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

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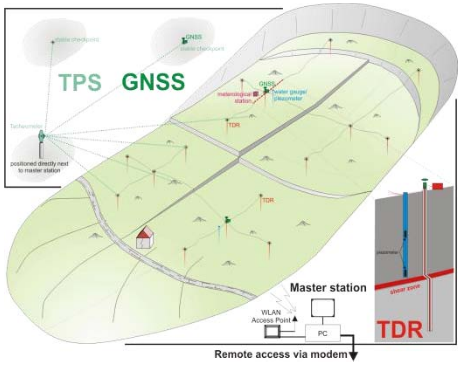

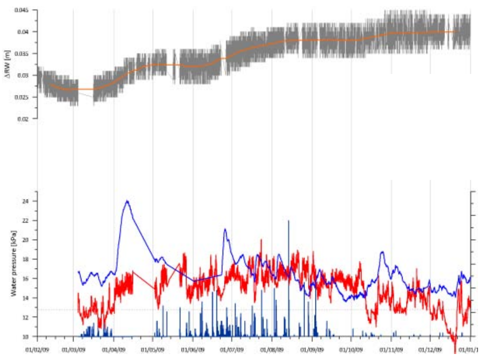

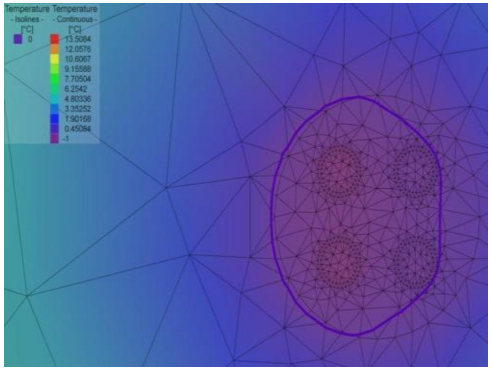

Technische Universität München
Section Landslide Monitoring, Analysis and Early Warning

Content

- 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

Bavaria: Hazard indication maps

- 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

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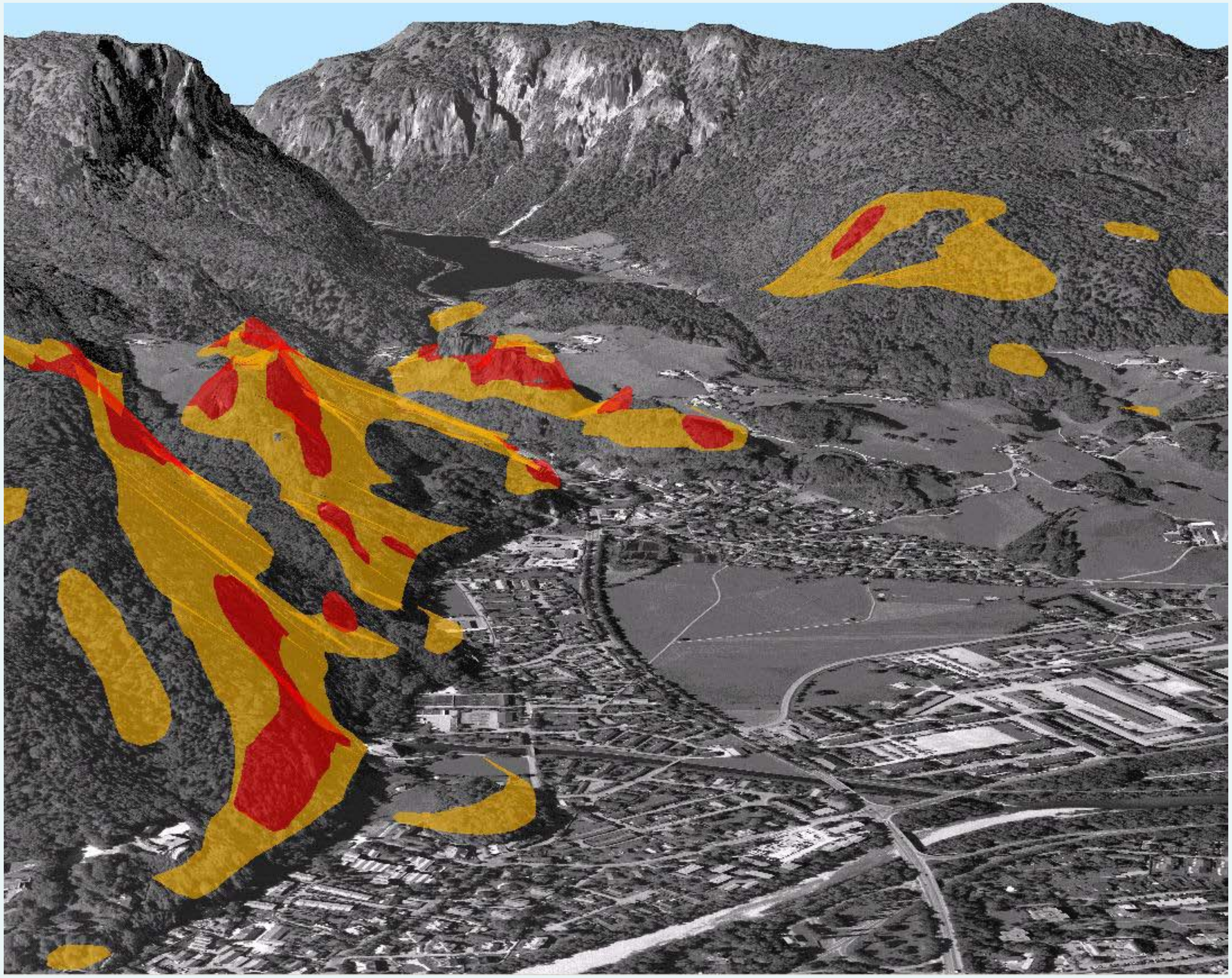
Example: Rockfall

alpEWAS
EARLY WARNING SYSTEM FOR ALPINE SLOPES

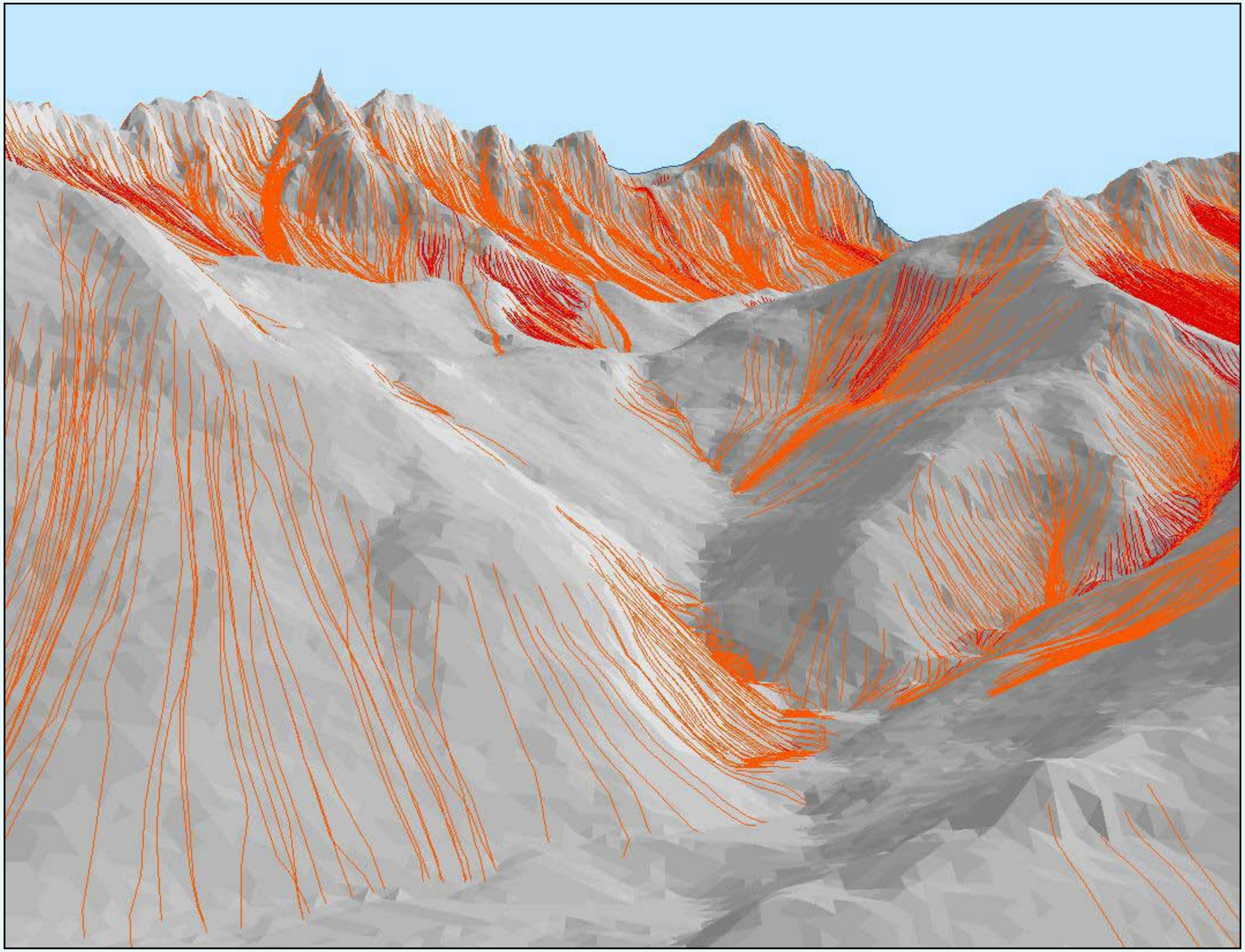
- Determination of potential detatchment areas



Based on:

- DEM
- Aerial photos
- Inventory
- Field observations

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

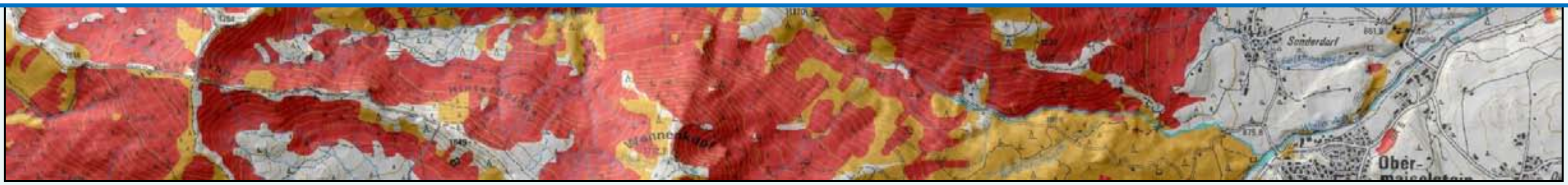


Based on:

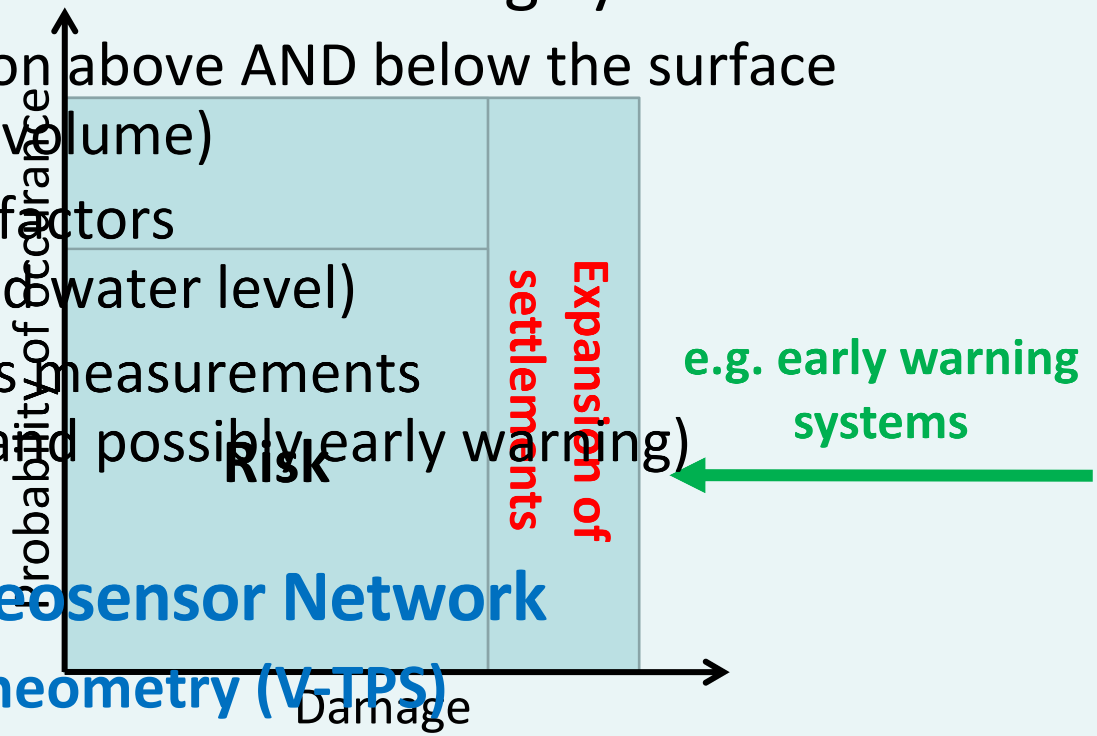
- DEM
- Aerial photos (land cover)

Hazard indication map

- 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



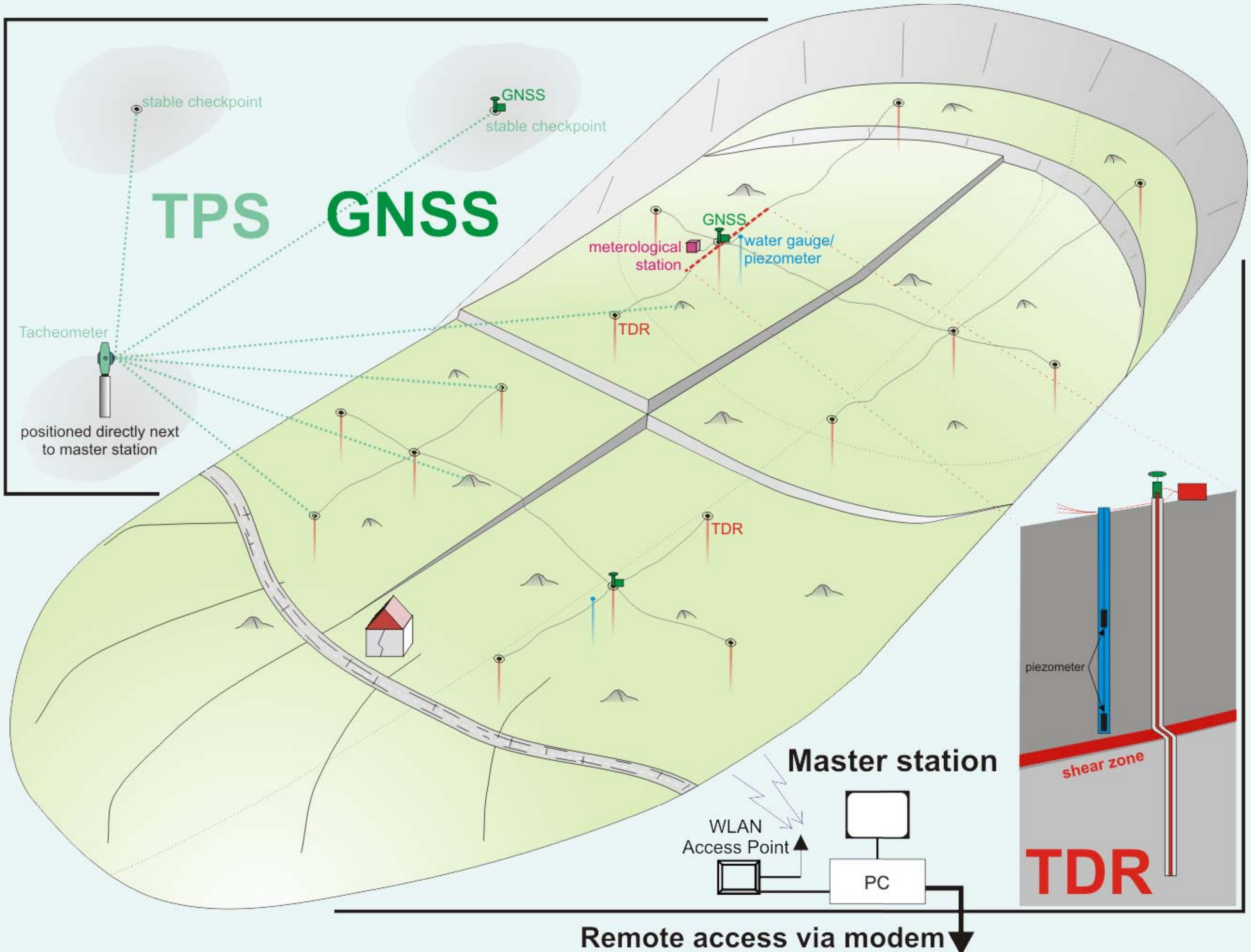
- Increase of landslide risk in alpine areas
- Need for economic measuring systems
  - Deformation above AND below the surface (landslide volume)
  - Triggering factors (e.g. groundwater level)
  - Continuous measurements (alarming and possibly early warning)



→ **alpEWAS Geosensor Network**

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

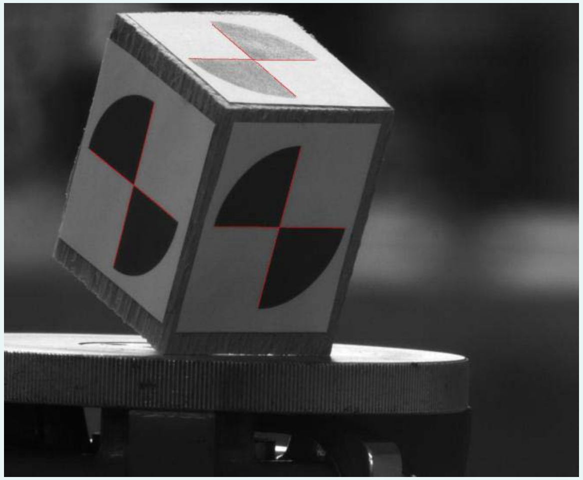
alpEWAS Geosensor Network

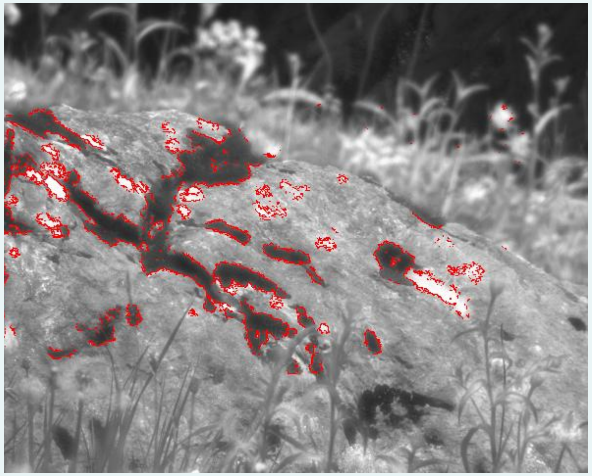


Video Tacheometry

- 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

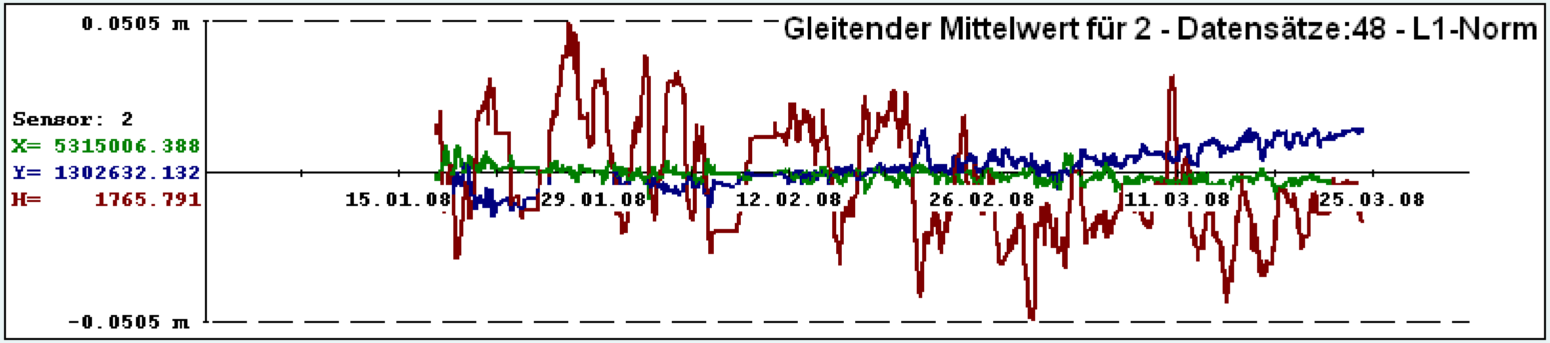




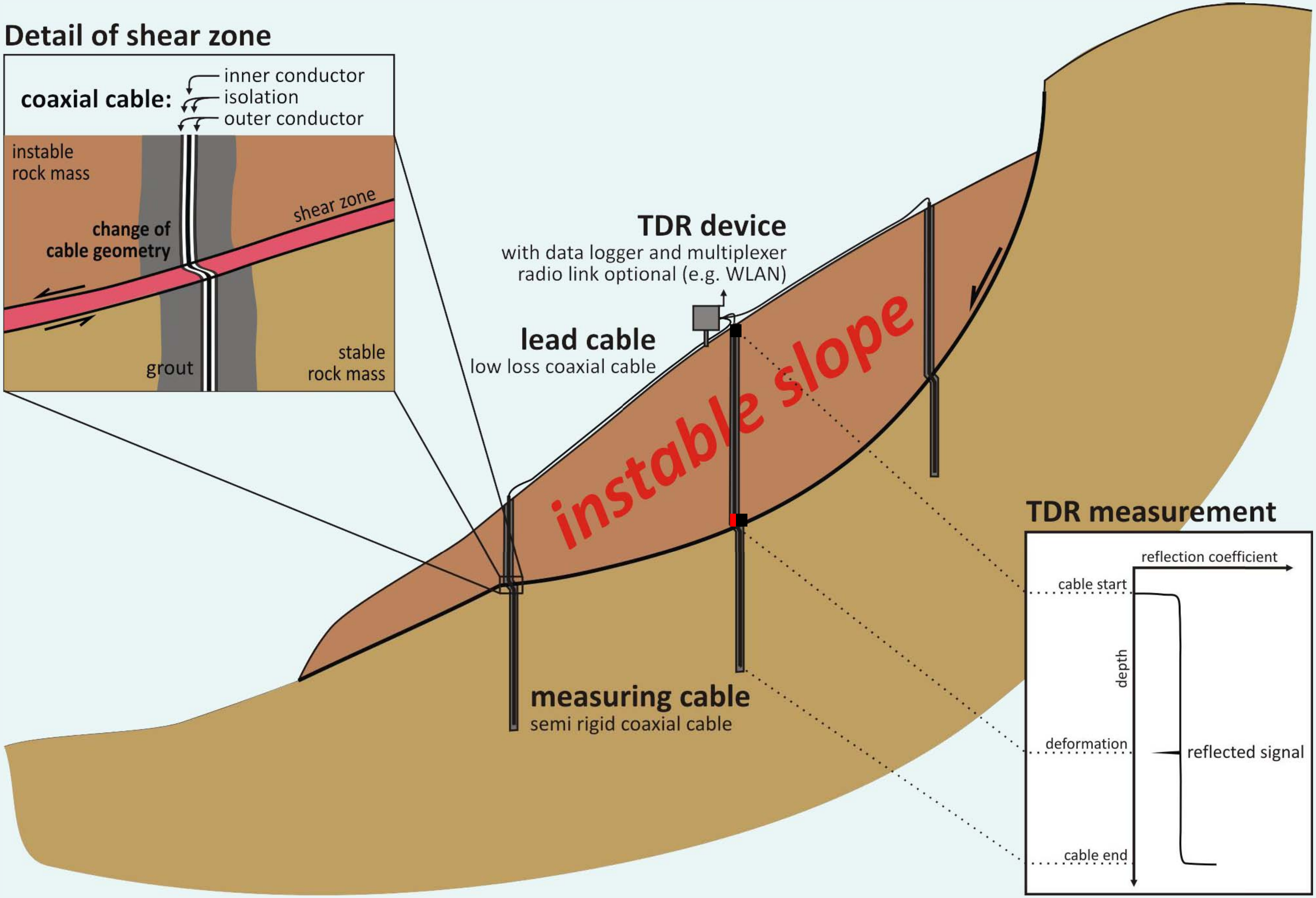
Low Cost GNSS

- 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



Time Domain Reflectometry (TDR)

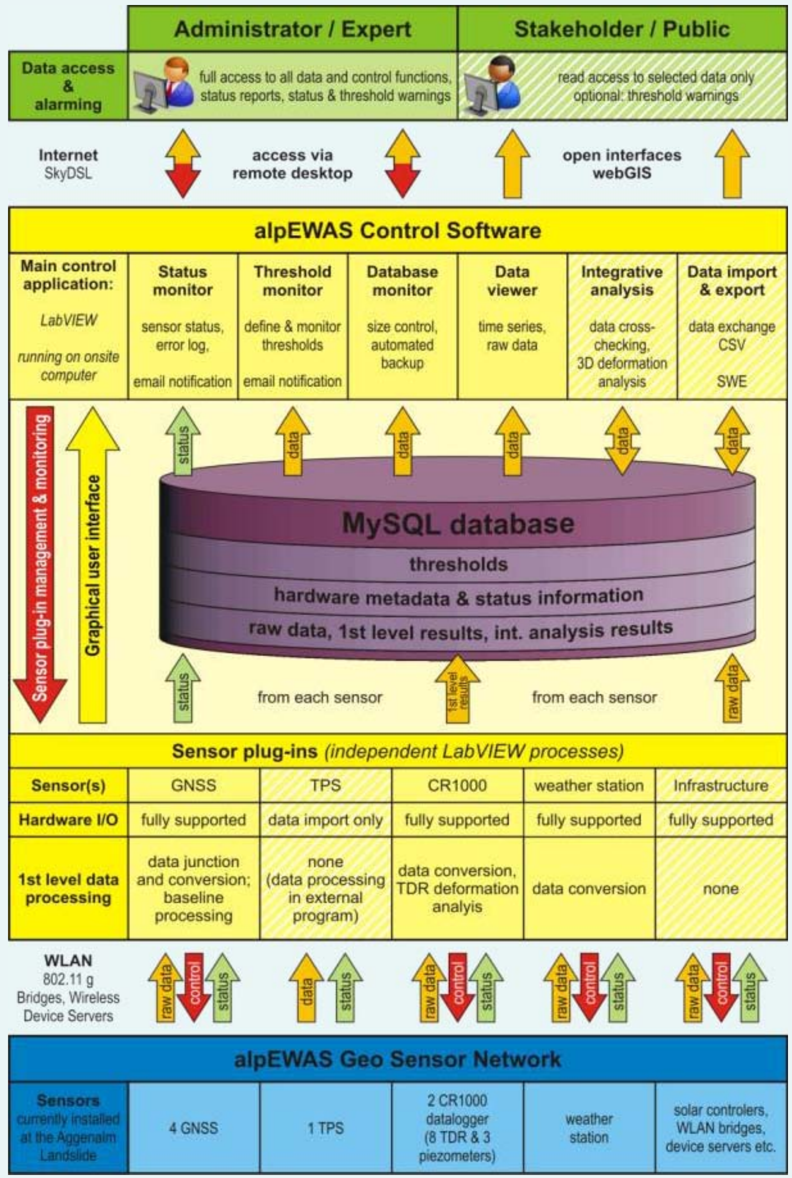


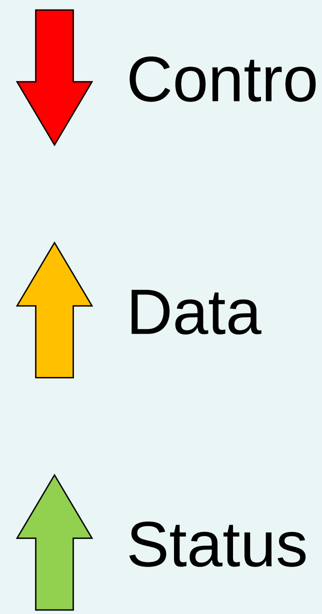
alpEWAS Control Data Management

User

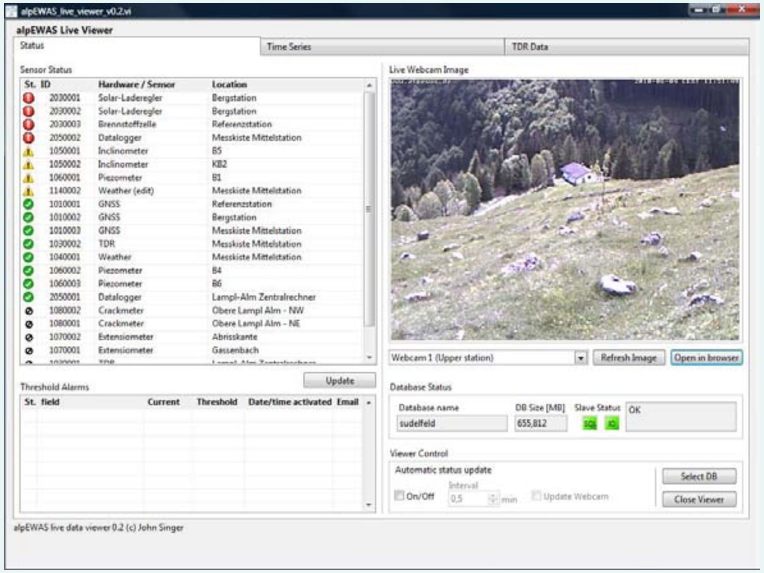
alpEWAS
Control Software

Geosensor-
network

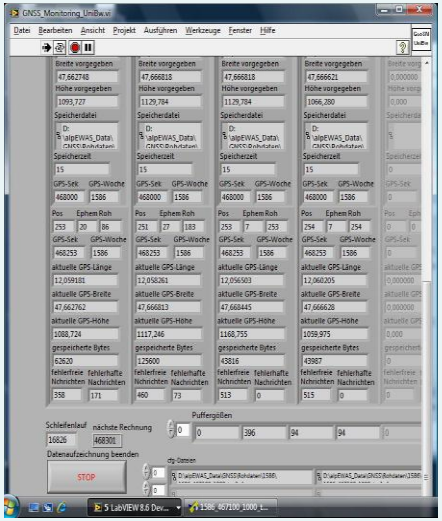




alpEWAS Control Data Management

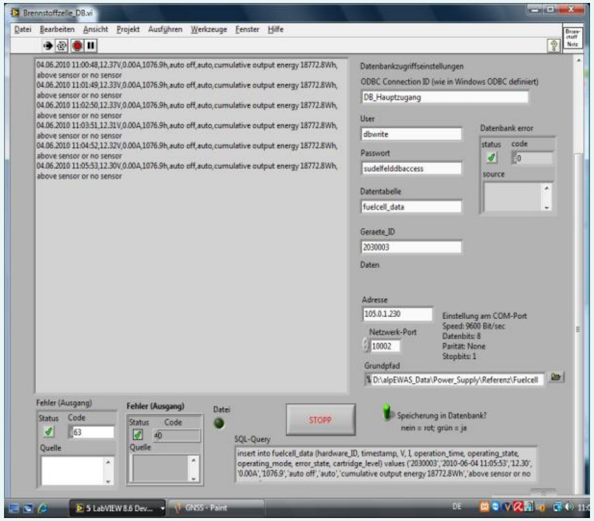


Data Viewer



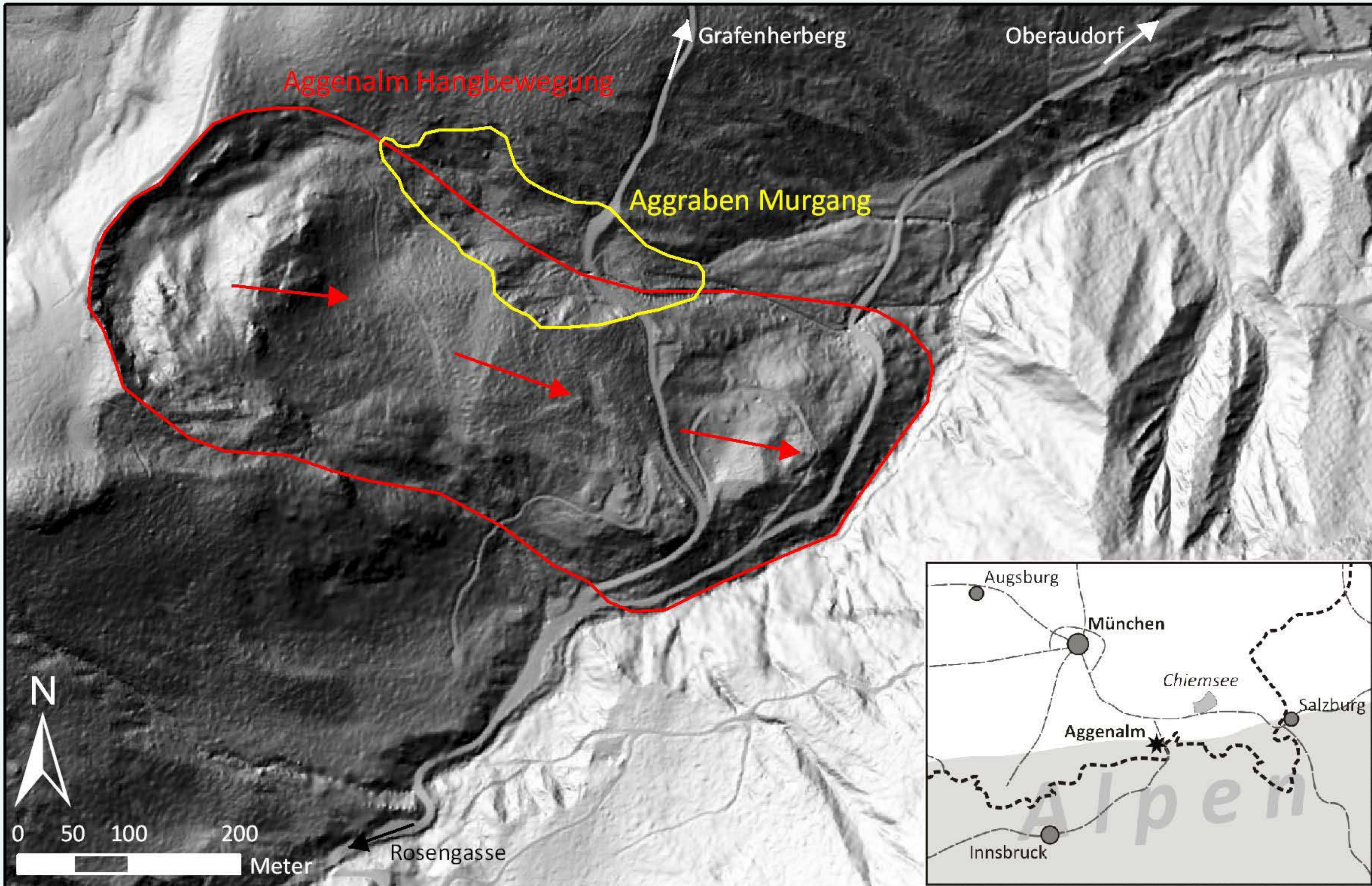
GNSS

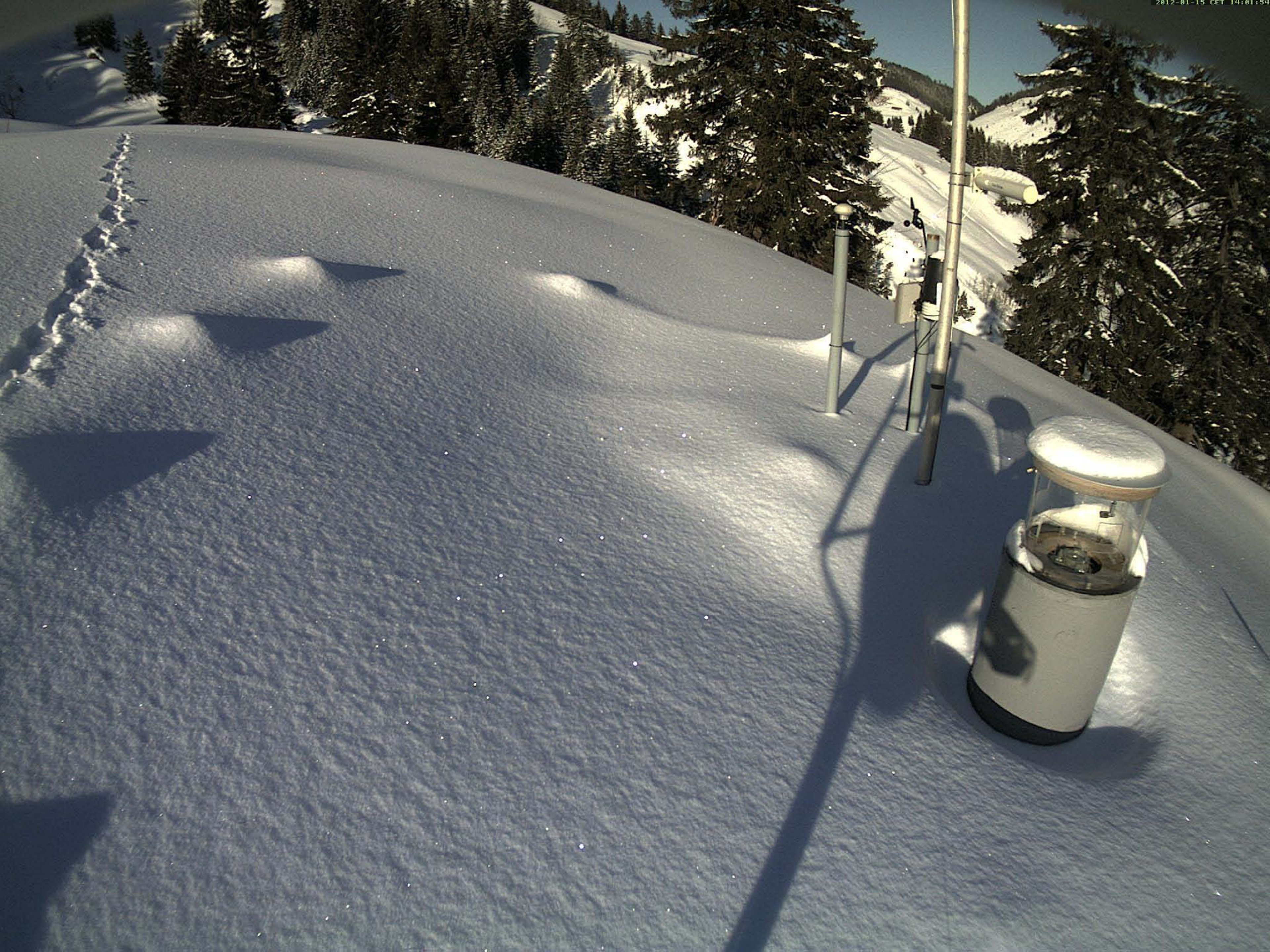
Meteorology



Power Management

Aggenalm Landslide

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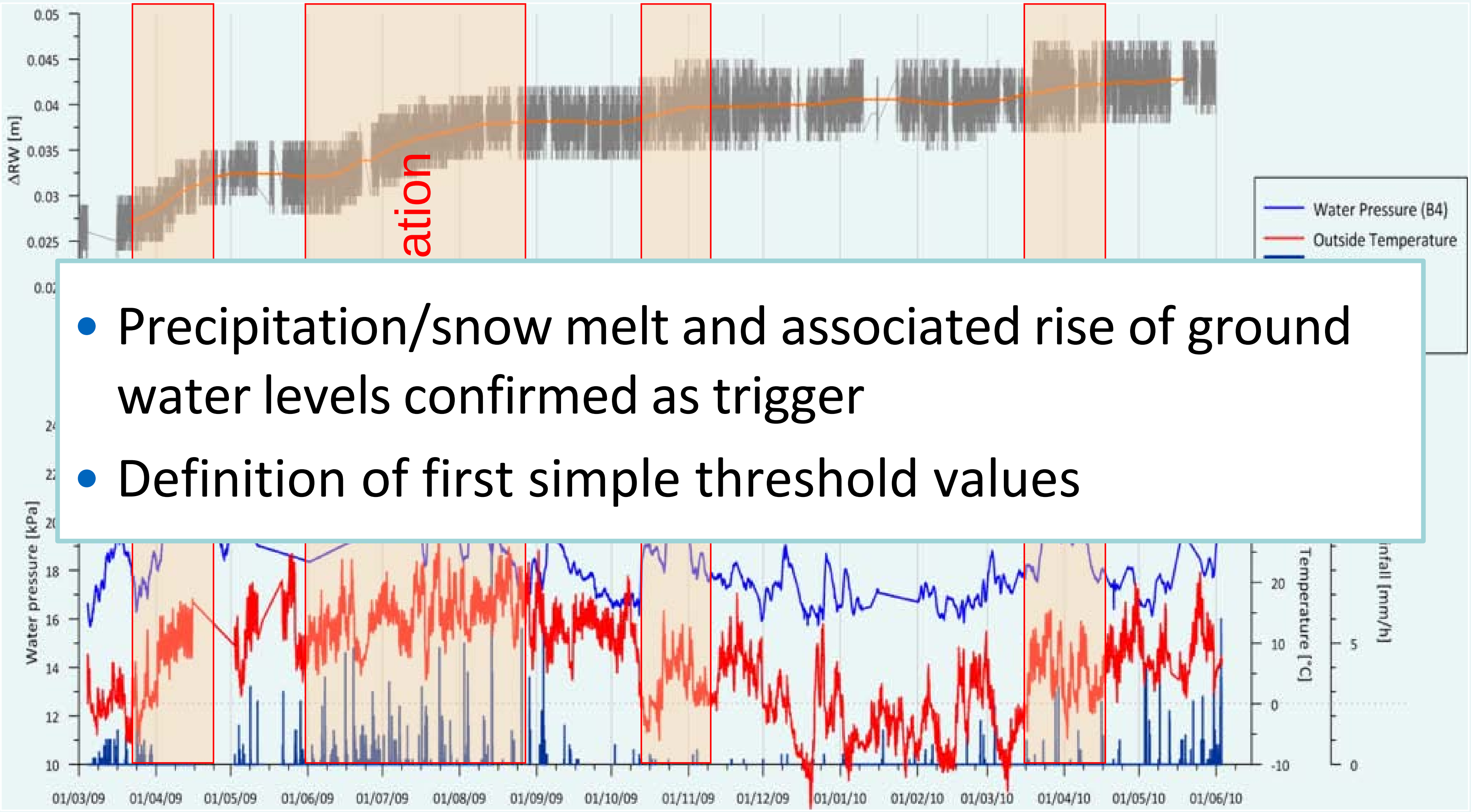
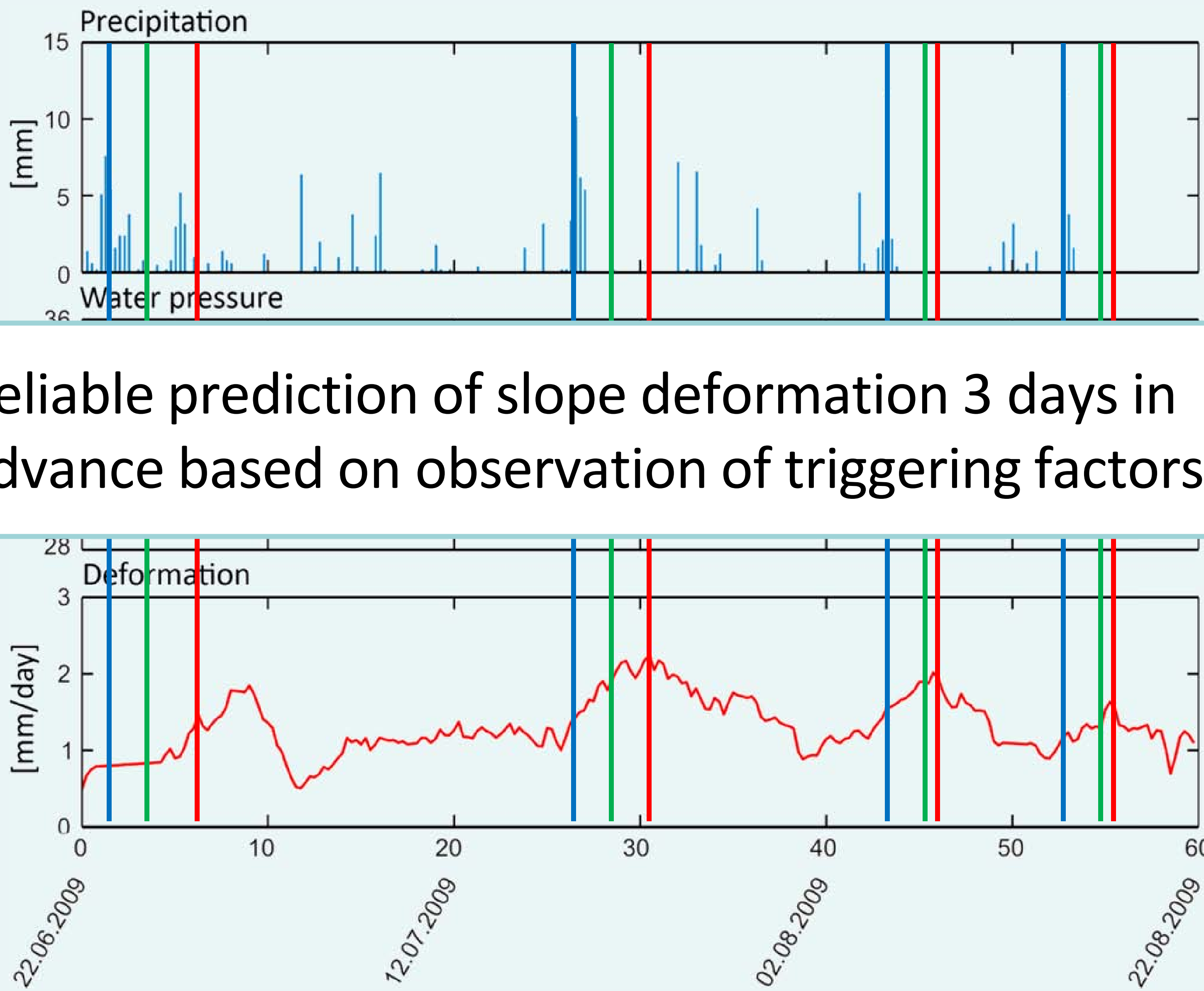
Aggenalm Landslide: Time Series



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

Is early warning possible?



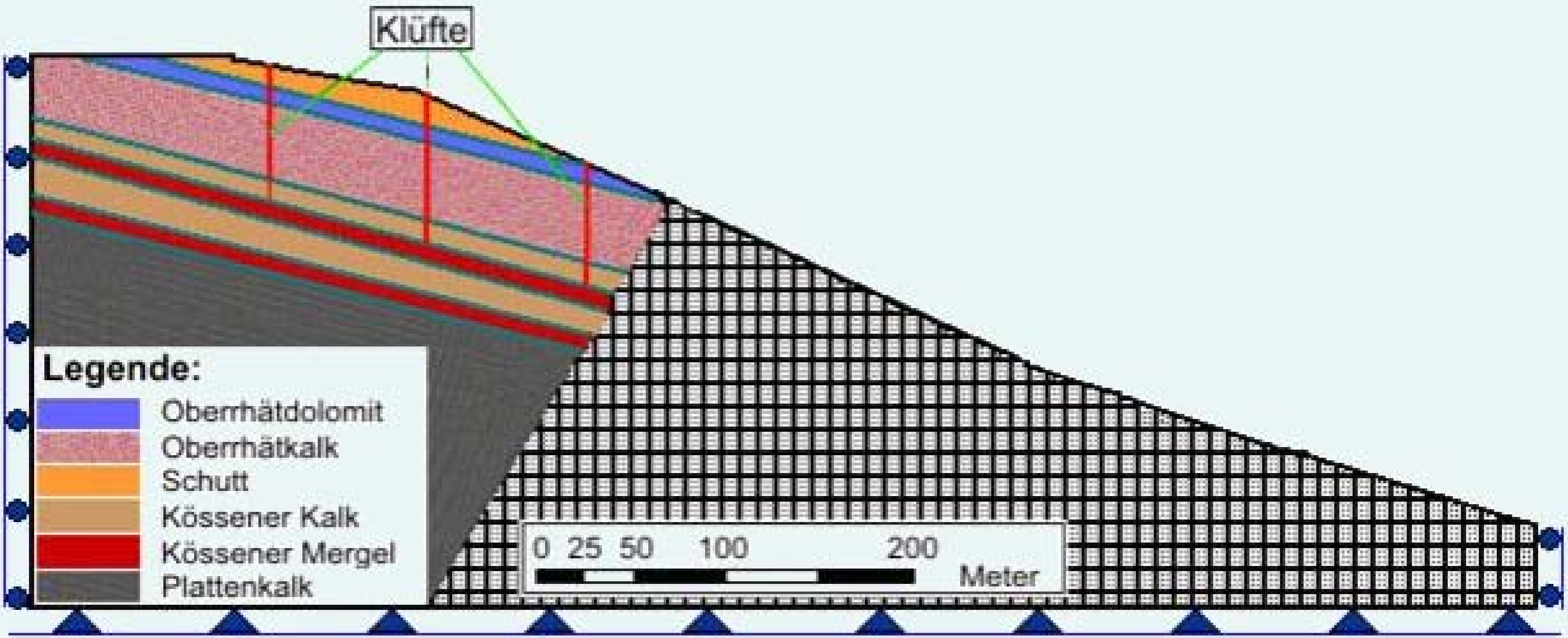
- Reliable prediction of slope deformation 3 days in advance based on observation of triggering factors

Definition of threshold values

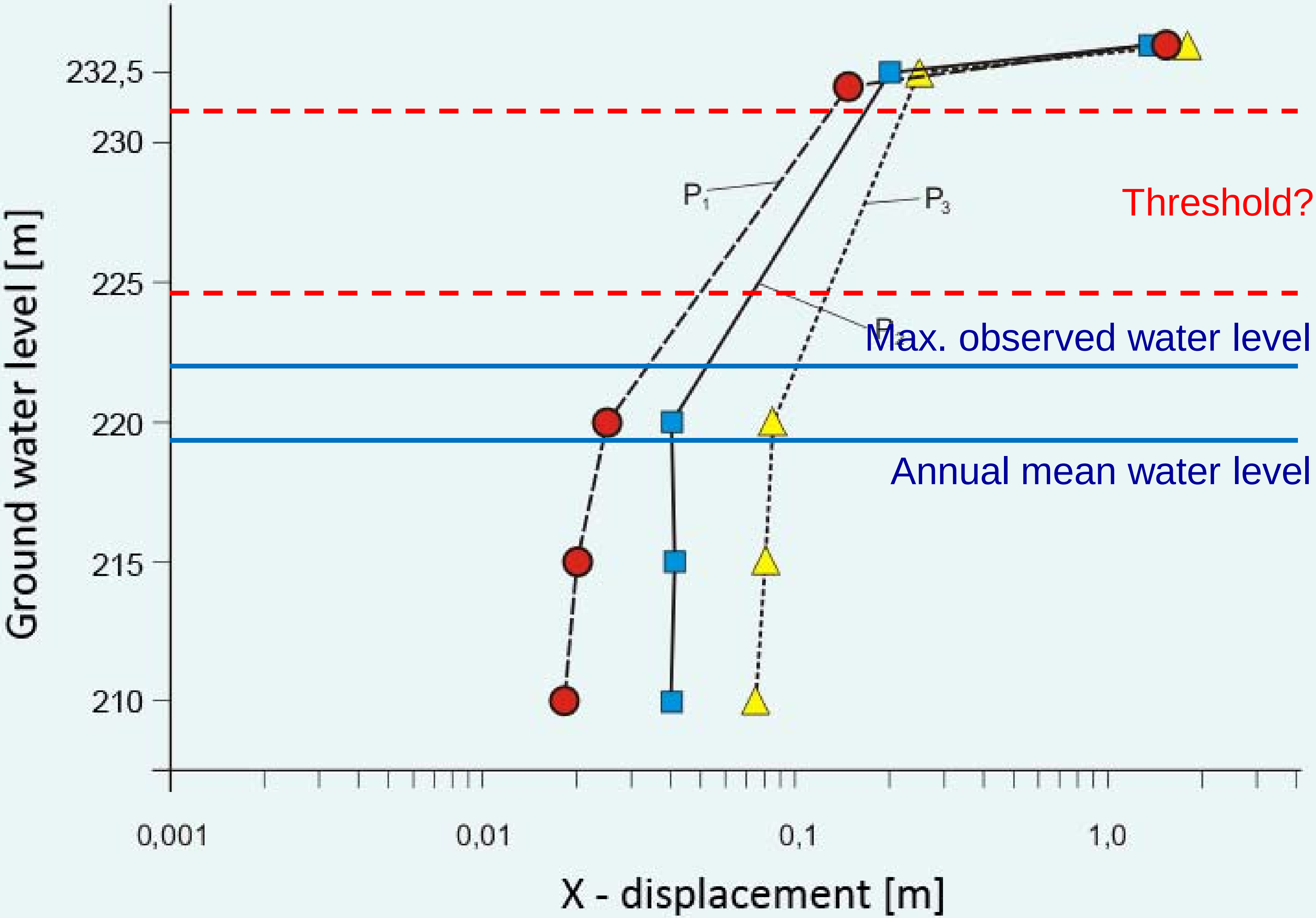
- Empirical observations
  - Threshold values for onset of slow deformations

- Numerical model (FLAC)
  - Validation using monitoring data
  - Simulation of extreme events
  - → Threshold values for catastrophic event

Numerical Model



Definition of threshold values



Synopsis

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

→ **3D deformation**

Type of movement

- Piezometer – ground water level
- Weather station – precipitation

→ **Influence on deformation**

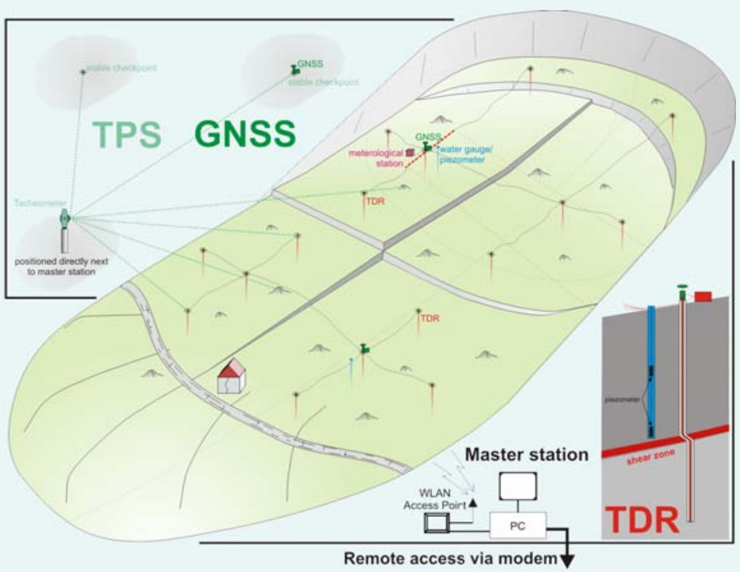
→ **Model development**

Trigger

- Definition of threshold values
- Continuous acquisition
- Remote data access

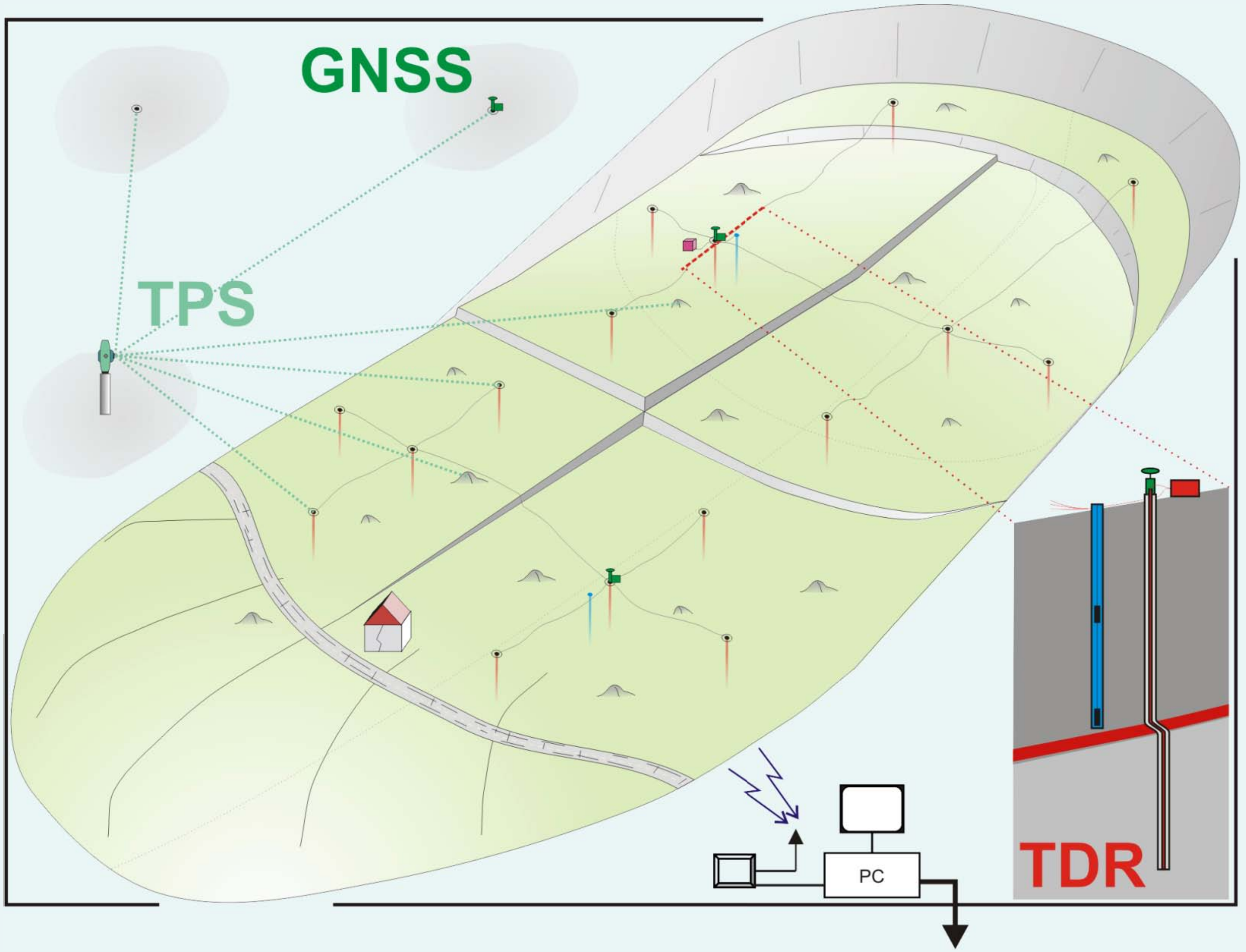
→ **Early warning system**

Online



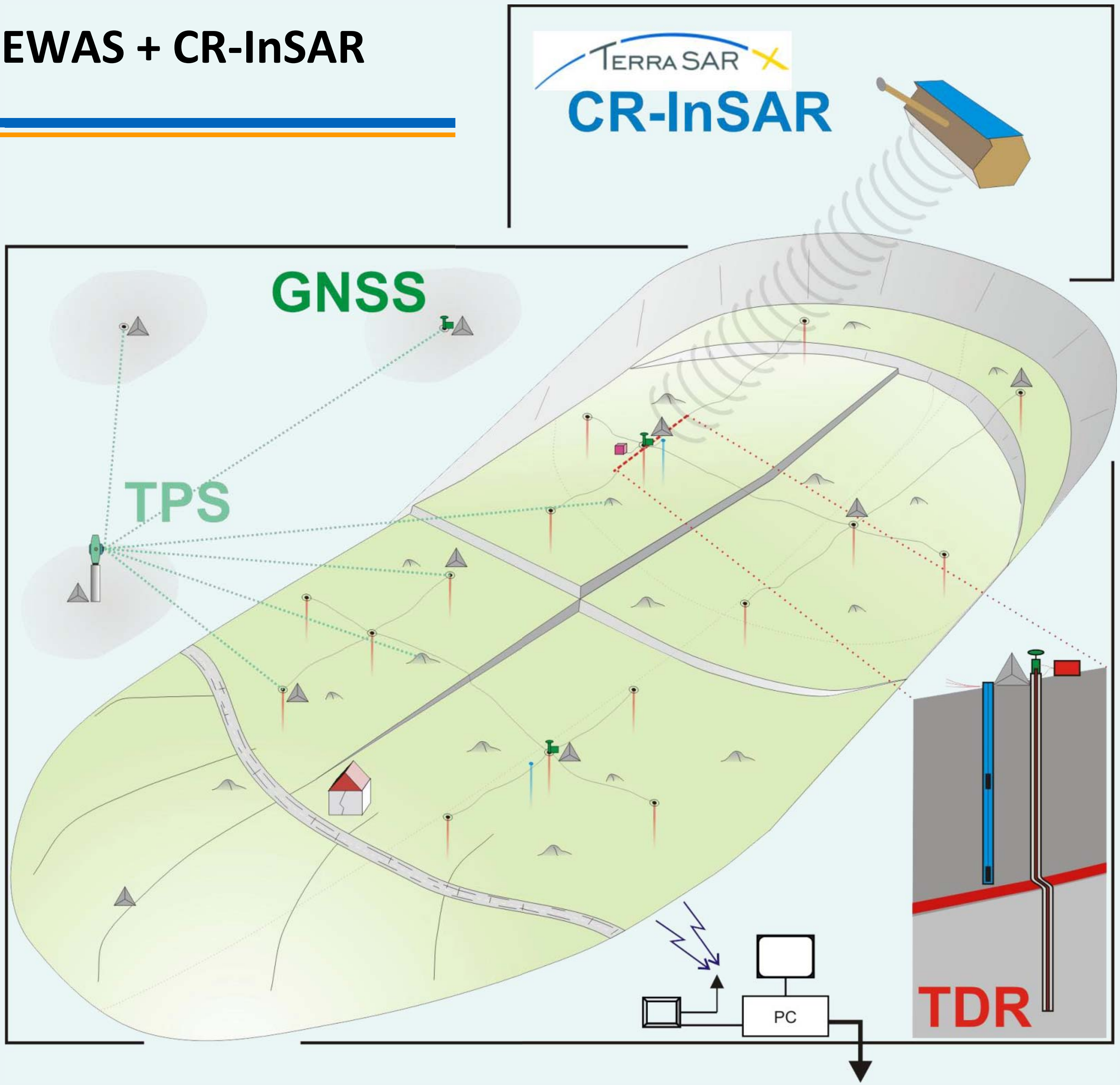
CR-InSAR – Corner Reflector InSAR

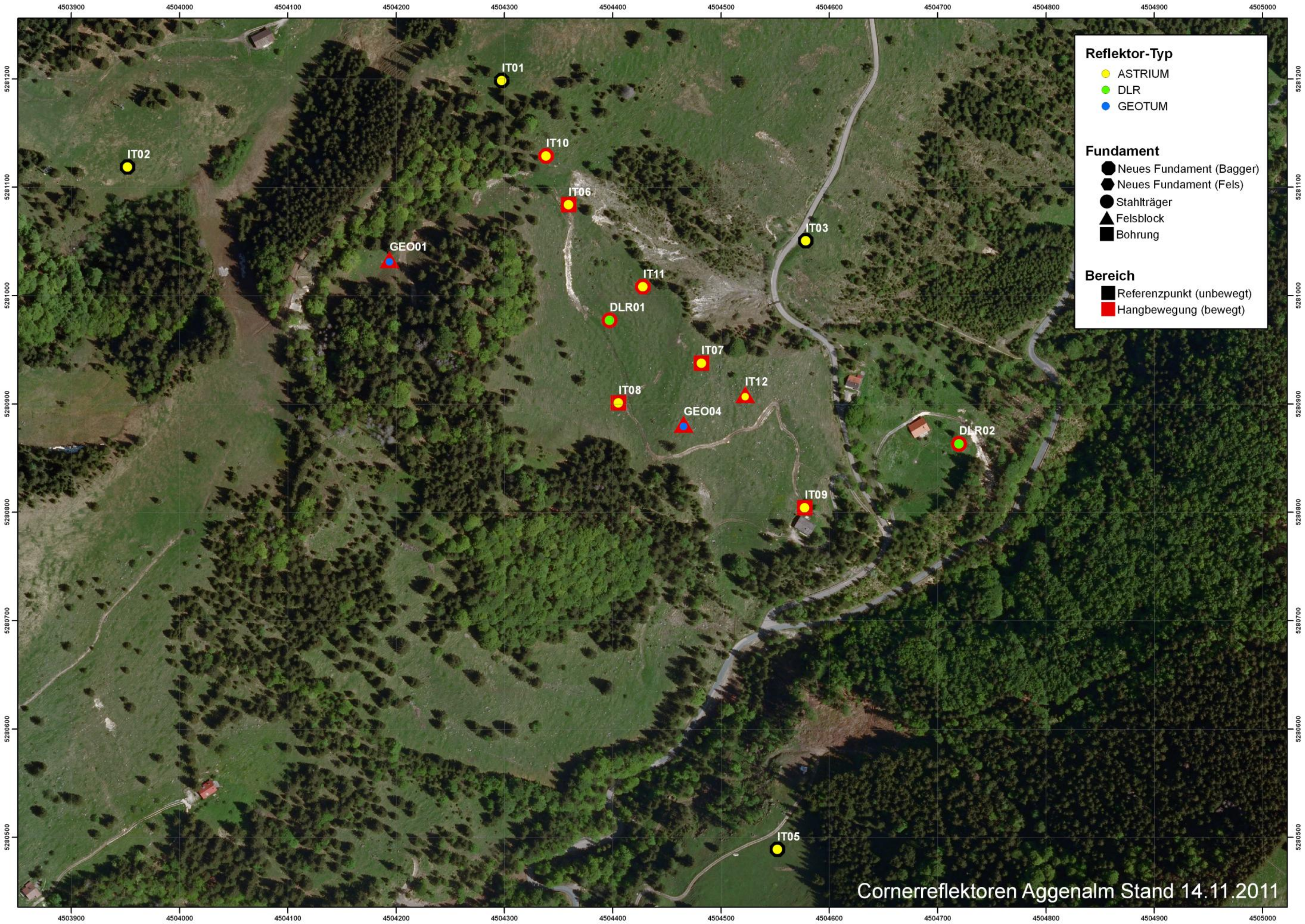
- Artificial Persistent Scatterers
- Increase of PS point density
- Only for comparably small areas of interest


GNSS
TPS
PC
TDR

alpEWAS + CR-InSAR

- 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)
IT01
IT02
IT03
IT05
IT06
IT07
IT08
IT09
IT10
IT11
IT12
GEO01
GEO04
DLR01
DLR02
Cornerreflektoren Aggenalm Stand 14.11.2011




www.alpewas.de



Utilization of geothermal energy in Bavaria

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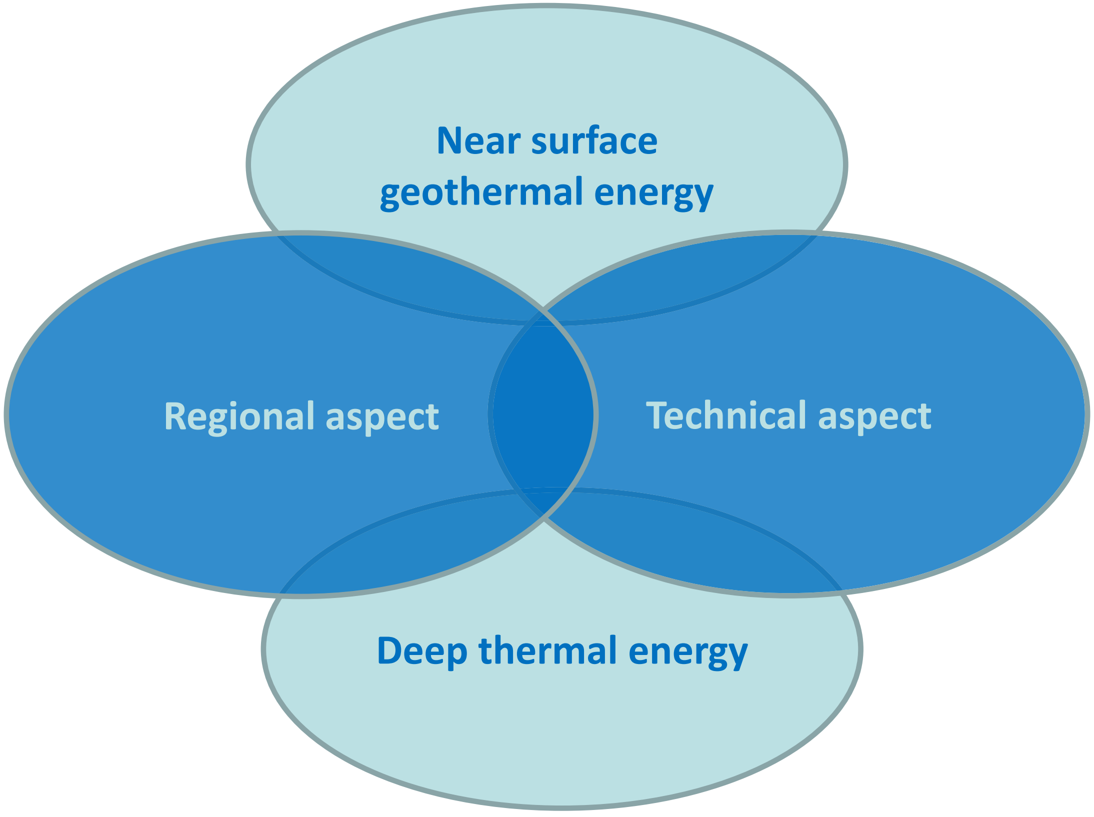
Fields of Work



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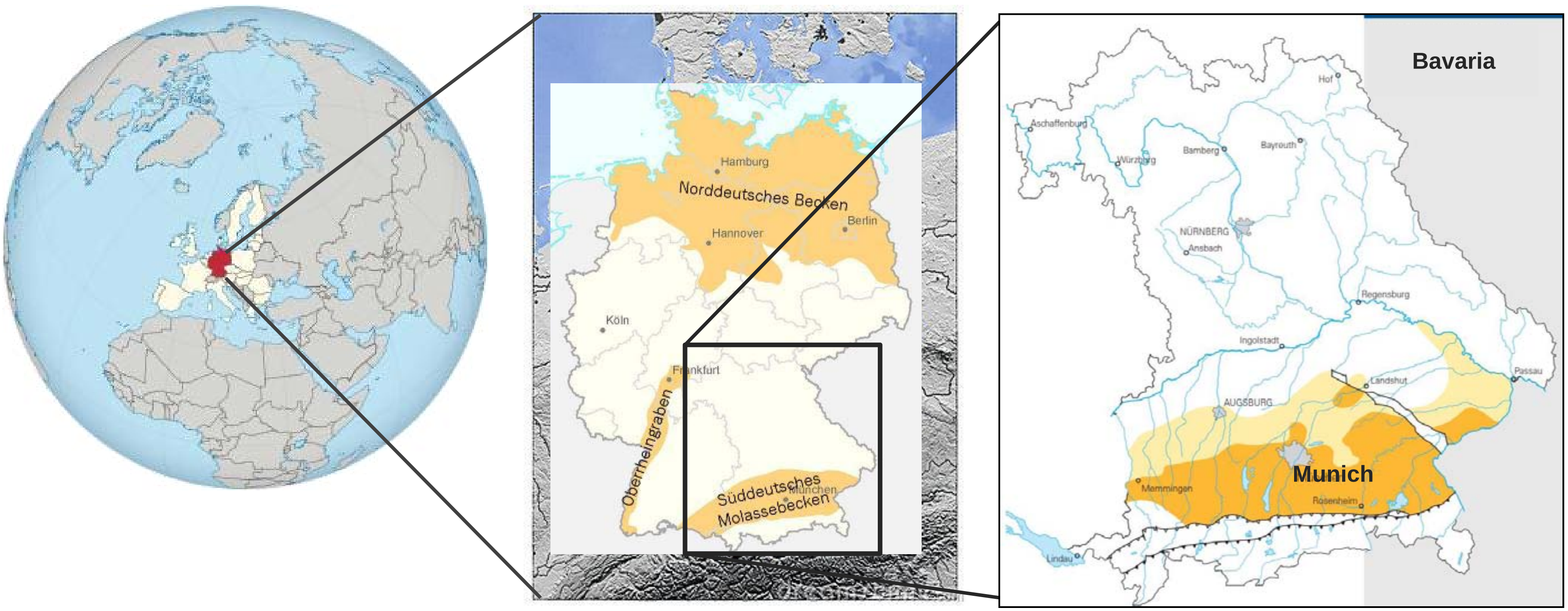
Deep thermal energy
Geothermal Potential of South Germany

Areas with favourable geological conditions for Geothermal Energy



Areas with favourable geological conditions for Geothermal Heat production

Areas with accetable geological conditions for Geothermal Heat production

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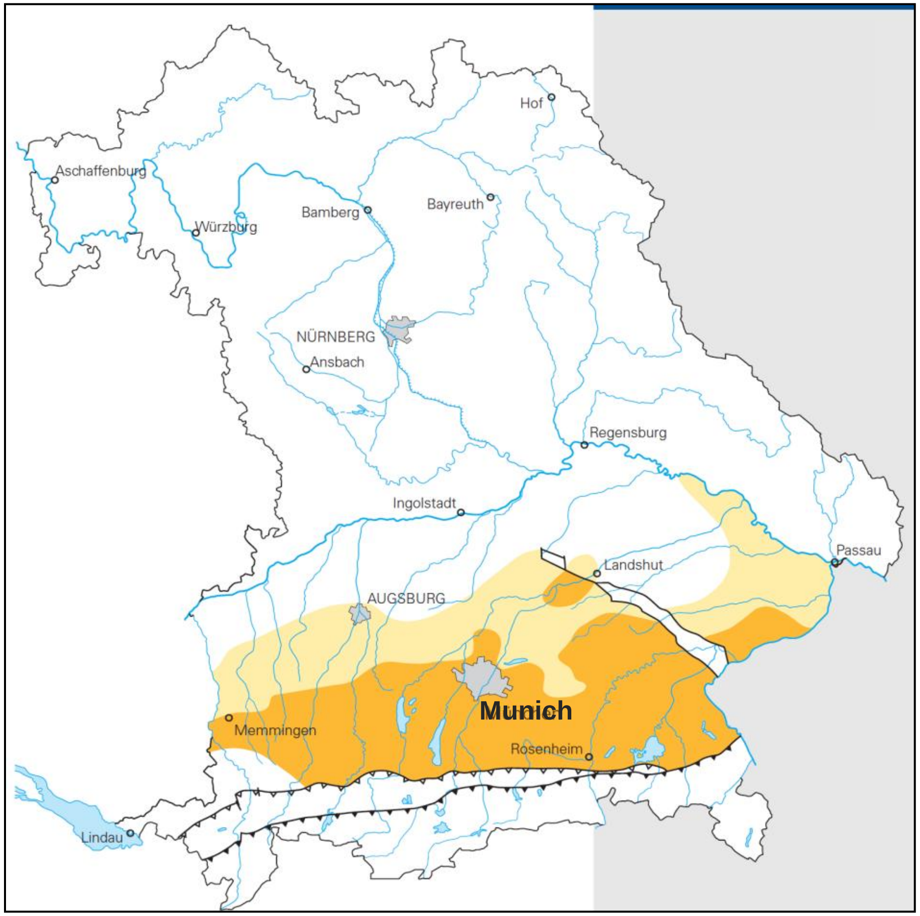
Deep thermal energy
Geothermal Potential of South Germany



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

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

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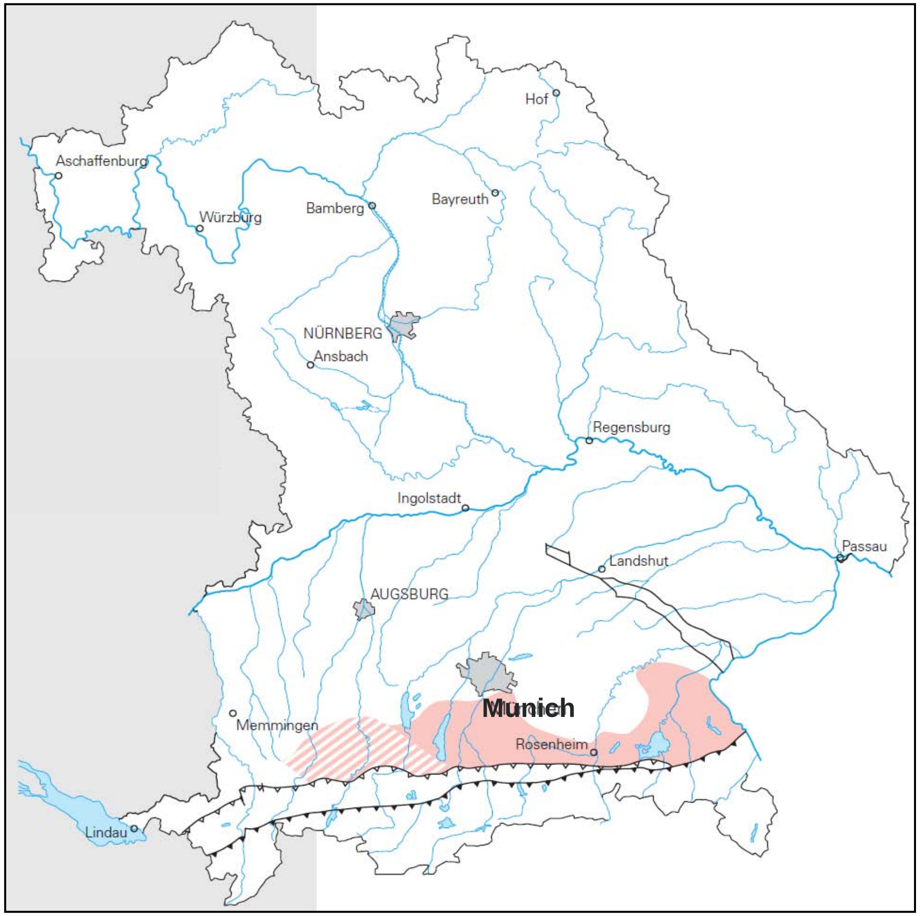
Deep thermal energy
Geothermal Potential of South Germany



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

Areas with accetable geological conditions for Geothermal **electricity generation**

limited by
- production rate
- thermal gradient

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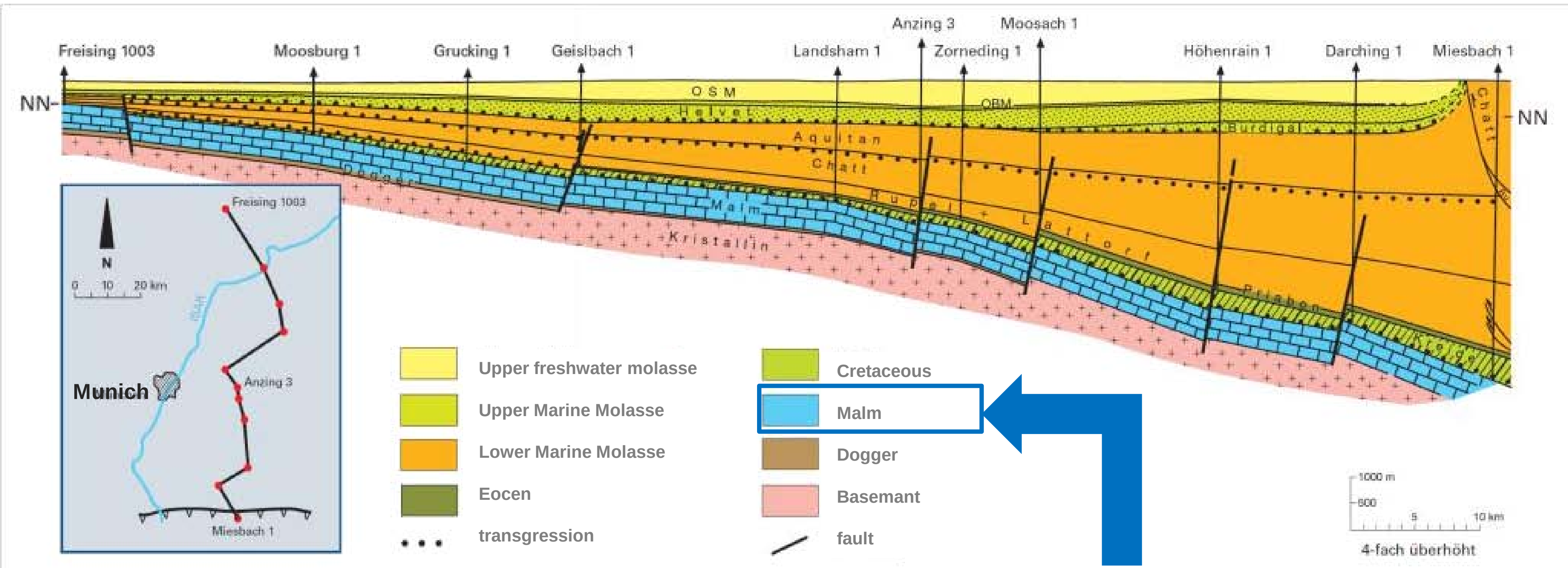
Deep thermal energy
Geological Cross Section



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

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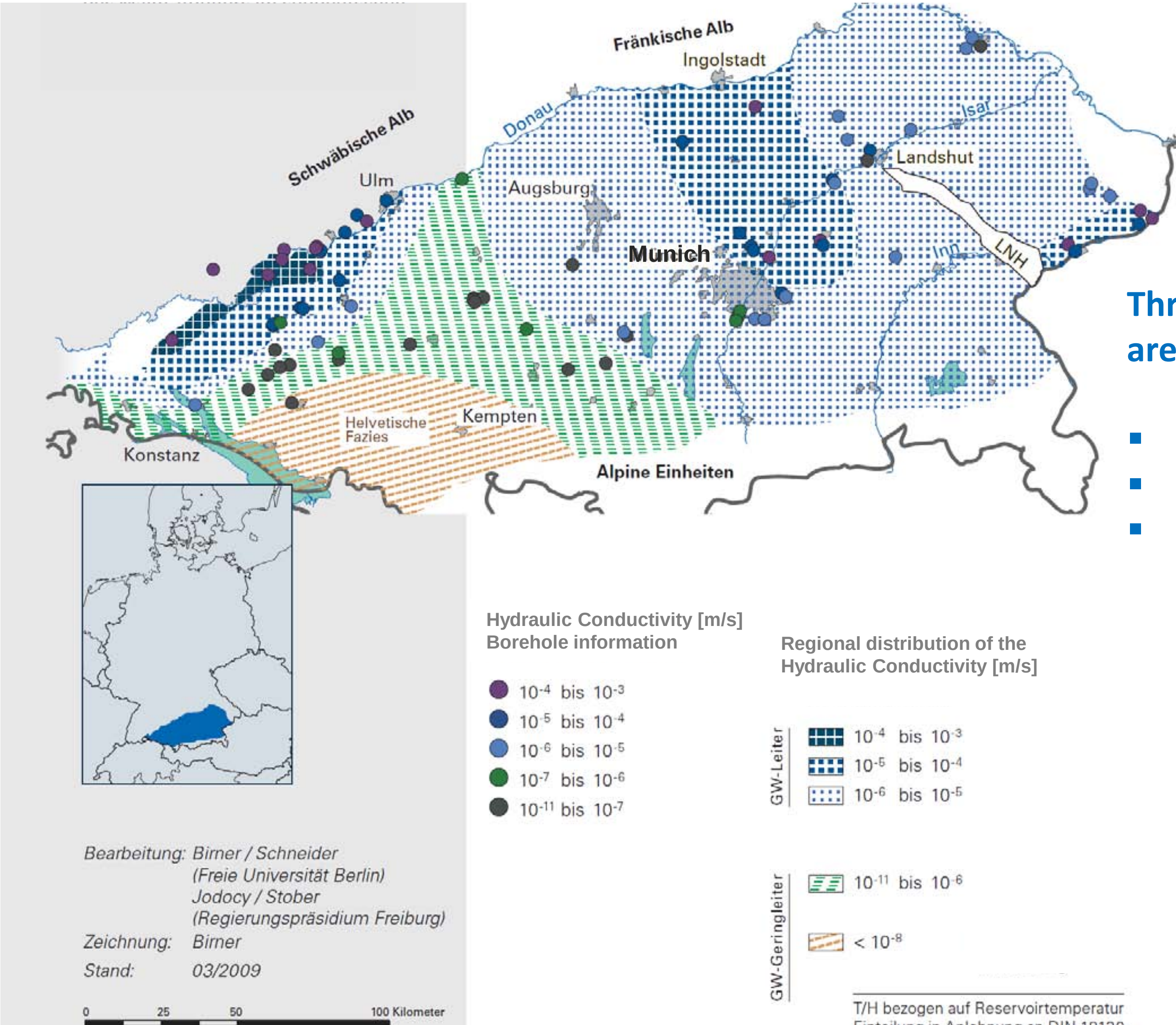
Deep thermal energy
Hydraulic Conductivity of the Malm Aquifer



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

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

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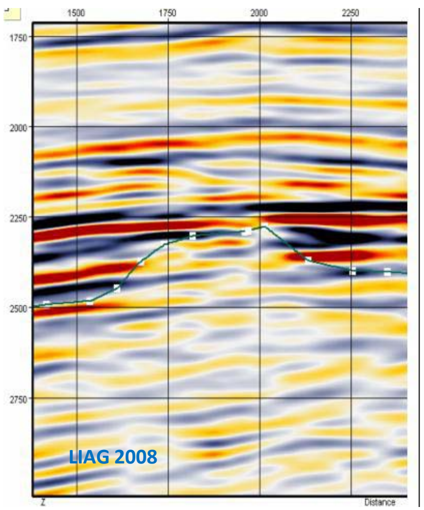
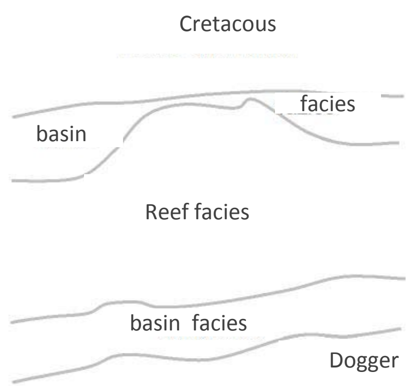
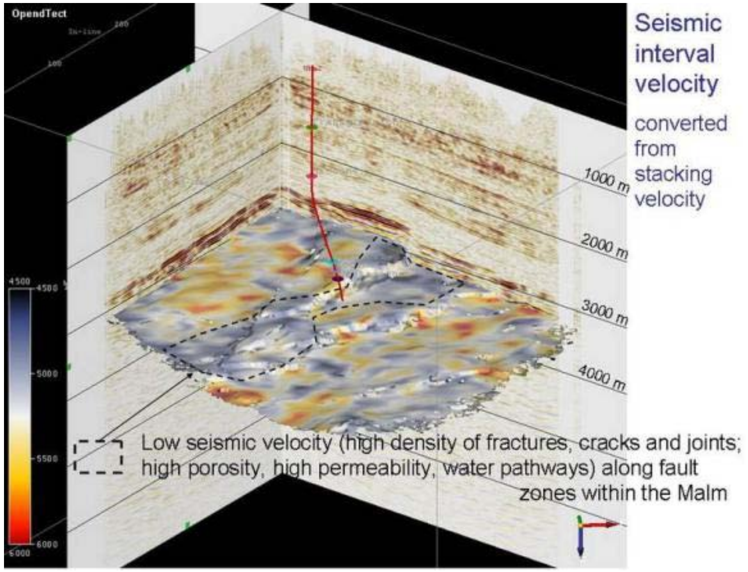
Deep thermal energy
Hydraulic Conductivity of the Malm Aquifer



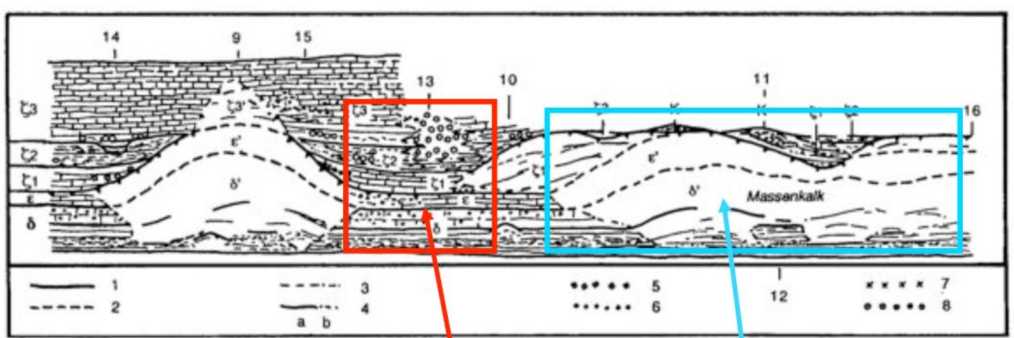
Example Lithofacies



Example fractures and karst structures



LIAG 2008



basin facies:
- low Permeability
- bad conditions

Reef facies:
- high Permeability
- good conditions

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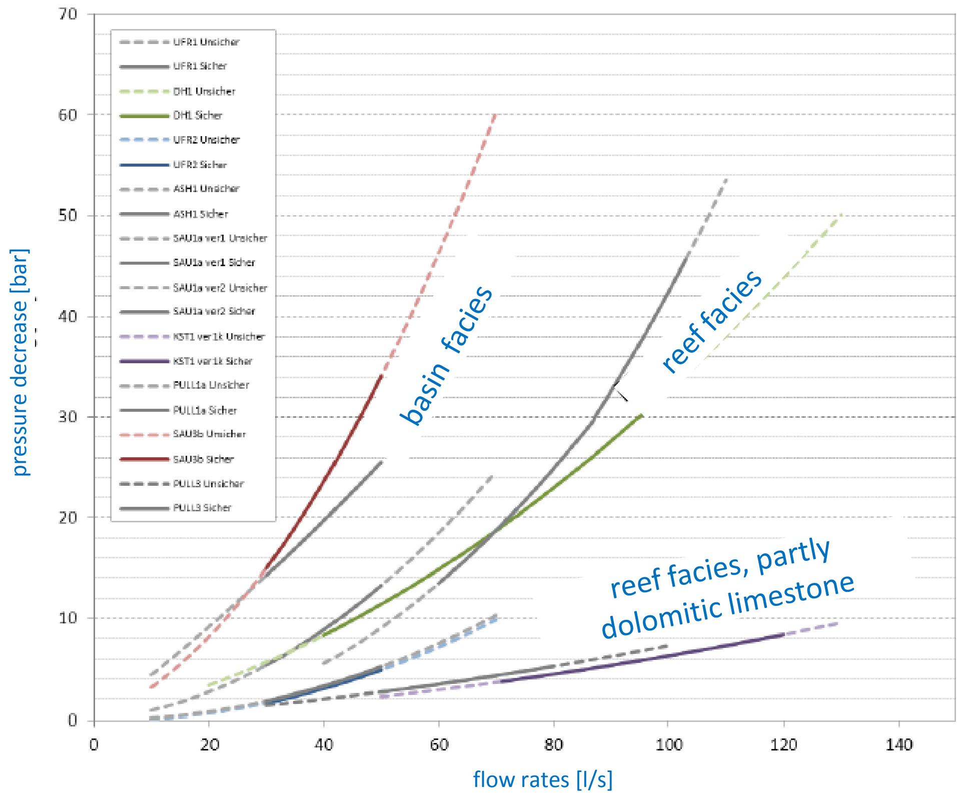
Deep thermal energy
Facies Analysis -



Research Topics:

- flow rates prediction
- temperature prediction
- reservoir modelling

→ mainly Southern Germany

cooperation: local engeneering offices and regional government

ERDWERK

SWM Stadtwerke München

→ Oversea studies (USA)

cooperation:

Munich RE

Near surface geothermal energy
Groundwater in Munich

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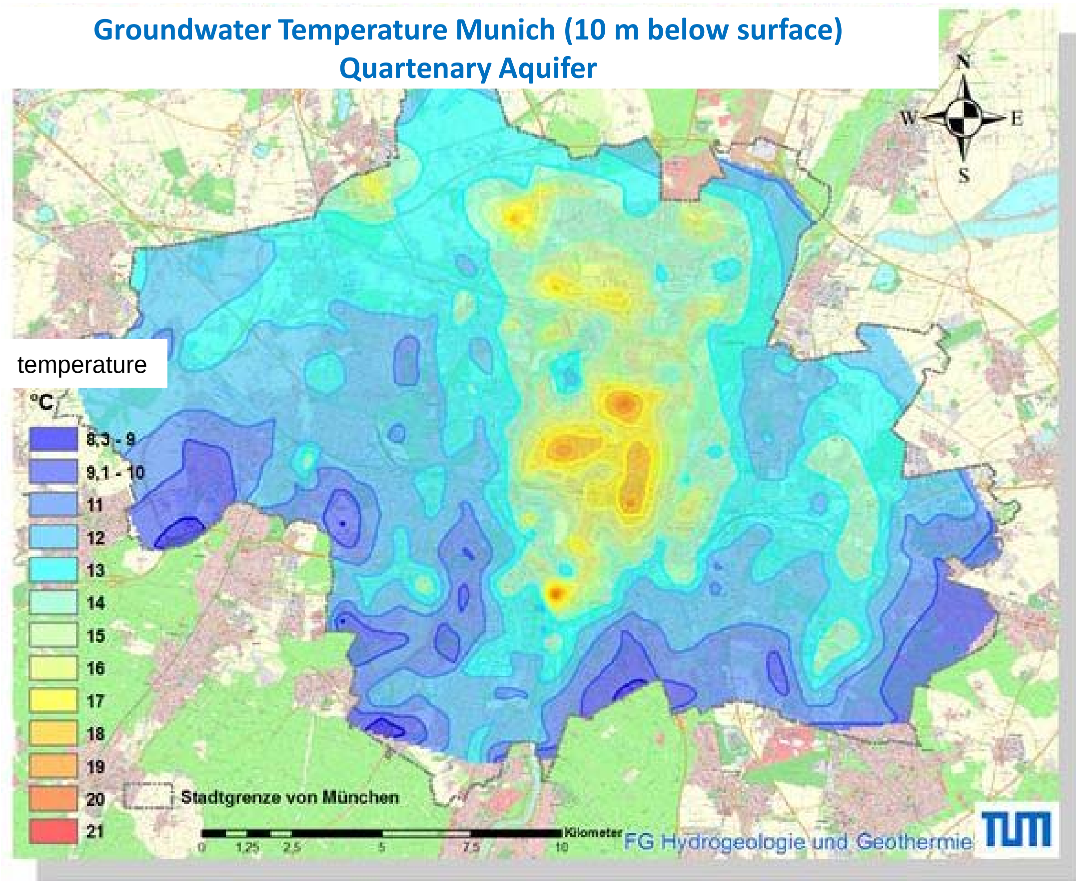
Groundwater Temperature Munich (10 m below surface)
Quartenary Aquifer



Munich Quartenary Aquifer:

- high hydraulic conductivity
- high aquifer thickness

→ good conditions using goundwater for heating and cooling

- temporarly and locally very high groundwater temperatures

→ anthropgenic effect

There is a Need for a

Geothermal Groundwater Managment Tool

to avoid resource conflicts
in the future

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Near surface geothermal energy
Groundwater Management Tool

Parametrisation

Influences of the temperature variability

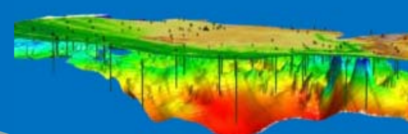
→ e.g. Quantify rejected heat from:
- subway
- district heating network
- buildings
- …

Estimation of the geothermal parameters

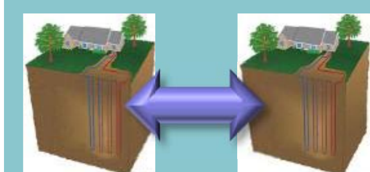
e.g.:
thermal conductivity distribution
(Measurements with the Thermal Conductivity Scanner)

Estimation of hydraulic parameters

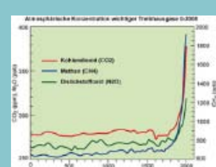
Groundwater heat transport model



Optimisation of the existing geothermal installations



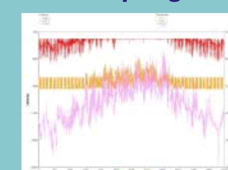
Geothermal potential with respect to climate change



Simulation and Prognosis

Geothermal potential with respect to urban development

Interface groundwater heat model with thermal energy system simulation programs



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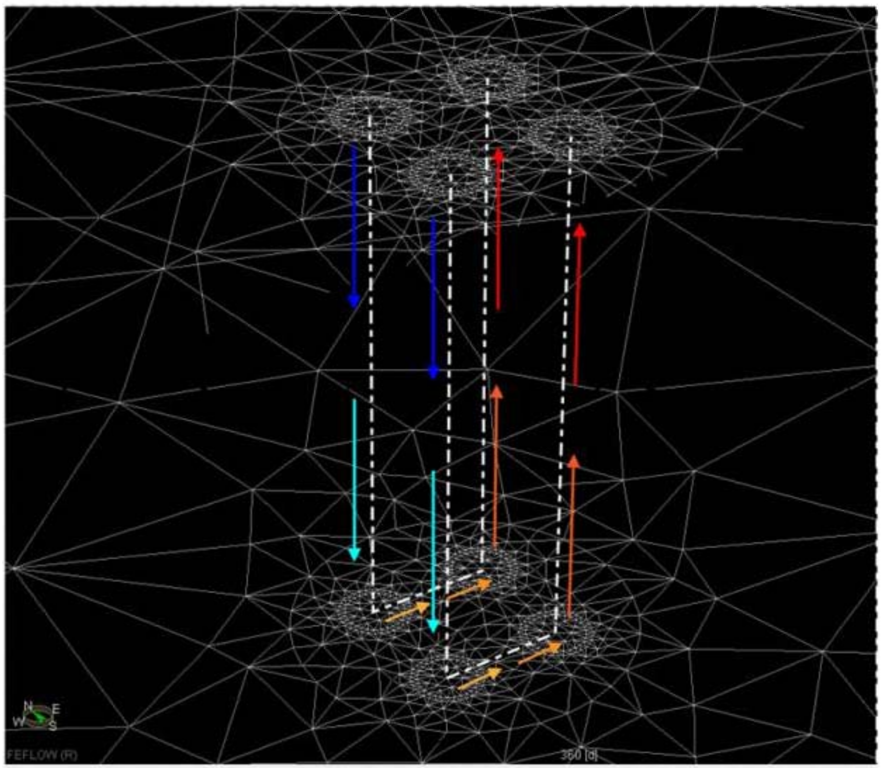
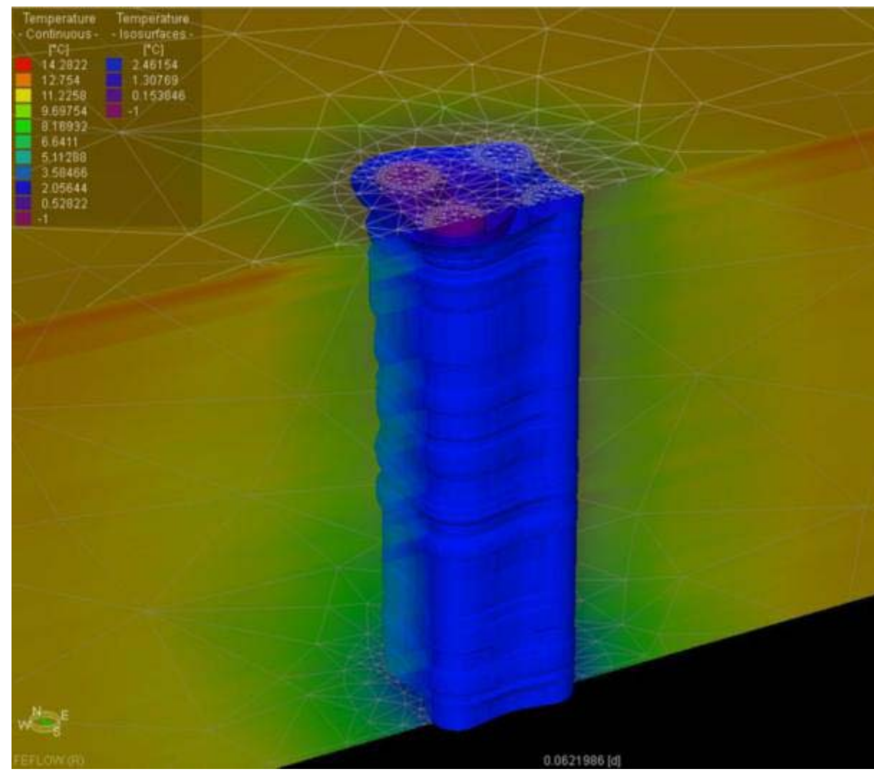
Near surface geothermal energy
Simulation of a borehole heat exchanger

Simulation of the frost action boundary at a borehole heat exchanger

Inlet and Outlet temperature

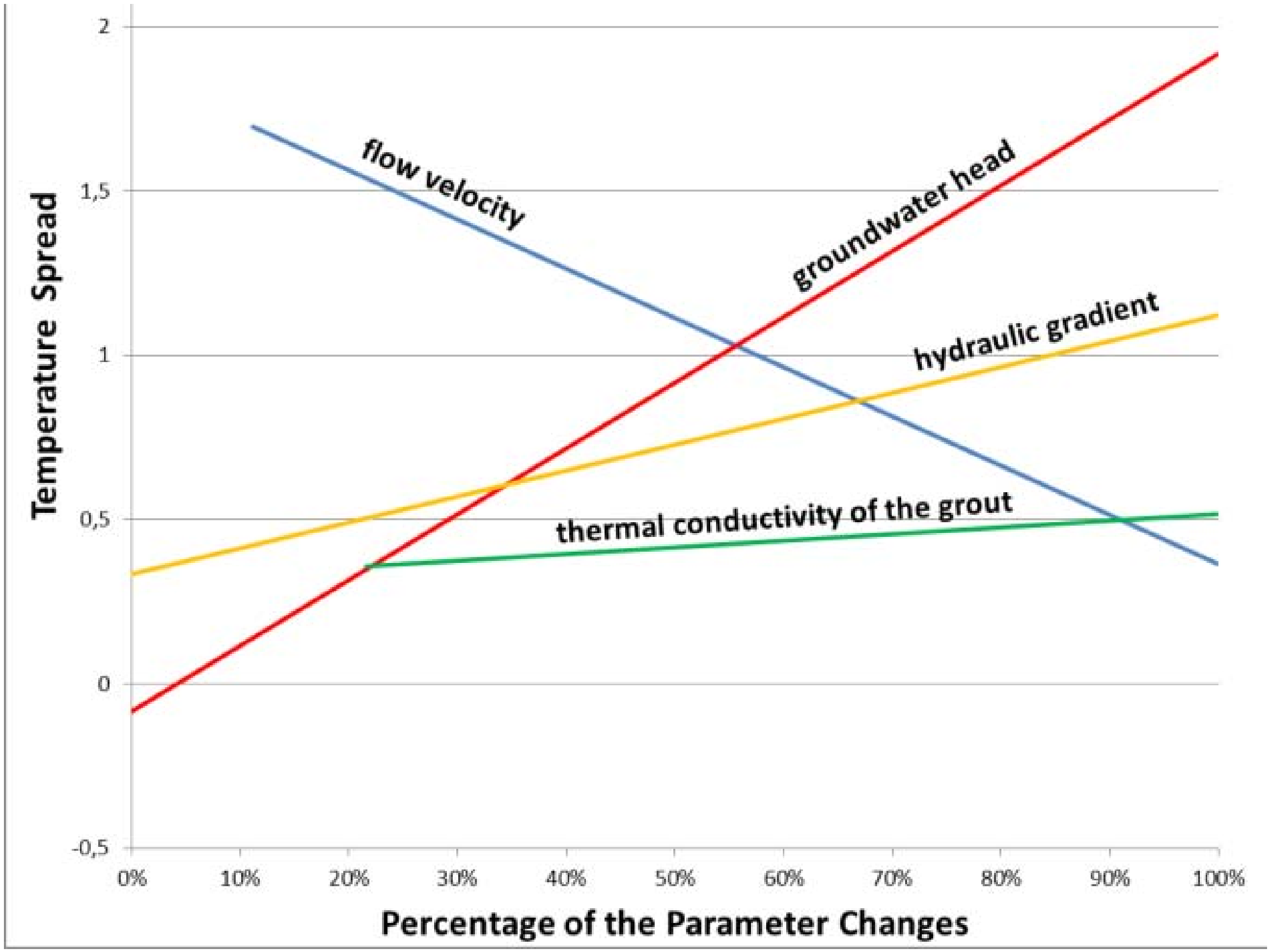




- Goal: Optimization of installation parameters

Near surface geothermal energy
Simulation of a borehole heat exchanger

Sensitivity analysis of the conditions to optimise the borehole heat exchangers



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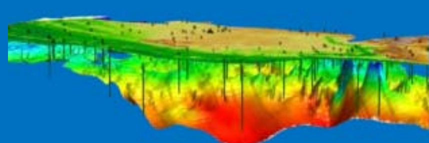
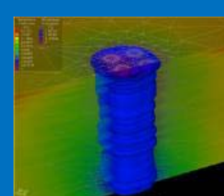
Near surface geothermal energy

Groundwater heat transport model



Simulation heat exchanger



Research Topic:

- **heat transport modelling parametrisation and prognosis**

cooperation: engeneering offices and regional government

DHI WASY

SWM Stadtwerke München

Landeshauptstadt München

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Thank you for your attention

I wish you a CO_2-limited future with geothermal energy