Water Quality in urban lakes: from continuous monitoring to forecasting. Application to cyanobacteria dynamics in Lake Enghien (France)

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PROLIPHYC Project

The **ProlipHyc project** has developed a continuous in-situ monitoring system for cyanobacteria in freshwater ecosystems. It consists in a measurement buoy equipped with meteorological sensors and immersed probes to measure water quality parameters (see Fig. 1). This system is able to provide a long-term, high-frequency monitoring of lakes and reservoirs. Data set obtained can be used in order (Le Vu et al., 2010):

1) To build lake status indicators for daily, seasonal and annual water quality assessment and for comparison with other water bodies;

2) To collect surveillance data series to observe the general patterns of the aquatic ecosystem and to assess long-term changes;

3) To feed a statistical short-term forecasting model for early warning of cyanobacteria blooms;

4) To validate a deterministic model of cyanobacteria dynamics which may highlight the factors controlling blooms.

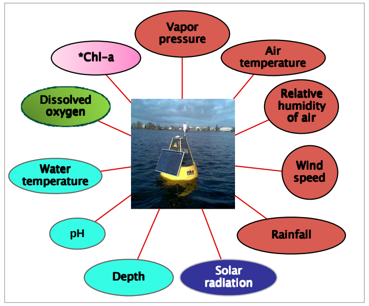

Fig. 1 : PROLIPHYC buoy measured variables (*Chl-a total and 4 phytoplankton groups)

Study site: Lake of Enghien-les-Bains

In 2009, such monitoring system was implemented in Lake Enghien-les-Bains (Paris suburbs, France, see Fig. 2 and Table 1). Lake Enghien is an urban shallow lake that plays a significant role in the stormwater management of its watershed by storing up to 100,000m³ 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 of *Planktothrix agardhii*, a potentially toxic cyanobacterium (Quiblier et al. 2008).

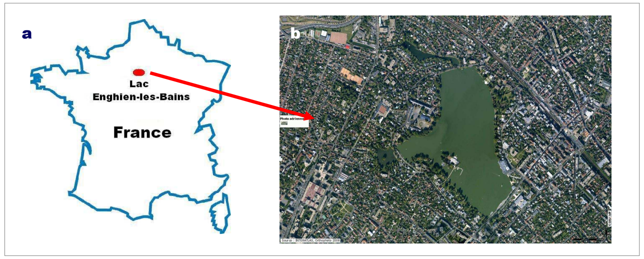

Fig. 2 : Lake Enghien: **(a)** Location in France, **(b)** Aerial vue of the lake and its neighbourhood (IAURIF 2008)

Lake				Watershed	
Mean depth	Max. depth	Area	Volume	Area	Population
1.3 m	2.65 m	41 ha	534,000 m³	54 km²	~ 200,000 inh.

Table 1: Lake Enghien characteristics

Water quality indicators

The time series can be used to infer indicators of cyanobacteria biomass, useful for lake management strategies. Three indicators, built from the raw time series, were proposed for Lake Enghien (see Fig. 3):

- Water temperature and oxygen saturation rate associated to daily maximal cyanobacteria concentration;
- Cyanobacteria daily variation rate

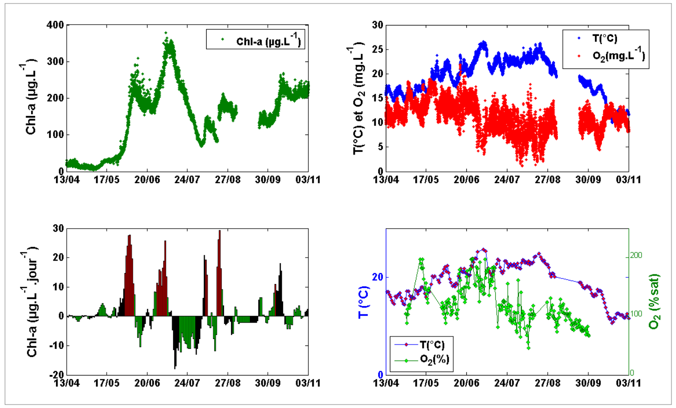

Fig. 3 : **Raw data: (a)** Chlorophyll-a concentrations **(b)** Water temperature and O_2 concentration. **Water quality indicators: (c)** Cyanobacteria daily variation rate **(d)** Water temperature and O_2 saturation related to cyanobacteria daily maxima.

Cyanobacteria modelling

The coupled model DYRESM-CAEDYM (DYCD) was used for deterministic simulation of cyanobacteria dynamics in Lake Enghien. DYRESM is a one-dimensional numerical model for predicting the vertical distribution of temperature in lakes and reservoirs (Imerito 2007). It was coupled to CAEDYM, the aquatic ecosystem model to simulate cyanobacteria dynamics (Hamilton and Schladow, 1997). The structure of DYCD coupled model is shown on Fig. 4.

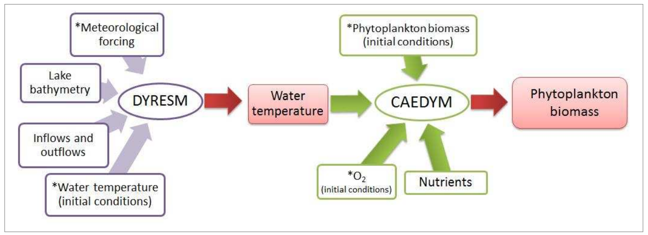

Fig. 4 : Dyresm-Caedym model structure (* Data from Prolipyhc buoy)

Parameter calibration was performed with data collected for 15 days (1-16 June 2009) and the validation during a 5-month period (17 June - 29 November 2009). Modelling results are presented for a 14-day period (2 – 15 July), when cyanobacteria biomass increased to the maximal concentration measured in 2009 and then decreased (see Fig. 5.b).

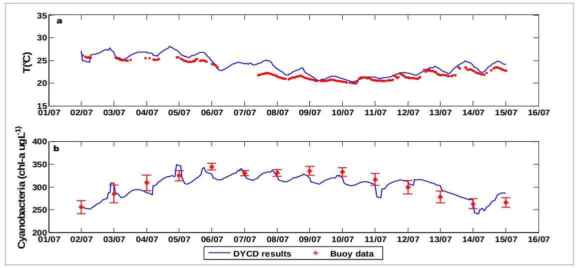

Fig. 5 : Data and modelling results in July 2009: **(a)** Water temperature and **(b)** Cyanobacteria. Red dots and error bars indicate the daily means and standard deviations.

Cyanobacteria forecasting

Two modelling approaches aimed at forecasting short-term *P. agardhii*'s dynamics are presented: the deterministic DYCD model and a neural network model (NNM).

DYCD predictive simulation uses weather forecast (© Météo-France) as meteorological forcing (see Fig. 4). The parameter values are those obtained by the 2009 calibration.

A recurrent neural network (Jeong et al. 2008; Diaconescu 2008) of Non-linear AutoRegressive with eXogenous inputs (NARX) type is applied at a 4-day horizon using:

- Cyanobacteria concentration and water temperature measured in the previous 4 days
- Air temperature forecasted for the next 4 days (© Météo-France)

Values measured from 1^{rst} to 30th April 2009 were used for the neural network learning step. The forecasting was then performed for successive 4-day periods from May to September 2009, a continuous learning being carried out on each previous 4 days. Short-term predictions of cyanobacteria biomass computed by NNM and DYCD for 04-07 July and 11-14 July 2009 are compared on Fig. 6. a and b.

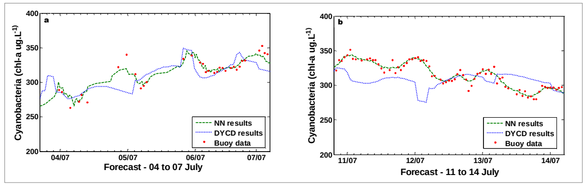

Fig. 6 : NNM and DYCD cyanobacteria forecasting in 2009: **(a)** 04-07 July **(b)** 11-14 July

The results of both models showed good agreement with observed values. The NNM performances benefited from the high frequency of the measurements. As it is easier to implement, it provides for lake managers an affordable support for anticipating cyanobacteria blooms.

Conclusion

This continuous in-situ monitoring and forecasting system for cyanobacteria in freshwater ecosystems provides high-frequency time series, compulsory for addressing research issues. It allows researchers to implement deterministic models of phytoplankton dynamics and stakeholders to assess long-term changes of the aquatic ecosystem functioning. Moreover, the measured data can be continuously processed to infer daily, seasonal or annual water quality indicators of the lake. Finally, a statistical short-term forecasting model can supply a prevision of the cyanobacteria biomass and possibly an early warning of blooms. The indicators and the forecasts can be displayed within an information system easily reached by the citizens and/or the stakeholders.

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