Application of the General Lake Model (GLM) to a large set of French water bodies

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ABSTRACT

We present an ongoing project whose objective is the application of the General Lake Model to study the thermal characteristics and long-term behaviour of the 476 largest French inland water bodies.

1 INTRODUCTION

Water temperature is one of the physicochemical parameters supporting the biological parameters in the Water Framework Directive. As such, it must be taken into account in the assessment of the ecological state or potential of inland water bodies.

Previously, though, it is necessary to know the thermal behaviour of water bodies under natural conditions in the case of lakes, taking into account interannual and intra-annual variability. For artificial and heavily modified water-bodies it is necessary to determine the thermal behaviour under the best ecological potential considering management technical constraints.

Although the availability of high quality temperature data is increasing thanks to continuous measurement systems, it is limited to a low number of water bodies. Instead, in the context of the recent meteorological conditions and different climate change scenarios, we intend to use the General Lake Model (GLM) to simulate the thermal behaviour of French water bodies under the scenarios of observed anthropogenic eutrophication and of no anthropogenic eutrophication. The effect of eutrophication will be approximated by way of water transparency.

2 DATA

2.1 *Complete set of water bodies*

This project aims to simulate water temperature in a set of 476 French water bodies of surface area above ~0.5 km^2, including 328 reservoirs, 64 natural lakes, 42 ponds, 36 gravel pit lakes and 6 quarry lakes.

Morphometric data (depth, surface area, and volume), geographic data (altitude, latitude, and longitude) and Secchi depth data were extracted from the French national lakes database ("plan_deau"), maintained by Irstea. Meteorological data were extracted from the 8 km resolution SAFRAN reanalysis [1], covering the French territory. Inflows were simulated by the model Loieau [2] and inflow characteristics were extracted through GIS processing from the CARTHAGE hydrographic database and DEM.

The main sources of data for the calibration of the model and the validation of the simulations were: 1) vertical in situ profiles of the French operational control and monitoring networks; and 2) satellite temperature measurements from the data set LakeSST [3].

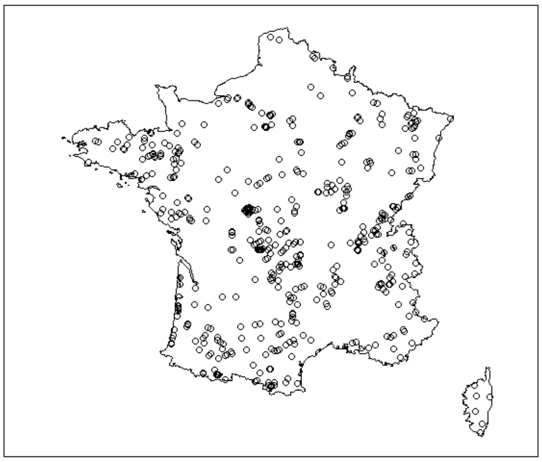

Figure 1. Location of the 476 studied water bodies.

2.2 *Individual sites*

Some sites were selected to test the application of GLM on a site by site basis. The criterion to select these water bodies was the existence of continuous temperature measurements and records of inflows and outflows. In some cases, regular Secchi depth measurements were also available. These data were provided by environmental agencies, water management bodies, enterprises, research groups, etc. Meteorological data were obtained from nearby meteorological stations. Efforts are under way to increase the number of water bodies in this data-rich set.

3 THE GENERAL LAKE MODEL (GLM)

The General Lake Model [4] simulates the vertical structure of water temperature, salinity and density in fresh water bodies. It is a physically-based model that takes into account surface heat exchanges, inflows and outflows and the main mixing and diffusion processes. We modified GLM v. 2.2 so that it could use a variable light extinction coefficient as input. GLM was already applied to simulate lake water temperature in a regional scale in [5], with an RMSE of 1.74 ºC for the surface temperature.

4 HYDRODYNAMIC SIMULATIONS

We coded a set of functions in Python 2.7 to read the available data and prepare the GLM input files. We followed a double approach depending on the set of water bodies used. At this stage, simulations were run without any calibration.

4.1 *Complete set*

We used a common simulation framework for the water bodies in the set. We used a constant light extinction coefficient. For reservoirs we assumed water was extracted from the bottom and that the outflow was equal to the total inflow. For the other types of water bodies, we assumed water left through a surface effluent, simulated as an overflow. The simulation period was 1999-2008, since Loieau simulated flows were only available till 2008.

These simulations will help us study the general error structure of the model. Preliminary results show a dependency of the mean absolute error (MAE) of surface temperature on lake altitude and/or lake depth (altitude and depth are positively correlated, Kendall's $\tau = 0.42$, p-value < 2.2e-16).

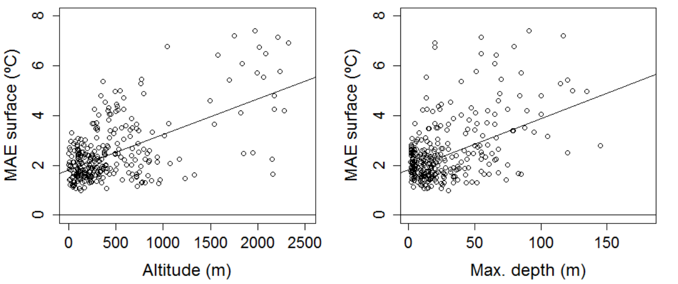

Figure 2. MAE of surface temperature as a function of lake altitude (left) and maximum lake depth (right).

4.2 *Individual sites*

The configuration of the model is adapted to the characteristics of the water body and available data. When enough data is available, we use a variable light extinction coefficient and the recorded forcing data.

We also ran additional simulations by replacing a forcing variable by the equivalent hypothesis used in the complete set simulations, to test the sensitivity of the model to the different hypothesis.

5 PERSPECTIVES

Our next steps include the determination of the cause of the observed error patterns, whether it is the model or the forcing hypotheses. After improving the simulations thanks to this information and calibrating the model, it will be possible to run simulations based on different water quality and climate change scenarios.

6 ACKNOWLEDGE

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