Recent Crustal Deformation and Seismicity in Southern Bavaria revealed by GNSS observations

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Commission for Geodesy and Glaciology
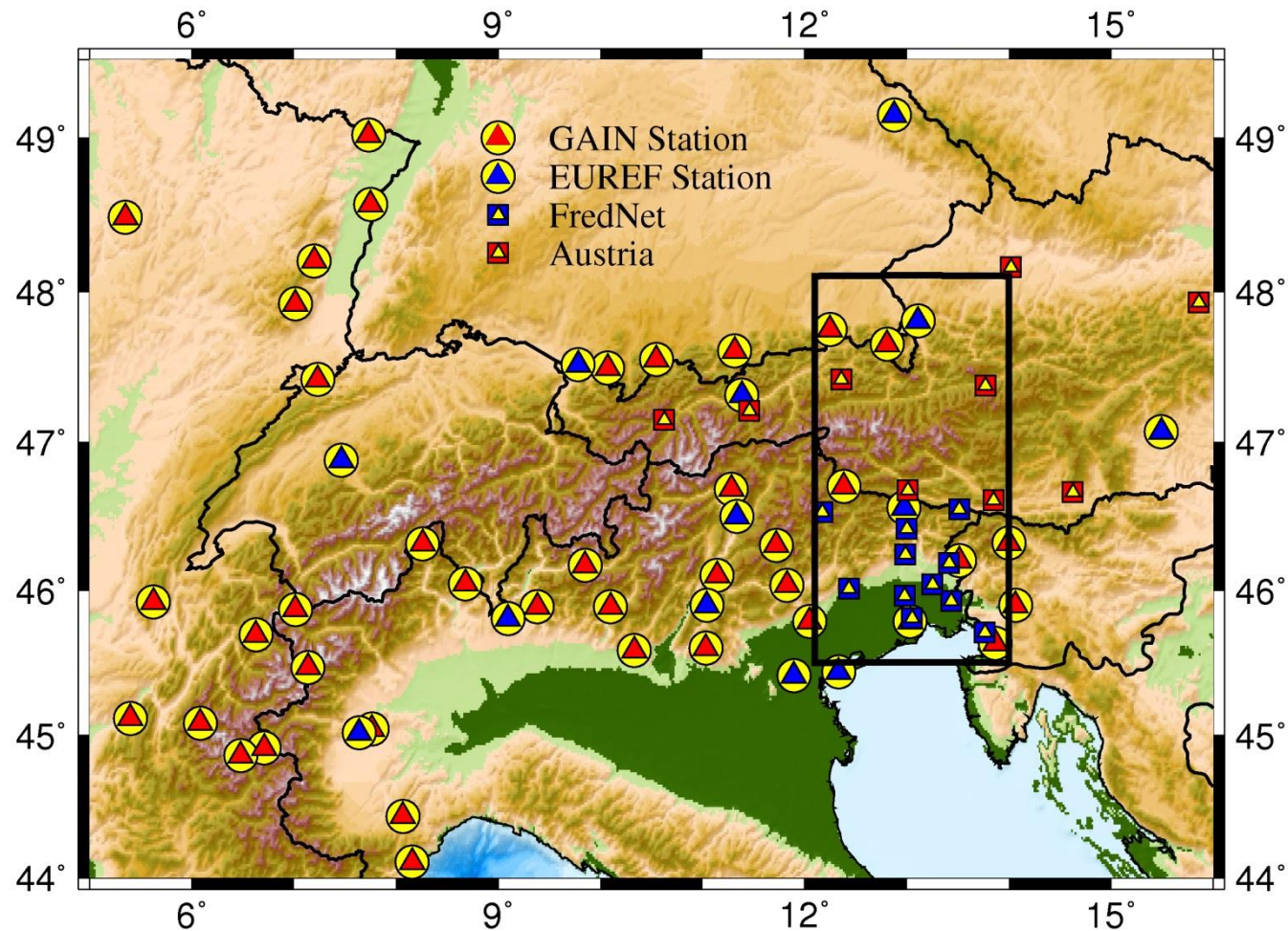
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CGE

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Motivation: ALPS-GPSQUAKNET Project

SA*POS*® Bavaria

- Maintained by the Bavarian Office for Surveying and Geographic Information

- Real-Time Positioning Service within Bavaria at the 1-2 cm level (within 10-30 seconds)

- Update of the equipment is/was frequent due to realizing the newest standards and methods
  - Consequently several inconsistencies in the time series based on equipment, FW, receiver settings etc.

- Network under consideration stretches only from the South of Bavaria to the river Danube

- Reference sites are spaced from 25-35 km.

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The **SA***POS*® Network

- Almost 40 sites installed
- Basically Trimble receivers (GNSS)
- Real Time network for positioning service
- Generally installed on buildings
- Good Infrastructure
- Maintained and operated from Munich

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Additional Sites

- Five sites installed and maintained by the DGFI (German Geodetic Research Institute)

- Located on the top of mountains from *Berchtesgaden* (East) to *Allgäu* (West)

- Height ranges between 1600-1900 m

- Almost no equipment changes (Antennas are maintained)

- These sites are also monitored by two absolute gravimetry campaigns (cooperation with BKG)
  - No significant changes in gravity observed

Data analysed with GIPSY 6.1.2

- Precise Point Positioning Mode was applied

- PPP Ambiguity fixing was conducted

  - Improved precision could be observed

Type	$S\varphi$	$S\lambda$	Sh [mm]
Float	1.9	2.7	6.0
Fix	1.8	1.8	5.8

- Reprocessed JPL orbits in the IGS08 were used

- Antenne calibration based on IGS_08.atx, only *type mean* was considered

- GMF mapping function was applied

- GPS only (still, GLONASS capability announced)

Time Series of Coordinate Residuals

FAHR
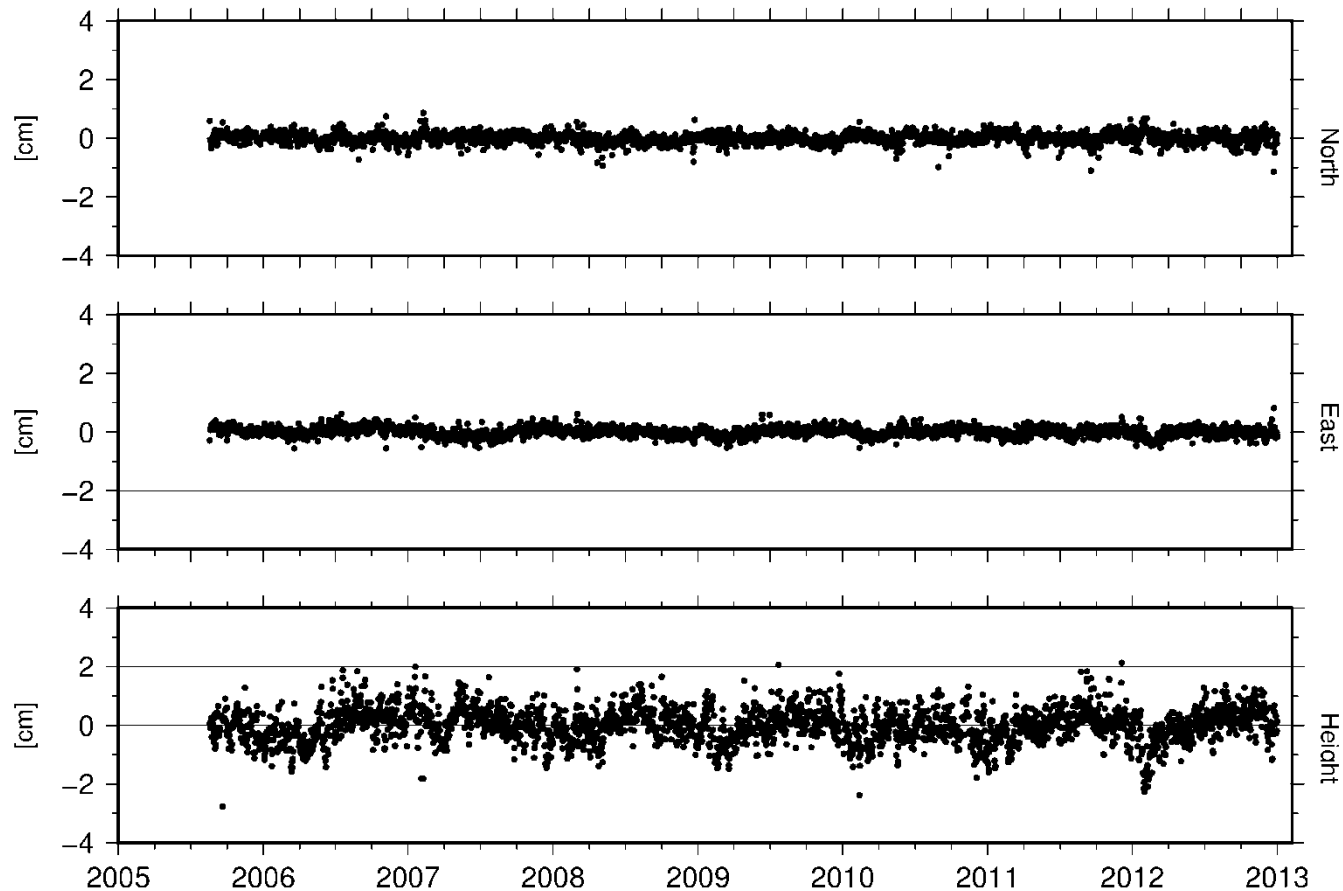
Time Series analysis using CATS

- CATS: GPS coordinate time series analysis software (S. Williams 2008)
- Time series of coordinates based on Precise Point Positioning as input
  - 7-8 years of data
- Removal of outliers
- Control of jumps in the time series based on station logs
  - Elimination of data, while site covered by snow
- Estimation of biases, seasonal signals and re-estimation of the linear velocity components
- Sophisticated computations of the stochastic properties by using different noise models

Uplift of the ALPS?

| Station	Start	End	Vφ	Vλ	Vh
BREI	15.9.05	31.12.12	15.88	20.38	0.92
FAHR	19.8.05	31.12.12	15.75	20.61	0.65
HGRA	26.7.05	31.12.12	15.79	20.06	0.97
HRIE	1.8.05	31.12.12	15.97	20.34	0.78
WART	3.8.05	31.12.12	15.71	20.72	0.92
MUC	25.6.04	31.12.12	16.02	19.99	0.42

[mm/a]

Vertical uplift between the plane (Munich) and the mountain crest of the Bavarian Alps cannot be determined significantly!

Focus: Horizontal Velocity Field (ETRS)
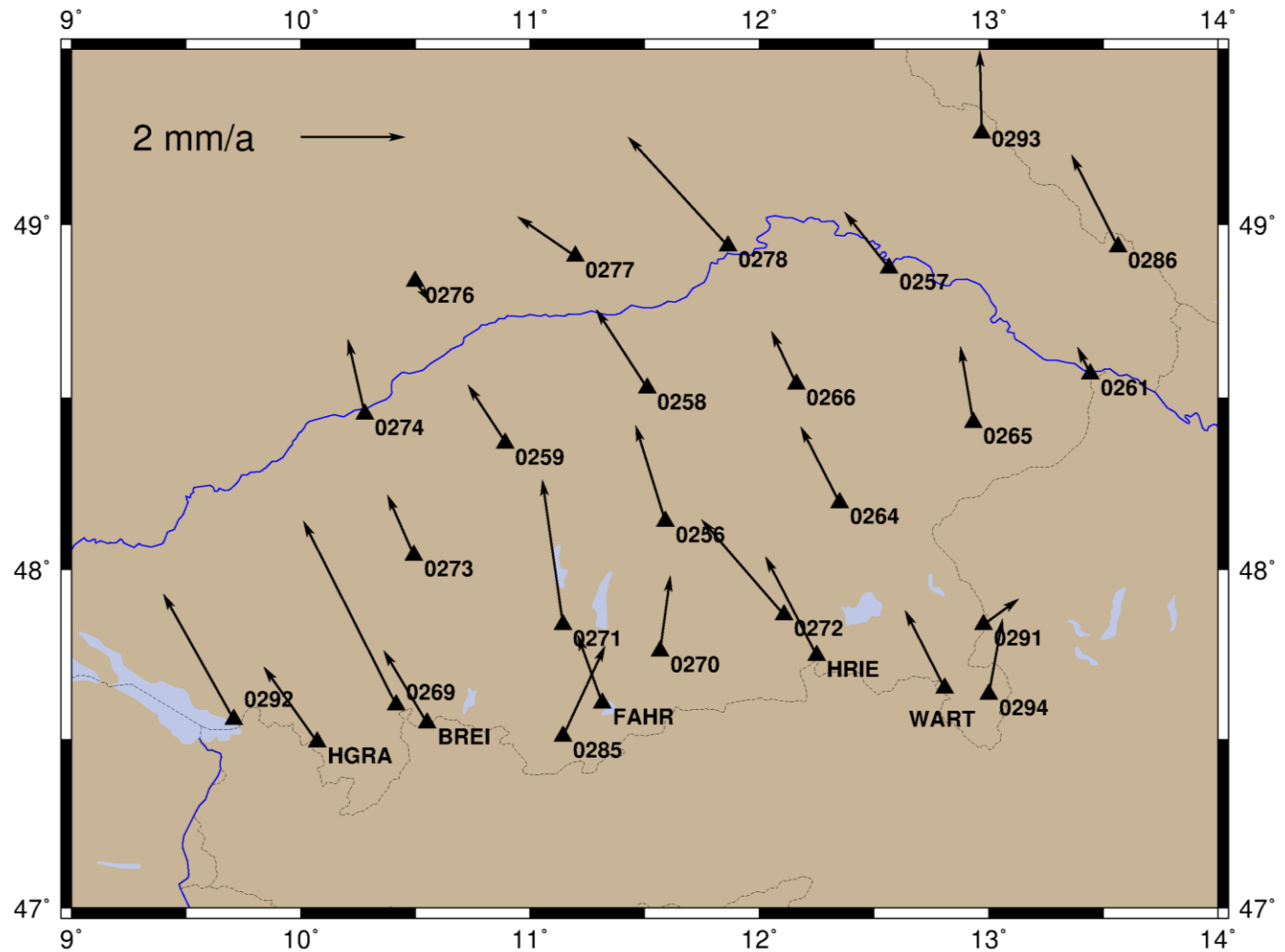
# Shear Strain based on horz. Velocities
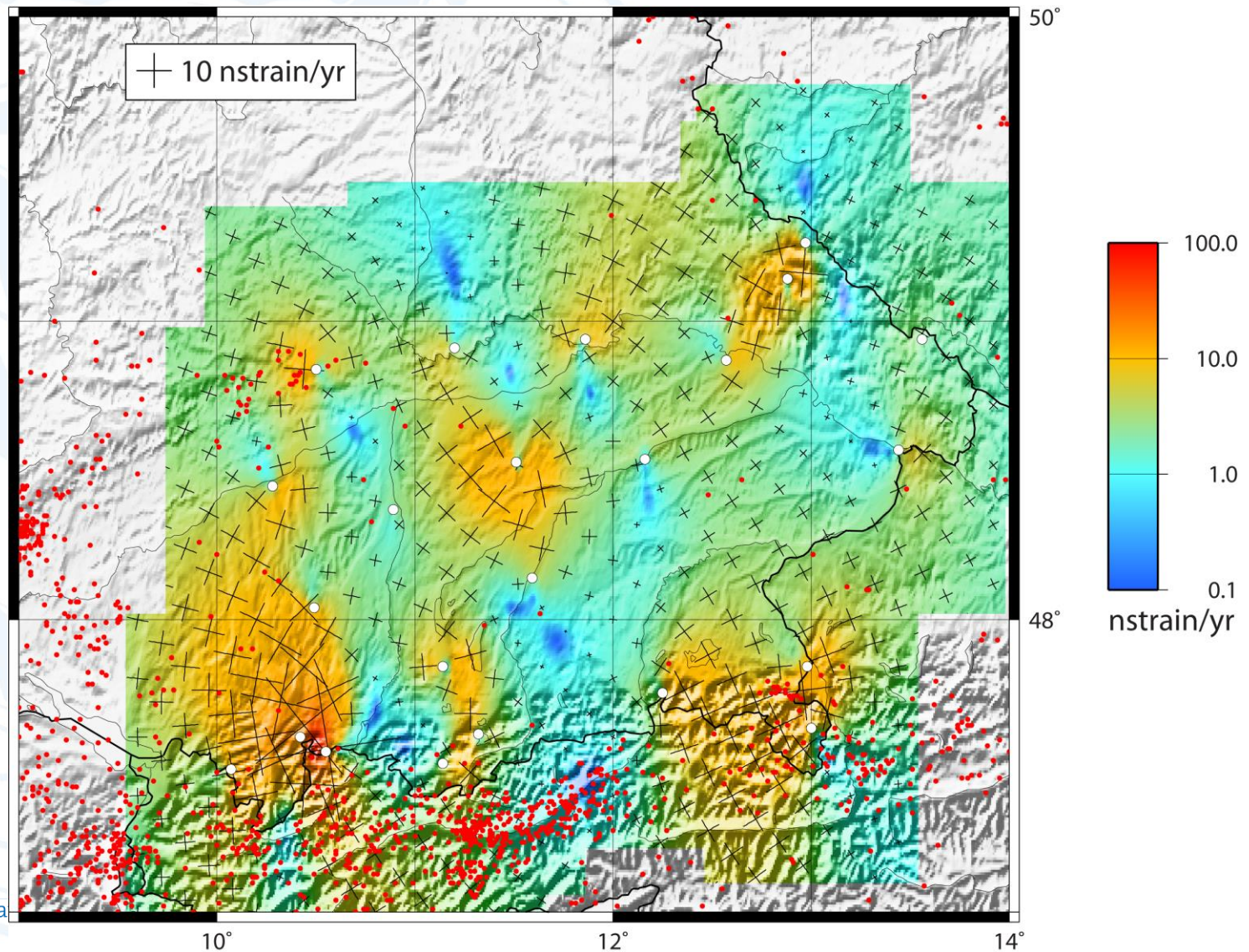
Areas of interest

- **Berchtesgaden**, south-eastern Bavaria
  - Known for higher seismicity
  - Mount ***Hochstaufen*** shows increased seismicity after rainfalls (swarms of earthquakes)
- **Allgäu**, south-western Bavaria
  - Signal might be influenced by station WERTACH, which has several times been rebuild
  - Review time series
- **Unterhaching** (south of Munich, Geothermal exploration
  - Earthquakes appear directly below the borehole

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Geothermal Exploration „Unterhaching"

Focal Mechanism

Coherence attributes (Lüschen et al. 2011)

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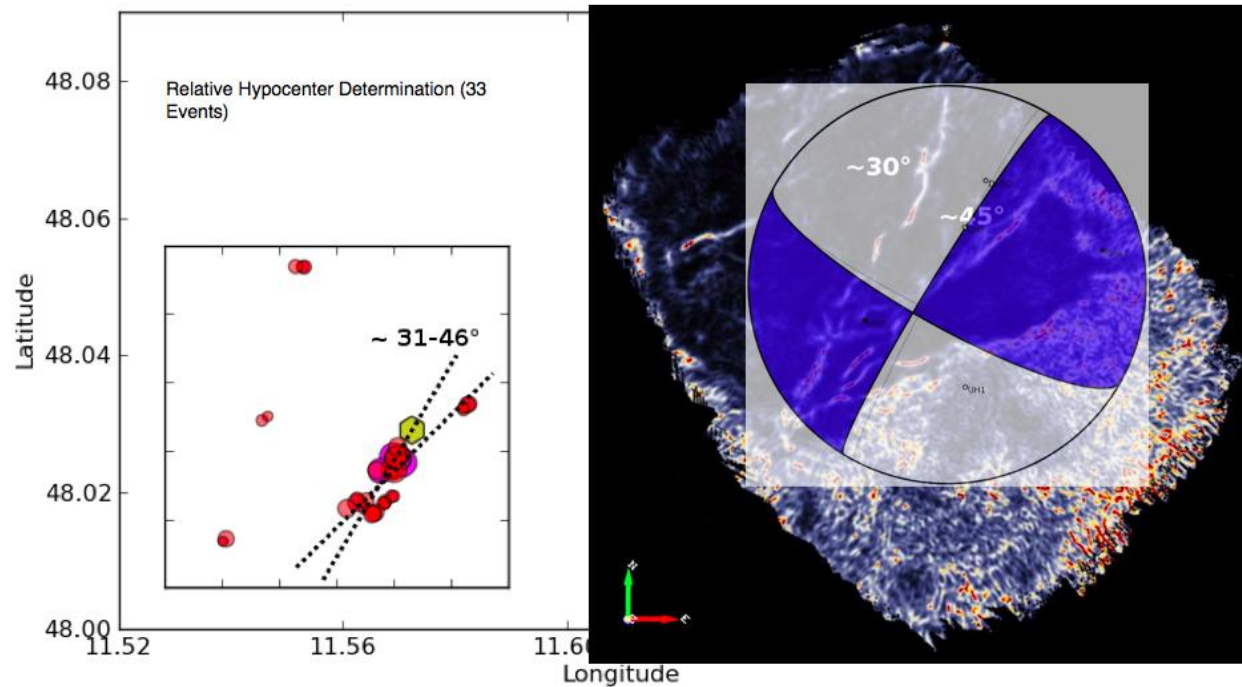
Summary & Outlook

- Signals are small but untypical for rigid plates

- Study the impact of the stress field outside of Bavaria

- Analysis of all available GNSS sites in the Alpine region (EPN, FreDNet, GAIN, RENAG and Austria)

- Analysis of the data also with BERNESE 5.2 (GPS+GLONASS)

- Focus on Berchtesgaden for intensified studies, adding other techniques (Geophysical sensors, InSAR, local GNSS networks, etc)
  - ▸ Research proposal submitted