Extreme events

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(with some slides from Jana Sillmann
and some thoughts from Claudia Tebaldi)

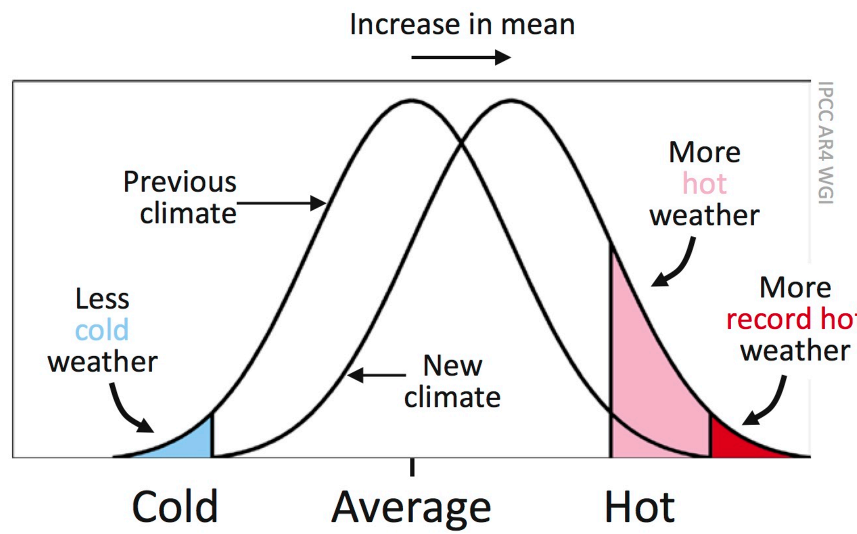
Extreme events

Through a precipitation lens

1. **Defining** extreme events
2. **Observing** extreme events
3. **Absolute** questions, **relative** answers
4. **Scales** of relevance: Going from **global** projections to **local impacts**

Challenges

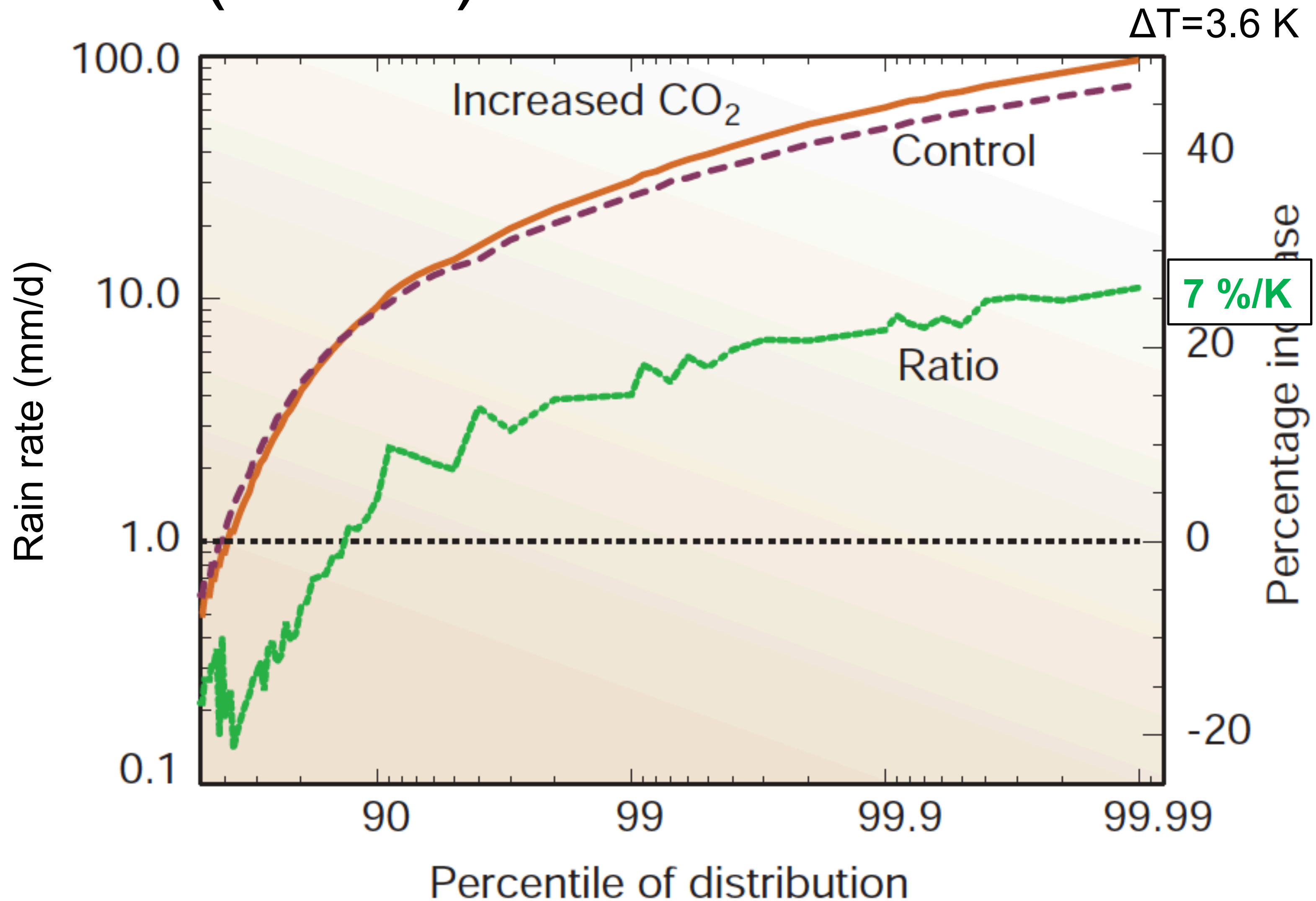
- Extreme events are **rare** in space and time
- Universally valid **definitions**
- Lack of observational **data**
- **Scale** mismatch between observation and model output



Approaches in IPCC AR5

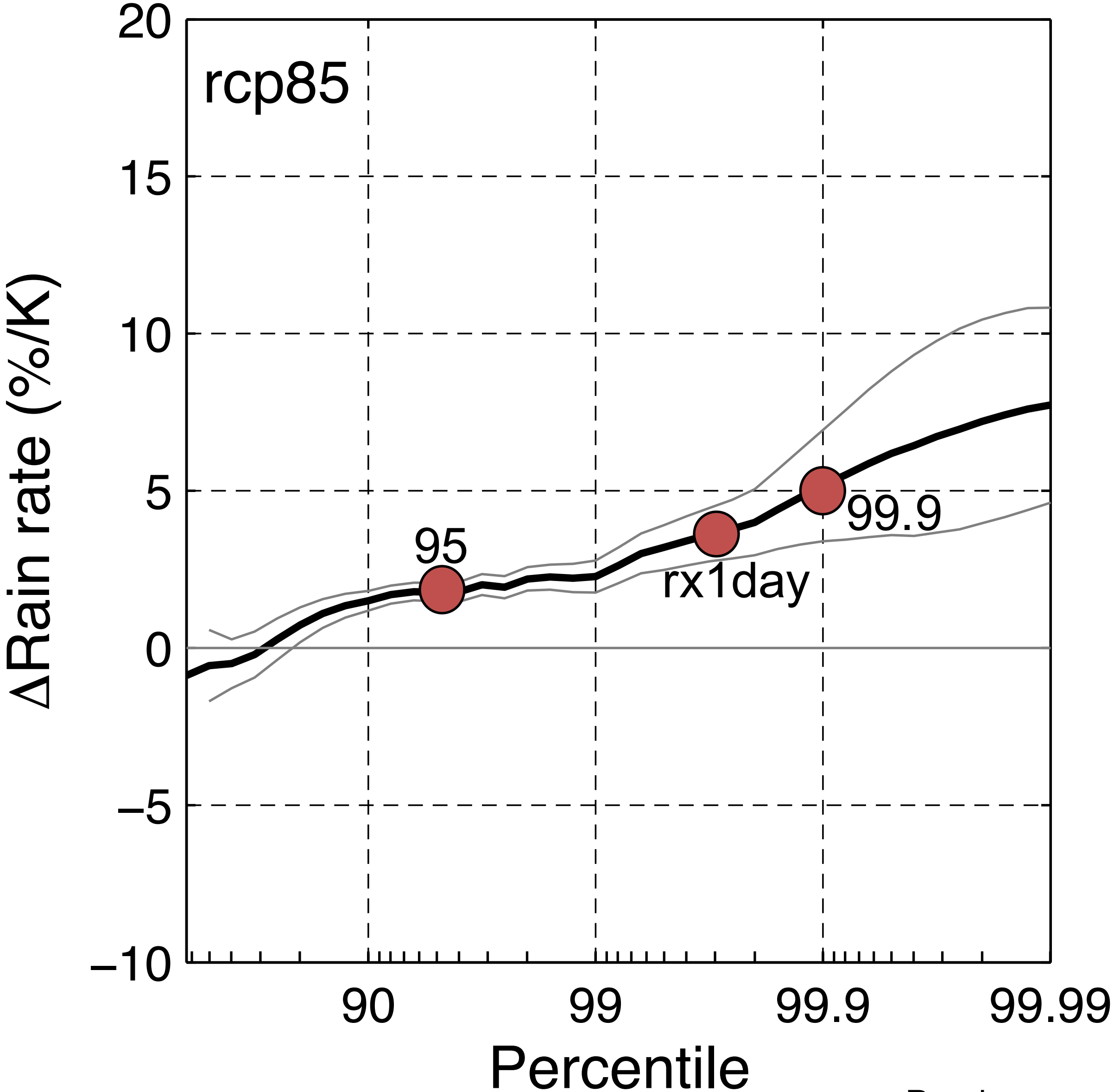
- **Indices** for climate extremes, such as defined by the Expert Team on Climate Change Detection and Indices (ETCCDI)
- Extreme value analysis → **Return values/periods**

Extreme precipitation projection from HadCM (~1998)



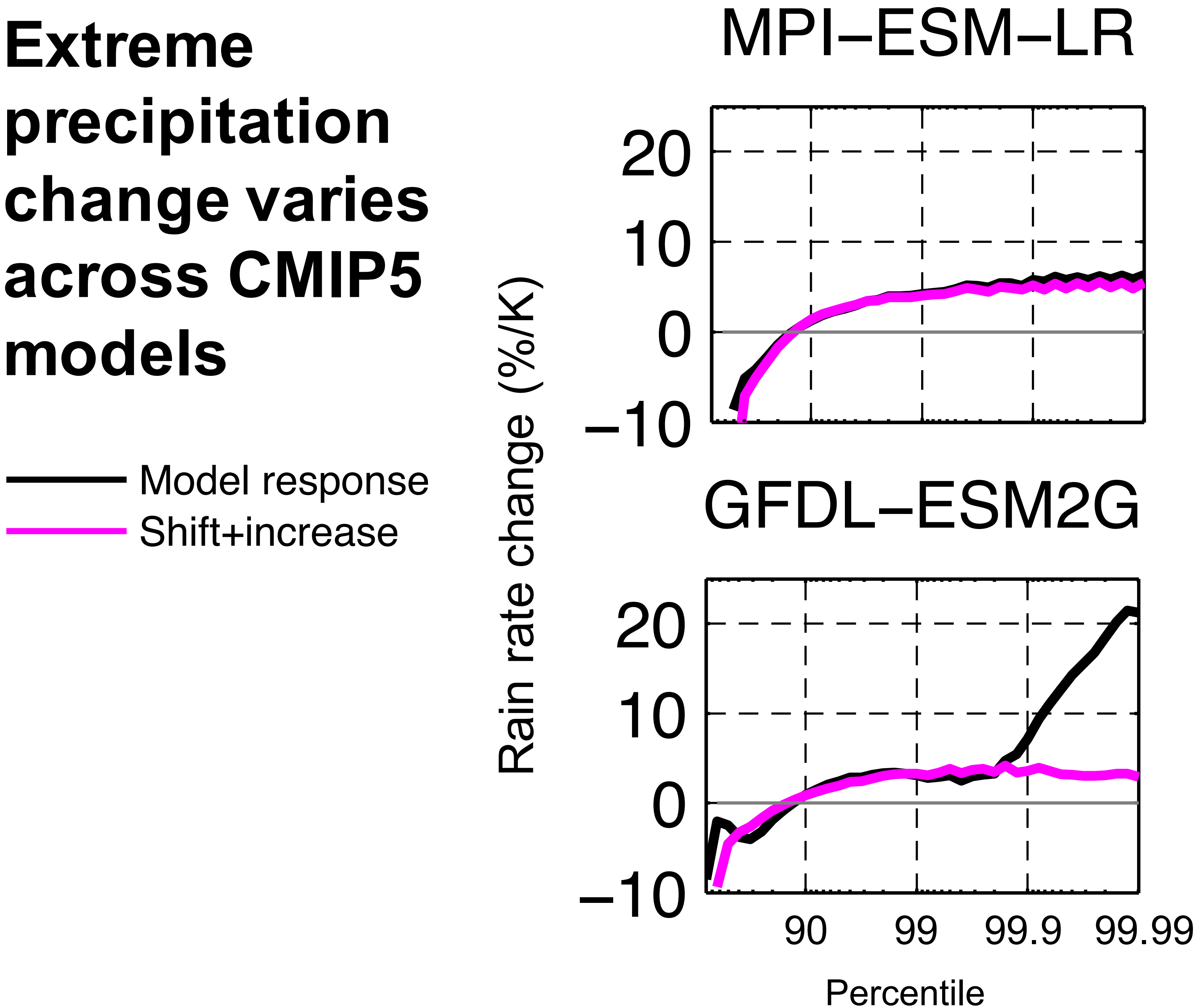
Allen and Ingram (2002)

CMIP5 Multi-model mean extreme precip change



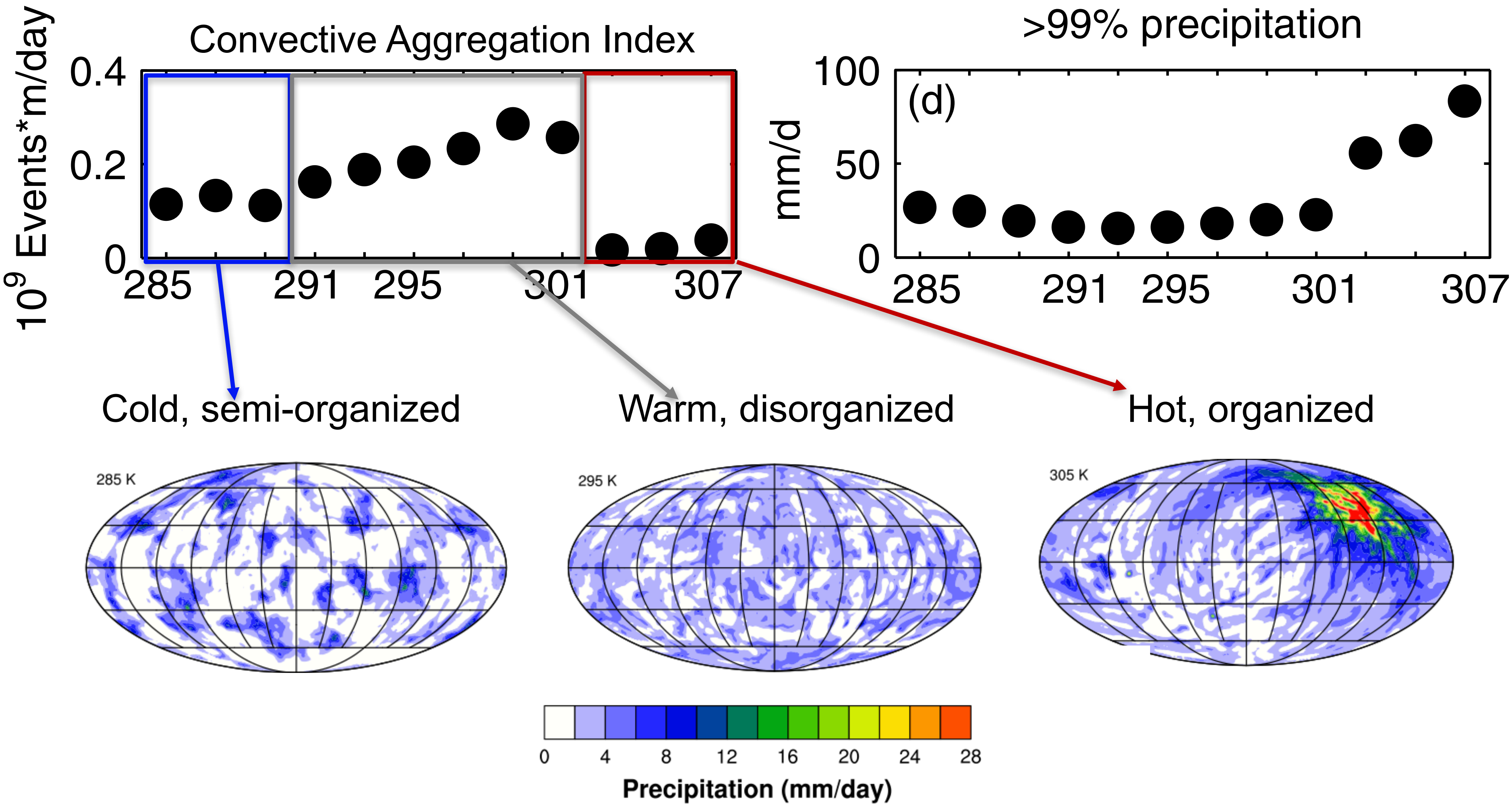
Pendergrass and Hartmann (2014)

Extreme precipitation change varies across CMIP5 models



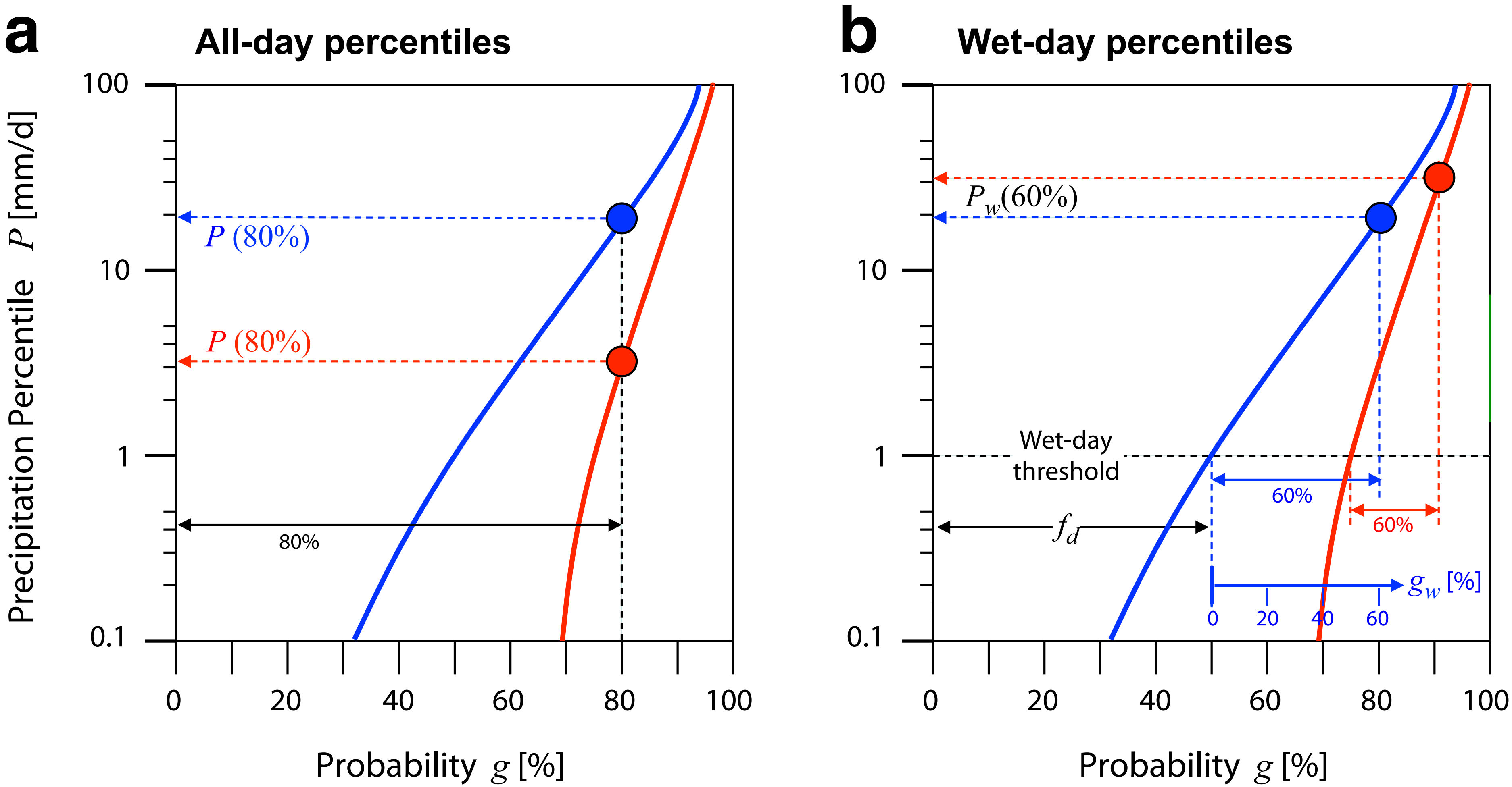
Pendergrass and Hartmann (2014)

Possible role for convective organization



Pendergrass, Reed, and Medeiros (2016)

Definition of extremes matters…

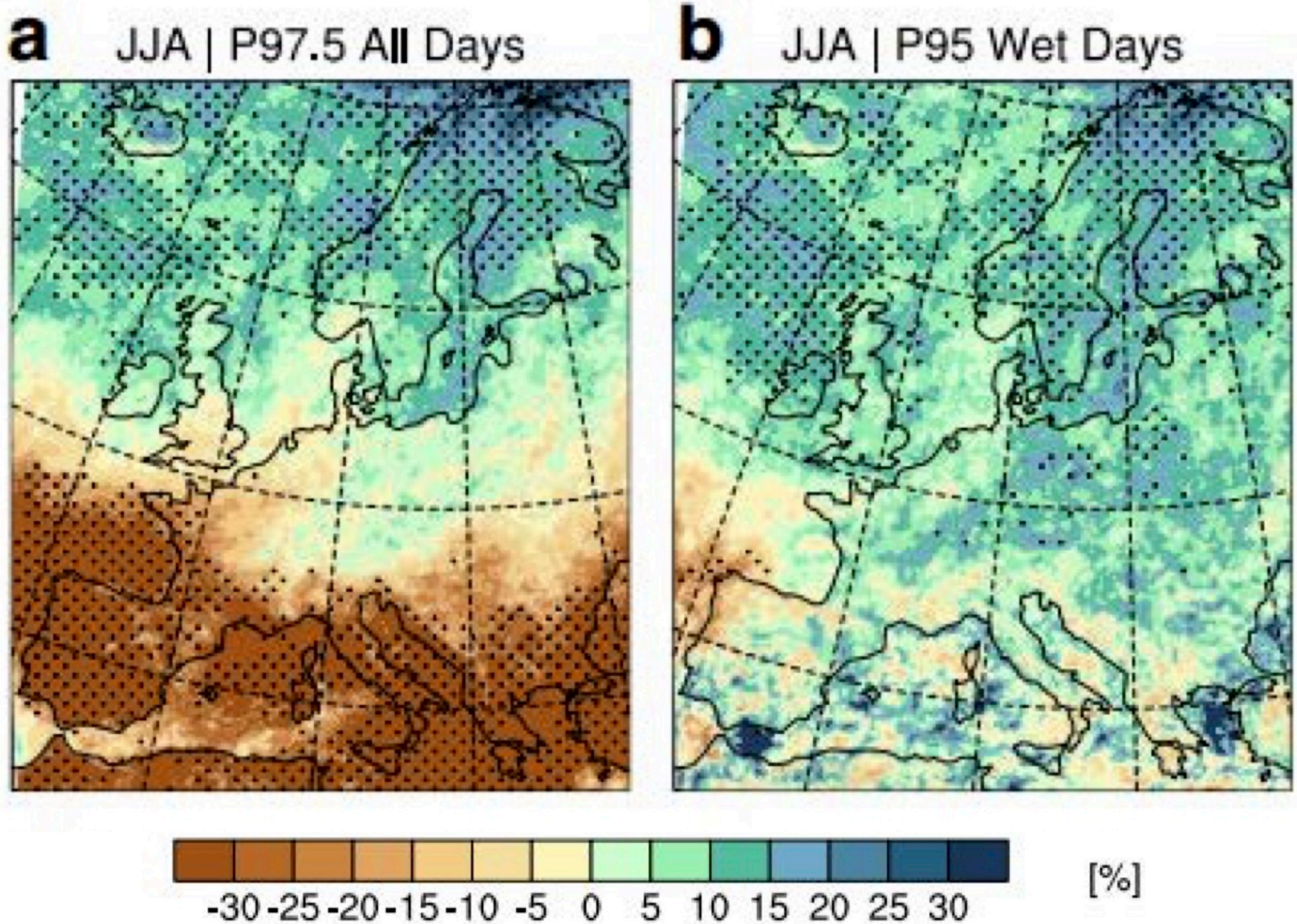


Wet-day percentiles are sensitive to the fraction of wet days and **can produce misleading results** when applied to climate change

Schär et al (2016) *Climatic Change*

Definition of extremes matters ...

Heavy summer precipitation changes from ENSEMBLE RCM simulations (SRES A1B)



Schär et al (2016) *Climatic Change*

Definition of extremes matters …

- **Climate Extremes Indices** as defined by the Expert Team on Climate Change Detection and Indices (ETCCDI) or Sector-Specific Climate Indices (ET-SCI)

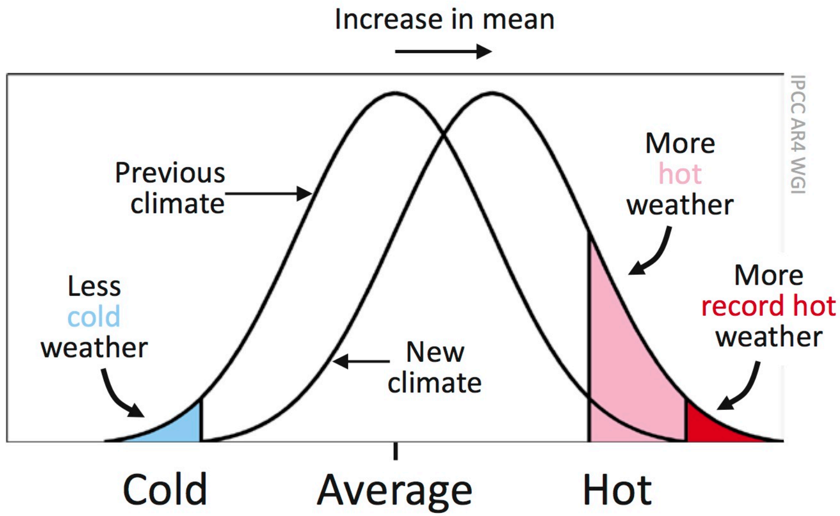
- **Percentile Indices,** e.g. p97.5, p99

- **Extreme Value Statistics** (e.g., return value estimation based on Generalized Extreme Value Distribution)

Approaches are complementary and should be used according to given context or scientific question

http://etccdi.pacificclimate.org/list_27_indices.shtml

developed an internationally coordinated set of climate indices
- core set consists of 27 descriptive indices



FD, ID, SU, TR
TX_n, TN_n, TX_x, TN_x
TN10p, TX10p, TN90p, TX90p
CSDI, WSDI
GSL, DTR

Rx1day, Rx5day
SDII
R10mm, R20mm, Rnnmm
CDD, CWD
R95pTOT, R99pTOT
PRCPTOT

focus on counts of days crossing a threshold; either absolute/fixed thresholds or percentile/variable thresholds relative to local climate

Indices for Climate Extremes (IPCC AR5)

Box 2.4, Table 1 | Definitions of extreme temperature and precipitation indices used in IPCC (after Zhang et al., 2011). The most common units are shown but these may be shown as normalized or relative depending on application in different chapters.

Index	Descriptive name	Definition	Units	Figures/Tables	Section
TXx	Warmest daily Tmax	Seasonal/annual maximum value of daily maximum temperature	°C	Box 2.4, Figure 1, Figures 9.37, 10.17, 12.13	Box 2.4, 9.5.4.1, 10.6.1.1, 12.4.3.3
TNx	Warmest daily Tmin	Seasonal/annual maximum value of daily minimum temperature	°C	Figures 9.37, 10.17	9.5.4.1, 10.6.1.1
TXn	Coldest daily Tmax	Seasonal/annual minimum value of daily maximum temperature	°C	Figures 9.37, 10.17, 12.13	9.5.4.1, 10.6.1.1, 12.4.3.3
TNn	Coldest daily Tmin	Seasonal/annual minimum value of daily minimum temperature	°C	Figures 9.37, 10.17, 12.13	9.5.4.1, 10.6.1.1
TN10p	Cold nights	Days (or fraction of time) when daily minimum temperature <10th percentile	Days (%)	Figures 2.32, 9.37, 10.17 Tables 2.11, 2.12	2.6.1, 9.5.4.1, 10.6.1.1, 11.3.2.5.1
TX10p	Cold days	Days (or fraction of time) when daily maximum temperature <10th percentile	Days (%)	Figures 2.32, 9.37, 10.17, 11.17	2.6.1, 9.5.4.1, 10.6.1.1, 11.3.2.5.1,
TN90p	Warm nights	Days (or fraction of time) when daily minimum temperature >90th percentile	Days (%)	Figures 2.32, 9.37, 10.17 Tables 2.11, 2.12	2.6.1, 9.5.4.1, 10.6.1.1, 11.3.2.5.1
TX90p	Warm days	Days (or fraction of time) when daily maximum temperature >90th percentile	Days (%)	Figures 2.32, 9.37, 10.17, 11.17 Tables 2.11, 2.12	2.6.1, 9.5.4.1, 10.6.1.1, 11.3.2.5.1,
FD	Frost days	Frequency of daily minimum temperature <0°C	Days	Figures 9.37, 12.13 Table 2.12	2.6.1, 9.5.4.1, 10.6.1.1, 12.4.3.3
TR	Tropical nights	Frequency of daily minimum temperature >20°C	Days	Figures 9.37, 12.13	9.5.4.1, 12.4.3.3
RX1day	Wettest day	Maximum 1-day precipitation	mm	Figures 9.37, 10.10 Table 2.12, 12.27	2.6.2.1, 9.5.4.1, 10.6.1.2, 12.4.5.5
RX5day	Wettest consecutive five days	Maximum of consecutive 5-day precipitation	mm	Figures 9.37, 12.26, 14.1	9.5.4.1, 10.6.1.2, 12.4.5.5, 14.2.1
SDII	Simple daily intensity index	Ratio of annual total precipitation to the number of wet days (≥1 mm)	mm day^{-1}	Figures 2.33, 9.37, 14.1	2.6.2.1, 9.5.4.1, 14.2.1
R95p	Precipitation from very wet days	Amount of precipitation from days >95th percentile	mm	Figures 2.33, 9.37, 11.17 Table 2.12	2.6.2.1, 9.5.4.1, 11.3.2.5.1
CDD	Consecutive dry days	Maximum number of consecutive days when precipitation <1 mm	Days	Figures 2.33, 9.37, 12.26, 14.1	2.6.2.3, 9.5.4.1, 12.4.5.5, 14.2.1

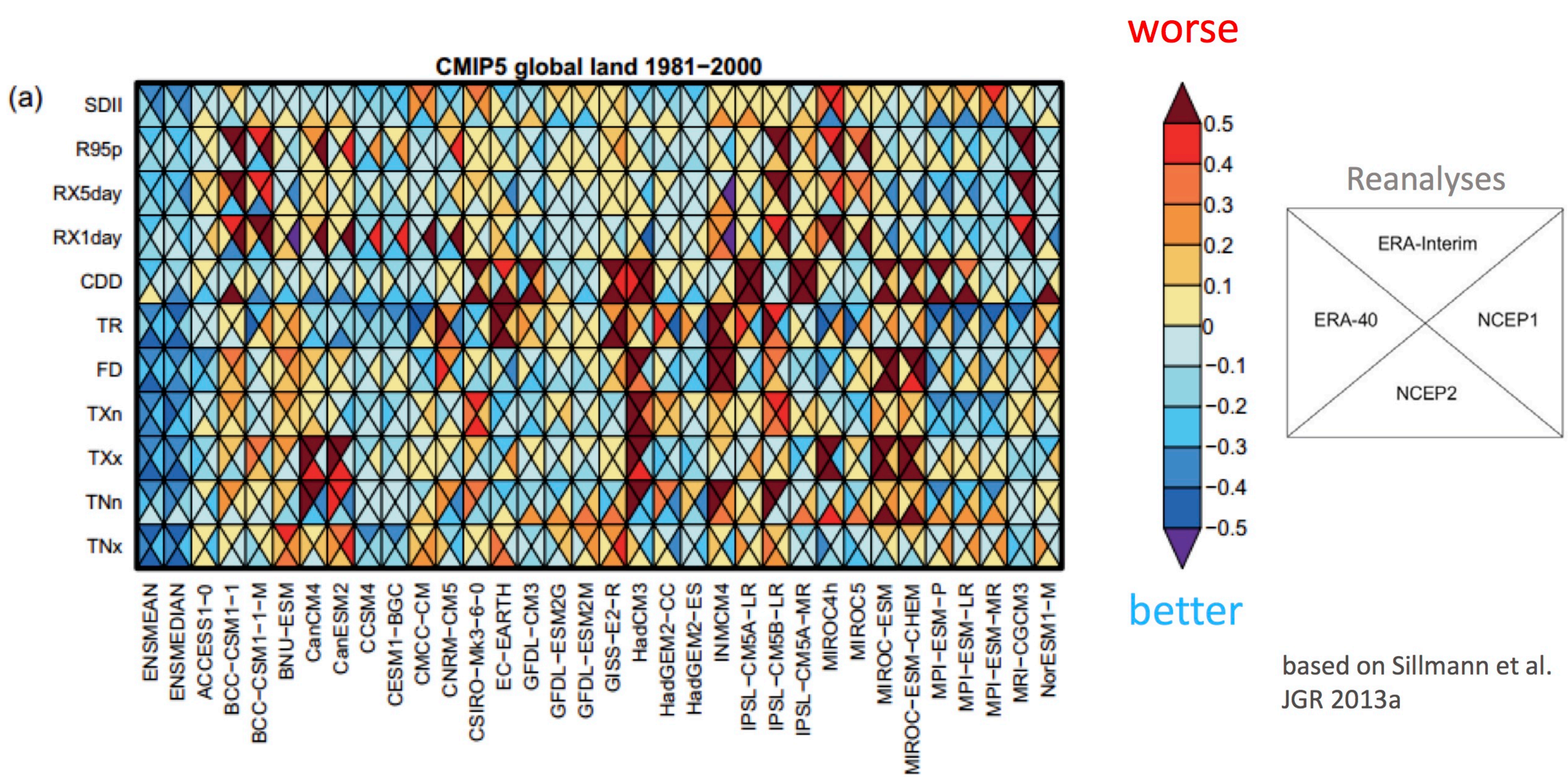
IPCC 2013

- No drought index

- More application relevant indices to support adaptation

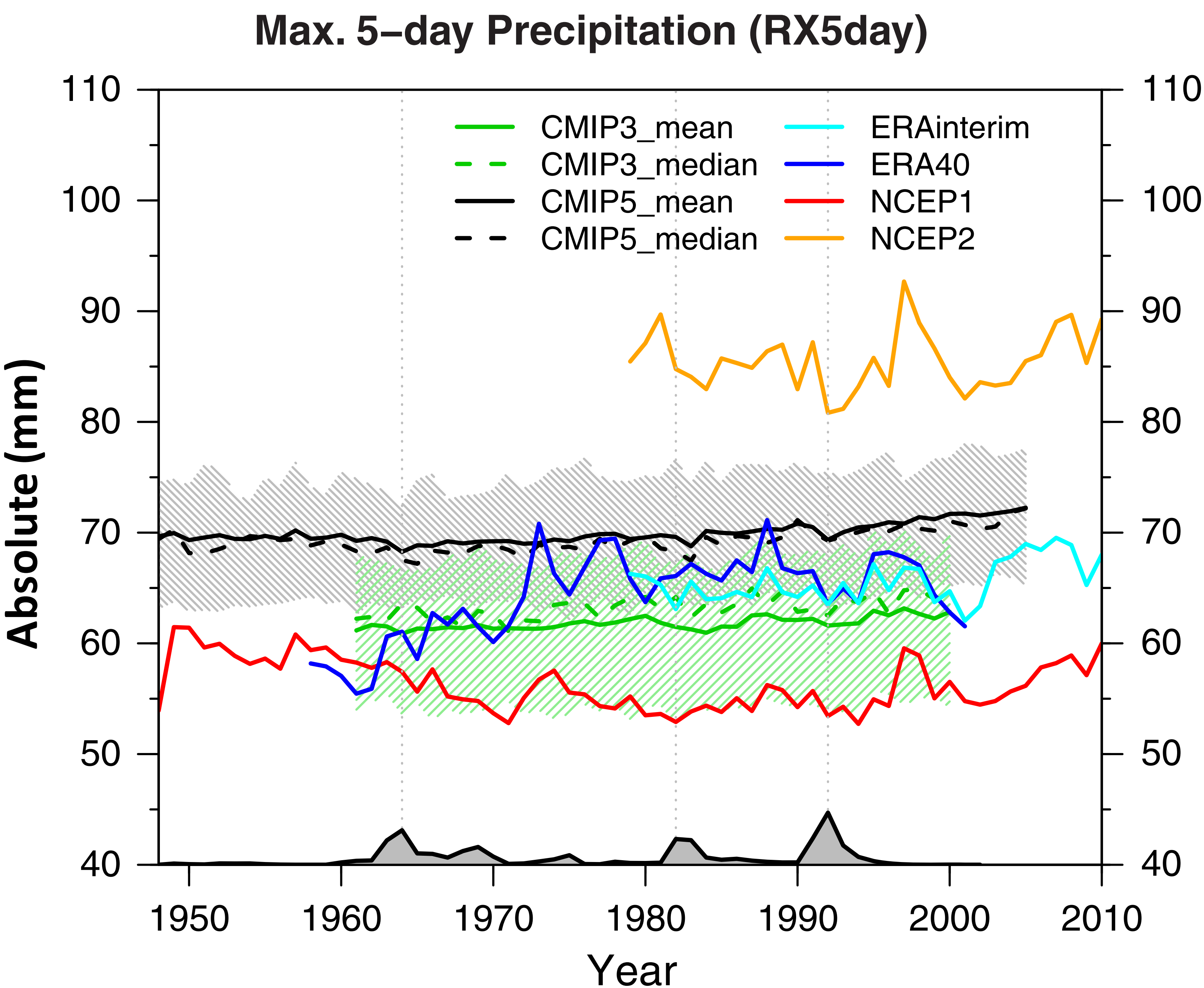
Model Evaluation

Chapter 9 IPCC AR5 WGI Evaluation of Climate Models



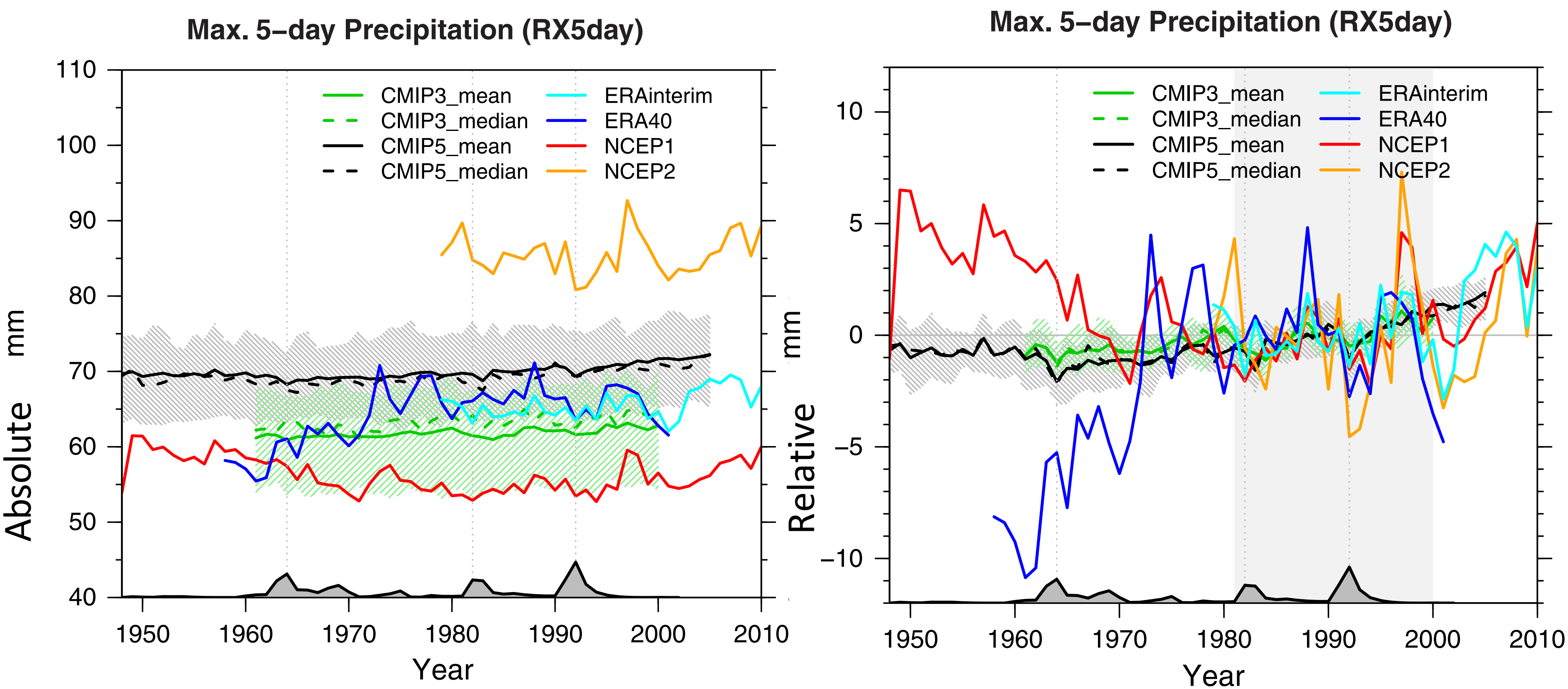
based on Sillmann et al. JGR 2013a

- **Differences between reanalyses** can be as large as intermodel spread
- Need for better global **coverage of observations** and improvement of reanalysis products
- Model and reanalysis **performance depends on region and index** under consideration



Sillmann et al (2013)

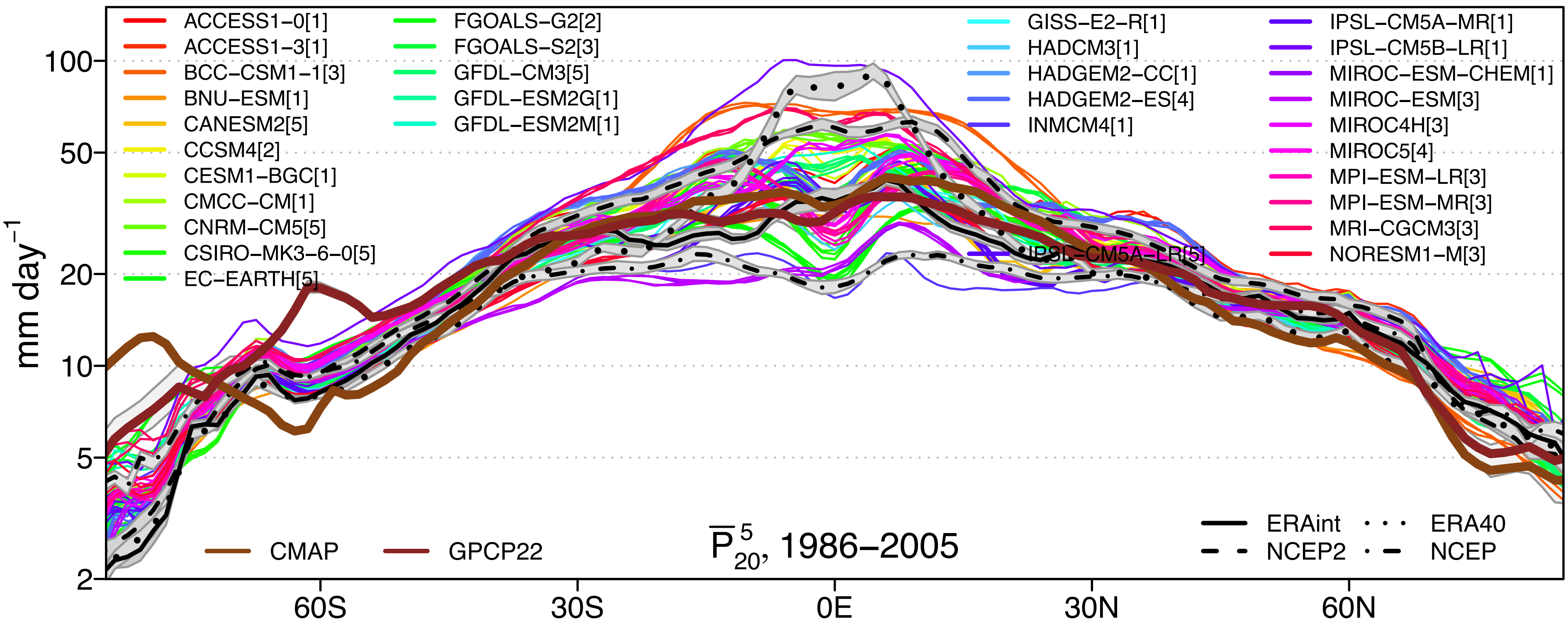
Global land mean



Sillmann et al (2013)

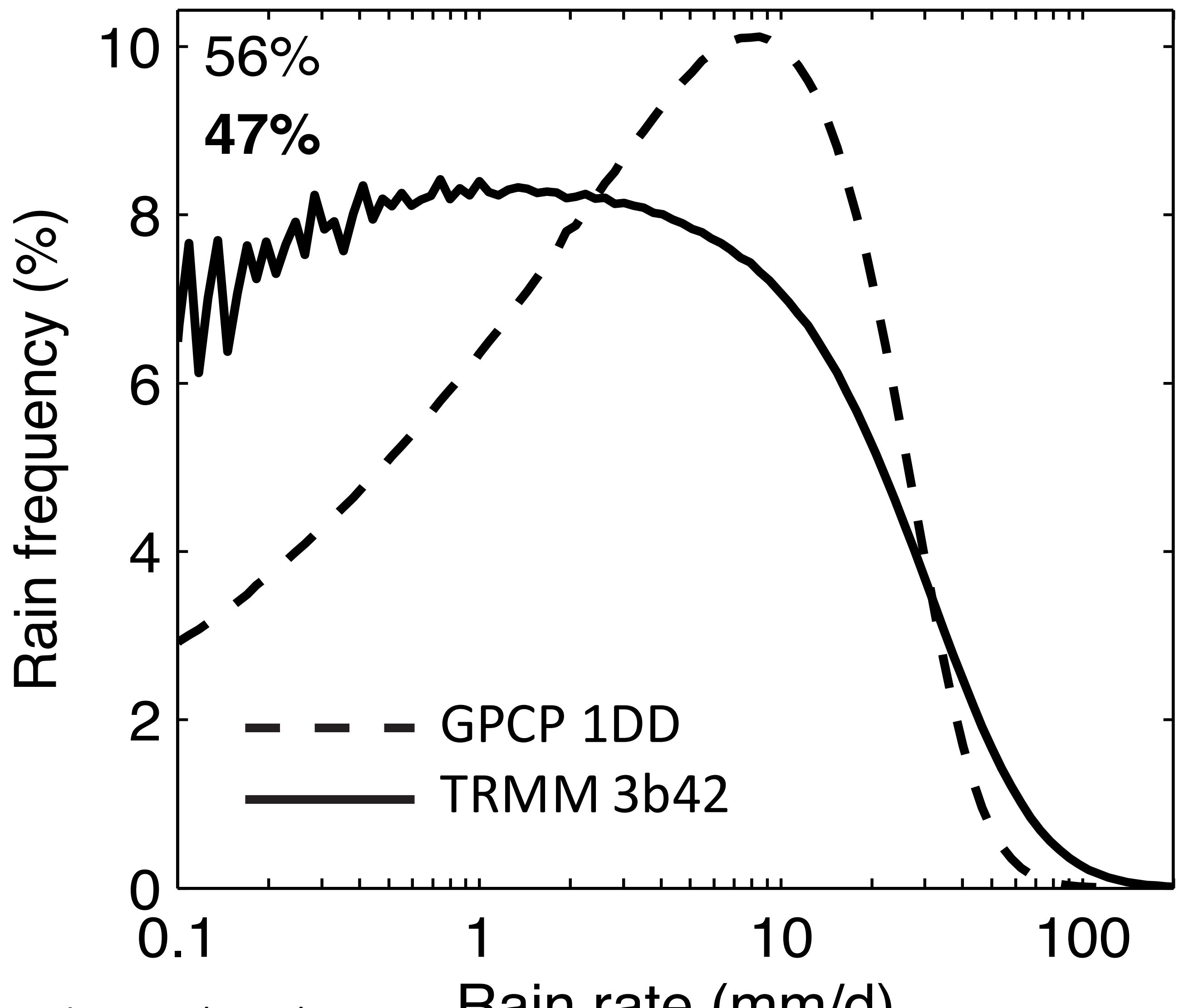
Global land mean

20-year return period of max 5-day precipitation



Kharin et al (2013)

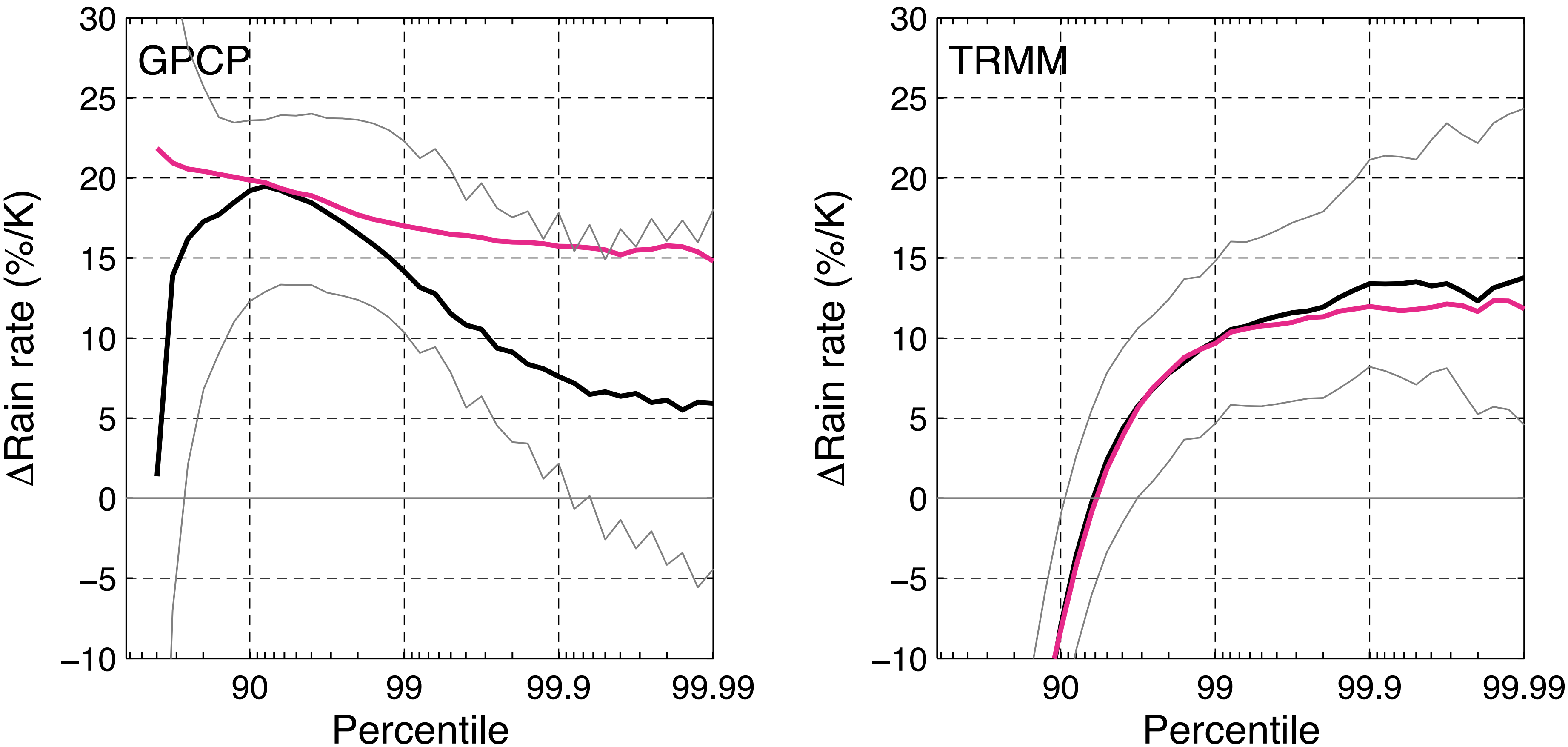
Observational datasets disagree on extremes



1997-2015
50 N-S
Daily, 1 °

Pendergrass and Deser (2017)

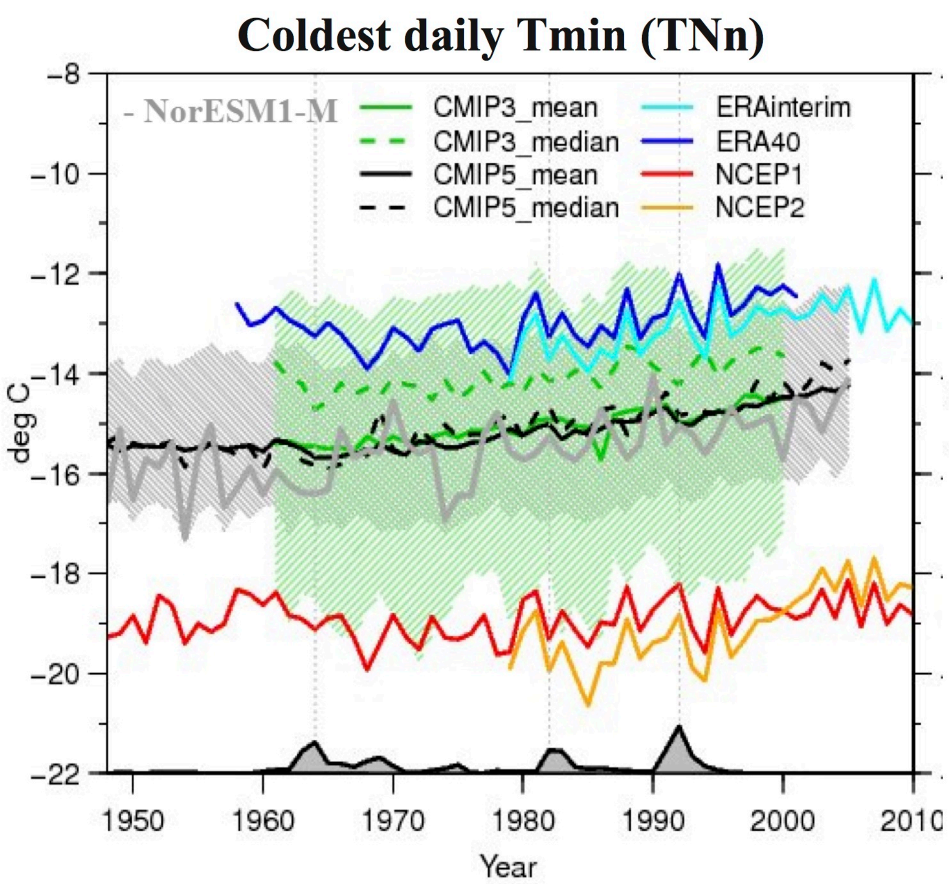
Observational datasets disagree on extremes

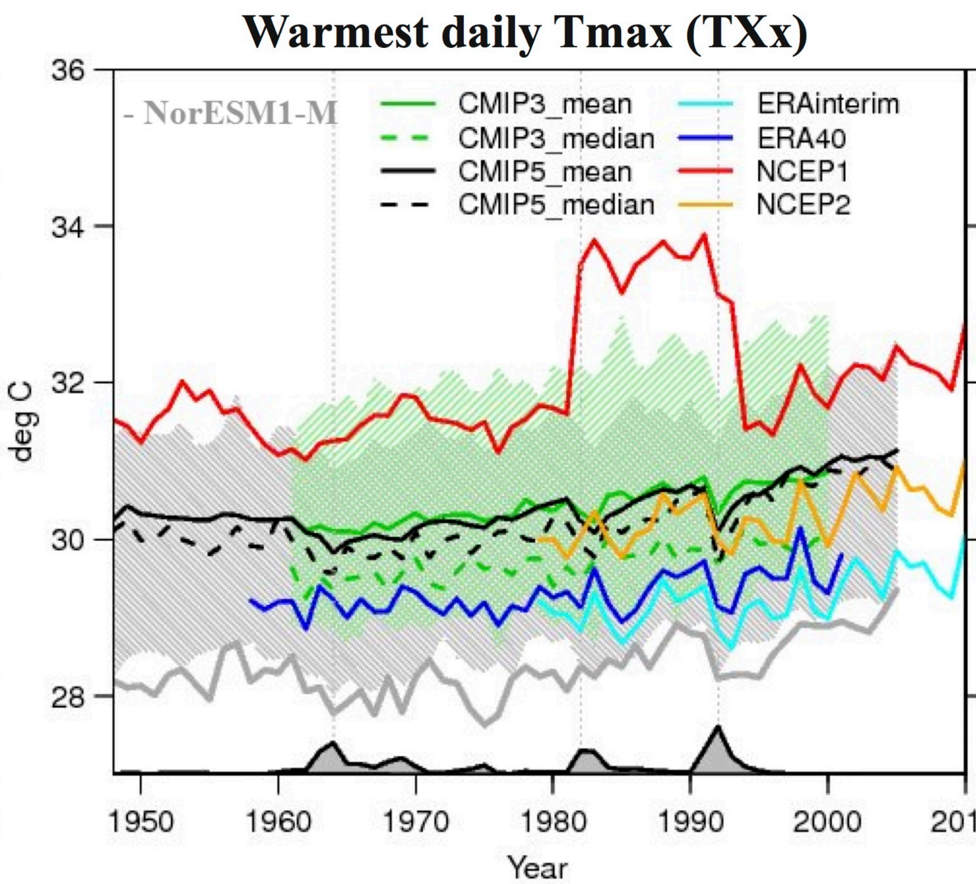


GPCP 1DD and TRMM 3B42 daily precipitation "observations" 1998-2012
Difference between composites of warm and cold ENSO months, 30 N-S

Pendergrass and Hartmann (2014)

Extreme temperature





Extreme temperature change is somewhat more robust across datasets and model simulations

Sillmann et al (2013)

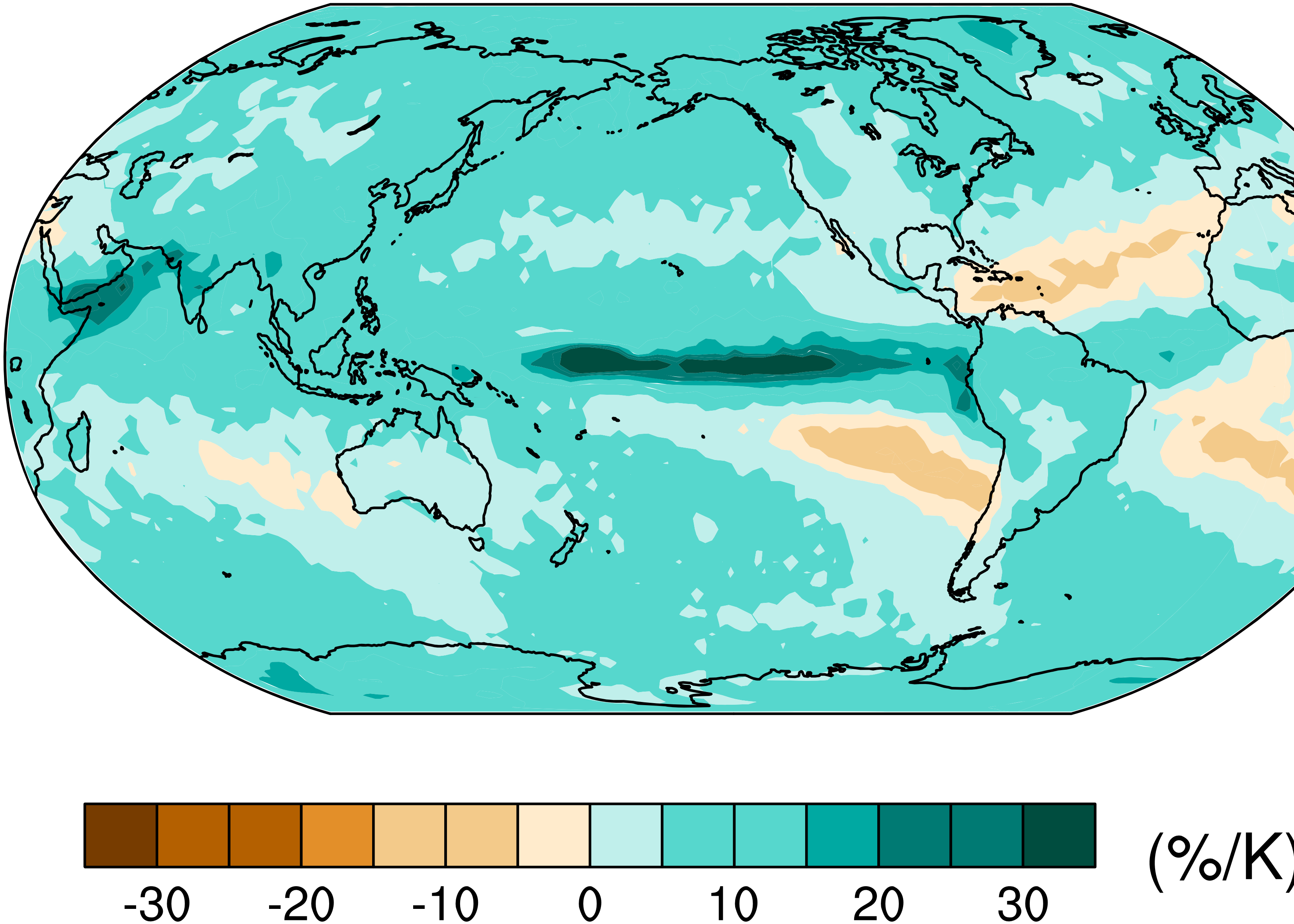
Global

Regional

Local

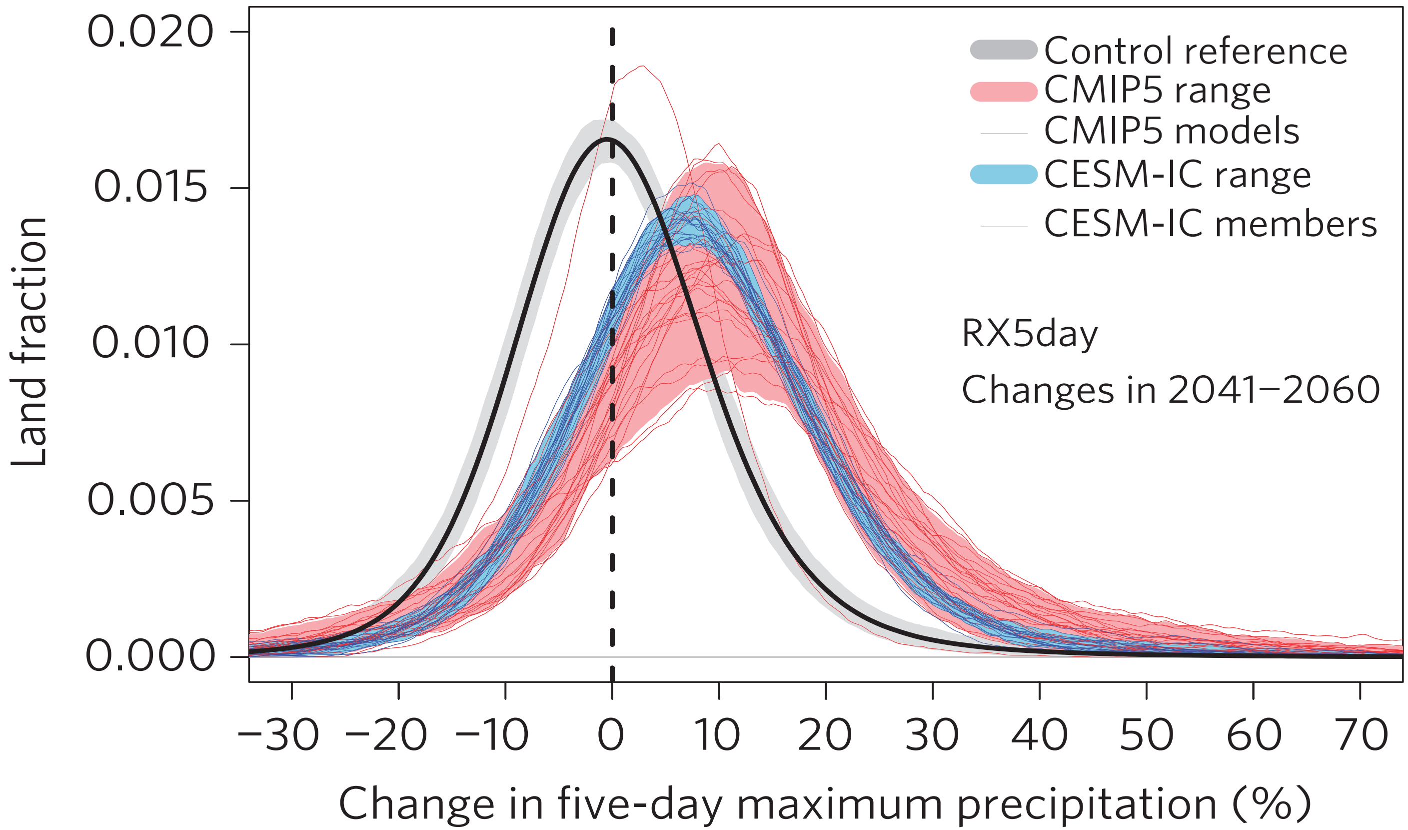
Century Decade Season Month Week Day Hour

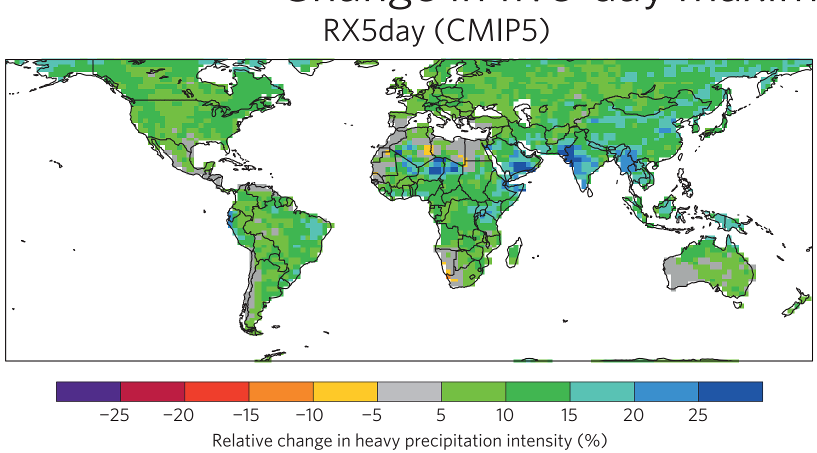
Projected extreme precipitation change



CMIP5 multi-model mean rx1day regressed against global mean T, RCP8.5

Robust signal for **spatially aggregated** extremes



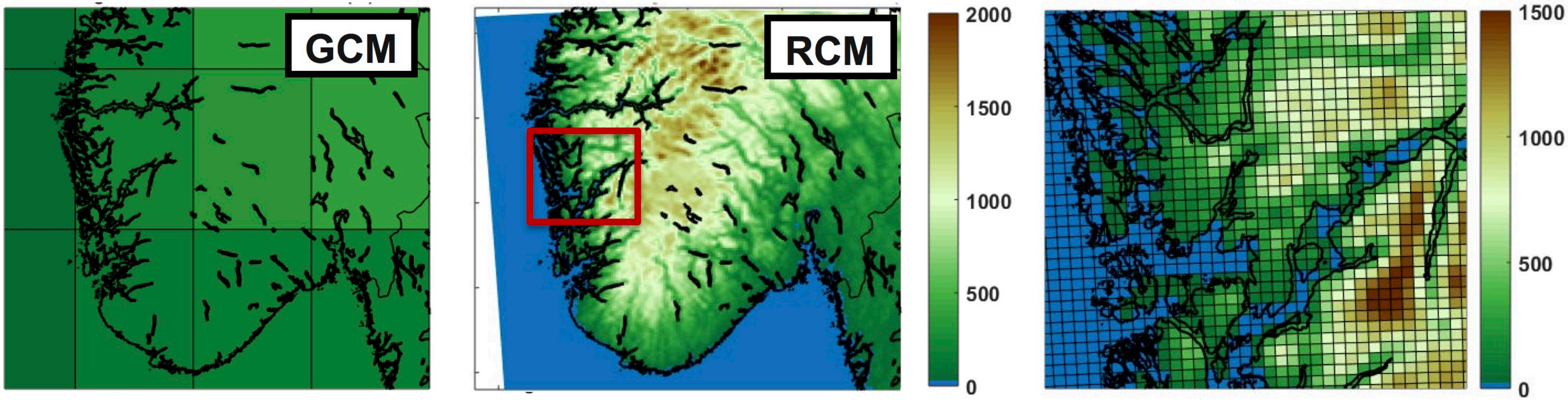


Fischer et al (2013)

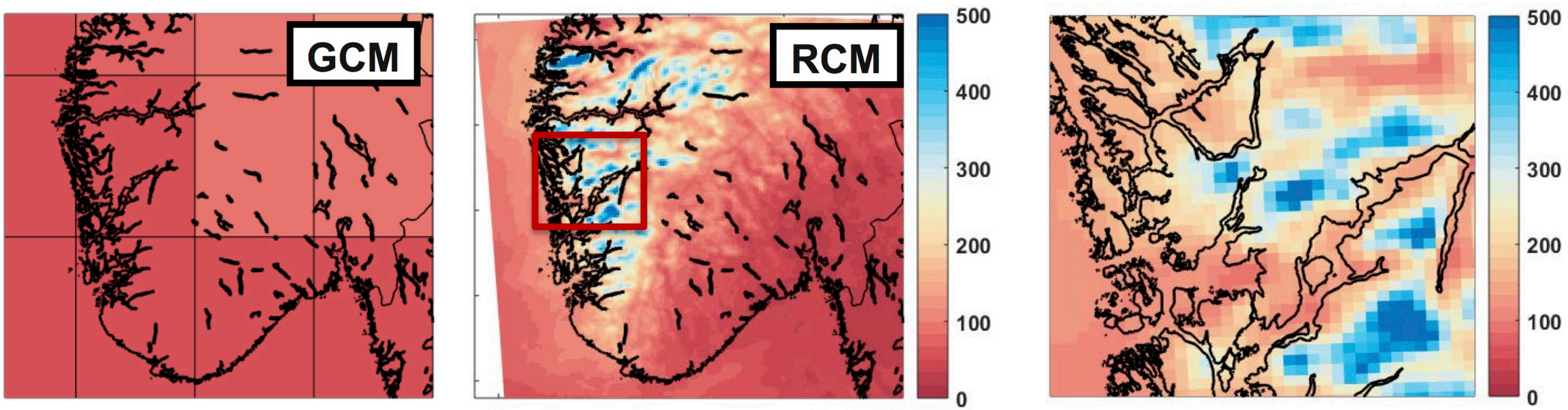
Getting to the scales of impacts …

Extreme Precipitation – High-Resolution

Terrain height (m)



Summer precipitation (mm/month)



Courtesy of Øivind Hodnebrog, projects HYPRE and SUPER @ CICERO Senter for klimaforskning www.cicero.uio.no Center for International Climate and Environmental Research - Oslo

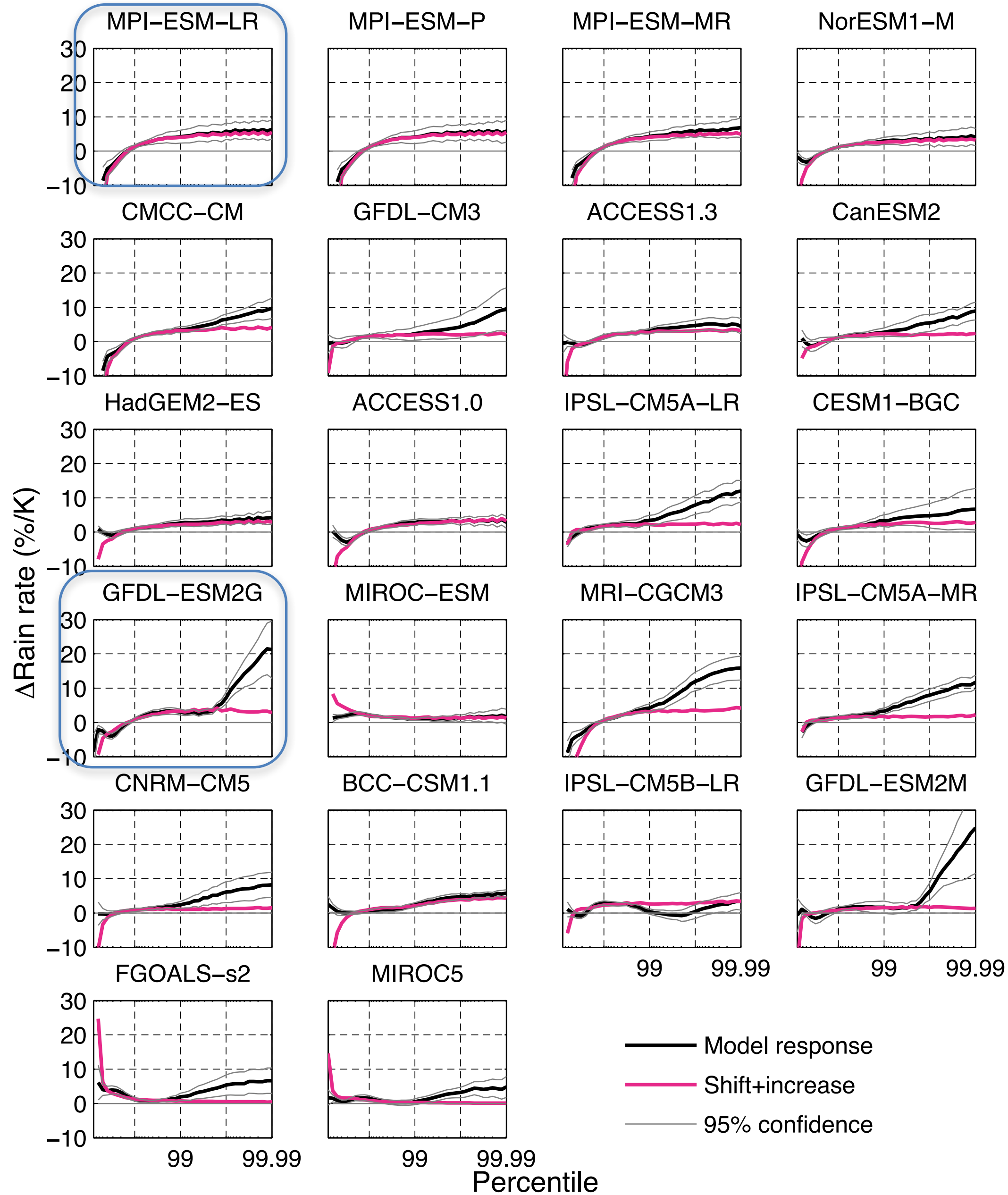
Key points

- Defining extremes is important
  - For many questions, the answer depends on the definition
  - Dedicated metrics for evaluating extremes are essential
- Observing extremes is challenging
  - And often there is a scale mismatch from models
- Climate models don’t capture extremes defined by absolute thresholds well
  - We have more confidence in relative behavior than absolute
- Providing answers on impact-relevant scales is a challenge

CMIP5 models, CO_2 increase scenario

Extreme precipitation change varies widely across models (see also O'Gorman 2012)

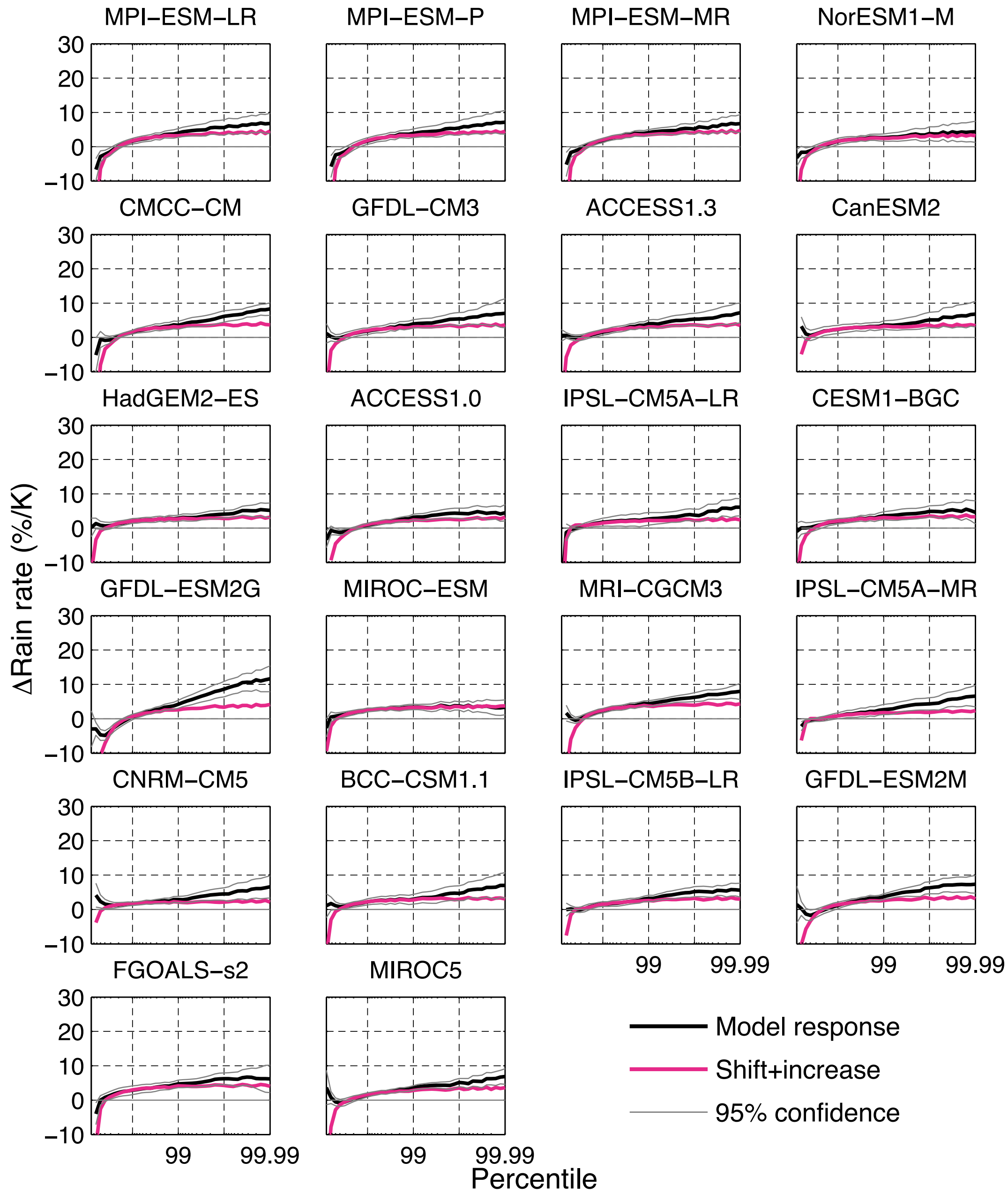
These variations are changes isolated at extremes



Pendergrass and Hartmann (2014) *JClim* Changes in the distribution of rain

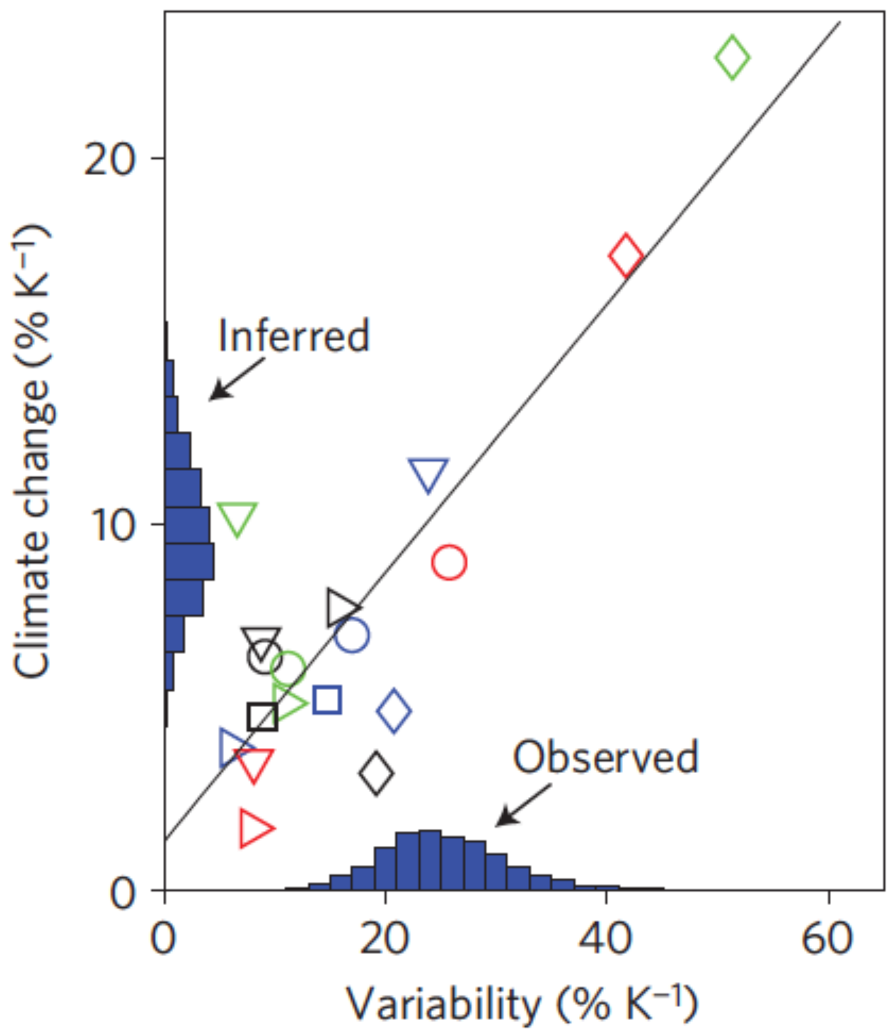
Extra-tropics (>30^{o})

Smaller but more consistent from the rest of the distribution



Pendergrass and Hartmann (2014) *JClim* Changes in the distribution of rain

Inter-annual variability of extremes is bigger than climate change response

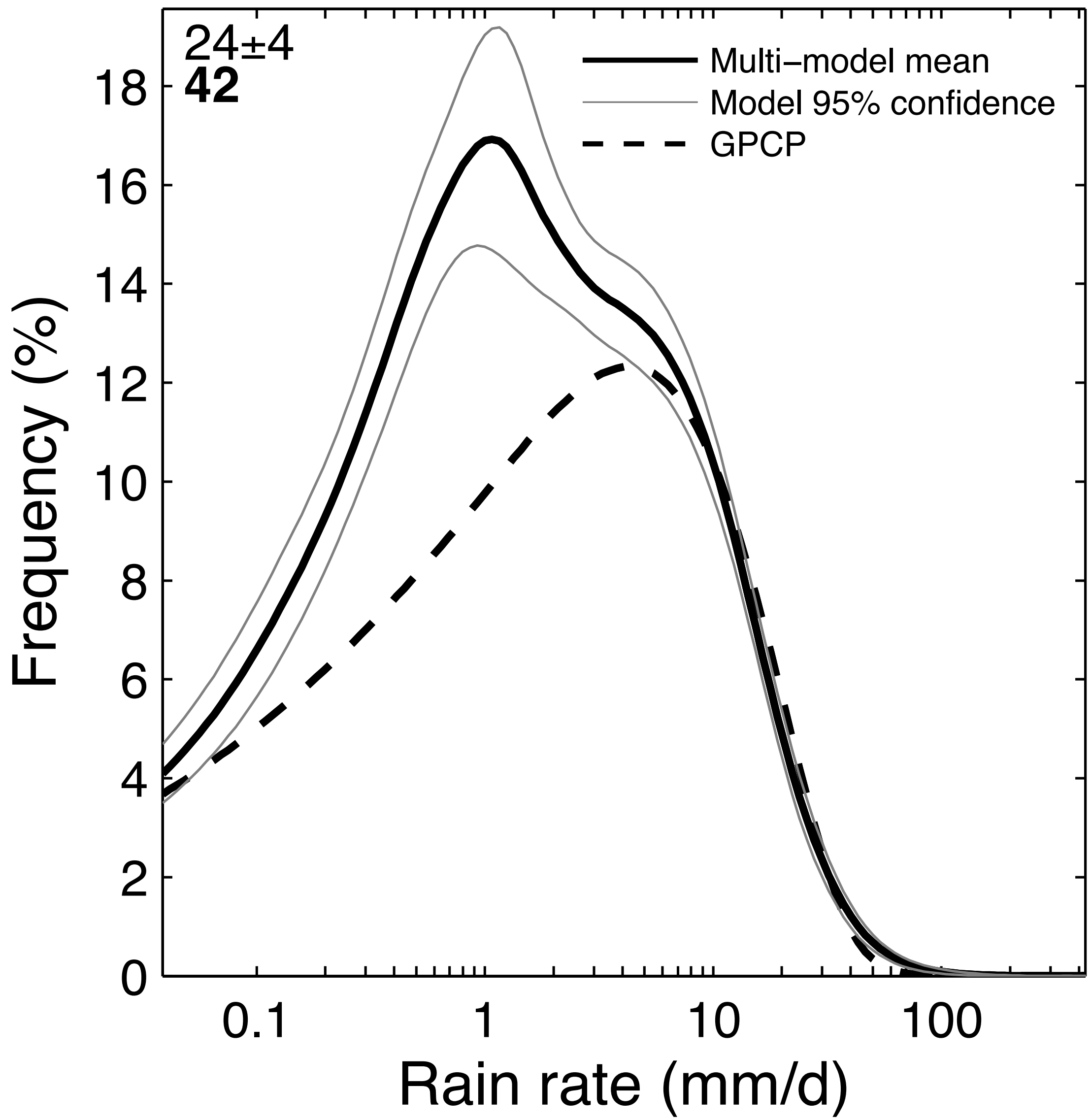


Tropical 99.9 percentile change in CMIP3 models

Bars: observations
Symbols: models
Variability: over ocean only
Change: whole tropics

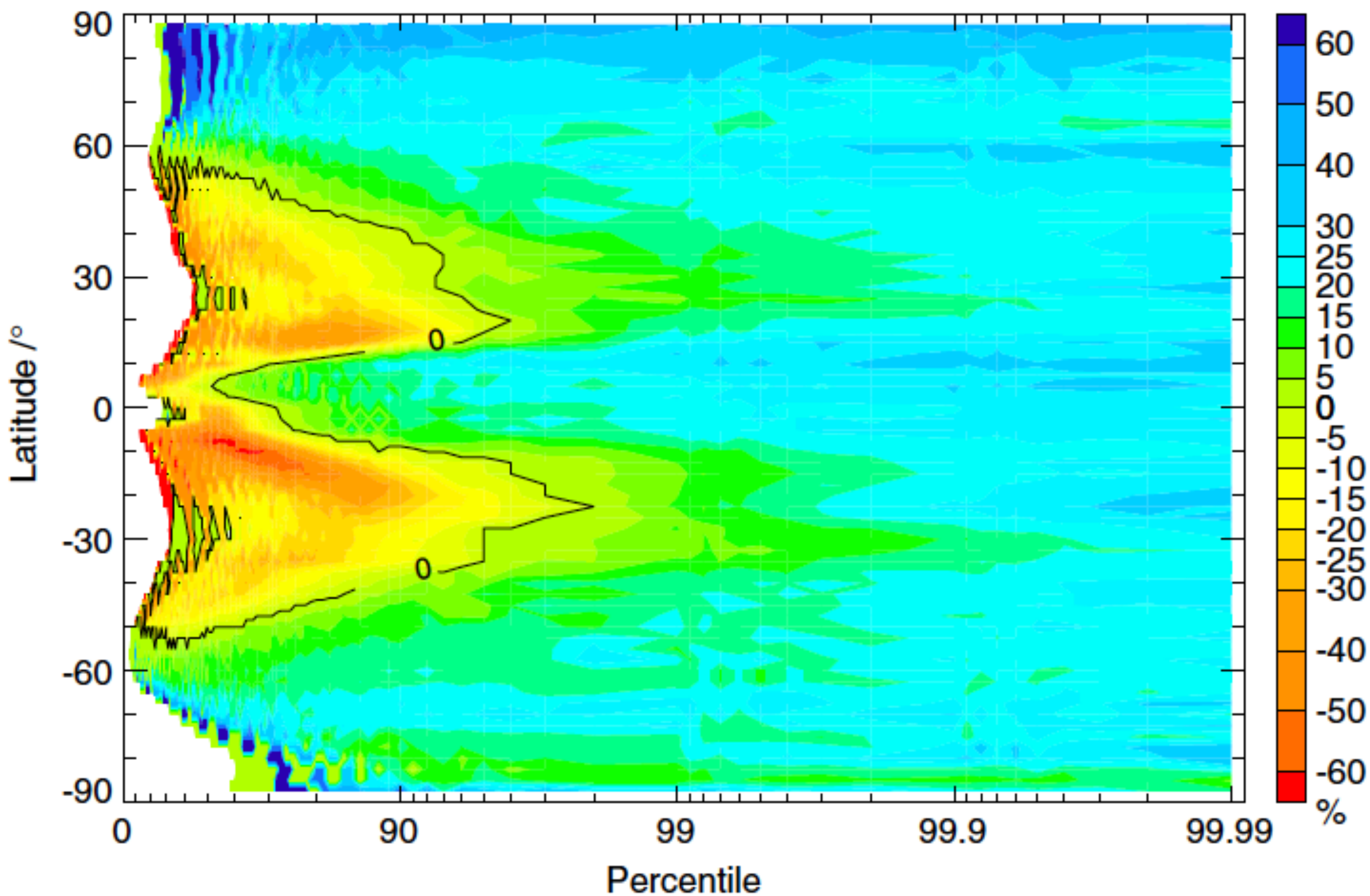
O'Gorman (2012)

Models agree with observations on heavy precipitation between than observations agree with each other

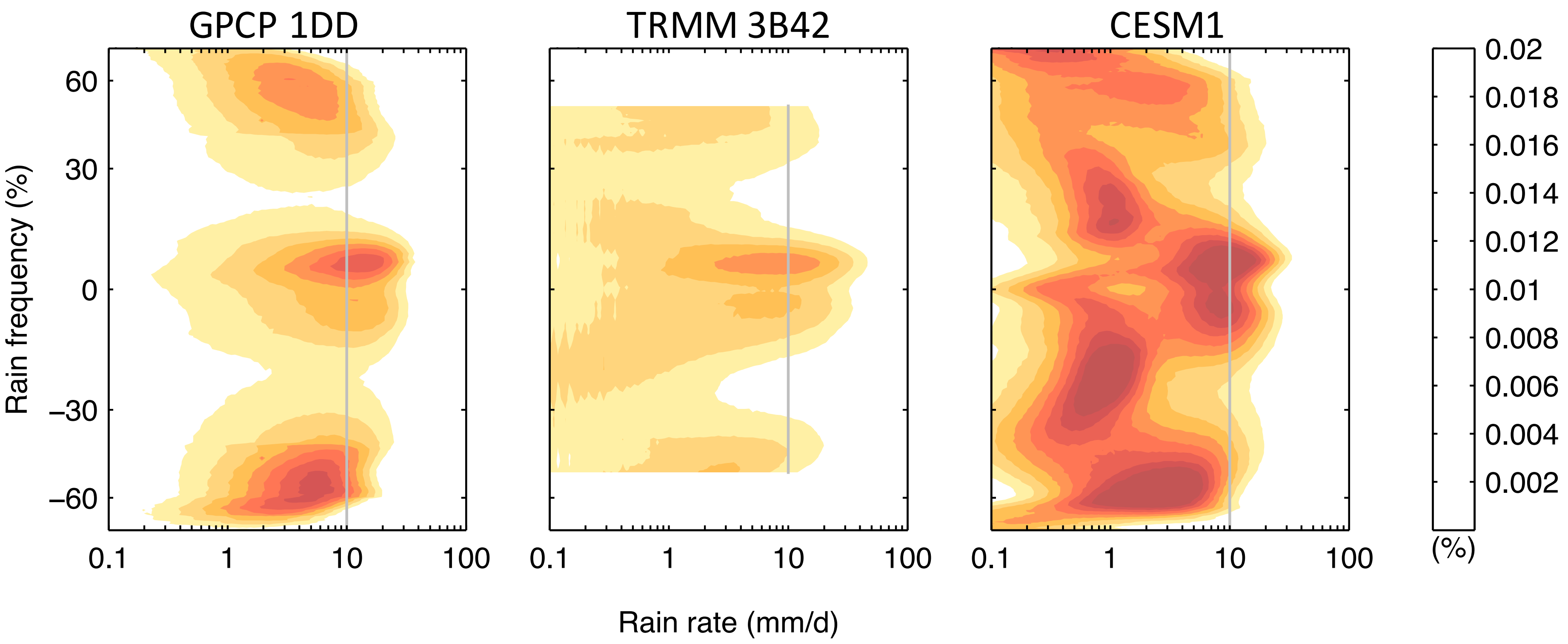


Pendergrass and Hartmann (2014)

Extreme precipitation change



Pall et al (2007)



Pendergrass and Deser (2017)