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3D Seismic Velocity Model of Alpine Region from Local Earthquake Tomography

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

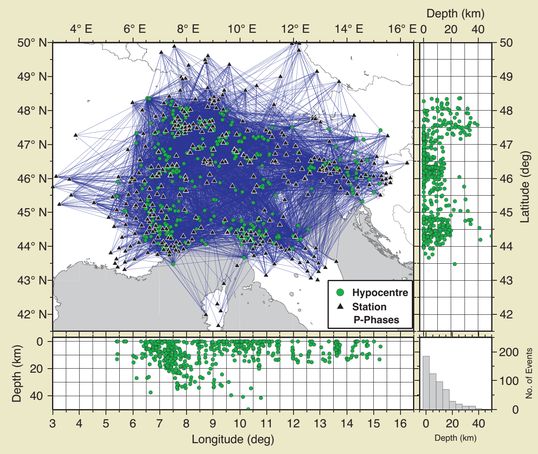
T. Diehl[1], E. Kissling[1], S. Husen[1,2] and N. Deichmann[2]
[1]Institute of Geophysics, ETH Zurich, Switzerland, email: diehl@tomo.ig.erdw.ethz.ch
[2]Swiss Seismological Service, ETH Zurich, Switzerland

Introduction

Present models of lithosphere structure and tectonic evolution of the Alpine arc show substantial structural differences in the crust and in the mantle between the western, central, and eastern Alps. To better understand these structural differences, detailed information on composition and physical state (i.e. fluid content, temperature) of the Alpine lithosphere are needed. Local earthquake tomography can be used to derive high-resolution three-dimensional P- and S-wave models. In this work, we present a 3D P-wave model for the greater Alpine region, based on highly consistent seismic phase data, which are re-picked from the original waveform data.

Consistent Phase Data

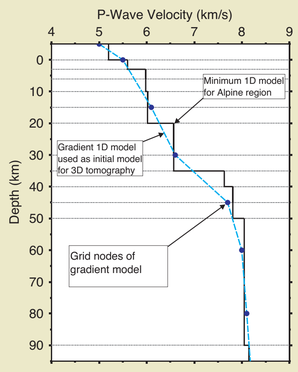
The seismic phase data used in this tomographic study is derived from automated repicking of first arrival P-waves in combination with an automatic quality assessment for each observation. In contrast to commonly used compilations of routine phase picks (e.g. ISC catalogue) our approach results in a highly consistent error assessment in terms of timing uncertainty and phase identification (see Figures below). As a consequence, the resolution and the reliability of the tomographic velocity image will be significantly improved.

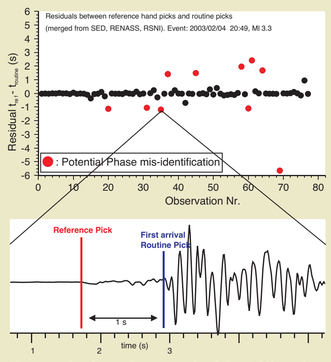


Data set used for 1D & 3D Inversion:
 # Stations: 391 (from 13 networks)
 # Earthquakes: 552 (1996-2007)
 # Phases Quality Class 0 (± 0.05 s): 5387
 # Phases Quality Class 1 (± 0.10 s): 4875
 # Phases Quality Class 2 (± 0.20 s): 1822
 # Phases Quality Class 3 (± 0.40 s): 1225
The resulting ray-coverage is shown in Figure above.

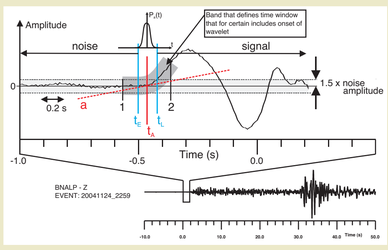
Model Setup

The setup used for the regional 3D model is tuned to resolve mid to lower crust anomalies. The horizontal grid spacing is 25 x 25 km in the central part of the model. The vertical gap between single node planes is 15 km. We use a regional minimum 1D model as initial model for the 3D inversion (see Figure right).



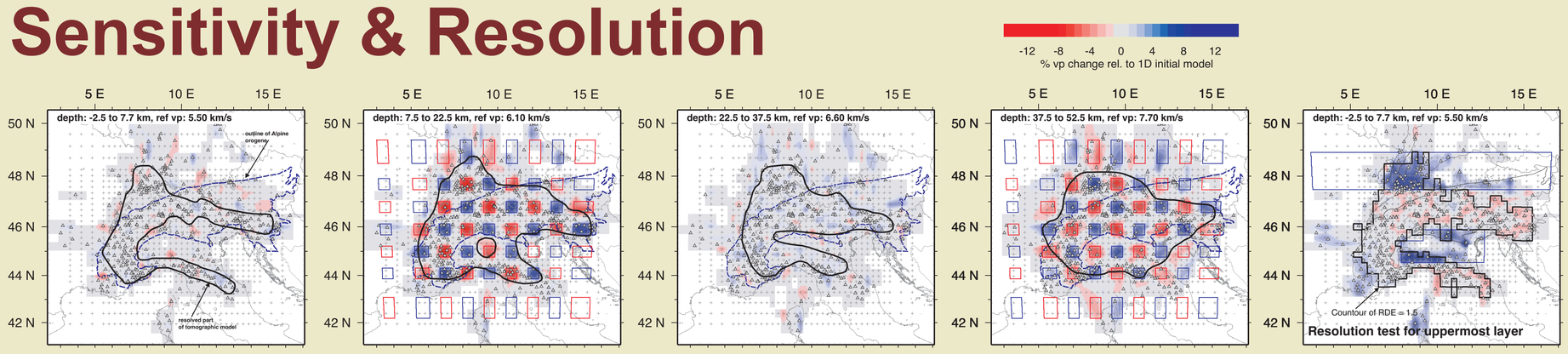


Example for phase mis-identification in routine phase data



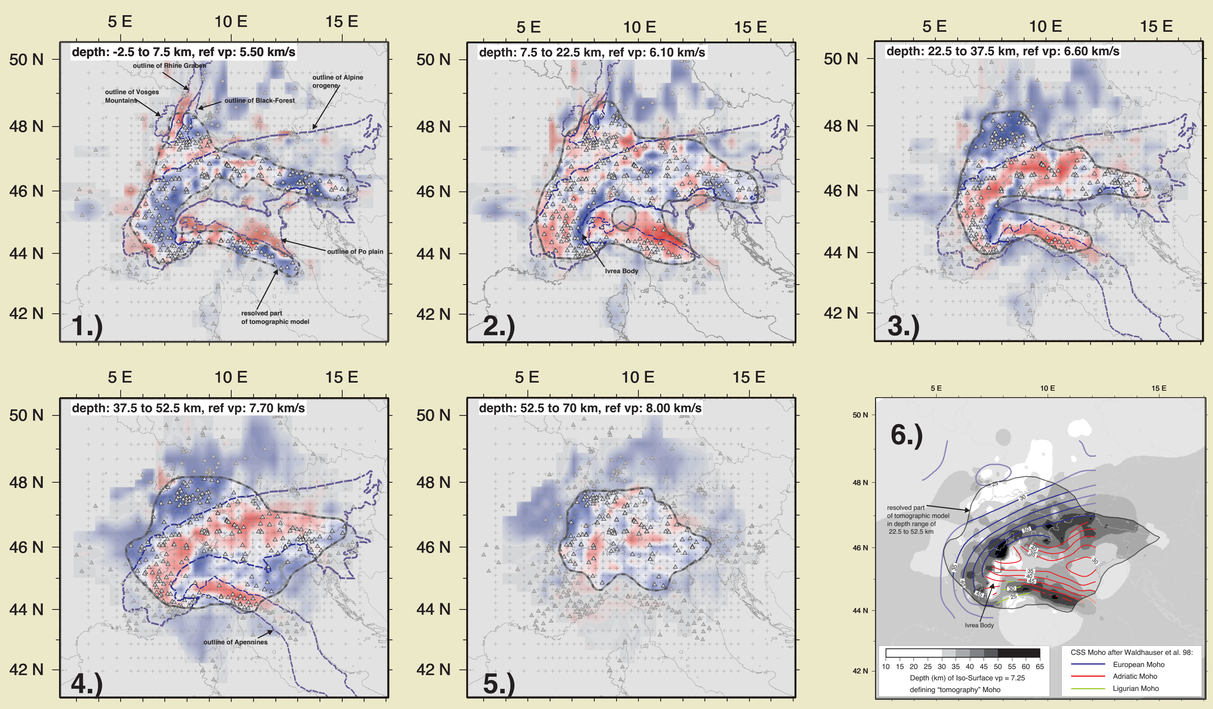
Consistent assessment of timing uncertainty for seismic phase onset

Sensitivity & Resolution



To assess sensitivity and resolution of the 3D model, synthetic tests were applied to the data set. The Figures on the left show the results of a "checkboard" test. Preliminary resolution tests indicate reliable resolution for RDE > 0.15 (indicated by solid black line). Regions of critical resolutions are displayed in faded colours for all following horizontal and vertical cross-sections.

3D P-Wave Model



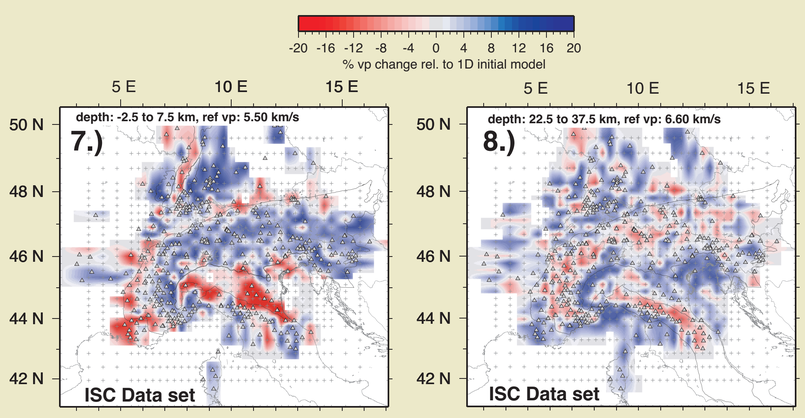
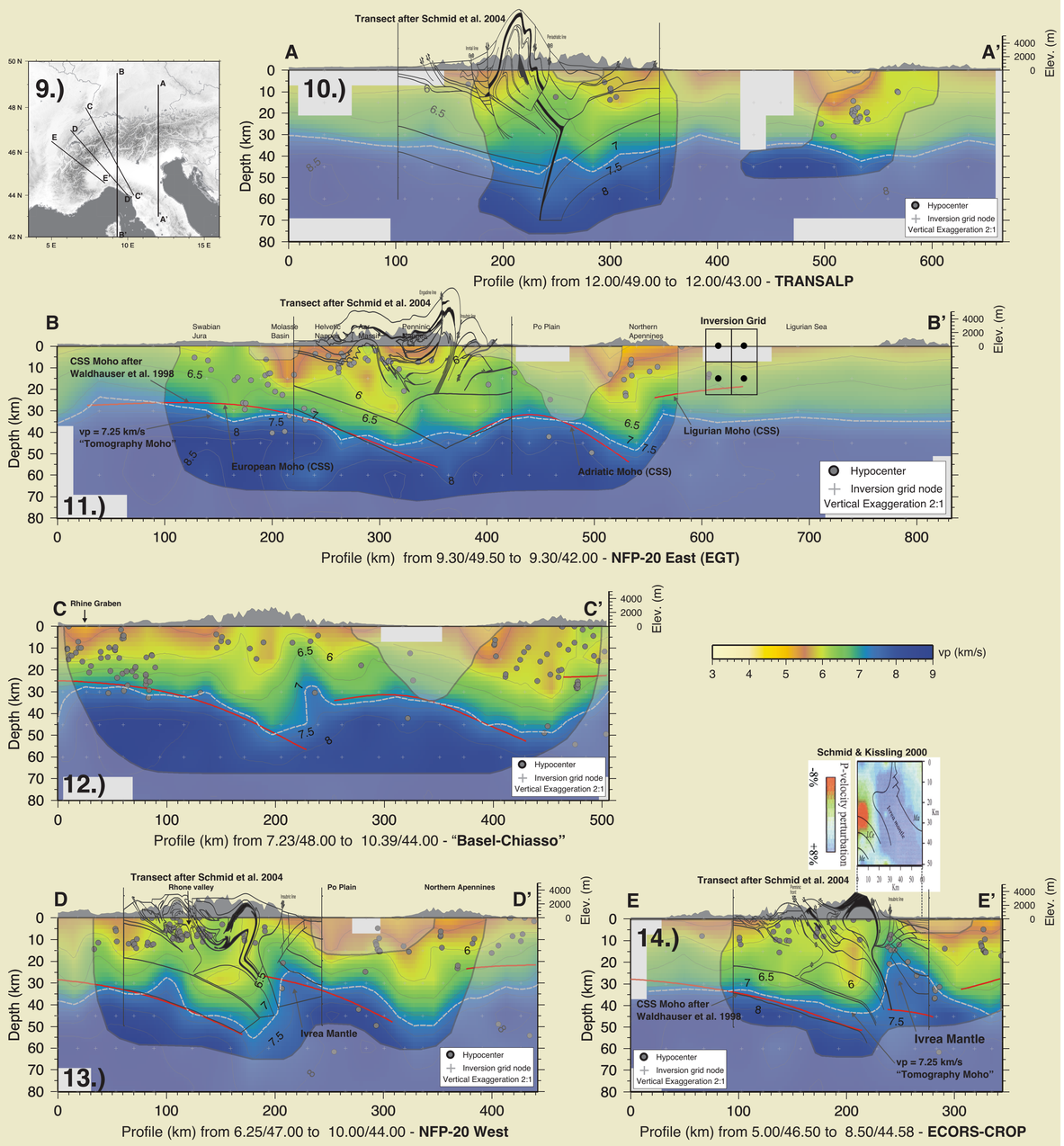


Figure 1-5: Horizontal cross-sections.
Figure 6: Moho topography as derived from CSS and tomography.
Figure 7-8: Tomography model based on ISC phase data.
Figure 9: Tracks of selected depth profiles.
Figure 10-14: Selected depth profiles. profiles



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Waldhauser, F., Kissling, E., Ansorge, J. and Mueller, S., 1998: 3D interface modeling with 2D seismic data: The Alpine crustal-mantle boundary, Geophys. J. Int., 135, 264-278.