Anthropogenic contribution to global occurrence of extremes

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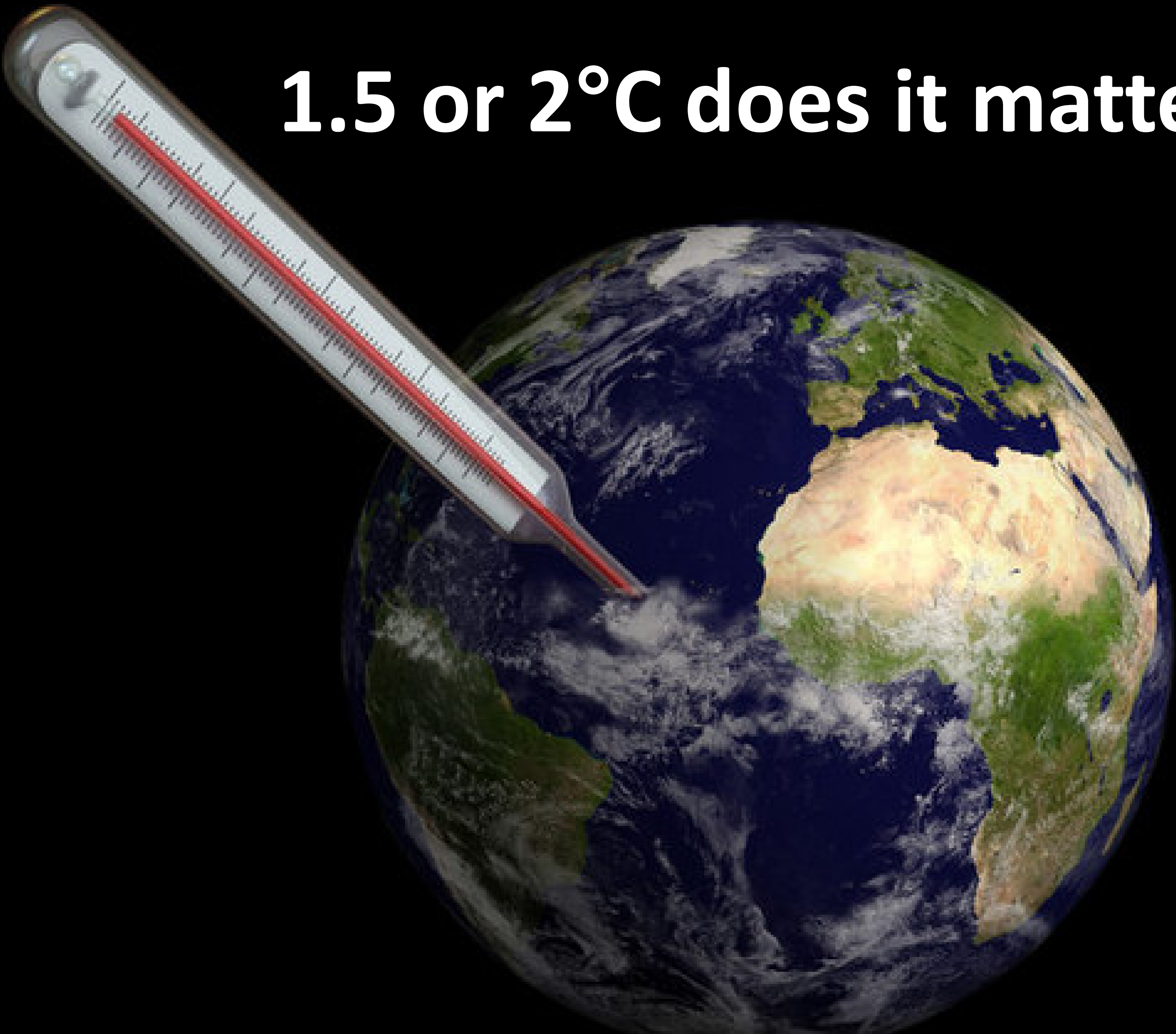
Outline

Half-a-degree matters in terms of extremes

Heat stress – multi-variate extremes are not necessarily more uncertain

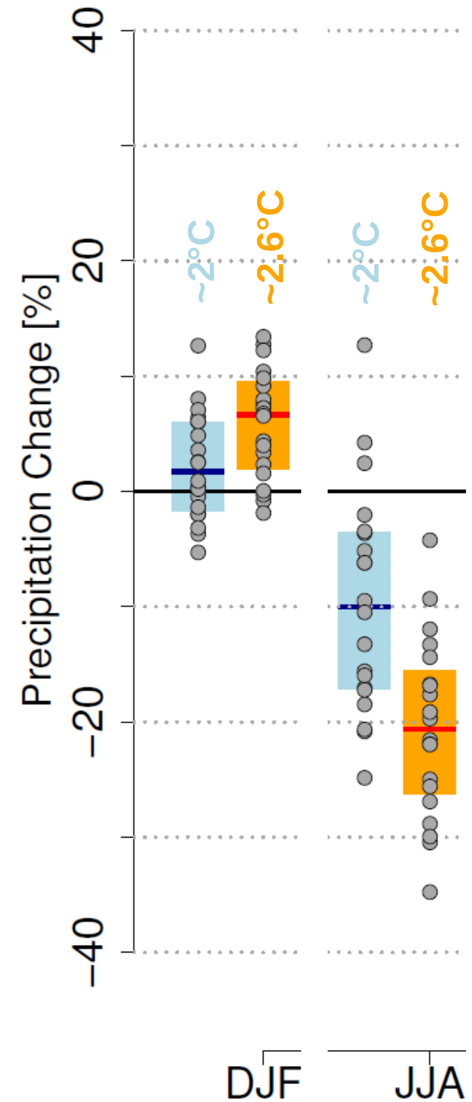
Anthropogenic contribution to changes in extremes

1.5 or 2°C does it matter?



1.5 or 2°C locally overlap

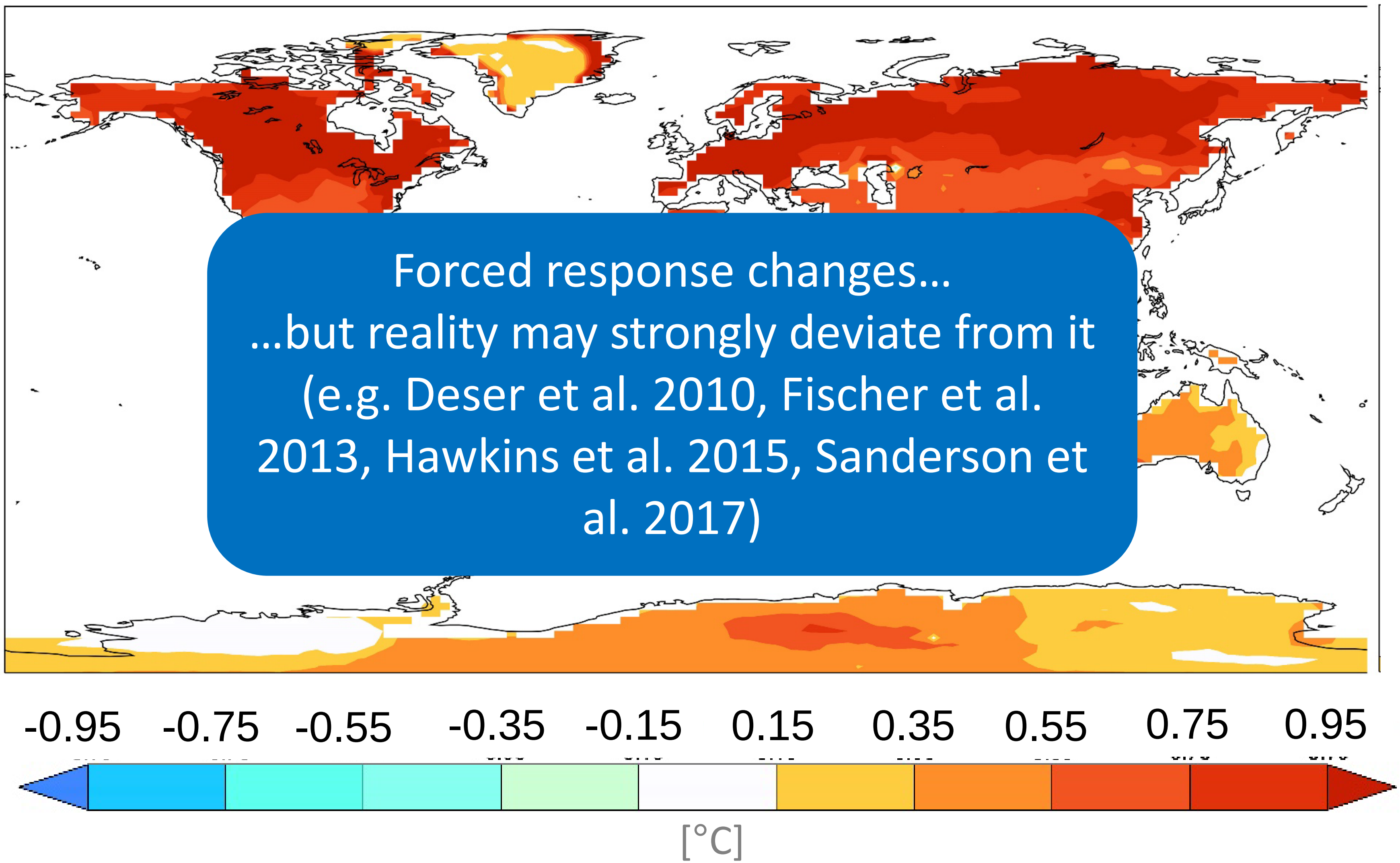
Range of local 30-yr means in large RCM ensemble (runs only differ in GCM initial conditions)



After Rosser 2013 (MSc thesis)

Change in hot extremes 2°C wrt 1.5°C

CAM4 Change in 20-yr return of period of 3-day temperature maxima

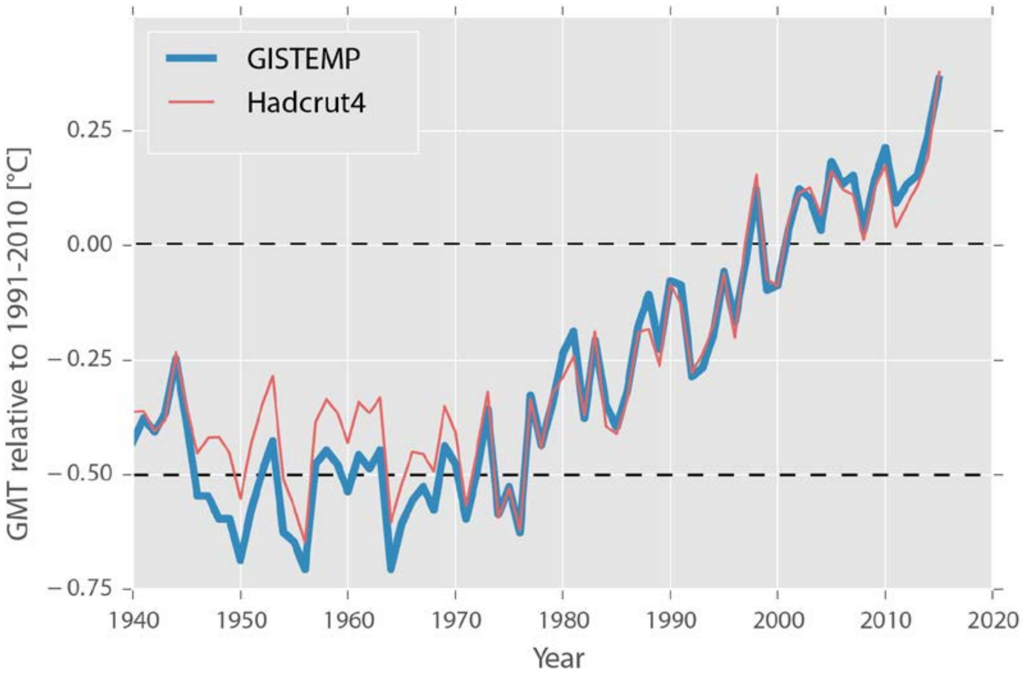


Forced response changes…
…but reality may strongly deviate from it (e.g. Deser et al. 2010, Fischer et al. 2013, Hawkins et al. 2015, Sanderson et al. 2017)

Analogy: 0.5°C warming in observations

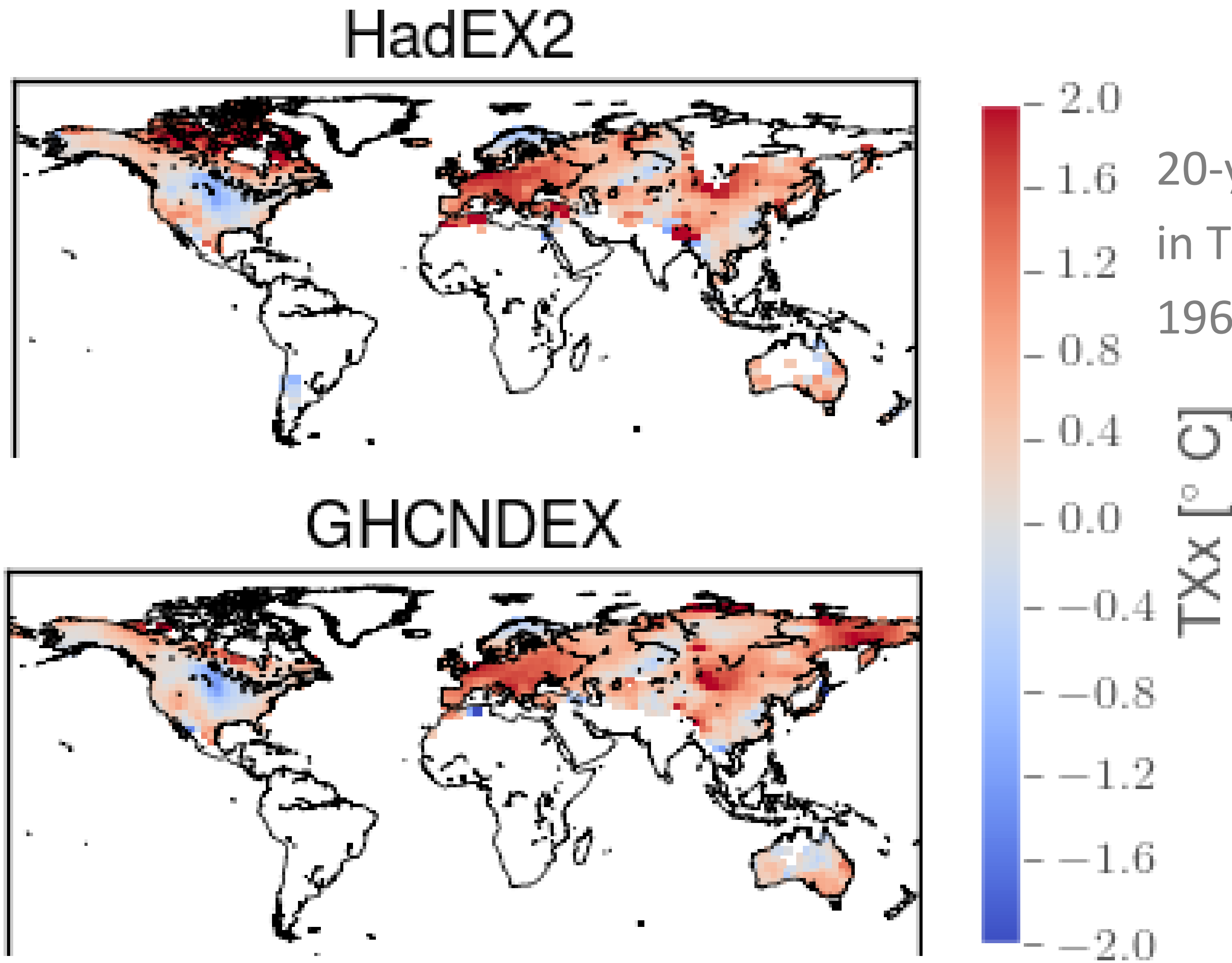
Most attribution studies refer to 1950s at the earliest
→ ~0.5°C warming

1991-2010 vs. 1960-1979
→ corresponds to 0.5°C GMT difference in GISTEMP



Schleussner, Pfleiderer and Fischer 2017, *Nature CC*

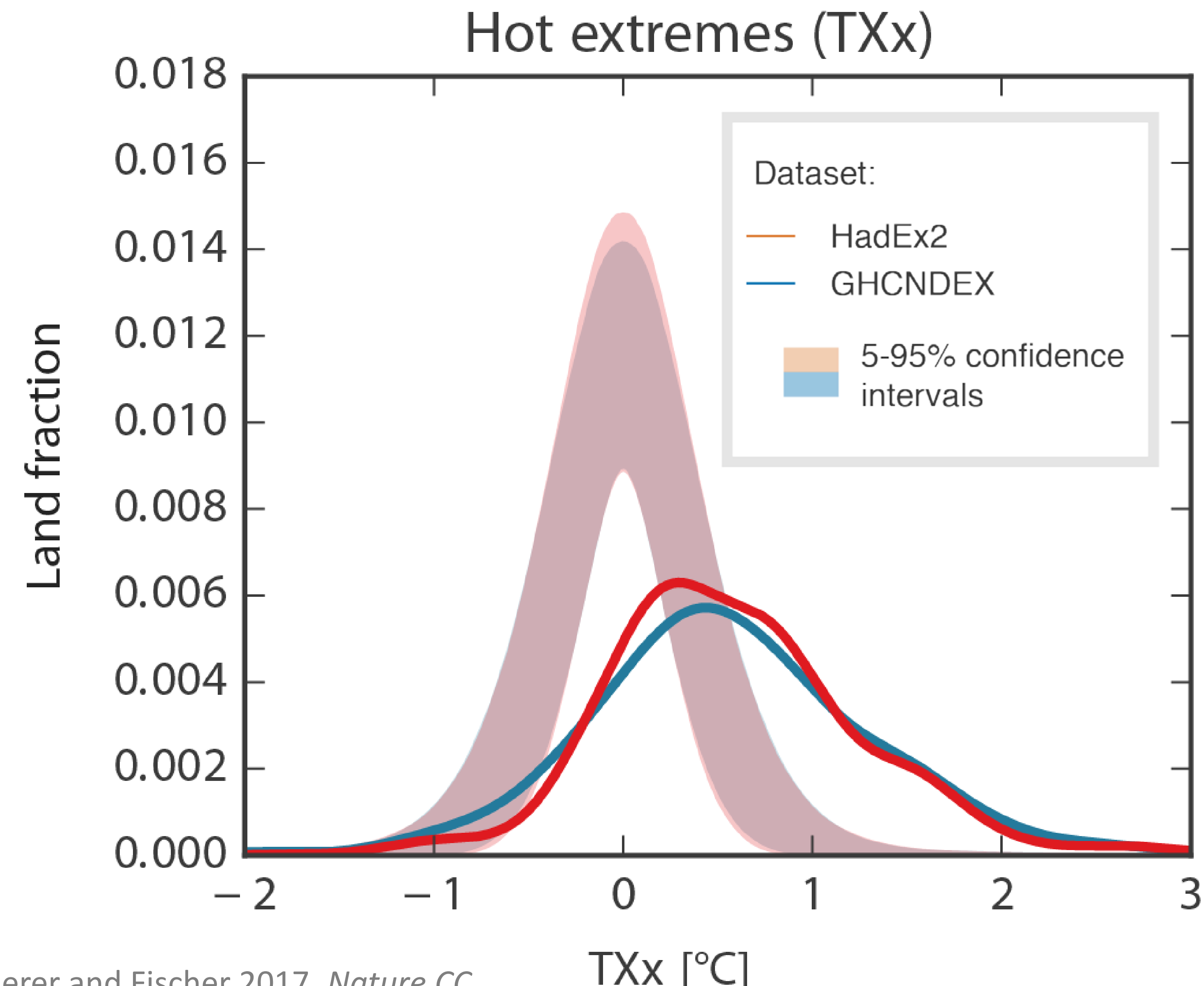
Pattern of hot extremes



20-yr means change in TXx 1991-2010 vs. 1960-1979

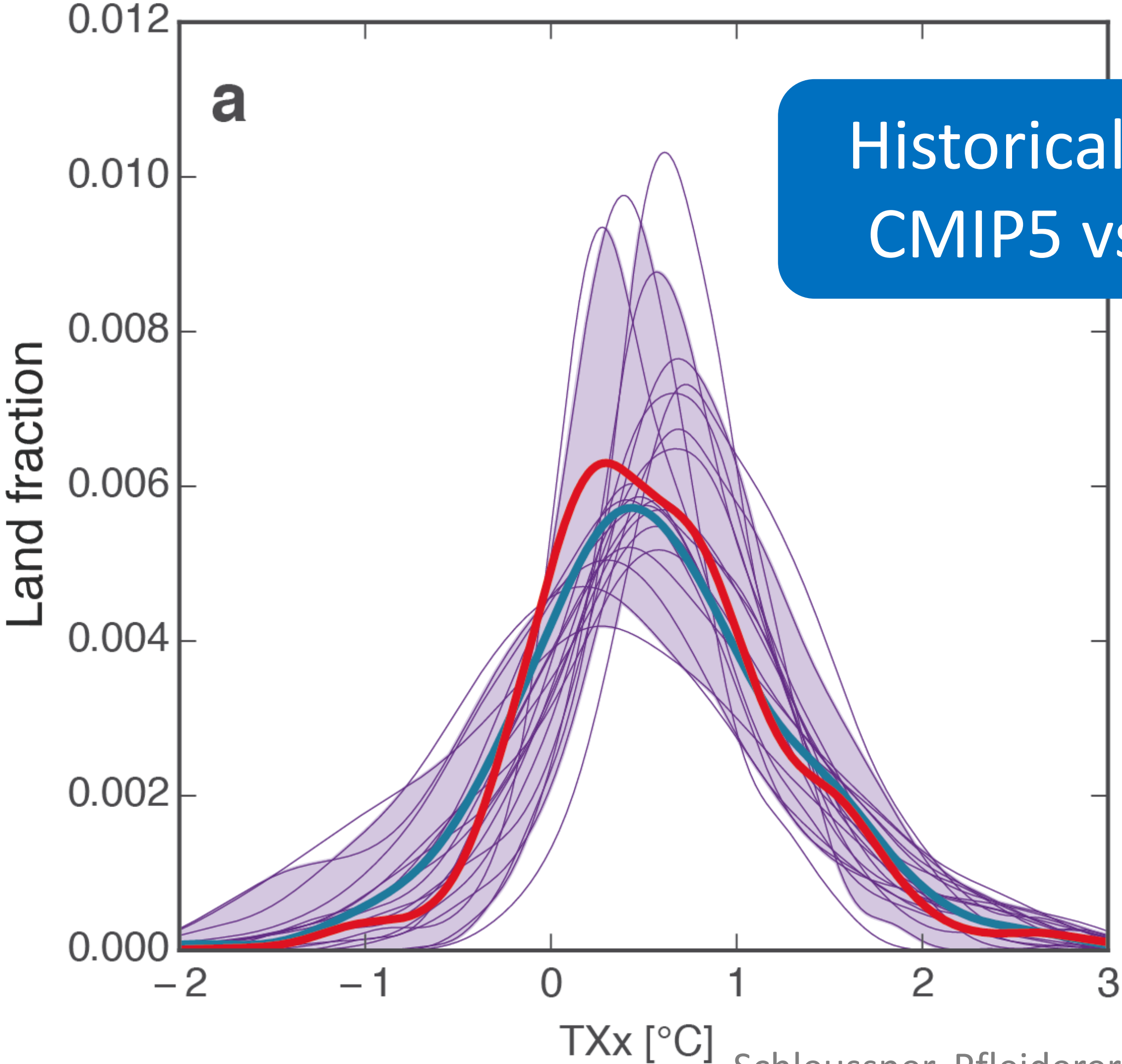
Schleussner, Pfleiderer and Fischer 2017, *Nature CC*

Hot extremes 1991-2010 vs. 1960-79



Schleussner, Pfleiderer and Fischer 2017, *Nature CC*

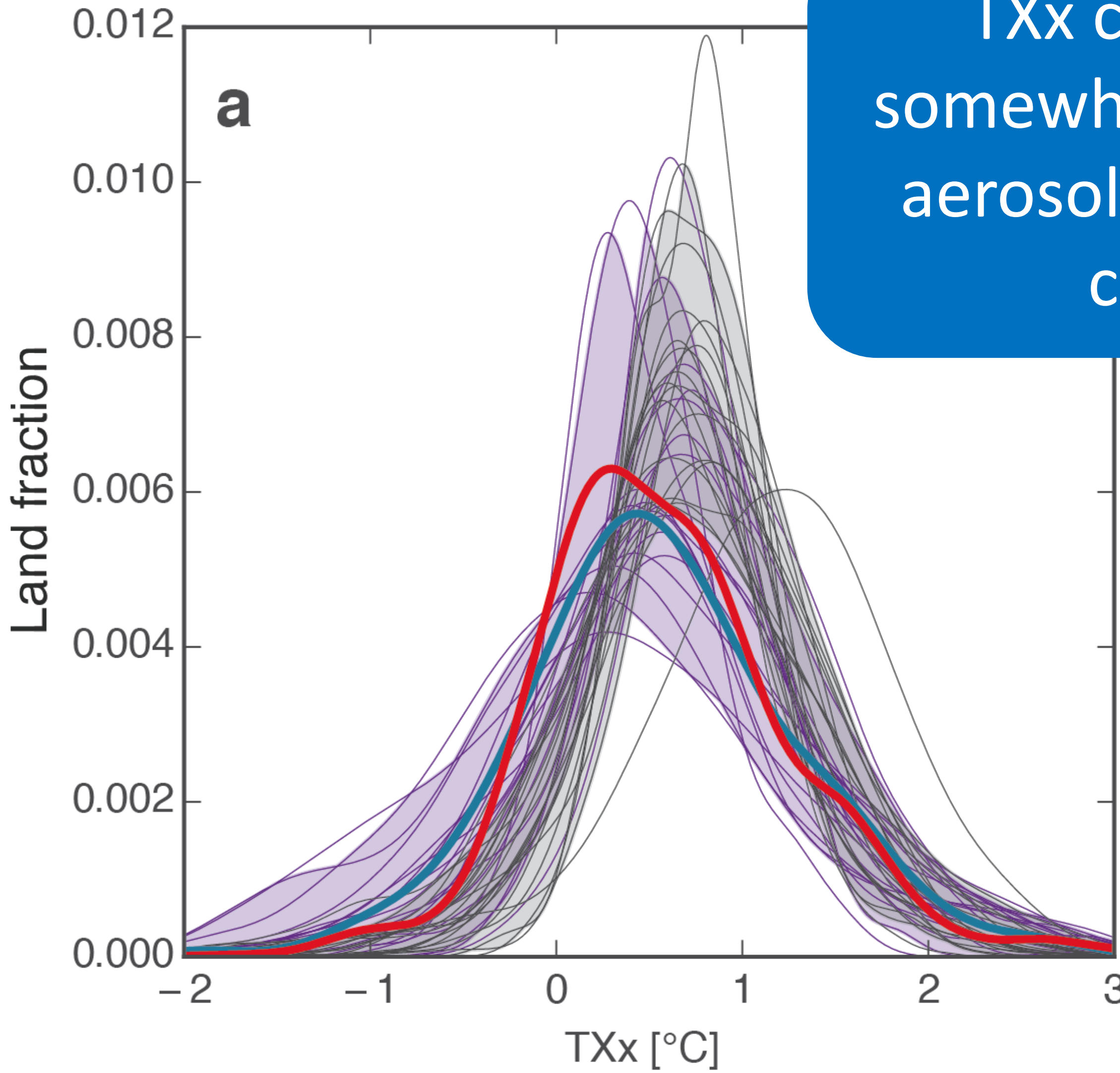
CMIP5 models are consistent with observations



Historical TXx changes in CMIP5 vs. observations

Schleussner, Pfleiderer and Fischer 2017, *Nature CC*

Historical 0.5°C consistent with 1.5 vs. 2°C



TXx changes are somewhat sensitive to aerosol and land use changes

Consistent with Fischer et al. (2014), *GRL and* Seneviratne et al. (2015*) Nature*

Caveats

- Analogy assumes forcing independence (not suitable e.g. for mean precipitation)
- Analogy is only informative at very large scales
- Threshold exceedances and most ecological and socio-economic impacts are highly non-linear
- Only for variables that “respond quickly” not suited for sea level rise, ice sheets and Alpine glaciers

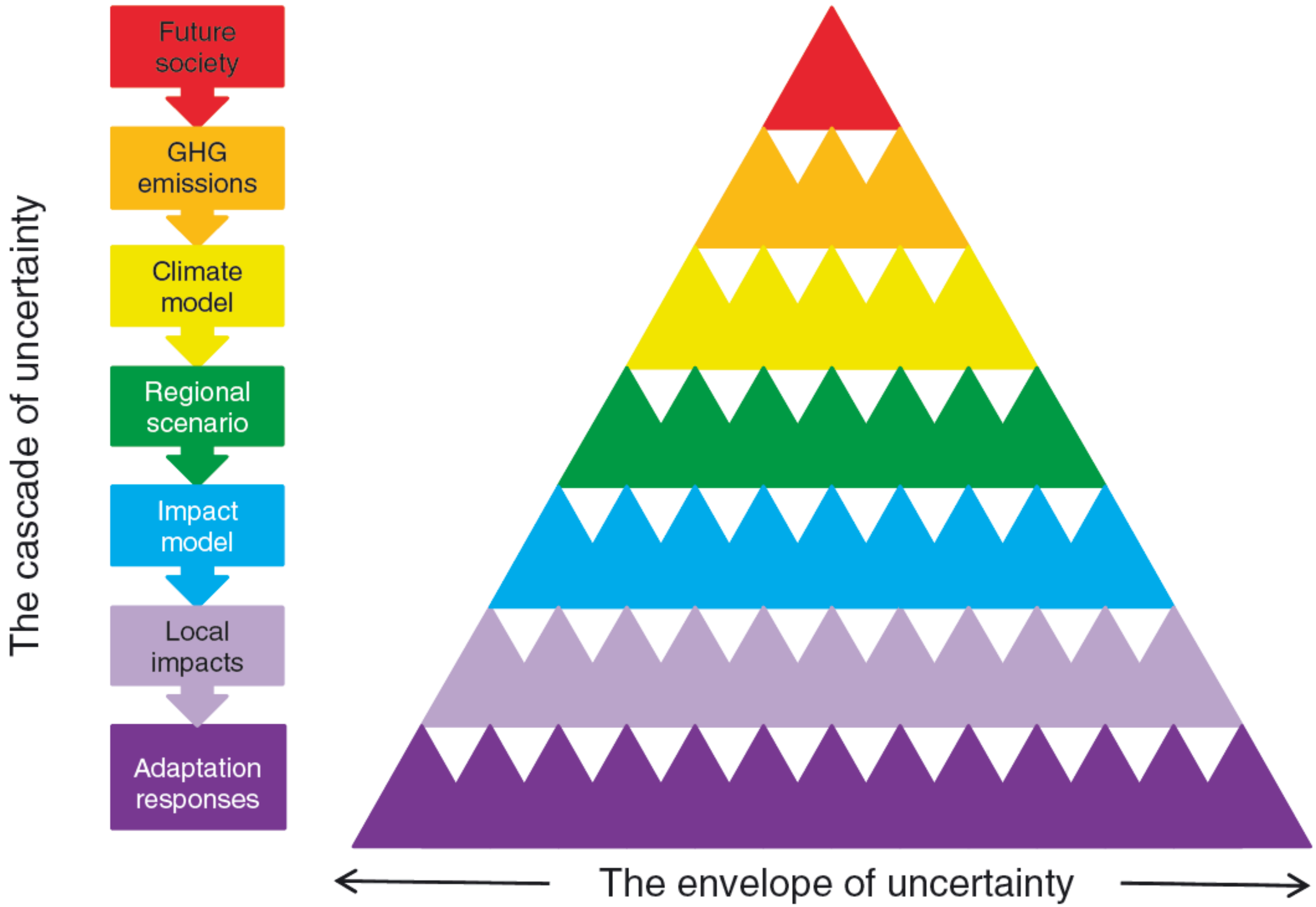
Half-a-degree matters for extremes

- Forced response differs but due to variability ranges locally overlap
- Aggregated globally difference is clear even for extremes

Heat stress – a multivariate problem

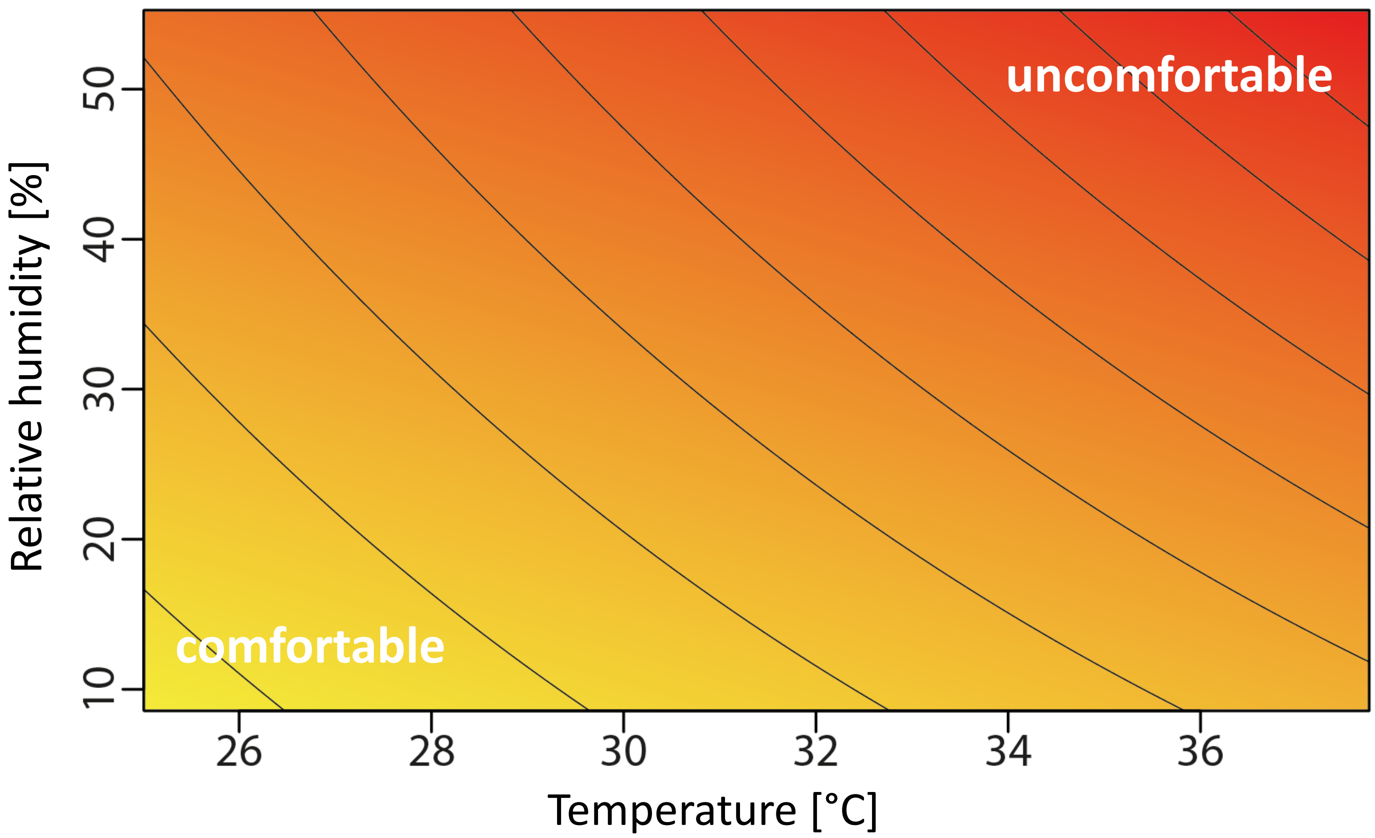
Karachi Pakistan 2015

Human discomfort



Wilby and Dessai, 2010, *Nature CC*

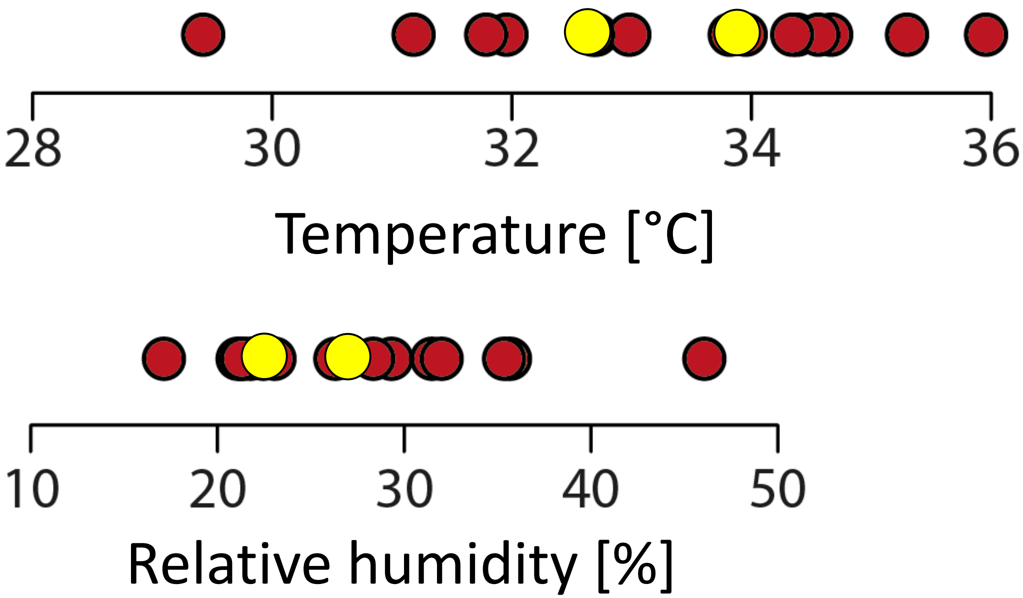
Human discomfort



$$W = 0.567T + 0.393e + 3.94$$

Heat stress in Southern Australia

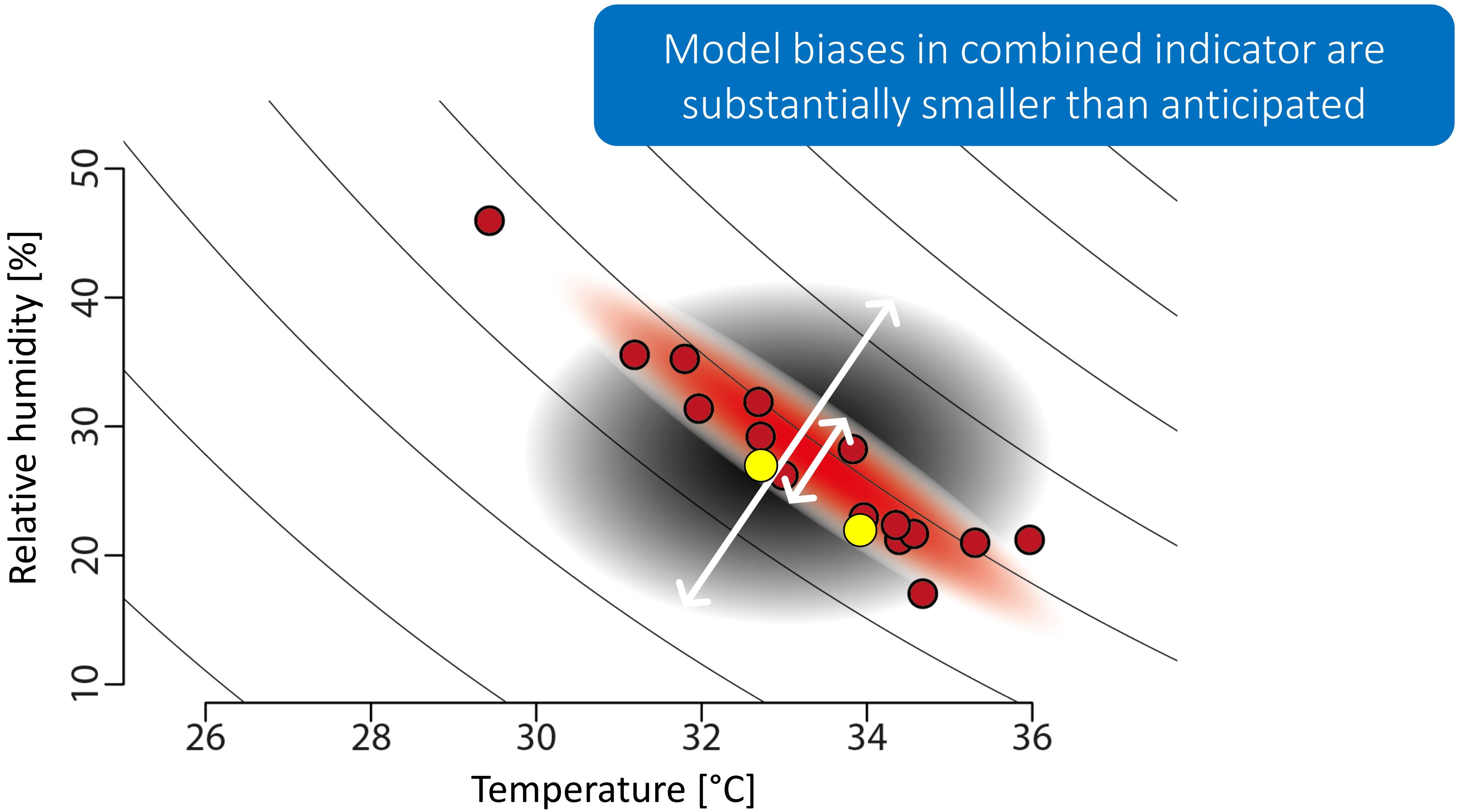
CMIP5 models (1% hottest days 1986-2005)



Major model spread and biases in T and RH

Fischer and Knutti, 2013, *Nature CC*

Heat stress in Southern Australia

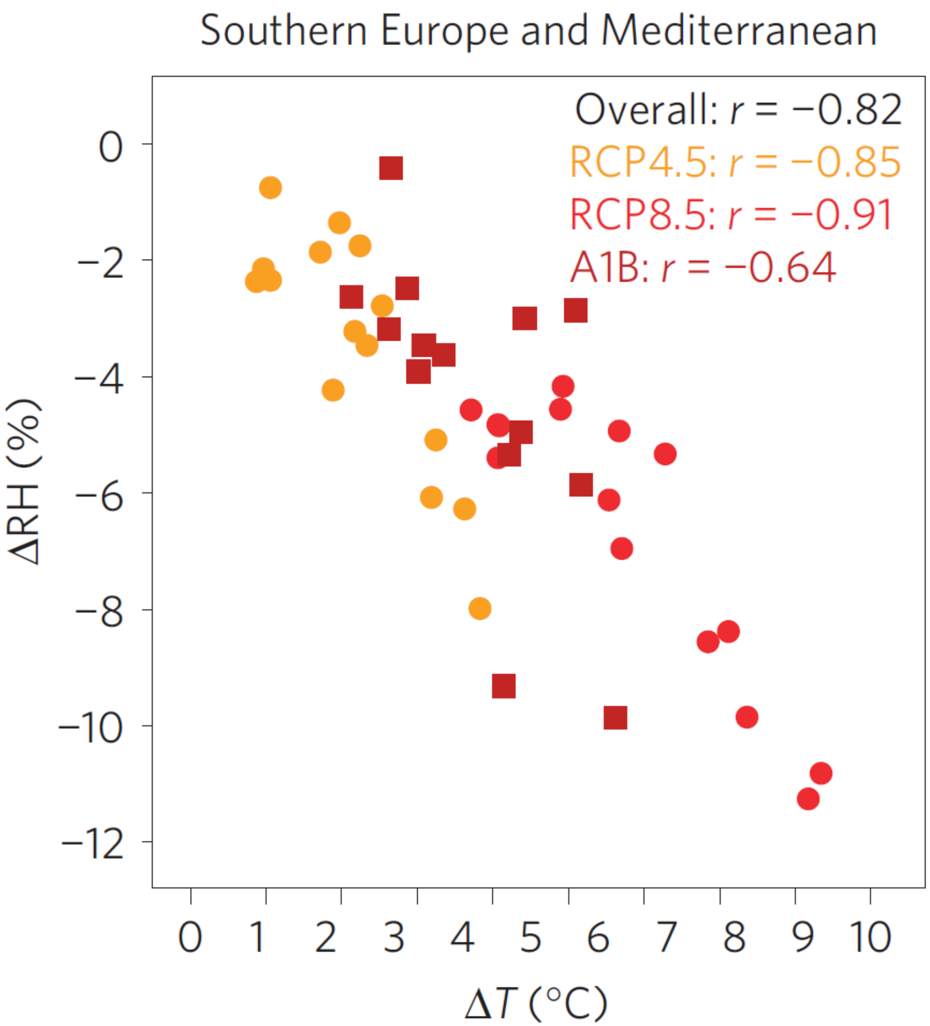


Fischer and Knutti, 2013, *Nature CC*

The hotter, the drier the air

ΔT vs. ΔRH (1% hottest days)

2081-2100 wrt 1986-2005



Fischer and Knutti, 2013, *Nature CC*

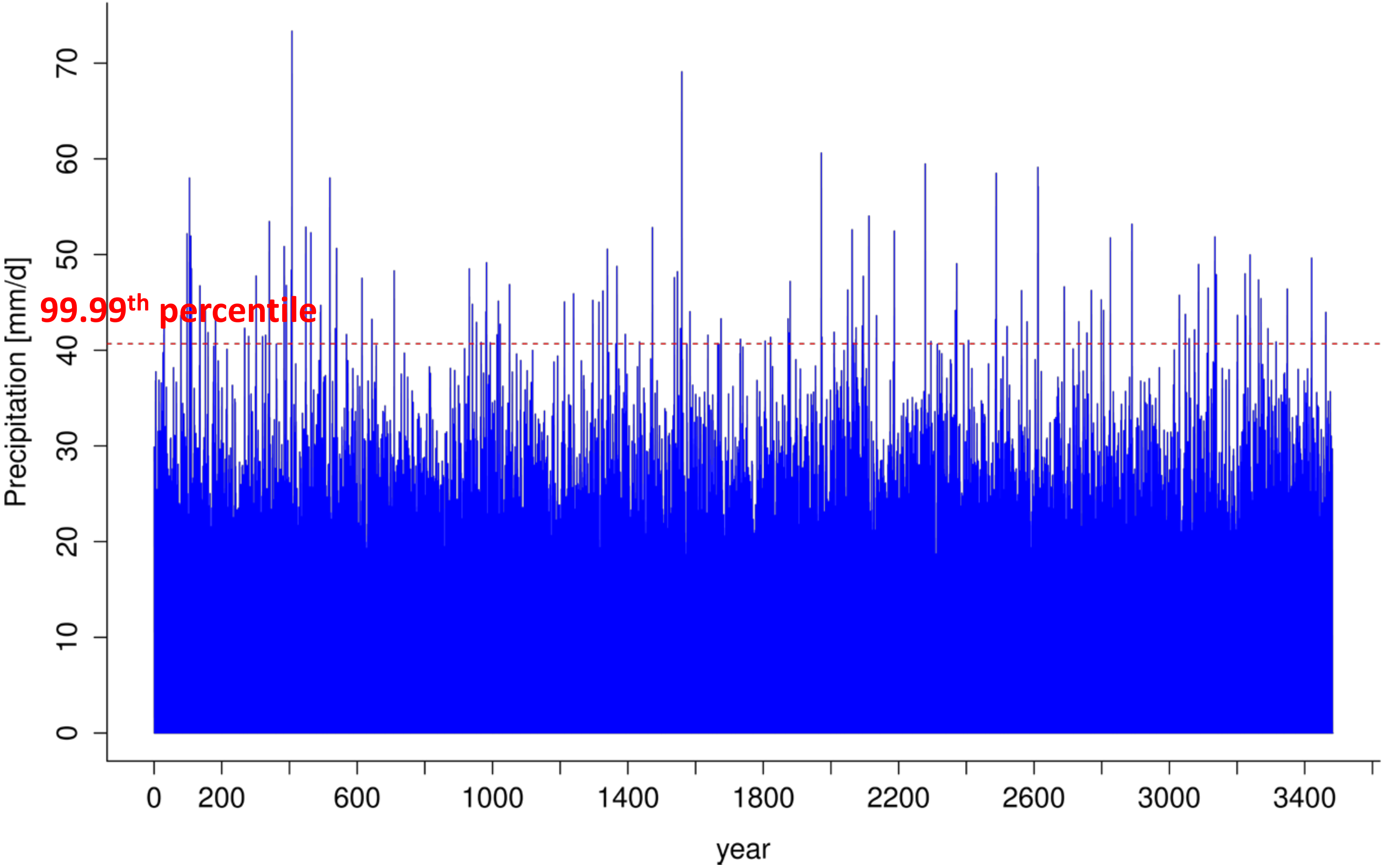
Take home message

Multi-variate approaches may reveal impact-relevant changes that are more robust than widely recognized

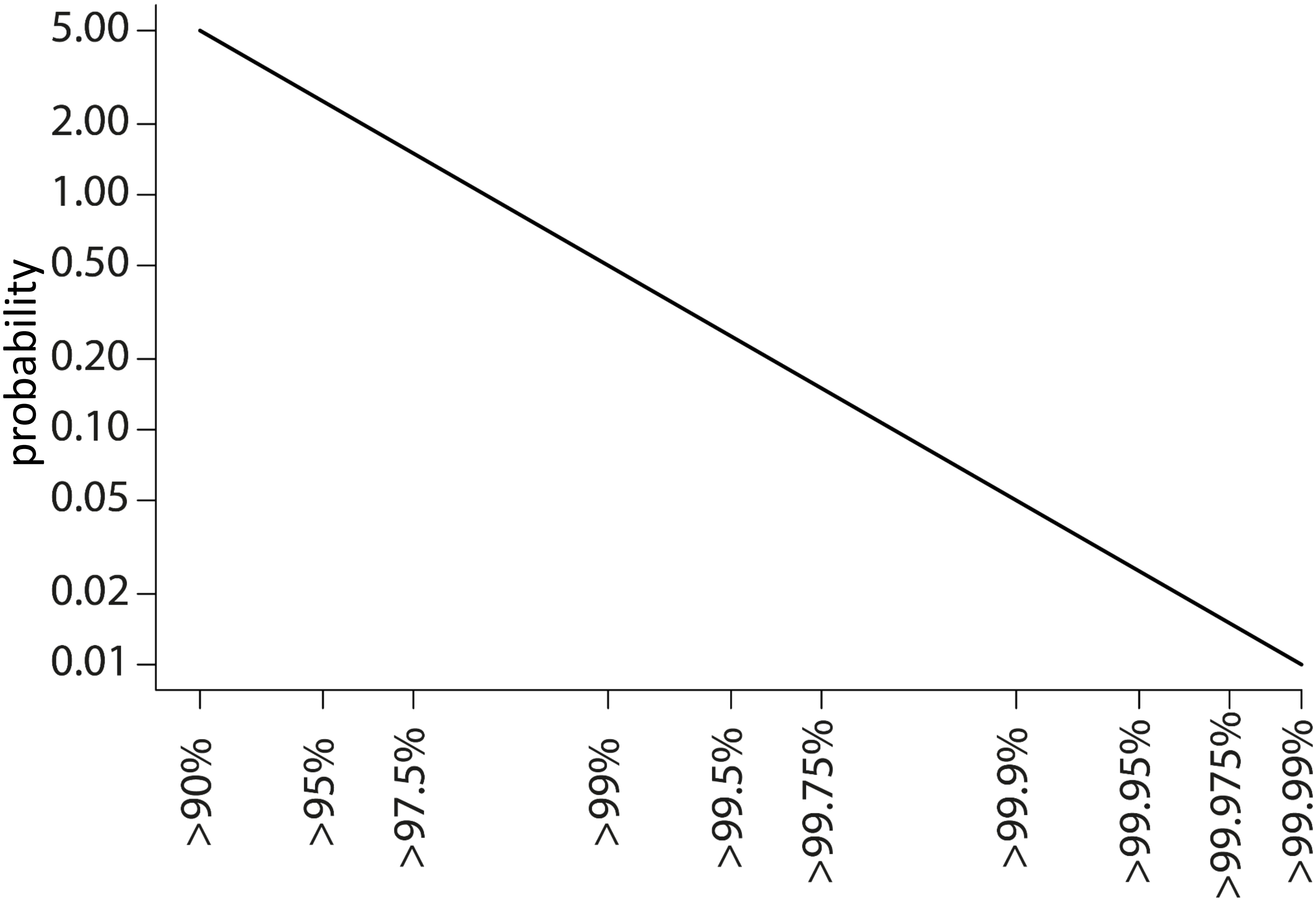

The challenge of detecting
the human influence

Locally natural variability is very large

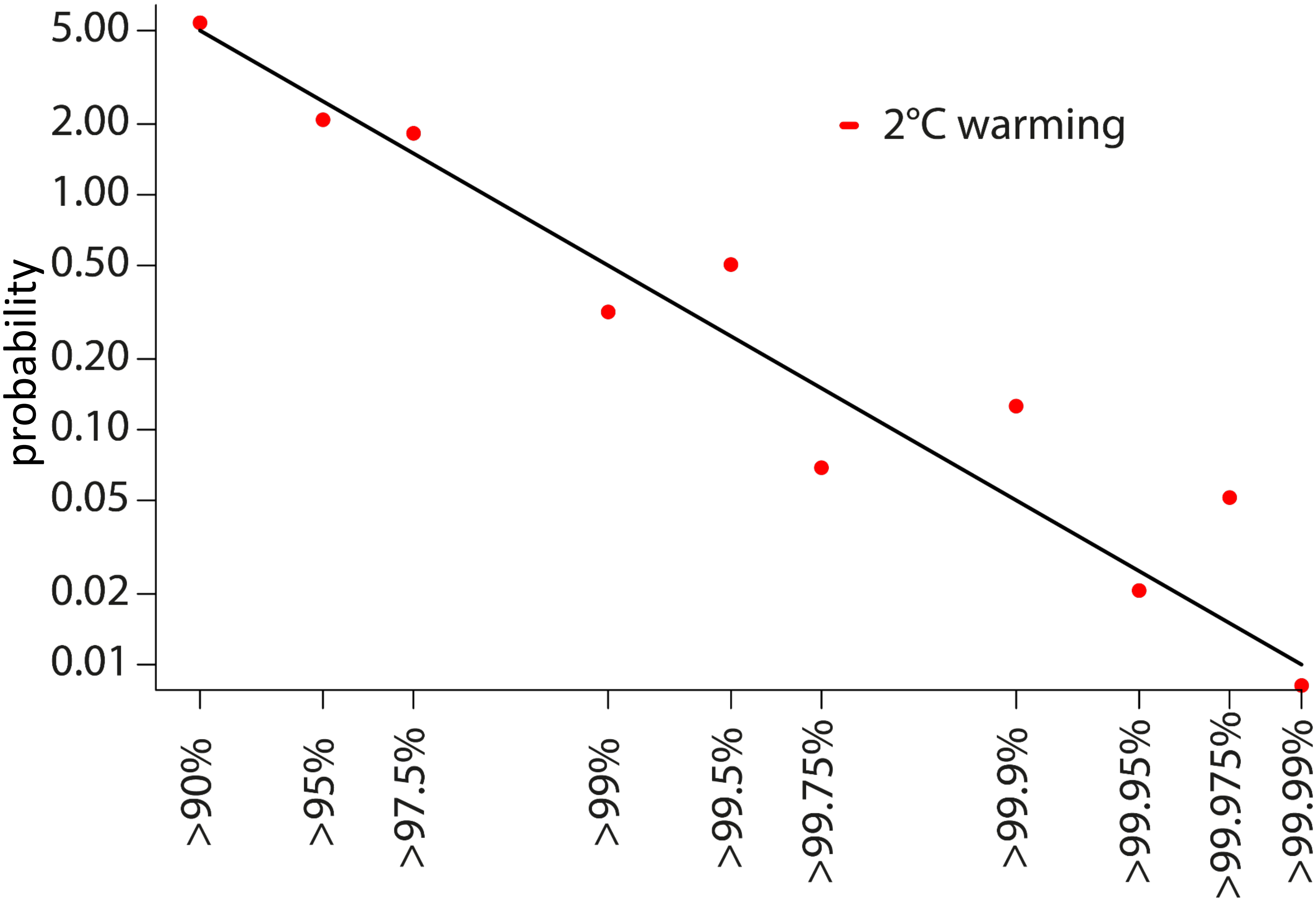
Daily precipitation in pre-industrial control run



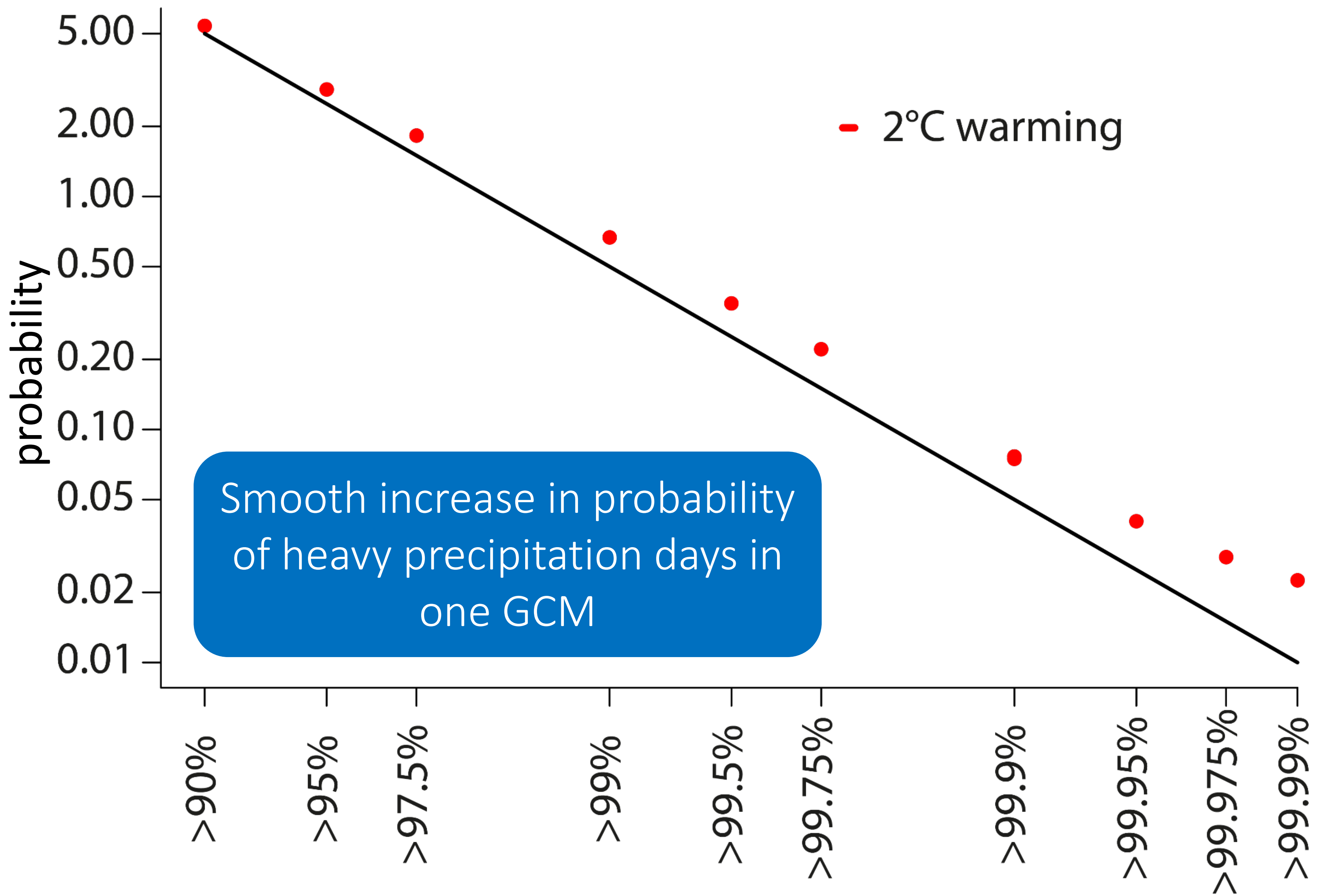
Pre-industrial precipitation distribution



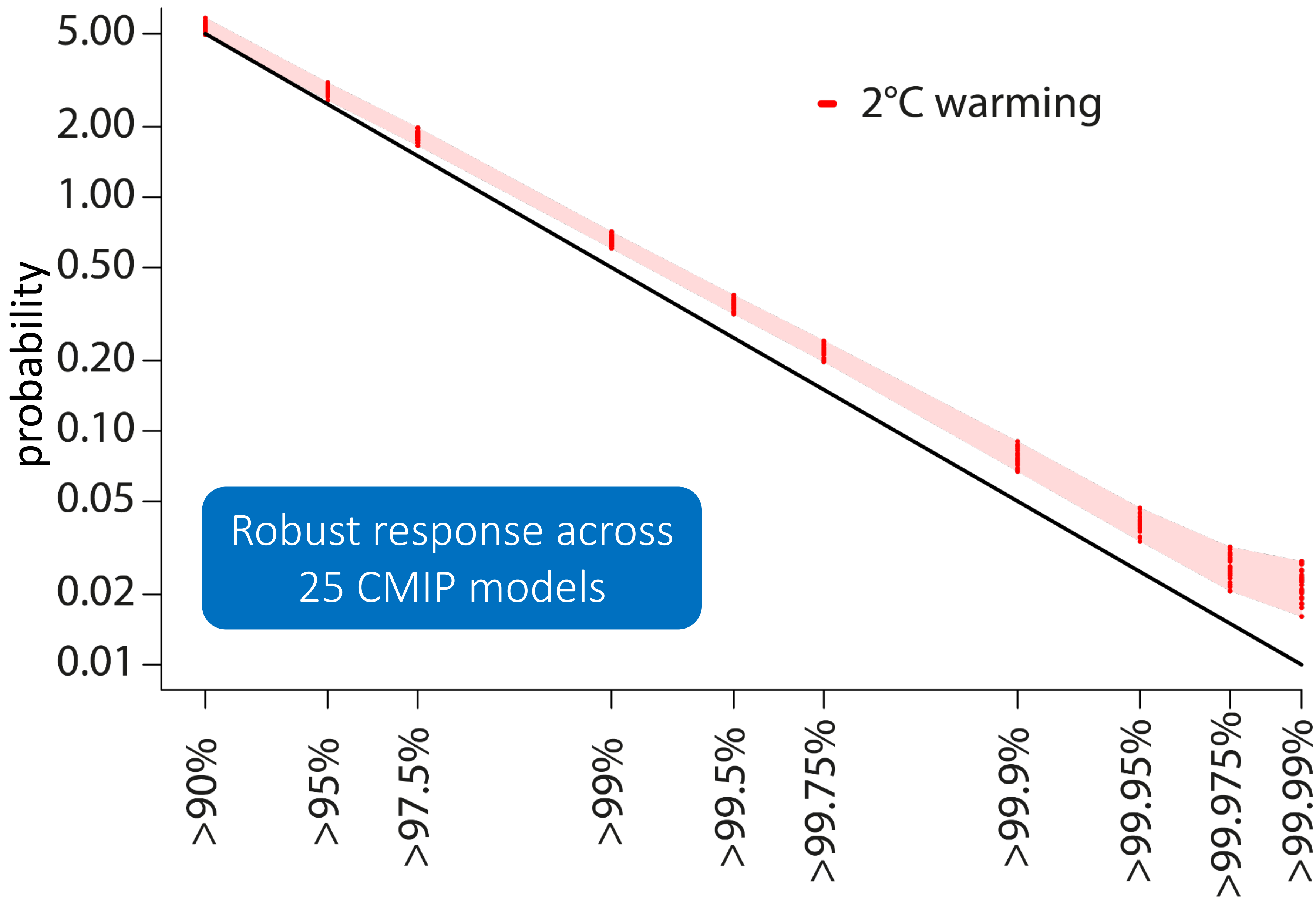
Noisy changes at one grid point



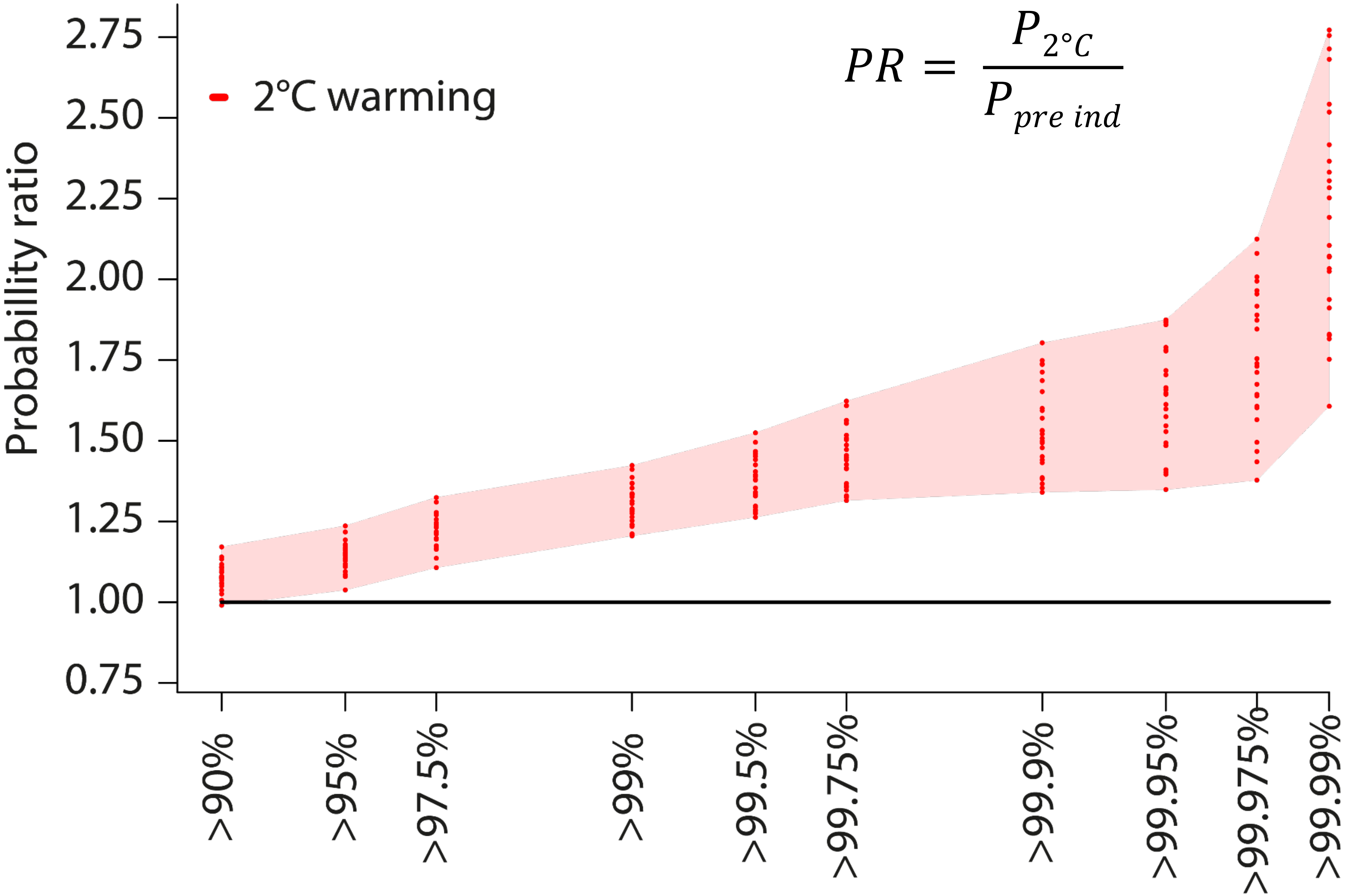
Heavy precipitation averaged over N Europe



Heavy precipitation days over N Europe



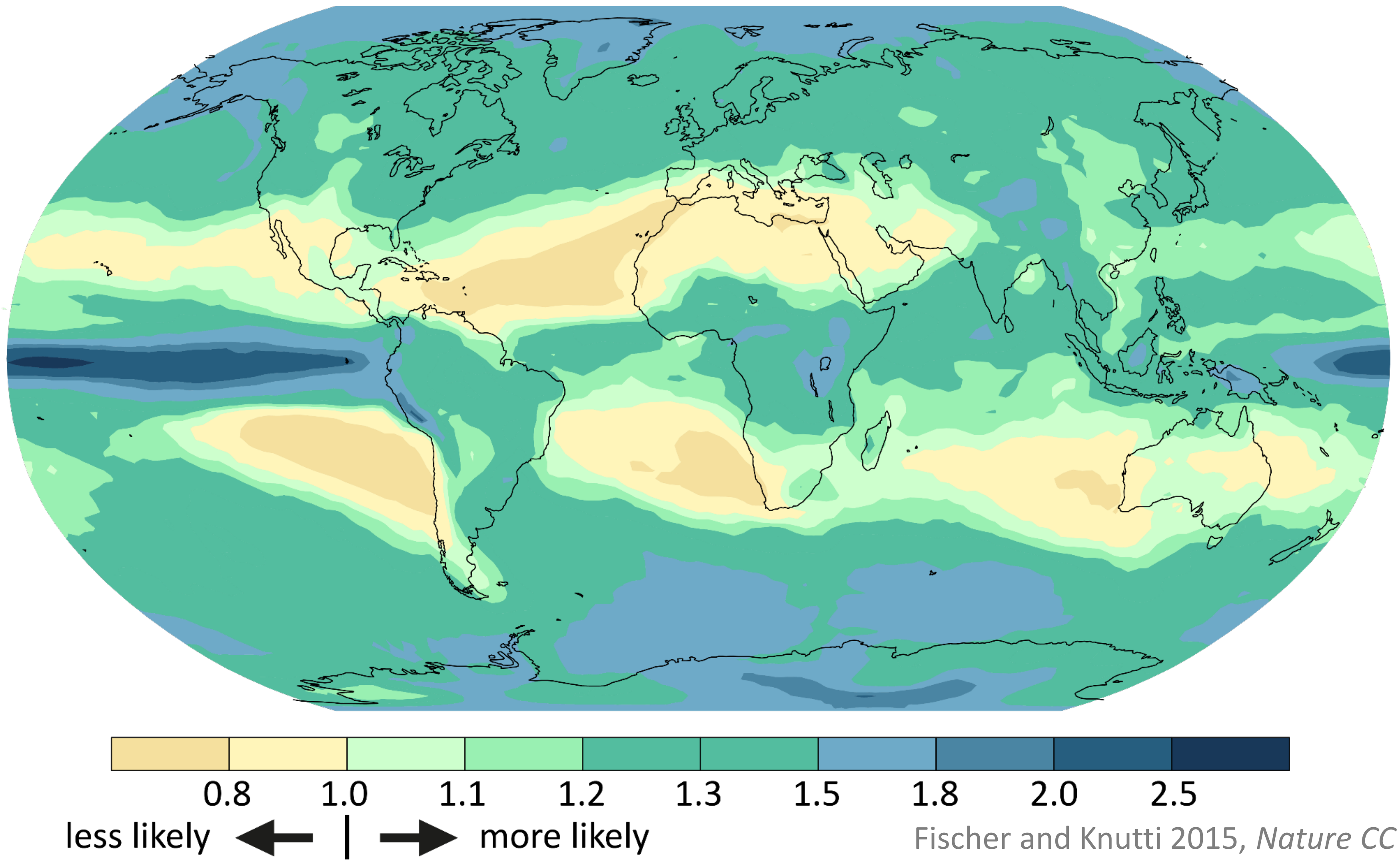
The more extreme – the greater the increase



Fischer and Knutti 2015, *Nature CC*

Probability ratio at 2°C warming

Multi-model mean exceedance of
pre-industrial 99% quantile of daily precipitation



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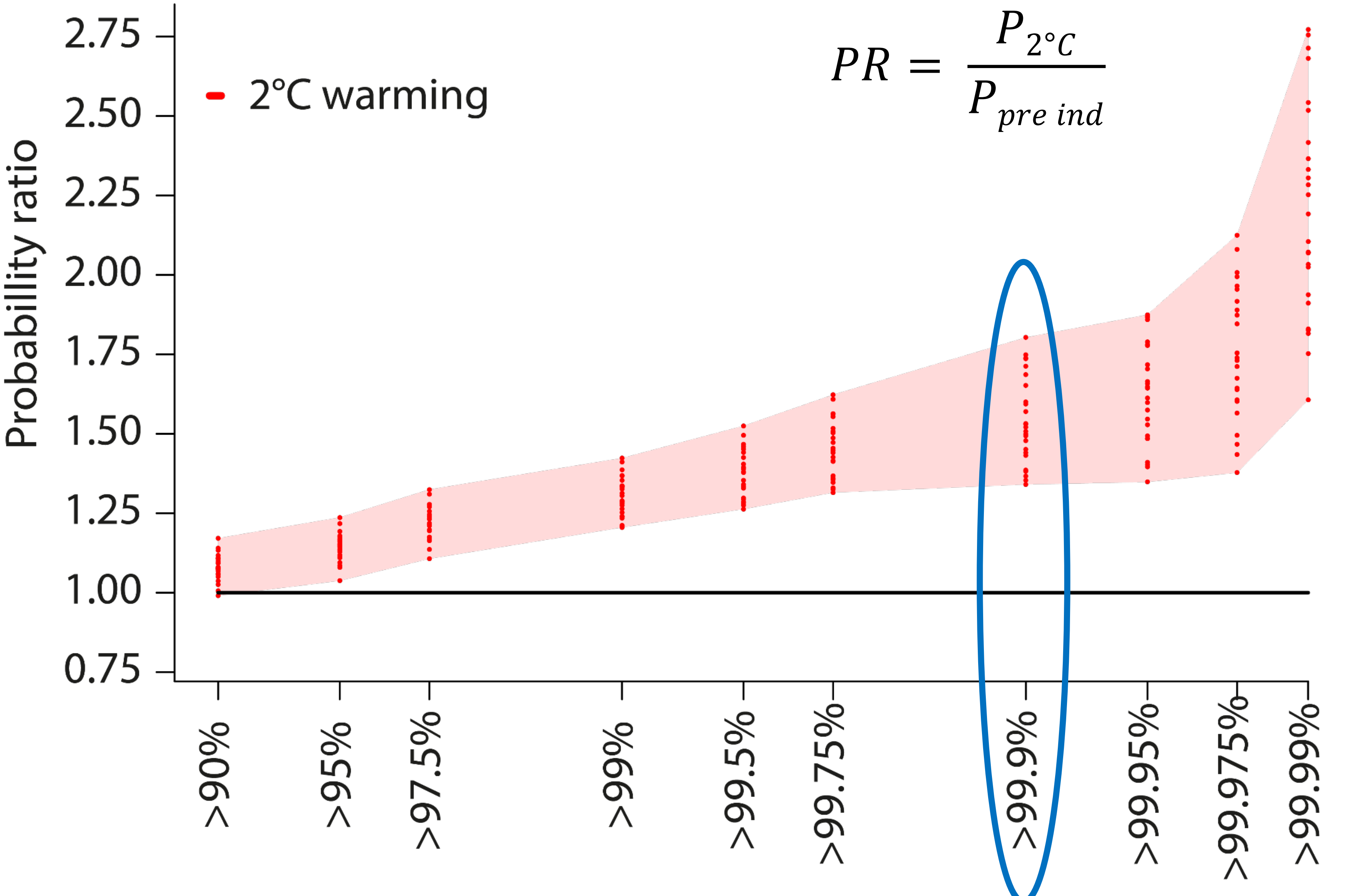
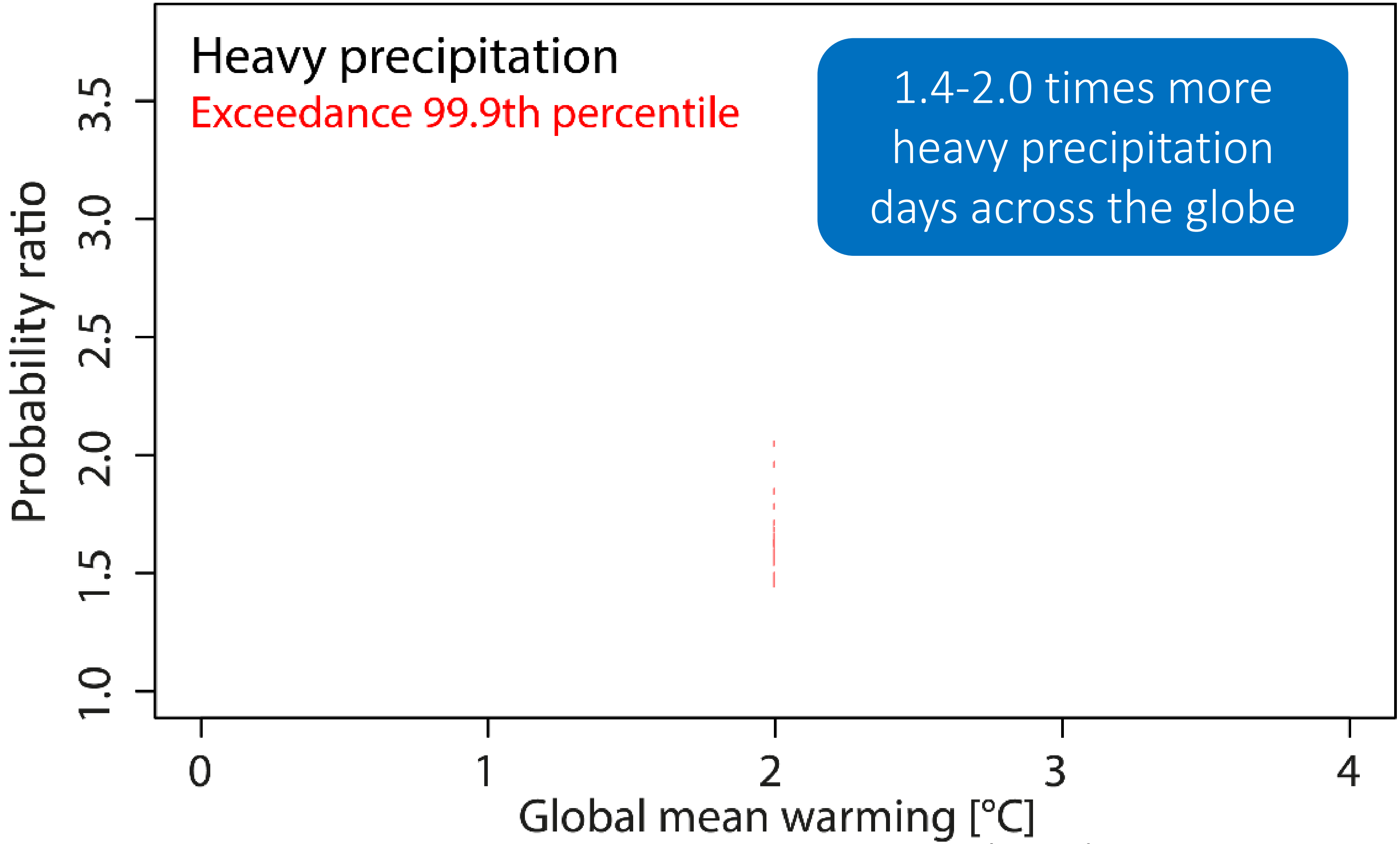
The more extreme – the greater the increase



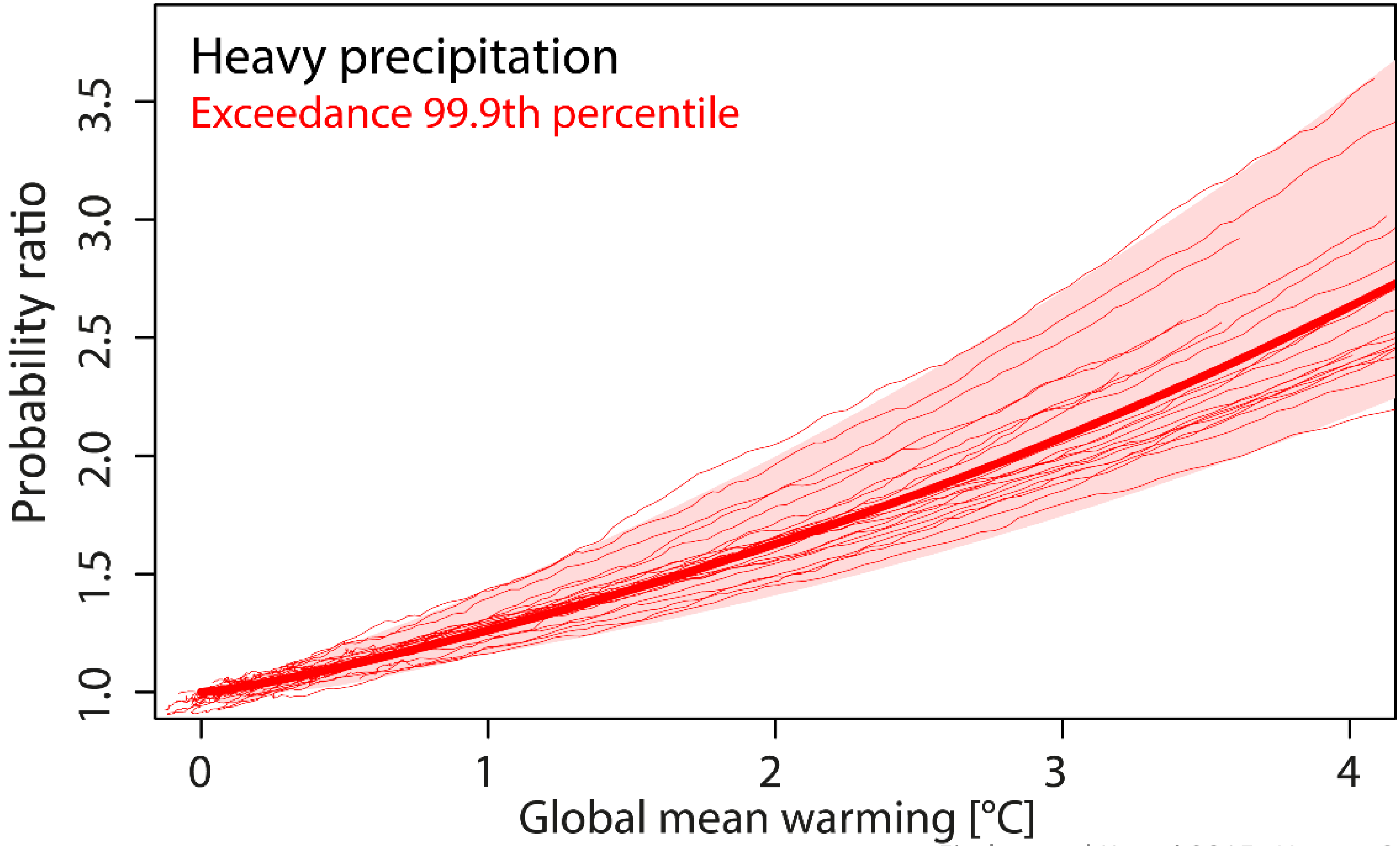
Fischer and Knutti 2015, *Nature CC*

Global land-only probability ratio



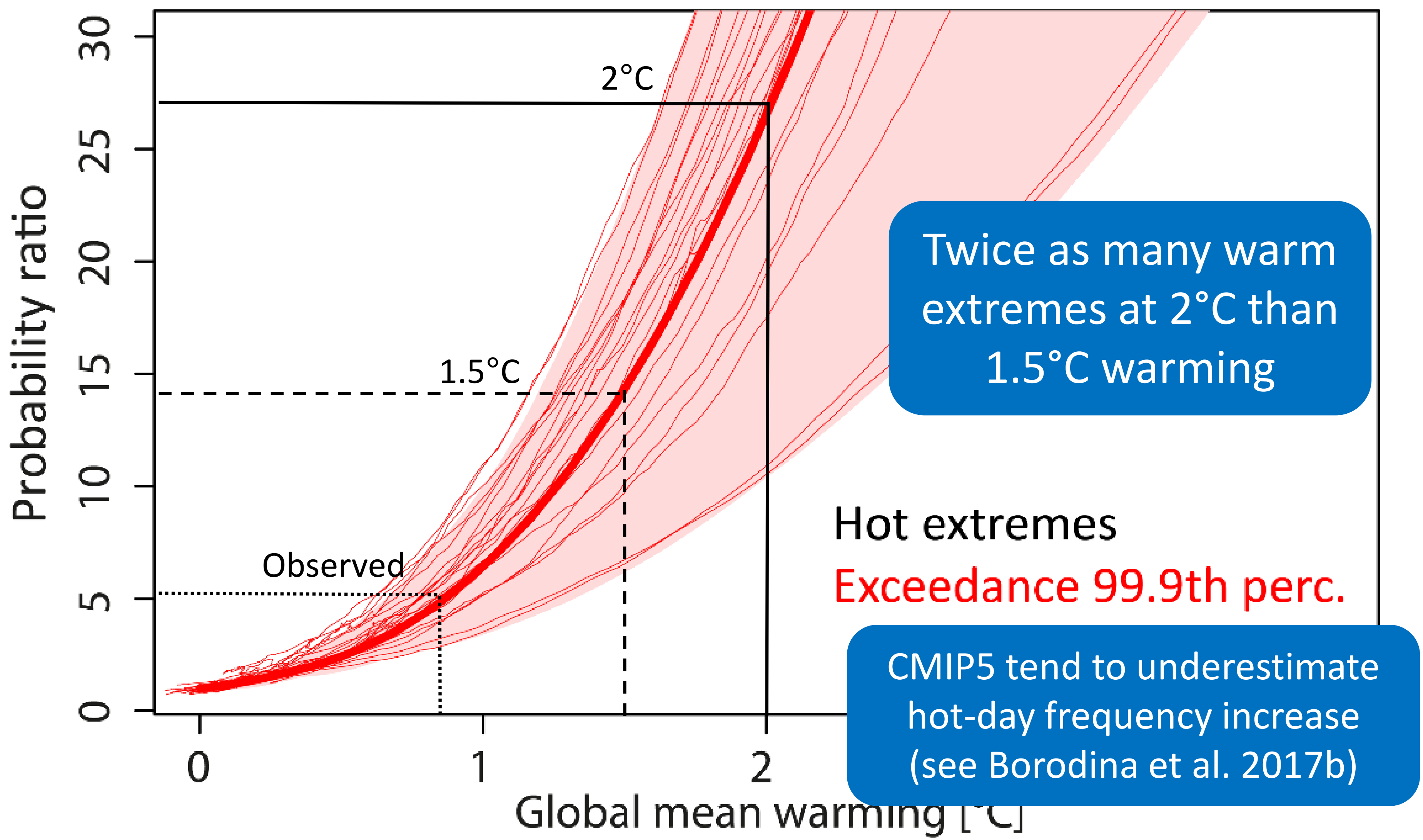
Fischer and Knutti 2015, *Nature CC*

Non-linear increase with warming



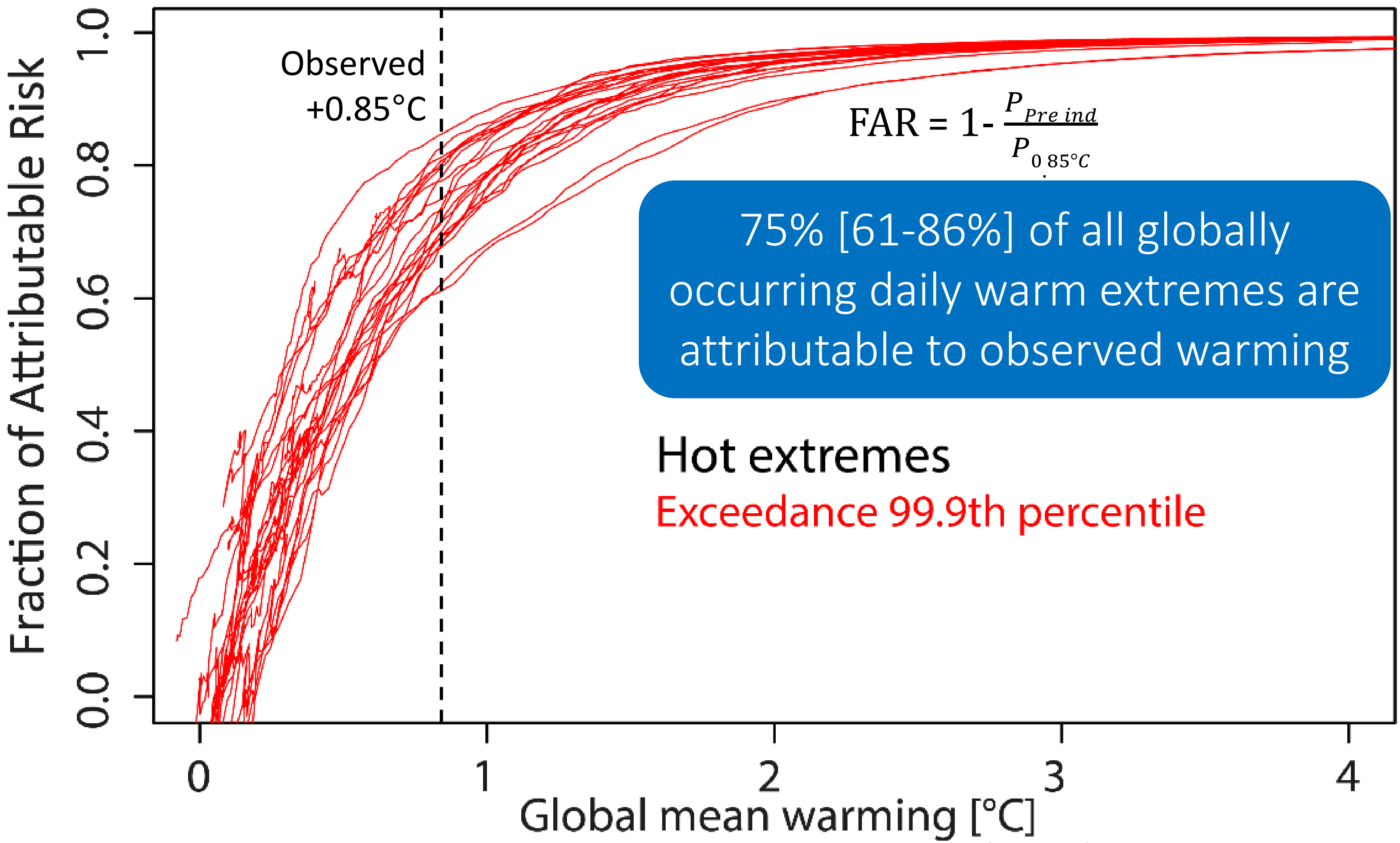
Fischer and Knutti 2015, *Nature CC*

Global warming targets matter



Fischer and Knutti 2015, *Nature CC*

Majority of warm extremes attributable



Fischer and Knutti 2015, *Nature CC*

2-step attribution

A substantial portion of today's
hot and heavy rainfall extremes
can be attributed to warming (step 1)
which is primarily anthropogenic (step 2)

Consistent with Hegerl et al. (2004), Min et al. 2011, *Nature*, Pall et al. 2011, *Nature,*
Zhang et al. (2013) *GRL,* and Zwiers et al. (2011) *J Climate…*

Anthropogenic contribution

- Anthropogenic warming has changed the odds of hot extremes and heavy rainfall extremes
- Continuing warming nonlinearly increases those odds
- Attribution is more robust at large spatial scales

Fischer, E. M., U. Beyerle, and R. Knutti (2013), Robust spatially aggregated projections of climate extremes, *Nature Climate Change*, 3 (12), 1033-1038

Fischer, E.M., and R. Knutti, (2015), Anthropogenic contribution to global occurrence of heavy-precipitation and high-temperature extremes, *Nature Climate Change*, 5, doi:10.1038/nclimate2051

Fischer, E.M., and R. Knutti, (2016), Observed heavy precipitation increase confirms theory and early models *Nature Climate Change*, 6, doi:10.1038/nclimate3110

Pfahl, S., P. O'Gorman, and E.M. Fischer (2017), Understanding the regional pattern of projected future changes in extreme precipitation, *Nature Climate Change*, 7, (6), 423{427, doi:10.1038/nclimate3287.

Schleussner, C.F., P. Pfleiderer, and E.M. Fischer (2017), In the observational record half a degree matters, *Nature Climate Change*, 7, 460{462, doi:10.1038/nclimate3320.