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Crust and upper mantle structure of the Ligurian Sea revealed by ambient noise tomography using ocean bottom seismometer data

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Introduction and Data

The opening history of the Liguro-Provencal backarc basin, which formed in conjunction with the Apennines-Calabrian subduction (Rollet et al., 2002 and Fig. 1), is key to understand the transition from continental to oceanic domains in the Ligurian Sea.

We use ambient noise tomography, a method established for onshore data, but seldom used on ocean bottom seismometer (OBS) data, tom image the crustal and upper mantle structure. Data from 22 OBS from the AlpArray offshore component LOBSTER and 22 temporary land stations from the AlpArray network (Fig. 2) in addition to 42 permanent land stations were available for the study.

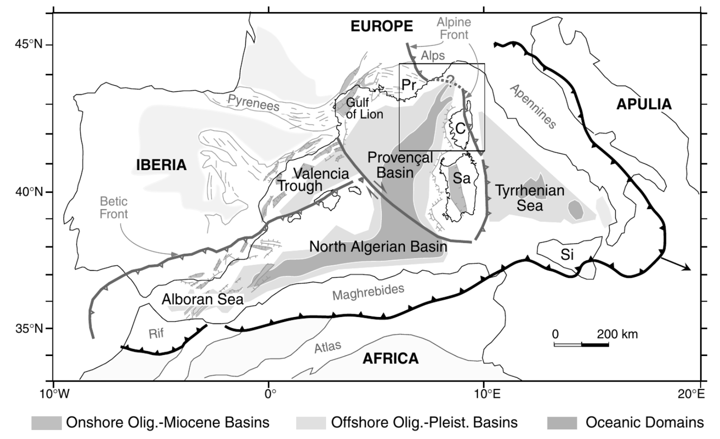


Fig. 1: *(left) Geological map of the region (Rollet, 2002).*

Fig. 2: *(right) Map of the study area and all stations used in our study. The OBS were deployed in June 2017 by the French RV Pourquois Pas? and recovered in February 2018 by the German RV Maria S. Merian.*

Methods

- Ambient Noise Tomography makes use of that part of seismological records, that - in earthquake studies - is called noise.
- By correlating the noise part of the signal one can estimate an empirical Green's function. Our processing follows Bensen et al. (2007). In addition to that, we remove compliance and tilt noise on the OBS after Crawford and Webb (1998, 2000).
- Compliance is a seafloor displacement caused by ocean surface waves, that introduce additional instrument acceleration (see Fig. 3 and 4).
- Cross-correlation functions of the corrected data were estimated for OBS-OBS and OBS-land station pairs (Fig. 5B). Additionally, land-OBS and land-land station pairs were calculated for A317A, ARBF and DIX.
- We derived Rayleigh wave group velocity dispersion curves using a multiple frequency technique (MFT) tool from Kiel University (based on Dziewonski, 1969). Examples are shown in Fig. 5B. We revised all dispersion curves manually, resulting in 1429 station pairs being used for the ambient noise tomography.
- For periods >20 s, we correlate 45 min recordings that include teleseismic events (1237 station pairs).

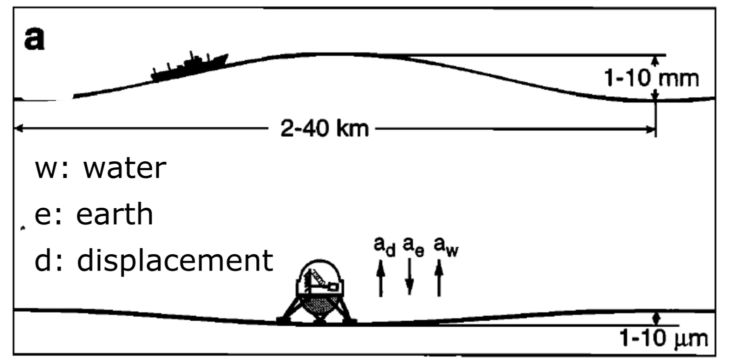
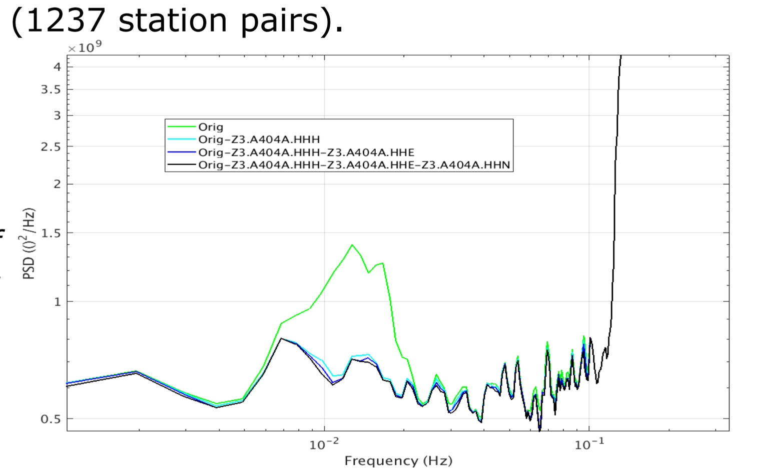


Fig. 3: *(left) Sketch of seafloor displacement caused by compliance (after Crawford et al., 1998).*

Fig. 4: *(right) Vertical component of OBS A404A on November 16th 2017 before (green) and after (black) compliance and tilt correction.*



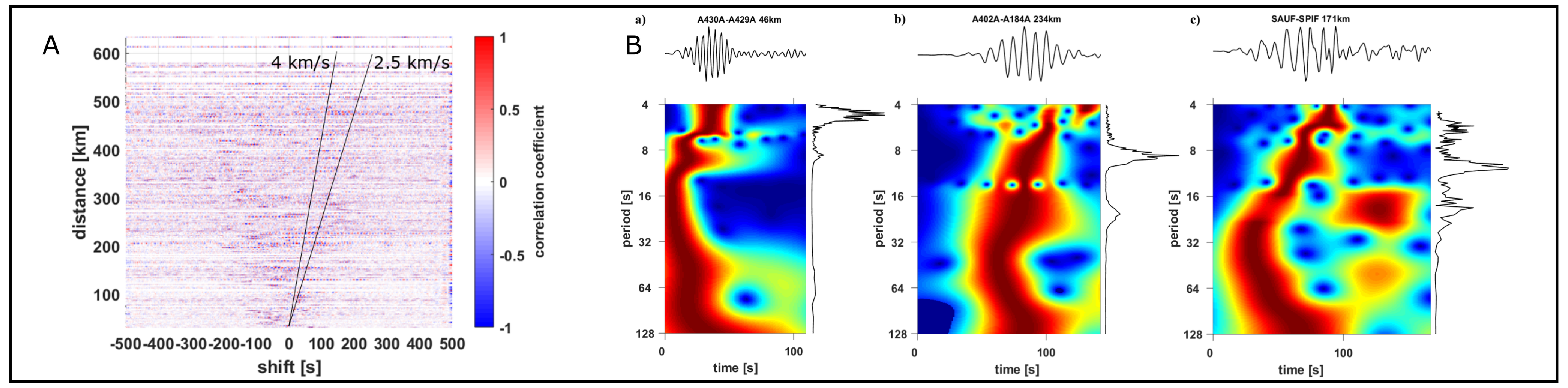


Fig. 5: *A) shows a section plot for all ambient noise station pairs. B) shows example MFT plots for ambient noise data for (coloured, from left to right) an OBS-OBS pair, an OBS-land pair and a land-land pair. The corresponding cross-correlation functions are shown above; stations and station distance is noted. Dispersion curves were manually picked at the maximum (red).*

Ambient Noise Tomography

- Based on the dispersion curves picked from MFT plots, we calculate 400 tomographies using random sets of 90% of the input data.
- From these inversions, we calculate mean group velocity maps (Fig. 6-I) and standard deviation (std) maps (Fig. 6-II).
- Fig. 6-I shows group velocity (v_g) maps for periods of 5-60 s.
- Anomaly A shows v_g < 2 km/s, v_g < 1.5 km/s locally; it is related to thick sediment layers (up to 8 km, Schettino and Turco, 2006).
- B shows group velocities of about 2.5 km/s. The anomaly gets smaller and, locally, slower for longer periods.
- C, with v_g > 3 km/s, corresponds to areas of volcanism (Lustrino et al., 2011).
- D as C, for longer periods it seems that both areas might be connected.

- For periods >= 20 s, the resolved area is small and homogenous. Starting at 40 s, we observe v_g > 4 km/s that can be associated to the mantle.

- The standard deviation plots (Fig. 6-II) show that the uncertainties are highest for areas of relatively low velocity; overall std values are low (< 15 %). Outer regions show no std due to the low resolution for this areas.
- 12 s and 15 s are not shown but similar to 10 s; 20-60 s show std < 5 %.

1D depth inversion

- We use the 2D group velocity maps as input for 1D depth inversion.
- We set up dispersion-files for every grid point of the map that include the group velocity and the standard deviation (used as error).
- We set up a starting model based on PREM and Dannowski et al. (2019).
- A 1D depth inversion (on Herrmann, 2013) is calculated for every point seperately, taking into account the local topography.
- The resulting shear velocities (v_s) are shown as 2D maps representing a layer each (Fig. 6-III).
- Shallow layers show v_s > 3 km/s in the Ligurian Sea. From 6 km on we see similar patterns as for the group velocity maps.
- For large areas (onshore and offshore) v_s seems to decrease with depth. This might be an artefact introduced by the varying water column. It could also stem from the choice of the layer thickness (which is fixed).

Summary and Conclusions

- For the ambient noise inversion (5 - 15 s), the 2D velocity slices show strong heterogeneities.
- The observed slow velocities in the Ligurian Sea likely correspond to sediments. Higher velocities east of Marseille and offshore western Corsica are related to volcanism (Lustrino et al., 2011).
- For the teleseismic inversion (20 - 80 s), the resolved area is smaller. The velocities indicate homogenous lower crust and upper mantle structures.
- The water column is not corrected for in the 2D tomography and influences the 1D depth inversion. We correct for the local water depth, but the effect of varying water depths along rays leads to uncertainties.
- We do not see indications for an oceanic spreading centre in the Ligurian basin.
- 1D inversion to be updated in future work.

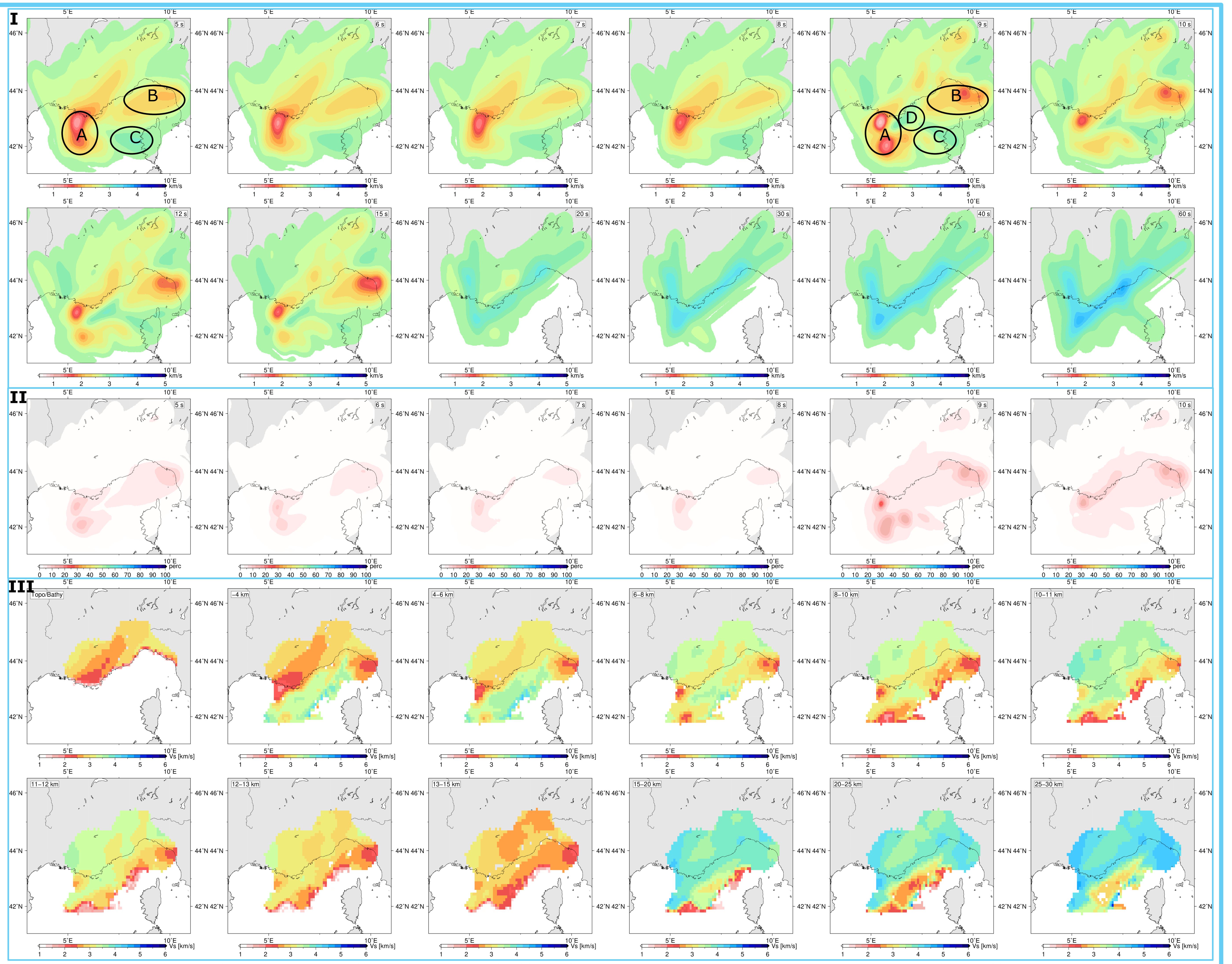


Fig. 6: *Top box: mean group velocity maps from ambient noise tomography (derived from 400 inversions using a random set of 90% input data each) for 5-60 s. Middle row: corresponding standard deviation maps for 5-10s. bottom box: depth slices from 1D depth inversions. The input area was reduced based on ambient noise checkerboard tests (not shown).*

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