Observed and projected changes in extremes

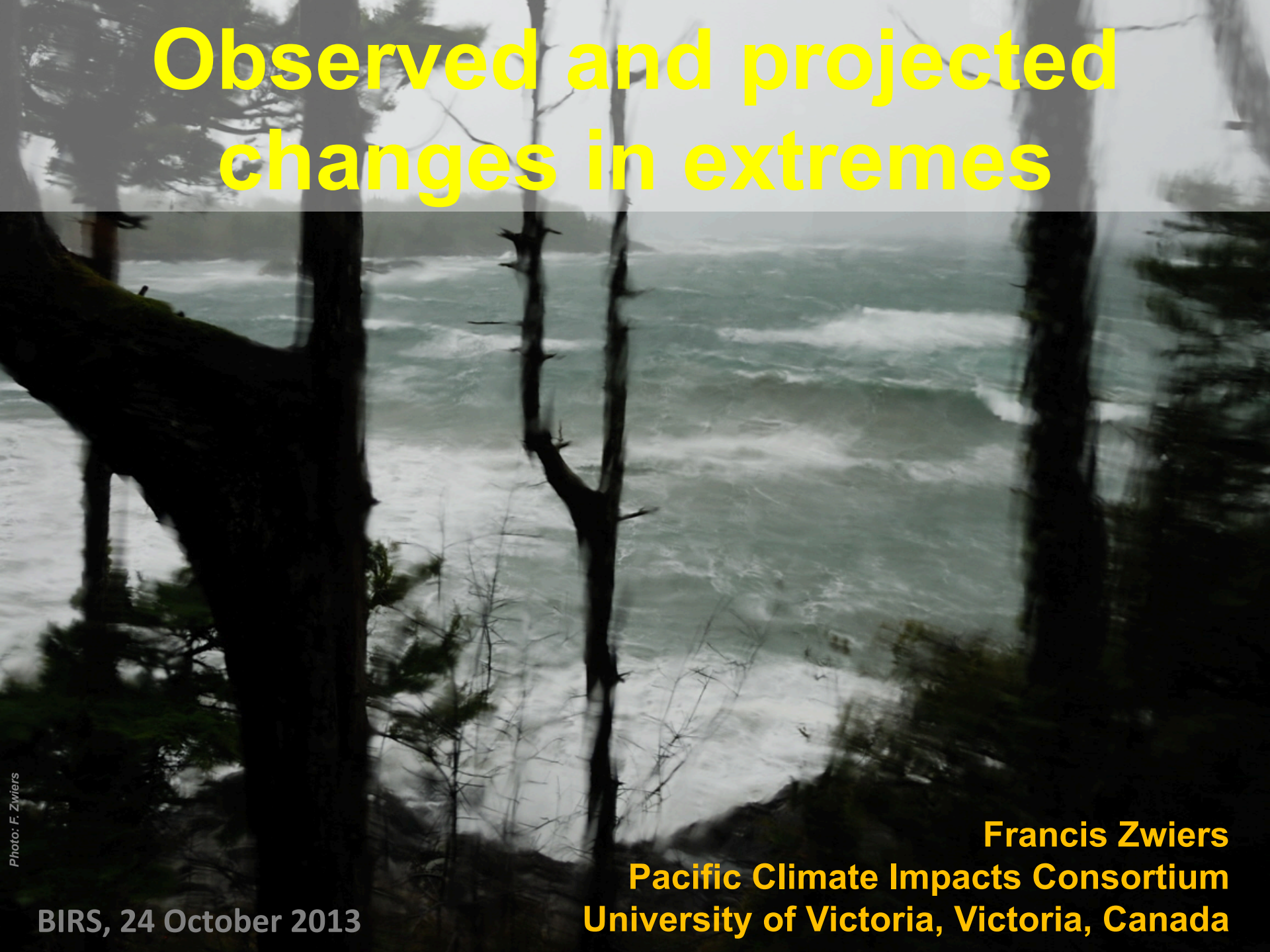


Photo: F. Zwiers

Francis Zwiers
Pacific Climate Impacts Consortium
University of Victoria, Victoria, Canada

BIRS, 24 October 2013

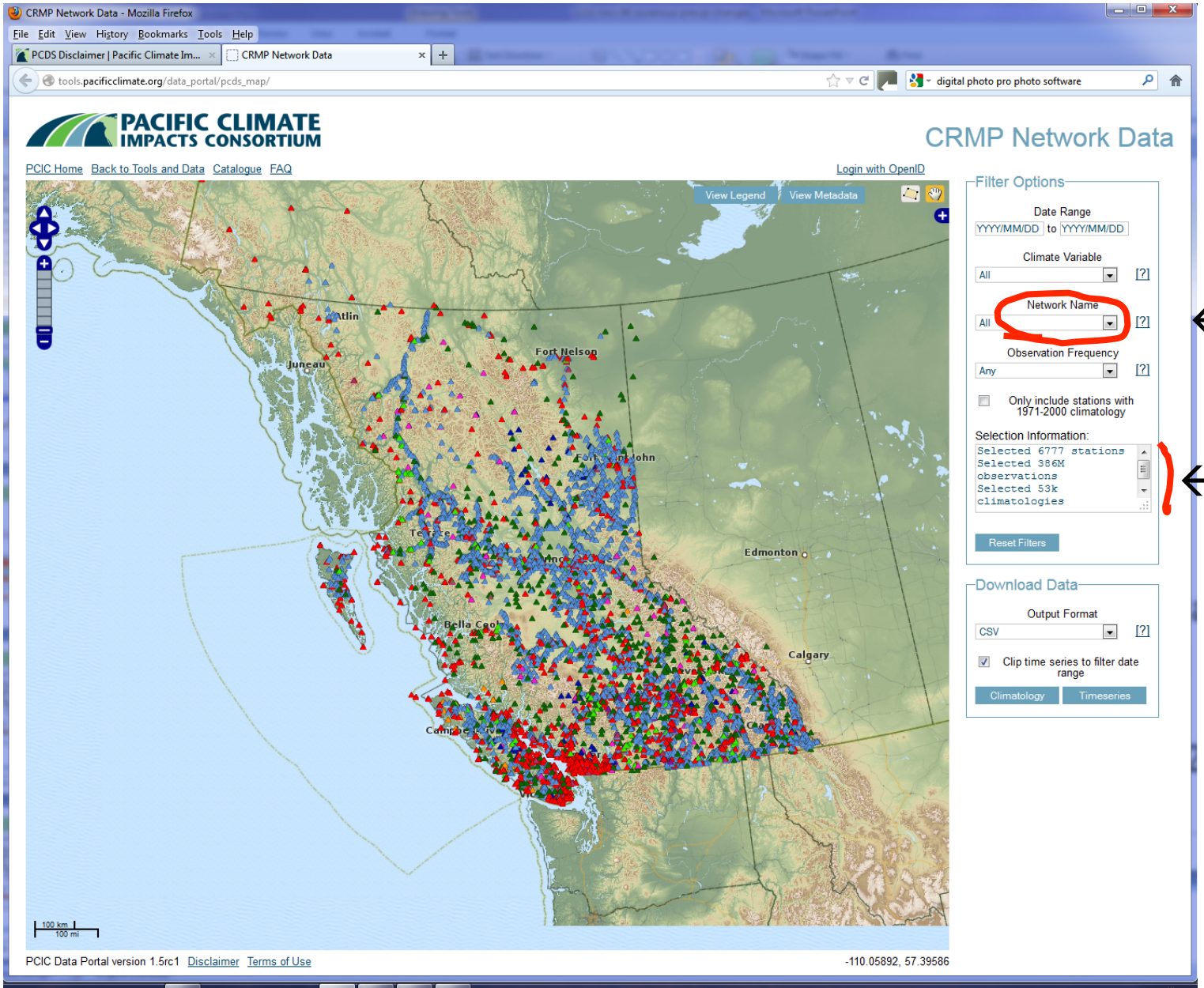
Outline

- Data
- Observed trends
- Extremes in models
  - Historical
  - Projected
- Detection and attribution of human influence
- Discussion

Photo: F. Zwiers

Some data products

http://www.pacificclimate.org/tools-and-data/pcds-portal



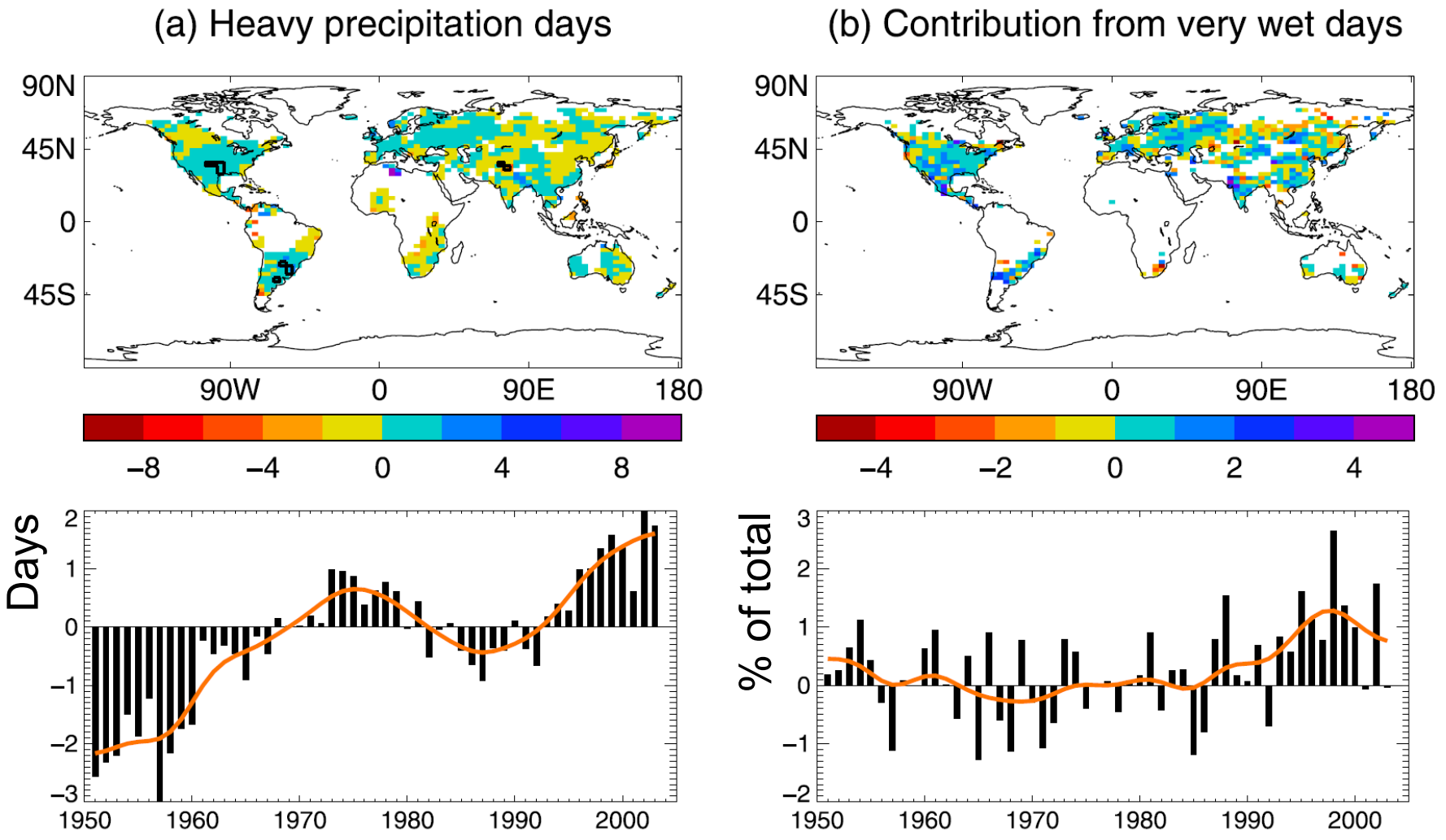
←14 networks

←6777 stations
386 million obs

HadEX (Alexander et al, 2006)

R10mm

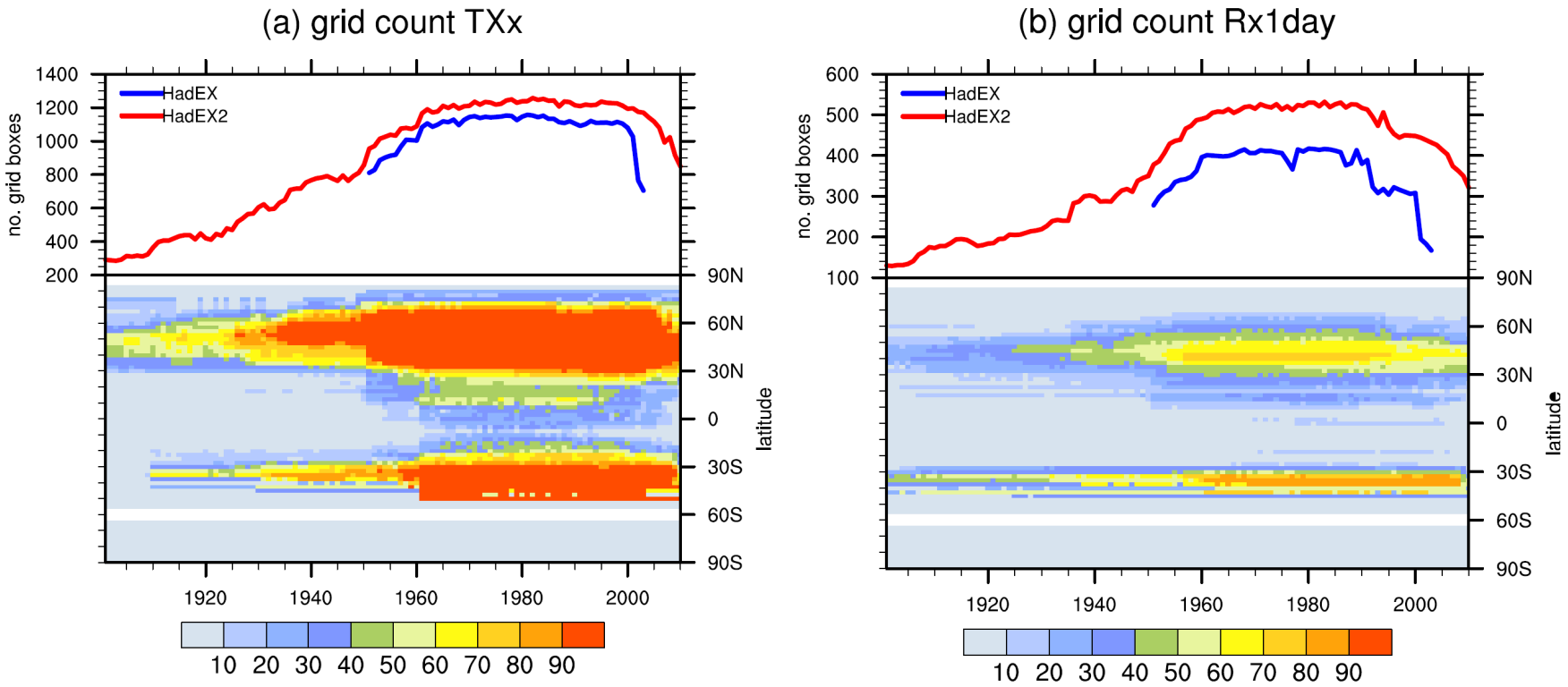
R95pTOT



Alexander et al (2006, Fig. 6)

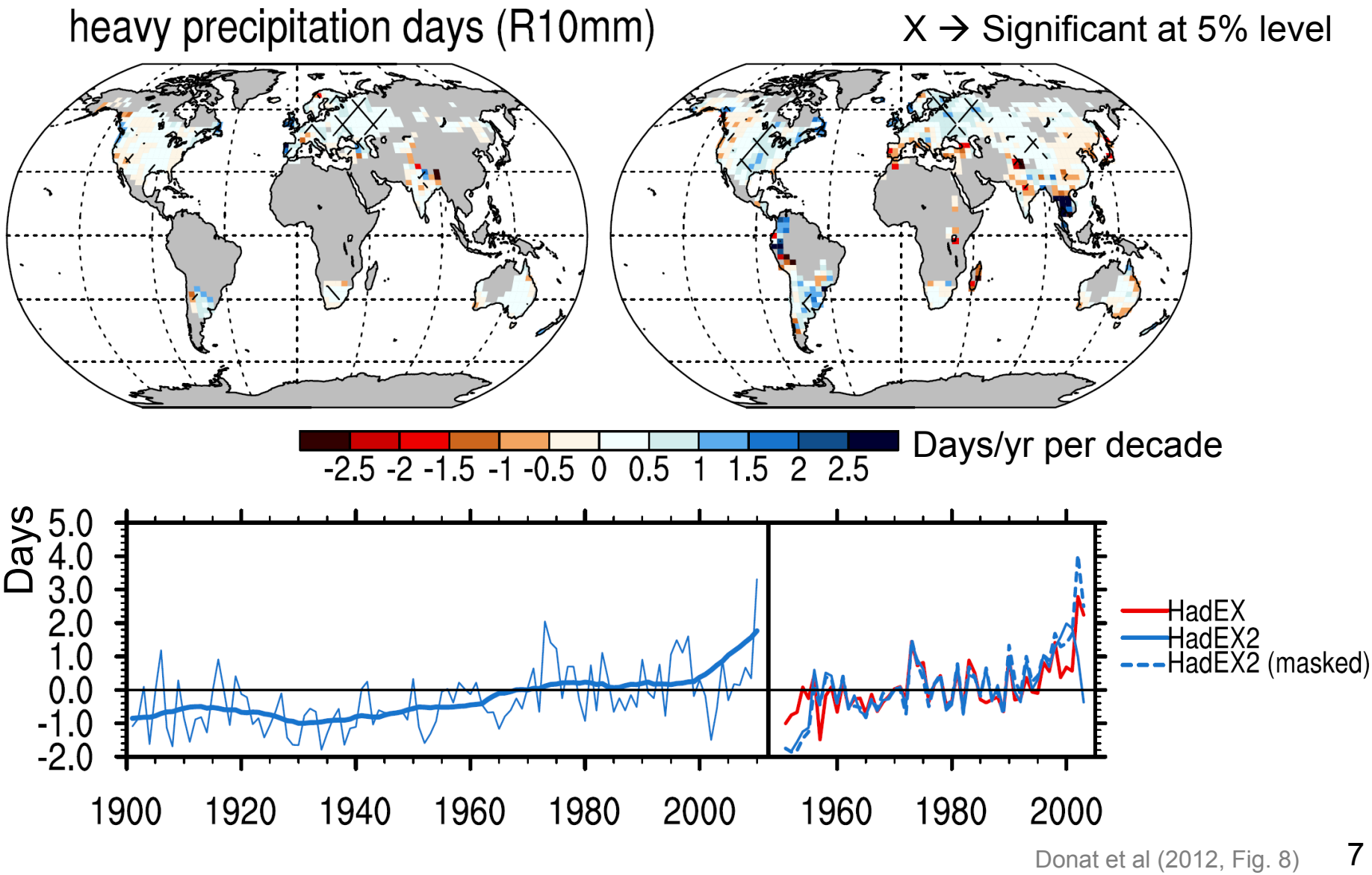
HadEX2 (Donat et al., 2013)

- 3.75°x2.5° grid boxes with data as a function of time, latitude
- More than 6000 temperature and 11000 precip stations
- From GHCN-D, ECA&D, SACAD, LACAD, workshops, etc



Donat et al (2013, Fig. 2)

Trend in freq. of heavy precip



Donat et al (2012, Fig. 8)

Adequacy of the observing system

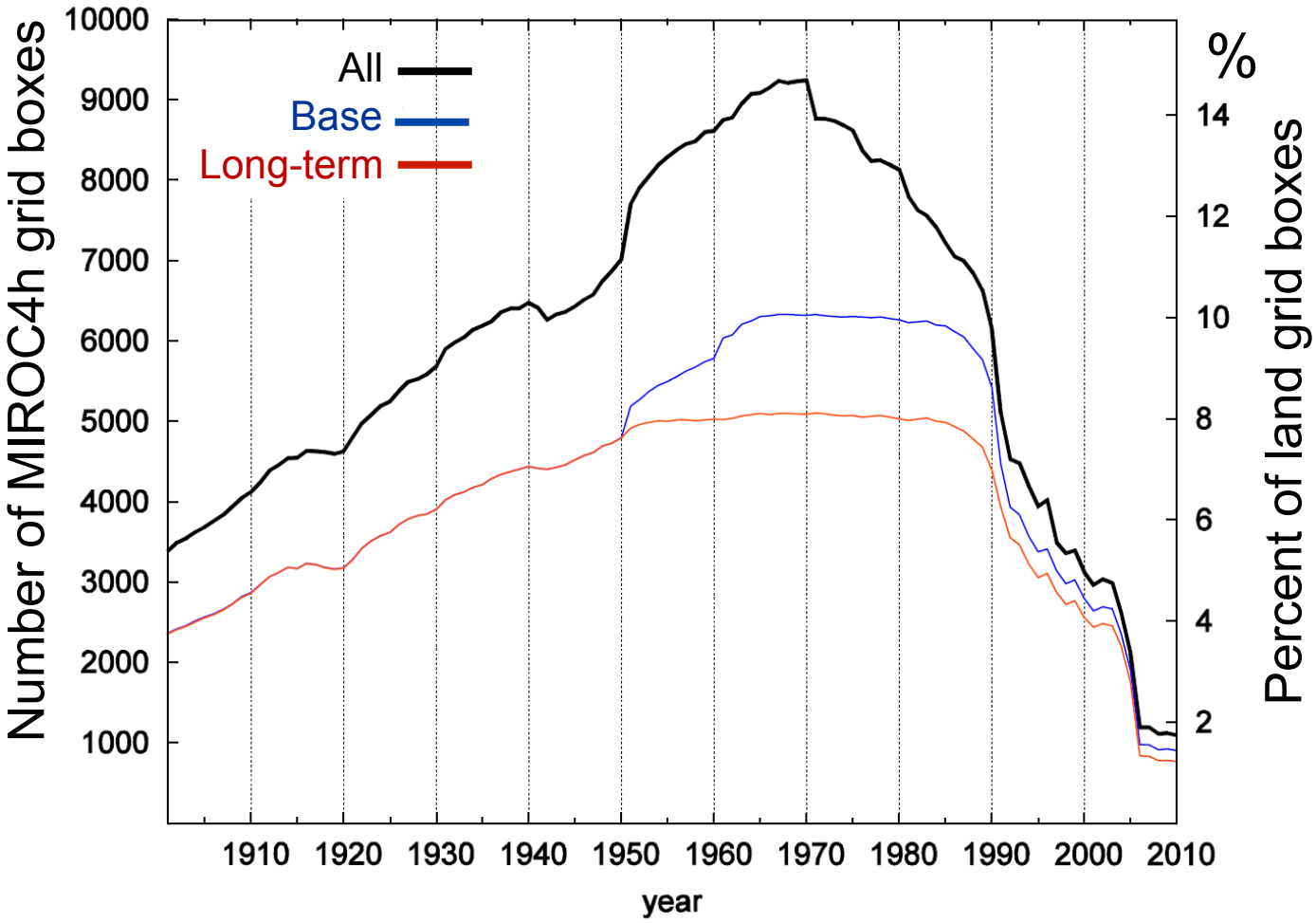
Wan et al, 2013, JGR

Wan et al, 2012

Use a high resolution global climate model to study efficacy of the available precipitation observing system

Idea is simply to mask the model output corresponding to availability of observations

- Can we estimate total precip?
  - Global land area or regionally
- Can we estimate trends?
- How does limited coverage affect trend detection?

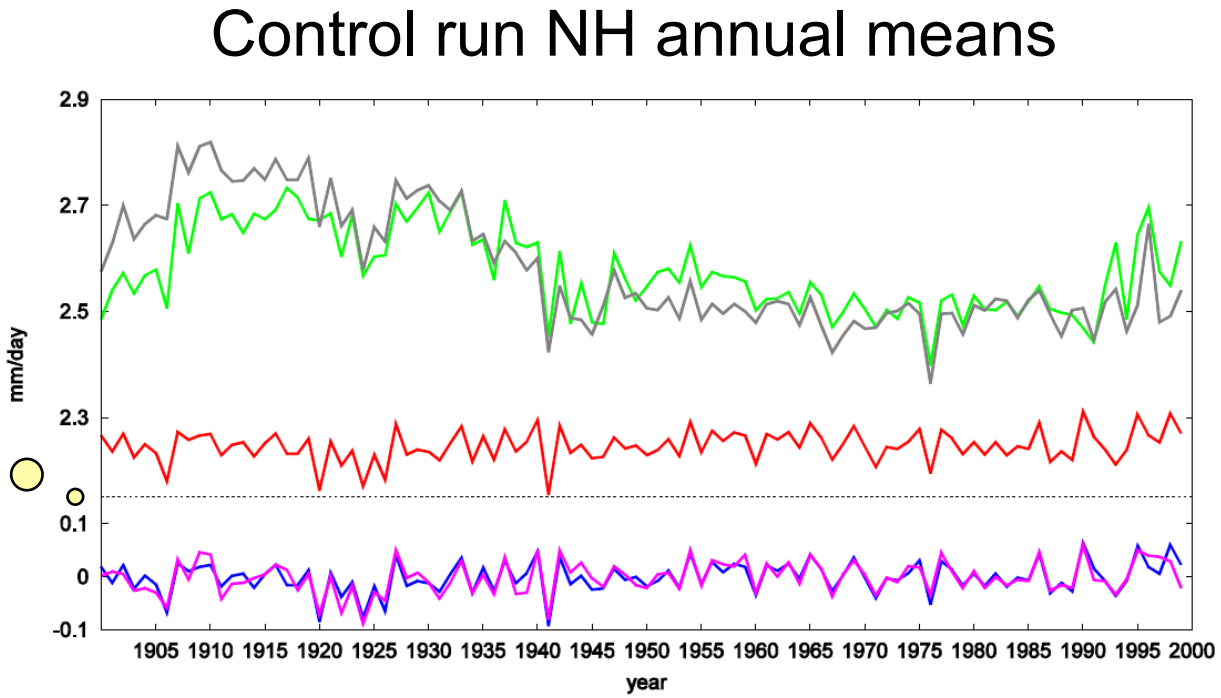


- **GHCN-M – 1901-2010**
- **Base (≥ 25 years in 1961-1990 base period)**
- **Long-term (base stations reporting earlier than 1950)**

Wan et al (2012, Fig. 1)

Affect of coverage changes over time

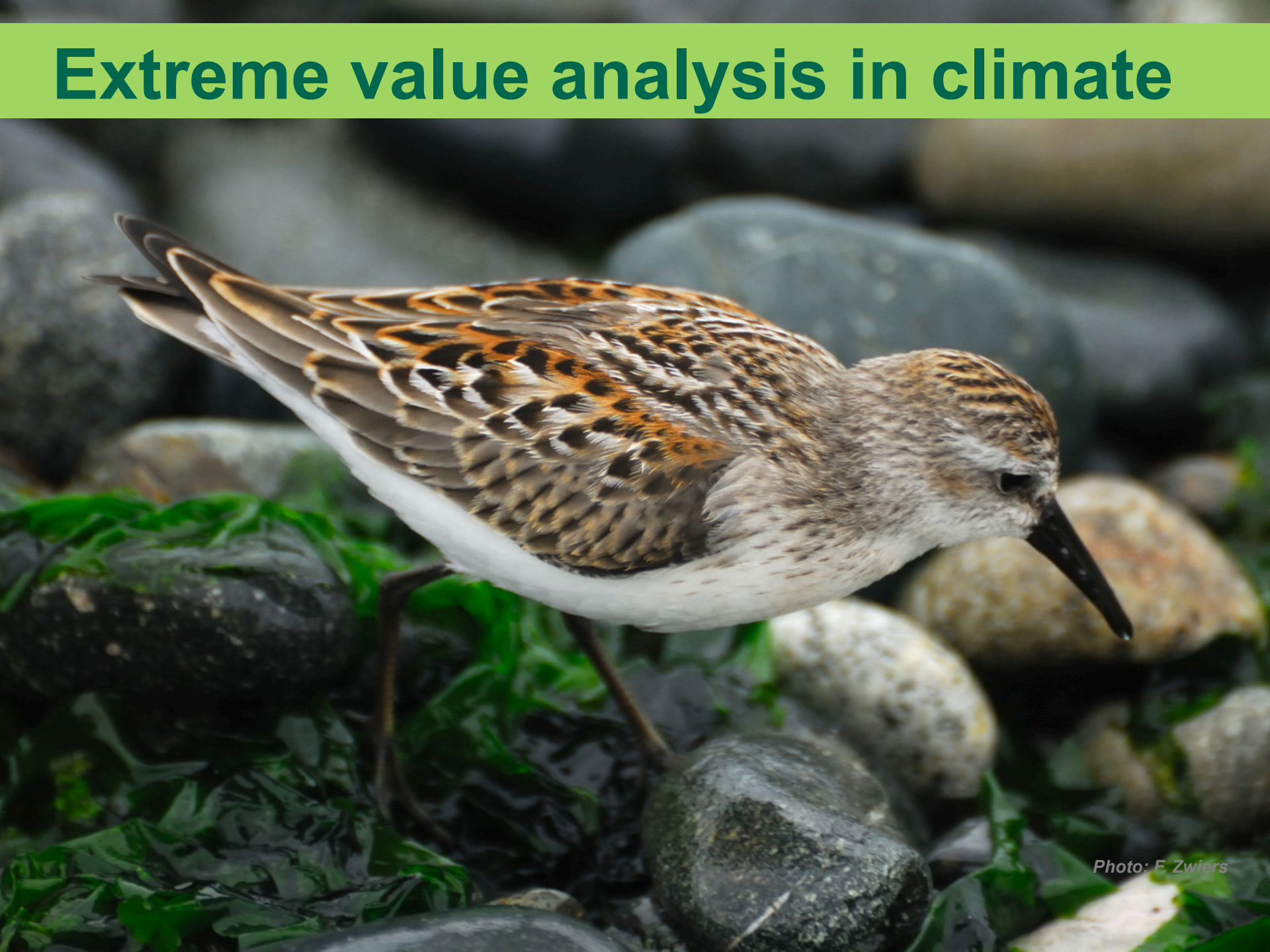
Note the change in scales



- All grid boxes
- Masked (grid boxes with at least one monthly GHCN-M report)
- Long term masked
- Anomalies from 1961-90 (full field)
- Anomalies from 1961-90 (masked field)

Wan et al (2013, Fig. 4)

Extreme value analysis in climate



Methods

- Mostly
  - Block maximum approach to EVA ➔ GEV distribution
  - Annual blocks of daily values
  - Point wise (spatial dependence not modelled)
  - Fitted via maximum likelihood with a "feasibility" constraint
  - Often with one or more GEV parameters dependent upon a covariate
- Also use a collection of "indices" coordinated through the ETCCDI

Trends in annual precip extremes

Westra et al, 2013, J Climate

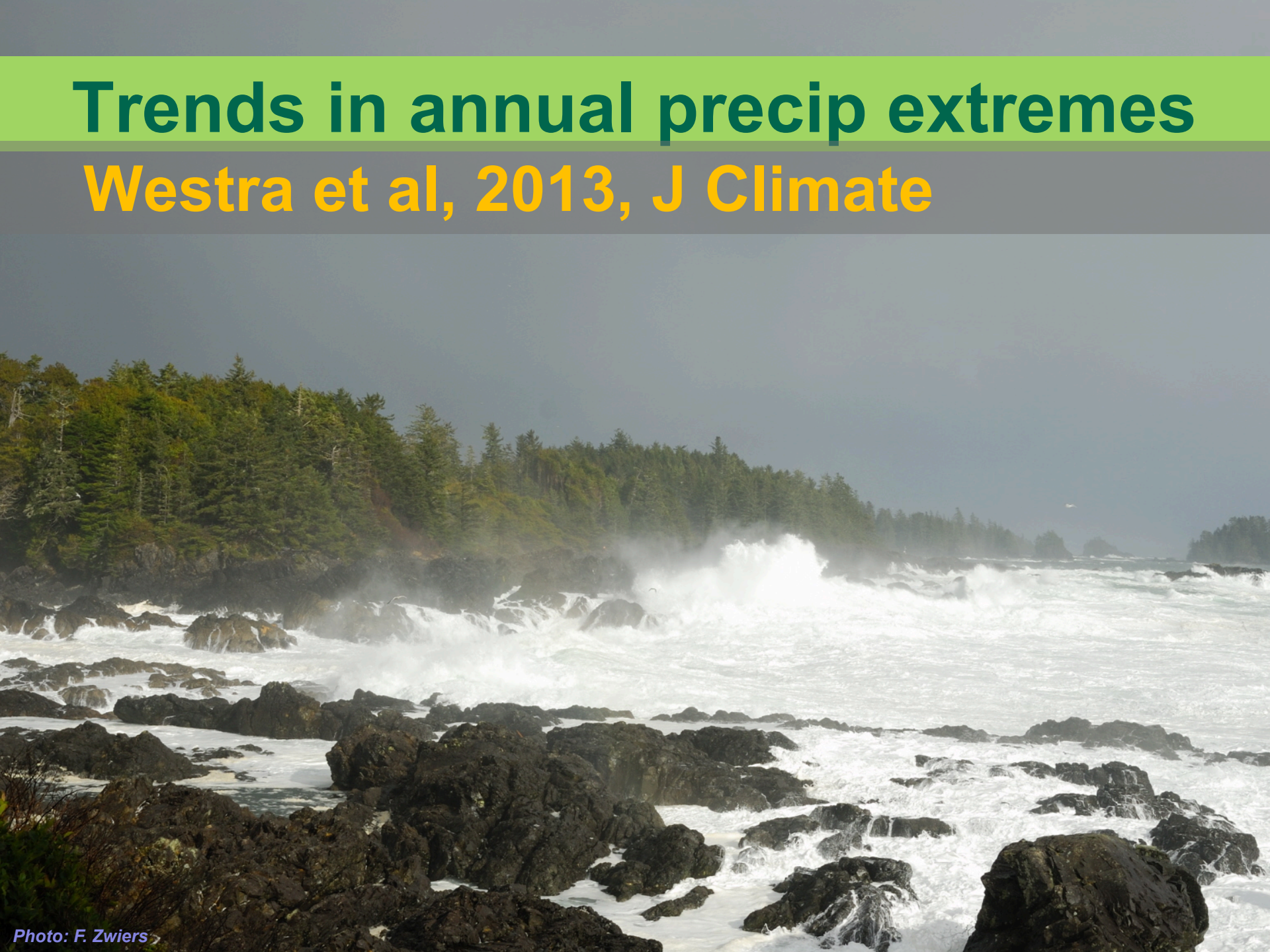
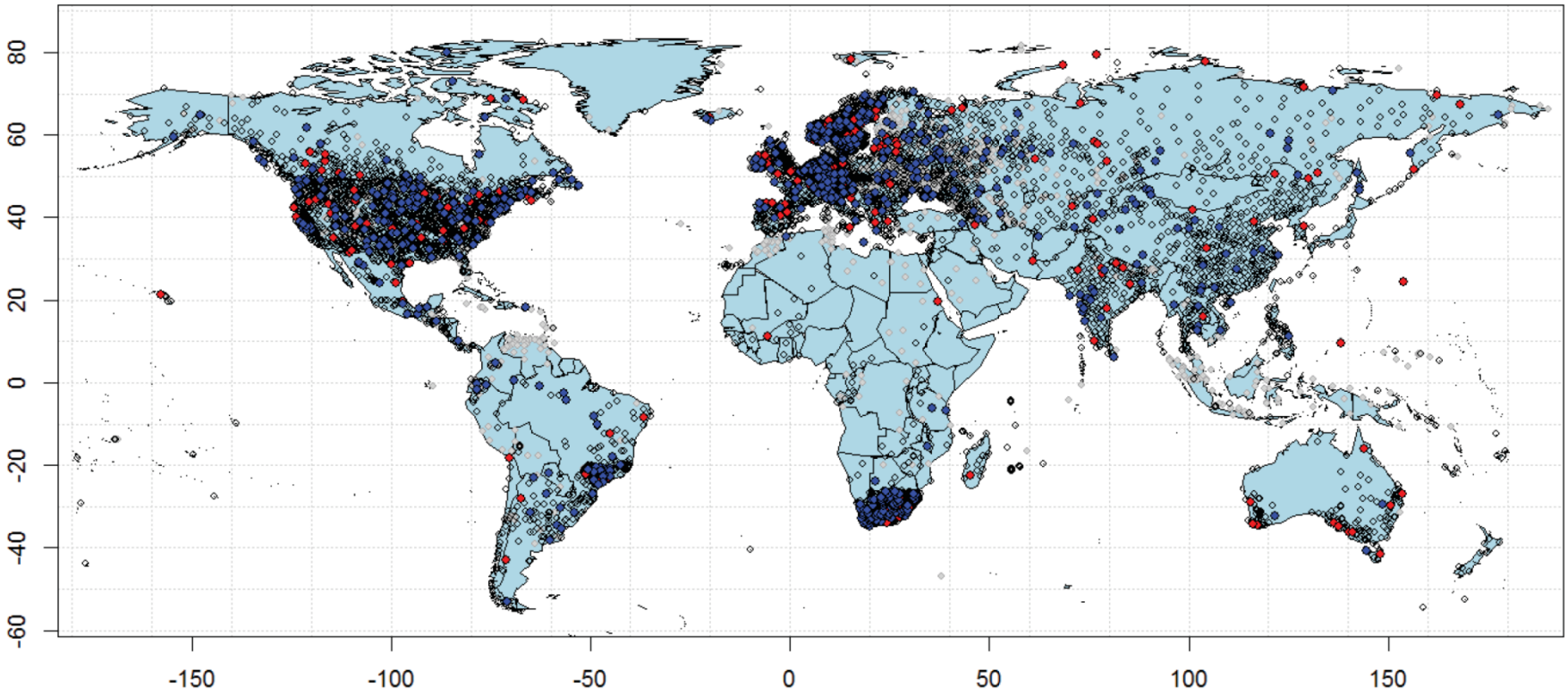


Photo: F. Zwiers

Observed local trends

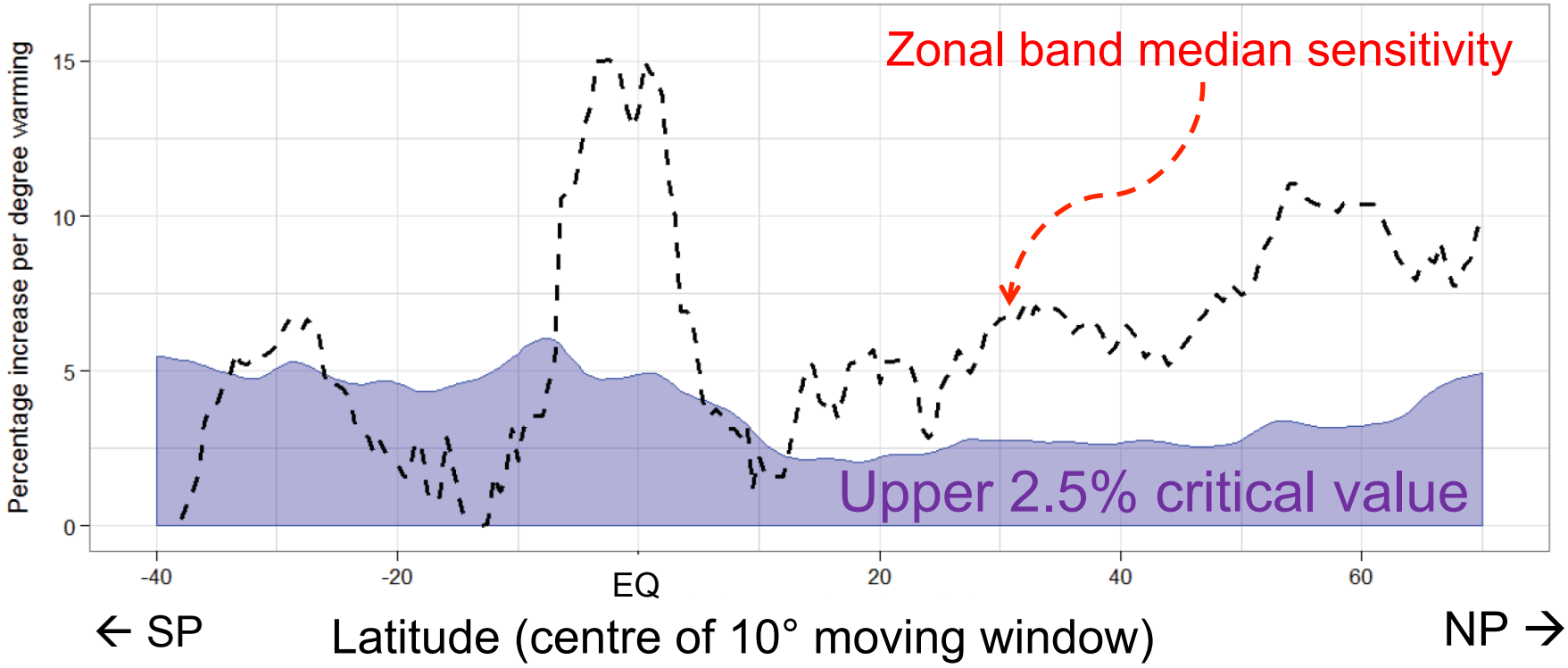


- 8376 stations with > 30 yrs data, median length 53 yrs
- Significant positive (8.5% of stations, expect 2.5%)
- Significant negative (2.2% of stations, expect 2.5%)
- Rejection rate similar everywhere

Westra et al (2013, Fig. 5)

Link with global mean temperature

- Use global mean temperature as a covariate in an extreme value analysis using the GEV distribution
- 64% of locations show a positive association
- Estimate of mean sensitivity over land is ~7%/K



Westra et al (2013, Fig. 5)

Questions arising …

- Is the apparent correlation spurious?
  - Would the Dow Jones Industrial Average correlate as well?
  - Co-integrating models used by econometricians do not extend easily to extremes …
- Need to use physical reasoning
  - Ensure that there is a physical basis for association with temperature
  - Explain why other explanations less plausible
- We'll come back to this …

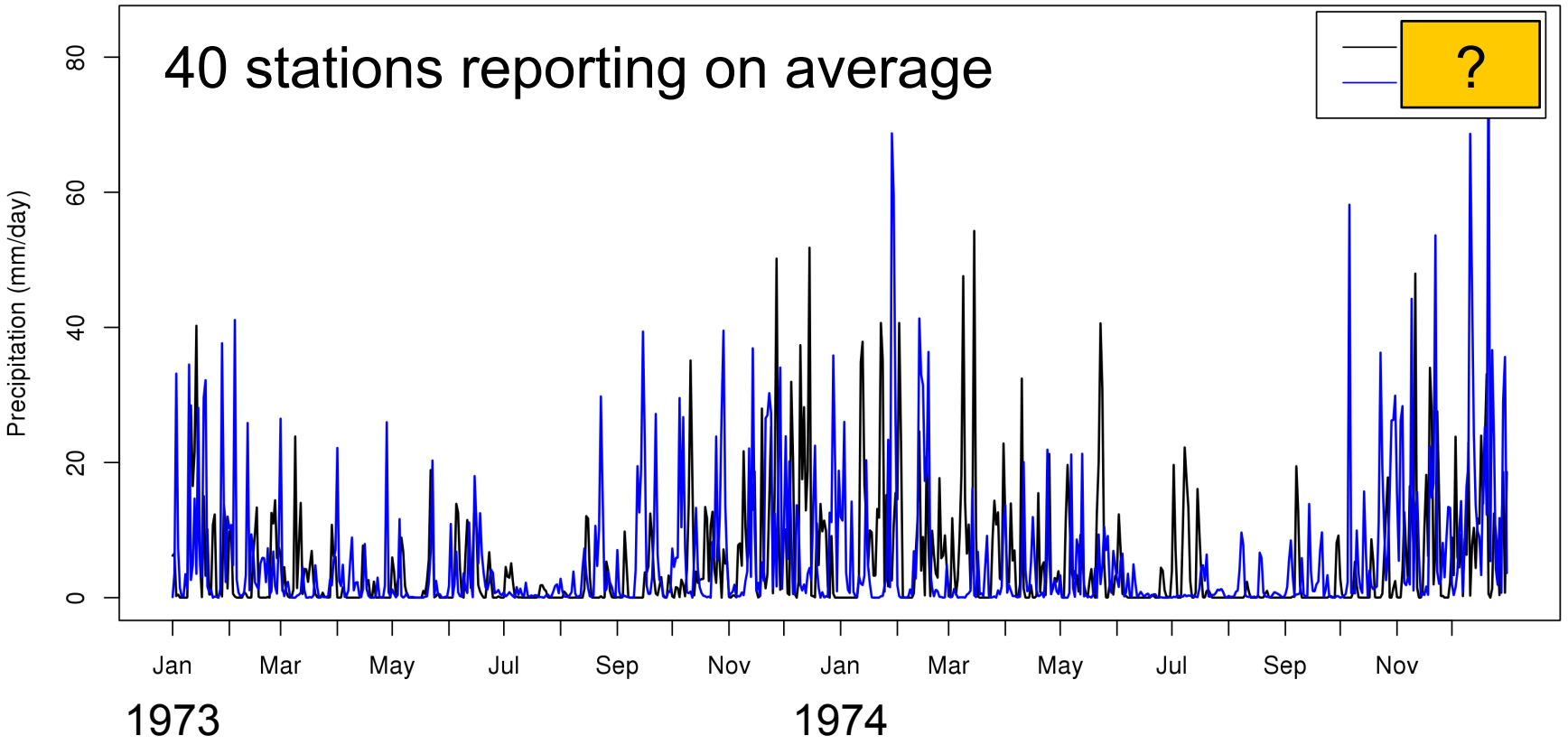
Extreme precipitation in CMIP5

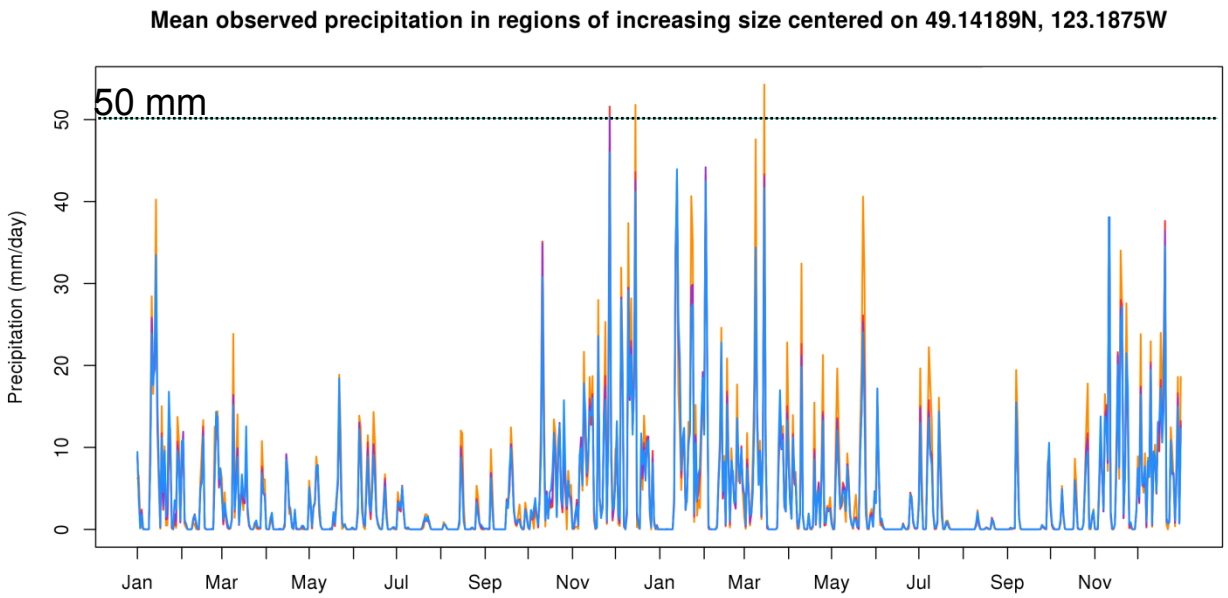
Kharin et al, 2013, Climatic Chang

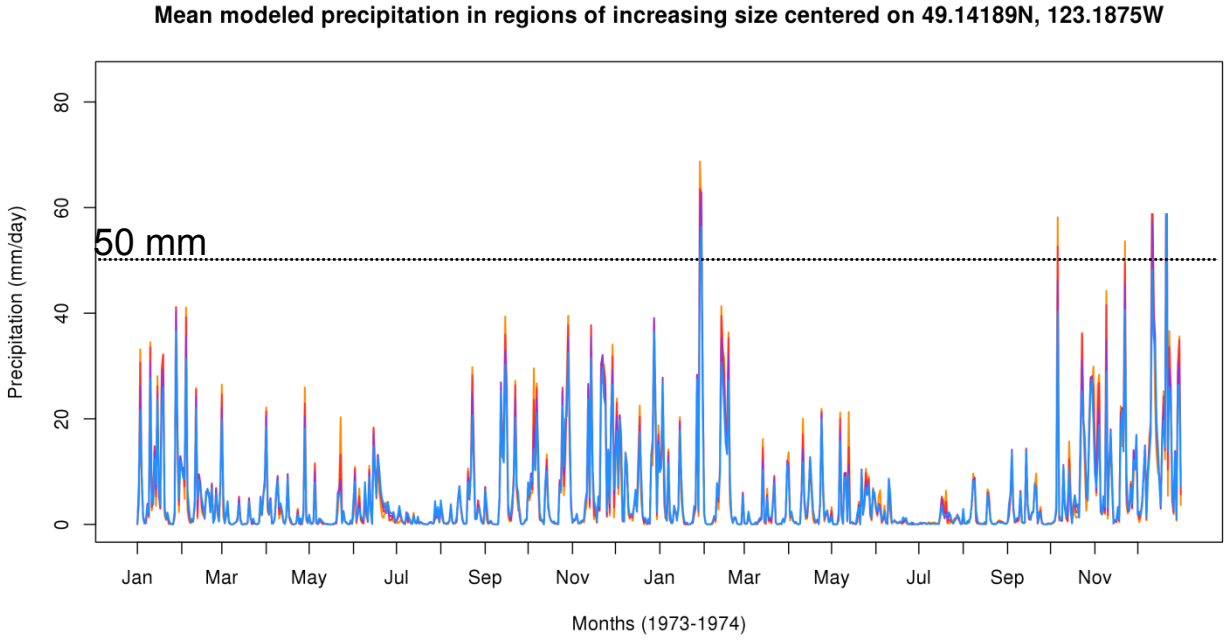
See also Sillmann et al, 2013a,b, JGR

Photo: F. Zwiers

Mean daily precipitation in the MIROC4h grid box centered on 49.1N, 123.2W (Vancouver)





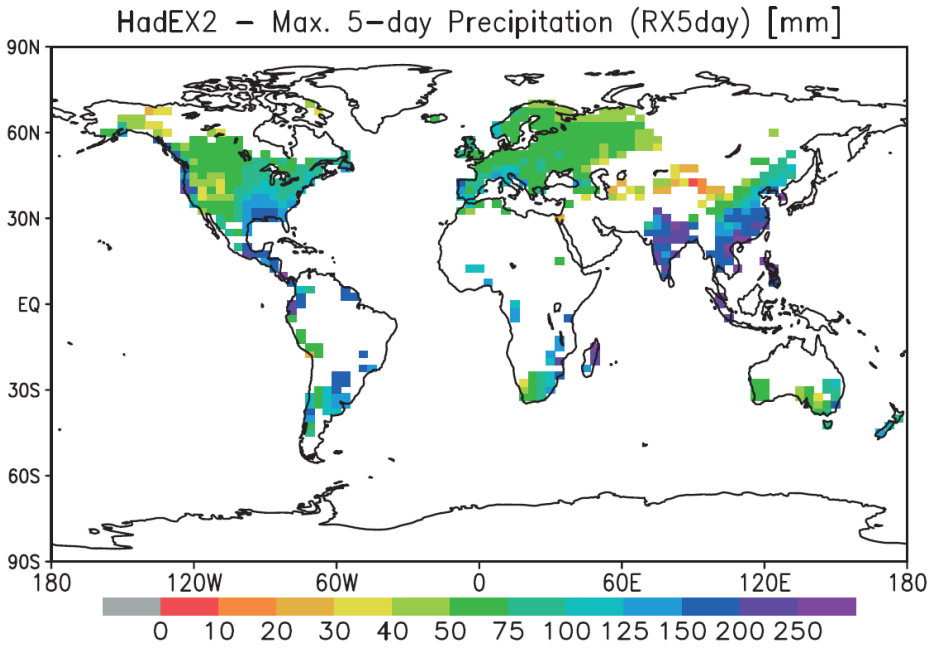


45km x 60km
(40 stations)
135km x 180km
(133 stations)
225km x 300km
(160 stations)
315km x 420km
(196 stations)

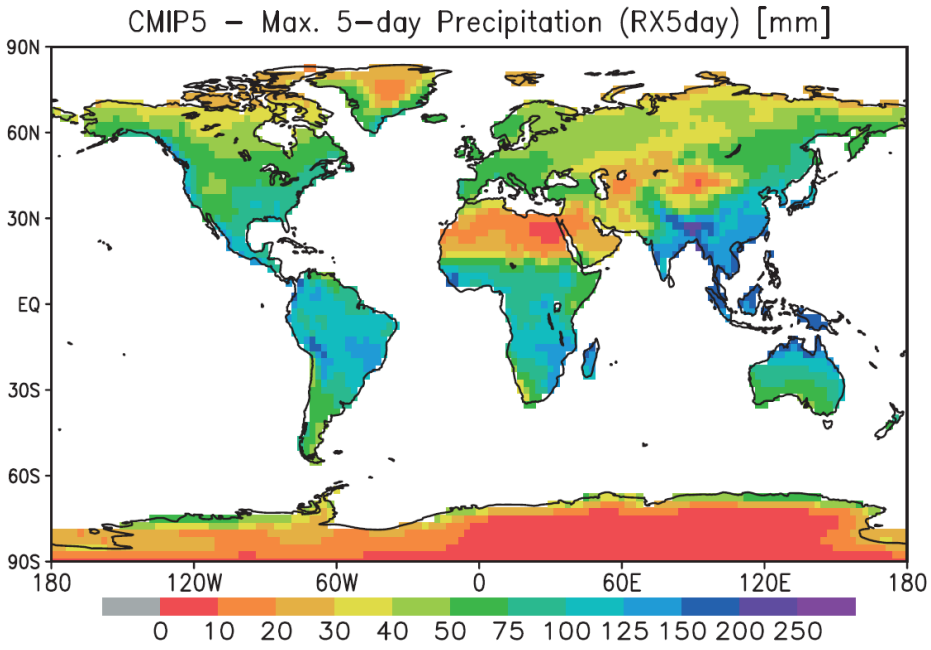
Courtesy B. Veerman, PCIC

5-day precip extremes (1981-2000)

HadEX2



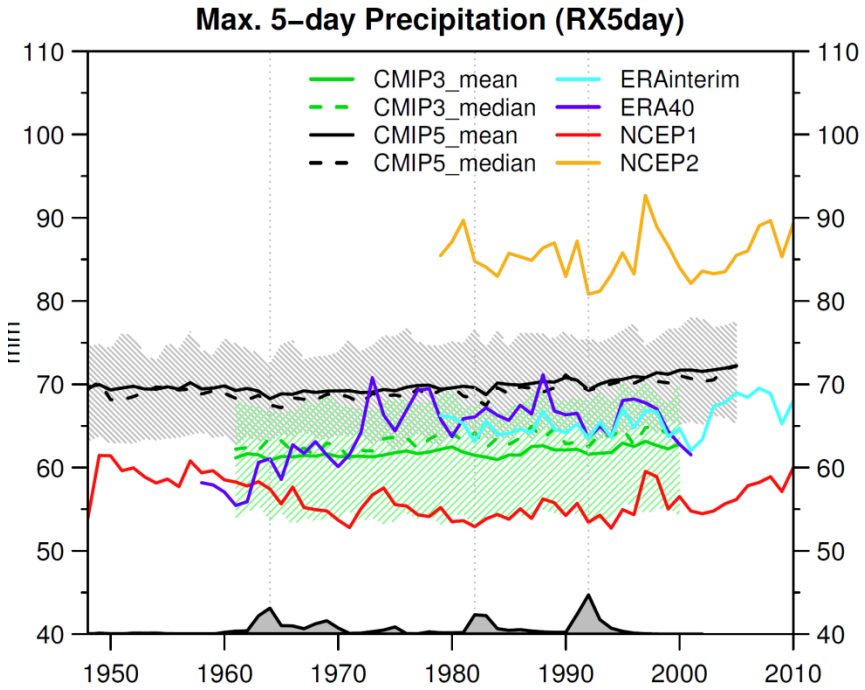
CMIP5 – 31 models



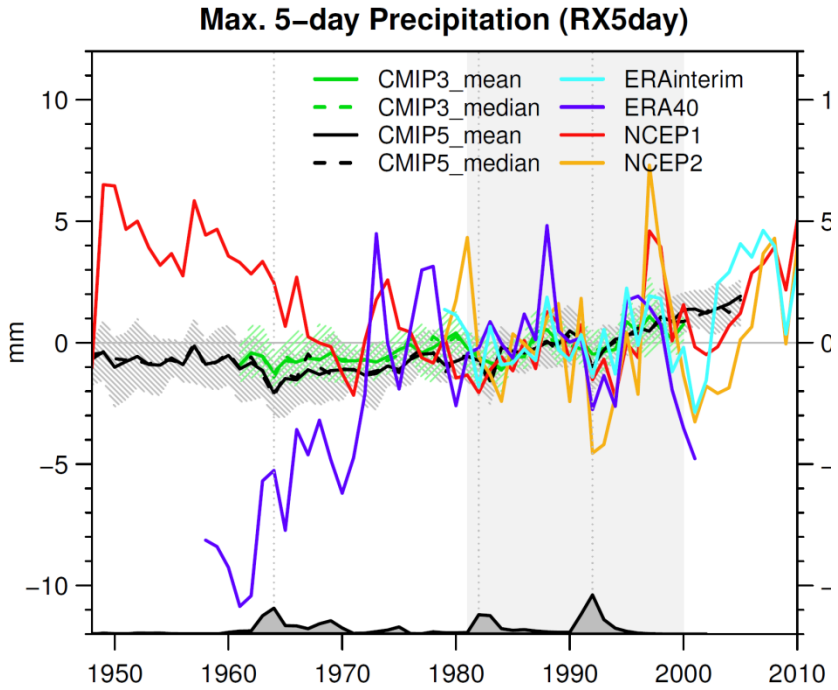
Sillmann et al (2013a, Fig. 6)

5-day precip extremes (trends)

Global land mean (full fields)

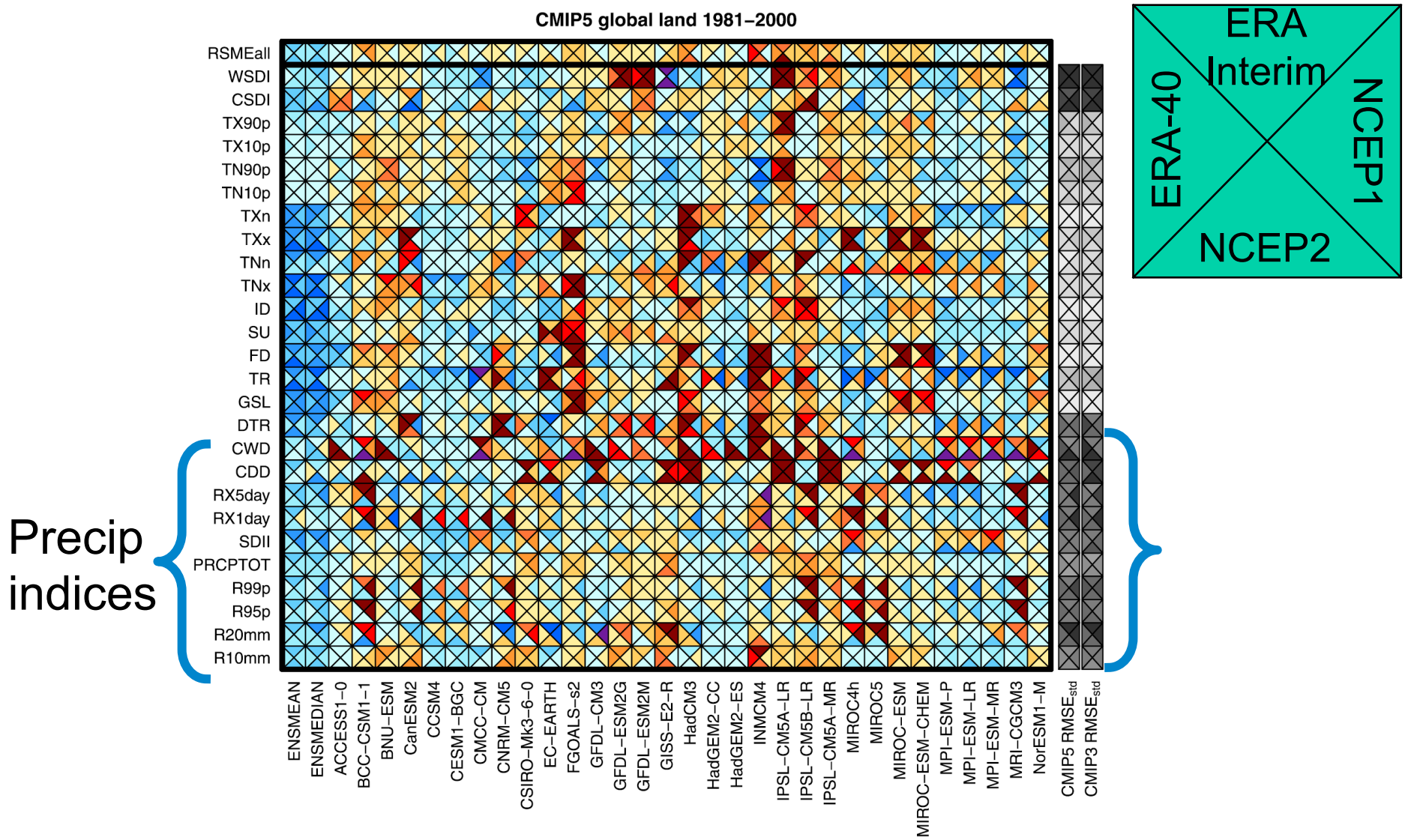


Global land mean anomalies relative to 1981-2000



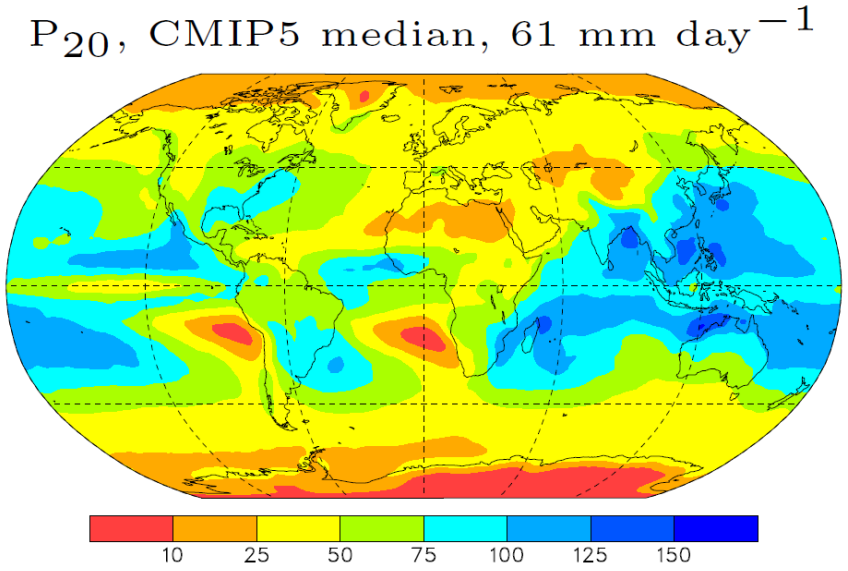
Sillmann et al (2013a, Fig. 8)

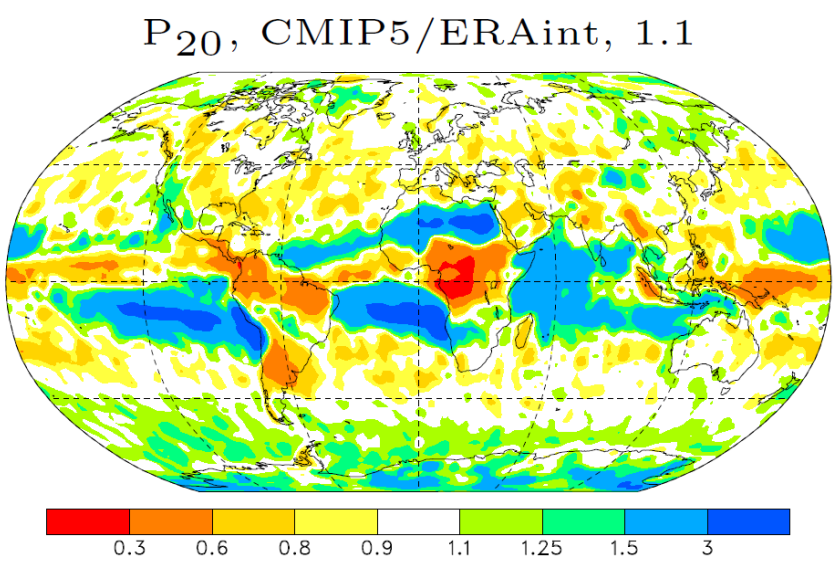
Overall evaluation of indices



Sillmann et al (2013a, Fig. 10)

20-year 1-day precip events (1986-2005)

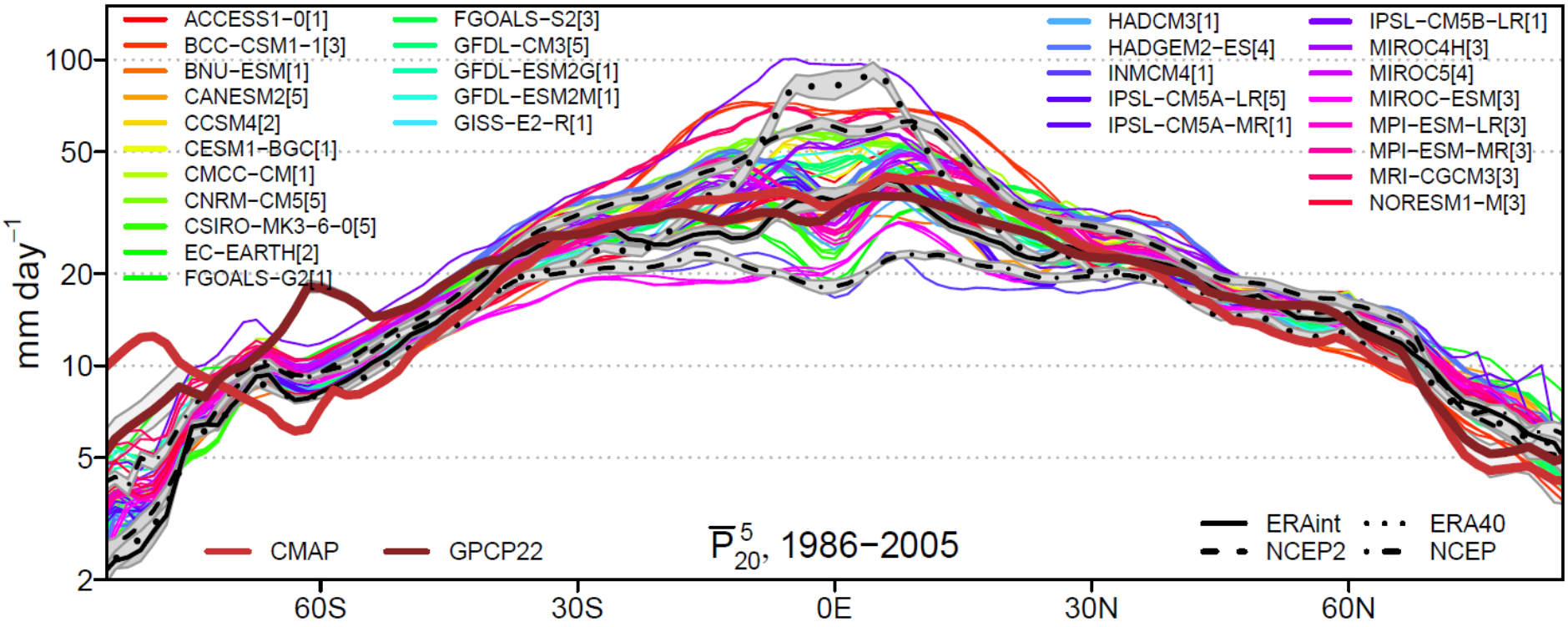




- Models compare reasonably well with reanalyses in mid-latitudes
- Great uncertainty in the tropics
- Note that precipitation is a “Type C” reanalysis product (i.e., no direct observational constraints and thus reanalysed values are predominately determined by the model)

Kharin et al (2013, Fig. 1)

Zonal means of 20-yr 5-day events



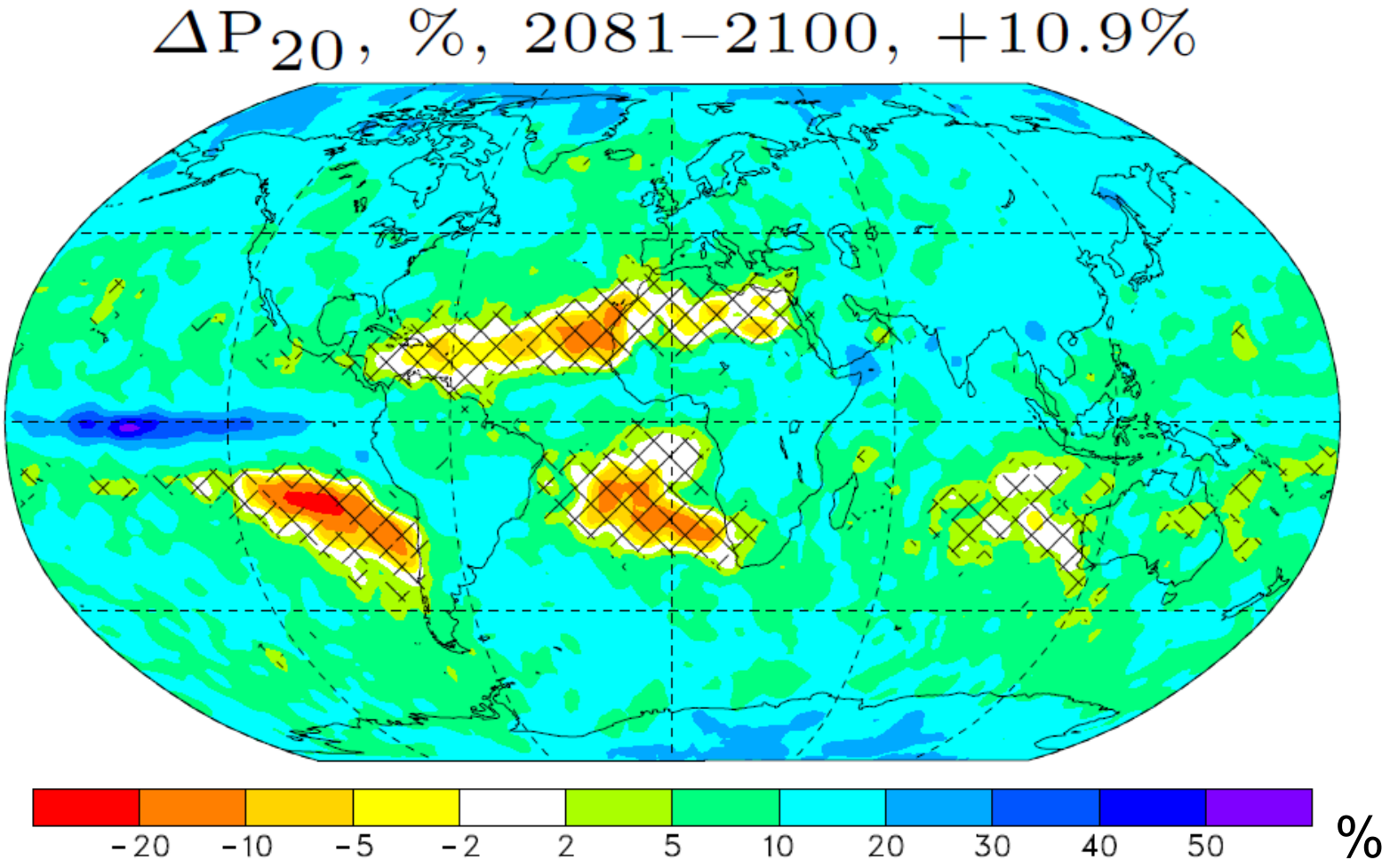
- Median model (not shown) compares quite well with GPCP and CMAP
- Models compare reasonably well with reanalyses at mid-latitudes
- Question of whether models reproduce precip correctly on resolved scales remains open

Kharin et al (2013, Fig. S5)

Projections

CMIP5 RCP4.5 precipitation projections

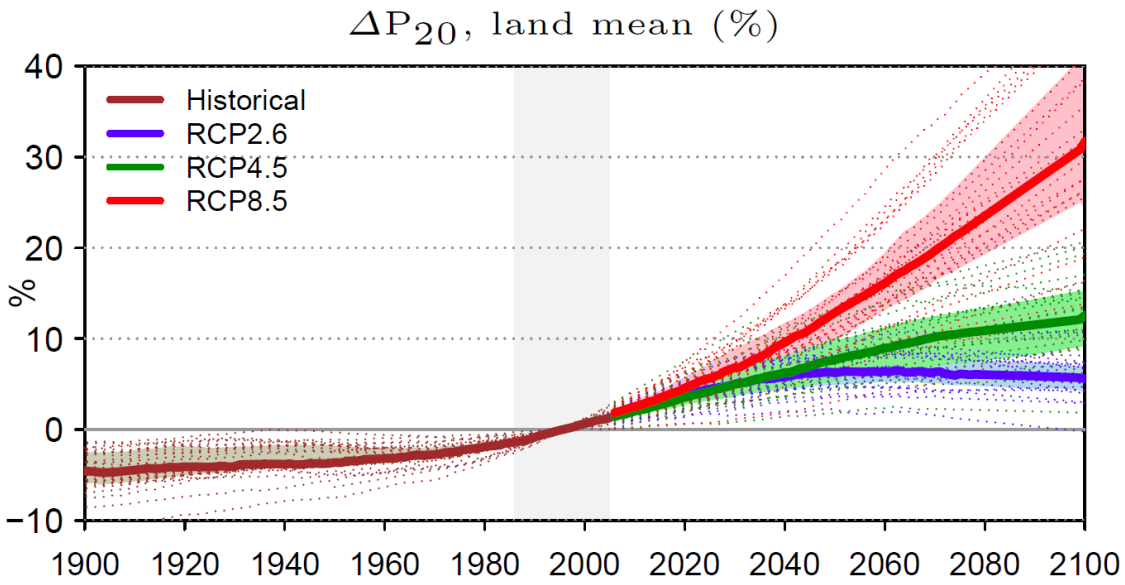
Change in 20-yr extremes relative to 1986-2005



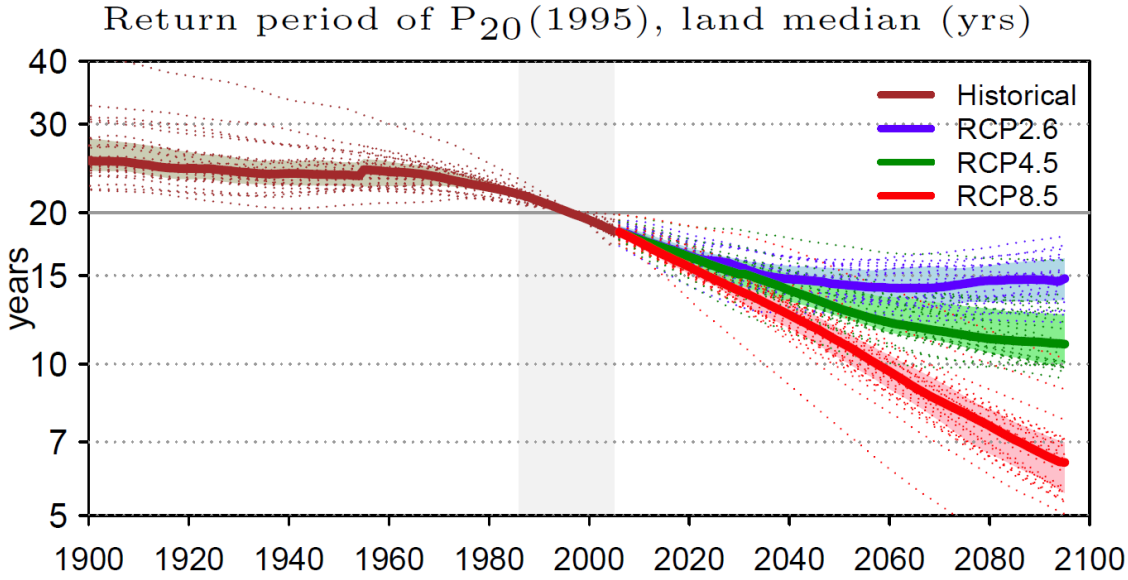
Kharin et al (2013, Fig. 4)

CMIP5 Projections of 20-yr 1-day events

Event magnitude
(relative to 1986-2006)



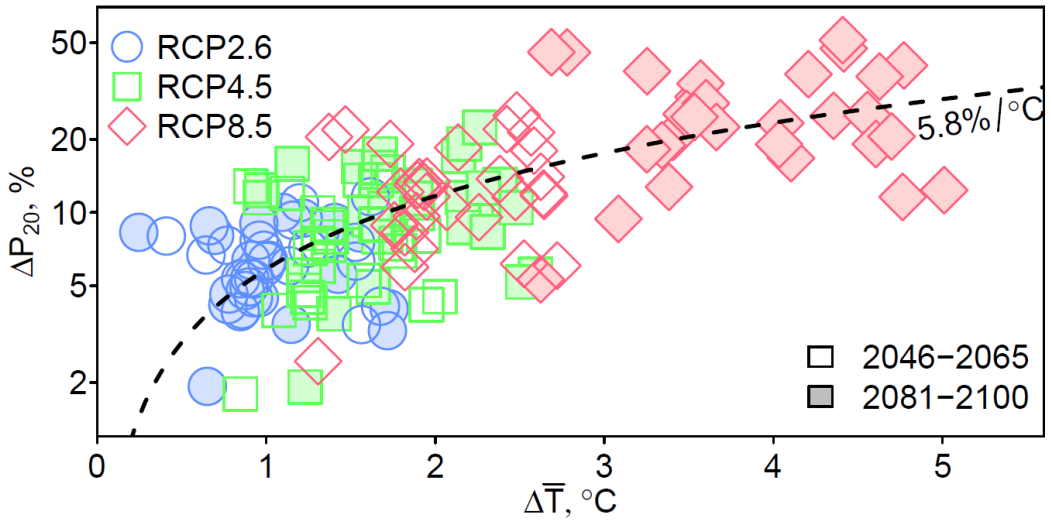
Return period
(relative to 1986-2006)



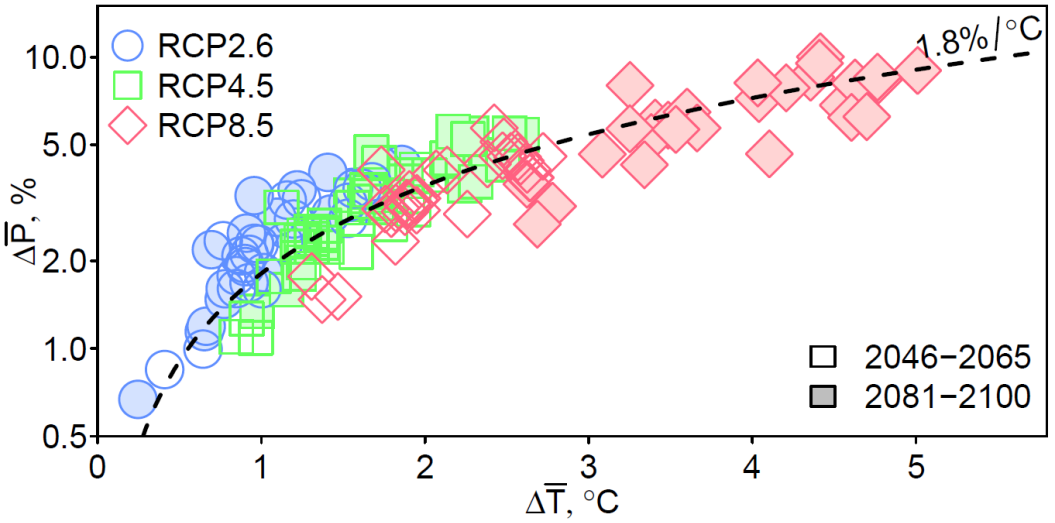
Kharin et al (2013, Fig. 2)

CMIP5 precipitation sensitivity

Planetary sensitivity of 20-year extremes



Sensitivity of global mean precipitation



Kharin et al (2013, Fig. 5)

Detection of human influence

Min et al, 2011, Nature

Zhang et al, 2013, submitted

Detection and attribution

- Standard D&A paradigm

$$\mathbf{Y} = \sum_{i=1}^{s} (\mathbf{X}_i - \boldsymbol{\delta}_i)\beta_i + \boldsymbol{\varepsilon}$$

- Approaches for extremes
  - Indices + standard paradigm
  - Transform + standard paradigm
  - Use standard paradigm to make inferences about changing extreme value distribution parameters
  - Include covariates in EV distribution parameters

University of Victoria

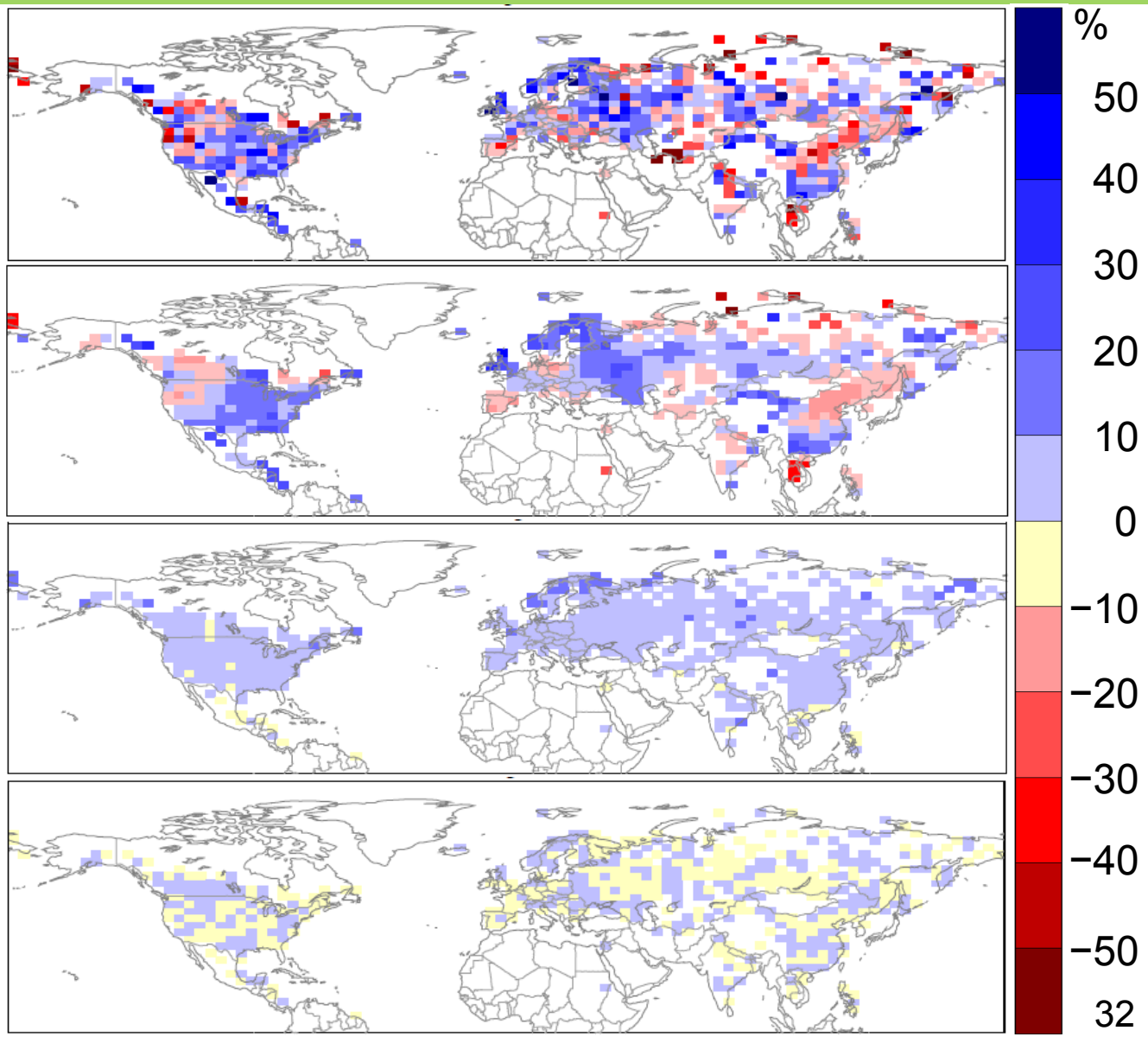
PI Trends (RX1D; 1951-2005)

OBS
(HadEX2 + Russia)

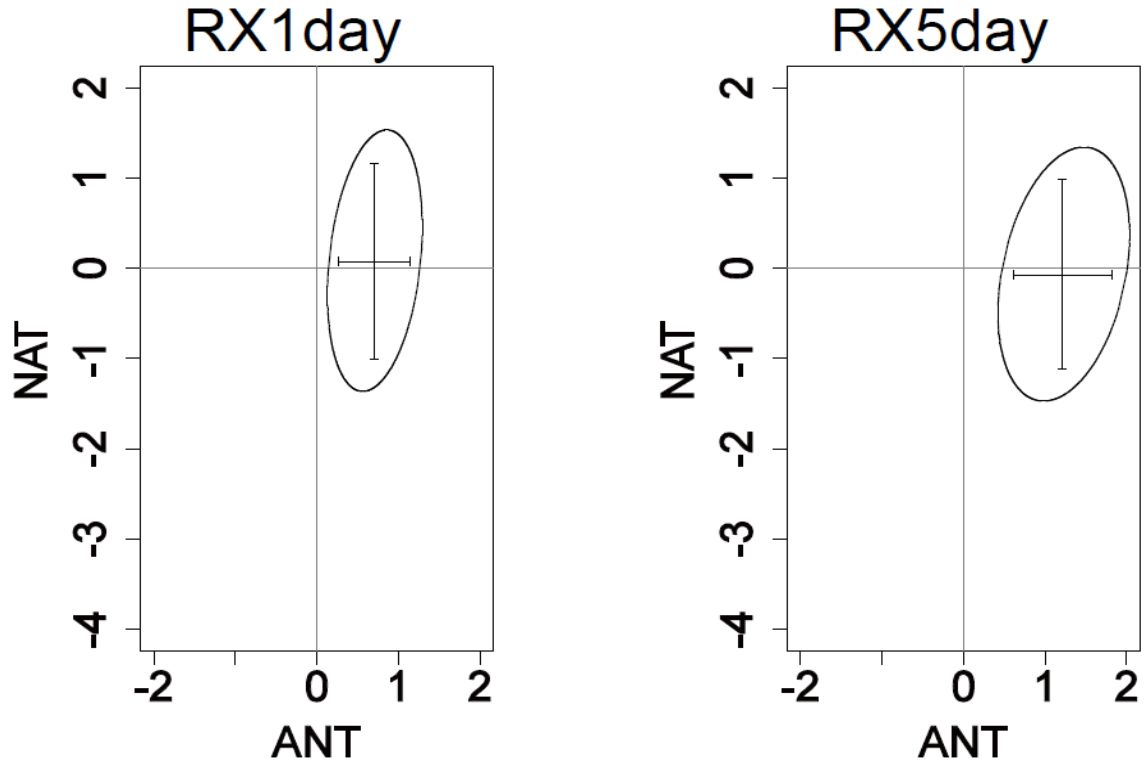
OBS
(Smoothed)

ALL

NAT



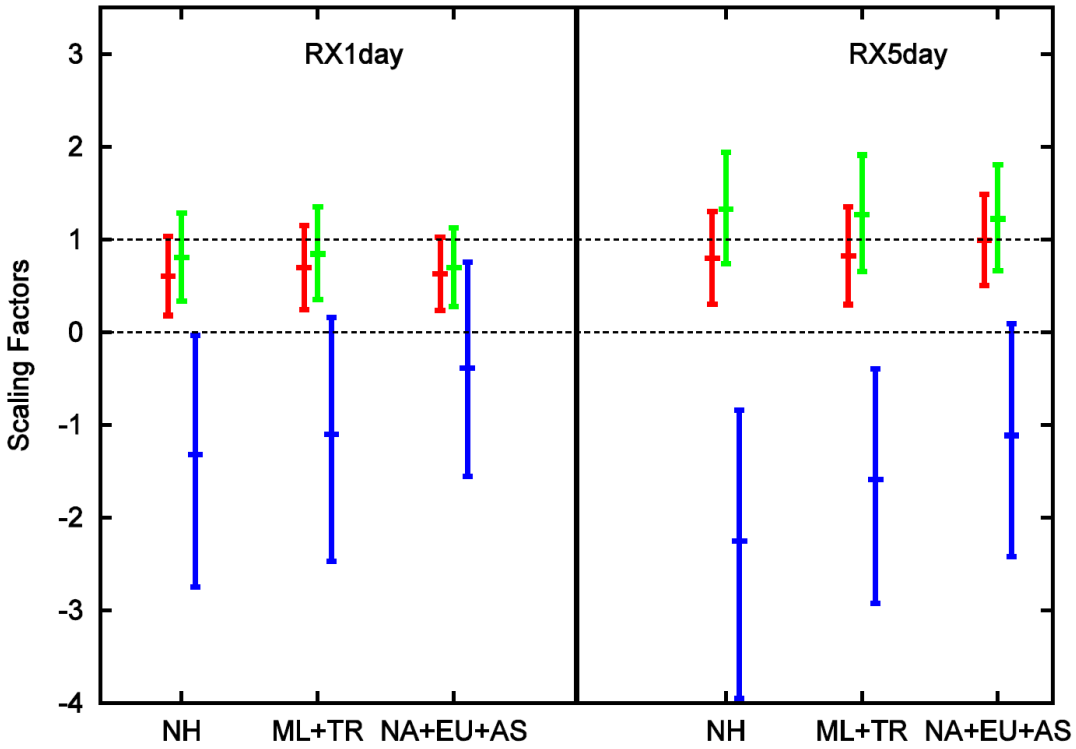
Detection results – 1951-2005



- Space-time (3 regions, 5 year means)
- 54 ALL runs (14 models), 34 NAT runs (9 models)
- No dimension reduction (>15000 years control, 31 models)

Detection results – 1951-2005

- ALL
- ANT
- NAT



- Single signal analysis
- 5-year, with 1, 2 or 3 spatial dimensions

Question arising …

- Is the detection spurious?

- Need to use physical reasoning
  - Ensure that there is a physical basis for association with temperature
  - Explain why other explanations less plausible

- But the space-time fingerprint does not discriminate very well …

$$\mathbf{Y} = \sum_{i=1}^{s} (\mathbf{X}_i - \boldsymbol{\delta}_i)\beta_i + \boldsymbol{\varepsilon}$$

Summary/Discussion

Photo: F. Zwiers

Summary/Discussion

- Making (very) slow progress on data
- Data limitations hinder detection (and attribution)
  - Longer records help, even if coverage is sparser
- Observed changes in precipitation extremes appear to follow the Clausius-Clapeyron relation
- It remains unclear whether models are really deficient in simulating precipitation change on the scales that they resolve
- CMIP5 provides some improvements over CMIP3 but uncertainties in reanalyses are at least as large as in free running models

Summary/Discussion

- Globally, model simulated changes in precipitation extremes follow C-C, but simulated precipitation sensitivity over land may be somewhat lower than observed
- Formal detection and attribution of change in precipitation extremes remains a challenge
  - Emerging global scale signal
  - There is not a lot of spatial structure to exploit
  - Regionally, natural variation dominates
  - Methods remain a challenge

Questions?

Photo: F. Zwiers

Photo: F. Zwiers