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Integrated water resources assessment: an approach for information exchange between natural science and socioeconomic models

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The assessment of the state of water resources has become a major concern in science and practice; mainly as a consequence of the implementation of the EU water framework directive but also in view of global climate change. It has become apparent that - in particular in global change research - it is inevitable to look at processes in an integrated way. An important tool in evaluating current and future developments in the water cycle are models that integrate the main physical components of the water cycle such as atmosphere, biosphere, rivers and groundwater with the socioeconomic part, i.e. human activities (water demand, land use etc.). A particularity of such integrated, coupled systems is that they are usually applied to river basins or catchments, i.e. the large scale. As fully integrated (holistic) model concepts do not exist (yet), the only means of integration is the coupling of existing disciplinary models. Model coupling, especially on the large scale, is always challenging and brings up interesting new questions. Here one of the most urgent questions however is how natural science models can be meaningfully and realistically linked to socioeconomic models, in particular if the latter are not just simple input-output models but equipped with a certain decision making potential. No matter if these 'decisions' are based on simple rule sets or on more sophisticated concepts, they rely on well interpretable information on changes within their domain of interest. In this respect, the 'decision making' model is not much different from a human decision maker who monitors his environment, samples information, analyses it and comes to a decision accordingly. Information provided by natural science models could be values of temperature and precipitation at a location, soil moisture, groundwater level or river discharge at a gauge. It is, however, not very helpful if such values (calculated for a specific location or area and a specific

point in time) are sent to the socioeconomic model without any interpretation. To give just one example to make this more transparent: a groundwater level value or even a groundwater time series cannot be interpreted meaningfully without the knowledge of a groundwater expert. A groundwater level trend cannot be interpreted without knowing the hydrogeological conditions of the location where it was calculated (or measured). In addition, a level calculated for a specific location is often not desirable in decision making. Here general trends and effective values for large areas are of greater importance.

In this contribution an approach for information exchange from natural science to socioeconomic models is introduced that was developed and first applied in the integrated project GLOWA-Danube (www.glowa-danube.de). It was mainly designed and first tested to provide information calculated by a groundwater flow model, a SVAT (soil vegetation atmosphere transfer) model and a river network (hydraulic) model to an actor based water supply and distribution model. The latter is a socioeconomic model in the sense that it simulates the decisions that water supply companies make if changes on the demand or supply side in their domain take place. The application of this approach is currently being expanded to other natural science - socioeconomic links in GLOWA-Danube. The essential purpose of the approach is the assessment of the quantitative state of groundwater resources. Groundwater resources in general are especially difficult to assess because of their three-dimensional nature, their limited accessibility and the resulting lack of data. Groundwater quality parameters can easily be measured if wells and boreholes are available but are often difficult to regionalize. The main focus of this contribution however is on the assessment of groundwater quantity. Groundwater quantity (or availability) has two aspects: water supply and the role of groundwater in ecology. In water supply the main question is if the water availability can meet the current and future demands (sustainability) of all current and potential future consumers. The first problem here is that the extent of a groundwater resource (width, depth ..) can not exactly be defined. A second problem is related to the main parameters that can be used in the assessment: groundwater (piezometric) levels and groundwater recharge. Even if they can be determined very accurately, the actual values of both parameters cannot directly be related to the actual quantity stored in a groundwater body or to the amount available in the future. For all future predictions, a trend analysis of the past is necessary. Unfortunately, every groundwater body reacts differently: reactions to changes of outer boundary conditions (withdrawal, climate change etc.) are damped and delayed; exchange with other aquifers takes place.

The developed approach is a generalized conceptual model to assess groundwater bodies on the regional scale based on a small set of physically-based, intuitively-understandable parameters and groundwater body characteristics. This model contains

a) an approach for meaningful, scale-appropriate delineation of groundwater bodies based on surface catchments and their intersection with active layers of the groundwater model, and b) a method to assess the state of such a groundwater body based on its geometric and hydraulic properties and a time series analysis of groundwater levels, groundwater recharge and river discharge. The assessment is carried out individually for each groundwater body. As a result a so-called 'flag' is calculated for each groundwater body and time step (here: one month), which can assume five discrete values (1...5). A value of 1 means very good, a value of 5 is very bad. Any decision maker or actor in a socio economic model can now use these simple, pre-interpreted values in its decision making process. It is very important to note that this approach leaves room for individual needs and preferences of each actor. The flags can be interpreted as warnings, prohibitions or laws and they can be fully abided or completely ignored, which seems to be an accurate analogy to reality. The advantage of the approach lies in the circumstance that the results are very simple and intuitively understandable but at the same time based on a thorough expert analysis of the natural conditions. It can be easily adapted to the particularities of any natural science and socioeconomic model and thereby fulfils the requirements needed to meaningfully couple them.