Global Rivers Heating Up:

Risks of high water temperatures under future climate and potential impacts for energy production and freshwater habitats

M.T.H. van Vliet [1], F. Ludwig [1], J.J.G. Zwolsman [2] and P. Kabat [1]

[1] Earth System Science and Climate Change, Wageningen University and Research Centre, PO Box 47, 6700 AA Wageningen, The Netherlands
[2] KWR Watercycle Research Institute, PO Box 1072, 3430 BB Nieuwegein, The Netherlands
E-mail corresponding author: ***michelle.vanvliet@wur.nl***

Introduction

There is a growing concern that climate change will negatively affect water for human use (e.g. agriculture, power generation, drinking water supply) and freshwater ecosystems. Especially the expected increase in the frequency and intensity of climate extremes (e.g. heat waves and droughts) might have adverse effects for water use. Impacts of climate change and climate extremes on hydrology have therefore been studied widely, but with a clear focus on water quantity aspects. In addition, it is also recognized that climate change and increases in the occurrence of heat waves will increase the risks of critically high water temperatures. This can have a direct impact on water quality and freshwater ecosystems and on the potential risks of cooling water shortage for industry and energy (thermal power). In addition, the quality of surface water for drinking water production could also be negatively affected by rising water temperatures [Fig 1 and 2].

The overall objective of this study is two-fold:

1) To assess the sensitivity of river temperatures to climate change and its induced changes in river flow for selected river basins globally.
2) To address the potential impacts of river temperature rises on the risks for cooling water shortage for energy (thermal power) production and freshwater habitat deterioration.

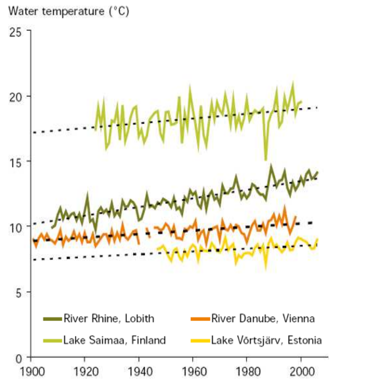

Figure 1: Observed rising trends in water temperature in European rivers and lakes (EEA, 2008).

Figure 2: Cooling towers of thermal power plants operating under high water temperatures and fish kill due to exceeded water temperatures.

Methodology and Results

To address these objectives, the following methodology is applied:

1) A global water temperature database has been created and statistical regression models based on air temperature and discharge were used to assess the sensitivity of water temperatures to different rates of atmospheric warming and changes in river flow for 160 river stations globally. Results indicated that water temperatures are particularly sensitive to warming under low river flows due to a reduced thermal capacity and limited dilution capacity for thermal effluents.

2) Therefore, an integrated hydrological and stream temperature modeling approach was used with the Variable Infiltration Capacity (VIC) macro-scale hydrological model and the deterministic water temperature model RBM that simulates water temperature based on heat exchange fluxes (Fig 3). These models are applied on a daily basis for large river basins globally on 0.5° x 0.5° resolution. Projections of daily river discharge and water temperature for the 21st century were produced by forcing the models with bias corrected output from three Global Climate Models (GCMs) for both the SRES A2 and B1 scenario.

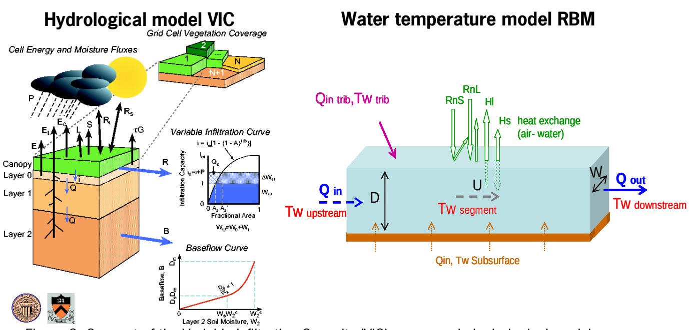

Figure 3: Concept of the Variable Infiltration Capacity (VIC) macro-scale hydrological model (http://www.hydro.washington.edu/Lettenmaier/Models/VIC/) and water temperature model RBM.

Results of the hydrological model show pronounced decreases in summer flow for several river basins globally for the end of the 21st century. Furthermore, a distinct decrease in river discharge of more than 50% is found even on a mean annual basis for several regions (Fig 4). Projected atmospheric warming and simulated decreases in river flow result in rises in water temperature, which are generally highest during summer (Fig 5). These water temperature rises may affect freshwater habitats (e.g. for salmon in the Columbia river) and usage functions like industry, energy and drinking water production.

Relative changes in mean annual river discharge globally

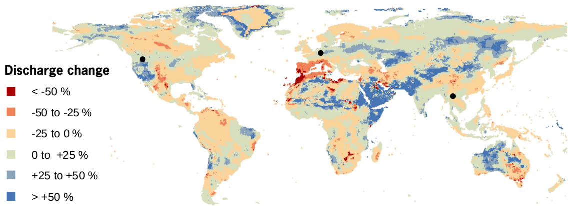

Figure 4: Simulated changes in mean annual river discharge simulated with the VIC hydrological model for ECHAM5 GCM SRES A2 scenario for the period 2080-2099 relative to 1980-1999. The black dots indicate the location of the river stations in Figure 5.

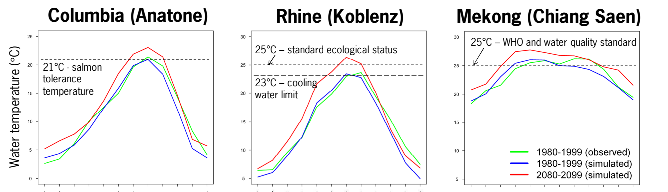

Figure 5: Mean annual cycles of observed [green] and simulated water temperature [blue] of the Columbia, Rhine and Mekong for 1980-1999 and for 2080-2099 based on ECHAM5 SRES A2 scenario [red].

3) The probability for exceeding critical water temperature thresholds were calculated using the daily water temperature simulations in combination with the following water temperature thresholds for the European rivers:

- 23°C standard which is a critical limit for cooling water discharge in European rivers (EEA, 2008).
- 25°C standard which is relevant for ecological status and drinking water production.

Table 1: Mean and 99 percentile of water temperature and mean number of days per year that 23°C and 25°C standard is exceeded for observed and simulated water temperature series for the reference period 1980-1999 [ref(obs) and ref(sim)] and future period 2080-2099 [sim(fut)] based on ECHAM5 A2 climate change scenario.

	Rhine (Lobith)			Danube (Budapest)			Rhone (Lyon)		
	ref (obs)	ref (sim)	fut (sim)	ref (obs)	ref (sim)	fut (sim)	ref (obs)	ref (sim)	fut (sim)
mean Tw (°C)	14.1	14.0	16.0	11.4	11.6	13.4	13.1	12.8	15.5
P99 Tw (°C)	25.5	25.3	28.3	24.0	24.1	27.5	24.9	24.4	30.3
n days Tw>23°C	30	34	64	9	9	30	24	27	62
n days Tw>25°C	5	6	23	3	4	13	3	5	33

Conclusions and Relevance

- River temperatures are particularly sensitive to warm atmospheric conditions during low river flows. Therefore, both the impact of atmospheric warming and changes in river flow on water temperatures should be considered in climate change impact studies.
- Increases in water temperature in combination with decreases in river flow projected for several river basins globally may have important consequences for maintaining current freshwater habitats and usage functions, like energy production.

The results of this study are relevant for defining large scale river basin management strategies and will enable the energy and drinking water sector to reconsider their strategies with regard to new technologies, production sites and associated infrastructure.

WATCH Water and Global Change

WAGENINGEN UR For quality of life