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Session L02 – Invited speaker
Real-time water quality forecasting in rivers using satellite data and dynamic models

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Abstract: Increasingly scarce water resources with growing global populations have exacerbated the problems of water quality in river systems and freshwaters in general. New methodologies to assess water quality and pollution issues are required and one approach is to make use of the increasingly valuable satellite data to predict environmental variables. A new approach to using these data has been demonstrated for the River Thames system and the Essex Colne River (UK), both of which are key water supply sources for London and South-East England, respectively. Satellite data has been used to create daily catchment average rainfall and temperature data and these data are used to drive dynamic, process based flow and water quality models in real time.

Keywords: *Water Quality Modelling, Rivers, Real-Time Forecasting*

1. INTRODUCTION

In the management and operational control of water resource systems, a major requirement is for information on present river conditions and on likely future changes in water quality. Water managers need to be able to respond quickly to emergency situations in order to protect and conserve water quality and maintain adequate water quality for public and industrial supply. Rising nitrate levels in rivers and groundwaters has placed pressure on water supply managers to keep public water supply reservoirs below the WHO limit of 11.3 mg/L for Nitrate-N. Spikes of high nitrate being flushed from catchments in late summer, once catchment soils have rewetted, can drive river and reservoir waters to high Nitrate-N concentrations which then require blending to ensure safe water supplies. At the same time there is increasing concern about the eutrophic effects of excess phosphorus and organic loads in catchments threatening ecology such as fish populations, macroinvertebrates and biodiversity. Also climate induced excess rainfall events trigger continuous sewer overflows (CSO) which affect the suitability of rivers and lakes for swimming and bathing due to the higher levels of pathogens in rivers. In this paper, we demonstrate a real-time monitoring and forecasting system for delivering water quality and flow information based on satellite data coupled to dynamic process-based models of flow and water quality.

2. METHODOLOGY AND RESULTS

In this paper we make use of the INCA suite of models (Whitehead et al., 1998a, Bussi et al, 2023) which have been developed specifically to be computationally fast as well as capture the key hydro-chemical, biological and dynamic processes affecting water quality. INCA has been applied to over 147 catchments worldwide, in every continent, so can be used in a wide range of climatic and terrestrial environments. Also, as the model is process based it can deal with any catchment size from a few hectares to thousands of square kilometers such as the Ganges or the Mekong. (See https://www.watres.com/software/INCA/ for further details and applications.)

The INCA model has been set up for 2 UK catchments (River Thames and the River Colne) and are driven by time series of data such as rainfall and temperature derived from the UK Met Office or online satellite data. Such real-time data have been used for many years for flood flow prediction but application to water quality forecasting has been limited. Here we demonstrate the application of a real-time forecasting system for both the River Thames in South-East England and the River Colne in Eastern England. Both are crucial rivers as they supply water to people and industry in London and Eastern England. Also, both have a very strong recreational following with many people enjoying the rivers for fishing, swimming, boating, rowing, canoeing etc and there are very active river trust and conservation groups monitoring and helping to manage the rivers and their tributaries (e.g. Thames 21, Action for the River Kennet and Oxford Waters Interest Group).

The overall strategy for the forecasting scheme is, as shown in Figures1 and 2, where satellite data are collected across a catchment or watershed and these data are then transformed and linked to a hydrological model and the INCA water quality model to generate flow and water quality data at key locations down a river system. The daily time series of flow and water quality data can then be displayed online to show recent and past changes in water quality. Also, rather like a weather forecast, the models and app can provide a forecast of the data into the future, up to 5 days ahead. This then provides a warning system for operational managers who might want to switch supplies if a significant pollution pulse is moving down the river system, or for other users of the river who might also want to avoid a pollution pulse. The forecast system can take advantage of the natural in-built dynamics of rivers, as all rivers have a delay transporting water down the system and this residence time can be significant (e.g. 2-5 days on the Thames). Also, rather like the weather forecasts, a probability can be assigned to any forecast, so that users can assess the forecast in terms of a familiar risk assessment.

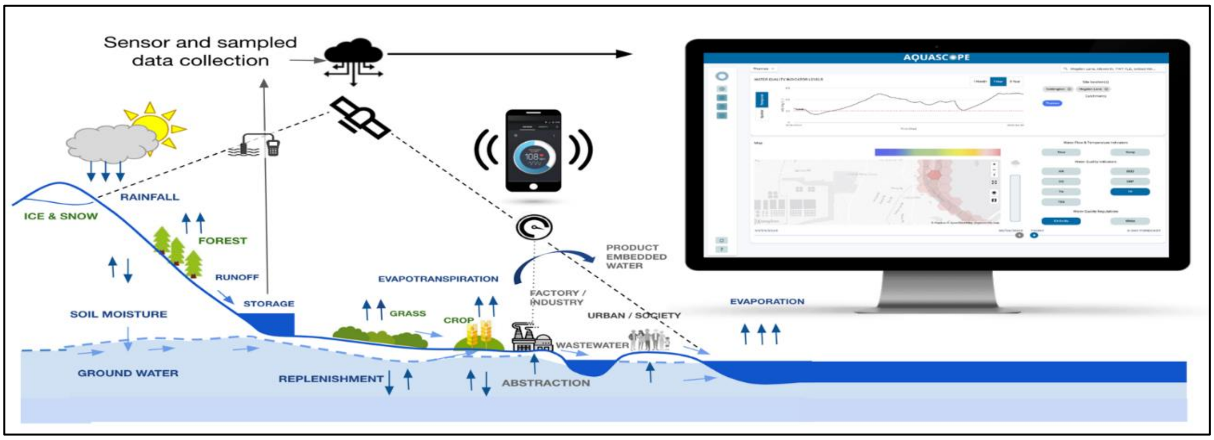

Figure 1. A typical catchment with water flows and sources of pollution from industry and farming, with satellites being used to monitor land use, daily rainfall and temperature with data being transferred via an online cloud system, with displays of rainfall, river flows and water quality on the system website.

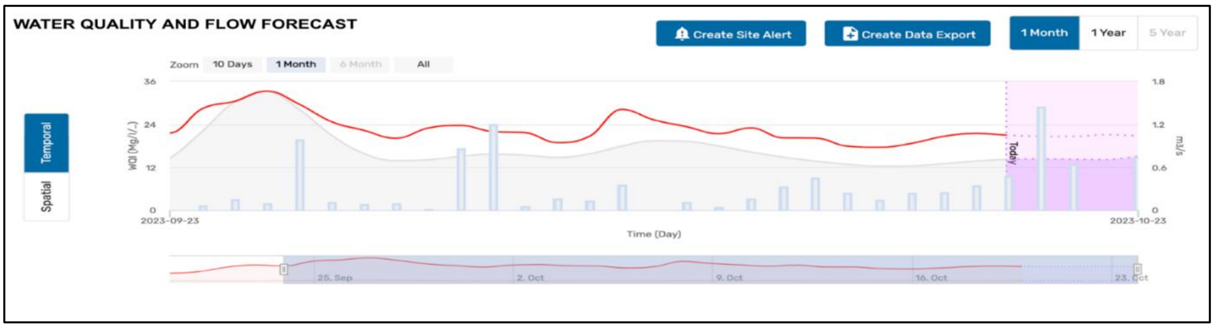

Figure 2. The Dashboard Display showing Rainfall, Flow and Nitrate Concentrations Simulated for the River Colne with a Three Day Forecast in pink.

3. CONCLUSIONS

The system presented here integrates data from multiple sources to enable satellite data, flow and water quality observations and models to work together in real-time to generate historical patterns of behaviour and forecasts for river systems. The models receive daily inputs of current and forecasted precipitation and temperature data which drive the real-time, daily water quality forecasts. All data, including historical records and real-time observations, are stored in a time series database and automated workflows, continually checking observed data against forecast data. The observed data acts as ground truth and helps fine-tune the model's parameters and predictions. This dynamic calibration process ensures that the system adapts to changing environmental conditions and is continuously improving. The entire workflow operates within a Software as a Service (SaaS) platform, making it accessible to a wide range of users and organizations. Users can access the daily water quality forecasts through an intuitive and user-friendly interface, allowing them to set up early warning alerts and conduct scenario modelling.

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