Climate change impact on streamflow: rain, snow and glacier melt components in the river Rhine

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Working group

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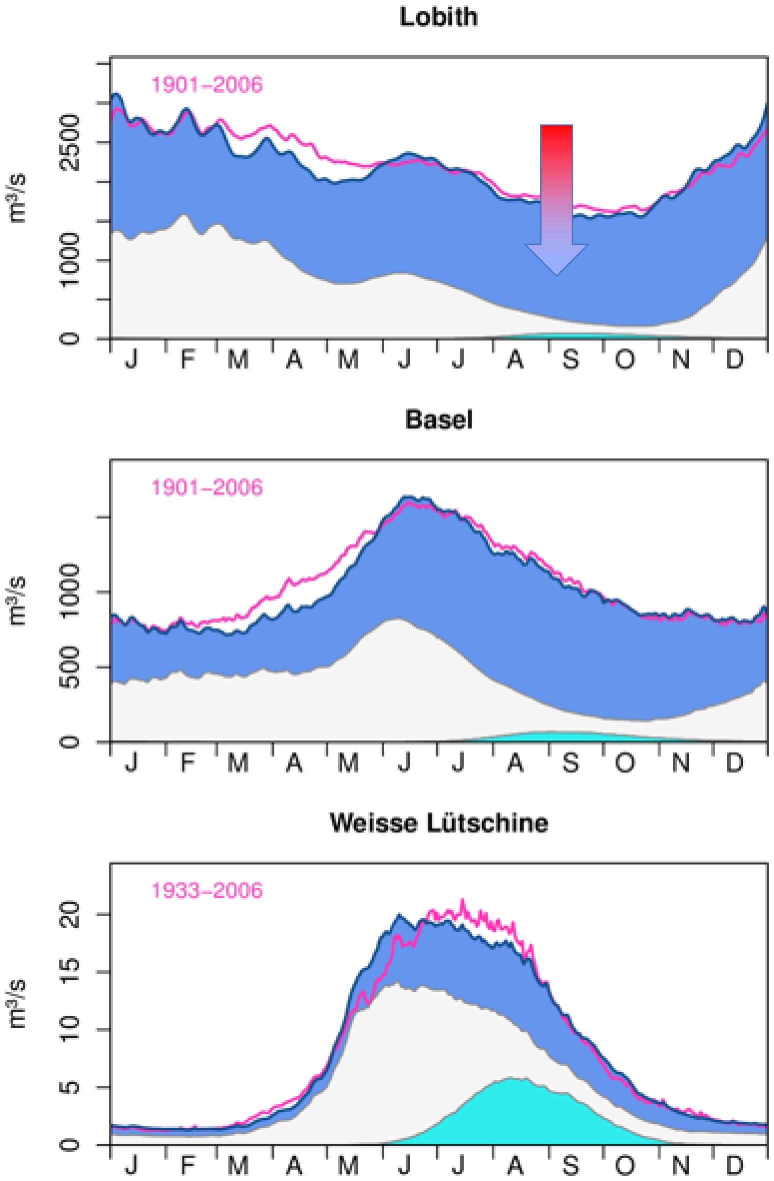
funded by the International Commission for the Hydrology of the Rhine Basin

1st Phase: the past

2nd Phase: the future

Aim: To quantify importance of Q_{rain}, Q_{snow}+Q_{Ice} for streamflow



Qrain component

Q_{snow} melt component

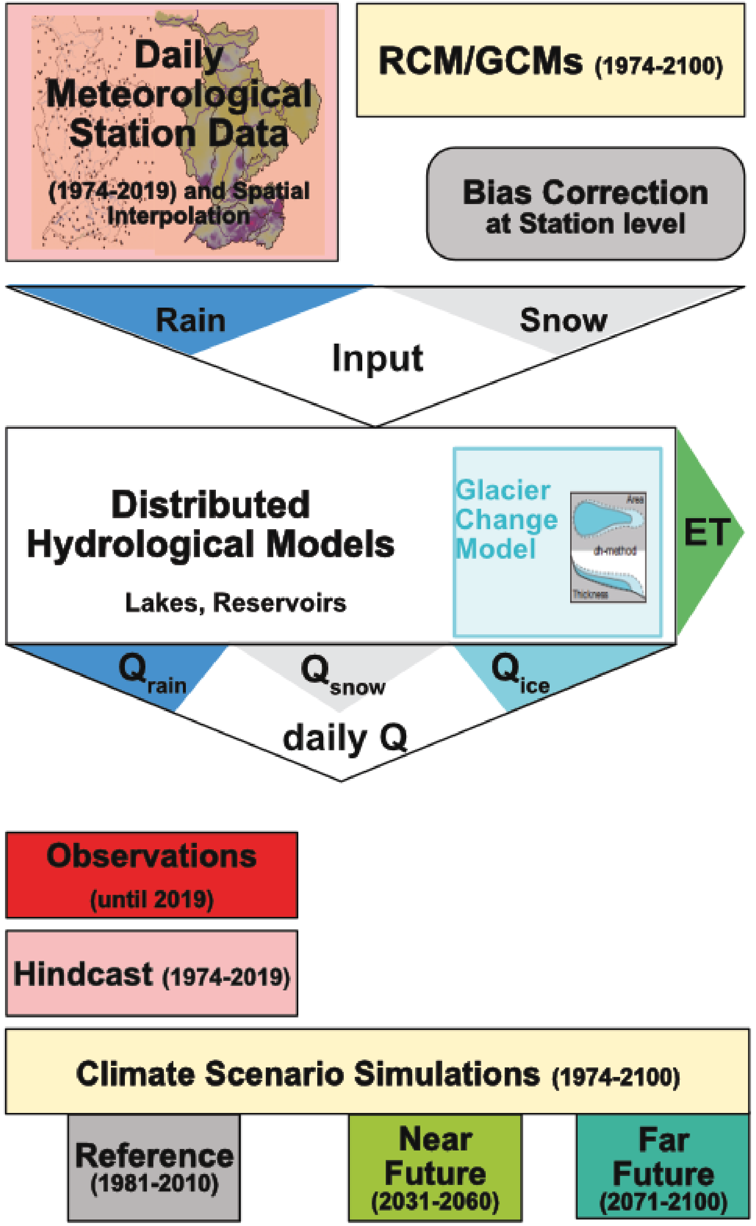
Q_{ice} melt component

<1% annually

larger On individual extreme low flow/hot-dry period days

- How how will these change?
- What are the effects on downstream low flows?

The modelling procedure



Selection from EURO-CORDEX

- Only RCP8.5 considered
- 7-member ensemble (5 GCMs, 2 RCMs)
- Overlap with other ensemble experiments in CHR-countries

Model chain

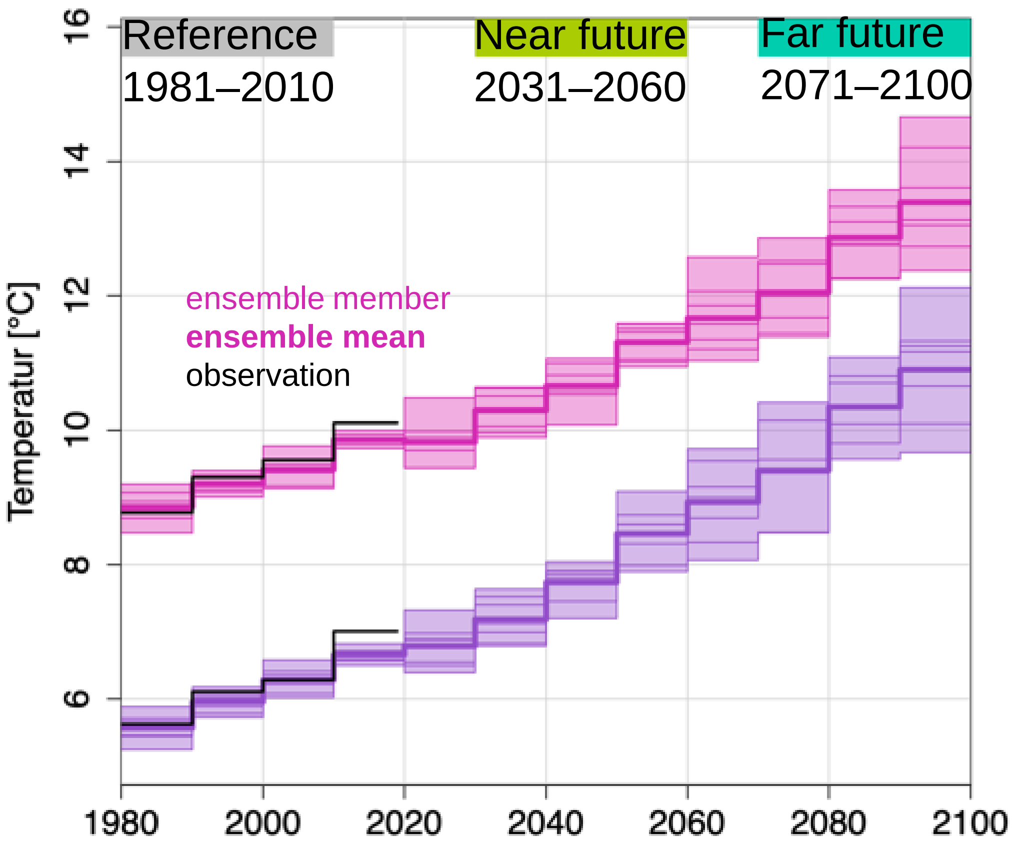
- Implemented reservoir and lake regulation
- Calibrated for headwaters
- Tracking the effect of the components

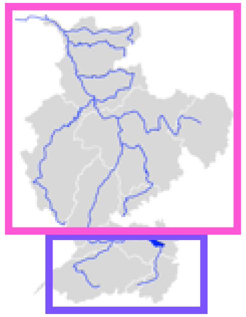
Model experiments – Two types

- Climate change scenarios: hydrology
- 'Stress tests' asking: what if 2018 weather will occur again in 2070 or 2100?

Transient climatic change: temperature

Mean temperature, all grid cells (°C)



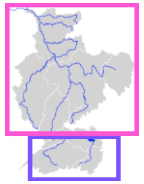


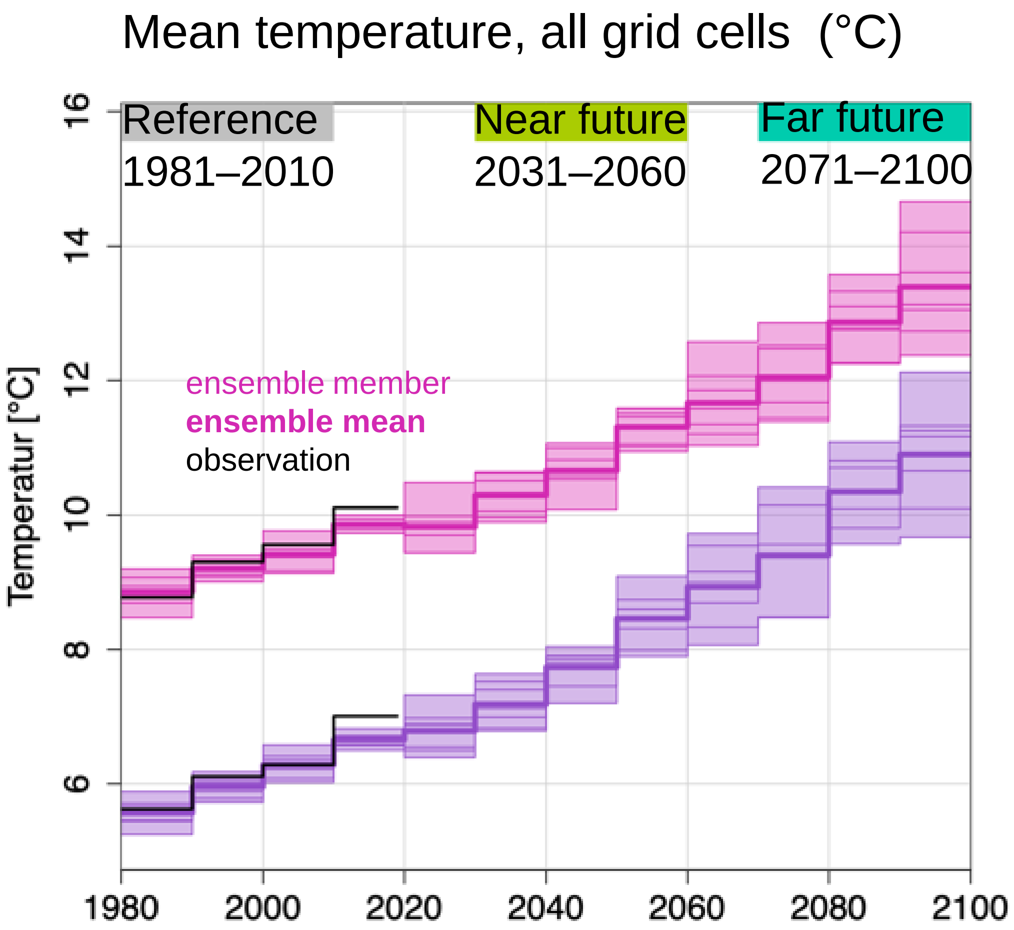
Rhine basin downstream Basel to Lobith

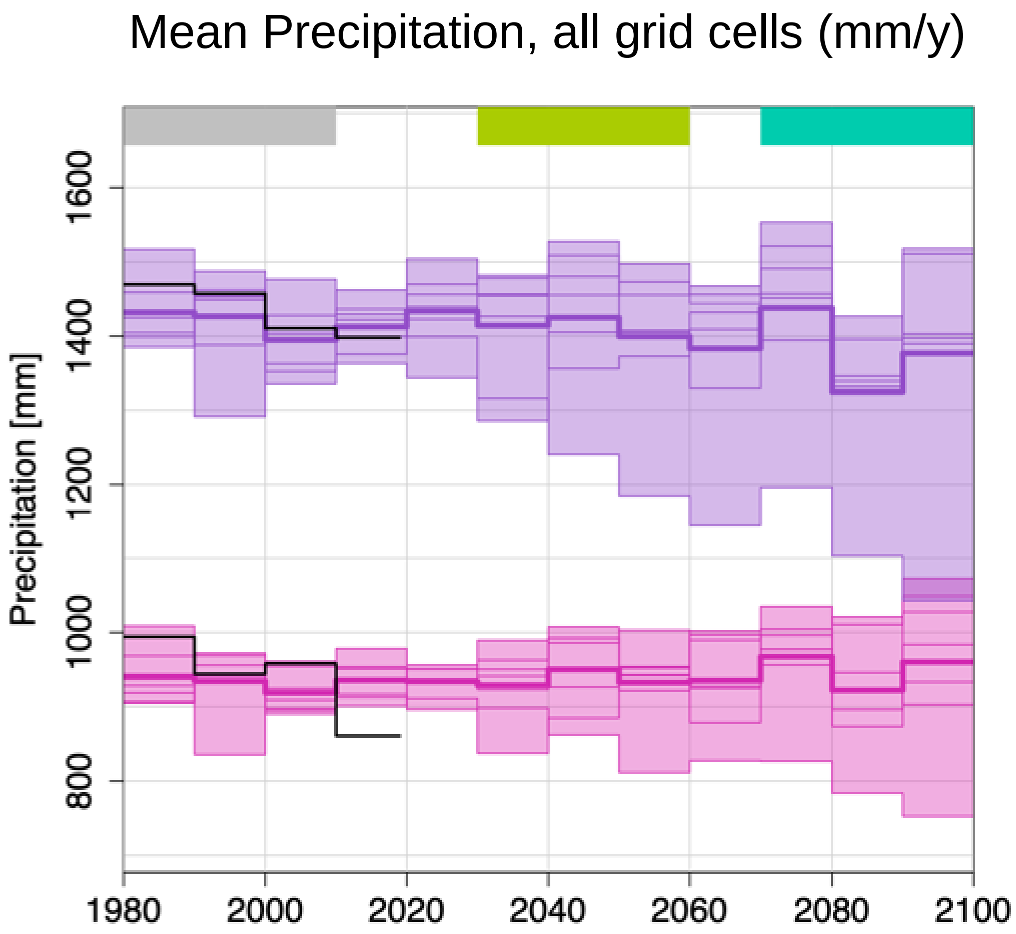
Rhine basin upstream Basel

- Warming, warming, warming !! already in reference period
- Ensemble spread increasing, esp. for far future

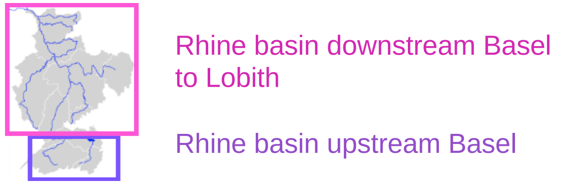
Transient climatic change





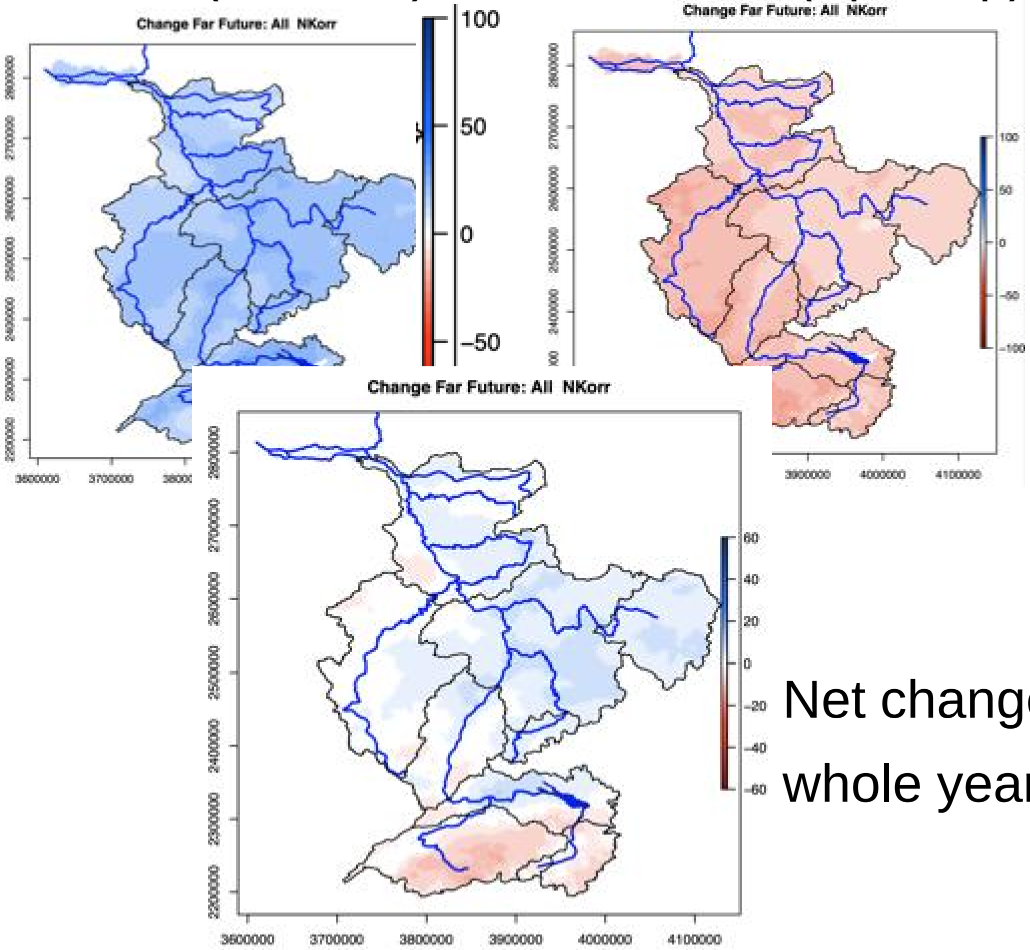


Future precipitation change



Winter (Oct-Mar)

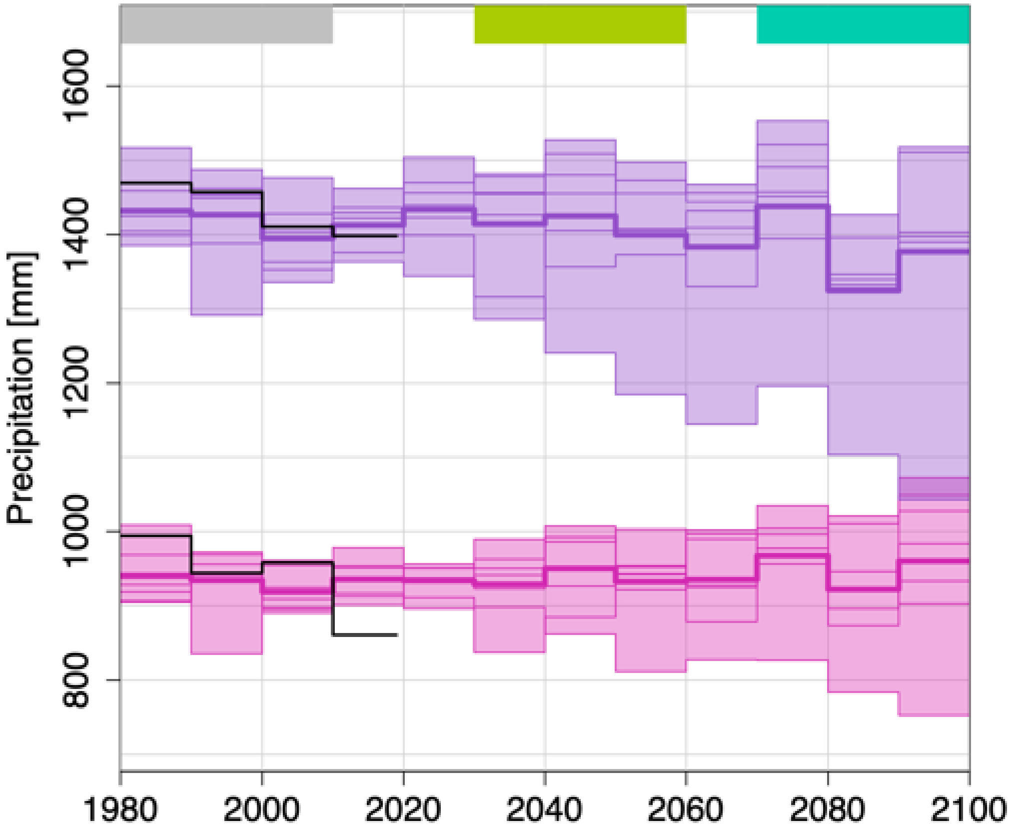
Summer (Apr-Sep)



Net change

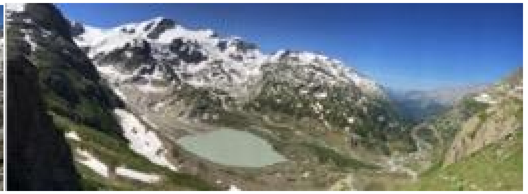
whole year

Mean Precipitation, all grid cells (mm/y)

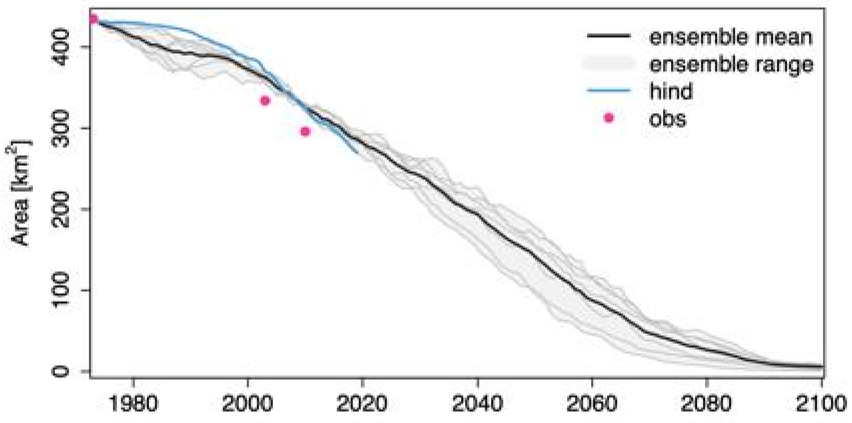


Modelled transient change in Qice

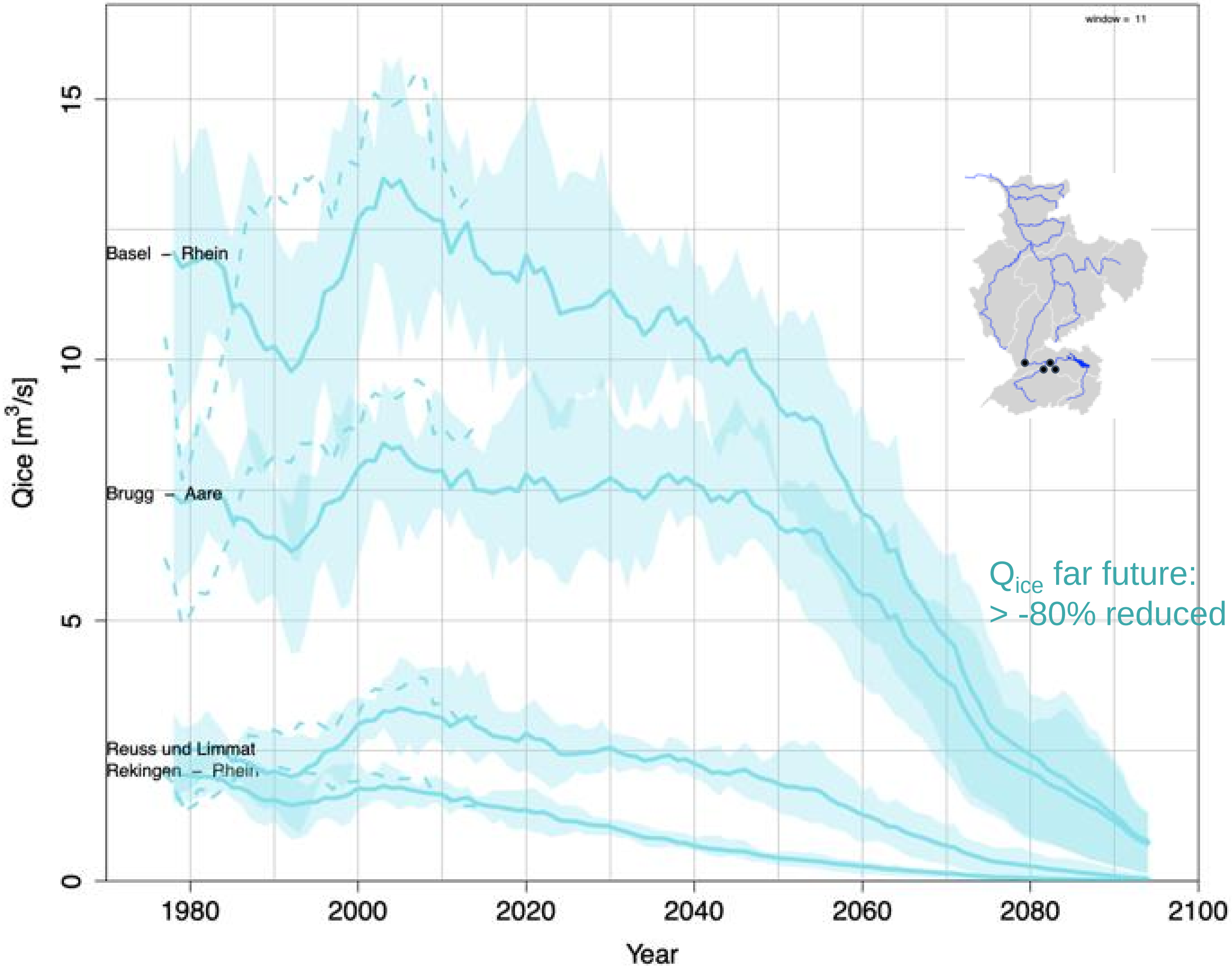

Glaciated headwaters


Deglaciating landscape

Glacier area

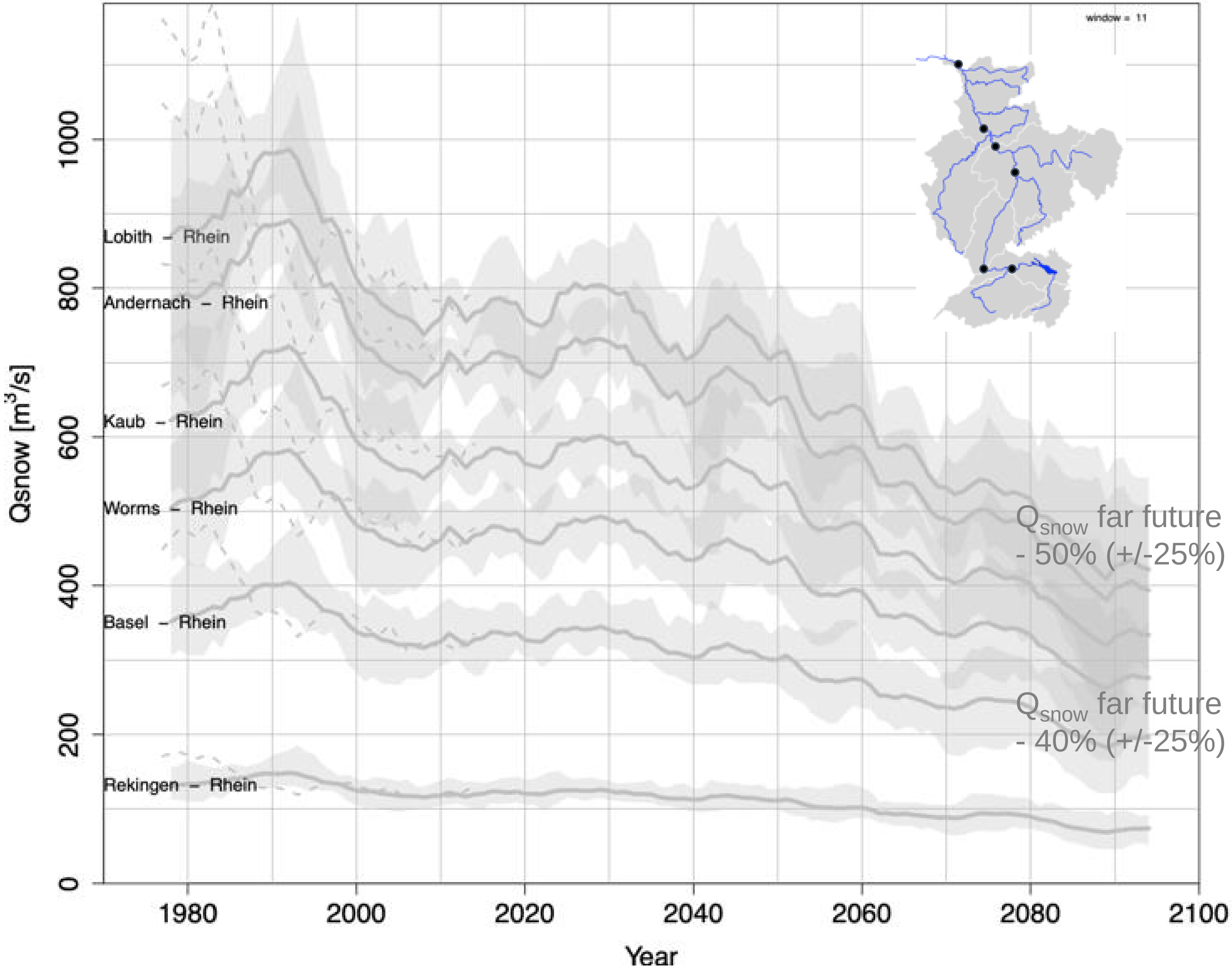


- Decline 'speed' varies in headwater regions and tributaries
- Overall decline at level of Rhine@ Basel since early 2000s



Modelled transient change in Qsnow

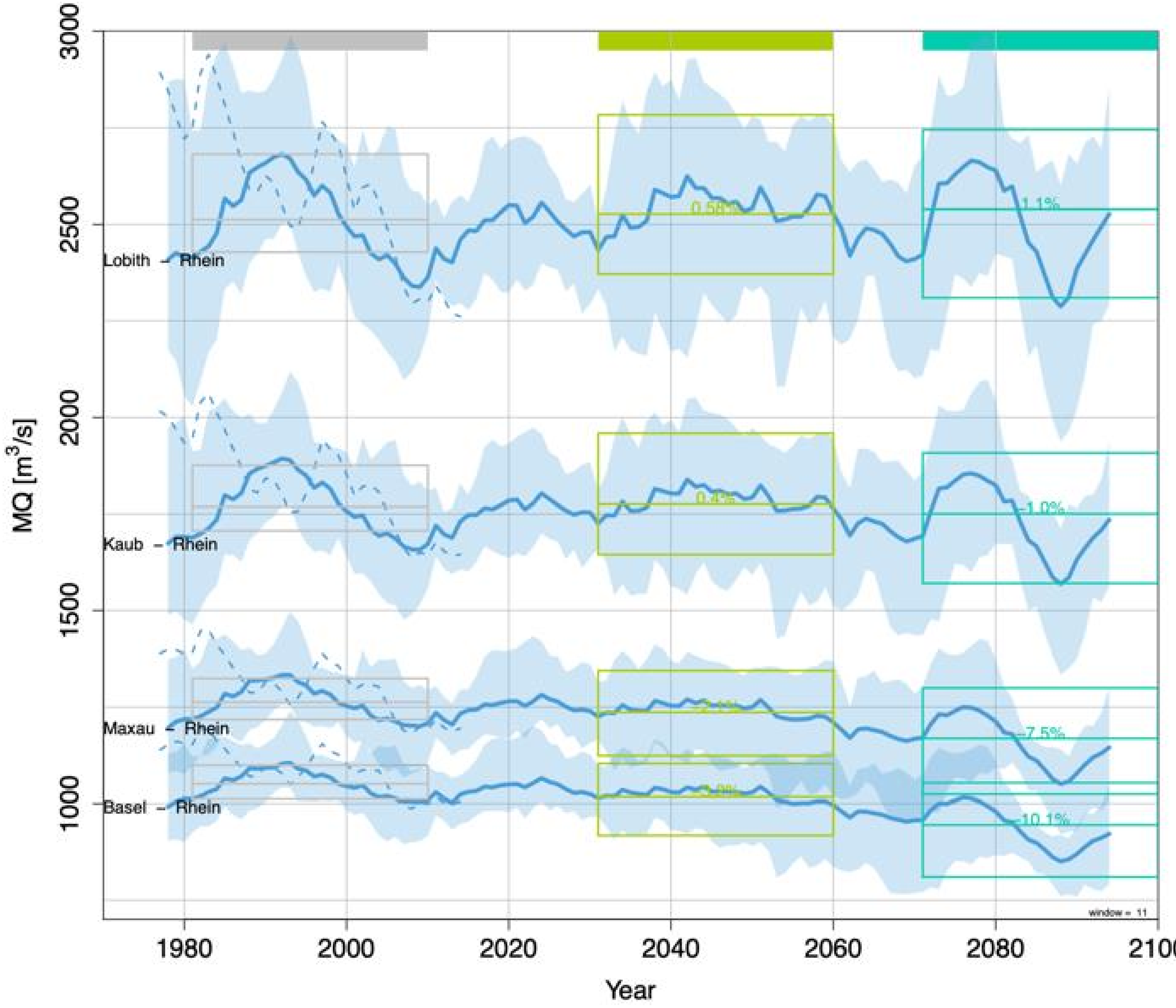
- Will decline, particularly in far future
- Uncertainty high
- But
  - ➢ a snow component will remain important
  - ➢ shorter duration snowpacks



Modelled transient change in mean annual streamflow

Total streamflow from the components

- Small changes
- Reductions ustream of Basel
- Little change downstream of Basel – compensation by increased net precipitation
- Uncertainty from climate models is high - fluctuations



Q far future
+ 1%

- 1%

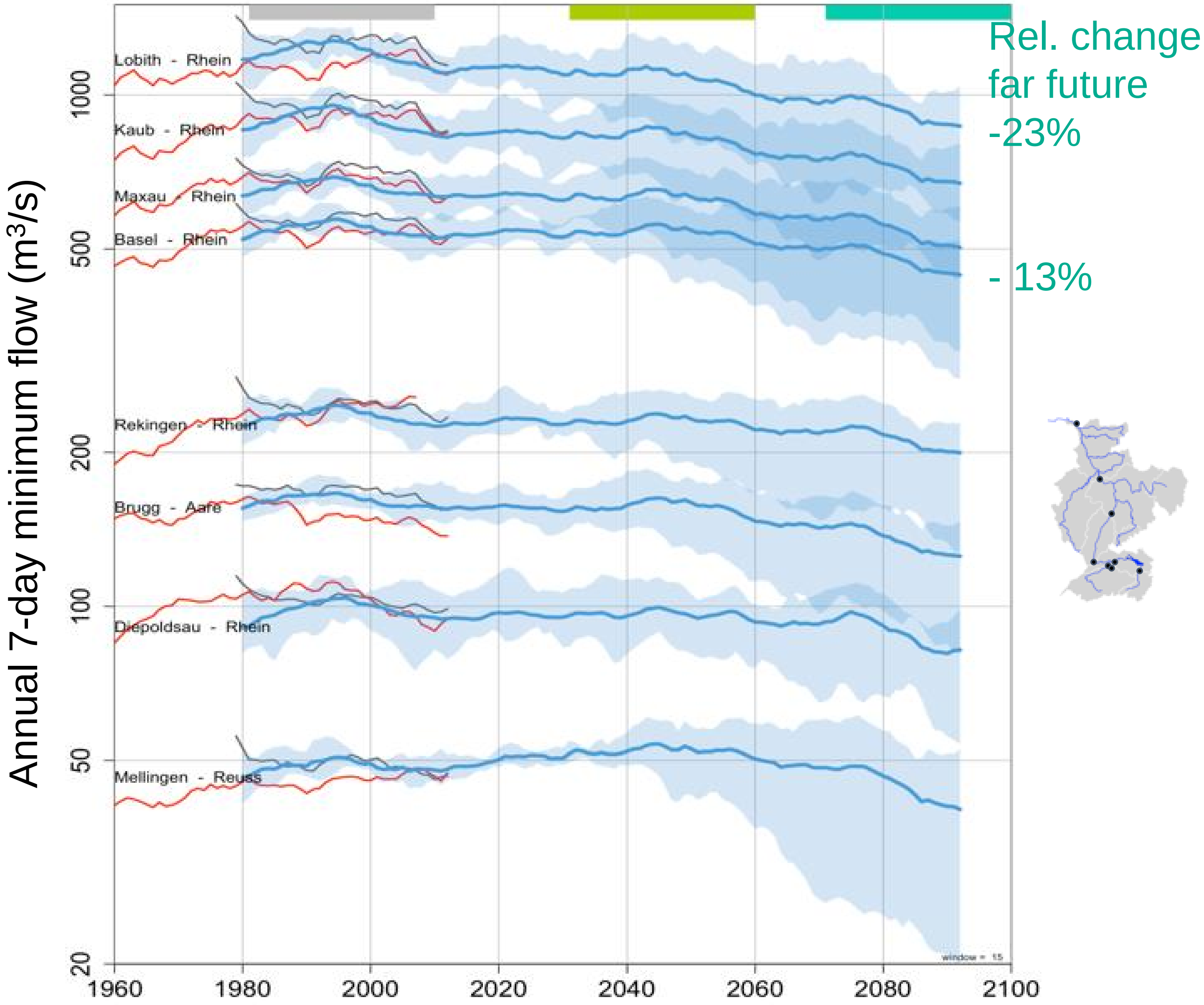
- 7%

- 10%

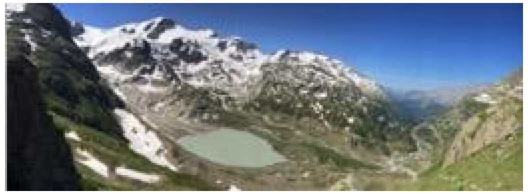
Modelled change in low flows

Summary

- Consistent direction of changes: reduction in Lower Rhine
- Upstream of Basel seasonal differences: increase of winter low flows, decrease of summer low flows

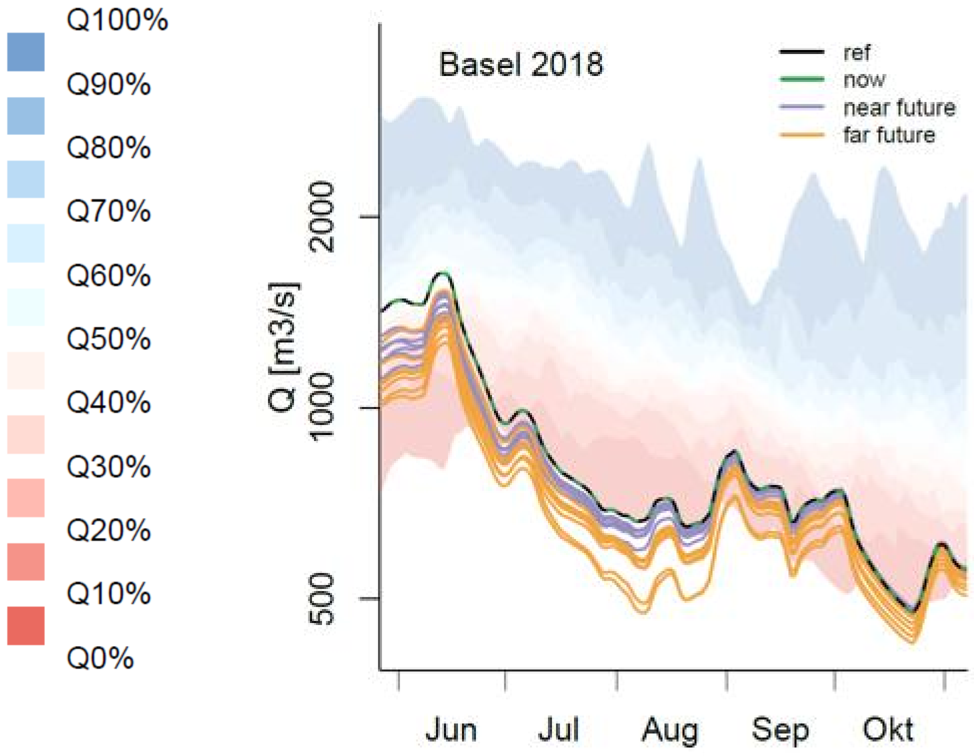


Stresstest model experiment: a known 'event', the (meteorological) drought of 2018 projected onto the future 'deglaciated' Rhine



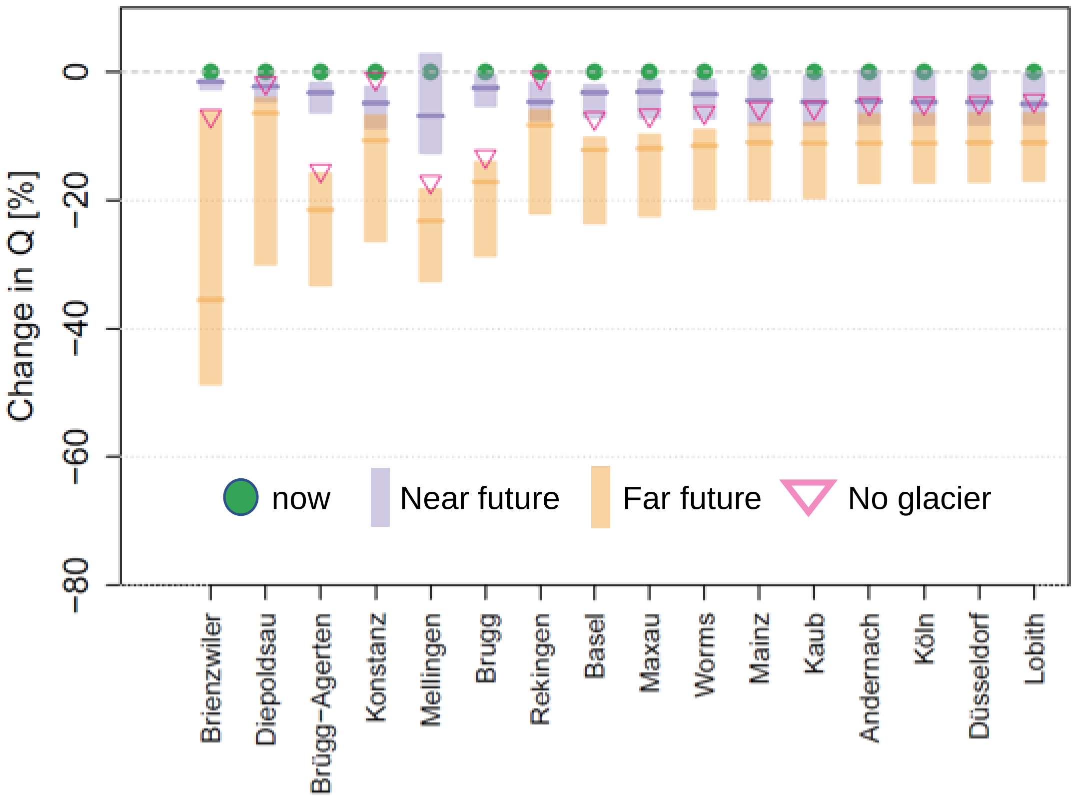
Background streamflow variability at Basel

Example of 2018
Projected into near and far future's landscape



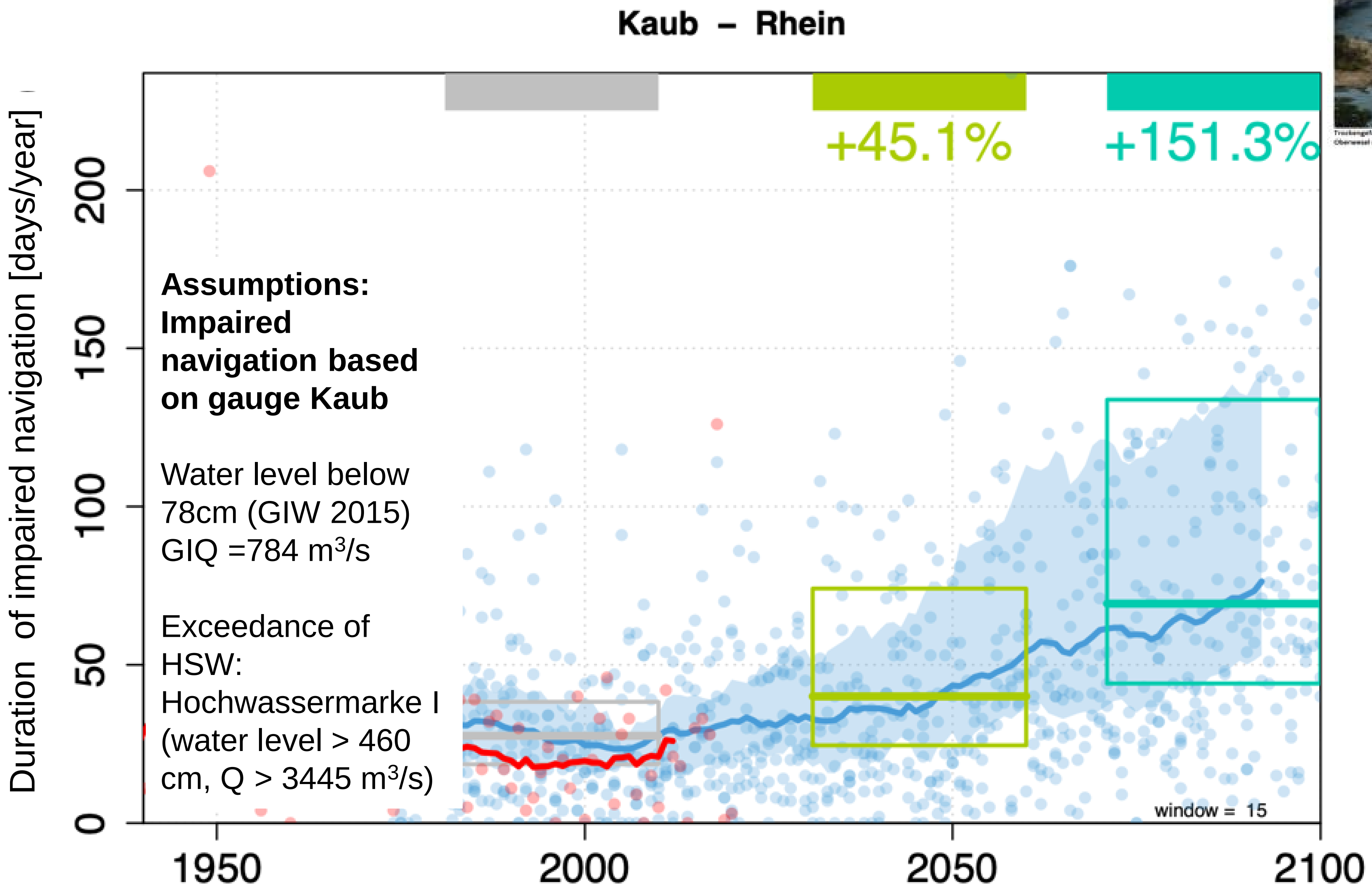
Results along the Rhine

- Same event will cause lower low flows everywhere
- Relative differences decrease downstream, esp. in far future, uncertainty is large

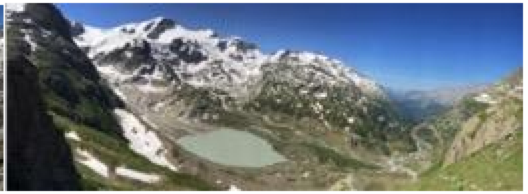


Van Tiel et al. (in prep)

Application to operational thresholds: navigation



Summary



- The ASG Model experiments quantify hydrological change by the process causes (Q_{comp})
- Rain component and related opposing water balance changes up and downstream adds uncertainty
- Snowmelt component changes are largest. Snow still present in the future (but short-term transitional?)
- Icemelt component will decline and diminish and hence not provide 'water from the bank' during future drought situations
- Consequently, low flow events and situations with water use restrictions will exacerbate considerably (which?)