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

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Cyanobacteria play a key role in aquatic environment restoration because toxic species generate troubles to human health and disrupt lake uses. In order to better understand the cyanobacteria dynamics in fresh water bodies, a continuous in-situ monitoring system was developed by the PROLIPHYC research project, funded by the French National Agency for Research (ANR). This system consists in a measurement buoy equipped on the one hand with meteorological sensors and on the other hand with immersed probes to measure water quality parameters. Meteorological variables: shortwave radiation, air temperature, wind speed, vapor pressure, rainfall, water temperature, and water quality variables: dissolved oxygen, conductivity, pH and chlorophyll-a (total and corresponding to four different algal groups) are measured at a 15-min time step, and sent to a database as a daily email. This paper will discuss the advantages of continuous monitoring for both research and management purposes. In addition, two different modelling approaches coupled with the continuous in-situ data collection are presented through the study case of Lake Enghien (France).

Long-term, high-frequency monitoring provides a diversity of applications for lake management at various time scales: from a straightforward, real-time display of the data to a medium-term deterministic modelling of phytoplankton dynamics (Le Vu et al. 2010). More precisely, these data sets can be used in order: (i) to build lake status indicators for daily, seasonal and annual water quality evaluation and for the comparison with other water bodies; (ii) to collect surveillance data series to observe the general patterns of the aquatic ecosystem and assess the impact of long-term changes both in natural conditions and widespread anthropogenic activities; (iii) to feed a statistical short-term forecasting model in order to provide an early warning of cyanobacteria blooms; and (iv) to validate a deterministic model of cyanobacteria dynamics which may highlight the factors controlling blooms. In 2009, such a monitoring system was implemented in Lake Enghien, a shallow urban lake (mean depth 1.3 m, 41 ha) frequently affected by blooms of the cyanobacterium Planktothrix agardhii.

This paper firstly presents the treatment applied to the data time series to infer indicators of cyanobacteria biomass variation. In a second part, the short-time forecasting of cyanobacteria biomass is described. This model, a recurrent neural network (Jeong et al. 2008; Diaconescu 2008) of Non-linear AutoRegressive with eXogenous inputs (NARX) type predicts the growth of P. agardhii at a 3-day horizon, using the Chl-a concentration, the water temperature measured in the past 3 days and the air temperature forecasted for the next 3 days. Values measured from 1rst to 30th April 2009 were used for the neural network learning step. The validation was then conducted for successive 3-day periods from May to September 2009.

In the last part, the results of a medium-term, deterministic model are discussed. The water temperature and the cyanobacteria biomass are computed with the coupled one-dimensional hydrodynamic and ecological model Dyresm-Caedym (Hamilton & Schladow 1997) . The 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). The results of both modelling approaches showed good agreement with observed values. Their performances benefited from the high frequency of the measurements. Short-term forecasting provides lake managers with reliable information to anticipate cyanobacteria blooms. Medium-term modelling was considered convenient for modelling cyanobacteria dynamics in an urban lake. Moreover, a helpful tool to devise management strategies can be built by linking the Dyresm-Caedym model with a watershed hydrological model. This will allow us to propose different scenarios of watershed changes and then to simulate the lake response.

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