MuDak-WRM: Multidisciplinary data acquisition as key for a globally applicable water resource management

Sustainable management of reservoirs – defining minimum data needs and model complexity

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ABSTRACT

The overall objective of the MuDak-WRM project is the development and application of a globally applicable management system for reservoirs and their basins. To succeed in this development, two major sub-goals have to be fulfilled. We will develop a methodology for a minimum monitoring to assess water quality. Additionally, the complexity of existing models needs to be reduced, to address globally restricted data and budget availability. The project includes monitoring of catchment and in-lake processes. Two case study sites were selected beforehand, the Große Dhünn reservoir in Germany and the Passauna reservoir in south-east Brazil. The monitoring results used for model parametrization lead to an improved system understanding, which again is the basis to define crucial monitoring parameters in space and time. With this information the efforts for an effective water quality observation will be reduced. A continuous assessment of the mass flux into the reservoir, water quality changes inside the reservoir as well as seasonal land cover changes have been successfully monitored in high resolution for an entire year. At the same time a water balance model has been set up in close relation to a catchment emission model.

INTRODUCTION

The core product of MuDak-WRM is a model for the prediction of medium to long term changes in water quality in reservoirs which is as simple as possible and uses globally available data. The key aspect is to reduce the complexity of the underlying scientific-mathematical approaches and the data required for the future model to enable the application of the model with reasonable effort and in a meaningful way in developing countries. The interdisciplinary research group on the German side is a consortium of four research and five industry partners. Each work package is handled by one or two German partners. On the Brazilian side, three research and four industry or public partners are involved in the project, so that the areas of competence are mirrored. In most cases the used models for water quality prediction and decision support for reservoir operators are too complex and data demanding for a world wide application. Limited understanding of processes in the catchment and the reservoir, so far hinders the development of simplified approaches. The project hypothesis is, that water quality of reservoirs changes on long-term scales due to changes in the catchment (input fluxes), and that these reactions can be modelled and verified by the assessment of monitoring data. The MuDak team aims at providing an applicable approach, which can be used by international reservoir operators and authorities to describe the actual status of one reservoir and to assess the potential future development of water quality under consideration of certain management options, like afforestation and waste water treatment plant development. This approach will deliver answers to achieve the sustainable development goals (SDGs).

METHODS

To solve the addressed challenges and to answer the scientific questions the project consortium is split into three methodological-technical parts. Three work packages produce primary data from field measurements, which is passed on for in-situ verification and the validation of models. Three work packages set up and adapt a water balance model (LARSIM) (Ludwig & Bremicker 2006), an emission model (MoRE) (Fuchs et al., 2017) and a hydrodynamic model combined with a water quality- and sediment transport model (Delft 3D) for the case study and derive approaches for a reduction of complexity (Figure 1). In order to reduce the complexity, the models are first developed to run with the best possible input data. From this stage on the input data will be reduced in terms of temporal and spatial resolution as well as measurement quality itself. Unnecessary model parts can be excluded from the calculations to reduce complexity. The aim is to find the minimum data demands for the models and to still reproduce the critical water quality status in a reservoir and the related long-term usage of the reservoir. The third part works on the integration of both, campaign-based and as real-time data, into a web framework that allows for standardized measurement data exchange among software components. This framework is called the Sensor Web (Botts et al. 2008).

The principal workflow is developed along two reservoir case studies (Figure 2). The first region, Große Dhünn reservoir (managed by Wupperverband), is used as a "best case" scenario in terms of data availability. The developed models are transferred to Passauna reservoir (managed by Sanepar), where a long time series of quality data and catchment information is missing. After further development and reduction a final simplified model version will be produced. This model will be applied by the reservoir operator in the Piraquara 2 catchment to predict water quality changes of the reservoir. By the transfer to a new catchment the functionality as well as the transferability of the product can be assessed.

Monitoring encompasses activities in the catchment like continuous water sampling at the river inflow to assess the particle and nutrient flux to the reservoir, sediment and soil sampling and the analysis of satellite imagery (Sentinel-1 with radar sensor and Sentinel-2 with optical sensor, revisiting time of ca. 6 days) to retrieve land use and land cover change and further model input parameters like Albedo- and LAI (Leaf Area Index).

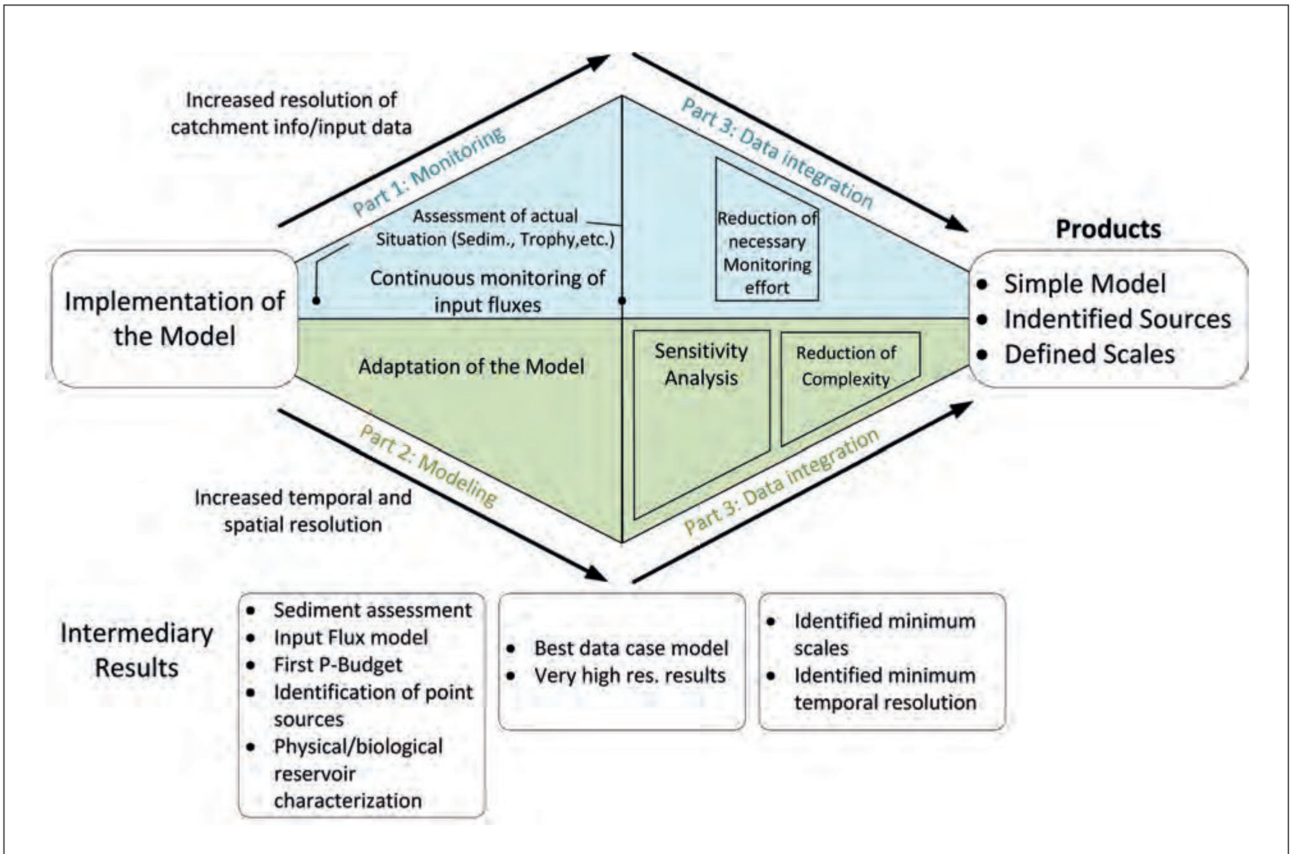

Figure 1: Methodological project approach.

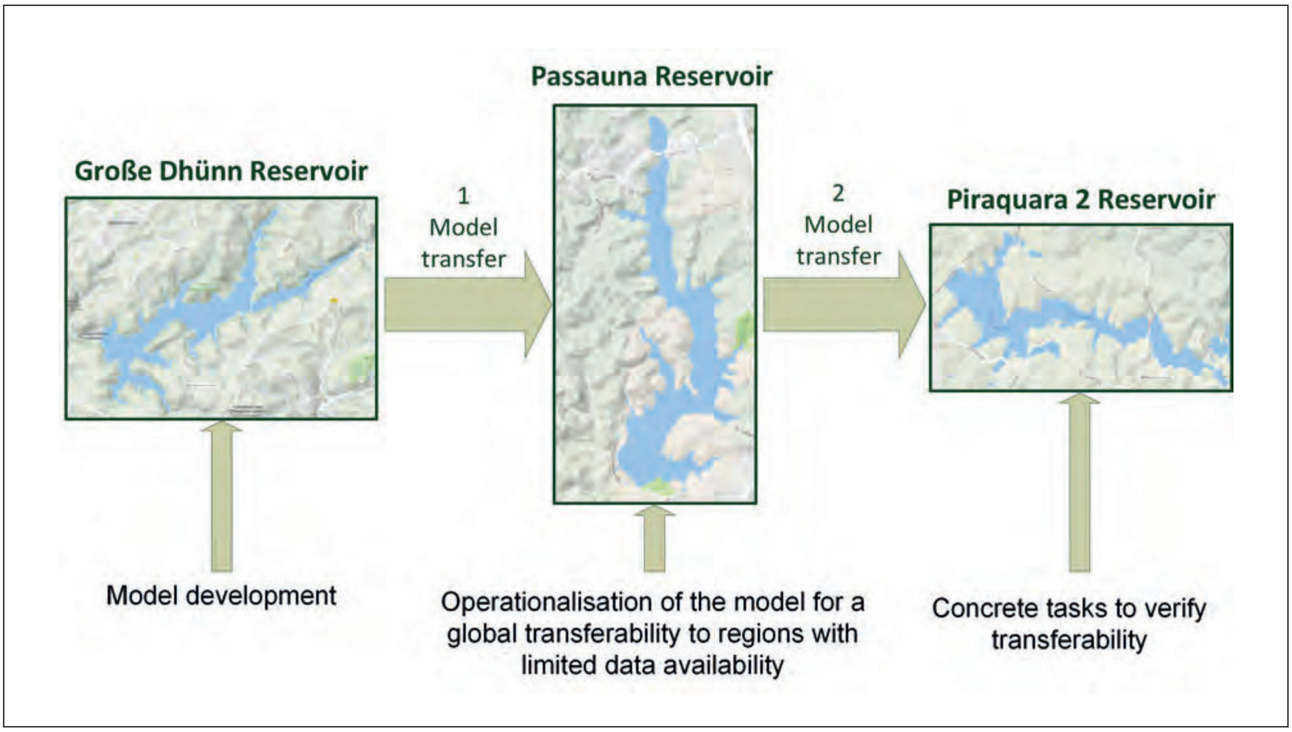

Figure 2: Model development and case study transfer work flow

Reservoir monitoring includes real-time water quality measurements on a platform (Figure 3) at the water intake in Passauna reservoir combined with monthly water sampling campaigns. Additionally an upward looking Acoustic Doppler Current Profiler gives insights in internal flow velocities and flow directions. The detailed investigation of in lake processes is complemented by campaign-based drone flights to better understand the spatial distribution of quality parameters (e.g. turbidity and chlorophyll conc.) and to bridge the information to the satellite imagery.

INTERIM RESULTS AND DISCUSSION

During four individual large measurement campaigns at Passauna and three measurement campaigns at the Große Dhünn Reservoir pre-dam the actual ecological and operational state of the reservoirs was evaluated. Water quality sensors were successfully tested at the Große Dhünn reservoir and were installed permanently later on in the Passauna reservoir. The Wupperverband has been operating a Sensor Web framework since more than ten years and serves a smaller set of real-time-data for the reservoir. During the project this homogeneous measurement data pool is extended by sampling data, taken during the project measurement campaigns. All data is available to researchers and the operators in a standardized manner.

Sedimentation assessment revealed that the siltation process in the pre-dam of the Große Dhünn reservoir is relatively slow due to limited erosion in the catchment. In contrast to this, the Passauna reservoir is affected by significant siltation and accumulation of nutrients, even though the actual status is mesotrophic. Continuous water sampling is ongoing and therefore final data and water quality model results are not available yet. However, for the big pre-dam of the Dhünn reservoir, the impact of various numerical and physical parameters was examined in sensitivity analyses adopting a 3D model. Collected input data for the hydrological model and the emission model was pre-processed and the first model runs were conducted. At the moment the modelled water balance is integrated into the emission model to calculate the sediment and nutrient flux into the reservoirs. The emission model results then will be validated by the measured fluxes in the rivers.

Partners from all work packages participated in an extended training and transfer session during five days. In parallel to the monitoring activities, the applied methods and tools were explained to employees from the operating company in theory as well as in the field. Additionally, bi- and trilateral meetings took place to exchange work package-specific demands from the company and authorities.

CONCLUSIONS & OUTLOOK

In order to investigate the formulated research hypothesis and to increase the process understanding as well as to reduce the model complexity and data demand, the following steps have been accomplished so far. In February 2019 the one year continuous measurement will be completed and obtained data will be processed to feed the models. The following steps were completed successfully:

- One year of continuous input flux monitoring at the Passauna River.
- Using satellite remote sensing to derive land use classes and several model parameter values
- Long-term high-resolution measurements of water quality in the reservoir and over 10 intensive sampling campaigns conducted.
- Testing of cutting-edge monitoring technology (hyperspectral sensors (drone- & boat-based), sediment penetration measurements, optical in-situ quality sensors)
- Real-time water quality data integration with the Sensor Web
- 3D numerical sensitivity analyses for one pre-dam of the Dhünn reservoir focusing on the effect of stratification processes on fine sediment transport.
- Watershed emission modelling and water balance modelling completed.

On a cooperation level, the MuDak-team is exited, that an intense and fruitful cooperation was established with Sanepar, a Brazilian reservoir operator as well as two Brazilian universities (Federal University of Paraná and University Positivo), several authorities and The Nature Conservancy (TNC). Sanepar contributed to the project with logistics, data access and even funding to purchase a joined research vessel. The universities contribute by providing 10 scholarships for PhD students working on different parts of the MuDak project.

After the finalization of the models (LARSIM, MoRE and Delft 3D) the sensitivity analysis will be performed. The models will be tested to produce relevant and correct results with reduced and simplified input data. Towards the end of 2019 central quality parameters together with temporal and spatial resolution demands will be defined. The Sensor Web framework, which already organizes data for the Große Dhünn reservoir will be extended with data from Sanepar to seamlessly access and visualize information on the Web. Not only will the product be introduced to potential users, but also will we distribute the scientific and technical outcomes to a broad range of target groups inside and outside the scientific community.

The MuDak-WRM team thanks all Brazilian partners and especially the colleges from Sanepar and the UFPR for huge efforts in the field, laboratory and for a great cooperation.

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