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GLACE-CMIP5 experiment: Update

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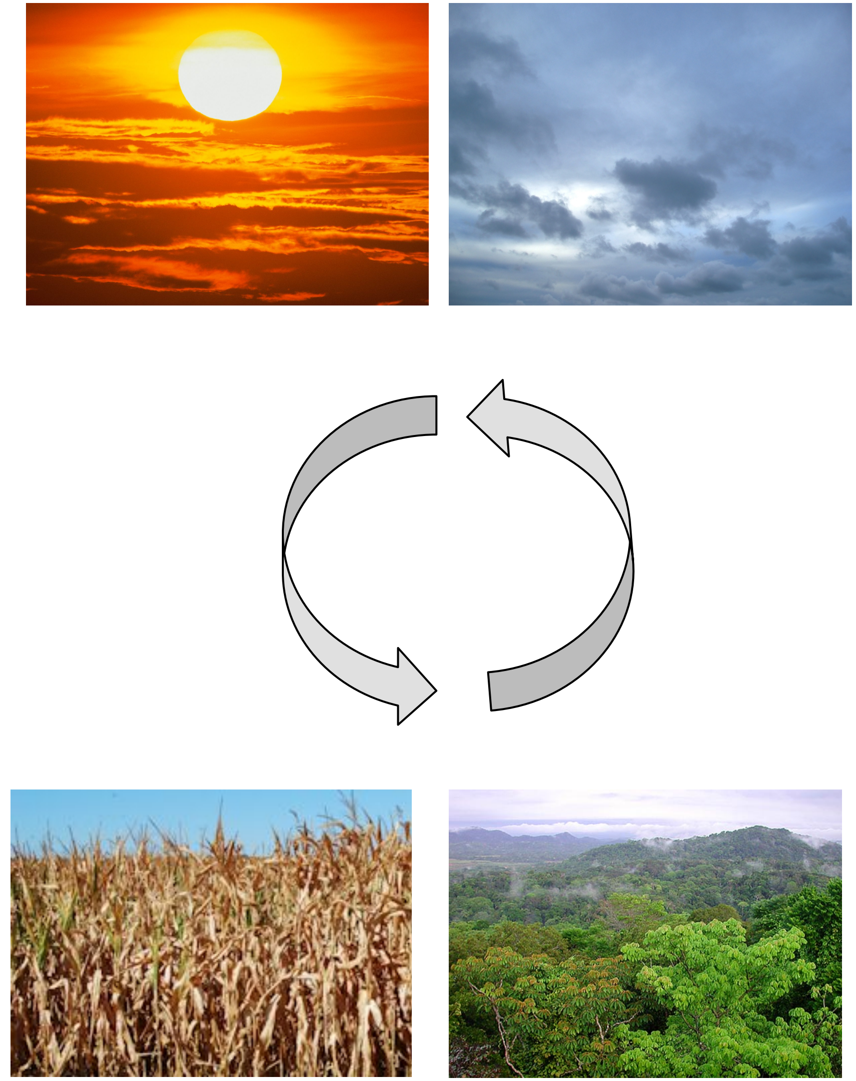
Aims of GLACE-CMIP5:

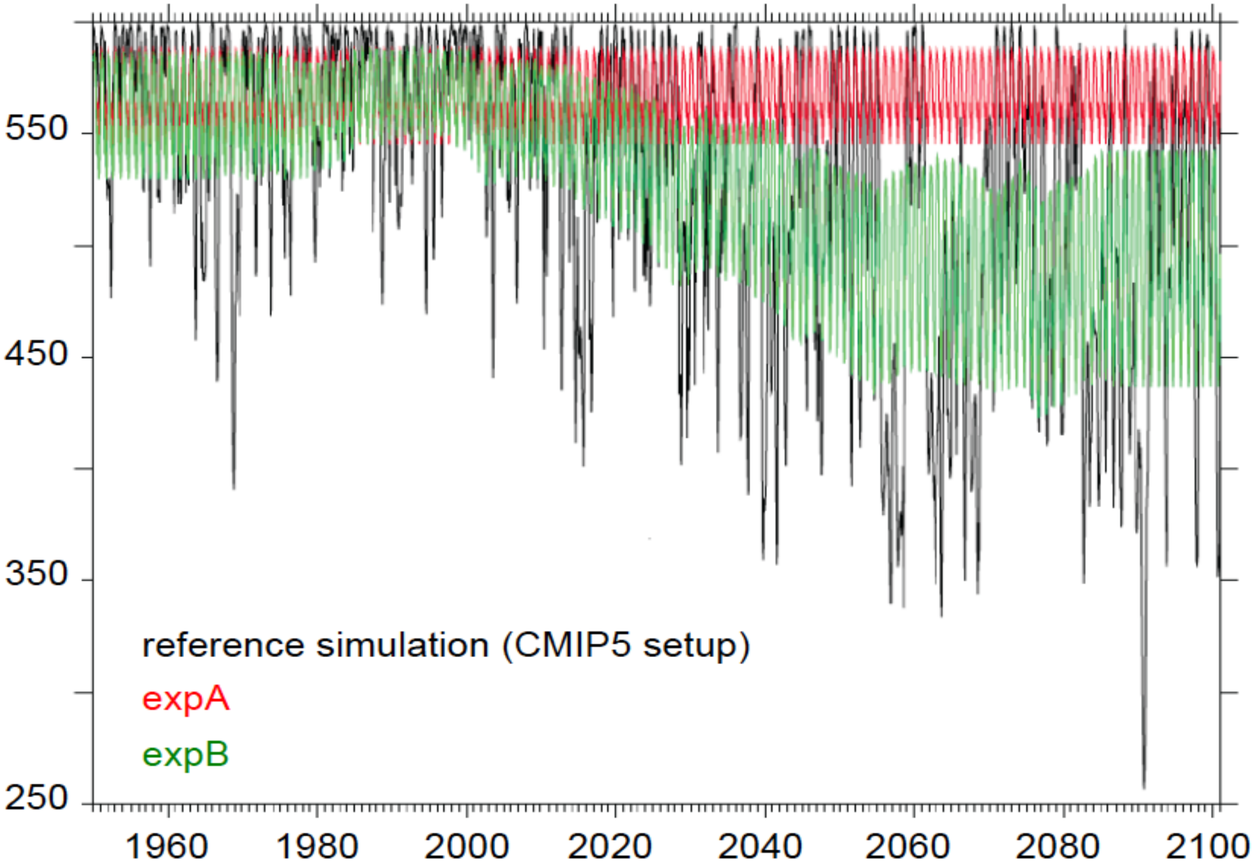
Investigate effects of changes in soil moisture content and soil moisture-climate coupling in future climate

Contribution to climate change signal?



Experimental set-up

Soil moisture (point in Central Europe)



GLACE-CMIP5 investigates the impact of **decadal changes in soil moisture** on climate

(Focus on climate-change projections ≠ GLACE-1 and GLACE-2: Focus on sub-seasonal and seasonal forecasting)

(Seneviratne et al. 2013, GRL)

Experimental set-up

Experiment #1A: GC1A85

- Rerun AR5 climate change projections for RCP8.5/4.2 (i.e. concentrations-driven) with seasonal cycle of soil moisture set to *1971-2000 climatology*
- SST and sea ice: *Prescribed* from "master" simulation
- Atmospheric CO_2: *Prescribed* (4.2)
- Transient land use: *Prescribed* from "master" simulation

Experiment #1B: GC1B85

- Same as #1A with seasonal cycle of soil moisture set to *transient climatology (running mean over 30-year period; in first 15 years use 1950-1979 climatology, in last 15 years use 2071-2100)*

Experimental set-up

Experiment #1A: GC1A85

- Rerun AR5 climate change projections for RCP8.5/4.2 (i.e. concentrations-driven) with seasonal cycle of soil moisture set to *1971-2000 climatology*
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Experiment #1B: GC1B85

- Same as #1A with seasonal cycle of soil moisture set to *transient climatology (running mean over 30-year period; in first 15 years use 1950-1979 climatology, in last 15 years use 2071-2100)*

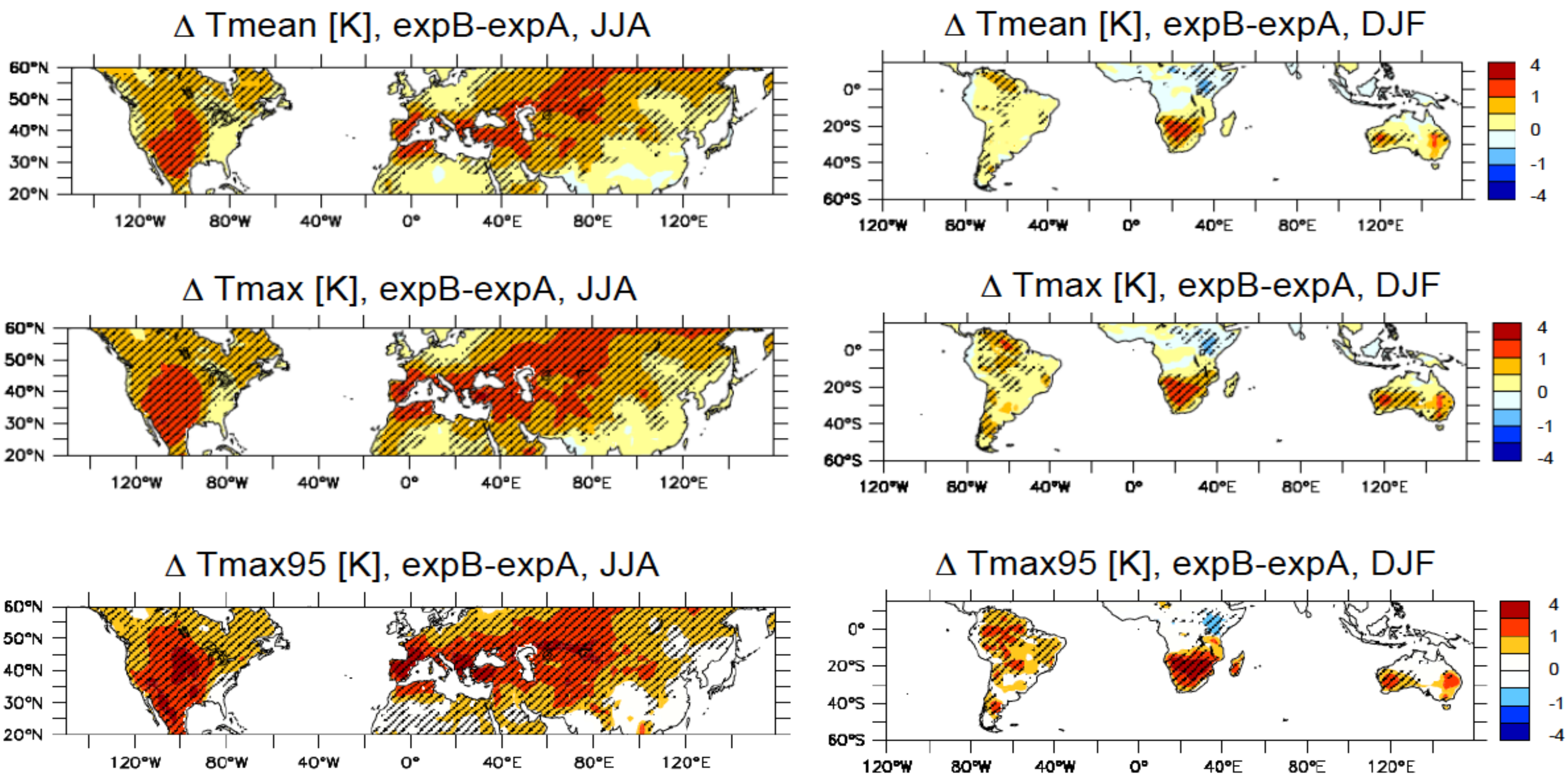
Experiment #1C (OPTIONAL): GC1C85

- Rerun AR5 climate change projections for RCP8.5/4.2 (i.e. concentrations-driven) with CO_2 levels for photosynthesis set to 1971-2000 climatology
- SST and sea ice, transient land use: prescribed from "master simulation"

Participating groups

- **Design:** ETH Zurich (Sonia Seneviratne), KNMI (Bart van den Hurk)
- **Database:** ETH Zurich (Martin Hirschi, Micah Wilhelm, Tanja Stanelle, Sonia Seneviratne)
- **MPI-ESM:** Stefan Hagemann, Victor Brovkin, Martin Claussen
- **CESM:** Dave Lawrence, Matthew Higgins
- **EC-Earth:** Arndt Meier, Ben Smith, Markku Rummukainen, Bart van den Hurk
- **GFDL:** Alexis Berg, Sergey Malyshev, Kirsten Findell
- **IPSL:** Frederique Cheruy, Agnès Ducharne, Joséfine Ghattas, Jean-Louis Dufresne
- **ACCESS:** Ruth Lorenz, Andy Pitman

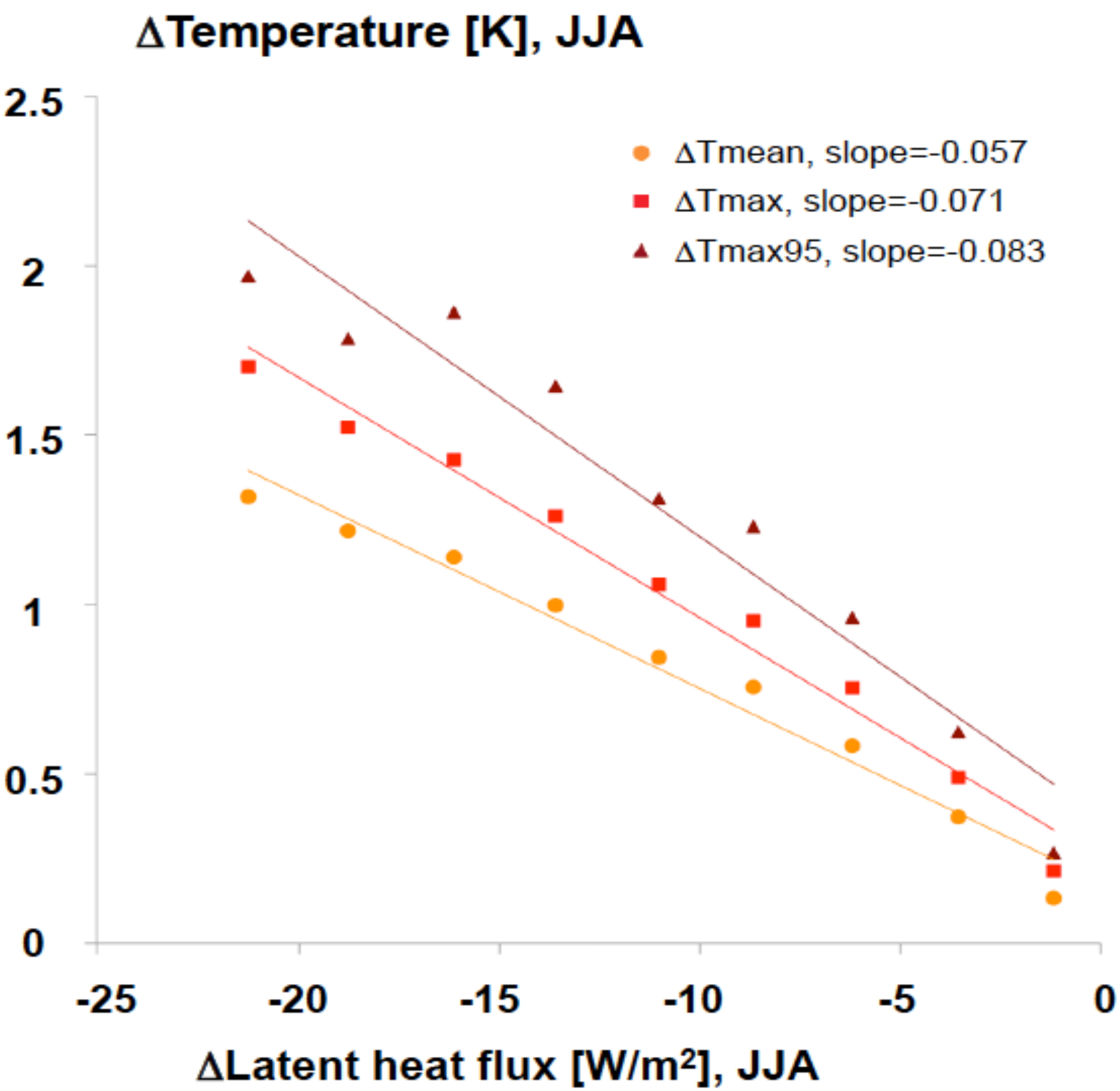
Temperature impacts



Stronger impacts on Tmax than on daily mean temperature
Stronger impacts on temperature extremes (Tmax95)
Presence of non local effects (generally downwind)

(Seneviratne et al. 2013, GRL)

Temperature impacts



Clear linear scaling between ΔLH and ΔT (with different sensitivities for Tmean, Tmax, and Tmax95)

Effects of up to 2K

(Seneviratne et al. 2013, GRL)

New developments and papers

New articles and analyses:

- A. Berg et al.: T-P correlation (J. Climate, 2015)
- W. May et al.: Effects on monsoons (Climate Dynamics, 2015)
- R. Lorenz et al.: Impacts on extreme indices (JGR, 2016)
- **A. Berg et al.: Aridity study (Nature Climate Change 2016)**
- **M. Vogel et al.: Impacts of soil moisture on regional scaling of temperature extremes (submitted to GRL)**

Impact of soil moisture feedbacks on aridity

nature climate change

LETTERS

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Land–atmosphere feedbacks amplify aridity increase over land under global warming

Alexis Berg[1]*, Kirsten Findell[2], Benjamin Lintner[3], Alessandra Giannini[1], Sonia I. Seneviratne[4], Bart van den Hurk[5], Ruth Lorenz[6], Andy Pitman[6], Stefan Hagemann[7], Arndt Meier[8], Frédérique Cheruy[9], Agnès Ducharne[10], Sergey Malyshev[11] and P. C. D. Milly[12]

Impact of soil moisture feedbacks on aridity

Background: Several studies have reported an increase in aridity measured by the aridity index (P/Ep) in climate projections *(e.g. Scheff and Frierson 2015, J. Climate; Sherwood and Fu 2014, Science)*

NB: Ep vs P is not a good measure of changes in moisture availability (e.g. Roderick et al. 2015, WRR; Milly and Dunne 2016, Nature Climate Change)
- However, this is not the topic of the present study…

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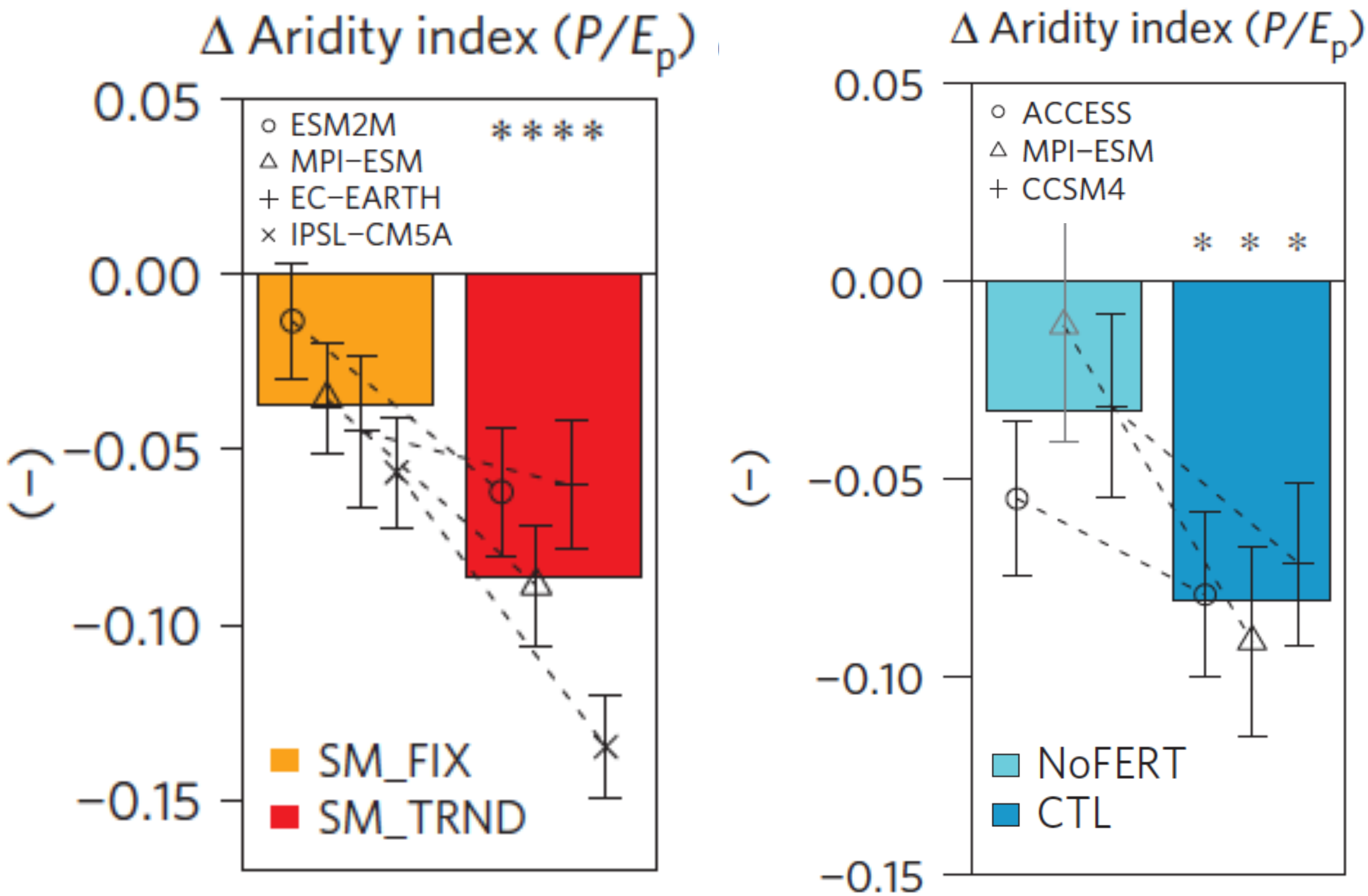
Question: What is leading to the strong change in P/Ep? Atmospheric scientists suggest that this can be explained alone by atmospheric and ocean processes...

Impact of soil moisture feedbacks on aridity



(Berg et al. 2016, Nature Climate Change)

PERSPECTIVE

doi:10.1038/nature16542

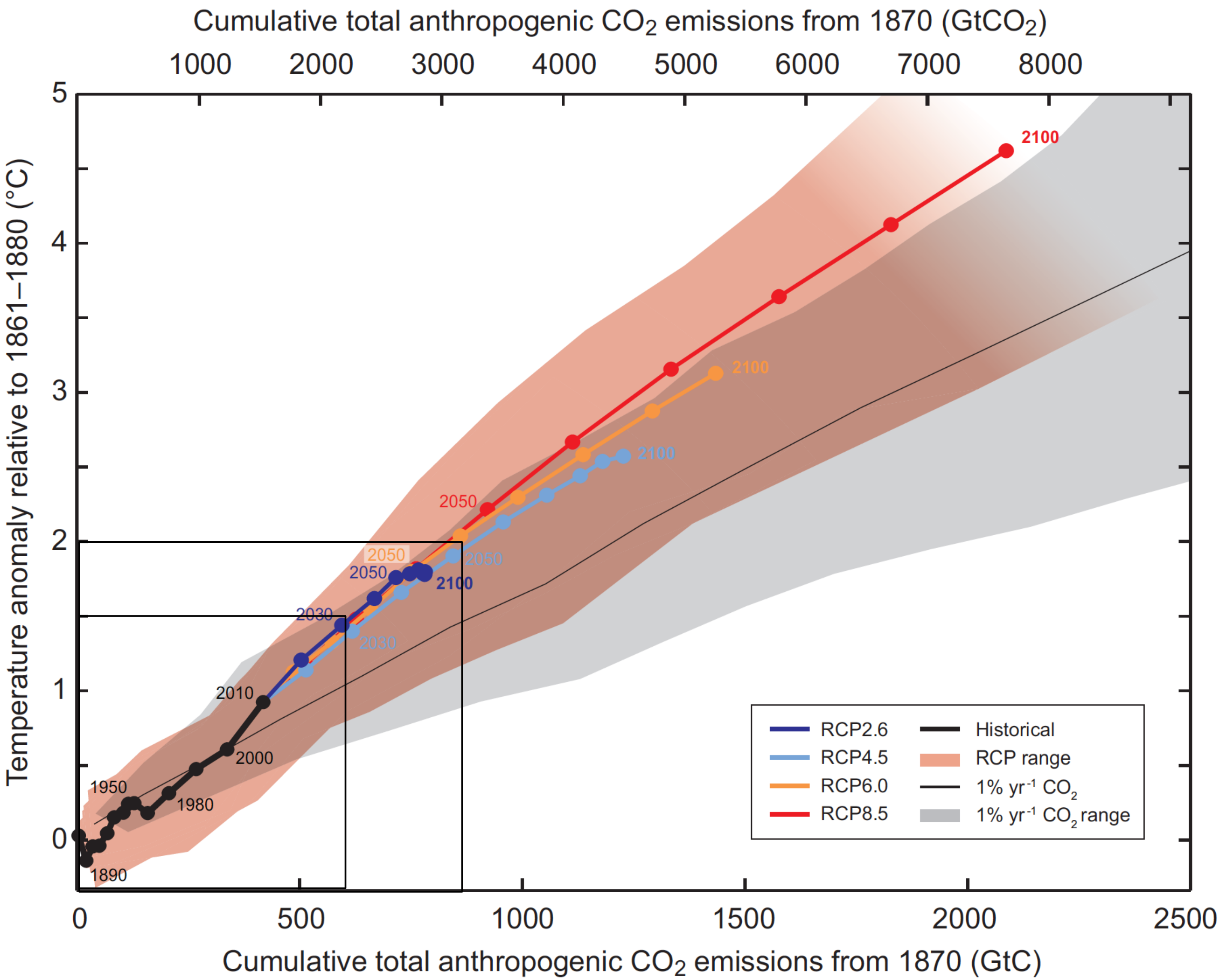
Allowable CO_2 emissions based on regional and impact-related climate targets

Sonia I. Seneviratne[1], Markus G. Donat[2,3], Andy J. Pitman[2,3], Reto Knutti[1] & Robert L. Wilby[4]

Global temperature targets, such as the widely accepted limit of an increase above pre-industrial temperatures of two degrees Celsius, may fail to communicate the urgency of reducing carbon dioxide (CO_2) emissions. The translation of CO_2 emissions into regional- and impact-related climate targets could be more powerful because such targets are more directly aligned with individual national interests. We illustrate this approach using regional changes in extreme temperatures and precipitation. These scale robustly with global temperature across scenarios, and thus with cumulative CO_2 emissions. This is particularly relevant for changes in regional extreme temperatures on land, which are much greater than changes in the associated global mean.

(Seneviratne et al. 2016, Nature)

Link between cumulative CO_2 emissions and global T°



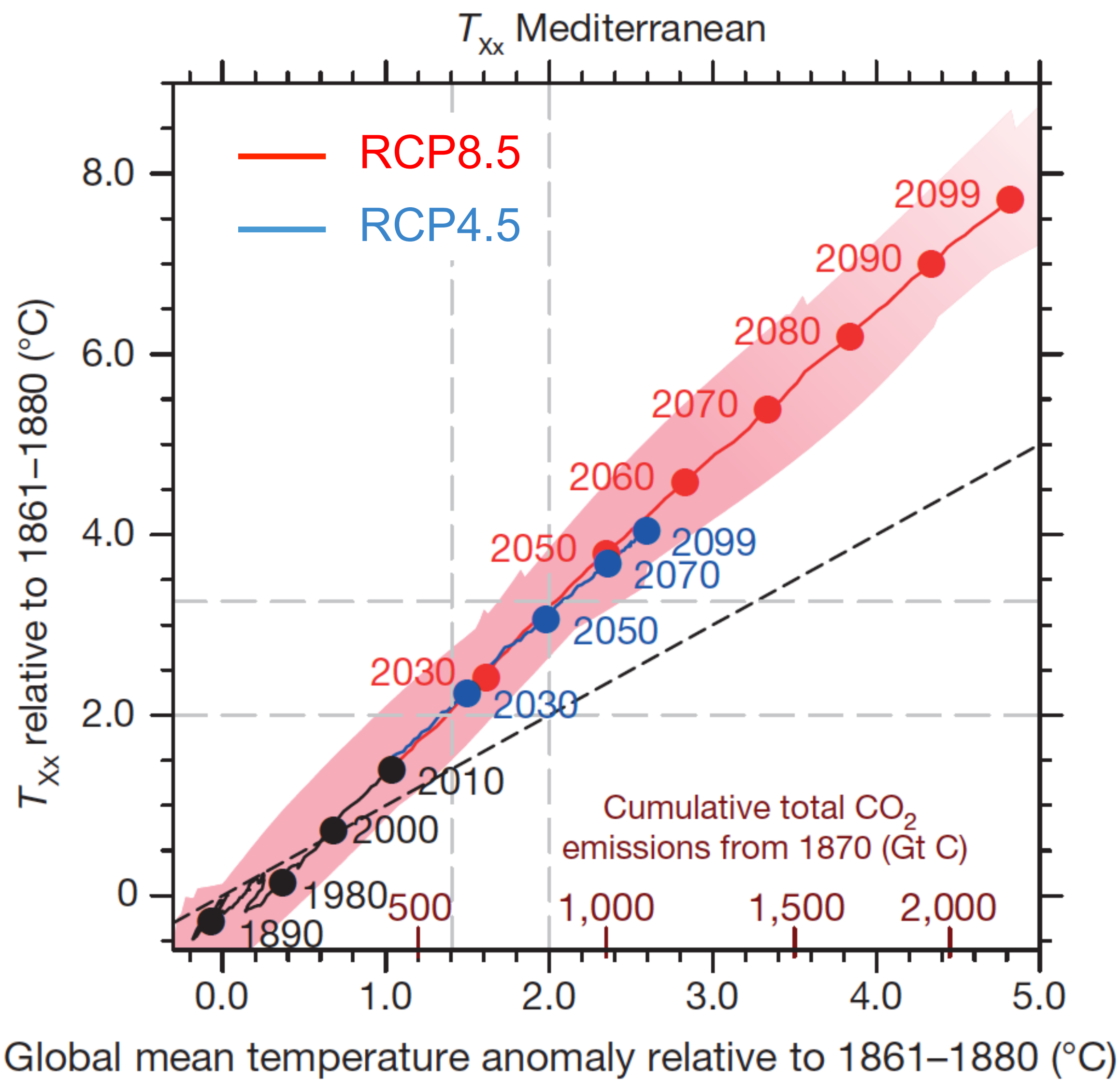
Direct link between cumulative CO_2 emissions and climate response

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

How about regional changes & impacts?

(IPCC 2013)

Relating regional climate targets with CO_2 emissions

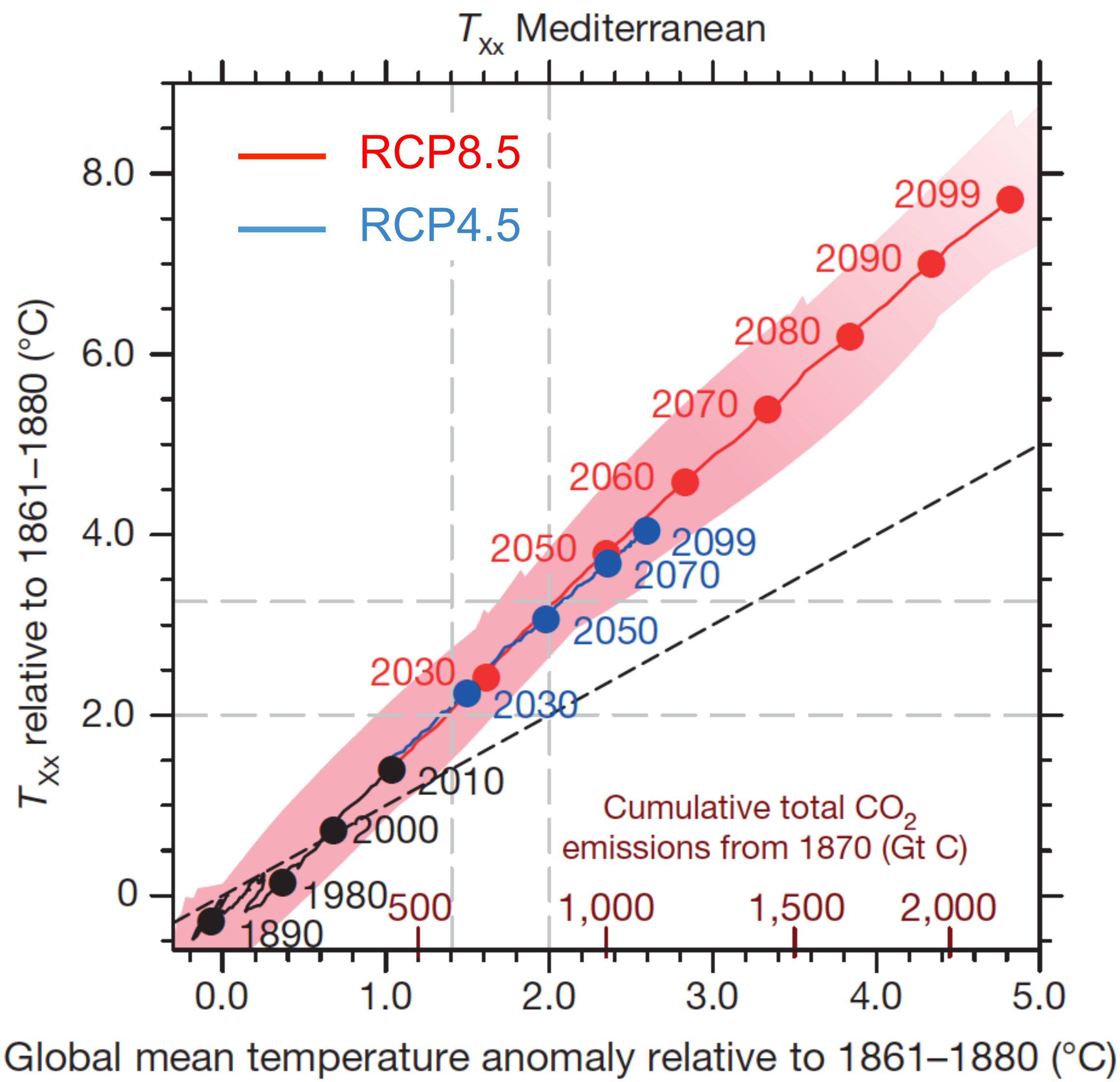


Results:

- Almost linear scaling for multi-model mean *(see also Fischer et al. 2014, GRL)*
- Pattern independent of emissions scenario!
- Tool to define impact-based targets?

(Seneviratne et al. 2016, Nature)

Relating regional climate targets with CO_2 emissions



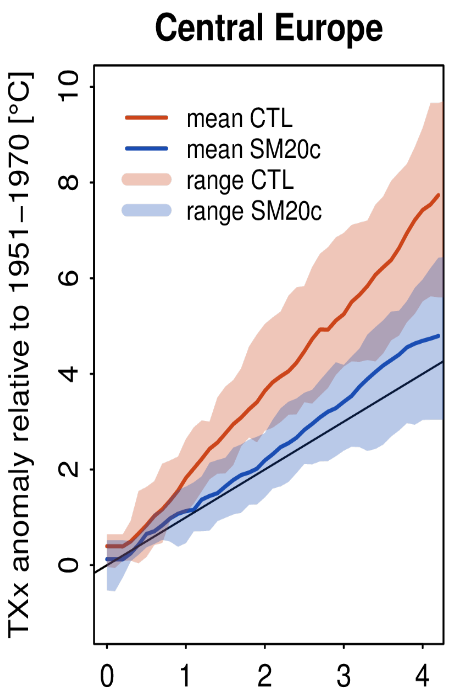
Results:

- Almost linear scaling for multi-model mean *(see also Fischer et al. 2014, GRL)*
- Pattern independent of emissions scenario!
- Tool to define impact-based targets?
- How about role of soil moisture feedbacks?

(Seneviratne et al. 2016, Nature)

Uncertainties in scaling: Impact of soil moisture-T feedbacks

Scaling for GLACE-CMIP5 experiments



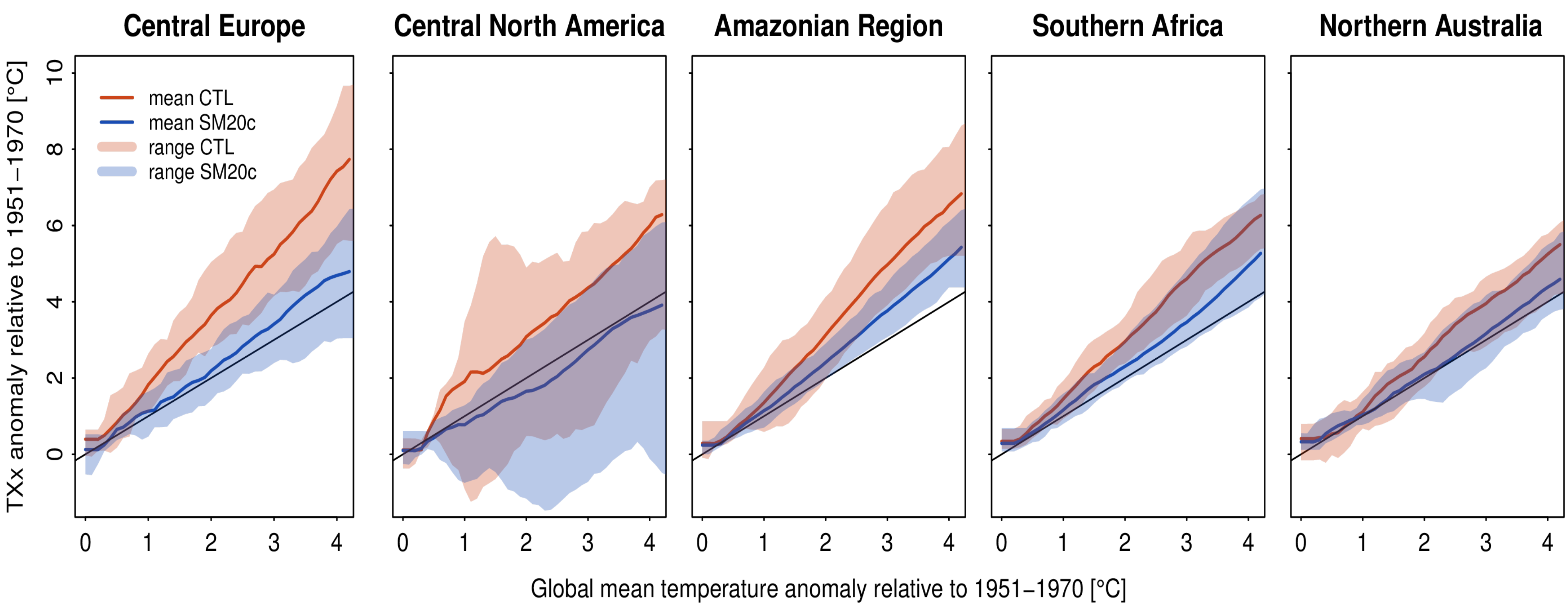
Global mean temperature increase relative to 1951-1970 [°C]

Soil moisture feedbacks (mean projected drying) explain much of the departure from the global mean response for regional temperature extremes in mid-latitudes

(Vogel et al., submitted to GRL)

Role of soil moisture – temperature feedbacks

Scaling for GLACE-CMIP5 experiments

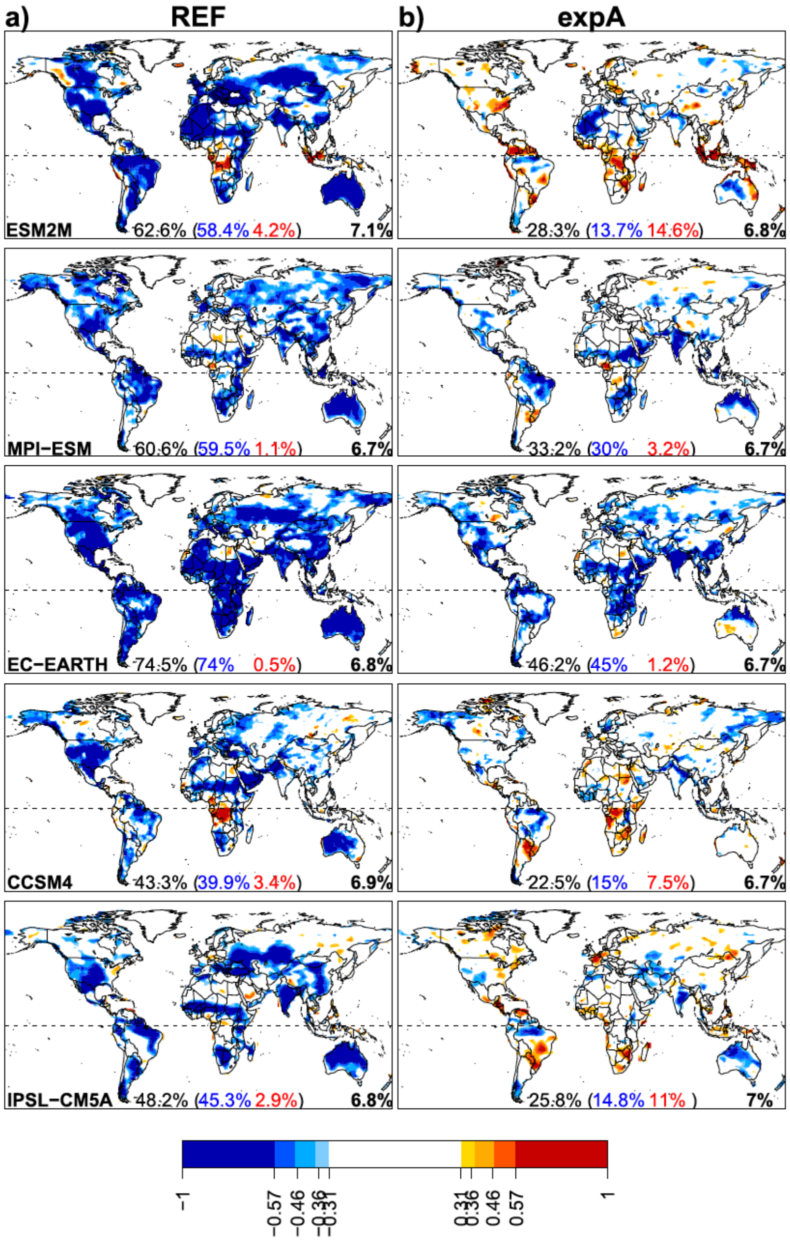


(Vogel et al., submitted to GRL)

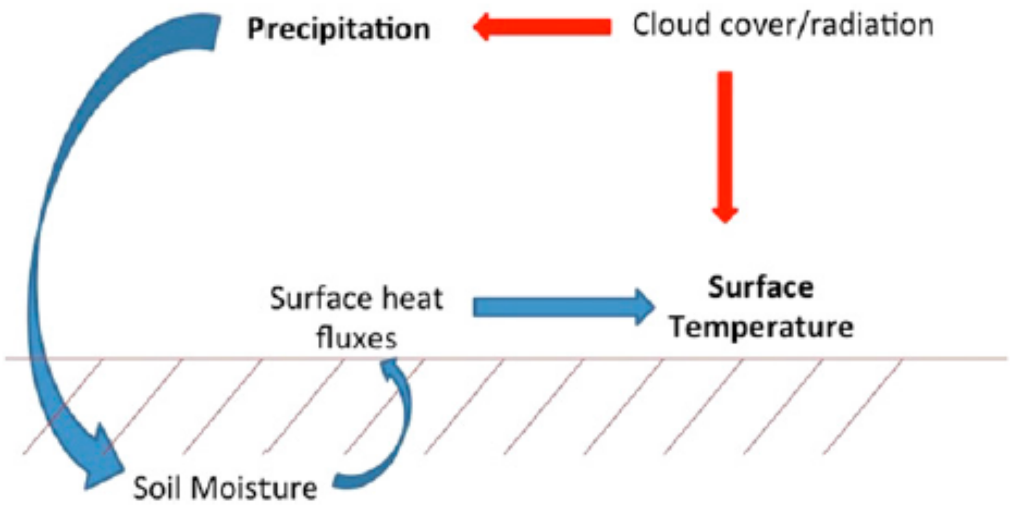
Conclusions

- **High relevance of soil moisture-climate feedbacks for climate change projections**
  - **Clear effect on temperature diagnosed in simulations**, strongest for extreme Tmax values
  - **Some effects on precipitation**, but more model dependent
- **Several further analyses on-going**
- **GLACE-CMIP5 serves as blueprint for LS3MIP experiment**

Correlation of temperature and precipitation

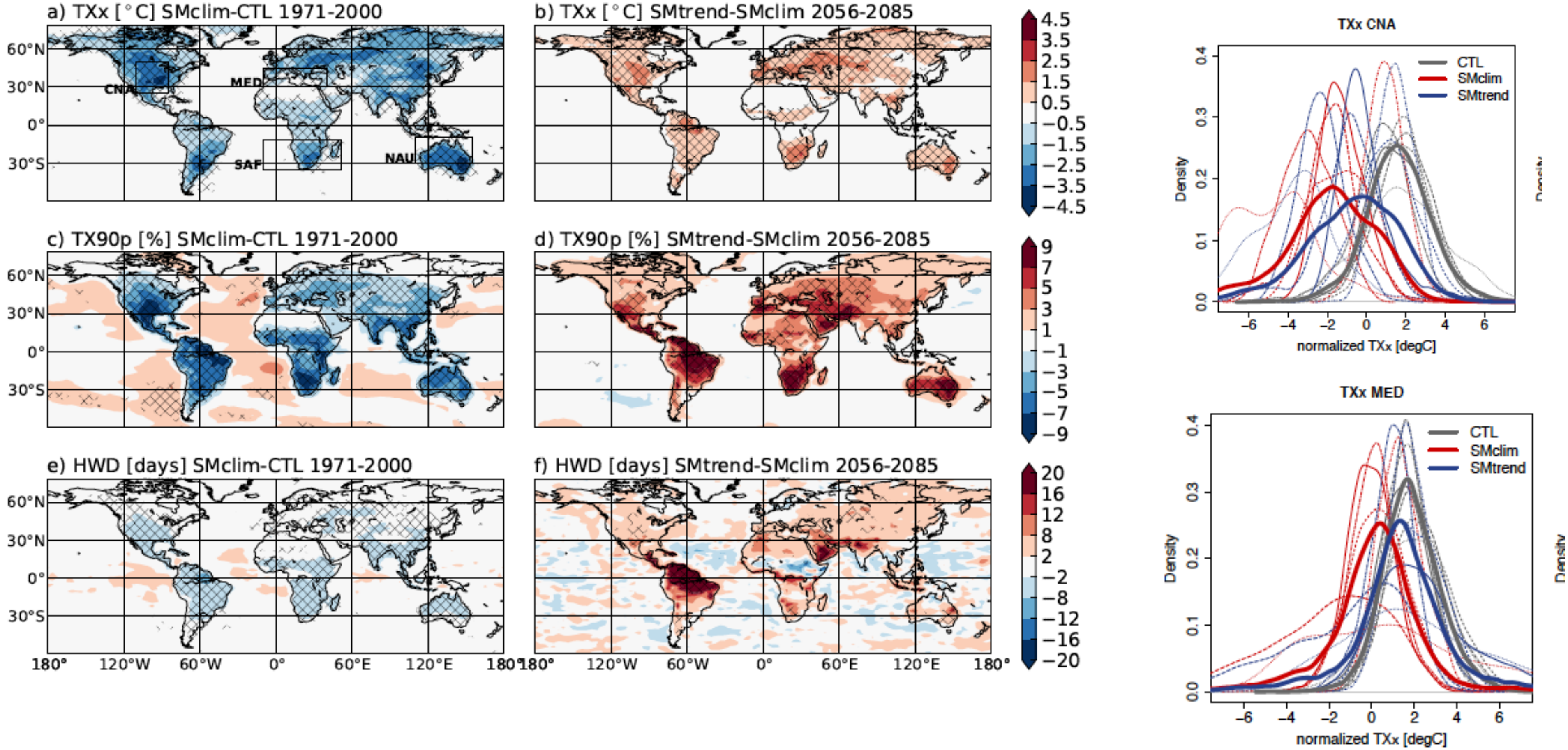


Is the (zero-lag) anticorrelation between temperature and precipitation due to soil moisture feedbacks or cloud control?



(Berg et al. 2015, J. Climate)

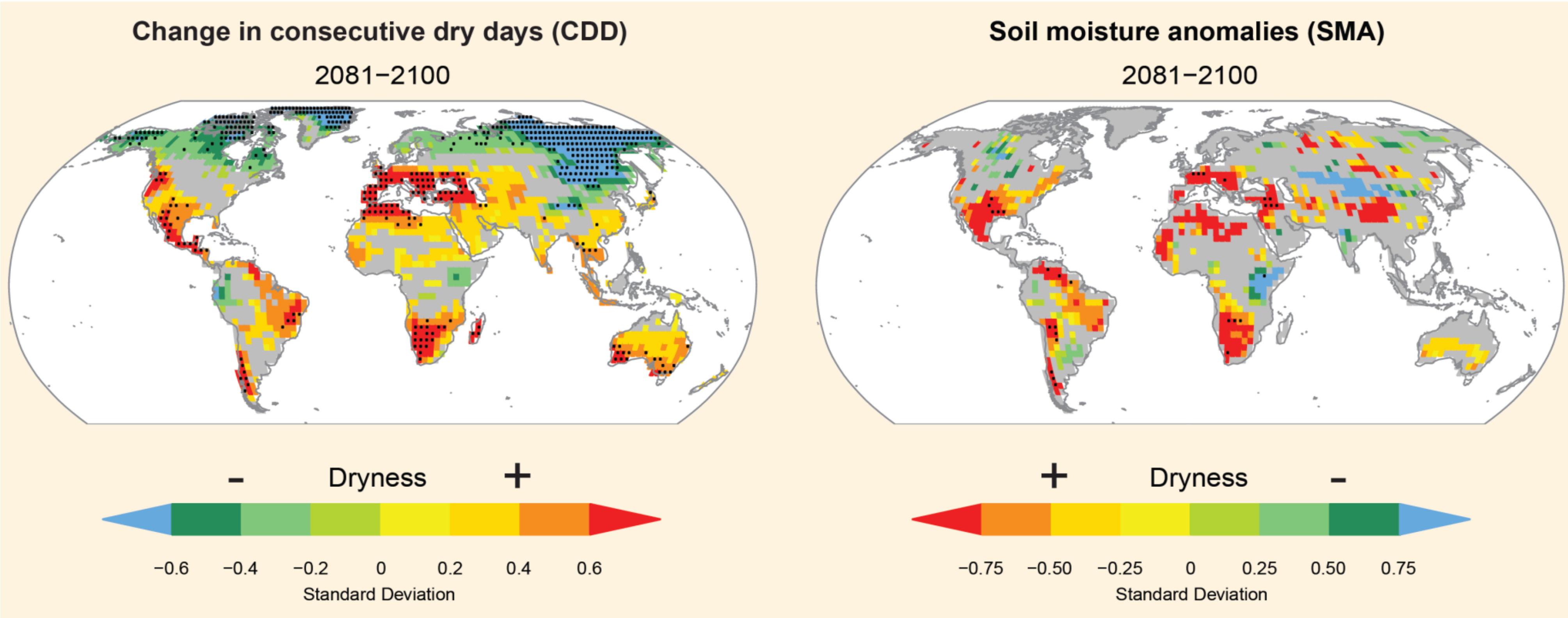
Analysis for extreme indices



Confirmation of strong effect of soil moisture-climate feedbacks for temperature extremes in present and future; less clear effects for precipitation extremes

(Lorenz et al. 2016, JGR)

Projected dryness changes (IPCC SREX)



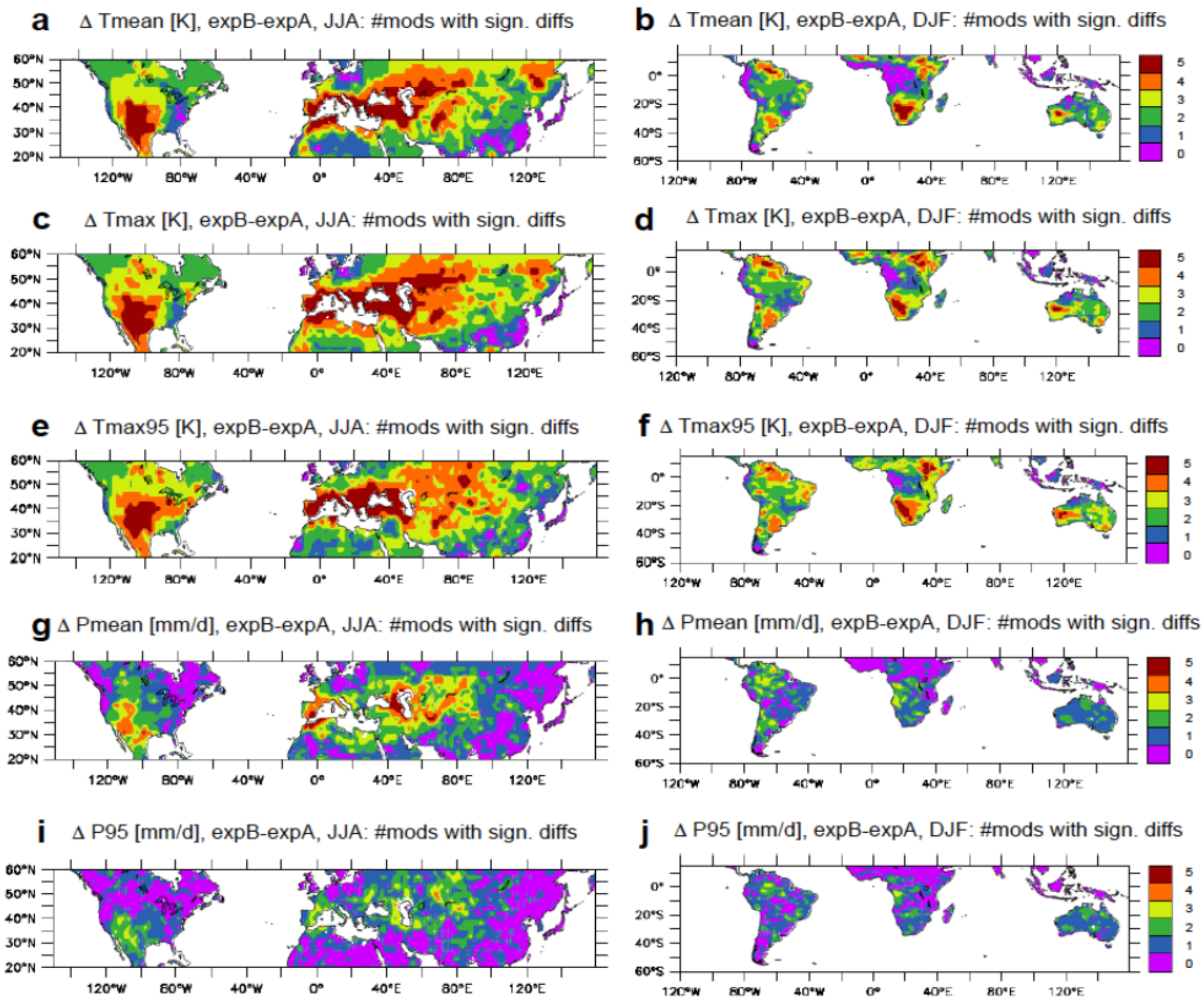
Gray shading: less than 66% model agreement on sign of change

Coloured shading: ≥ 66% model agreement on sign of change

Stippling: ≥ 90% model agreement on sign of change

(IPCC 2012, SREX SPM; Seneviratne et al. 2012: http://ipcc-wg2.gov/SREX/)

Statistical significance



Differences generally statistically significant for all models for temperature (a-f)

Less robust signal for precipitation, especially for extremes (g-j)

(Seneviratne et al. 2013, GRL)