Federal Ministry of Education and Research

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GLOWA Danube

The use of groundwater indicators to detect climate change impacts and violation of sustainability rules

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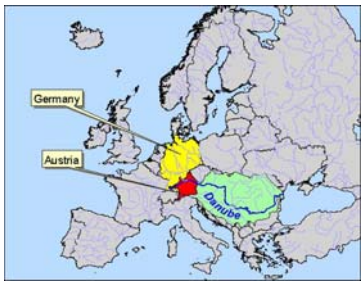
Outline

- Part A – **General Considerations** about Indicators and Indices for Groundwater Resources Assessment and Management:
  - Where and why indicators are required and how they can be used
- Part B – The **GLOWA-Danube case study**,
  - Indicator development to evaluate the Effects of Global Change in the Upper Danube catchment (Germany)



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Definitions

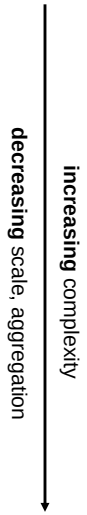
- **Indicator**: a **pointer** or a **signal** to show the state or a development of something; **ideally** : **one indicator** that can be used to assess the state of a **whole system**
- **Index**: often understood as a **more abstract** combination/calculation of several indicators

Part A: Indicators - General Considerations and Issues

- "**Multi-Dimensionality"** of Indicator Development:
  - Scaling Issues: spatial and temporal scale of validity, complexity, degree of aggregation
  - Field of application - who will use the indicator, what purpose is it made for?
  - Indicator basis: Measurements, observations, estimates or derived from models?

Types of Indicators – Classification by Purpose and Users

- "**Public**" Indicators:
  - Indicators, used to inform the public about state and development of eco-systems
  - → usually "simple" (good …bad)
- "**Political**" Indicators:
  - Indicators, required for policy and decision making on higher administrative levels
  - → less simple, expert advise available
- "**Management**" (operational) Indicators:
  - Indicators, used for the actual management of technical systems on regional or local level
  - site specific, local scale, short time term observations
  - → Very specific, technical
- "**Scientific**" Indicators:
  - Indicators, used for analysis and validation of processes on a scientific level
  - → Complex, problem specific, very diverse; "expert only"

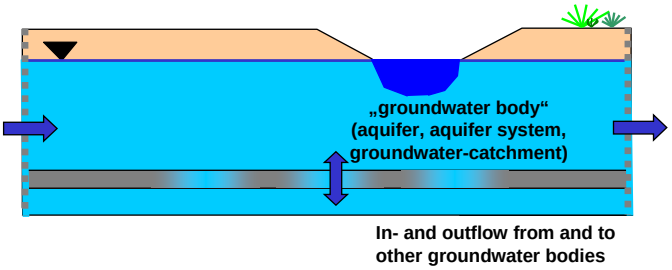


Problems and Issues of Indicator Development (Selection)

- Area and period of **validity**: For which area and period is an indicator significant or relevant?
- Interpretability and Comparability site specific effects: Does an indicator mean the same at any location?
- Dependency on other parameters: Is an indicator directly related to a certain problem or process
- Data availability: Spatial and temporal frequency of measurements

Area of **validity**

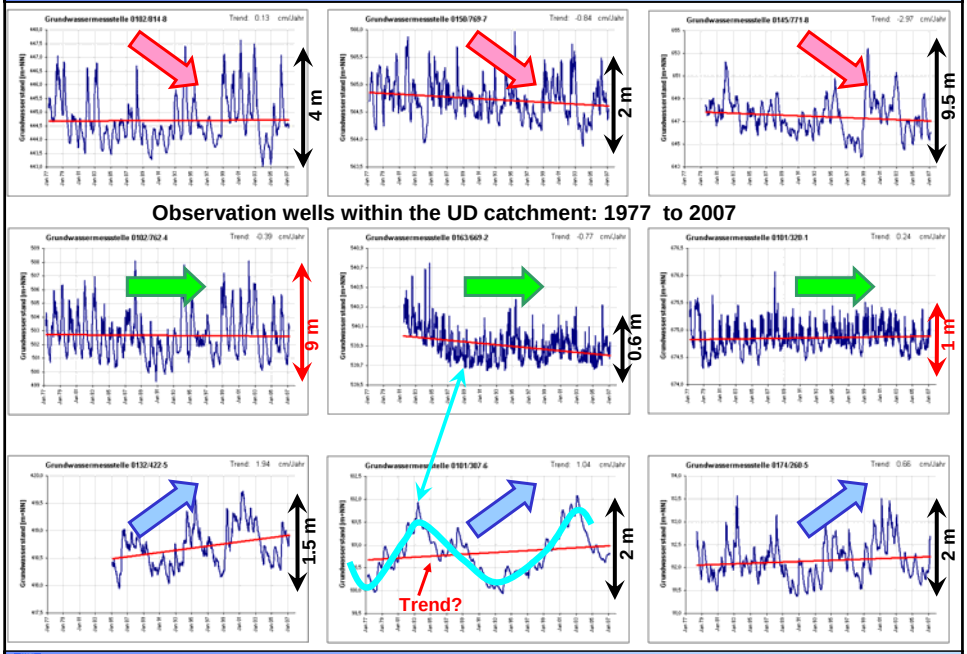
- **Delineation** of Groundwater Resources
  - 3-dimensional, often extremely heterogeneous, inaccessible → little data
  - No clear limits, location and nature of boundaries depending on potentials



Indicator Problems

- Area and period of validity: For which area (Groundwater = 3D !) and period of time is an indicator significant or relevant?
- **Interpretability** and **Comparability** - dependence on site specific effects: Does an indicator mean the same at any location?
- Dependency on other parameters: Is an indicator directly related to a certain problem or process?
- Data availability: Spatial and temporal frequency of measurements

Interpretability and **Comparability** of Indicators - Groundwater Levels

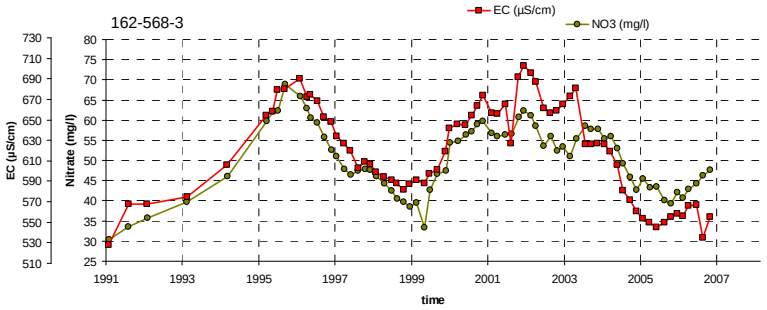


Indicator Problems

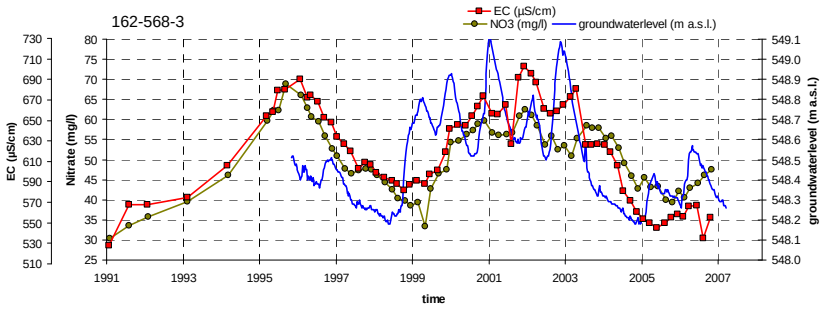
- Area and period of validity: For which area (Groundwater = 3D !) and period of time is an indicator significant or relevant?
- Interpretability and Comparability site specific effects: Does an indicator mean the same at any location?
- **Dependency** on other parameters: Is an indicator directly related to a certain condition or process ?
- Data availability: Spatial and temporal frequency of measurements

Dependency of processes: Nitrate

Nitrate in Groundwater: Indicator for (agricultural) anthropogenic contamination.
Changes of Nitrogen concentration: Indicator to measure the success of changed agricultural practices



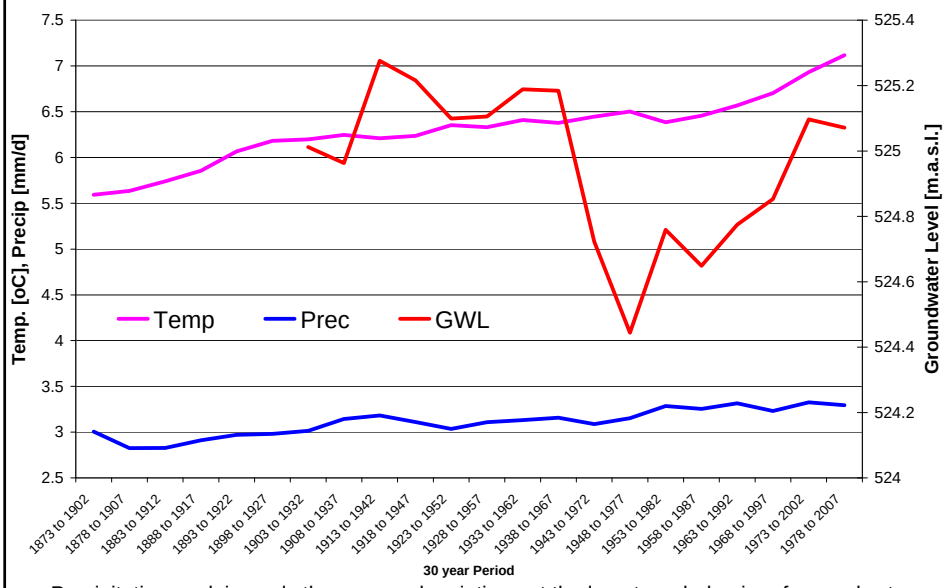
Dependency of processes



Indicators to monitor Climate Change and Human Impacts

- **Issues to be considered:**
  - Can Climate Change and Human Impacts be separated?
  - Will the behavior of an indicator be the same under conditions of climate change as it was in the past?

Means of GWL, Temperature and Precipitation for 30-year Periods



Precipitation explains only the seasonal variation not the long term behavior of groundwater

Changes of chemical conditions in Groundwater after 2003

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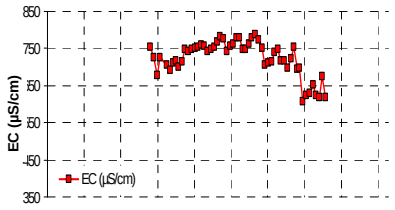

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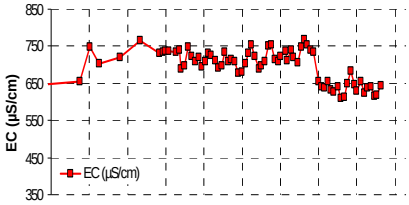

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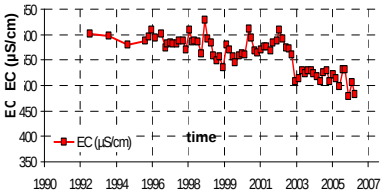

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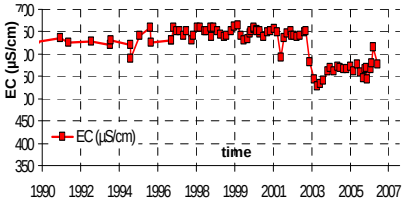
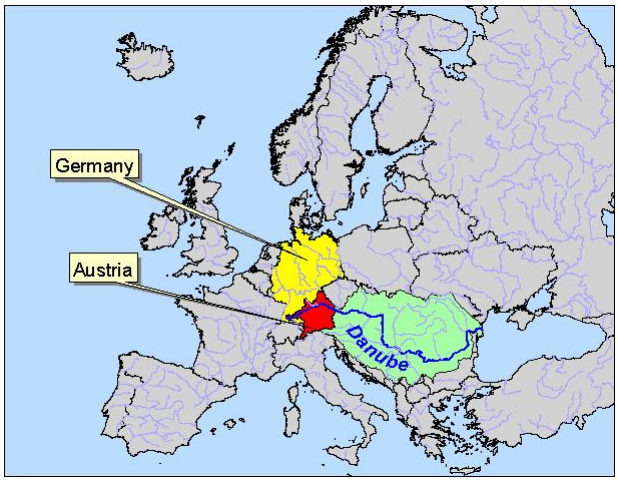


Project Background - GLOWA-Danube: Summary

- Impacts of Global (Climate) Change on the Hydrological Cycle within the Upper Danube Basin (Germany, ~ 77,000 km²)



- Decision Support System **DANUBIA** : 16 coupled models to simulate Global Change Scenarios

Indicator development in GLOWA-Danube (Example: Groundwater Quantity)

- **Scope** of the GLOWA Groundwater Indicator Approach:
  - Applicable for **Decision Making** on the **Regional Scale**
  - Evaluation of **long term** impacts of **Climate Change** and **Human Impacts**
  - Indicators development based on **Model** results

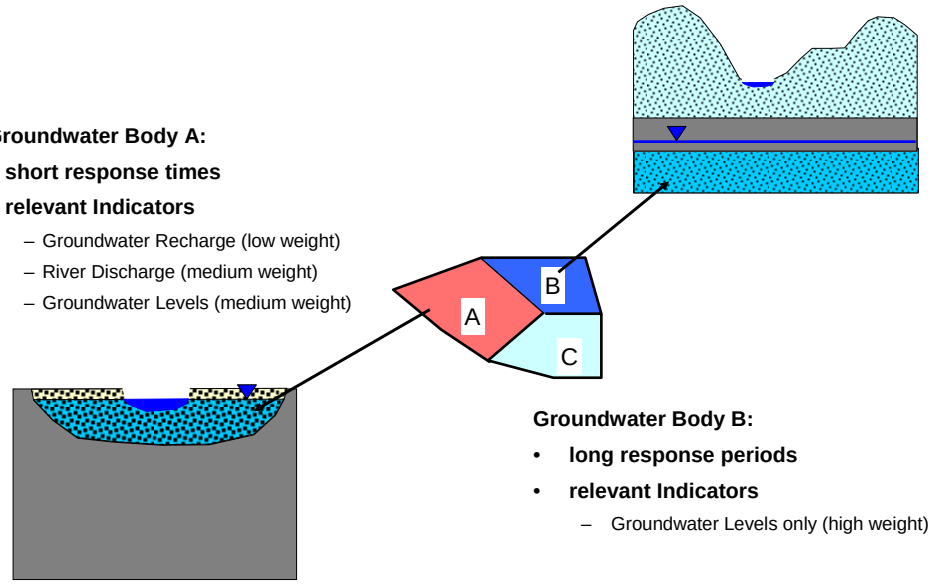
  → Indicators to be used by decision makers and the public, yet developed on the basis of scientifically sound hydrogeological expertise

Example: Index development for groundwater quantity

Leading Idea: There is not one **single** indicator that describes the quantitative state of different types of groundwater resources alone. Therefore a weighted combination of:

- **Groundwater Levels**
  - directly measurable indicator - but site specific
- **Groundwater Recharge**
  - estimated indicator, integral
- **Baseflow (Groundwater Discharge)**
  - estimated indicator, integral

Spatial Aggregation, characteristic response periods and weighting of indicators:



Groundwater Body A:

- **short response times**
- **relevant Indicators**
  - Groundwater Recharge (low weight)
  - River Discharge (medium weight)
  - Groundwater Levels (medium weight)

Groundwater Body B:

- **long response periods**
- **relevant Indicators**
  - Groundwater Levels only (high weight)

The 'Flag' concept of GLOWA-Danube to express an aquifers state

For 405 groundwater bodies:

Groundwater Level
Groundwater Recharge
Baseflow

spatially aggregated to **groundwater bodies**

⇨ Evaluation of trends for **characteristic response periods**

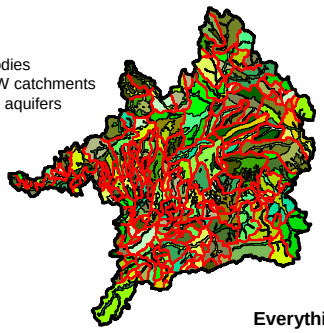
⇨ classification based on comparison with **reference periods**

⇩

Categorization using a **weighted combination** of different indicators

⇩

405 bodies
155 SW catchments
4 main aquifers

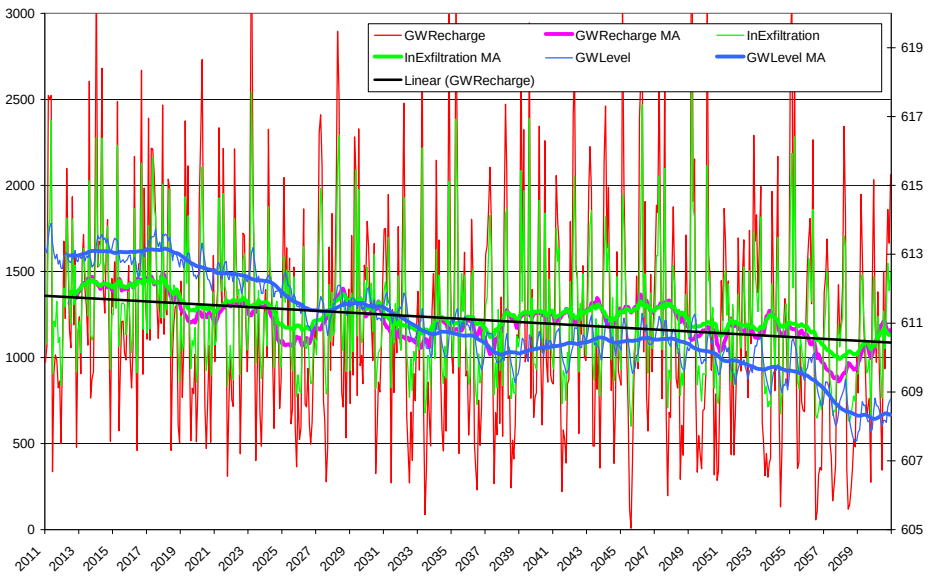


Groundwater Quantity Index ("Flag")

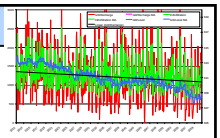
Everything is fine → **critical** → **catastrophic**

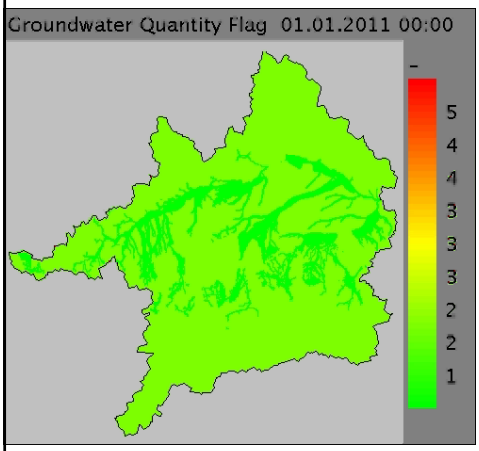
1	2	3	4	5

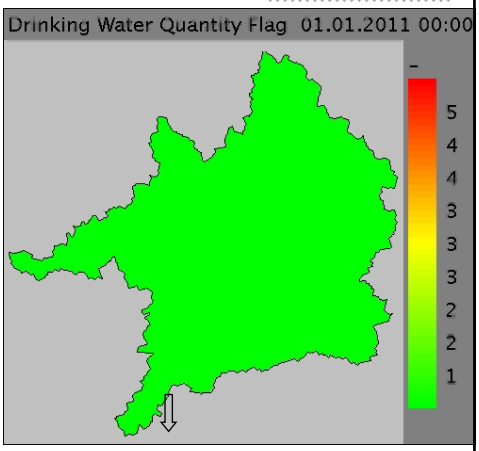
Climate Scenario „Baseline“ (50 years, IPCC based)



Baseline Flag Movies







Everything is fine → critical → catastrophic

Groundwater Quantity Index (“Flag”)

1 2 3 4 5

General Conclusions: Indicators for Groundwater Resources Assessment

Some recommendations for Groundwater Indicator Development:

- Indicators must be adapted carefully to the hydrogeological conditions
- An appropriate delineation of groundwater bodies is required
- Assessment should never be based on one single indicator
- Dependencies of indicators on other processes should be carefully checked
- Indicator interpretation must consider the uncertainties of underlying models (aggregation; trends instead absolute values etc…)
- Indicators should be simple enough to be discussed with practitioners , decision makers and stakeholders, yet they should be scientifically sound
- Always talk to stakeholders and practitioners to find out whether the proposed indicators are helpful for decision making

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Regional scale assessment of groundwater resources quantity with respect to water supply issues and the ecological role of groundwater

Thank your for your attention!