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How to use new online monitoring techniques to improve river water quality modeling at the river reach scale

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Abstract: High spatial and temporal resolution monitoring systems are needed to improve our knowledge on flow and matter transport pathways and substance transformation. The presentation will introduce a new online water quality monitoring system as part of the UFZ TERENO Hydrological Observatory “Bode” and show how this new information can improve river water quality modelling. Additional low flow measurement campaigns including delta ^{18}O and delta ^{15}N isotope analyses of nitrate have been used to identify denitrification processes on a selected lower river reach. It will be demonstrated how high resolution data can be used in combination with a process based river water quality model (Boyacioglu et al. 2011) to improve model identification. The multi objective calibration helps in combination with cross validation to assess the information content of the data (Rode et al 2007). It is explained how a sound monitoring concept can be used in combination with process-based river water quality modelling to improve our knowledge on in-stream nutrient retention.

Keywords: Water Quality Model, Online Sensors, Multi Objective Calibration

1 INTRODUCTION

River water quality models are increasingly used to assist in solving complex problems in the management of water resources at the river basin scale. These models (e.g. Quale2E, WASP5, Mike 11) are implemented in order to quantify the substance transformation in lotic waters and to investigate the impact that changed boundary conditions have on the aquatic system. The data requirements for water quality models increase with the complexity and scope of application and can be specific to the management question at hand. Because process-based river water quality models in general describe biological mechanisms like phytoplankton growth or grazing by zooplankton, they are typically characterized by a high complexity and a large number of parameters, and therefore the equifinality problem is accentuated (Arhonditsis et al., 2006). Thus, a critical decision when selecting and/or developing a water quality model is the determination of the optimal model complexity for evaluating the effects of the potential management actions with an acceptable level of uncertainty.

A sound model identification comprising model calibration, validation and uncertainty analysis is a prerequisite for reliable predictions and scenario analysis of management actions and/or changing land use and climate. A calibrated model incorporates acquired knowledge about the systems (Beck (1991). Calibration does not only aim at finding parameter sets minimising a given objective function, but also at reducing the uncertainties of parameter values as well (e.g. Kuczera 1997, Gaume et al. 1998, Rode et al. 2010). Limited calibration data result in non-uniqueness of the optimized parameters; therefore, it is often difficult to identify a parameter set of a specific water quality model with a sufficient degree of certainty.

The simultaneous use of more than one model output variable can improve parameter identifiability (Gupta et al., 1998, Rode et al., 2007).

Recently new measurement techniques have been made available that allow the monitoring of a set of water quality variables with a temporally high resolution. These new techniques are able to measure not only conventional parameters like temperature or electric conductivity but also parameters like DOC or Nitrate-N. Because of the use of optical sensors, measurement can be conducted on 1 minute interval. A well implemented system of monitoring stations may allow getting new insights into transport mechanism of matter fluxes from land to water as well as into in-stream matter transformation and the modelling of these processes.

The objective of this presentation is therefore to introduce a new water quality monitoring system at the Bode River, Germany and to present first results of online measurement as well as low flow related measurement campaigns at a lower reach of the Bode River. Furthermore we will show how such data can be used identifying current state of the art river water quality models like WASP7 model (7th version of Water quality Analysis Simulation Program), which has been developed by the U.S. EPA (compare also Boyacioglu et al., 2011). It is aimed that the outcomes of the study will give information on how to adjust water quality monitoring schemes to reduce uncertainties in water quality predictions.

2 MATERIALS AND METHODS

2.1 The study area and data

The Bode catchment is part of the Saale river system. The Bode River is one of the best hydrological and meteorologically equipped meso-scale catchments in eastern Germany (long term data on climate, precipitation, discharge, and water quality parameters). The Bode River has a total size of 3297 km² with a dense discharge gauge station, precipitation and climate gauges network (29 discharge gauge stations, 2 rain gauge stations/100km²). The Bode River is moderately to heavily polluted by the nutrients phosphorus and nitrogen where diffuse inputs have a share of 77.2 % (nitrogen) and 70.2 % (phosphorus) with area weighted diffuse loads of 14.5 kg N/(ha/year) and 0.64 kg P/(ha/year). Within the frame of the implementation of the Global Change Hydrological Observatory (GCO) "Bode", a measurement program of high resolution water quality data is conducted at the Bode River. These new data will be made available for the proposed work. Water quality data from 6 on-line water quality measurement stations will be available at the river discharge gauge stations Silberhütte, Meisdorf, Hausneindorf, Thale, Hadmersleben and Stassfurt. Water quality multi-parameter probes provide continuous measurements (10-15 min frequency) of the water quality variables electric conductivity, temperature, pH-value, nitrate-N, ammonia-N, soluble oxygen, turbidity and chlorophyll a and SAC (specific adsorption coefficient) which can be used as surrogate for DOC. Additionally a regular biweekly sampling scheme has been implemented for further water quality constituents like phosphorus compounds. Beside these data long term monitoring data in the Selke/Bode River system at monitoring stations (Hedersleben, Wegeleben, Nienhagen, Oschersleben Staßfurt and Neugattersleben) are available on a monthly interval. These data comprise among others nutrients, salts and suspended sediments.

To investigate in-stream nutrient turnover, automatic samplers have been installed at all water quality monitoring stations. These samplers allow investigating further water quality variables which can not be measured with online sensors. We used these samplers for three low flow measurement campaigns at the river reach between Hadmersleben and Stassfurt in 2010 and 2011. All nitrogen compounds (nitrate-N, ammonia-N, nitrite-N, total N) have been analysed using a two hour sampling interval for two days at both monitoring stations. Because during low flow situations no tributaries contribute discharge to the selected river reach the measurements allow balancing nitrogen and identify nutrient losses within the 30 km river reach.

Water quality modelling will be carried out with the new WASP7 model including the new periphyton and phytoplankton modules which have recently been developed. Model calibration will be conducted based on upstream and downstream continuous measurements of nutrient compounds, Chlorophyll a as well as dissolved oxygen concentrations.

3 RESULTS

The online measurements of Chl a clearly reflect the occurrence of two algae blooms in summer 2010. Chl a concentrations reached high levels of 62 $\mu\text{g/l}$ and 82 $\mu\text{g/l}$. Figure 1 shows a clear diurnal variation of algae concentrations. This diurnal variation is also found for nitrate-N concentrations. This gives a clear indication of nitrate-N uptake by primary production and algae growth. Nitrate-N concentrations can vary 10% between day and night time during periods with high algae concentrations. The nitrogen balance calculations for the three low flow sampling campaigns suggest a loss of nitrogen between 10 and 20 % in the 30km reach. Losses were highest in August 2011 and lowest in October 2010.

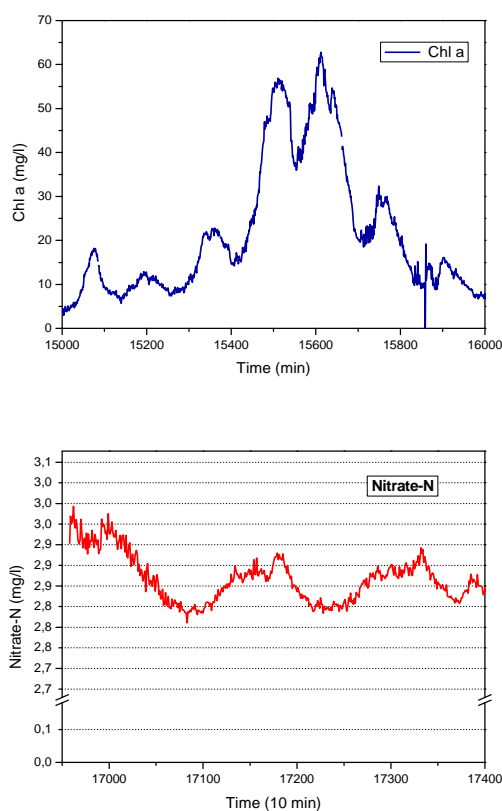


Figure 1. Chl a and Nitrate-N diurnal variations in summer 2010 at Stassfurt gauge station

These high nutrient resolution data allow simulation of nutrient in-stream conversion with high accuracy and distinguishing internal processes like primary production of phytoplankton and periphyton and associated nutrient uptake as well as further nutrient losses caused by in-stream denitrification. We will demonstrate how these processes can be identified using a combination of high resolution monitoring data and process-based river water quality modeling (WASP7). It is expected that the output of the research will assist the development of monitoring schemes to support the use of predictive river water quality models. The research can help to generate cost effective monitoring schemes by identifying data and data types with most information content and highest value for reducing predictive uncertainties of the applied river water quality model. It can be expected that the

findings are not restricted to German environmental conditions and the suggested calibration procedure is in general also applicable in catchment with deviating conditions outside of Germany. If online sensor technology data are valuable for the application of river water quality models the project may also support this monitoring technology abroad.

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