Some applications of EVA in climate science

Photo: F. Zwiers

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Outline

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

Photo: F. Zwiers

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

Trends in annual precip extremes

Westra et al, 2013, J Climate

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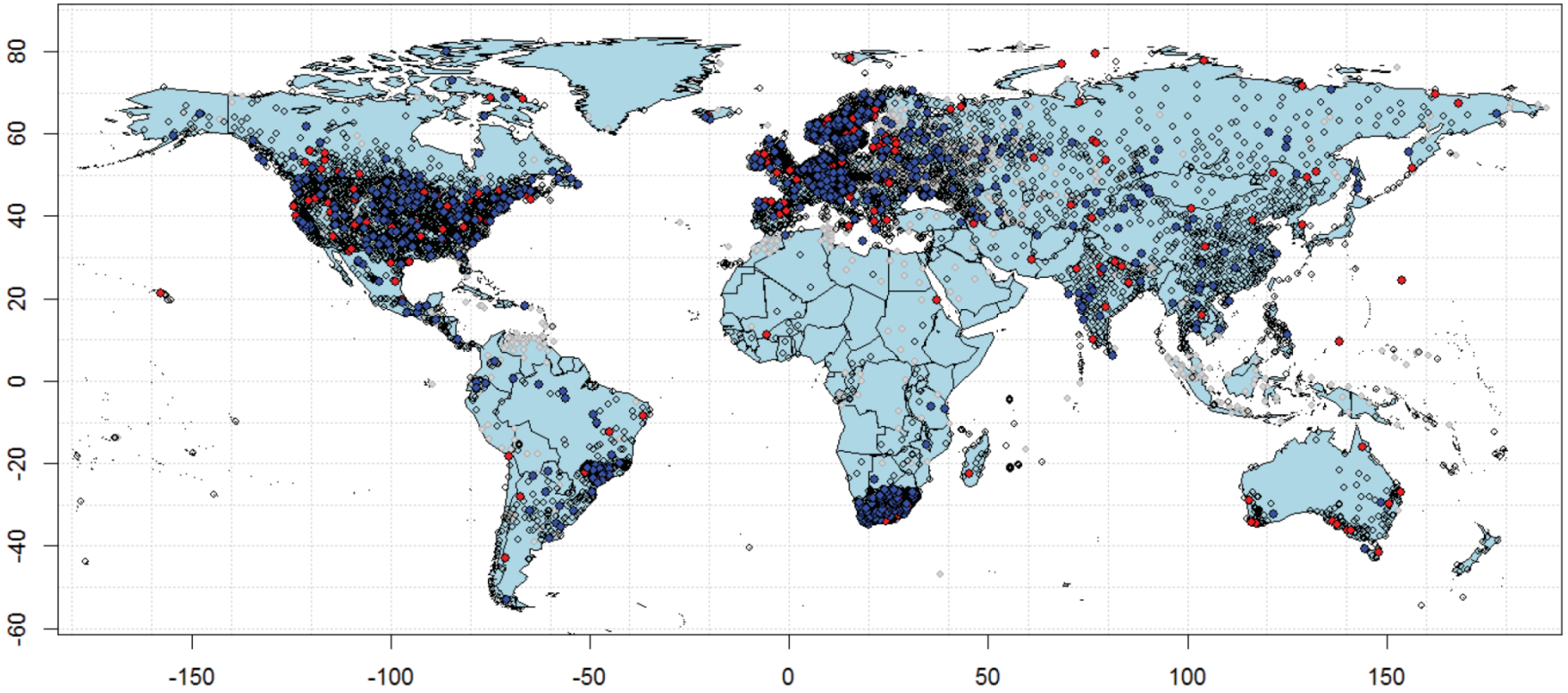
Observed local trends

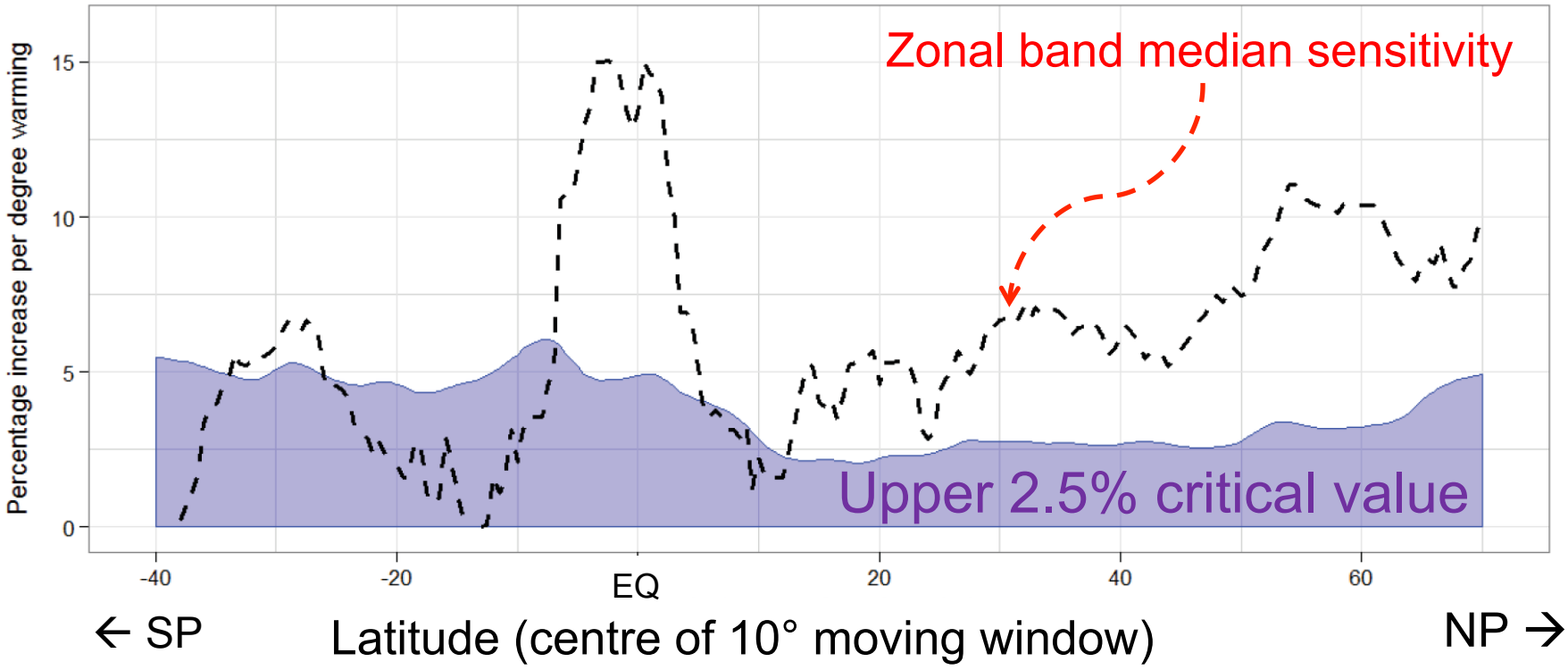


- 8376 stations with > 30 yrs data, median length 53 yrs
- Significant positive (8.5% of stations, expect 2.5%)
- Significant negative (2.2% of stations, expect 2.5%)
- Rejection rate similar everywhere

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

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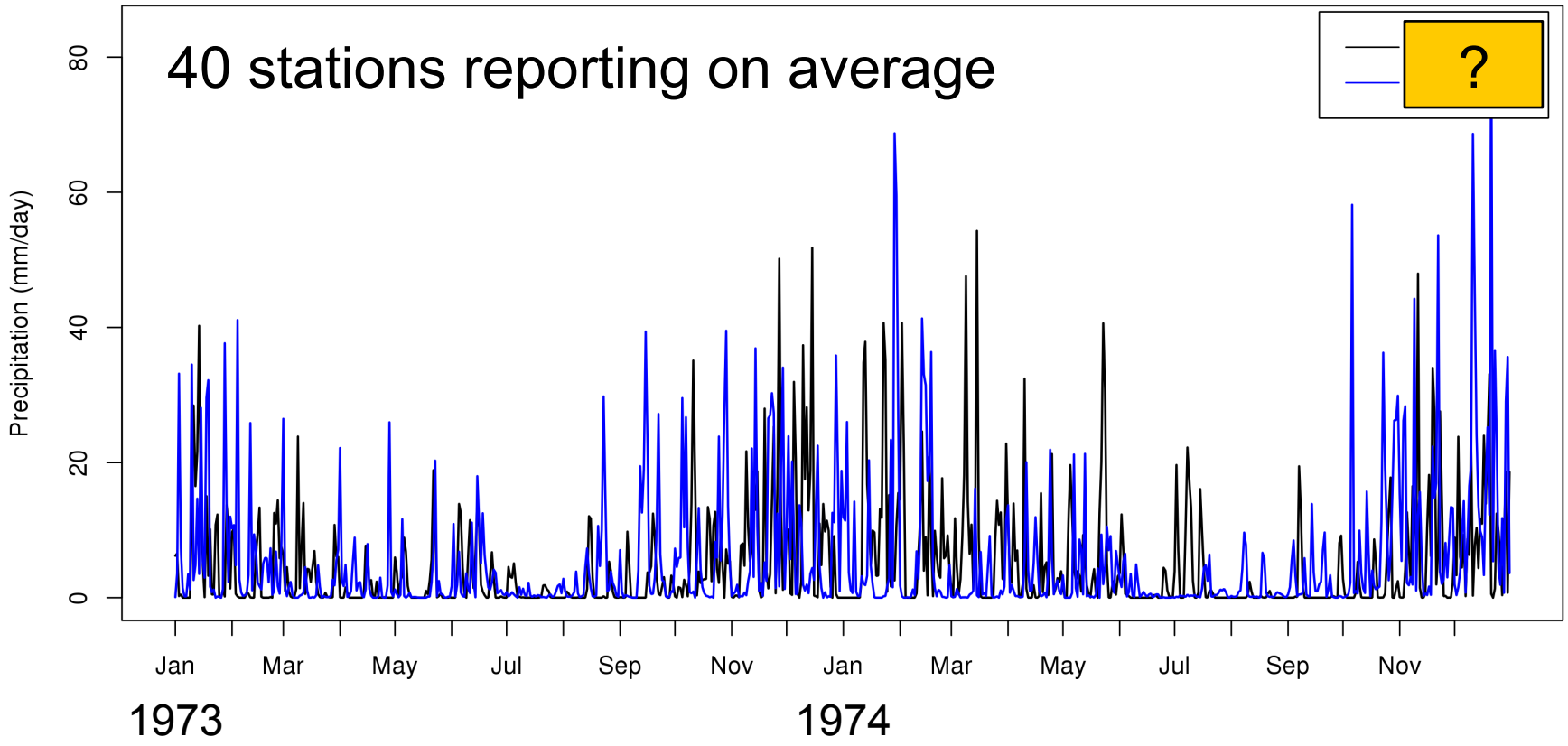
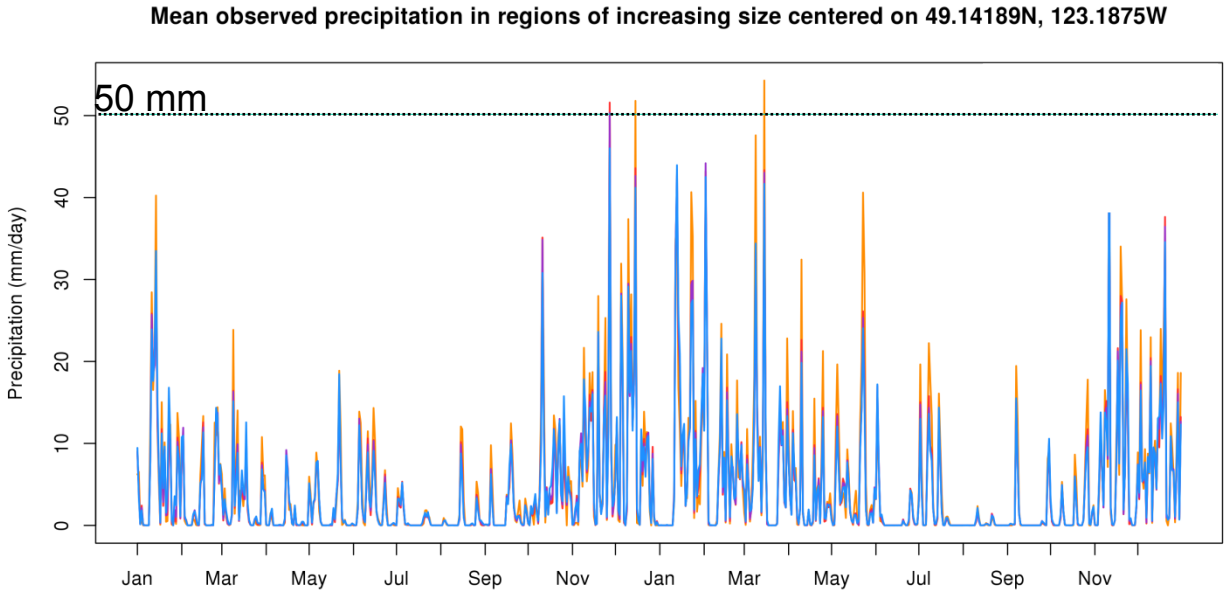
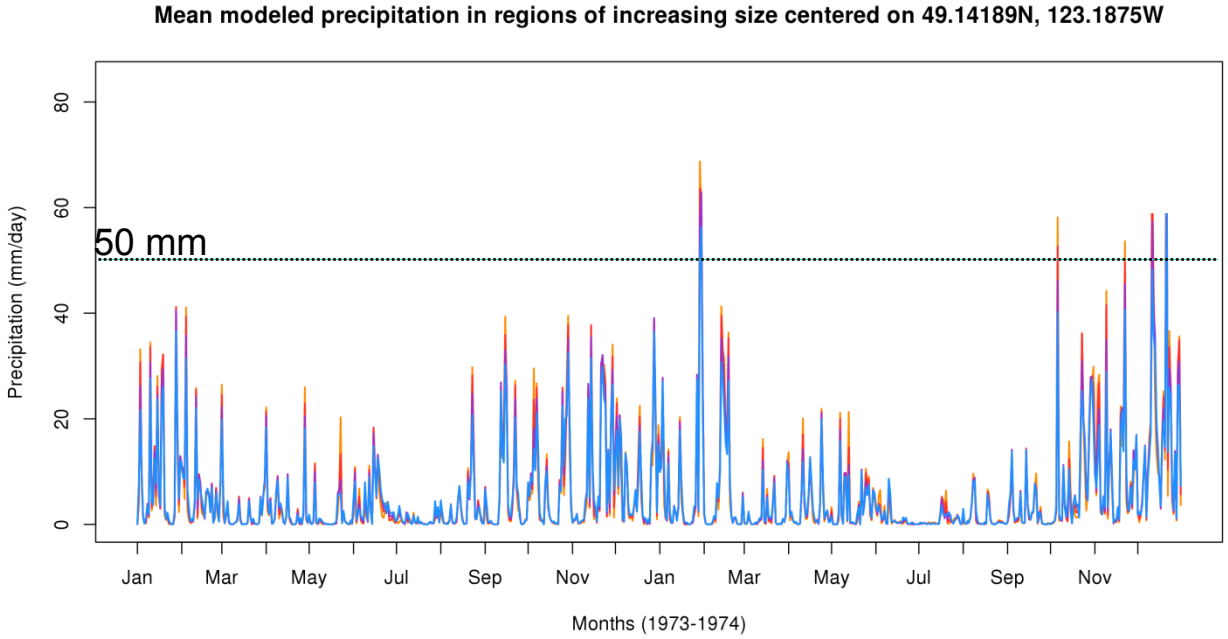
Mean daily precipitation in the MIROC4h grid box centered on 49.1N, 123.2W (Vancouver)



Courtesy B. Veerman, PCIC

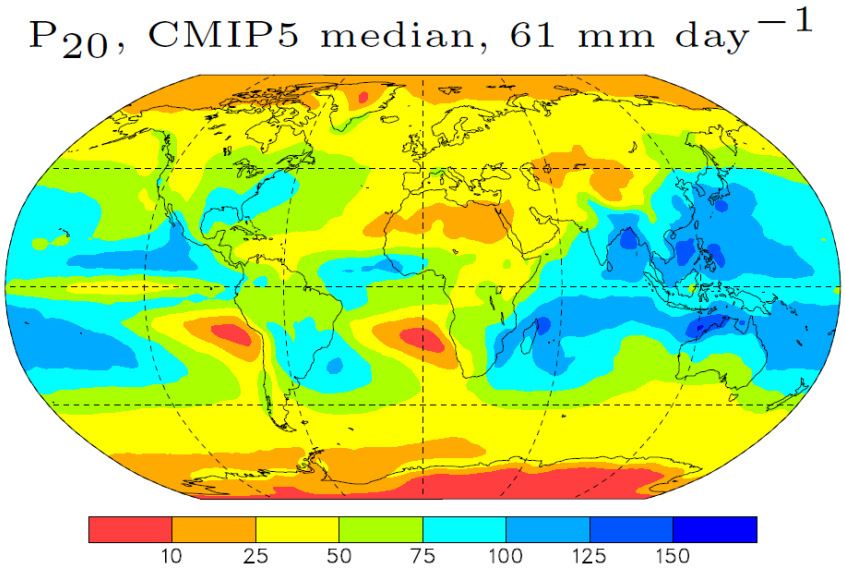


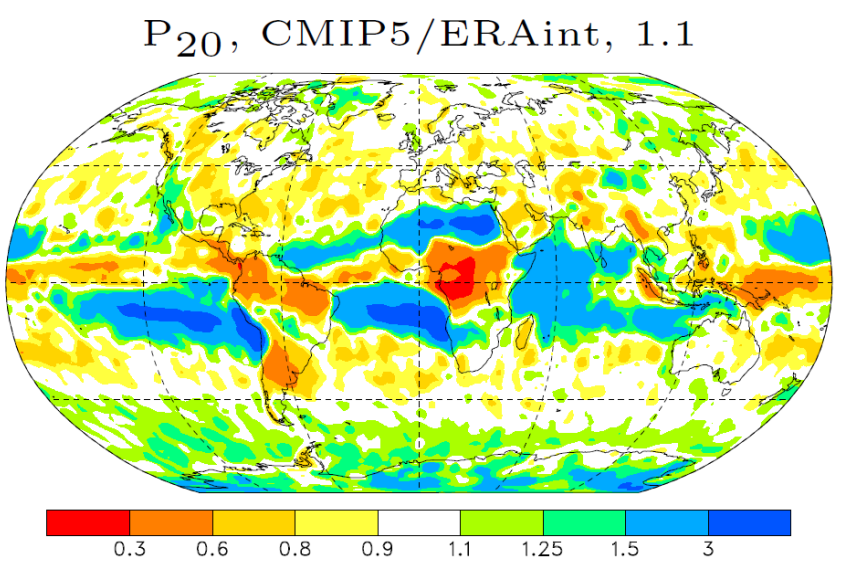


45km x 60km
(40 stations)
135km x 180km
(133 stations)
225km x 300km
(160 stations)
315km x 420km
(196 stations)

Courtesy B. Veerman, PCIC

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)

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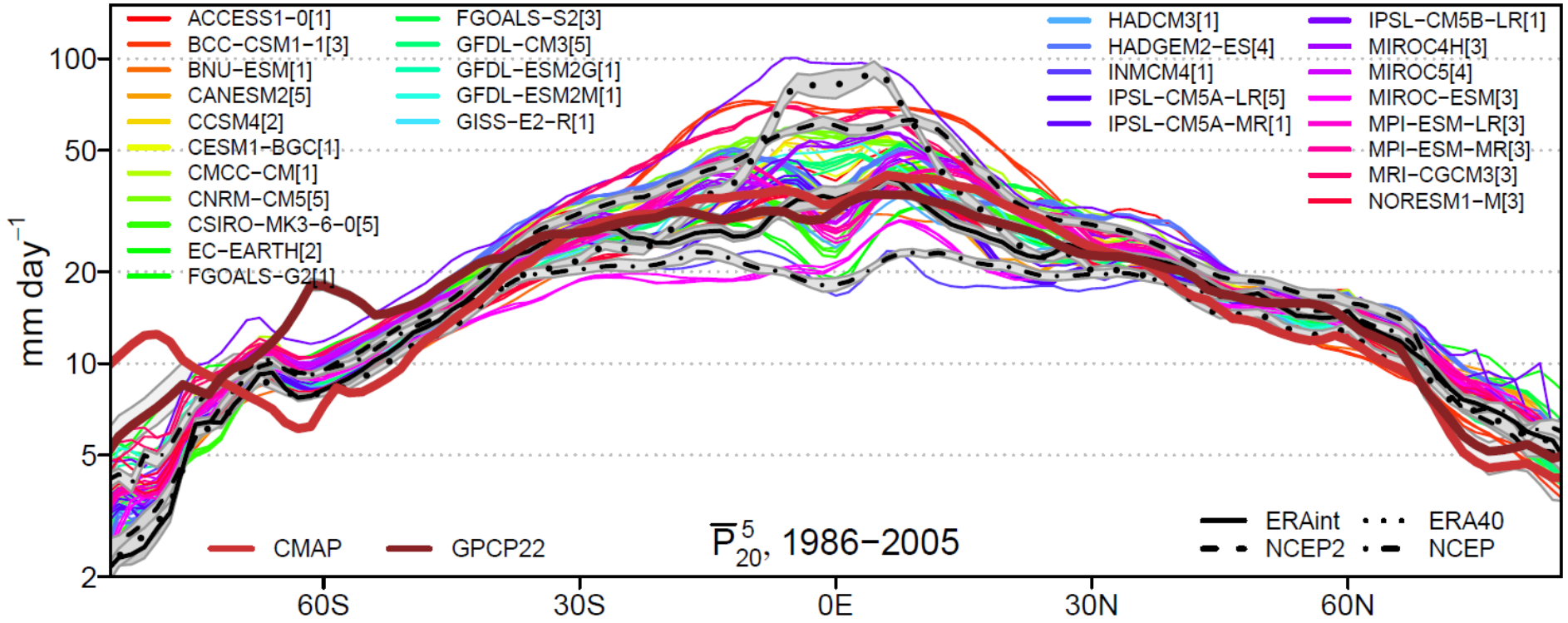
Zonal means of 20-yr 5-day events



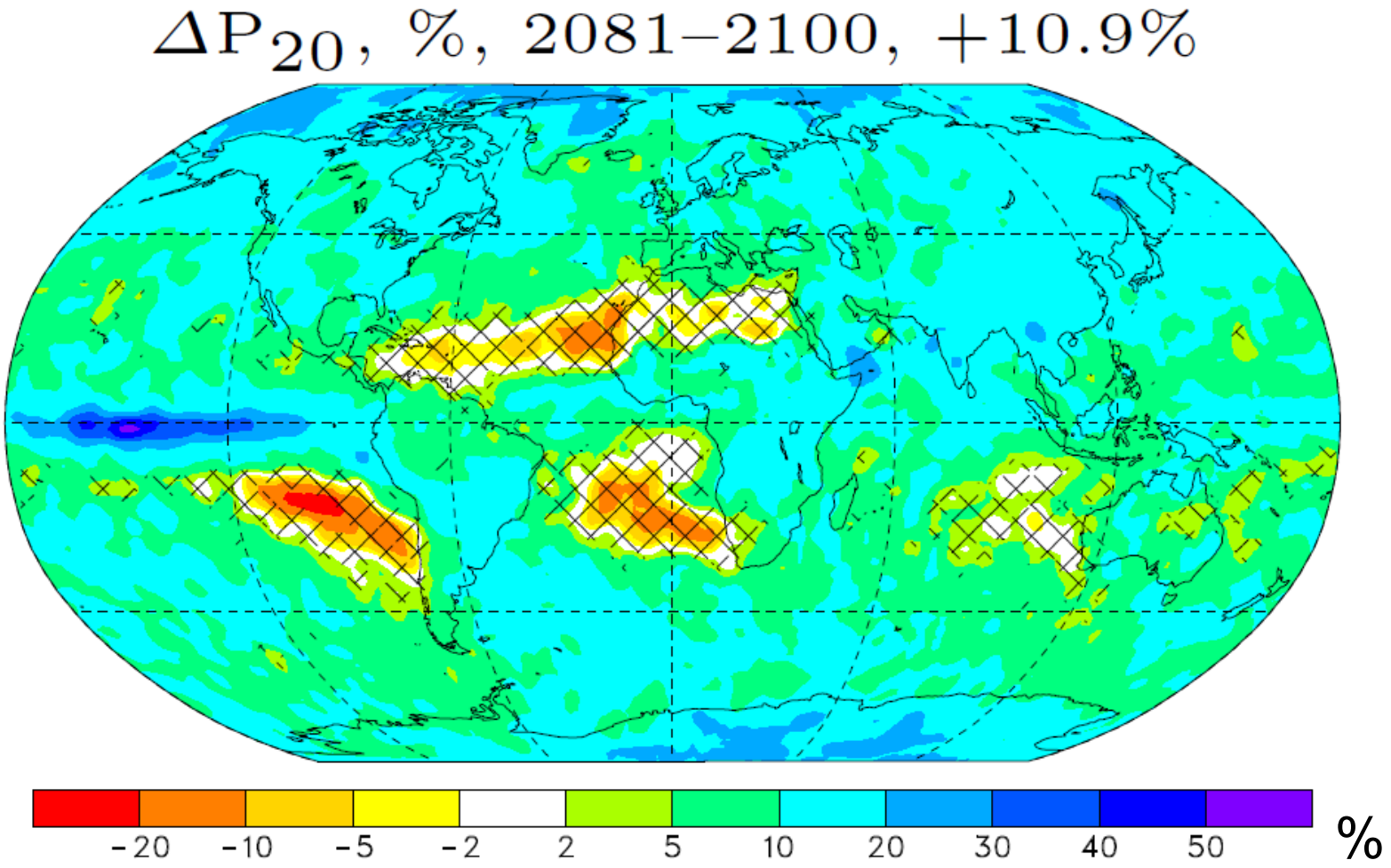
- Median model (not shown) compares quite well with GPCP and CMAP
- Models compare reasonably well with reanalyses at mid-latitudes
- Question of whether models reproduce precip correctly on resolved scales remains open

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)

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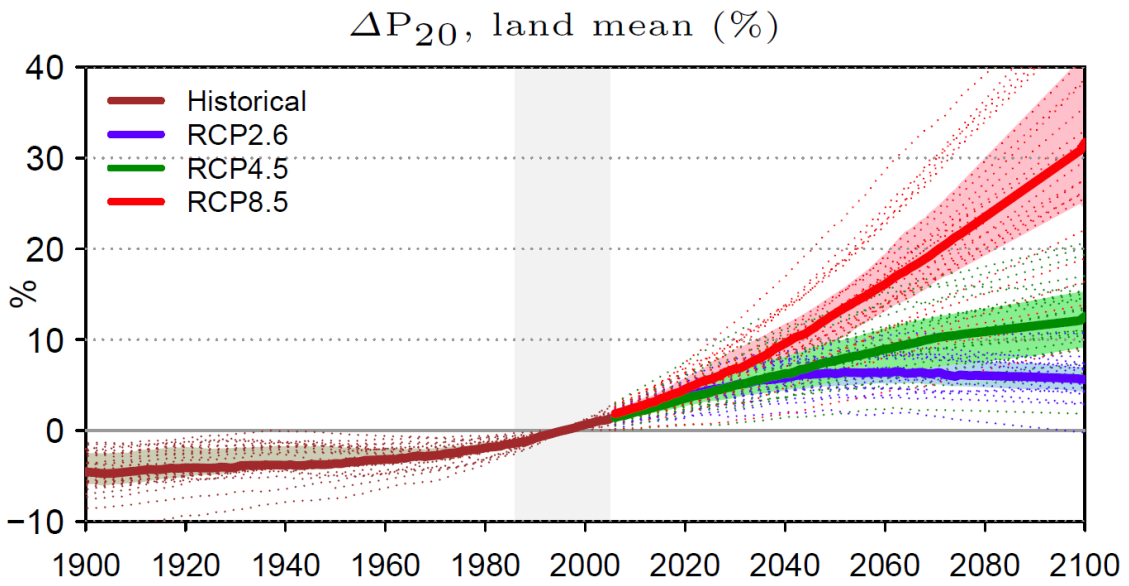
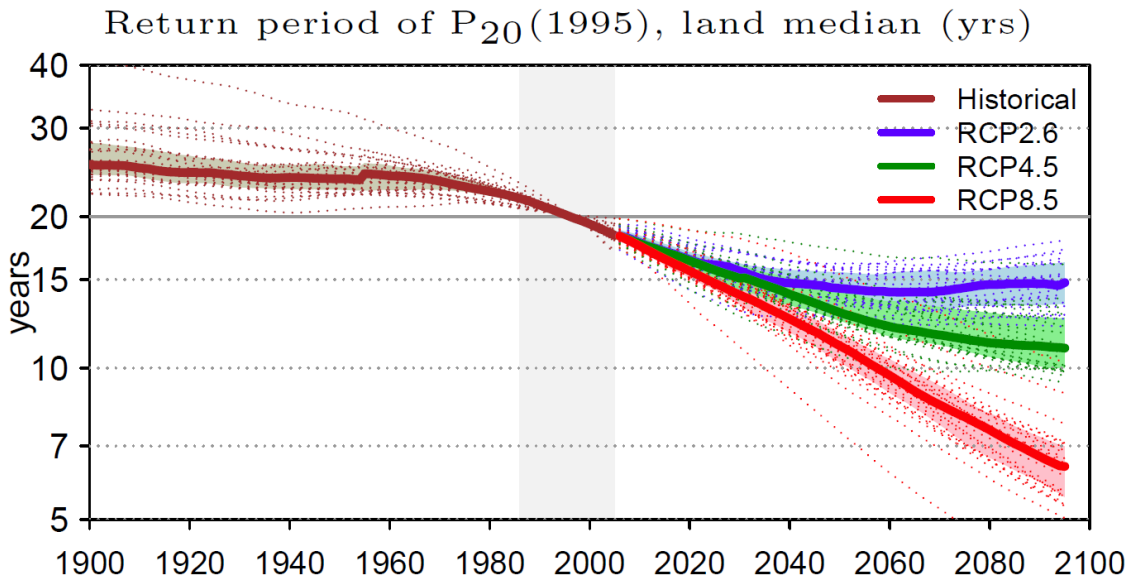
CMIP5 Projections of 20-yr 1-day events

Event magnitude (relative to 1986-2006)



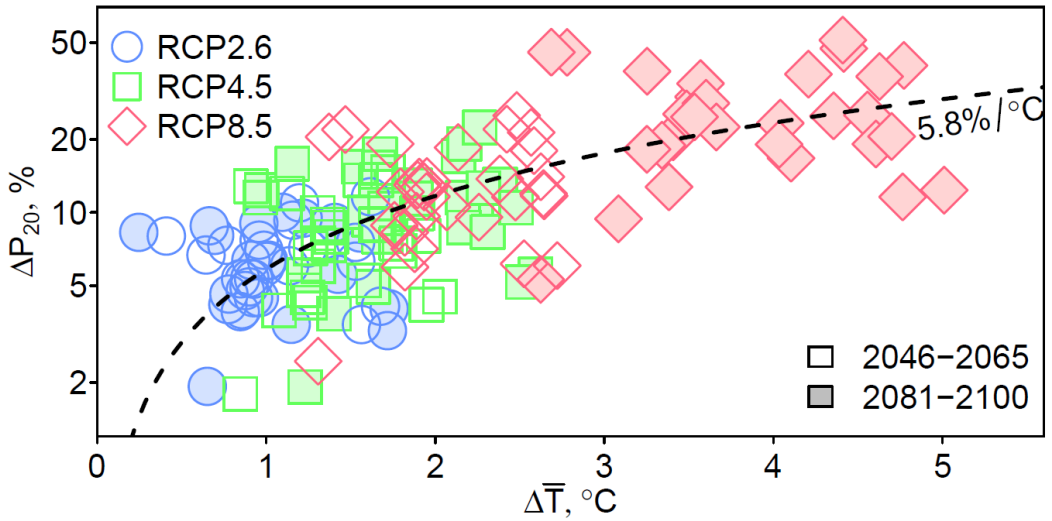
Return period (relative to 1986-2006)



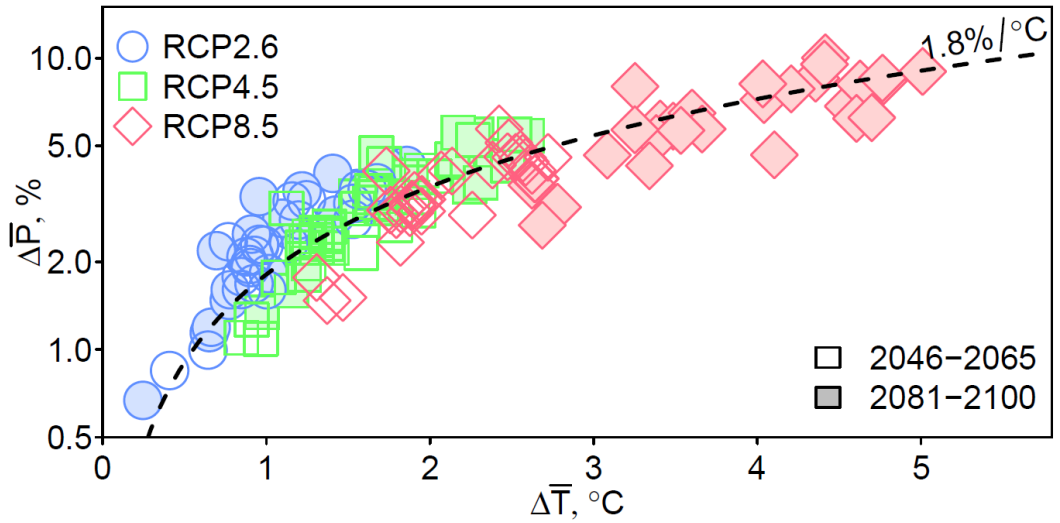
Kharin et al (2013, Fig. 2)

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

- 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

Min et al., 2011, *Nature*

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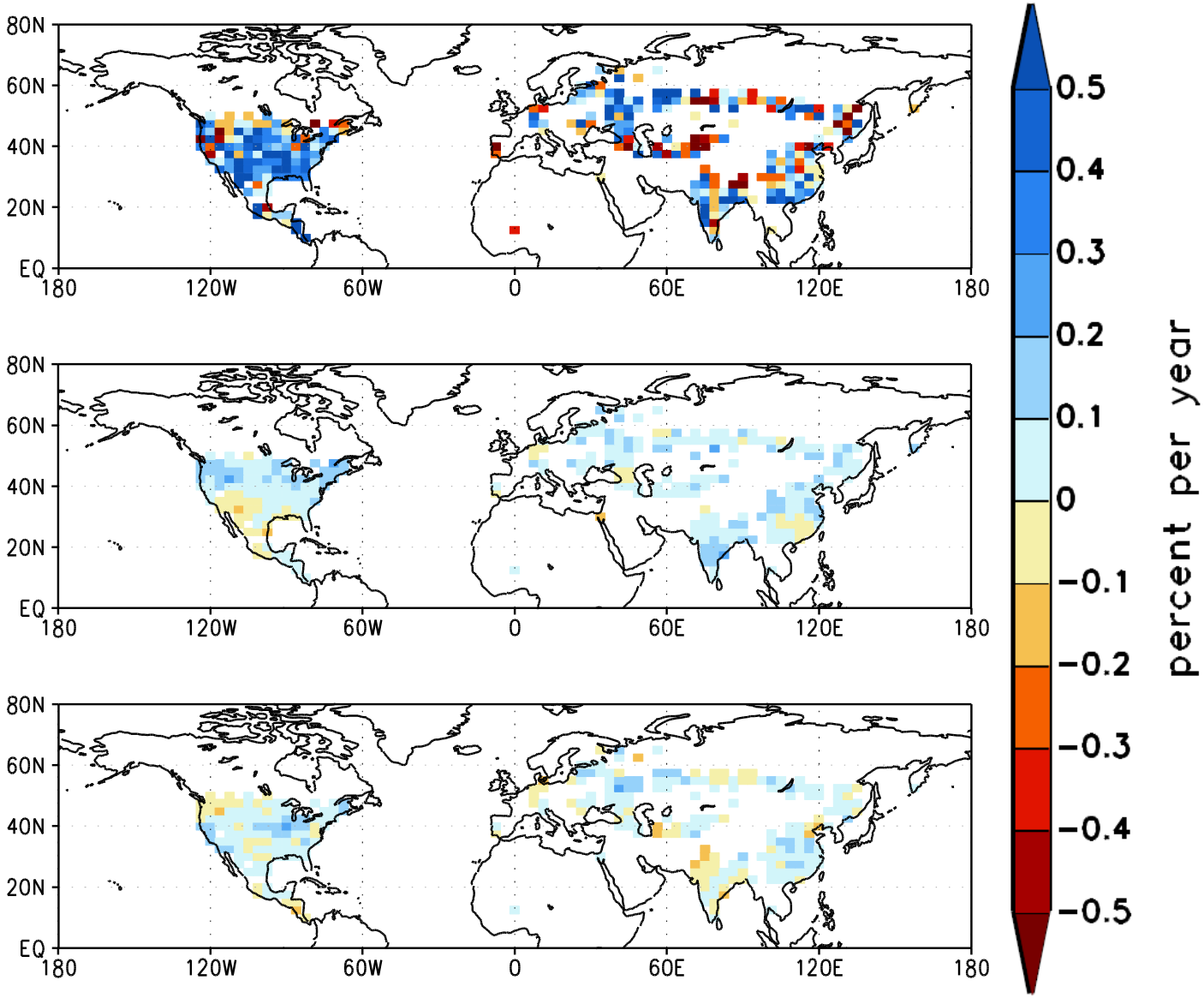
PI Trends (RX1D; 1951-1999)

OBS
(HadEX)

Models

ANT

ALL



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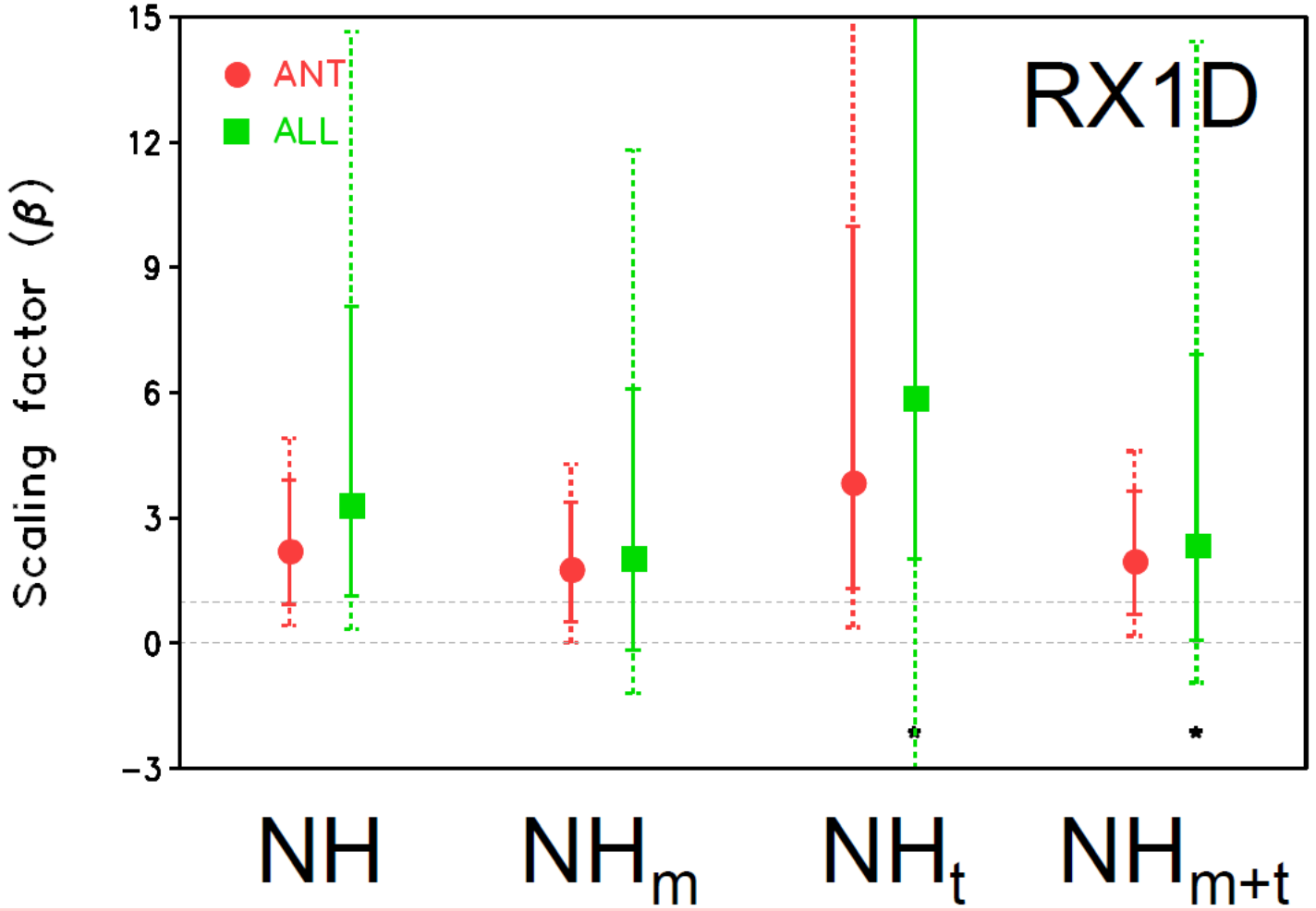
Detection results – 1951-1999



Min et al., 2011, *Nature*

- ANT scaling factors near 2-3

  ➔ model responses to ANT underestimated

Zhang et a., 2013, submitted

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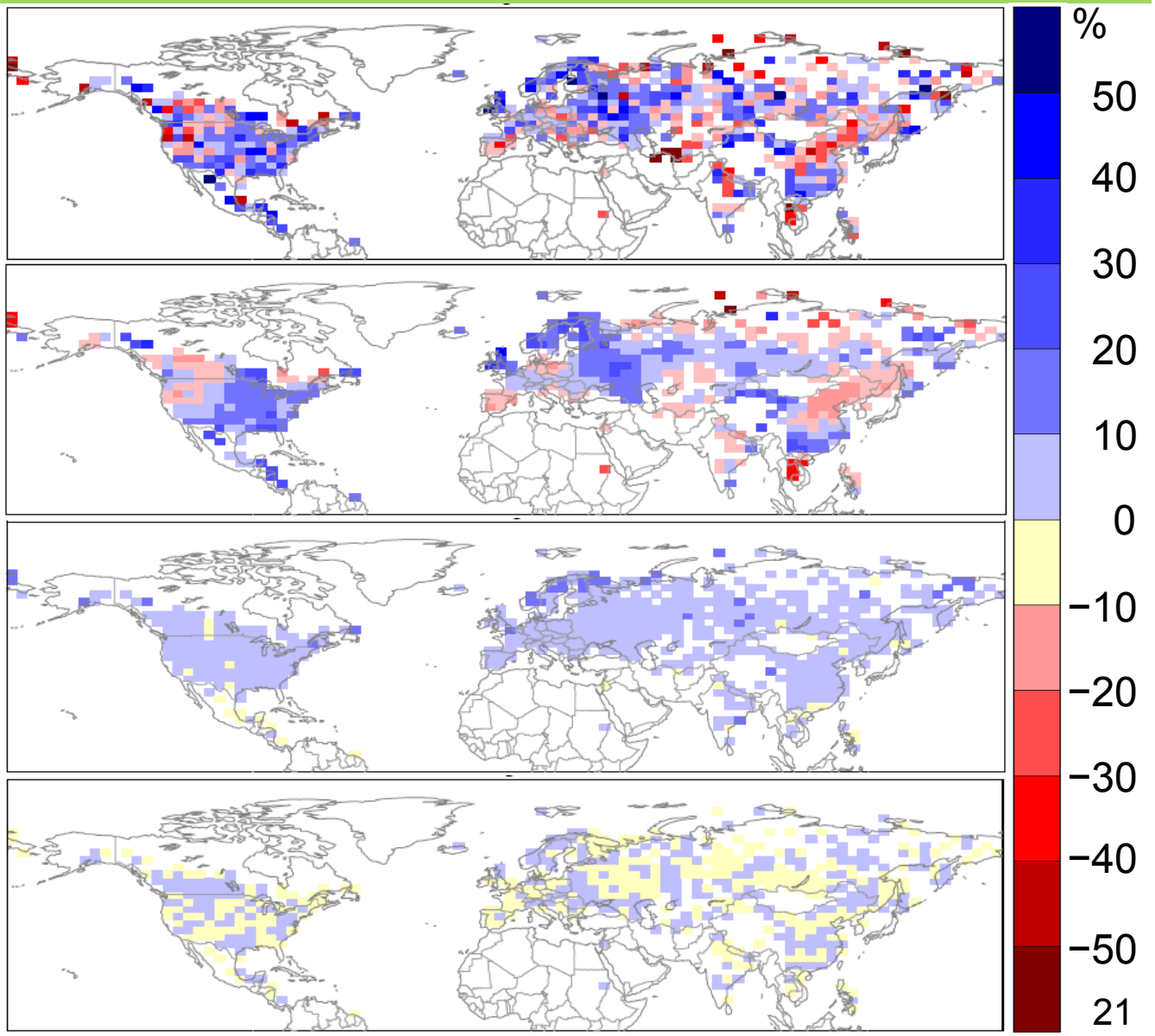
PI Trends (RX1D; 1951-2005)

OBS
(HadEX2 + Russia)

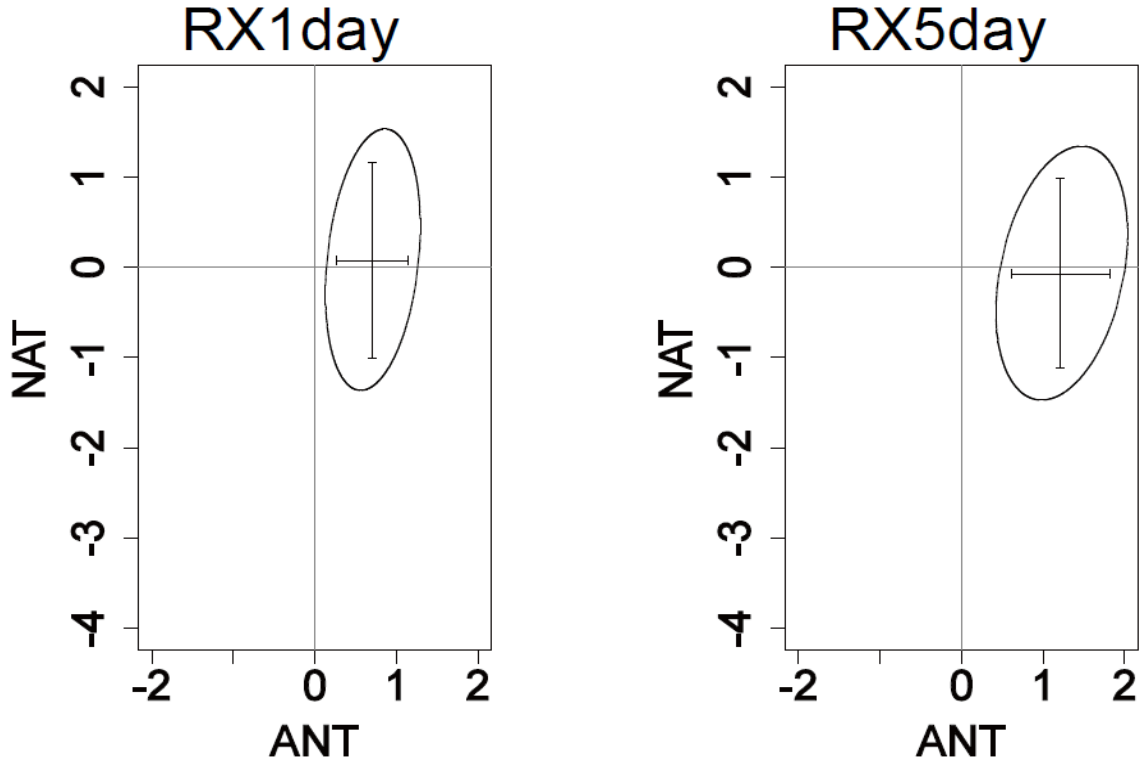
OBS
(Smoothed)

ALL

NAT



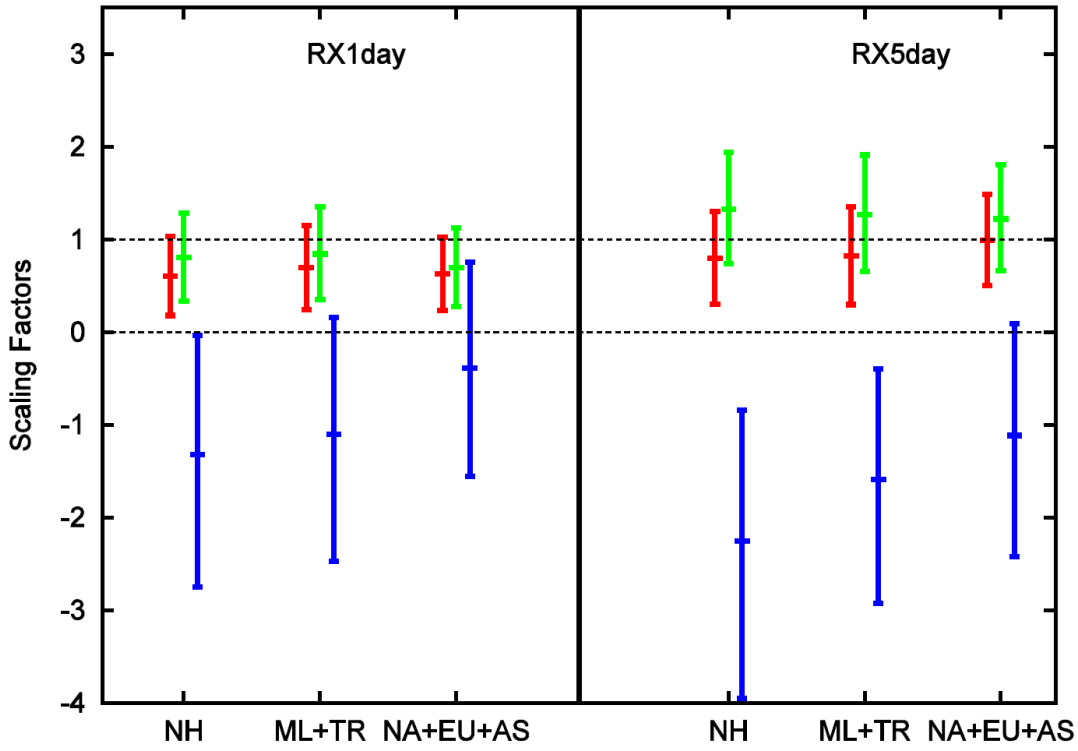
Detection results – 1951-2005



- 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

- Formal detection and attribution remains a challenge (there doesn't appear to be a lot of spatial structure that can be exploited)
- CMIP5 projections are consistent with those from CMIP3, and suggest that adaptation will be unavoidable, even under RCP2.6
- Globally, model simulated changes in precipitation extremes follow C-C, but simulated precipitation sensitivity over land may be somewhat lower than observed


Questions?
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