Using a multi-actor framework for simulating the interaction between various actors, water supply and groundwater in response to Global Change

ROLAND BARTHEL¹, STEFAN DABBERT², TIM REICHENAU³, ROLF HENNiker⁴, ANDREAS ERNST⁵, WOLFRAm MAUSER⁶

¹ Institute of Hydraulic Engineering, University of Stuttgart, Germany
² Institute for Farm Management, University of Hohenheim, Germany
³ Institute for Geography, University of Cologne, Germany
⁴ Institute for Informatics, LM-University Munich, Germany
⁵ Center for Environmental Systems Research, University of Kassel, Germany
⁶ Department of Geography, LM-University Munich, Germany

The Upper Danube Catchment (Germany, Austria, Switzerland)
### GLOWA – Global Change in the Water Cycle

- German Federal Ministry for Research and Education – National Global Change Research Initiative.
- Started: 2000, End: 2010
- 5 selected regional case studies (regional scaled catchments ~100,000 km²)


<table>
<thead>
<tr>
<th>Research Network:</th>
<th>Koordination:</th>
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</thead>
<tbody>
<tr>
<td>8 Universities</td>
<td>Coordinators</td>
</tr>
<tr>
<td>3 Research Facilities</td>
<td>1. LMU München</td>
</tr>
<tr>
<td>1 State Agency</td>
<td>2. Department Geographie</td>
</tr>
<tr>
<td>2 Consultants</td>
<td>3. Department Meteorologie</td>
</tr>
<tr>
<td>~ 40 scientist</td>
<td>4. Center for Environmental Systems Research, Kassel</td>
</tr>
</tbody>
</table>

1. Department Geographie, LMU München
2. Department Informatik, LMU München
3. Department Meteorologie, LMU München
4. Center for Environmental Systems Research, Kassel
5. Institut für Landw. Betriebslehre, Universität Hohenheim
7. Institut für Geophysik, Universität Innsbruck
8. Institut für Wasserbau, Universität Stuttgart
9. Institut für Geographie, Universität zu Köln
10. Max-Planck Institut für Meteorologie, Hamburg
11. Ifo – Institut für Wirtschaftsforschung, München
12. Bayerisches Landesamt für Umwelt, Hof
13. Institut für Organisationskommunikation IFOK, Bensheim
14. VISTA – Geowissenschaftliche Fernerkundung GmbH, München

Phase 1: Institut für Pflanzenökologie, Universität Bayreuth
Phase 1 und 2: IAWG, Ottobrunn
DANUBIA Global Change Simulation System

Upper Danube Catchment:
- Area: 77,000 km² (= California / 5)
- Population: 11.5 Mio.
- Elevation: 290 to ~4000 m

GLOWA-Danube – Einzugsgebiet Obere Donau

- Area: 77,000 km² (= California / 5)
- Population: 11.5 Mio.
- Elevation: 290 to ~4000 m
State of groundwater (Report to the European Community, according to E-WFD)

- Bodies of Groundwater classified as:
  - at risk
  - not at risk (of failing to meet the WFD objectives)

Water Framework Directive - Summary of River Basin District Analysis 2004 in Germany
Groundwater Quality Problems and Trends: **Nitrate**

〜 85% of groundwater pollution from agriculture

![Graph showing nitrate levels over time with an upward趋势 and European, national, and federal state directives, various measures, and "cooperation projects" indicated.]

Groundwater Quality Problems and Trends: **Atrazine**

- **Prohibited** in the European Union (Germany 1991, Austria 1995, France 2004)

![Graph showing atrazine levels over time with a decline trend.]
### Summary: Groundwater and Agriculture in the UDC

- The UDC is a **water rich region**, water scarcity is not an issue
- **Many different stakeholders** with conflicting interests (economical, ecological, social)
- **95% of drinking water** (domestic use) **from groundwater**
- Agriculture:
  - 50% of area cultivated land
  - Irrigated land less than 1% of cultivated land
- **Subsidies** (national, European): 15% of turnover, 65% of profit
- **Very strict water law** on three levels: European, National, Federal State Laws.
- **Information, Education, Cooperation projects** with farmers proved to be more successful than law enforcement

### Regional Consequences of Global Change

1) Observations
Climate Change – Observations: Temperature (1960-2006)

Summer Temperatures: + 2 degrees

Winter Temperatures: + 1.5 degrees

Climate Change – Observations: Precipitation 1960-2006

Summer Precipitation

Winter Precipitation
Groundwater Recharge (simulated using observed climate data)

~ 590 mm/a

Percolation annual sum; average for 1960-2005

Mean annual deviation from average per decade

Negative Werte, rot, gelb: mehr Perkolation, positive Werte, blau: weniger Perkolation als im langjährigen Mittel ???

Groundwater Quantity: Trends*

* observations without obvious anthropogenic influence
Groundwater response to Climate (Heads): Response Types

Climate Change Observations: Groundwater Quality

- Identification and quantification of cause and effects is extremely difficult
- Very little research on direct impacts of climatic change on groundwater quality has been carried out
Regional Consequences of Global Change

2) Simulation Strategies and Models

DANUBIA Simulation System

- 17 individual, fully coupled models
- Framework technology
- Open Source (Oct. 2010)
  www.glowa-danube.de

Actor
- Demography
- Economy
- Farming
- Household
- Tourism
- Water supply

Groundwater
- Groundwater Transport
- Groundwater Flow

Landsurface
- Biology
  - Channel Flow
  - Hydraulic Structures
  - Radiation Balance
  - Snow
  - Soil
  - Soil Nitrogen
  - Surface

Atmosphere
- Climate Generator
- RCM Interface
### Why multi-actor modeling?

- A) The assumption that socio-economic conditions do not change within 100 years does not make sense.
- B) Spatial variability of natural and socio-economic conditions requires spatially explicit modeling.

### Multi-Actor-Modeling of Global Change

- **An Actor** is an autonomous entity which is capable of reacting to system changes in an individual way → An actor makes decisions.
  - Household-, Farming-, Tourism-, Watersupply-, Economy, Demography-Actors

- **Actor-Types**: used to differentiate between different possibilities and preferences:
  - Example: Household-Actor - „traditional Type“ – „post materialist Type“

- Actors make decisions: they chose from available „Actions and Plans“
  - Example: Farming-Actor - Actions: Planting, Harvesting, Irrigating, Plans: chose crops for the next year → Landuse

- An **Actor-Model** simulates socio-economic processes as the sum of the individual decisions made by the different Actors and Actor Types
  - “process based”, spatially and temporally explicit modeling rather than data driven, empirical modeling
Regional Consequences of Global Change

3) Regional Global Change Scenarios

Elements of a regionalized Global Change scenario

- Global emission scenario (e.g. A1B - IPCC)
- Global Circulation Model (e.g. ECHAM5…)
- Downscaling (Global → Regional)
- Socio-Economic Trends (demography, environmental policies, prediction of demands …)
- ‘Storylines’ (e.g. more draughts → more reservoirs …, or increase energy crop production by 200% …)
### GLOWA-Danube Global Change Scenarios

<table>
<thead>
<tr>
<th>Choice 1: Climate Trends</th>
<th>Choice 2: Climate Type</th>
<th>Choice 3: Social Trends</th>
<th>Choice 4: Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPCC regional</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Information Cooperation</td>
</tr>
<tr>
<td>REMO regional</td>
<td>5 warm Winters</td>
<td>Free is fair</td>
<td>Subsidies for Water saving techn.</td>
</tr>
<tr>
<td>MM5 regional</td>
<td>5 hot Summers</td>
<td>Shared destiny</td>
<td>Build reservoirs</td>
</tr>
<tr>
<td>Trend Extrapolation</td>
<td>5 dry years</td>
<td></td>
<td>...</td>
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</tbody>
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### Socioeconomic and political scenarios

Why: Society and individuals will react to climate change - but how?

- **Future 1: „Free is Fair“**
  - Competition and free market,
  - Individual freedom,
  - Minimum of public welfare,
  - Individuals responsible for themselves.

- **Future 2: “Shared Destiny”**
  - Classical welfare state,
  - Social justice, equal opportunities,
  - Government has strong influence on economy.

- **Future 3: “business as usual”**

  de Vries, Perry 2007
Regional Consequences of Global Change

4) Results

Crop Production (3 selected districts)

Crop production compared to reference period (1996-2005)

- Wheat
- Sugar Beet
- Barley
- Fodder Maize

Climate Scenario: REMO-Baseline, Socio economic scenario: Performance
Farming-Actor Decisions: Land use changes

Towards Sustainable Groundwater in Agriculture, June 15-17, San Francisco, USA

Barthel

Nitrate concentration in soil water (Nitrogen Leaching)

Barthel
**Key consequences** for policy / policy makers / decision makers

- When offered simulation results on the **consequences of climate change** by scientists we recommend to think about the following issues:
  - Get involved in the definition of regionalized scenarios and in the model development as early as possible - otherwise you might not be able to use the results.
  - Prediction of consequences of Climate Change requires good simulation models but also meaningful, consistent, **Integrated scenarios**. Ask for a choice of scenarios!
  - Scenarios should address spatial and temporal variability of changes, including extremes.
  - Downscaling of global models to **regional conditions** is a yet largely unsolved problem. Ask for different options.
  - Climate Change research must be **integrated**. Ask if the models can capture the existing dependencies and feedbacks!
  - Before accepting model results, ask, if the developments in the past are fully understood and can be captured by the models. Are the models valid under different boundary conditions?
  - In particular consequences of Climate change for groundwater quality are largely unknown. Ask for more research!
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Thank you!