Challenges in understanding and projecting changes in extreme precipitation

Photo: F. Zwiers

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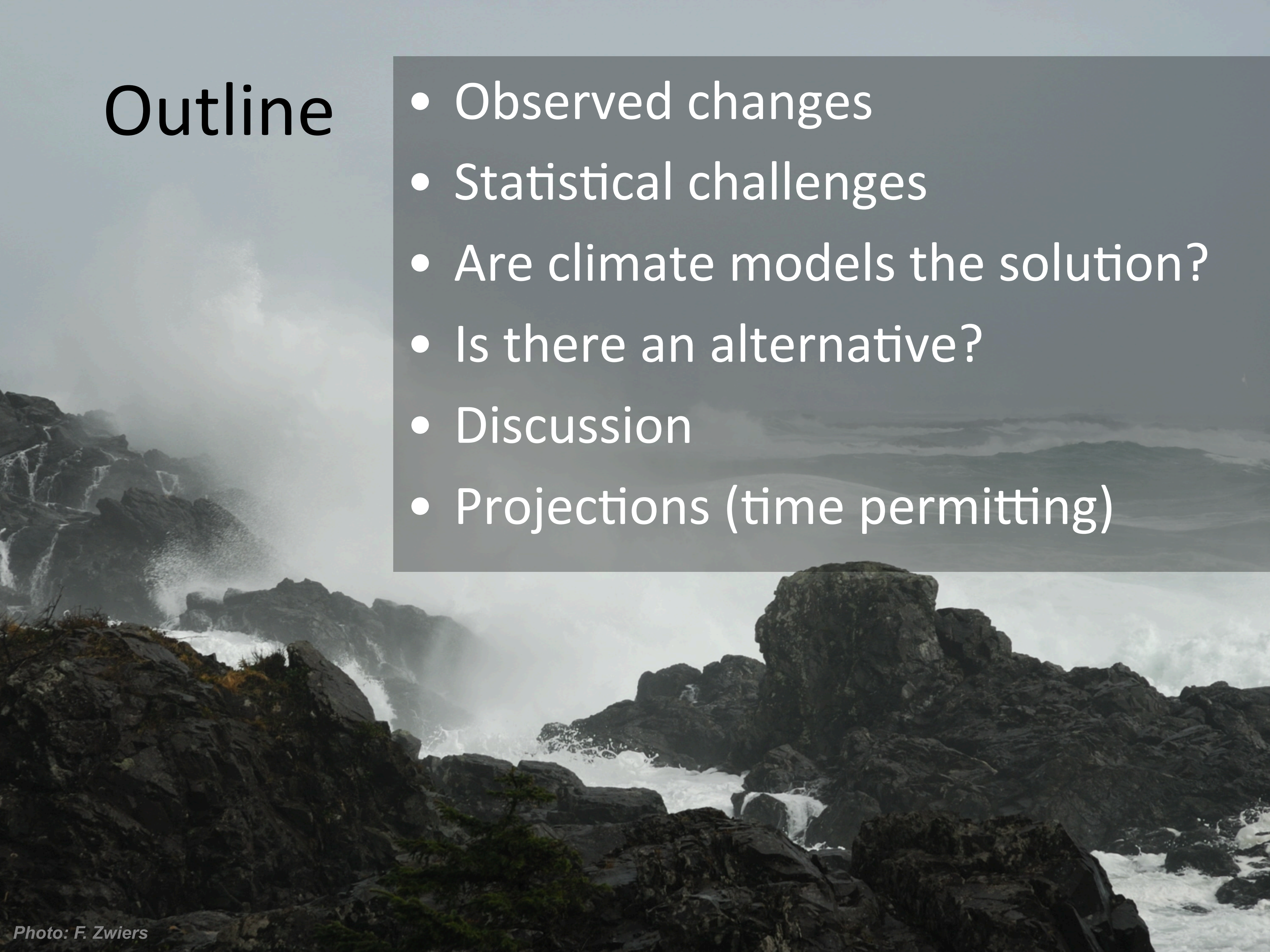
Outline
• Observed changes
• Statistical challenges
• Are climate models the solution?
• Is there an alternative?
• Discussion
• Projections (time permitting)
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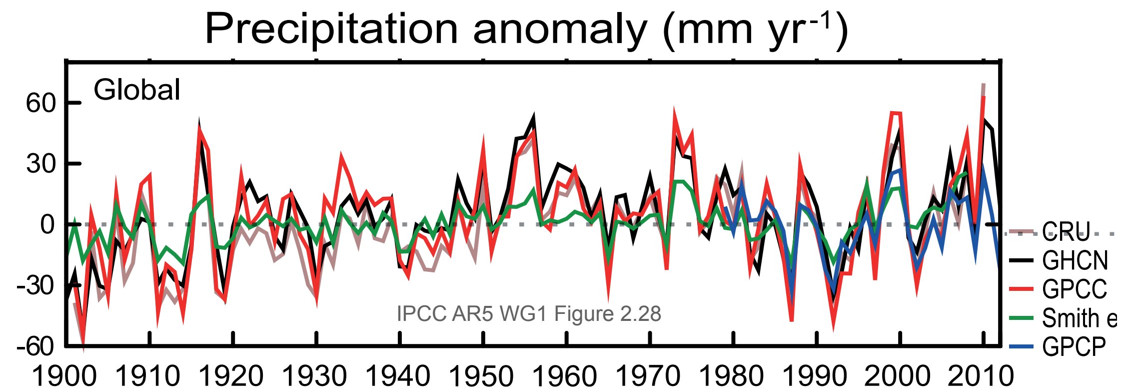
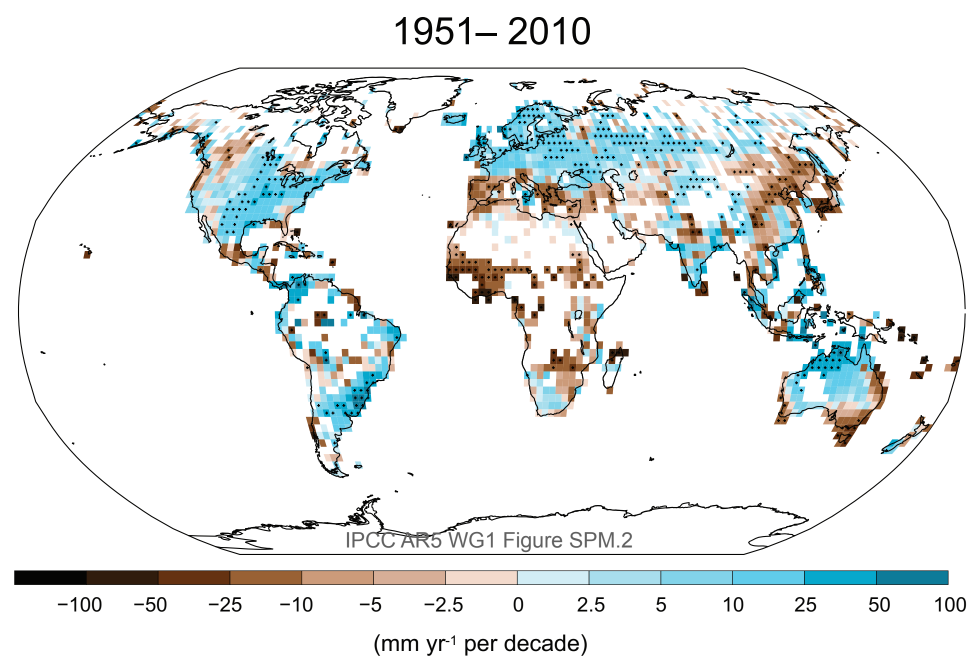
Observed changes - means

Changes in mean precipitation

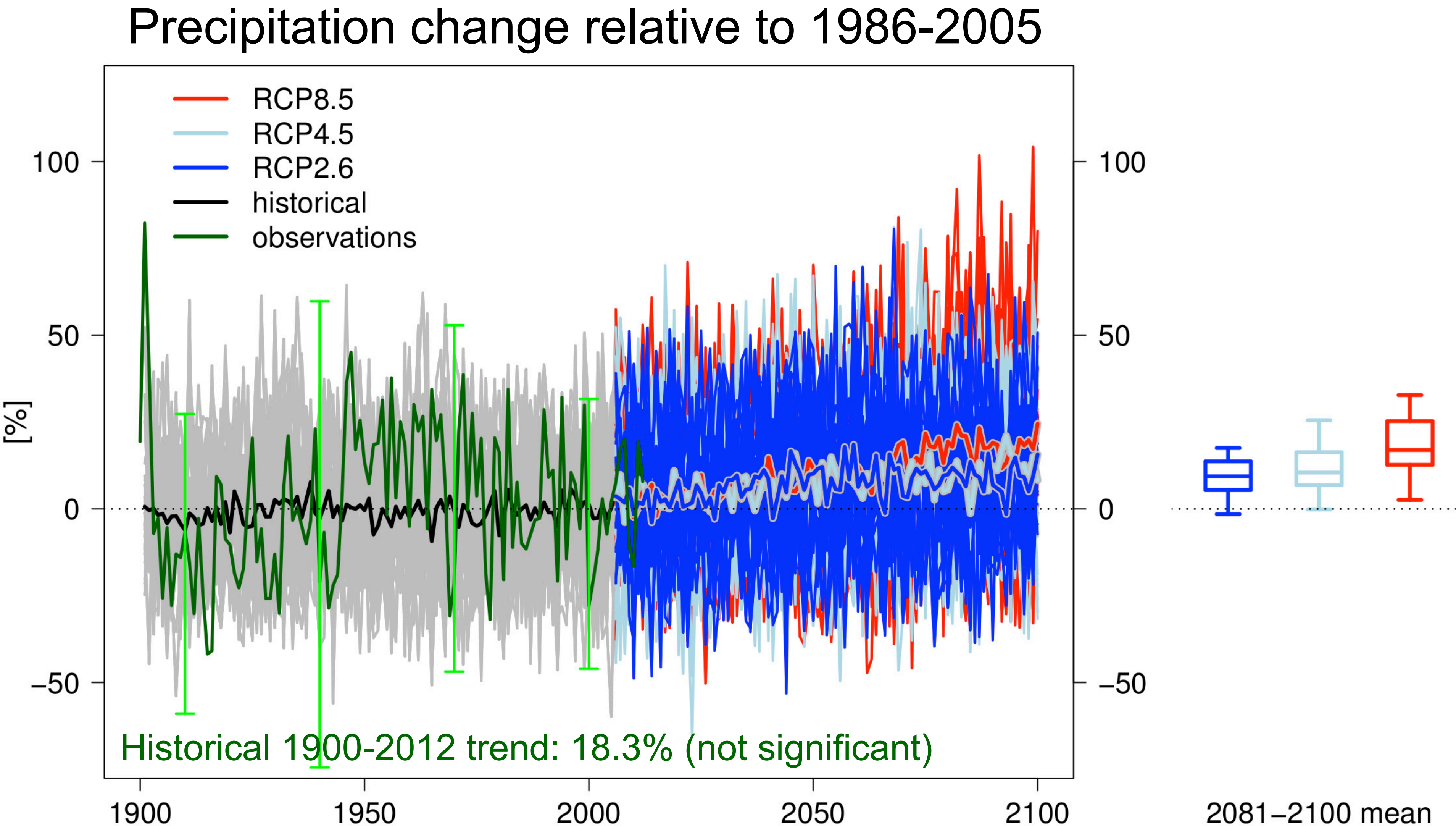
Global mean anomaly in annual accumulation



Trend in annual accumulation (GPCC)



Historical and future changes in BC - Winter (DJF)



Changes in mean precipitation

- Overall assessment (regional and even global) is relatively uncertain due to the state of the data
- Nevertheless, coherent regional patterns of change are discernable at broad scales
- Several studies that indicate there has been human influence on the distribution of precipitation at very large scales
- Provides some basis for thinking there might also be discernable changes in extremes (since to 0^{th} order, precipitation variability is proportional to the mean)

Observed changes - extremes

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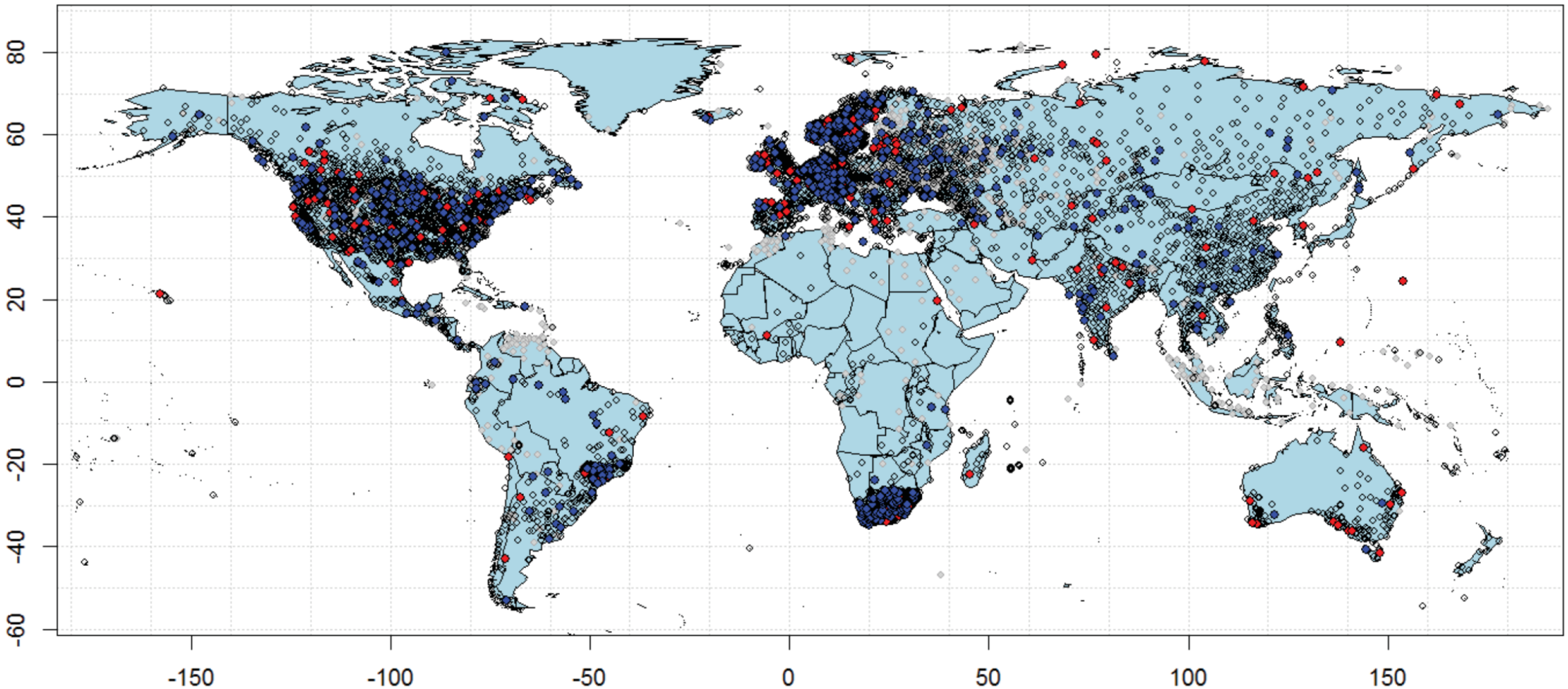
Trends in annual maximum 1-day precipitation

8376 stations with > 30 yrs data, median length 53 years



- Significant positive trends at 8.6% of stations (expect 2.5%)
  - Significant negative trends at 2.0% of stations (consistent with 2.5%)
- Using the GEV distribution
  - Trends are significantly associated with warming at 10% of stations
  - Estimate of mean sensitivity over land is ~7%/°C warming

Westra et al (2013, Fig. 5)

Changes in extremes

- IPCC says:
  - Frequency [of heavy precipitation] has *likely* increased in more land regions than where it has decreased.
  - Confidence varies regionally, [heavy precipitation] *very likely* has intensified in North America.
- Trends in individual records difficult to discern (detected in annual extremes of daily precipitation amounts at about 1-in-10 stations)
- Trends are at best estimated with large uncertainty
- Nevertheless, evidence broadly indicates that “stationarity” is dead

Statistical Challenges

Statistical challenges

- Univariate EVT is well developed and can accommodate non-stationarity (given adequate process knowledge to identify appropriate covariates)
- But, station records are
  - Limited in length
  - Difficult to homogenize
  - Sparse relative to their spatial representativeness
  - All of the above, only much more so, for sub-daily
- Leads to
  - Uncertain local return-level / return-period estimates
  - Very uncertain estimates (if any at all) of impact of non-stationarity

Spatial EVT

- Methods that take spatial dependence into account are rapidly developing
- Where the observing network is sufficiently dense, they have the potential to
  - Reduce uncertainty in return-level / return-period estimates, and possibly
  - Provide observationally constrained estimates of the effects of nonstationarity
- Some software is available, but still hard to use
- One avenue of statistical research is to find efficient ways to circumvent the direct modelling of pairwise dependence.


Are climate models the solution?
Photo: F. Zwiers

Are climate models the way forward?

- Changes in the extremes of daily precipitation that are predicted to have occurred over the past 50-60 years are detected in obs at a global scale
- But changes are not expected to be reliably detectable in individual station records
  - Low signal-to-noise ratio, short observational record
  - Mismatch between the scale that is simulated and that which is observed
  - Considerable climate model limitations
- Climate models that simulate local-scale processes explicitly are in development, but the cost will be prohibitive, possibly for decades

Is there an alternative?

If not climate models, then what?

- Finding the climate model that is best at a given location, and using its projections at that location to scale idf curves is not likely to be robust
  - Even assuming that the representation of processes responsible for local-scale extreme precipitation is not a concern, if non-stationarity is only discernable with probability 1/10th at any one location, how do we reliably decide on the model that is locally best?
  - And even if we can identify the model that is locally best, what about its performance everywhere else?

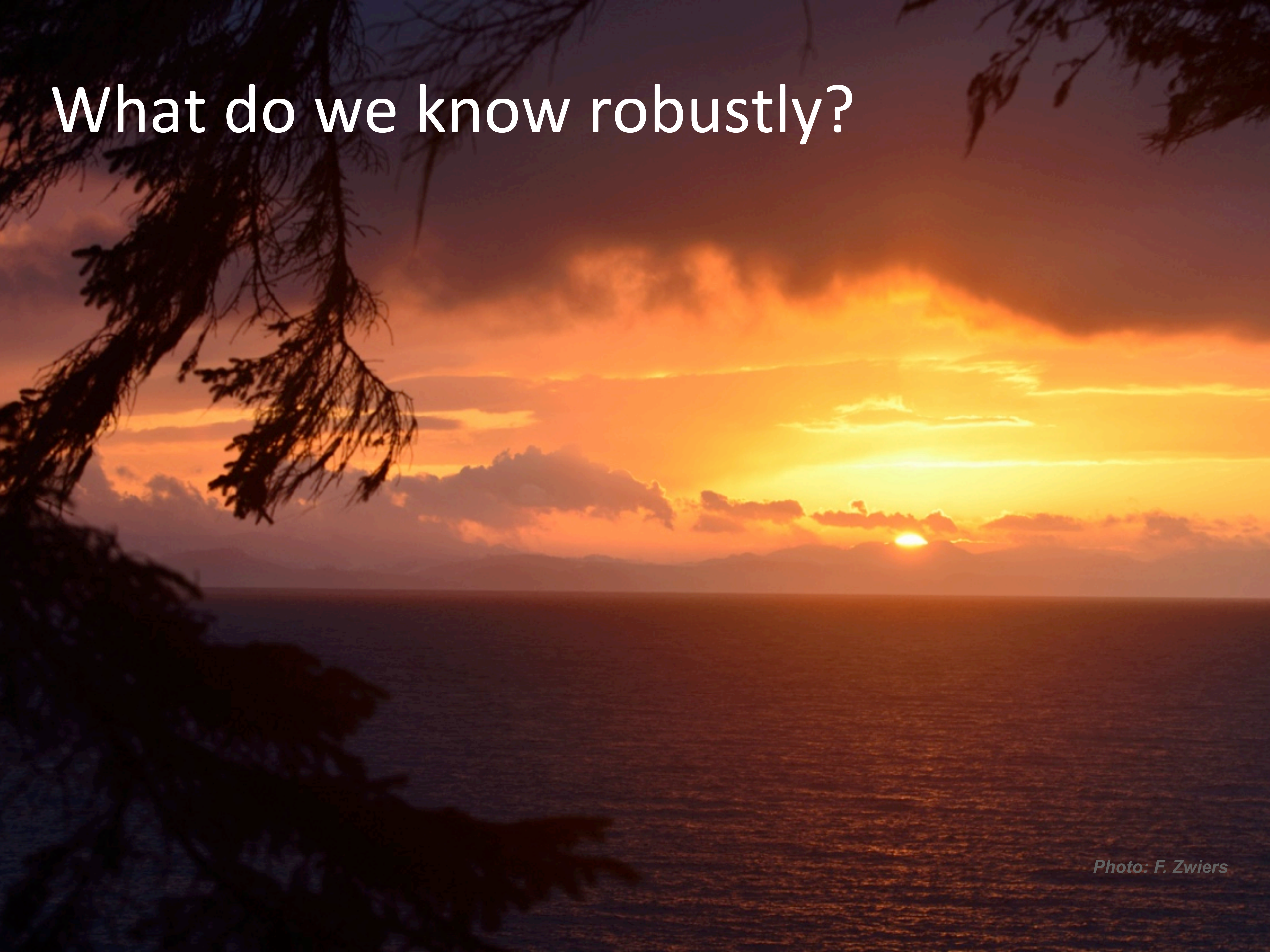
Rather than direct model application …

- Continue to develop spatial EVT

- Improve operational practice in its application
  - We can do better than fitting the Gumbel distribution by the method of moments at individual locations and for individual accumulation periods

- Identify the findings from climate models that are robust, and use them to scale return-level estimates

What do we know robustly?



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What is robust?

- Clausious-Clayperon predicts ~7% increase in the saturation vapour pressure of water per °C warming
  - This theoretically predicted increase in water vapour is observed and is simulated by climate models
  - Mean precipitation increases more slowly (observed and modelled, reasons are understood)
  - Daily precipitation extremes are observed to increase at about the C-C rate when considering “global” data
  - Global climate models simulate similar increases ubiquitously over mid-latitude land areas
  - Experimental very high resolution models that represent local scale processes explicitly seem to confirm this finding

Discussion

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Model assessment and projections

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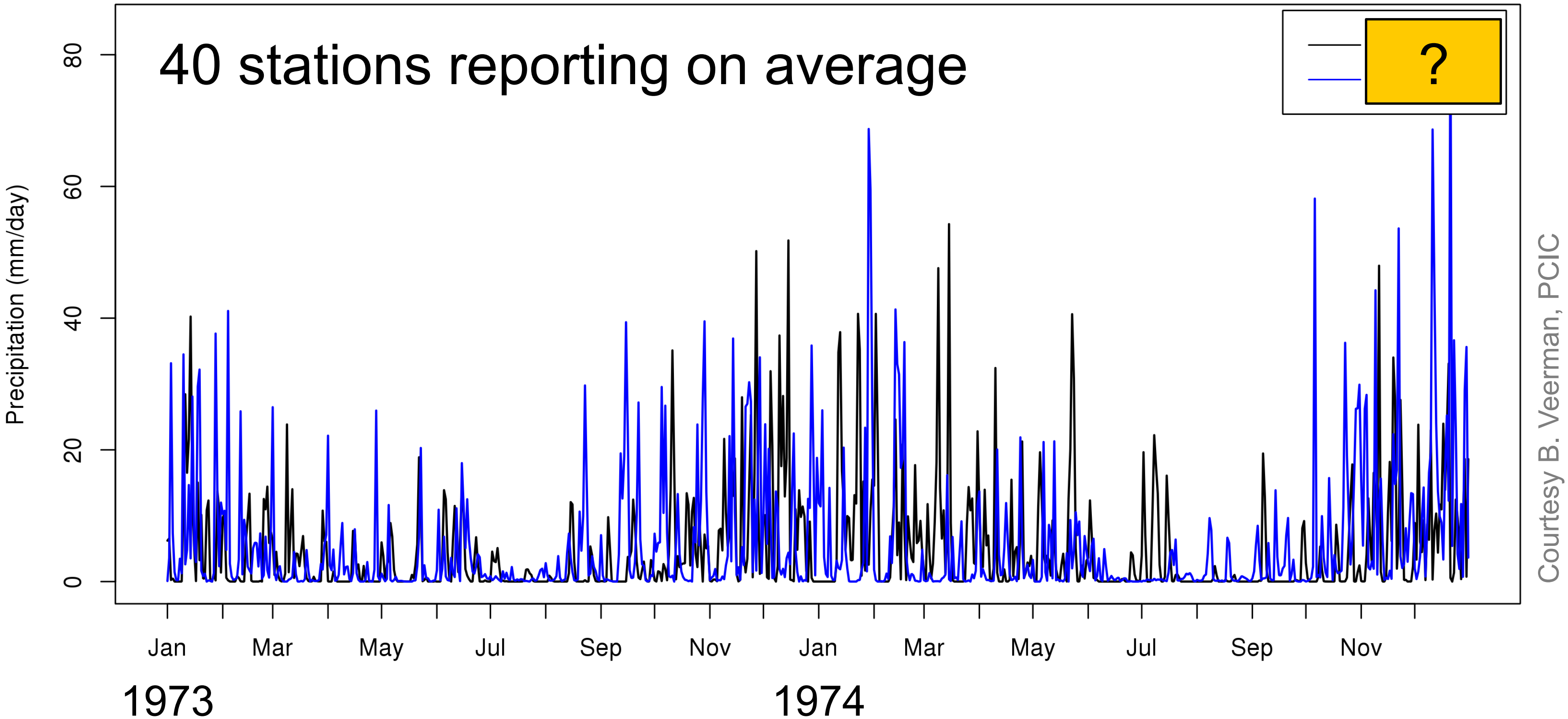
Mean daily precipitation in the MIROC4h grid box centered on 49.1N, 123.2W (Vancouver)



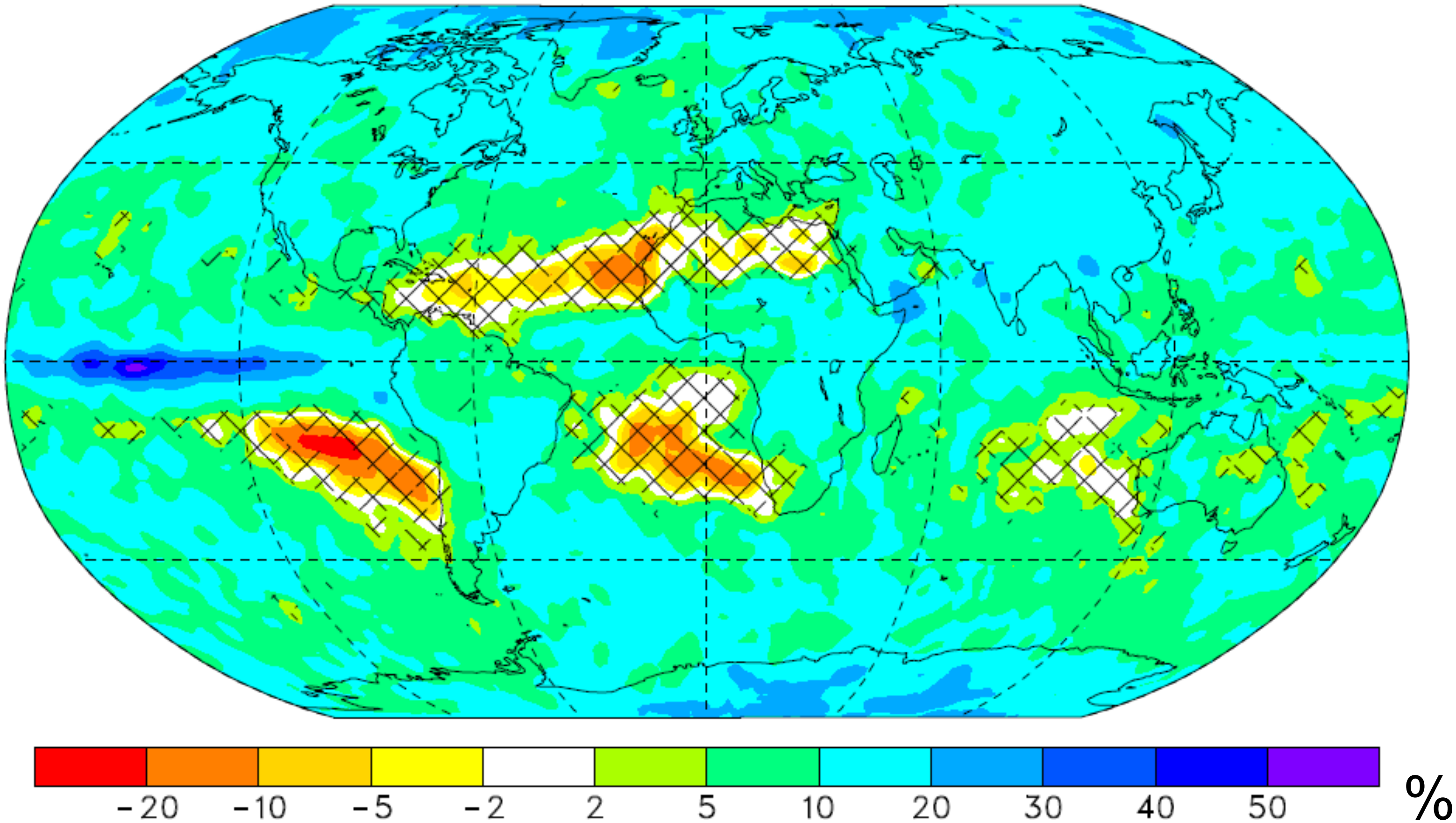
For some evaluation of CMIP5 models wrt precipitation extremes see

- for indices, Sillmann et al (2013, JGR),
- for long-period return values, Kharin et al (2013, Climatic Change)

CMIP5 RCP4.5 precipitation projections

Change in 20-yr extremes relative to 1986-2005

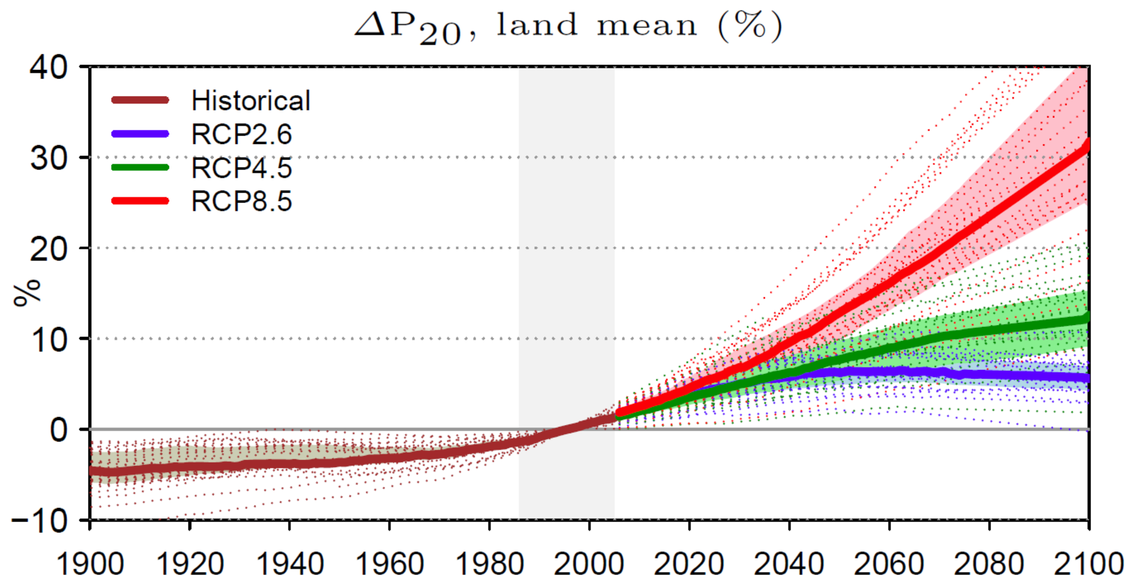
ΔP_{20}, %, 2081–2100, +10.9%



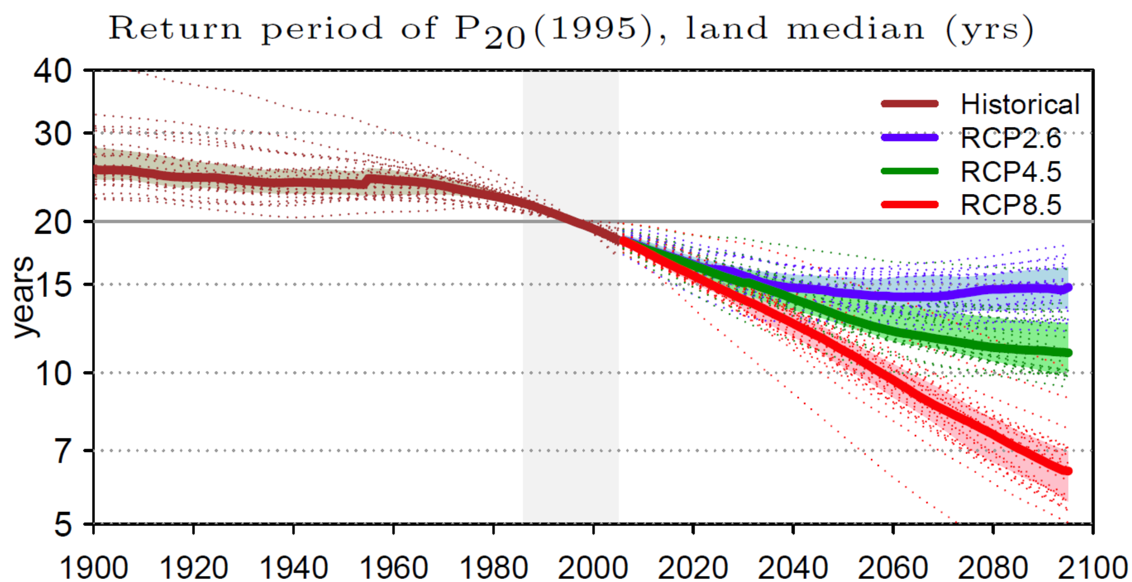
Kharin et al (2013, Fig. 4)

CMIP5 Projections of 20-yr 1-day events

Event magnitude
(relative to 1986-2006)



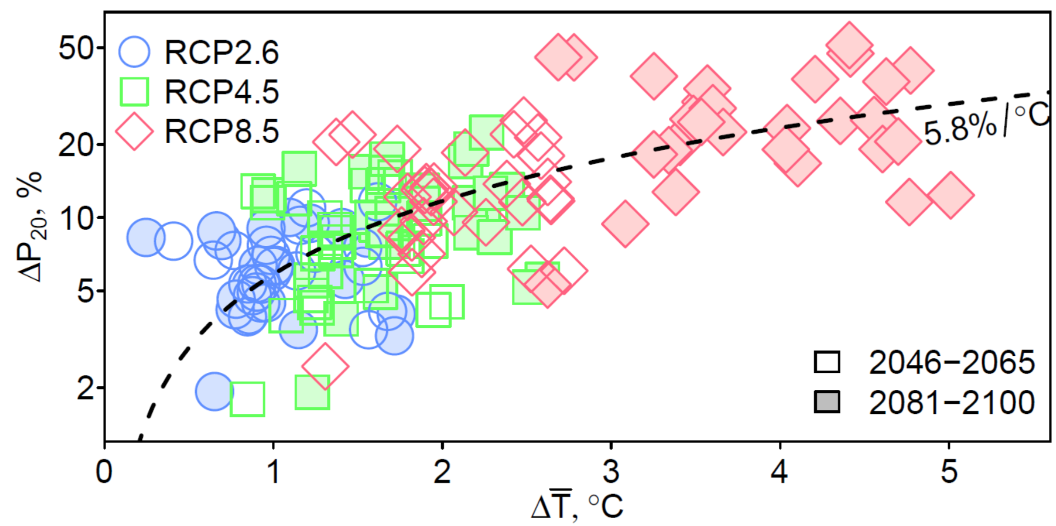
Return period
(relative to 1986-2006)



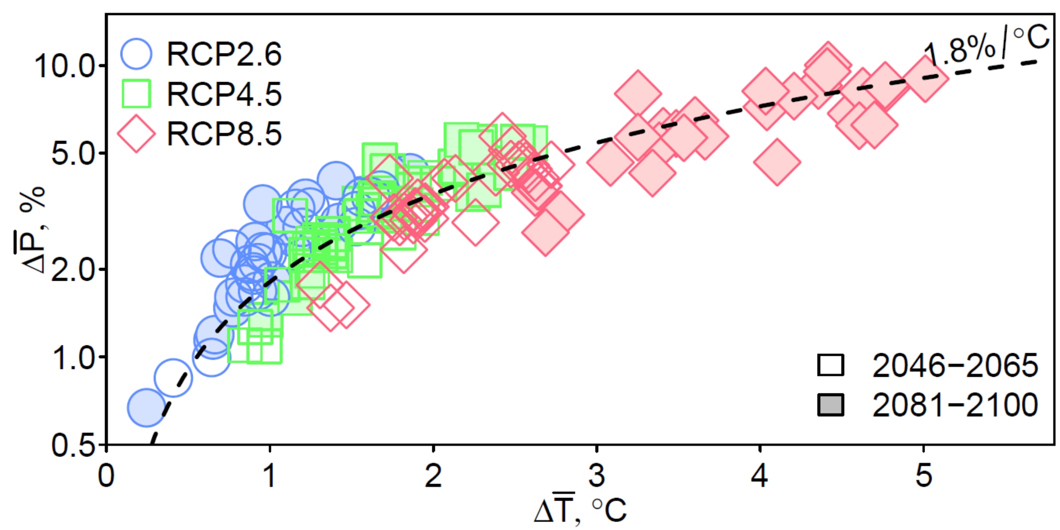
Kharin et al (2013, Fig. 2)

CMIP5 precipitation sensitivity

Planetary sensitivity of 20-year extremes



Sensitivity of global mean precipitation



Kharin et al (2013, Fig. 5)