18. October 2018
MGS 2018 - Prague

A water quality model for the Czech part of the river Labe/Elbe: Application for recent state and scenarios of climate change

Luboš Mrkva[1], Volker Kirchesch[2], Andreas Schöl[2]
[1]Faculty of Science, Charles University; [2]Bundesanstalt für Gewässerkunde, Koblenz

OUTLINE

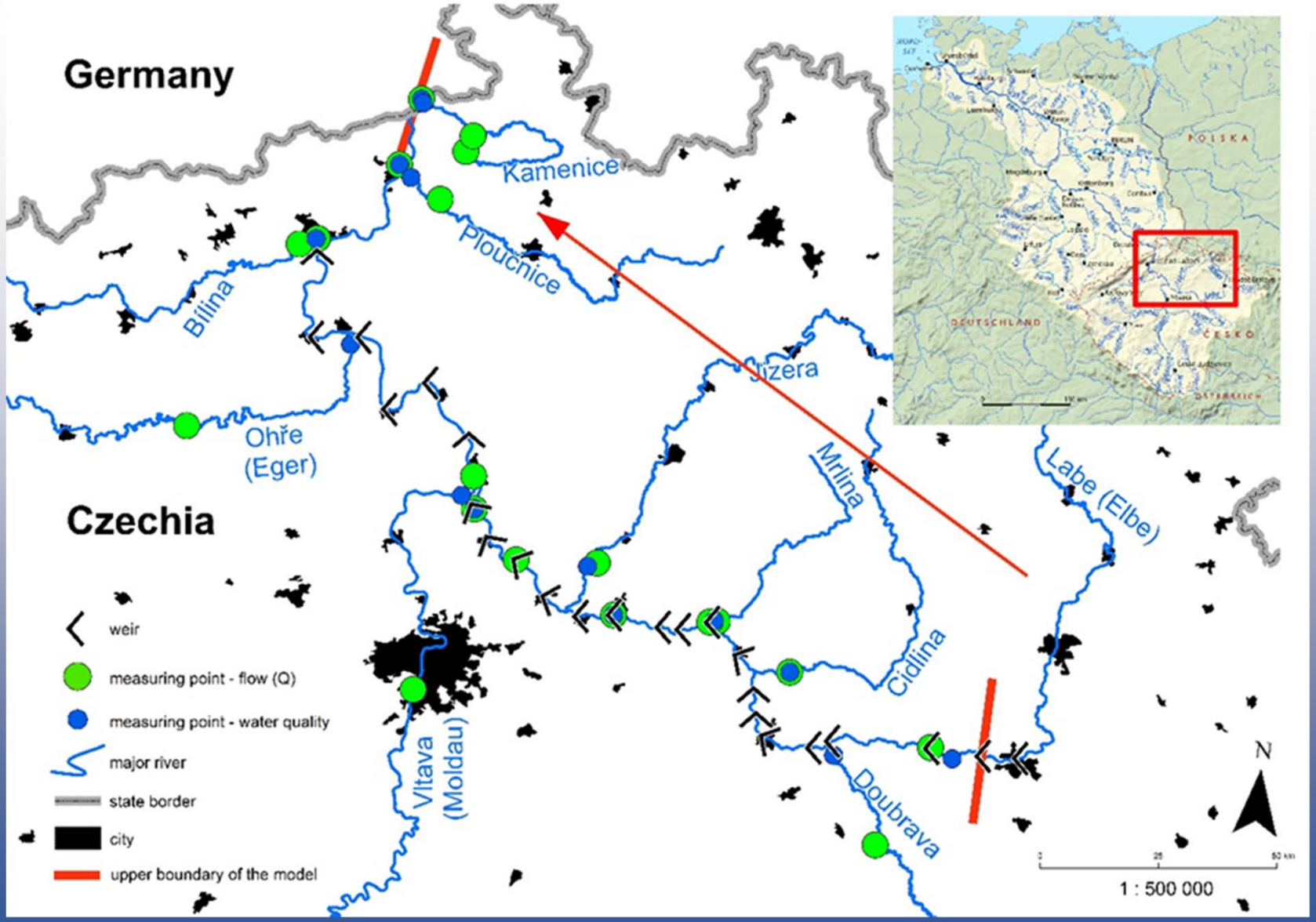
1. Introduction
2. Study area
3. Methods, data source and model validation
4. Water quality of the recent state (2010 - 2015)
5. Possible impact of the climate change
6. Conclusion

INTRODUCTION

- water quality is an enduring problem
- increasing demand for water
- the availability of water of acceptable quality will increasingly be a "hot" topic
- simulate and analyse the recent state (2010-2015) of the water quality of the river Czech part of the Labe/Elbe
- predict and quantify the possible effects of climate change on the water quality parameters
- QSim an instrument for the simulation and prognosis of the oxygen, nutrient and plankton dynamics in running waters is used
- QSim was developed by the Federal Institute of Hydrology in Koblenz (BfG, Germany)

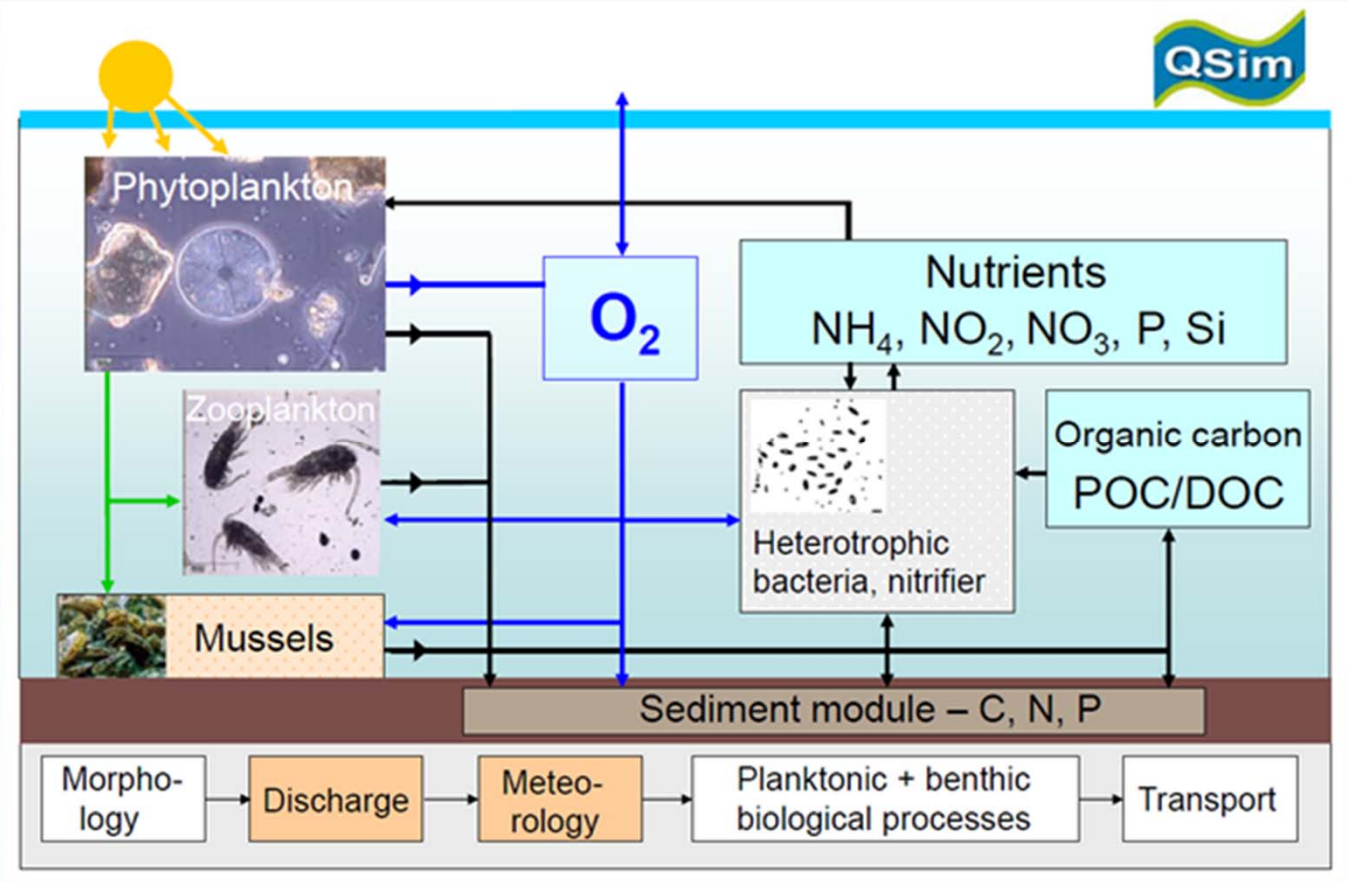
STUDY AREA

- upper boundary: Srnojedy weir (river km 960.8)
- lower boundary: Czech-German border (km 726.6)
- 9 tributaries
- 23 navigation dams



MODEL QSIM (**Q**ualitäts**Sim**ulation)

- QSim is a one-dimensional model
- QSim is an instrument for simulating and predicting the mass balance and plankton dynamics in running waters
- important feature is the combination of a hydraulic model (HYDRAX) for the simulation of the runoff with a quality model (QSim) for the simulation of the water quality



Model construction of QSim

INPUT DATA

- Date regarding river morphology, discharge, water level, meteorology, water quality are required to define the boundary conditions of the model.
- These data were provided by the Elbe River Basin Authority (SOE), the Ohře River Basin Authority (SOE), the Vltava River Basin Authority (SOE) and the Czech Hydrometeorological Institute (PVL, POH, PLA and CHMI).

Discharge profiles						Water quality profiles					Water quality parameters	
river	station	mouth - km	river - km	average Q [$m^3.s^{-1}$]	data source	river	station	mouth - km	river - km	data source	parameter	unit
Elbe	Přelouč		951,18	52,89	PLA	Elbe	Valy		954,73	PLA	water temperature	[°C]
Elbe	Lysá nL		878,07	60,00	PLA	Elbe	Lysá nL		878,07	PLA	dissolved oxygen (mg O_2/l)	[mg/l]
Elbe	Obříství		843,50	87,22	PLA	Elbe	Obříství		843,50	PLA	COD	[mg/l]
Elbe	Děčín		740,52	289,54	PLA	Elbe	Děčín		740,52	PLA	amonium nitrogen (NH_4-N)	[mg/l]
Elbe	Schmilka/Hřensko		726,59	294,14	PLA	Elbe	Schmilka/Hřensko		726,59	PLA	nitrite-Nitrogen (NO_2-N)	[mg/l]
Doubrava	Žleby	931,30	23,71	2,49	PLA	Vltava/Moldau	Zelčín	837,20	4,50	PVL	nitrate nitrogen (NO_3-N)	[mg/l]
Cidlina	Sány	907,90	6,79	4,25	PLA	Ohře/Eger	Terezín	792,50	2,70	POH	total nitrogen (TN)	[mg/l]
Mrlina	Nymburk	896,49	0,75	1,35	PLA	Cidlina	Sány	907,90	6,79	PLA	total Phospor (TP)	[mg/l]
Jizera	Předměřice nJ	869,20	11,50	23,00	PLA	Mrlina	Nymburk	896,49	0,75	PLA	orthophosphospores (PO_4-P)	[mg/l]
Vltava/Moldau	Praha	837,20	25,10	168,38	DPGG	Jizera	Tuřice	869,20	11,20	PLA	silicate (SiO_2)	[mg/l]
Ohře/Eger	Louny	792,50	53,40	32,50	POH	Bílina	Ústí nL	766,00	0,20	POH	pH value	
Bílina	Trmice	766,00	3,76	6,39	POH	Ploučnice	Březiny	741,10	3,70	POH	alkalinity (m-value)	[mmol/l]
Ploučnice	Benešov nPl	741,10	10,90	9,65	POH	Kamenice	Hřensko	728,10	0,50	POH	suspended matter	[mg/l]
Kamenice	Srbská K. + Chřibská Kamenice	728,10	14,5 + 1,4	1,75	POH	Doubrava	Záboří	931,30	1,40	PLA	calcium (Ca)	[mg/l]
Elbe	Kostelec nL		856,92	91,31	DPGG						conductivity	[µS/cm]
Elbe	Mělník		836,65	240,99	DPGG						BOD_5	[mg/l]
											chlorophyll - α	[µg/l]

List of discharge and water quality monitoring stations and list of available water quality parameters

Processes and input variables in Qsim.

Processes	Input variables
Discharge Sedimentation Heat budget Light climate Calcium-carbon dioxide budget Oxygen and nutrient budgets Bacterial growth Nitrification Algal growth Macrophyte growth Zooplankton growth Growth of benthic filter feeders	**Morphological and hydrological**: Cross sections, discharge
	Meteorological: Global radiation, air temperature, cloud cover, humidity, wind velocity
	Physical and chemical: water temperature, oxygen, chemical oxygen demand, nitrate, ammonium, ortho-phosphate, silicate, pH, alkalinity, seston
	Biological: Biological oxygen demand (carbon-derived and nitrification-derived), biomass of planktonic algae (chlorophyll a) and proportion of diatoms, green algae and cyanobacteria, zooplankton (abundance of flagellates and rotifers), benthic algae, macrophytes, benthic filter feeders (*Dreissena polymorpha, Chelicorophium curvispinum*)

- some biological parameters are not available
- The grazing effect of the active benthic filter feeders (in particular mussels), which was not taken into account for the first model runs, was taken as a possible cause for overestimation.
- Therefore, a scenario DP was created which uses data derived from the macrozoobenthic monitoring program of the Elbe River form Elbe Data Information System and from another studies about quite similar rivers (e.g. Danube) to estimate the abundance of *Dreissena polymorpha* (DP) at the initialisation of the model.
- For the whole model area, the same density of mussels was chosen at the initialisation. The assumed density of *Dreissena* is 270 Ind/m^{2}.

MODEL VALIDATION

- slope S, coefficient of determination R^2, Nash-Sutcliffe efficiency (NSE), relative error (REL) and percent bias (PBIAS)
- The simulated values of flow and water temperature were very similar to the measured values
- Likewise, nutrient concentrations, especially N and Si, show great consistency with the measured data.
- The deviations between measured and model values of P are bigger, but overall the model results can be considered as sufficient.
- Chlorophyll-α and oxygen concentrations differ clearly from the measured data. Therefore, the DP scenario is created to improve the model performance. After this improvement, the chlorophyll-α and oxygen values can be considered as acceptable.
- A performed statistical validation of the model results shows a level comparable to the results of other river models.
- For example for parameter chlorophyll the mean value of R^2 is 0,581, a study on the Danube has an average of 0.585 and a study on the Rhine 0.665. In another paper, the authors compared the results of 153 water quality models with an average value of R^2=0.48. The average NSE of the Elbe model is 0.343. In the German part of the Elbe, the average result for the period 1999 - 2003 is 0.493 and in the case of the Danube it is 0.350.

CLIMATE CHANGE SCENARIOS

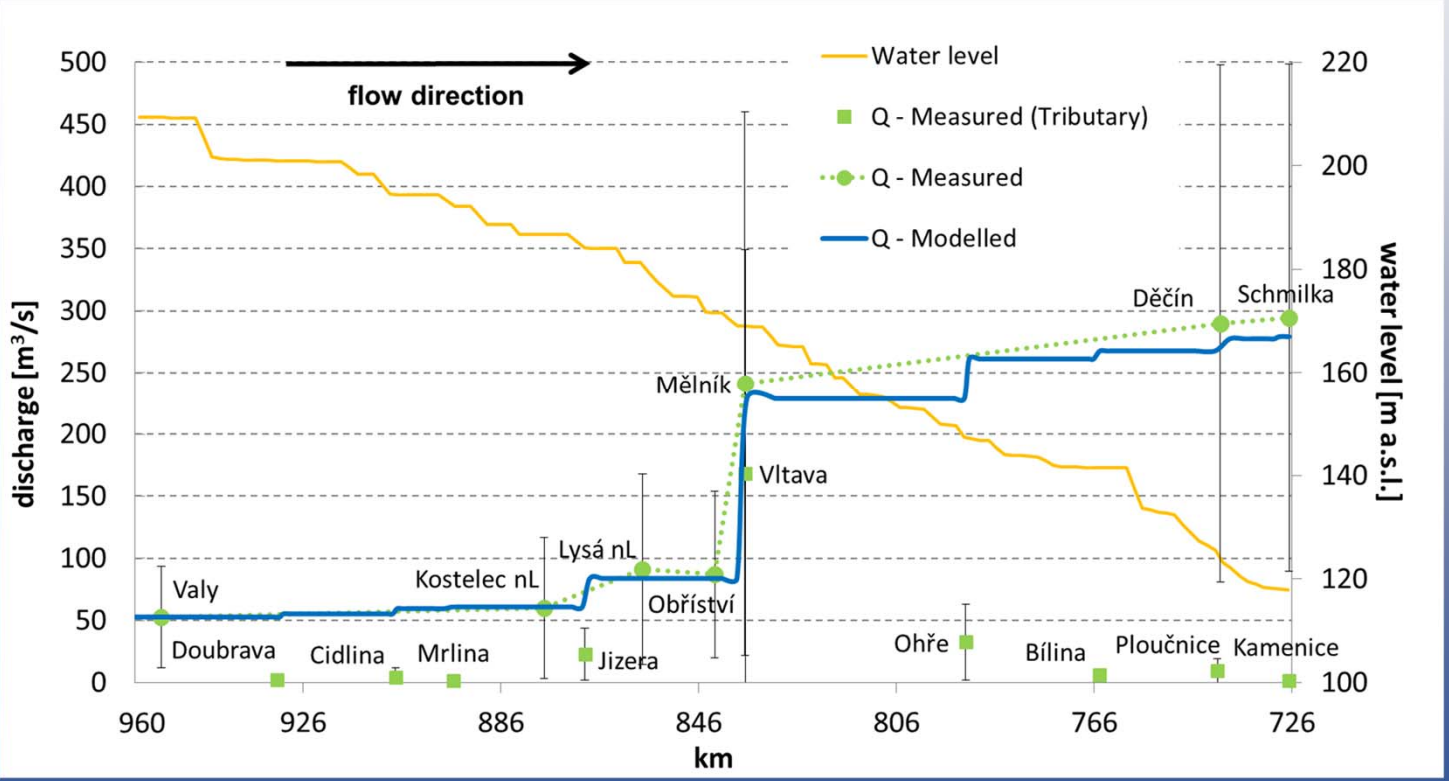
- the data representing the possible change of climate conditions are obtained from the project "Support for long-term planning and proposal for adaptation in the field of water management in the context of climate change" by the TG Masaryk Water Research Institute in cooperation with the CHMI
- the reference period is compared to the „near future“ 2021-2050 (NF - 2035) and the „far future“ 2071-2100 (FF - 2085).
- a total of six different climate change scenarios based on three climate model chains were used

control model	model	acronym	source
ECHAM 5	REMO	REMO_EH5	Max-Planck Institut (MPI), Germany
Had CM3Q0,Q3,Q16	CLM	CLM_Q0	Federal Swiss Institute of Technology(ETHZ)
ARPEGE	ALADIN-CLIMATE/CZ	ALA_ARP	CHMI, Czech Republic

- the modelling of the future water quality is only driven by the changes of the climatic parameter air temperature and hydrological parameter runoff
- based on air temperature data, for all tributaries and the model start the input data of the future water temperature were calculated
- other input values are the same as in the reference period

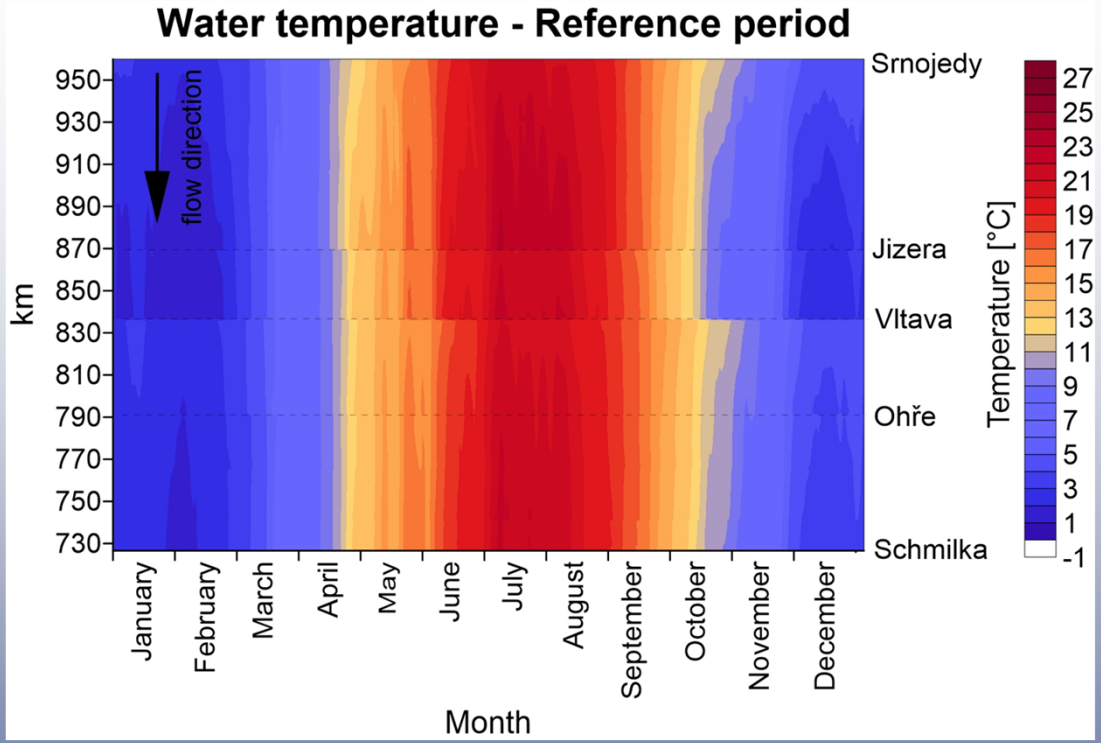
WATER QUALITY OF THE RECENT STATE

- Reference period (2010 – 2015)
- Measured and model values

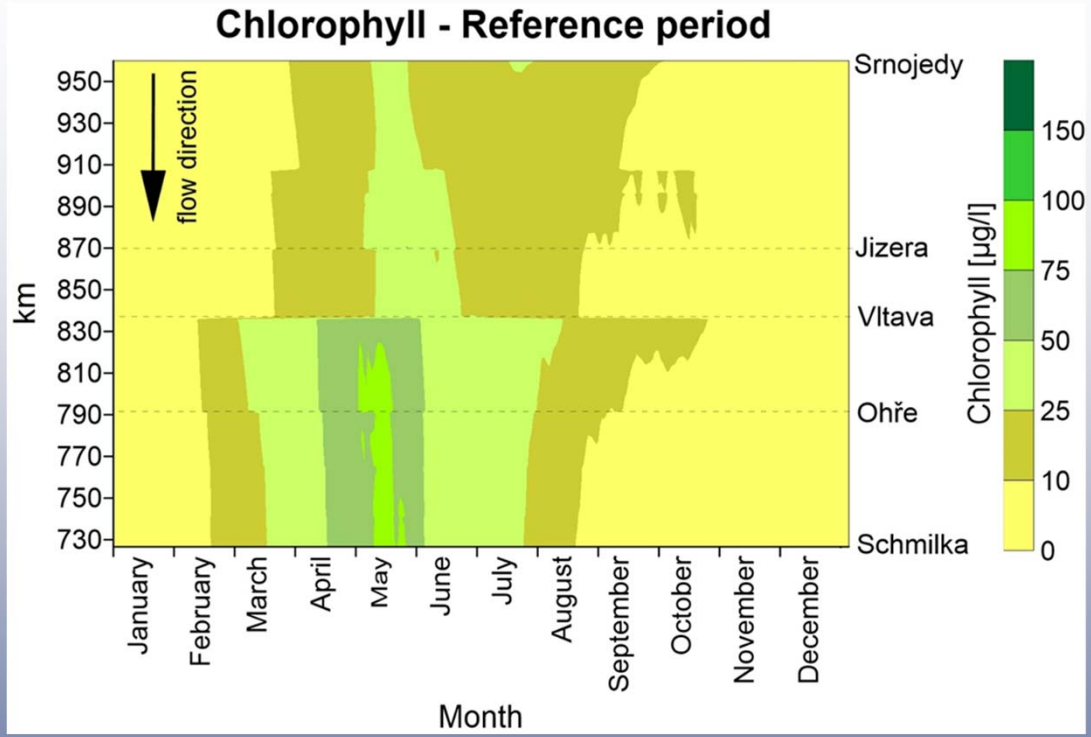


Discharge
Longitudinal profile of the measured (green points and line) and modeled (blue line) average outflows and mean water levels (yellow line) from Srnojedy (km 960) to Schmilka (km 726).

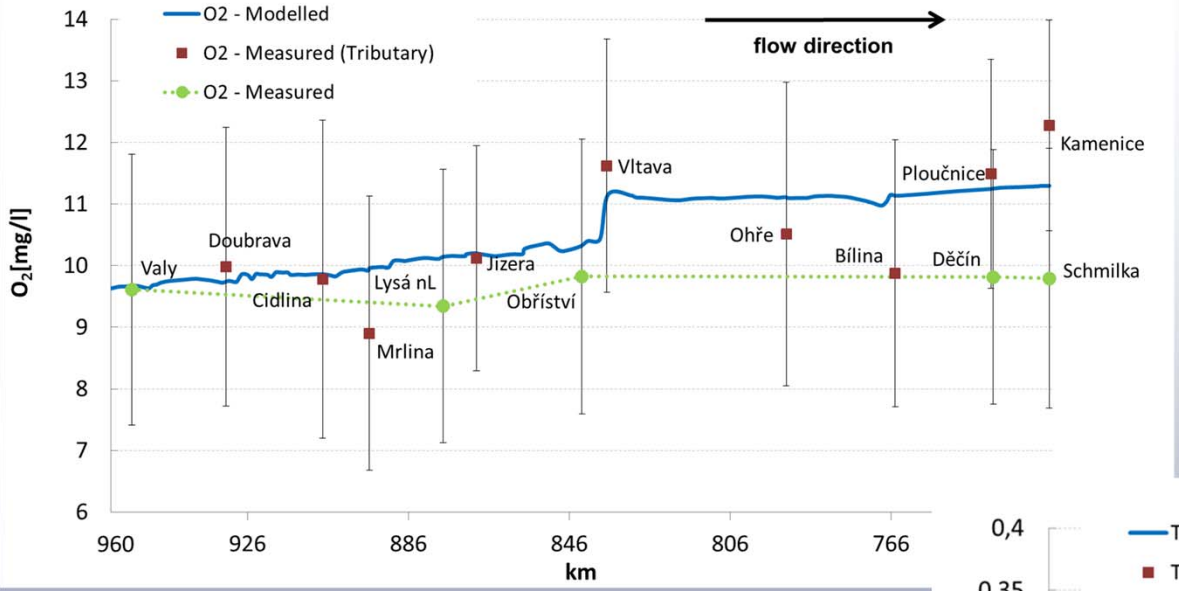
The mean **flow time** in the reference period to the mouth of the Vltava (km 836) and to the Czech – Germany border (km 726)



Development of the **water temperature** during the year in the longitudinal profile of the Elbe. Average values of the reference period.

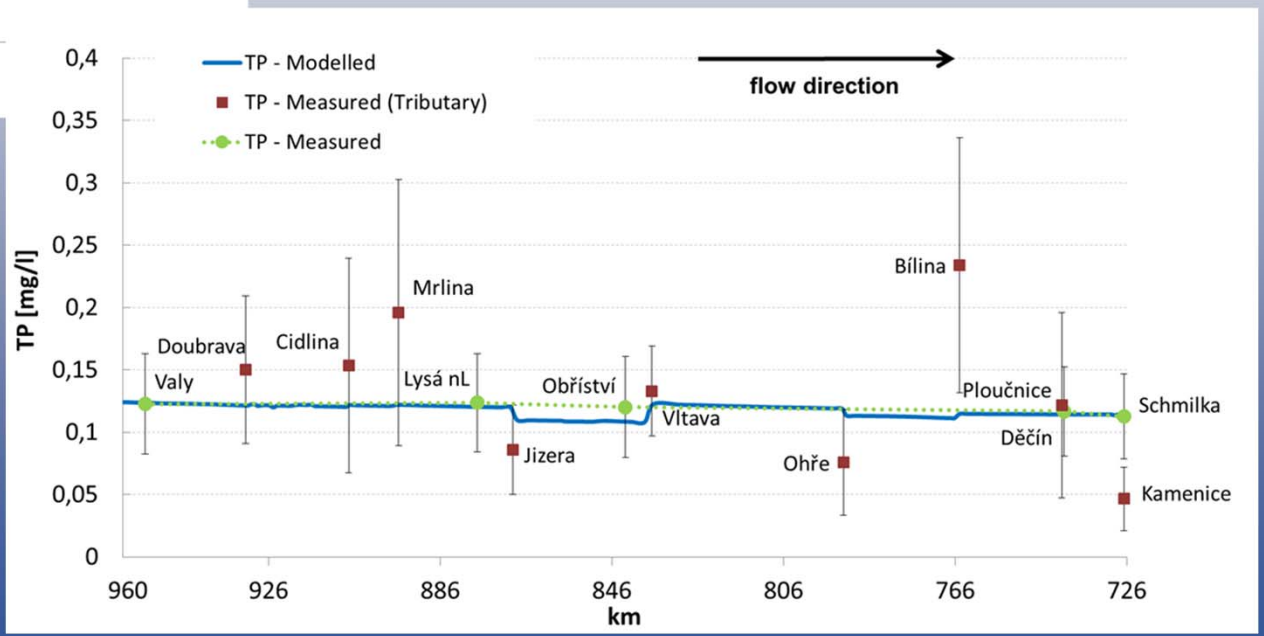


Development of the **chlorophyll - α** concentration during the year in the Elbe longitudinal profile



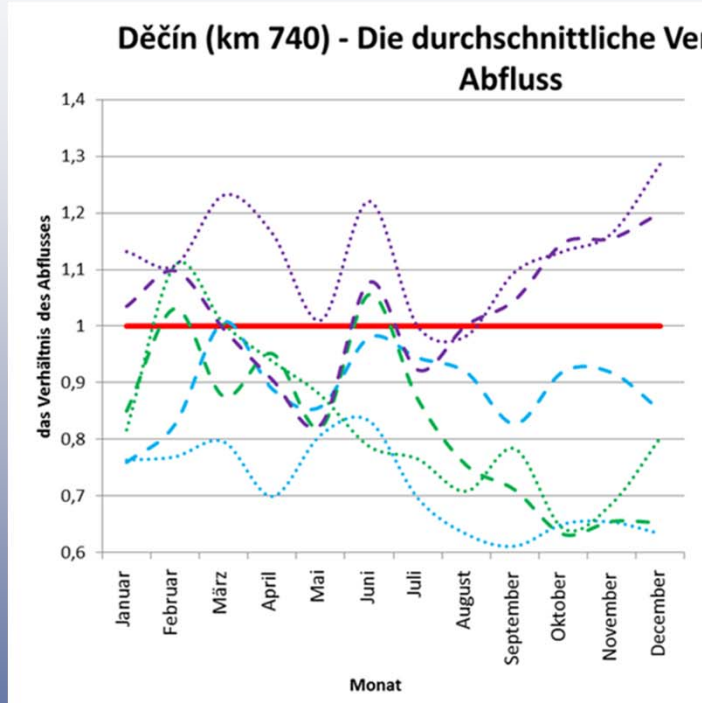
Longitudinal profile of measured (green points and line) and modeled concentration (blue line) of **dissolved oxygen (O2)** from Srnojedy (km 960) to Schmilka (km 726). Average for the period 2010 - 2015.

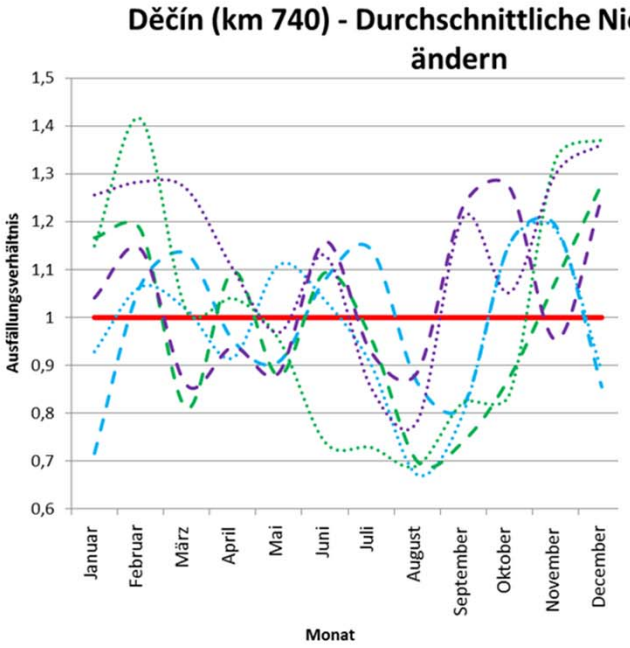
Longitudinal profile of measured (green points and line) and modeled concentration (blue line) of **total phosphorus (TP)** from Srnojedy (km 960) to Schmilka(km 726). Average for the period 2010 - 2015.

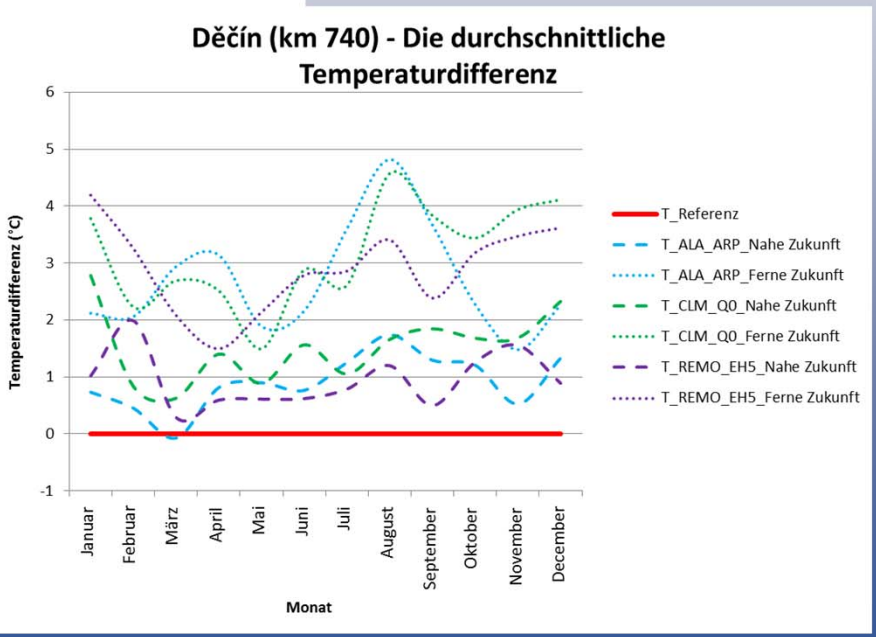


POSSIBLE IMPACT OF CLIMATE CHANGE

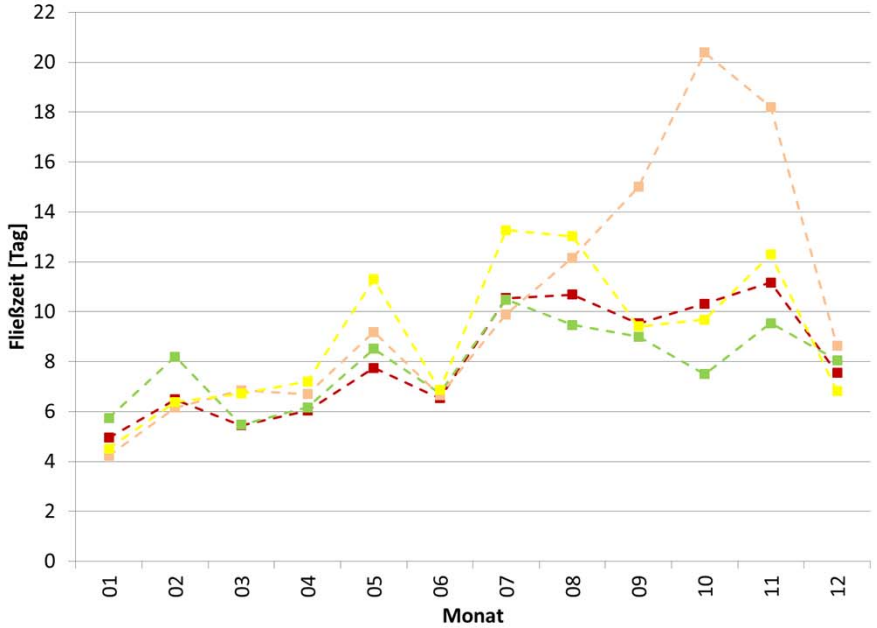
- Changes at the Děčín profile for individual scenarios and periods.





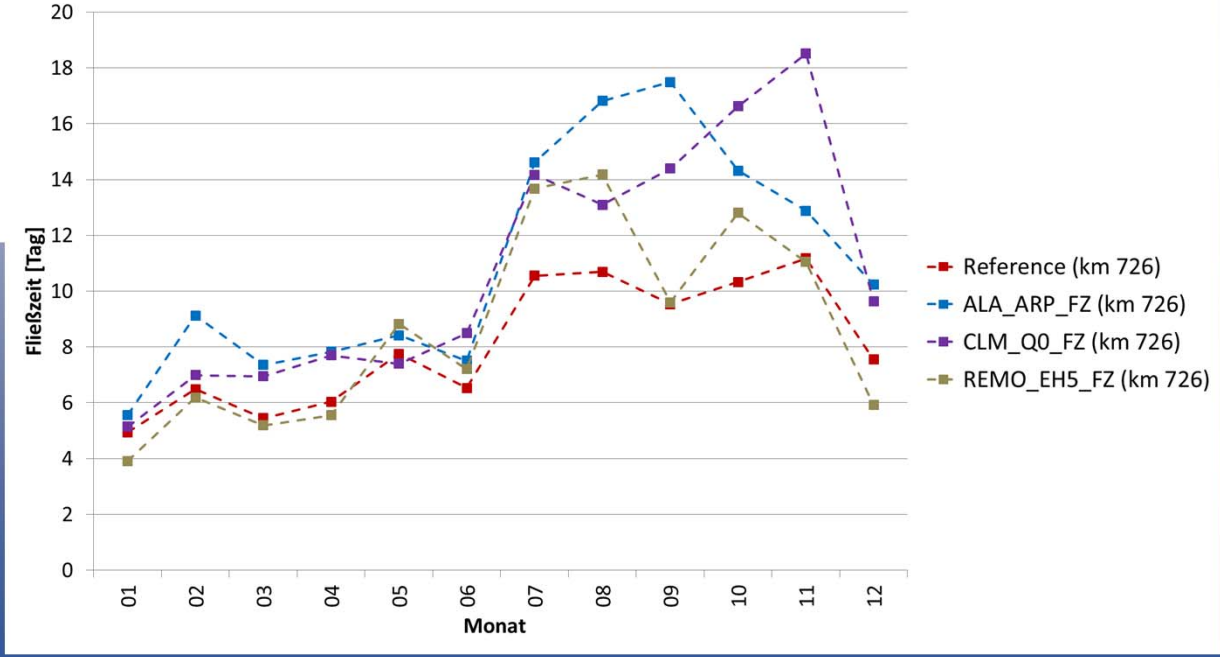


FLOW TIME

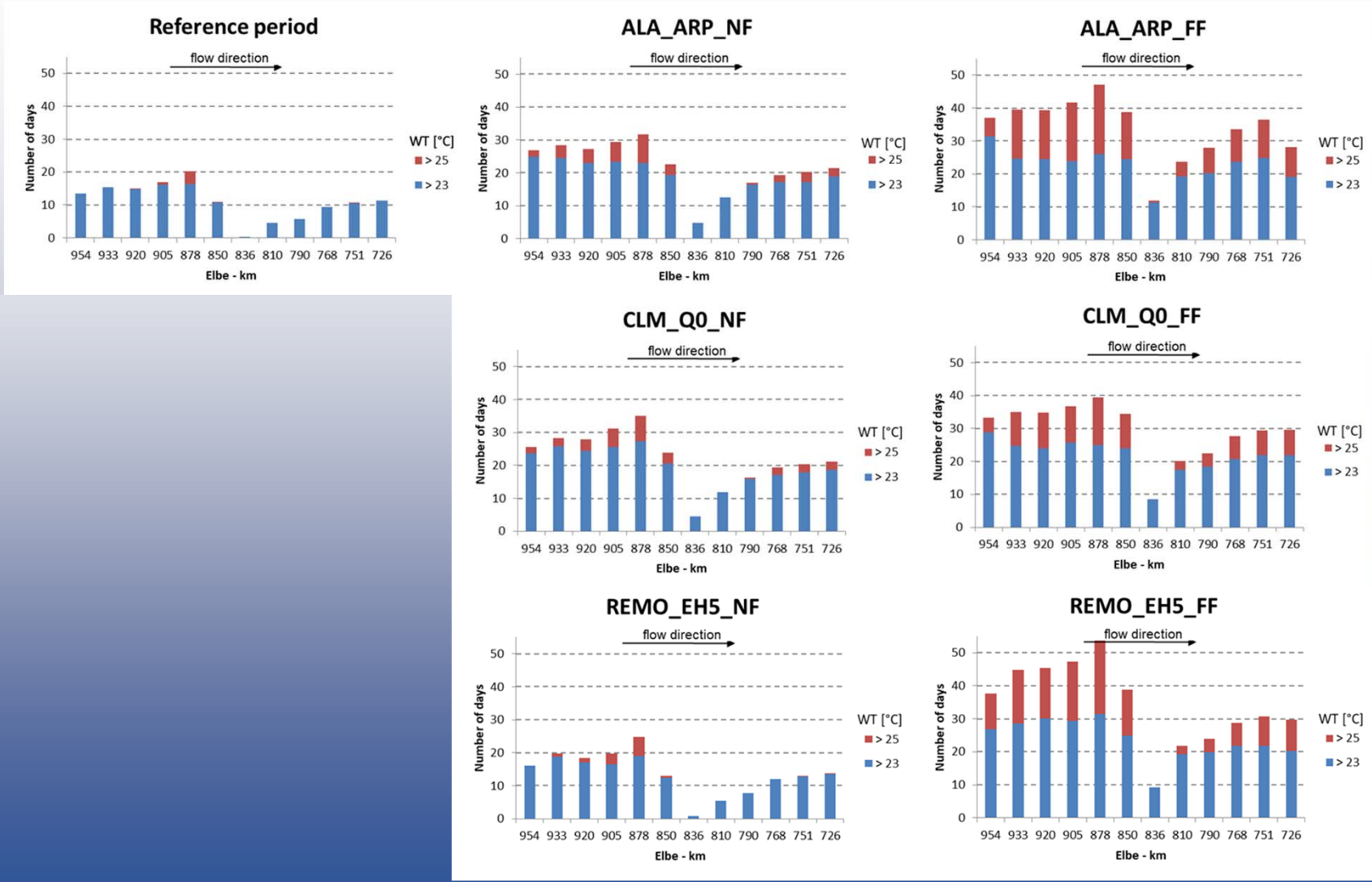


The mean flow time in the **near future** to the lower limit of the model (km 726)

The mean flow time in the **far future** to the lower limit of the model (km 726).

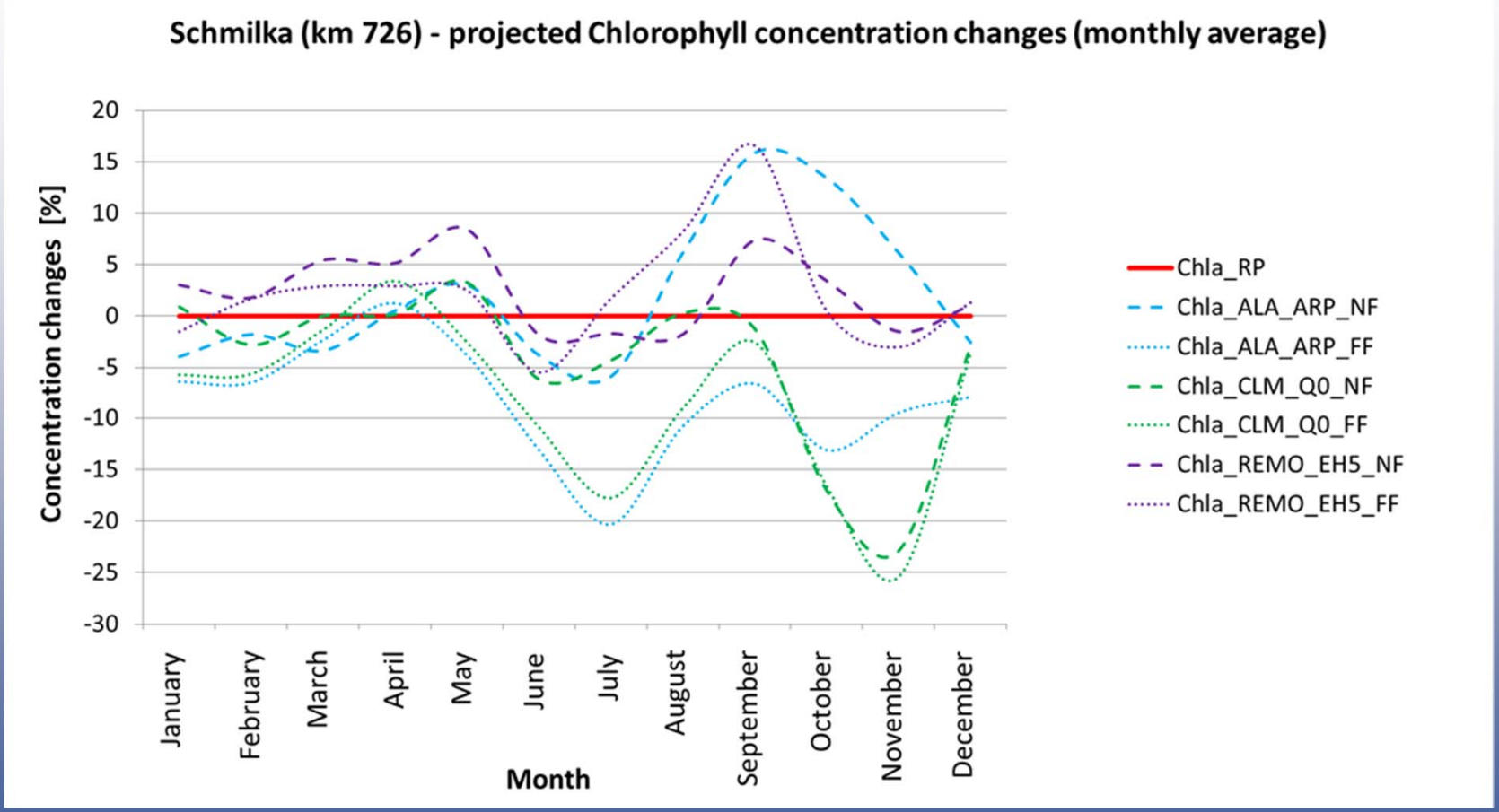


WATER TEMPERATURE



Comparison of the number of days exceeding temperature 23°C and 25°C in the longitudinal profile for different climatic scenarios.

CHLOROPHYLL - α concentration



Projected chlorophyll concentration changes.

CONCLUSION

- question of reliability of the model results
- better results by including the predation pressure of Dreissena on the phytoplankton
- extended measurement campaign
- the prediction of future developments is based only on climate change (weather and discharge changes)
- socio-economic changes are not taken into account
- results may be interpreted only as possible scenarios for estimating the future evolution of surface water quality

Thank you for your attention.

mrkva.lub@gmail.com; mrkval@natur.cuni.cz