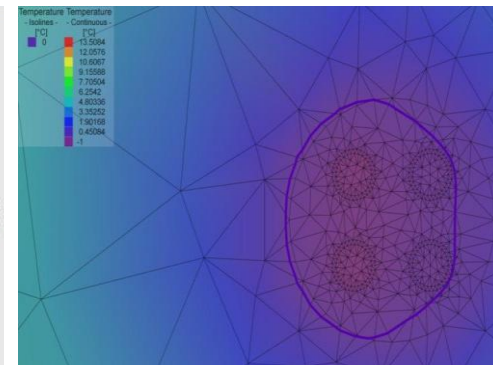
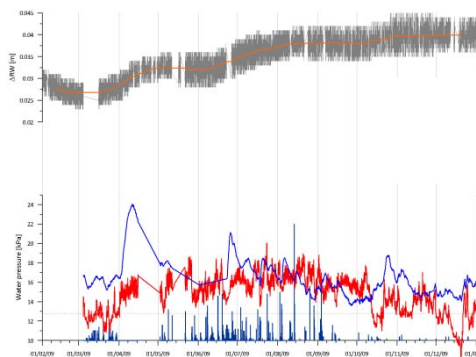
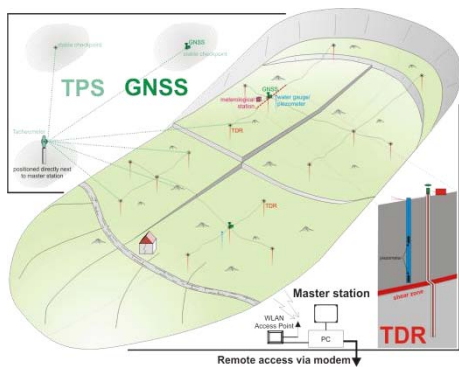


Alpine hazard management and utilization of geothermal energy in Bavaria, Germany

Prof. Dr. John Singer

Prof. Dr. K. Thuro, Prof. Dr. Th. Wunderlich, Prof. Dr. O. Heunecke,
Prof. Dr. Kai Zosseder



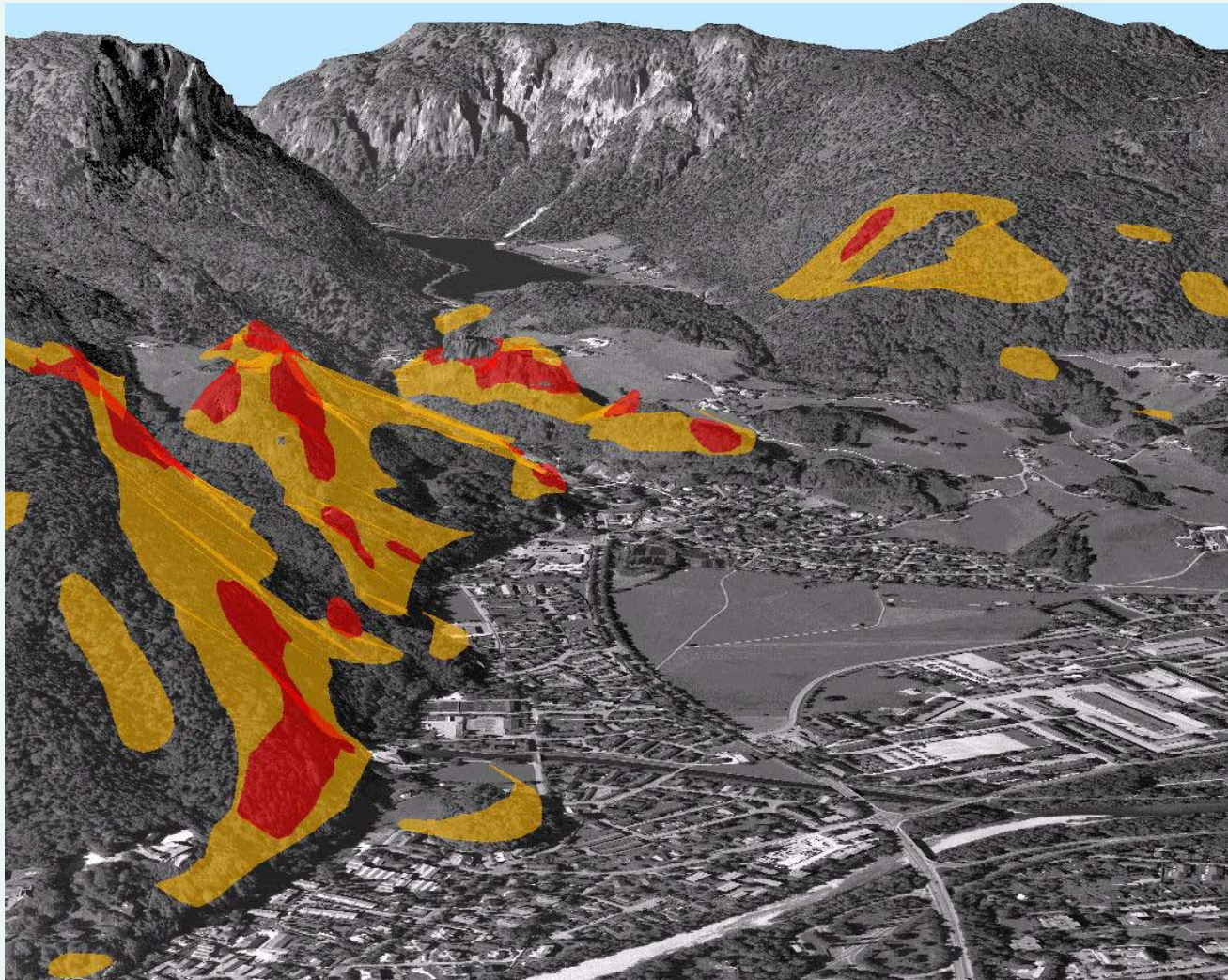


- Landslide hazard management
 - Hazard indication maps
 - Monitoring and early warning: the alpEWAS project
 - Radar remote sensing
- Utilization of geothermal energy
 - The geothermal potential Southern Germany
 - Deep geothermal energy
 - Near surface geothermal energy



- Issued by the Bavarian State Office for the Environment for the high mountain areas
- Hazards covered:
 - Rockfall
 - Shallow and deep seated landslides (excluding debris flows)
 - Dolines and sinkholes
- Gives information on the hazard situation based on
 - Empirical observations (landslide inventory)
 - Detailed geological and topographic information
 - Numerical models

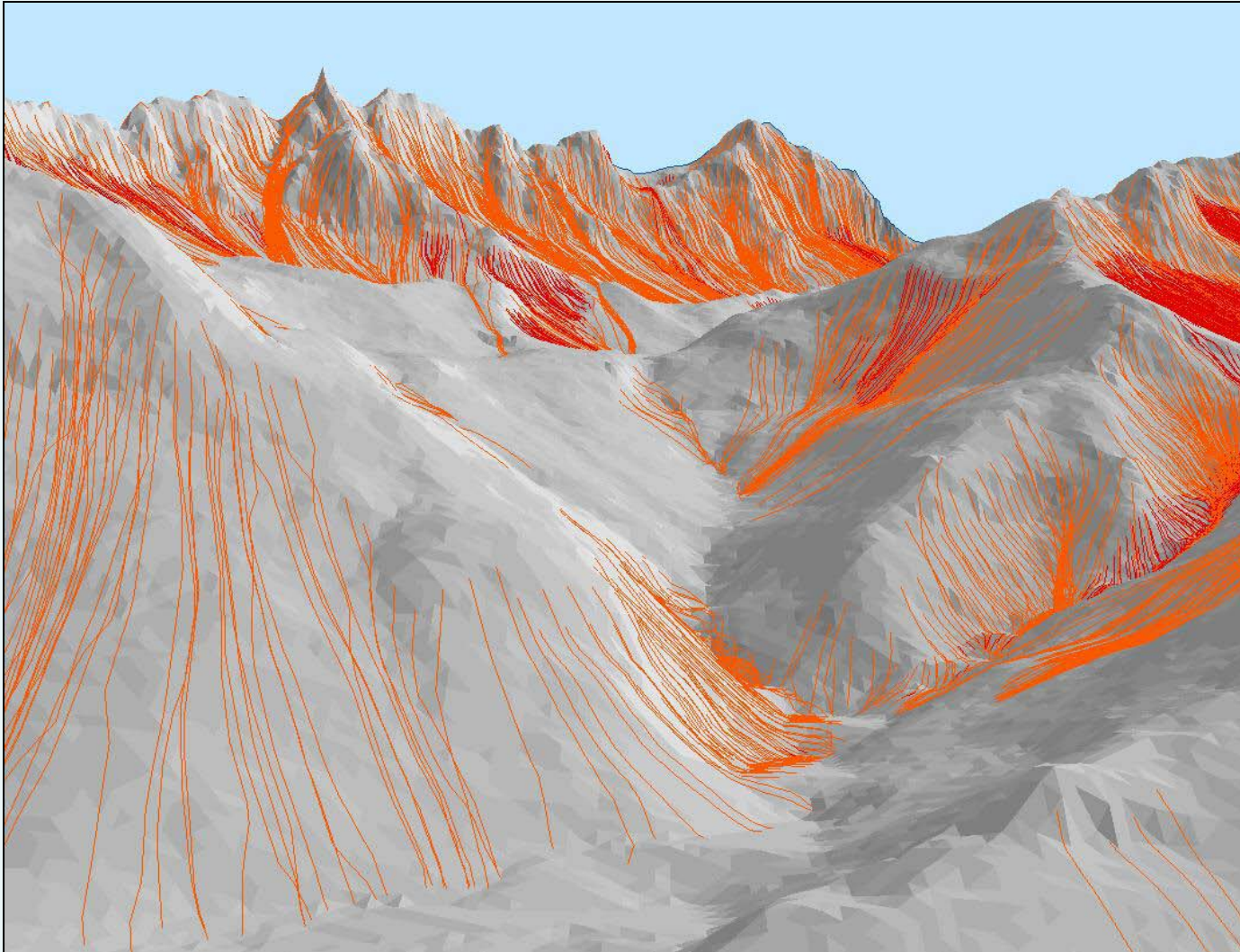
- Determination of potential detachment areas



Based on:

- DEM
- Aerial photos
- Inventory
- Field observations

- Run-out Simulation using 3D-Rockfall-Model

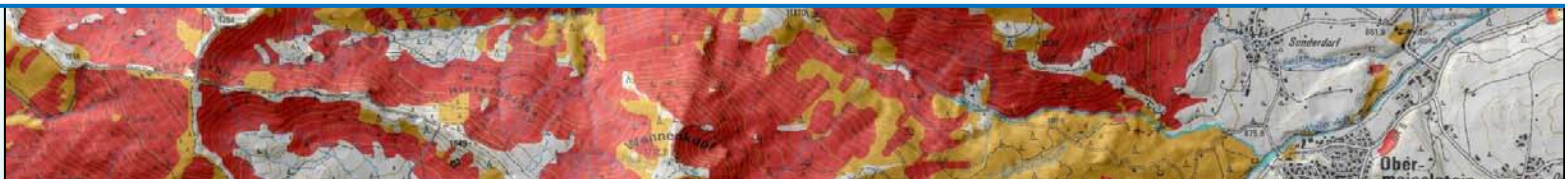


Based on:

- DEM
- Aerial photos (land cover)



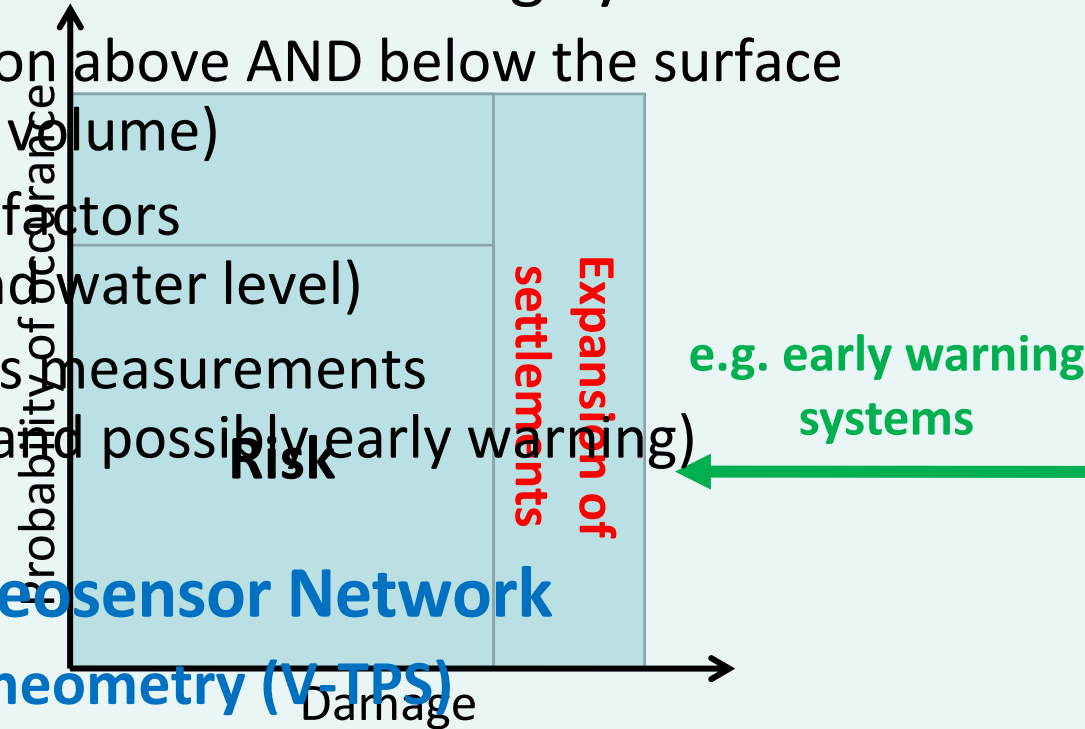
- Overview of landslide *hazard distribution*
- Identification of *conflicts* with current and future land use
- In case of high damage potential:
site specific analysis and mitigation measures





- Increase of landslide risk in alpine areas
- Need for economic measuring systems

- Deformation above AND below the surface (landslide volume)
- Triggering factors (e.g. groundwater level)
- Continuous measurements (alarming and possibly early warning)

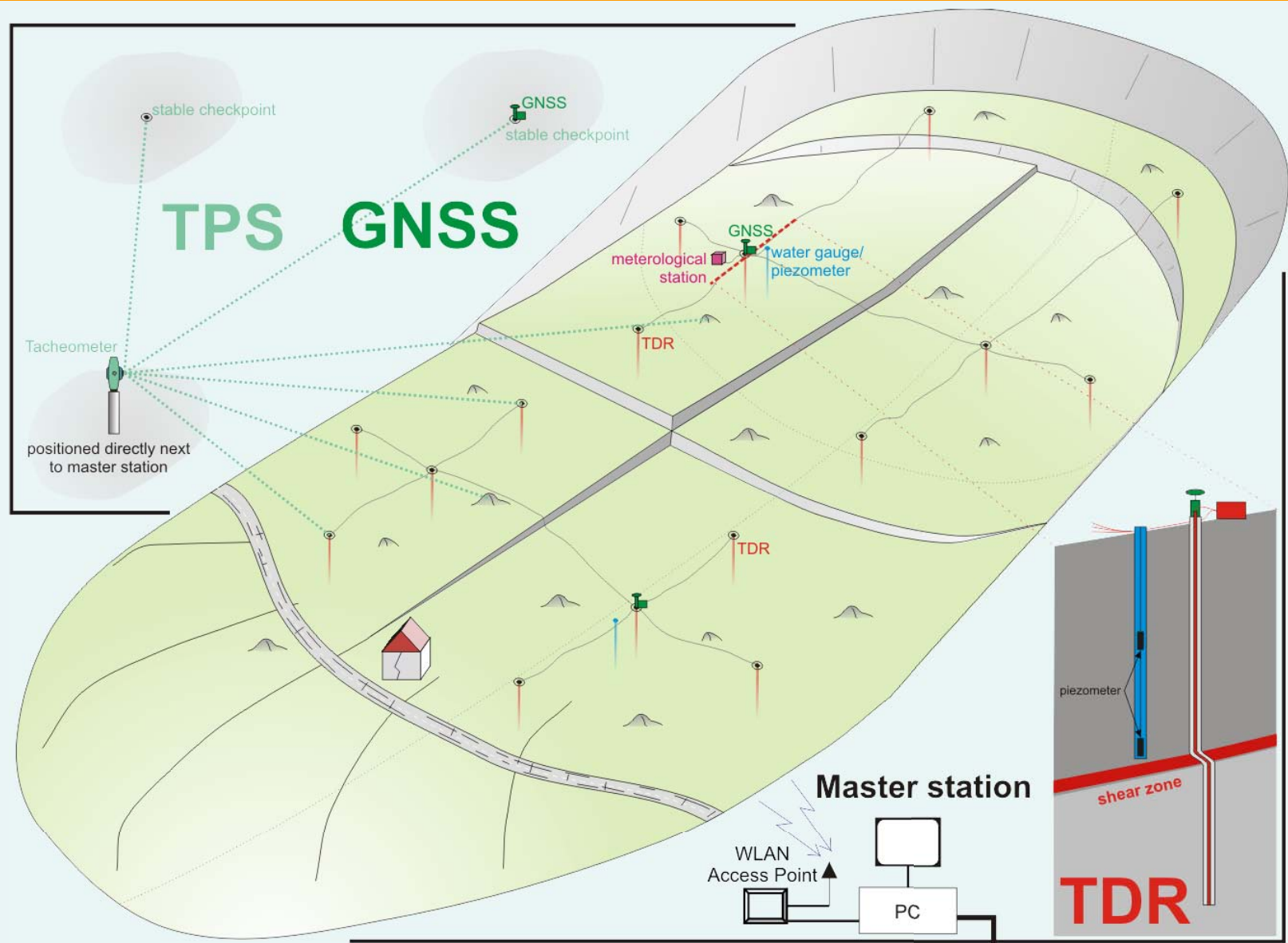


→ alpEWAS Geosensor Network

- Video Tacheometry (V-TPS)
- Low Cost Global Navigation Satellite System (LC-GNSS)
- Time Domain Reflectometry (TDR)



alpEWAS Geosensor Network



TPS GNSS

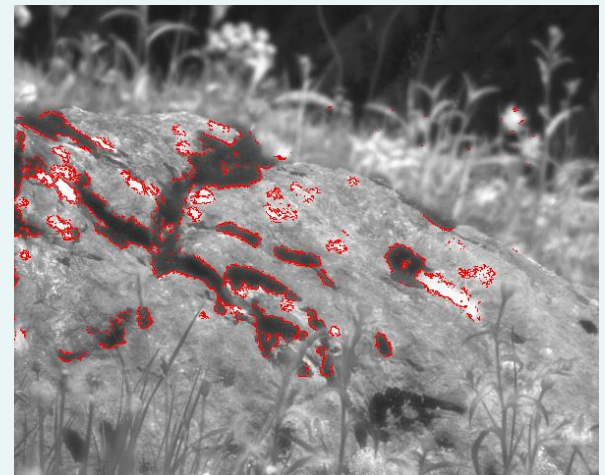
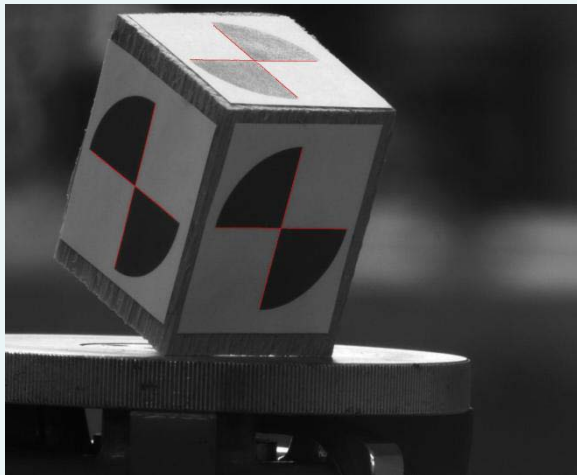
Tacheometer
positioned directly next
to master station

Master station
WLAN
Access Point
PC

Remote access via modem

piezometer
shear zone
TDR

- Precision tacheometer + high resolution digital camera
 - Arbitrary natural targets (no need for artificial targets)
 - Target detection based on image analyses (intensity, edges)
 - Intelligent target selection
- Flexible contact-free measuring system
- Limited range, depends on visibility of targets

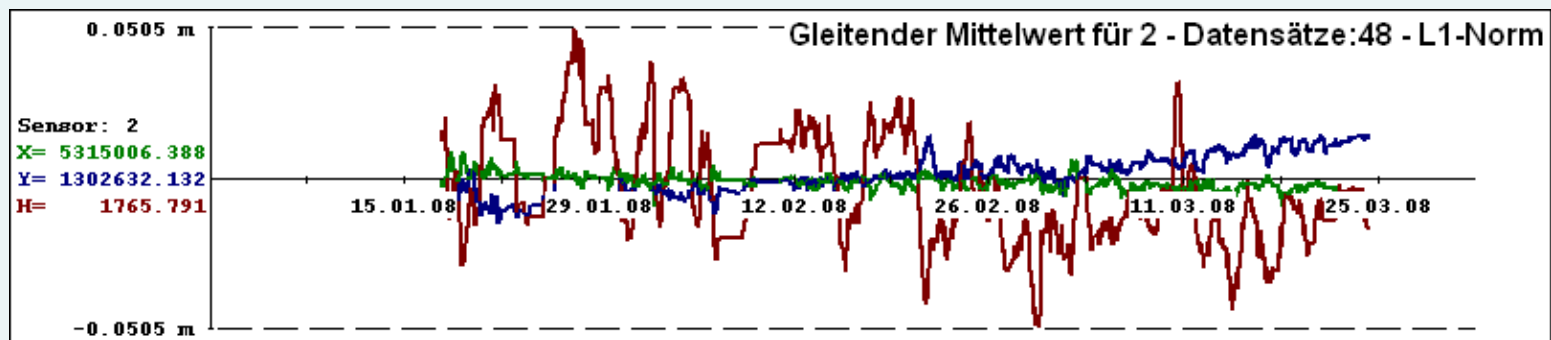


- Low cost GNSS sensors

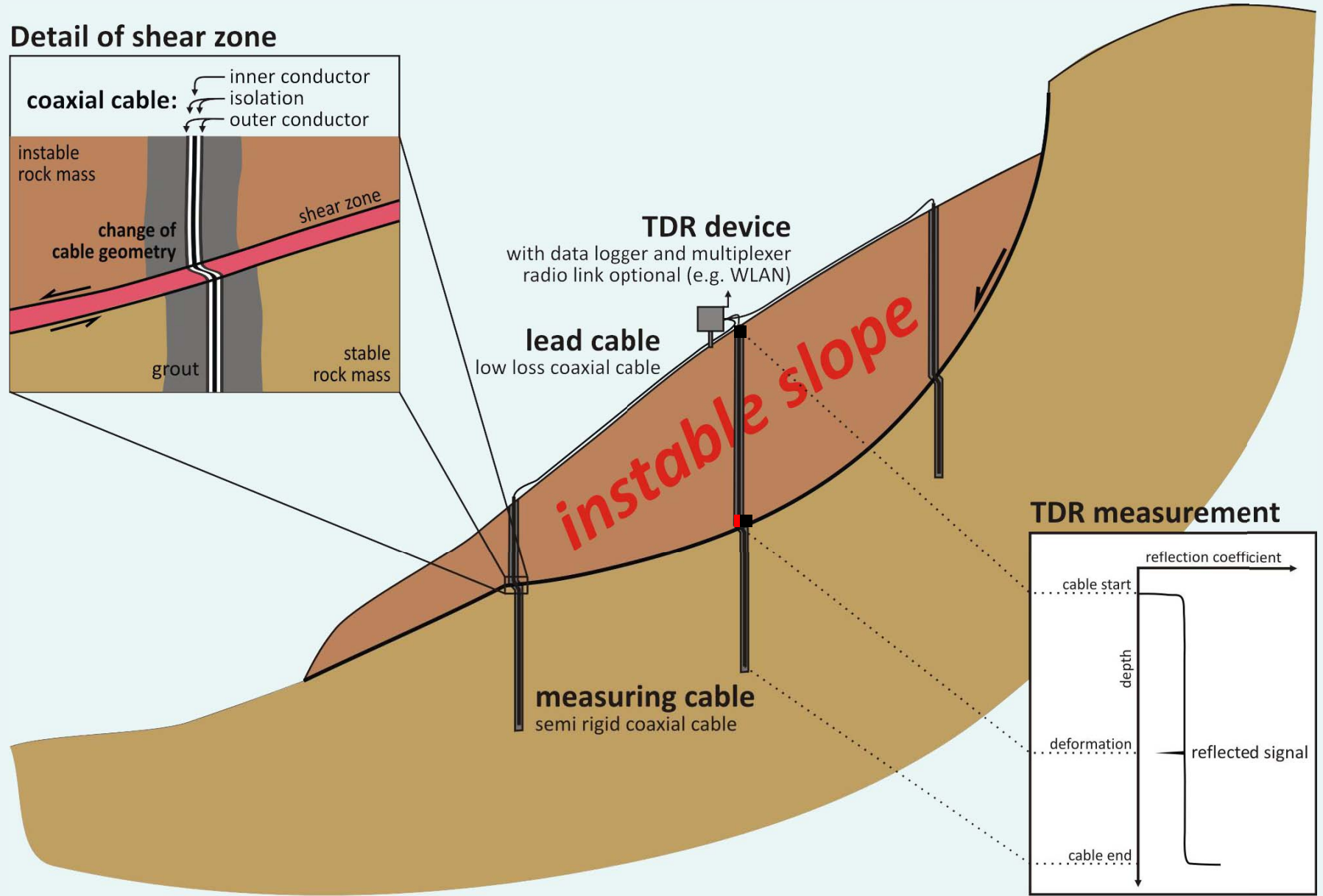
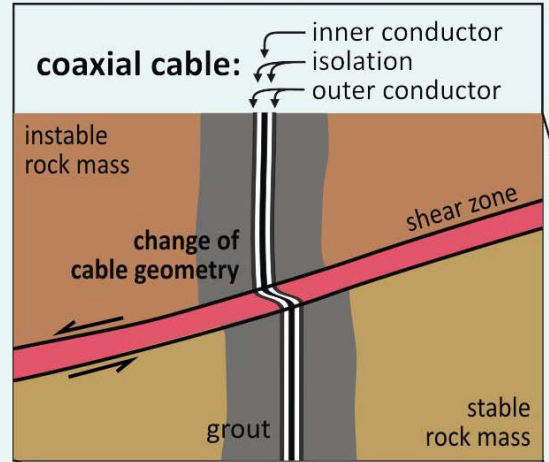
- Use of L1 carrier phase only
- Post processing of data segments (filtering, smoothing)
- Near real time base line processing
- Sub-centimeter accuracy

→ weather independent, continuous

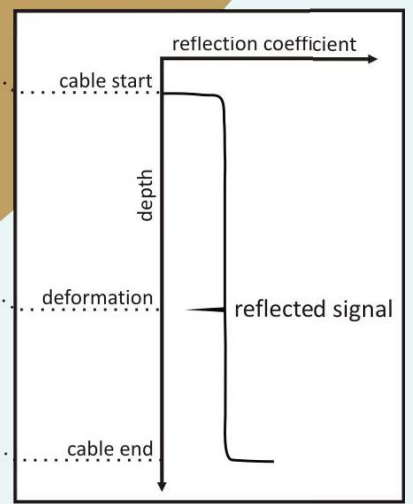
→ punctual information



Detail of shear zone



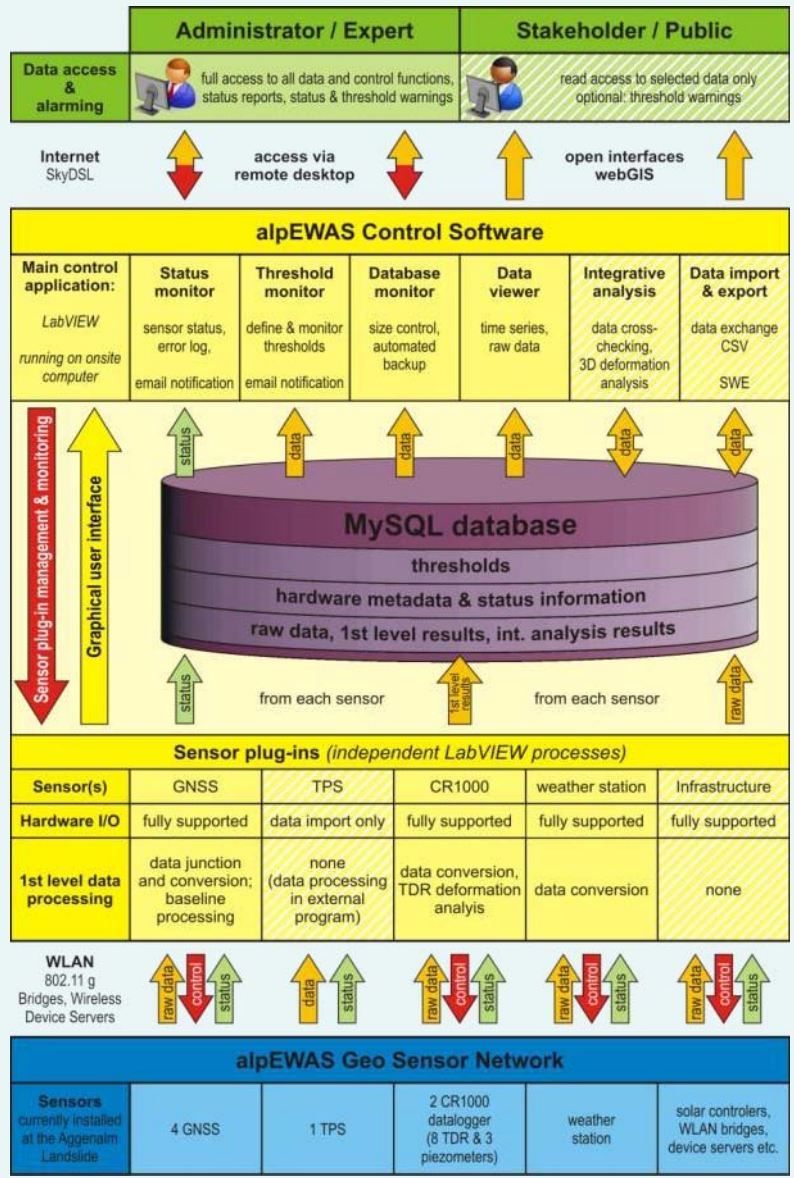
TDR measurement



User

alpEWAS Control Software

Geosensor-network



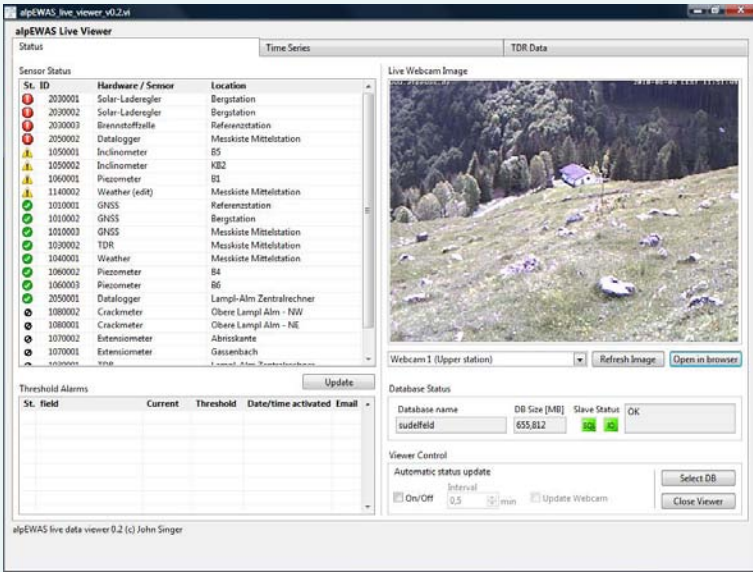
Control



Data



Status



alpEWAS Live Viewer

Status | Time Series | TDR Data

Sensor Status

St. ID	Hardware / Sensor	Location
2030001	Solar-Laderegler	Bergstation
2030002	Solar-Laderegler	Bergstation
2030003	Brennstoffzelle	Referenzstation
2030002	Datalogger	Messkiste Mittelstation
1055001	Inclinometer	B5
1055002	Inclinometer	KB2
1060001	Piezometer	B1
1140002	Weather (edR)	Messkiste Mittelstation
1010001	GNSS	Referenzstation
1010002	GNSS	Bergstation
1010003	GNSS	Messkiste Mittelstation
1030002	TDR	Messkiste Mittelstation
1040001	Weather	Messkiste Mittelstation
1060002	Piezometer	B4
1060003	Piezometer	B6
2050001	Datalogger	Lampf-alm Zentralrechner
1080002	Crackmeter	Obere Lampf Alm - NW
1080001	Crackmeter	Obere Lampf Alm - NE
1070002	Extensionmeter	Abbrückente
1070001	Extensionmeter	Gassenbach

Threshold Alarms

St. field	Current	Threshold	Date/Time activated	Email

Viewer Control

Automatic status update: On/Off Interval: 0.5 min Update Webcam: Close Viewer

Data Viewer



alpEWAS Live Viewer

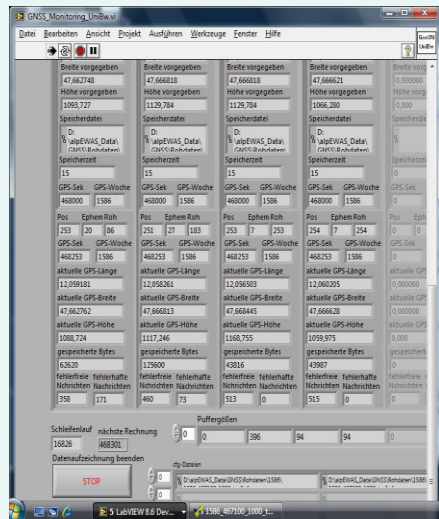
Status | Time Series | TDR Data

Weather (Upper central station) - Temp_Out
Weather (Upper central station) - Rainfall
Piezometer (B4) - water_pressure

Time Series Graph: Temp_Out (red line), Rainfall (blue bars), water_pressure (green line)

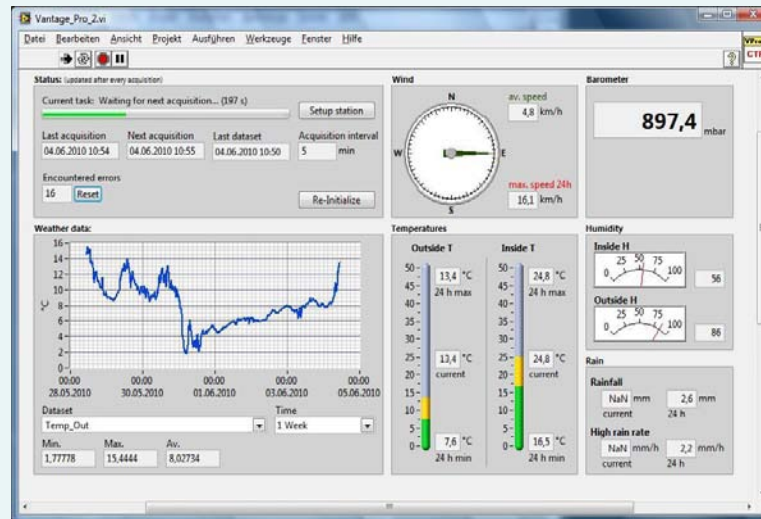
Time: 28.05.2010 to 05.06.2010

Viewer Control: On Sensor: Weather, Dataset: Temp_Out; Sensor: Rainfall, Dataset: Rainfall; Sensor: Piezometer, Dataset: water_press



GNSS Monitoring Unibw

Table with columns: Breite vorgegeben, Höhe vorgegeben, Speicherdatei, ID, Name, GPS-Sek, GPS-Woche, Pos, Ephem Roh, GPS-Sek, GPS-Woche, gespeicherte Bytes, fehlerfreie Nachrichten, 538, 171, 480, 73, 513, 0, 513, 0



Vanlage_Pro_2v1

Status: Waiting for next acquisition... (197 s)

Barometer: 897.4 mbar

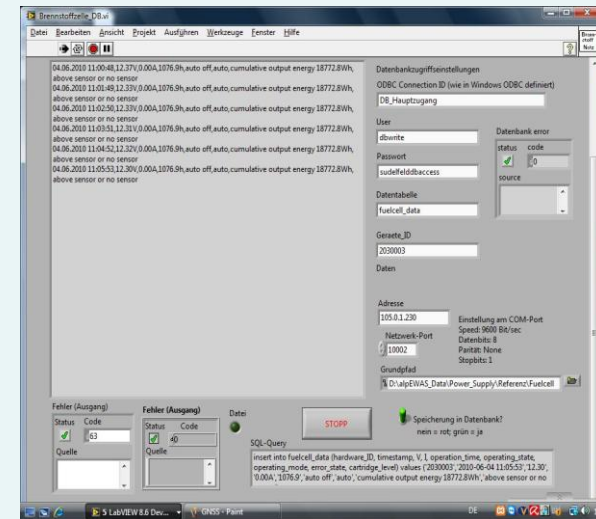
Wind: av. speed 4.8 km/h, max. speed 24h 16.1 km/h

Temperatures: Outside T 13.4 °C, Inside T 24.8 °C

Humidity: Inside H 56, Outside H 86

Rain: Rainfall 2.6 mm, High rain rate 2.7 mm/h

Weather data graph: Temp_Out vs Time



Brennstoffzelle Data

Database configuration settings: ODBC Connection ID, User: abente, Password: wade@alpsaccess, Datenbank error status: code, source

Address: 105.0.1.230, Network-Port: 9000, Database: B, Password: None, Stepsize: 1

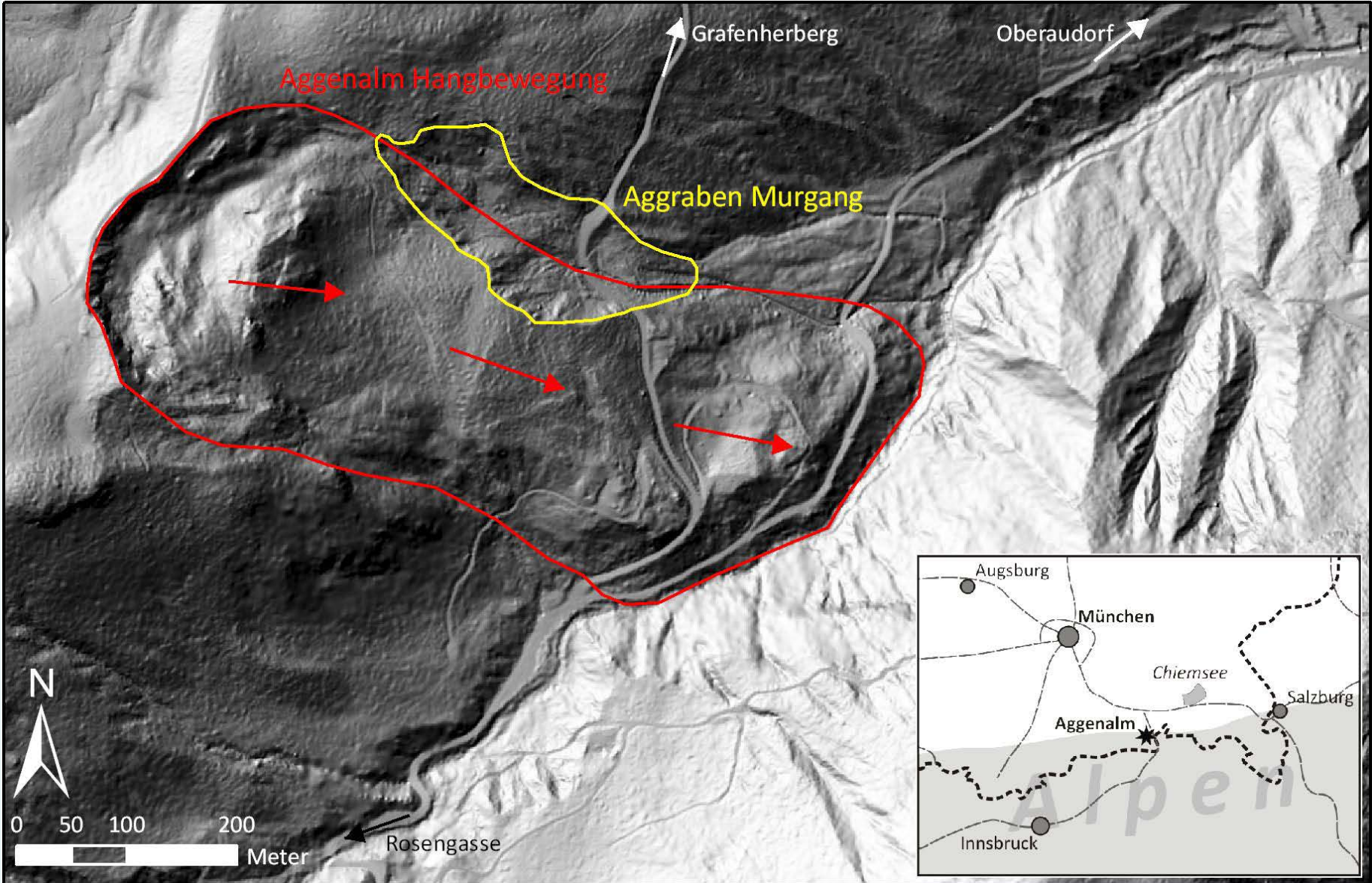
SQL-Query: insert into fuelcell_data (hardware_id, timestamp, V_1, operation_time, operating_state, operating_mode, error_state, cartridge_level) values (2030003, 2010-06-04 11:05:53, 12.30, 0.00A, 1076.9, auto, off, auto, cumulative output energy 18772.8Wh, above sensor or no sensor)

GNSS

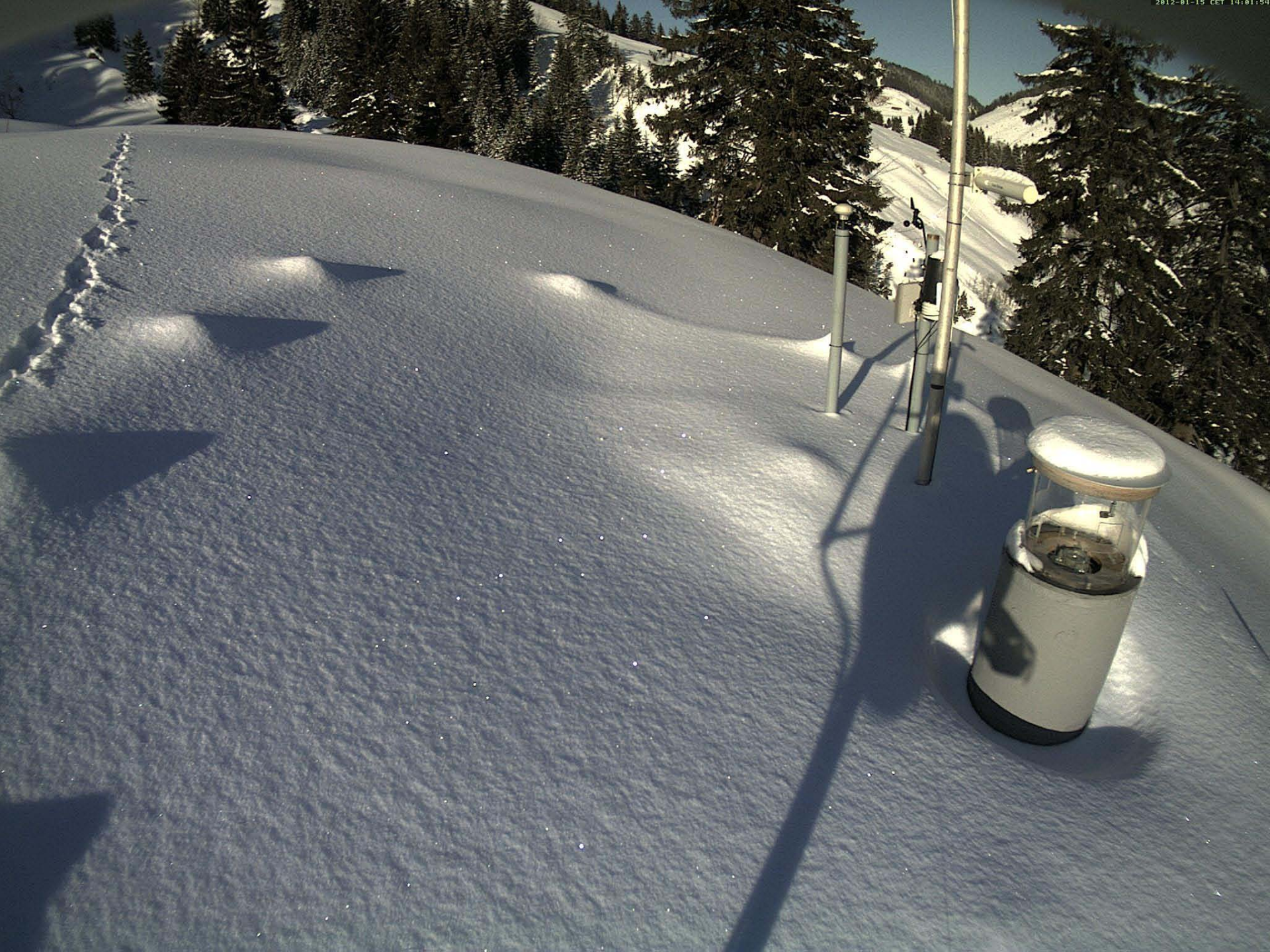
Meteorology

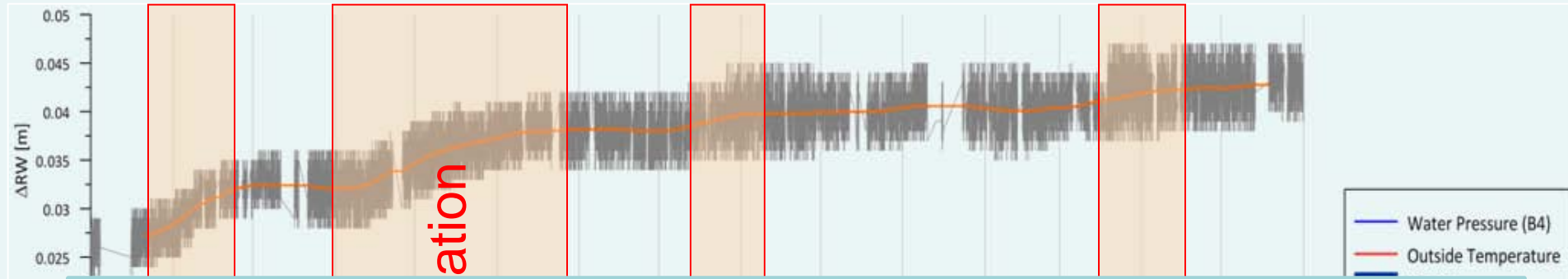
Power Management

Aggenalm Landslide

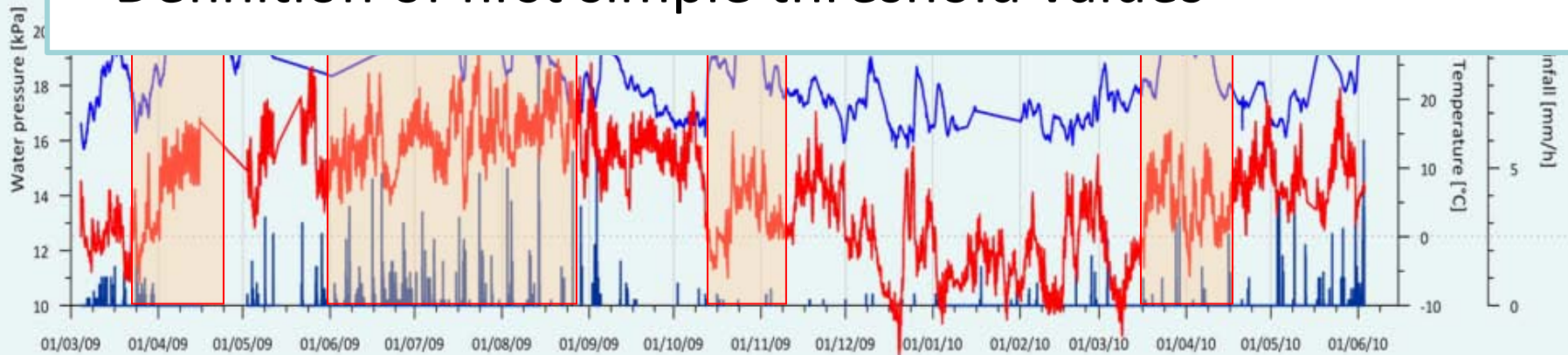






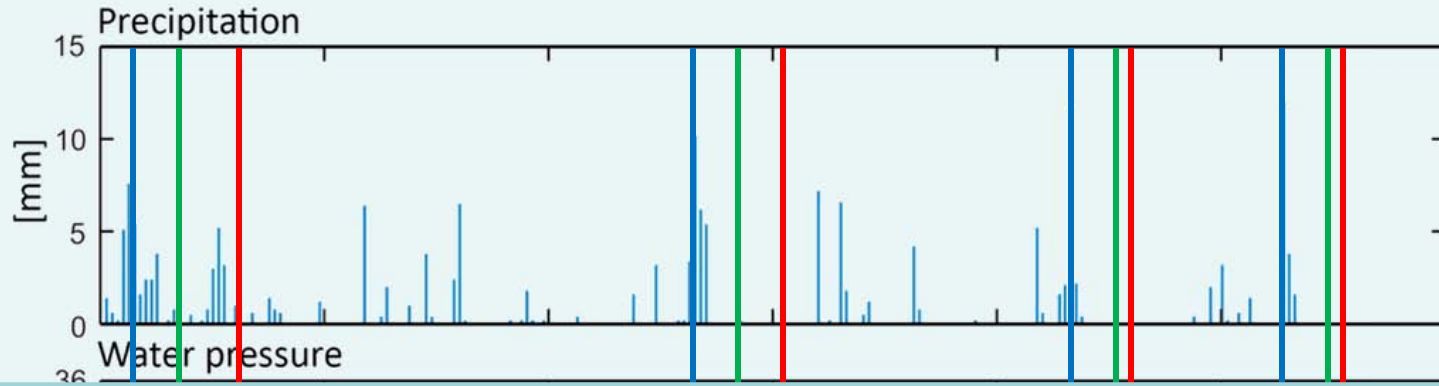


- Precipitation/snow melt and associated rise of ground water levels confirmed as trigger
- Definition of first simple threshold values

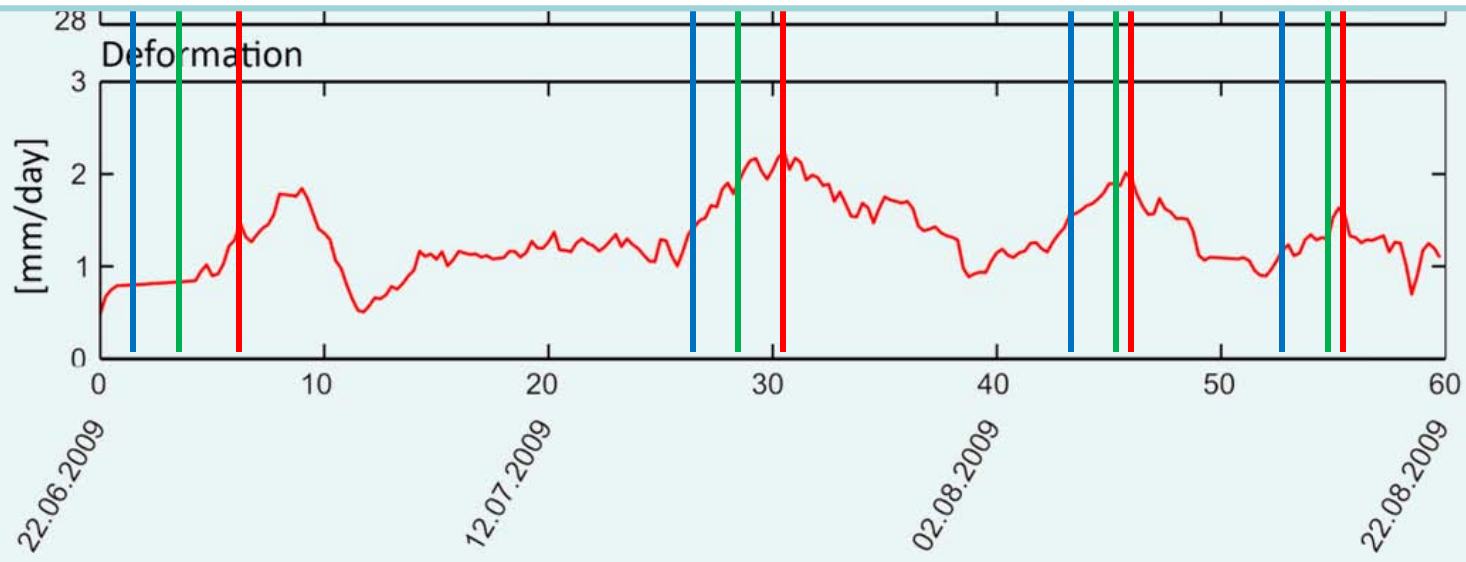




Is early warning possible?



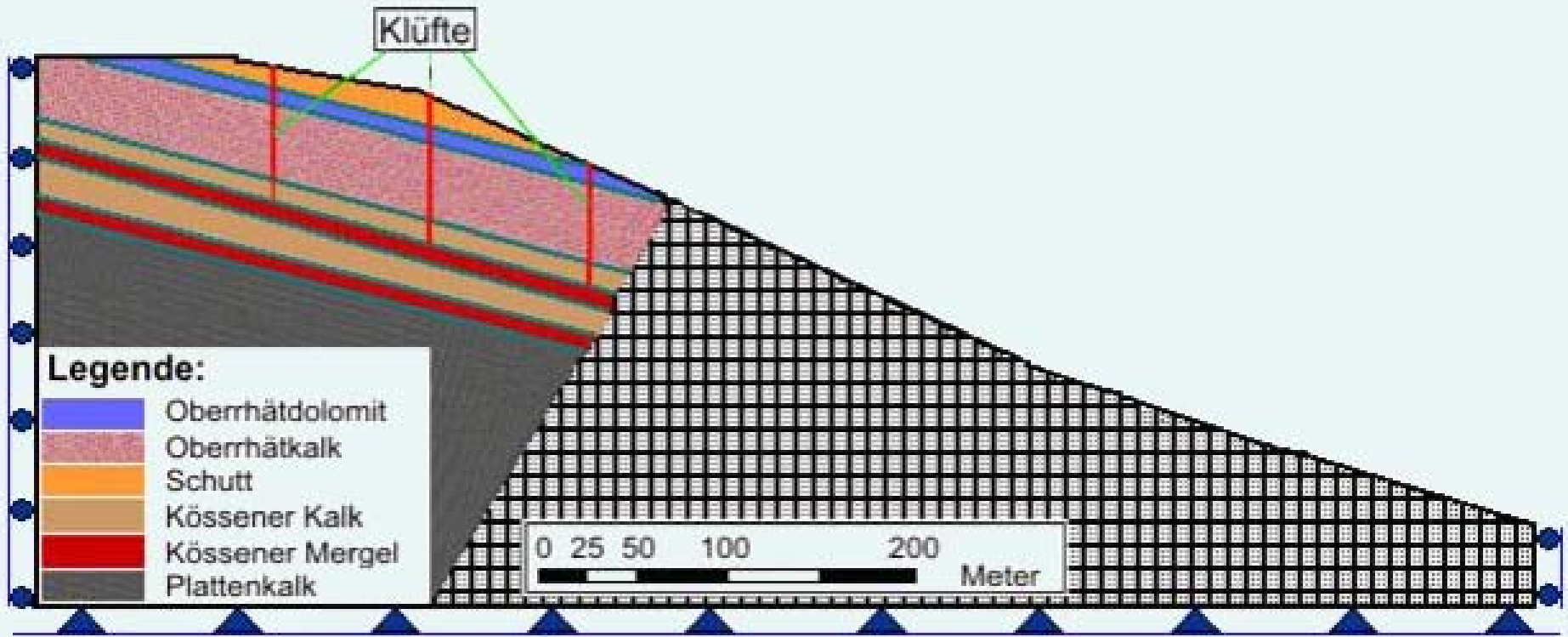
- Reliable prediction of slope deformation 3 days in advance based on observation of triggering factors

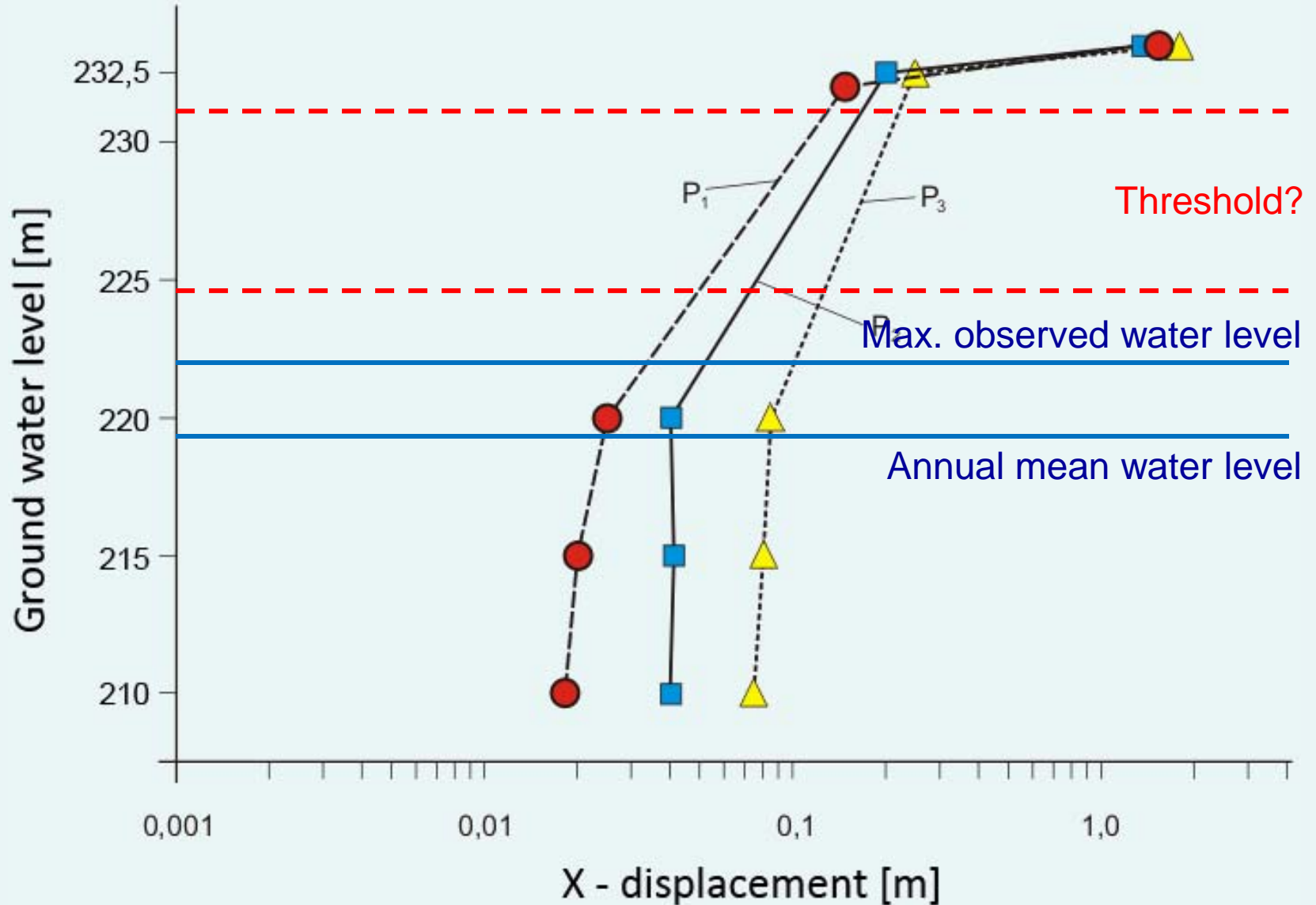




Definition of threshold values

- Empirical observations
 - Threshold values for onset of slow deformations
- Numerical model (FLAC)
 - Validation using monitoring data
 - Simulation of extreme events
 - Threshold values for catastrophic event





- LC-GNSS – surface deformations – punctual
- VTPS – surface deformations – extensive
- TDR – subsurface shear deformation – punctual
- **3D deformation**

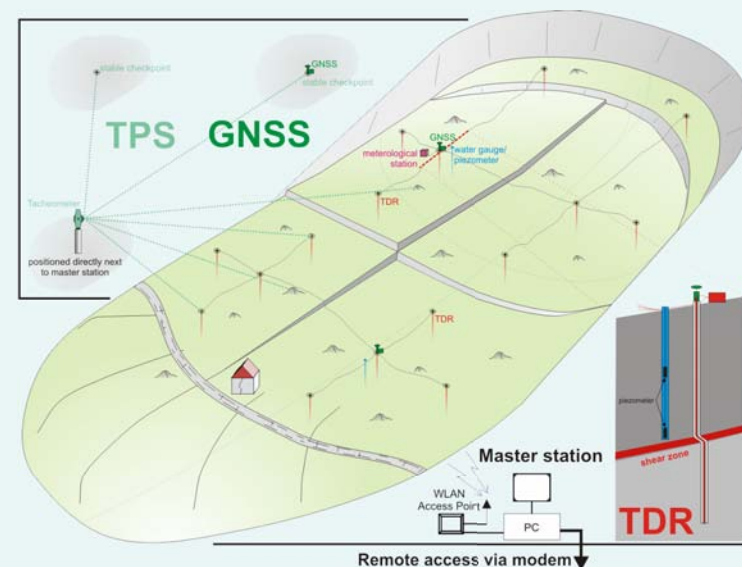
- Piezometer – ground water level
- Weather station – precipitation
- **Influence on deformation**
- **Model development**

- Definition of threshold values
- Continuous acquisition
- Remote data access
- **Early warning system**

Type of movement

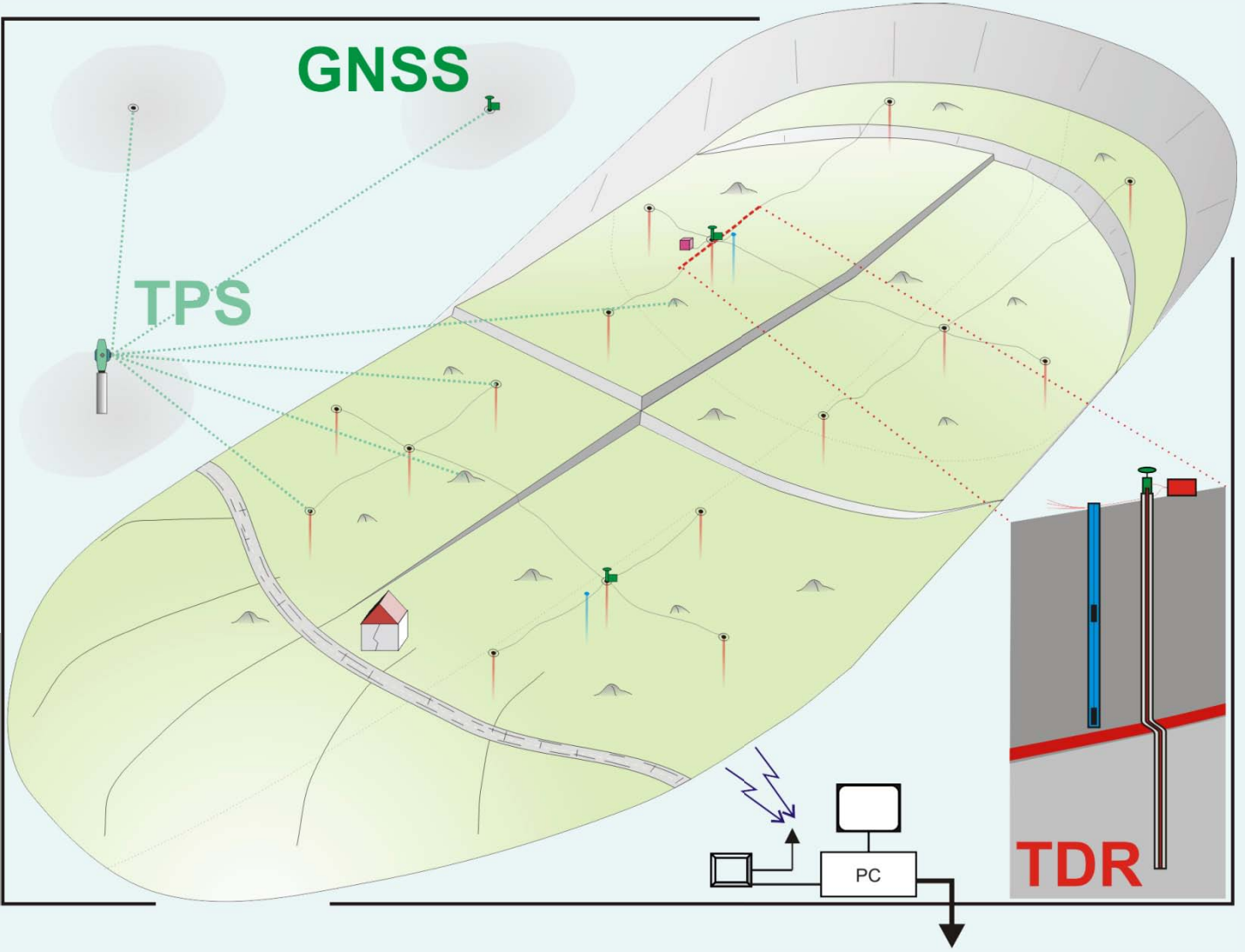
Trigger

Online



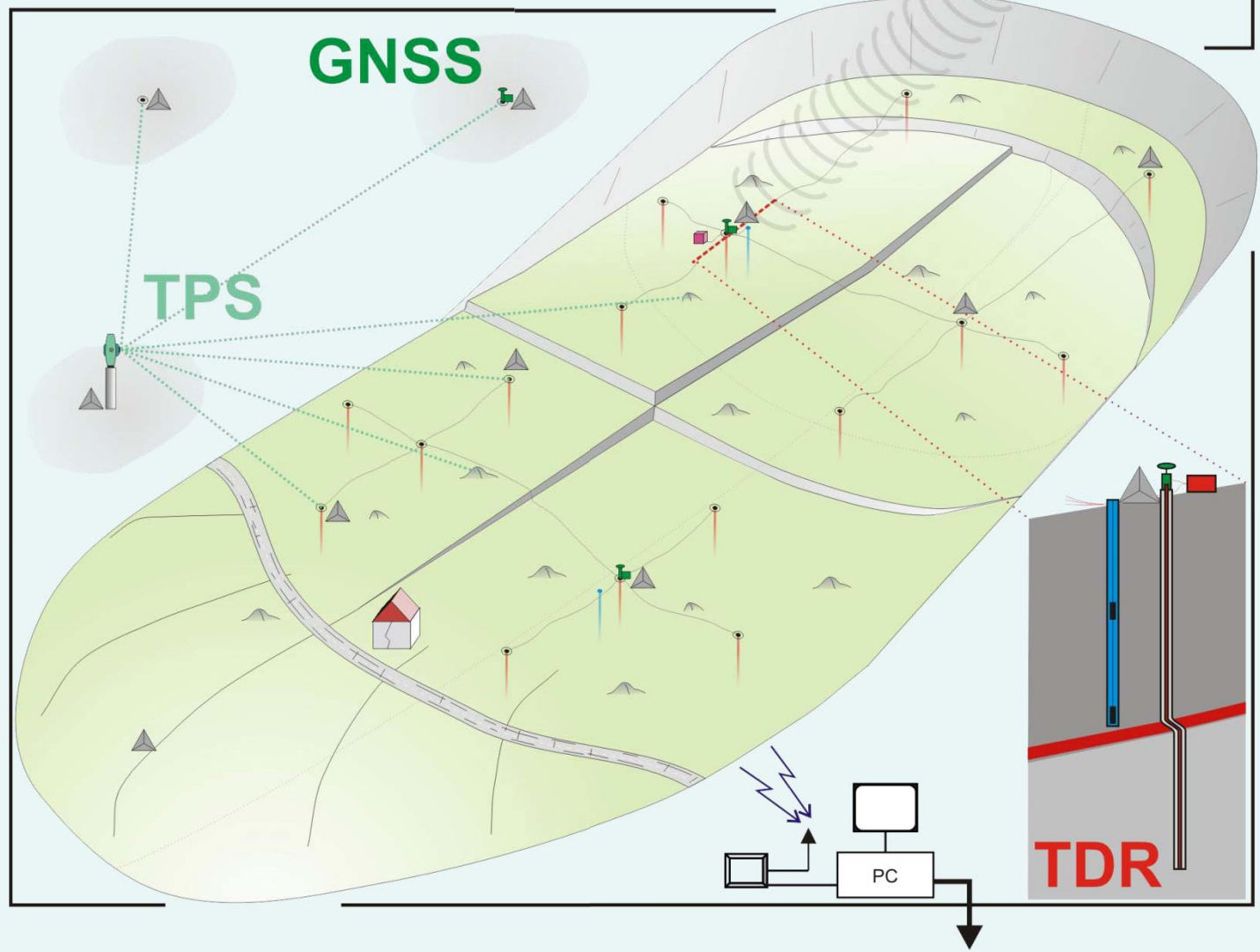
- Artificial Persistent Scatterers
- Increase of PS point density
- Only for comparably small areas of interest







- 19 reflectors
- 3 refl. types
- heating
- Crosscheck between GNSS, TPS, CR-InSAR
- Consolidation of monitoring network
- Data integration





Reflektor-Typ

- ASTRIUM
- DLR
- GEOTUM

Fundament

- Neues Fundament (Bagger)
- Neues Fundament (Fels)
- Stahlträger
- ▲ Felsblock
- Bohrung

Bereich

- Referenzpunkt (unbewegt)
- Hangbewegung (bewegt)

Cornerreflektoren Aggenalm Stand 14.11.2011



www.alpewas.de

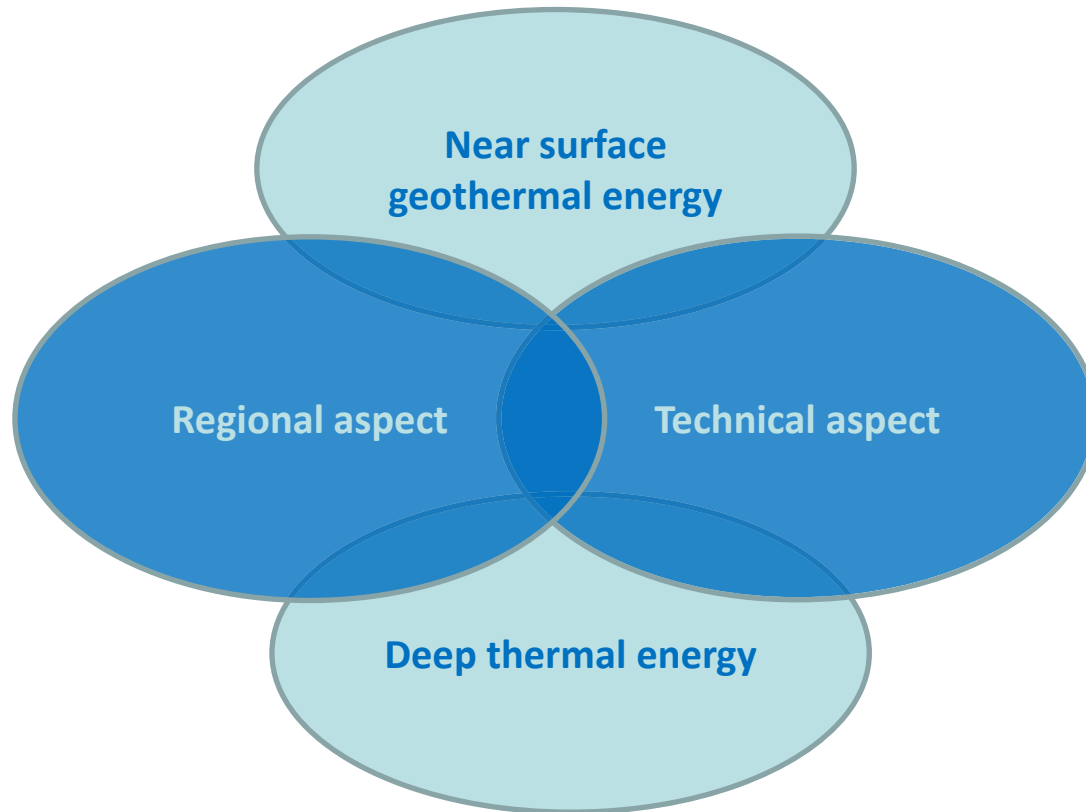




Utilization of geothermal energy in Bavaria



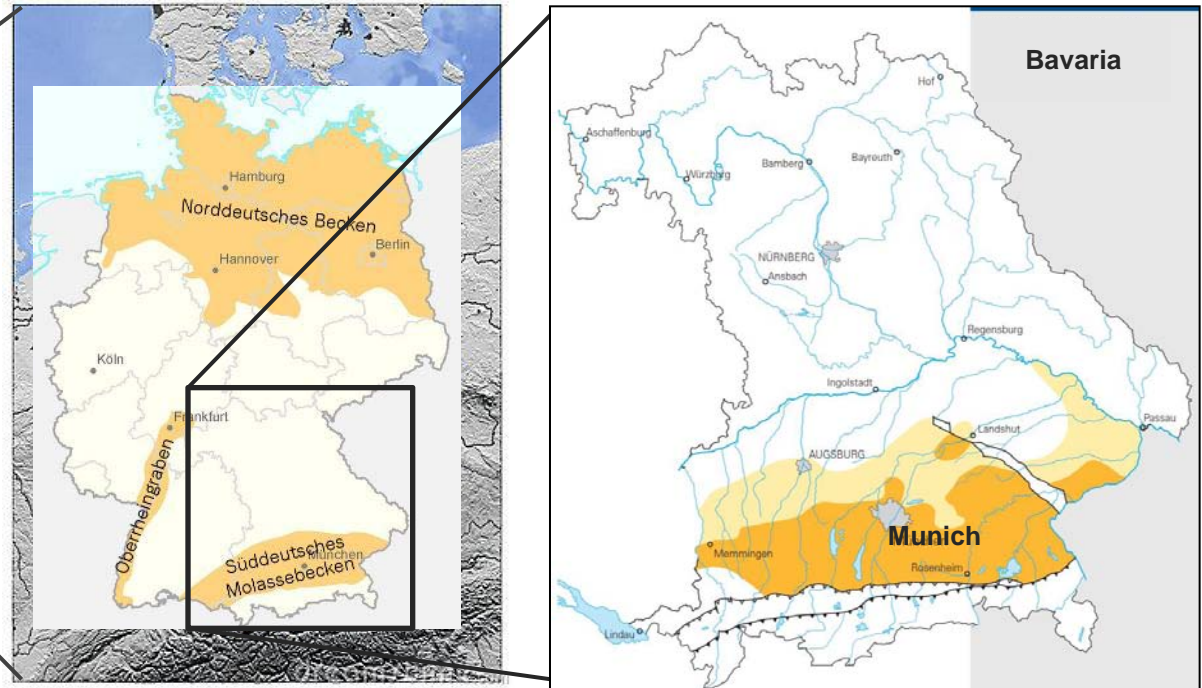
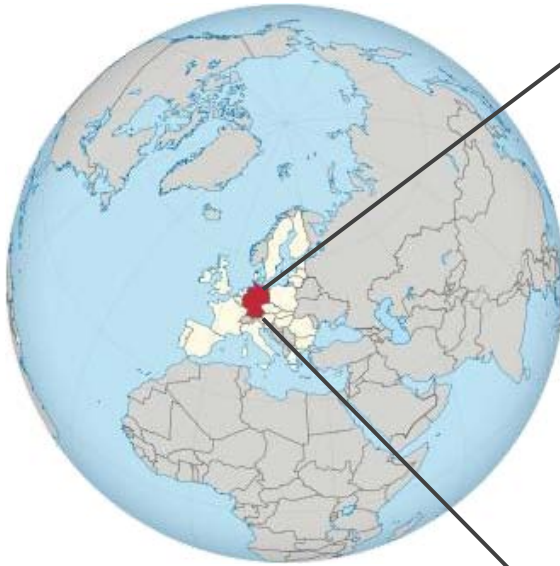
Fields of Work



Deep thermal energy

Geothermal Potential of South Germany

Areas with favourable geological conditions for Geothermal Energy

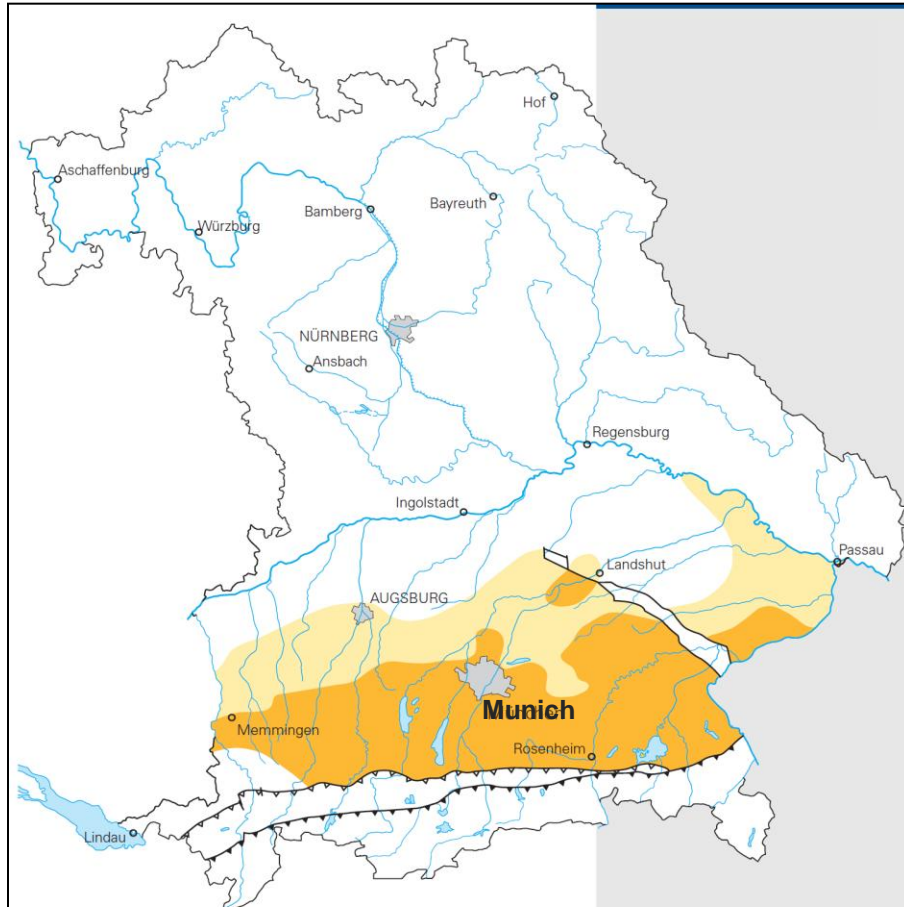


Areas with favourable geological conditions for Geothermal Heat production

Areas with acceptable geological conditions for Geothermal Heat production

Deep thermal energy

Geothermal Potential of South Germany

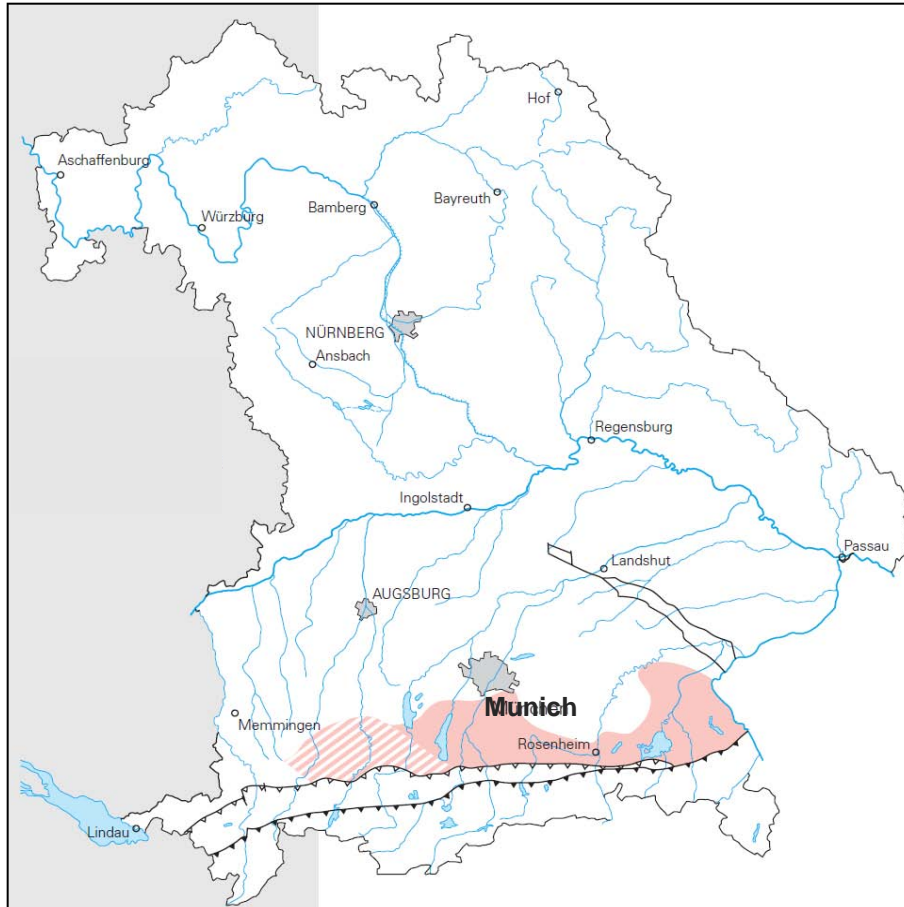




Areas with favourable geological conditions for
Geothermal **Heat production**



Areas with acceptable geological conditions for
Geothermal **Heat production**

Deep thermal energy Geothermal Potential of South Germany



-  Areas with favourable geological conditions for Geothermal **electricity generation**
-  Areas with acceptable geological conditions for Geothermal **electricity generation**

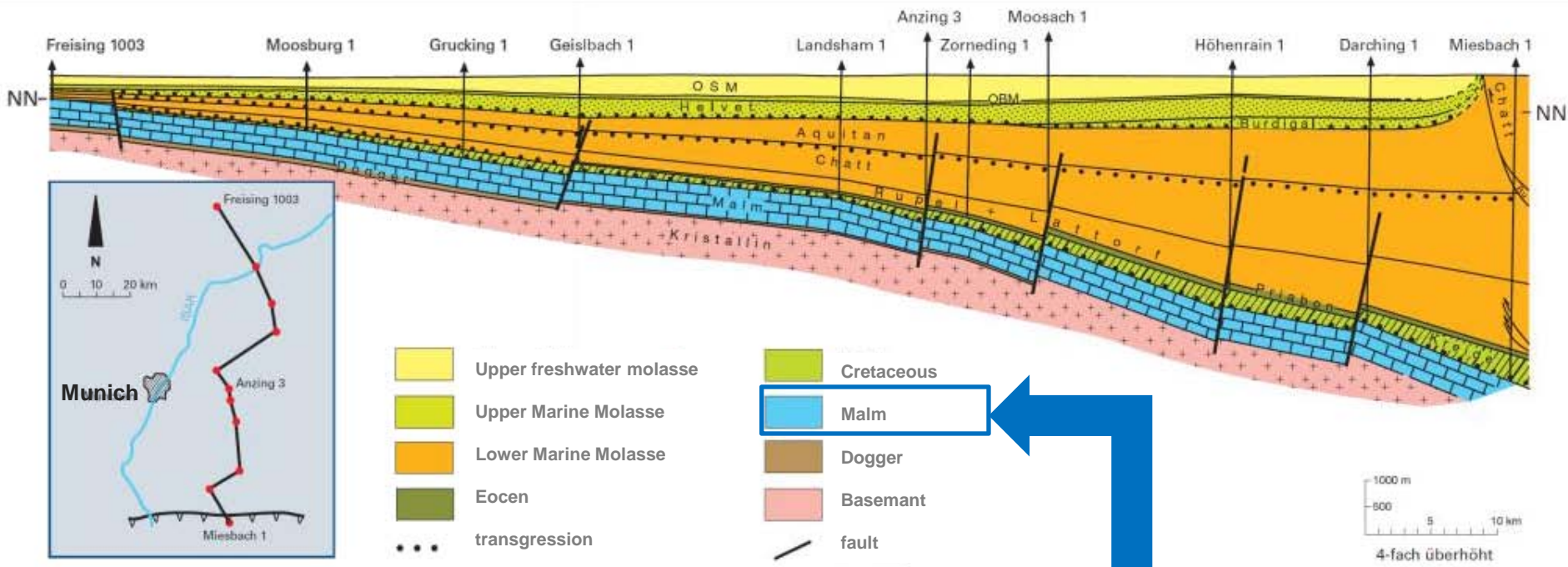
limited by

- production rate
- thermal gradient



Deep thermal energy Geological Cross Section

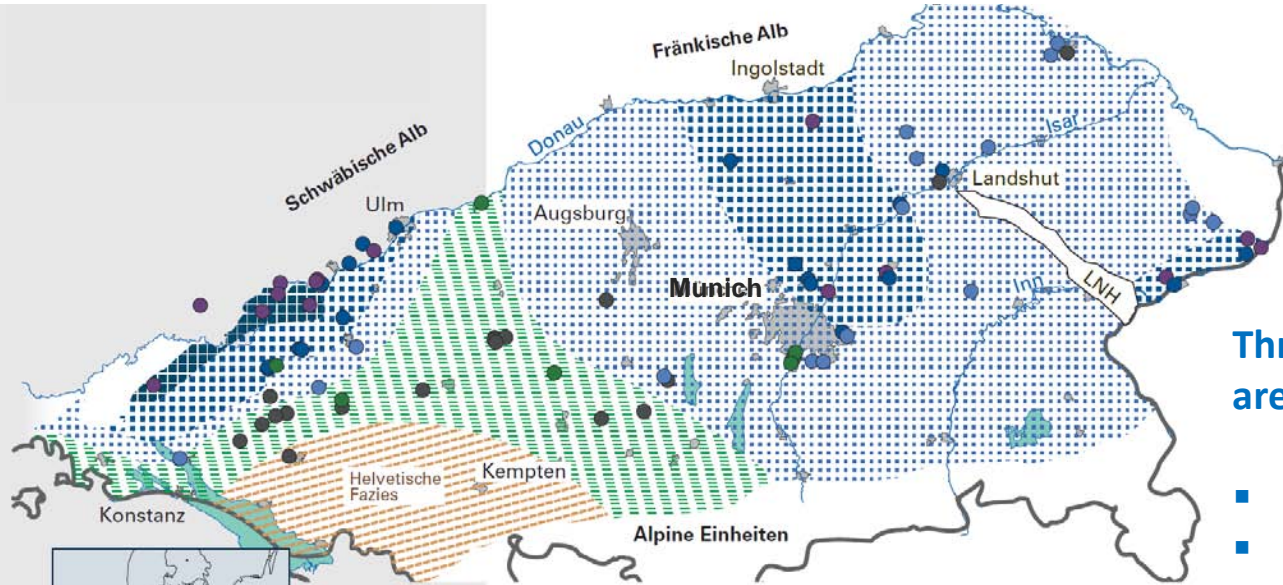
Department Hydrogeology and Geothermal Energy



Malm Aquifer is the most important aquifer for deep thermal energy
→ relevant temperatures and relevant flowrates

Deep thermal energy

Hydraulic Conductivity of the Malm Aquifer



Three aspects of the Malm facies are important for a high flowrate:

- tectonic structures (fractures)
- karst structures
- reef facies

Hydraulic Conductivity [m/s]
Borehole information

- 10^{-4} bis 10^{-3}
- 10^{-5} bis 10^{-4}
- 10^{-6} bis 10^{-5}
- 10^{-7} bis 10^{-6}
- 10^{-11} bis 10^{-7}

Regional distribution of the
Hydraulic Conductivity [m/s]

- GW-Leiter
- 10^{-4} bis 10^{-3}
 - 10^{-5} bis 10^{-4}
 - 10^{-6} bis 10^{-5}

- GW-Geringleiter
- 10^{-11} bis 10^{-6}
 - $< 10^{-8}$



Bearbeitung: Birner / Schneider
(Freie Universität Berlin)
Jodocy / Stober
(Regierungspräsidium Freiburg)

Zeichnung: Birner
Stand: 03/2009

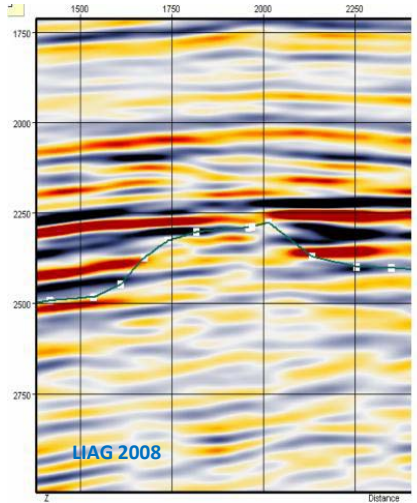
0 25 50 100 Kilometer



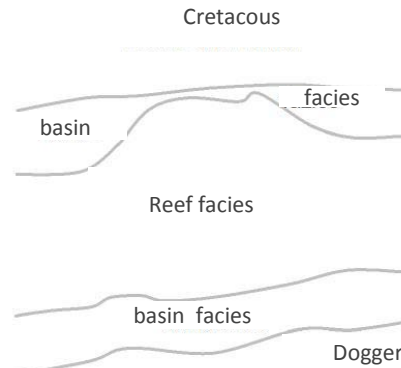
Deep thermal energy

Hydraulic Conductivity of the Malm Aquifer

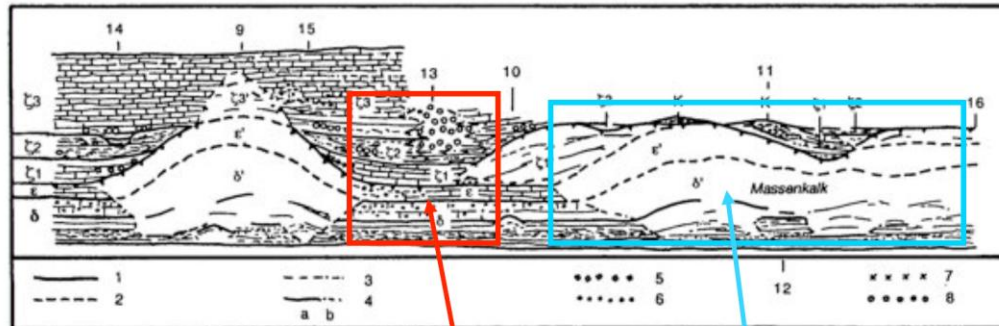
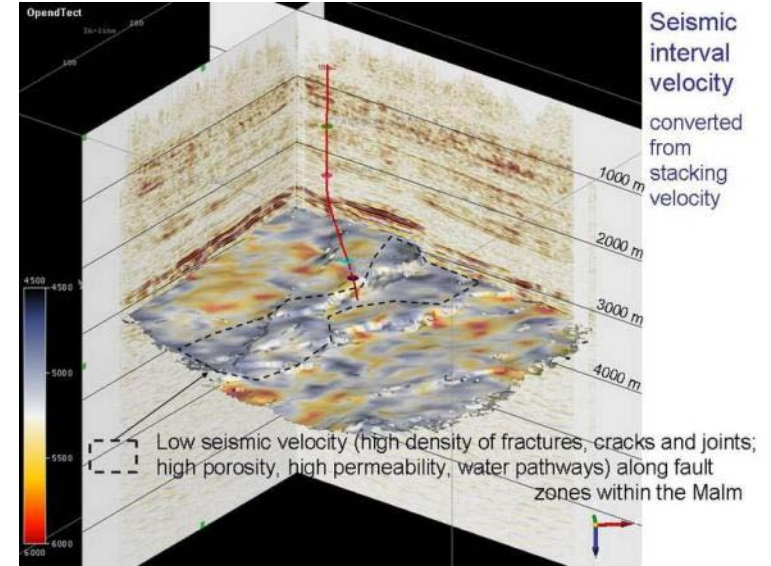
Department
Hydrogeology and
Geothermal Energy



Example Lithofacies

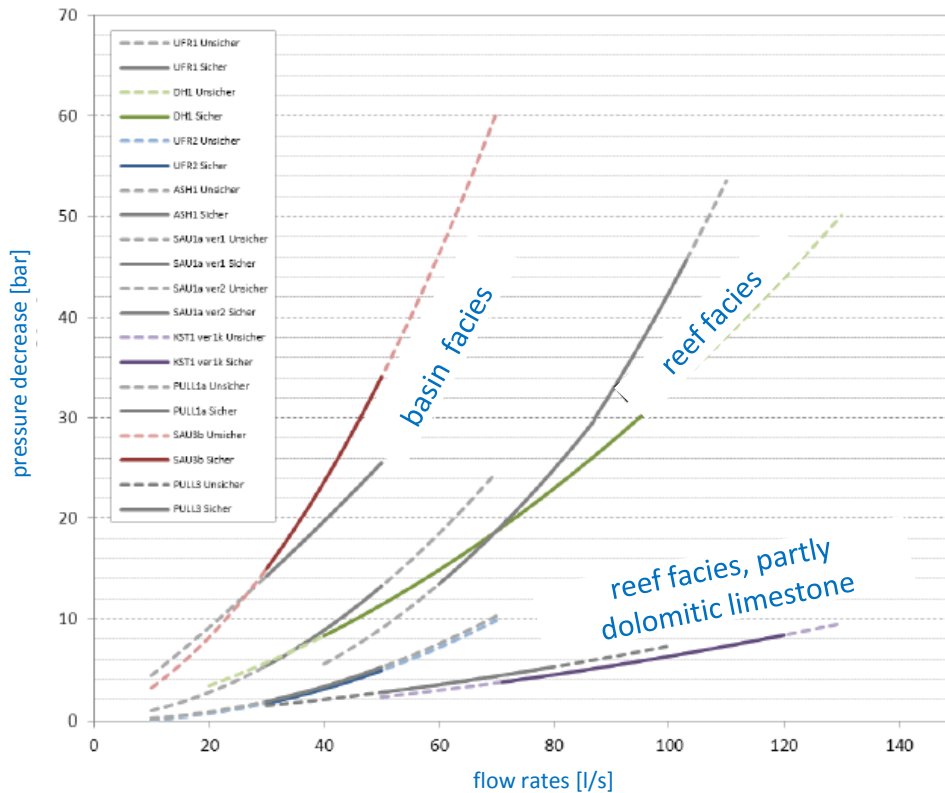


Example
fractures and karst structures



- basin facies:**
- low Permeability
 - bad conditions

- Reef facies:**
- high Permeability
 - good conditions



Research Topics:

- flow rates prediction
- temperature prediction
- reservoir modelling

→ mainly Southern Germany

cooperation: local engineering offices
and regional government

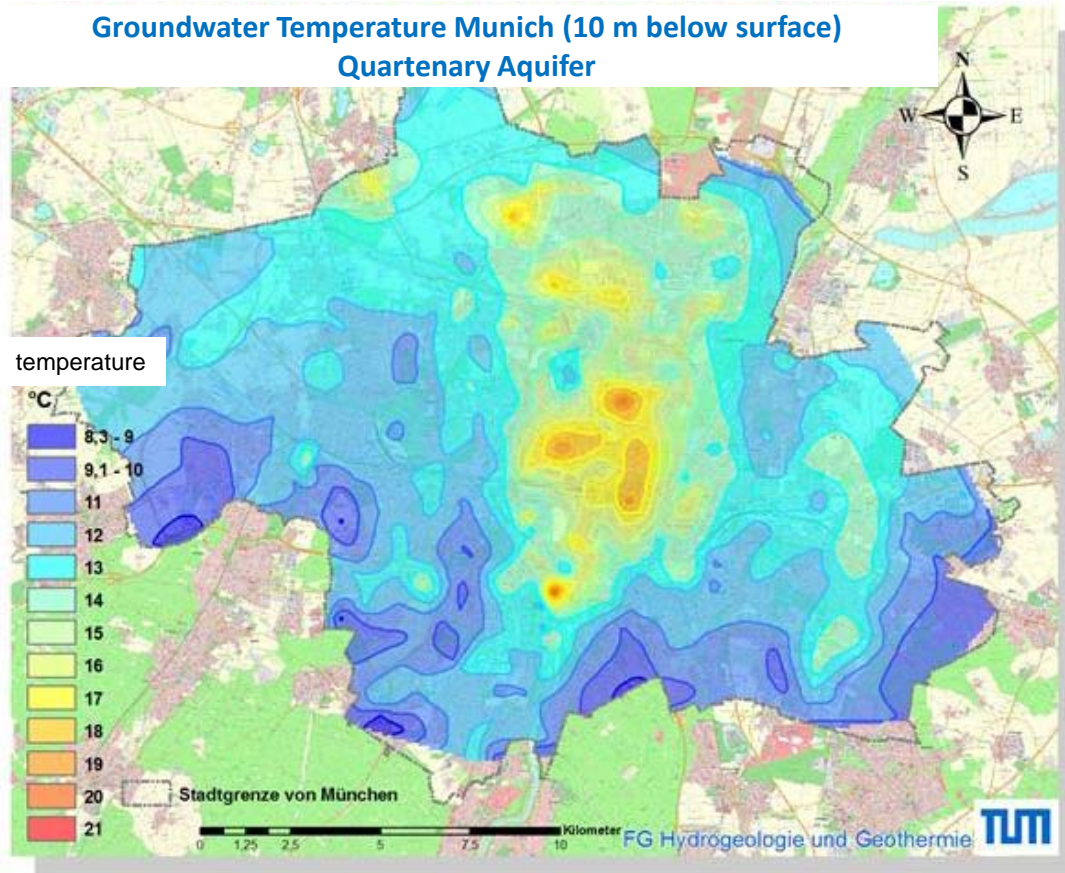


→ Oversea studies (USA)

cooperation:



Groundwater Temperature Munich (10 m below surface)
Quaternary Aquifer



Munich Quaternary Aquifer:

- high hydraulic conductivity
- high aquifer thickness

→ good conditions using groundwater for heating and cooling

- temporarily and locally very high groundwater temperatures

→ anthropogenic effect



There is a Need for a
Geothermal Groundwater Management Tool
to avoid resource conflicts
in the future



Near surface geothermal energy Groundwater Management Tool

Department
Hydrogeology and
Geothermal Energy

Estimation of the geothermal parameters



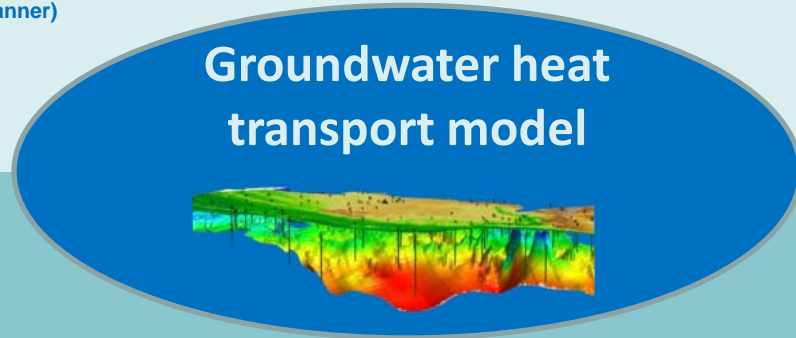
e.g.:
thermal conductivity distribution
(Measurements with the Thermal Conductivity Scanner)

Parametrisation

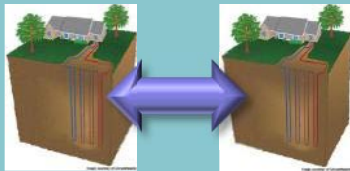
Influences of the temperature variability

- e.g. Quantify rejected heat from:
- subway
 - district heating network
 - buildings
 - ...

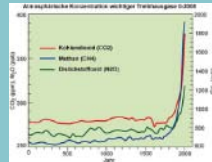
Estimation of hydraulic parameters



Optimisation of the existing geothermal installations

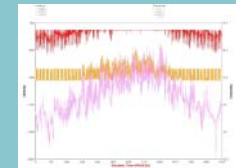


Geothermal potential
with respect to climate change

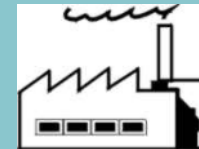


Simulation and Prognosis

Interface groundwater heat model
with thermal energy system
simulation programs

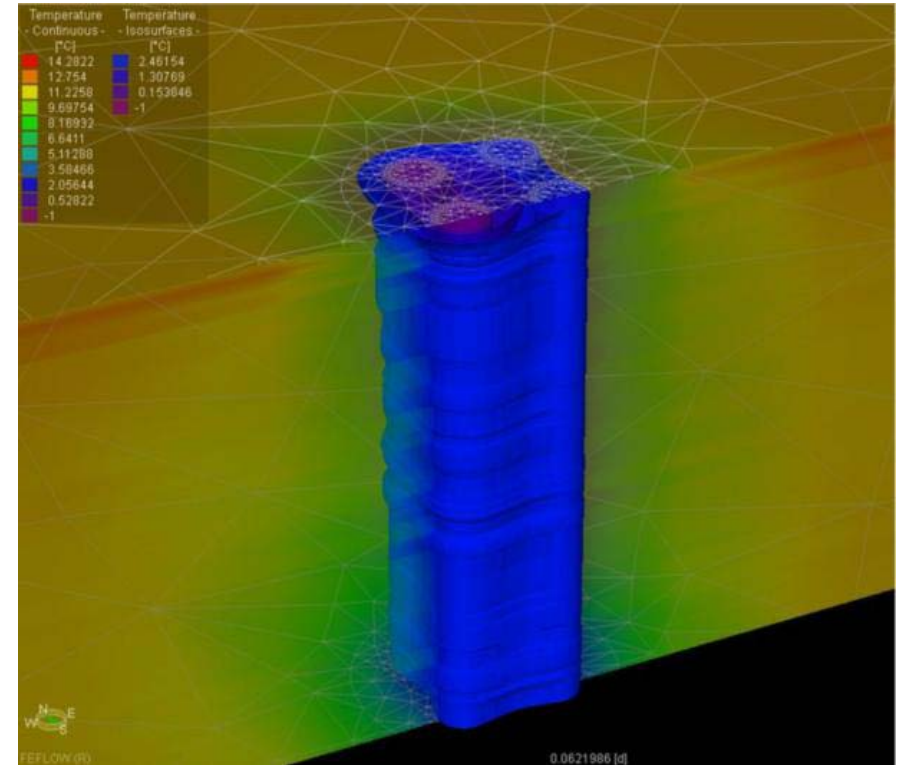
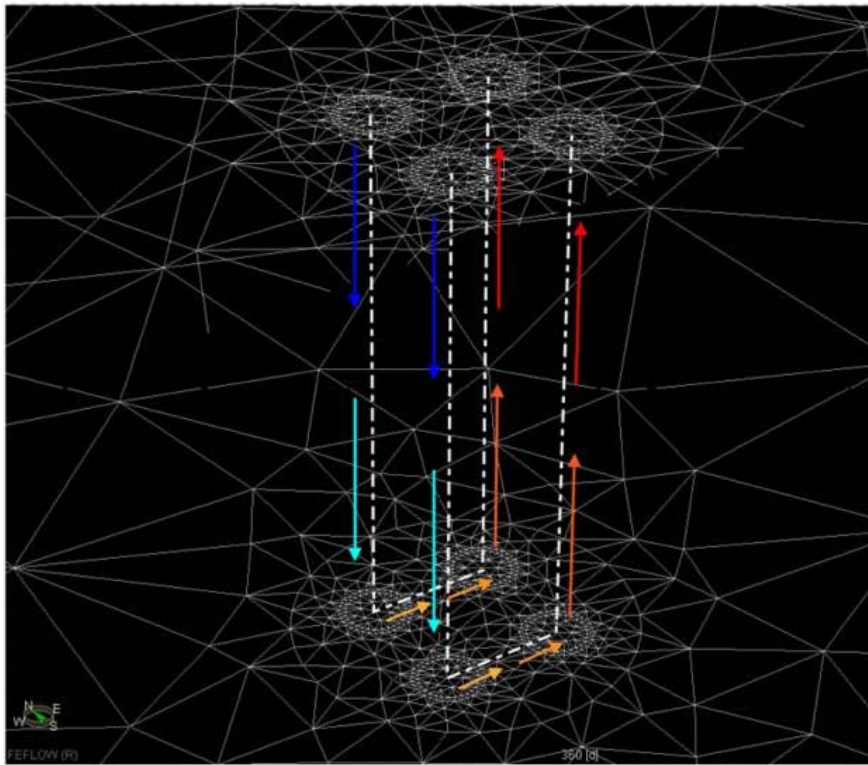


Geothermal potential
with respect to
urban development



Simulation of the frost action boundary at a borehole heat exchanger

Inlet and Outlet temperature

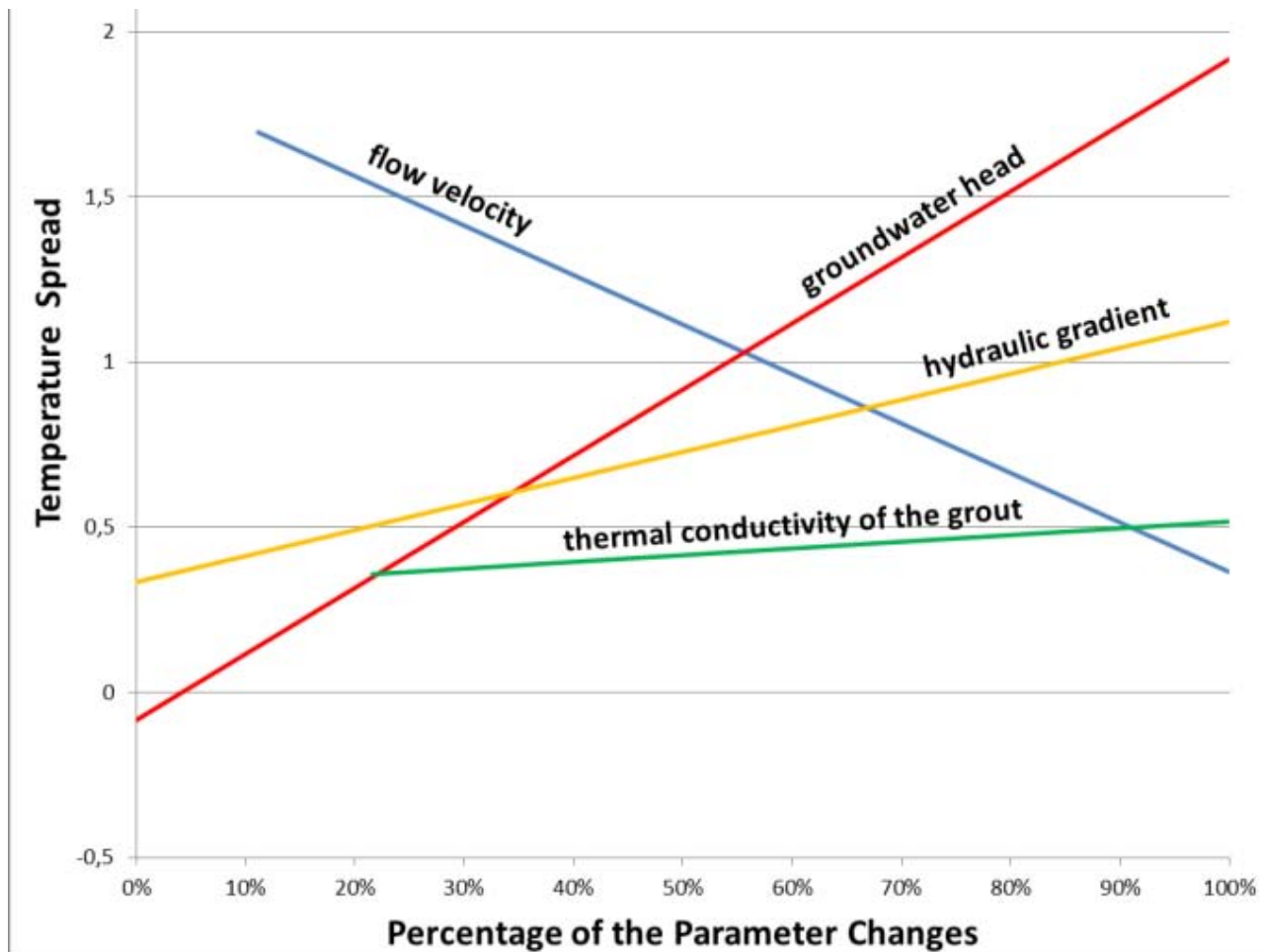


- Goal: Optimization of installation parameters

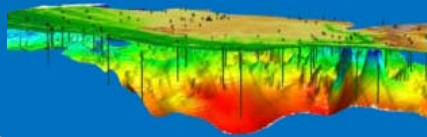
Near surface geothermal energy

Simulation of a borehole heat exchanger

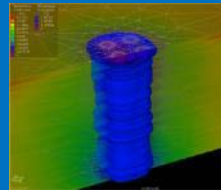
Sensitivity analysis of the conditions to optimise the borehole heat exchangers



Groundwater heat transport model



Simulation heat exchanger



Research Topic:

- heat transport modelling
parametrisation and prognosis

cooperation: engineering offices
and regional government





Department
Hydrogeology and
Geothermal Energy

Geothermal Energy

Utilization of geothermal energy in Bavaria

Thank you for your attention



I wish you a CO₂-limited future with geothermal energy