Could climate change cancel out the results of water quality control measures at Lake Balaton?

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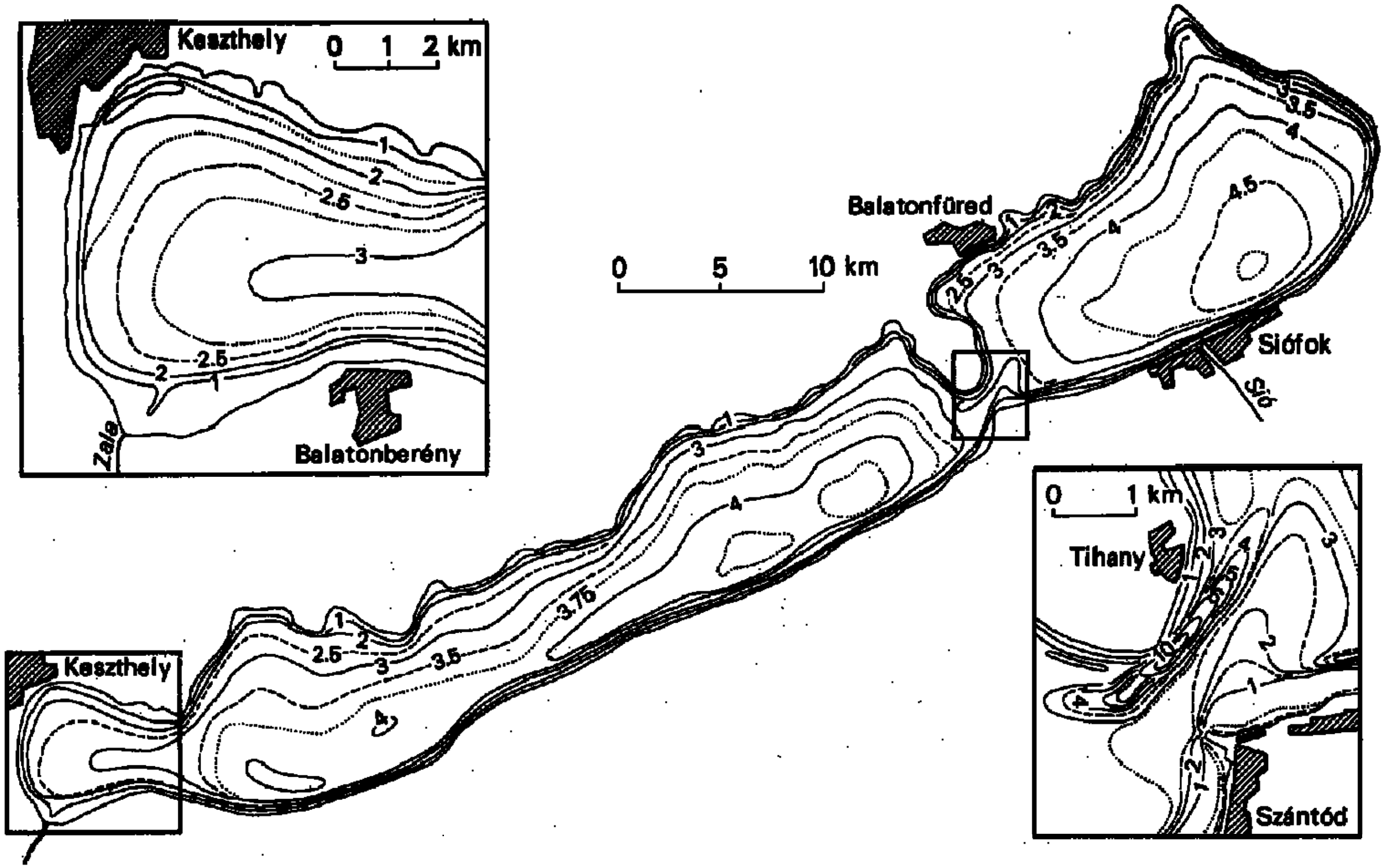
Contents

Bathymetric map of Lake Balaton

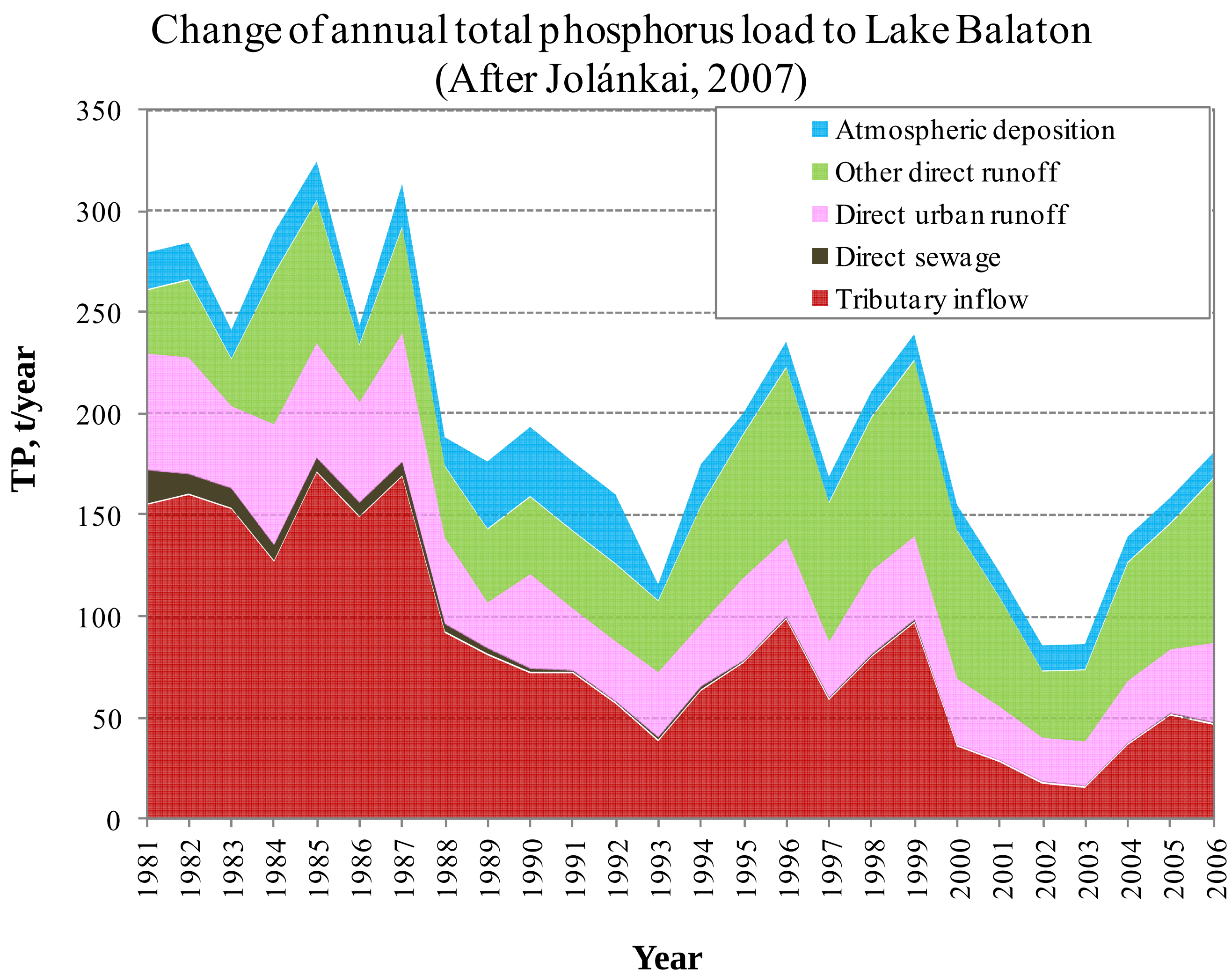
- an extremely shallow lake



Water quality control measures implemented

- Restoration of the Kis-Balaton wetlands (21+54 km^2, second stage is still under construction)
- Development of the sewer system (>90% sewer connection ratio in shoreline municipalities)
- Introduction of phosphorus precipitation and stricter effluent P standards at sewer treatment plants
- Diversion of treated STP effluents to other watersheds
- Banning of liquid manure technologies at livestock breeding farms on the watershed
- Reduction of the use of fertilizers on the watershed (a "spontaneous measure" due to re-privatization of land)

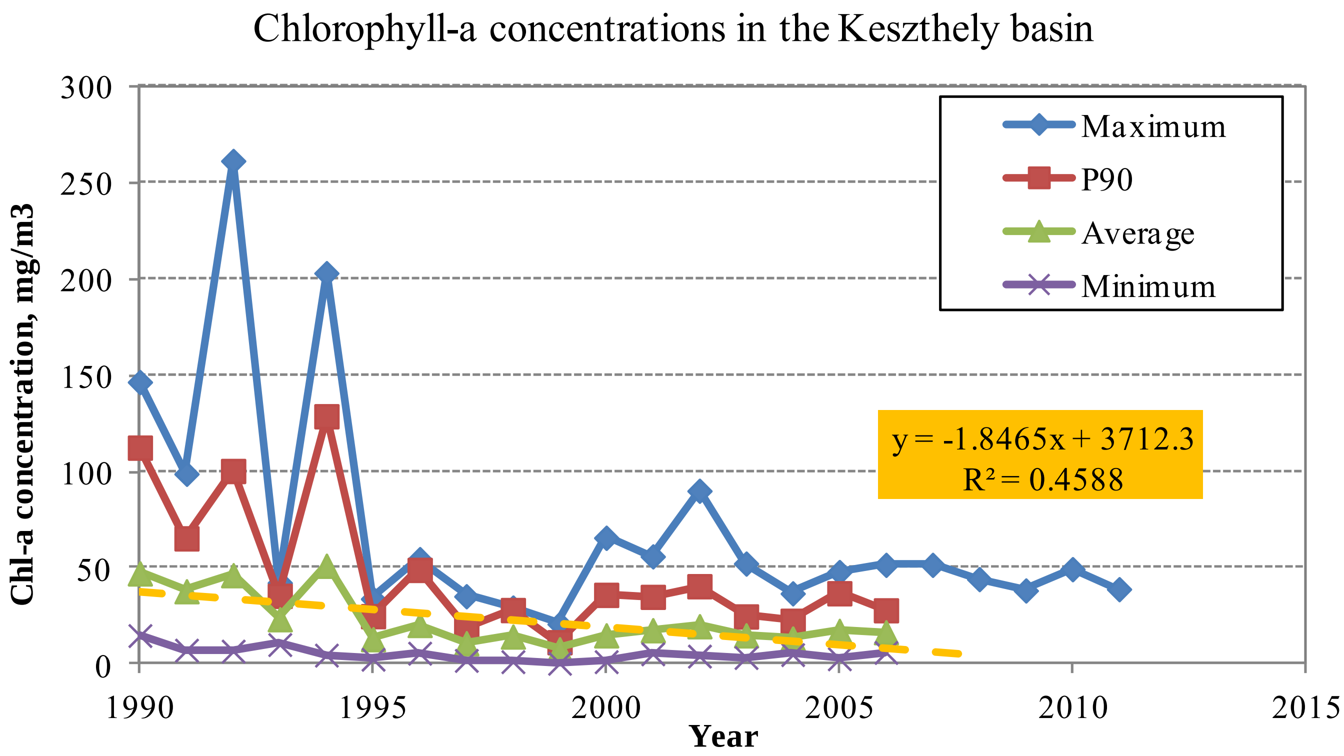
Change of total phosphorus load to Lake Balaton



Water quality trends

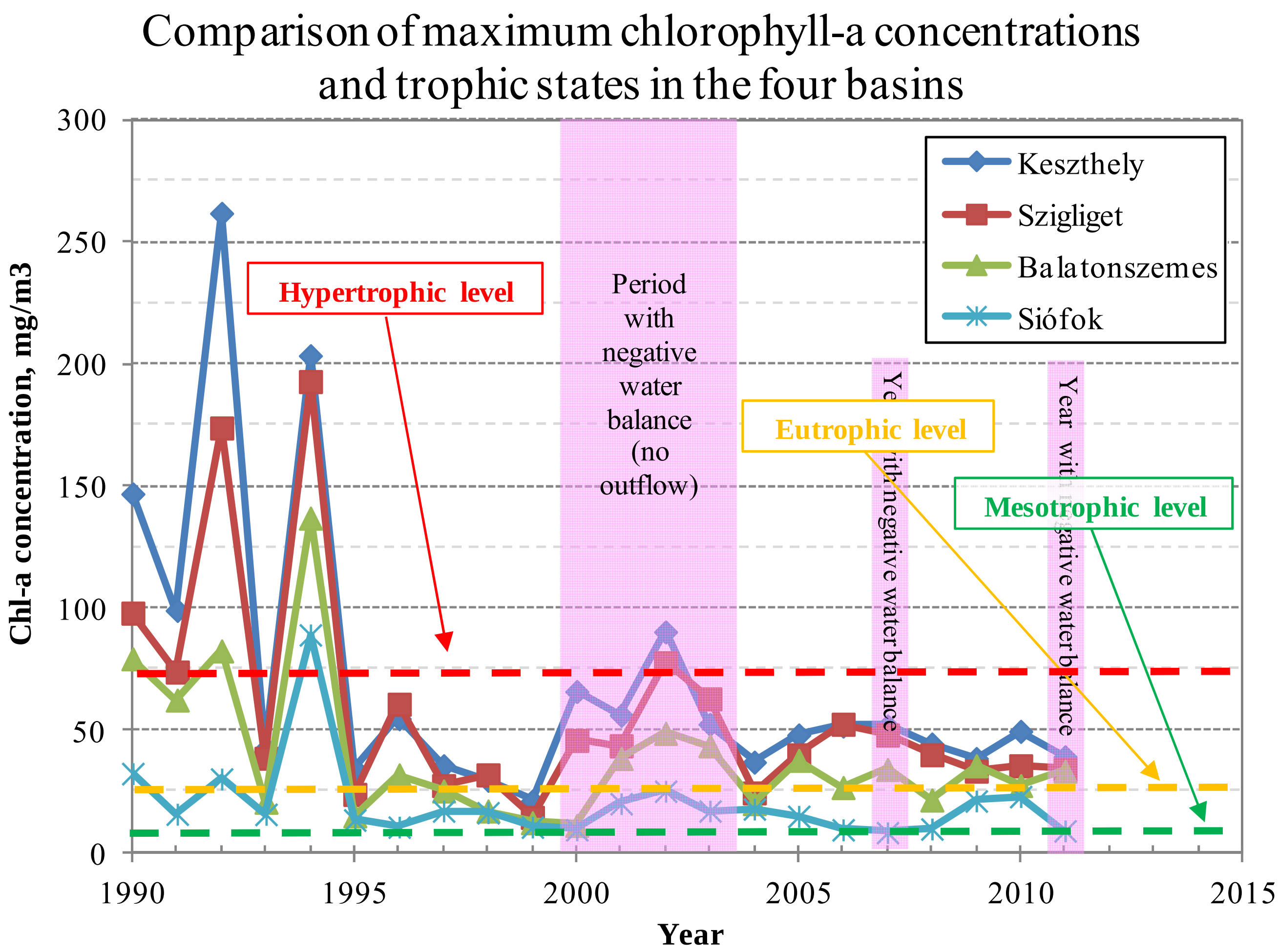
Keszthely basin (Basin 1) having the poorest water quality

Improving trend except the 2000 – 2003 period



Water quality trend in the four basins

Improving trend except the 2000 – 2003 period



Effect of water exchange on salt content

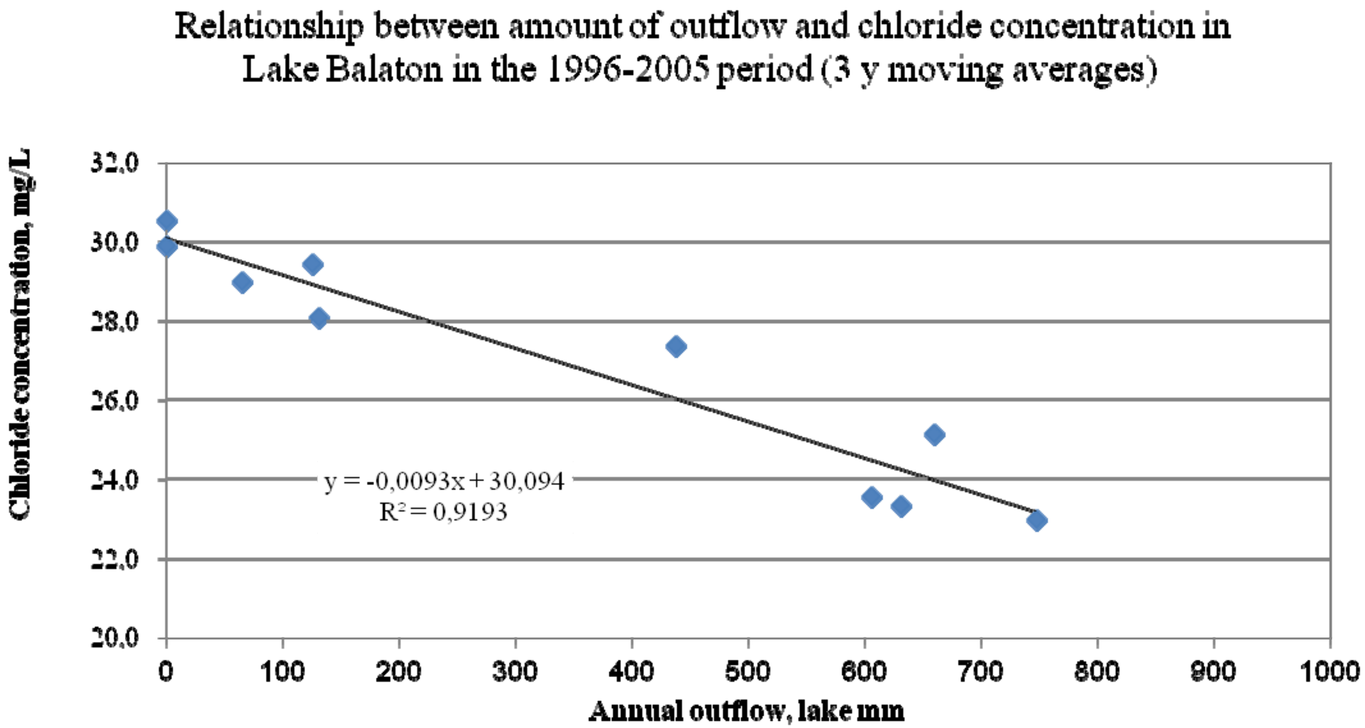
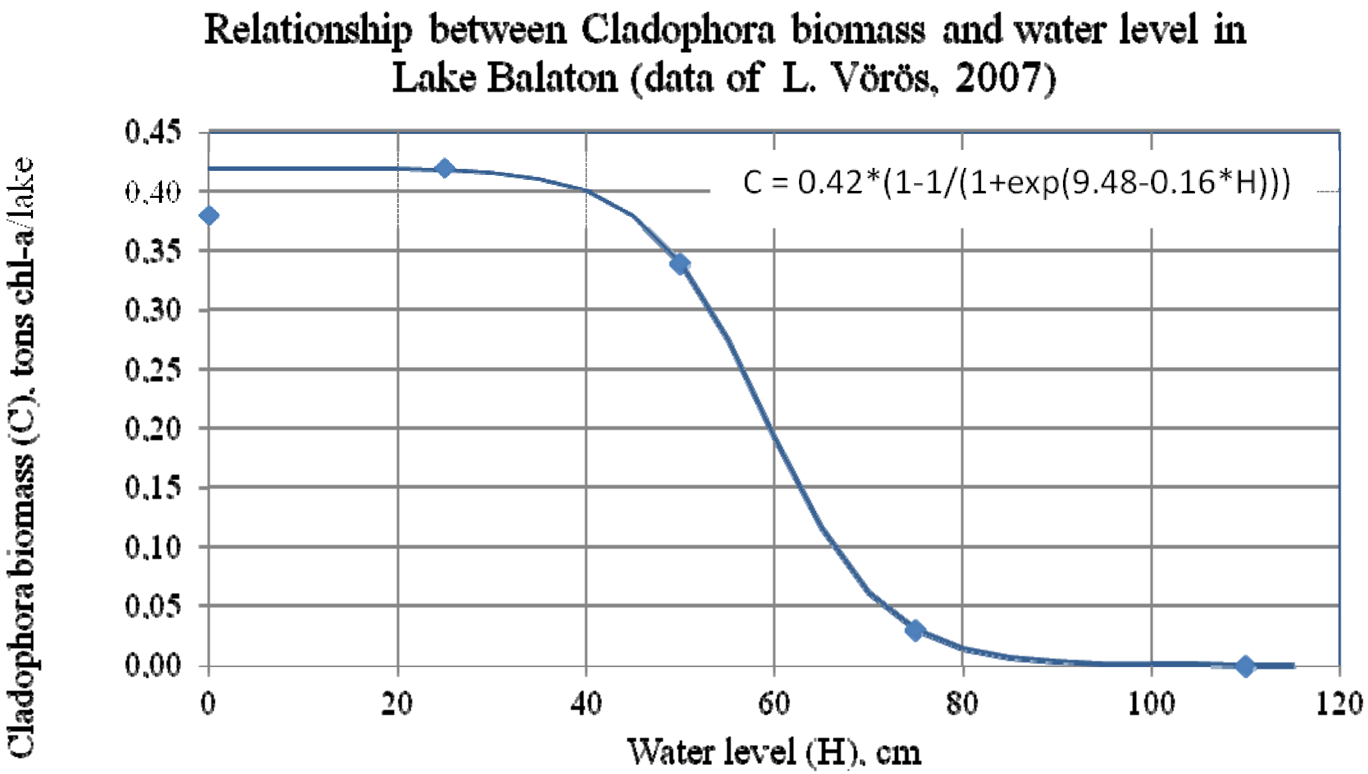


Image of filamentous green algae (Cladophora glomerata) bloom in 2003

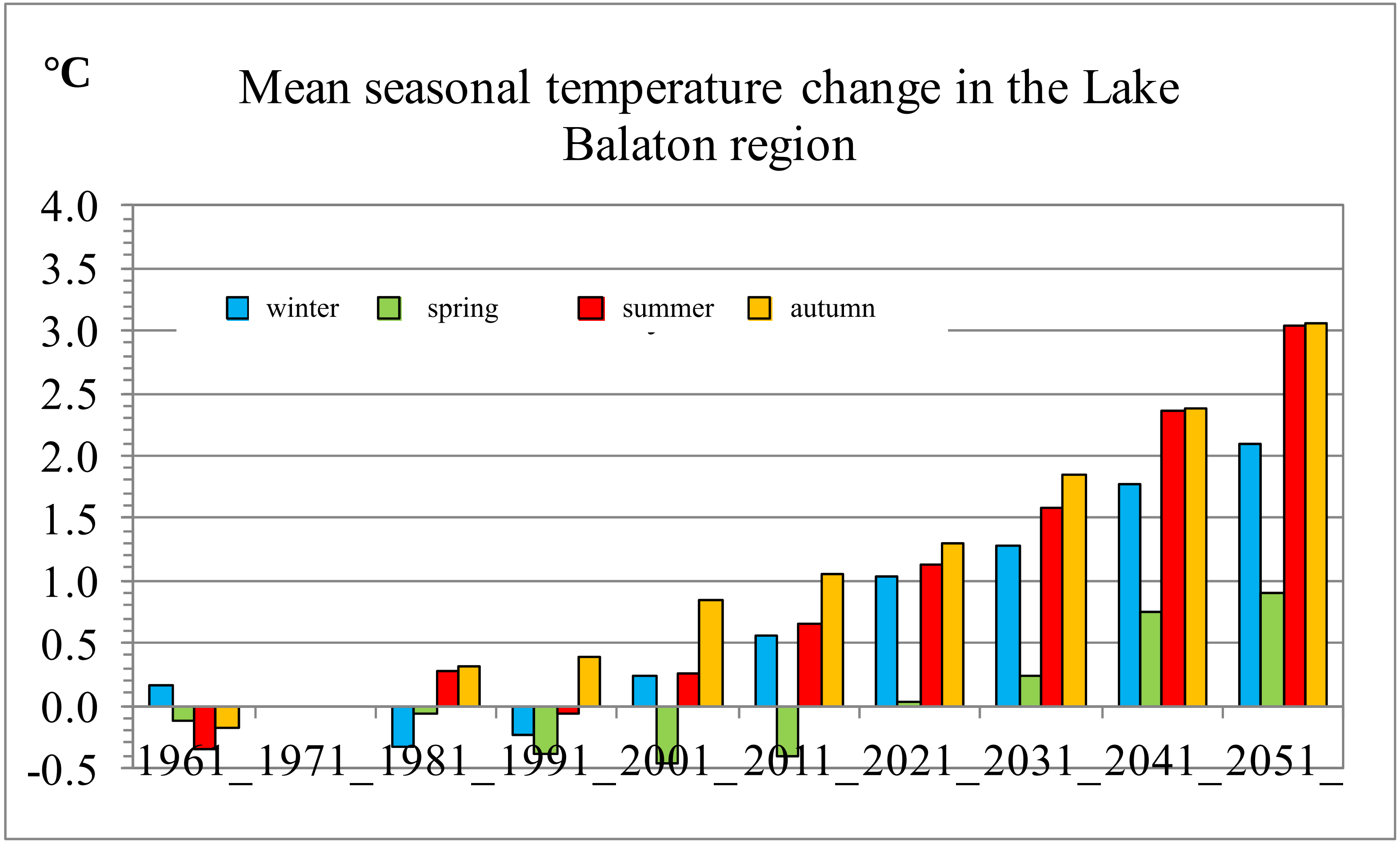
Filamentous green algae growth on the bottom of extremely shallow areas

- a logistic relationship

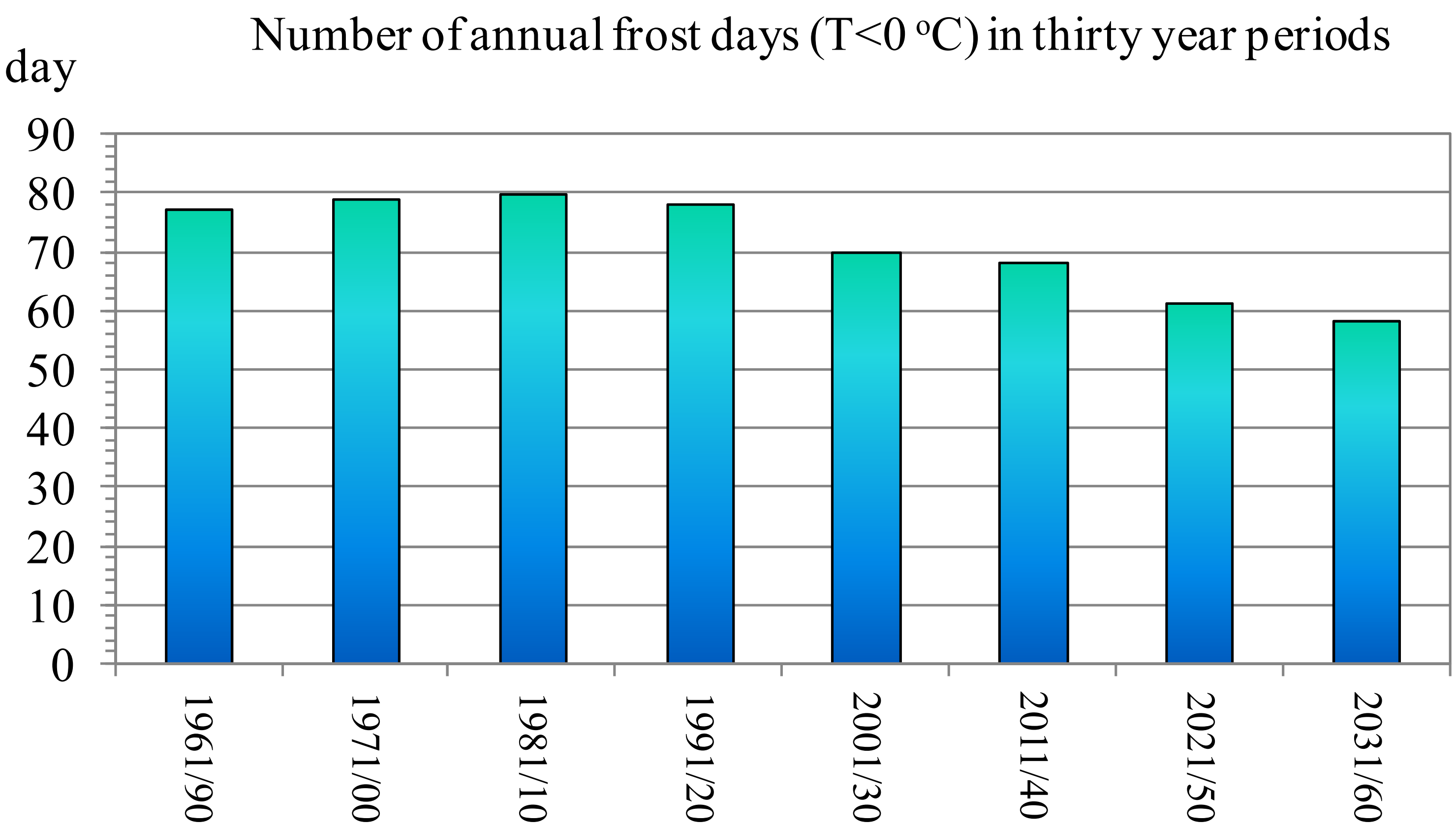


- not included in water quality monitoring system

Climate change I.

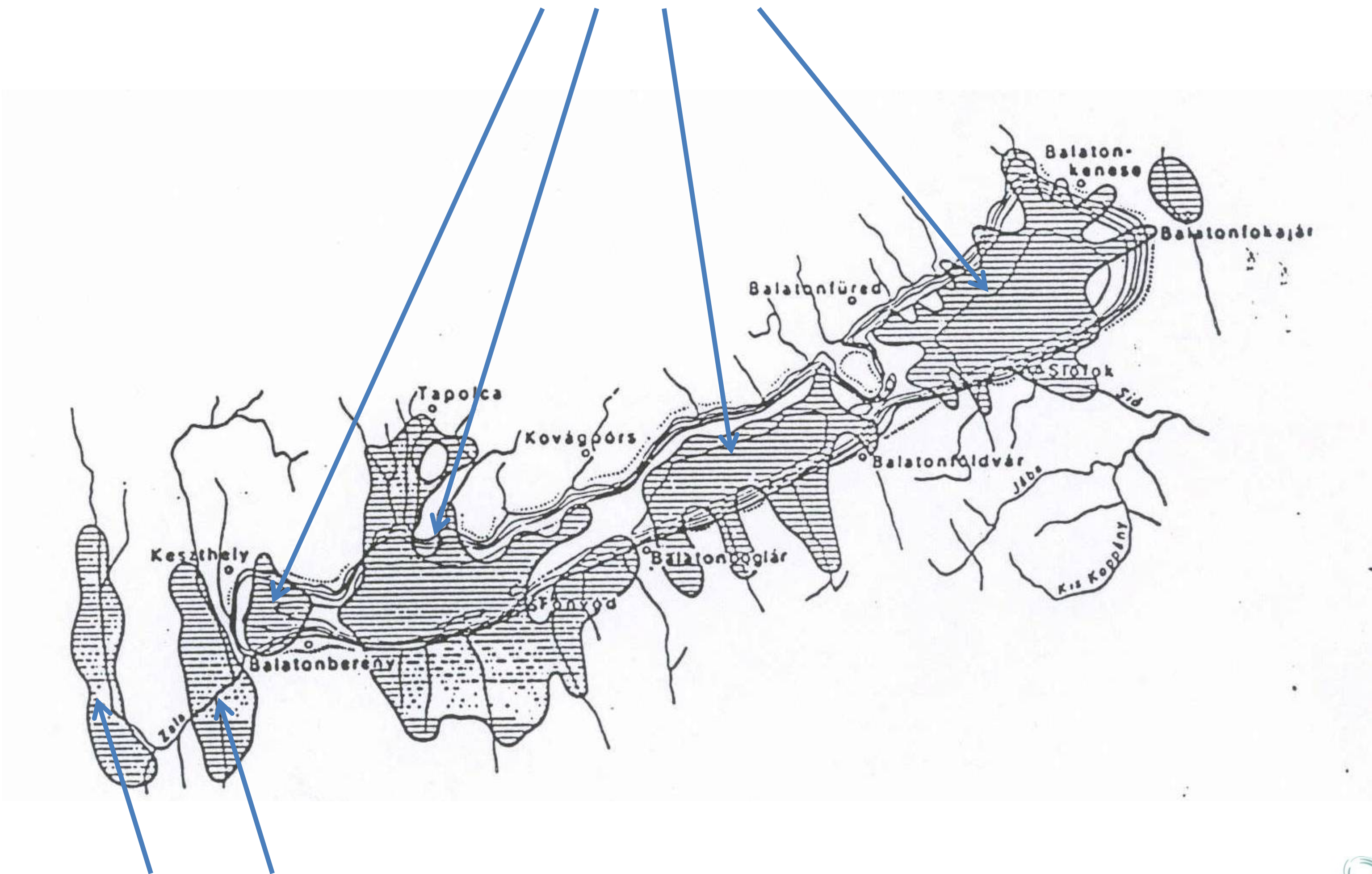


Climate change II.



Lake Balaton ca. 20 thousand years ago

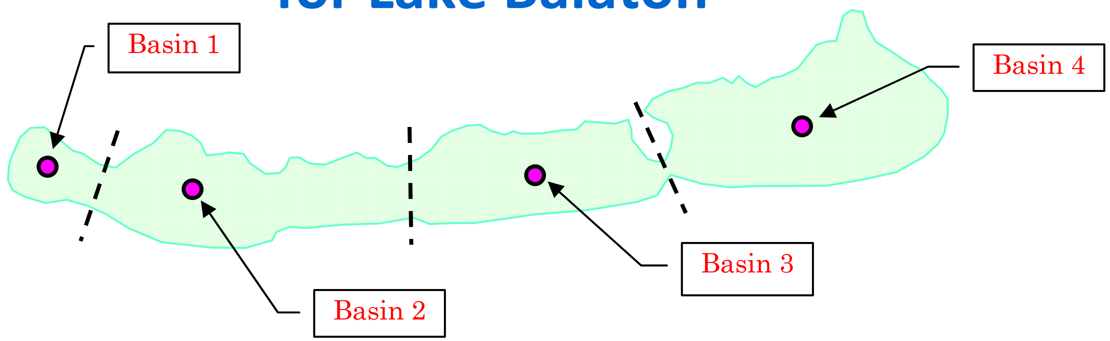
- four basins

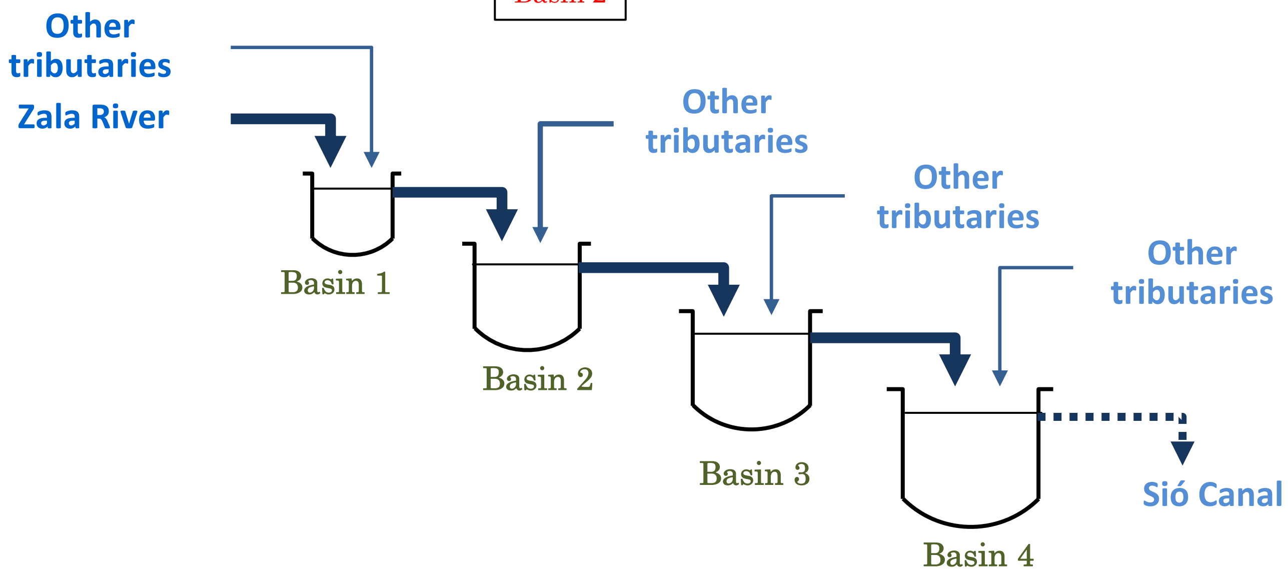


Kis-Balaton wetland

(from Lajos Lóczy senior)

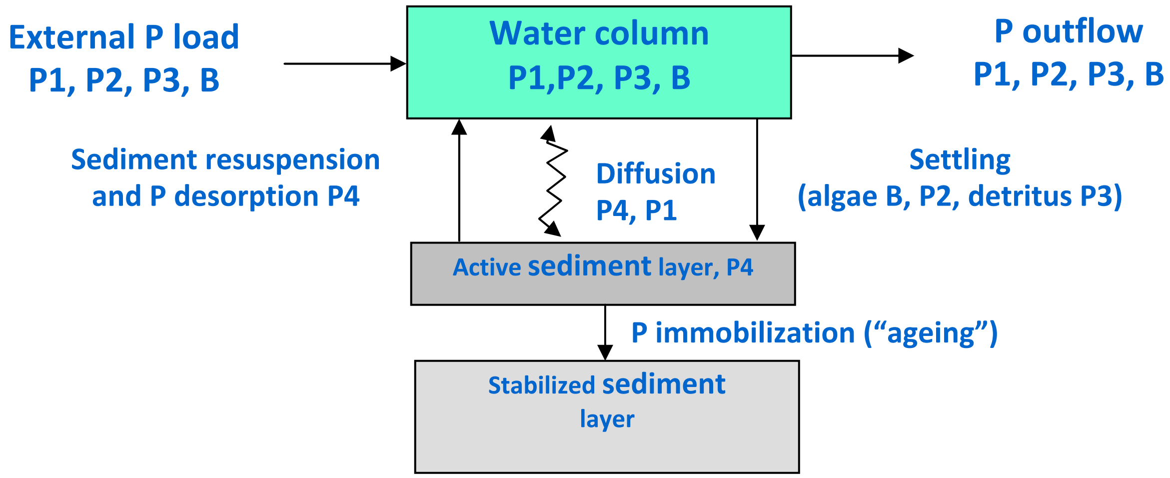
The four-basin completely mixed tanks model for Lake Balaton





Property	Unit	Basin 1 Keszthely	Basin 2 Szigliget	Basin3 Balatonszemes	Basin 4 Siófok	Total
Area	km2	36.3	145.1	187.4	219.7	588.5
Average Depth	m	2.36	2.97	3.34	3.81	3.36
Volume	million m3	86	431	626	836	1978

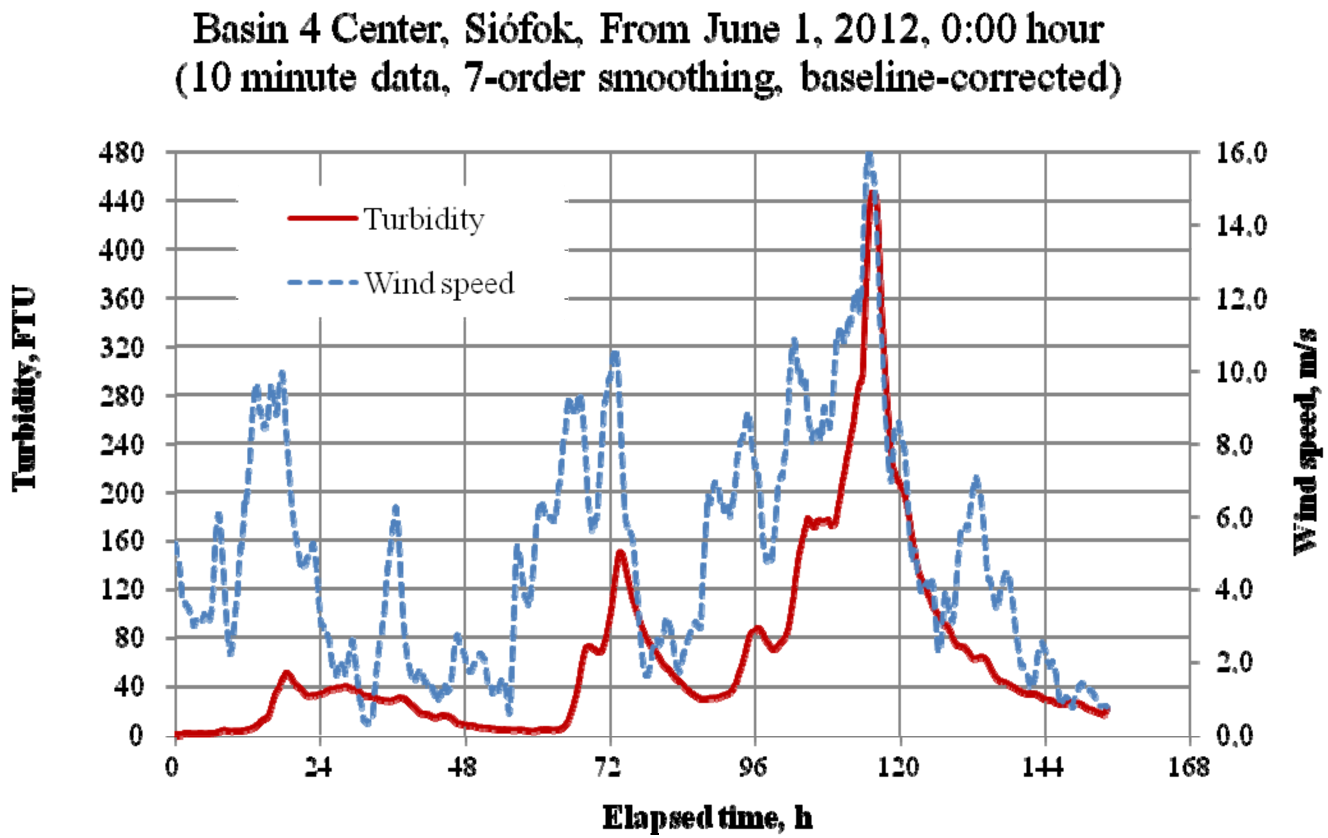
Conceptual scheme of the model with sediment interaction



P1 = Dissolved inorganic phosphorous,
P2 = Algal phosphorous,
P3 = Detrital phosphorous,
P4 = Sediment available phosphorus
B = Algal biomass

One blue-green algae species is considered (C. raciborskii)

Wind induced sediment resuspension in Lake Balaton



Data of the online WQ monitoring system

Data suggest that resuspension is less frequent than it was thought before

Modelling exercise

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Mathematical model:

- mass balances for the state variables,
- daily time step,
- 4 completely mixed tanks
- 20 nonlinear differential equations

Suspended sediment concentration is calculated separately with the wind induced resusupension model of Wake (2003)

Two climate scenarios (B1, A1b)

covering 80 years with 20 year time steps

Two phosphorus load scenarios

with 25% and 50% load reduction

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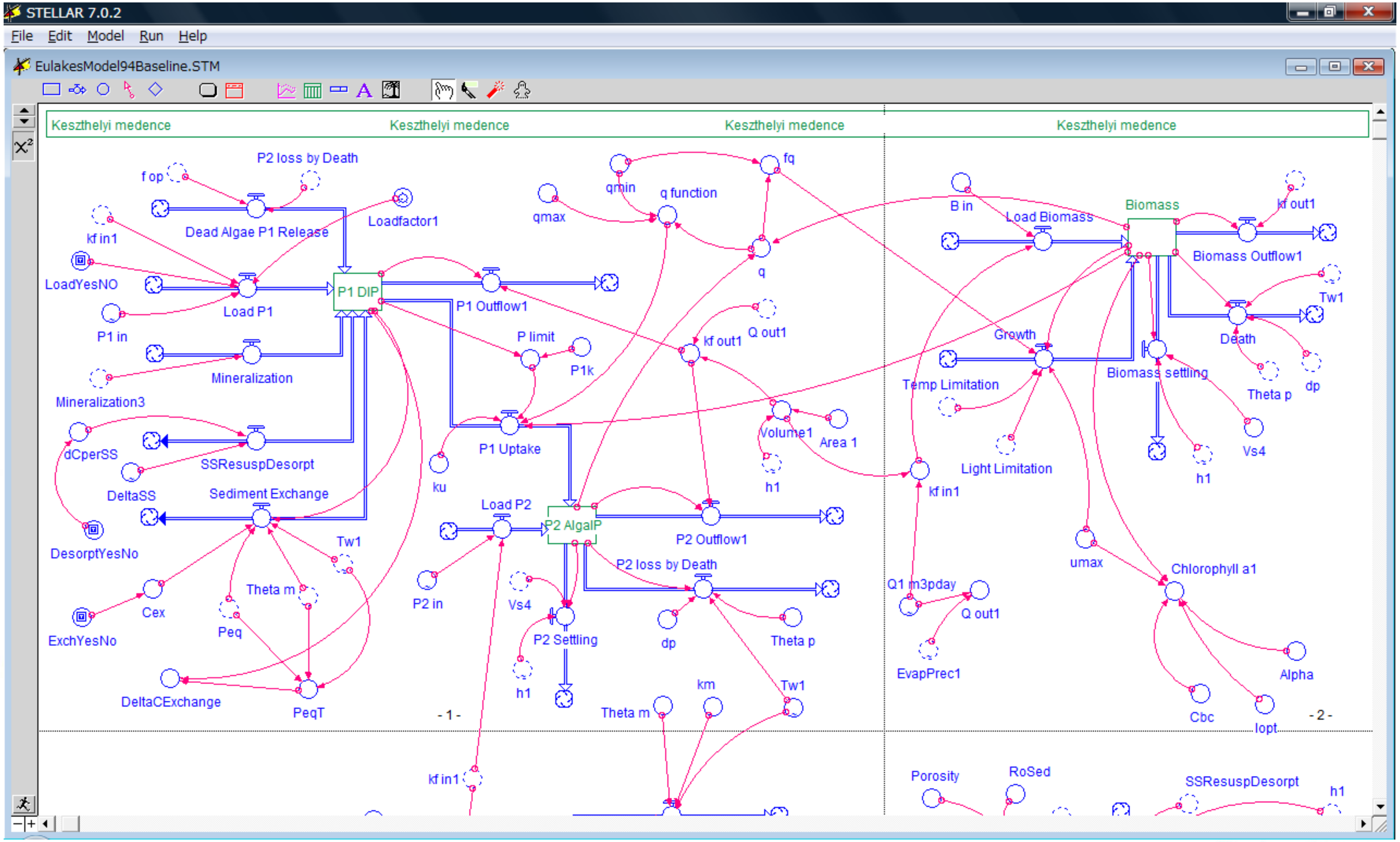
Part of the model graph layer with stocks, flows and values



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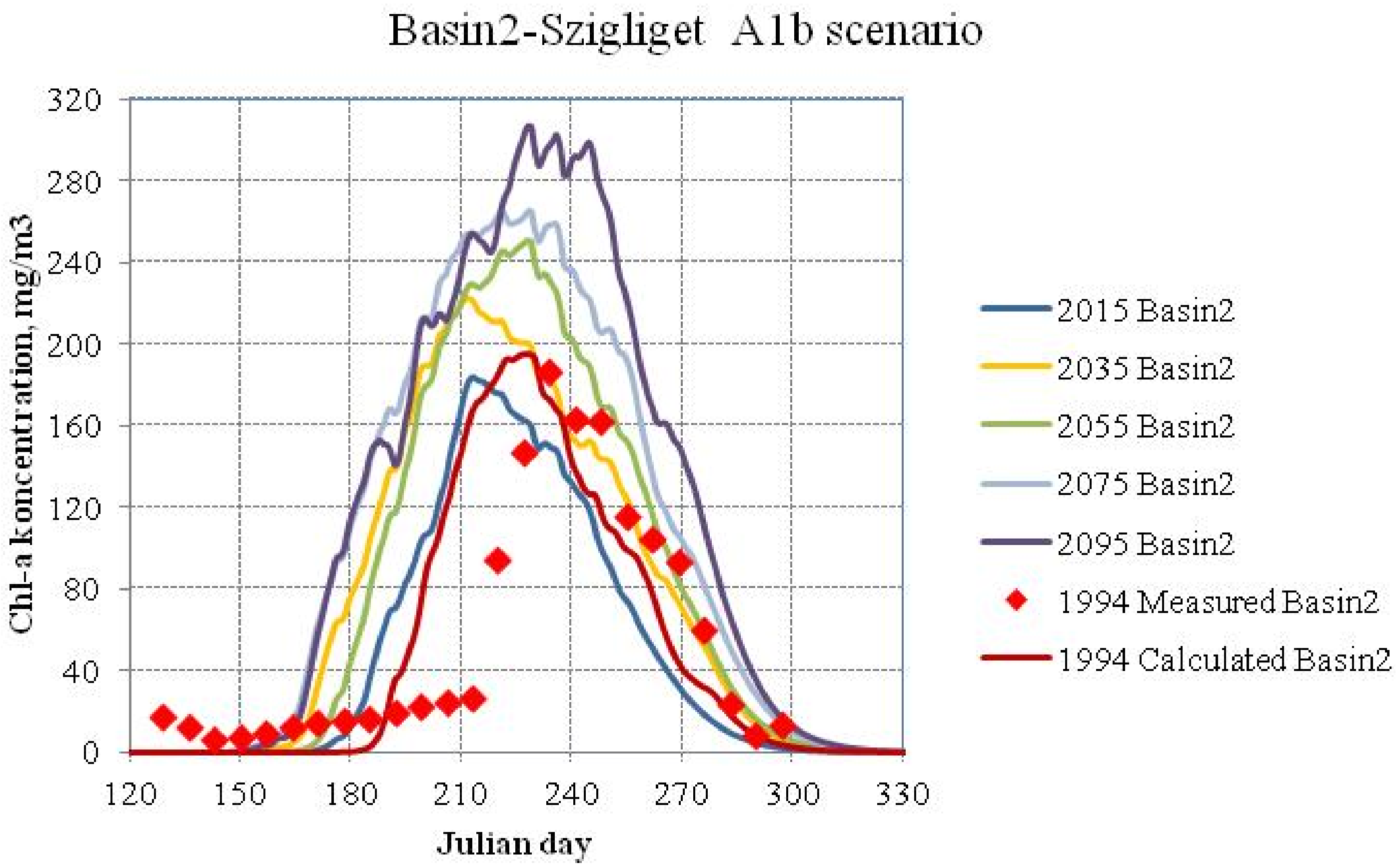
Results of model calculations I.

with A1b climate regional scenario

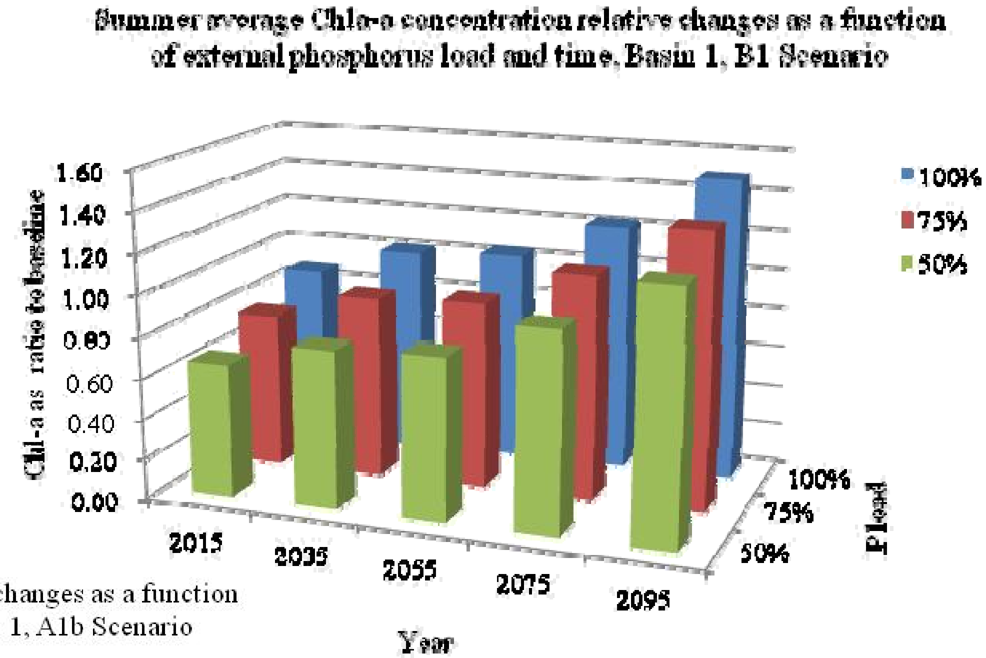


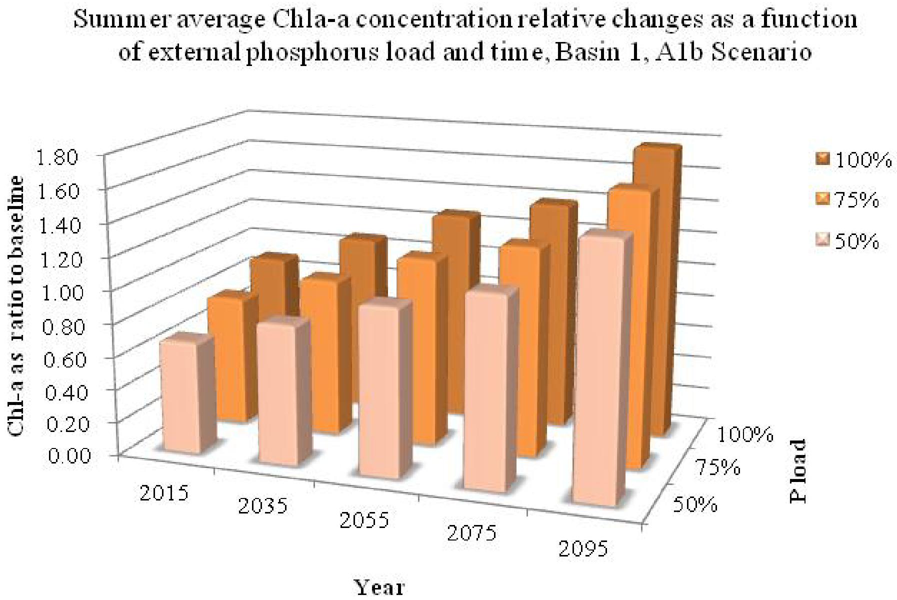
Regional climate prediction data were provided by the Austrian Institute of Technology, J. Züger et al., 2012.

Results of model calculations II.

with B1 and A1b regional climate scenarios and P load reduction scenarios

Summer AVERAGE chlorophyll-a concentrations





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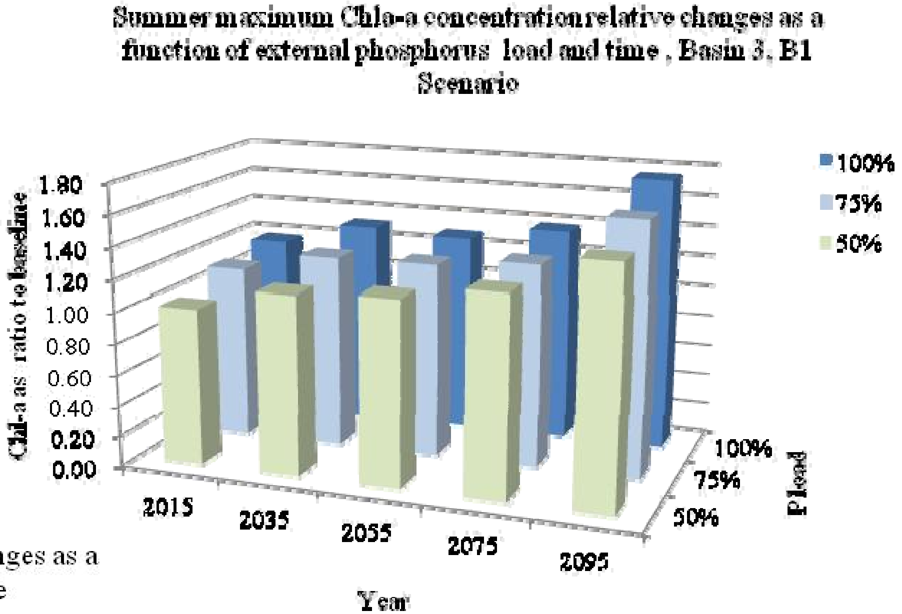
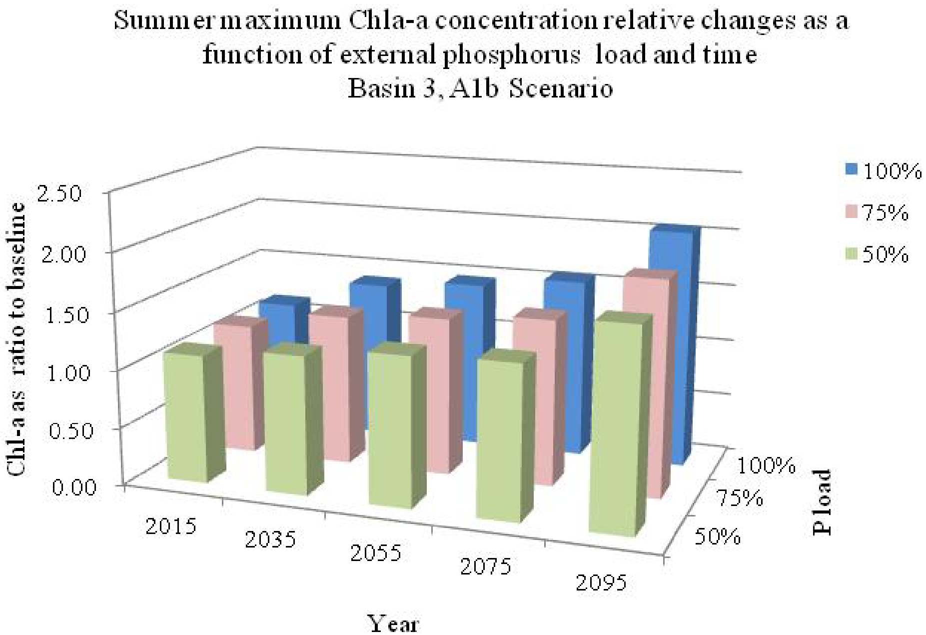
Results of model calculations III.

with B1 and A1b regional climate scenarios and P load reduction scenarios

Summer MAXIMUM chlorophyll-a concentrations





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Conclusions

- The model calculations show that the summer average chl-a concentrations are expected to increase considerably with climate change in case of both climate scenarios
- The summer maximum chlorophyll-a concentrations also increase but to a lesser extent
- A1b scenario resulted in slightly larger increases both in summer averages and maximums
- A 50% external P load reduction can compensate the climate effects up to about year 2035
- After 2055, the adverse impacts of climate change overrides the effects of load reduction

- Ambitious phosphorus load reduction efforts should be continued at Lake Balaton
- A more complex model taking into account other algae species and elements of the food web may result in higher reliability of predictions

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