Regional climate sensitivity and its modulation by land surface processes

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• 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
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$^\circ$

Direct link between cumulative CO$_2$ emissions and climate response

A global T$^\circ$ target can be linked to cumulative emissions target

(IPCC 2013)
Direct link between cumulative CO$_2$ emissions and climate response

A global $T^\circ$ target can be linked to cumulative emissions target

What are the implications for regional extremes?

(IPCC 2013)
Does a 2C global warming target imply a 2C warming everywhere and all the time?

(Seneviratne et al. 2016, Nature)
Does a 2C global warming target imply 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

Mediterranean warming, warmest day of the year [C]

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

(Seneviratne et al. 2016, Nature)
Regional extremes vs global climate change

- 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)

Mediterranean warming, warmest day of the year [C]

![Graph showing regional extremes vs global climate change](image)

(Seneviratne et al. 2016, Nature)
Also scaling found for warming of minimum temperatures and changes in heavy precipitation
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Complex regional scaling: Example from 2 regions

Contiguous US

Central Europe

IPCC SREX regions
Complex regional scaling: Example from 2 regions

*T*xx contiguous USA

*Tx*, CEU

Global mean temperature anomaly relative to 1861–1880 (°C)

Cumulative total CO₂ emissions from 1870 (Gt C)

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Complex regional scaling: Example from 2 regions

**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
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)
Correlation NHD E-Int and preceding 3mn SPI CRU

NHD: # hot days
SPI: Standardized Precipitation Index

(Mueller and Seneviratne 2012, PNAS)
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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Prescribed soil moisture to present-day levels in projections to assess impact of soil moisture changes for projections

Mean drying of the soil is explaining added warming in extremes in several land regions
(Vogel et al. 2017, GRL)
Soil moisture – temperature feedbacks are the main driver for the projected temperature extremes amplification in mid-latitudes!

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\[
\frac{dT_{x_{reg}}}{dCO2} = \frac{dT_{glob}}{dCO2} + \frac{dT_{x_{reg}}}{dsm} \frac{dsm}{dCO2}
\]
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Regional climate sensitivity as additional controlling factor beside global climate sensitivity!

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Reducing impacts

Global mean temperature anomaly relative to 1861–1880 (°C)

$T_{xx}$ relative to 1861–1880 (°C)

- RCP8.5
- RCP4.5
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 1-2°C 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)
Impacts of no-till farming on regional temperature extremes:

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

*(Davin et al. 2014, PNAS)*
Land use and climate change: Biophysical impacts

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]

Land use scenarios (albedo increases, irrigation)

1:1 line

(Hirsch et al. 2017, JGR)
Regional vs global climate change: Biophysical effects of land use

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

(Hirsch et al. 2017, JGR)
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High-emissions scenarios still need to be avoided…

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

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Land use and climate change

Regional vs global climate change: Biophysical effects of land use

Consider sustainability of land use changes!

Land use scenarios (albedo increases, irrigation)

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(Hirsch et al. 2017, JGR)
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Through vegetation, the water and carbon cycles are interlinked.

Land: sink for ca. 30% of CO$_2$ emissions

(Sellers et al. 1997, Science)
Outline

• Relating changes in global temperature to regional extremes and impacts

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• Soil moisture and the carbon cycle

• Conclusions
• Amplification of regional changes in temperature extremes with changes in global temperature (ca. 50% in mid-latitude) due to soil moisture-temperature feedbacks
Conclusions and outlook

• Amplification of regional changes in temperature extremes with changes in global temperature (ca. 50% in mid-latitude) due to soil moisture-temperature feedbacks

• Regional climate sensitivity:
  • Associated uncertainty can be larger than for global climate sensitivity!
  • Land processes are strong control
• Amplification of regional changes in temperature extremes with changes in global temperature (ca. 50% in mid-latitude) due to soil moisture-temperature feedbacks

• 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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