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What makes it difficult to predict extreme climate events in the long time scales?

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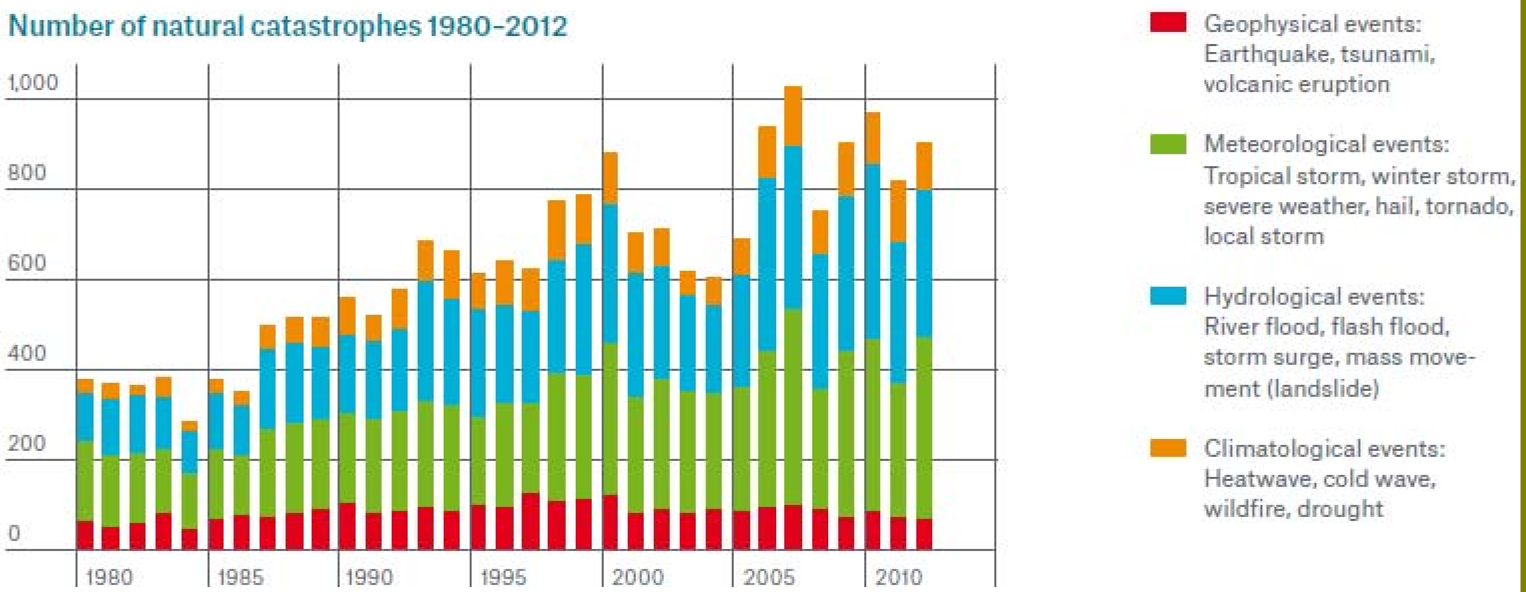
IPCC Definition

An **extreme weather event** is an event that is rare within its statistical reference distribution at a particular place. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the **10th or 90th** percentile.

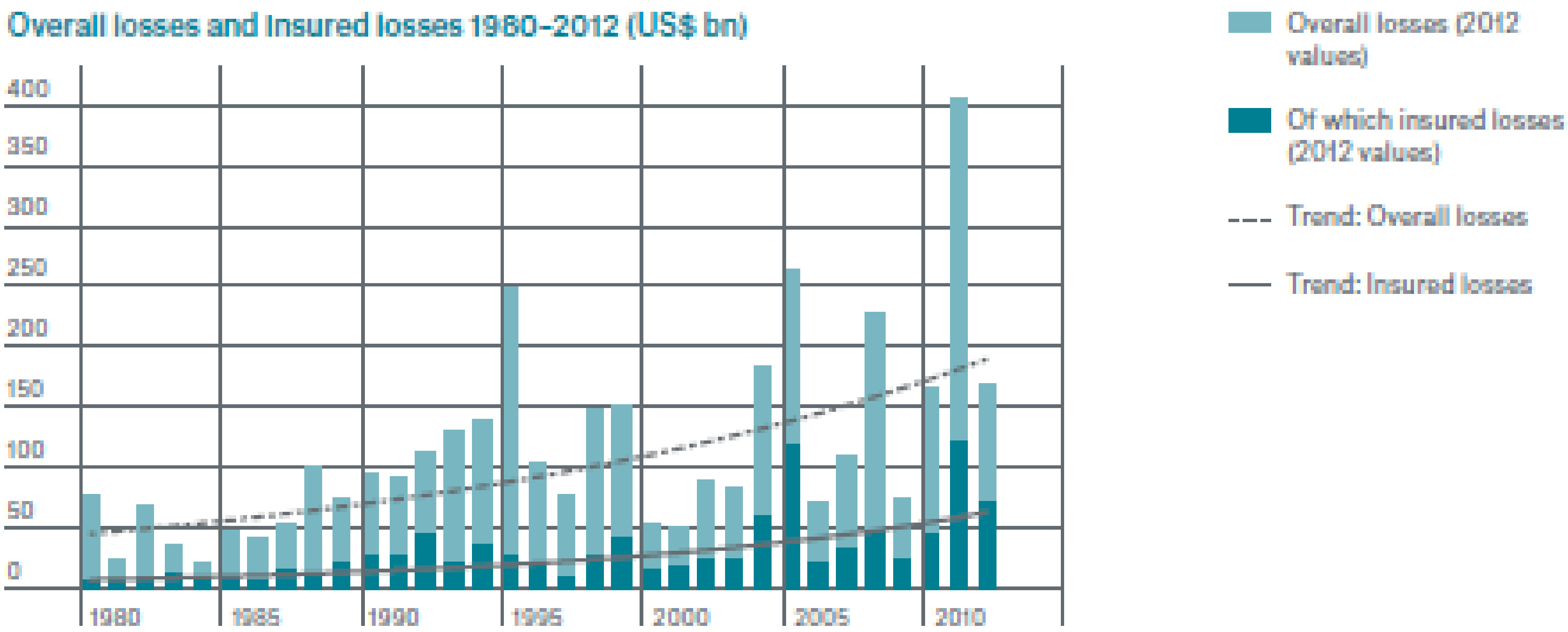
By definition, the characteristics of what is called extreme weather may vary from place to place.

Extremes

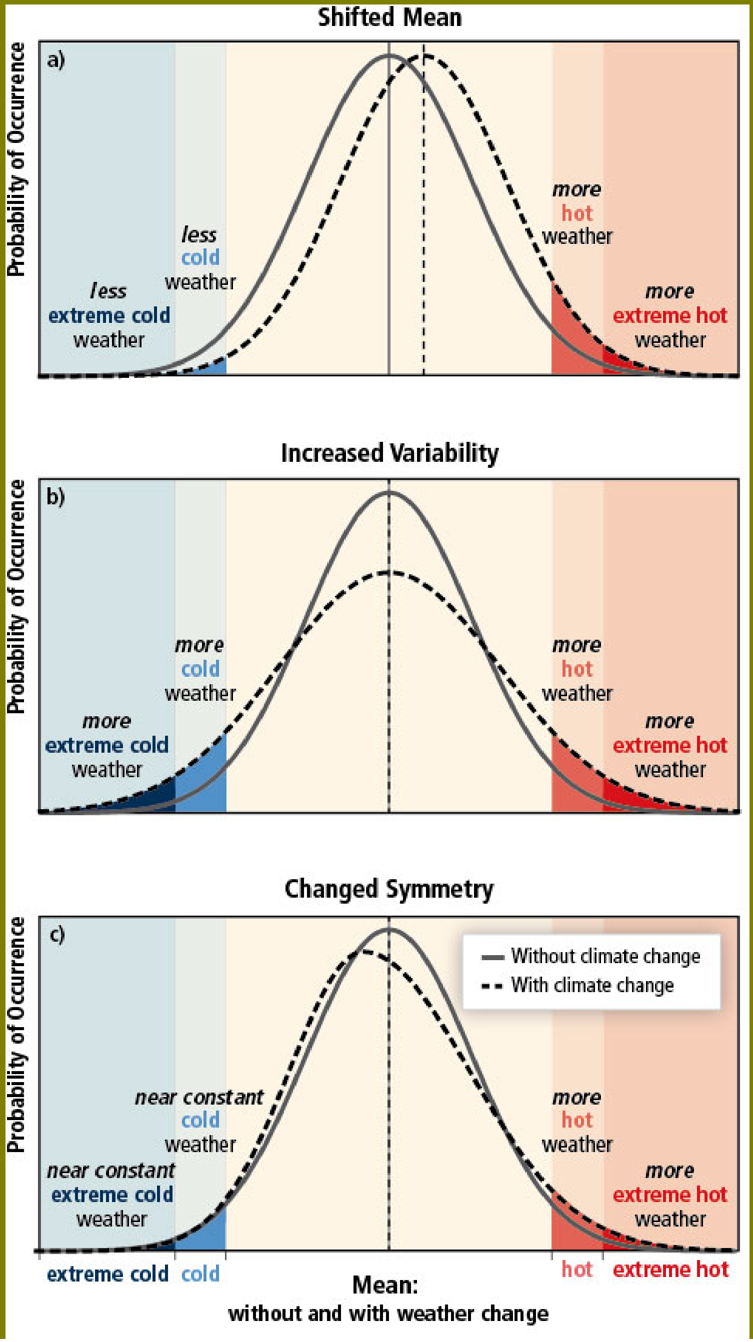
- Heat waves could be few days to weeks long
- Short duration (from minutes to hours) high extremes cause flash floods, landslides, soil erosion, etc.
- Extremes of below average on longer timescales can impact water availability
- Surface hydrological responses to precipitation is non-linear



Source: Munich Re, 2013



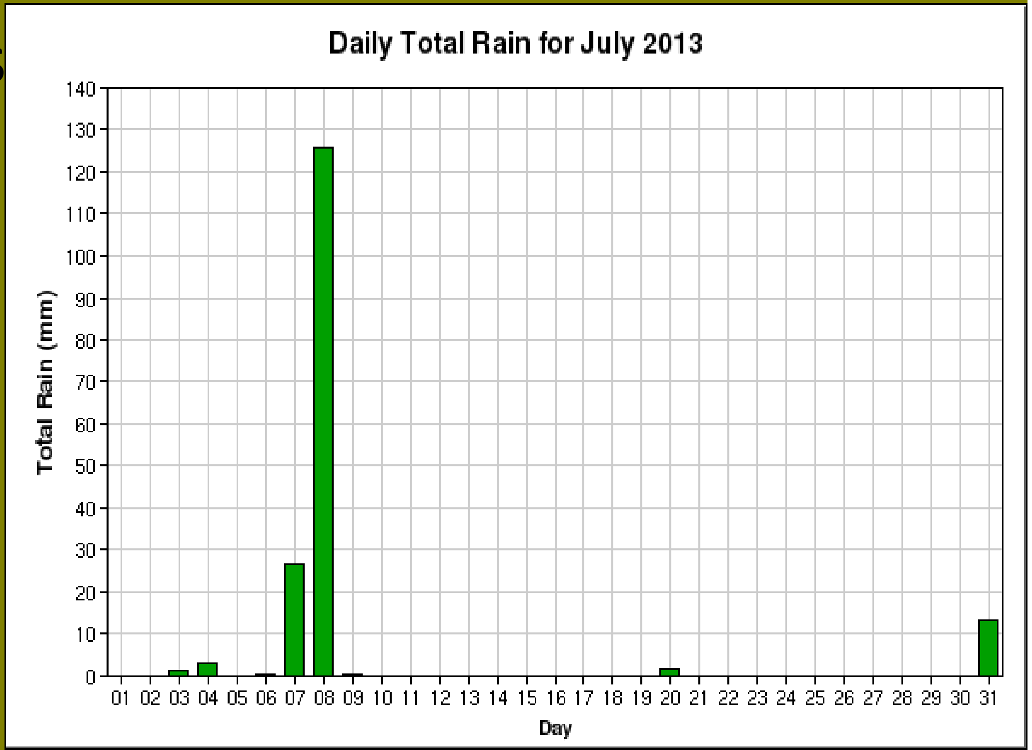
Changed *mean*, *variability* and *symmetry*

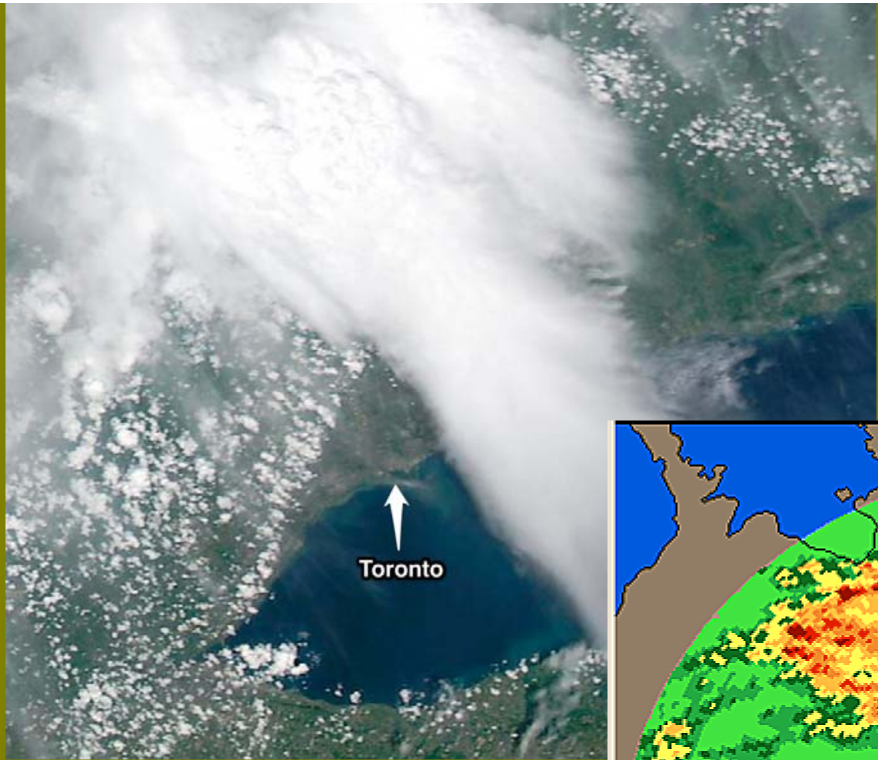


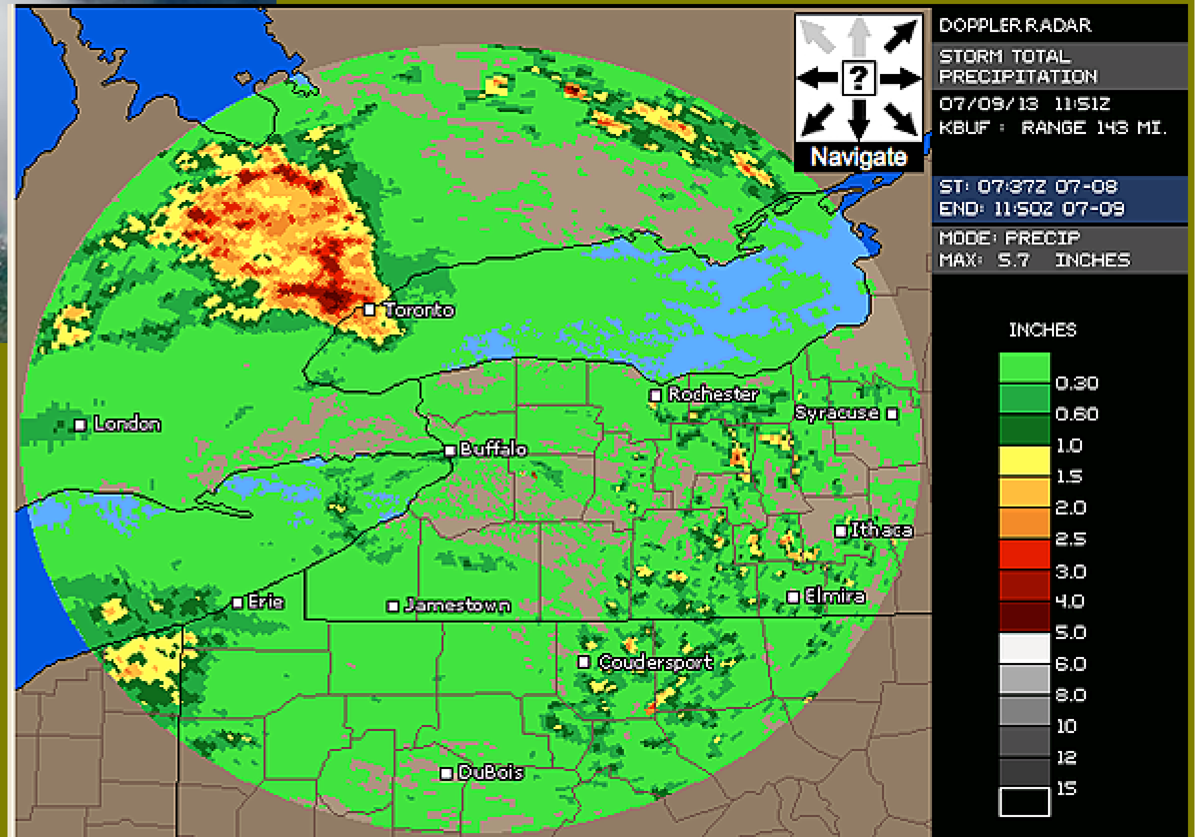
Source: IPCC, 2007

Extreme July 8, 2013 Rainfall in Toronto

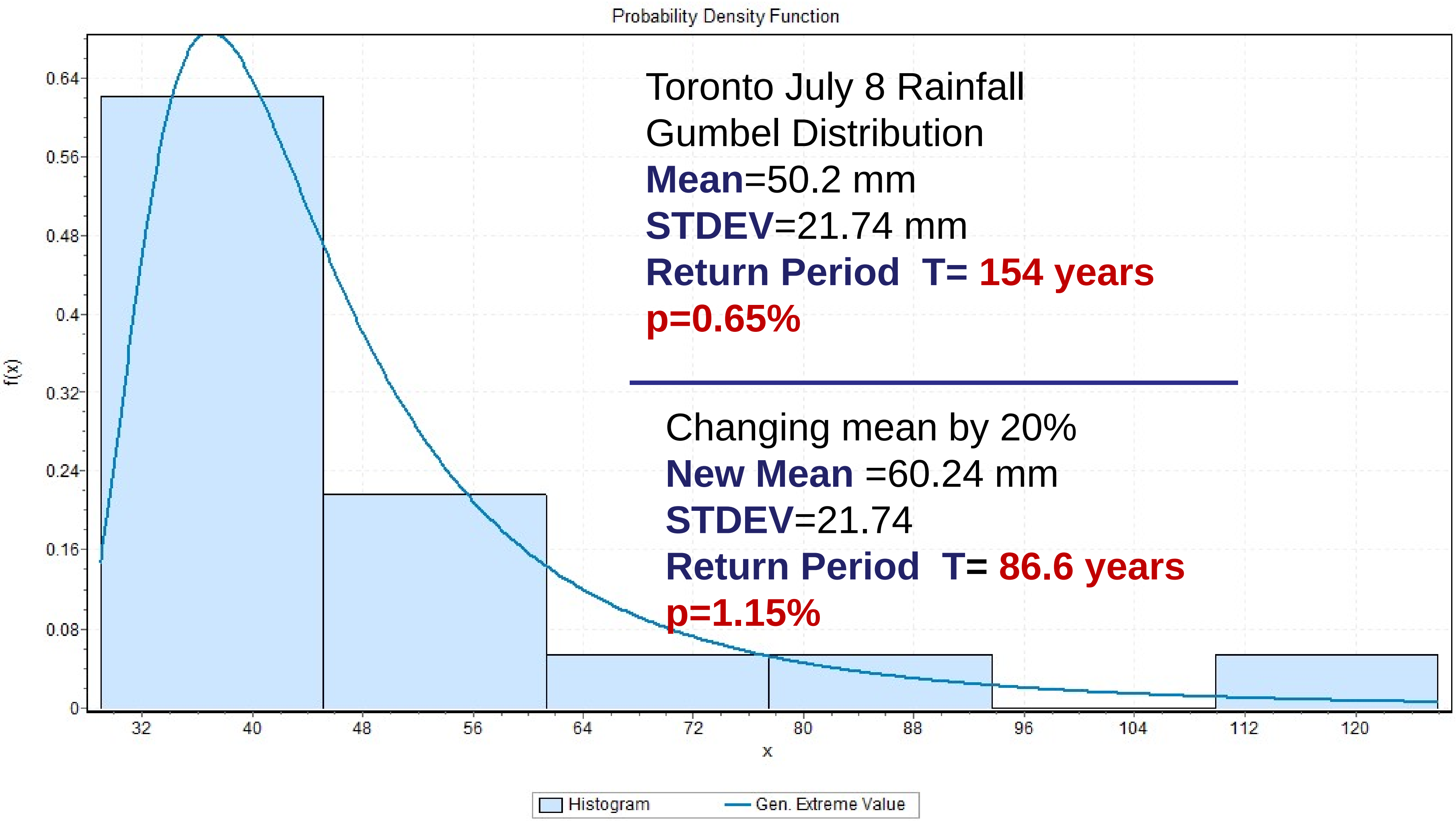
- 126 mm fell over 24-hours
- 98 mm in just two hours
- Broke the 60-years record
- Typical of rainfall of the entire month
- 300,000 people lost electricity
- About a billion $ loss




Toronto

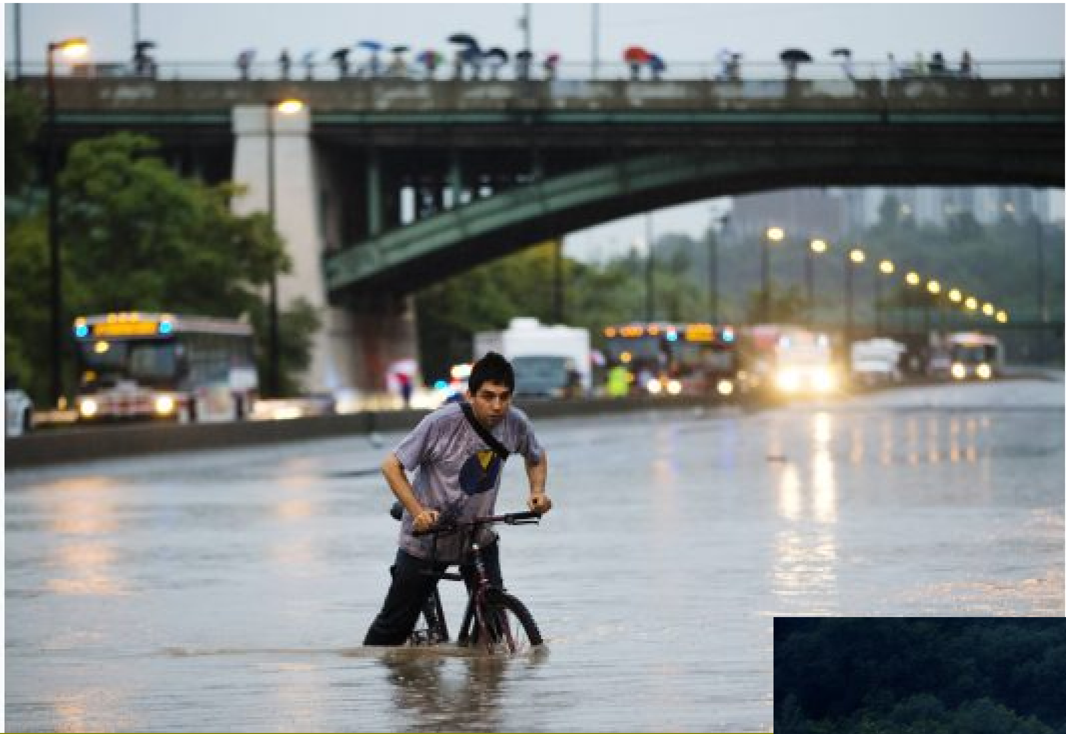

Navigate
DOPPLER RADAR
STORM TOTAL PRECIPITATION
07/09/13 11:51Z
KBUF : RANGE 143 MI.
ST: 07:37Z 07-08
END: 11:50Z 07-09
MODE: PRECIP
MAX: 5.7 INCHES
INCHES
0.30
0.60
1.0
1.5
2.0
2.5
3.0
4.0
5.0
6.0
8.0
10
12
15
Toronto
London
Buffalo
Rochester
Syracuse
Ithaca
Elmira
Erie
Jamestown
Coudersport
DuBois

Fitting the Distribution at Lester B. Pearson Airport



Toronto July 8 Rainfall
Gumbel Distribution
Mean=50.2 mm
STDEV=21.74 mm
Return Period T= 154 years
p=0.65%

Changing mean by 20%
New Mean =60.24 mm
STDEV=21.74
Return Period T= 86.6 years
p=1.15%



Mean Temperature & Precipitation

- Climate models include substantial detail on physical processes
- Projections vary from model to model
- Robustness is looked for
- Models are pretty good at temperature projections
- Complexity arises for precipitation projections
- Sign of changes in precipitation vary regionally

CMIP5 Summary: Extremes

Temperature

- Intensification of temperature and precipitation based indices
- Stronger changes in seasonal minima (TN) in northern latitudes
- Uniform distribution of seasonal maxima (TX)
- small shifts in the mean of the temperature

distribution in the tropical region can lead to larger changes in the exceedance rates than in the high variability extra tropical regions

Source: Sillman et al., 2013

CMIP5 Summary: Extremes

Precipitation

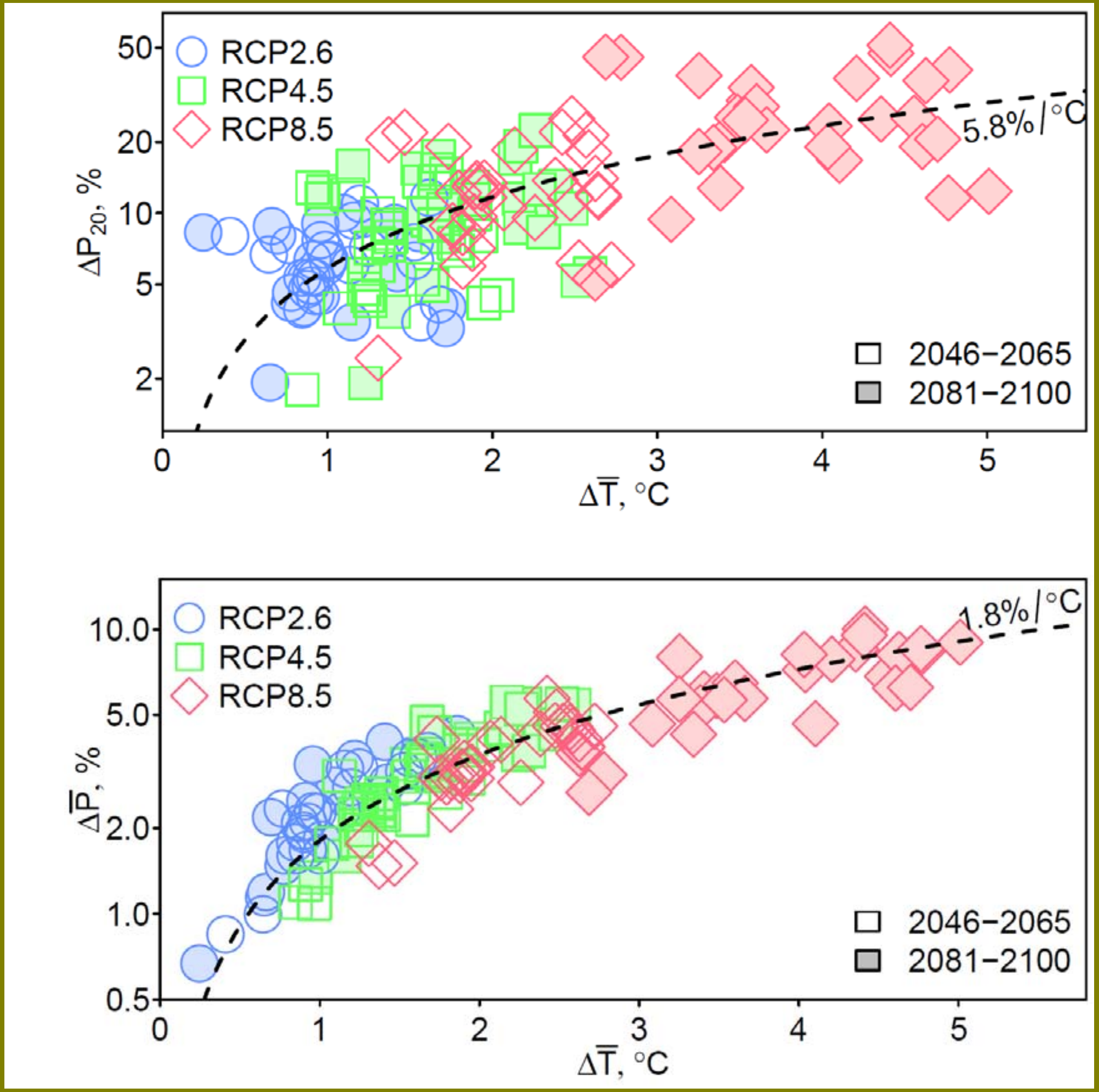
- Extreme precipitation increases proportionally faster than total wet-day precipitation (PRCPTOT).
- Changes in very wet days (R95p) indicate that extreme precipitation generally increases in most regions
- In Australia, Central America, South Africa and the Mediterranean region where a precipitation decrease and longer dry spells, captured by the consecutive dry days (CDD) index
- In Mediterranean region, although dry conditions become more severe, precipitation can be much more extreme when it does occur

Source: Sillman et al., 2013

CMIP5 Precipitation Sensitivity

Planetary sensitivity of 20-year extremes

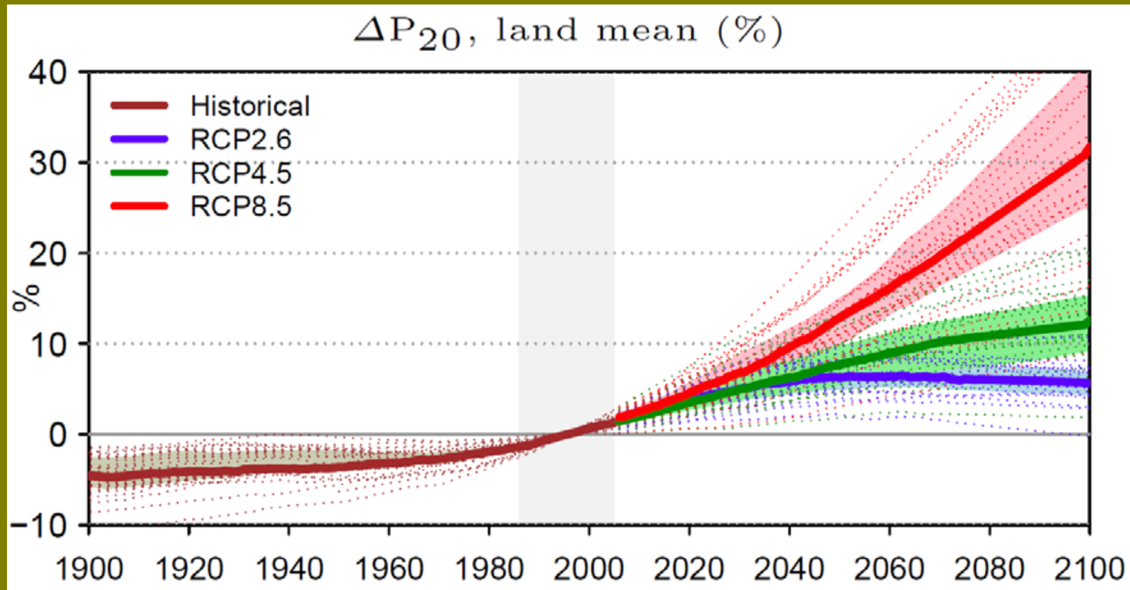
Sensitivity of global mean precipitation



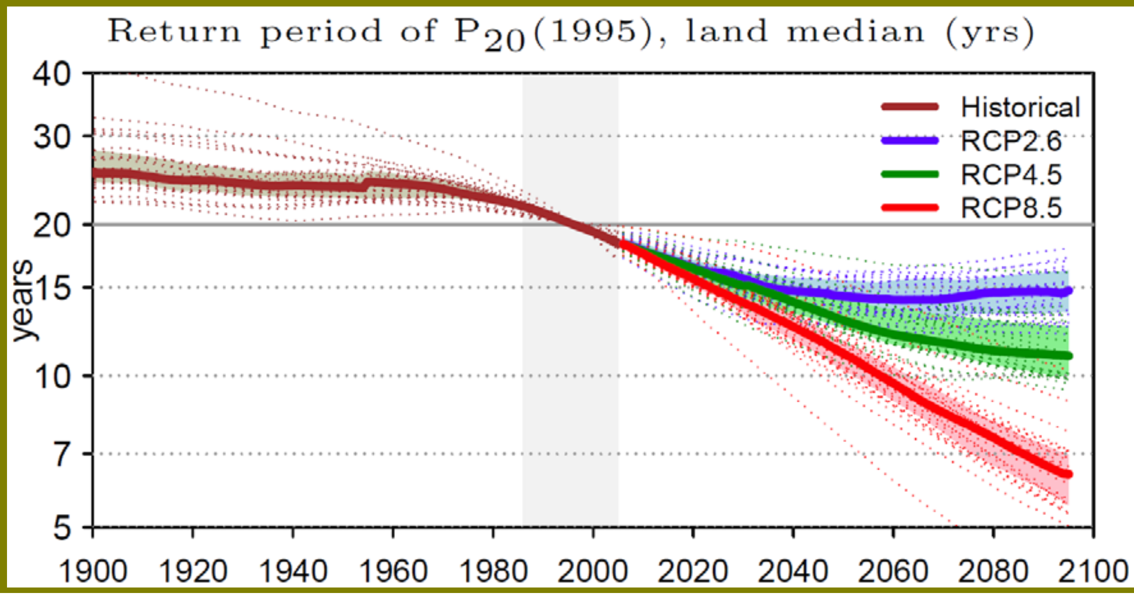
Kharin et al (2013,)

CMIP5 Projections of 20-yr 1-Day Events

Event magnitude
(relative to 1986-2006)



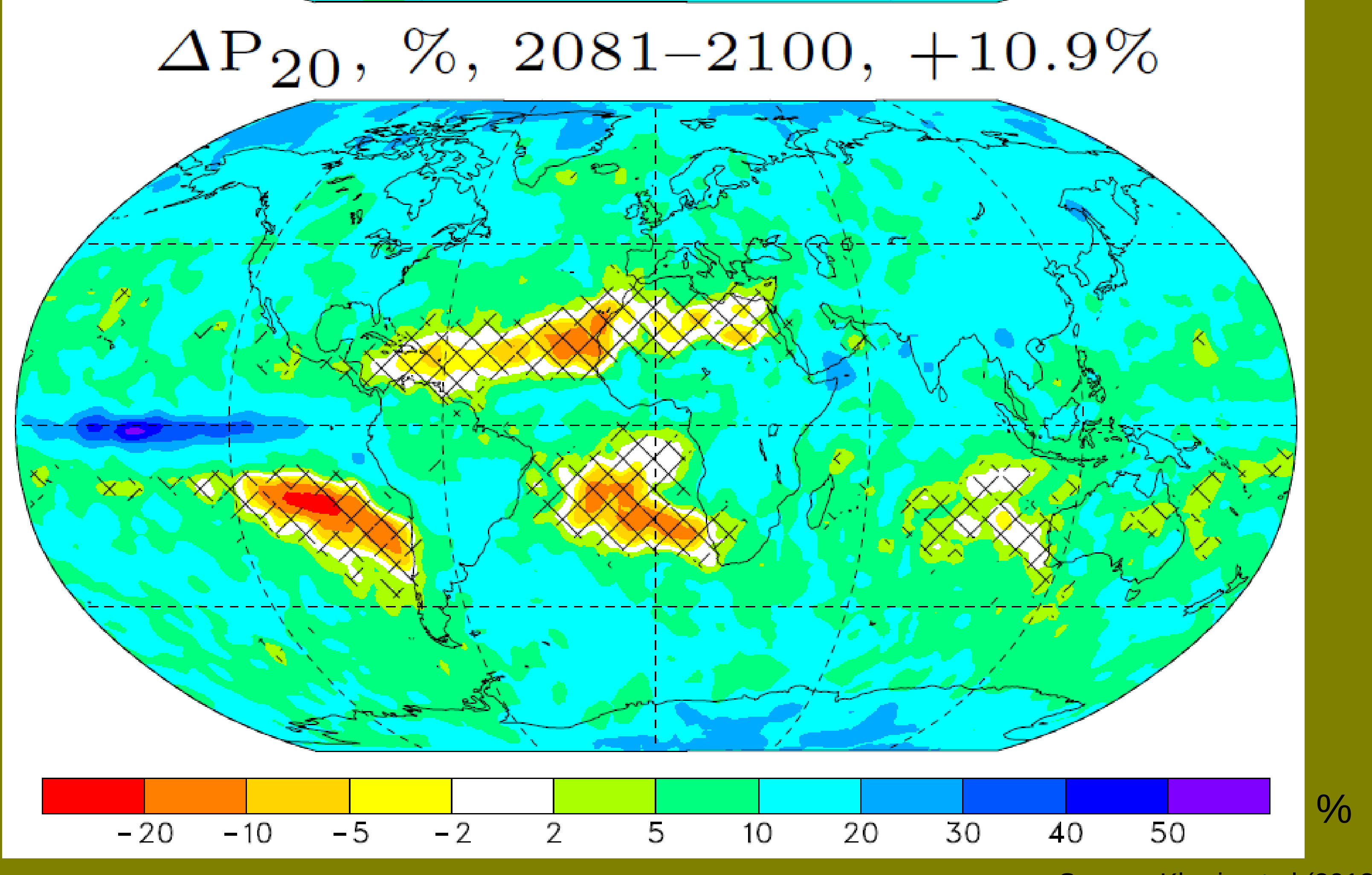
Return period
(relative to 1986-2006)



Kharin et al (2013)

CMIP5 RCP4.5 precipitation projections

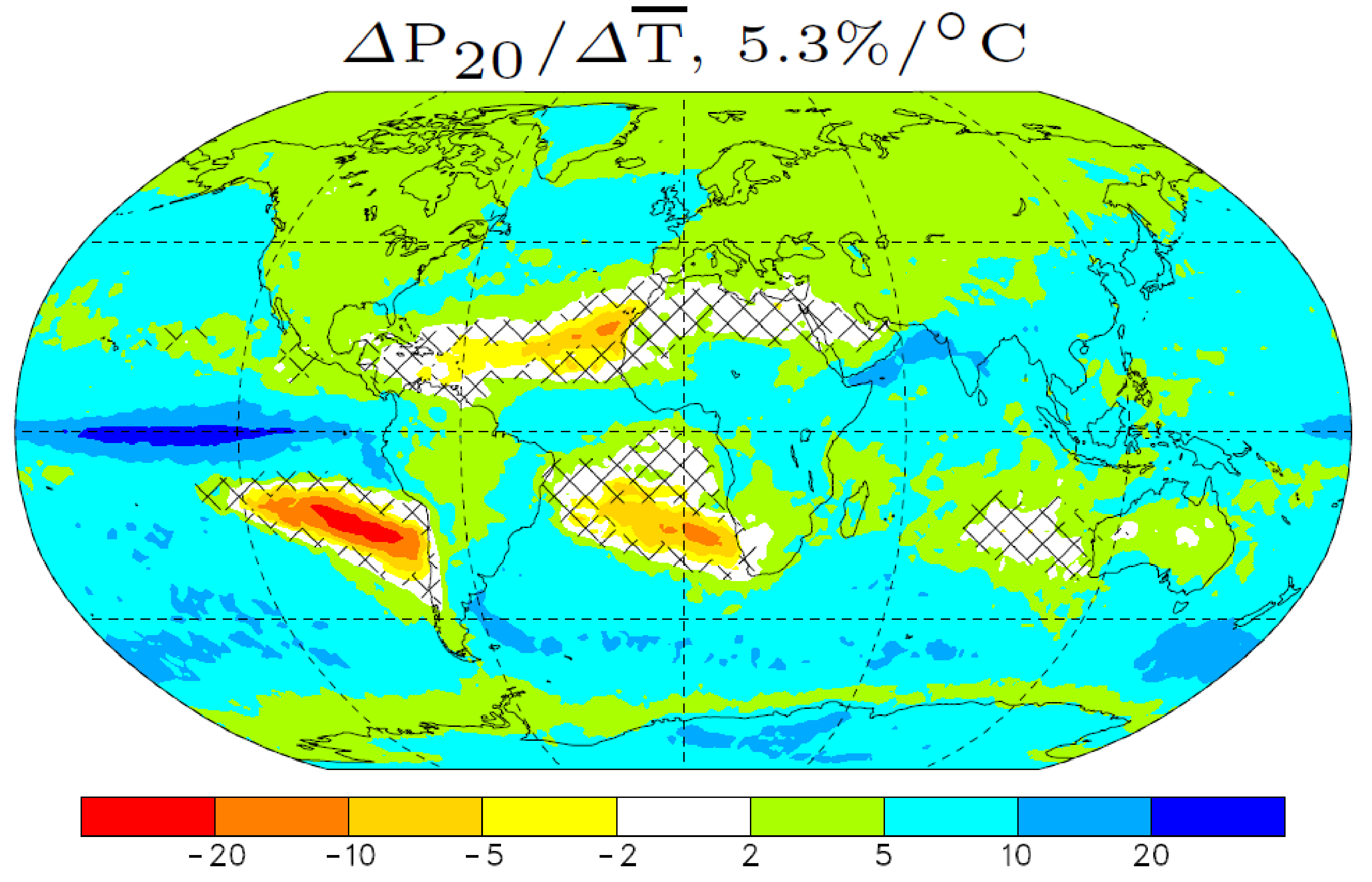
Change in 20-yr extremes relative to 1986-2005



Source: Kharin et al (2013)

CMIP5 Precipitation Sensitivity

Local sensitivity of 20-year extremes



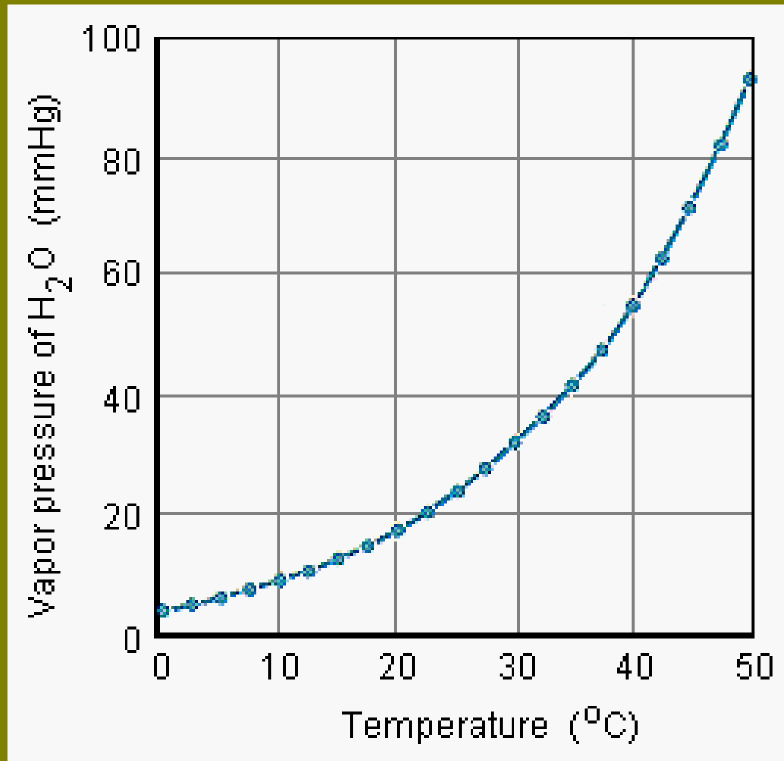
Source: Kharin et al (2013)

The Clausius-Clapeyron Equation

$$P = Ae^{-\Delta H_{\text{vap}}/RT}$$

R= Gas constant
A=Unknown constant

$$ln\frac{P1}{P2} = \frac{\Delta H_{\text{vap}}}{R}(\frac{1}{T2} - \frac{1}{T1})$$



The Clausius-Clapeyron Equation

- The '**absolute humidity**' must be increasing at the **Clausius-Clapeyron** rate
- In most models, global precipitation increase substantially less than this rate (Held et al., 2006)
- Balance of energy fluxes that determines precipitation changes
- In the global mean, evaporation must be equal to precipitation (O'Gorman et al., 2012)

Extremes

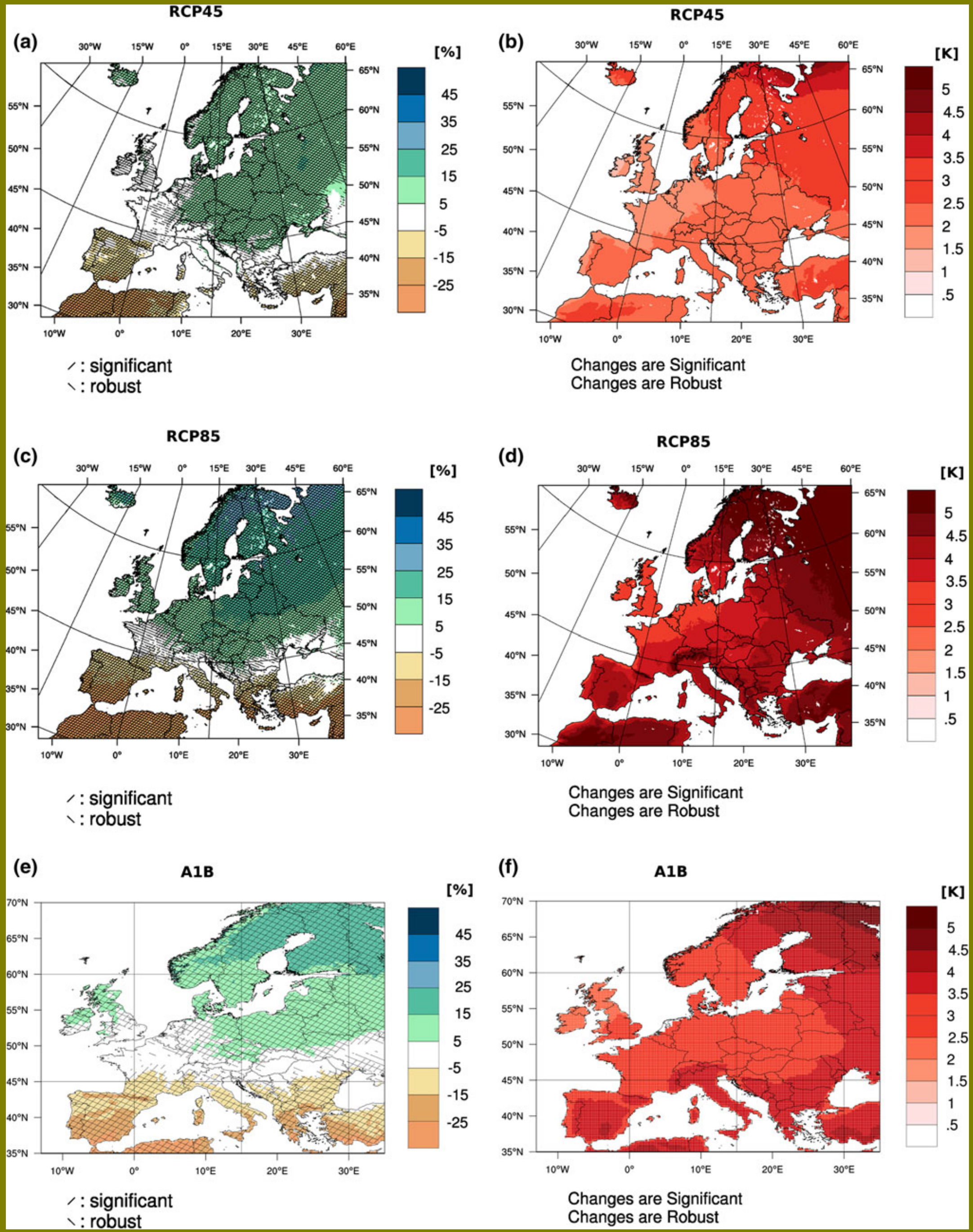
- Climate models project increases over extreme precipitation with global warming rates mostly within that of saturation humidity increases.

- Puzzling phenomenon:

  "Extreme precipitation on short timescales increases with temperature exceeding the ***Clausius-Clapeyron*** rate" (Lenderink et al., 2008; Utsumi et al., 2011; Lenderink et al., 2011).

- The ***Clausius-Clapeyron*** rate is startling, but could perhaps be understood better when considering changes in the dynamics of moisture fluxes with precipitation clouds (Muller et al., 2011; Singleton et al., 2011).

High Res. Scenarios From EURO-CORDEX Project



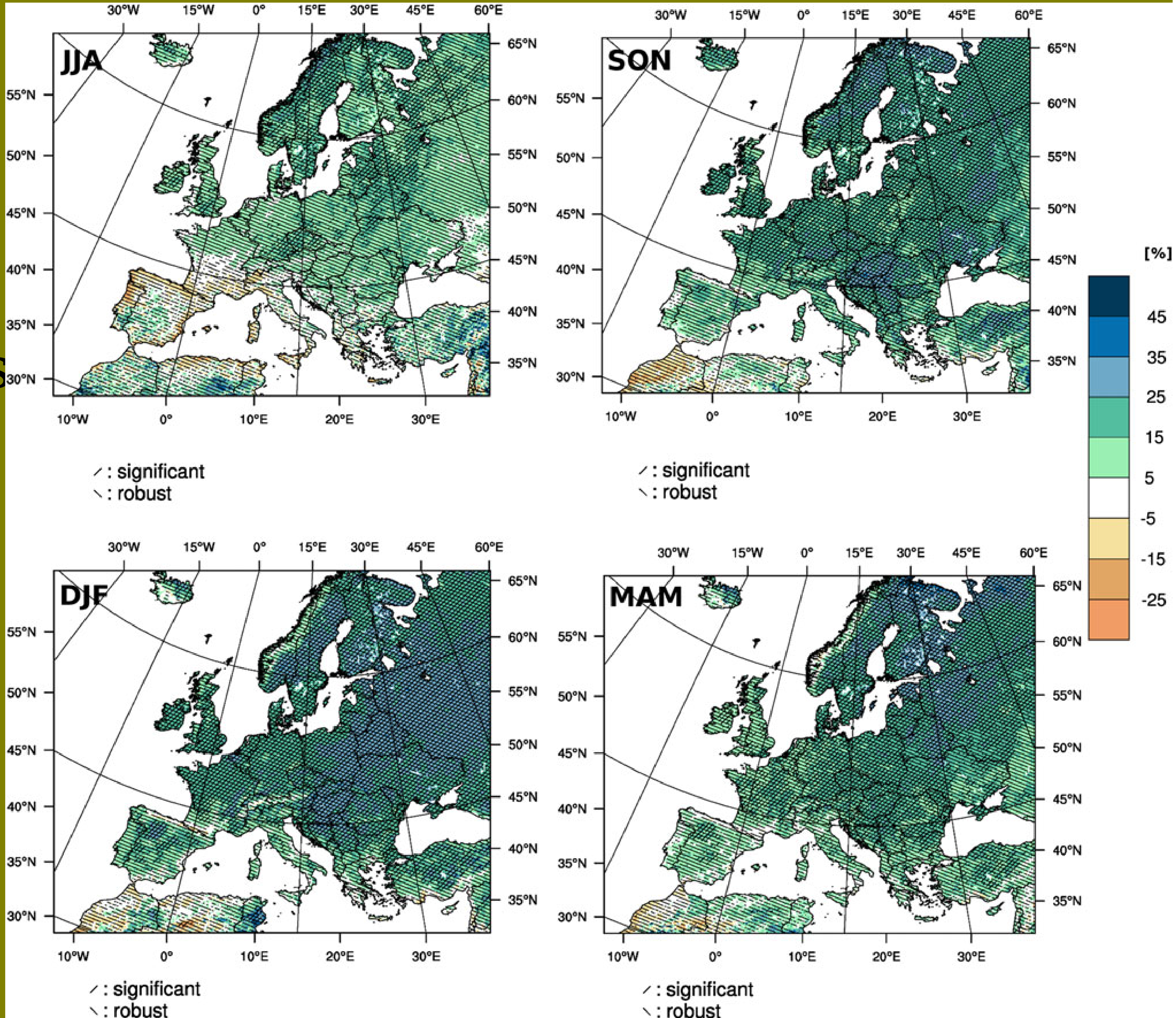
Extreme Indices

- “Heavy precipitation”-intensity of the precipitation events as the 95th percentile of the daily precipitation (only days with >1mm/day were considered.
- Dry spells-periods at least 5 consecutive days with daily precipitation below 1 mm.
- Heat waves-two definitions were used

-three consecutive days exceeding 99th percentile of the daily maximum temperature of May to September season of the control period (1971-2000).

-5 consecutive days daily maximum temperature exceeding the mean max. temp of May to September by at least 5^{o}C.

Extremes from EURO-CORDEX Project



EURO-CORDEX: Major Conclusions

- Northward shift of Mediterranean drying evolution and slightly stronger mean precipitation increases over Europe.
- Clearly visible in the change pattern for heavy precipitation. It is related to better resolved physical processes like:

    -convection and heavy precipitation

    -better representation of surface characteristics and their spatial variability
- RCMs provide higher daily precipitation intensities than the GCMs. They provide a significantly different climate change of daily precipitation intensities resulting in a smother shift from weak to moderate and high intensities.

Extremes: Major Limitations

- The state of historical observational records
- Limitations in the statistical and other tools that are used for analyzing observed changes in extremes
- Limitations in the understanding of the processes that are involved in the production of extreme events
- The ability to describe the natural variability of extremes with models and other tools
- Reducing uncertainty in our understanding of historical changes in extremes over the instrumental period as a prerequisite to confidently predicting changes over the next century.

Source: Zwiers et al., 2013

Extremes: Major Limitations

- Due to limited resolution, current global climate models do not simulate precipitation extremes that are of the same intensity as those that are observed in station data (Chen and Knutson, 2008).
- We are yet to resolve the "scale" issue regarding the physical processes of extremes (Zwiers *et al*., 2013)
- Understanding the role of large scale low frequency variability such as the ENSO on the intensity and frequency of extreme precipitation
- Challenge of understanding the "multi-variable climate extremes"
- Reliable detection and attribution of changes in extremes, depends heavily upon *the ability of models to simulate the natural background variability of the climate system* .

“While our understanding of how climate change affects extreme weather is still developing, evidence suggests that extreme weather may be affected even more than anticipated. Extreme weather is on the rise, and the indications are that it will continue to increase, in both predictable and unpredictable ways.”

Source: www.climatecommunication.org

Still a Long Way to Go…

Photo: Man Wu (http://www.flickriver.com/photos/manwu/popular-interesting/)