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

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Abstract

The present and future state of our water resources has become a major concern in science and practice – not only because of the European Water Framework Directive. In particular in Global Change research it is inevitable to look at processes in an integrated way. An important tool 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.). One important question is, how natural science models can meaningfully and realistically be linked to socioeconomic models.

In this contribution an approach for information exchange from natural science to socioeconomic models is introduced. The essential purpose of the approach is the assessment and communication of the quantitative and qualitative state of groundwater resources on the regional scale. It is based on a small set of physical, intuitively-understandable parameters and groundwater body characteristics. As a result a so-called ‘flag’ is calculated for each groundwater body and time step which 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 approach was developed within the framework of GLOWA-Danube and implemented in the DSS DANUBIA. The socioeconomic models in DANUBIA follow a multi-actor approach. (e.g. a farmer or a household type) base their decisions (e.g. decisions on crop types) partly on these flags.

Principles of Groundwater Resources Assessment

Groundwater resources are difficult to assess because of their three-dimensional nature, their temporal variability and the resulting lack of data. One problem here is that the extent of a groundwater resource (width, depth) can not be exactly defined – impermeable, well defined boundaries do only exist in textbooks. The main parameters included in the assessment are groundwater (geostatistical) levels and groundwater recharge which can usually only be determined point wise or not very accurately. Actual values of both parameters can not directly be related to the actual stored quantity in a groundwater body or to the amount available in the future. For that purpose a trend analysis of the past is necessary. Every groundwater body reacts differently: reactions to changes of outer boundary conditions (withdrawal, climate change etc.) are ramped and delayed, exchange with other aquifers takes place. Simple schematic examples are shown below:

Example 1: Reactions of two simple schematic aquifers with different geometrical properties to recharge. Even if the same recharge rate leads to the same head change the consequences for the status (both in terms of supply and in ecology) is quite different.

Example 2: Reactions of three schematic aquifers with different density to the groundwater table (A and B) or covered by impermeable layers in the unsaturated zone.

The approach to assess and interpret the state of Groundwater Resources

The presented approach is a scale-appropriate delineation of groundwater bodies and a method to assess the state of such a groundwater body (zone) based on its geometric and hydraulic properties and a time series analysis of groundwater levels, groundwater recharge and river discharge. A ‘flag’ is calculated for each groundwater body and time step (here: one month). Any decision maker or actor in a socioeconomic model can now use these simple, pre-interpreted values in its decision making process. 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 - as in reality.

Changes of natural systems are usually measured and quantified by means of characteristic parameters (here e.g.: recharge and groundwater levels). However, changes of these parameters cannot be used as absolute measures of the state of a groundwater resource since they include site specific characteristics. Consequently, they can not be used directly in decision making: they have to be interpreted. A groundwater level or a groundwater level time series can only be analyzed meaningful by a groundwater expert, who knows the local hydrogeological characteristics of the site where the measurement was taken. To couple natural science models and socioeconomic models meaningfully and realistically it is therefore necessary to include this expert knowledge in the modelling process and interpret physical signals into categorized intuitively understandable output.

Conclusion 2: The state of a resource has to be categorized in order to be used in decision making – to make the decision making process transparent and understandable for all actors (or models) involved. The approach suggested here aims at bridging a gap between groundwater experts and decision makers. Complex processes are reduced to flags: everything is fine (1), critical situation (2), catastrophe situation (3).

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was developed within the framework of the Global Change research activities and is an important tool to support the decision making process.

The assessment of Global Change impacts on the availability of water and the sustainability of water resources management activities is a key issue in integrative hydrological research. The development of methods for sustainable water resources management under globally changing boundary conditions requires the integration of transdisciplinary expertise. The principle objective of the GLOWA-Danube project is to support the analysis of water-related Global Change scenarios and the investigation of sustainable methods for future water resources management in the Upper Danube Basin (77,000 km²) by means of the Global Change decision support tool DANUBIA.

DANUBIA

DANUBIA integrates 16 natural and socio-economic simulation modules within five main components: Atmospheres, Land-surface, RiverNetwork, Groundwater and Actor. The data exchange between the different components as well as between single simulation models is realized via corresponding interfaces.

The Upper Danube Catchment: Upper Danube (Upper Austria, Germany, Slovakia) – 10,500 km² (9% of the entire Danube catchment of 110,000 km²). The GLOWA-Danube project is an attempt to support the analysis of water-related Global Change scenarios and the investigation of sustainable methods for future water resources management in the Upper Danube Basin (77,000 km²) by means of the Global Change decision support tool DANUBIA.

Conclusions

– The state of a resource has to be categorized in order to be used in decision making – to make the decision making process transparent and understandable for all actors (or models) involved. The approach suggested here aims at bridging a gap between groundwater experts and decision makers. Complex processes are reduced to flags: everything is fine (1), critical situation (2), catastrophe situation (3).

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