Reflection of seismic surface waves at the northern Apennines

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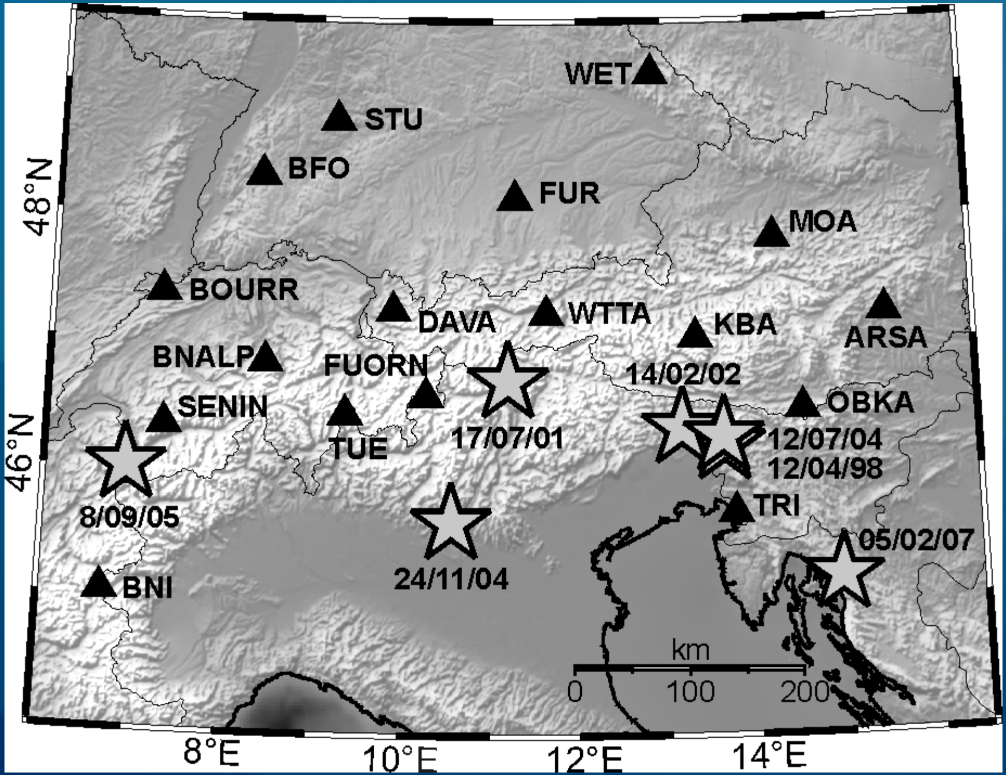
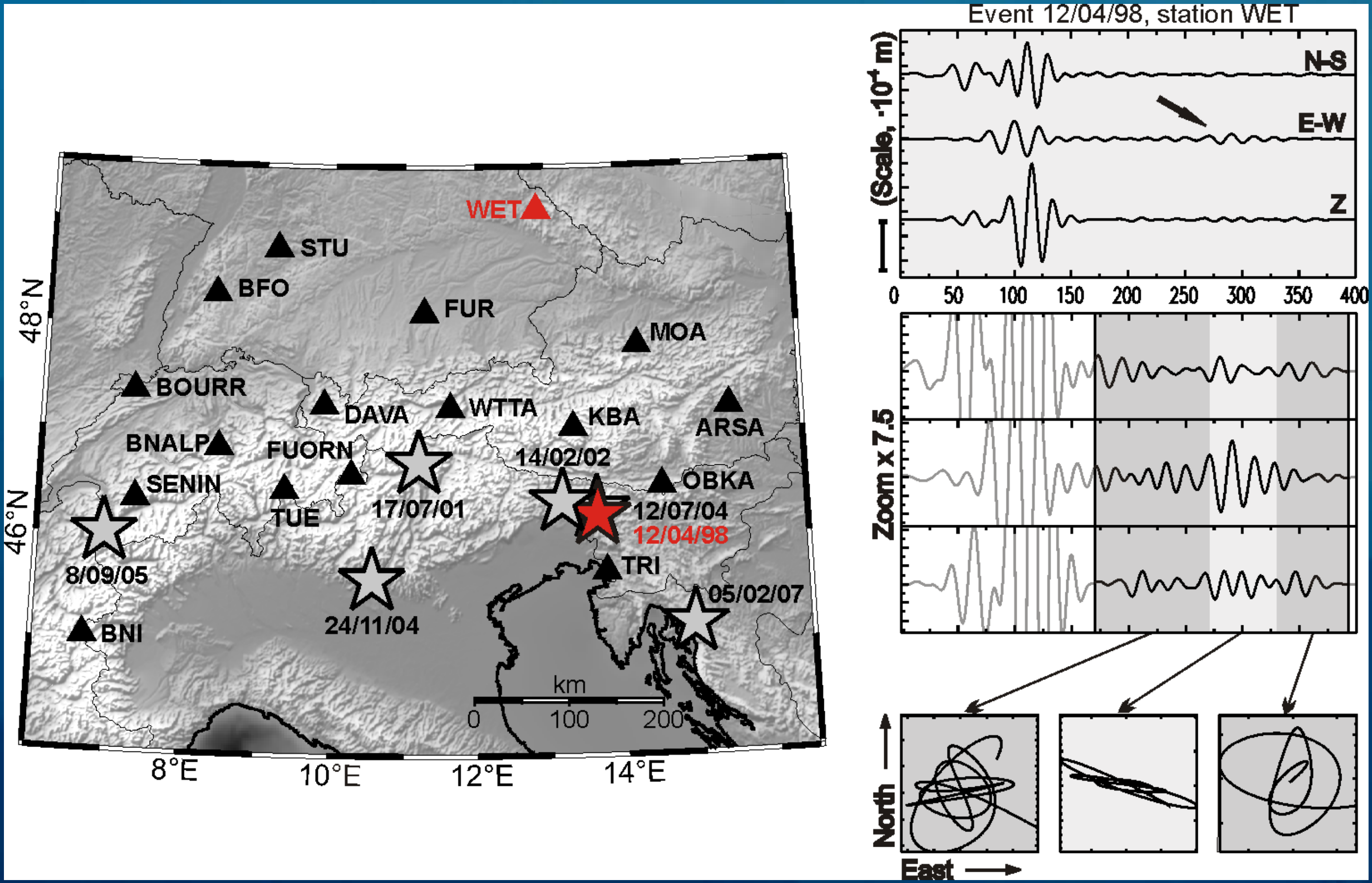
SPICE (MRTN-CT-2003-504267)

Surface wave observations in the Alpine area



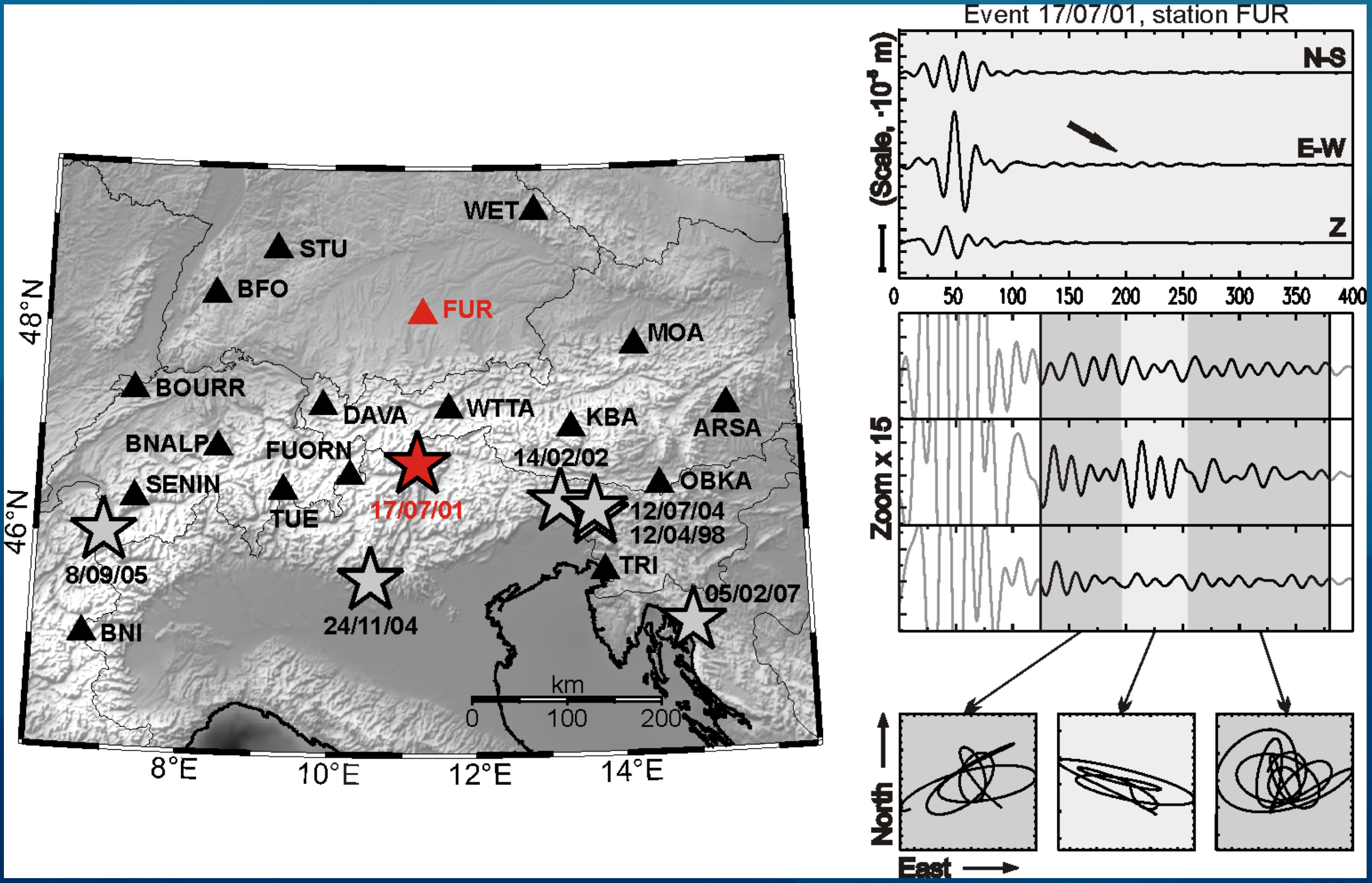
Moderate earthquakes 1998-2007 (Mw 4.4 to 5.6, stars) and seismic broadband stations (triangles) in the wider Alpine area

Surface wave observations in the Alpine area



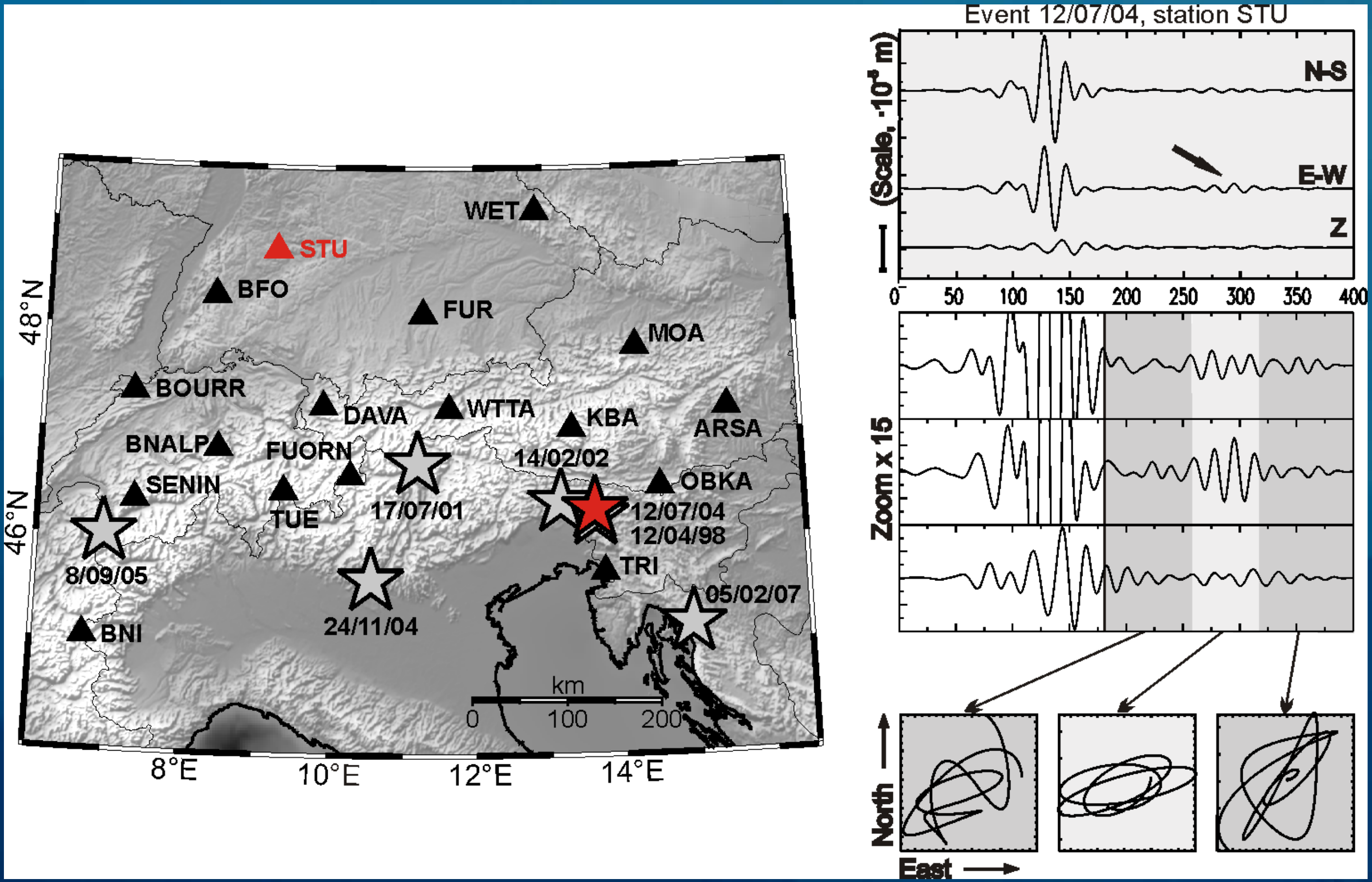
Late coda arrival for the 1998 Bovec (Slovenia) earthquake at station WET

Surface wave observations in the Alpine area



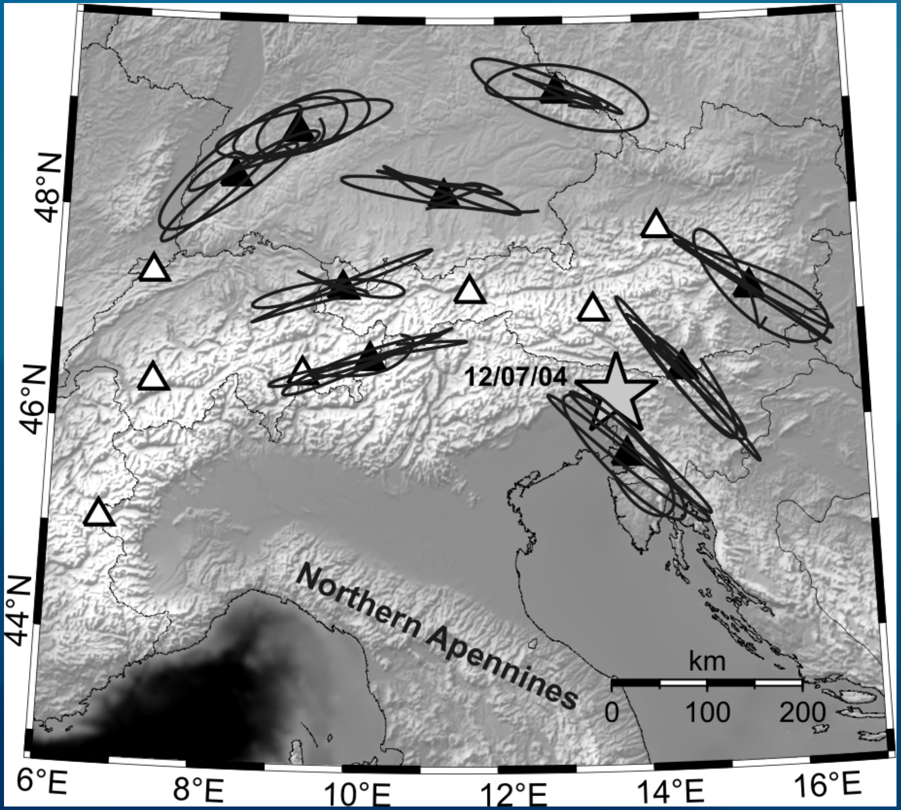
Late coda arrival for the 2001 Meran (N-Italy) earthquake at station FUR

Surface wave observations in the Alpine area



Late coda arrival for the 2004 Kobarid (Slovenia) earthquake at station STU

Surface wave observations in the Alpine area

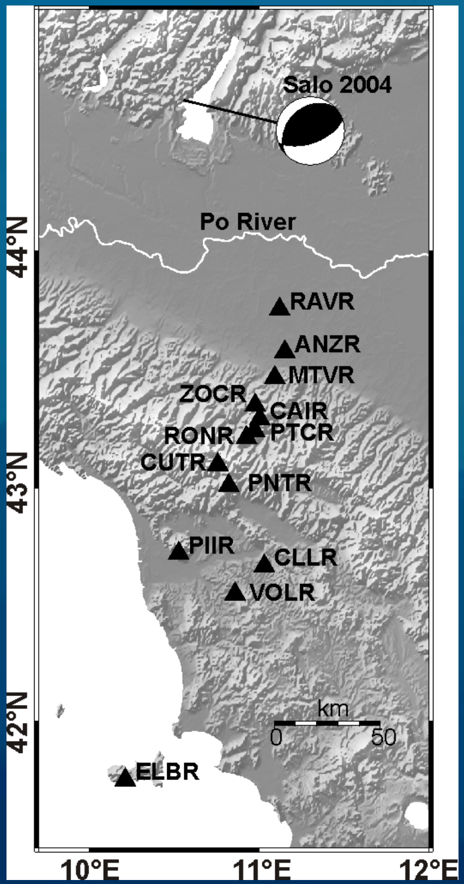


Polarization of late coda Love wave arrivals for the 2004 Kobarid earthquake

The pattern of signal polarization outlines curved wavefronts that approach the station network from the south, suggesting a scenario of Love wave reflection at an obstacle at some distance south from the stations

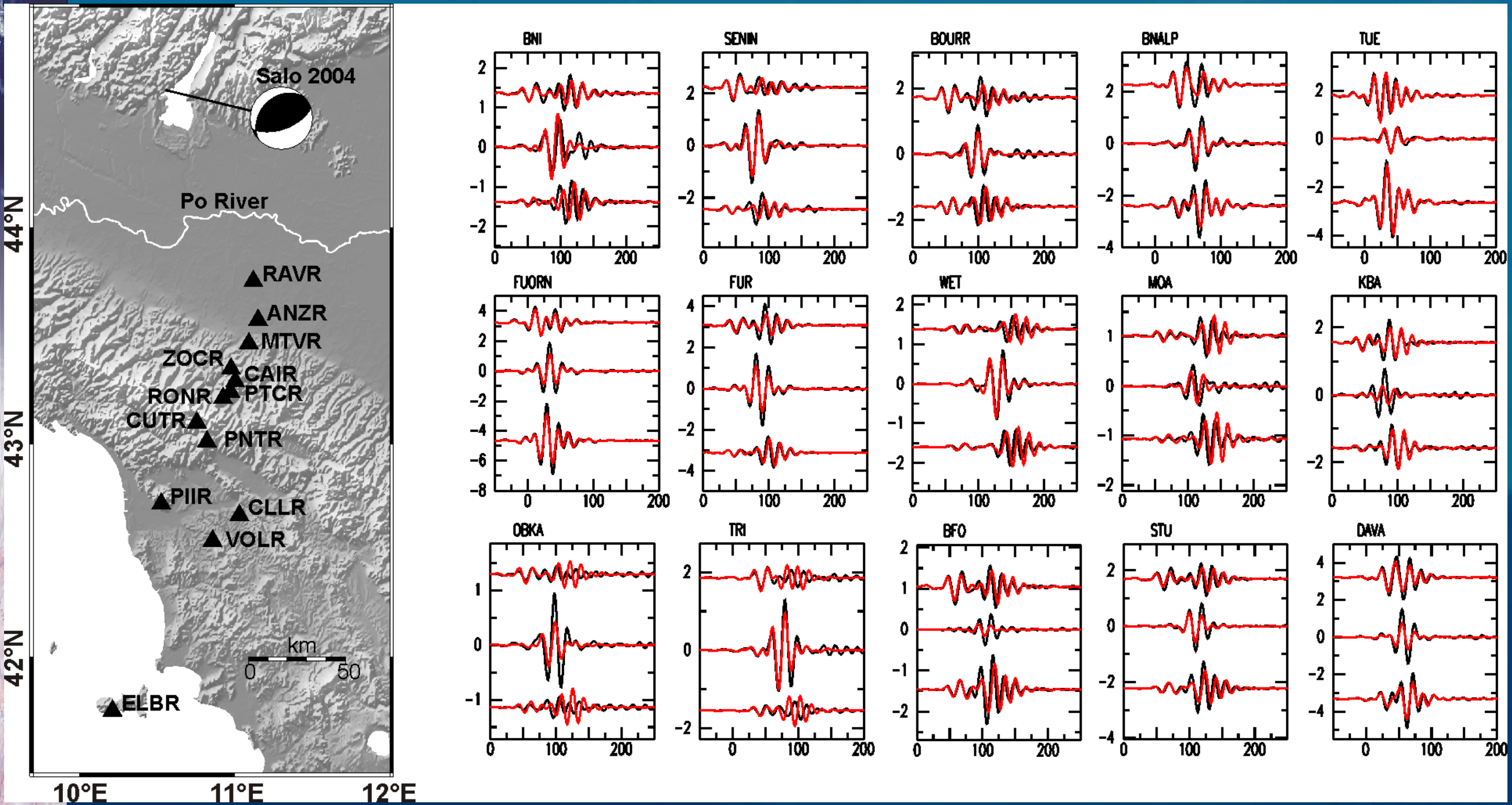
At this point, we propose an origin of the late signals as reflection from the northern Apennines!

Surface wave observations across the northern Apennines



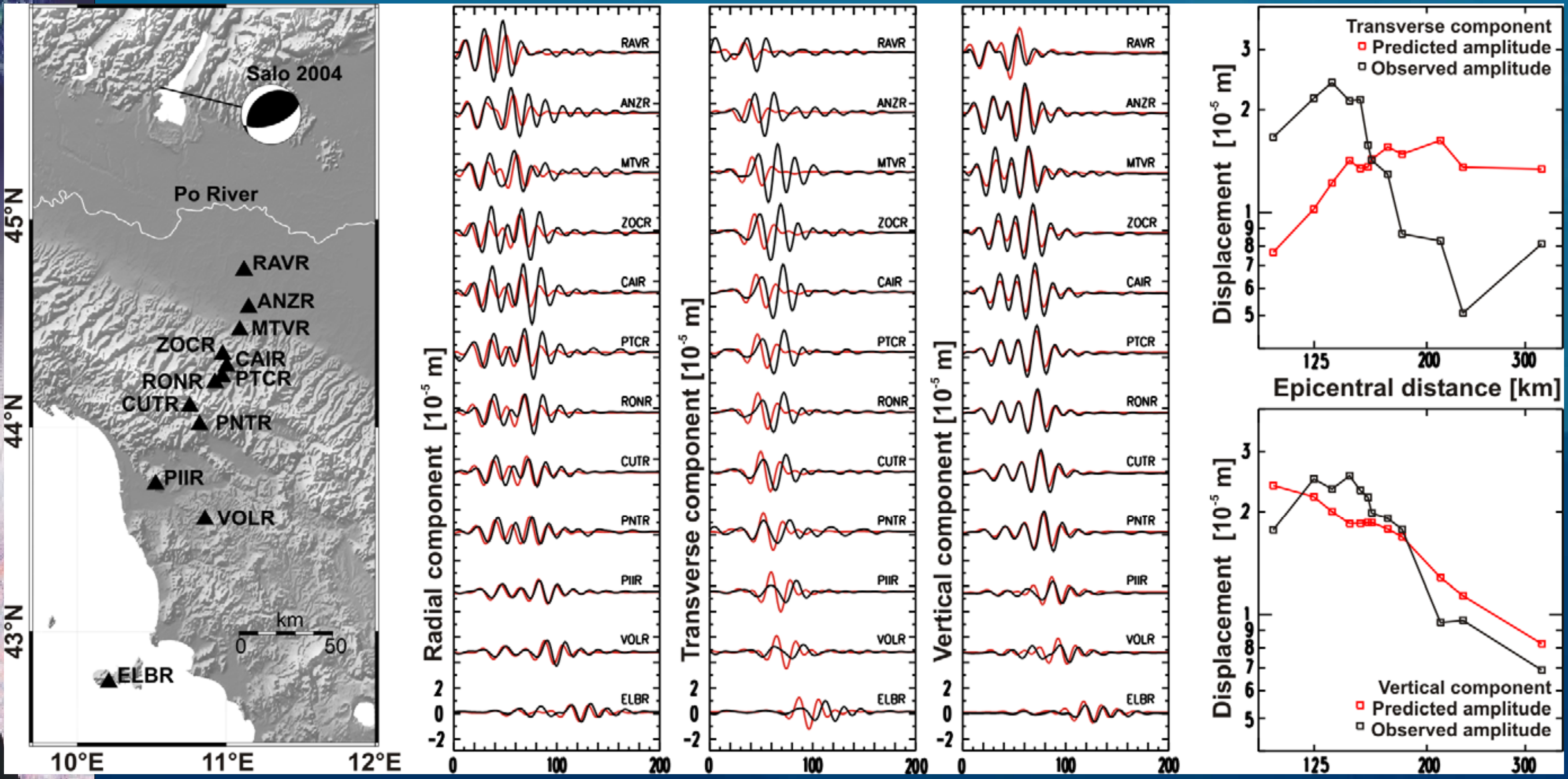
The 2004 Salò earthquake was recorded at a transect of temporary broad-band stations across the northern Apennines (RETREAT experiment).

Surface wave observations across the northern Apennines



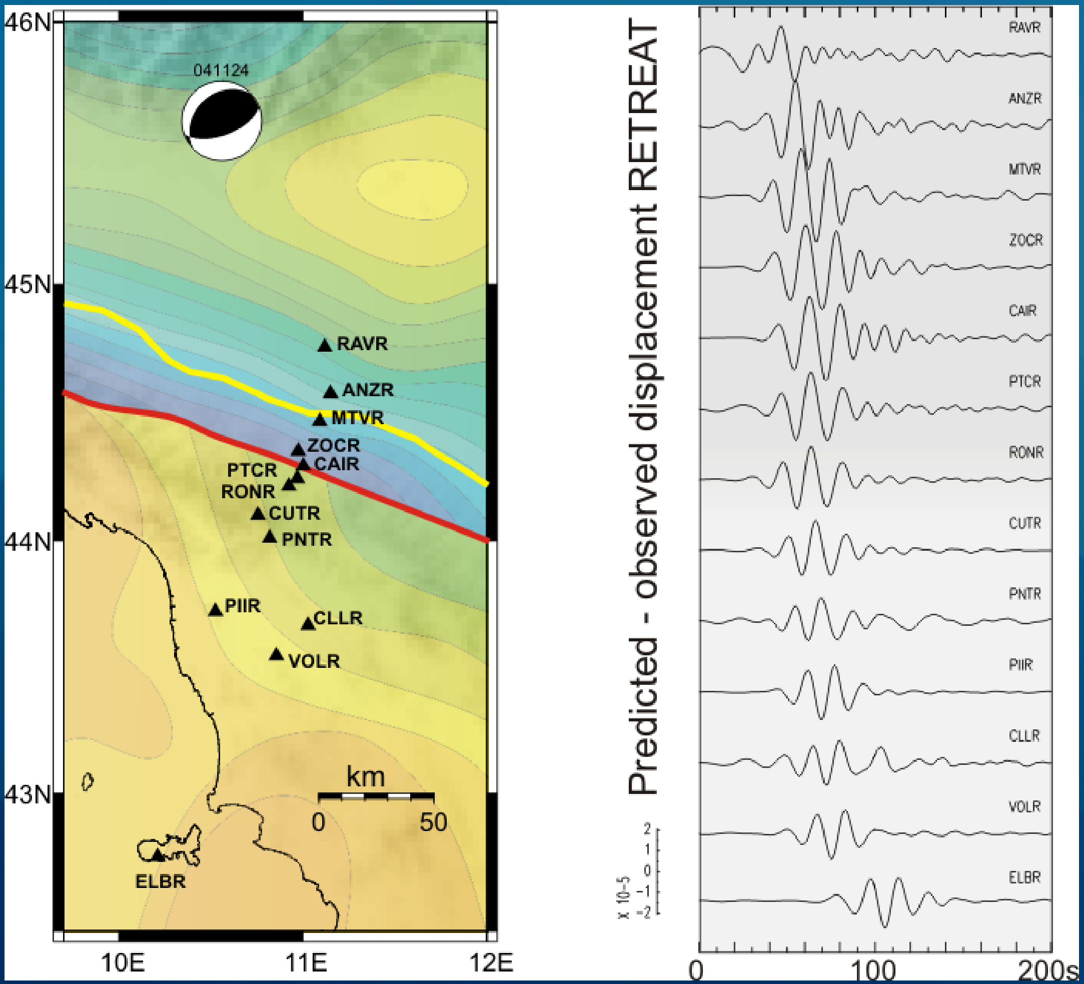
Moment tensor inversion in a smooth 3D earth model leads to good waveform fits in the wider Alpine area (15-35s periods, red predicted, black observed)…

Surface wave observations across the northern Apennines



…but along the RETREAT transect, at much shorter epicentral distance on average, they are far less accurate, especially on the horizontal components

Surface wave observations across the northern Apennines

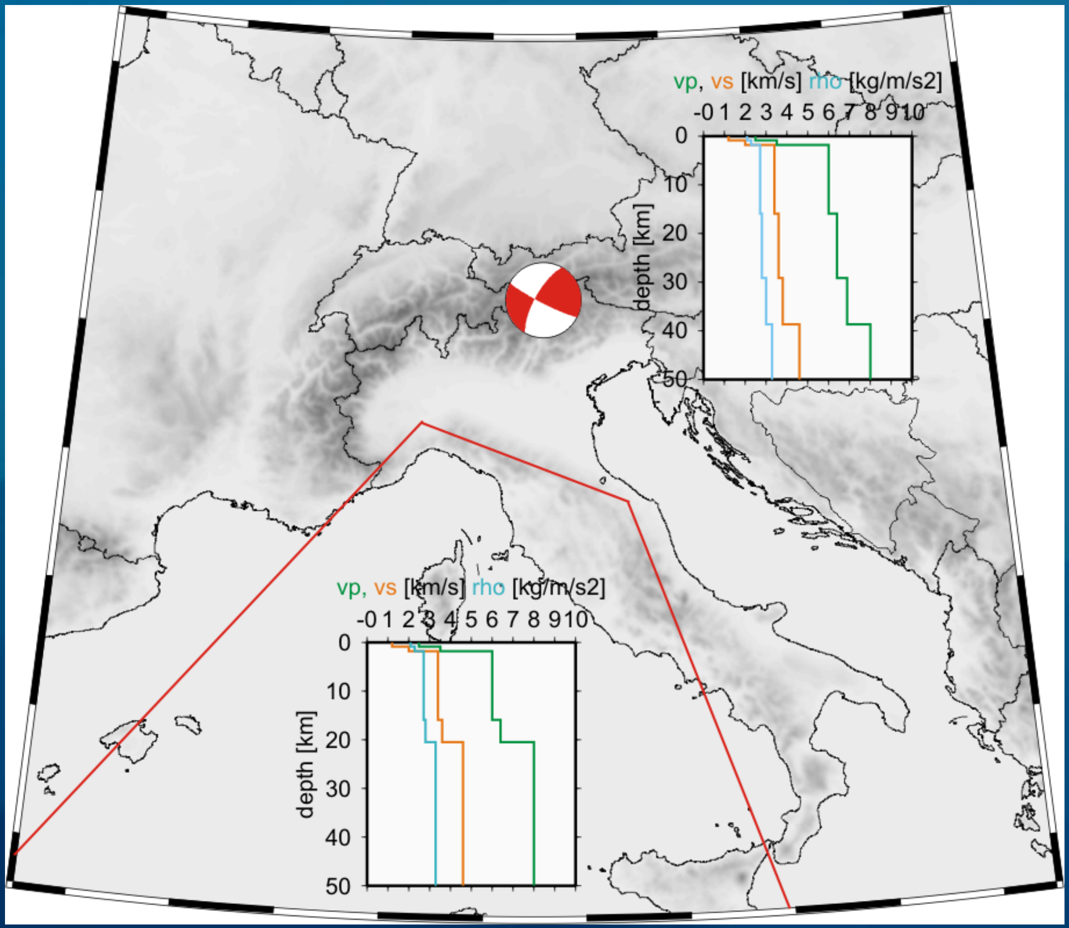


Difference seismograms (predicted minus observed waveforms) show similar waveforms south of stations RONR-CUTR

This is close to a major change in depth of the continental Moho (red line), and significantly offset from the edge of the Po Plain sedimentary basin (yellow line)

Moho topography from Ziegler and Dèzes, 2006

Spectral element modelling of reflected surface waves:



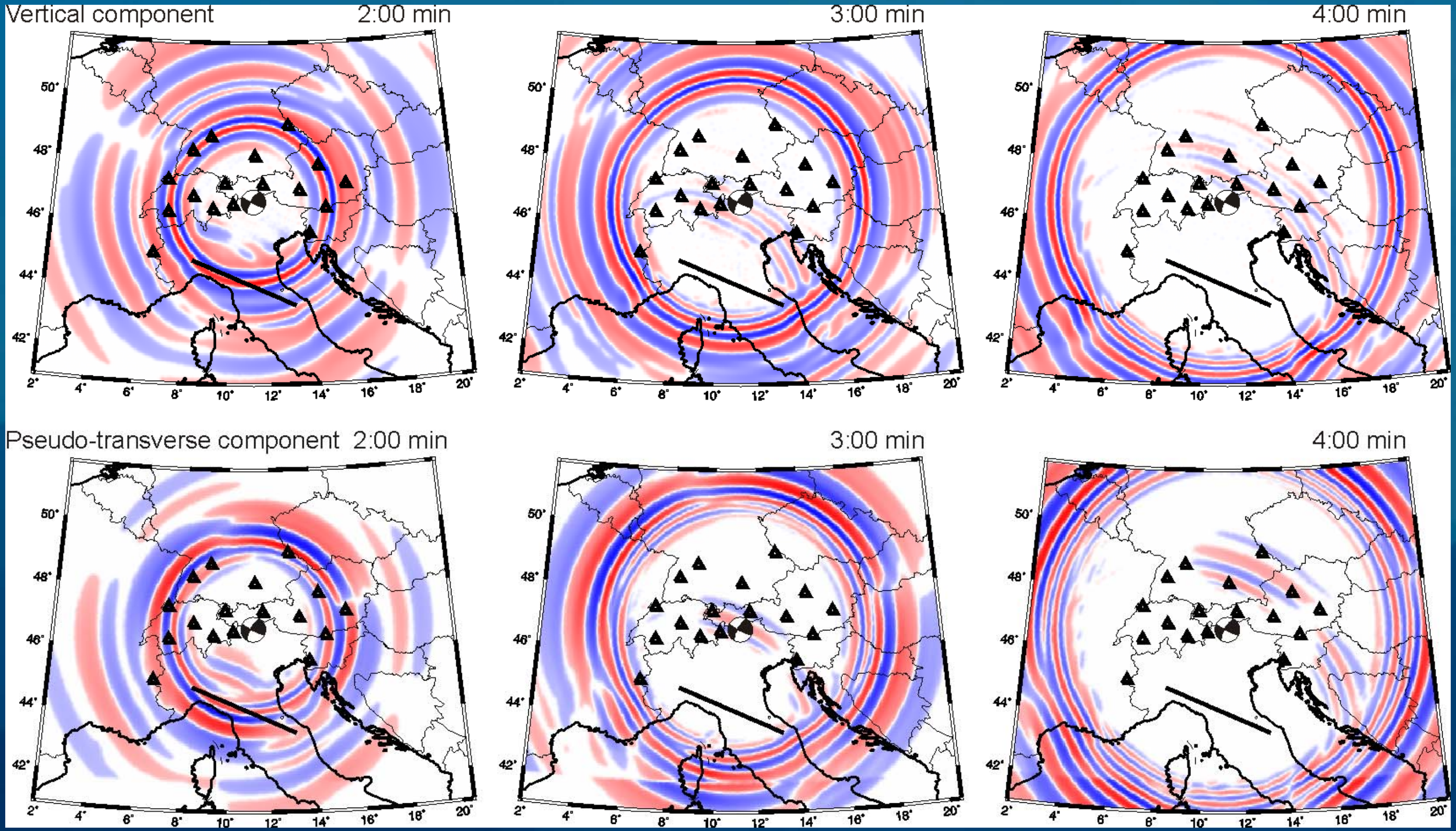
SEM code SPECFEM3D (Komatitsch and Tromp, 2002), 1D model + Moho offset at the Apennines.

3 different Moho offsets are tested:
40 km -> 30km
40 km -> 20km
40 km -> 10km

Additionally, we test a 5% increase in crustal P and S velocity across the Apennines.

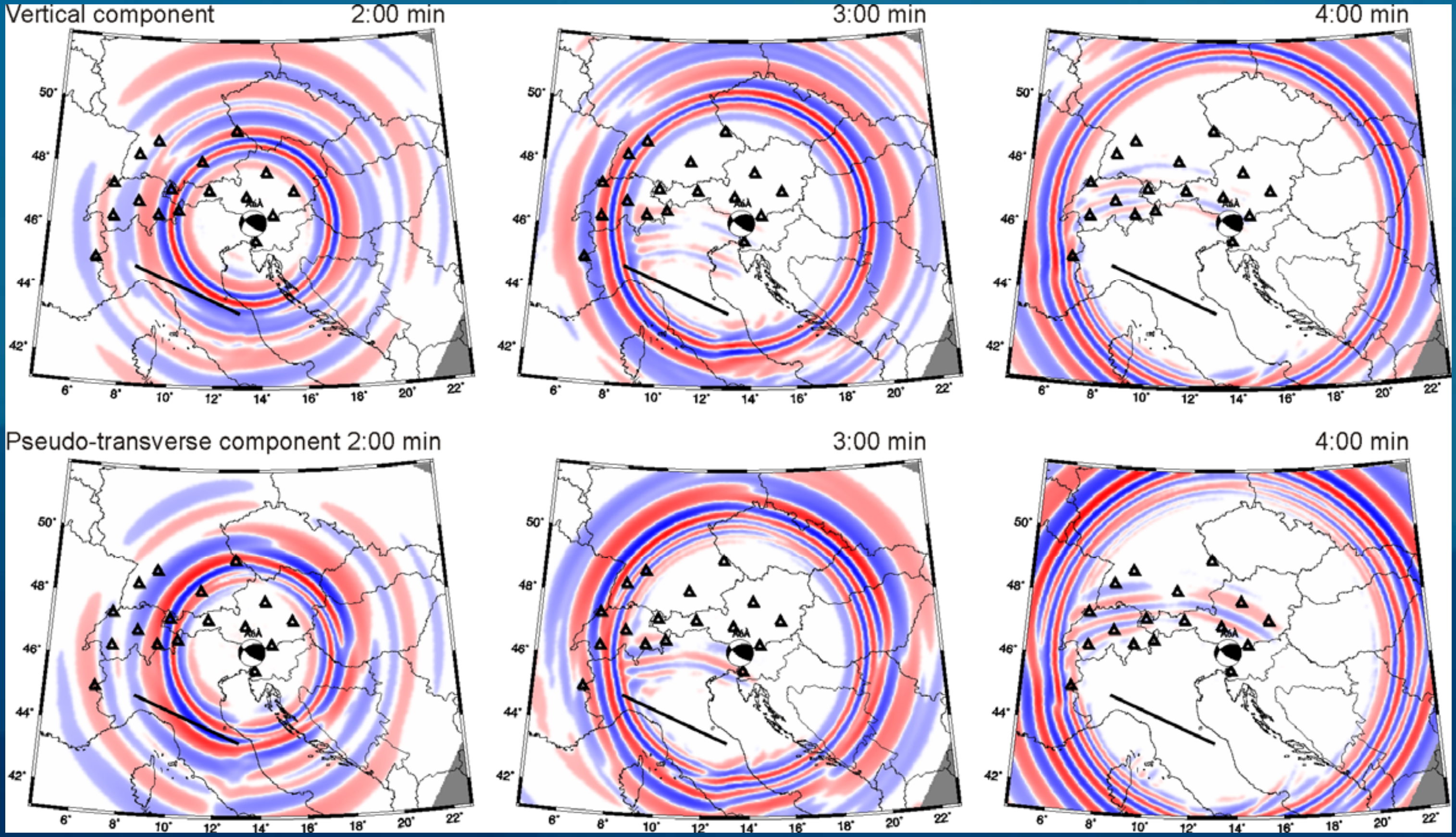
Amplitudes of reflected waves are sensitive to the model.
Best results for 20 km Moho step and 5% velocity increase.

Modelling reflected surface waves: 2001 Meran earthquake



Snapshots of velocity wavefield. Reflected Rayleigh waves are shown in the vertical component (top row), reflected Love waves in the transverse component relative to the mirror image of the epicenter (bottom row).

Modelling reflected surface waves: 2004 Kobarid earthquake



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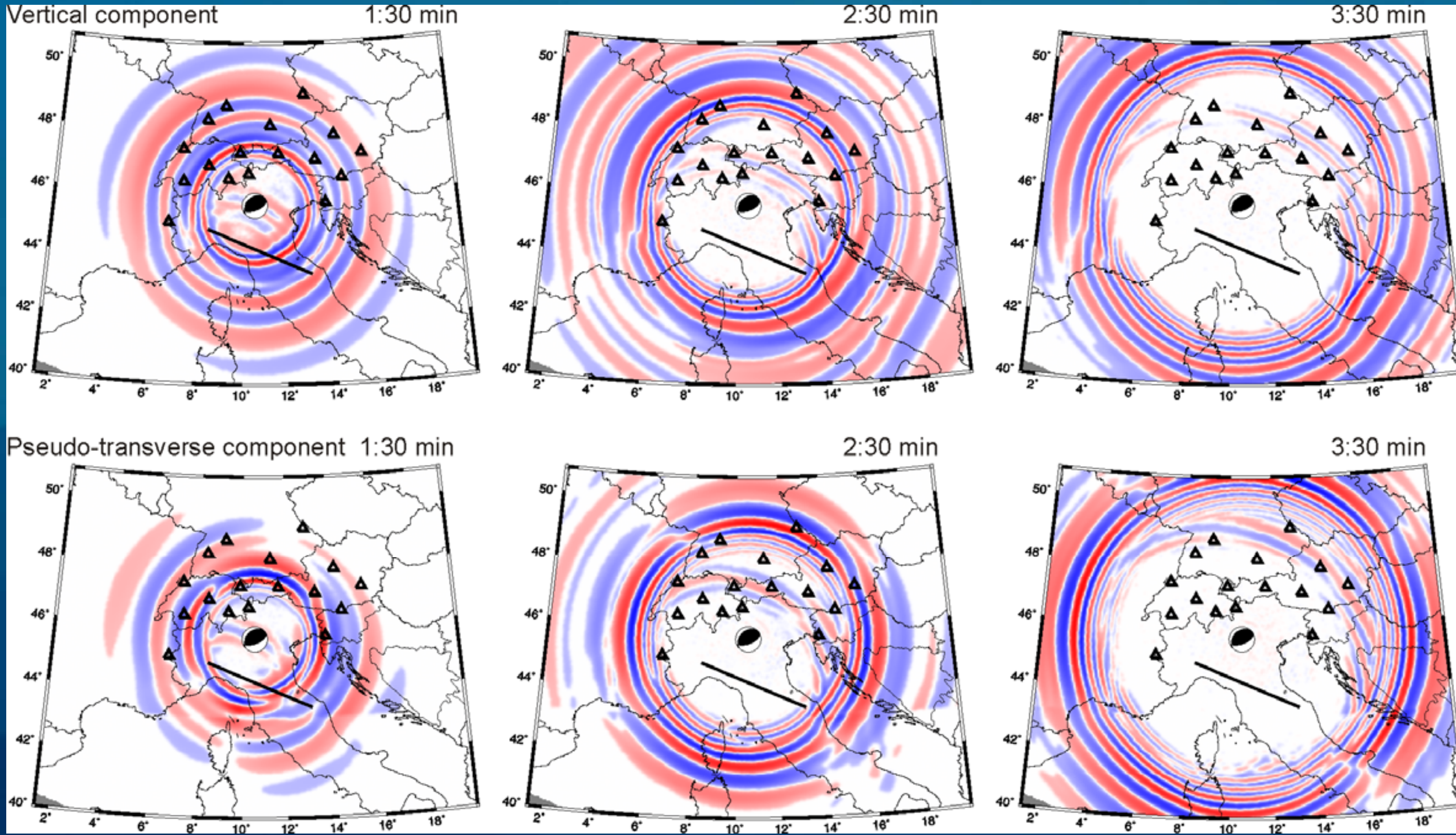
Modelling reflected surface waves: 2004 Salò earthquake



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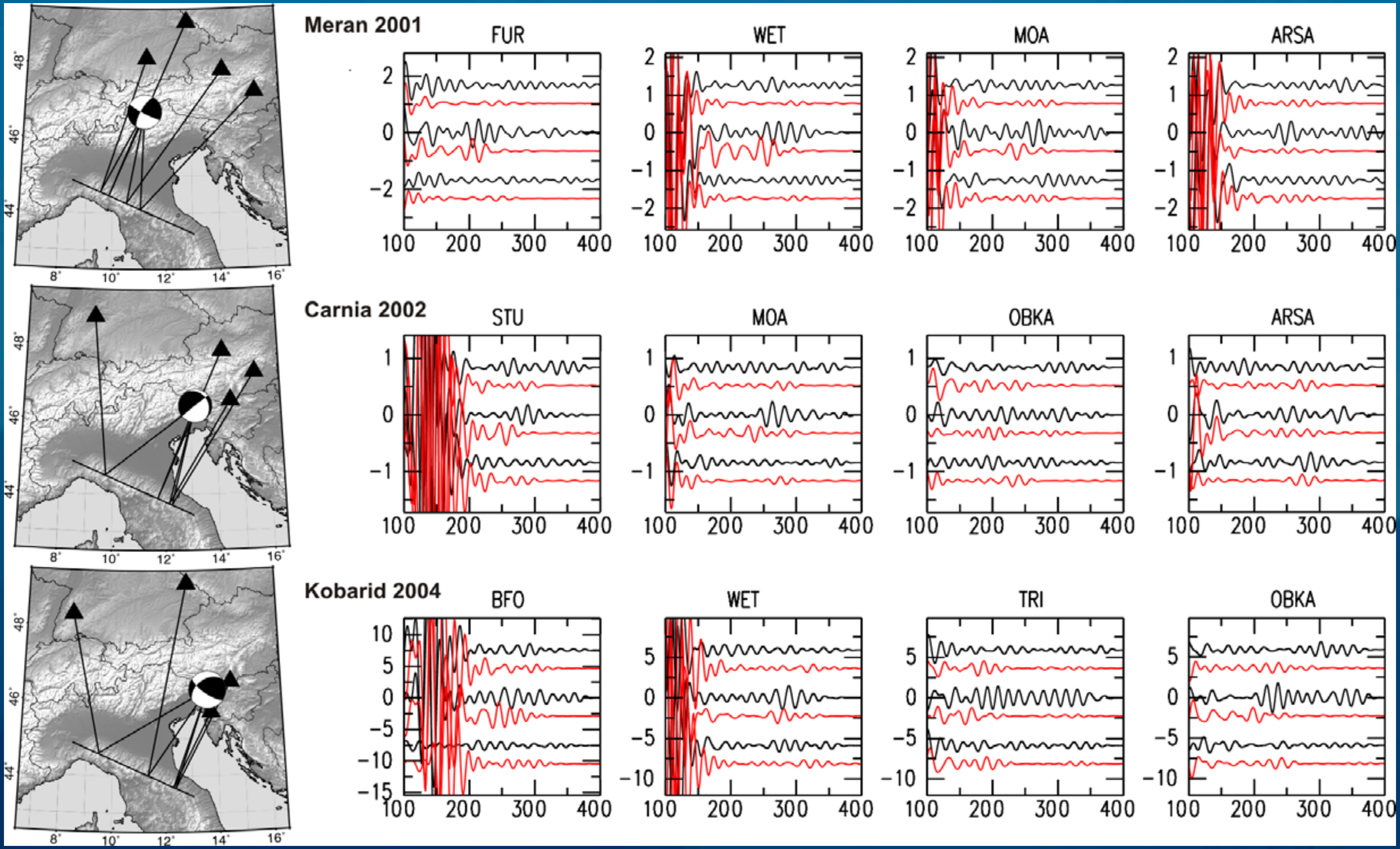
Modelling reflected surface waves



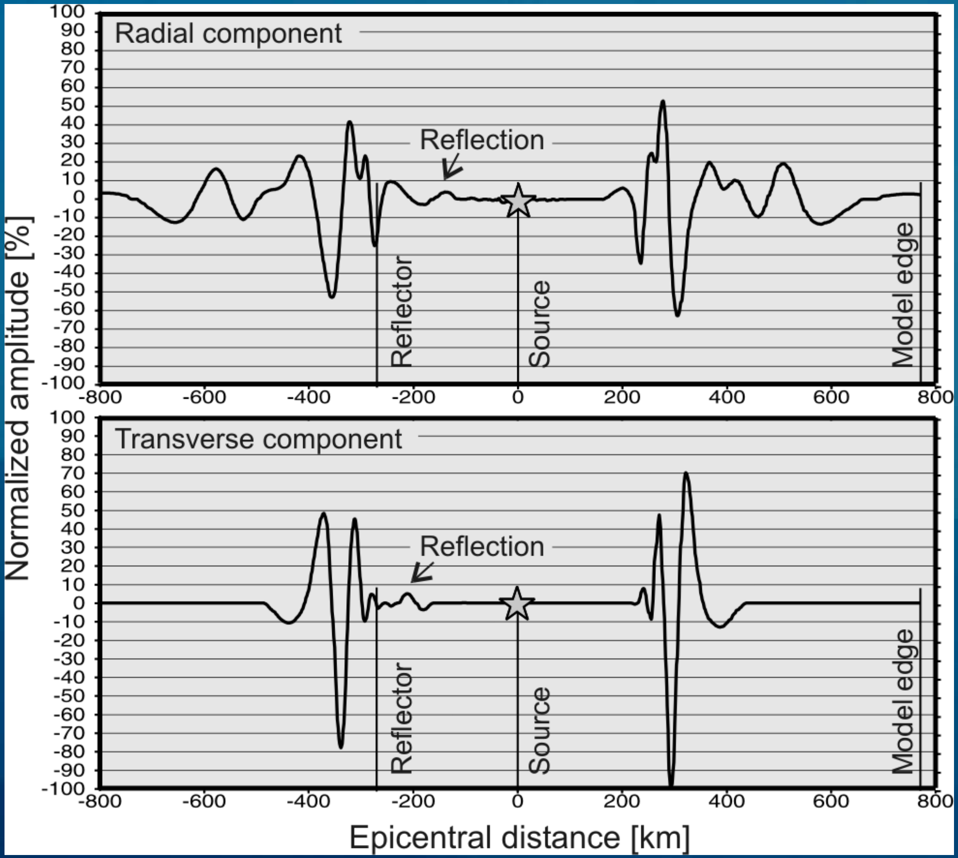
Observed intermediate period waveforms (15s-35s, black) and synthetic predictions (red) from spectral element simulations of wave propagation across the northern Apennines Moho step

- Seismic surface waves with periods of 15 to 20 s are reflected laterally at the northern Apennines.

-From 3D forward simulations, we attribute the reflection to a continuous, ~270 km long offset in the crust-mantle boundary under the mountain belt, with vertical throw of ~20km, thus supporting a deep crustal root under the outer side of the Apennines fold and trust belt, and significant crustal thinning on the inner side
-> reflected surface waves may be useful to constrain deep structure.

-Reflections are relatively large in amplitude and a relevant contribution to the regional wave field
-> surface waves reflection may cause complications in seismological data analysis?

Modelling reflected surface waves



Normalized amplitudes of radial and transverse synthetic wavefields after 120 s elapsed time, along a profile perpendicular to the Moho step and for a vertical strike-slip source.

Amplitude reflection coefficients estimated from synthetic and observed waveforms are ~7% for both, Love and Rayleigh waves

Waveforms of transmitted waves (left) are substantially modified during passage across the model discontinuity -> complications in seismological data analysis

More details in “Reflection of seismic surface waves at the northern Apennines”, EPSL, in press.

Thank you!