Tailored scenarios for streamflow climate change impacts based on the perturbation of precipitation and evapotranspiration

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Research problem

When studying the hydrological impacts of climate change:

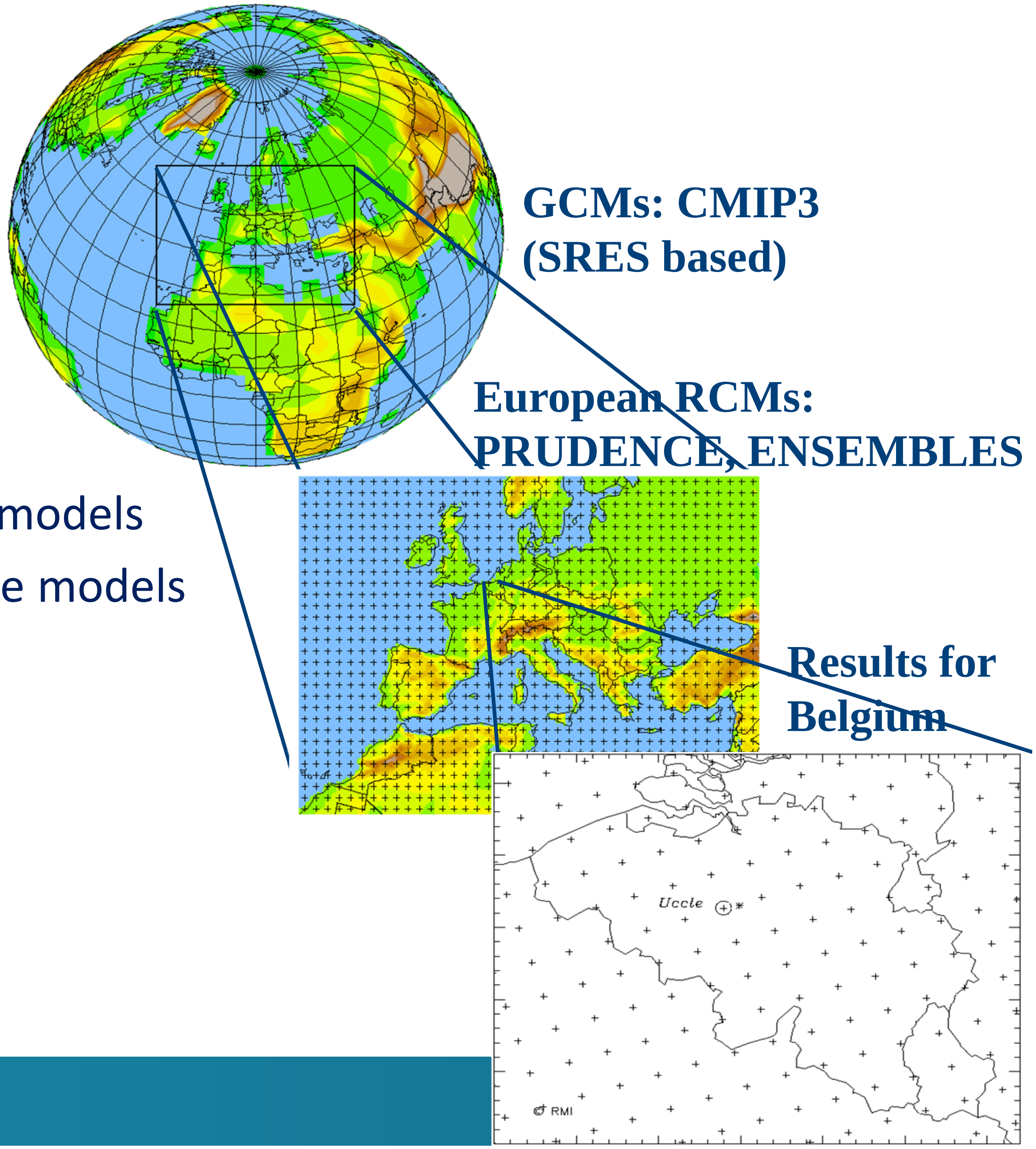
The number of available climate change simulations grows

Ensemble of climate model outputs

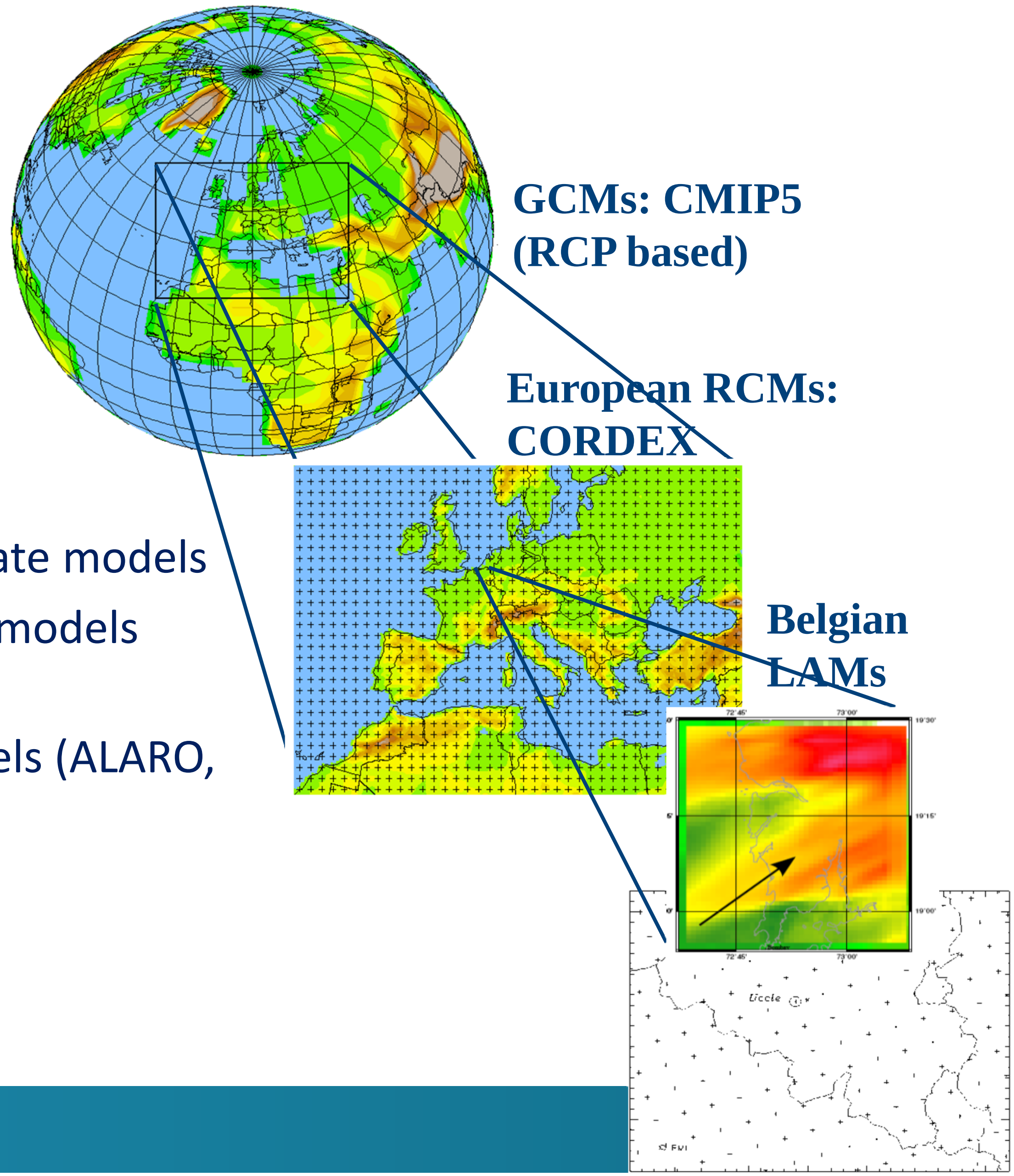
Belgium, 2005 - 2010:

CMIP3 (SRES) based:

- 44 runs with 21 global climate models
- 57 runs with 10 regional climate models (PRUDENCE, ENSEMBLES)



Ensemble of climate model outputs



Belgium, 2015:

CMIP5 (RCP) based:

- >200 runs with 34 global climate models
- 22 runs with regional climate models (EURO-CORDEX)
- Few runs with local area models (ALARO, CCLM, 3-4km resolution)

Research problem

The number of available climate change simulations grows

- Need to develop few synthesized scenarios

- Research hypothesis: these synthesized scenarios depend on the specific (type of) impact application

➡ **Tailored climate scenarios**

(impact-centric scenarios instead of climate-centric scenarios)

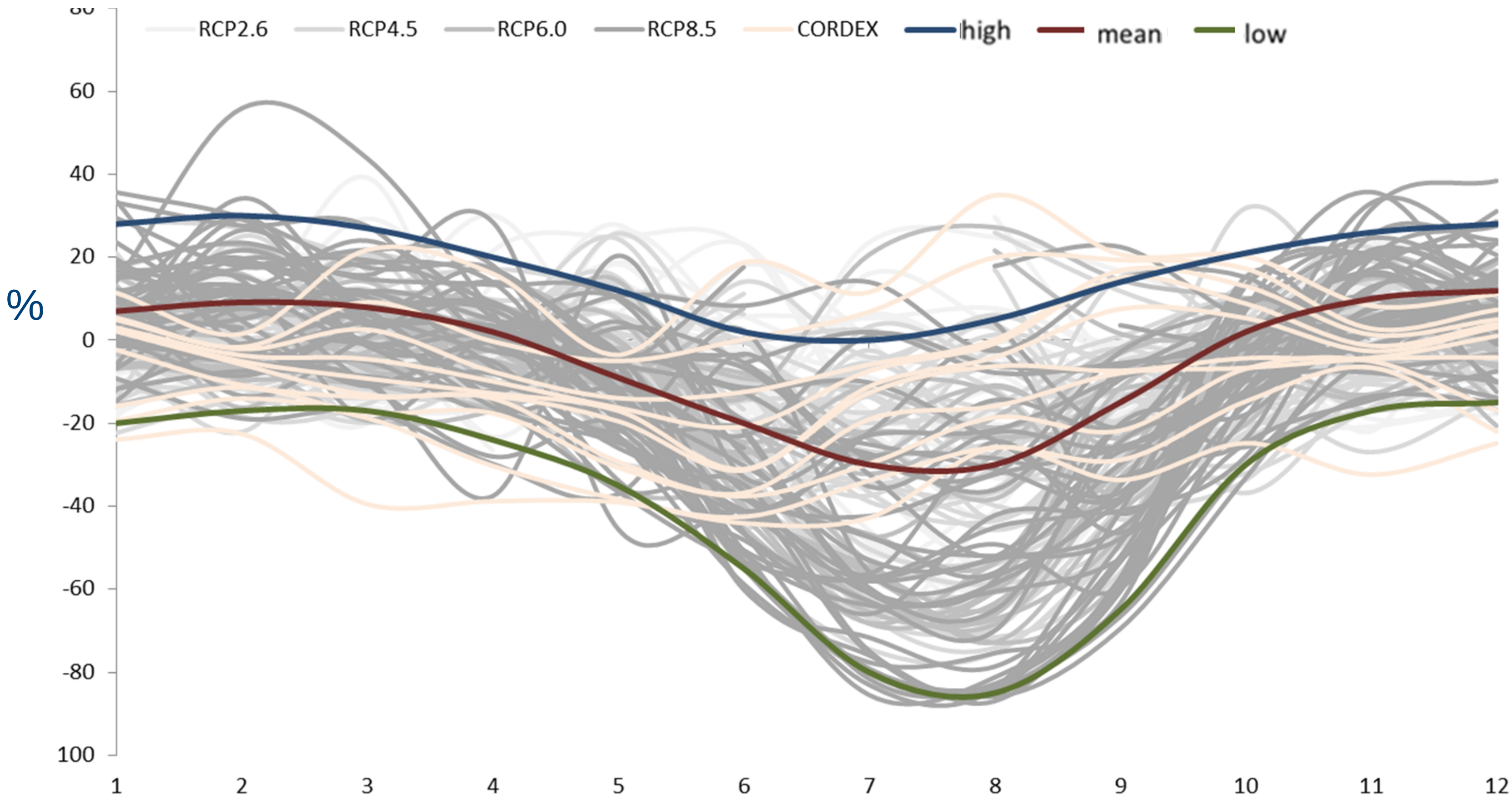
Proposed tailoring process

Step 1: Obtain climate change signals from all available climate model runs

Climate change signals

>200 GCMs CMIP5 (RCP based) for Belgium: change for 100 years (2000 -> 2100):

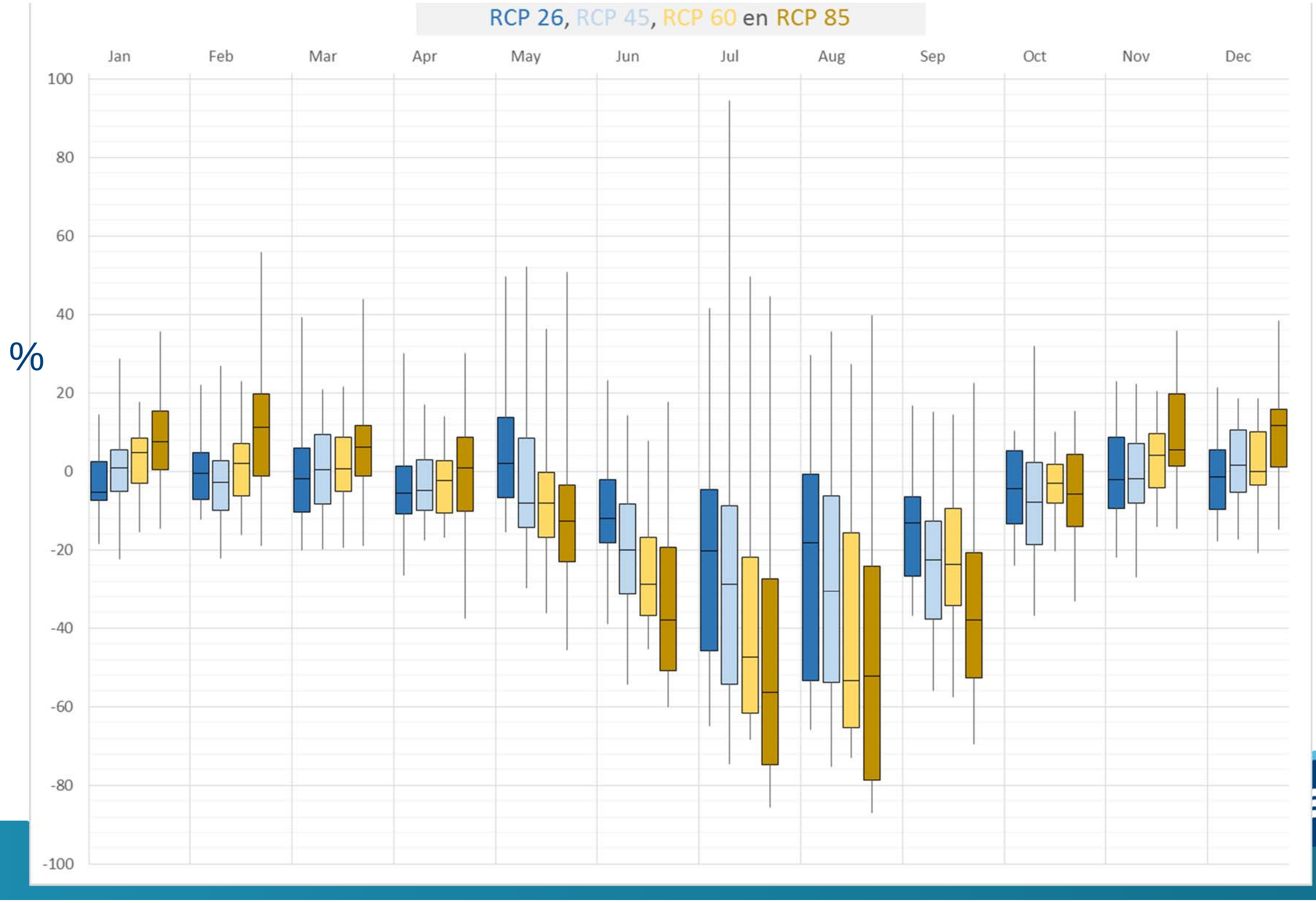
Change in mean monthly rainfall:



Climate change signals

>200 GCMs CMIP5 (RCP based) for Belgium: change for 100 years (2000 -> 2100):

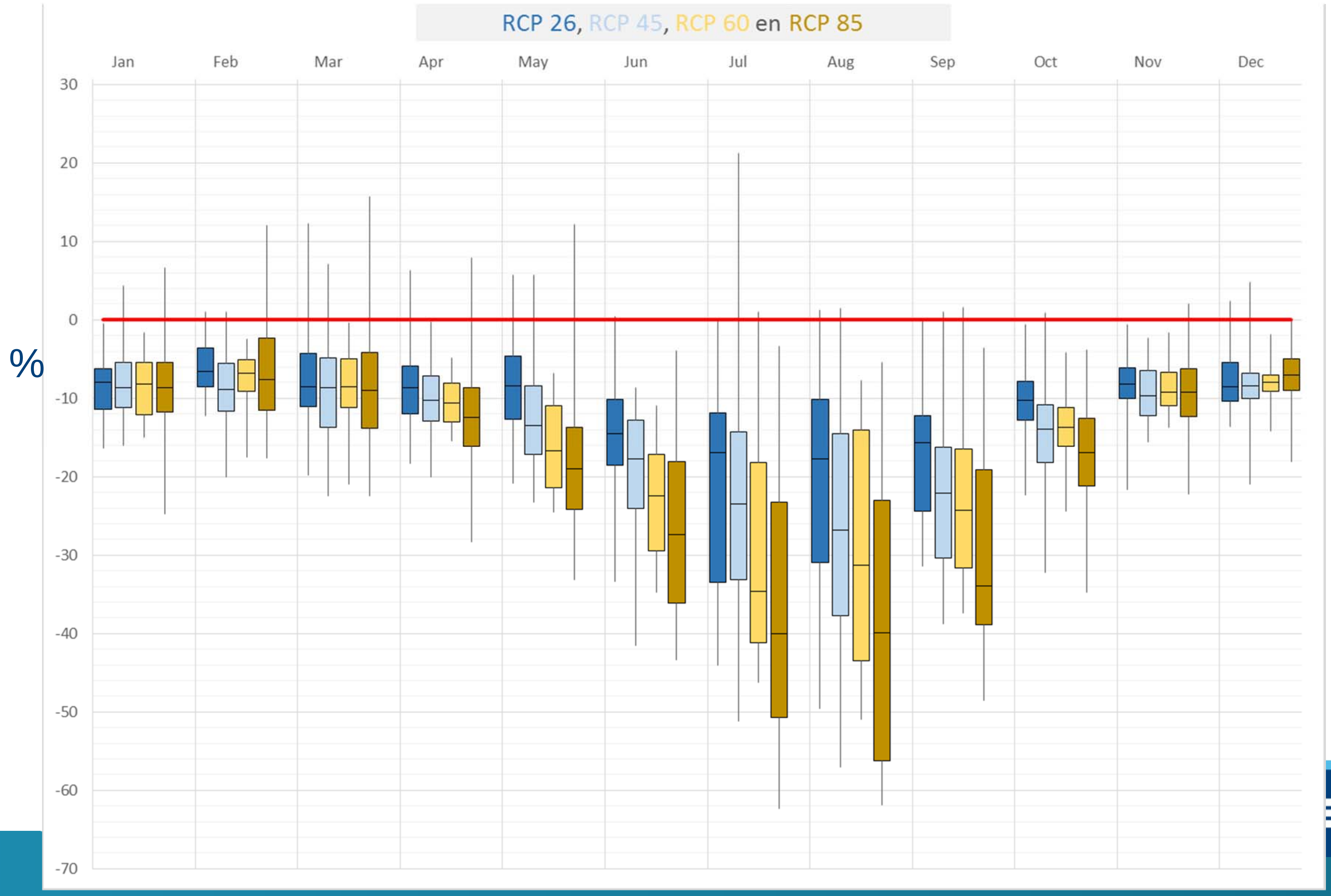
Change in mean monthly rainfall:



Climate change signals

>200 GCMs CMIP5 (RCP based) for Belgium: change for 100 years (2000 -> 2100):

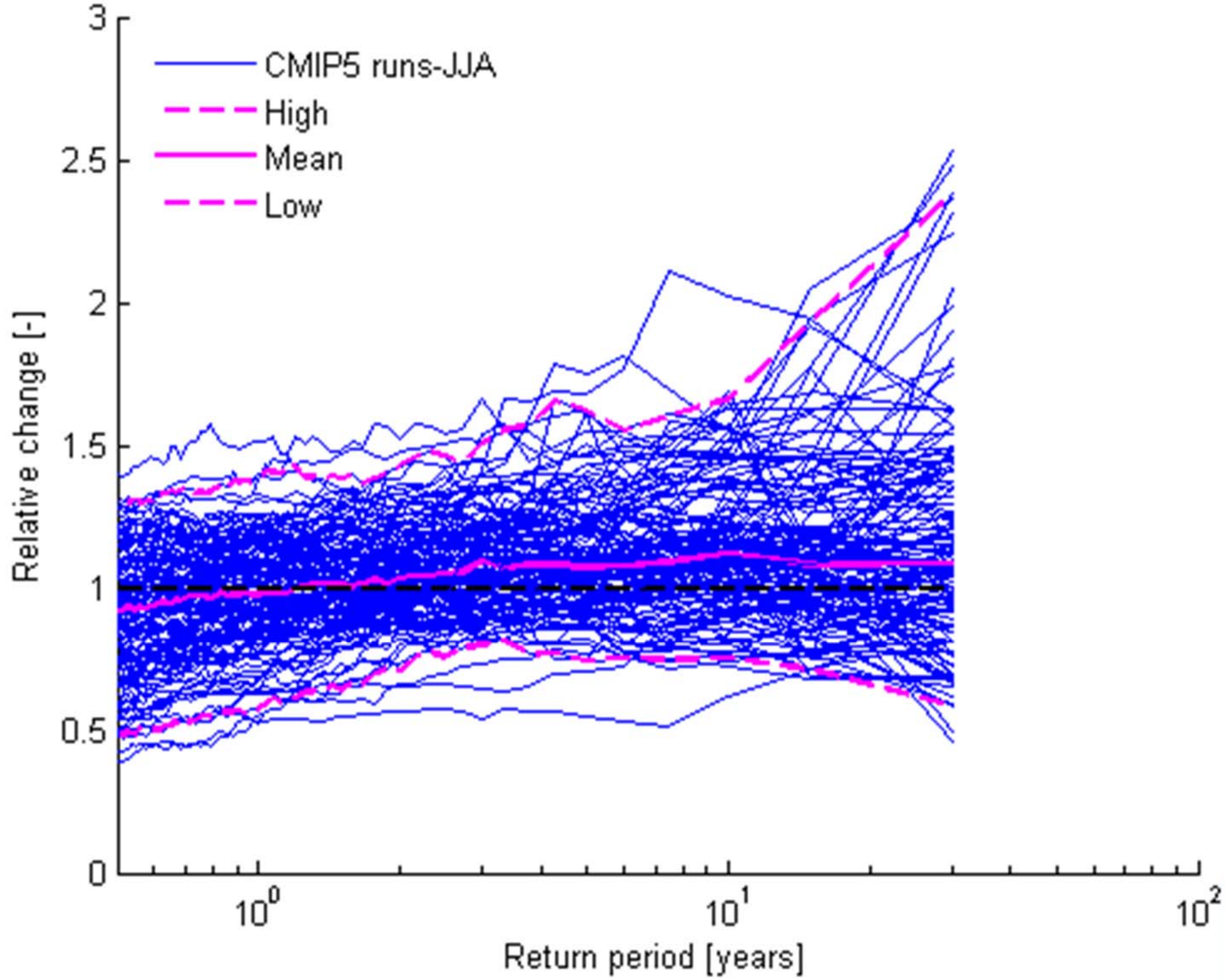
Change in wet day frequency (per month):



Climate change signals

>200 GCMs CMIP5 (RCP based) for Belgium: change for 100 years (2000 -> 2100):

Change in extreme rainfall quantiles:



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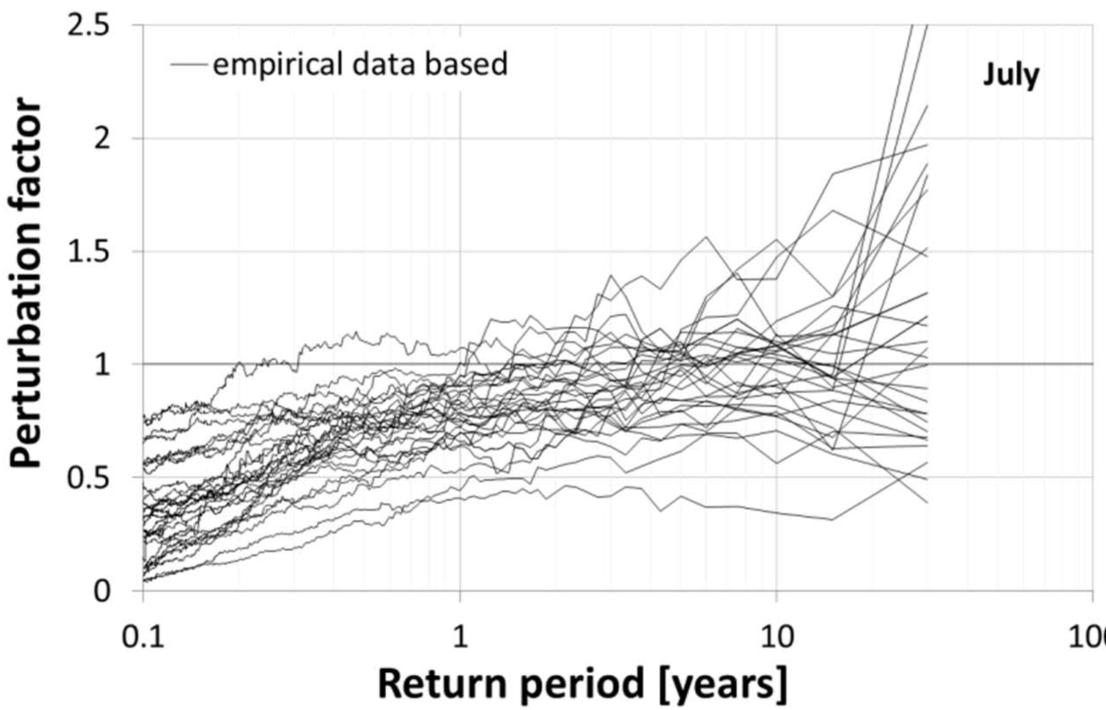
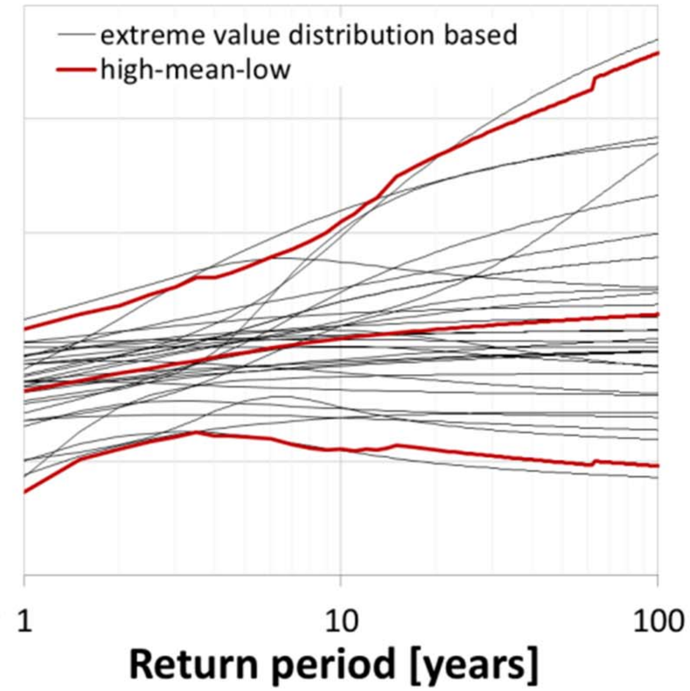
Climate change signals

30 RCMs for Belgium: change for 100 years (2000 -> 2100):

Change in extreme rainfall quantiles:



GPD extreme value distribution calibration:



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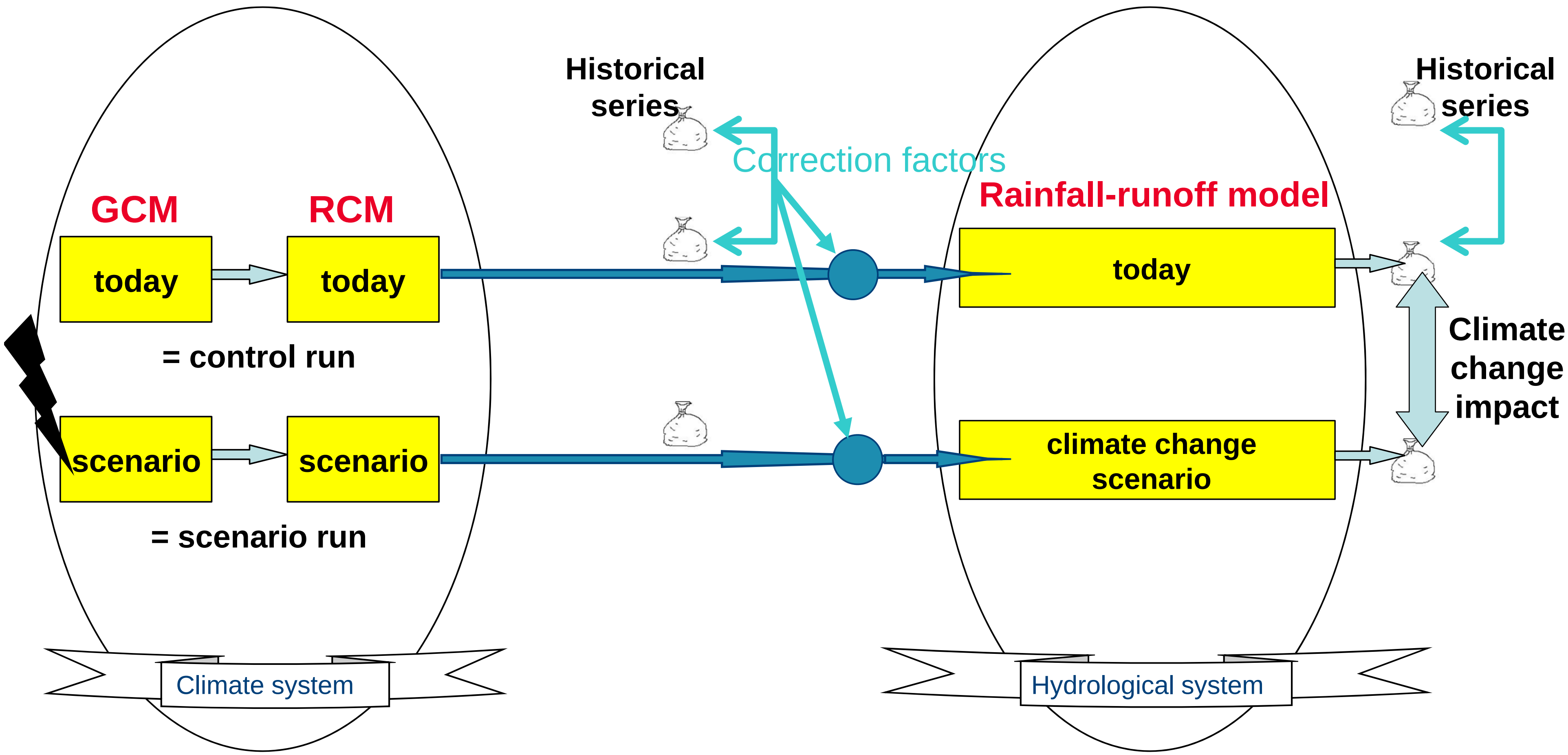
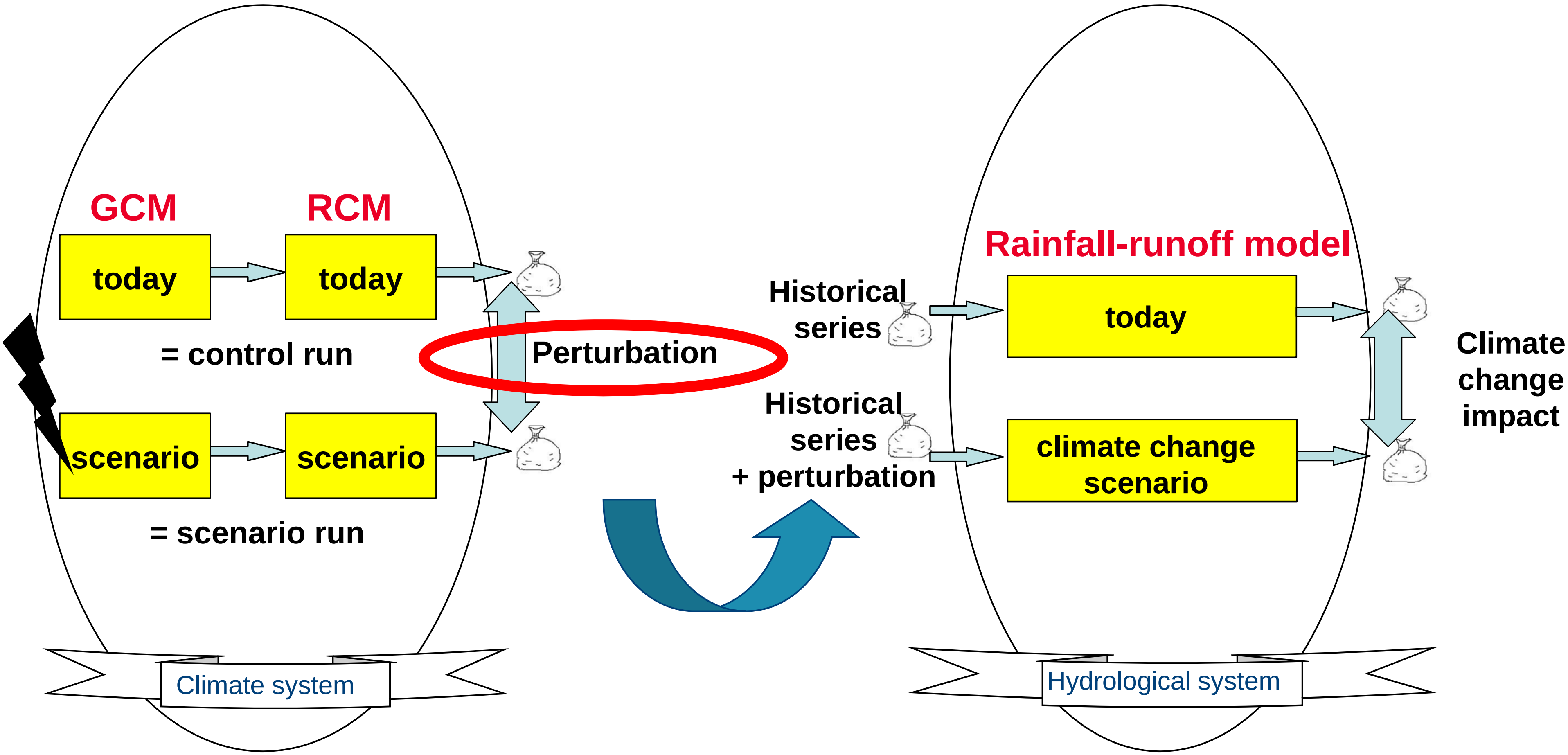
Direct forcing approach

Bias correction



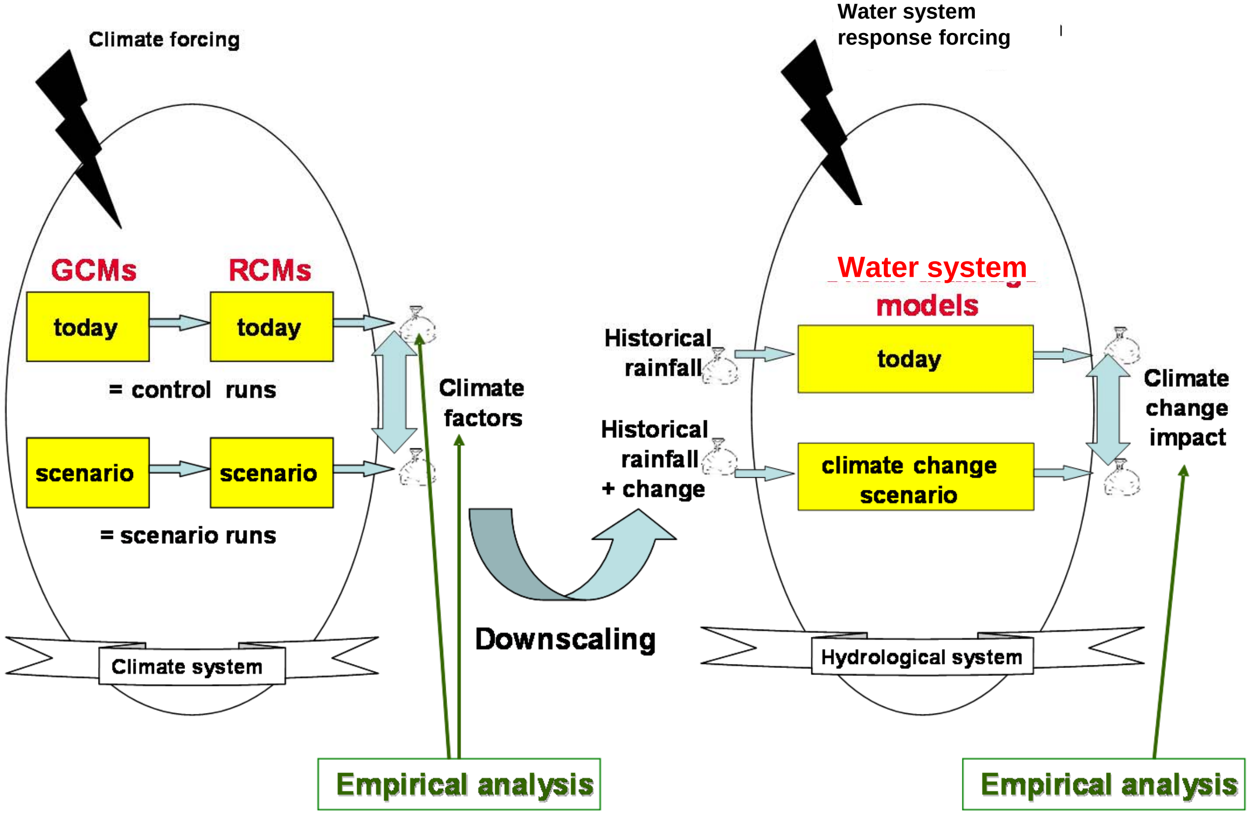
"Delta approach" or perturbation approach or MOS approach



Model Output Statistics (MOS)
Perturbation = Change
e.g. Perturbation factors / Change factors / Climate factors

Quantile perturbation method

Combined spatial and temporal downscaling and bias correction



Change factors depend on:

- ✓ Temporal & spatial scale
- ✓ Return period
- ✓ Time of the year (month, season)
- ✓ …

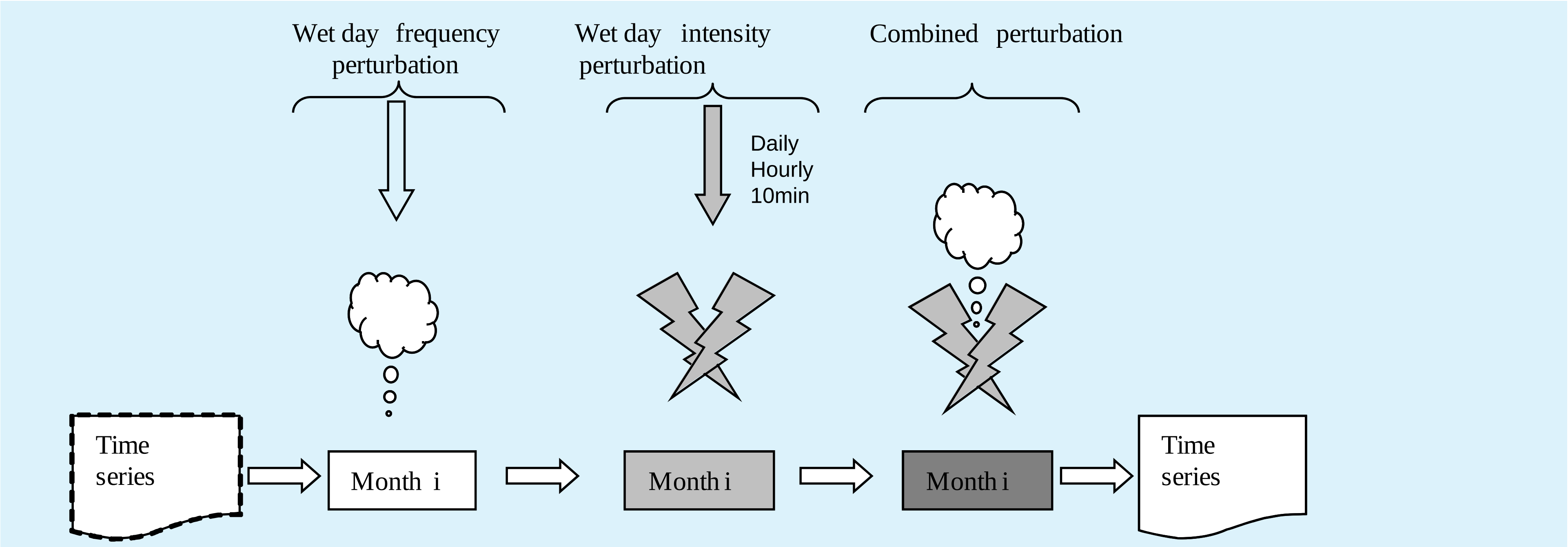
for:

- ✓ Rainfall intensity
- ✓ Rain storm frequency
- ✓ Dry spell duration
- ✓ …

Ntegeka, V., Baguis, P., Roulin, E., Willems, P. (2014), 'Developing tailored climate change scenarios for hydrological impact assessments', ***Journal of Hydrology***, 508C, 307-321

Climate perturbation tool

- Perturbs historical series to high/mean/low climate scenarios
- Time scales: daily, hourly, 10-minutes
- Based on quantile perturbations:
  - change in rain storm frequency and rain storm intensity
  - dependent on return period and season
- Time horizons till 2030, 2050, …, 2100



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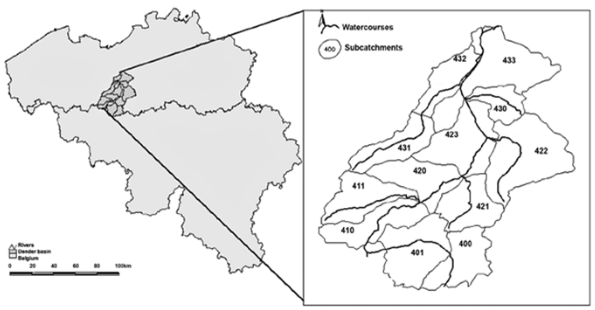
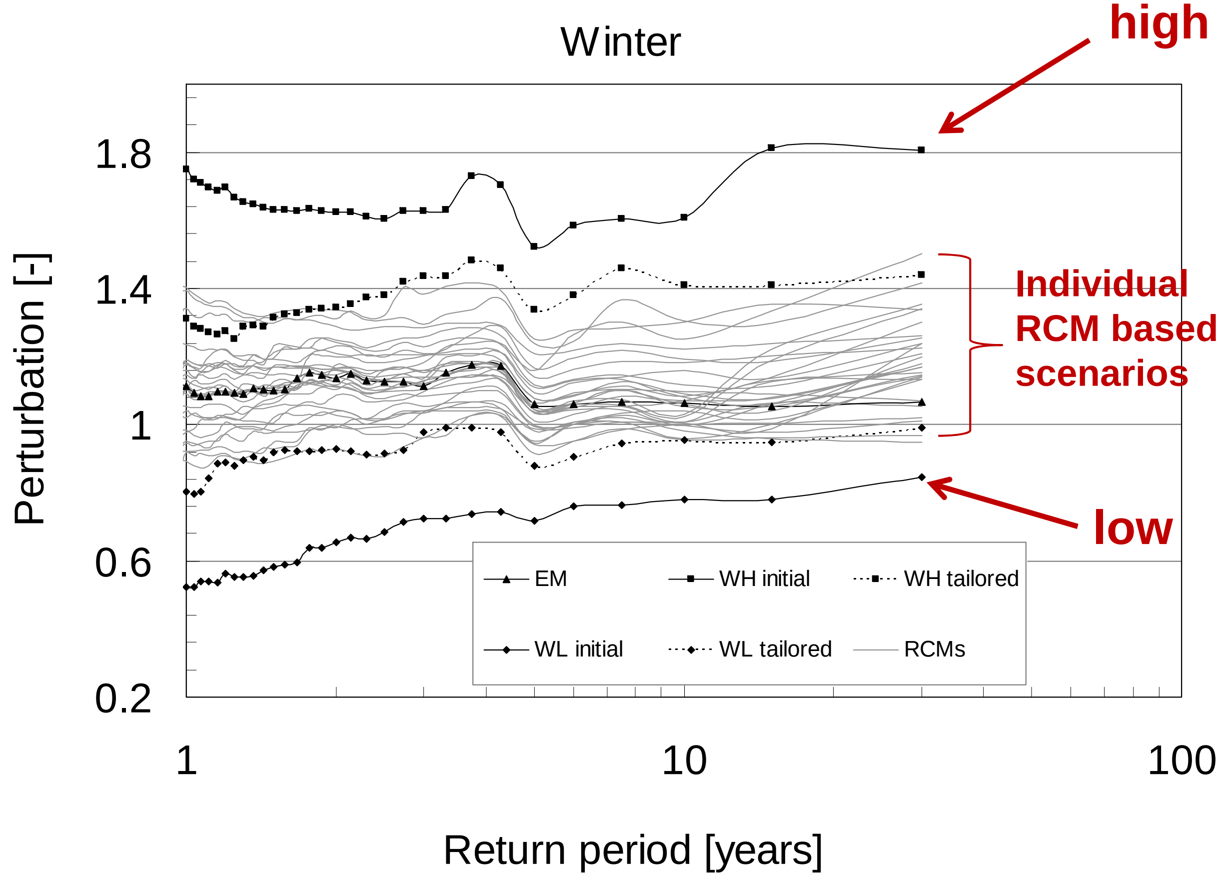
Result for selected catchment

Molenbeek catchment (Erpe-Mere, Belgium):



Example:

Impacts on hourly river peak flows vs. return period:



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Proposed tailoring process

Step 2: Check the hydrological impacts of the climate change signals from selected climate model simulations

(based on a simplified (computationally less expensive) impact model)

“Back-tracking” of extreme flows from driving scenarios

: which meteorological input combinations give the highest-mean-lowest hydrological impacts ?

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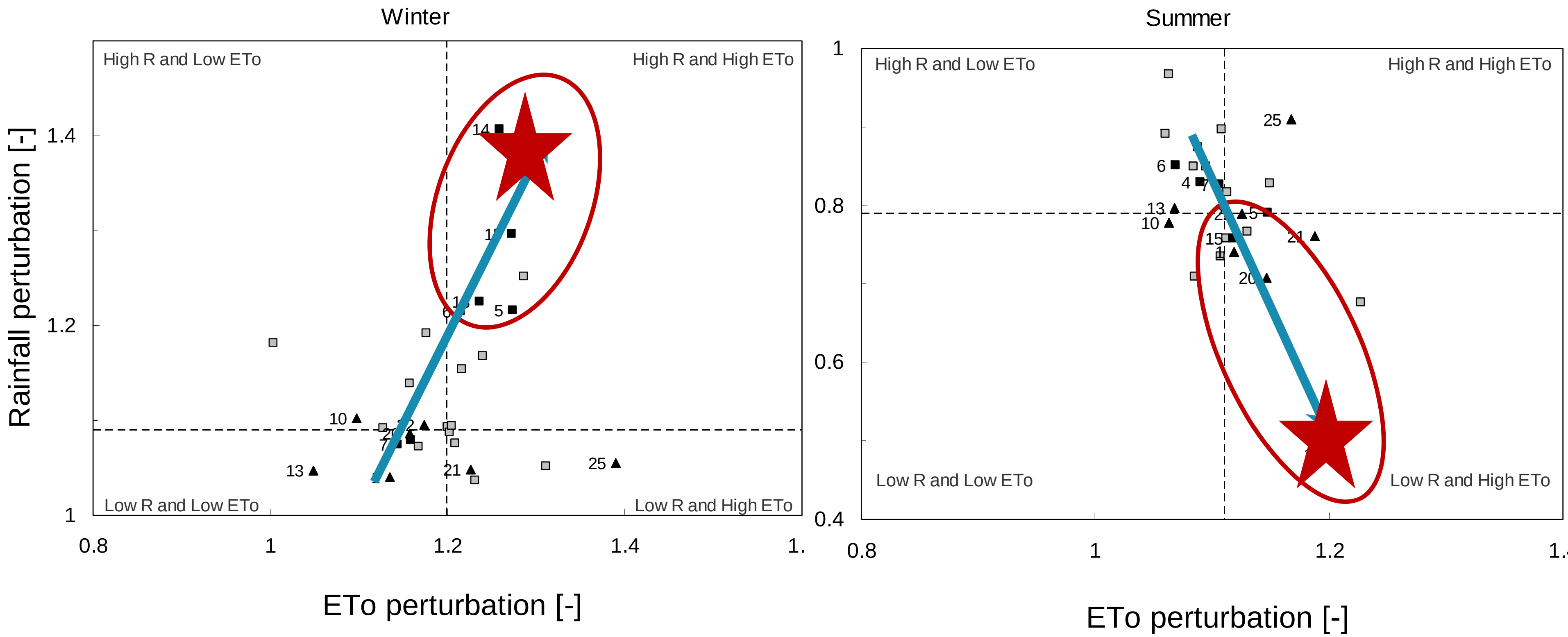
Proposed tailoring process

Step 3: Inter-seasonal tracing of rainfall changes, but also of rainfall – T/ETo changes

High – river flood scenario?



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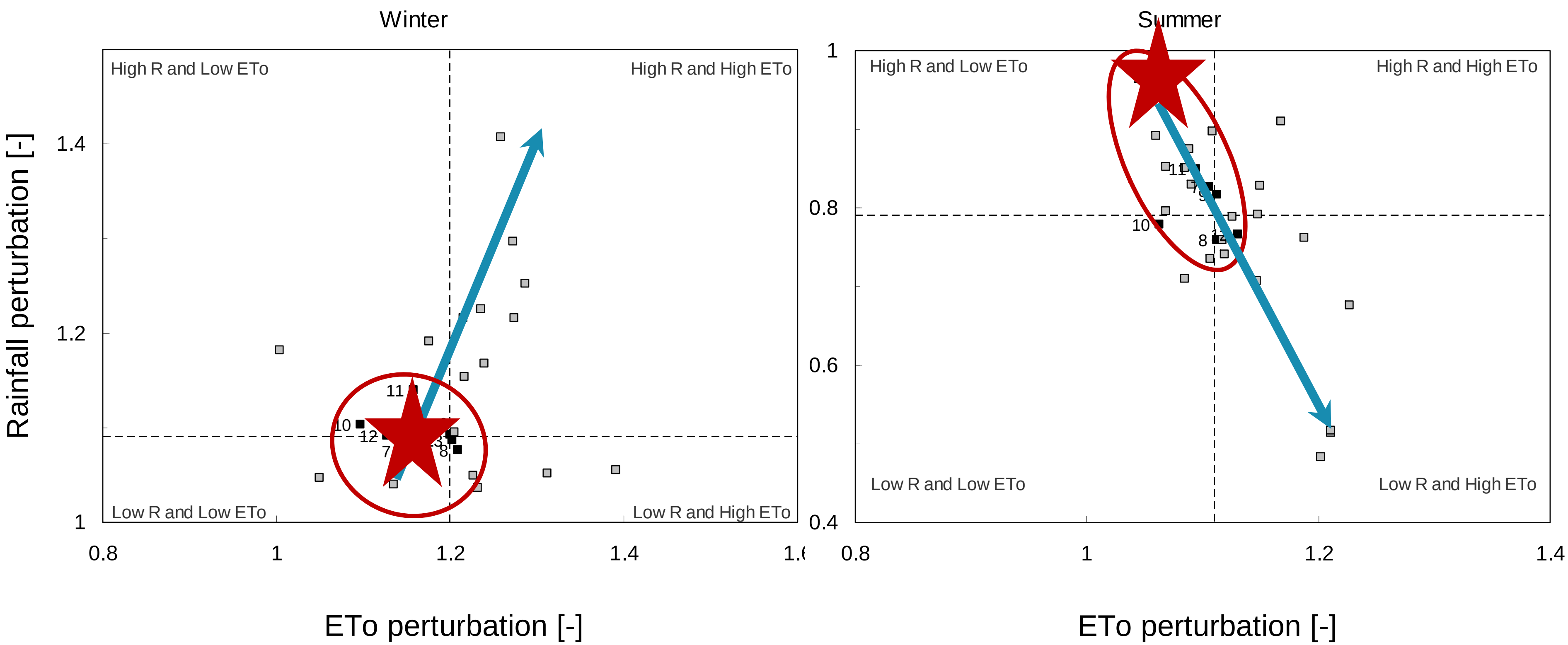
Proposed tailoring process

Step 3: Inter-seasonal tracing of rainfall changes, but also of rainfall – T/ETo changes

High – sewer flood scenario?



Proposed tailoring process

Step 4: Obtain tailored scenarios for studying impacts

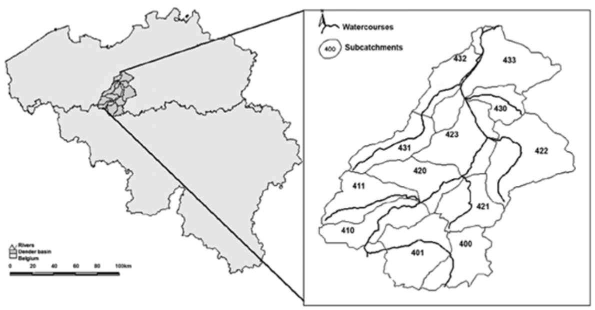
Our focus: impacts on hydrological extremes (high & low flows rivers & urban drainage):

4 tailored scenarios considered:

- *HW (High/wet Winter): high river flood scenario*
- *HS (High/conv. Summer): high sewer flood scenario*
- *LS (Low/dry Summer): extreme low flow scenario*
- *EM: Ensemble Mean/mild scenario*

Result for selected catchment

Molenbeek catchment (Erpe-Mere, Belgium):



Example:

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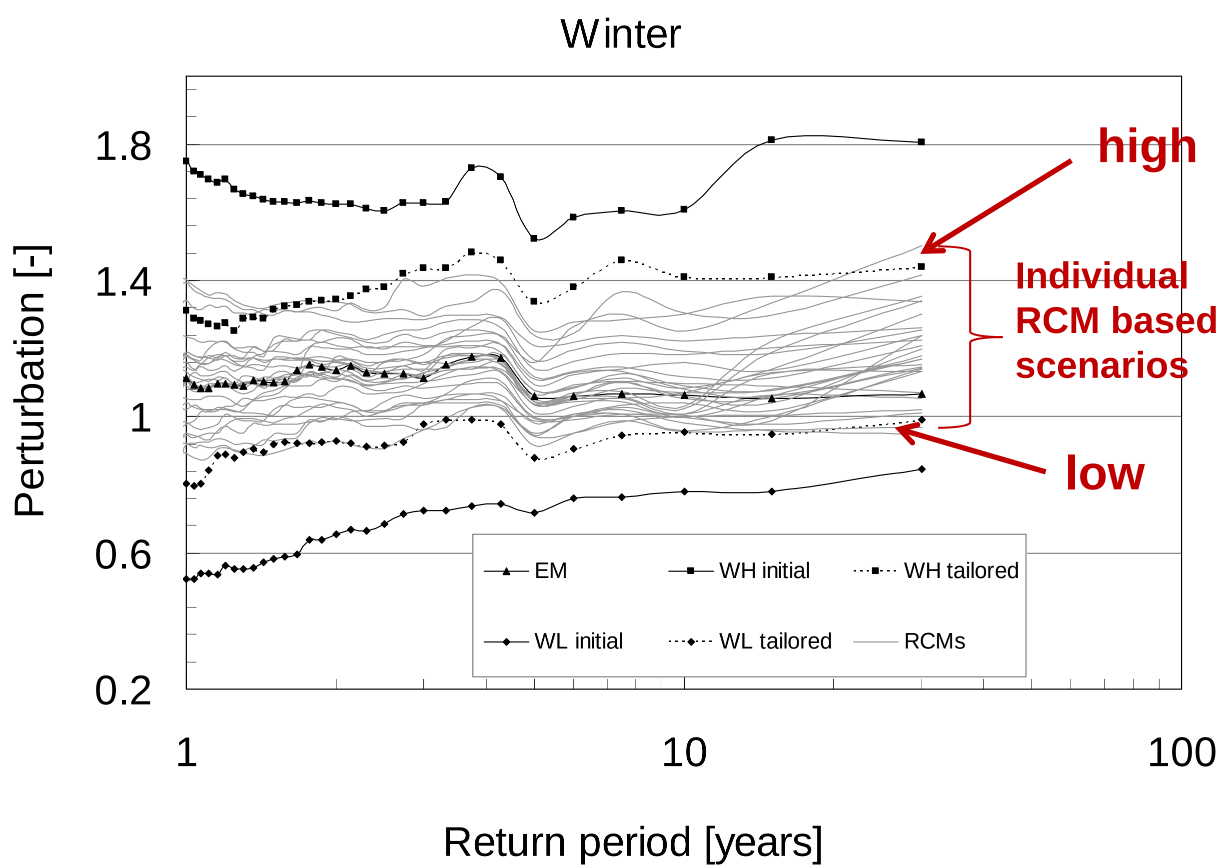

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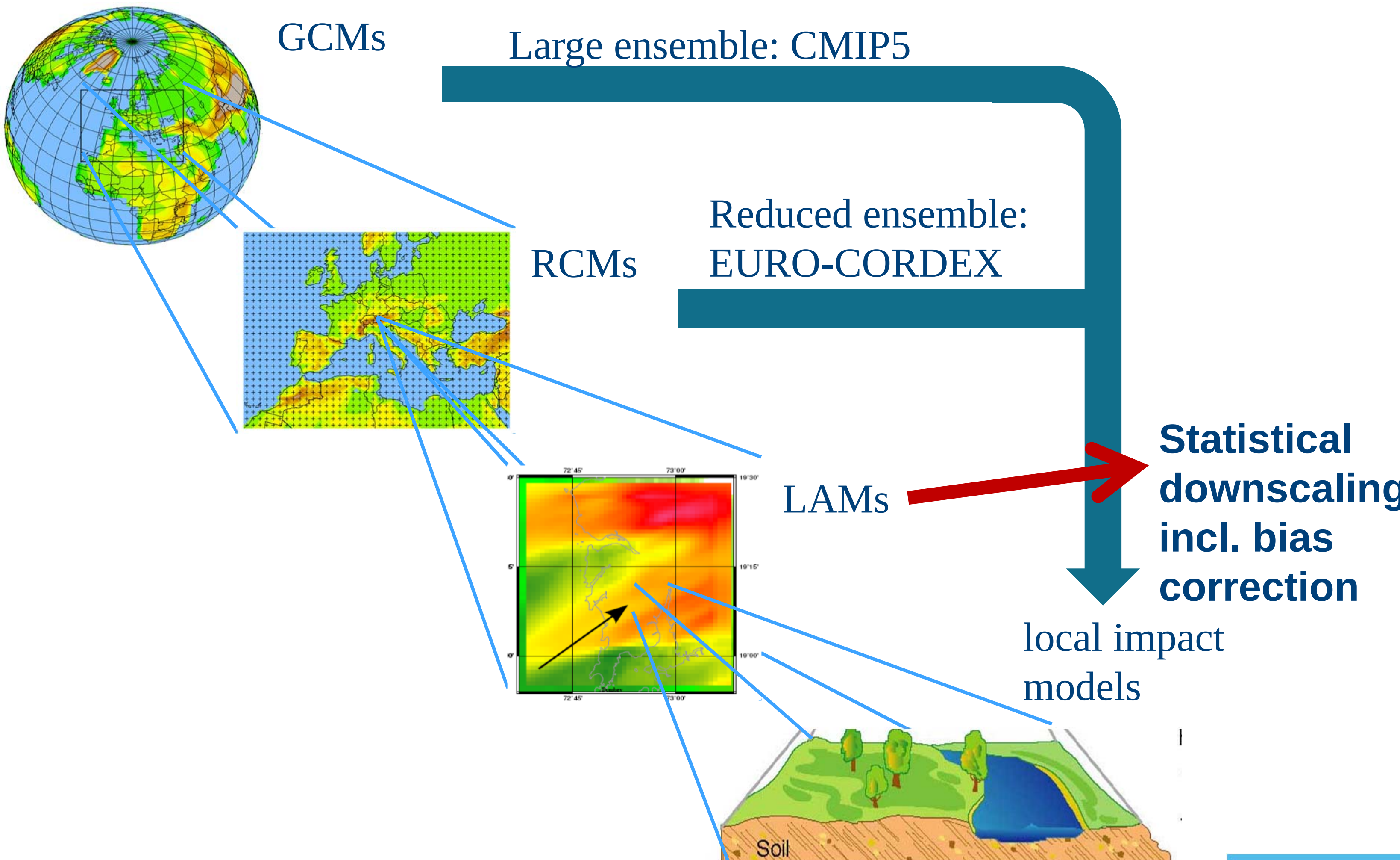
Statistical downscaling



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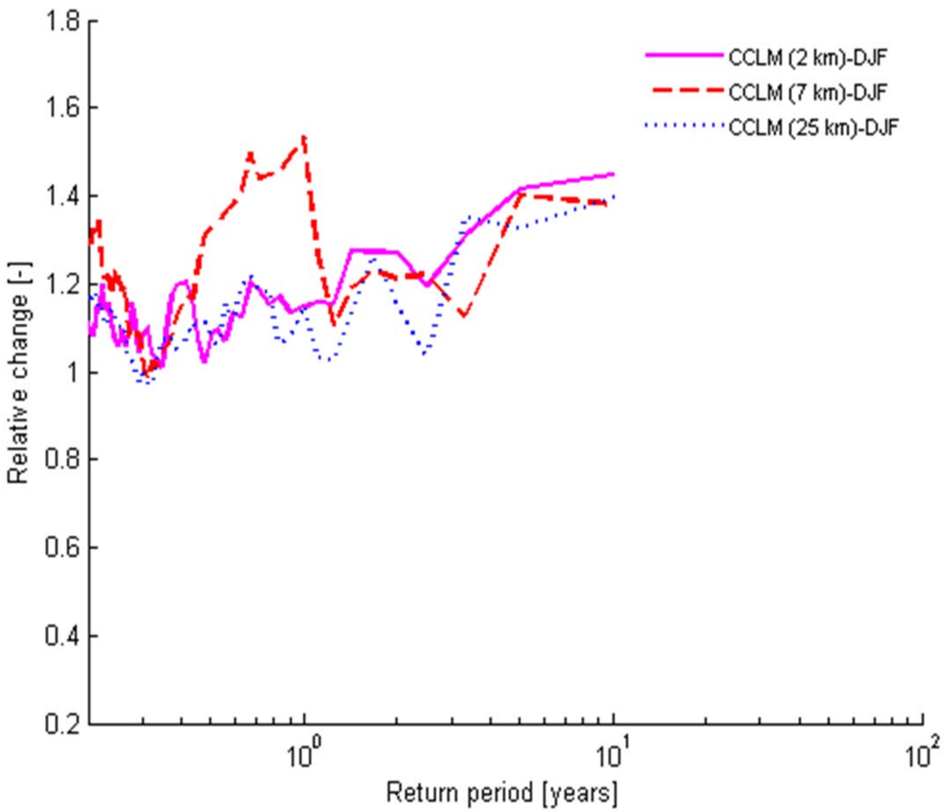
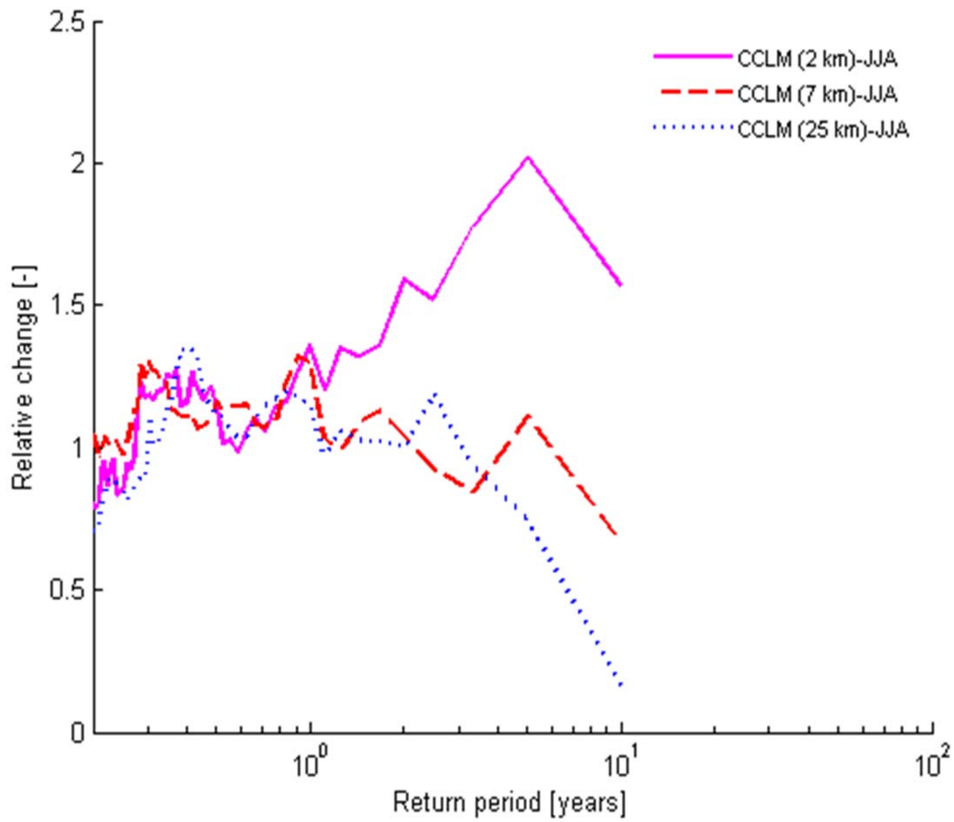
Climate change signals
: fine vs. coarse resolution climate models?





CCLM model runs: *Van Lipzig et al. (2015)* KU Leuven

Conclusions

We moved **from climate-centric scenarios to impact-centric scenarios**:

- development of few synthesized scenarios that reveals full uncertainty range (available climate model runs)
- based on careful examination of inter-seasonal P-T/ETo changes and "back-tracing" of impact results: design climate scenarios that facilitates specific type of impact studies (hydrological extremes in our case)

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More info…

Ntegeka, V., Baguis, P., Roulin, E., Willems, P. (2014), ‘Developing tailored climate change scenarios for hydrological impact assessments’, Journal of Hydrology, 508C, 307-321

Willems, P., Arnbjerg-Nielsen, K., Olsson, J., Nguyen, V.T.V. (2012), ‘Climate change impact assessment on urban rainfall extremes and urban drainage: methods and shortcomings’, Atmospheric Research, 103, 106-118

Willems, P. (2013). ‘Revision of urban drainage design rules after assessment of climate change impacts on precipitation extremes at Uccle, Belgium’, Journal of Hydrology, 496, 166–177

Willems P., Vrac M. (2011), ‘Statistical precipitation downscaling for small-scale hydrological impact investigations of climate change’, Journal of Hydrology, 402, 193–205

Tabari, H., Taye, M.T., De Troch, R., Termonia, P., Saeed, S., Brisson, E., Van Lipzig, N., Willems, P. (2015), ‘Local impact analysis of climate change on precipitation extremes: Are high-resolution climate models needed for realistic simulations?’, In preparation

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