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Heated rivers:
Learning from energy and climate change scenarios along a 700 km Rhine stretch

Foto: Lingen, BfG

Motivation

This work updates a report by the ICPR (2014). It results from work by an expert group of the International Commission for the Protection of the Rhine (ICPR) on future Rhine water temperature development in one of the largest rivers in Europe.

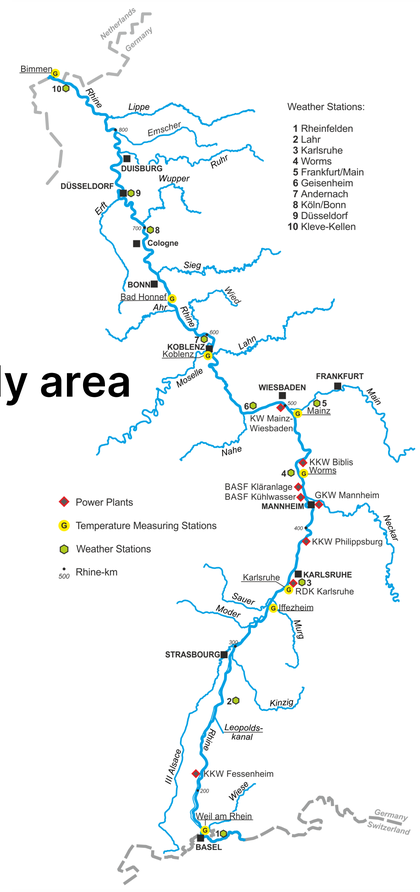
Research questions

- How does heat input by power plants modify Rhine water temperature?
- What is the impact of climate change on Rhine water temperature?

Methods

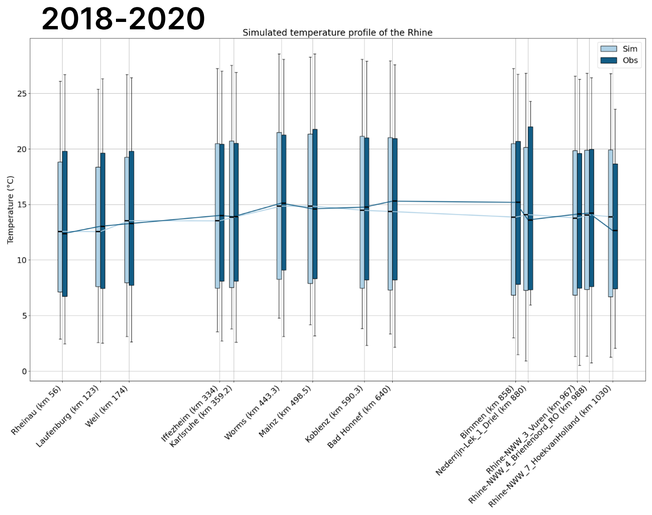
- The BfG's water quality model QSim (see QR-Code below) is used to simulate the water temperatures in the German section of the Rhine from Basel (km 164) to Bimmen (km 865), with and without heat input for the years 2018 - 2020.
- To simulate climate change, a BfG model ensemble compiled by the DAS-Basisdienst for IPCC AR5, "high emission" scenario business as usual (RCP 8.5) was applied (www.das-basisdienst.de).

Study area



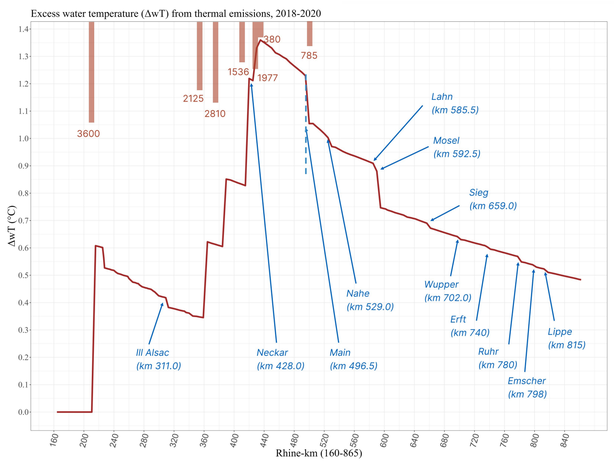
Results of energy scenarios

2018-2020



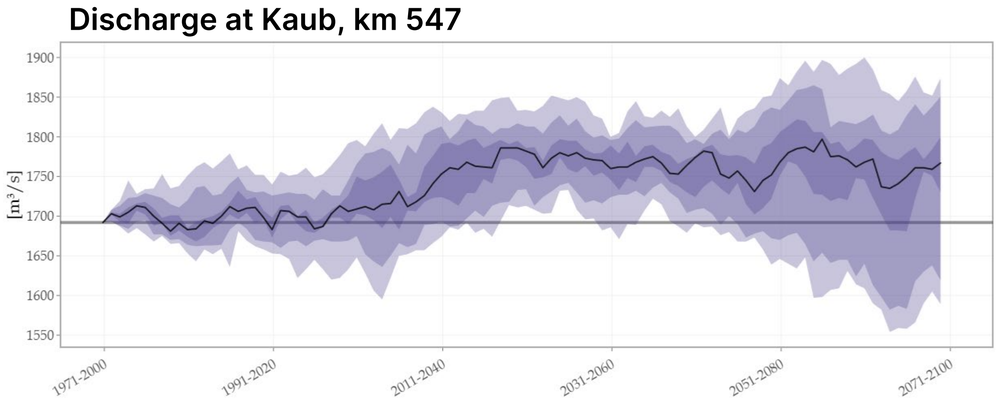
- Water temperatures are well reproduced by the model
- The difference with and without heat input depends on the location along the Rhine, the difference is largest in the upper Rhine where the larger power plants are located.
- The largest excess temperature difference due to thermal emissions 2018-2020 amounted to 1.36 °C at km 435 downstream of BASF. At Koblenz (km 590), it was 0.88 °C.
- The tributaries' effect on the Rhine temperature 2018-2020 varied.

Koblenz km 590	RMSE	MAE	PBIAS	NSE	R^2
without heat input	1.36 °C	1.15 °C	-7.60 %	0.96	0.993
with heat input	0.65 °C	0.52 °C	-1.60 %	0.99	0.995

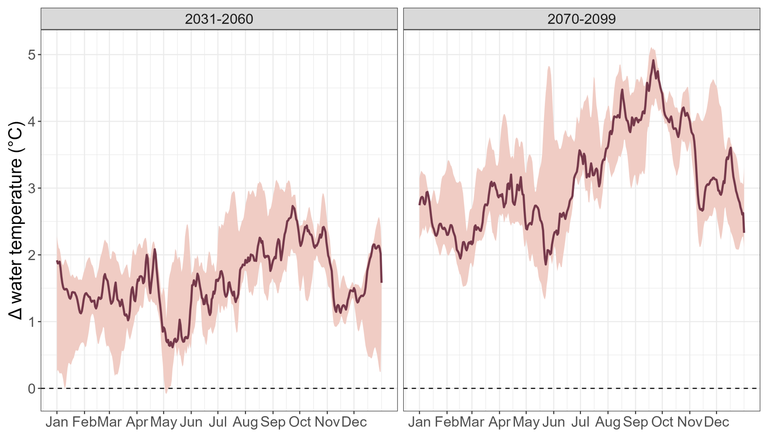


Results of climate change scenarios

Discharge at Kaub, km 547



Water temperature difference at Kaub, km 547

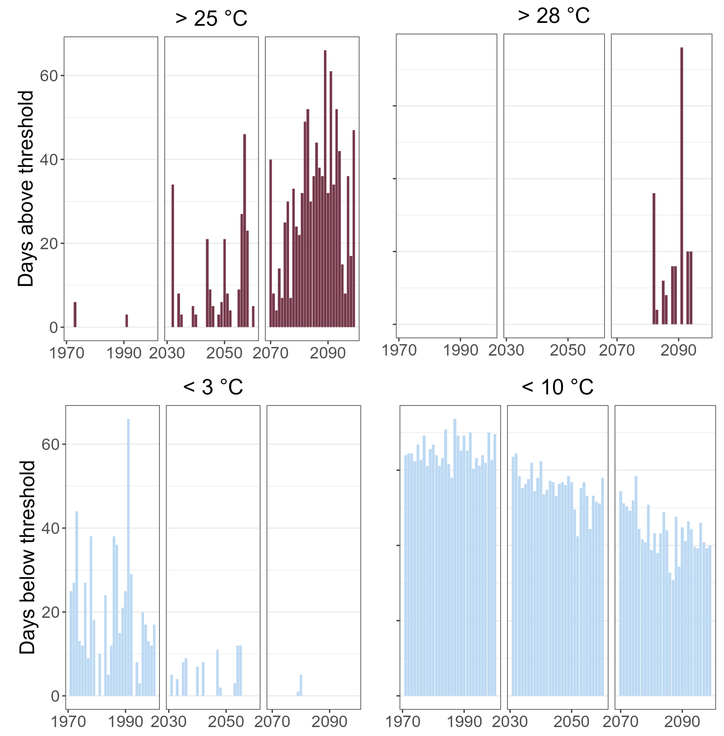


Average of mean discharge MQ (Nov-Oct) and percentiles of the BfG model ensemble (from outside to inside): 15./85., 25./75., 40./60., 50. (black line).

Change of water temperature in Kaub, km 547. Shown is the difference of BfG ensemble median, minimum and maximum between reference and future scenarios without heat input.

- The discharge will increase on average by 4 % in both the Near and Far Future, with a higher spread of the ensemble in the Far Future.
- Despite higher future discharge, average water temperatures in the Rhine will rise, within +1.1 and +2.2 °C in the Near Future and within +2.7 and +3.8 °C in the Far Future.
- As a consequence, the frequency of ecologically relevant thresholds increases considerably in the future. At Koblenz (km 590) the number of days above 25°C increases from 0.3 days in the reference scenario to 8.0 days in the Near Future and 31.4 days in the Far Future. The number of days below 10°C decrease from 163 days in the reference scenario to 139 days in the Near Future and 110 days in the Far Future.
- For the climate change scenarios, the influence of thermal input was neglected.

Ecologically relevant thresholds at Koblenz, km 590



Number of days per year exceeding different ecologically relevant thresholds (3°C, 10°C, 25°C and 28°C) at Koblenz (km 590) for reference and future scenarios simulated with the BfG ensemble without heat input.

Summary

The actual heat input in the Rhine results in a temperature increase between 0.35 and 1.35 °C depending on the location along the Rhine.

Simulated climate change led to a temperature increase of +1.1 to +2.2 °C in the Near Future and of +2.7 to +3.8°C in the Far Future. Here, possible thermal input was neglected.

This warming is reflected by an increase of days above/below ecologically relevant thresholds.
An Update of the ICPR-report will be available end of 2024.

Reference: ICPR (2014): Estimation of the effects of climate change scenarios on future Rhine water temperature development. Extensive Version. Report No. 214. https://www.iksr.org/en/public-relations/documents/archive/technical-reports/technical-reports-search/page

BfG biennal model workshop

BfG water quality model QSim