Future amplification of hot extremes due to land-atmosphere interactions – understanding and reducing the model uncertainties

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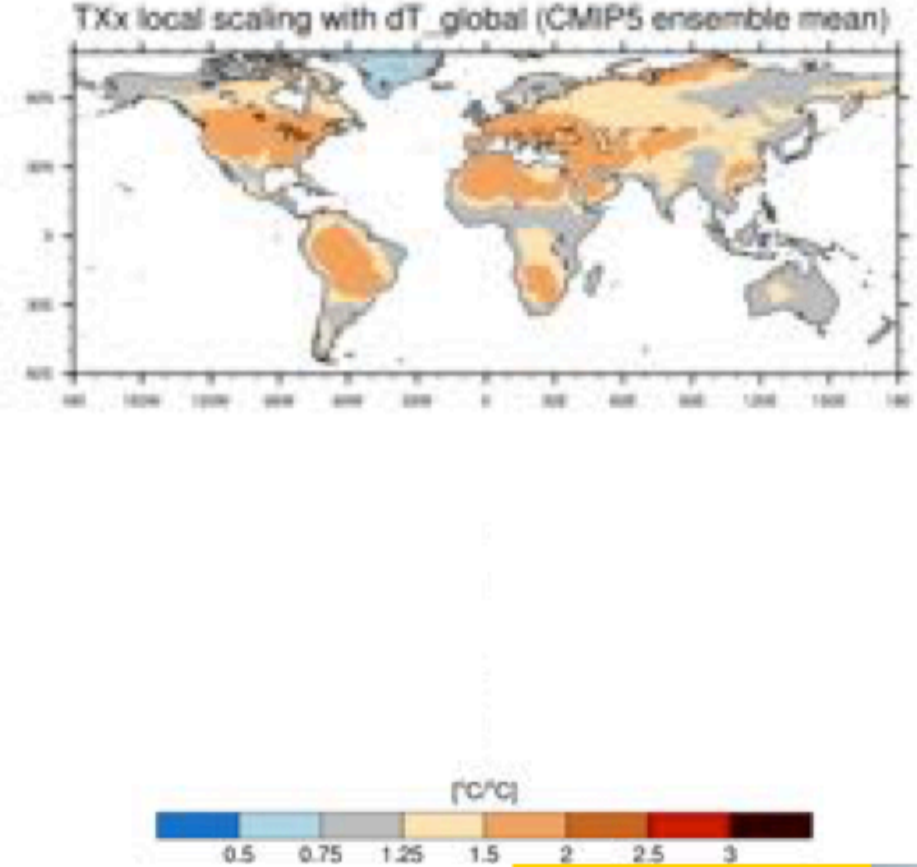
CMIP5 projected changes in hot extremes

Regional changes in TXx (hottest day temperature) per degree of global warming:



Goal: <u>Understand the different warming rates:</u>

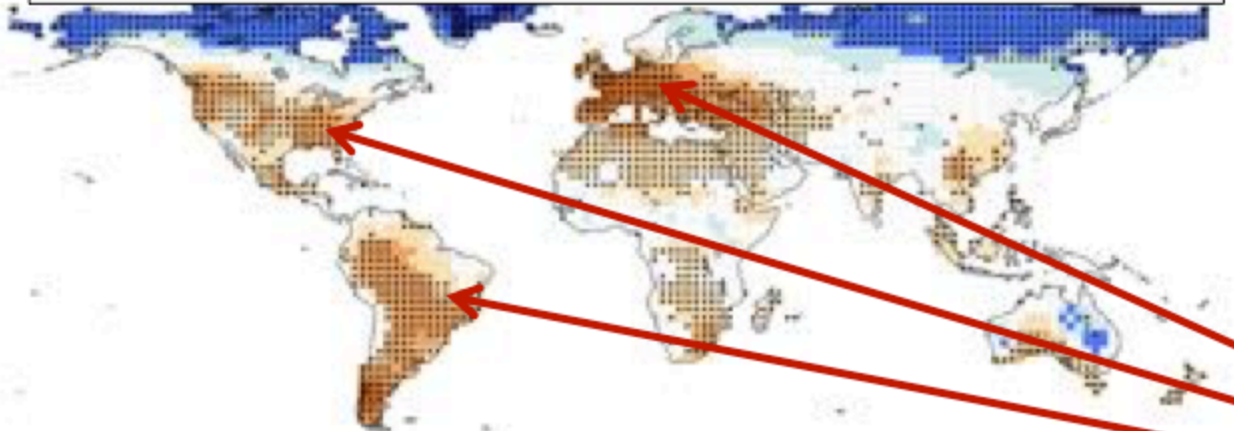
→ Regional differences
→ Model differences

→ Reduce inter-model uncertainties?

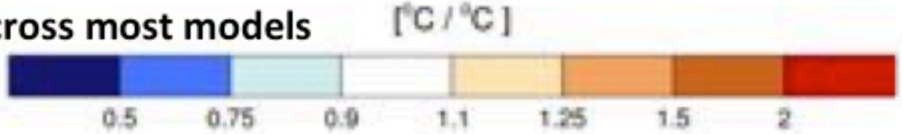
Accelerated warming of hot extremes relative to mean temperatures

Approach: local ***mean warming*** rates account for some differences,
local processes may ***amplify extreme over mean*** warming

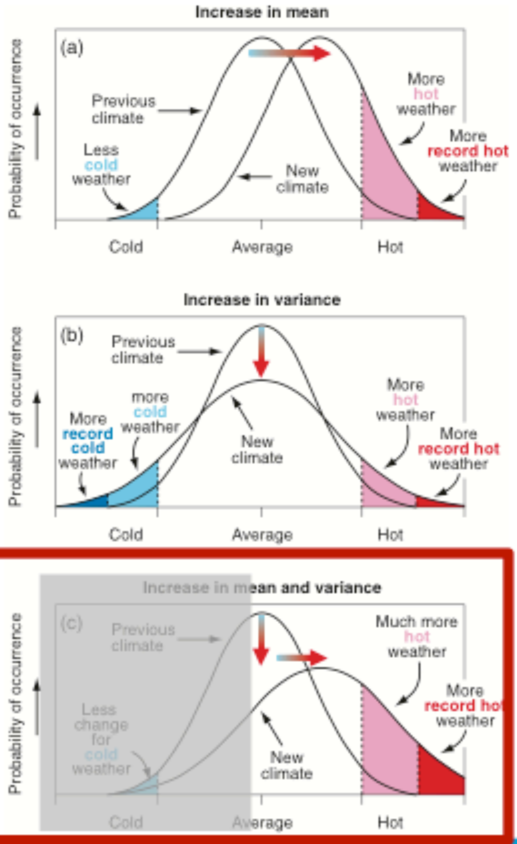
ΔTXx / ΔTmean CMIP5 ensemble mean (2070-2099) – (1951-1980)



Stippling = spatial patterns of change robust across most models



[Donat et al. 2017, *GRL*]



[IPCC, 2001]

What drives the regional amplification of hot extremes?

At each grid cell, record the date of the hottest day to **investigate relationship to other variables on that hottest day**.

For example, **Evaporative Fraction** (partitioning of surface heat fluxes (latent Q_e and sensible Q_h) as proxy for soil moisture)

$$EF = Q_e / (Q_e + Q_h)$$

[also checked changes in cloud cover (radiation), atmospheric circulation (advection) related to hottest day]

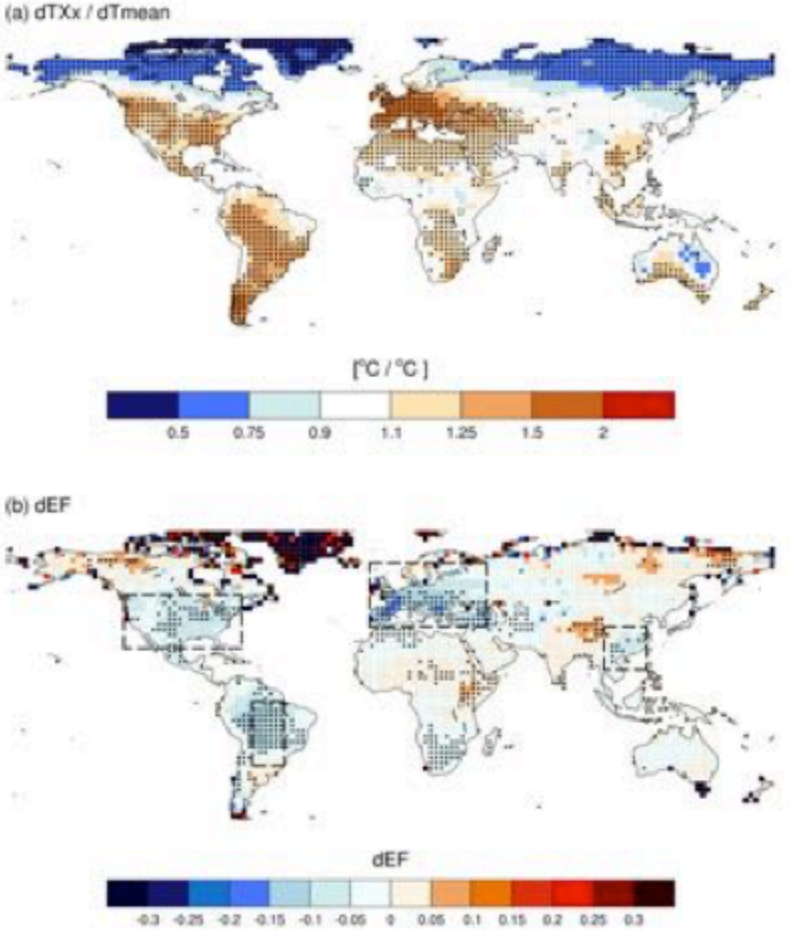
Comparing the relationships between models and observations to evaluate the land-atmosphere feedbacks related to hot extremes

☹ very sparse (if any) long-term observations of soil moisture, heat fluxes, evaporation or related variables at daily resolution

☺ soil moisture in summer is strongly related to seasonal precipitation during spring/summer; long-term observations of monthly precipitation exist with good coverage of global land area, in particular Northern Hemisphere

→ to compare models vs observations: use precipitation in preceding 3 months (SPI) as proxy for moisture / EF on the days when heat extremes occur

ΔTXx/ ΔTmean and ΔEF (on hottest day), CMIP5 mean



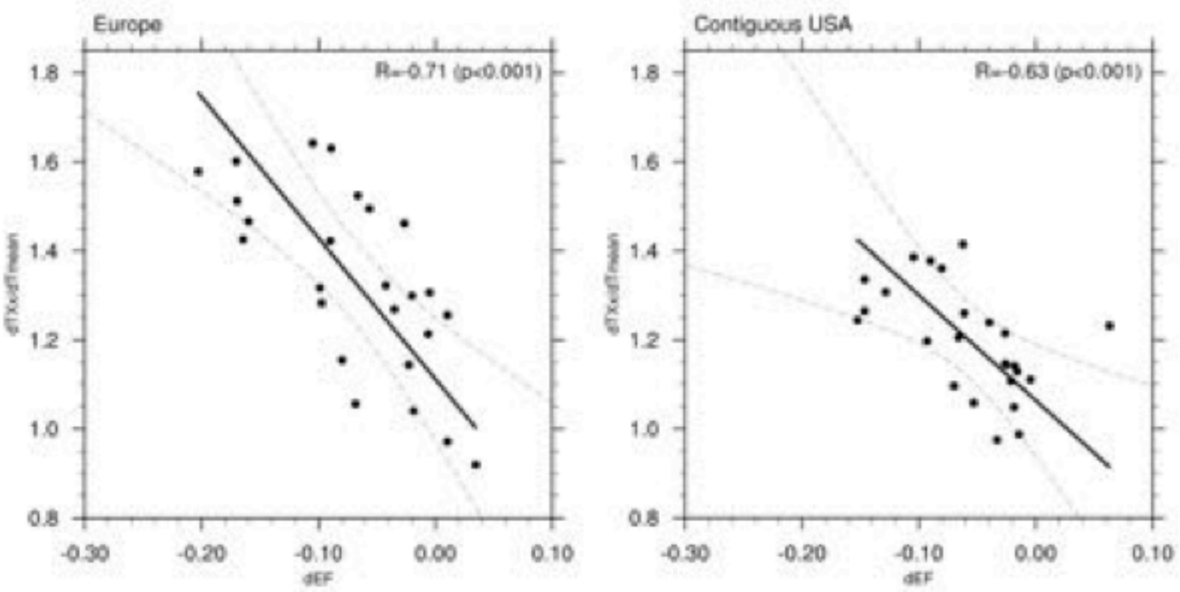
[Donat et al. 2017, *GRL*]

→ Regions with strongest ΔTXx/ ΔTmean amplification characterised by reduction in EF on the day of the hot extreme

→ Land-atmosphere feedbacks explain much of the global pattern of amplified warming of hot extremes over mean warming

Inter-model uncertainties: Relationship between ΔEF (on hottest day) and ΔTXx/ΔTmean

[Donat et al. 2017, *GRL*]

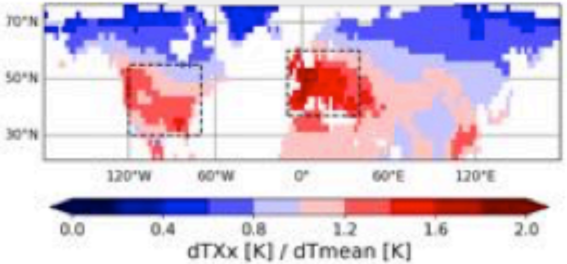


→ In the regional 'hot spots' of largest ΔTXx/ΔTmean:

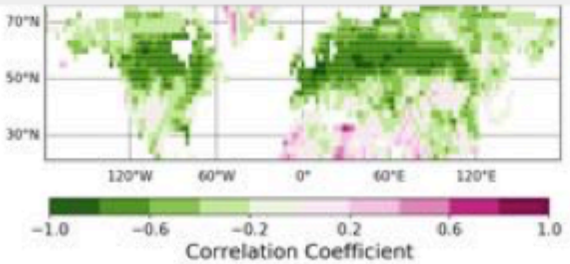
Models with stronger EF reduction have stronger accelerated warming of TXx

Relationship between TXx changes and preceding precipitation

ΔTXx/ΔTmean



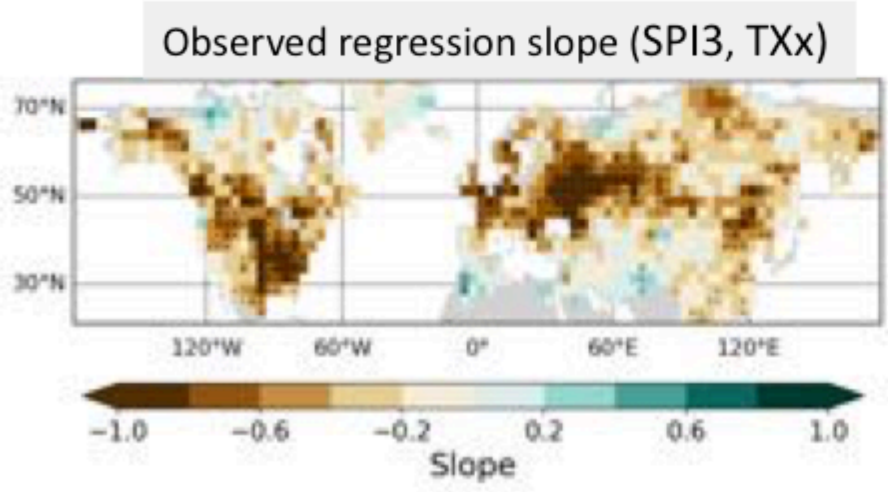
Correlation dSPI3 – (ΔTXx/ΔTmean)



→ Significant relationships between ΔSPI3 (preceding the hot extreme) and ΔTXx: models with stronger reduction in seasonal P simulate stronger amplification of ΔTXx/ΔTmean

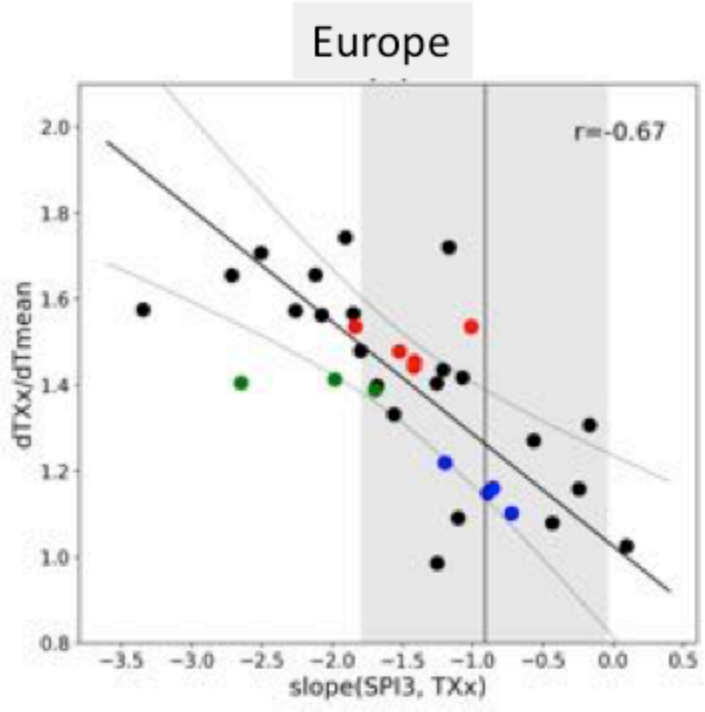
→ Effects of internal variability small compared to inter-model differences *(coloured dots = different runs of same model)*

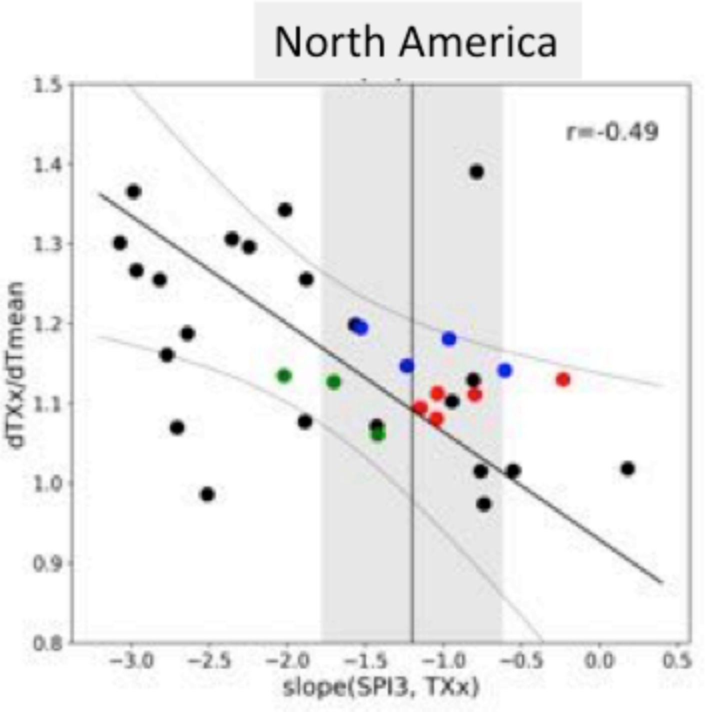
TXx response to moisture variability



→ In Europe and North America: Models with stronger TXx response to precipitation variability in the past climate simulate stronger amplification of ΔTXx/ΔTmean in the future

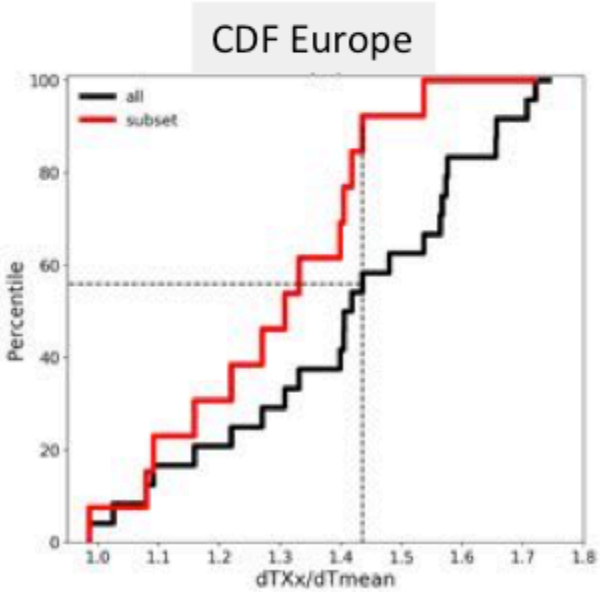
TXx changes related to strength of SPI-TXx response

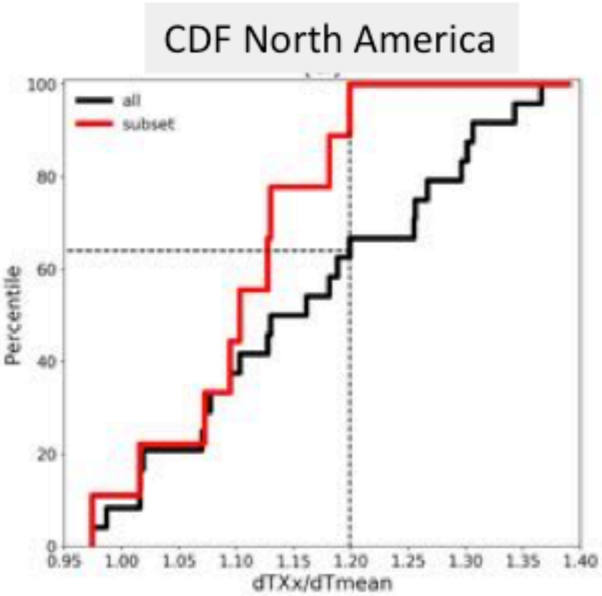




→ Most models tend to show stronger SPI-TXx response than observed

CMIP5 ensemble constrained by observed SPI-TXx relationship





Using only models in which the SPI-TXx relationship is similar to observations

→ reduces the probability of strongest ΔTXx/ΔTmean amplification

→ reduces the uncertainty of future projected TXx changes

Summary

- climate model simulations show distinct **'hot spots'**, robust across most CMIP5 models, where **daily hot extremes warm faster than mean temperatures**
- These 'hot spots' are related to **changes in surface energy fluxes**, consistent with drying soils, leading to accelerated warming on the days hot extremes occur
- **Uncertainty** of future simulated changes in hot extremes is **controlled by** (1) future changes in seasonal precipitation, and (2) strength of the SPI-TXx relationship in the models
- Constraining (2) based on observations **reduces the probability of strongest amplification** of hot extremes, and **reduces range of future projections**

Thank you for listening. **email: m.donat@unsw.edu.au**

Thank you.

More details for part 1 (EF-TXx relationship):

Donat, M. G., A. J. Pitman, S. I. Seneviratne (2017), Regional warming of hot extremes accelerated by surface energy fluxes, Geophysical Research Letters, 44, 7011–7019, doi:10.1002/2017GL073733

More details for part 2 (constraining based on observed SPI-TXx relationship):

On request, currently under review.

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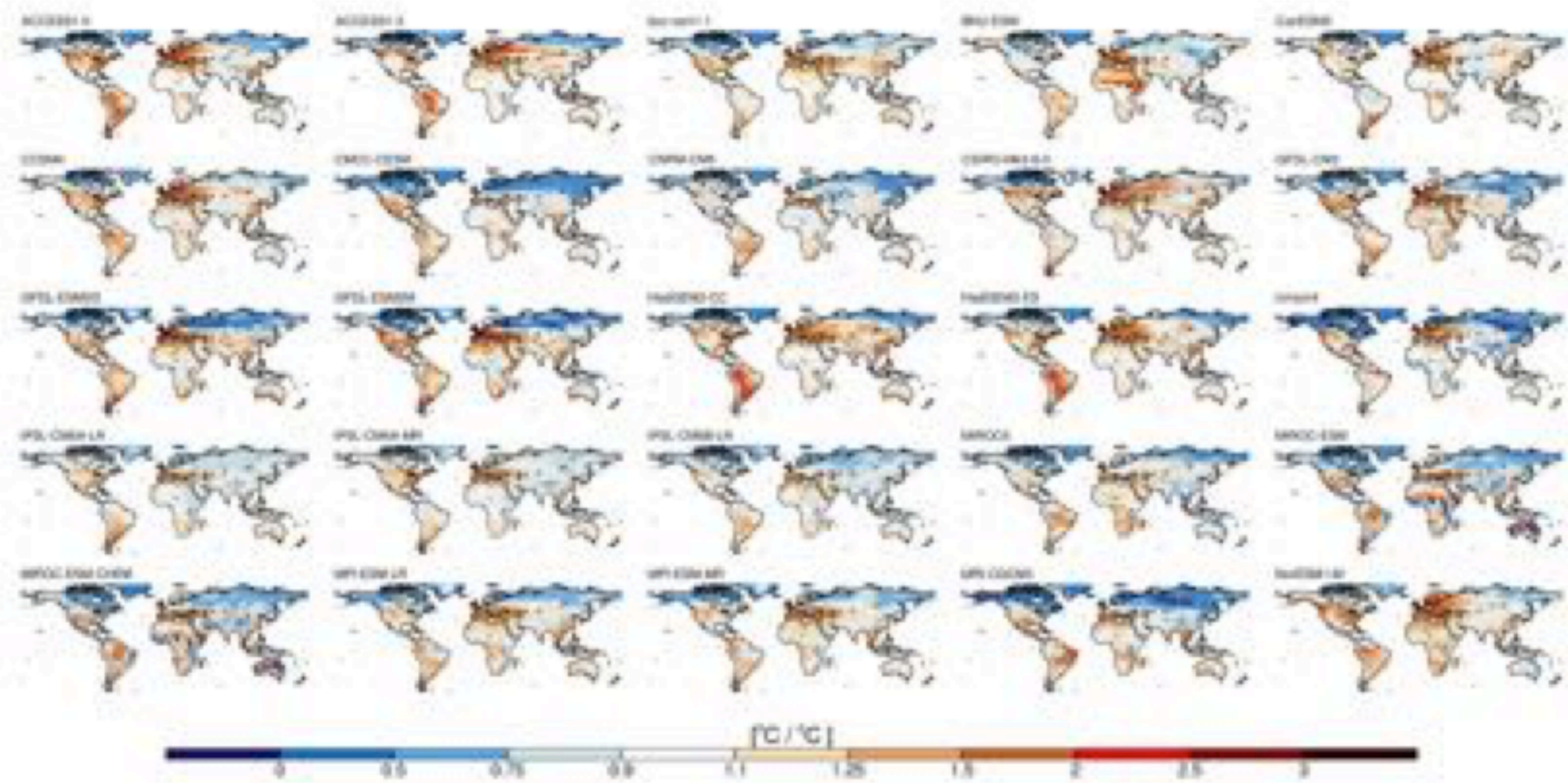
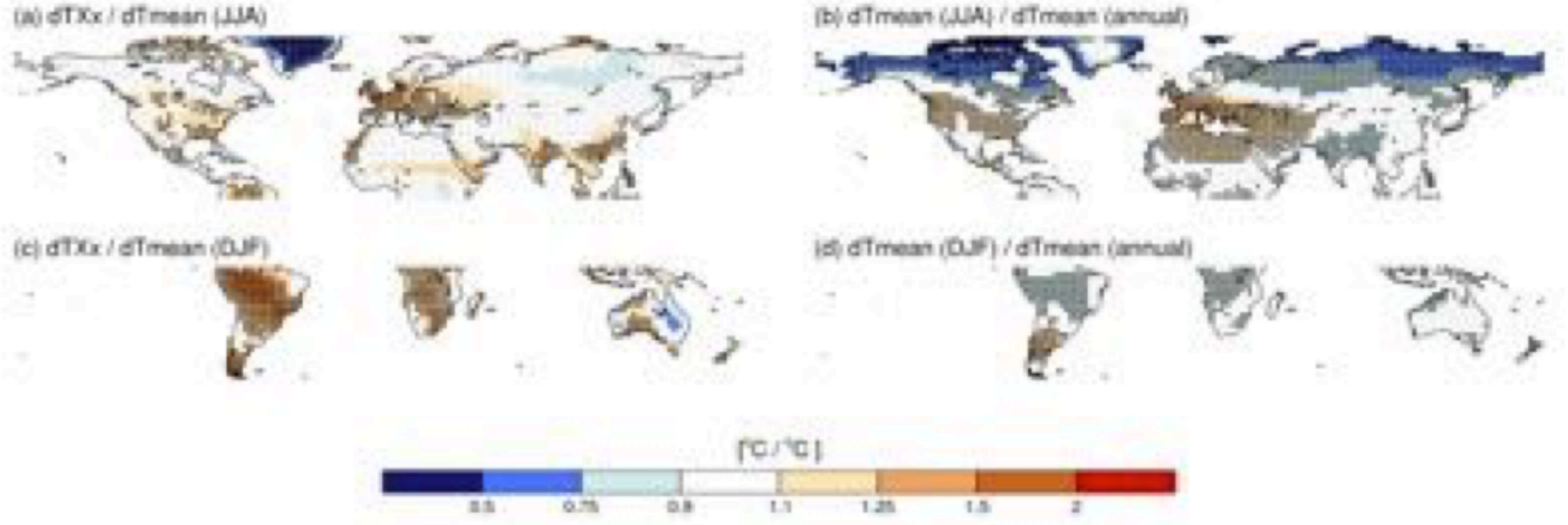
dTXx/dTmean spatial pattern robust across most models



[Donat et al. 2017, *GRL*]

[amplification TXx over seasonal mean]



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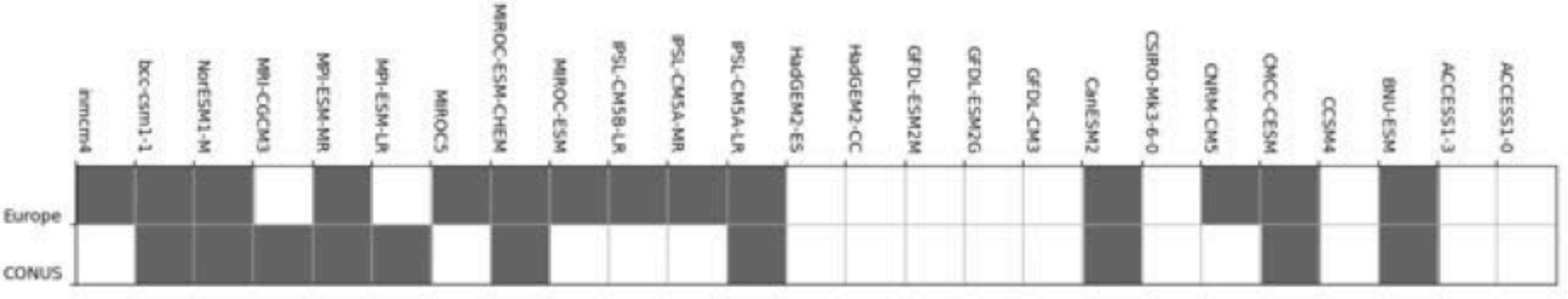
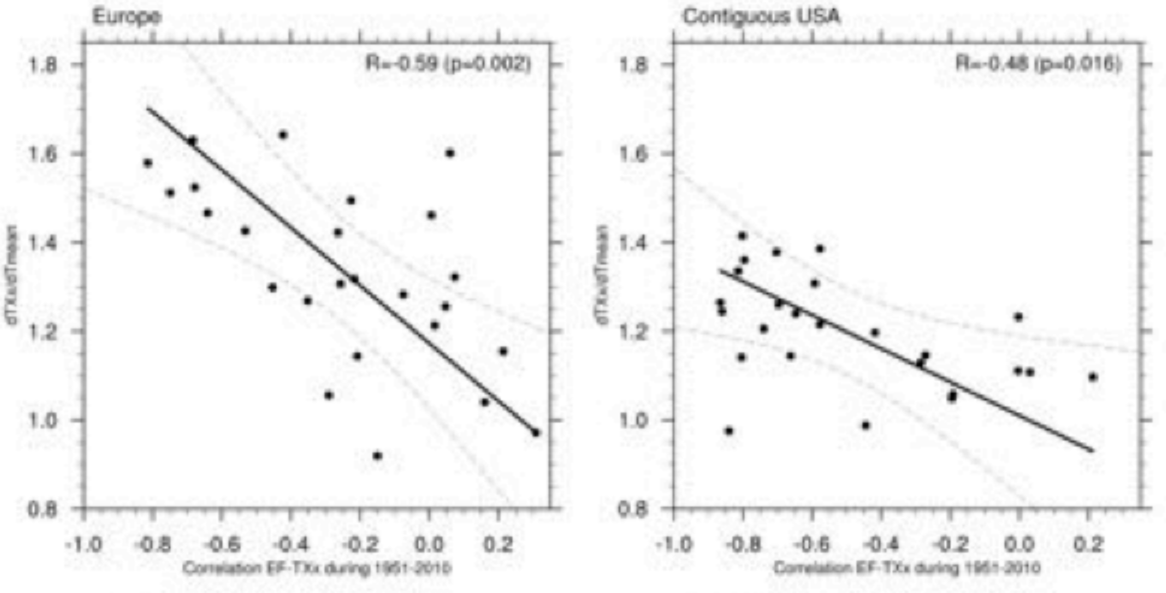
Models passing the observational constraint (white)



Relationship between (past) EF-TXx correlation and ΔTXx/ΔTmean

[Donat et al. 2017, *GRL*]



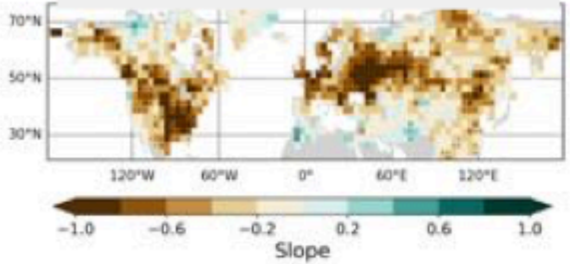
→ In the ΔTXx/ΔTmean regional 'hot spots':

Models in which TXx is more strongly related to EF in past climate show stronger future amplification ΔTXx/ΔTmean

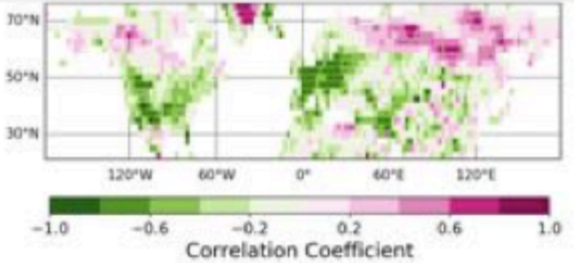
→ **can we determine if some simulations are more realistic than others?**

TXx changes related to strength of SPI-TXx response

Observed slope (SPI3, TXx)



Correlation slope(SPI3,TXx) – (ΔTXx/ΔTmean)



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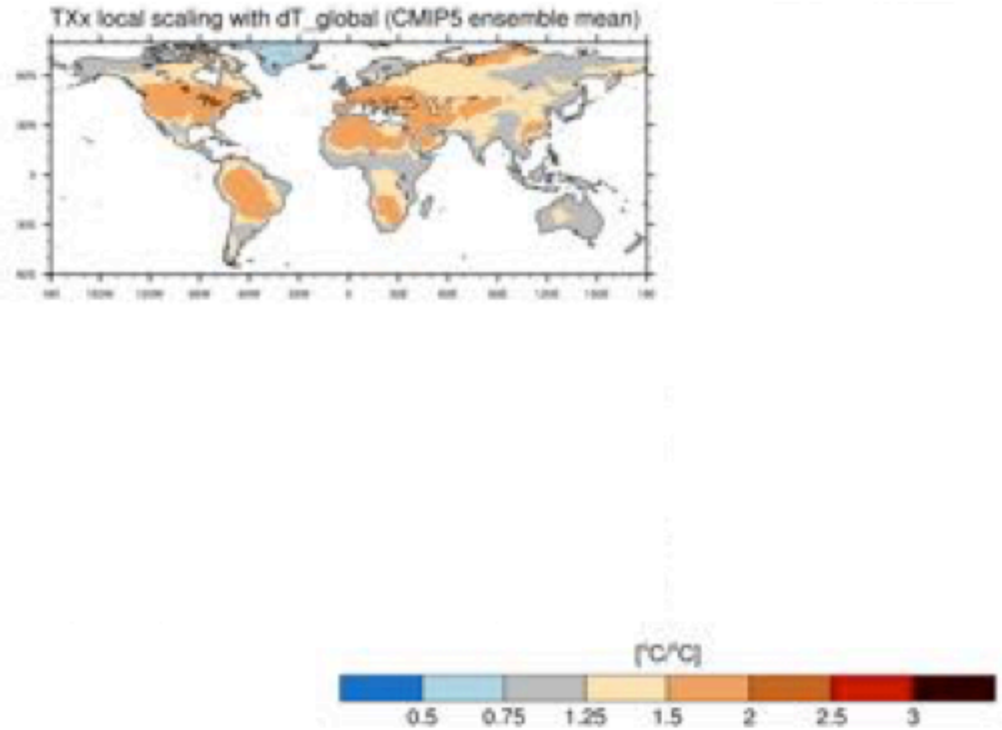

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