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Model-based assessment of urban water management strategies for a shallow dimictic lake

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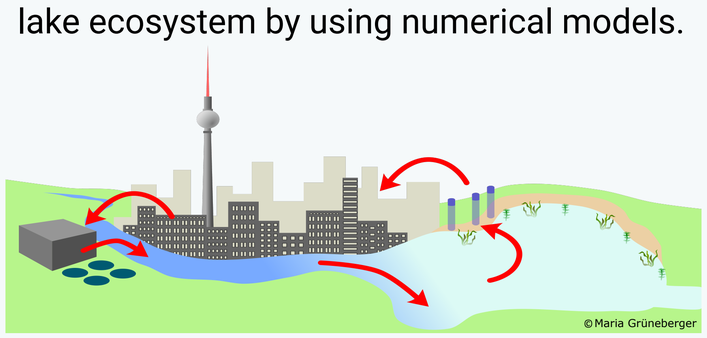
Highlights

- Lake Tegel can become monomictic
- Urban water management can mitigate effects of climate change on lake system
- 1D model sufficient for deep basin, but 2D is needed for whole dendritic lake

Background: Urban surface waters

The aim of the Research Training Group 'Urban Water Interfaces' is to process our understanding of urban water systems. Especially urban lakes are heavily connected to natural as well as technical interfaces in the form of a water management system. These water bodies can be vulnerable to external loadings and changes, for instance climate change.

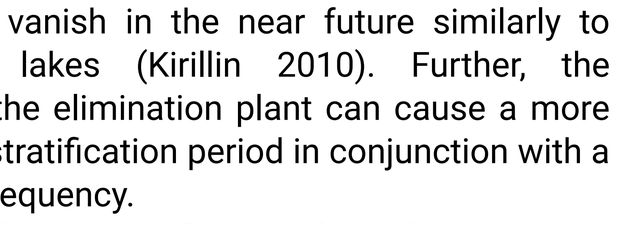
Our aim is to investigate the impact of external alterations (water management, meteorological conditions, catchment) on the lake ecosystem by using numerical models.



'Semi-closed' urban water cycle: treated effluents are discharged into streams, then lakes and later abstracted for drinking water production

Study site: Lake Tegel

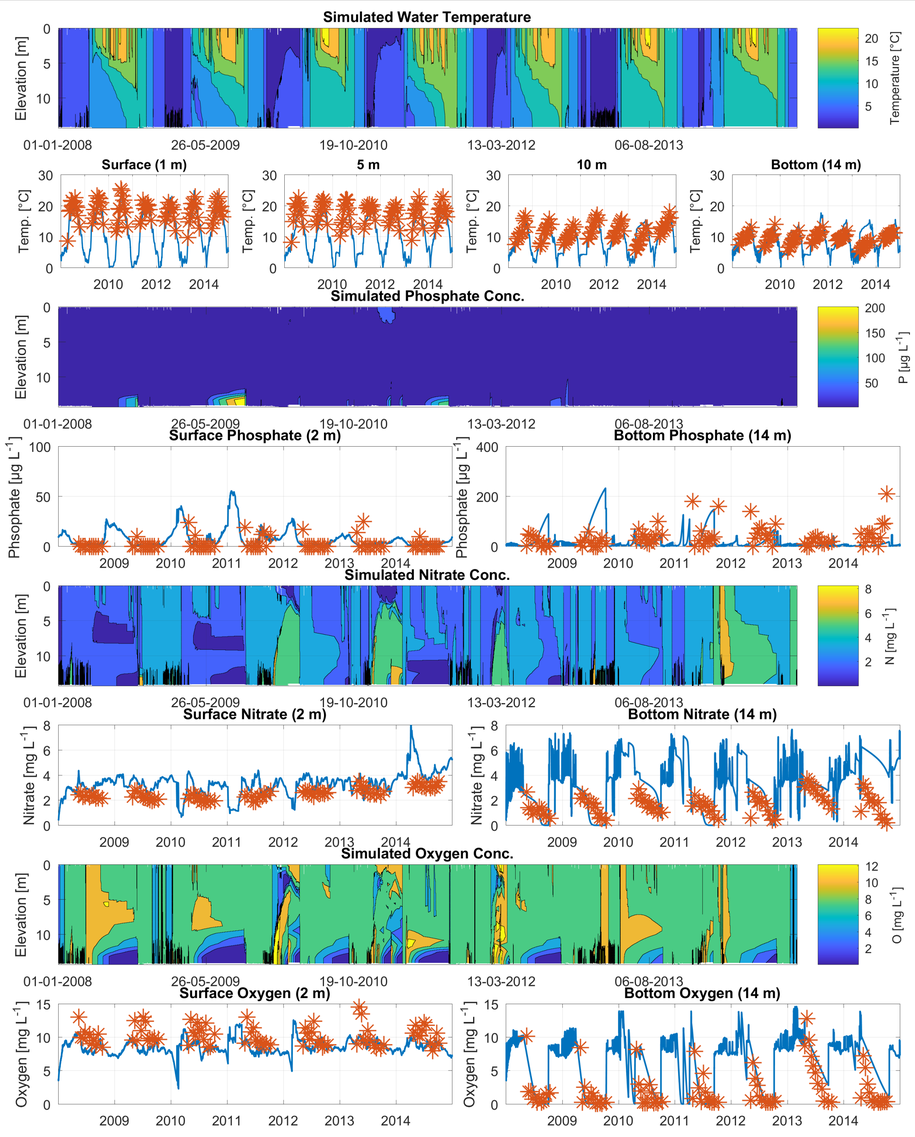
Lake Tegel is a dimictic shallow lake (max. depth 16 m) in Berlin, Germany. Due to severe eutrophication events in the past, an advanced water management system was set up around Lake Tegel.



Lake Tegel: morphometry and important flow boundaries

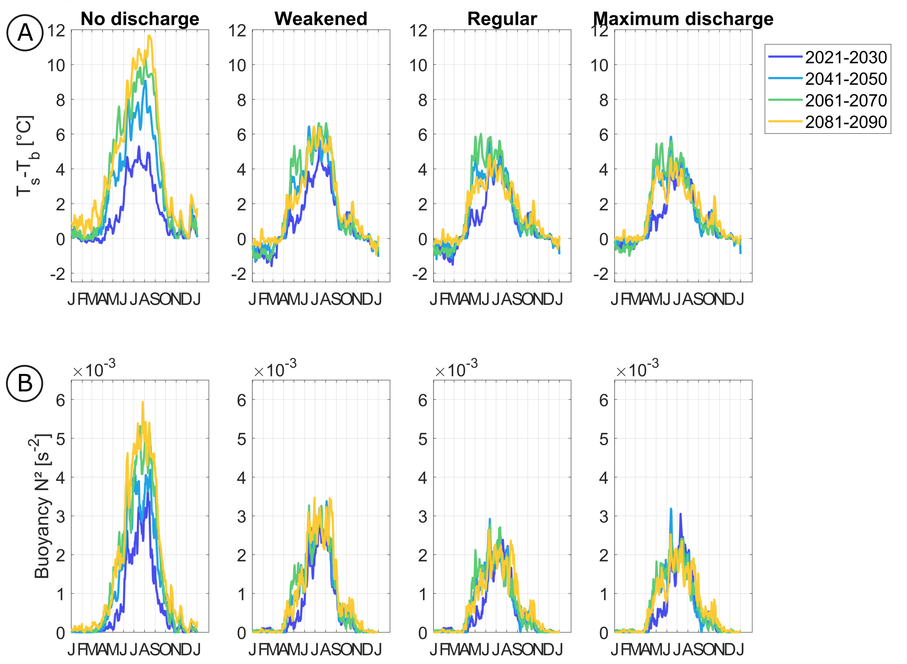
1D-modelling using GLM-AED2

We applied the hydrodynamic vertical 1D model GLM coupled to the water quality module AED2 to Lake Tegel. The model was calibrated and validated with field data from 2008-2014 of water temperatures as well as concentrations of (ortho)-phosphate, nitrate and dissolved oxygen. For calibration of the model parameters we employed the derivative-free evolutionary CMA-ES algorithm (Hansen 2006). The model achieved a good fit for water temperatures (NSE 0.74) and was able to replicate the seasonal patterns of the lake: depletion of nitrate and dissolved oxygen as well as an accumulation of phosphate during summer. Nonetheless, the model strongly overestimated the internal phosphate flux.



Calibration and validation period 2008-2014 (red crosses represent field data)

Using projected meteorological data, we investigated the impact of climate change and alternative discharge regimes of an elimination plant on Lake Tegel for the period 2008-2100. The winter stratification period of Lake Tegel will vanish in the near future similarly to other regional lakes (Kirillin 2010). Further, the deactivation of the elimination plant can cause a more stable summer stratification period in conjunction with a high buoyancy frequency.



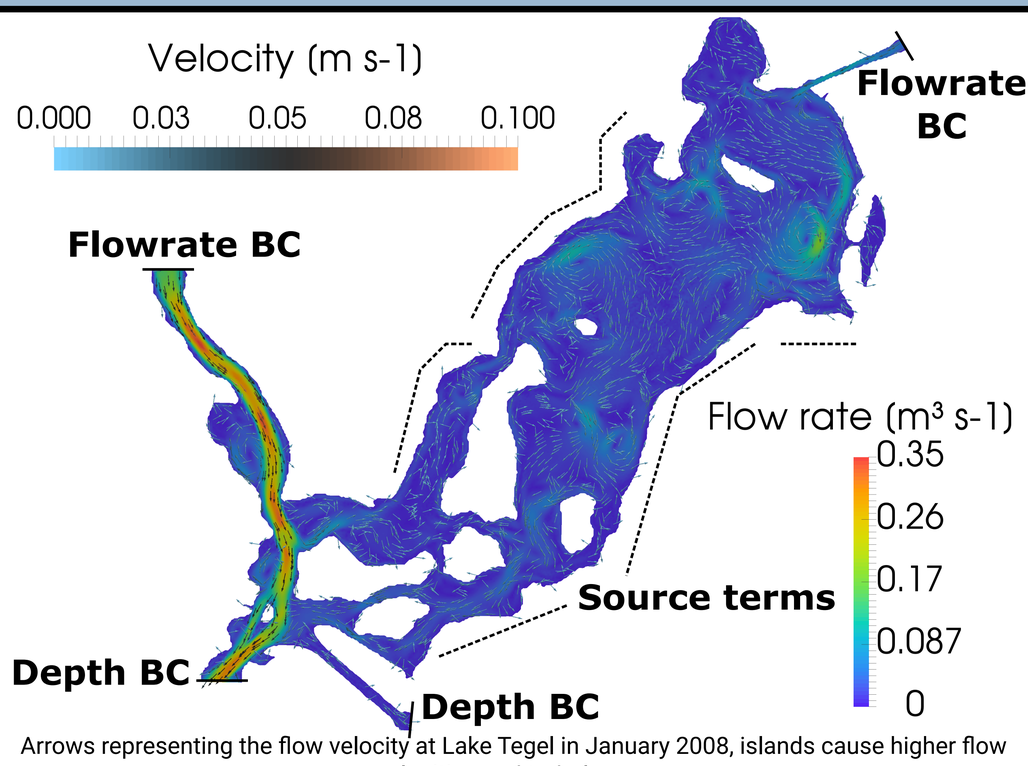
Impact of alternative discharge regimes on the lake. A: daily mean water temperature differences [°C] between surface and bottom layer. B: daily mean buoyancy frequency N² [s^{-2}].

2D-modelling using TELEMAC-MASCARET

To address the complex hydrodynamic situation of Lake Tegel, we applied the free-surface depth-averaged flow model TELEMAC-2D to Lake Tegel with the following characteristics:

- mesh spatial resolution 3-31 m
- four boundary conditions
- 99 constant source terms to simulate bank filtration
- transient wind speed data [m s^{-1}]
- k-epsilon turbulence model
- Strickler law with a coefficient of 56 m$^{1/3}$ s^{-1}.

As preliminary work, we simulated the transient flow conditions for the year 2008.



Arrows representing the flow velocity at Lake Tegel in January 2008, islands cause higher flow velocities and turbulences

Outlook

(1) Calibration of TELEMAC-2D model by comparing the simulated distribution of electrical conductivity [µS cm^{-1}] with field data (Schimmelpfennig 2012)
(2) Coupling TELEMAC-2D with DELWAQ to simulate water quality processes under alternative boundary conditions (→ adding 3rd dimension)
(3) Quantification of retention times of contaminants and nutrients
(4) Finding adaptive water management measures

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Questions?
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