Identification of critical states of water resources on the regional scale under conditions of global climate change using a multi-actor based water supply model

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Abstract

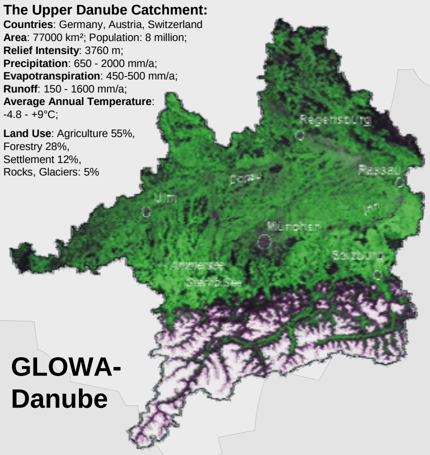
GLOWA-Danube (www.glowa.org) is an interdisciplinary, international project that aims to develop integrated strategies and tools for water and land use management. It is primarily concerned with the effects of **Global Change** on the water cycle of the Upper Danube river basin (Germany, ~80.000 km²). Within GLOWA-Danube 16 natural and social science simulation models are integrated in the coupled simulation system DANUBIA.

Here we present the development of 'DeepWaterSupply', a **model of the water supply sector** comprising water extraction, treatment and distribution. DeepWaterSupply acts as a link between the natural 'supply side', simulated by a groundwater and a surface water model, and the socio-economic 'demand side', simulated by a household, tourism, farming and economy model of water consumption in the respective sectors.

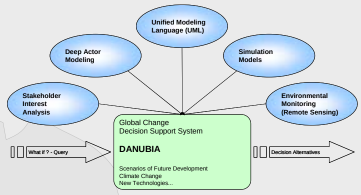
The assessment of **Global Change** impacts on the availability of water and the sustainability of water resources management activities is a key issue in **integrative hydrological research**. The development of methods for sustainable water resources management under globally changing boundary conditions 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.

The Upper Danube Catchment:
Countries: Germany, Austria, Switzerland
Area: 77000 km²; Population: 8 million;
Relief Intensity: 3760 m;
Precipitation: 650 - 2000 mm/a;
Evapotranspiration: 450-500 mm/a;
Runoff: 150 - 1600 mm/a;
Average Annual Temperature: -4.8 - +9°C;

Land Use: Agriculture 55%,
Forestry 28%,
Settlement 12%,
Rocks, Glaciers: 5%



GLOWA-Danube



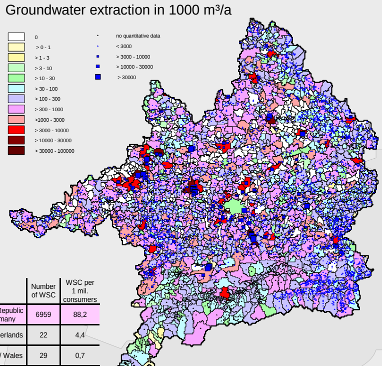
DANUBIA

DANUBIA integrates 16 natural-science and socio-economic simulation models within five main components: Atmosphere, Land-surface, Rivernetwork, Groundwater and Actor.

The data exchange between main components as well as between single simulation models is specified by corresponding interfaces.

Water supply in the upper Danube basin

Groundwater extraction in 1000 m³/a



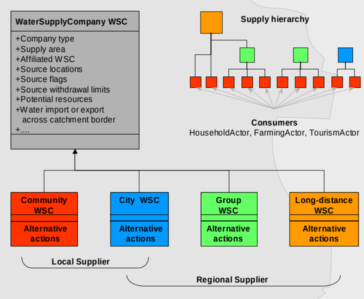
	Number of WSC	WSC per 1 mil. consumers
Federal Republic of Germany	6959	88,2
The Netherlands	22	4,4
England / Wales	29	0,7
France	5	0,13

From: Aktionskonzept: Nachhaltige und wettbewerbsfähige deutsche Wasserwirtschaft. BMBF, 2000.

In the upper Danube basin, the dominant sources of drinking water are groundwater and spring water (>95%). The responsibility for water supply lies with the community, resulting in a large number of local companies. Areas with sub-optimal hydro-geological conditions for water extraction, found mainly north of the Danube, are additionally served by group or long-distance suppliers. Through this three-tier organization of water supply, a high degree of security is given, although quality problems in particular give a growing cause for concern.

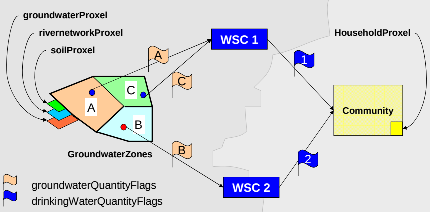
The WaterSupply Actor

Two types of WSC are represented: local and regional. WSC have access to groundwater or river water sources, each of which has a withdrawal capacity. Consumers' drinking water demands are added up on a community basis. Each community can be supplied by a local supplier, a regional supplier, or both.



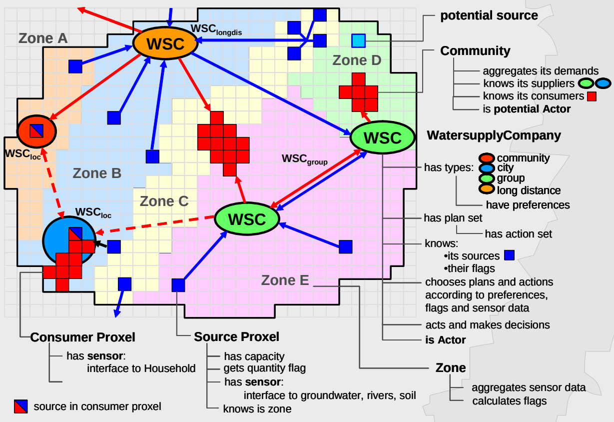
Integration - Communication

For 405 zones, each representing an aquifer or sub-aquifer, the qualitative state of groundwater resources is expressed in the form of graduated 'groundwaterQuantity Flags'. Determining the state is dependent upon a number of aquifer attributes as well as the time-dependent variables groundwater level, recharge and river discharge and total in/exfiltration. Decision making is based on these flags (see POSTER EGU06-A-06195).

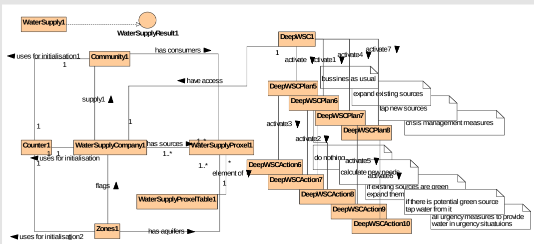


Model Conceptionalisation

The central tasks of the WaterSupply model are twofold: 1) the assessment of the state of the water resources and its communication to the consumers, and 2) the simulation of the state of the water supply infrastructure, distribution and groundwater extraction within the upper Danube basin, with the water supply company (WSC) as its main actor. In doing so, the WaterSupply model acts as an „interpreter" between the natural science and socio-economic Danubia components and aims to identify regions in which conflict may arise due to water stress in the future.



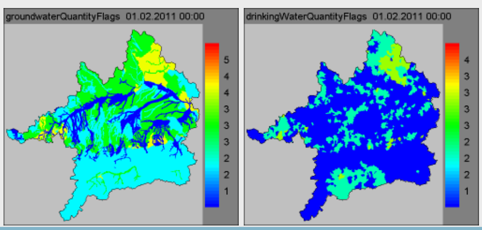
Deep WaterSupply Implementation

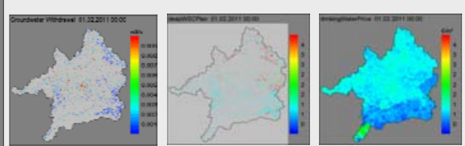


The deep WaterSupply model consists of three central classes: Zones, Communities and WSC. At each time step, groundwaterQuantityFlags are calculated for each Zone, the drinking WaterDemands read from the actor models are aggregated per Community and related to the supplying WSC to be communicated to the Groundwater and Rivernetwork models via the proxels containing sources Furthermore, each WSC analyses its ability to meet demands while respecting resource limits by comparing the current demands, withdrawal capacities and resource flags. Depending upon the WSC type, one or more of presently four possible „plans" to adapt to supply or demand side changes is then carried out: business as usual, expand existing resource, tap new resource and crisis management. Last but not least, the water price is calculated per community based upon a function developed by the Economy group. Export parameters include drinkingWaterSupply, drinkingWaterPrice, groundwaterQuantityFlag, drinkingWaterQuantityFlag (a weighted groundwaterQuantityFlag), groundwaterWithdrawal, and riverwaterWithdrawal.

Results

The following pictures show sample results from a (very dry) 30 year (2001-2031) scenario for the year 2011. The quantitative state of groundwater resources degrades perceptibly over the ten years. This can be compensated on the drinking water side to some degree by regional WSC. The remaining undersupplies should be interpreted as areas with potential future water use conflicts, in this case most noticeably the „Bayerischer Wald" in the NE of the catchment. The absolute values of under-supplies are highly dependent upon the interpretation of the quantitative state of the resources and what responses are modelled on behalf of the WSC.





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