Online Groundwater Model

for Irrigation Water Allocation in the Heihe Mid-reach, China

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1. Background

The project

The project entitled "Rehabilitation and management strategy for over-pumped aquifers under a changing climate" is a Sino-Swiss research project funded by the Swiss Agency for Development and Cooperation (SDC). It tackles the challenges posed by groundwater over-pumping in arid regions in the context of climate change on two pilot sites in China: the **Heihe River Basin** (Gansu Province) and **Guantao County** (Hebei Province, North China Plain). The core element of the project is the implementation of a **real-time groundwater monitoring, modelling and controlling system.** The key notion is to explore the potential and the application of modern scientific knowledge and technology in the field of water resources on two real-world case studies.

The site

In the Heihe River Basin restrictions in surface water abstraction and an increase in groundwater pumping have lead to a lowering of the groundwater table. Surface water is centrally managed and distributed through a top-down network of irrigation canals. Meanwhile, groundwater wells are numerous, scattered across the region and privately owned, thus making reductions in pumping hard to enforce. The water authorities have responded to aquifer overexploitation with the introduction of IC-card metering systems on agricultural wells. The IC card carries the water right of each user and pumps will stop operating once the quota is exhausted. This will allow to control the pumping rates in order to prevent further groundwater depletion and eventually foster water table recovery. Likewise, the availability of automatic monitoring data offers new opportunities to improve the decision-making process by means of introducing feedback mechanisms into the irrigation water cycle.

2. What we developed

We close the feedback loop by introducing an online groundwater simulation tool for the local authorities, which is periodically updated and recalibrated using monitoring data. The goal is to facilitate the planning of irrigation water allocation with respect to its impact on local and adjacent groundwater levels. Understanding the heterogeneous temporal and spatial response of the aquifer to anthropogenic impacts as well as its interaction with other elements of the water cycle (e.g. streamflow, infiltration of irrigation water etc.) presents a challenge. Our tool, based on a finite differences numerical groundwater model (MODFLOW), captures these systemic properties and allows the decision maker to assess the effect of different water allocation scenarios. The novelty concerns the fact of the model being embedded in an interactive web-interface, accessible to the user through the internet with all standard web browsers of computers, tablets or smartphones.

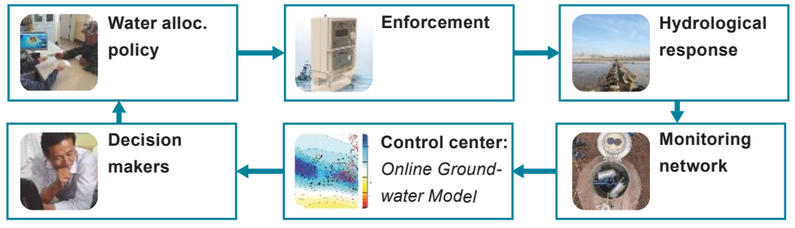

Fig. 1. Control feedback loop: hydrological monitoring data is routed to a control center where it is used to drive decision support systems. The decision makers can use these models to improve their understanding of the system and conduct scenario analyses.

3. Features of the tool

3.1 Easy online accessibility: a novelty in the realm of groundwater modelling

Traditionally, most groundwater studies have eventually been condensed and delivered in the form of reports. These contain a set of scenarios addressing different operational alternatives, sensitivities and uncertainties. The reason is partly, that the deployment of a groundwater modelling software requires specialized expertise and can often be performed by professional modellers only. We introduce a simplified and customized interactive shell where the groundwater model itself is made available to the user (client) not acquainted with those technicalities. The application can be accessed and operated remotely through a website regardless of location and device. Such an interface offers an entirely new perspective on groundwater modelling by allowing the users themselves to instantly design and experiment with management alternatives.

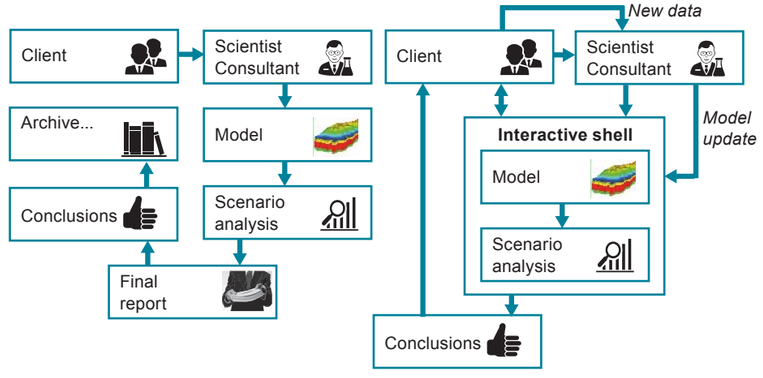

Fig. 2. Proposed approach, where the model itself is embedded into an interactive shell and made available to the client to experiment with.

3.2 Efficient updating and maintenance

Upon availability of new data or other information, the model can be recalibrated and updated remotely. Periodical updates incrementally improve the model and thus enhance the predictive quality of the forecast. Updates include for example changes in model structure resulting from new insights, recalibration upon new data availability or filtering updates (e.g. using Kalman Filter) where initial conditions and parameter ensembles are updated.

3.3 Instant response and fluid interaction

The scenario settings can be manipulated through sliders and drop-down menus. As the sliders' values are modified, the model will immediately recalculate and display the new results. This is made possible using reactive elements. The numerical model as well as the back-end interaction between user-interface and MODFLOW are conceived such as to use minimal computational resources. On the current hosting server calculation time, including data transmission, amounts to 3-4 seconds per run.

3.4 Customized user friendly operation

The user options of the present version have been tailored to the needs of the water authorities in the Heihe River Basin. The graphical user interface could however also be modified and linked to other parameters. The fundamental settings for the Heihe Basin authorities currently include:

- The selection of one out of 21 irrigation districts
- Specification of the irrigated area within the district
- Modification of the irrigation water requirement per unit area (e.g. by water saving irrigation or change of cropping system)
- Modification of the ratio of surface water to groundwater use
- Variation of the forecasting time horizon

Advanced options include simulation of changes in streamflow or boundary inflow, resulting for instance from changes in flow regime due to climate change.

3.5 License free software

The utilized software including operational system is free of charge and available as open source. The graphical user interface was created using the Shiny application by RStudio.

3.6 The Model

The actual MODFLOW groundwater model is based on a 129x156-cells structured grid of 1kmx1km square cells in a single layer. It includes: 1) the interaction with the stream, 2) recharge from irrigation infiltration 3) drainage from springs and wetlands and 4) the boundary inflow from seepage on alluvial fans at the foot of the surrounding mountains.

More information: www.ifu.ethz.ch/GWM

Try it out now! ⟶ http://129.132.30.22

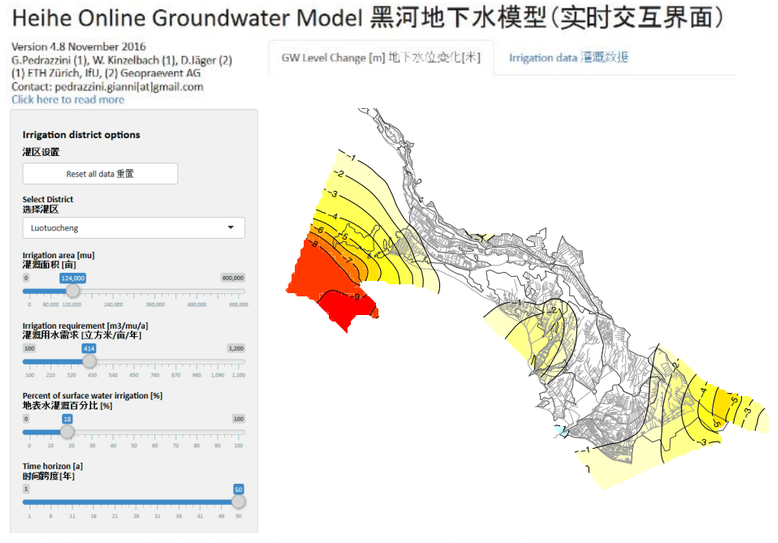

Fig. 3. Screenshot of the interactive Online Groundwater Model user interface. The contour map shows the predicted changes in groundwater level for the current scenario (red: increase, blue: decrease).

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