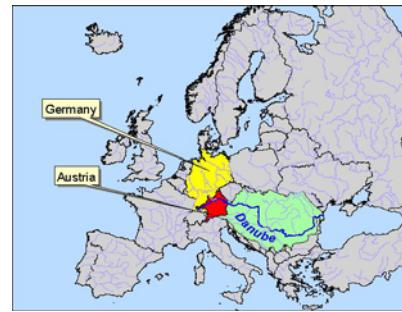


## GLOWA-Danube ([www.glowa-danube.de](http://www.glowa-danube.de)): Summary

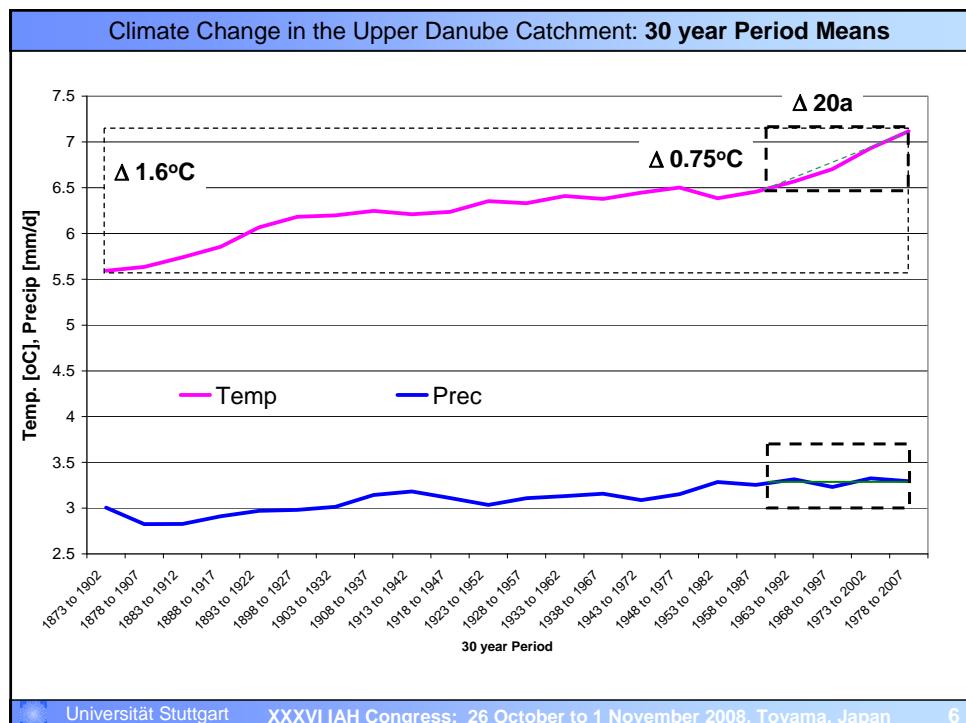
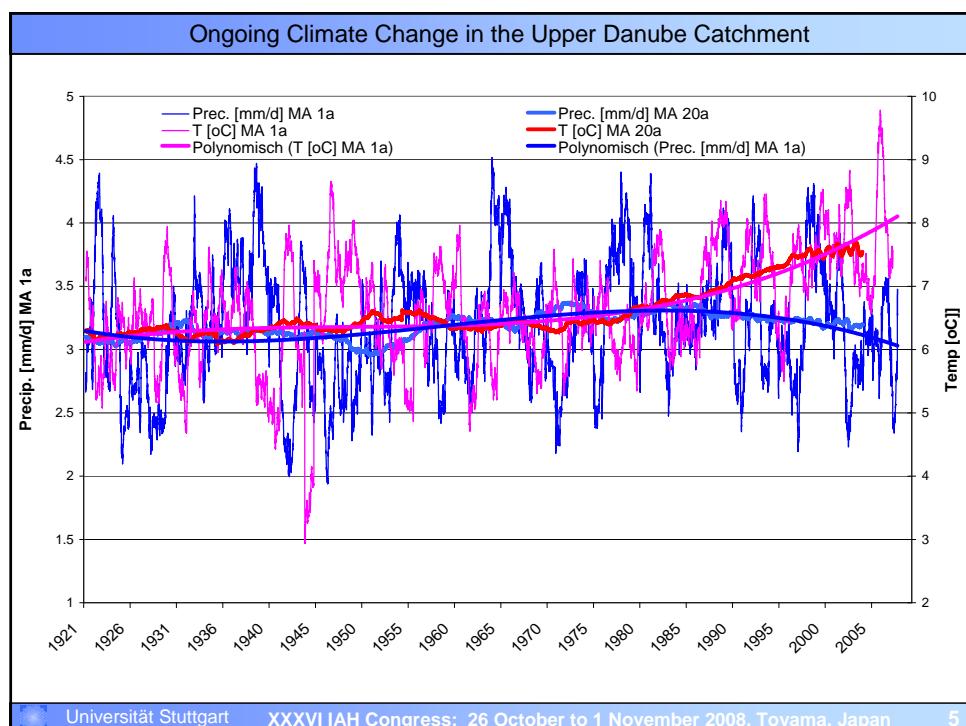
- **Consequences of Global Change in the Upper Danube Catchment** (Water Supply, Land Use, Agriculture, Economy, Tourism ..)
- **Decision Support System ‘DANUBIA’**, comprised of 16 fully coupled individual models
- **Integrated / Interdisciplinary Approach:** 12 research groups from different disciplines (Meteorology ... Tourism Research)
- **Subproject Groundwater and Watersupply at Stuttgart:**

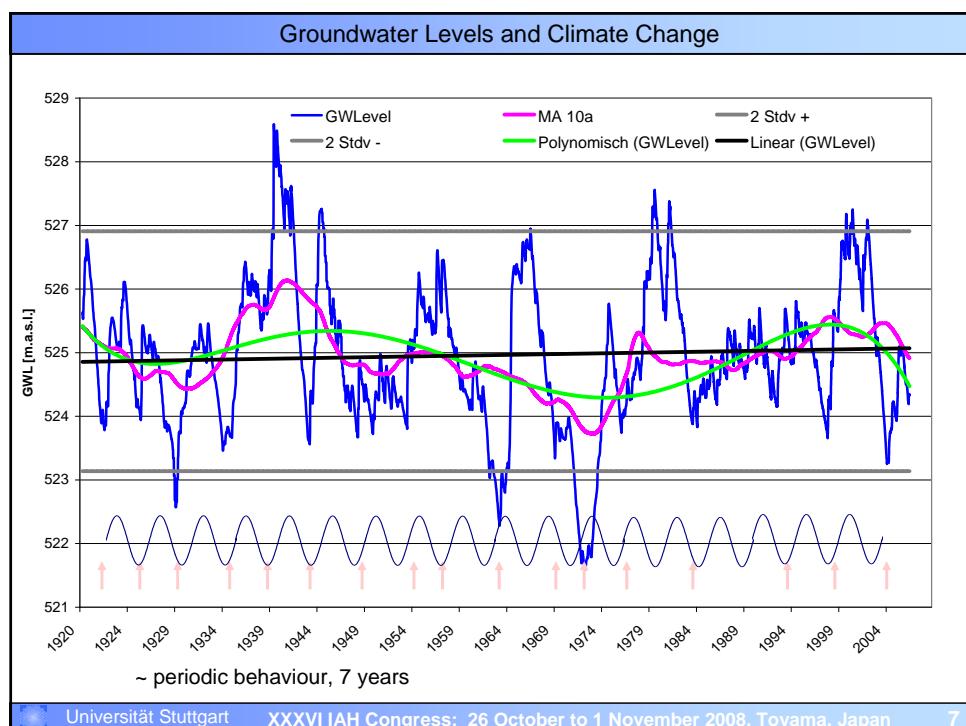
- Groundwater flow model plus a module for Nitrogen Transport
- Watersupply and –distribution model



## Groundwater Resources Assessment in GLOWA-Danube

- Key Questions:
  - How will the groundwater system of the Upper Danube Catchment react to Global Change / Climate Change (Quantity / Quality)?
- Two different approaches
  1. Process based, deterministic **models** to predict *groundwater recharge*, *piezometric head*, *base flow*, *storage*, *Nitrate concentrations* etc. for different regional **IPCC based Climate Scenarios**
  2. **Analysis of the behavior of the groundwater system in the past based on observations (time series)**
    - Model results unsatisfactory - better means of calibration and validation
    - Groundwater processes on the regional scale poorly understood
    - Climate Change is ongoing: What can we learn from the past to make predictions for the future

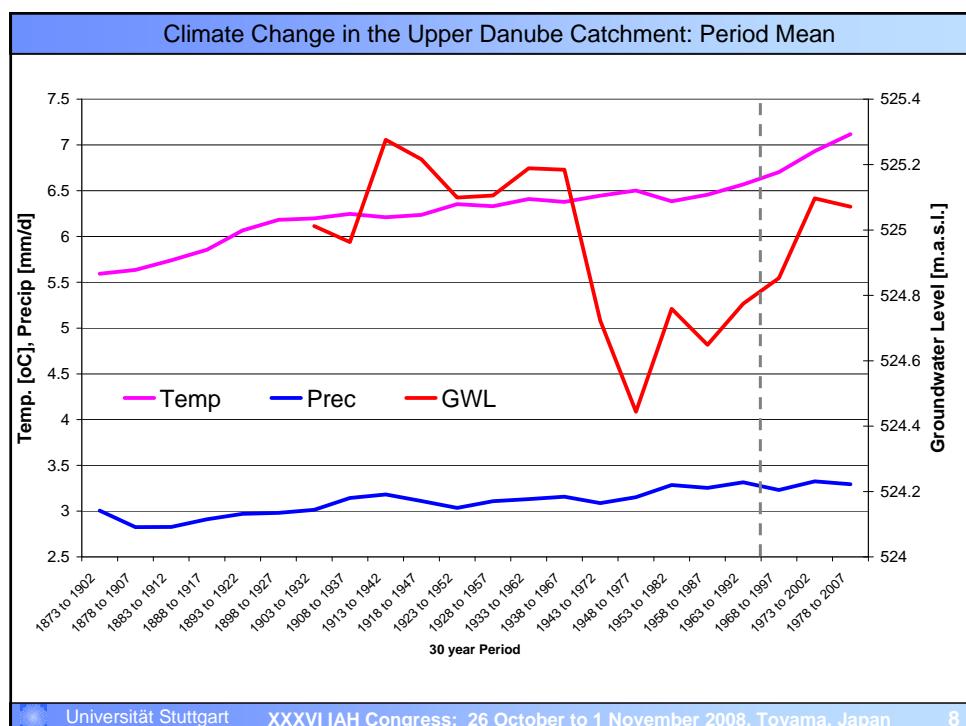




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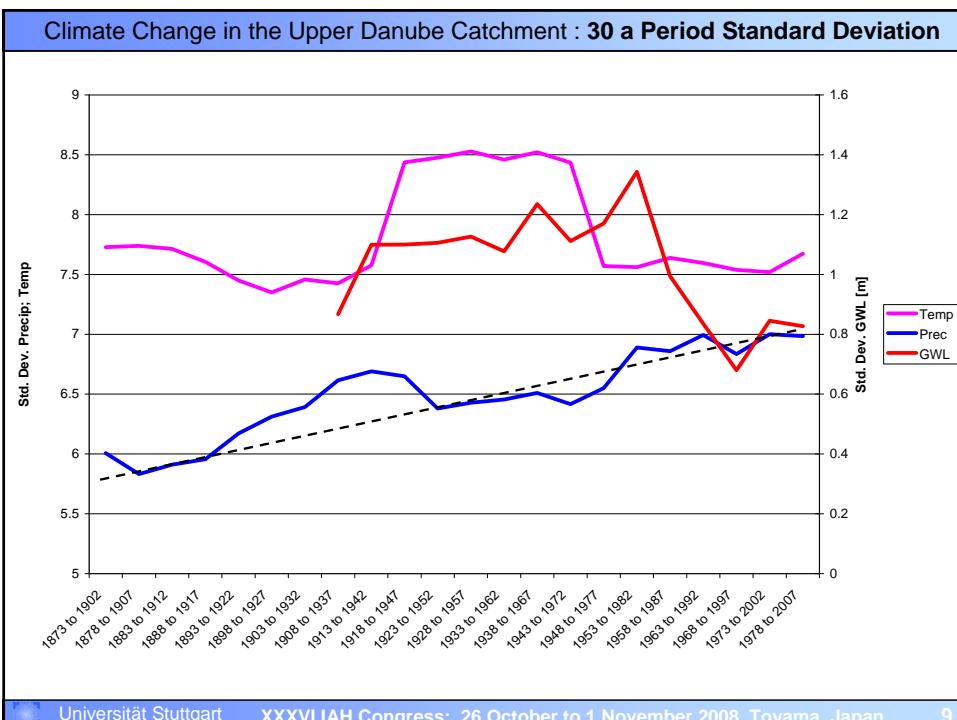
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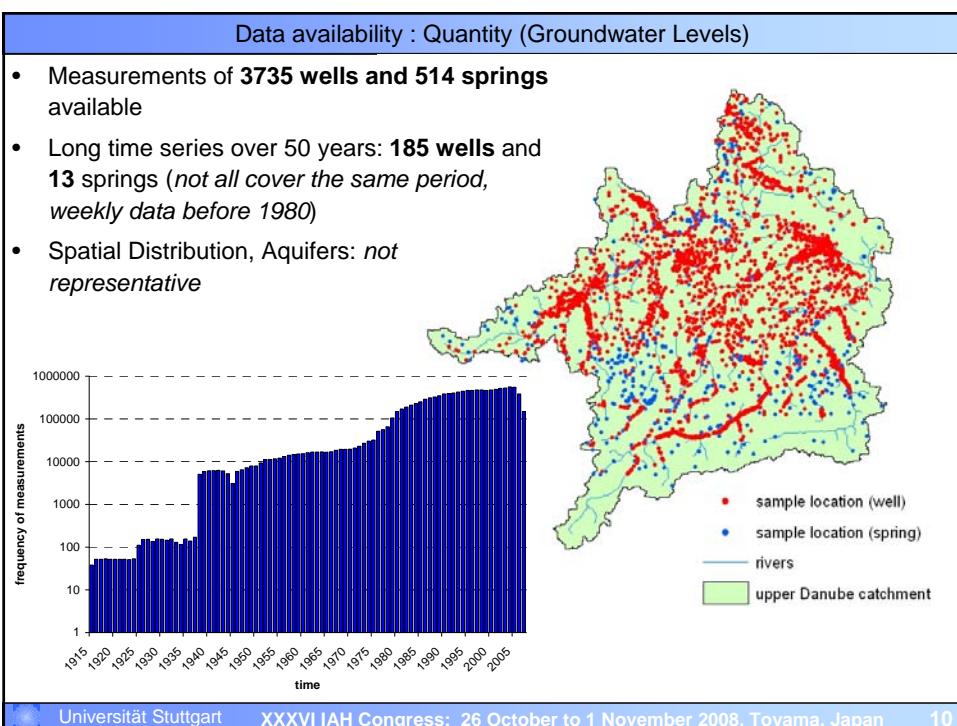
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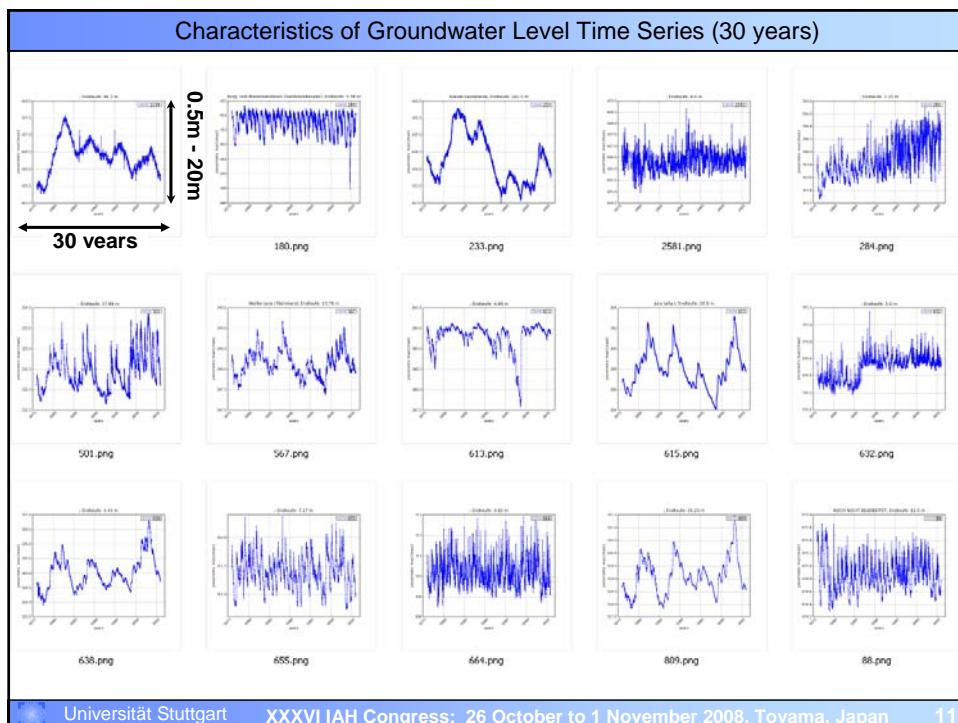
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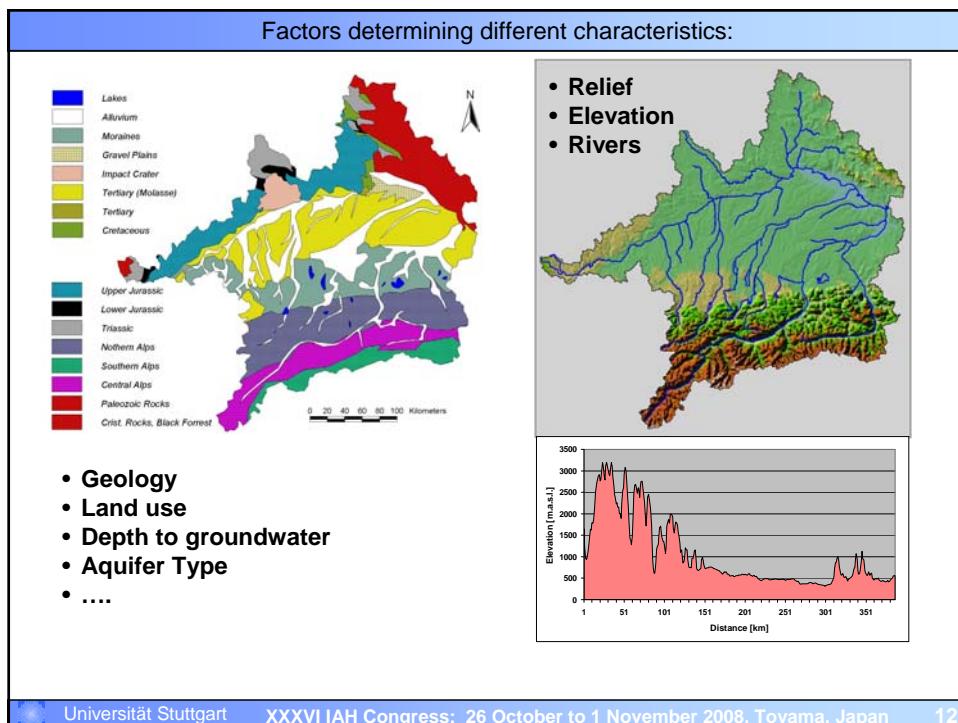
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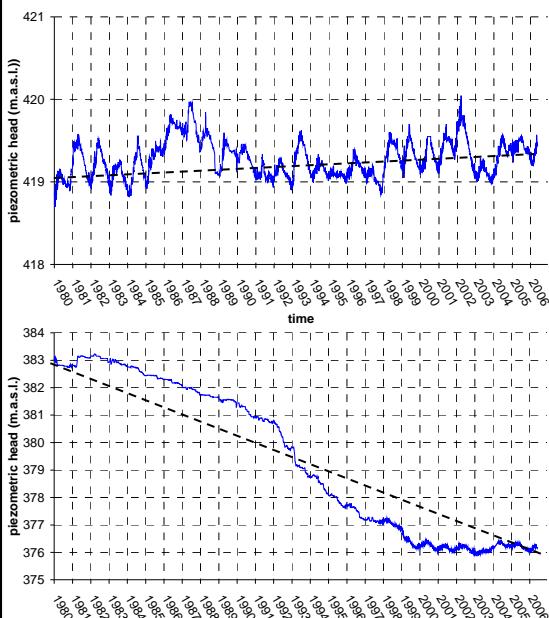


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## Influence of Aquifer Type



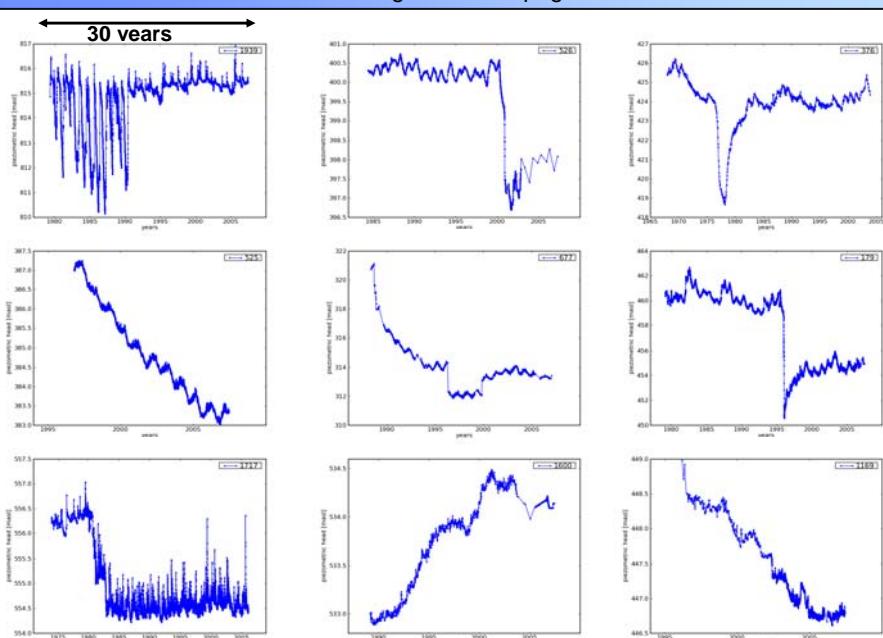
- Horizontal Distance between wells ~2m
- Upper Aquifer: Alluvium
- Lower Aquifer: Sandstone

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## Climate Change or Anthropogenic Effects?



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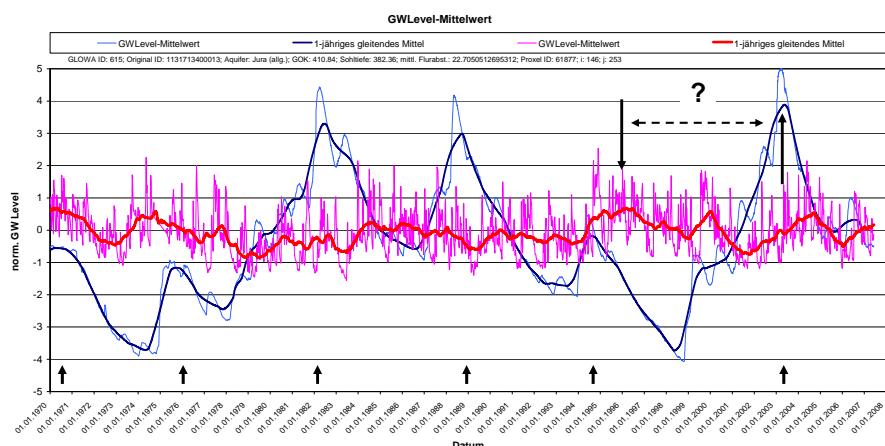
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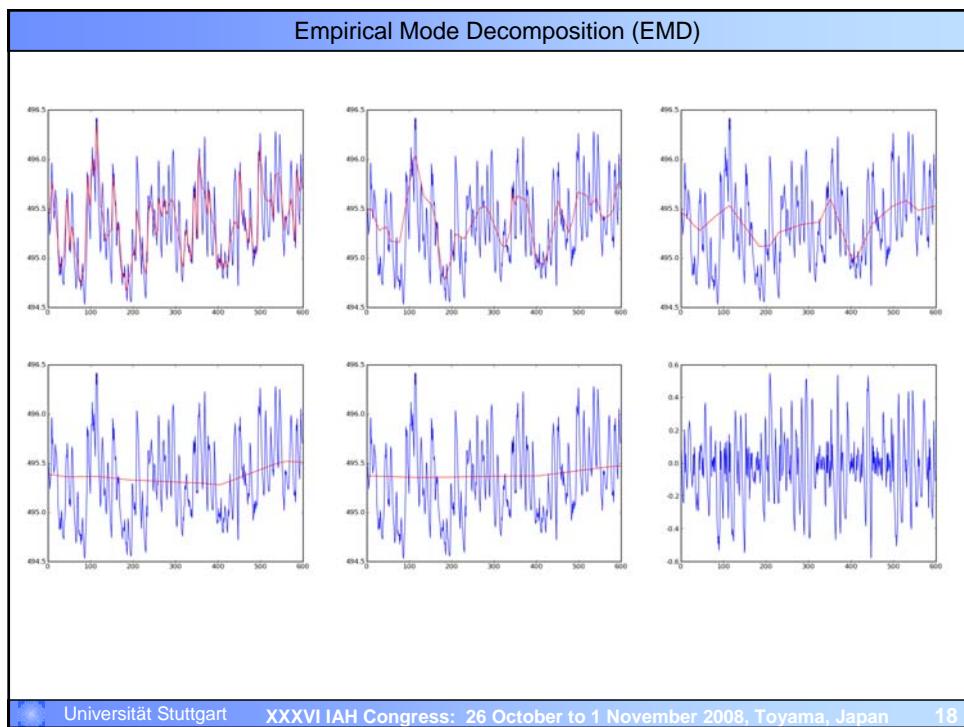
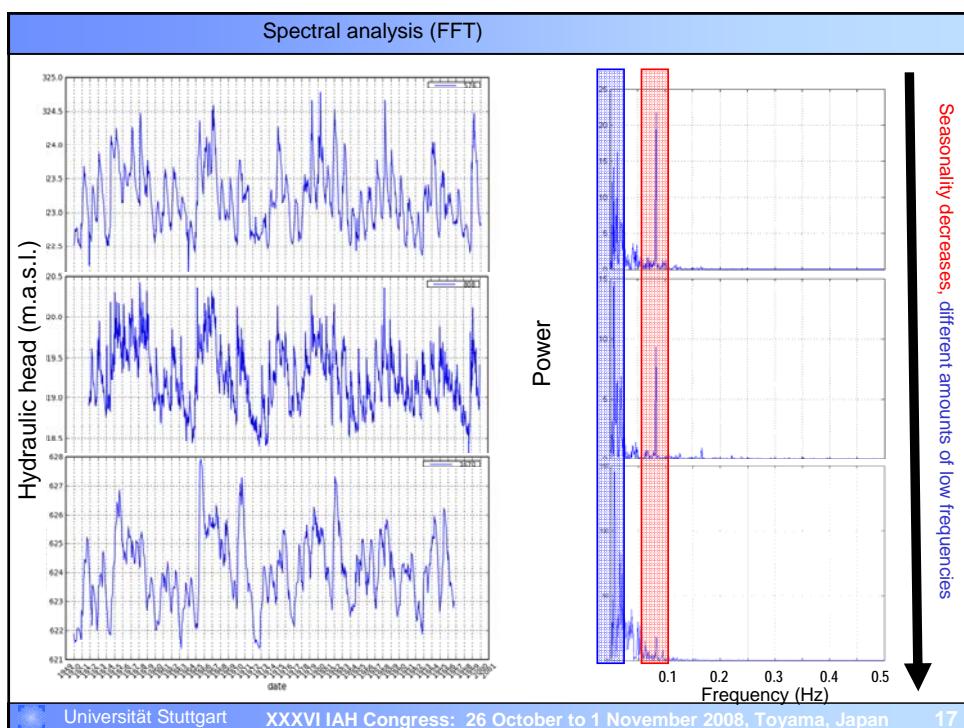
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## Approaches to analyze and use the different characteristics

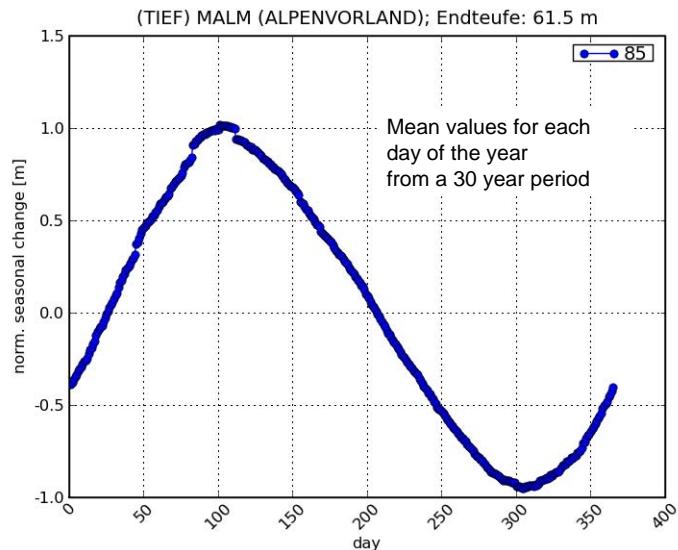
1. Find out what determines the **characteristics** of a groundwater observation well:
  - a) Determine (simple) statistical descriptors to describe the characteristics (standard deviation, coefficient of variance, skewness, distribution type and PDFs etc)
  - b) Determine the natural factors than have an influence on the time series characteristics (geology, thickness and properties of the unsaturated zone, landuse, distance to surface waters, aquifer flow regimes)
2. Analyze the temporal behavior and relations of groundwater and climate time series:
  - Trend, break points, wavelet analysis, spectral analysis (e.g. FFT); autocorrelation, covariance, cross correlation ...
3. Perform multivariate statistical analysis, cluster analysis, geostatistics etc. to **categorize** the results of 1.) and 2.)
4. Derive algorithms (transfer functions) to predict time series from climate input and location (**regionalization of results**)

## Analysis of spectral information

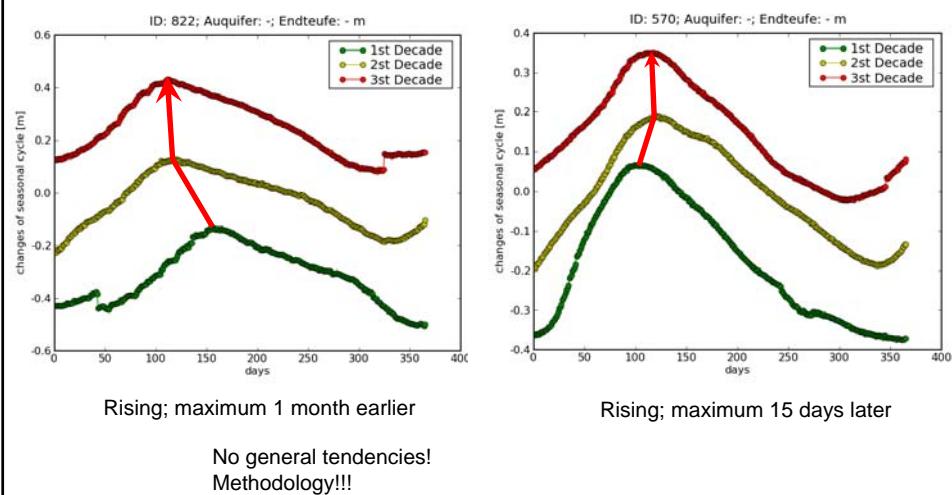


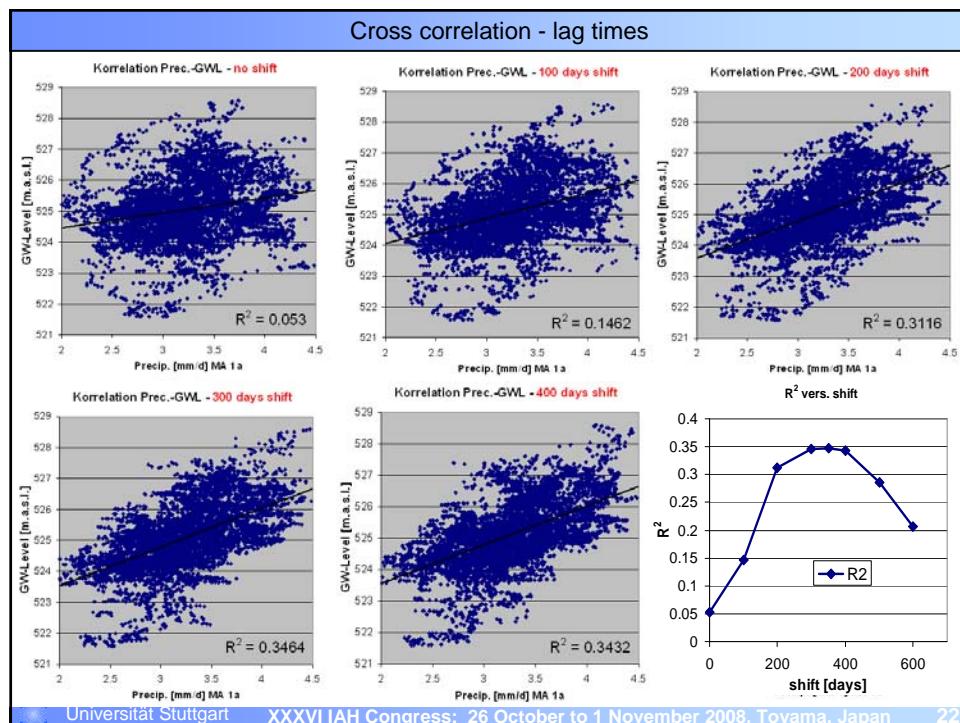
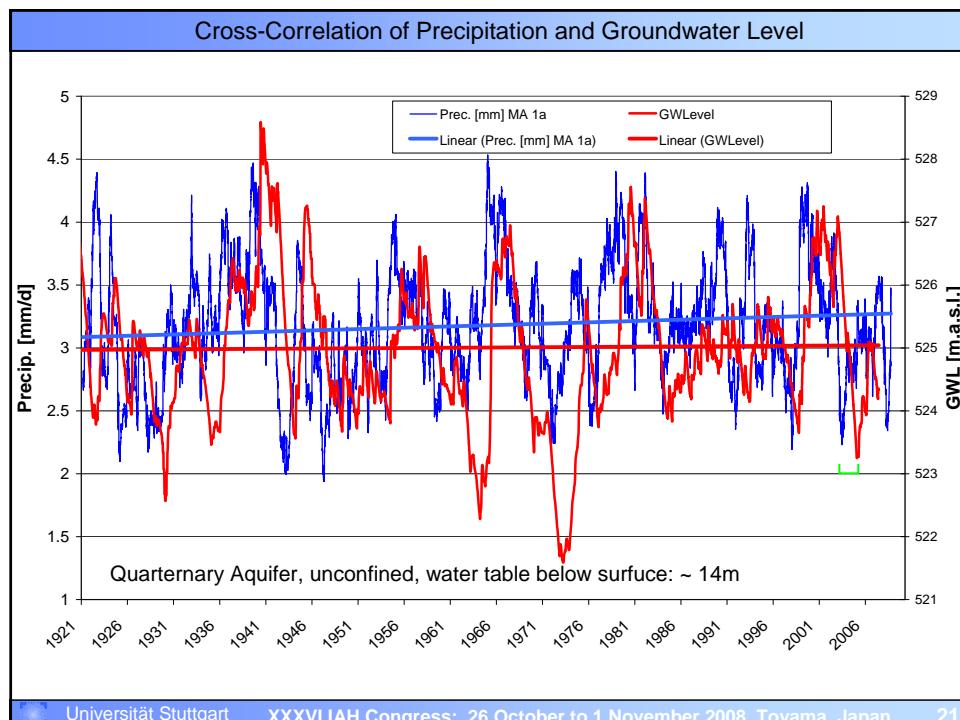


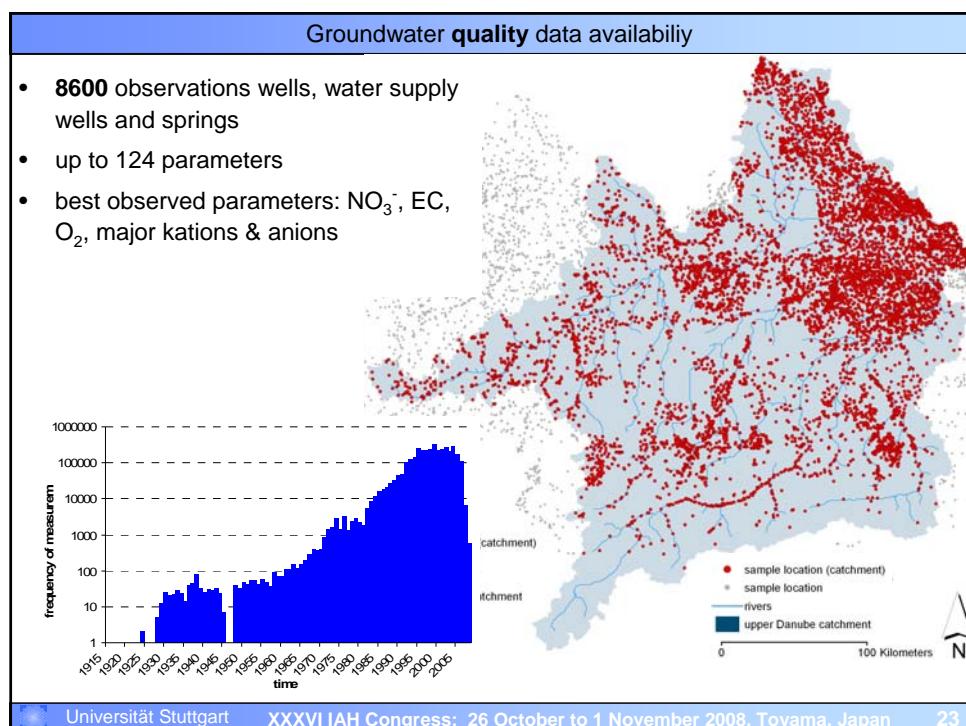
## Analysis of Seasonality to detect climate change



## Changes of Seasonality



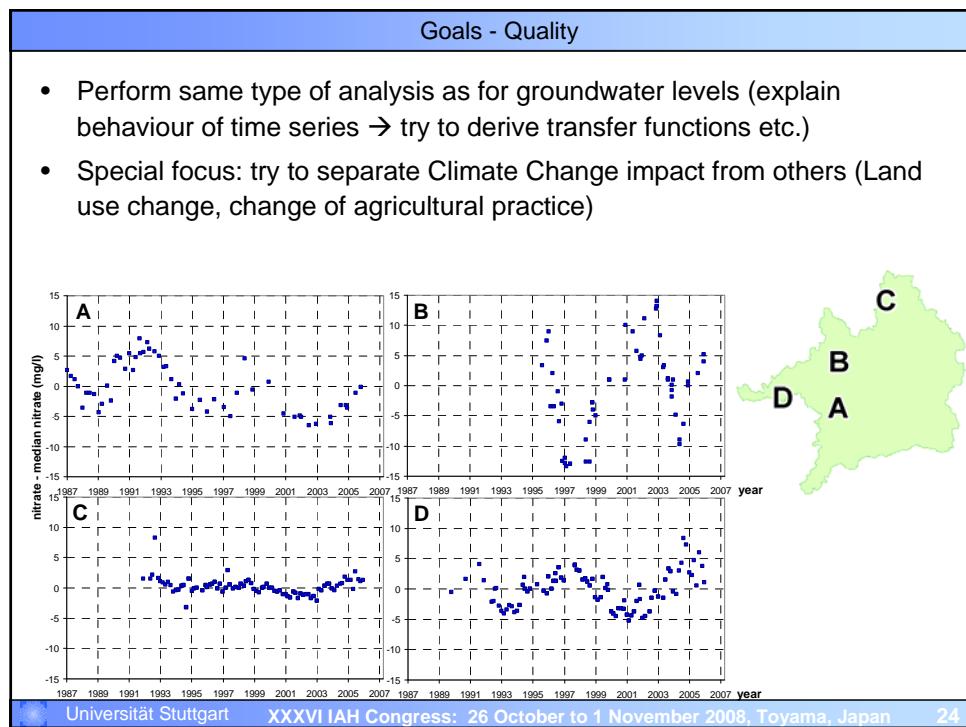


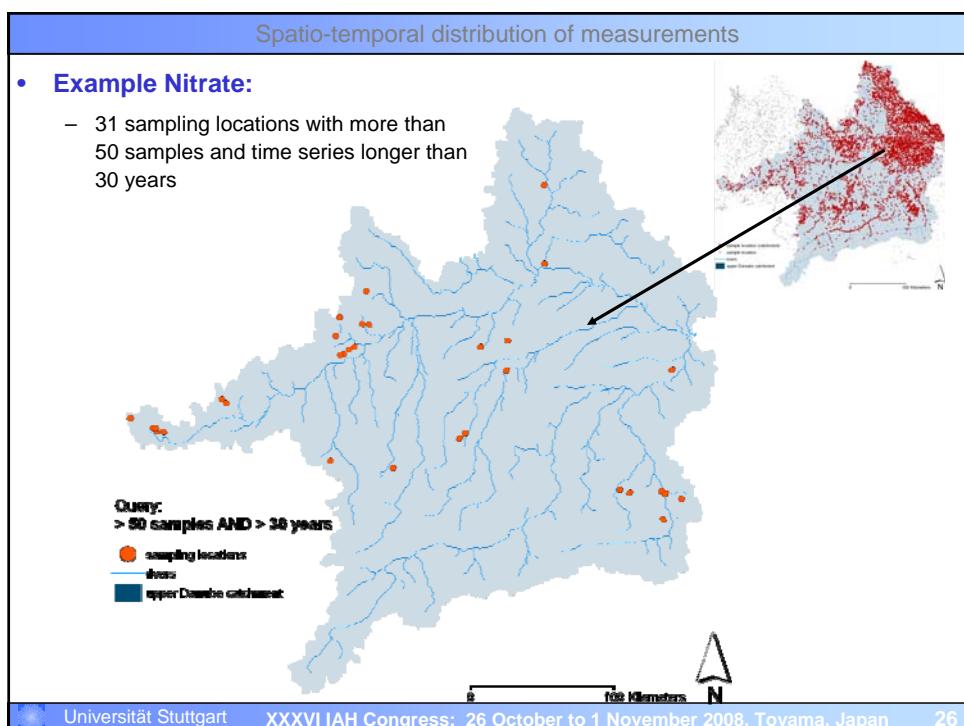
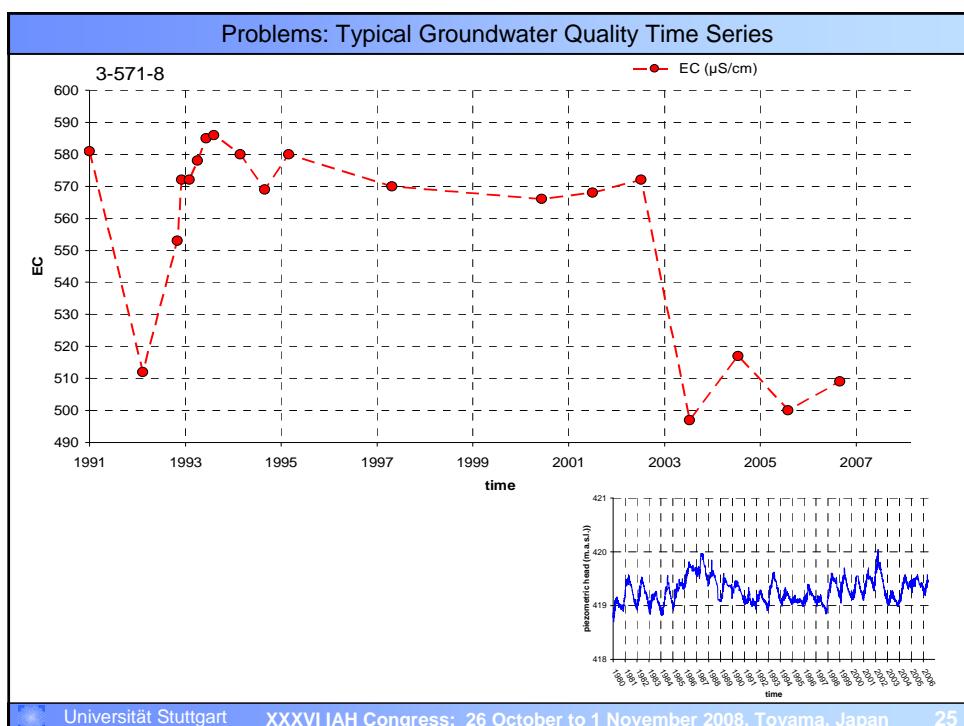


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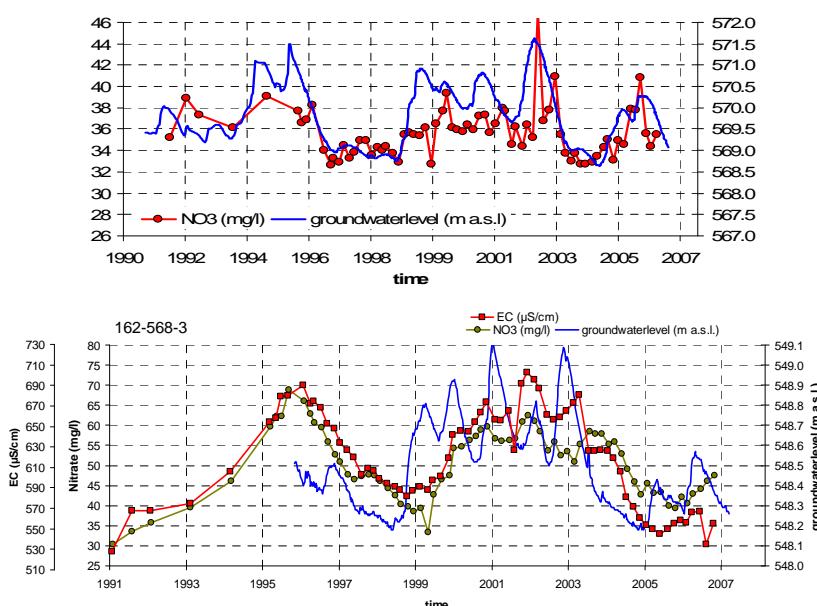


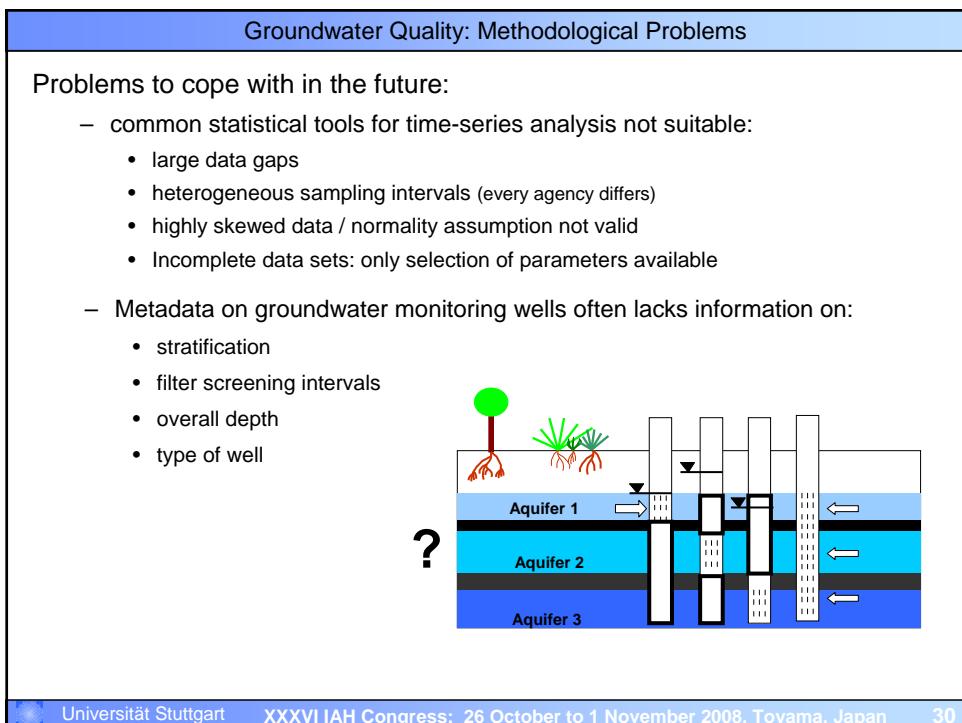
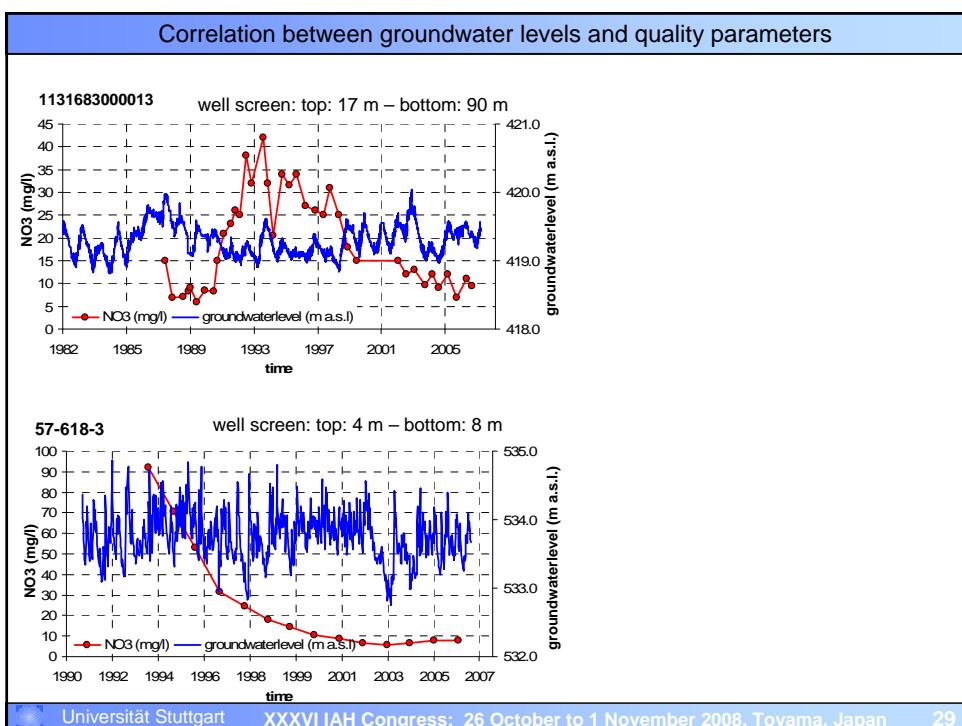


Therefore

- Special Focus:
  - Try to fill gaps using secondary information (e.g. groundwater level where applicable)
  - Regionalization: spatial interpolation based on secondary information

Correlation between groundwater levels and quality parameters





### Preliminary Conclusions

1. Climate Change is ongoing in the Upper Danube Catchment
2. Changes of Temperature and Precipitation have an obvious influence on groundwater resources, both quality and quantity
3. The influence is much stronger and clearer on Groundwater Quantity and much more difficult to detect for Quality
4. Changes of long term statistics (=„Climate Change“) are often **not obvious** from observations, because:
  - Anthropogenic influences on groundwater chemistry and quantity seem often to be stronger than climate change influences
  - The groundwater system reacts delayed and damped and time series of groundwater observations are too short to show significant changes
  - Groundwater Systems slowly adapt to climatic conditions by establishing new equilibrium conditions - the dynamics of these processes are not understood yet
  - Available data are strongly biased as the observation network is not representative for all aquifers
  - The relevant processes are highly non-linear and interrelated in yet unknown ways
  - We have not applied or developed the appropriate methods yet ...?
5. There is still a lot of work to do!

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