Modelling cyanobacteria blooms in urban lakes.
Application to Lake of Enghien-les-Bains
Talita Silva, Brigitte Vinçon-Leite, Bruno J. Lemaire, Briac Le Vu, Nicholas Escoffier, François Prévot, Catherine Quiblier, Bruno Tassin

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Context
The ecosystems in urban lakes are very vulnerable to human pressure because of their specific physico-chemical characteristics, and are exposed to the pressures of their environment. The high intake of nutrients in these environments encourages blooms of phytoplankton, including toxic cyanobacteria, disrupting their use and causing health problems (Catherine et al., 2008). This work focuses on the implementation of a predictive model of cyanobacteria blooms in urban lakes. It is part of a project whose objective is to improve monitoring and warning system, in real-time, of phytoplankton blooms in freshwater ecosystems.

Lake of Enghien-les-Bains
Lake of Enghien-les-Bains is located in the Val d’Oise, France (48°56’8’’N, 2°18’E) (Fig. 1). It is an urban shallow lake (maximum depth: 2.5 m; mean depth: 1.3 m; area: 41 ha; volume: 534 000 m³). It is a significant site in the stormwater management of its watershed (54 km², over 200 000 inhabitants) by storing up to 100000 m³ of rainwater. The lake receives wastewater discharges from inappropriate connections in the stormwater network. This input results in a deterioration of the water quality and the lake is frequently affected by cyanobacteria blooms (Quiblier et al., 2008). In July 2009, the cyanobacterial biomass has reached 300 µg Chl-a L⁻¹ (Silva, 2010). The prevailing species, Planktothrix agardhii, is potentially toxic and is usually found in the first meters of the water column in shallow turbid eutrophic lakes.

Fig. 1: Lake Enghien: Location in France (A) Watershed (B) Air view (C) Landscape view (D)

DYRESM-CADEYM
DYRESM is a one-dimensional numerical model for predicting the vertical distribution of temperature and density in lakes and reservoirs. It is based on the Lagrangian layer scheme (Jerrita et al., 2007). DYRESM was coupled to CAEDYM, the aquatic ecosystem model to simulate the cyanobacteria dynamics (Hamilton and Schladow, 1997). The input data are the lake morphometry, inflows, outflows, meteorological forcing (wind speed, air temperature, solar radiation, rainfall, cloud cover and vapor pressure), and the initial conditions for all variables to model (Fig. 2).

Measurement buoy
The data required for modelling (except the lake morphometry, flows and the nutrients) were obtained from a freshwater-adapted measurement buoy installed on the lake in November 2008. This buoy was located at the deepest region of the lake and it was equipped with meteorological sensors and immersed measuring probes of water quality parameters (Fig. 3). The measurements were performed in high frequency, every 30 min, at a depth varying from 0.50 to 1.0 m (for water parameters). Data were transmitted through GPRS protocol to a database as a daily email. If a shorter time step was necessary, the buoy may be remotely queried, which allows the continuous monitoring in a real-time of the physical-chemical conditions of the lake.

First results
The DYRESM model was run for the period from 1st April to 17th August 2009, the most favorable period of the year and therefore, more favorable to cyanobacteria blooms (Fig. 4A). The maximum and minimum layer thickness was defined, respectively 0.16 m and 0.79 m. The modelling of the cyanobacteria dynamics was conducted during a shorter period, from 1st to 20th June 2009 when cyanobacteria are the prevailing phytoplankton group (Fig.4B).

Fig. 4: Buoy measurements: water temperature (A) and phytoplankton biomass (B)

The model performance was checked by using 4 indicators: the correlation coefficient, the arithmetic mean of the errors, the standard deviation of the errors and the root mean square value of the errors (RMS). The error arises from the difference between the model predictions for water temperature and phytoplankton biomass and the measures from the buoy, at the same time and at the same depth.

Discussion
The thermal model was able to adequately represent the daily cycles and the seasonal changes in water temperature (Fig 5A). Moreover, despite the shallowness of the lake, a thermal stratification at a depth of 2.0 m was noted during the summer (Fig 5B).

Fig. 5: Model results versus buoy measurements for water temperature (A) and water temperature profile simulated (B)

Concerning the biological simulation, the negative value of the arithmetic mean indicates that the model underestimates the phytoplankton biomass (Fig 5A), and this has been stated in several studies on cyanobacteria that nutrient concentration is very significant to phytoplankton growth (Quiblier et al., 2008). In an urban lake, the stormwater discharge may play a role in triggering the proliferation of phytoplankton because nutrient load can rapidly increase during rainfall events. Therefore, the underestimation of the model results for the phytoplankton biomass may be related to the rain occurred during the simulation period (Fig 6B).

Fig. 6: Model results versus buoy measurements for phytoplankton biomass (A) and rainfall during the simulation period (B)

Knowledge about nutrient inputs is necessary to improve the model results, especially during rainfall events. To consider the influence of these factors, zooplankton and phytoplankton community should be taken into account because of the competitive relationship to be imposed on a cyanobacterial model validated on a data different from that used for calibration which will make it usable as a tool for predicting short and medium term cyanobacteria blooms in urban lakes such as Lake of Enghien-les-Bains.

Conclusion and perspectives
These results show the advantage of coupling this type of model with high frequency measurements, to simulate the phytoplankton biomass in a shallow urban lake. The model showed a good performance in simulating the cyanobacteria dynamics in an urban shallow lake. Moreover, DYRESM-CADEYM can be employed as a predictive model of phytoplankton blooms based on the chlorophyll and nutrient concentrations and on the weather forecast.

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1. Université Paris-Est, LEEUS, École des Ponts ParisTech, 6-8, avenue Blaise Pascal, 77455 Marne la Vallée, France; 2. LEGOS, 18 avenue Édouard Belin 31401 Toulouse, France; 3. Musée National d’Histoire Naturelle, Equipe SEM, 57 Rue Cuvier, 75231 Paris – France; 4. Université Paris Diderot, LGE, IPGP, Case 7052, Paris 7. 75205 France