# A plethora of noise

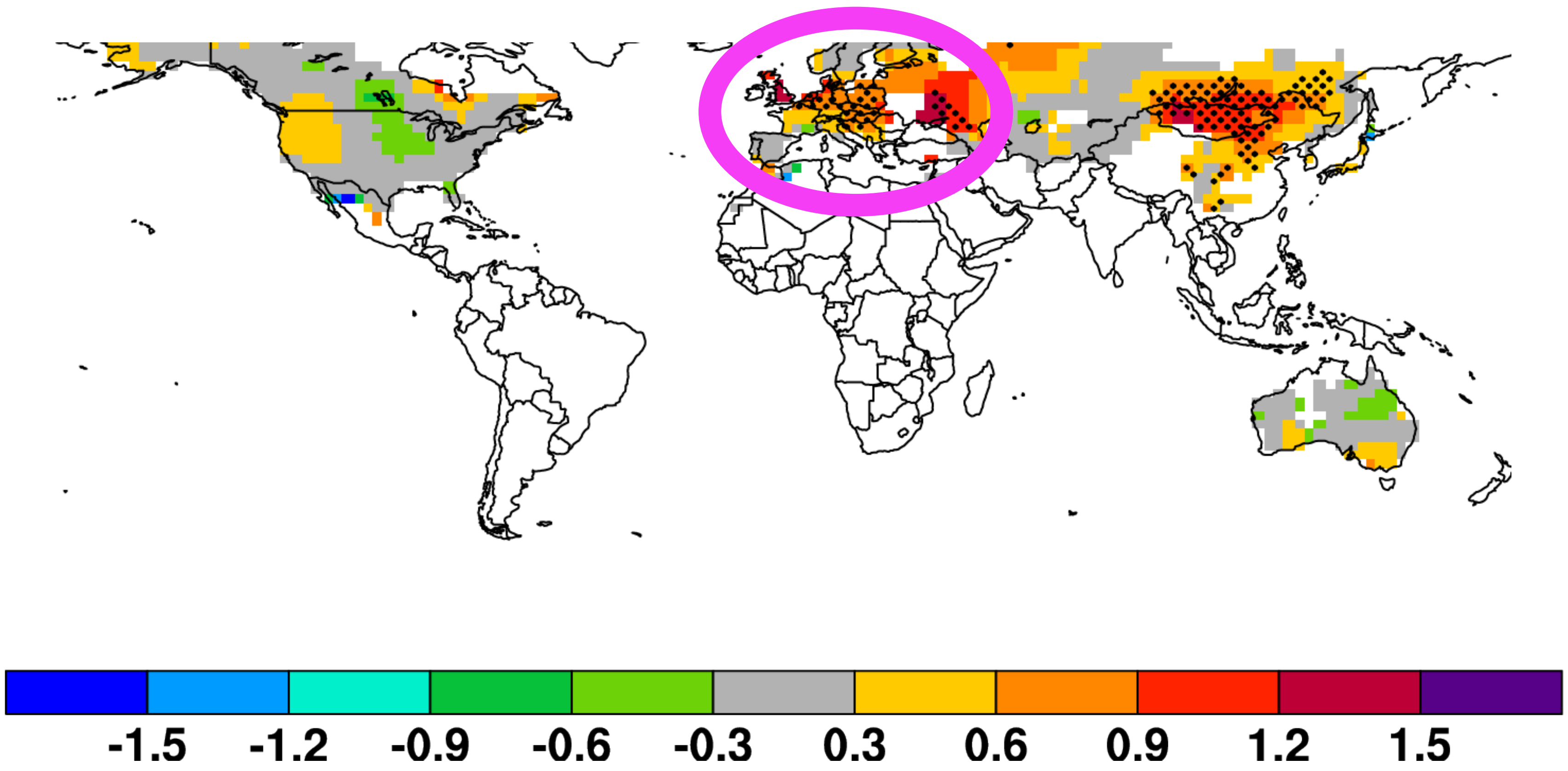
## The challenge of evaluating models given abundant internal variability?

Erich Fischer
ETH Zurich, Switzerland

Thanks to Reto Knutti, Jan Sedlacek, Urs Beyerle (ETH)
Ed Hawkins, Rowan Sutton, Pierluigi Vidale (Reading)

# Observed trends in hot extremes

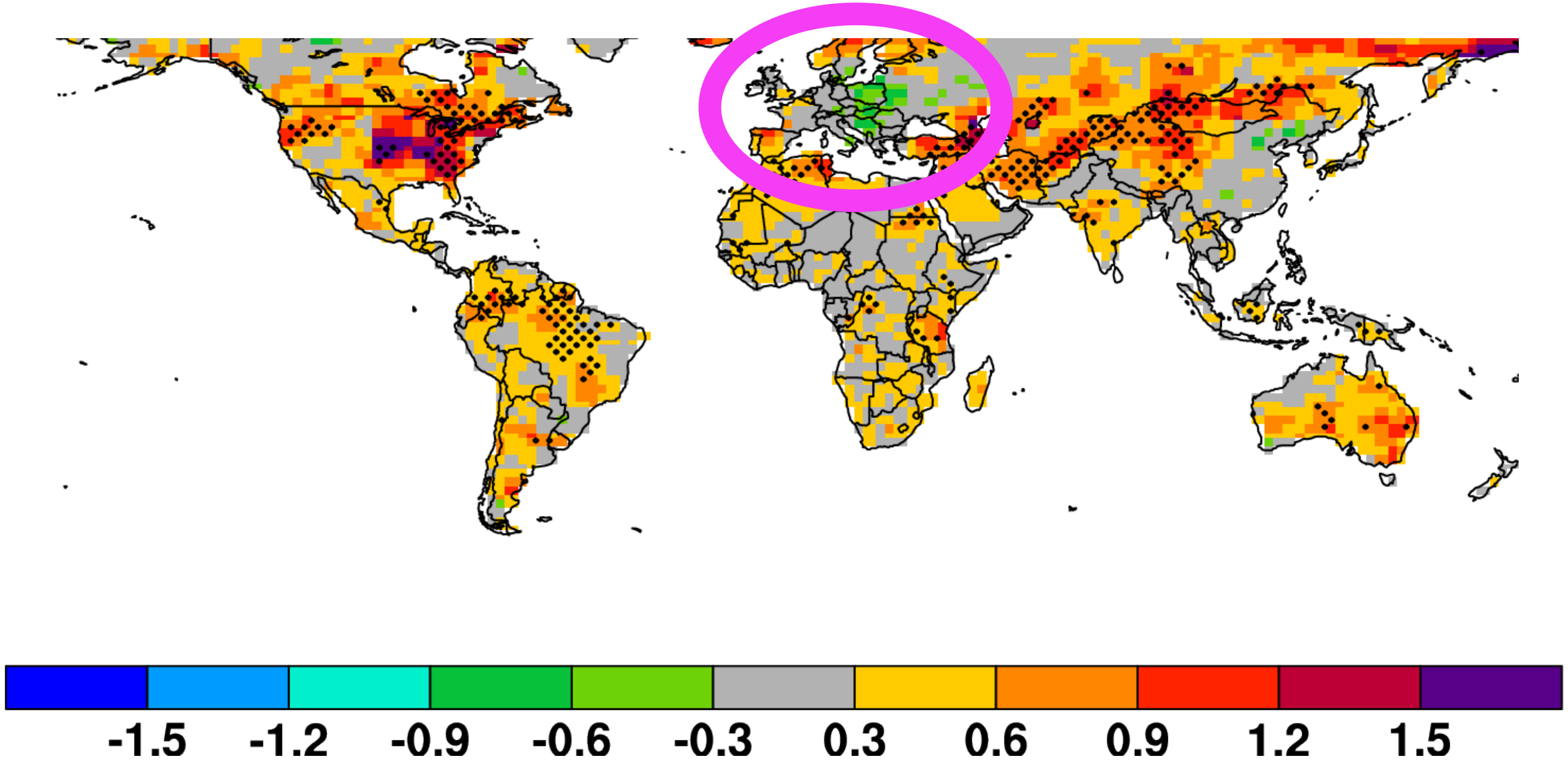
Trends in TXx 1979-2010 (GHCNDEX)




Fischer and Knutti (2014), *Geophys. Res. Letters*

# Poor agreement

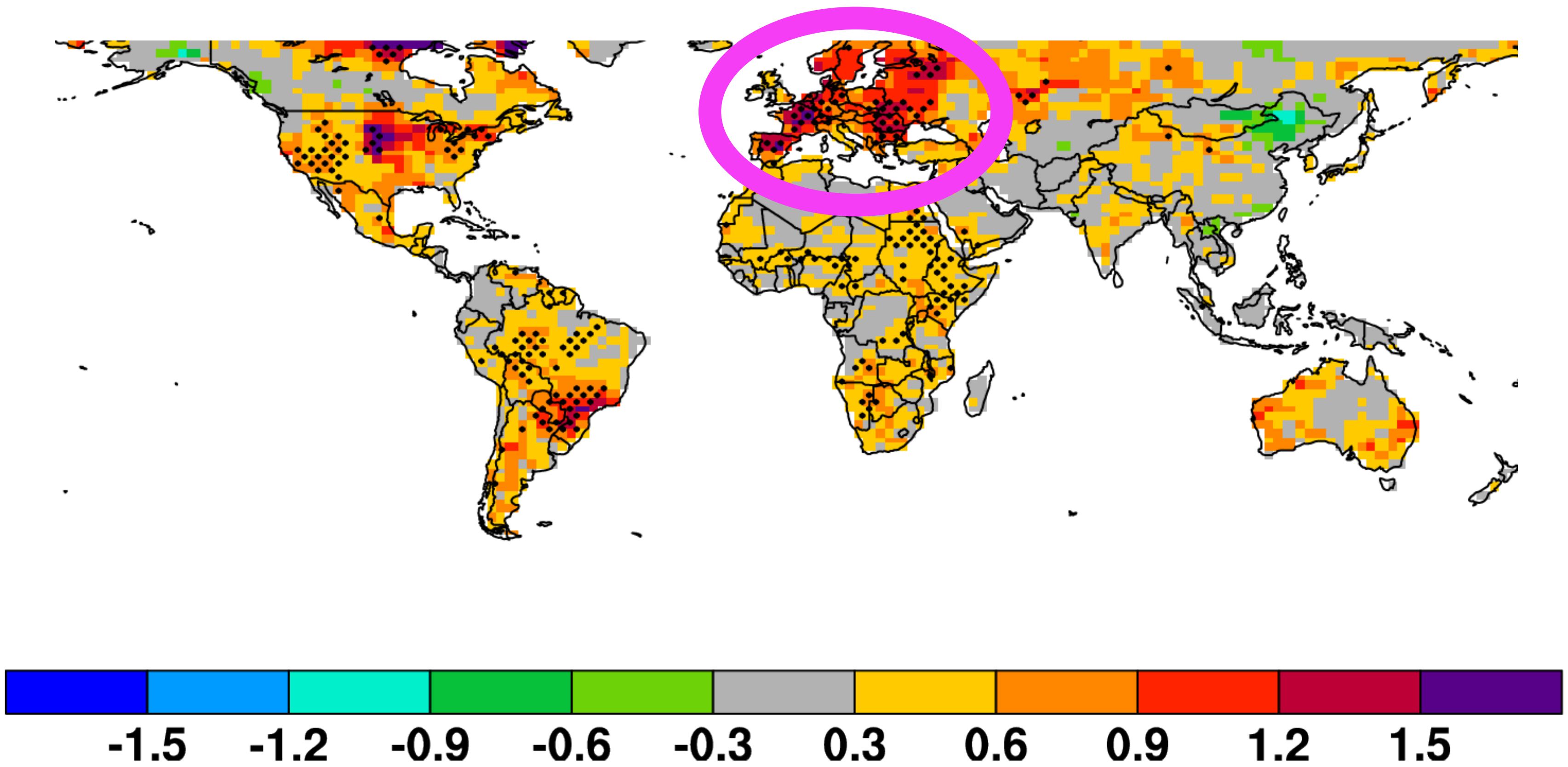
Trends in TXx 1979-2010 (CESM)




Fischer and Knutti (2014), *Geophys. Res. Letters*

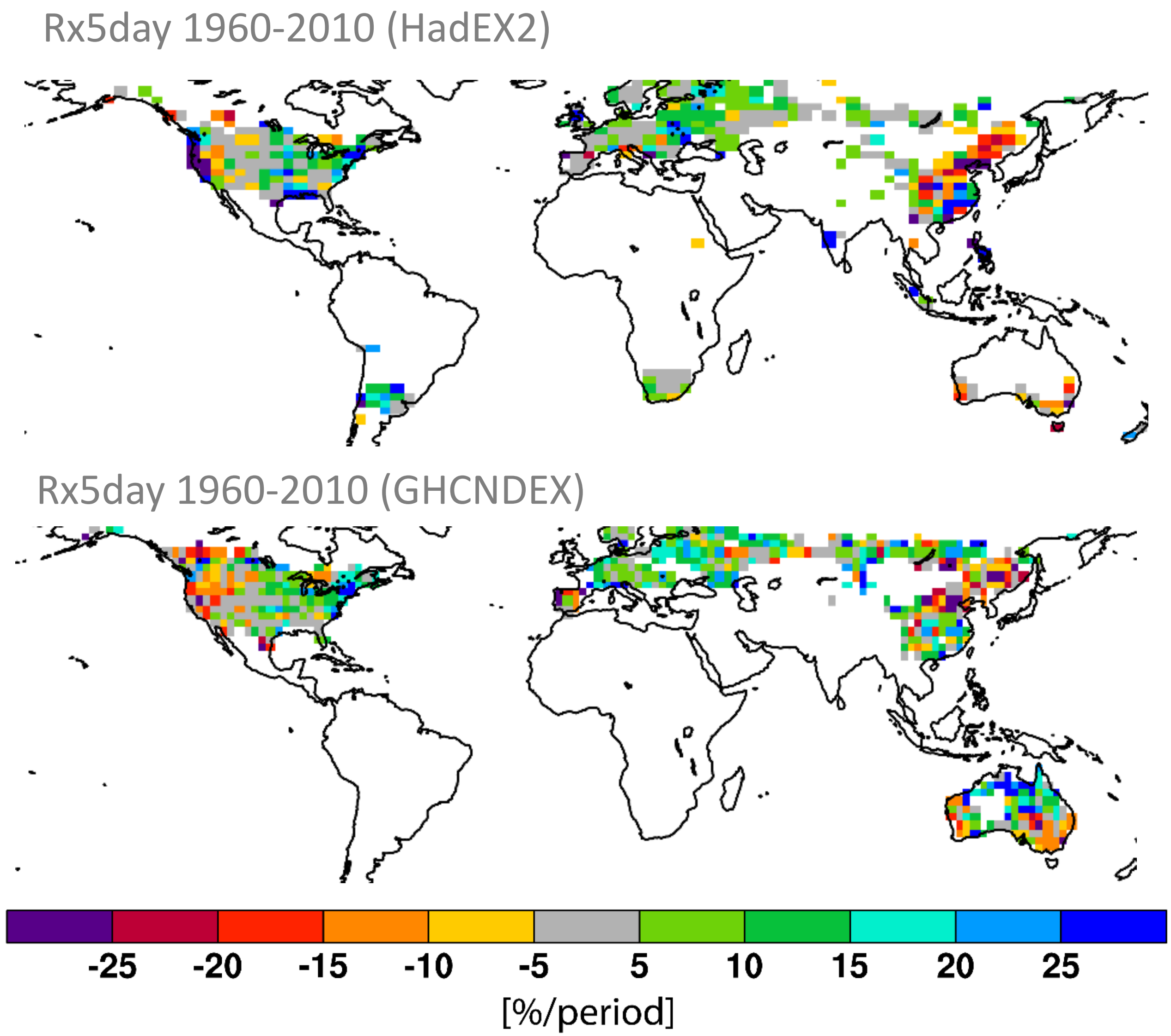
# Good agreement

Trends in TXx 1979-2010 (CESM)



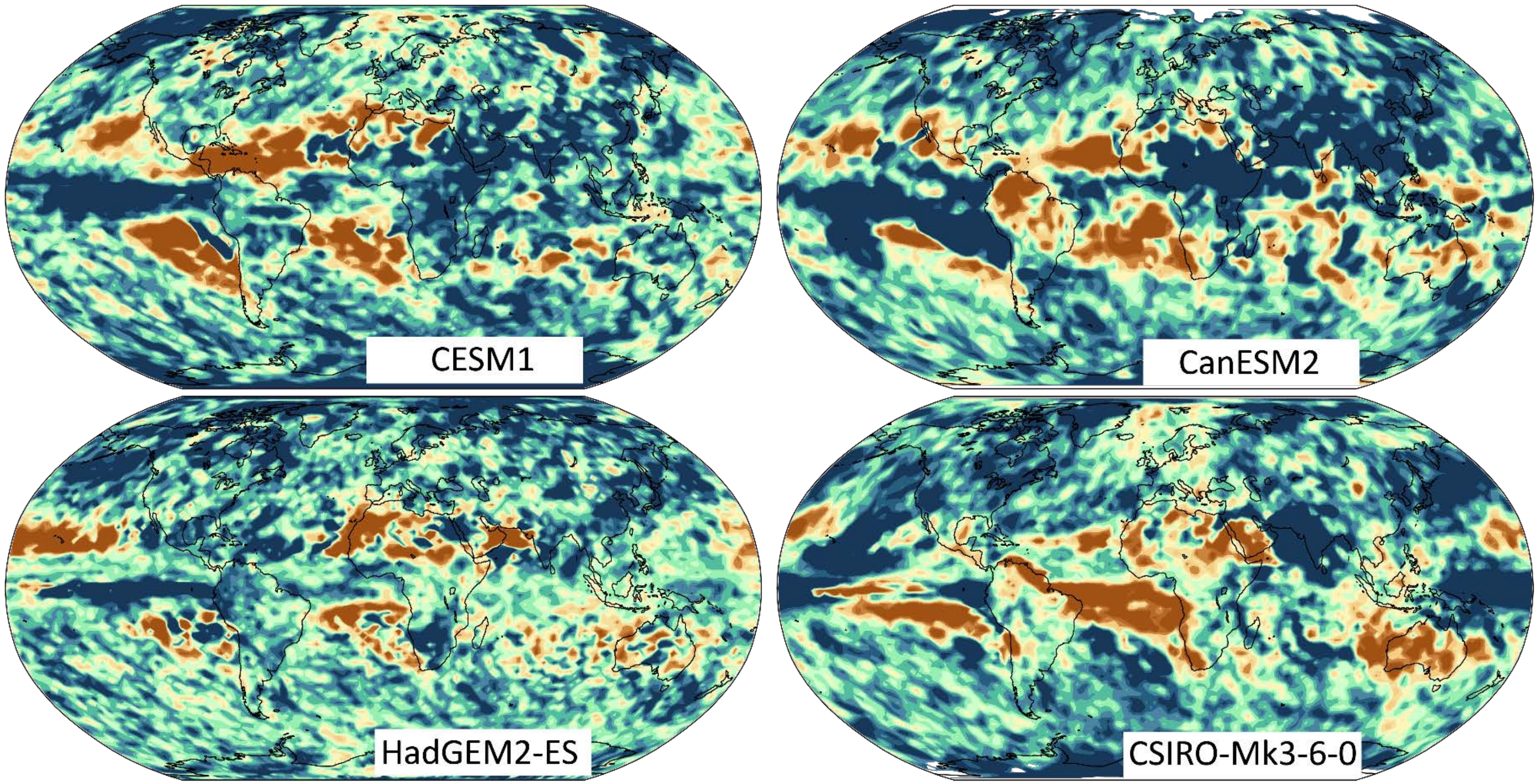

Fischer and Knutti (2014), *Geophys. Res. Letters*

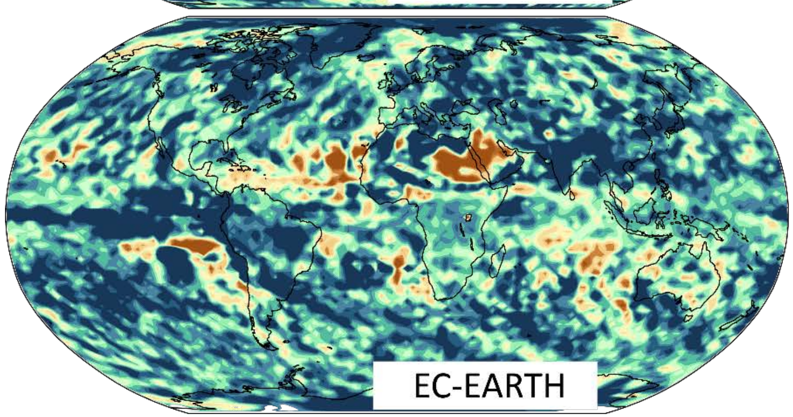
# Heavy precipitation trends

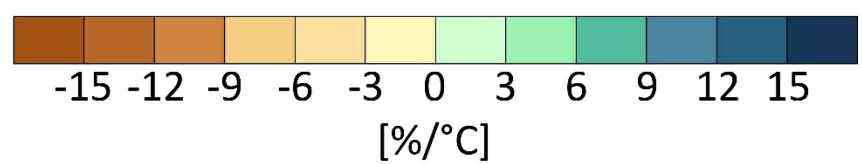



Fischer and Knutti (2014), *Geophys. Res. Letters*

# Do GCMs agree on the precip intensification?



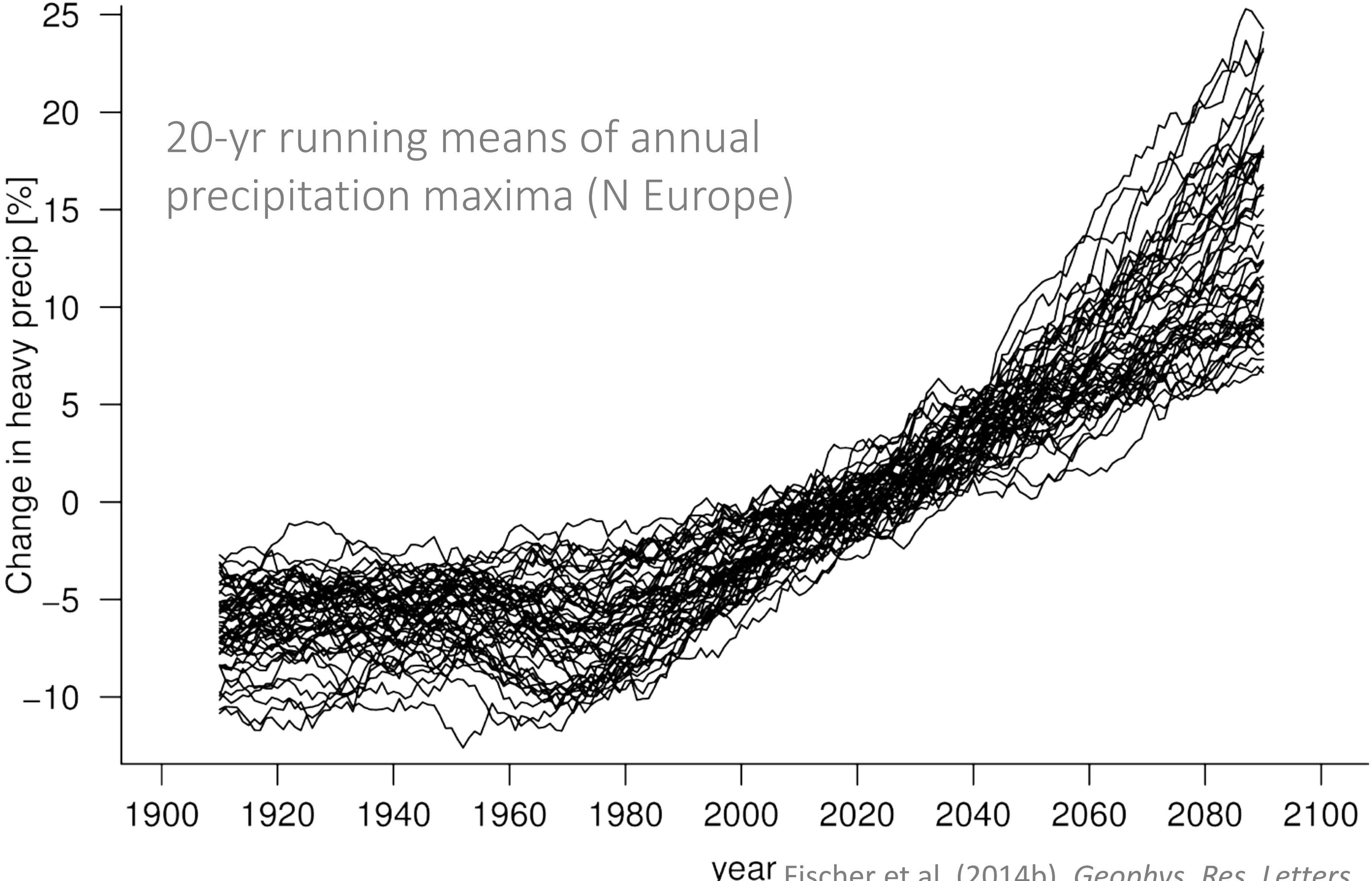




Annual precipitation maxima change (Rx1day) in 20th century

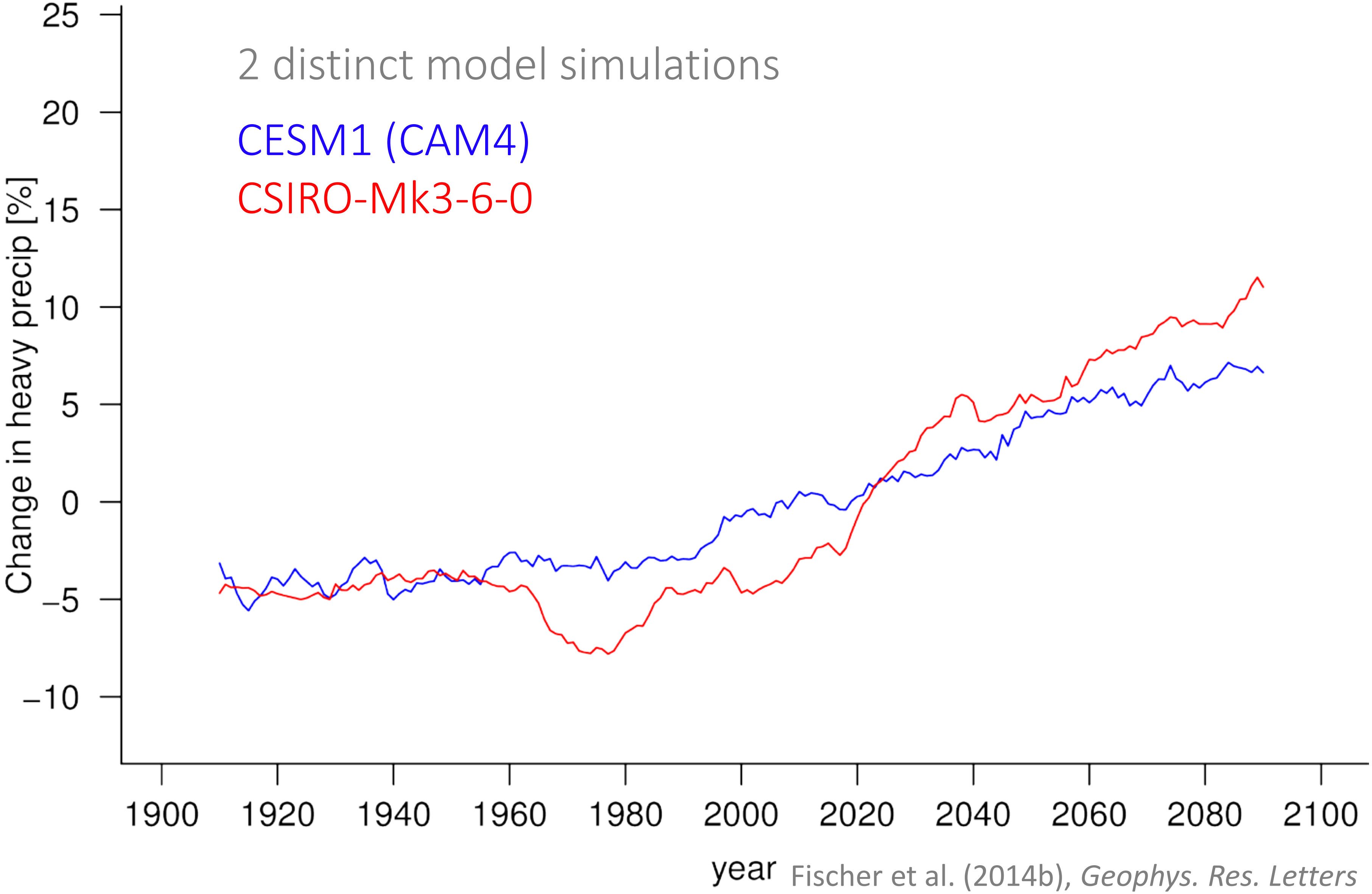
Fischer et al. (2014b), *Geophys. Res. Letters*

# Large differences even in running means



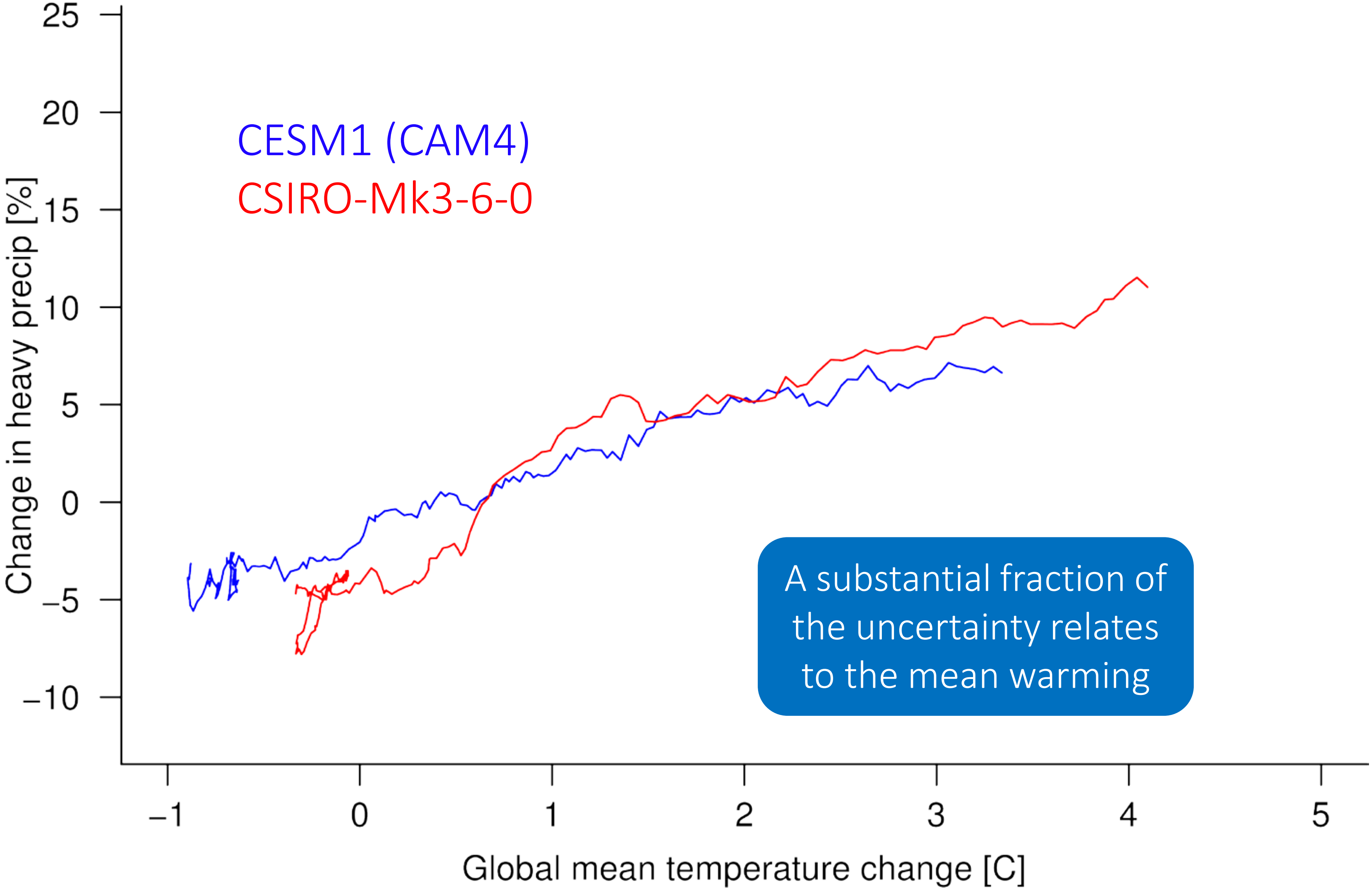

Fischer et al. (2014b), *Geophys. Res. Letters*

# Two example model runs



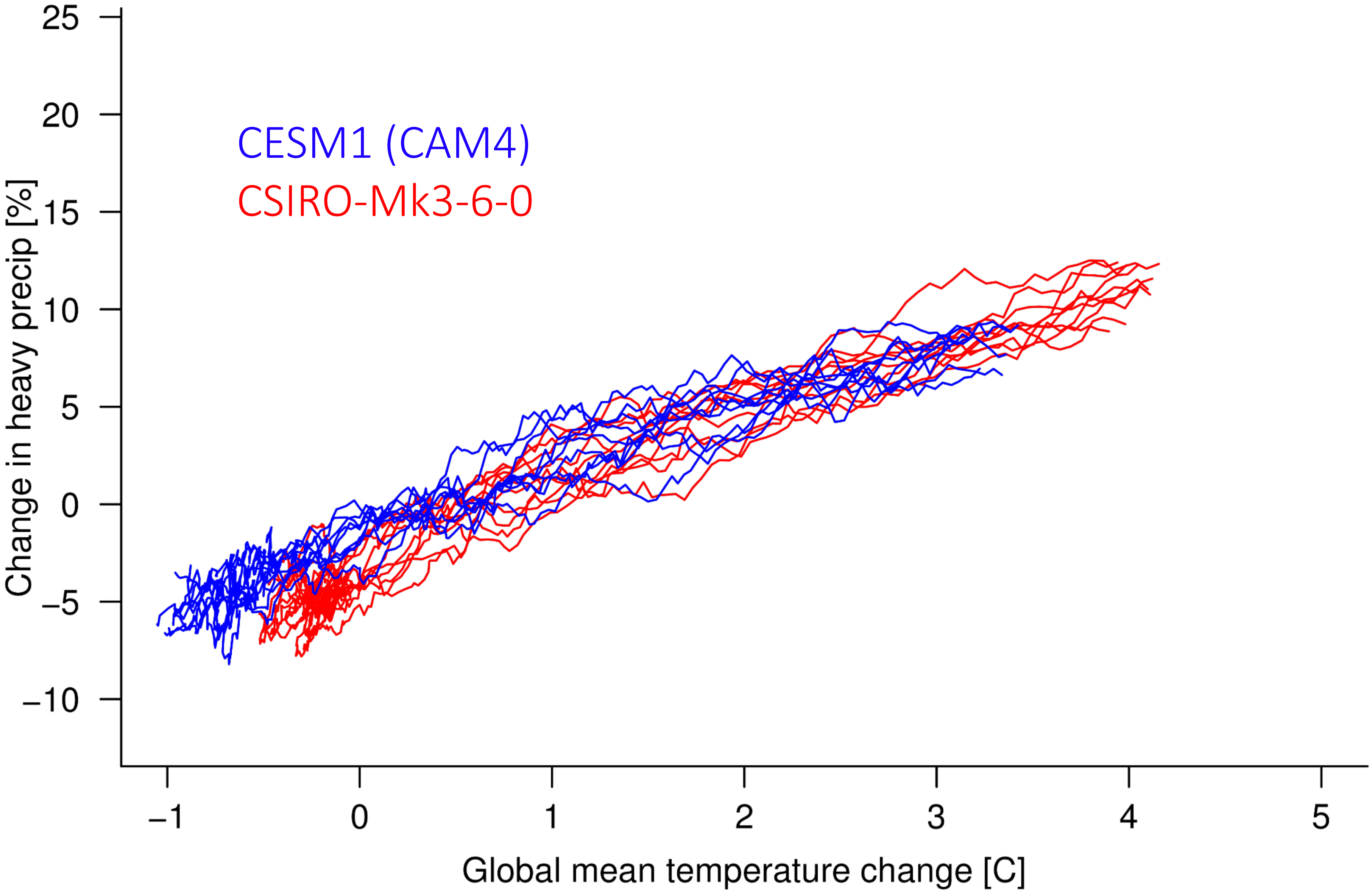

Fischer et al. (2014b), *Geophys. Res. Letters*

# Scaling with global mean temperature

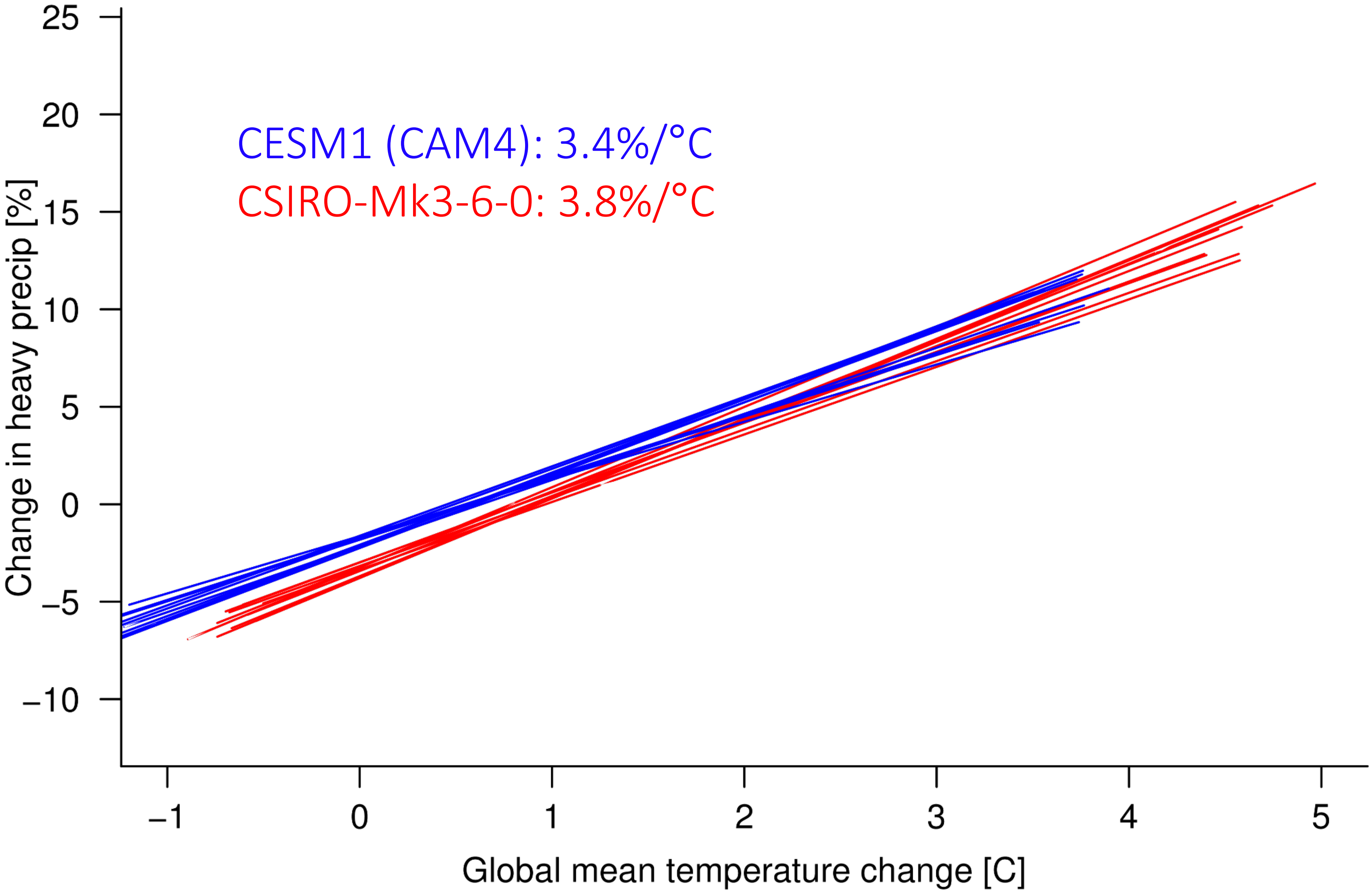



A substantial fraction of the uncertainty relates to the mean warming

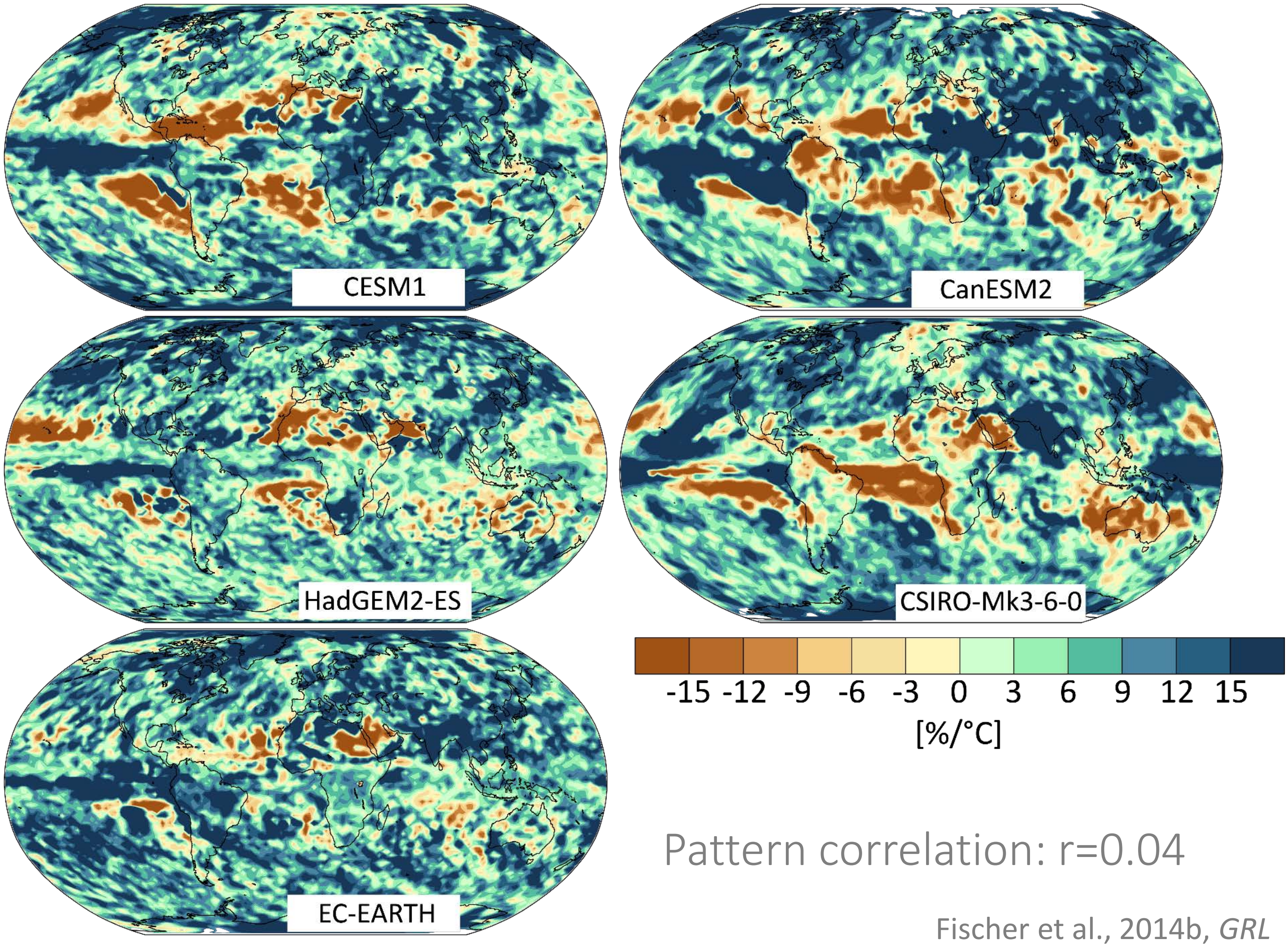
# Scaling with global mean temperature



# High agreement in forced signal



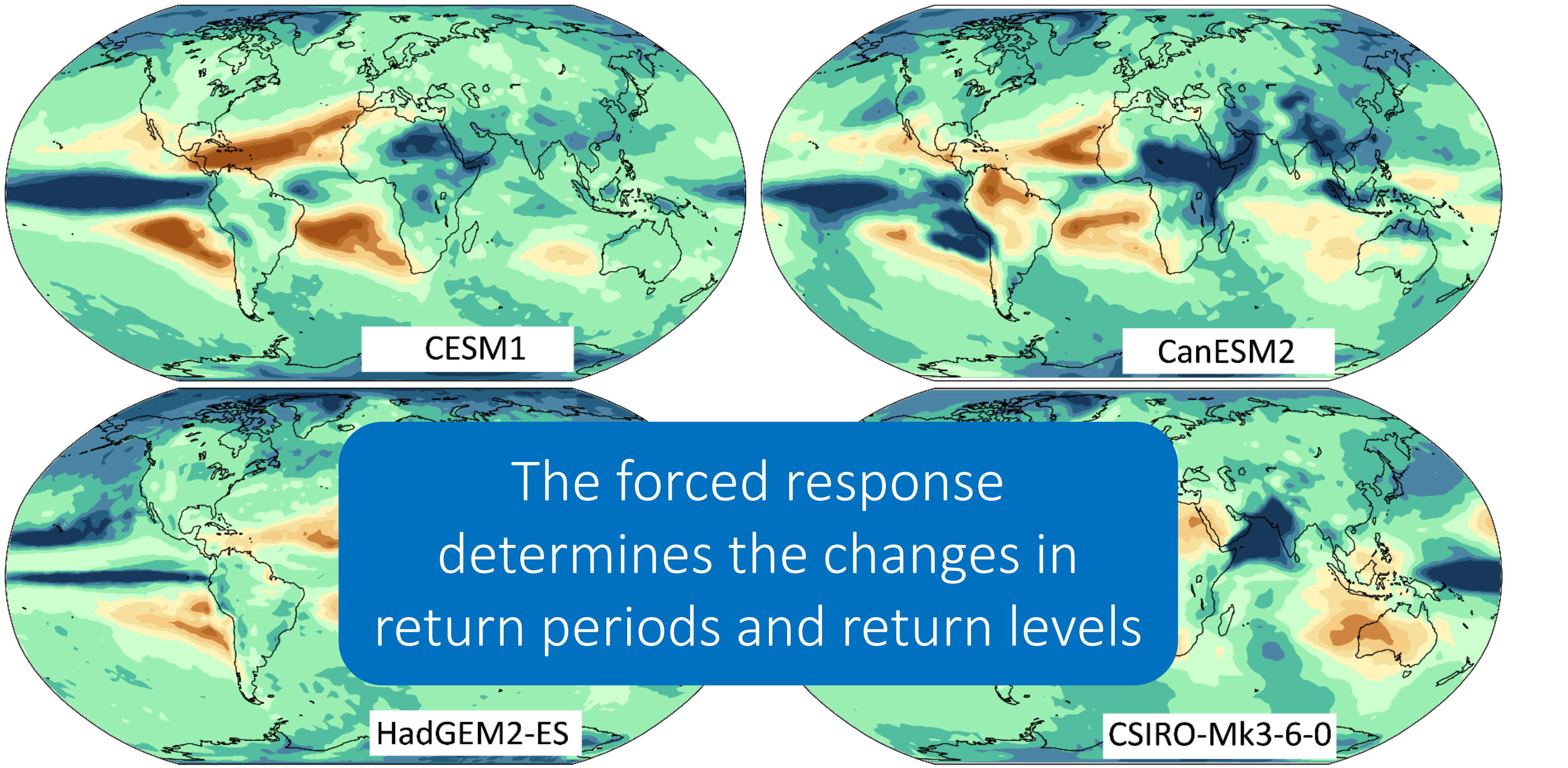
# Poor agreement in observational period



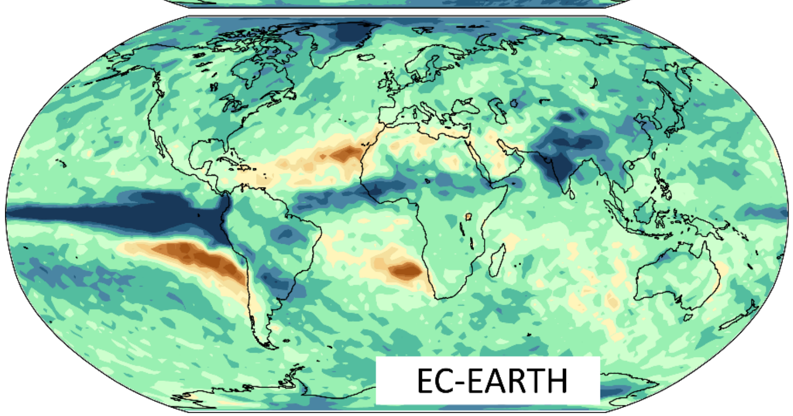

Pattern correlation: r=0.04

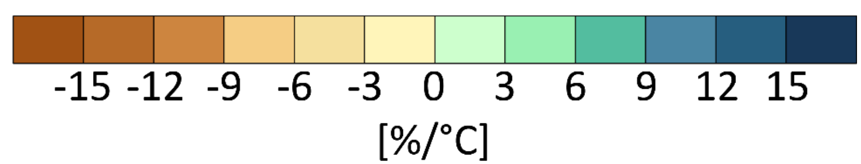
Fischer et al., 2014b, *GRL*

# High agreement in forced signal




The forced response determines the changes in return periods and return levels




Pattern correlation: r=0.59

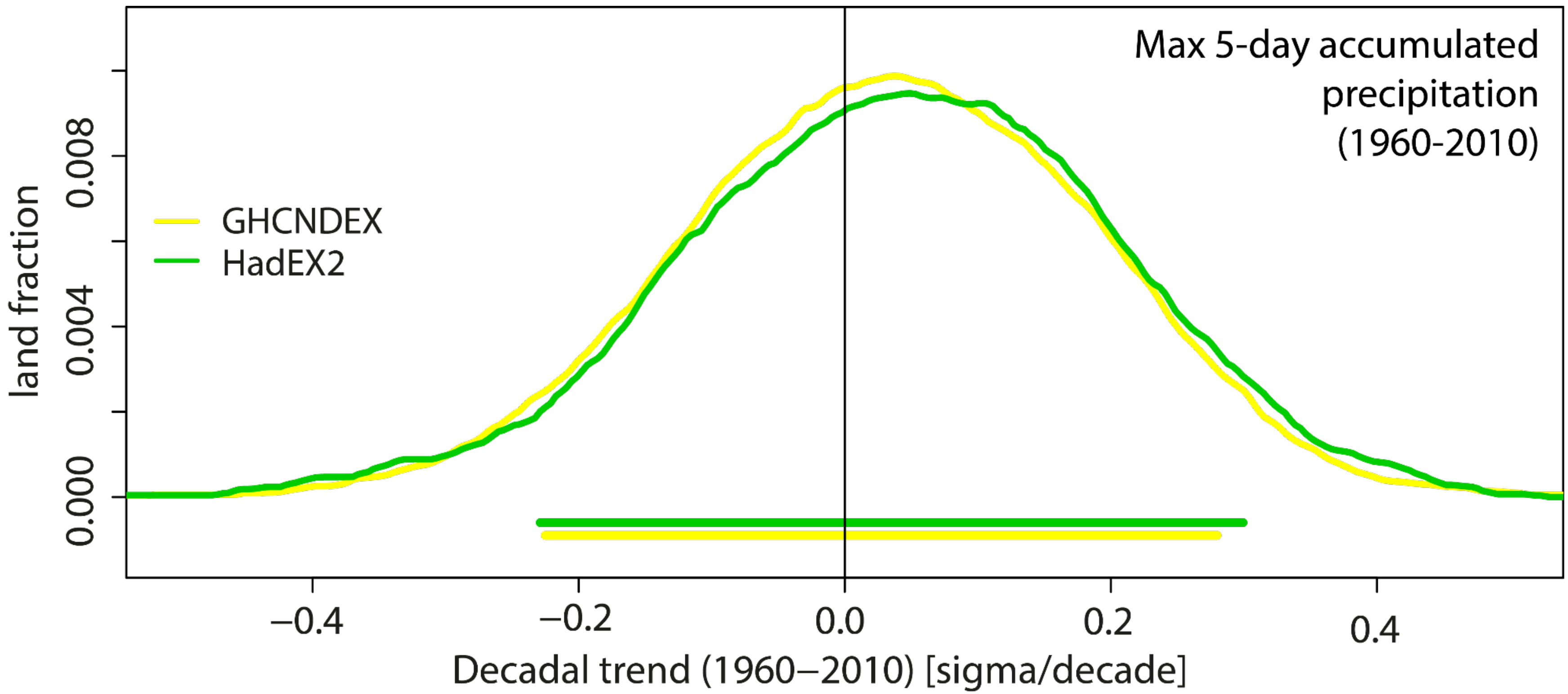
Across CMIP5 models: r=0.51

Fischer et al., 2014b, *GRL*

see also Zhang et al. 2013, *GRL*

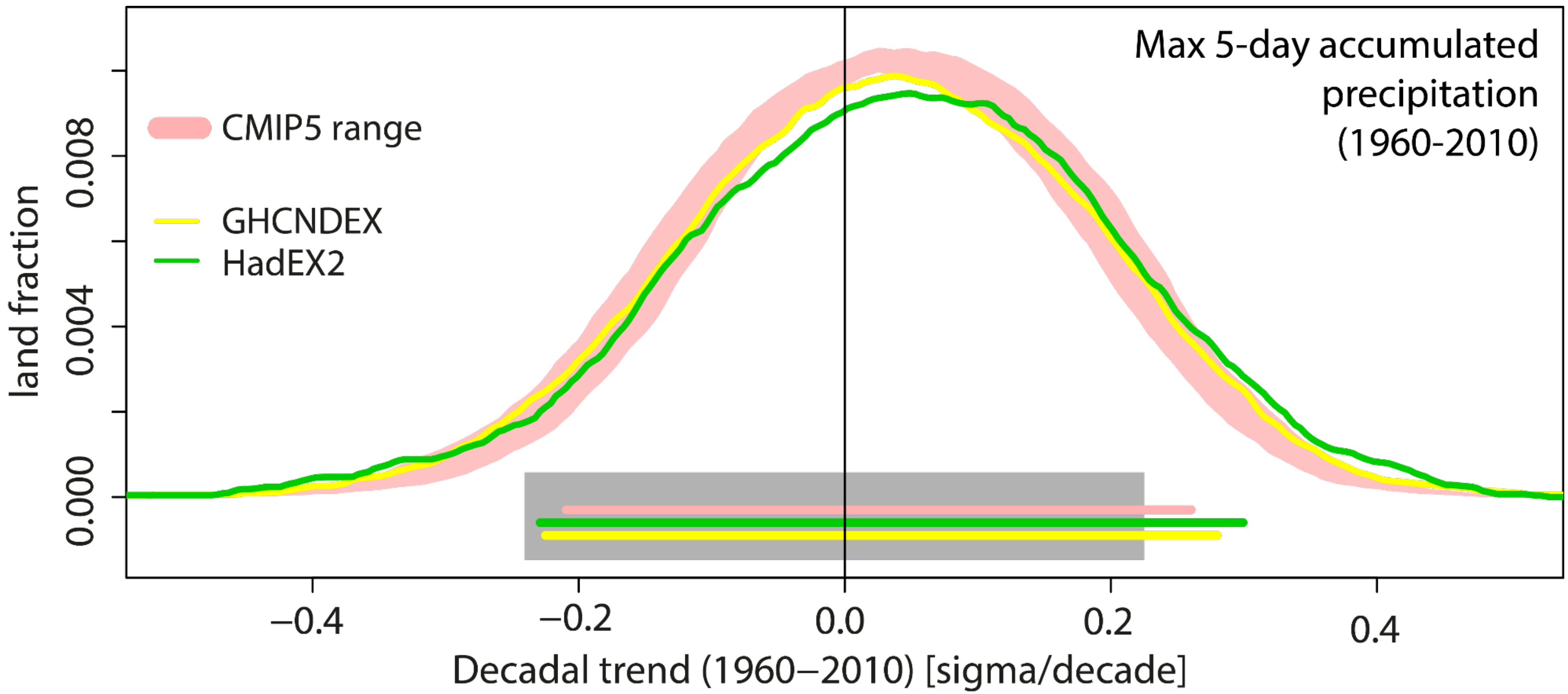
# Models consistent – but wrong?

# The spatial probability perspective




Fischer and Knutti (2014), *Geophys. Res. Letters*

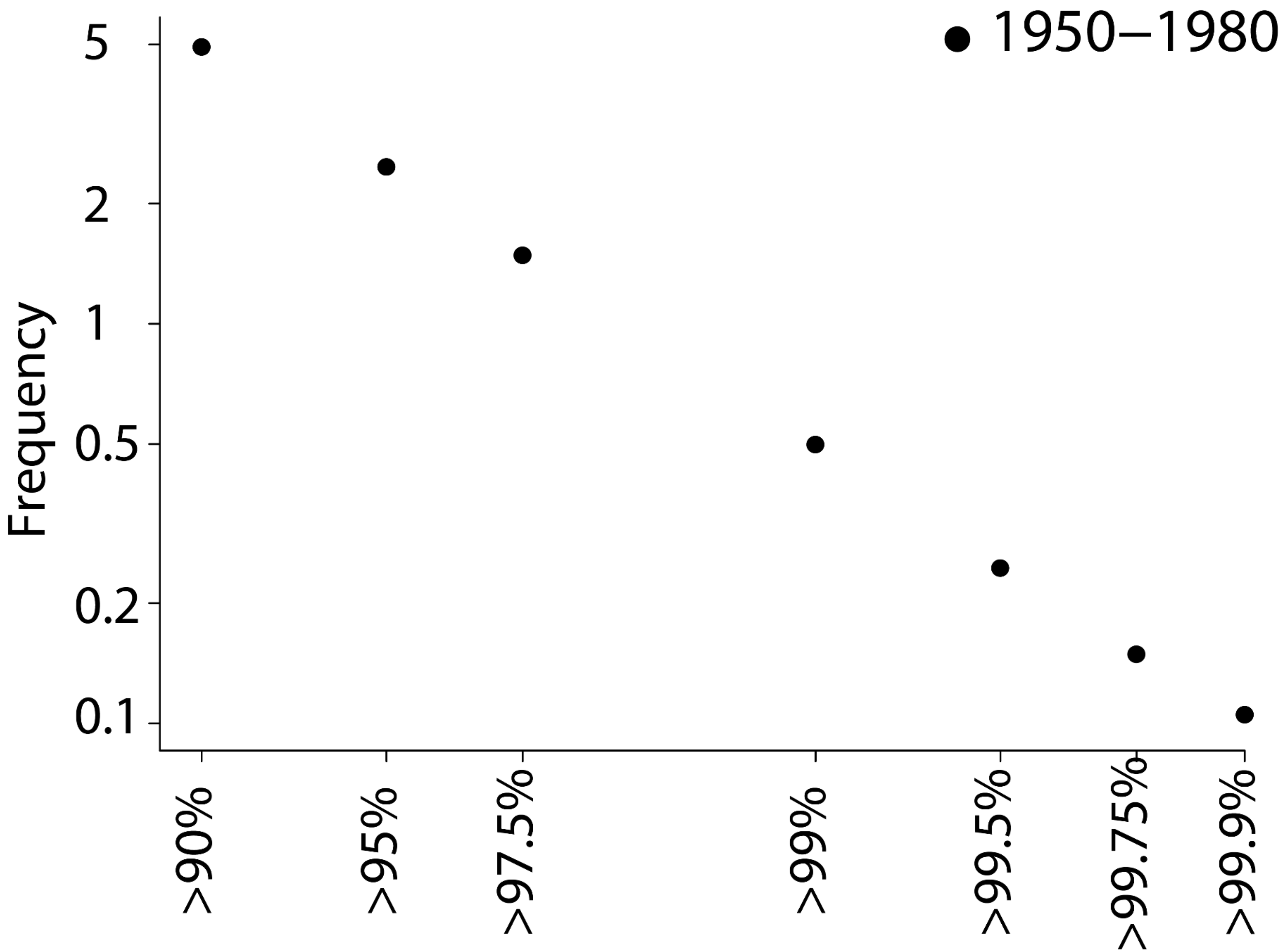
# The spatial probability perspective




Fischer and Knutti (2014), *Geophys. Res. Letters*

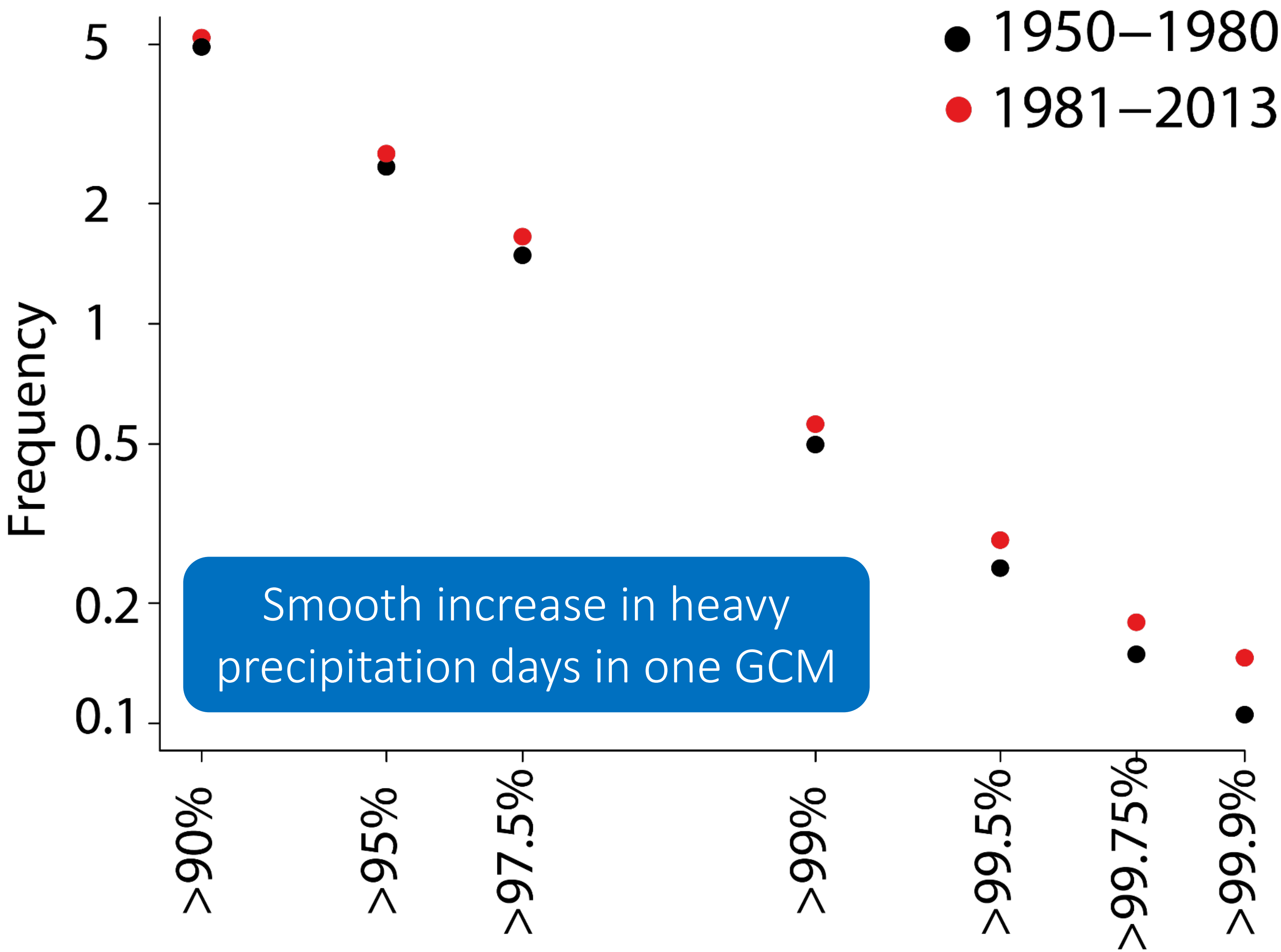
# Changes in the tail of the distribution

# Daily precip binned for N Europe



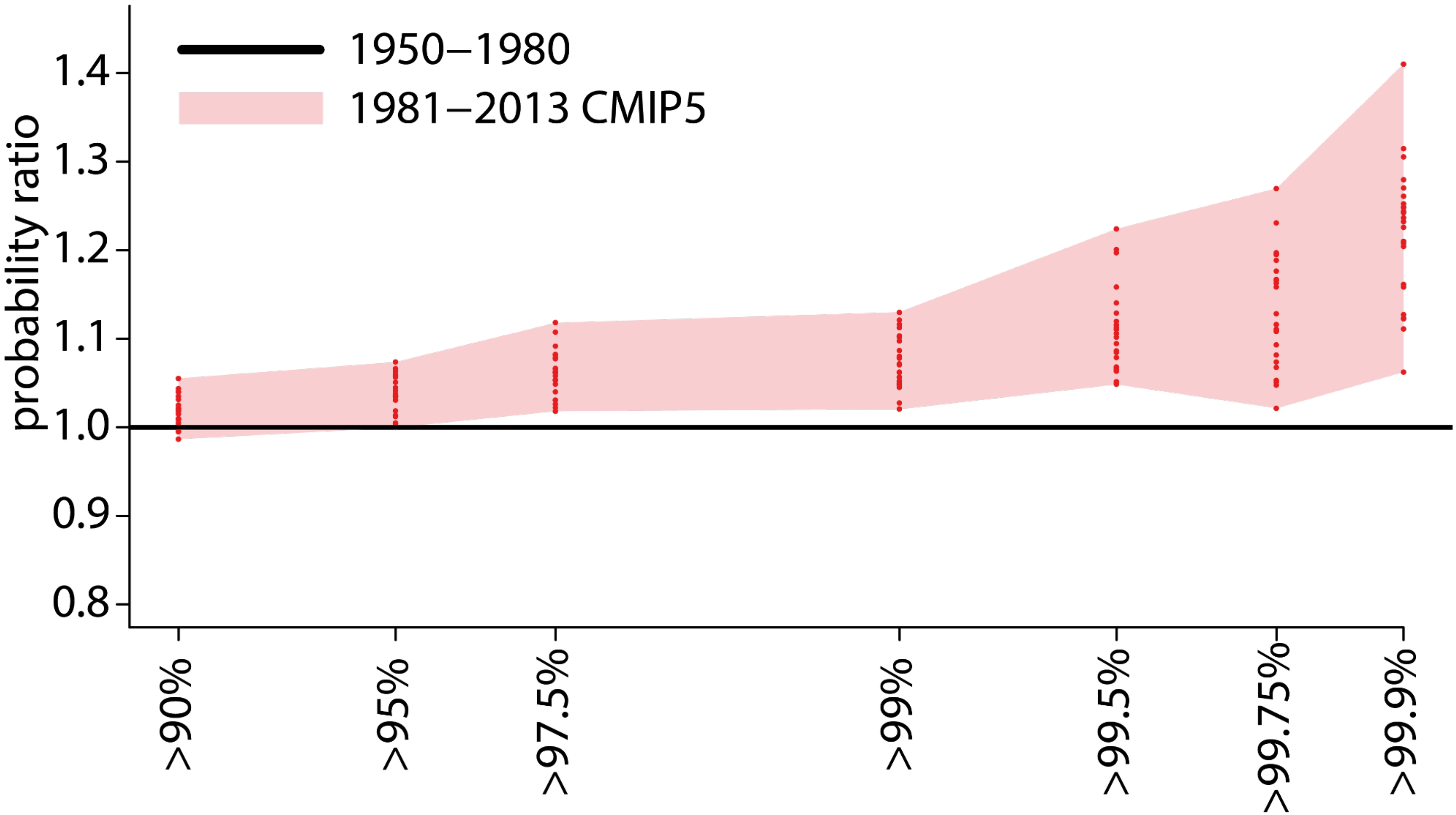

Based on Fischer and Knutti 2015, *Nature CC*

# More heavy precipitation over N Europe



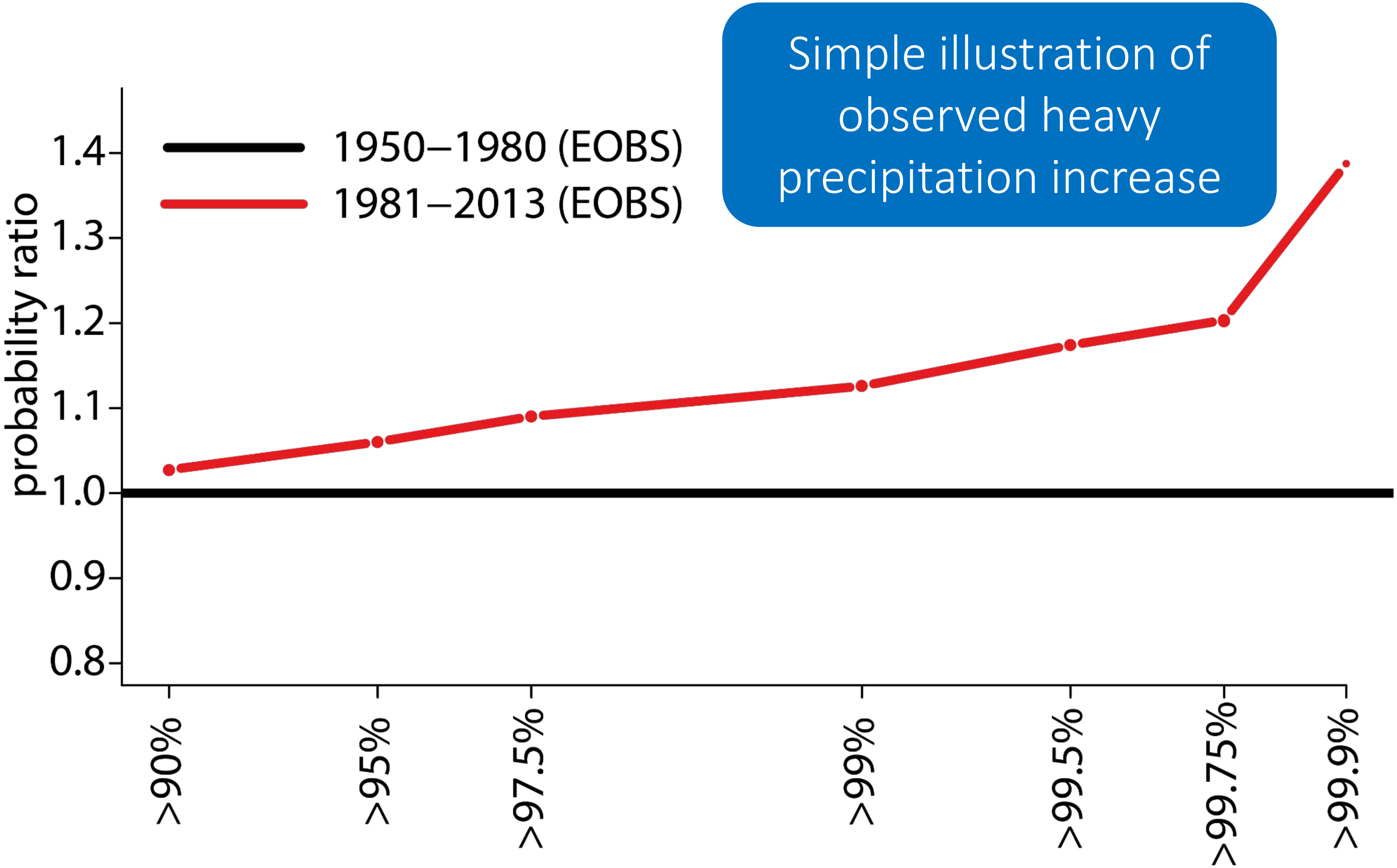

Based on Fischer and Knutti 2015, *Nature CC*

# Probability ratio for heavy rainfall (GCMs)



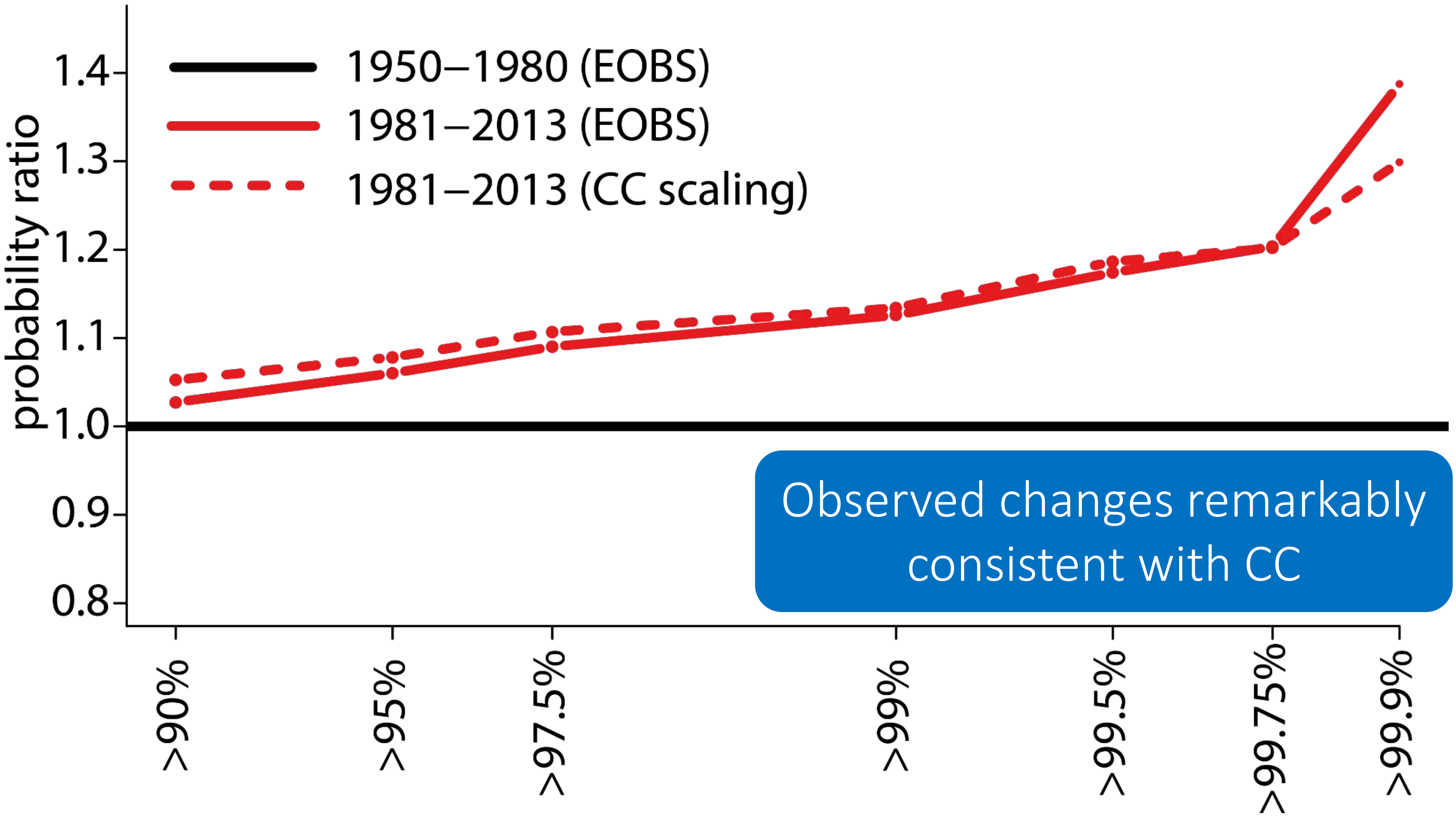

Based on Fischer and Knutti 2015, *Nature CC*

# Observed rainfall intensification (EOBS)




Based on Fischer and Knutti 2015, *Nature CC*

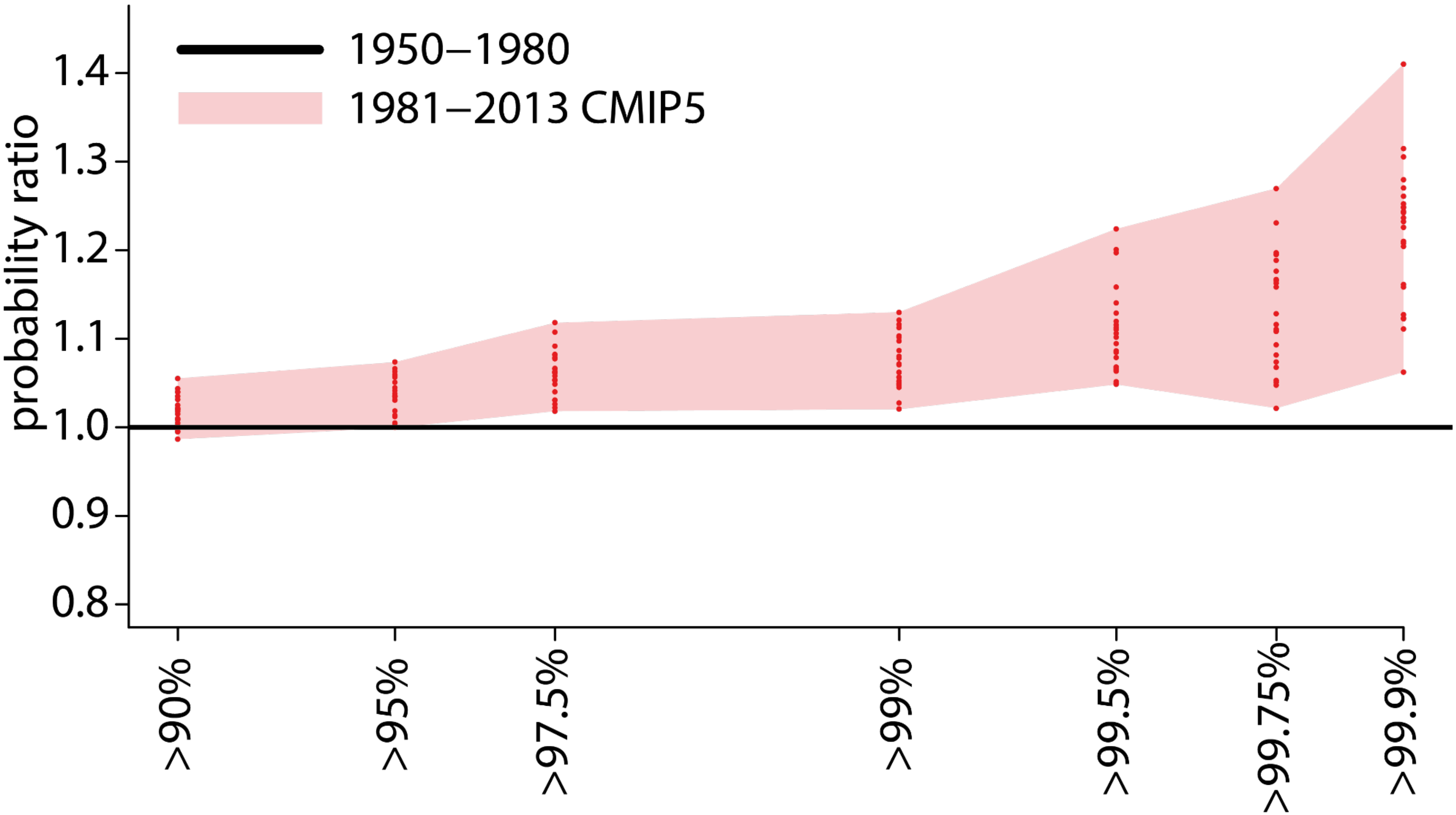
# EOBS scaled by Clausius-Clapeyron




Observed changes remarkably consistent with CC

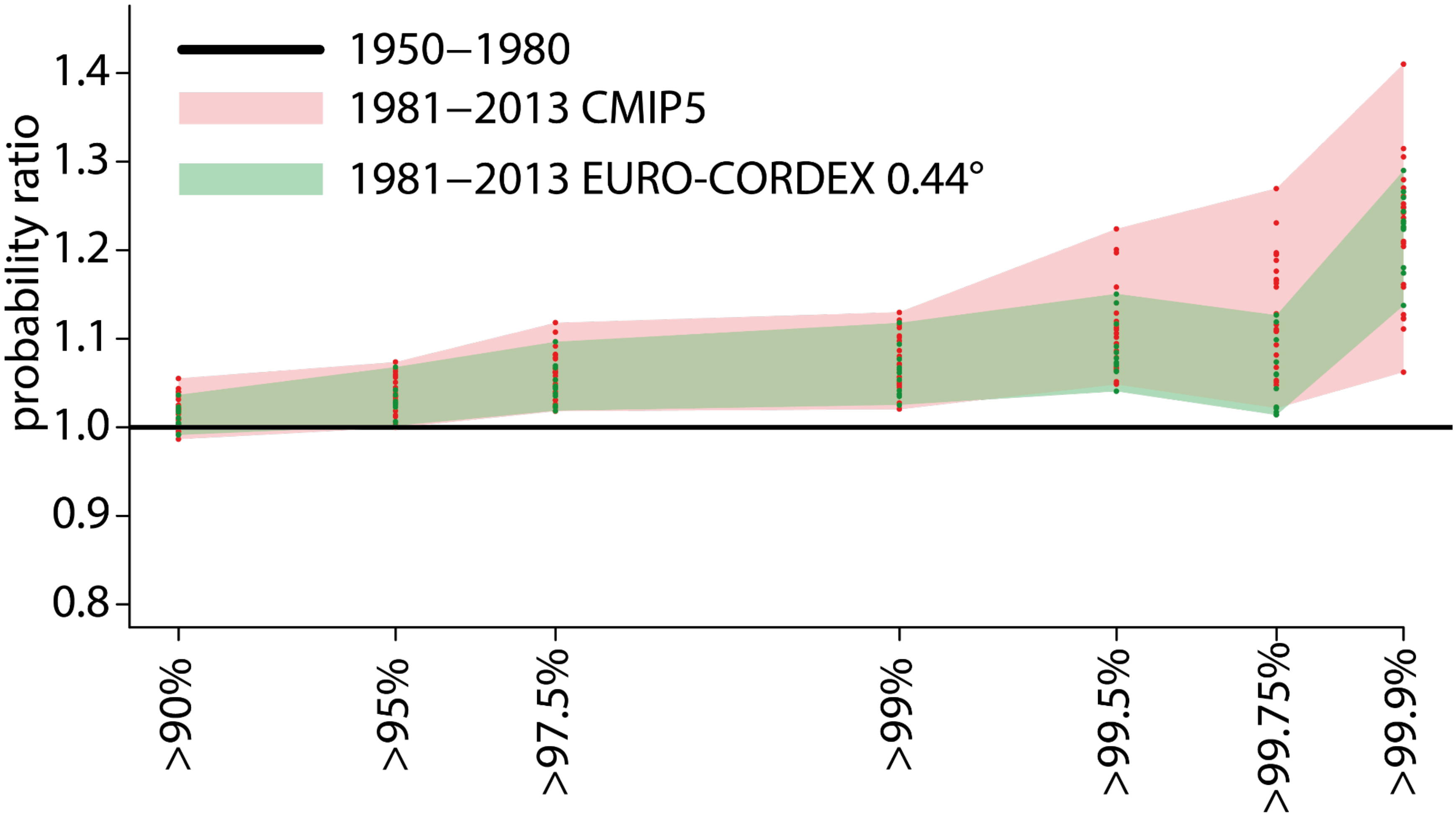
Based on Fischer and Knutti 2015, *Nature CC*

# Intensification over Europe (GCM)



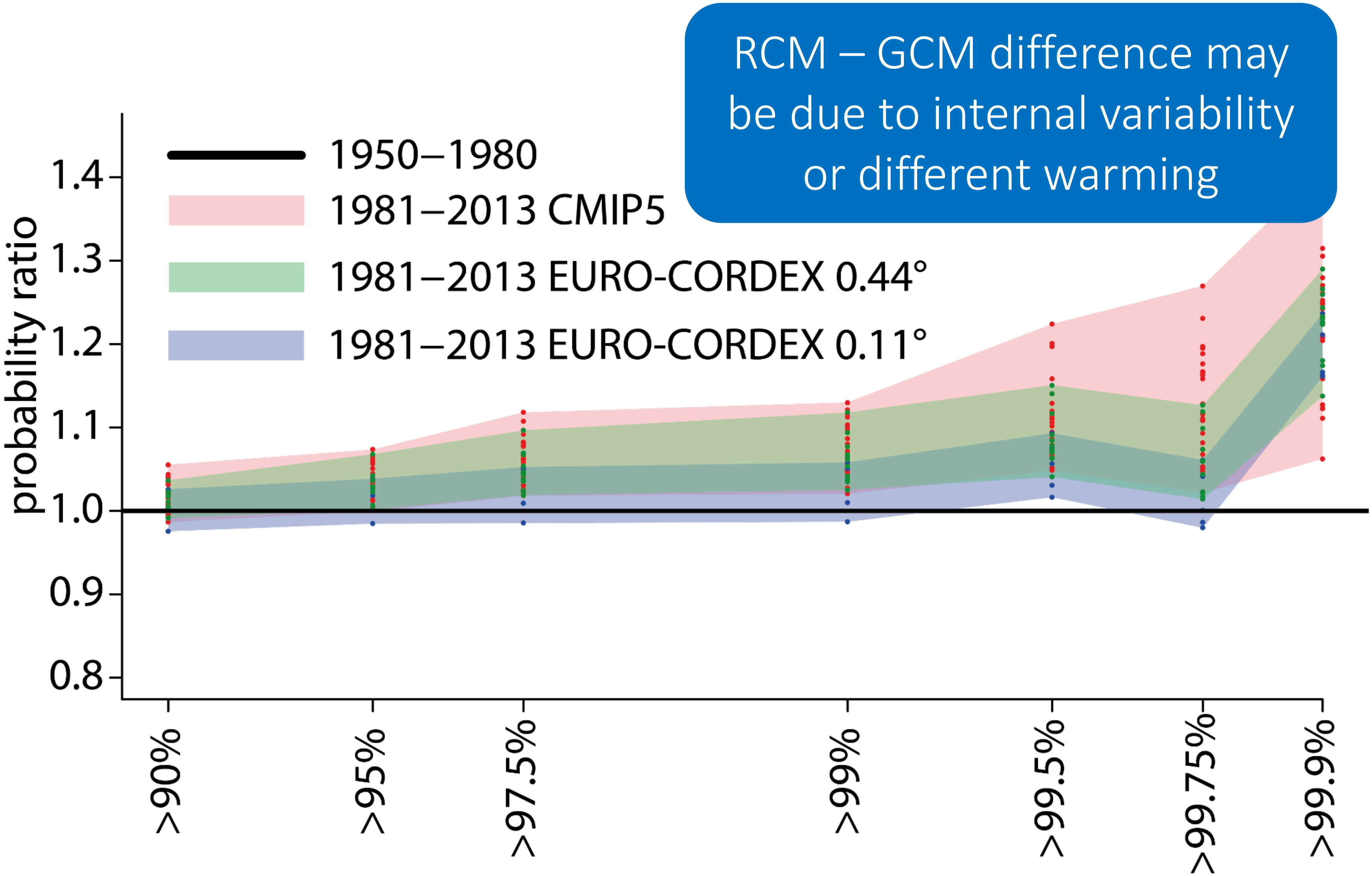

Based on Fischer and Knutti 2015, *Nature CC*

# Intensification over Europe (EURO-CORDEX)




Based on Fischer and Knutti 2015, *Nature CC*

# High-resolution EURO-CORDEX runs




Based on Fischer and Knutti 2015, *Nature CC*

# Caveats and open questions

Deep and shallow convection is parameterized in all models shown!

Changes consistent for the right reasons?
Underestimation due to parameterized convection?

How reliable are the trends in observations?
Inhomogeneities, undercatch and gridding issues?

Model deficiencies in representation of driving processes e.g. representation of blockings, boundary layer dynamics and land-atmosphere interactions.

# Conclusions

Internal variability represents a major challenge to evaluation of trends

Spatial aggregation is a promising approach in presence of variability

Model agreement on the forced response of precipitation and temperature extremes is higher than widely recognized

Daily precipitation intensification is consistent across the model hierarchy and with observations

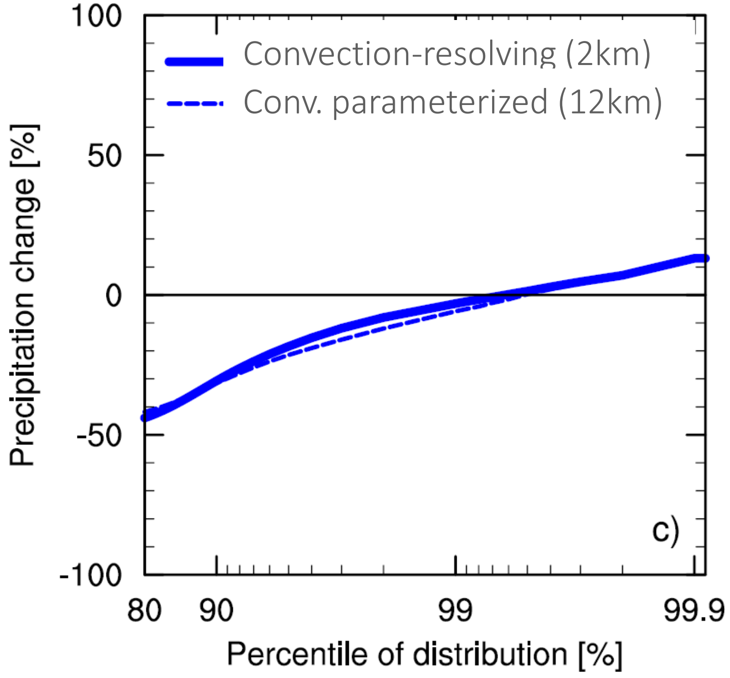
Fischer, E.M., U. Beyerle and R. Knutti, 2013: Robust spatially aggregated projections of climate extremes, *Nature Climate Change*, doi:10.1038/nclimate2051

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

Fischer, E.M., J. Sedláček, E. Hawkins and R. Knutti, 2014: Models agree on forced response pattern of precipitation and temperature extremes, Geophys. Res. Lett., 10.1002/2014GL062018.

Fischer, E.M., and R. Knutti, 2014: Detection of spatially aggregated changes in temperature and precipitation extremes, *Geophys. Res. Lett.,* 10.1002/2013GL058499

# Consistent at daily scale

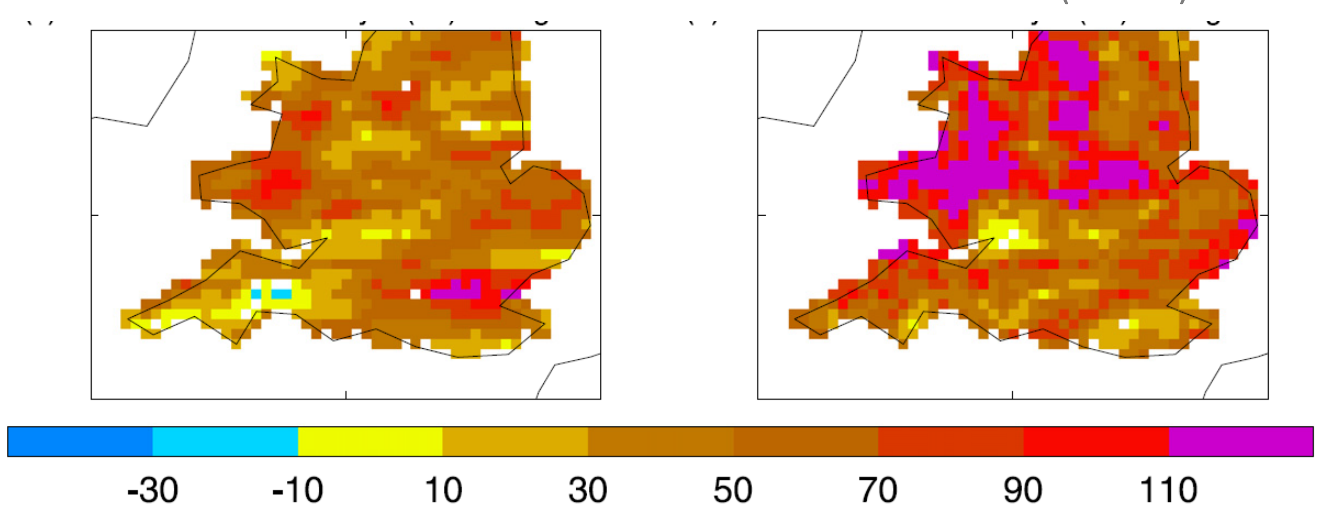



First results suggest that changes at daily scale are consistent

Ban et al., 2015, *GRL*

Parameterized (12km)

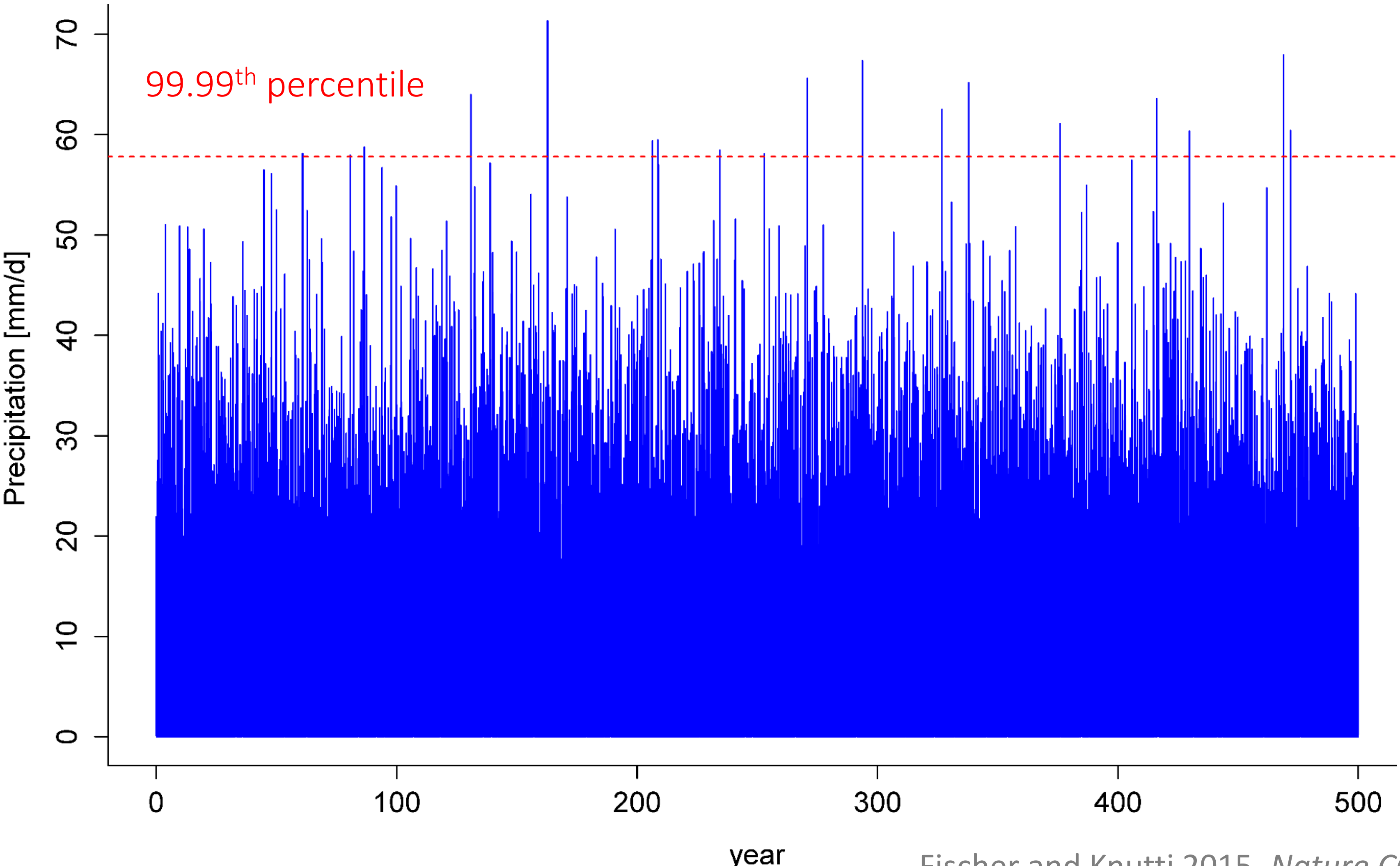
"Resolved" (1.5km)




Chen et al., 2014, *ERL*

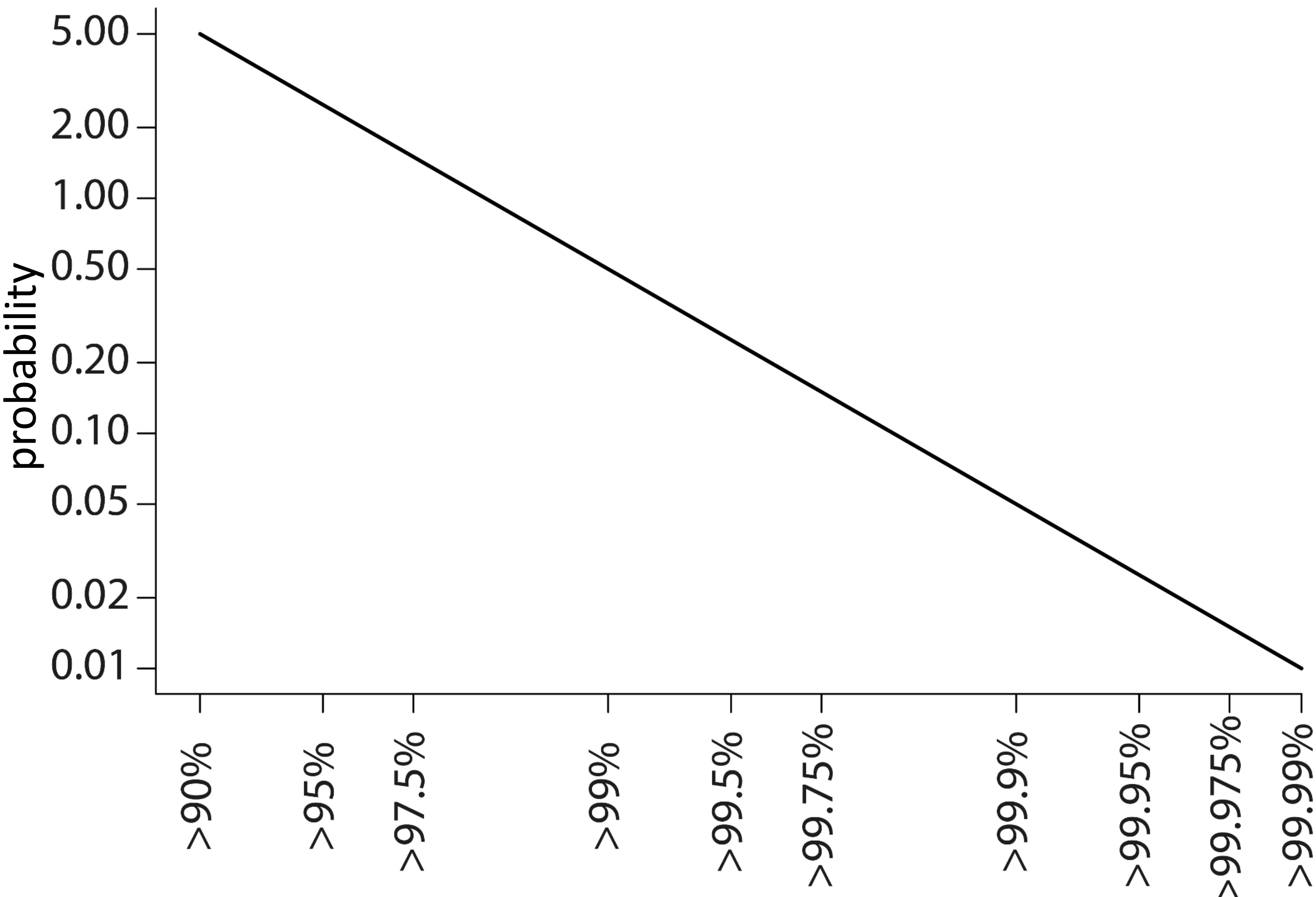
# Pre-industrial precipitation series

Percentiles defined on all days in pre-industrial control simulations



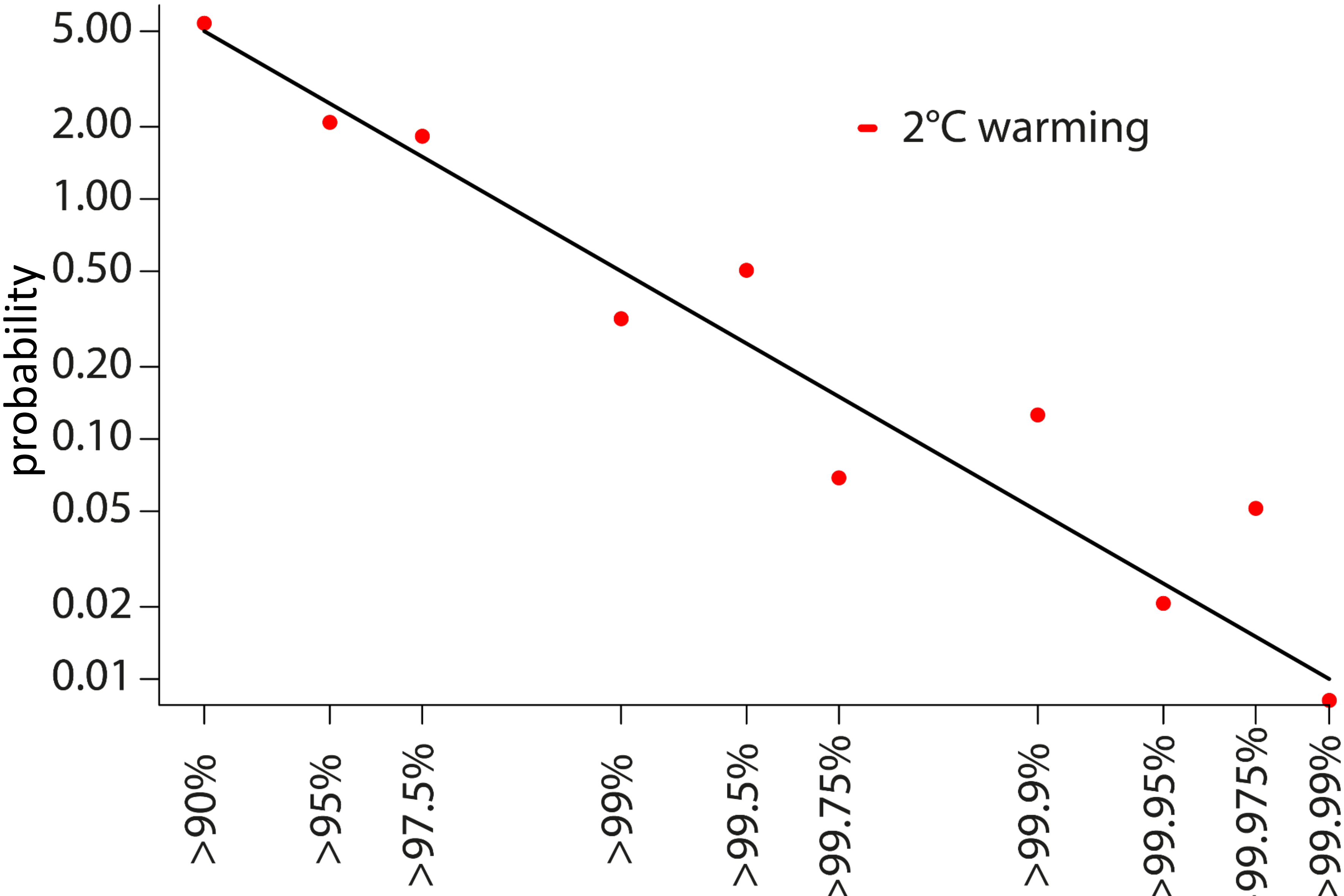

Fischer and Knutti 2015, *Nature CC*

# Pre-industrial precipitation distribution



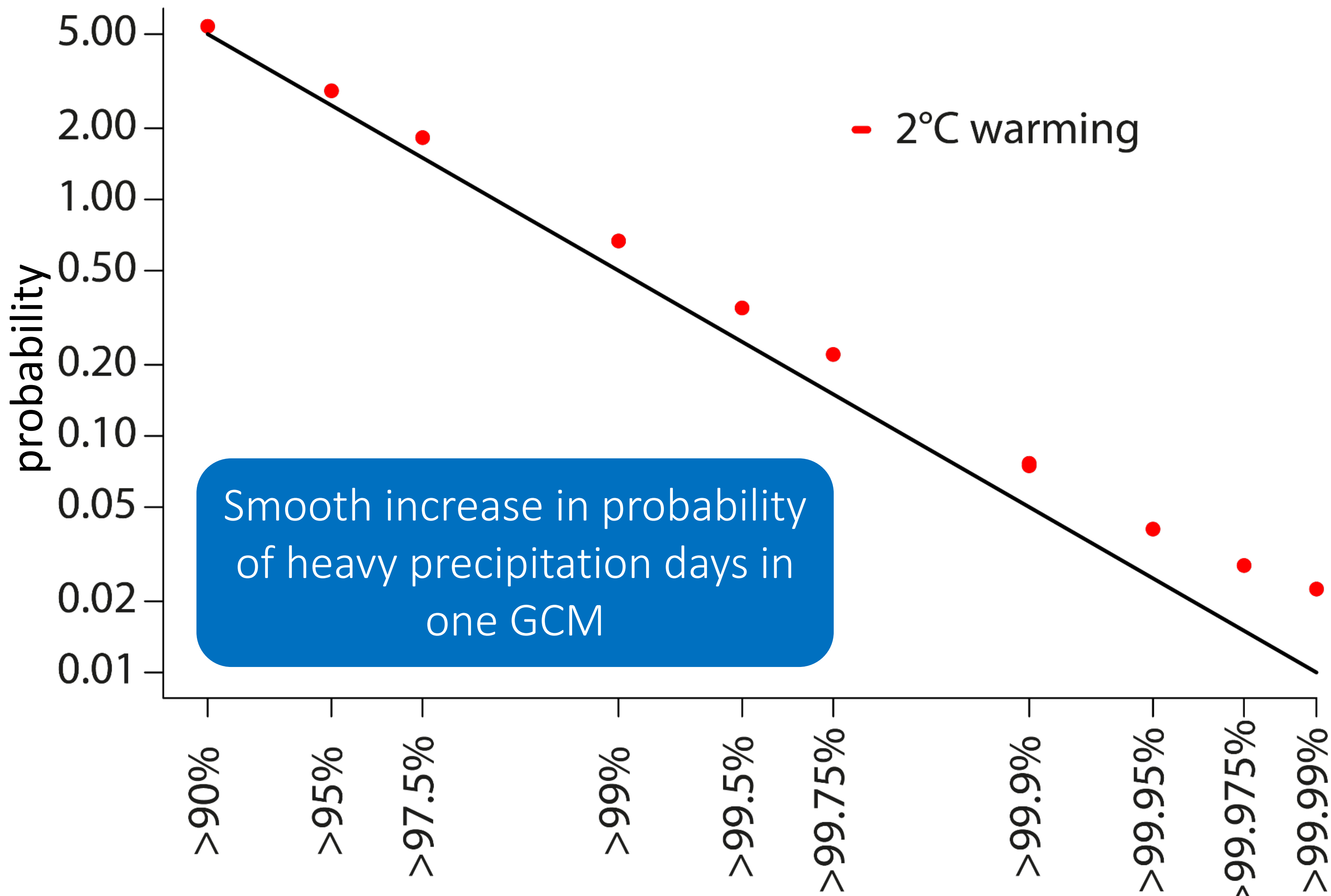

Fischer and Knutti 2015, *Nature CC*

# Noisy changes at one grid point



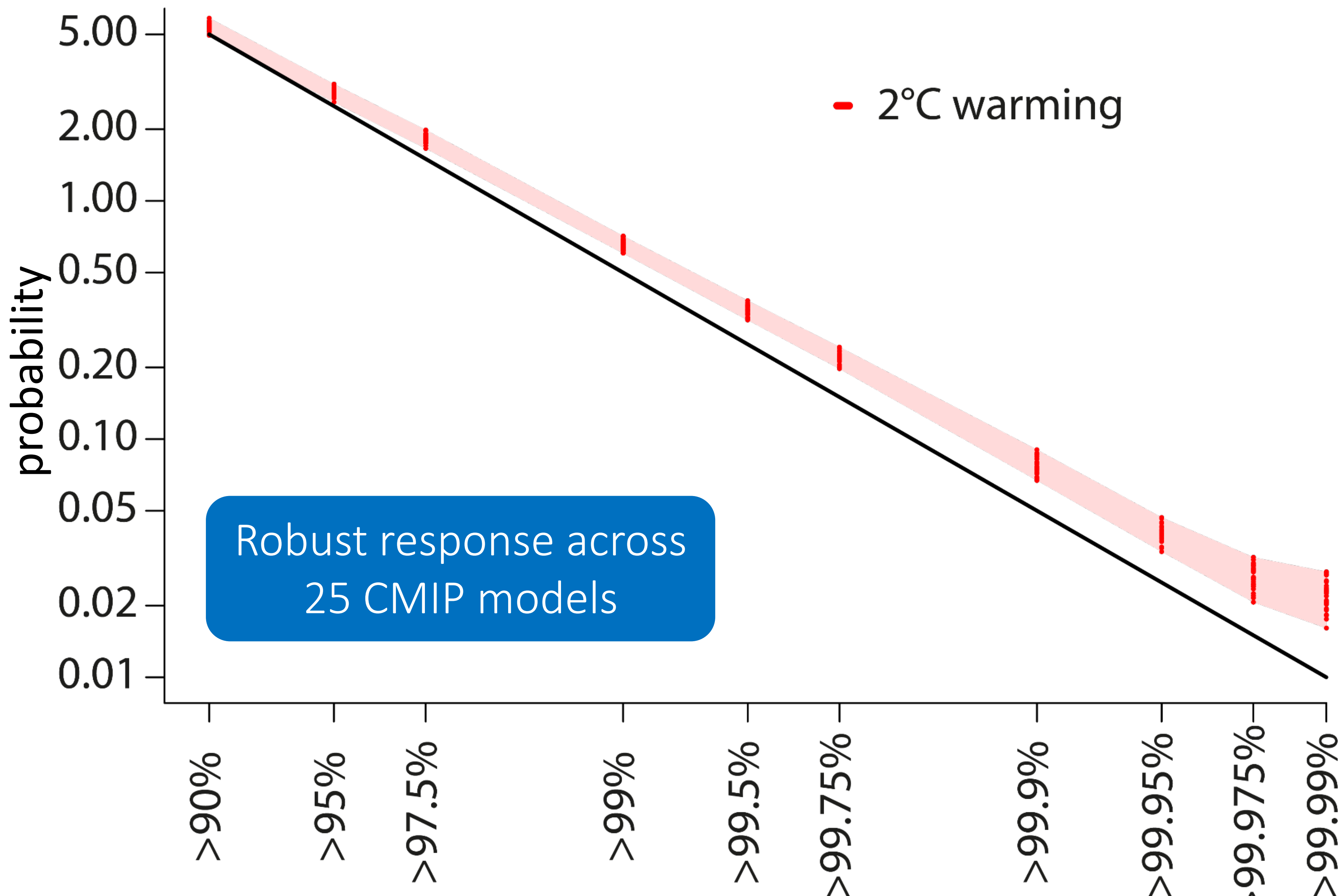

Fischer and Knutti 2015, *Nature CC*

# Heavy precipitation averaged over N Europe



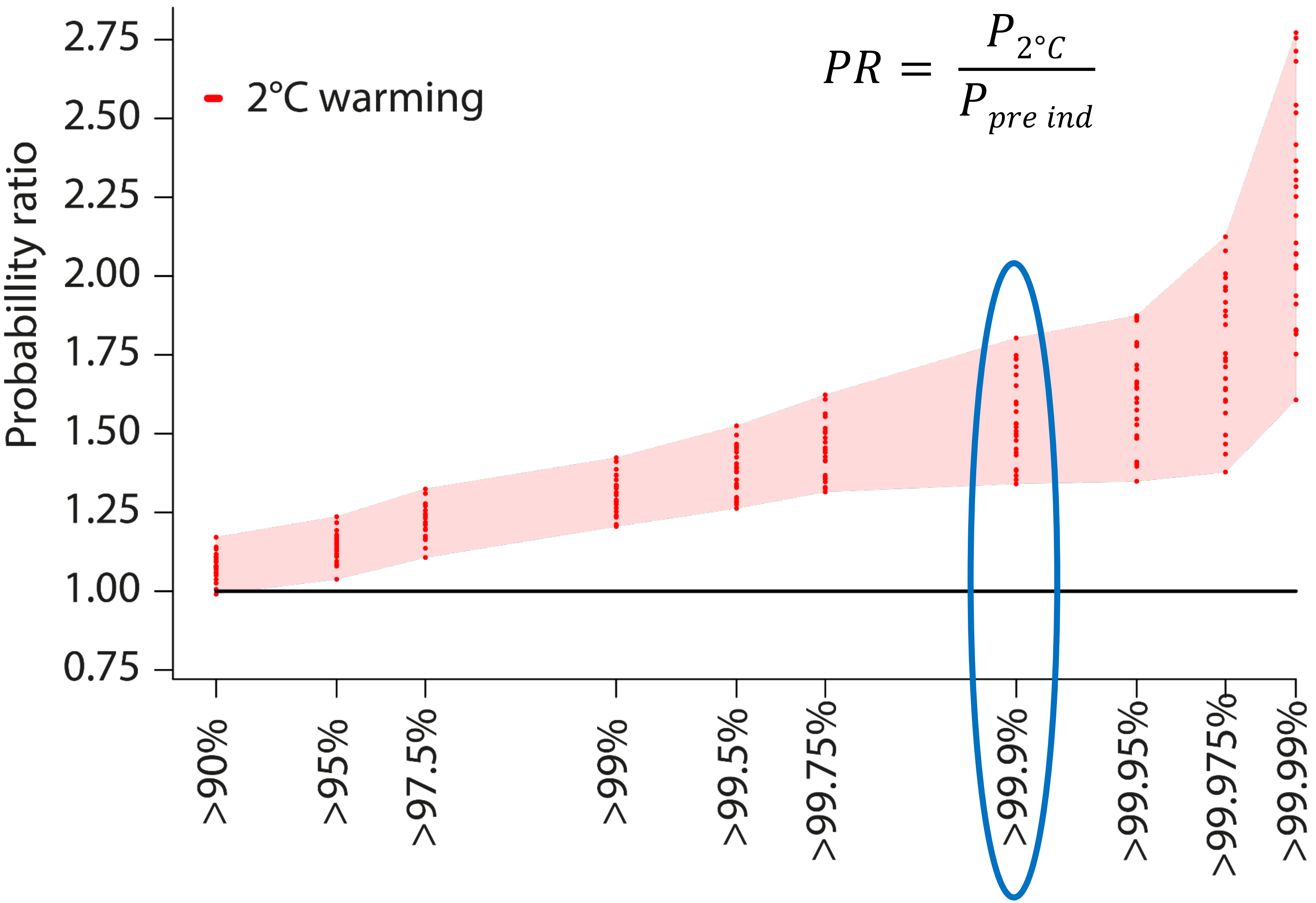

Fischer and Knutti 2015, *Nature CC*

# Heavy precipitation days over N Europe



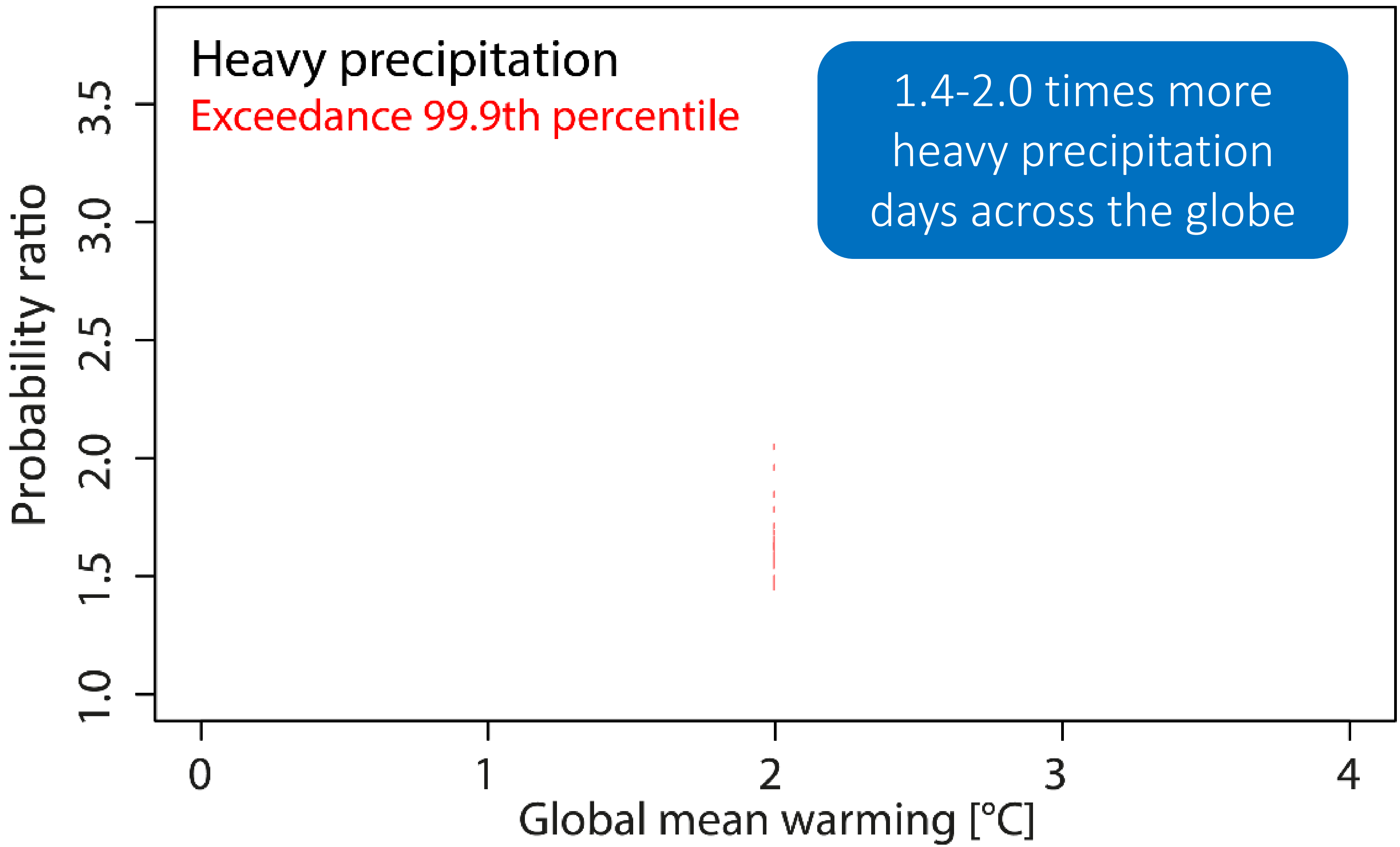

Fischer and Knutti 2015, *Nature CC*

# The more extreme – the greater the increase




Fischer and Knutti 2015, *Nature CC*

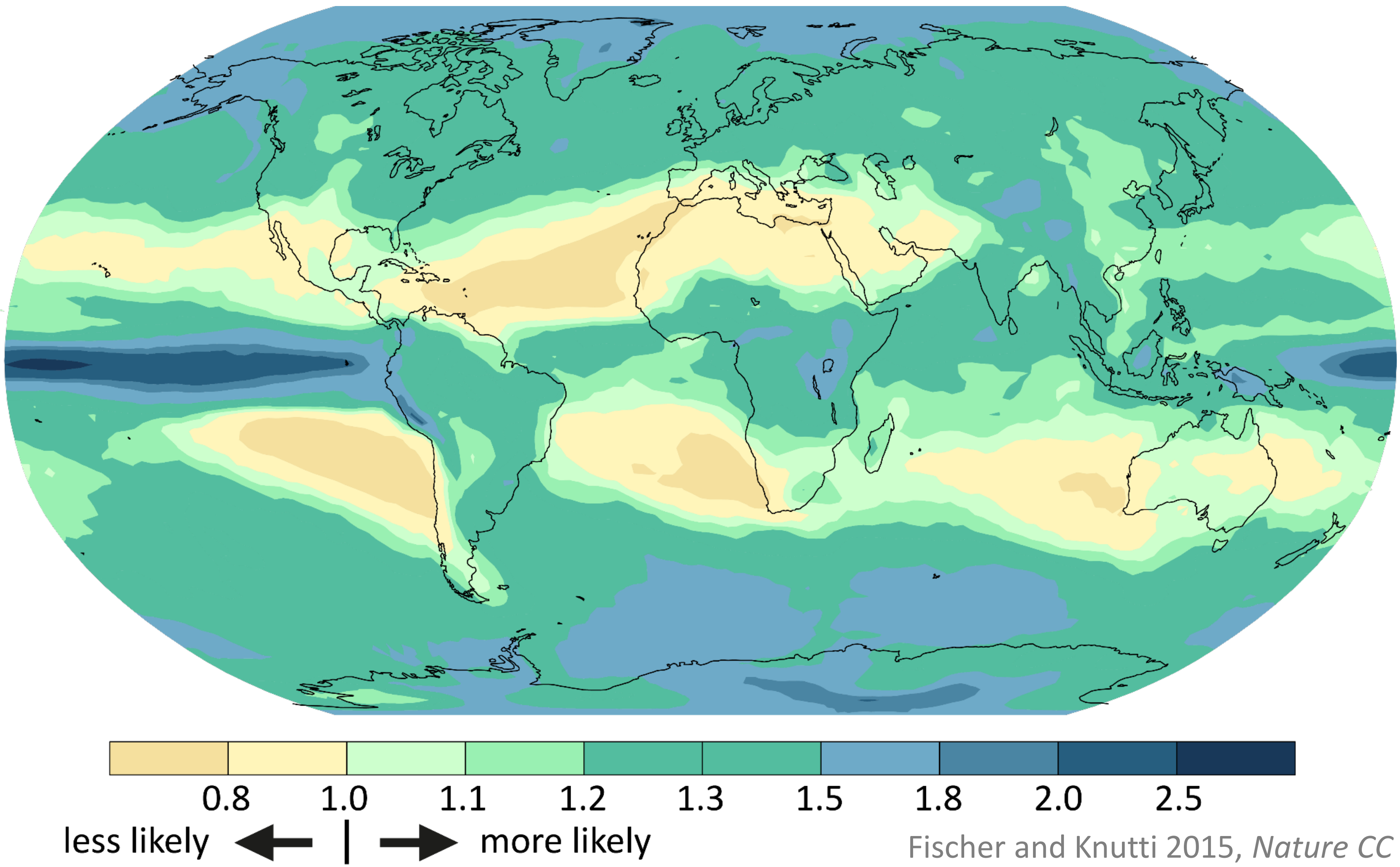
# Global land-only probability ratio




Fischer and Knutti 2015, *Nature CC*

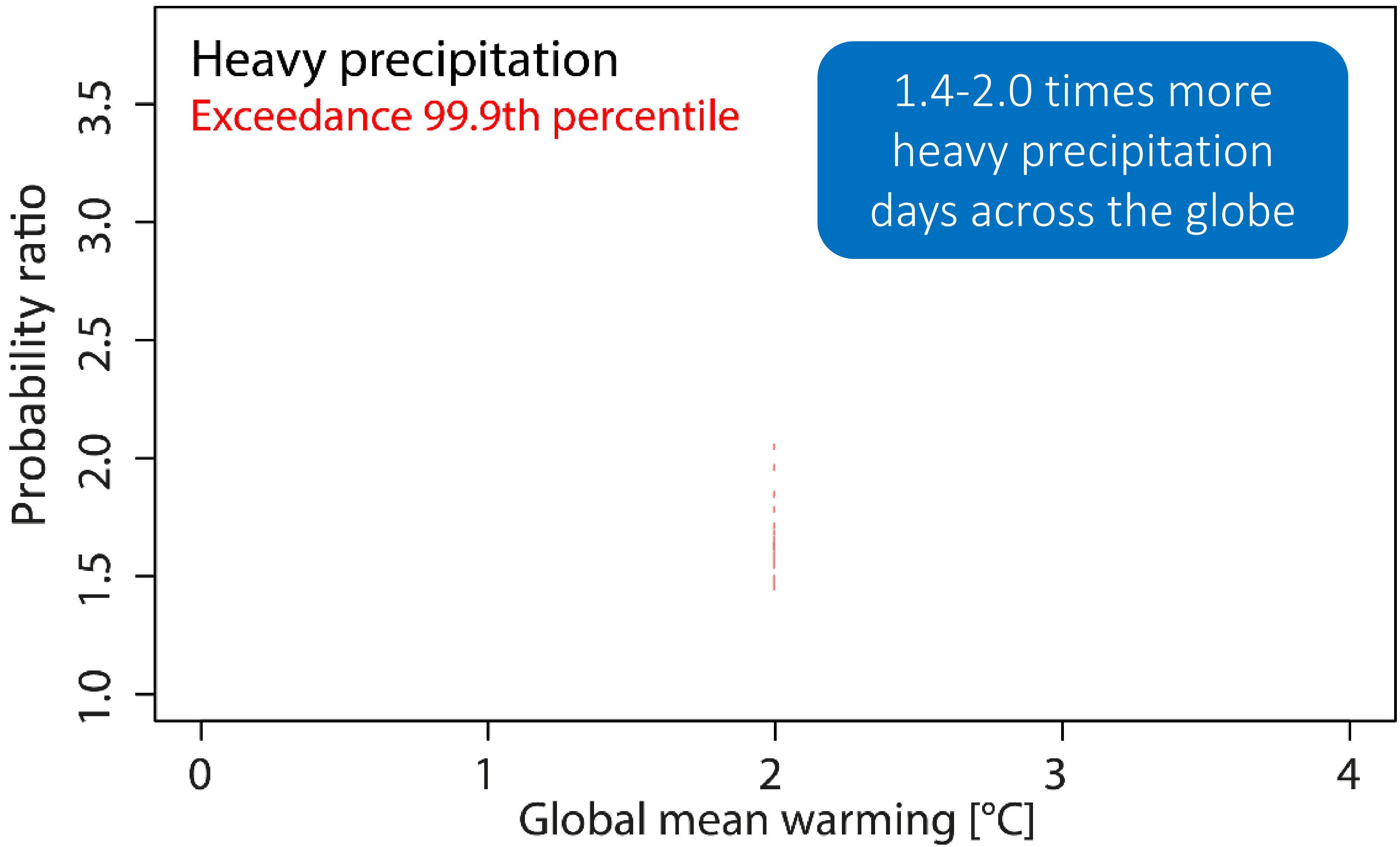
# Probability ratio at 2°C warming

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



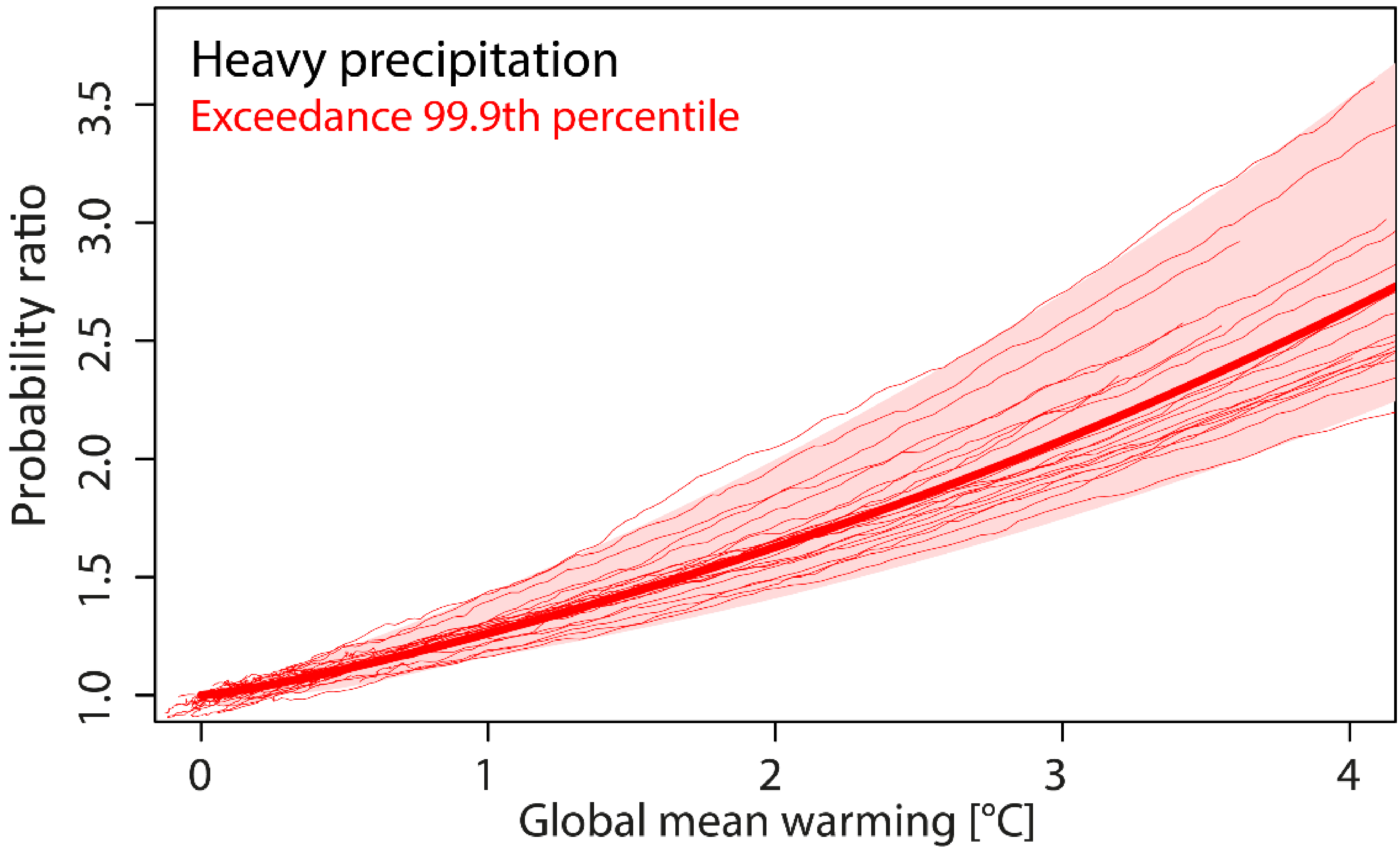

Fischer and Knutti 2015, *Nature CC*

# Global land-only probability ratio



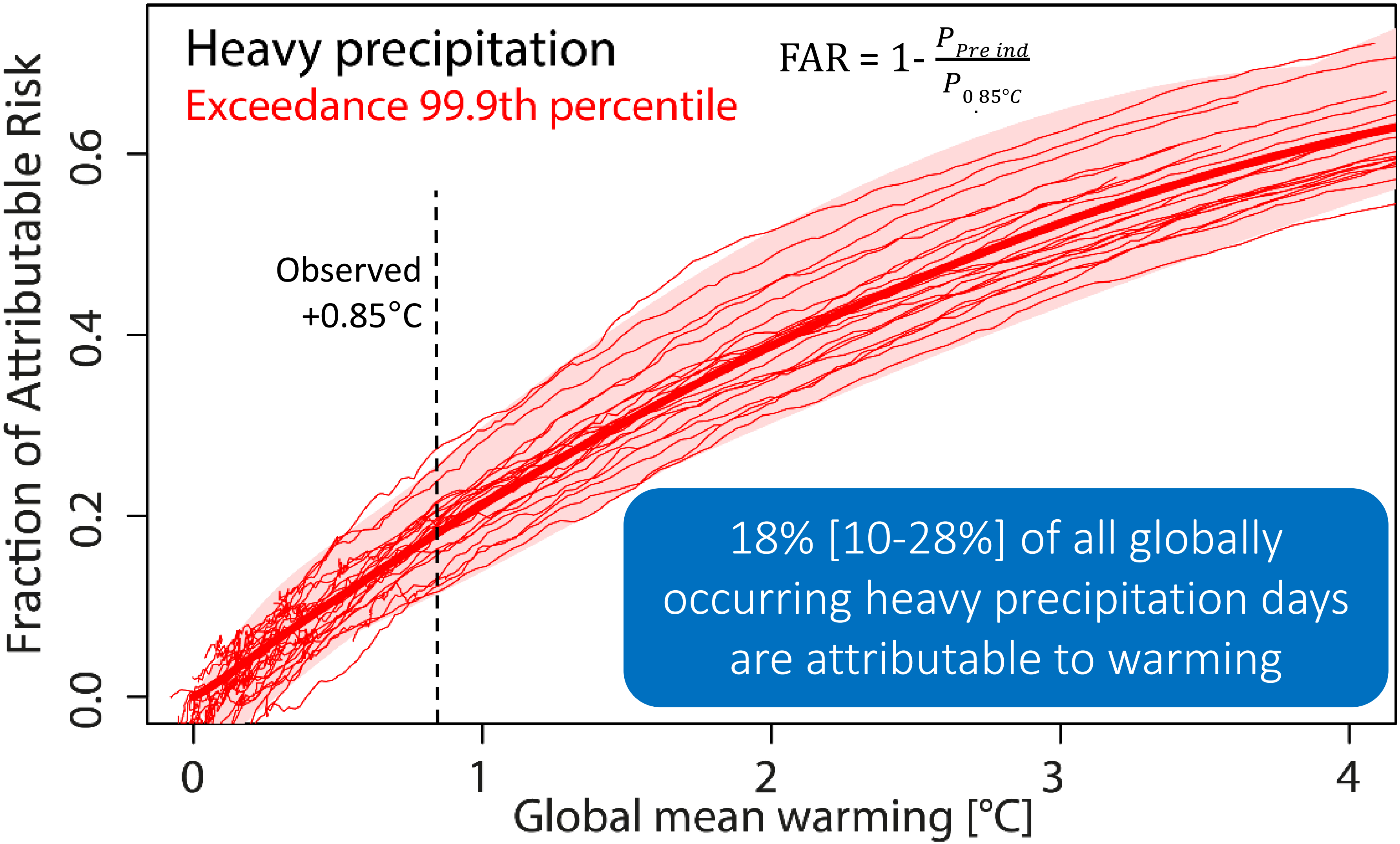

Fischer and Knutti 2015, *Nature CC*

# Non-linear increase with warming




Fischer and Knutti 2015, *Nature CC*

# The attributable fraction of occurrence



# Caveats and open questions

Model deficiencies in representation of driving processes e.g. representation of blockings, boundary layer dynamics and land surface feedbacks

Same weather in warmer and moister climate? – Or substantial dynamical changes?

Deep and shallow convection is parameterized in all models shown

.

## References

Fischer, E.M., U. Beyerle and R. Knutti, 2013: Robust spatially aggregated projections of climate extremes, *Nature Climate Change*, doi:10.1038/nclimate2051

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

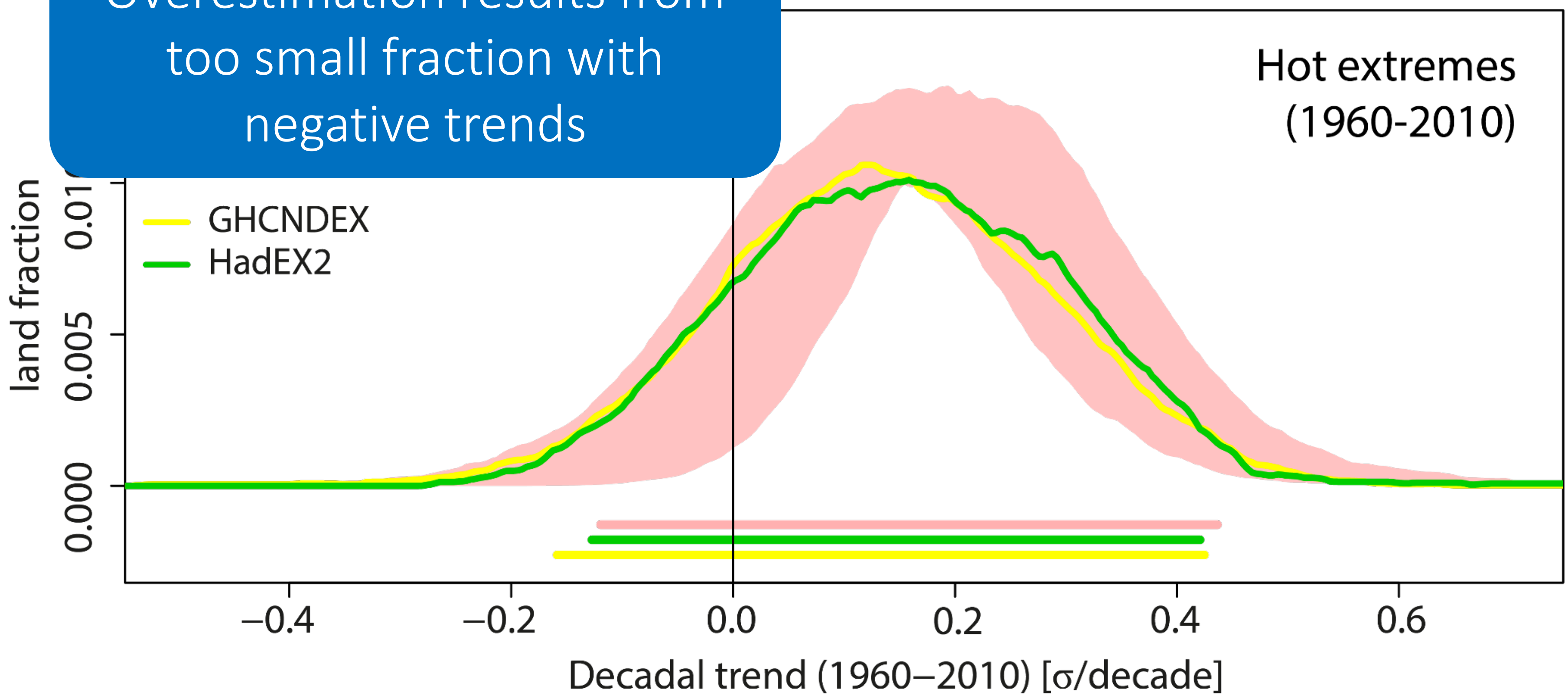
Fischer, E.M., 2014: Autopsy of two mega-heatwaves, *Nature Geoscience*, doi:10.1038/ngeo2148

Fischer, E.M., J. Sedláček, E. Hawkins and R. Knutti, 2014: Models agree on forced response pattern of precipitation and temperature extremes, Geophys. Res. Lett., 10.1002/2014GL062018.

Fischer, E.M., and R. Knutti, 2014: Detection of spatially aggregated changes in temperature and precipitation extremes, *Geophys. Res. Lett.,* 10.1002/2013GL058499.

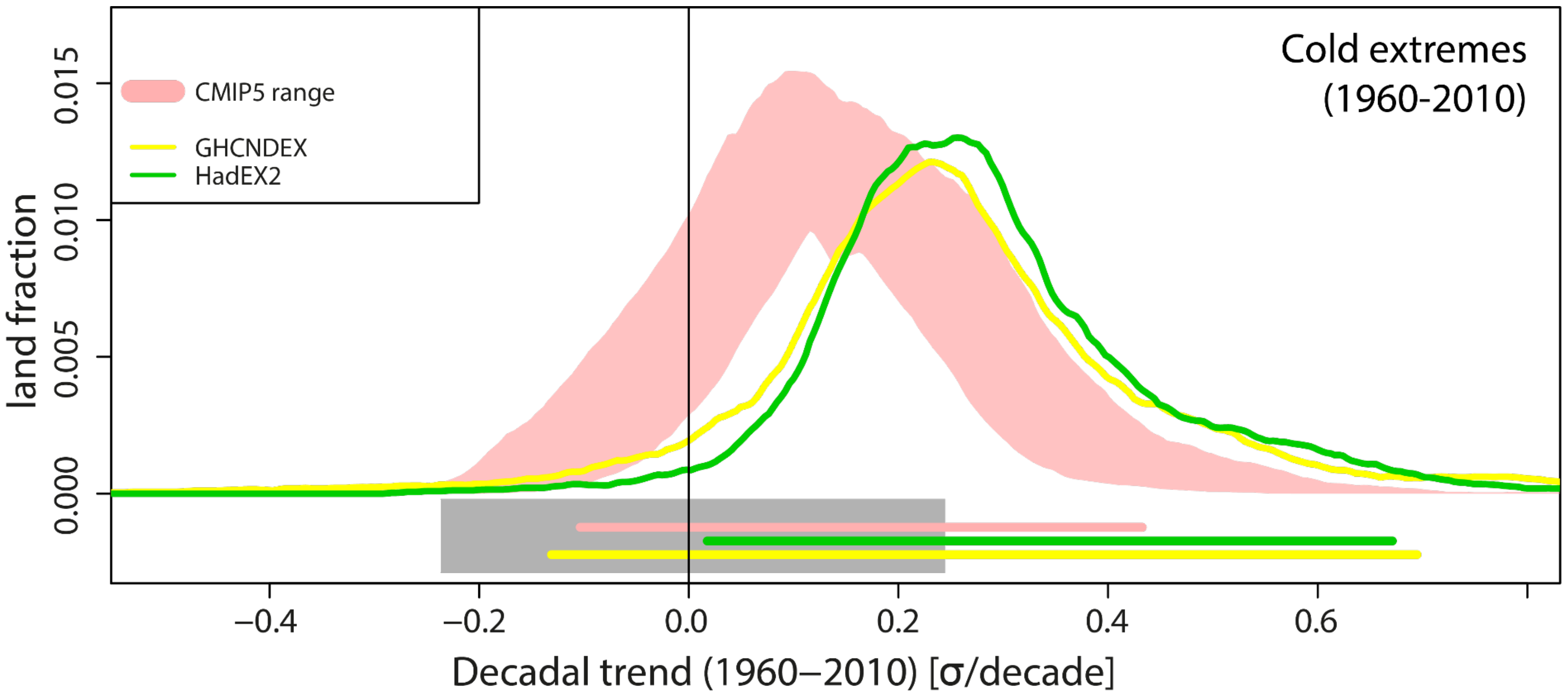
# Model overestimate trends in hot extremes

Overestimation results from too small fraction with negative trends



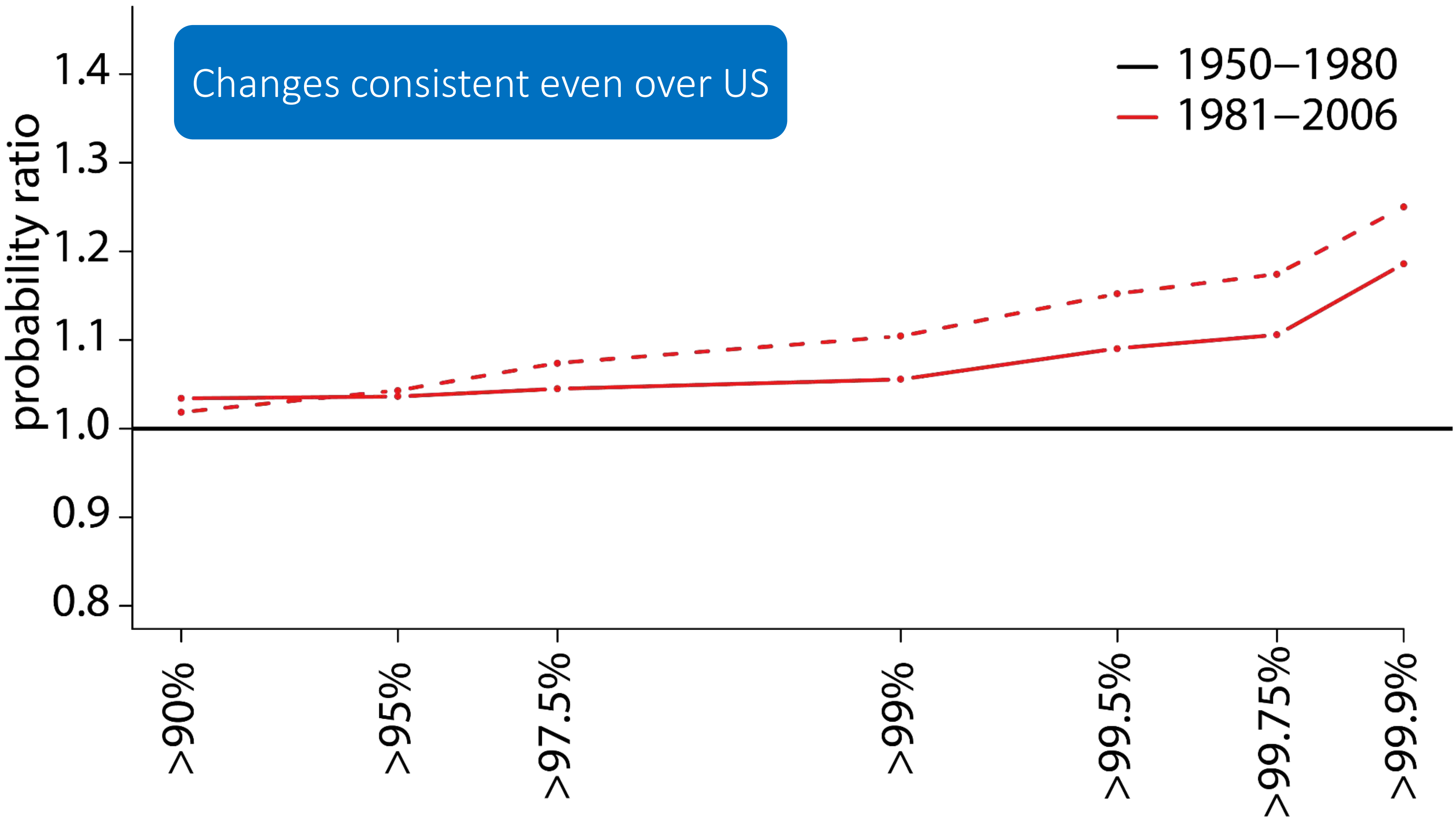

Fischer and Knutti (2014), *Geophys. Res. Letters*

# Underestimated trends in cold extremes




Fischer and Knutti (2014), *Geophys. Res. Letters*

# Observations for Northeastern US



# CMIP5 simulations for Northeastern US