Antelope and focal mechanism estimation from waveform stacking: first steps

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Outline

- Introduction
- DC waveform stacking method
- Needs for Antelope
- Outlook

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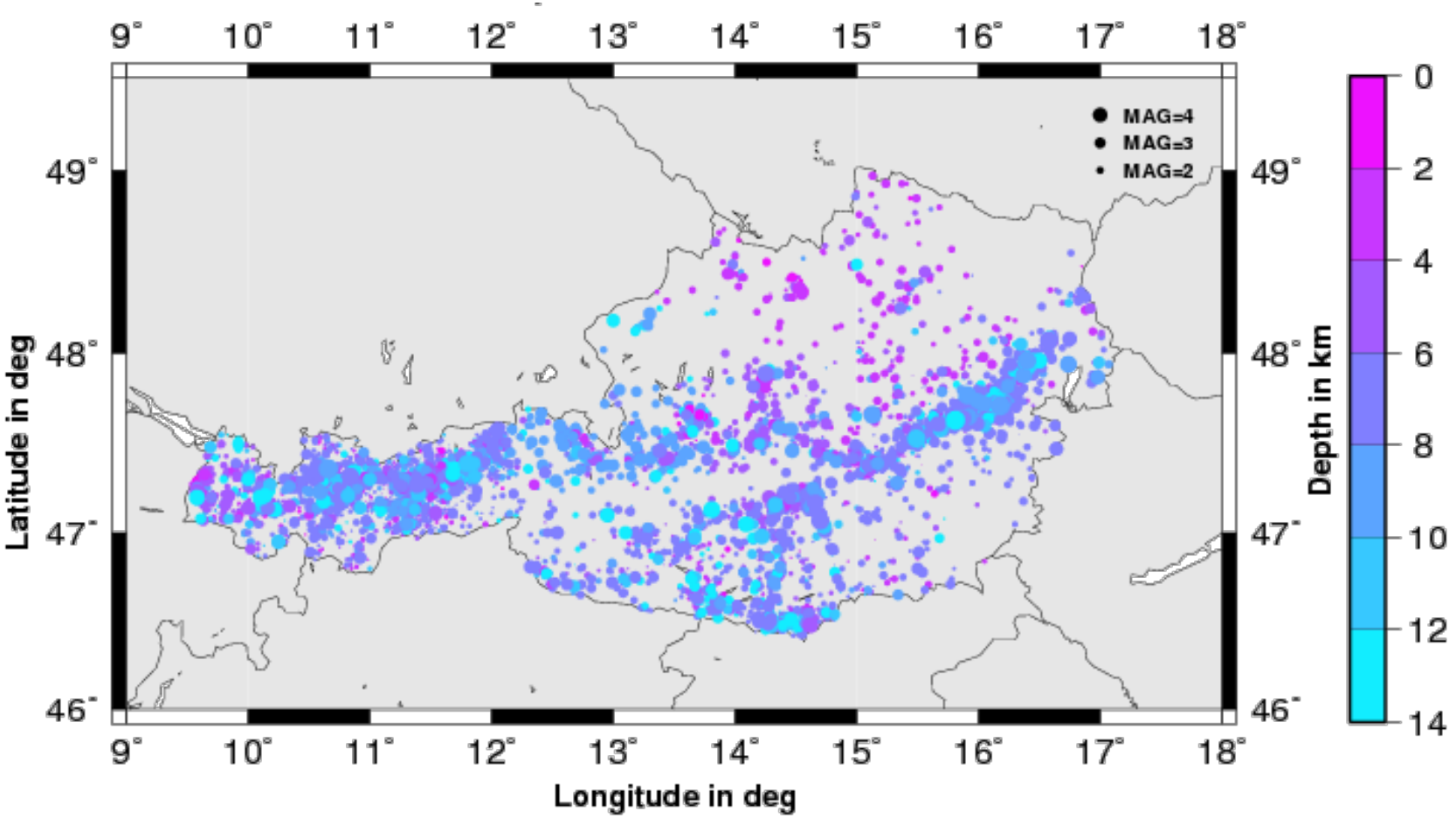
Earthquakes located in Austria since 1900



- Over 9000 earthquakes located in Austria and recorded at the ZAMG since 1900.
- Seismic hazard map indicate a_h up to 1.2 m/s^2 (10%, 475 year return period)

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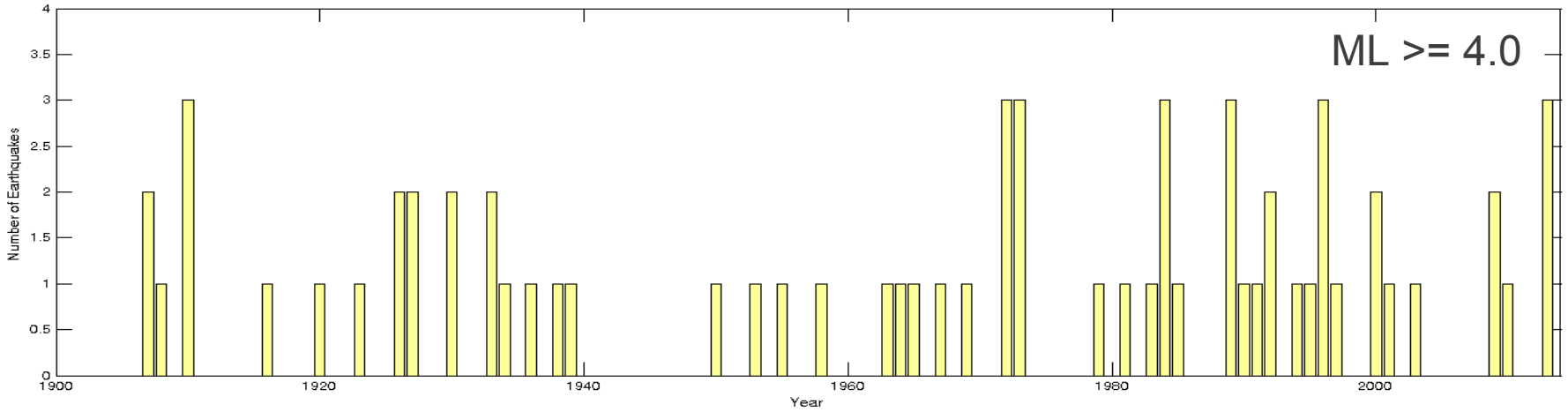
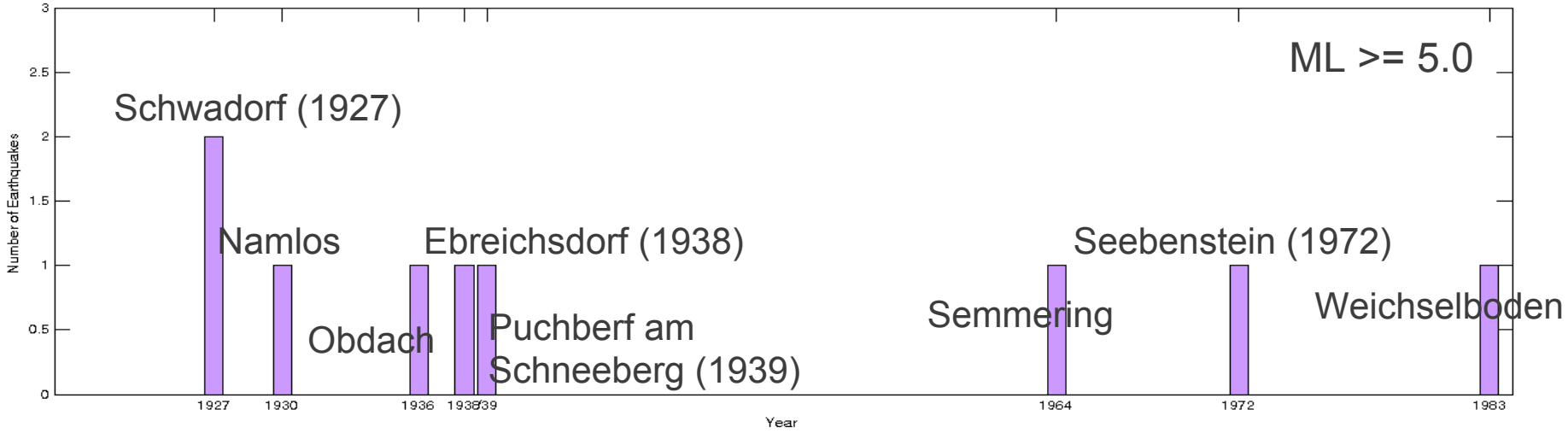
Significant Earthquakes in Austria since 1900





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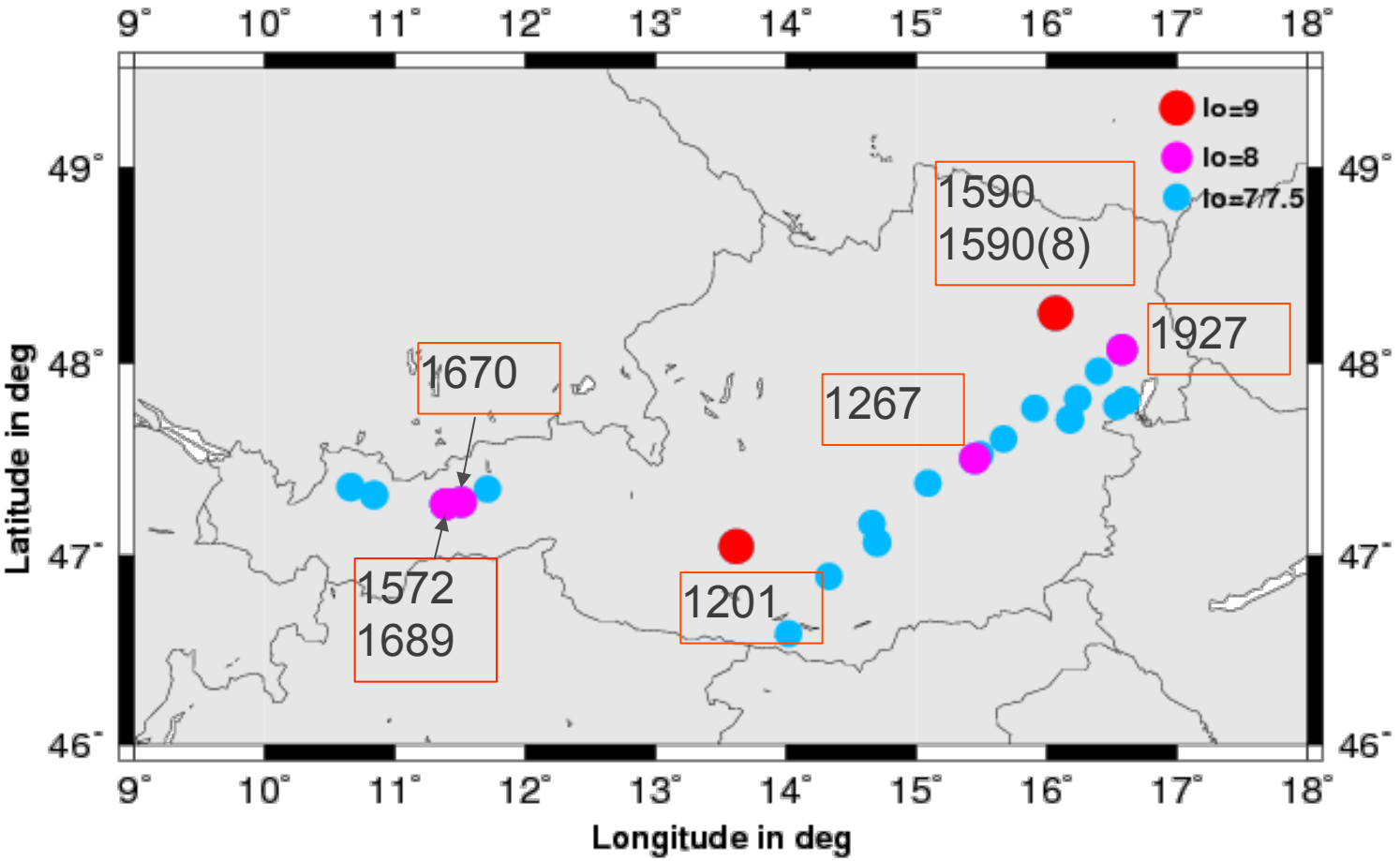
Historic Earthquakes with Heavy Damages



I_o=9
1201 Katschberg
1590 Ried/Riederberg

I_o=8
1267 Kindberg
1572 Innsbruck
1590 Ried/Riederberg

1670 Hall in Tyrol
1689 Innsbruck
1927 Schwadorf

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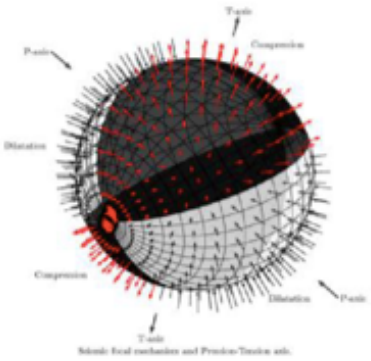
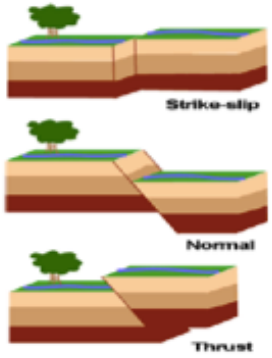
Moment Tensor Inversion

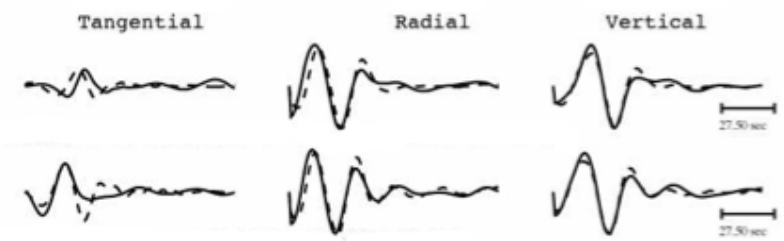


Radiation pattern



Focal mechanism

- Methods: waveform matching, first motion polarity analysis
- Applications:
  - USGS Ml > 5.5
  - ETH Ml > 4.5
  - Stich et al. (2003) Ml > 3.5



Waveform matching, GF's

First motion polarity analysis'

- Problems for regions like Austria: waveform matching (Dreger & Helmberger, 1993) not really applicable, first polarity analysis biased by subjective interpretation of the first motions

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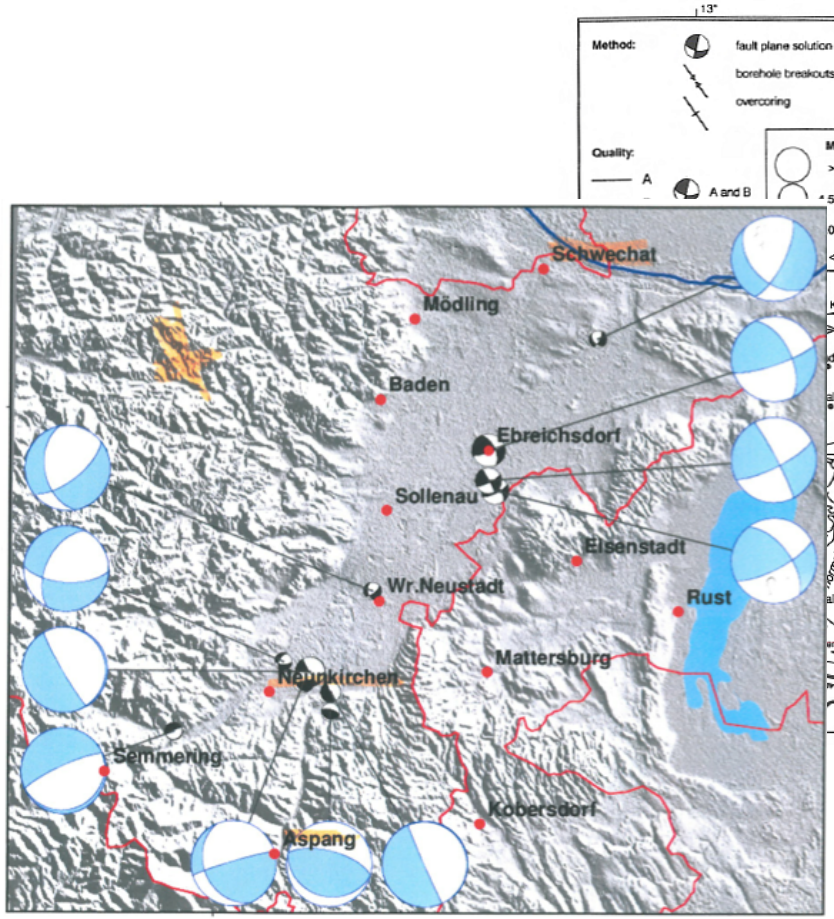
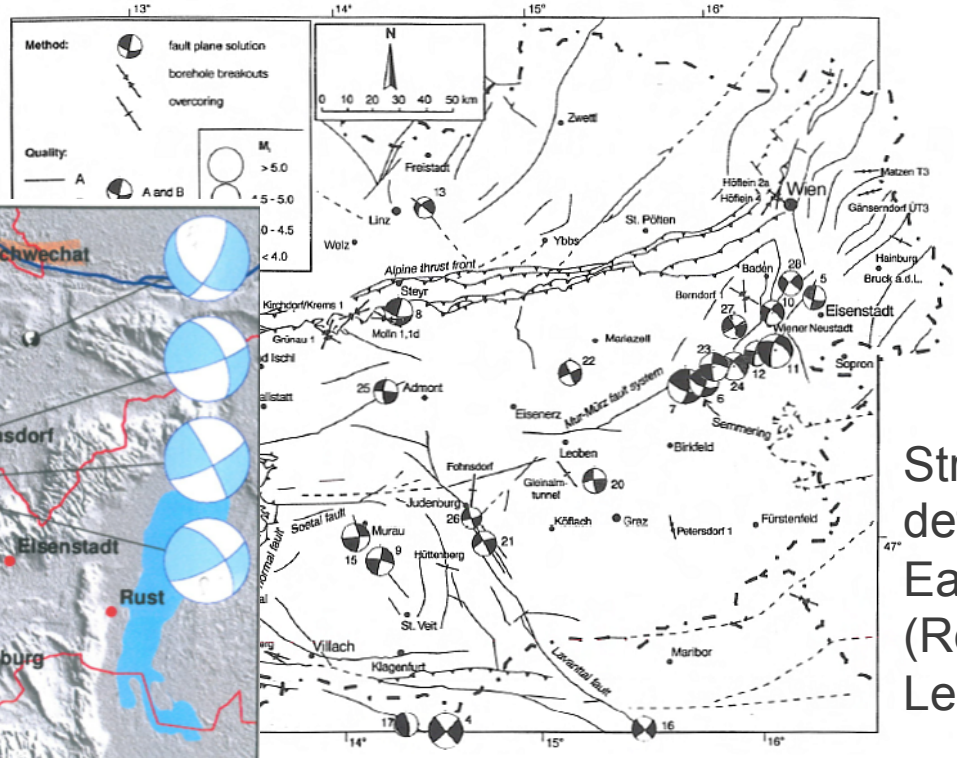
Previous studies on focal mechanism in Austria

- since 1965 first motion polarity analysis (F.Reiter, FPS):
- about 110 events (60 with Ml > 3)





Stress field and deformation in the Eastern Alps (Reinecker & Lenhardt, 1999)

Focal mechanisms in the Southern Vienna Basin, ZAMG (196?-2013)

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Aims

• Apply an objective method to increase knowledge on focal mechanisms in the Eastern Alps

• Compute reliable focal mechanisms for a region with moderate seismicity (Ml=2.5 and up) and for signals with low S/N ratio

• Use a (semi-automatic) algorithm in daily routine work; use pre-existing db (CSS3.0) & waveform access structure from Antelope 5.3+

>> apply DC waveform stacking method developed during the ALPAACT project from our partner at the Institute of Geodesy and Geophysics (Vienna University of Technology)

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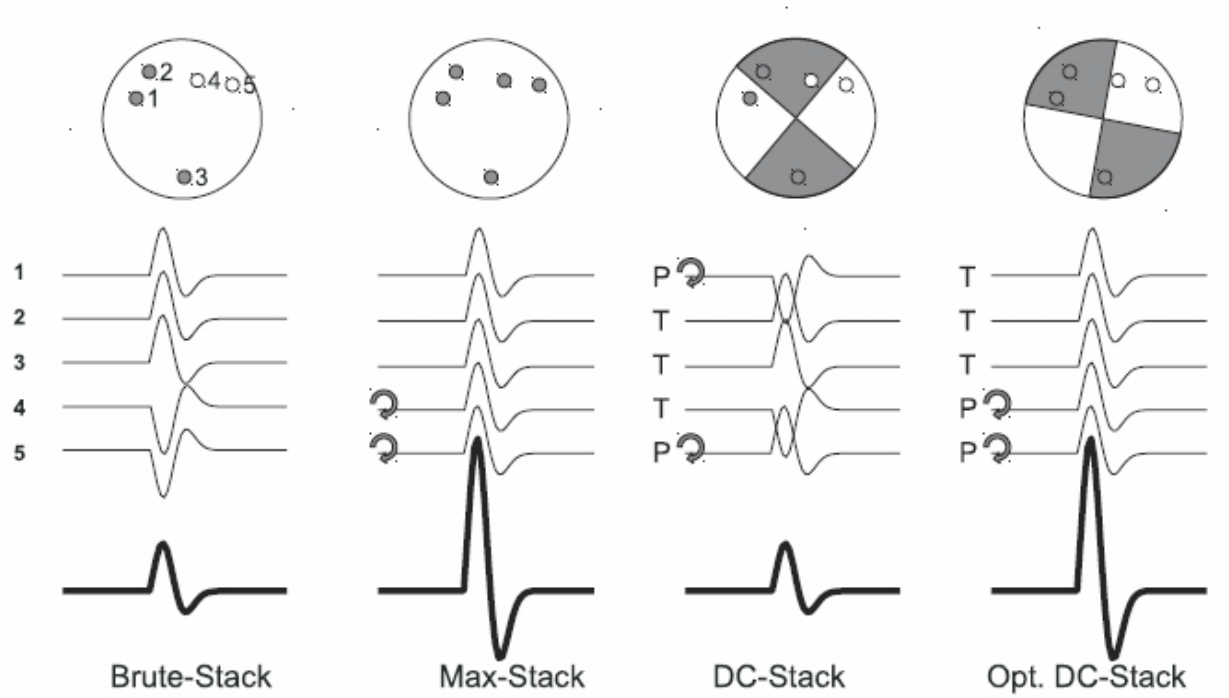
DC waveform stacking method

- Double-couple (DC) inversion with P-,SH-, SV polarities (isotrop medium)
- Method was introduced by Weginger & Brückl, 2014 (EGU)
- Available source code in Matlab (GNU GPL)



Weginger & Brückl, 2014

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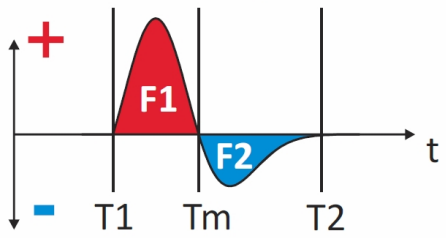
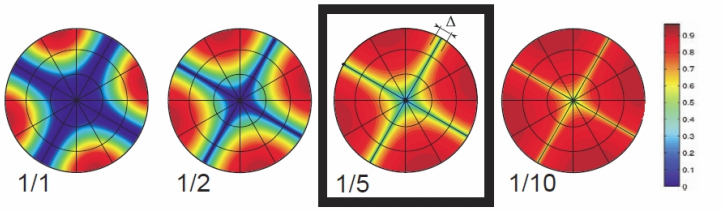
Objective function, Grid Search

Objective Function (OF) -> max!



$$OF = (F1_{stack} - F2_{stack}) * Semblance_{stack}$$

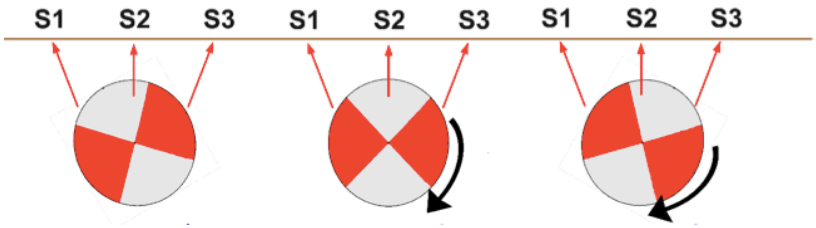
Weighting: S/N, distance to nodal plane



Weginger & Brückl, 2014

Global grid search for Opt. DC stack:

1. Euler rotations for T- and P-Axis > theoretical radiation pattern and polarities
2. Re-orientation of polarities
3. Stacking, Semblance, OF



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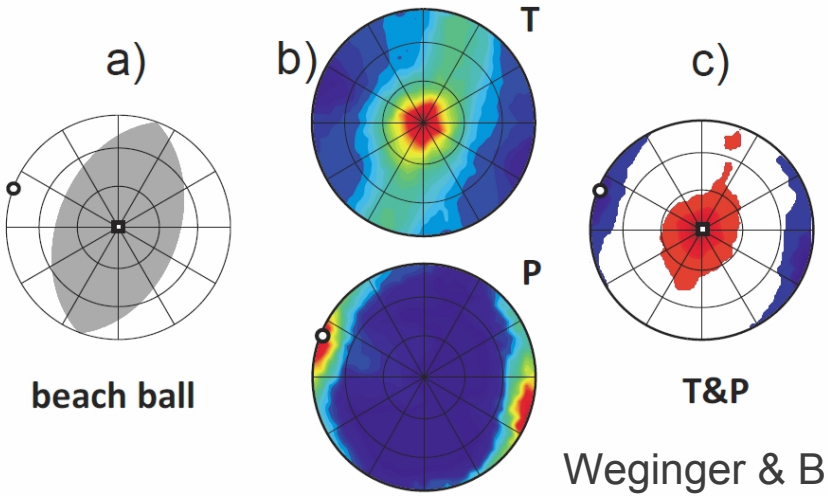
Result and Presentation

- T- and P- axis
- Orientation of focal and auxiliary plane(strike,dip,rake/slip)

a) Beach ball

b) T-, and P- Axis separated (good inspection of whole solution space)

c) T-, and P- Axis combined



Weginger & Brückl, 2014

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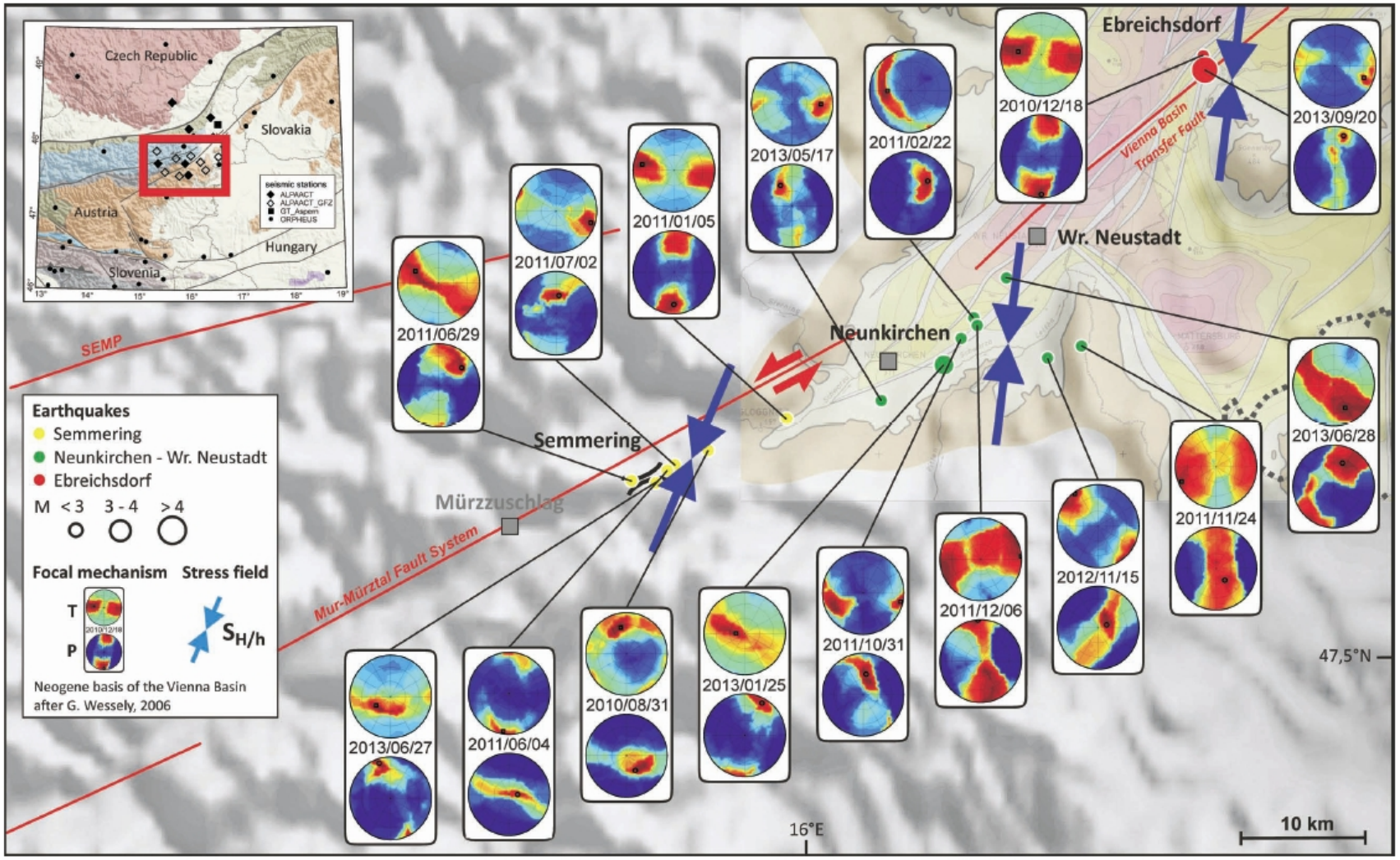
Examples from Real Data (Vienna Basin)



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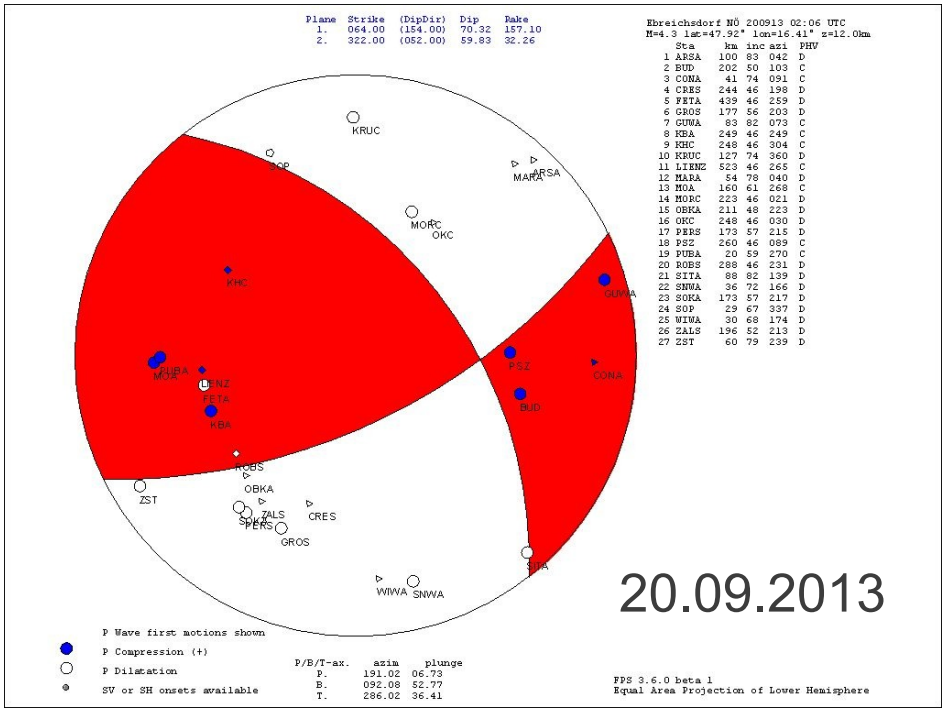
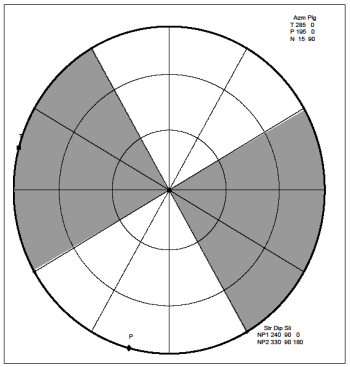
Example Comparison

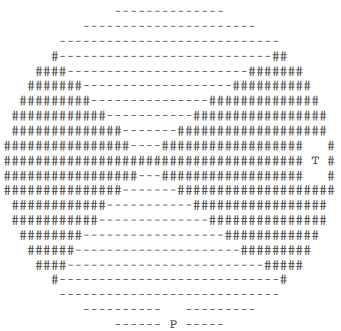


20.09.2013

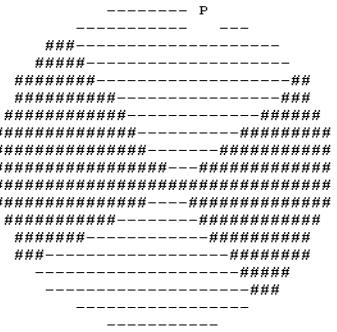
- Ml=4.2 event located close to Ebreichsdorf (Vienna Basin) on September, 20th, 2013
- Depth=12km
- I_0=5-6° (EMS-98)



Technical University Vienna



Saint Louis University



GFZ solution

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Needs for Antelope

Missing

- Unaffected picking of polarities (e.g. display envelope, energy, ..)
- Take off angles for azimuth and dip at the hypocenter
- Transformation to R, T, Z and picking at these components

Existing

- Store focal parameters (db)
- Display beach ball (dbevents)

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Outlook and further steps

- Parameter exchange between Antelope and the new stacking code
- Rewrite stacking code in Python 2.7
- Parameter calibration and sensitivity analysis of stacking method
- Systematic comparison with own manual solutions and that of SLU, OGS, GFZ for stronger events
- Definition of Ml threshold for reliable solutions and re-computation for past events
- Interpretation with mapped faults, velocities and stress field

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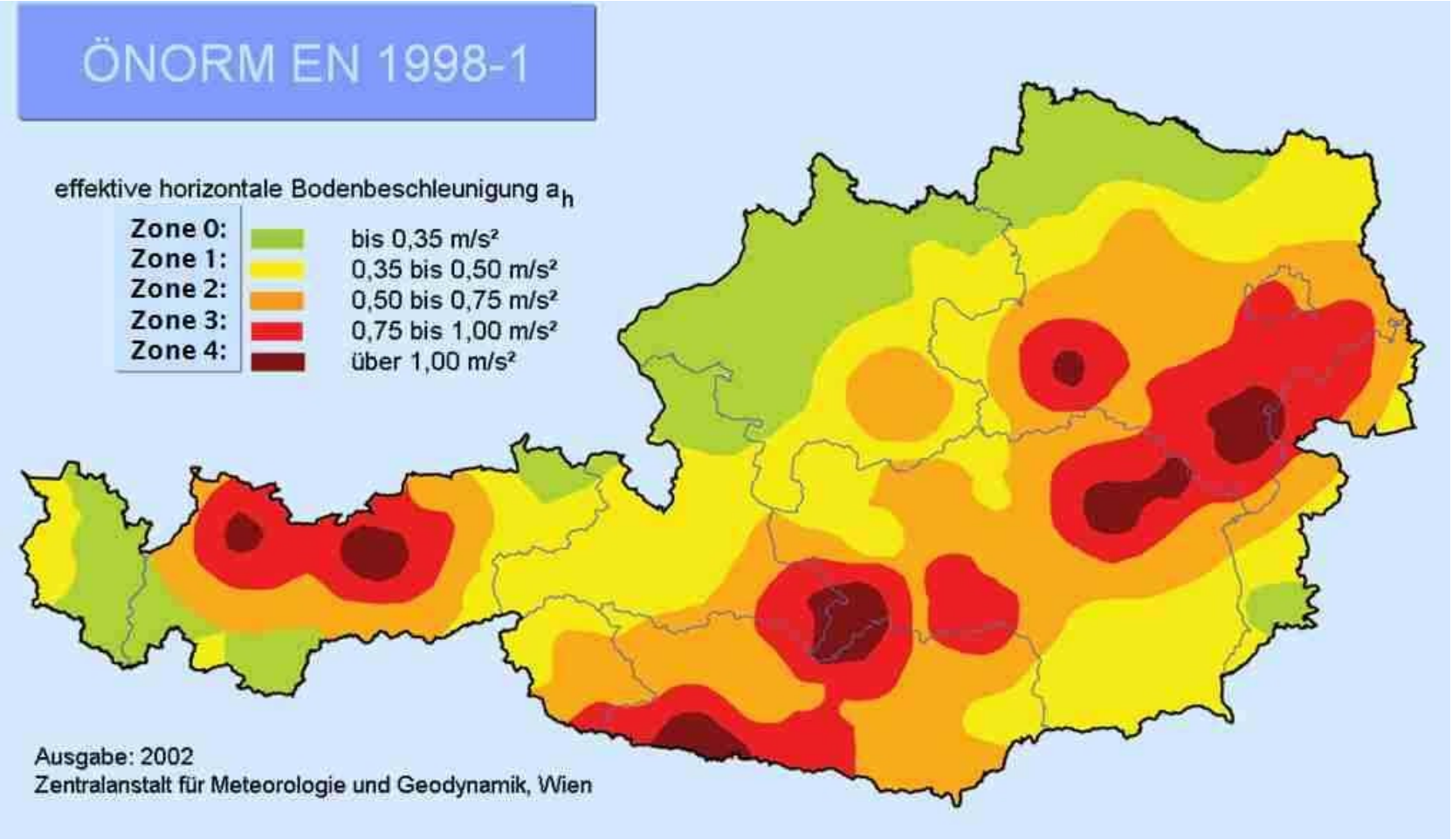
Hazard Map



This Hazard was based on our earthquake catalogue including events from historic earthquake studies and produced in 2002.

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