Individual-based modelling of cyanobacterial blooms: Physical and physiological processes

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Acknowledgments

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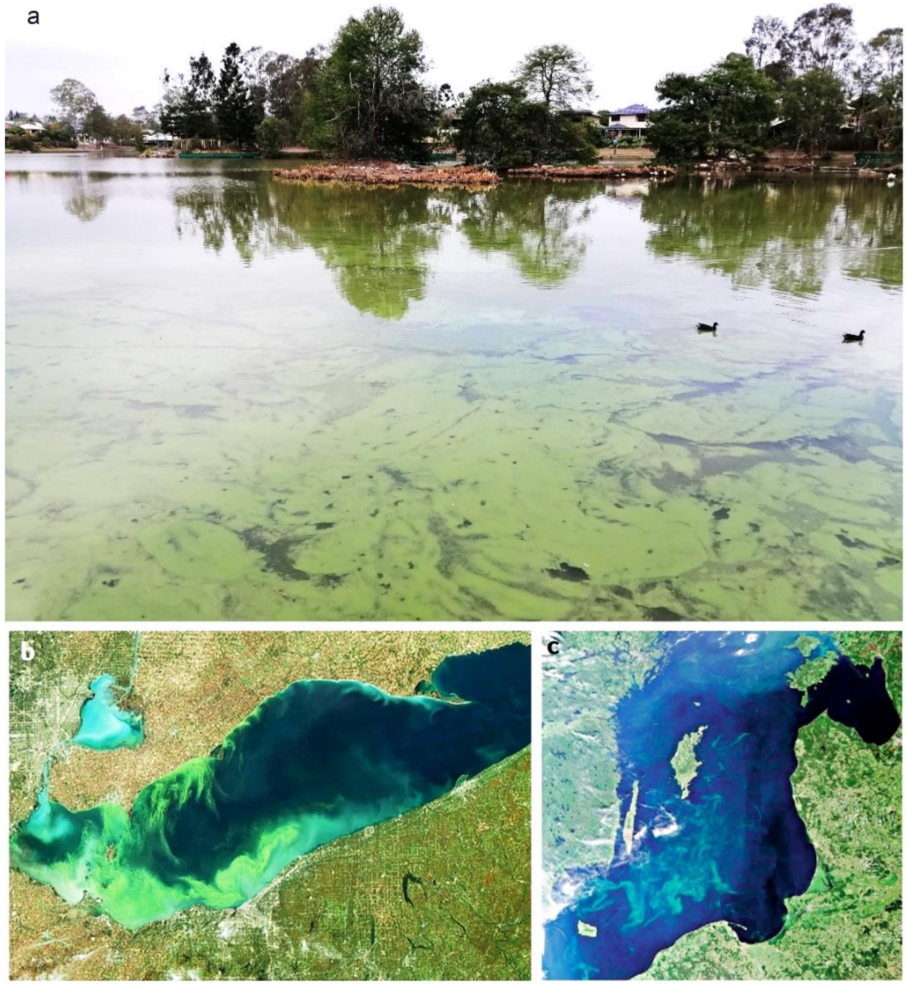
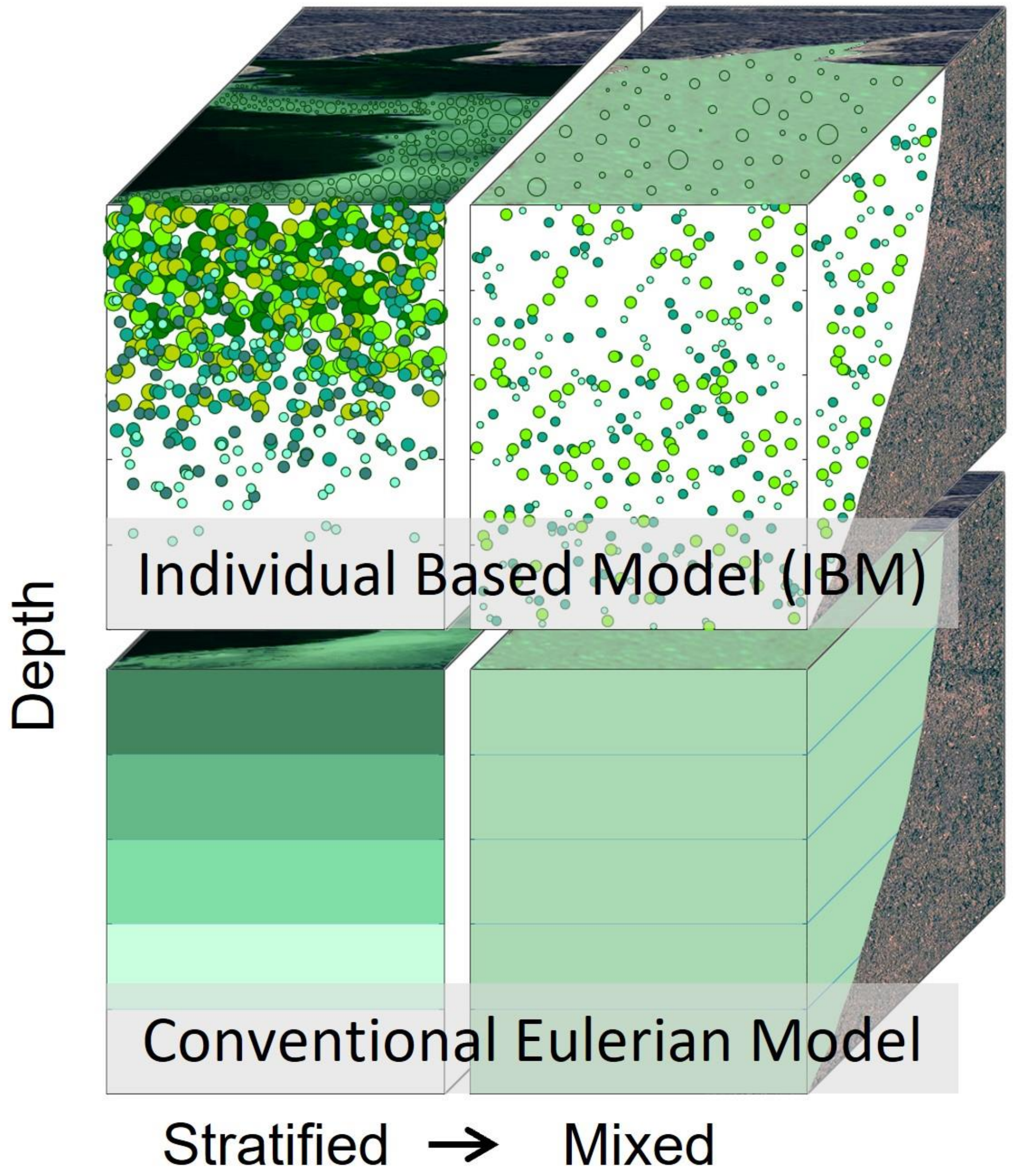
Cyanobacterial blooms (CyanoHABs)



Examples of waterbodies suffering from cyanoHABs: Forest Lake (a) Lake Erie and (b) and the Baltic Sea (c) (Huisman et al., 2018)

Dolichospermum spp. (formerly *Anabaena* spp.) (Huisman et al., 2018)

Process- based modelling

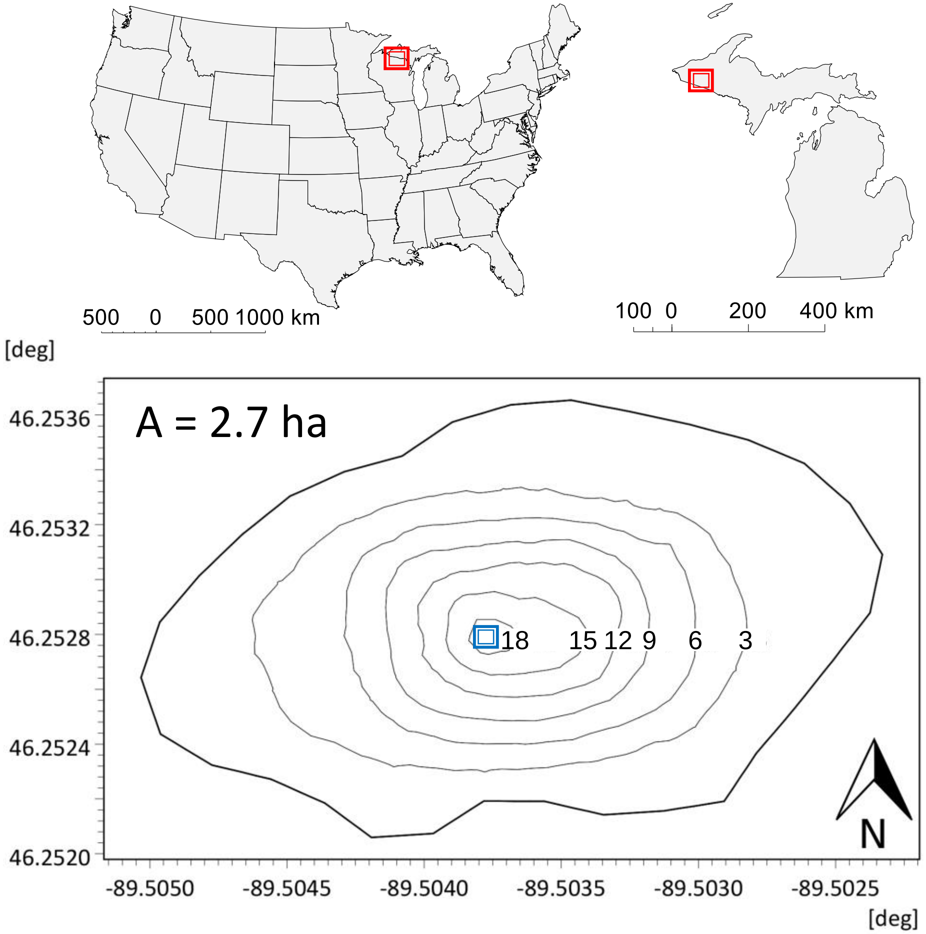


Objectives and novelty

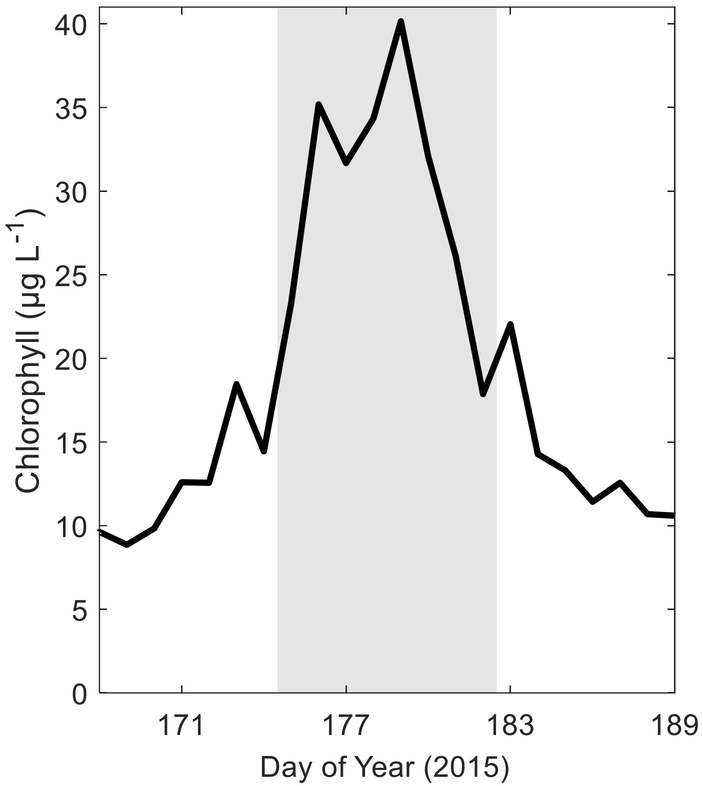
- Objectives:
  - to develop an individual-based model (IBM) of *Dolichospermum* growth, respiration, light-induced fluorescence quenching and transport
  - to investigate the effects of thermal stratification and mixing on the bloom dynamics

- Novelty:
  - In our IBM, for the first time, we incorporate antecedent environmental history and adaptive physiological traits of cyanobacteria into a process-based model.

Study site

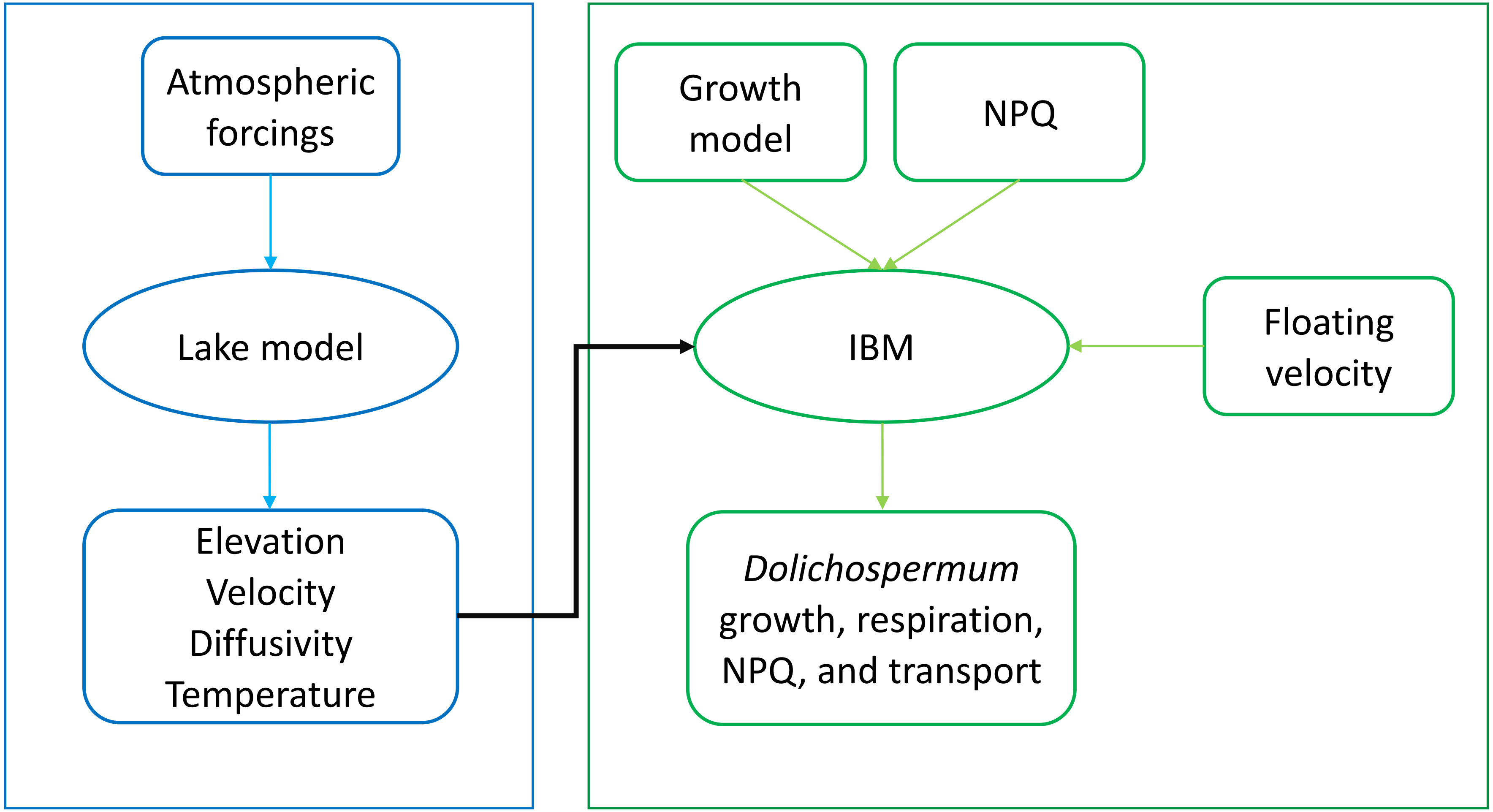


Bathymetry (m) of Peter Lake. The red and blue insets indicate the location of the lake in Michigan, USA, and monitoring site, respectively.



Variations in chlorophyll *a* in Peter Lake in 2015 under the nutrient enrichment experiment. The shaded area shows the modelling period.

Modeling chain



Conceptual diagram of the modeling system showing the components of the lake model and IBM.

Growth model

Maximum growth rate of a filament at 20 °C (Reynolds, 1989):

$$\mu_{max} = 1.142(sv^{-1})^{0.325}$$

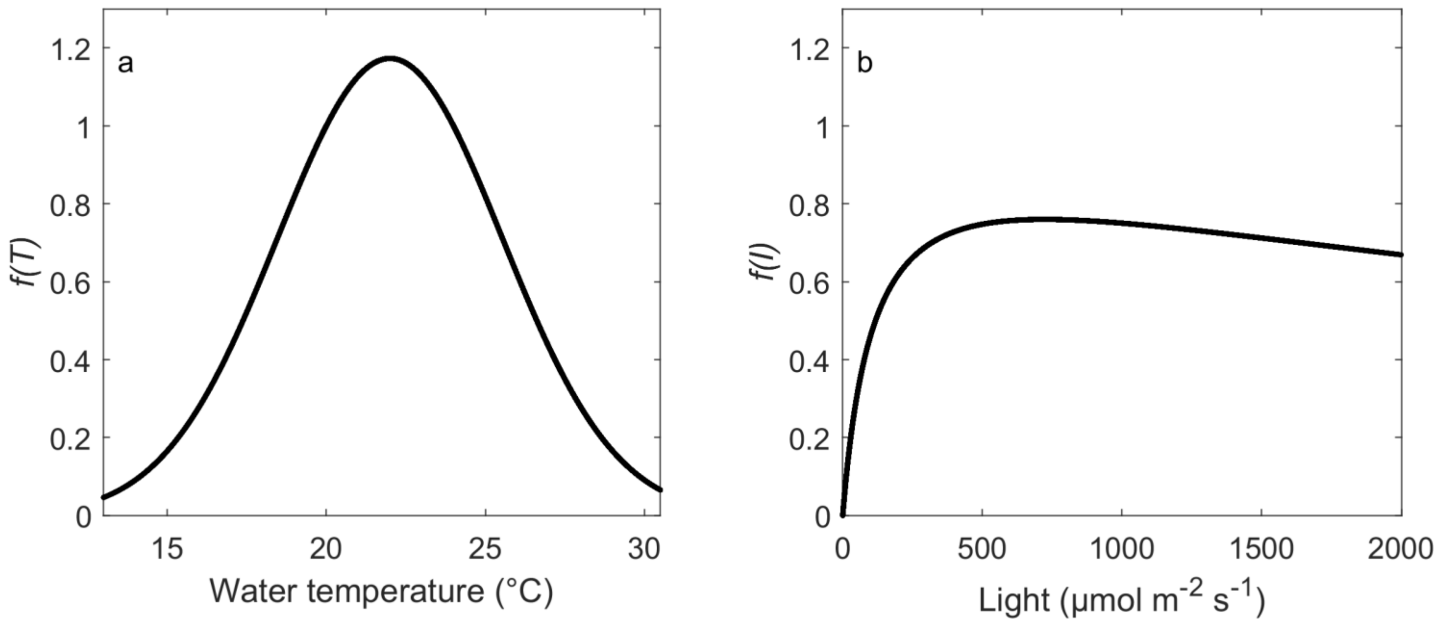
Net growth rate (Robson and Hamilton, 2003; Hellweger et al., 2008):

$$\mu_{net} = \mu_{max} f(T) f(I) - R\theta^{(T-20)}$$

$$f(T) = \exp\left(-\left(\frac{T - T^0}{q}\right)^2\right)$$

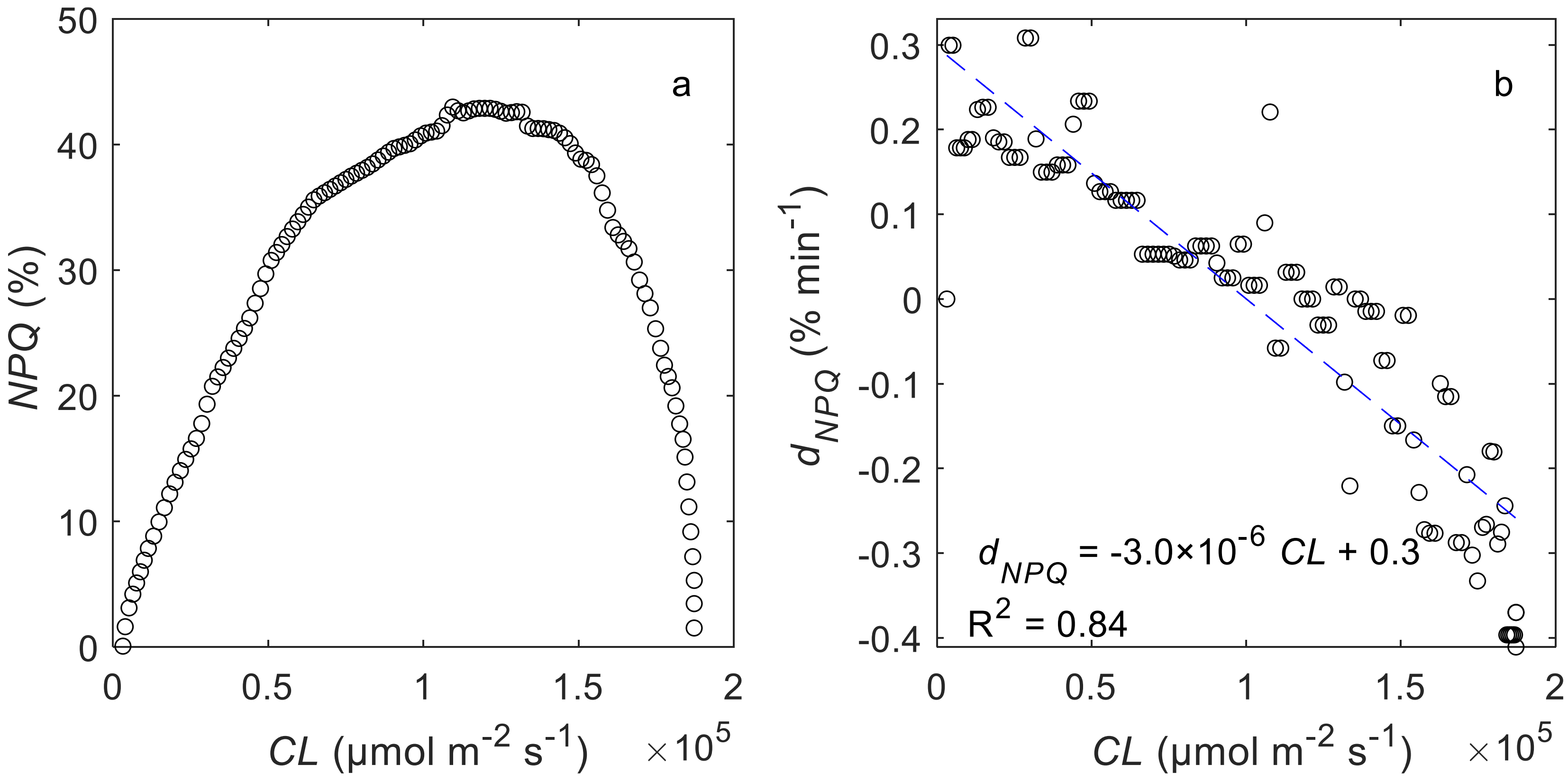
$$f(I) = \frac{I}{I + e + uI^2}$$

s : surface area of the filament; v : volume of the filament; $f(T)$ and $f(I)$: functions applied to regulate growth dependence on temperature and light.



The temperature (a) and light limitation functions (b).

NPQ model



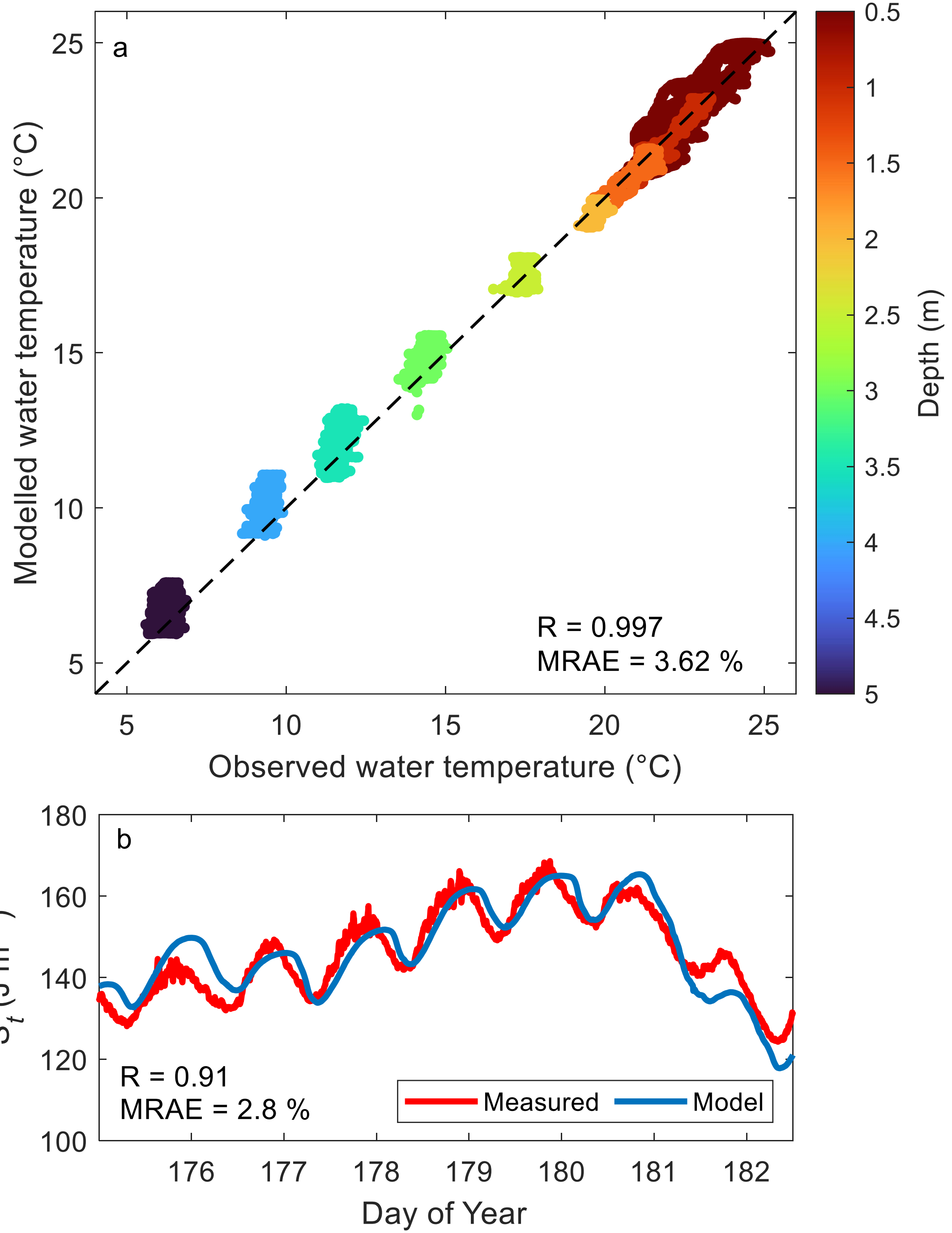
Nonphotochemical quenching (NPQ) observed by Rousso et al. (2021) (a) and rate of NPQ (d_{NPQ}) (b) versus cumulative light dose (CL) with a built-in recovery.

Based on rate of NPQ ($d_{NPQ,t}$), nonphotochemical quenching at the current time step (NPQ_t) was calculated as:

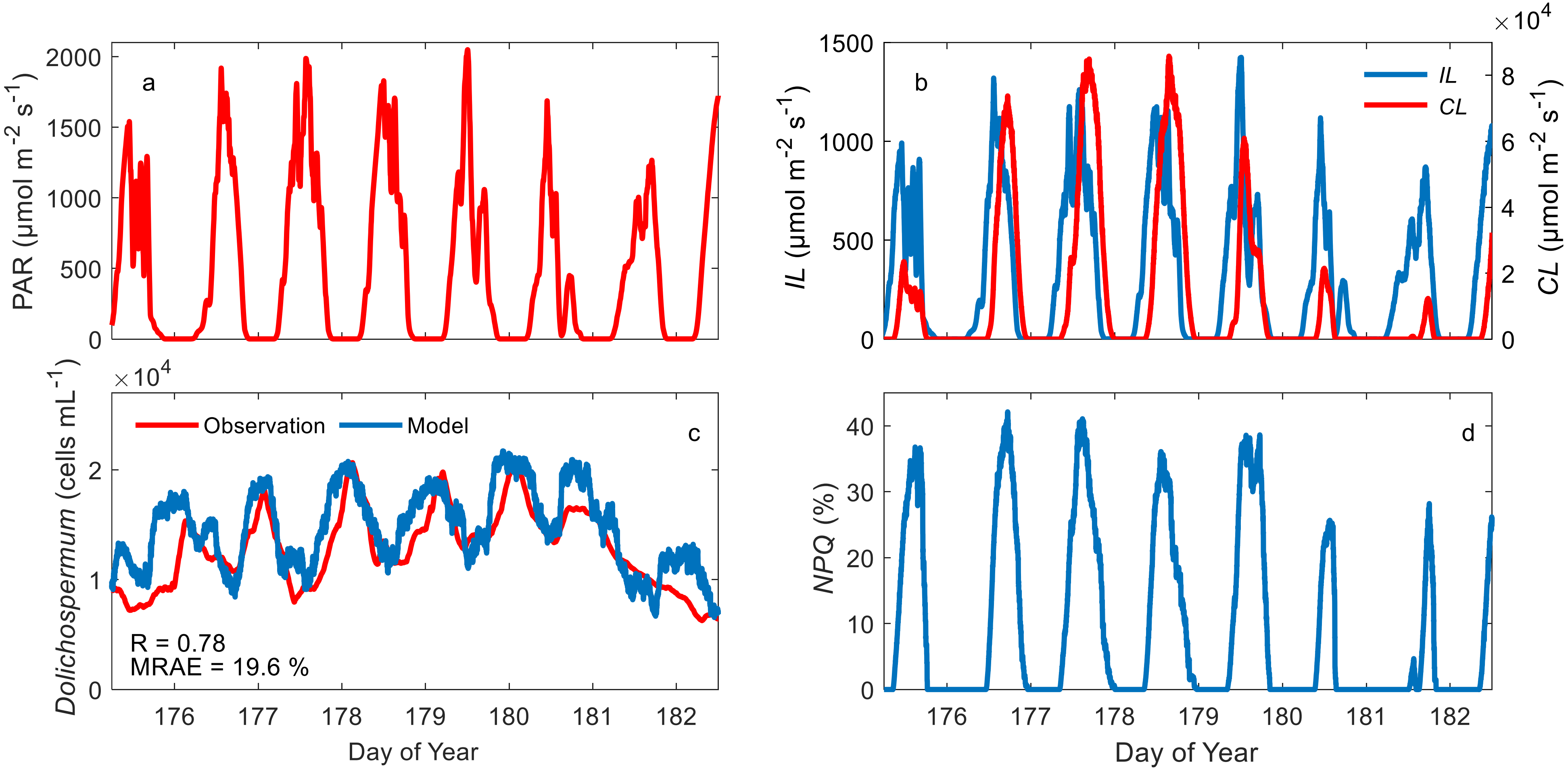
$$NPQ_t = NPQ_{t-1} + d_{NPQ,t}$$

Lake model results

Comparison of simulated water temperatures with measurements (a) and Schmidt stability (S_t) (b) in Peter Lake in 2015. The dashed line (a) corresponds to the 1:1 line.

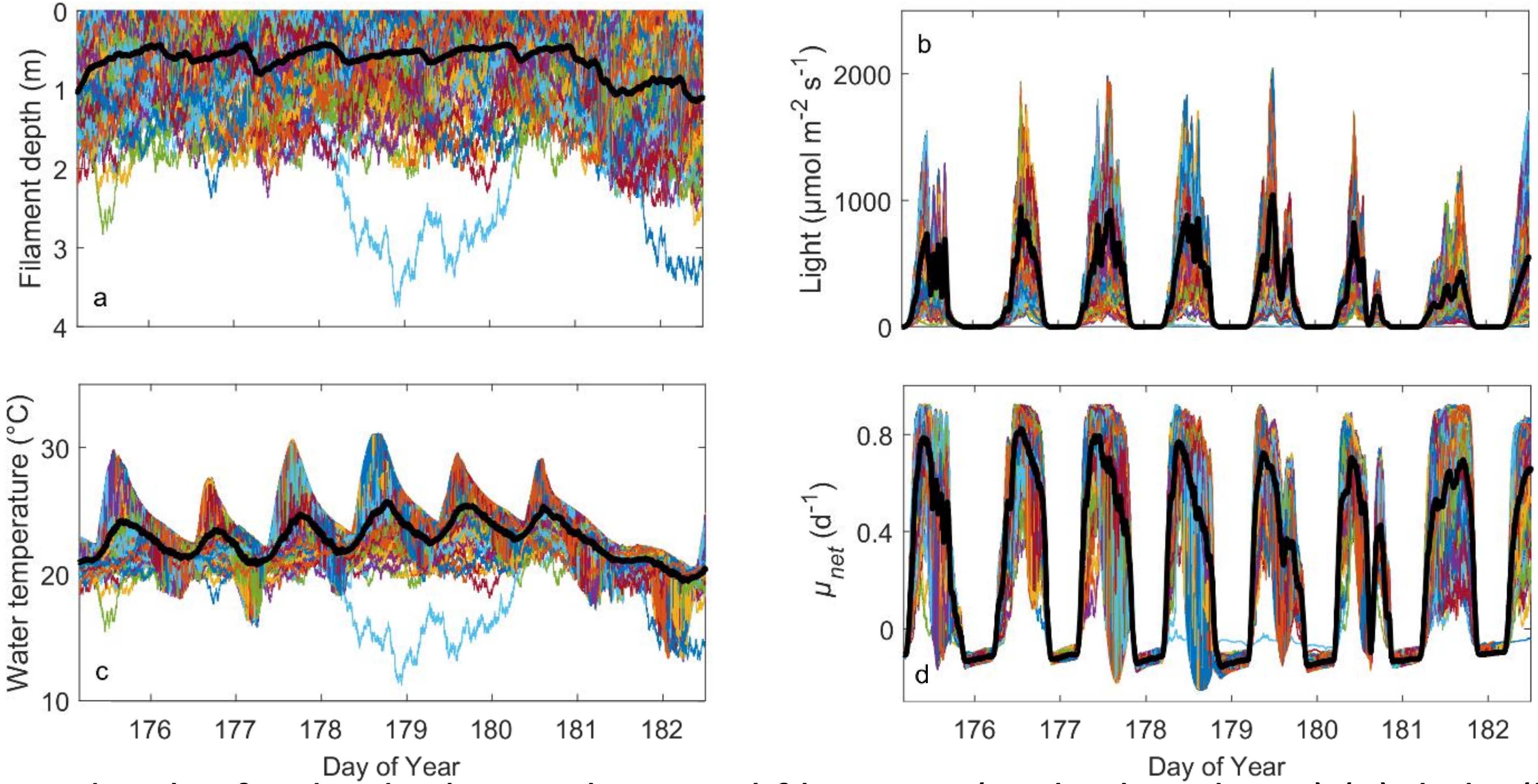


IBM results



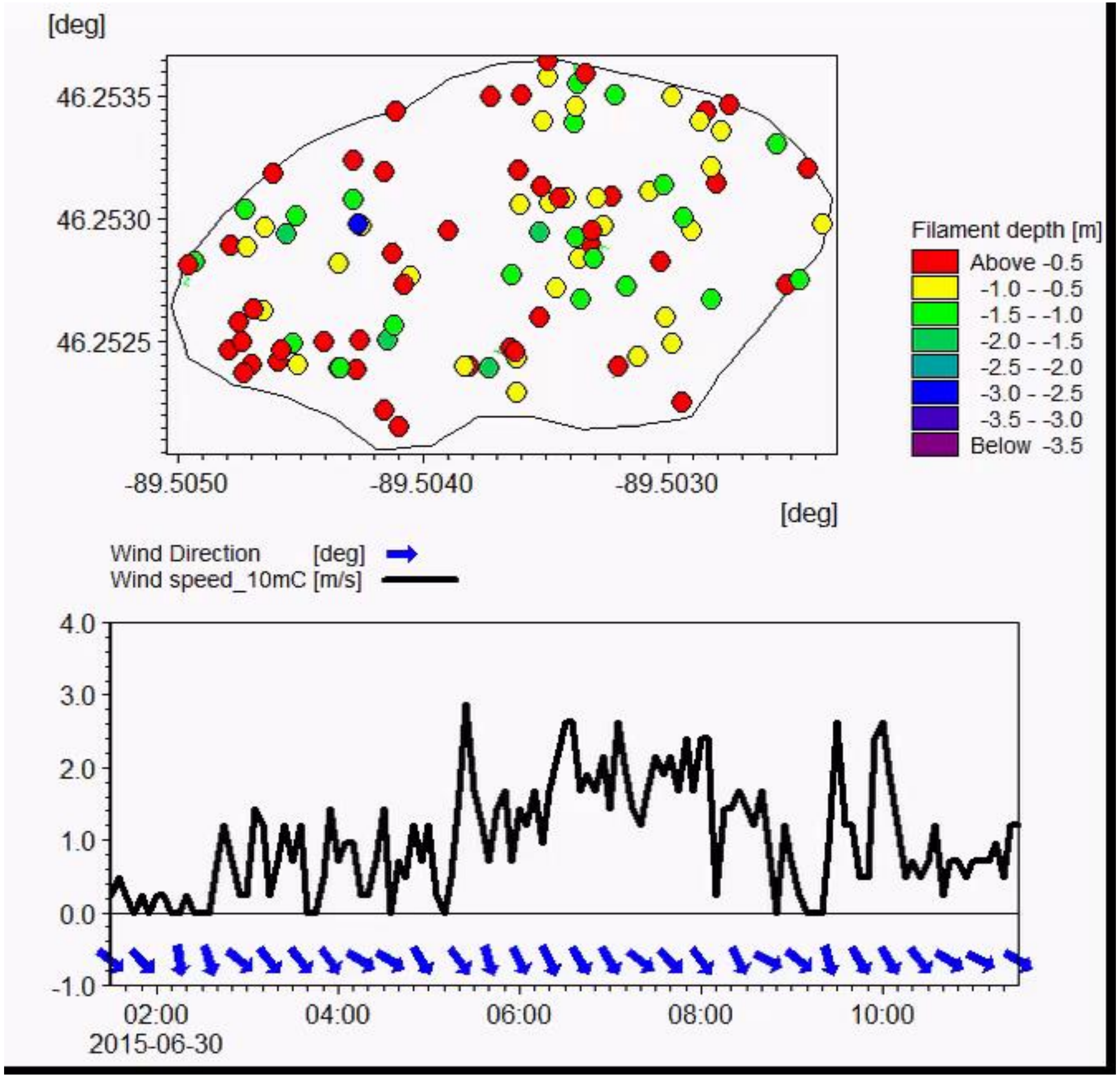
Variations in surface PAR (a), instantaneous (*IL*) and cumulative (*CL*) light dose (b), and comparison between modelled and 3-h moving average of observed *Dolichospermum* cell counts in the top 0.75-m layer (c) in Peter Lake in 2015. Nonphotochemical quenching (*NPQ*) was shown in (d).

IBM results



Variations in depth of individual cyanobacterial filaments (multiple colours) (a), light (b), water temperature (c), and net daily growth rate, μ_{net} (d) experienced by the filaments in Peter Lake in 2015. The thick black lines represent mean values at each time step.

3D distribution of filaments in Peter Lake on day of year 181



Conclusions

- The results demonstrate high fluorescence quenching and long photo-physiological relaxation periods during stratification.
- The results also show low quenching and rapid relaxation in response to low light exposure history of filaments as the mixing layer deepened.
- Thermal stratification caused an increase in cyanobacterial biomass because of filament accumulation at the surface coupled with the high growth rate
- Mixing led to rapid reduction in biomass due to entrainment of filaments in the mixed layer as it deepened, combined with the low growth rate.

THANK YOU!

References

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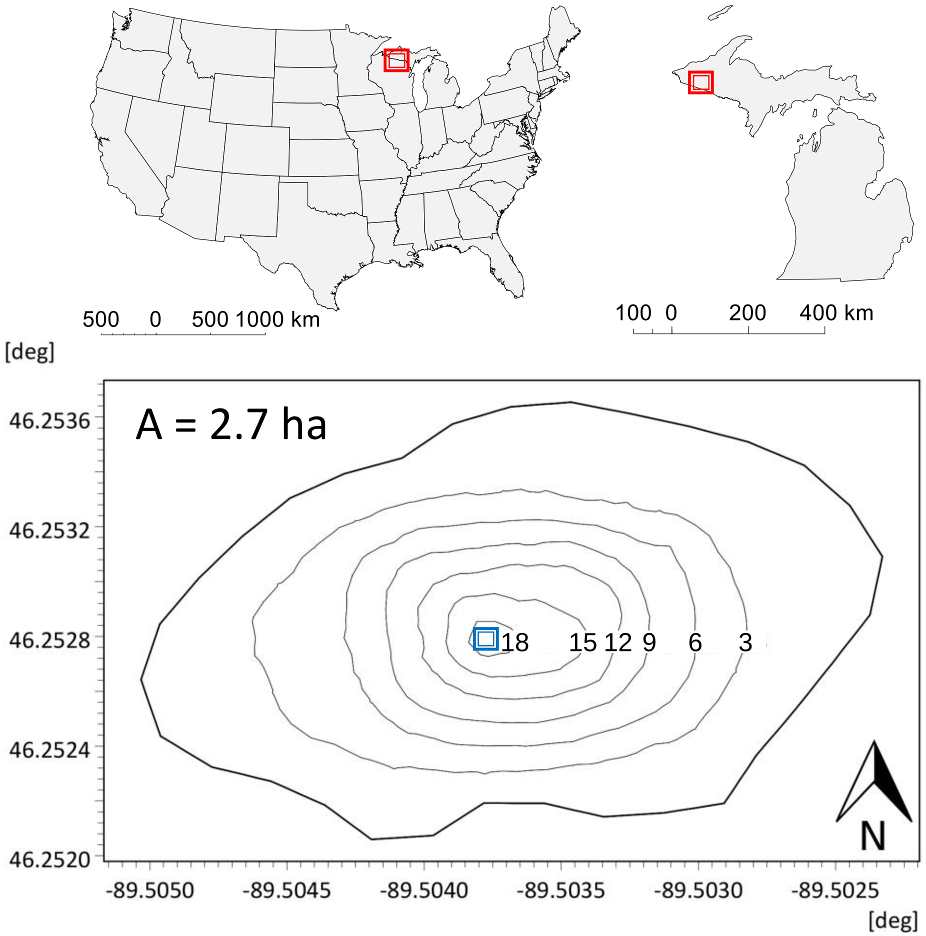
Study site



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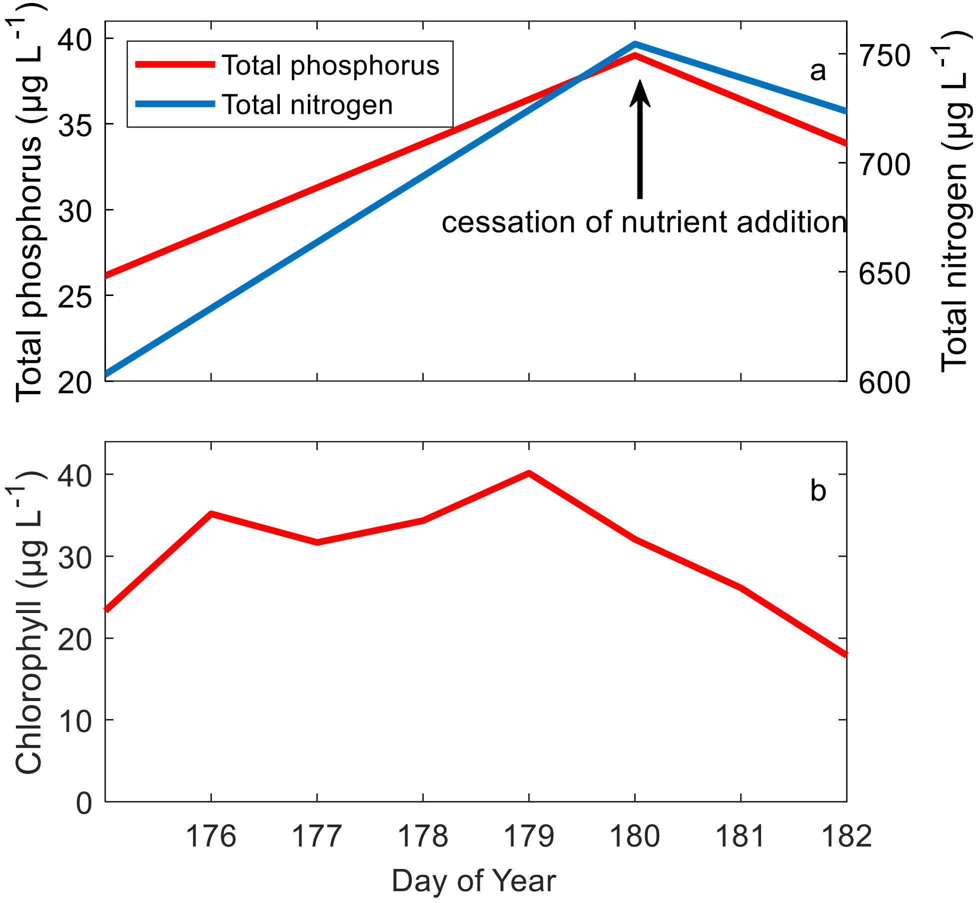

Variations in TP and TN concentrations (a), and chlorophyll *a* (b) in Peter Lake in 2015 under the nutrient enrichment experiment.