KU LEUVEN

Uncertainties in Impact Assessment of Climate Change on Rainfall Extremes in the Lake Victoria Basin



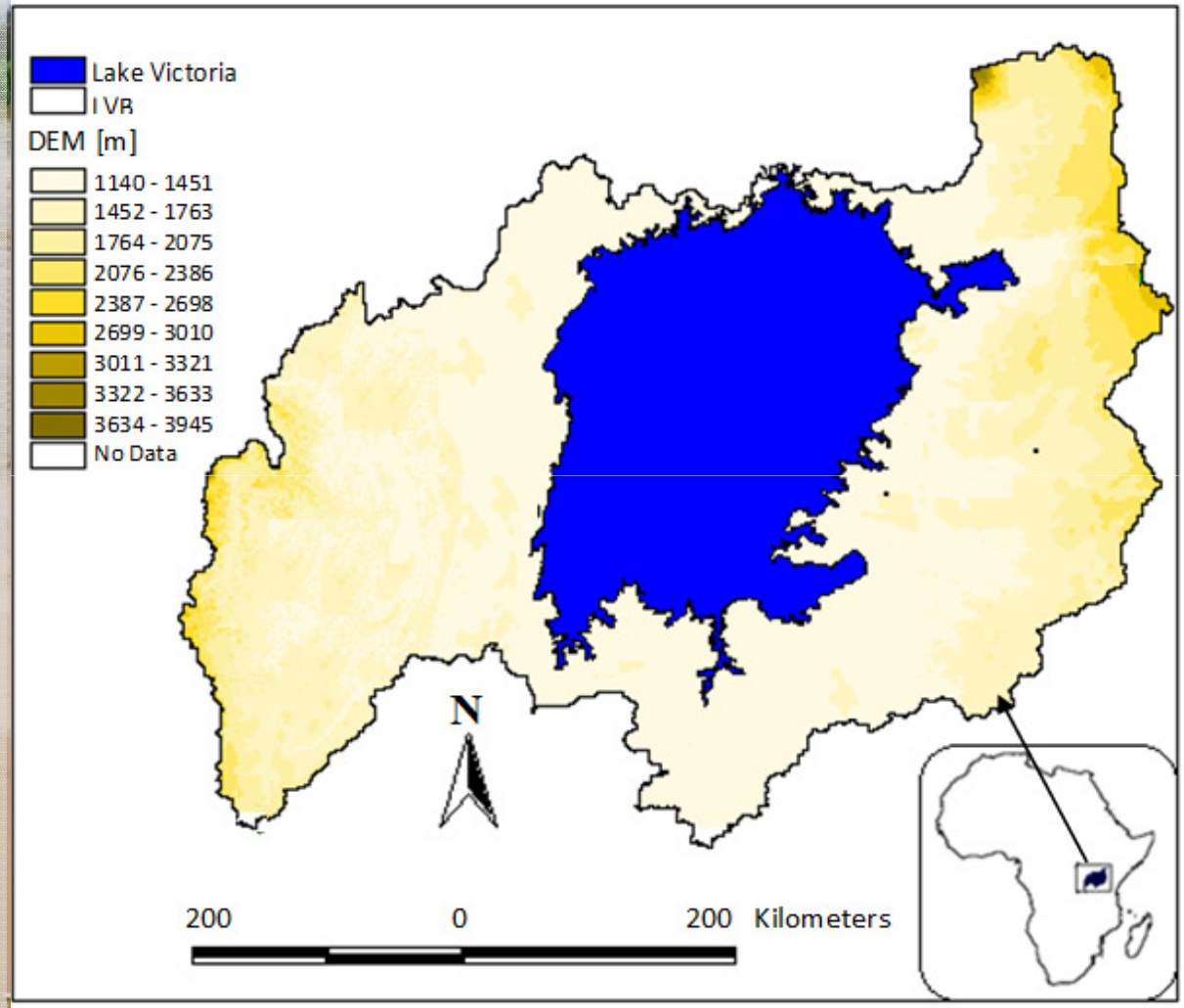
C. Onyutha, P. Nyeko-Ogiramoi & P. Willems

July 28th, 2014





Why Lake Victoria Basin?



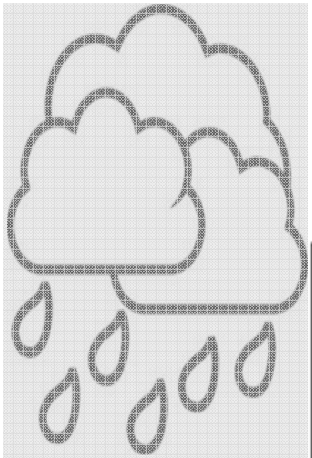
World
LVB has 2nd largest fresh water lake

R. Nile
Key source

Extreme rainfalls
episodes of floods
+ loss of lives
+ damage to prop.

Population
- so high
- increased poverty

Need for proper mgt of water resource

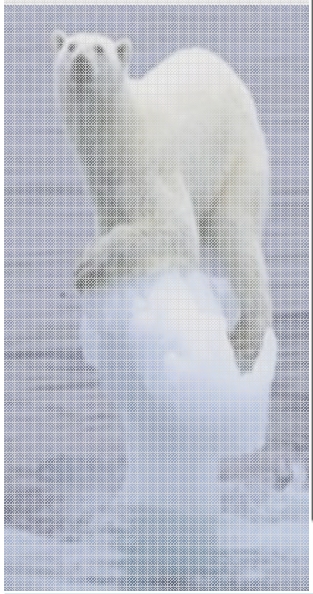


Scenarios

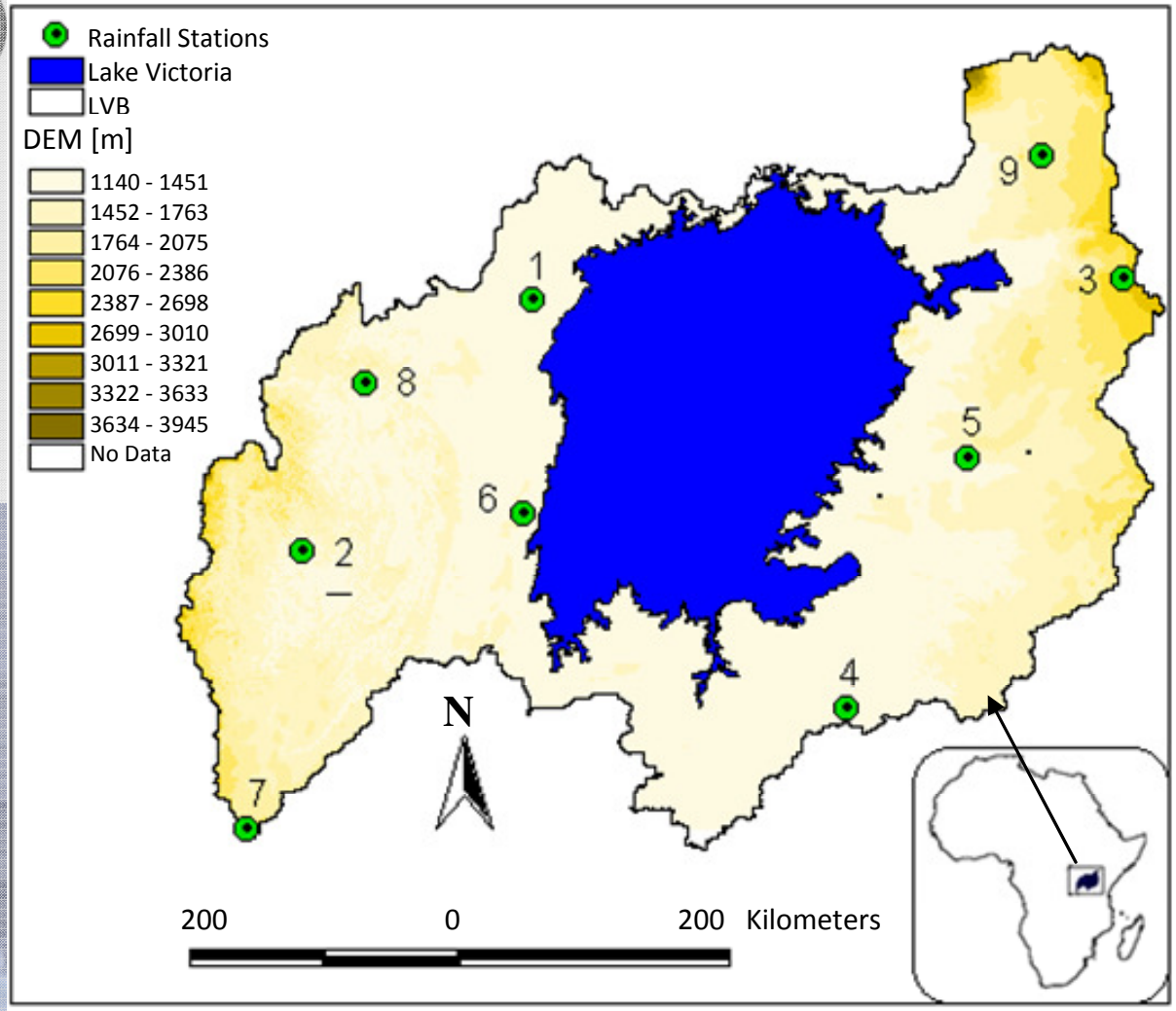
B1-550ppm of CO_2

A1B-720ppm of CO_2

A2-850ppm of CO_2



Data



Rainfall

1961-2000

GCMs

14 – CMIP3

7 – CMIP5

Control/Hist. sim

20 – CMIP3

17 – CMIP5

Fut. Projections

53 – CMIP3

35 – CMIP5

Horizon

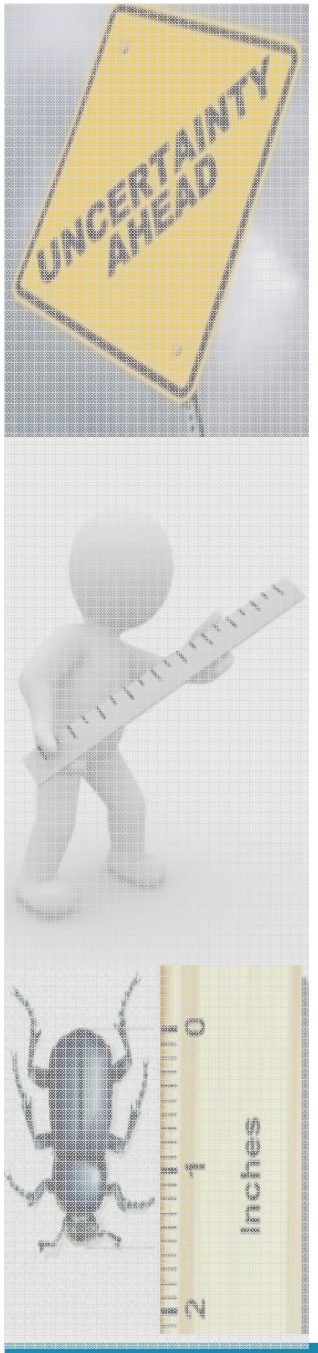
2049-2065 [2050s]

2081-2100 [2090s]

Scenarios

B1, A1B, A2 – CMIP3

rcp4.5, 6.0, 8.5 – CMIP5



Sources of uncertainty

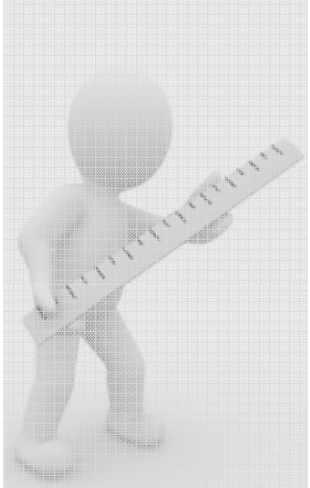
Those due to:

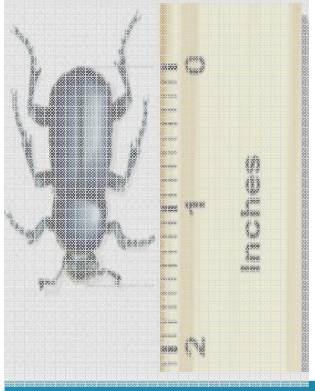
→ **Sampling extremes**

→ **Inter-GCM differences**

→ **Difference between statistical downscaling methods**







Uncertainty – sampling of extremes

Data limitation: sampling extremes

→ **Risk based applications:** - detailed representation - rainfall

→ **Planning, Design & Operation:** accurate descriptive study - extremes & recurrence rates - **long-term series**

→ **Extreme value analysis:** Data scarce area - short-term series –**extrapolation**

→ **Predictive uncertainty:** - large - **important to quantify for decision making**



Quantifying uncertainty

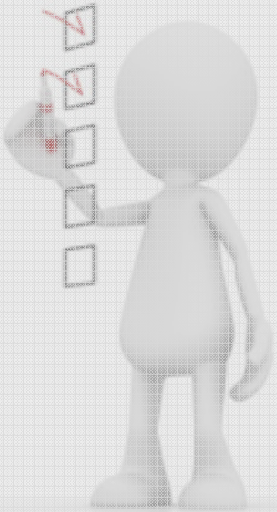
How ?

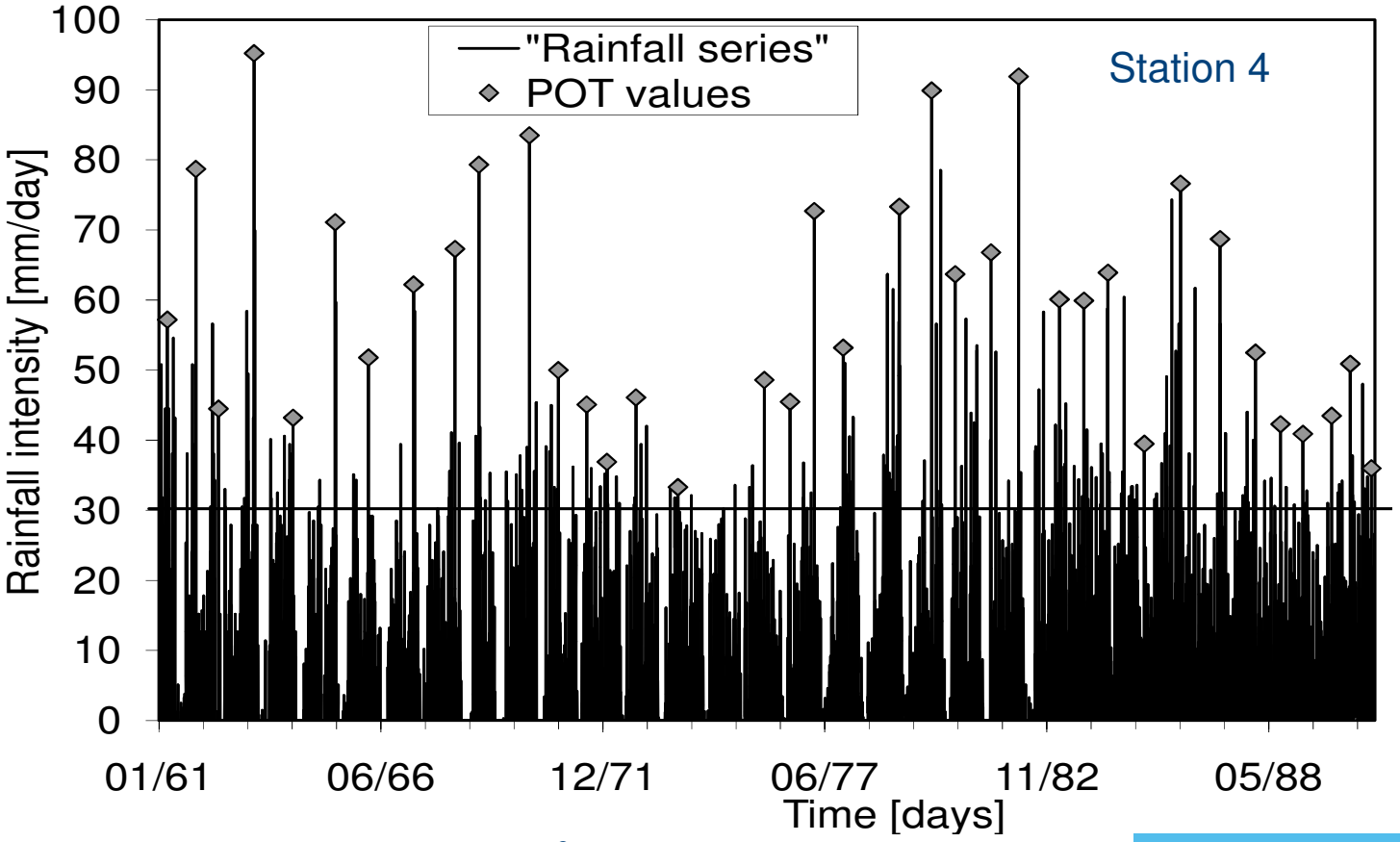
→ **Extract independent extremes** – AMS/PDS

POTs

EVD fitting

Resampling



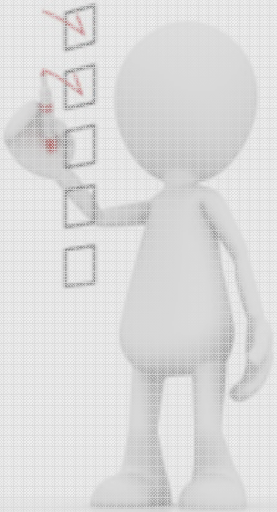




POTs

EVD fitting

Resampling

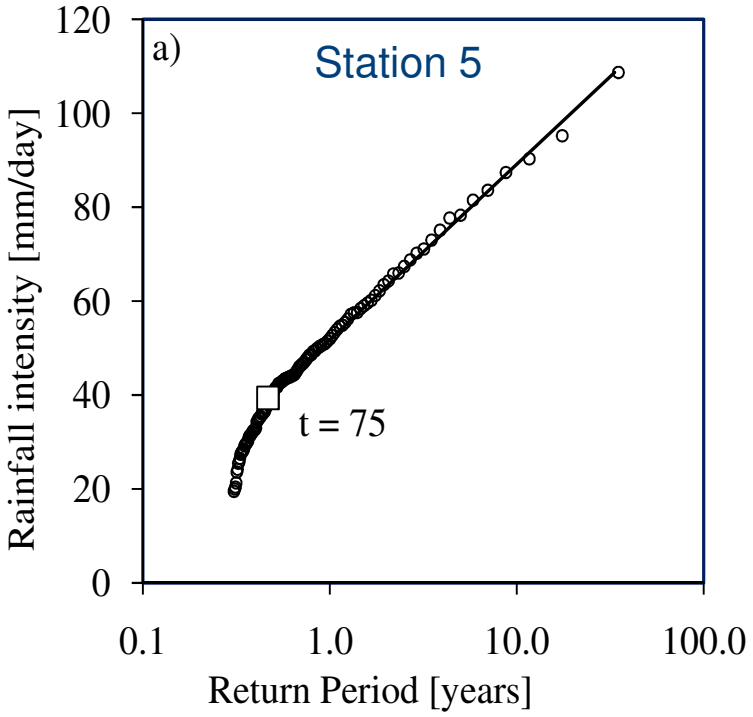


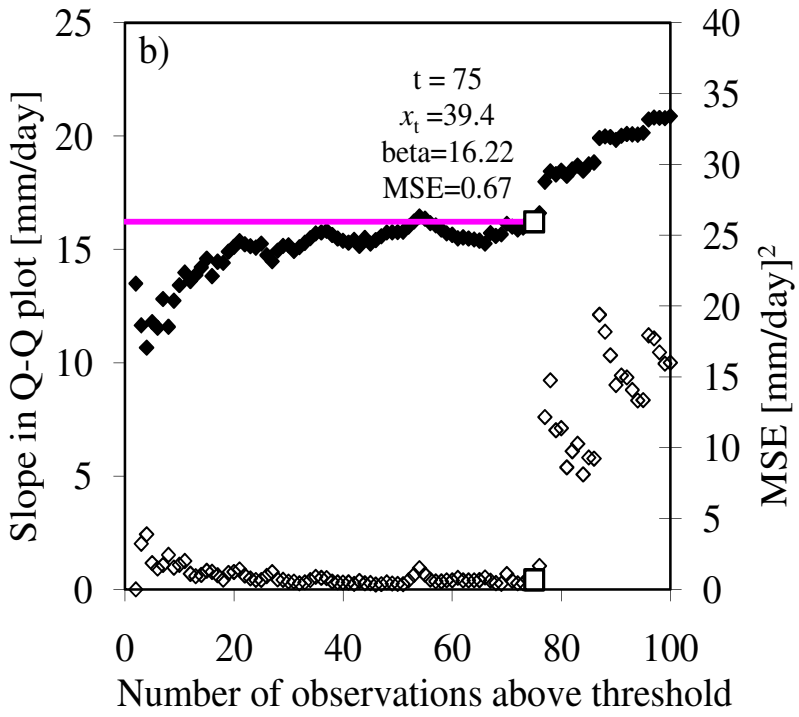
Quantifying uncertainty

How ?

→ **Parameter estimation** – GPD(loc, scale, shape) - fit distribution - Q-Q plot

→ **Method** – Weighted Linear Regression*





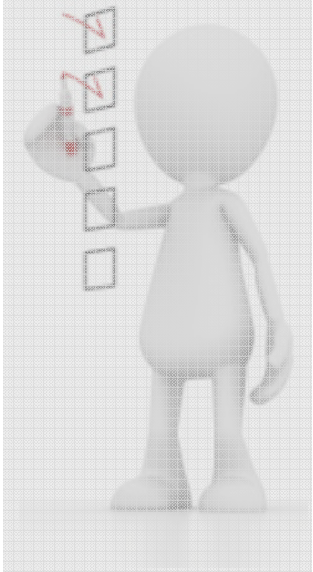
*Onyutha, C. & Willems, P. (2014). Uncertainty in calibrating generalised Pareto distribution to rainfall extremes in Lake Victoria basin. Hydrol. Res. Doi:10.2166/nh.2014.052



POTs

EVD fitting

Resampling



Quantifying uncertainty

How ?

→ **Uncertainty on extremes**– resampling - Jackknife – at 5% lev. Sig

a) **Delete i^{th} event** from POTs of size w

b) **Determine $\Theta(\beta,\gamma,x_t)$** of EVD using (w -1) POTs

c) Steps (a) and (b) **repeate**d w times

d) **Rank** w sets of **$\Theta(\beta,\gamma,x_t)$** in descending order

e) **Upper and lower limits** are determined from $[0.025\times w]^{th}$ and $[0.975\times w]^{th}$ $\Theta(\beta,\gamma,x_t)$

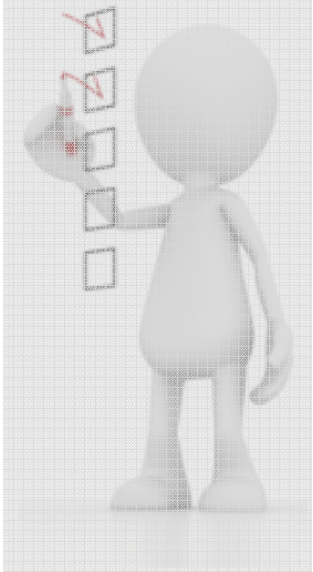
f) 95% CI determined using (e) above



POTs

EVD fitting

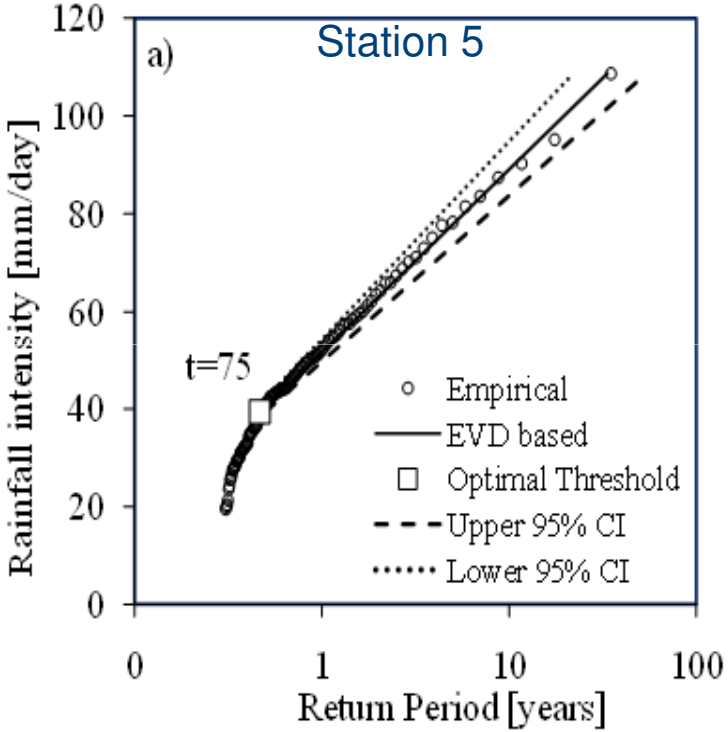
Resampling



Quantifying uncertainty

How ?

→ **Uncertainty on extremes**– resampling - Jackknife – at 5% lev. Sig

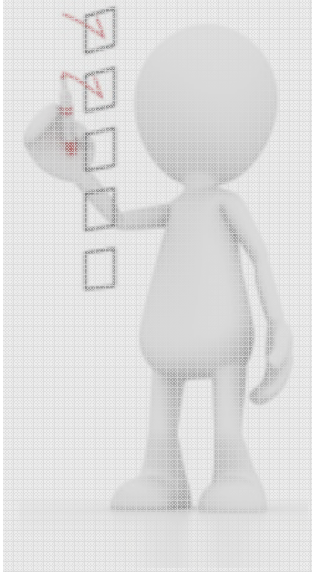




POTs

EVD fitting

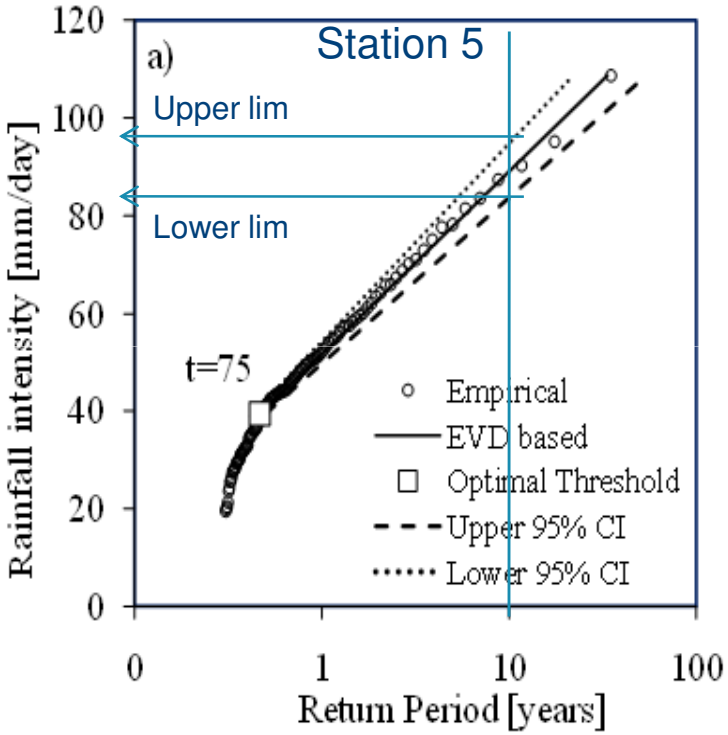
Resampling



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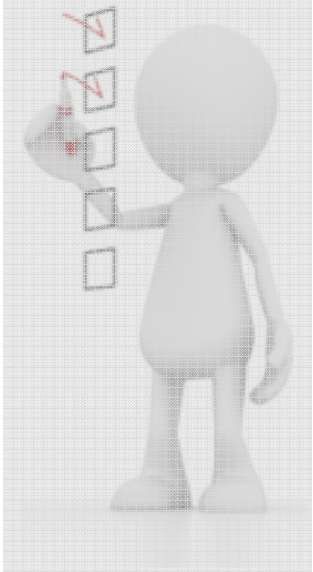




POTs

EVD fitting

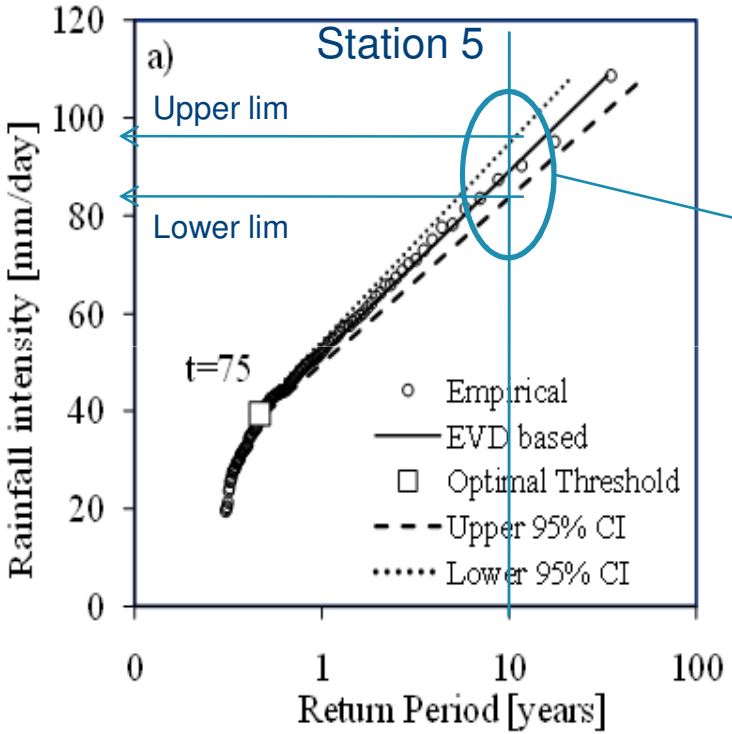
Resampling

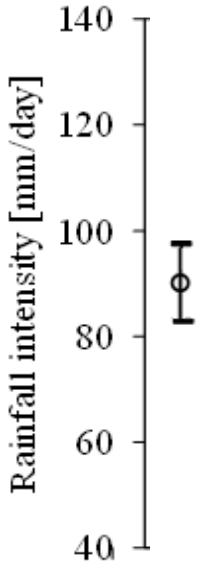


Quantifying uncertainty

How ?

→ **Uncertainty on extremes**– resampling - Jackknife – at 5% lev. Sig



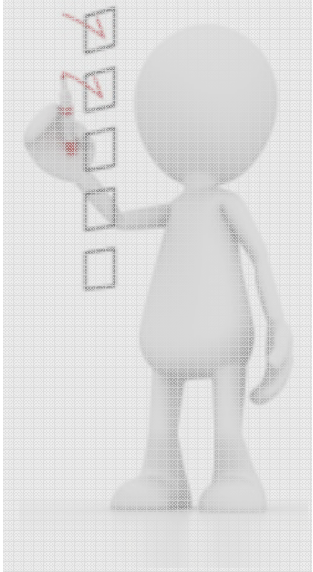




POTs

EVD fitting

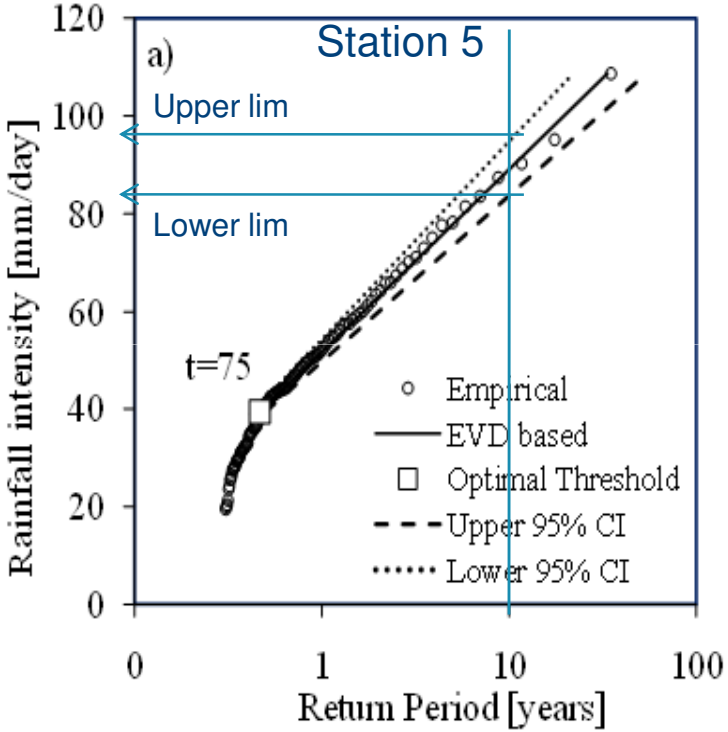
Resampling

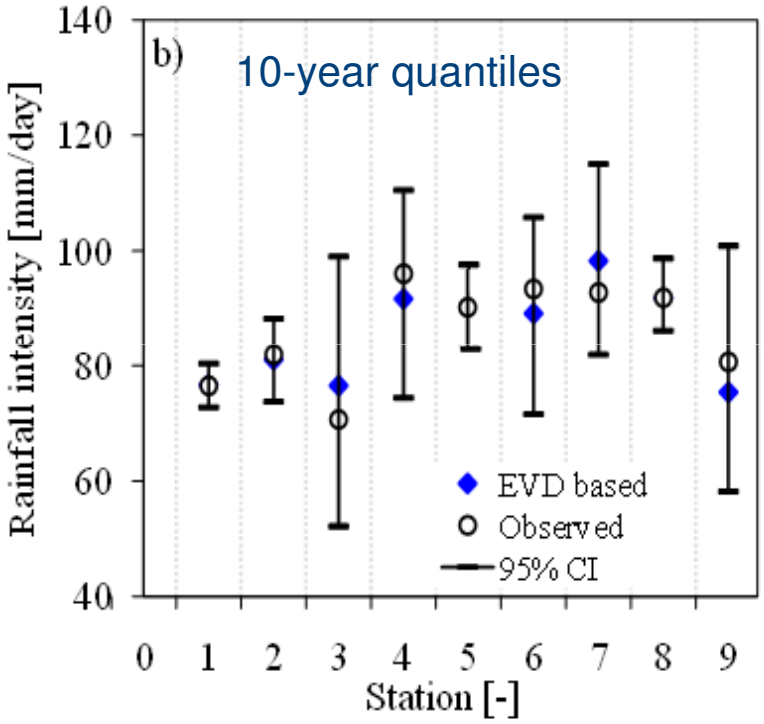


Quantifying uncertainty

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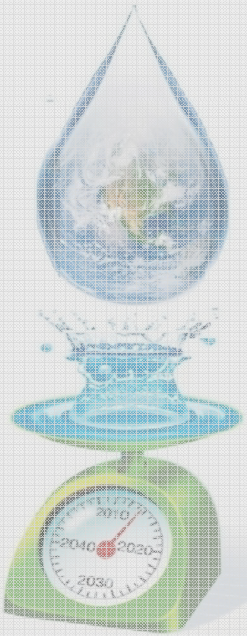




→ **10 years < 40** data record length(1961-2000)– what if, say 100 years is used?

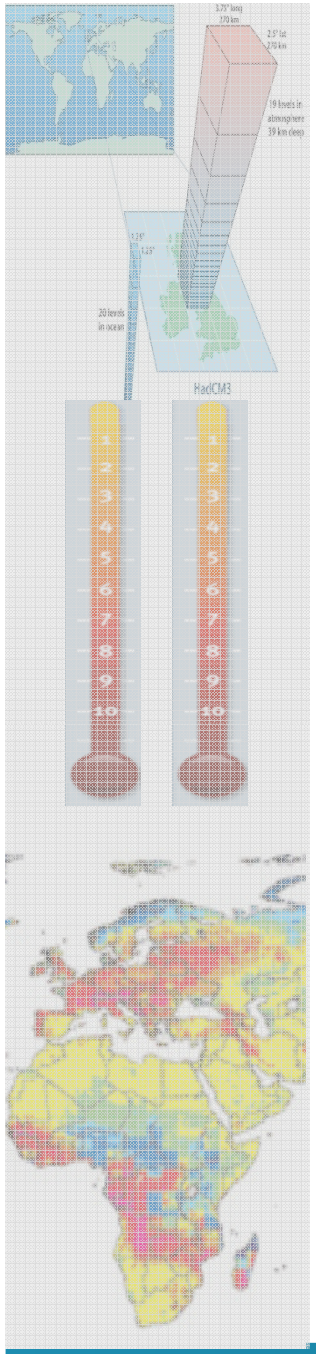


Climate change & Extremes







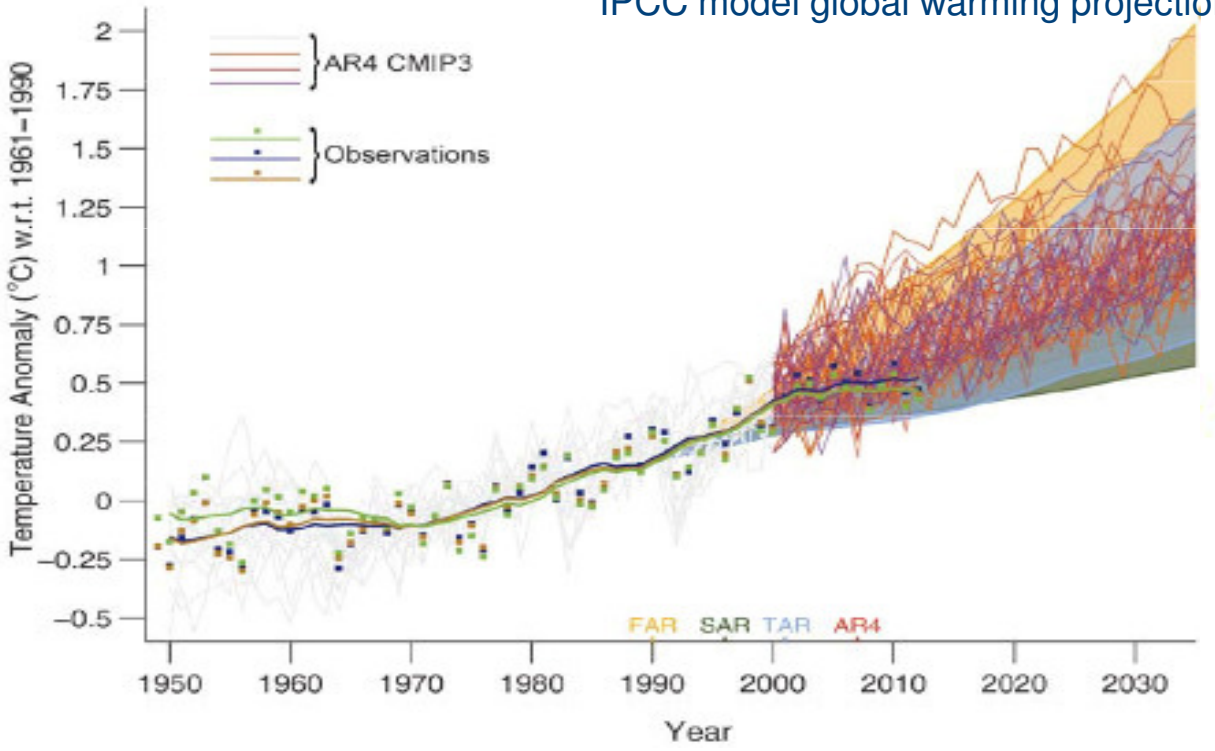


Inter-Global climate model differences

Climate change: Managers confronted - impact on hydro-clim. Extremes

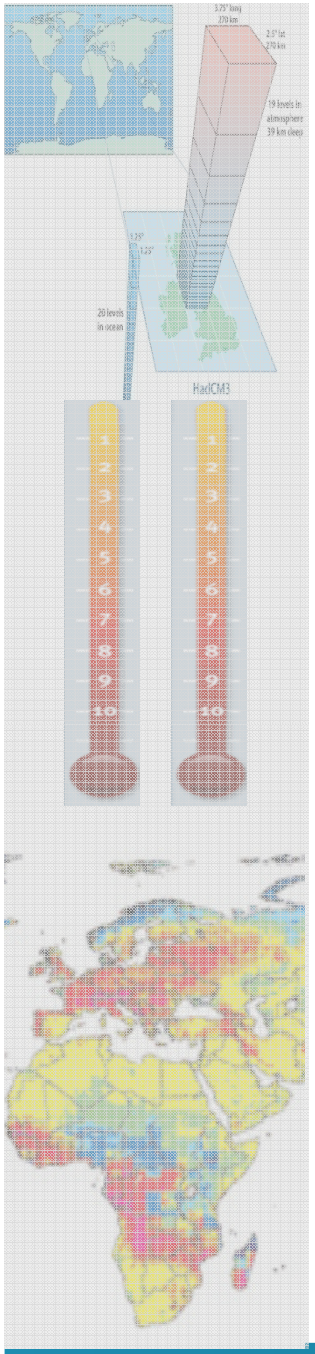
→ **Impact analysis :** - not uncertainty-free - large differences exist

IPCC model global warming projections



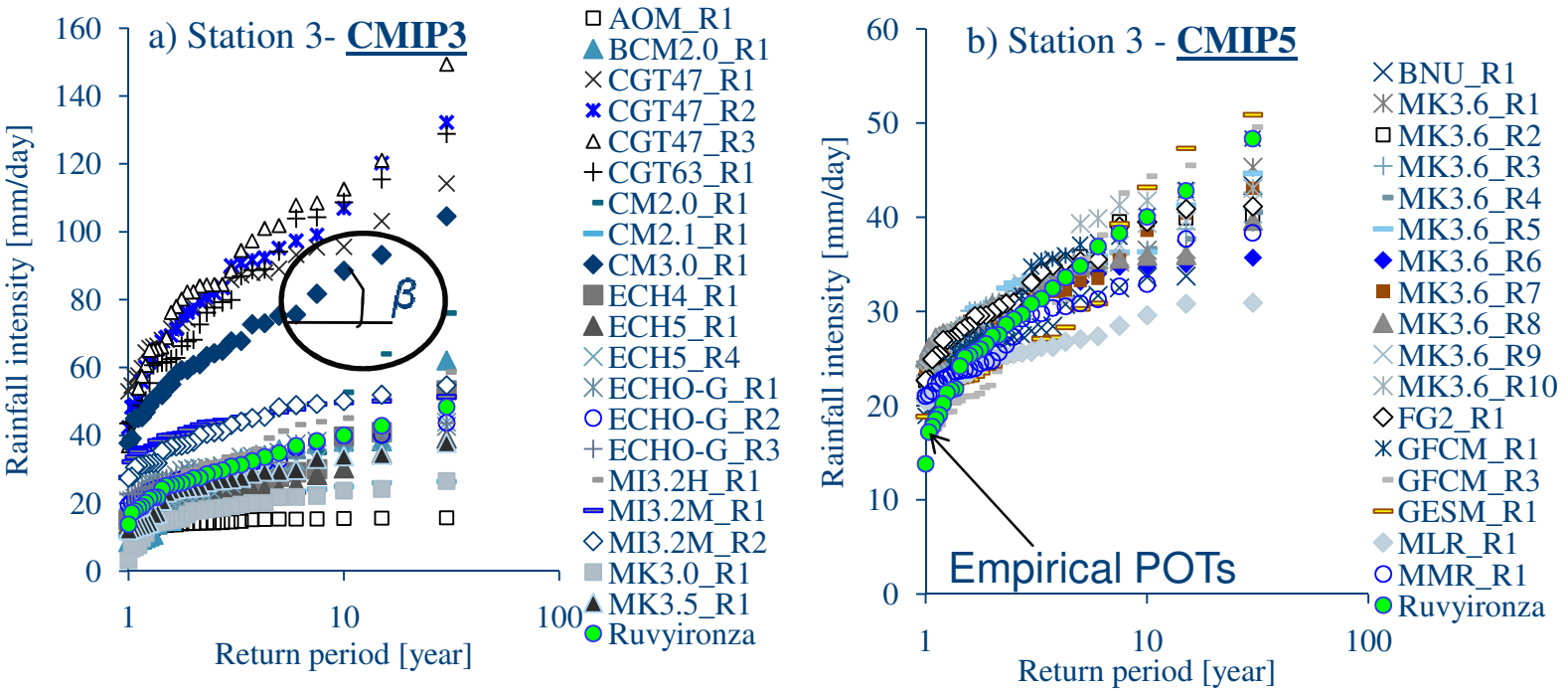


Source: IPCC (2013) report

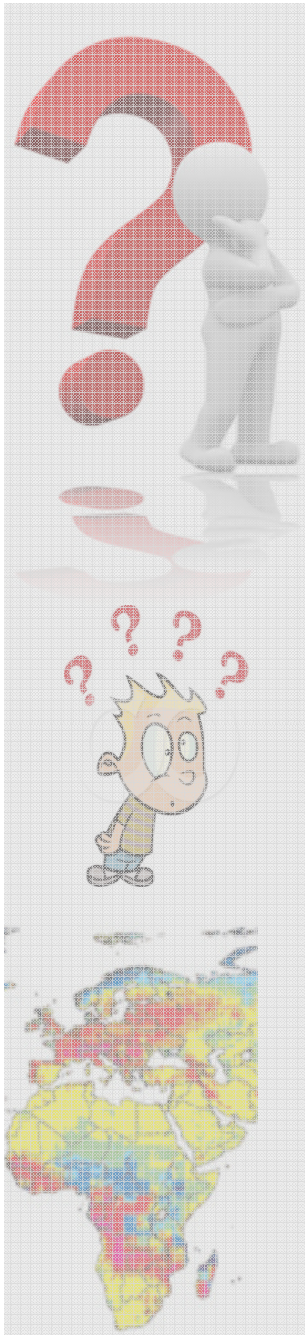


Inter-GCM differences

→ **Inter-compare GCMs:** metrics - Bias, SEE, *β*-related

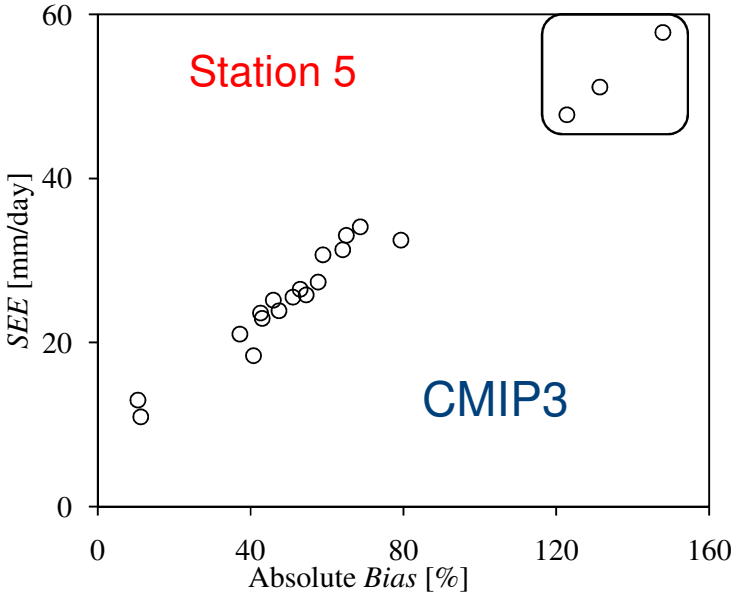


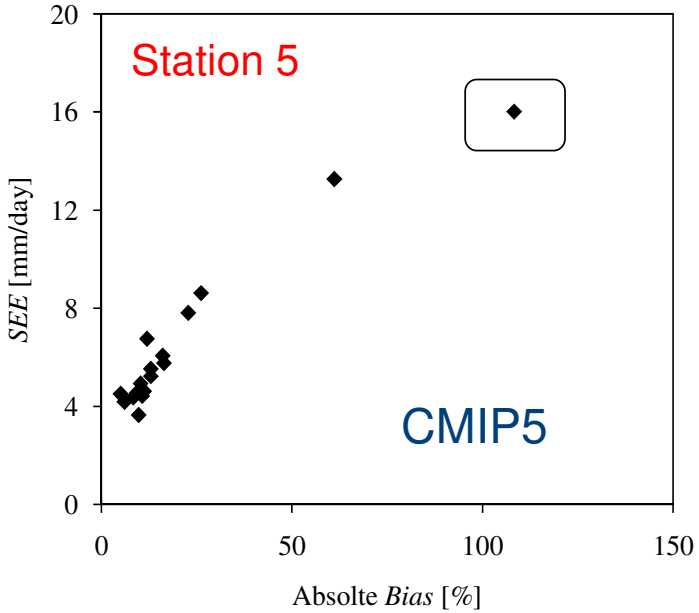
A higher value of *β* means higher variations in extreme rainfall intensity



Inter-GCM differences

→ **Bias versus SEE:** - quantifying differences btn control runs & empirical series



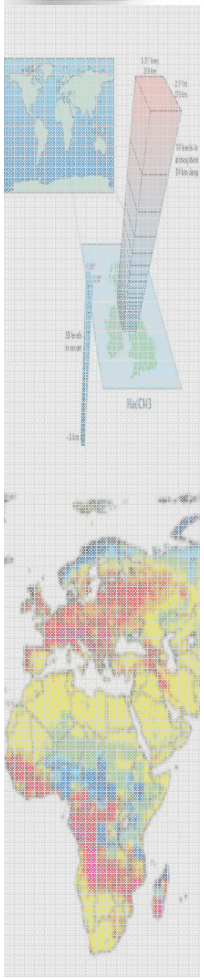


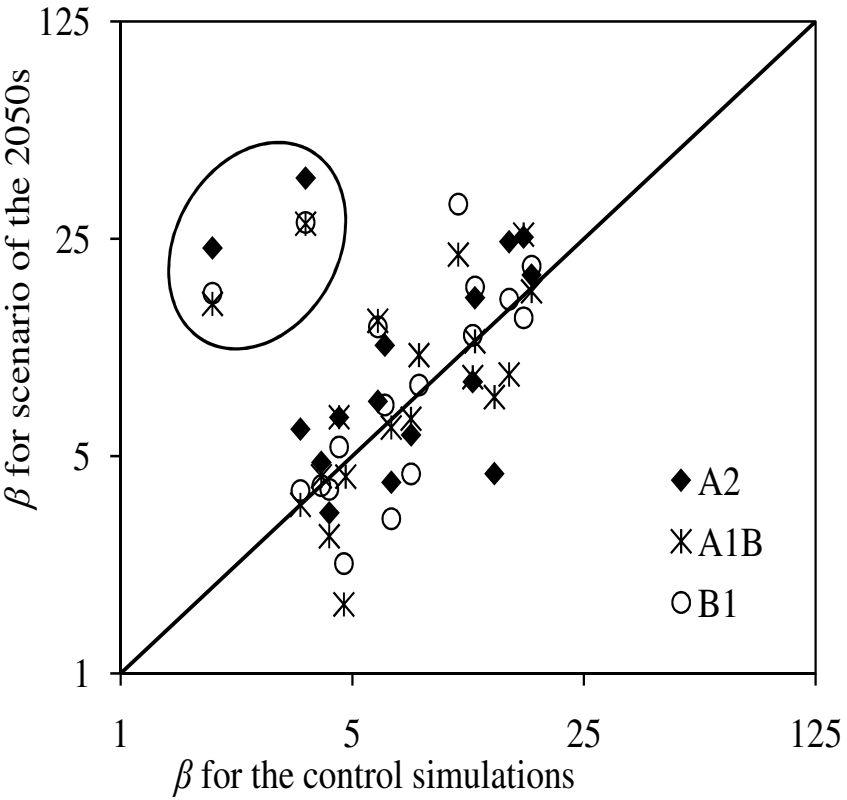


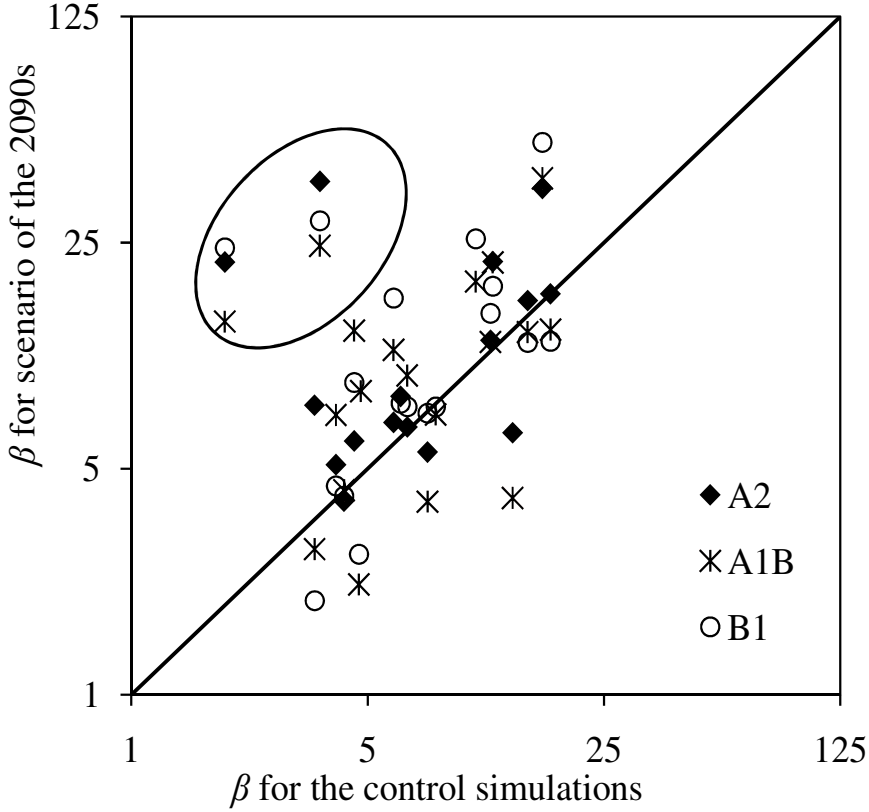
Inter-Global climate model differences

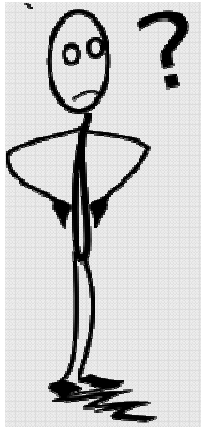
→ **Control versus scenario:** β – EVD scale parameter

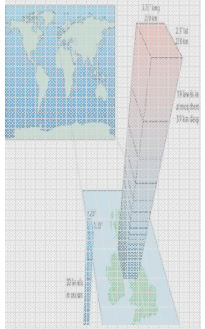
Station 5 – CMIP3

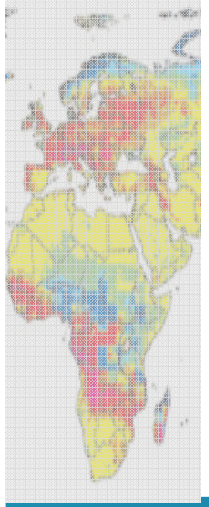






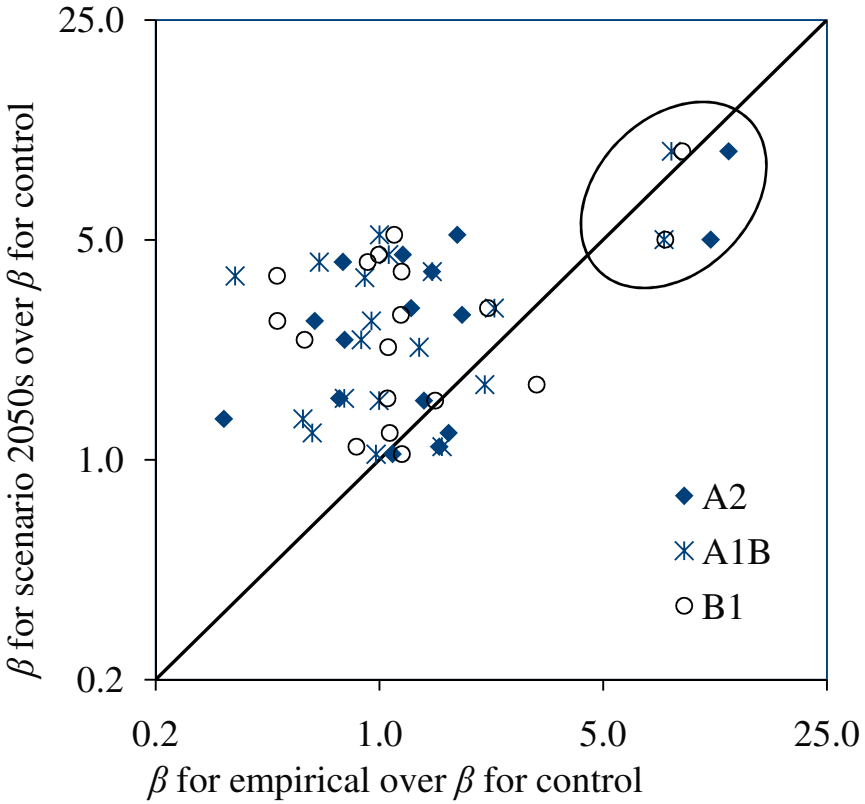


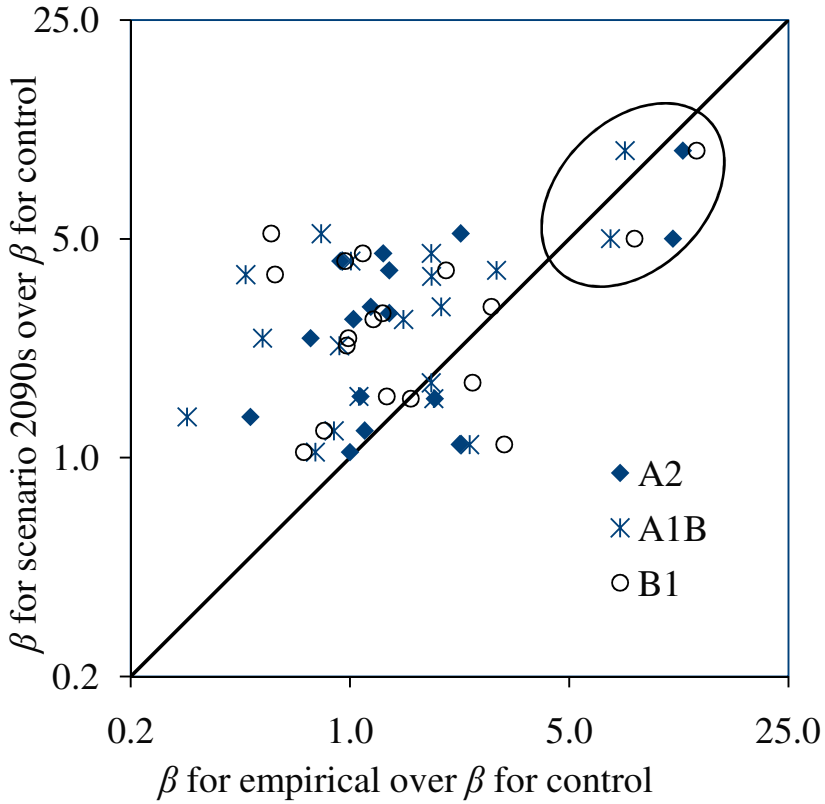


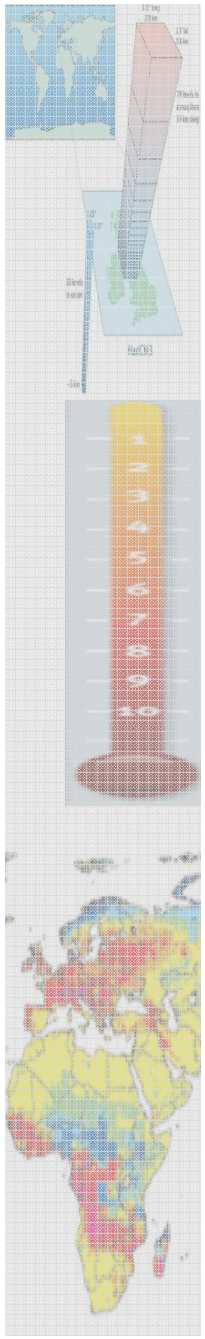


Inter-Global climate model differences

→ **Combining empirical, control and scenario:** Station 5 – CMIP3



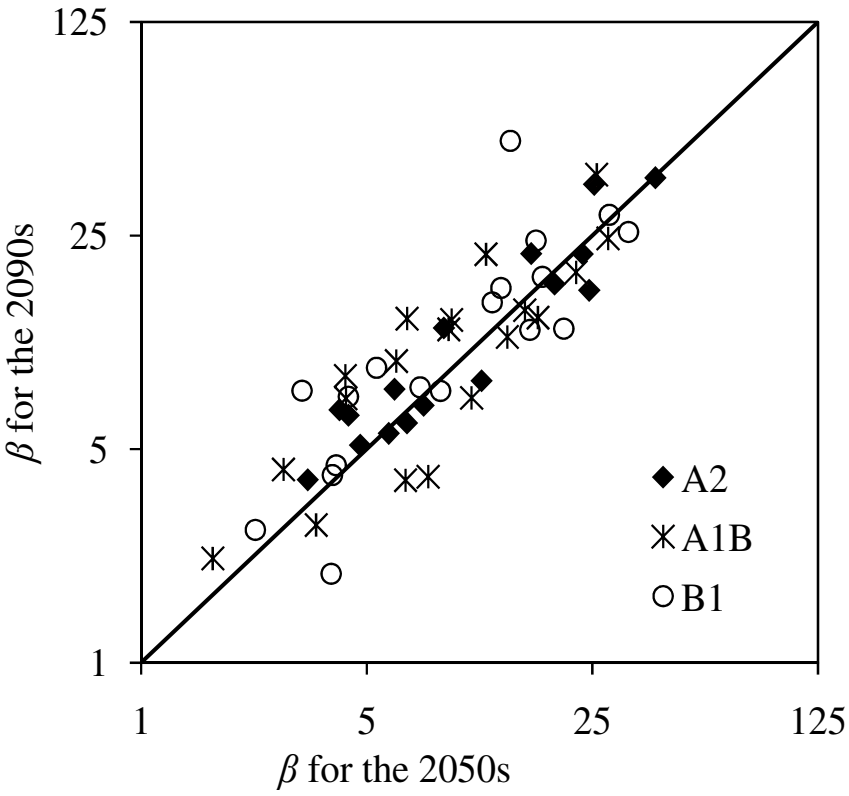


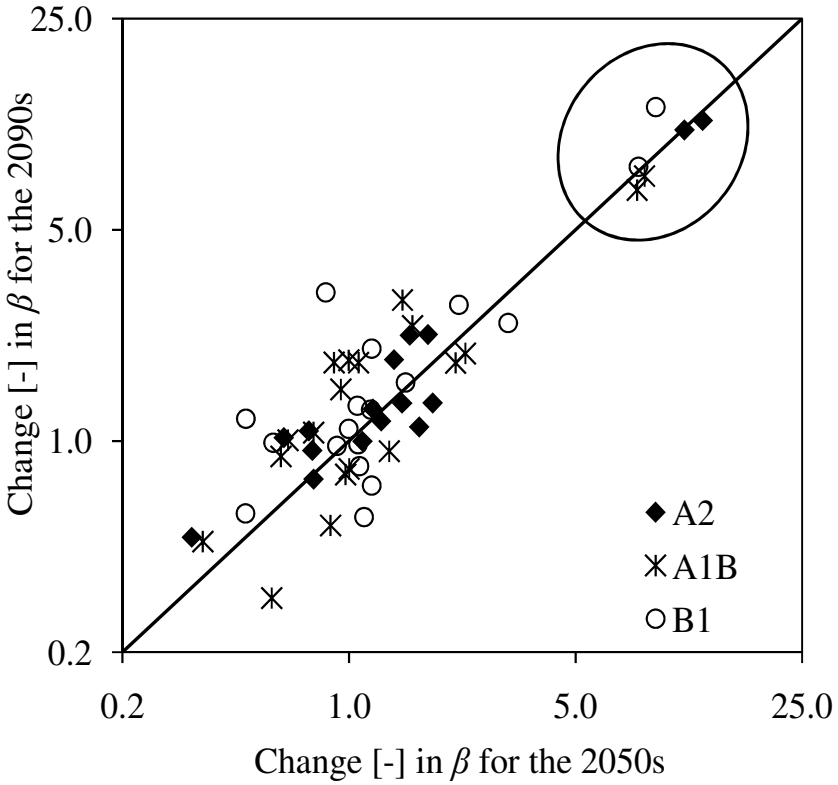


Inter-GCM differences

→ **Control versus scenario:** change in β

Station 5 – CMIP3







Inconsistency of the GCMs

What should I do?

→ **Seive-out the GCMs:**

- Poor performance for:
  - CMIP5 by GFDL-ESM-2G_R1 at station 9
  - CMIP3

by	at station(s)
CSIRO-MK3.0,R1	4 and 6
GISS-AOM,R1	5 and 9
GFDL-CM2.0,R1	5





→ **Decision:** Downscale – consistent GCMs



Difference in statistical downscaling

what methods?

→ **Delta:** changes in mean of rainfall

$P_{Fut,d}$ = future daily rainfall
$P_{Obs,d}$ = the observed daily series
$P_{Sce,m}$ = mean of GCM scenario series for month *m*
$P_{Con,m}$ = mean of GCM control series for month *m*

$$P_{Fut,d}\ [mm/day] = P_{Obs,d} \times \frac{P_{Sce,m}}{P_{Con,m}}$$





Difference in statistical downscaling

what methods?

→ **Delta:** changes in mean of rainfall

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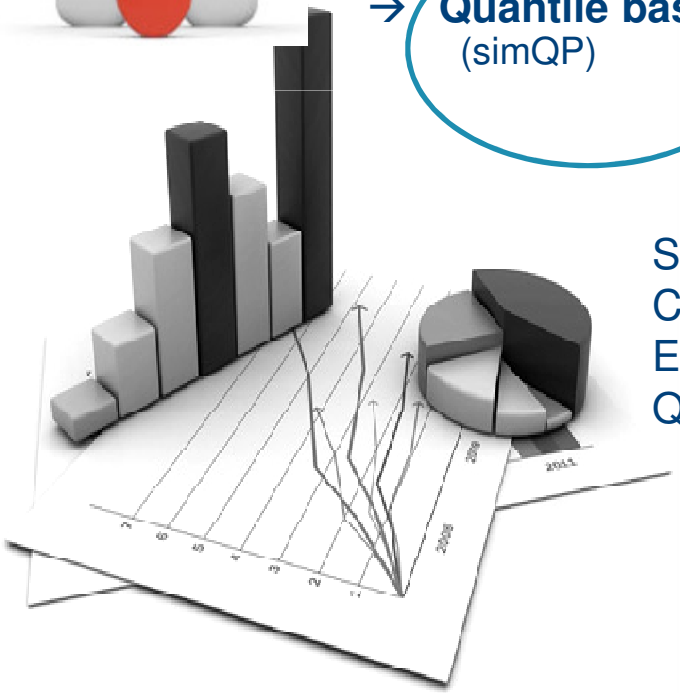
→ **Quantile based:** (simQP)

$$P_{Future}(i)\ [mm/day] = ex_i \times \frac{sx_i}{cx_i}$$

Thresh. >1 mm/day…RelQp

$$P_{Fut}(i)\ [mm/day] = ex_i + |sx_i - cx_i|$$

Threshold<1 mm/day…AbsQp



Scenario series - quantiles $sx_1 \geq sx_2 \geq \ldots \geq sx_i \ldots\ldots \geq sx_B$;
Control series quantiles $cx_1 \geq cx_2 \geq \ldots \geq cx_i \ldots\ldots \geq cx_B$;
Empirical quantiles $ex_1 \geq ex_2 \geq \ldots \geq ex_i \ldots\ldots \geq ex_B$;
Quantile pert. factors $Qp_1 \geq Qp_2 \geq \ldots \geq Qp_i \ldots\ldots \geq Qp_B$,
relative $Qp_i = sx_i/cx_i$



Difference in statistical downscaling

what methods?

→ **Delta:** changes in mean of rainfall

$$P_{Fut,d}\ [mm/day] = P_{Obs,d} \times \frac{P_{Sce,m}}{P_{Con,m}}$$

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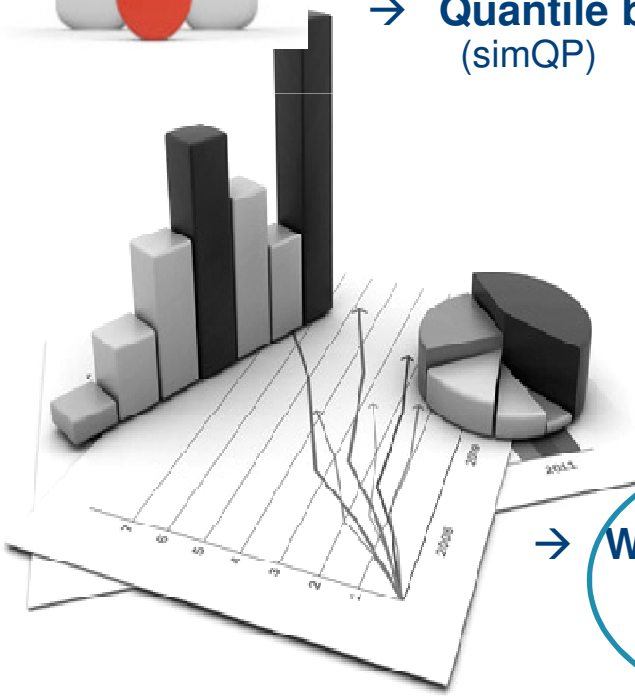
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Threshold<1 mm/day…AbsQp

Scenario series - quantiles $sx_1 \geq sx_2 \geq \ldots \geq sx_i \ldots \geq sx_B$;
Control series quantiles $cx_1 \geq cx_2 \geq \ldots \geq cx_i \ldots \geq cx_B$;
Empirical quantiles $ex_1 \geq ex_2 \geq \ldots \geq ex_i \ldots \geq ex_B$;
Quantile pert. factors $Qp_1 \geq Qp_2 \geq \ldots \geq Qp_i \ldots \geq Qp_B$,
relative $Qp_i = sx_i/cx_i$



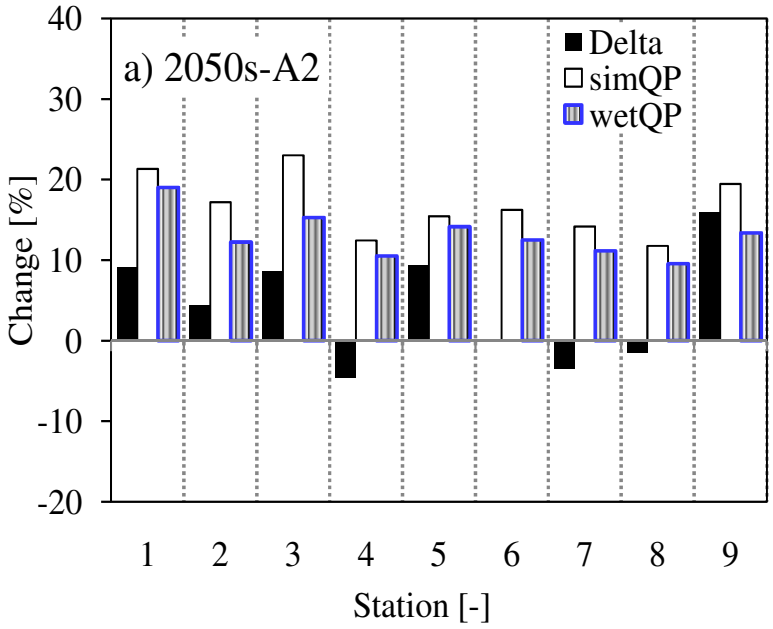
→ **Wet spell-based:** similar to simQP but addition/removal of wet spell

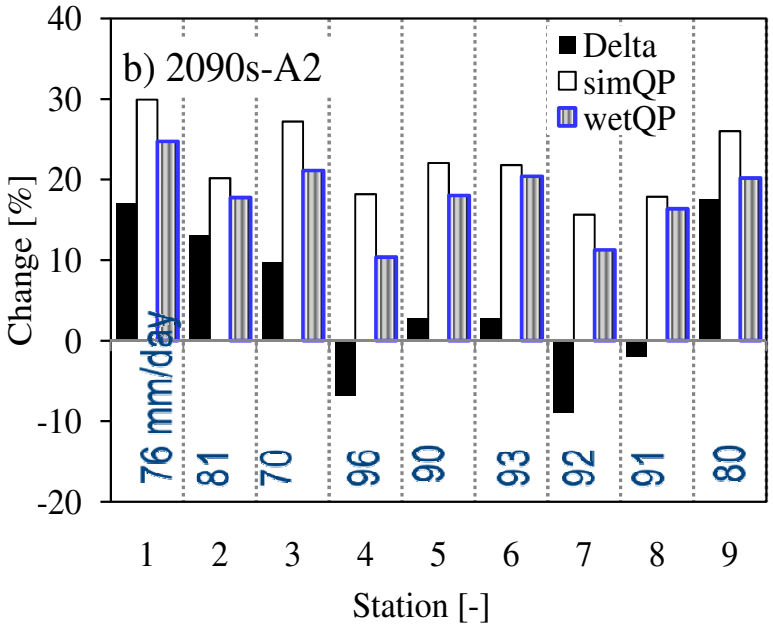
Changes in rainfall extremes

→ **Changes in rainfall extremes:** Change [%] = $(x_e - x_g)/x_g*100$

where x_e = 10-year empirical quantile

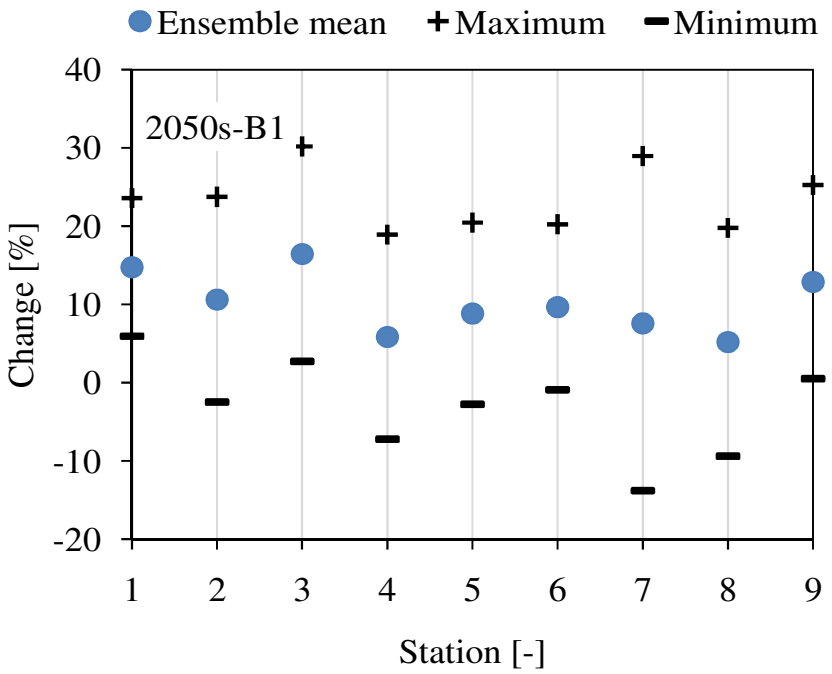
x_g = 10-year GCM-based quantile

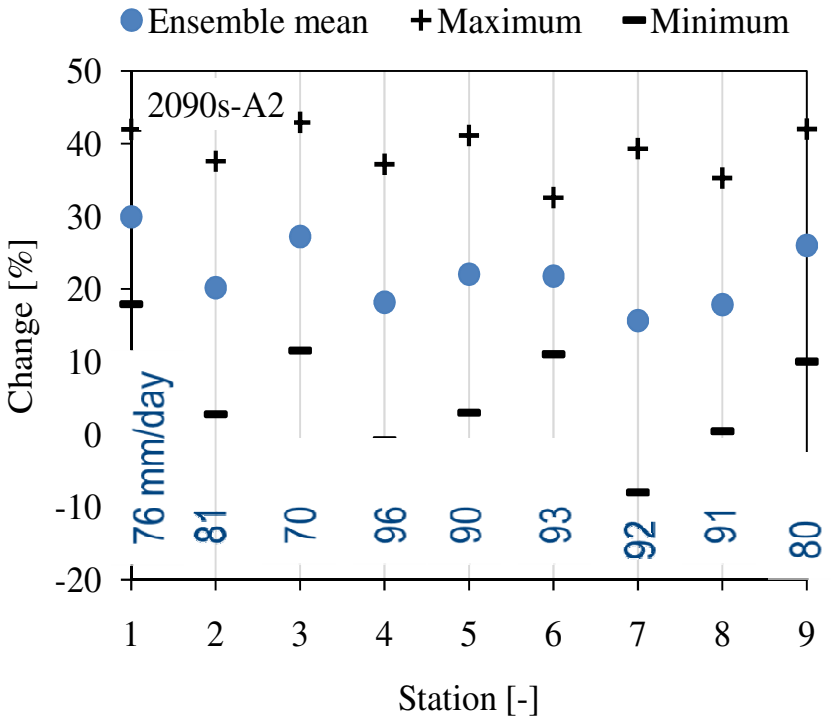


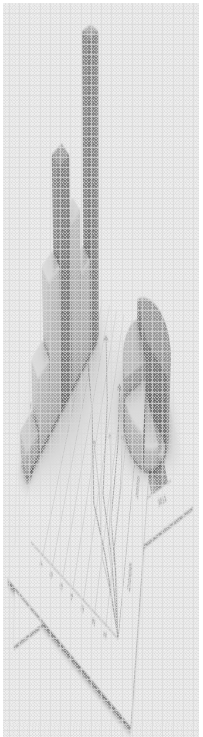


Changes in rainfall extremes

→ **Range of change in 10-year rainfall quantile –** simQP using CMIP3







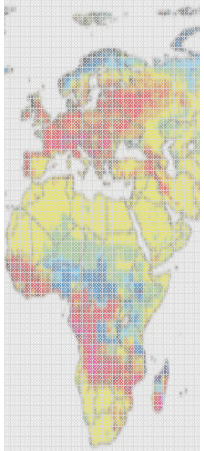
Combining diff. sources of uncertainties

✓Station 7:

Sampling uncertainty:

upper limit:	118 mm/day
Estimated :	92 mm/day
Lower limit:	84 mm/day

Inter-GCM differences – projection of changes[%]:

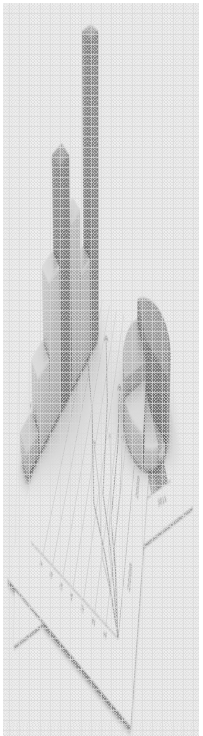


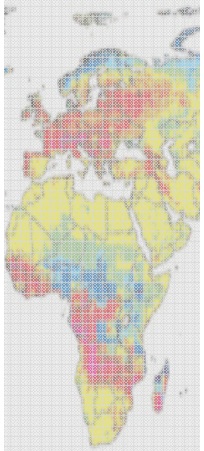
CMIP3 -2090s – A2

	Mean	Min	Max
Delta	-9	-24	2
simQP	16	-6	40
wetQP	12	1	37

CMIP5 -2090s – rcp8.5

	Mean	Min	Max
Delta	-4	-16	3
simQP	12	-4	29
wetQP	10	-3	22





Conclusions

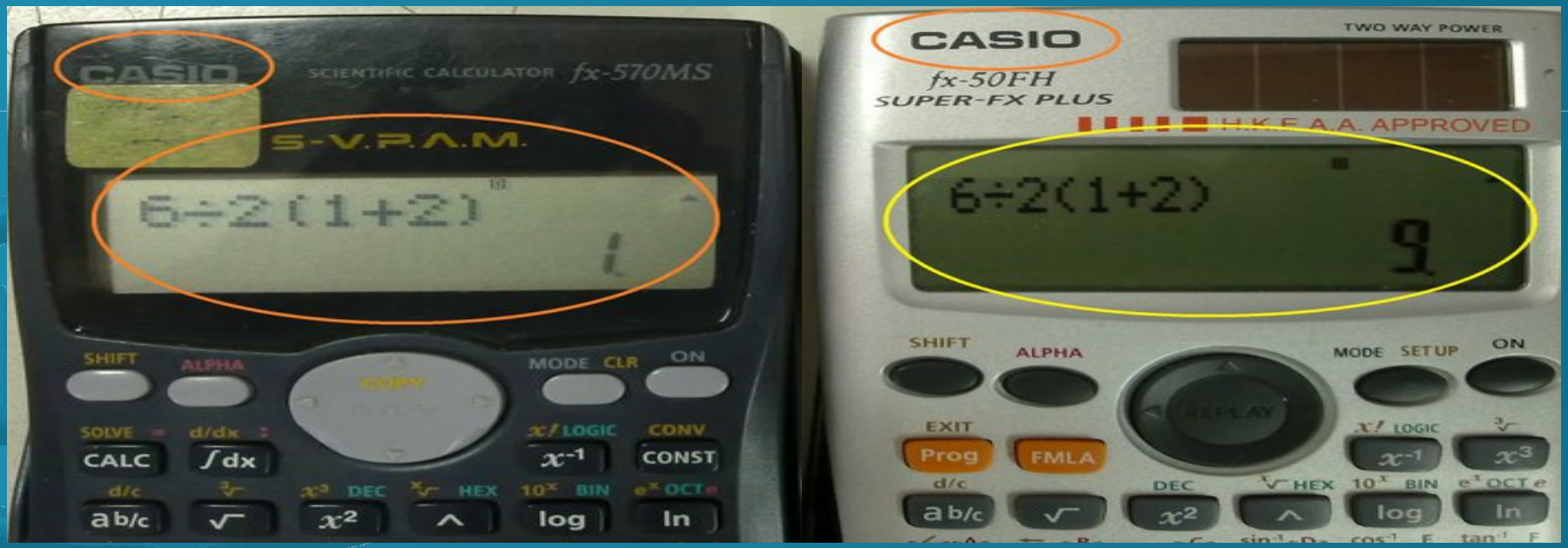
→ Need to quantify uncertainty in sampling of extremes– data limitation

→ Inter-GCM differences be used to select those to be downscaled

→ Choice of a downscaling method – objective driven

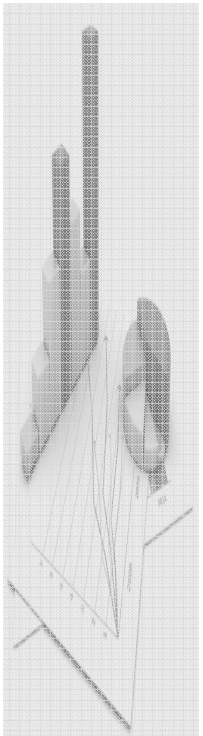
THANKS FOR LISTENING

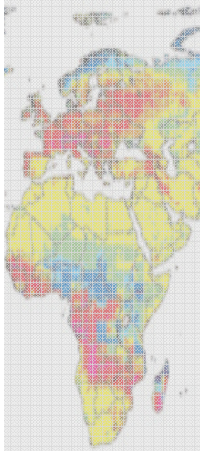
….. statistical testing of errors show their presence but not their absence



charles.onyutha@bwk.kuleuven.be

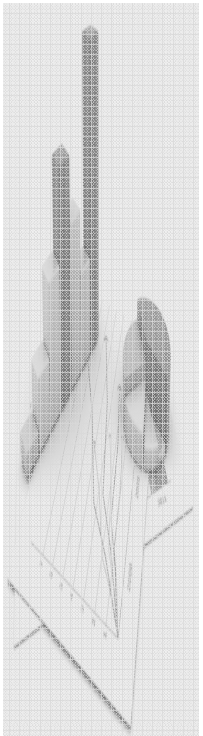
KU LEUVEN





GCMs-CMIP3 & 5

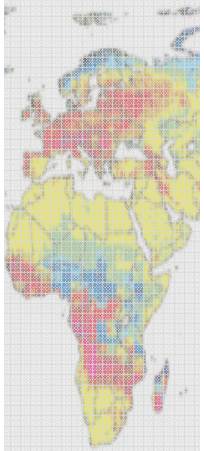
Model identity	IPCC model identity	Available control and scenario runs
AOM	GISS-AOM	Run1: Ctrl, A1B and B1
BCM2.0	BCCR-BCM2.0	Run1: Ctrl, A1B, B1 and A2
CGCM3.1(T47)	CGCM3.1(T47)	Run1, Run2, Run3: Ctrl, A1B, B1 and A2
CGCM3.1(T63)	CGCM3.1(T63)	Run1: Ctrl, A1B and B1
CM2.0	GFDL-CM2.0	Run1: Ctrl, A1B, B1 and A2
CM2.1	GFDL-CM2.1	Run1: Ctrl, A1B, B1 and A2
CM3.0	INM-CM3.0	Run1: Ctrl, A1B, B1 and A2
ECHAM4	MPI- ECHAM4-OM	Run1: Ctrl, A1B and A2
ECHAM5	ECHAM5/MPI-OM	Run1: Ctrl, B1 and A2, Run4: Ctrl,
ECHO-G	ECHO-G	Run1: Ctrl, B1 and A2; Run2, Run3: Ctrl, A1B, B1 and A2
MIROC3.2(hires)	MIROC3.2(hires)	Run1: Ctrl, A1B, B1 and A2
MIROC3.2(medres)	MIROC3.2(medres)	Run1: Ctrl, B1; Run2: Ctrl, A1B, B1 and A2
MK3.0	CSIRO-MK3.0	Run1: Ctrl, A1B, B1 and A2
MK3.5	CSIRO-MK3.5a	Run1: Ctrl, A1B, B1 and A2
BNU	BNU-ESM	Run1: His, rcp4.5 and rcp8.5
MK 3.6	CSIRO-MK3.6	Run1-10: His, rcp4.5 and rcp6.0, Run10: rcp8.5
FG2	FGOALS-G2	Run1: His, rcp4.5 and rcp8.5
GFCM	GFDL-CM	Run1: His, rcp4.5, rcp6.0 and rcp8.5, run3: His, rcp4.5
GESM	GFDL-ESM-2G	Run1: His, rcp4.5 and rcp6.0
MLR	MP-ESM-LR	Run1: His, rcp4.5 and rcp8.5
MMR	MP-ESM-MR	Run1: His, rcp4.5 and rcp8.5



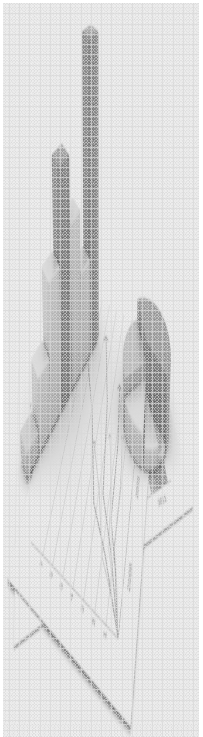
Independence criteria

✓based on threshold values for (Willems 2009)[1] :

- ❑ the time between two successive independent rainfall intensity peaks,
- ❑ the ratio of the min. rainfall intensity btn the two peaks over the peak value,
- ❑ the peak height



[1]Willlems, P. (2009). A time series tool to support the multi-criteria performance evaluation of rainfall-runoff models. *Environ. Model. Softw.* **24**, 311–321.



Combining e.g. sampling unc. & inter-GCM diff.

✓Station 1:

Statistical uncertainty:

upper limit: 80 mm/day

Estimated : 76 mm/day

Lower limit: 72 mm/day

Inter-GCM differences – Changes[%] in the 2090s-A2 –CMIP3:

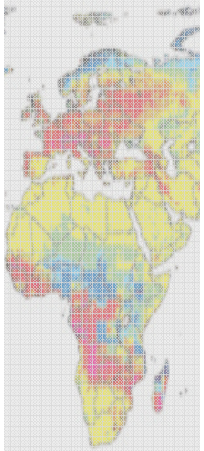
Maximum: 42%

Mean : 30%

Minimum: 19%

If choices for a design value of 78 mm/day and allowance of 40% (due to climate change) are made,

Final value => 78*(100+40%)/100 = 109.2 mm/day

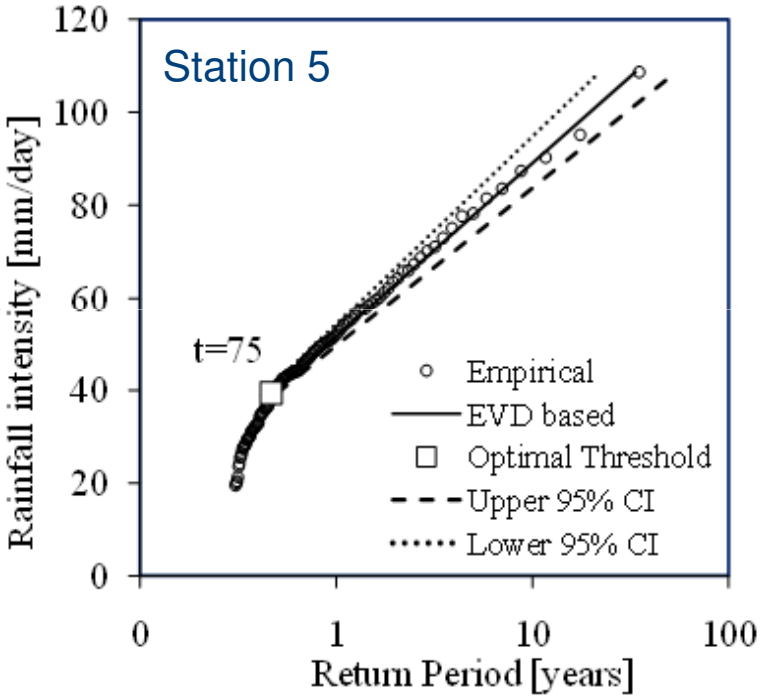




Quantifying uncertainty

POTs
EVD fitting
Resampling

→ **Uncertainty on extremes**– resampling - Jackknife – at 5% lev. Sig



Procedure

a) *i^{th} event is deleted from POTs of size w*

b) *$\Theta(\beta,\gamma,x_t)$ of EVD determined using (w-1) POTs*

c) *Steps (a) and (b) repeated w times*

d) *w sets of $\Theta(\beta,\gamma,x_t)$ ranked in descending order*

e) *Upper and lower limits of the $\Theta(\beta,\gamma,x_t)$ are determined from $[0.025\times w]^{th}$ and $[0.975\times w]^{th}$*

f) *95% CI determined using (e) above*