Research in support of the EU Water Initiative www.euwi.net

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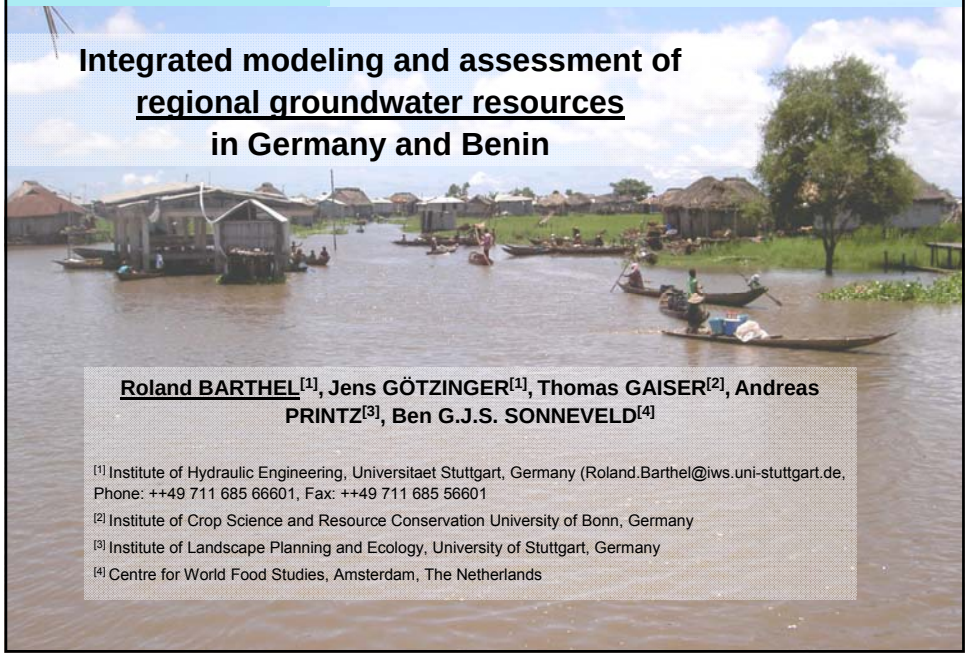
funded by the European commission

Integrated modeling and assessment of regional groundwater resources in Germany and Benin



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Scope of this Presentation

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→ **Water Resources Management** requires often a **Regional Approach** (interaction between different parts of catchments, different hydrological systems, different users, upstream-downstream relations, sources and sinks ….).

→ Water Resources Management on the Regional Scale requires **Integrated Approaches** (Groundwater - Surface Water, Natural Processes – Socio-economic Factors …)

→ **Groundwater Management** is very often an essential part of Water Management, however: Integrated Management does not mean “Aquifer Management” (see “*River Basin Management Plans*” - WFD)

→ **Management requires Models:** to predict the effects of human interventions (social, economical, technical changes) as well as Climate Change

→ **Regional Integrated Groundwater Models** are required.

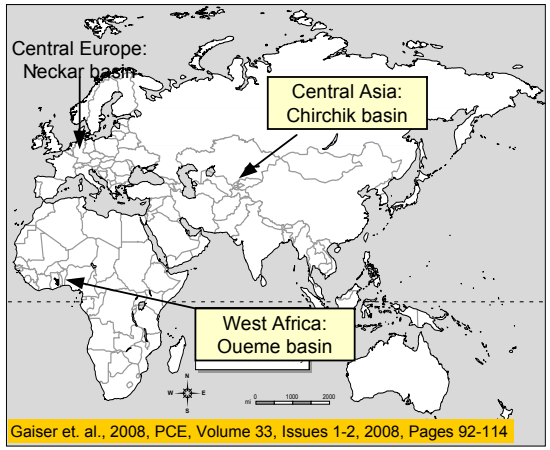
Key Questions

- How can we meaningfully model, assess and manage groundwater resources on the regional scale to meet the requirements of Integrated Water Resources Management?
- Are regional, integrated numerical groundwater models a suitable tool?

RIVERTWIN (www.rivertwin.org)

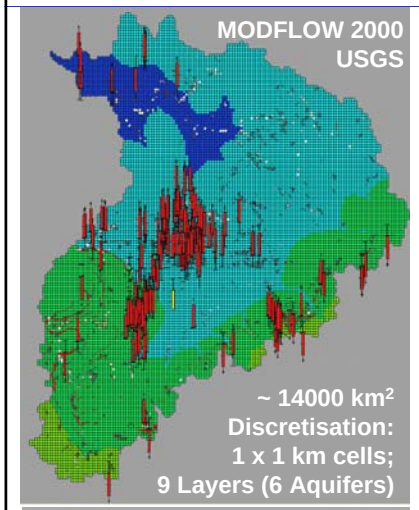
'A Regional Model for Integrated Water Management in Twinned River Basins'

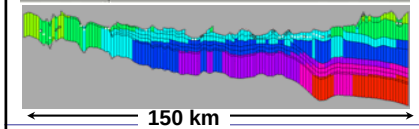
- Apply the principles of the **European Water Framework Directive** (WFD) to other continents.
- Develop the integrated **water and land use management tool MOSDEW (9 data-coupled sub-models)**



11 Partners, 6 Countries

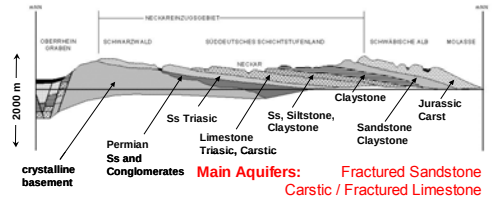
Groundwater Model - Neckar Catchment

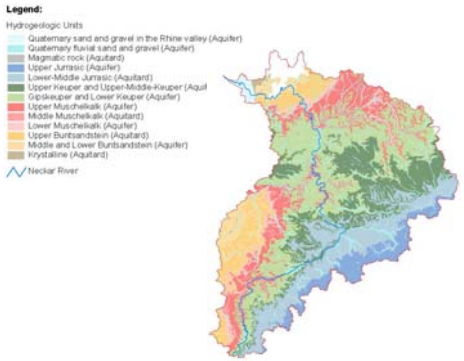




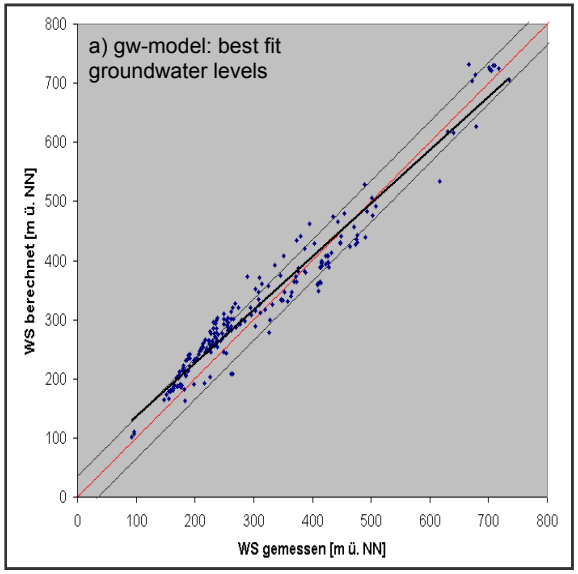
150 km

180 km



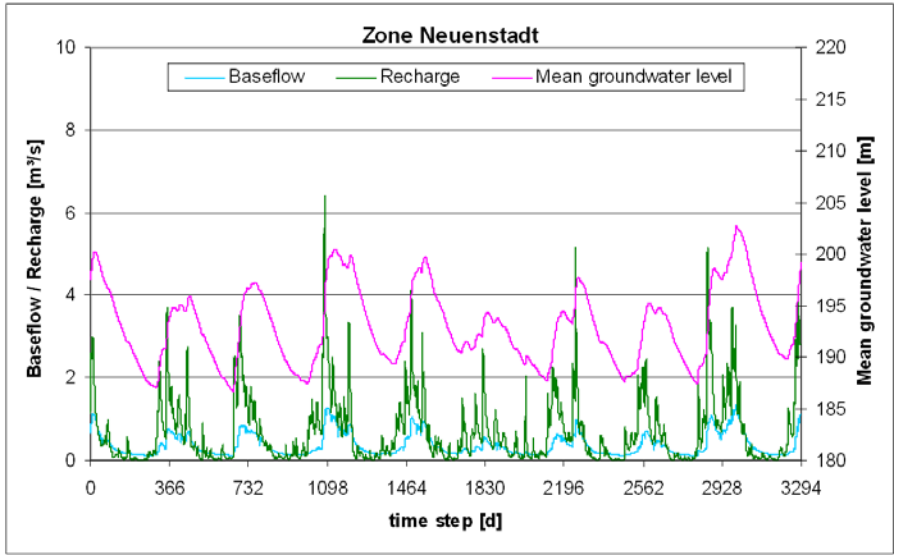


Model Results - Stationary Calibration

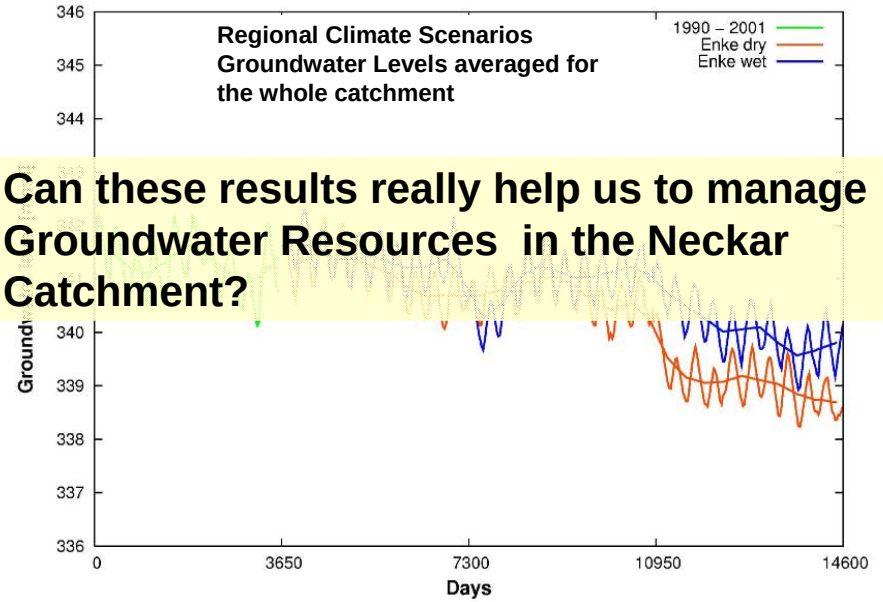


y = 0.9x + 46,5
R^2 = 0,9521
MAE = 30,77 m
RMSE = 30,91 m

Transient Model Results

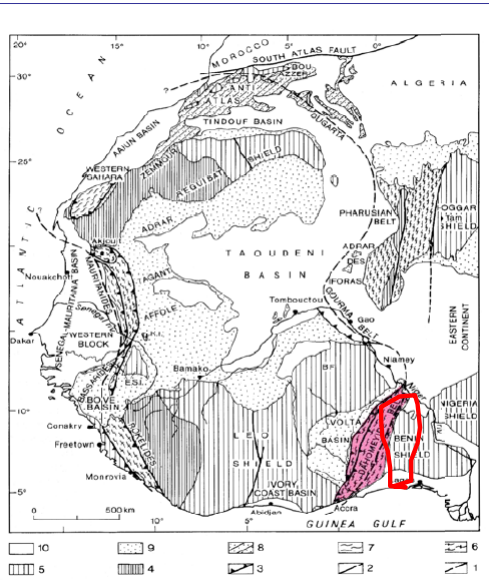


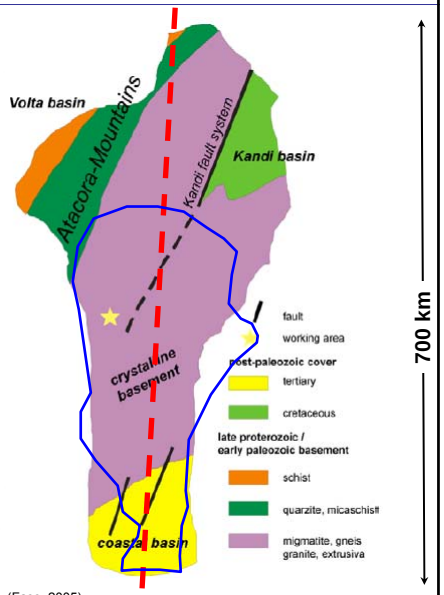
Scenarios Simulations



Can these results really help us to manage Groundwater Resources in the Neckar Catchment?

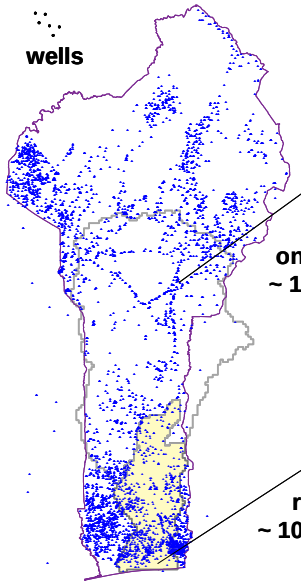
Benin - Ouémé-Basin: Geology



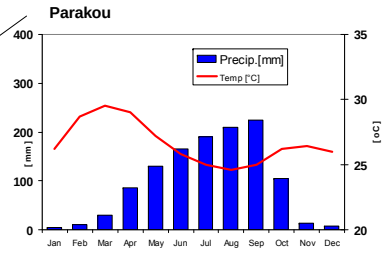


(Fass, 2005)

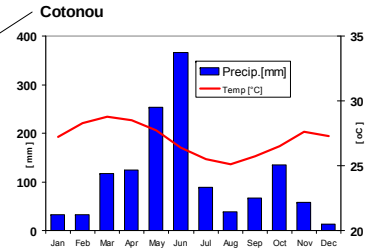
Water Availability: Climate; Wells



one rainy season
~ 1000 – 1200 mm



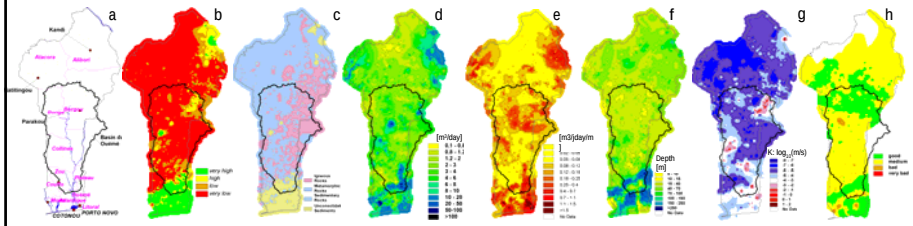
two
rainy seasons:
~ 1000 – 1500 mm



Rivertwin: Groundwater Resources Assessment in Benin

1. **"Data Driven" Approach:** Regionalization of Data from a countrywide database (~5,000 wells)
   - Groundwater Availability and Quality, Hydraulic Parameters, Extraction Potential
   - Socio-Economic Analysis of Groundwater Accessibility, Extraction Costs and Health Aspects
   - ***Barthel, R., Sonneveld, B.G.J.S., Götzinger, J., Keyzer, M.A, Pande, S., Printz, A. & Gaiser, T.:*** *Integrated Assessment of Groundwater Resources in the Ouémé Basin, Benin, West Africa. - Physics and Chemistry of the Earth (available online doi:10.1016/j.pce.2008.04.001)*
2. **"Model Driven" Approach**: Groundwater Flow Model Coupled to Hydrological Model to evaluate Climate Scenarios
   - *Barthel, R., Jagelke, J., Gaiser, T., Printz, A. & Götzinger, J. (2008): Aspects of choosing appropriate concepts for modelling groundwater resources in regional Integrated Water Resources Management – Examples from the Neckar (Germany) and Ouémé catchment (Benin). - Physics and Chemistry of the Earth, Parts A/B/C Volume 33, Issues 1-2, 2008, Pages 92-114*

Results: A) Data Driven Approach



a: important locations and administrative boundaries
b: potential of the aquifers (yields)
c: aquifer rock type
d: maximum yield [m^3/day]
e: specific yield [m^3 per day per 1m filter length]
f: average depth of the wells
g: hydraulic conductivity [m/s]
h: natural groundwater quality (not influenced by human activity)

Regionalized hydraulic and well properties (3*3km grid)

Biggest Problem:
>5000 well data, but only very few, short time series available

Data partly unreliable or not comparable

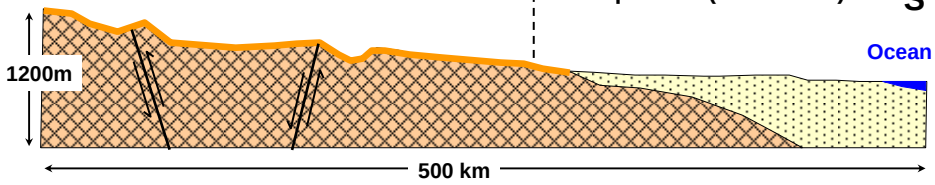
Groundwater Flow Modeling

Crystalline Basement,

- thin <u>weathered 'saprolitic' layer</u> with varying thickness on top (0-20m),
- locally intensively fractured (**fault zones**)
- otherwise **no connected regional groundwater systems**

Coastal **Sedimentary** Basin,

- gently dipping,
- **weakly consolidated**
- **porous aquifers and aquitards (sand & silt)**



bad conditions for regional groundwater flow modelling

good conditions for groundwater flow modelling

Problems in both parts: Very few time series, groundwater recharge very difficult to determine

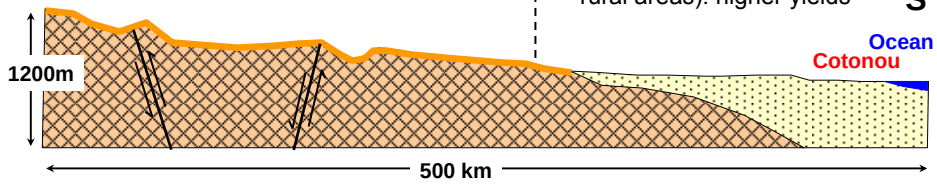
Groundwater related Management Issues

Crystalline Basement:

- shallow (dug) wells in Saprolite: low yields, **strong dependency on seasons**
- deep drilled wells in fracture zones: low to medium yields (hand or motor pump)

Coastal S**edimentary** Basin,

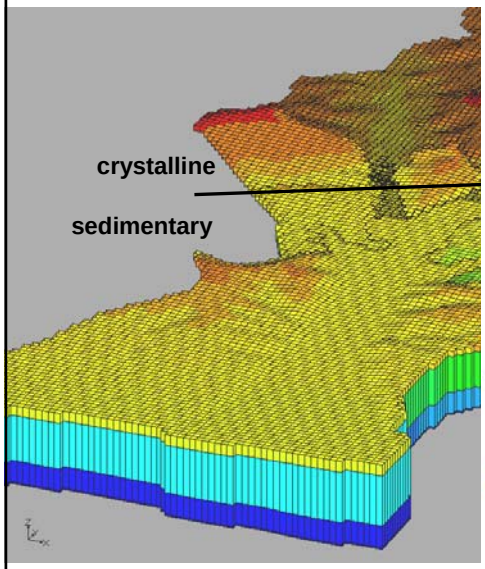
- Shallow and deep (dug!) wells in rural areas: medium yields, seasonal variations
- deep drilled wells and well fields to supply big cities (and rural areas): higher yields

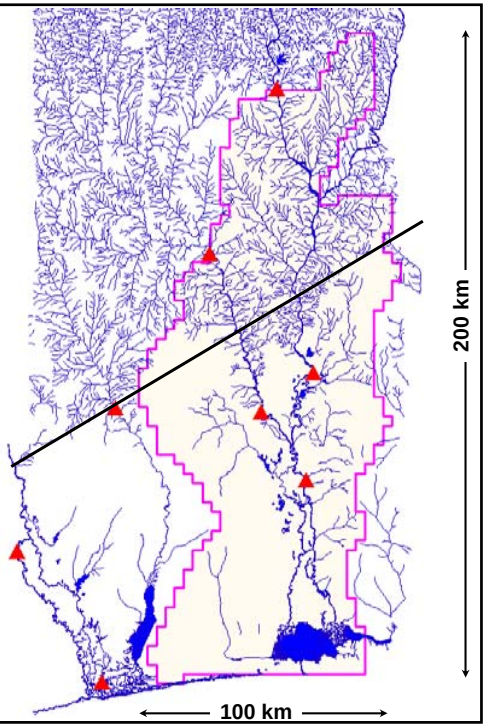


Unfavorable, unreliable conditions for groundwater extraction with low, seasonally varying yields

good conditions for groundwater extraction

Groundwater Flow Model





Using the Model for Management? Rural Areas

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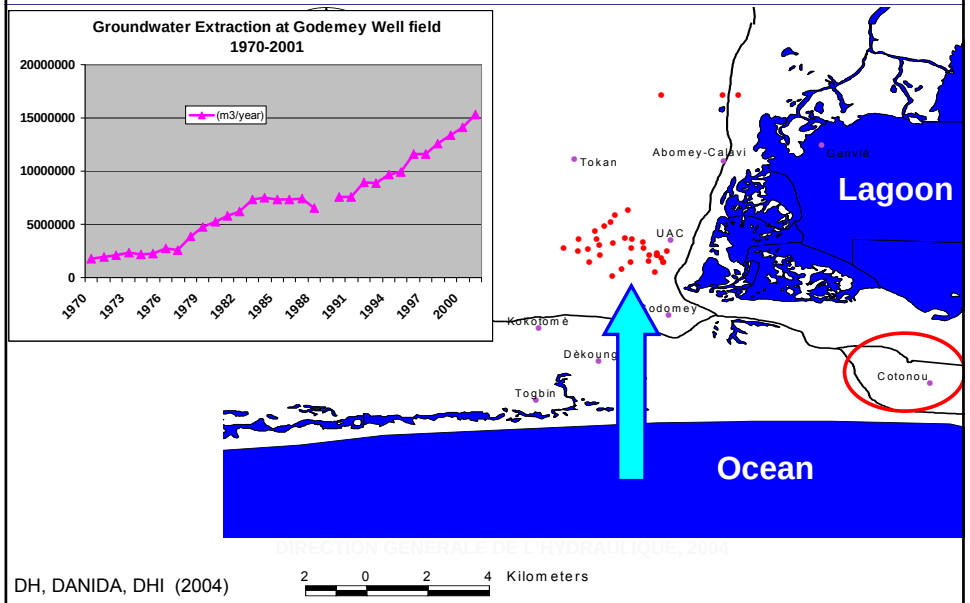
Problem 1: Hygienic Conditions / Water Quality

Problem 2: low Yields, Scarcity in the dry season

Shallow, unprotected wells, Strong climatic influences (dry season)

Using the Model for Management? Urban Areas



Using the Model for Managment? Summary:

- **Northern Crystalline Region / Rural Areas:**
  - Management Tasks: Optimizing well locations and well design to improve yield, reliability **and hygienic conditions**
  - **problems that have to be worked on the local scale**
- **Southern Coastal Plateau / Urban Areas:**
  - Management Tasks: development of new resources, prevent seawater intrusion, prevent depletion
  - **problems that mainly have to be worked on the local scale**
- **Specific Regional Problems:**
  - High Fluoride concentrations
- **In General:**
  - Management Tasks: Assess and predict groundwater availability under changing boundary conditions - increase reliability and reduce effect of seasonality on water availability
  - **problems that have to be worked on both on the local and regional scale - yet not necessarily using groundwater flow models**

Benin Case Study: Questions & Answers

- **Is the geological situation suitable for regional groundwater flow modelling?**
  - Yes in the South, no in the North
- **Is the data availability sufficient for regional groundwater flow modelling?**
  - No. Transient data missing, other data inaccurate, not reliable)
- **Are there any groundwater related tasks that require a basin wide, integrated, regional groundwater flow model?**
  - there are many specific problems but they require local models or no (numerical) model
  - there are regional problems (water availability in the dry seasons) but they do not require (necessarily) a 3D groundwater flow model

Conclusions

- Accuracy of RGM results is often too low to be meaningfully applied to management problems (often local scale)
- Regional scale groundwater management problems can often be solved with hydrological or water balance approaches. Main issue: Groundwater Recharge rather than Groundwater Flow.
- **But**, regional groundwater flow models can be beneficial anyway, because:
  - Even if the results are not good, they help to better understand groundwater systems and interactions with surface water, unsaturated zone and climate
  - Thus, they can enhance the applicability of hydrological models in the field integrated water management
  - They are a good means for checking the plausibility of other models and to come to reliable spatially and temporally distributed groundwater recharge calculations.
  - **They guarantee that hydrogeological conditions are taken into account and that a hydrogeologist is involved in the project!**

Thank you for you attention!