

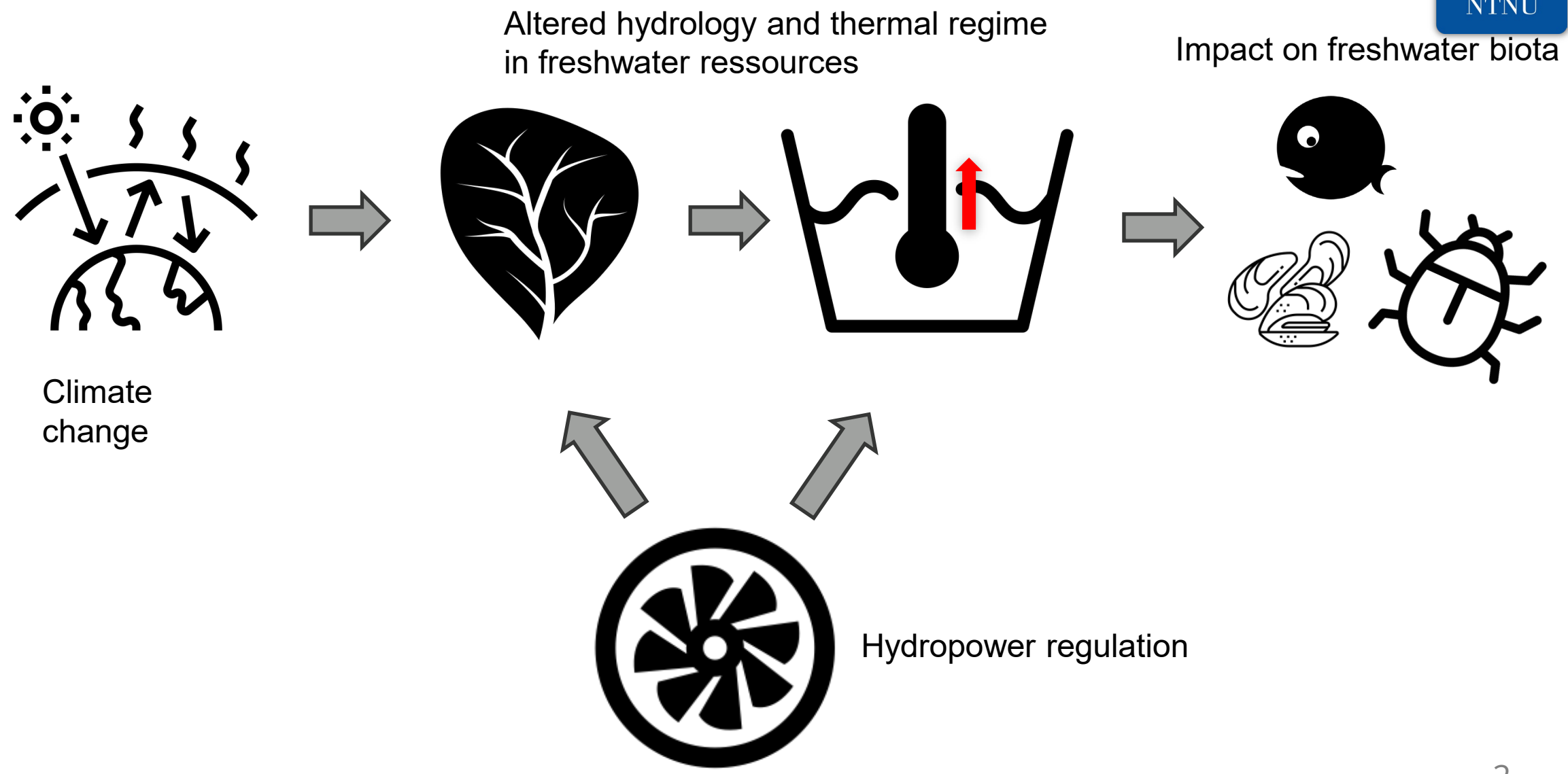


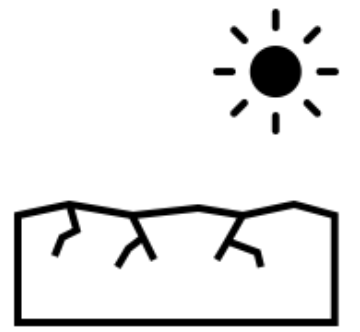
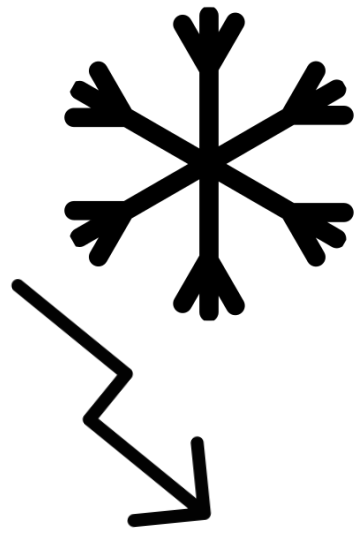
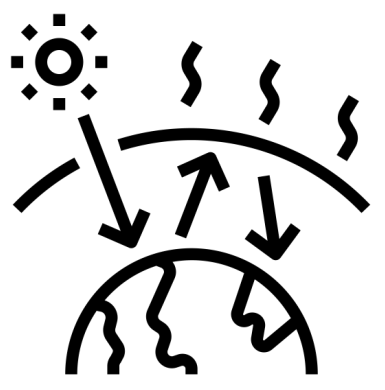
COOLHYDRO

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with Prof. Tor Haakon Bakken and Prof. Knut Alfredsen

Sustainability in Hydropower 2023 conference

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Main research targets

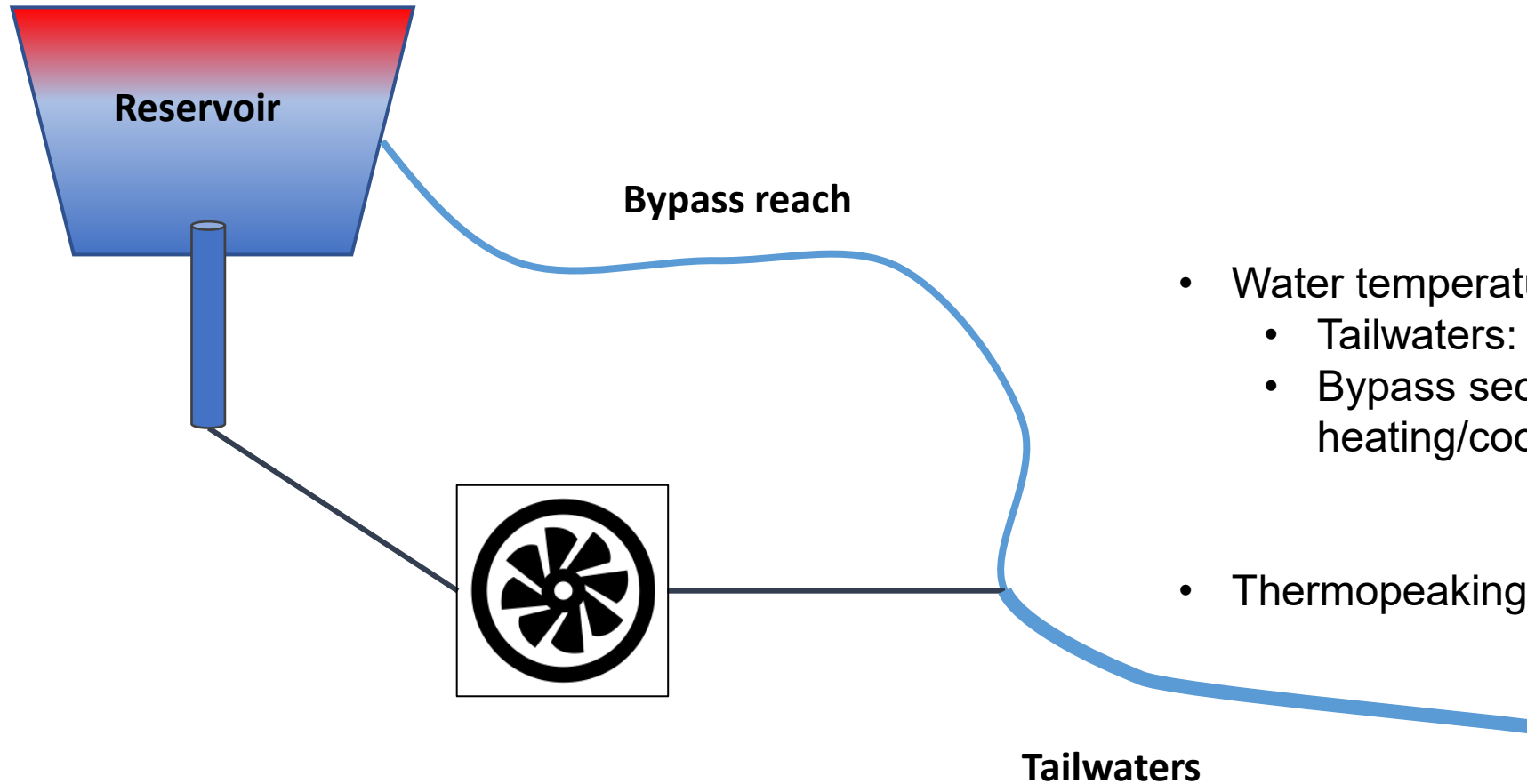


1. Assess freshwater temperature changes
 - Temporal: historic and future
 - Regulated vs. unregulated
 - All of the above



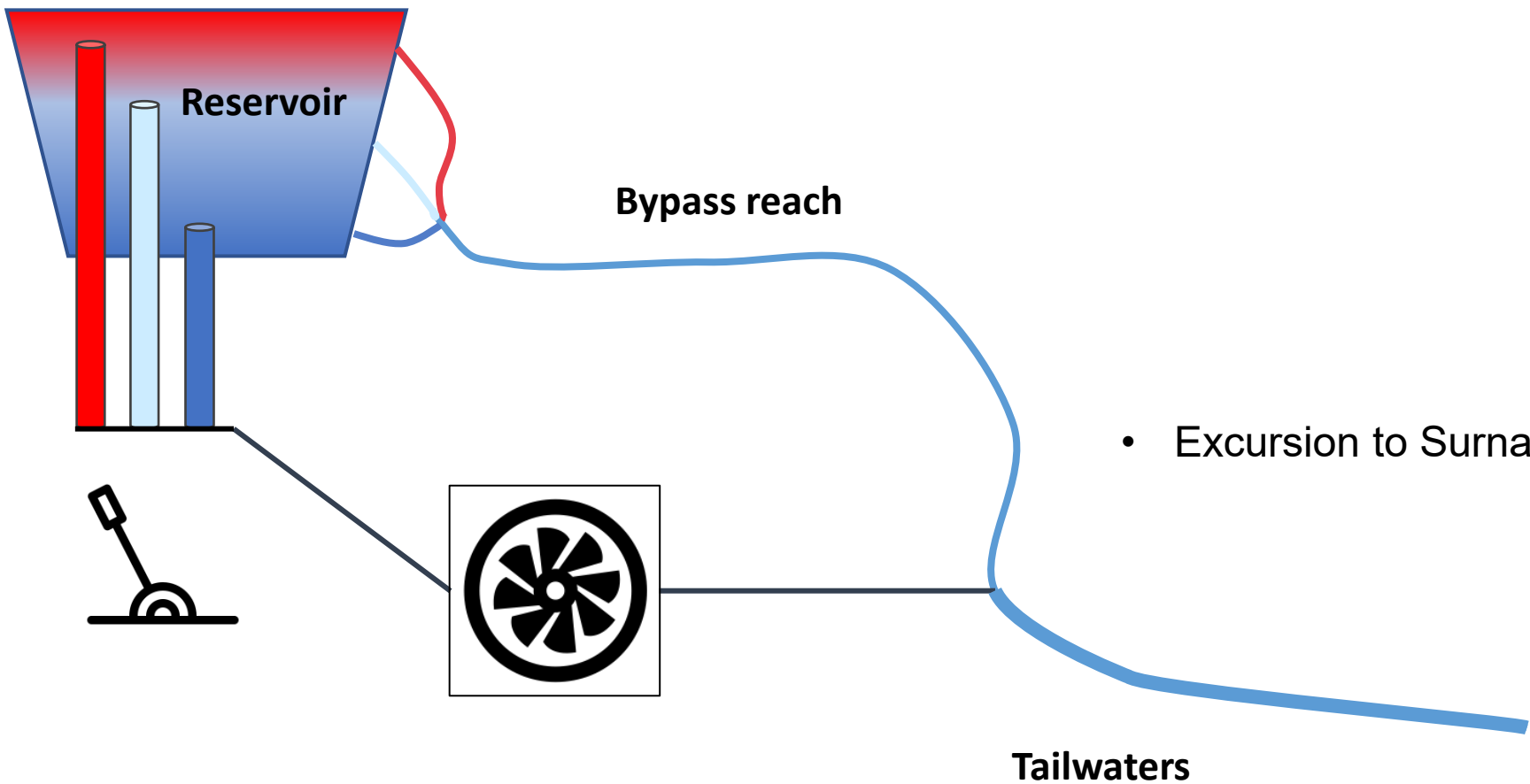
2. Can targeted cold-water releases mitigate temperature extremes?

Typical Norwegian set-up



- Water temperature
 - Tailwaters: reservoir dominated
 - Bypass section: atmospheric heating/cooling
- Thermopeaking may occur (ramping)

Typical Norwegian set-up – with flexible intake



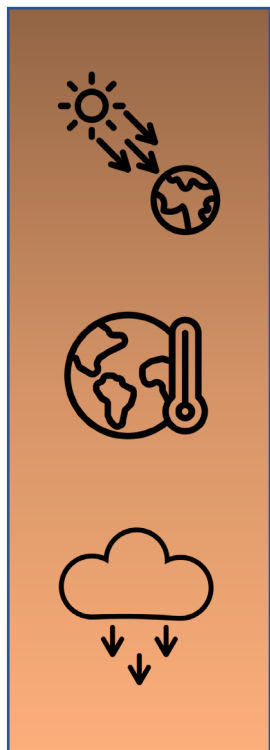
- Excursion to Surna: Trollheimen power plant



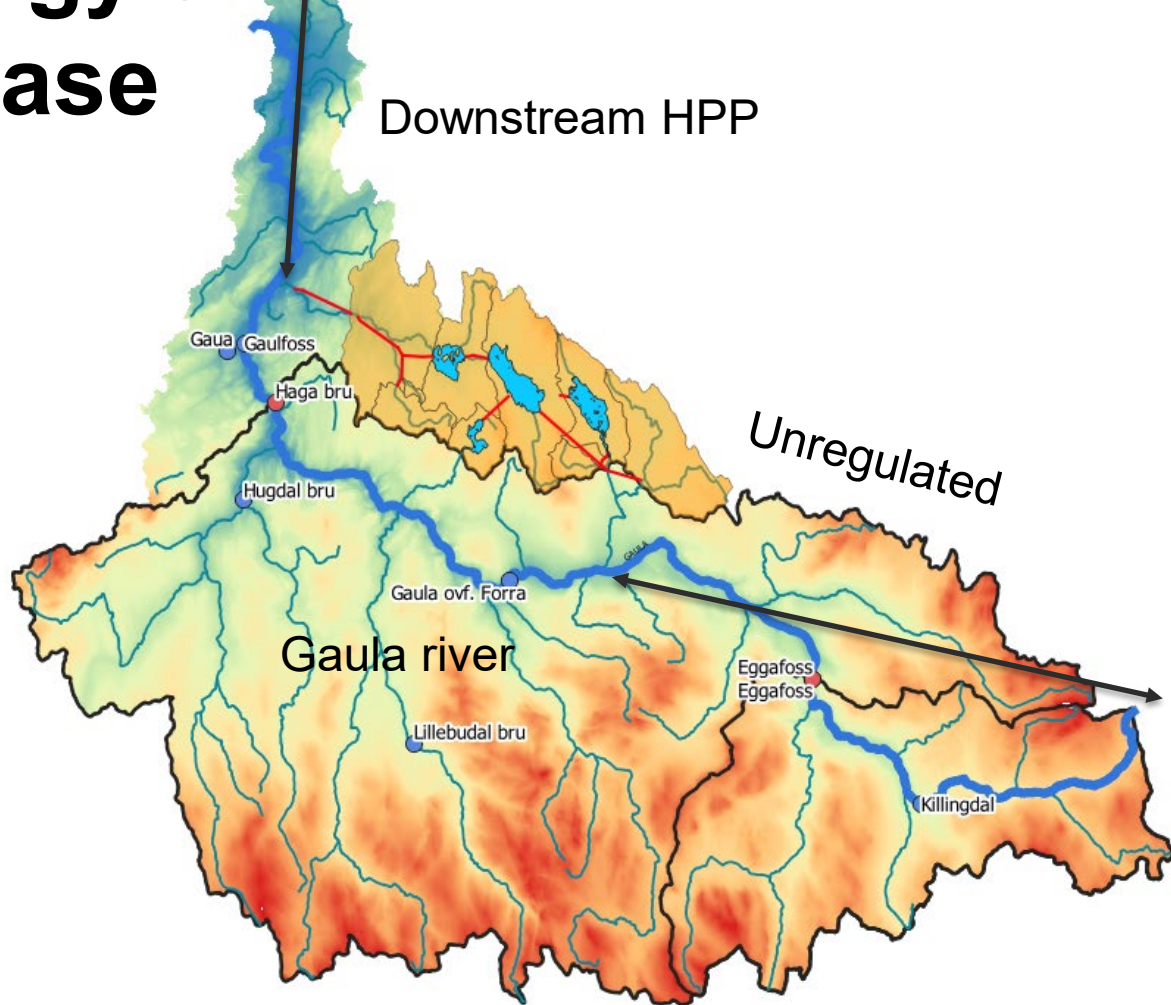
Methodology and first test case



NTNU



Downscaled
CMIP 5 / 6



HYPE (Inflow, T and HP regulation)

MyLake (Lake dynamics)

HEC-RAS (River dynamics)



Analysis of
temperature
distribution



Optimization of
flow releases

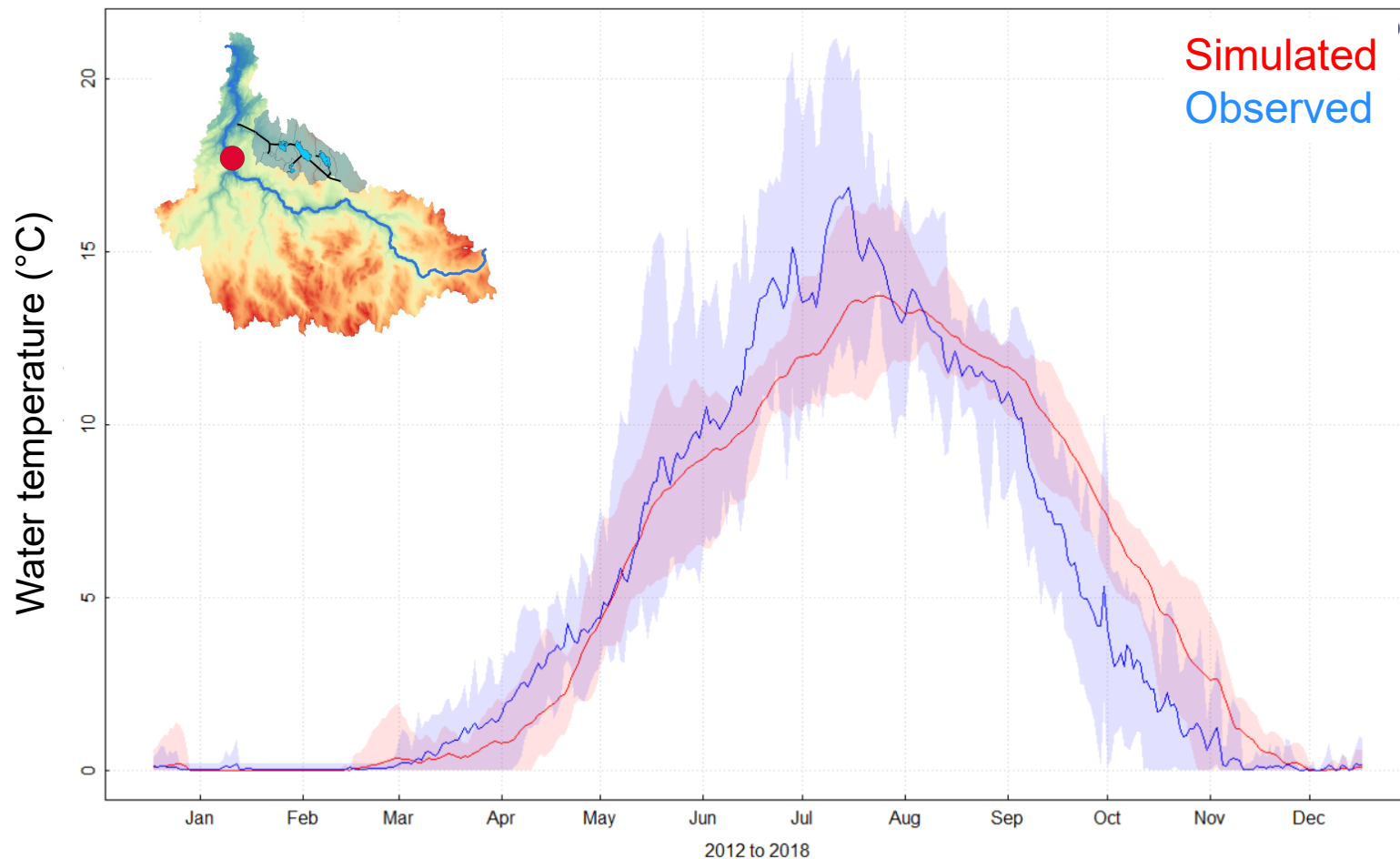
Preliminary modelling results

Annual water temperature regime – Haga bru (mean and 25%-75% percentiles)

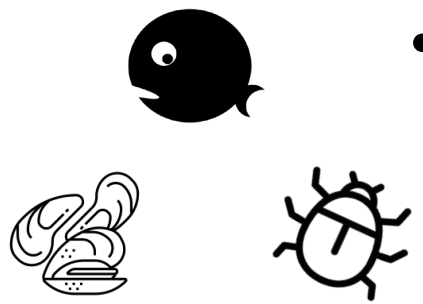
- Follows overall trend



- Extremes
- Early Freezing in winter
- Variability
- Lag

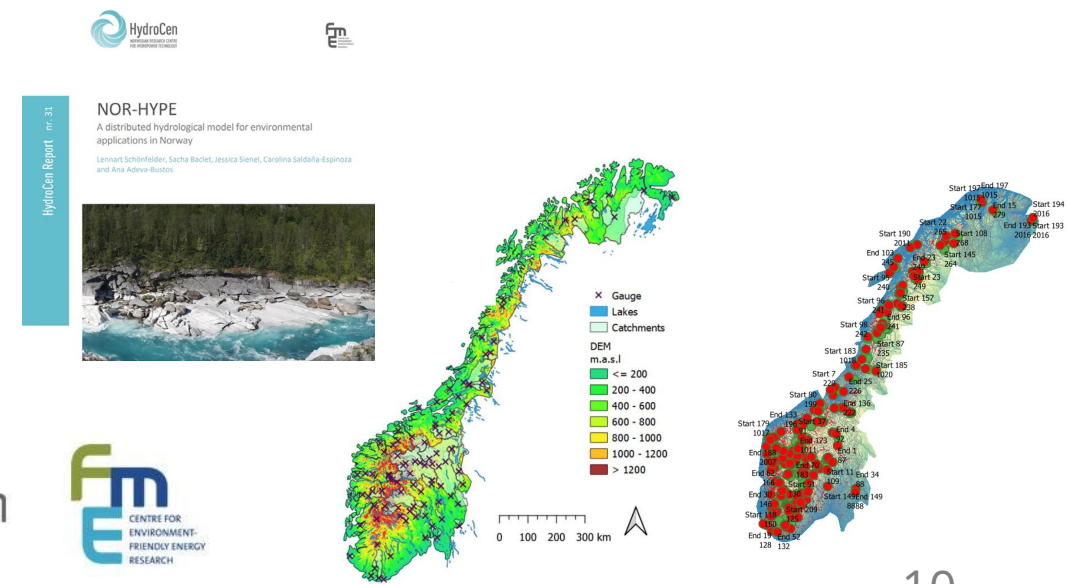


Outlook / future work



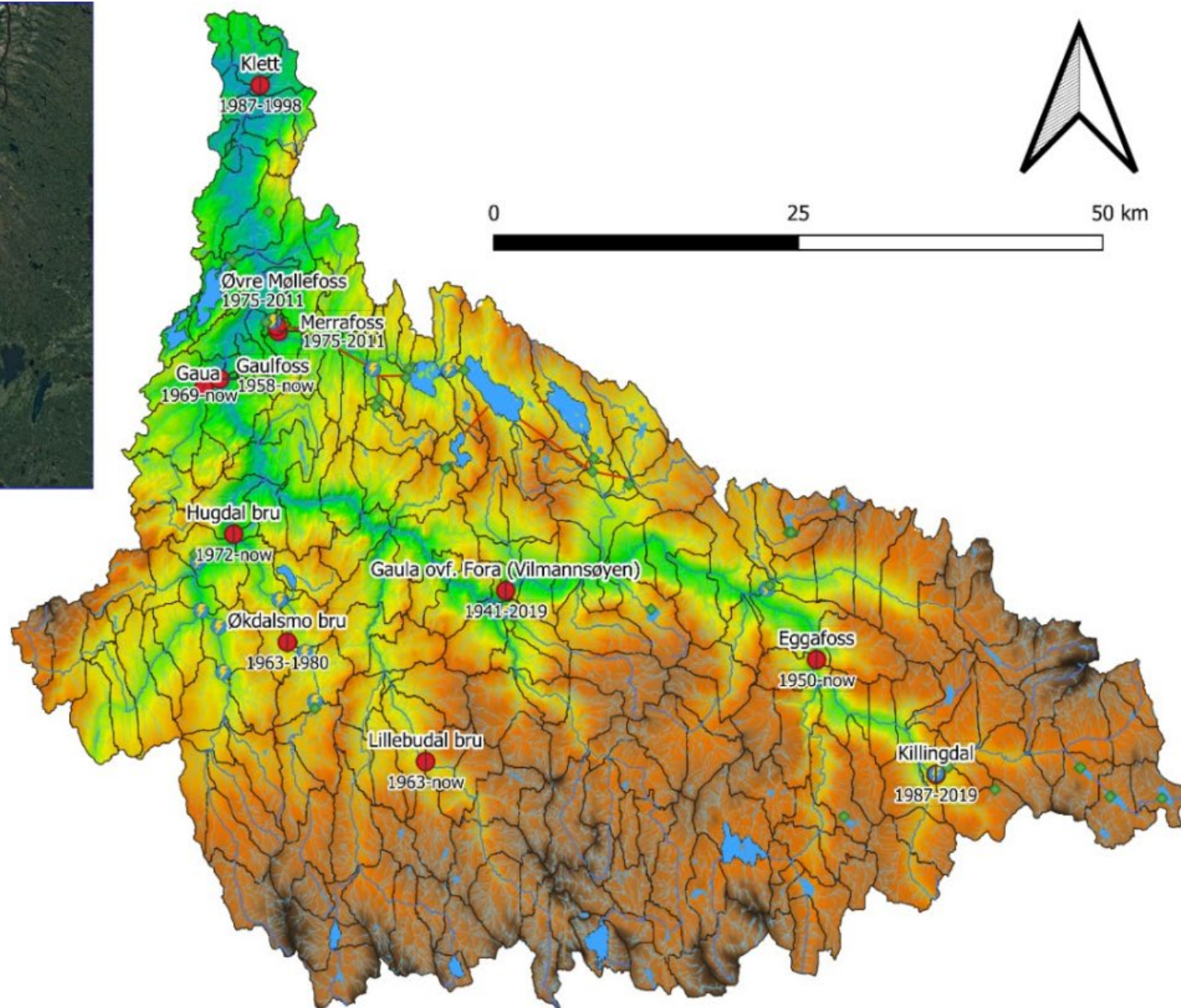
- Temperature targets
 - Key species thresholds
 - Reference conditions (historic periods, IHA)

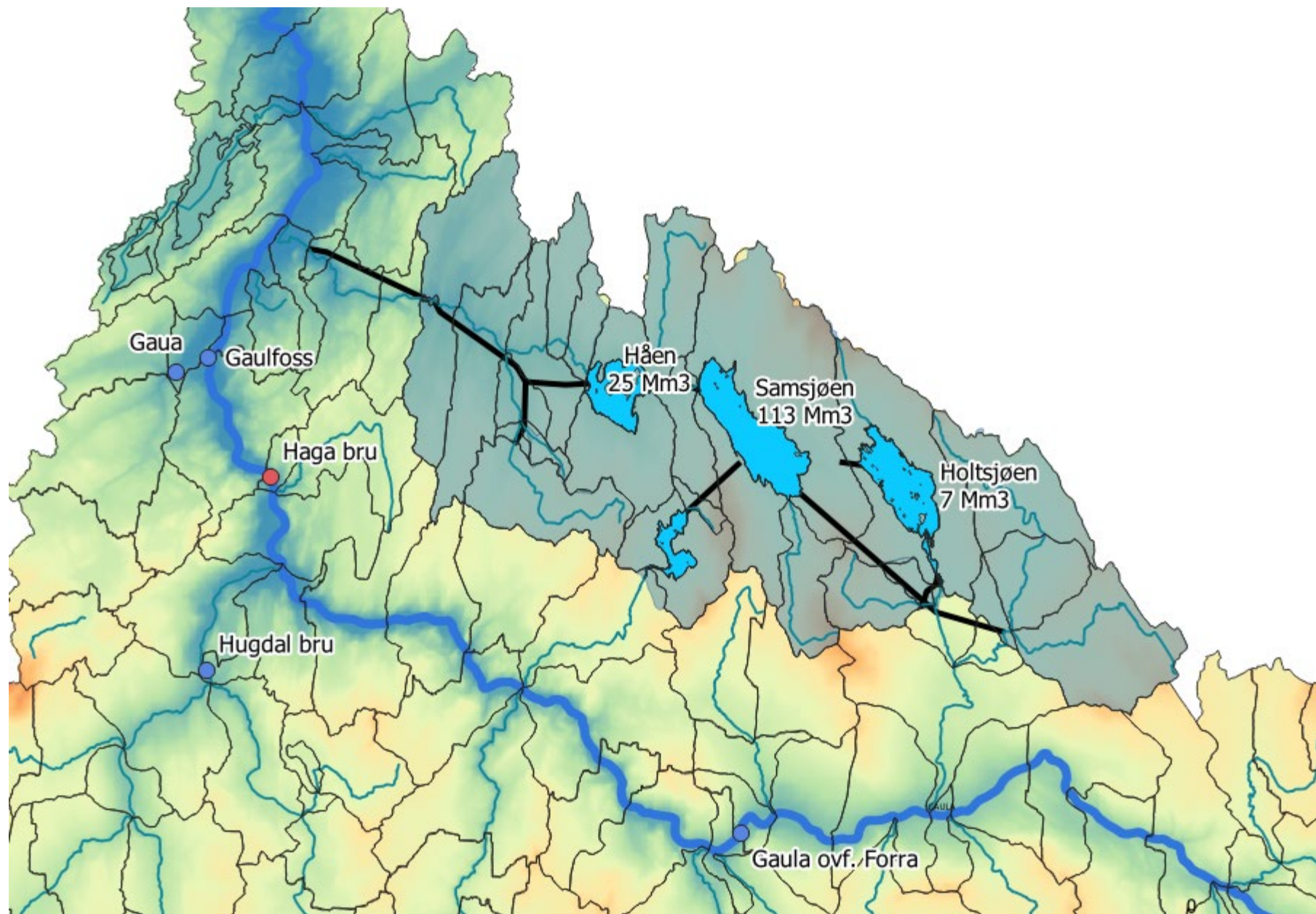
- Regionalization



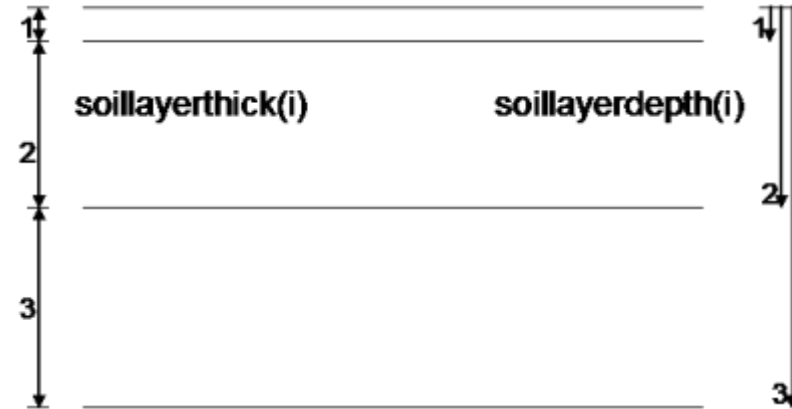
**Thank you for
your attention**

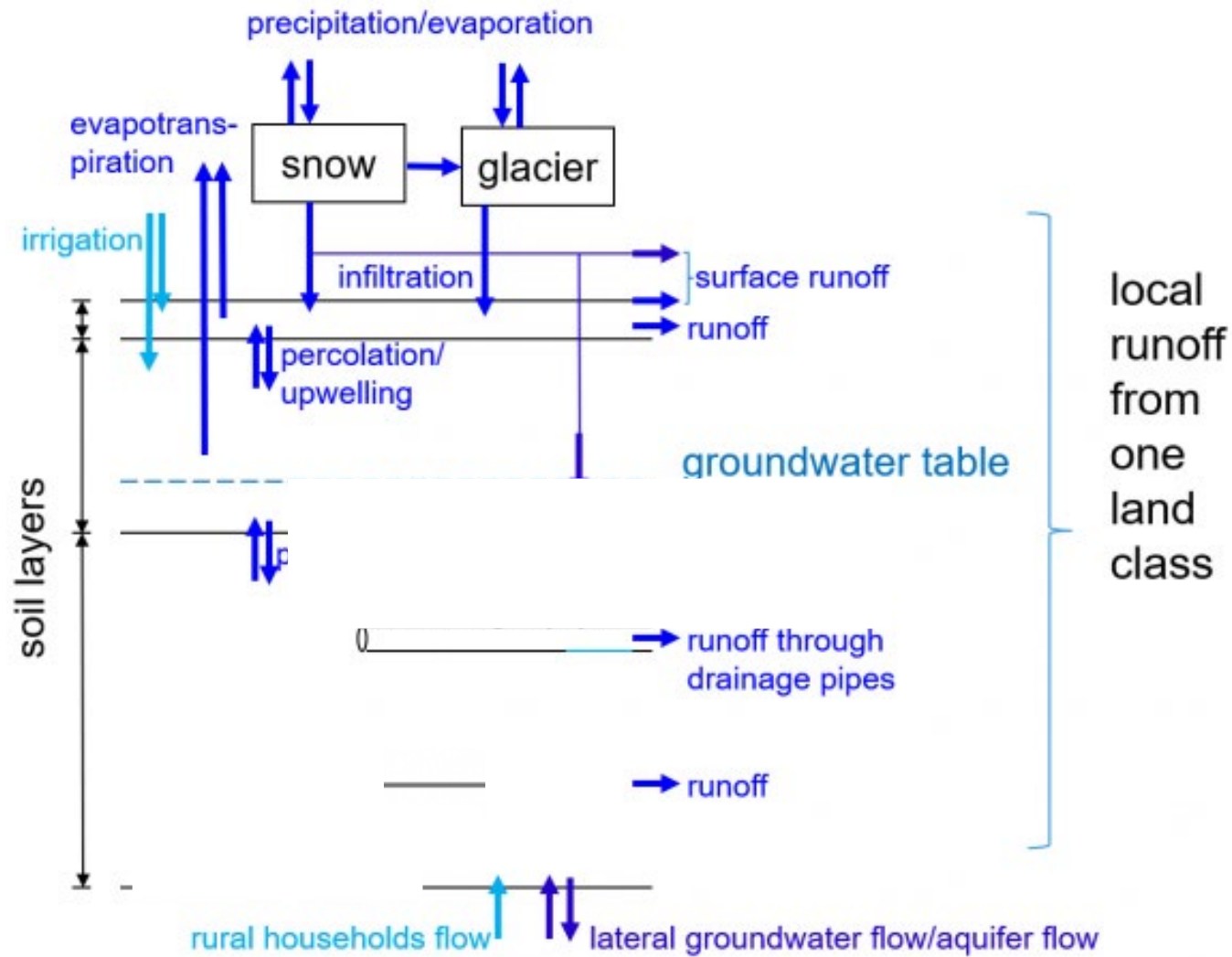
Addendum





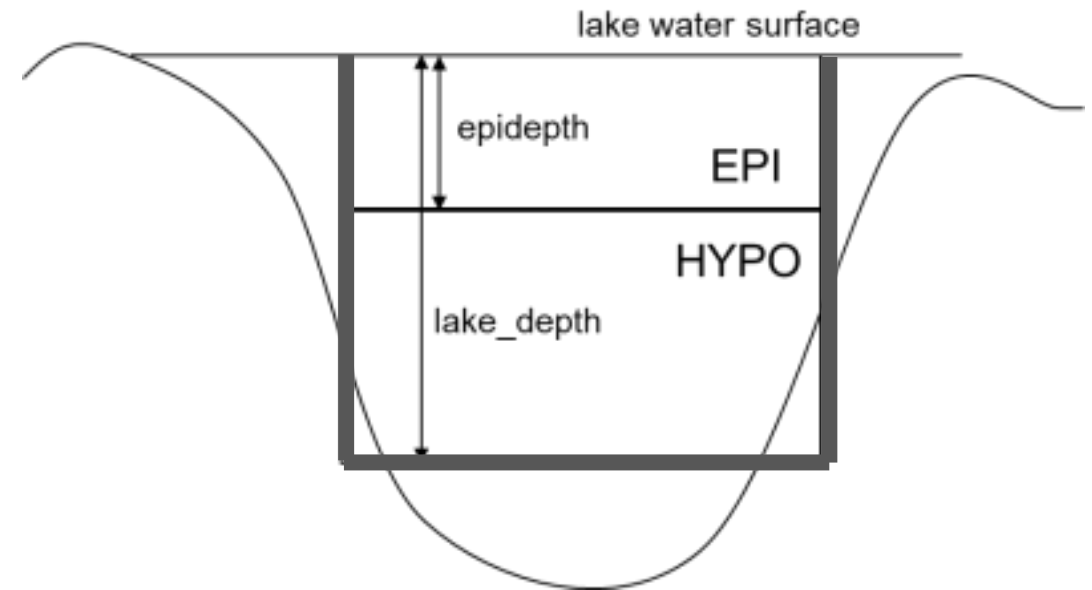
- Precipitation
- Heat exchange:
 - Soil – water
 - Soil – atmosphere
 - Water – atmosphere



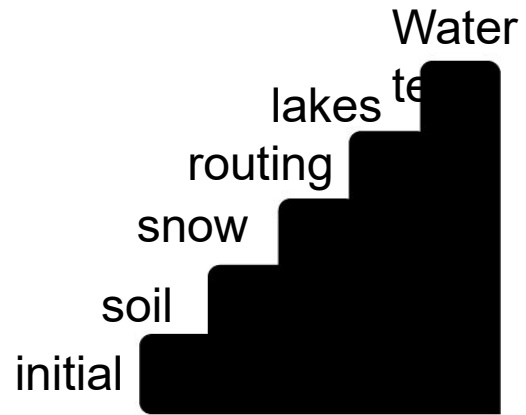


Lake modelling in HYPE

- Forced mixing (spring and autumn)
- 2 vertical zones
- Simplified to «vertical bucket»

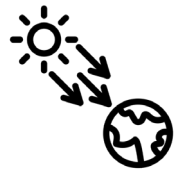
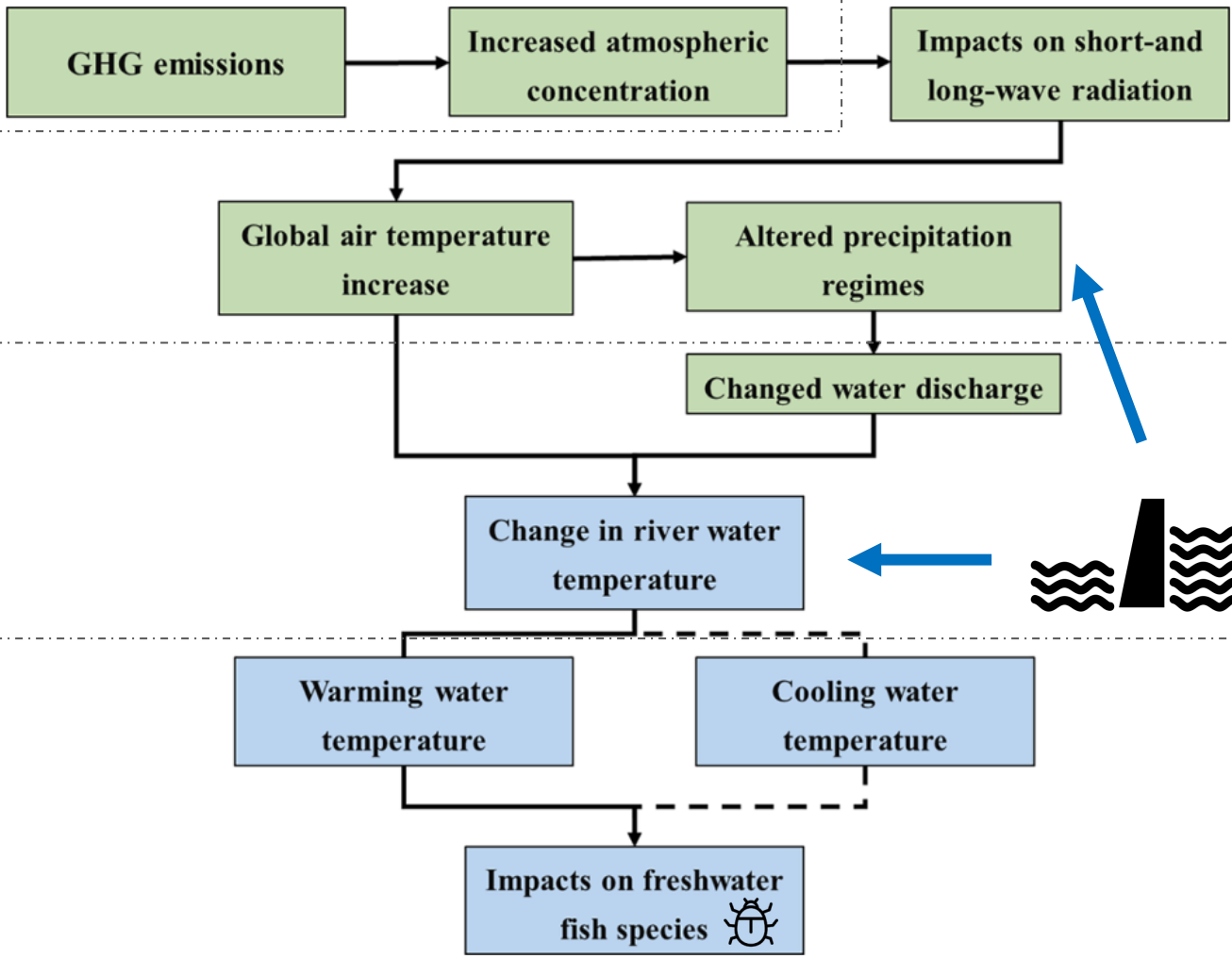


Performance – Calibration – intermediate results



Station	KGE - Discharge	NSE - water temperature
Gaula ovf Forra	0.41	-
Gaulfoss	0.67	-
Eggafoss	0.53	0.86
Lillebudal bru	0.55	-
Gaua	0.62	-
Hugdalen bru	0.57	-
Killingdal	0.40	-
Haga bru	-	0.88
Average	0.53	0.87

Detail level	Variable	Data set	Historical	Future scenarios
Base hydrological model	Precipitation Temperature	SeNorge2018	1957-2019	1970 - 2099
	Land use fractions	Corine land cover 2018	x	?
Water temperature model	T_max, T_min	SeNorge2018	1957-2019	1970 - 2099
	Elevation, Latitude	Norgeskart		x
	Water covered area	“Arealressurskart” by kartverket		x
Hydropower	Water transfer	Concession document		



HYPE model

MyLake model

- Analysis
- Hydrology
 - Temperature
 - Relate to biota



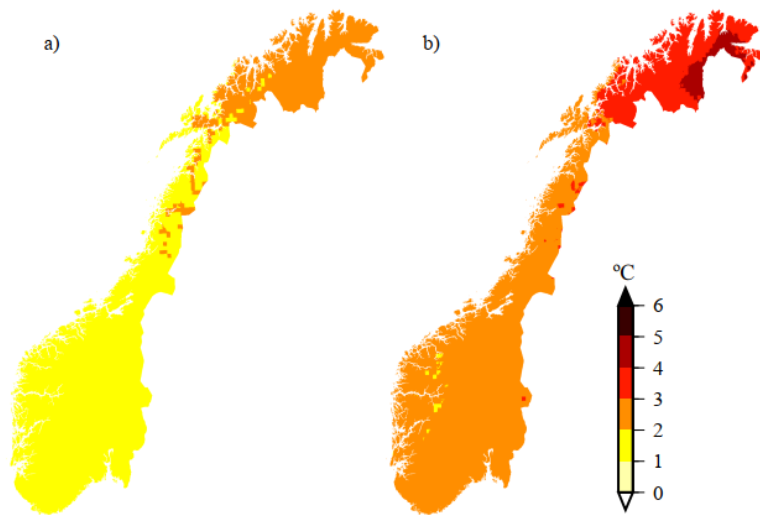


Figure 9. Median change in annual mean temperature based on 10 RCM runs for RCP4.5 between the reference period (1971-2000) and the projection periods a) 2031-2060 and b) 2071-2100.

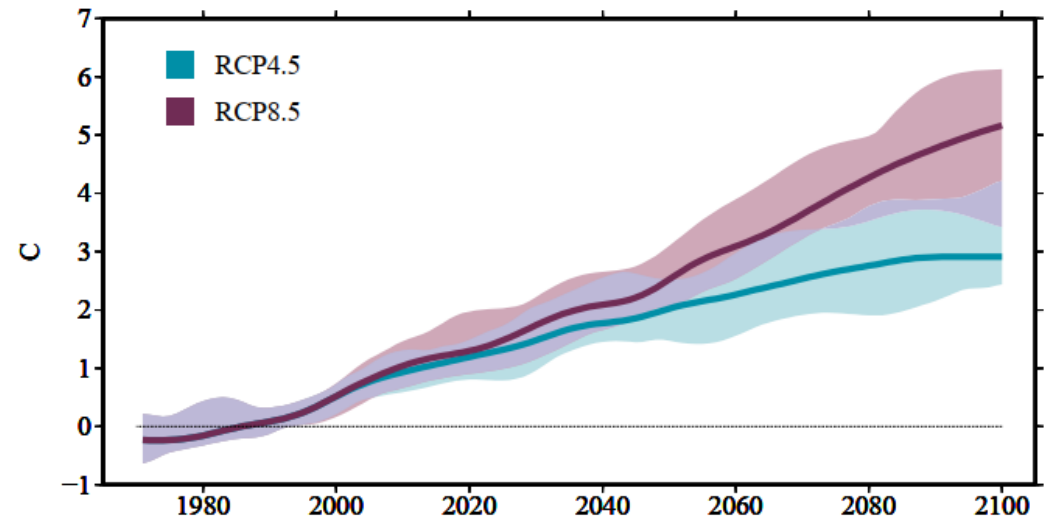


Figure 8. Change in annual mean temperature for Norway relative to the reference period (1971-2000). The blue and red lines show the median values for the ensemble of 10 RCM runs for RCP4.5 and RCP8.5. To remove short-term variability, both curves are smoothed using a 30-year Gaussian filter. Shaded areas surrounding the temperature curves indicate the spread of the RCM results (10th and 90th percentiles).

Model overview Norwegian scale

[Report about the Norwegian model set-up](#)

