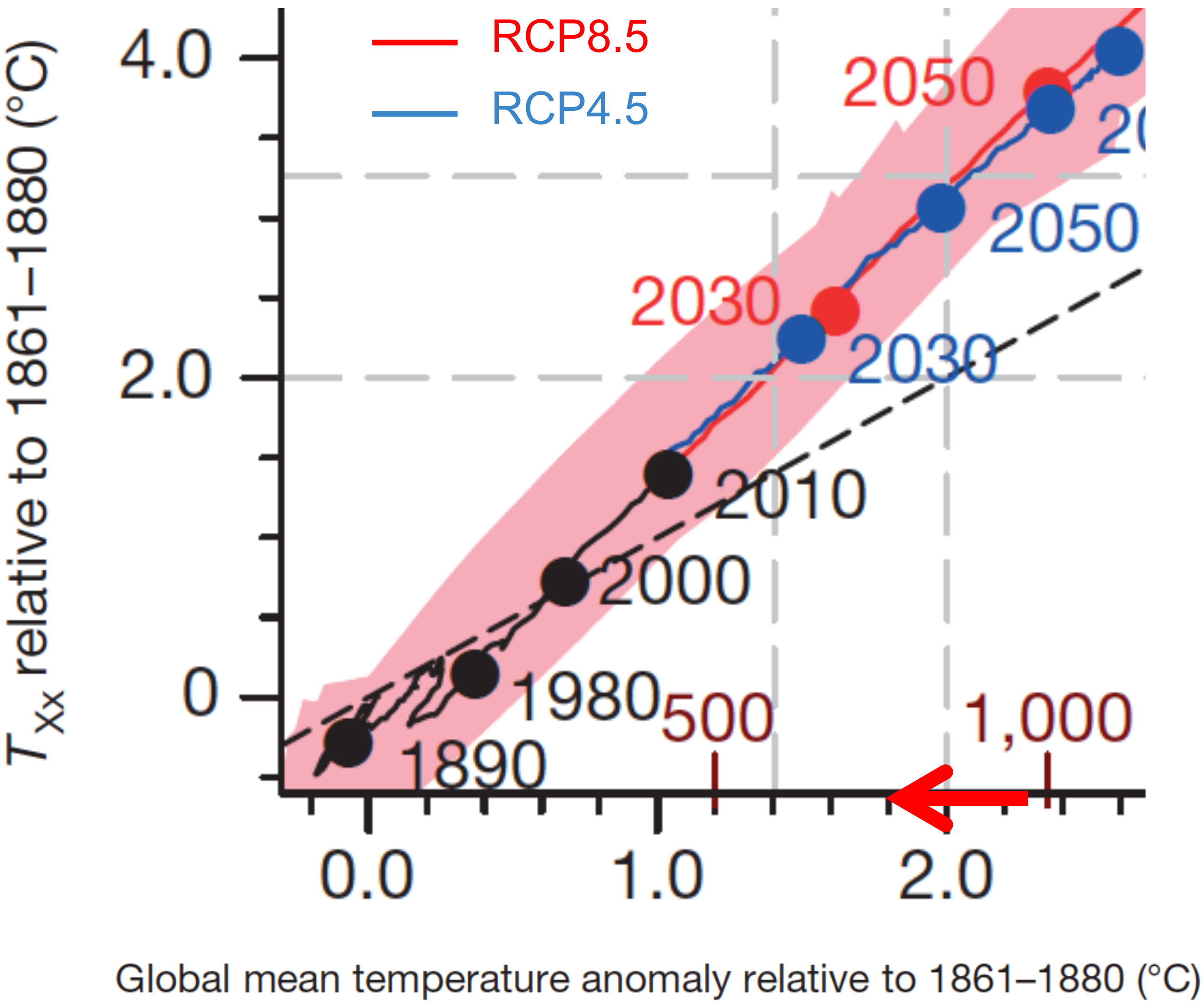
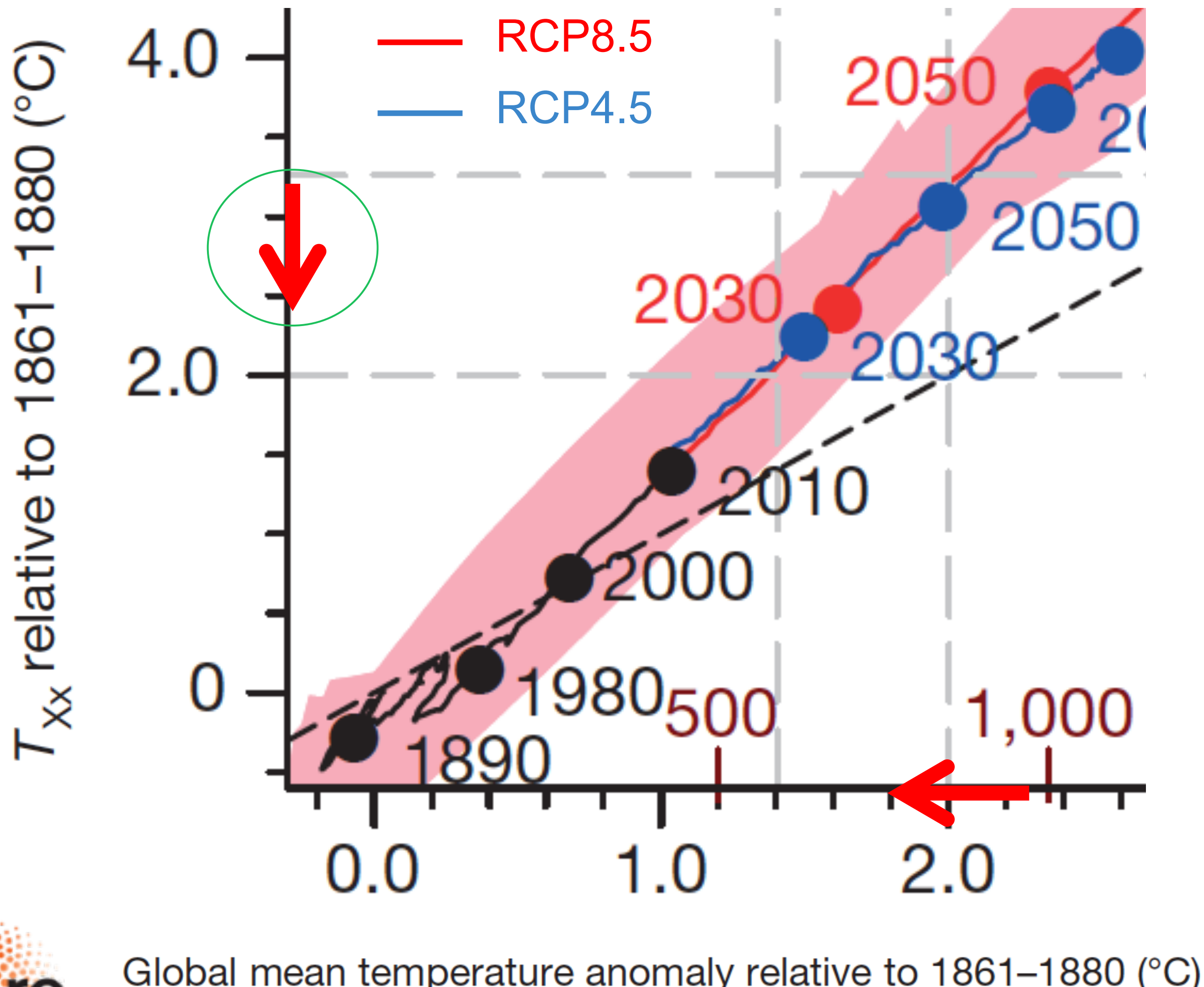
Reducing impacts

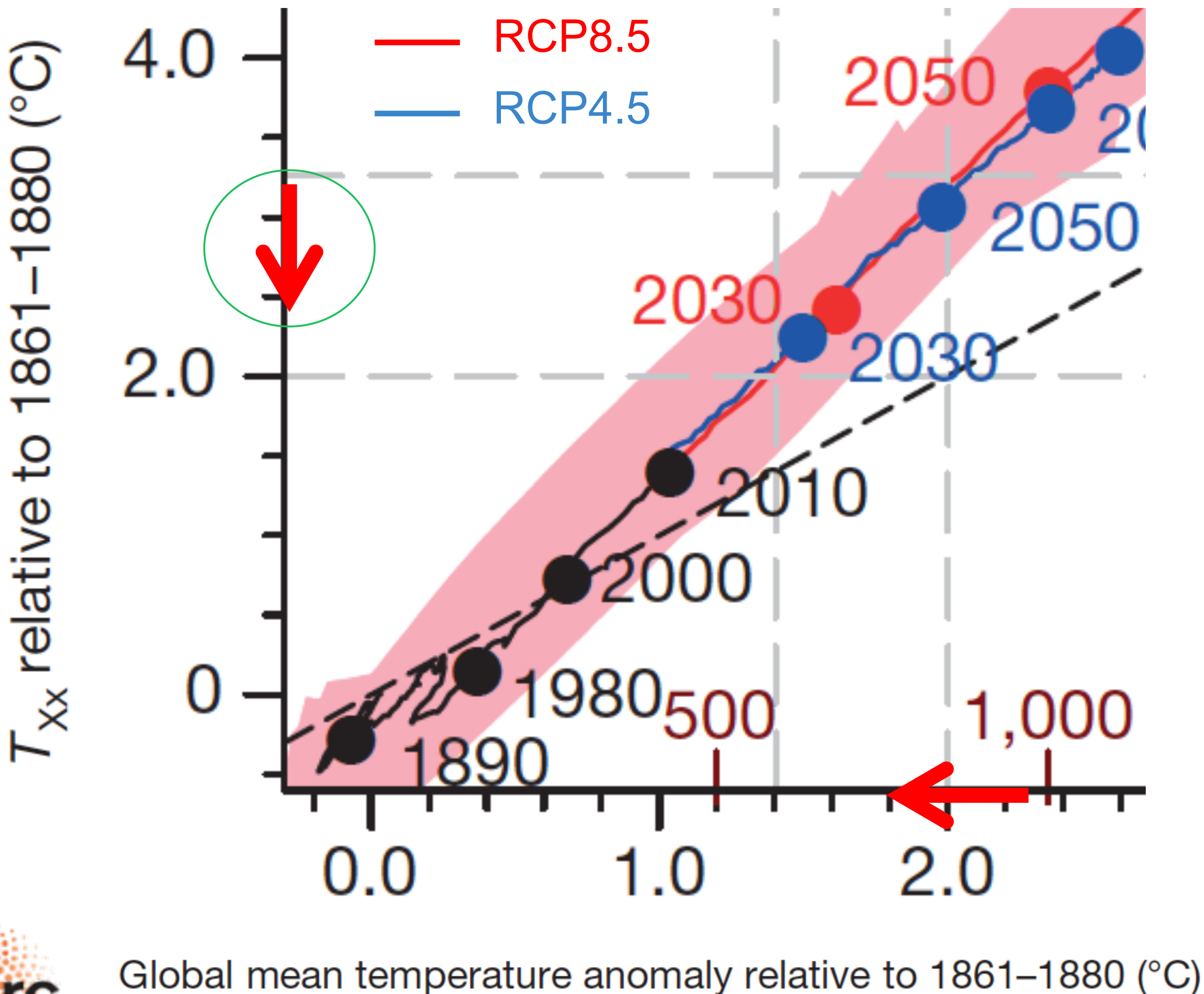


Reducing impacts



Regional scale increases in temperature extremes could also be reduced through a **reduction of the land-based amplification**

Reducing impacts



Regional scale increases in temperature extremes could also be reduced through a **reduction of the land-based amplification**:

Regional "land climate engineering":

-Increased albedo *(e.g. Davin et al. 2014, PNAS; Seneviratne et al. 2018, Nat. Geo)*

-Irrigation *(e.g. Thiery et al. 2017, JGR)*

Cooling of up to 1-2C regionally….

Biophysical effects of land use changes

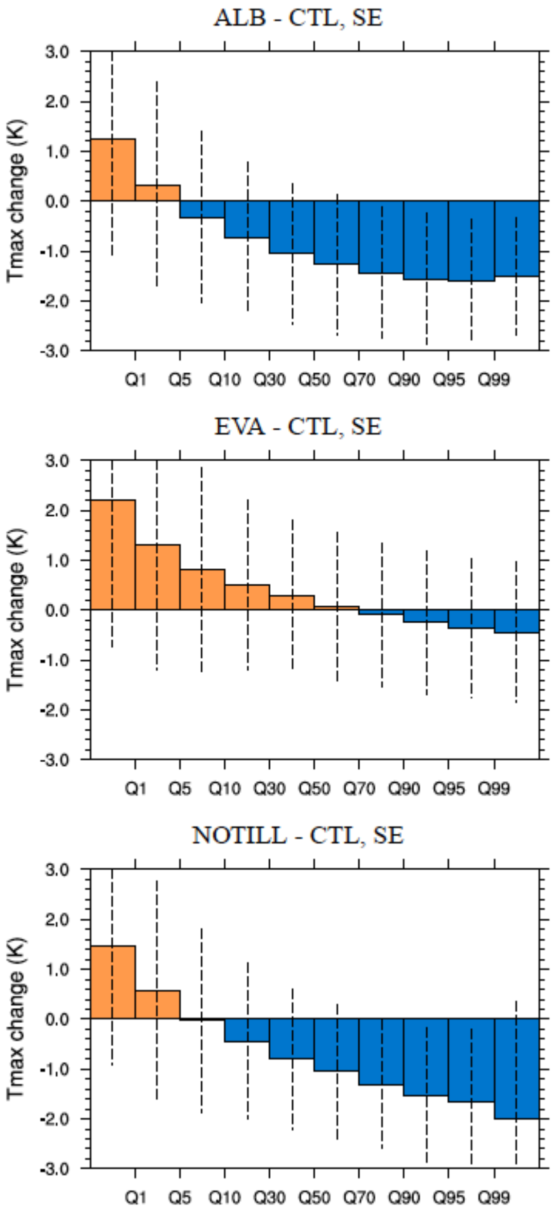
Biophysical effects of land use changes

Substantial co-benefits (no-till farming)
Substantial trade-offs (e.g. afforestation)

Agricultural management and temperature extremes

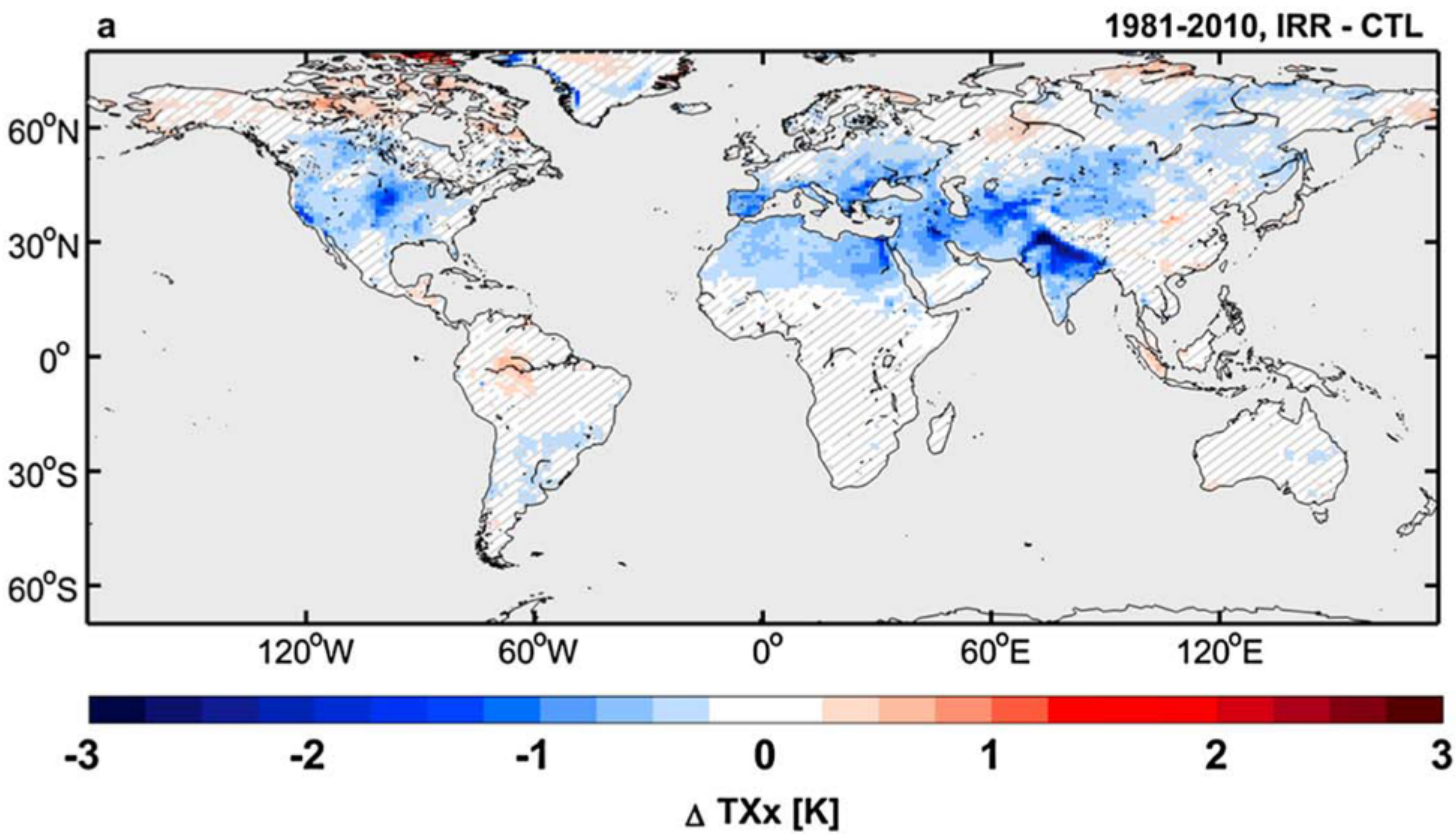
Impacts of no-till farming on regional temperature extremes:

Preferential cooling of hot extremes both from albedo and evaporation effects (up to 1-2C)!



(Davin et al. 2014, PNAS)

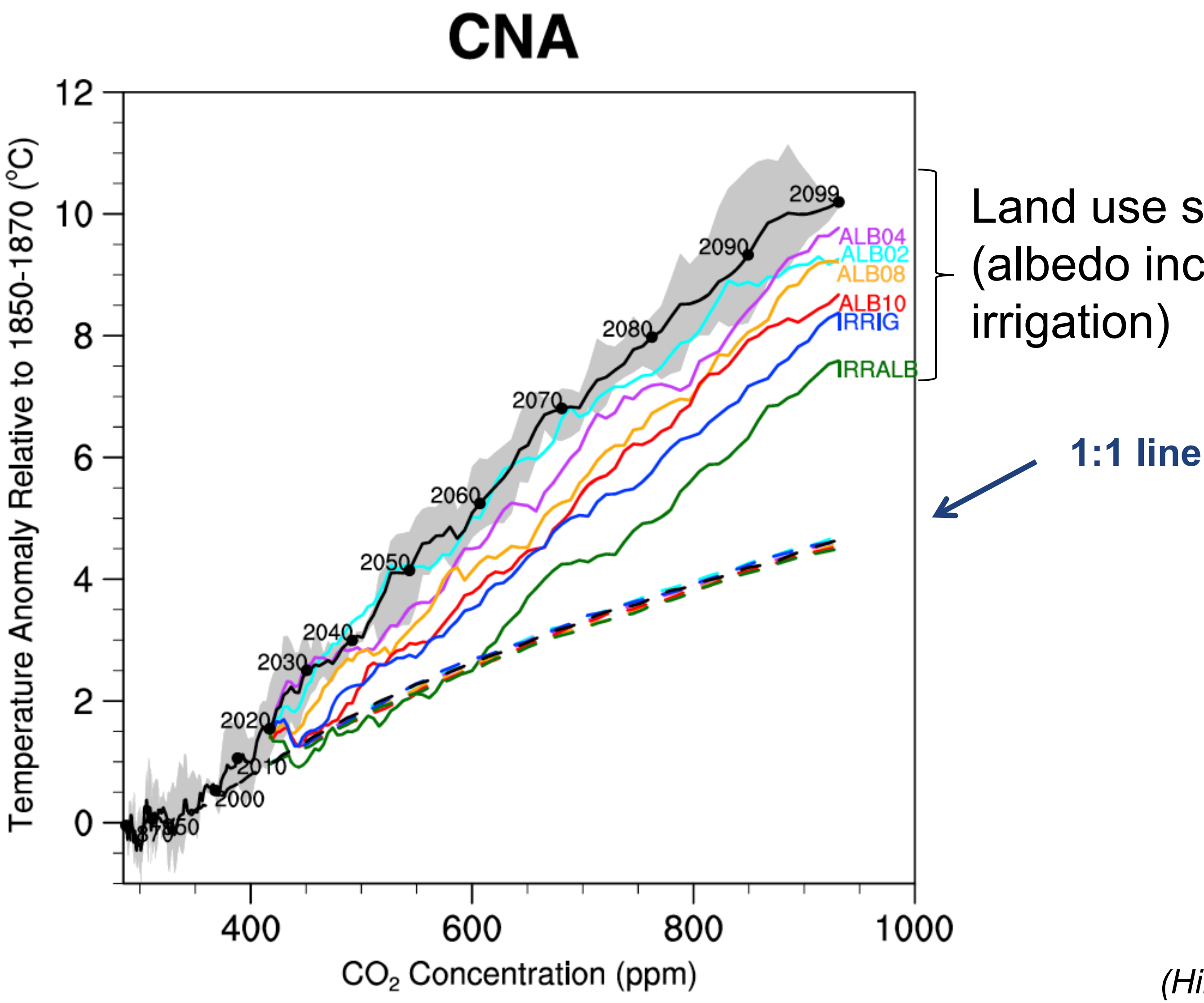
Present-day impacts of irrigation



(Thiery et al. 2017, JGR)

Regional vs global climate change: Biophysical effects of land use

Central North American warming, warmest day of the year [C]



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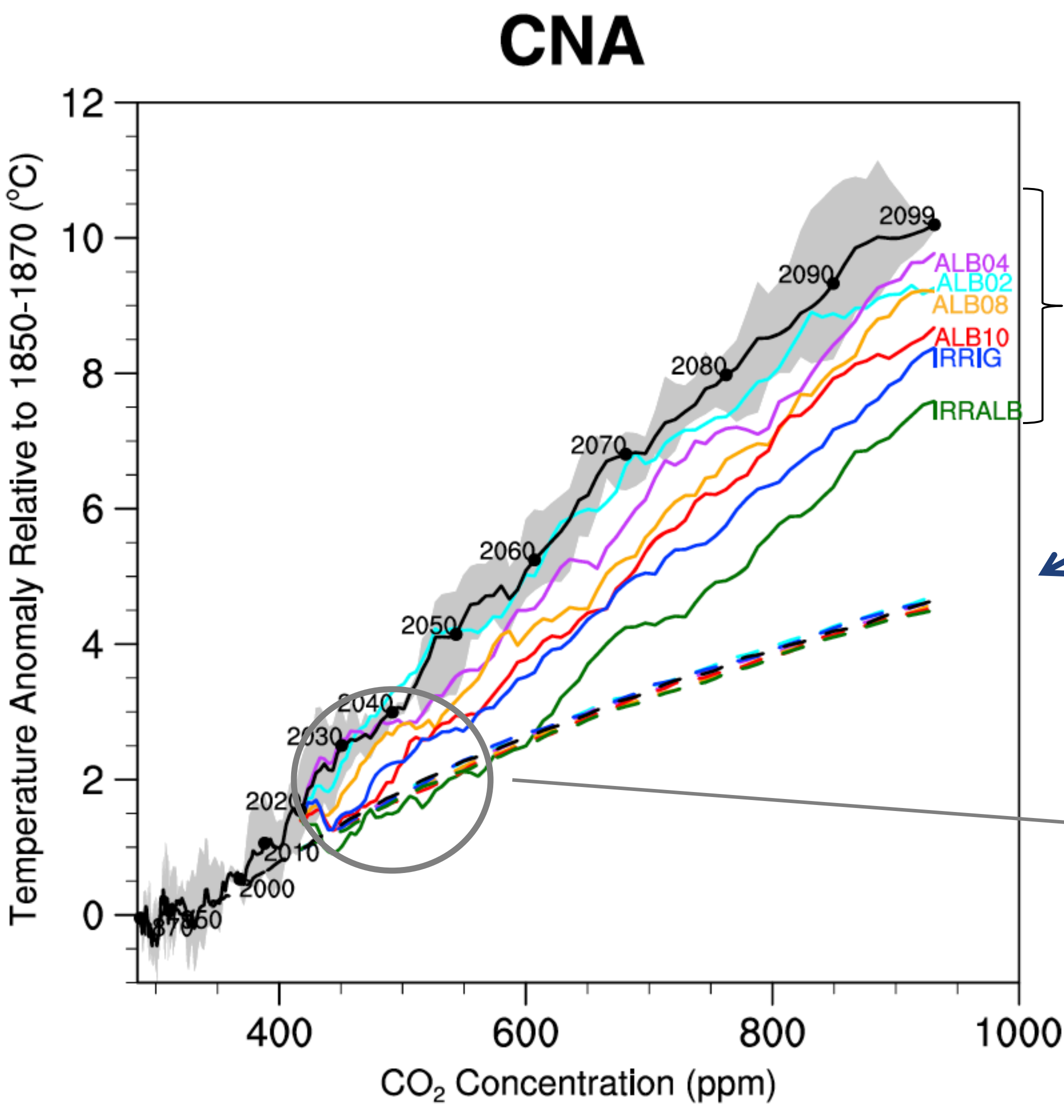

Land use scenarios (albedo increases, irrigation)

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Land use effects are particularly relevant for low-emissions scenarios!

(Hirsch et al. 2017, JGR)

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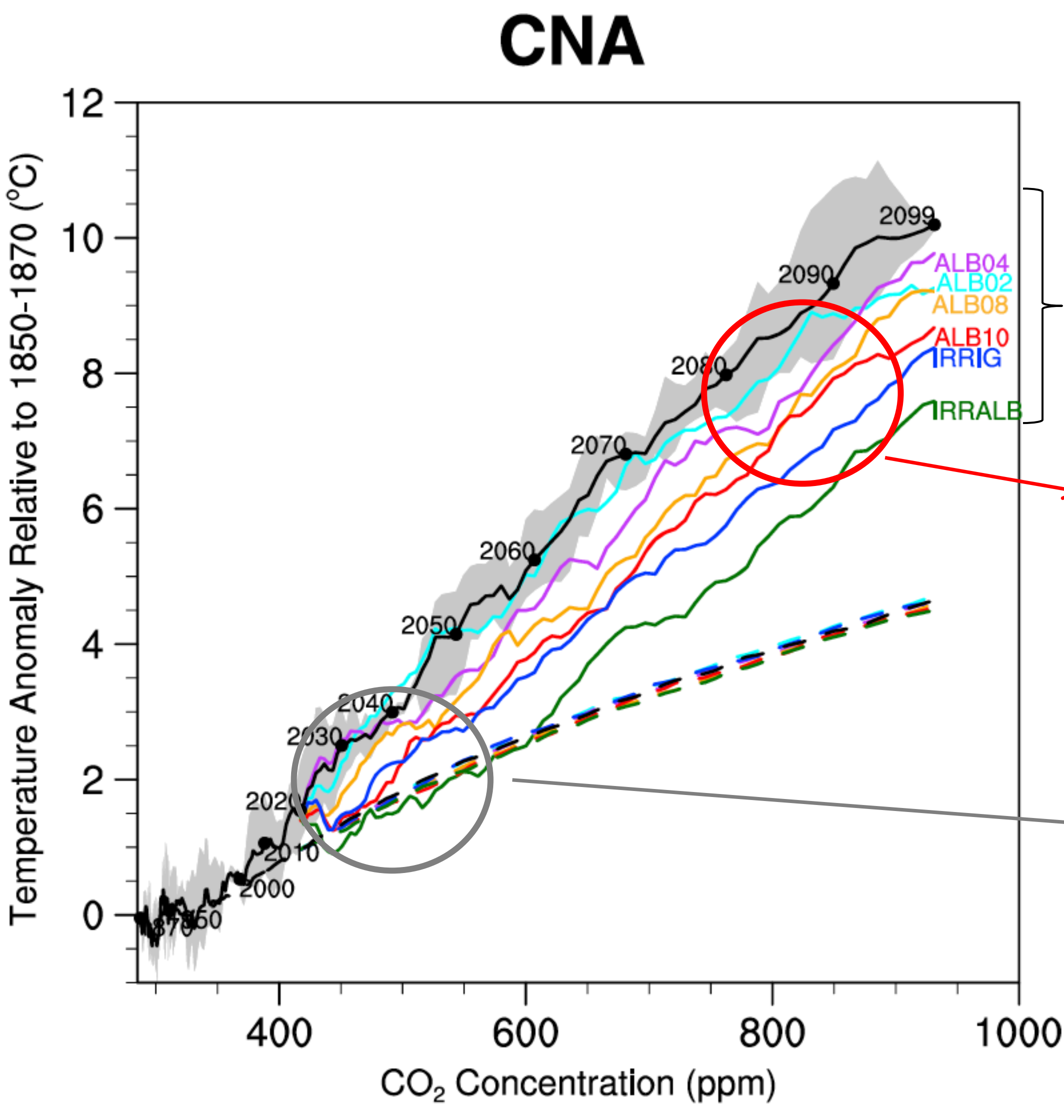

Land use scenarios (albedo increases, irrigation)

High-emissions scenarios still need to be avoided…

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Regional vs global climate change: Biophysical effects of land use

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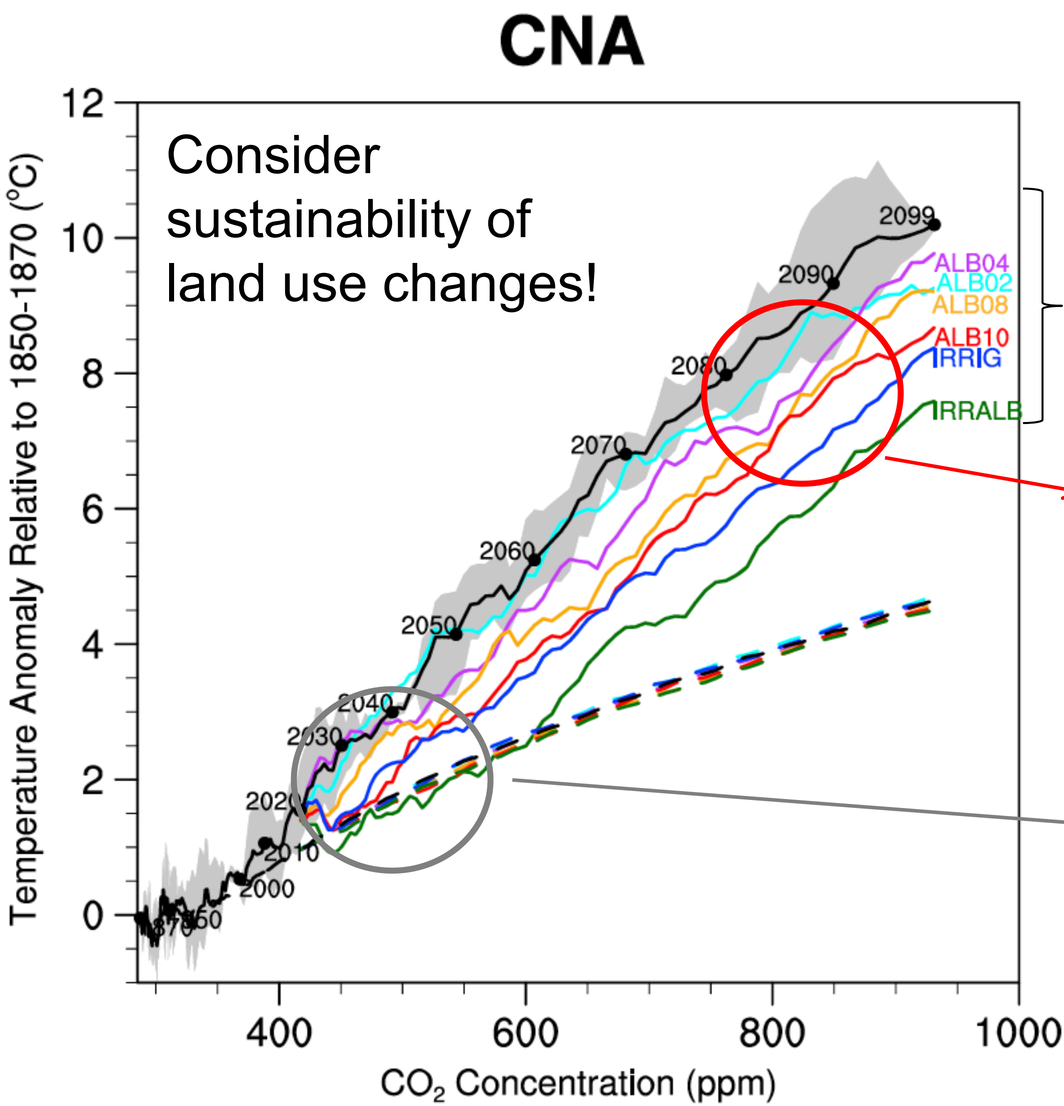

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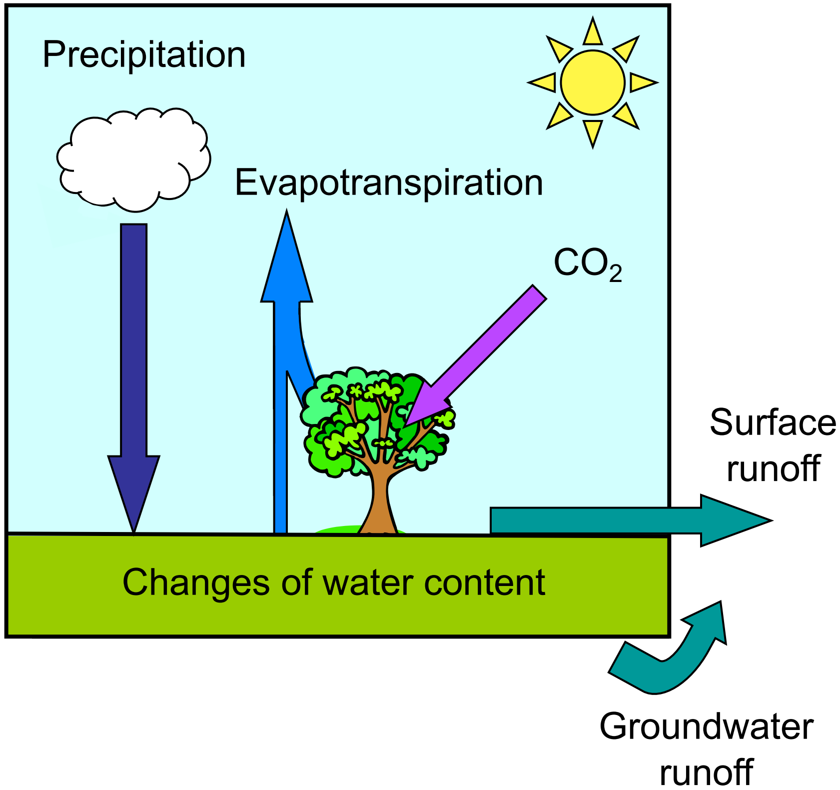
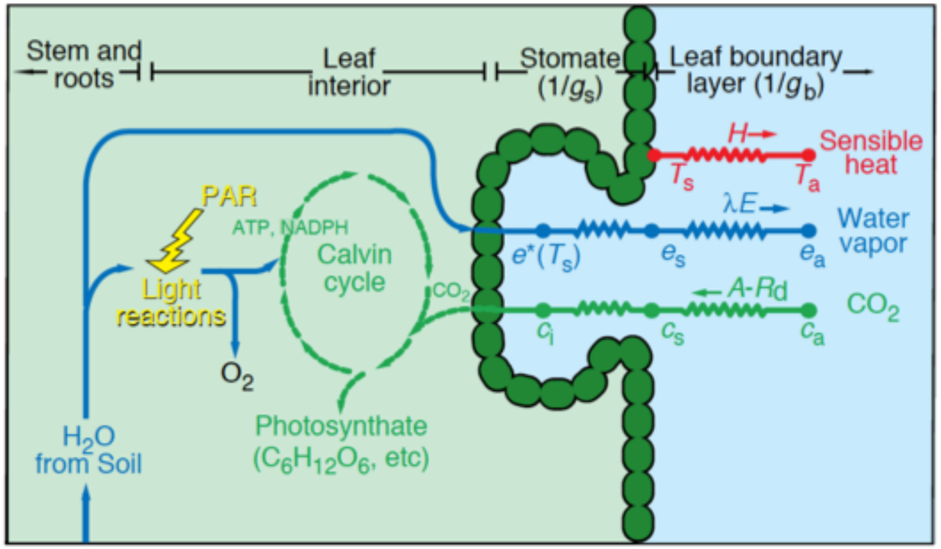
Vegetation-mediated water - CO_2 interactions

Through vegetation, the water and carbon cycles are interlinked





(Sellers et al. 1997, Science)

Land: sink for ca. 30% of CO_2 emissions

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Conclusions and outlook

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Conclusions and outlook

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- Regional climate sensitivity:
  - Associated uncertainty can be larger than for global climate sensitivity!
  - Land processes are strong control

- Land forcing plays a major role for low-emissions scenarios

- Soil moisture can also affect global climate through impacts on carbon cycle!

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Regional vs global climate change: Biophysical effects of land use

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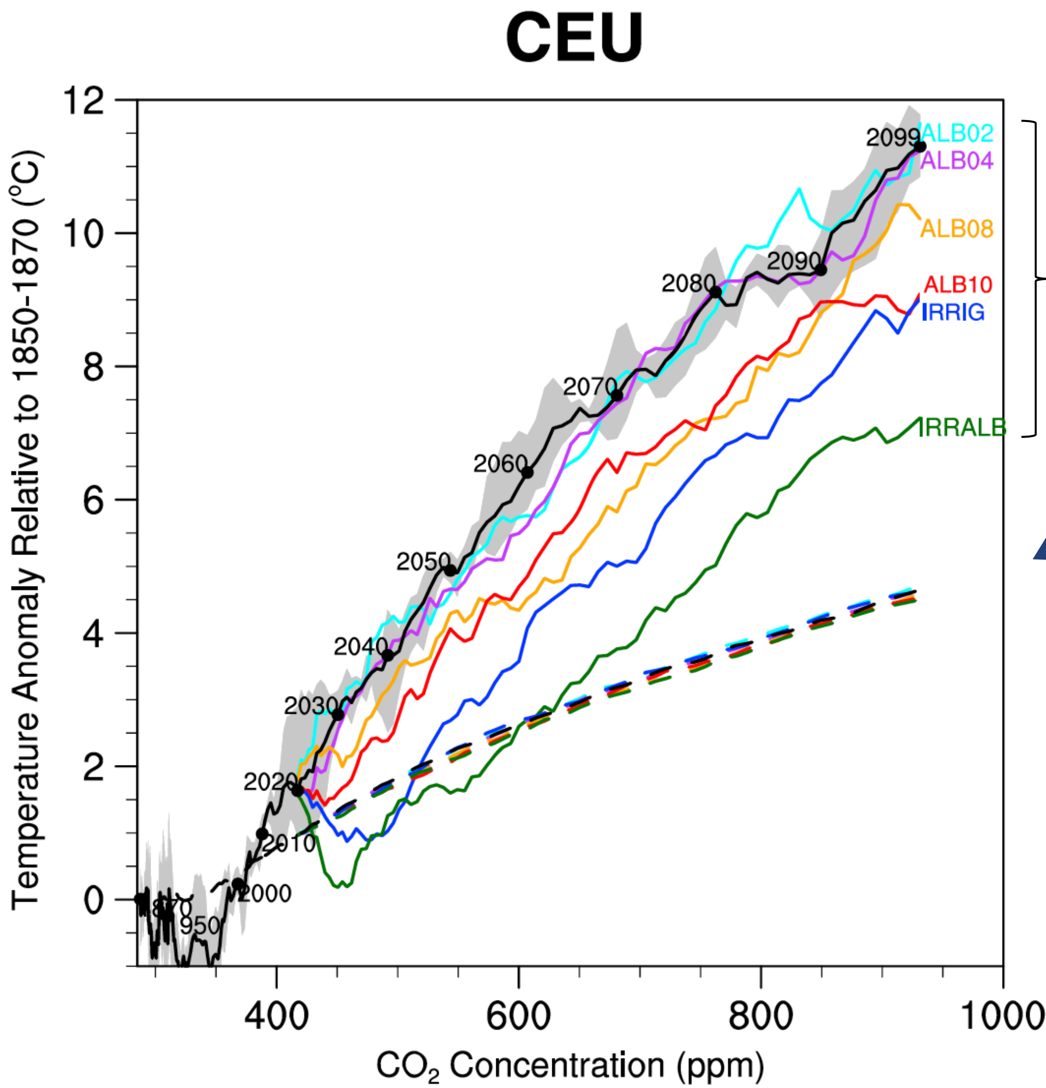

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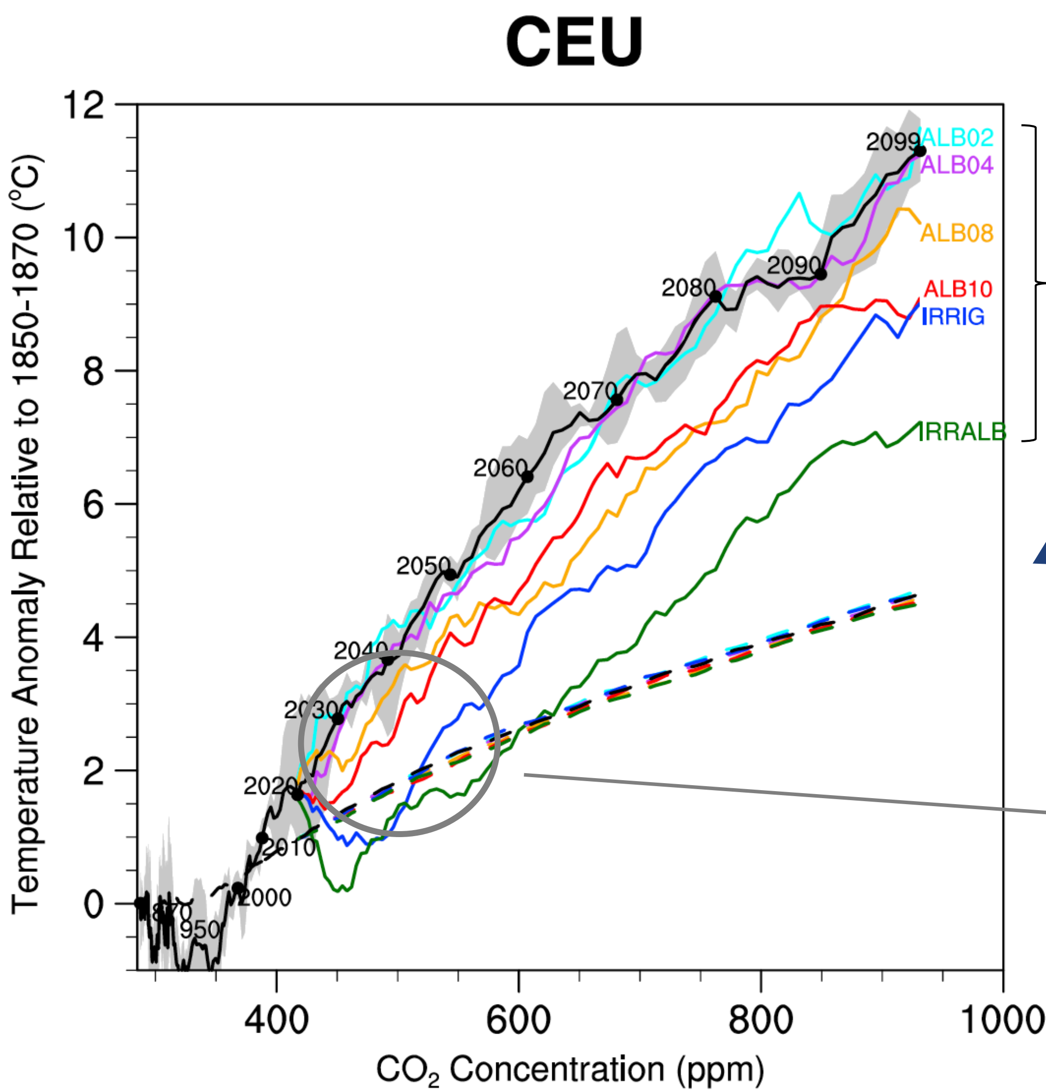

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