MSM71 – Lobster: First results of 3D Travel Time Tomography of the Liguro-Provincial Basin and Coastal Western Alps using data from Cruise MSM71

L. Murray-Bergquist[1], D. Lange[1], A. Dannowsk.i[1], H. Kopp[1,2], M. Thorwart[2], E. Le Breton[3], W. Crawford[4], MSM71 Cruise Participants, and the AlpArray Working Group

1 GEOMAR, Helmholtz Zentrum für Ozeanforschung, Kiel, Germany
2 Christian-Albrechts-Universität (CAU) Kiel, Kiel, Germany
3 Freie Universität Berlin, Berlin, Germany
4 Institut de Physique du Globe de Paris, Paris, France

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Introduction

The Liguro-Provincial Basin opened as a back-arc basin related to the Apennines-Calabria subduction zone retreat. However, today the basin has finished opening, and local seismicity shows that the basin is now under compression. Most seismicity recorded in the basin is found at the northern end, and large earthquakes, such as the historic 1887 Mw 6.3-7.5 near Imperia, Italy, have been known to occur in the area [Larroque, 2012]. If another large earthquake were to occur in the basin it could cause a large degree of damage due to the densely populated coastline. To understand the risks posed by potential earthquakes and tsunamis in the area it is crucial to gain a better understanding of the tectonics of the Liguro-Provincial Basin, from shallow faulting in the basin to the deeper structures of the subduction zones. With this aim we intend to use the seismic data collected on Cruise MSM71 in combination with an earlier seismic data set and local seismicity in the basin to create a 3D P-Wave travel time tomography model of the Liguro-Provincial Basin from Corsica to the South-Western Alps. This project is part of the DFG funded Priority Program "Mountain Building Processes in Four Dimensions (MB-4D)", the German component of the AlpArray initiative.

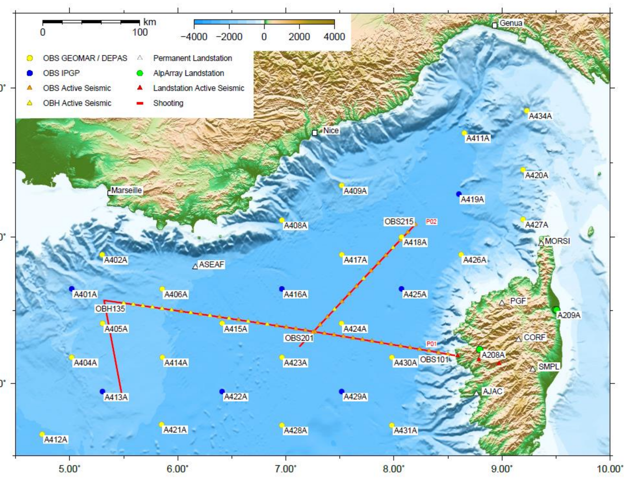

Figure 1: Map of the Liguro-Provincial Basin with OBS and some land stations marked, shot profiles are marked in red.

Geologic Setting

- The Liguro-Provincial Basin is a highly complex tectonic setting lying between two major orogenies: the Western Alpine belt and the Apennine system
- The basin formed as a back-arc basin related to the Apennines-Calabria subduction zone retreat
- Opening began in the late Oligocene and continued into the early Miocene with the counter-clockwise rotation of the Corsica-Sardinia block
- The area is now under compression, with shortening of 0.3-1.5 mm/year along the northern margin [Larroque, 2012]
- There are huge topographic gradients, with heights of >3 km in the Alps descending to depths of −2.5 km in the center of the basin over a distance of ~100 km [Béthoux, 2008]
- The crust and upper mantle show strong heterogeneity, and a strong gradient in the Moho which is fairly shallow in the basin center, ~12.5 km depth, and deepens sharply at the coastlines to ~50 km under the Alps and ~25 km under Corsica.

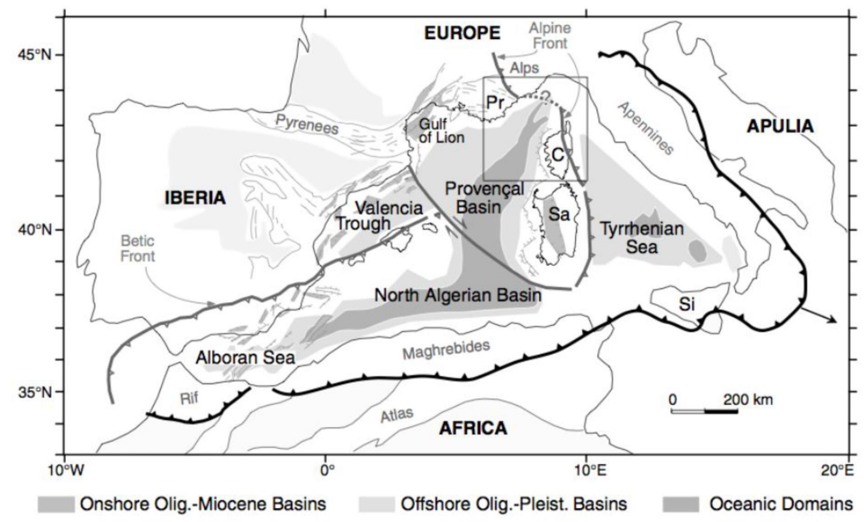

Figure 2: Map of the larger area around the Liguro-Provincial Basin showing the Alpine and Apennine subduction zones. Figure taken from Rollet et al. 2002.

First Attempt in TOMO3D

The velocity colour scale of Figs. 4 and 5, has been clipped to between 2 and 8.5 km/s, which should be a reasonable velocity range for this area. However, as can be seen in Fig. 5, the velocities shown in this first attempt increase steeply with depth in some areas reaching up to 18km/s by 10km depth. This is not reasonable, and could be due to low ray coverage. Clearly more needs to be done to reach a stable and robust model, and the first step is improving the ray coverage going into the model.

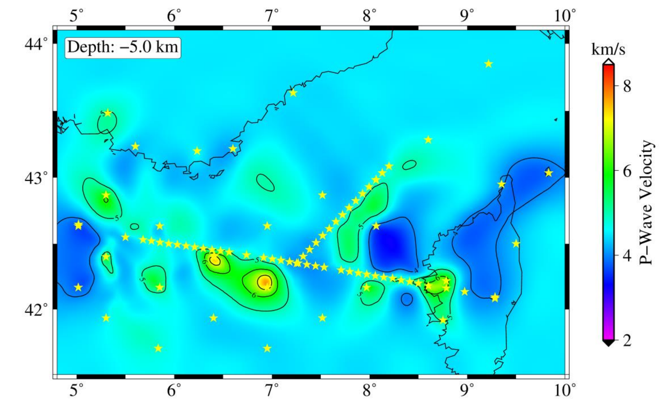

Figure 4: Map of the Ligurian Basin overlain by a horizontal cross-cut of the first P-Wave velocity model at 5 km depth from the surface. Yellow stars mark station locations.

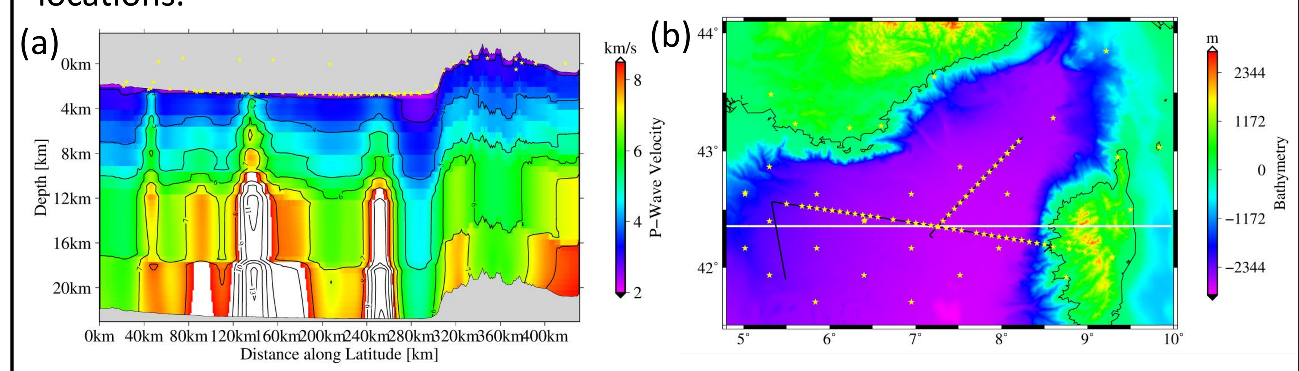

Figure 5: (a) Vertical slice of the first P-Wave velocity model, the x-axis shows the distance in km along a set line of latitude, the y-axis shows depth from sea level, and the colour scale shows the modelled P-Wave velocity. (b) Map of the Ligurian Basin, black lines show the airgun shot profiles, yellow stars mark station locations, and the white line shows the trace of the slice shown on top.

Ray Coverage

The first attempt at modelling the basin quickly reached unbelievable velocities in some areas, likely due to poor ray coverage, especially at depth. To create a stable, realistic model the ray coverage must be increased. To achieve this we have added shots recorded at land stations from the 2008 GROSMarin experiment [Dessa, 2011]. The ray paths of the stations and shots used in the first attempt are shown below in Fig. 6, and the improved ray coverage with the added GROSMarin profiles are shown in Fig. 7.

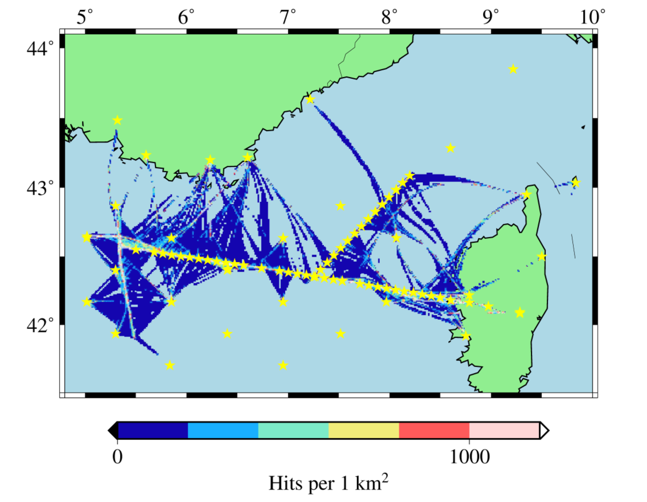

Figure 6: Ray coverage between shots from the 2018 MSM71 Lobster Cruise and the stations used in the first attempt at a 3D model shown in the previous section.

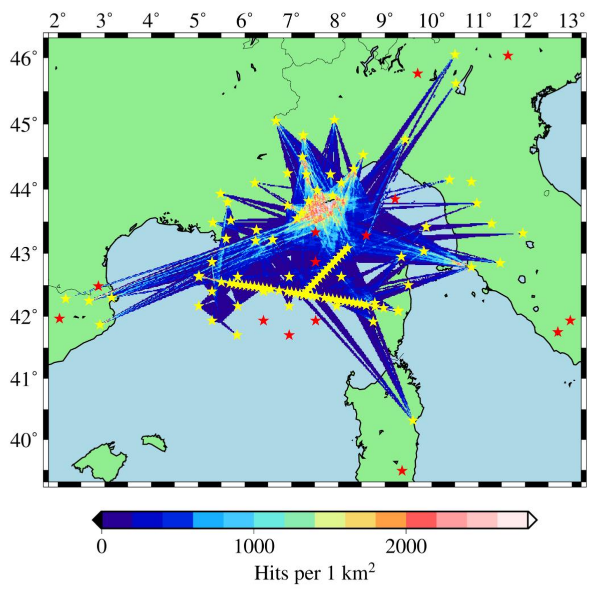

Figure 7: Ray coverage between shots from the 2018 MSM71 Lobster cruise and the 2008 R/V L'Atalante cruise and an increased number of stations in the area. Stations are marked by yellow stars where shots were observed, and red stars where not.

Data & Methods

- 29 OBS were deployed in June 2017, these recorded for about 8 months until they were picked up towards the end of February 2018
- Two seismic airgun profiles were shot February 2018, one from Corsica west towards mainland France and one from near the middle of that profile towards the northeastern end of the basin (see Fig. 1)
- Additional OBS were set out in a short-term deployment along the two profiles during the shooting
- In general, the data quality is very good, and shots are observed at some stations far in land
- However, some OBS in the basin have very poor data quality and only the water wave is observed, which could be due to large salt deposits

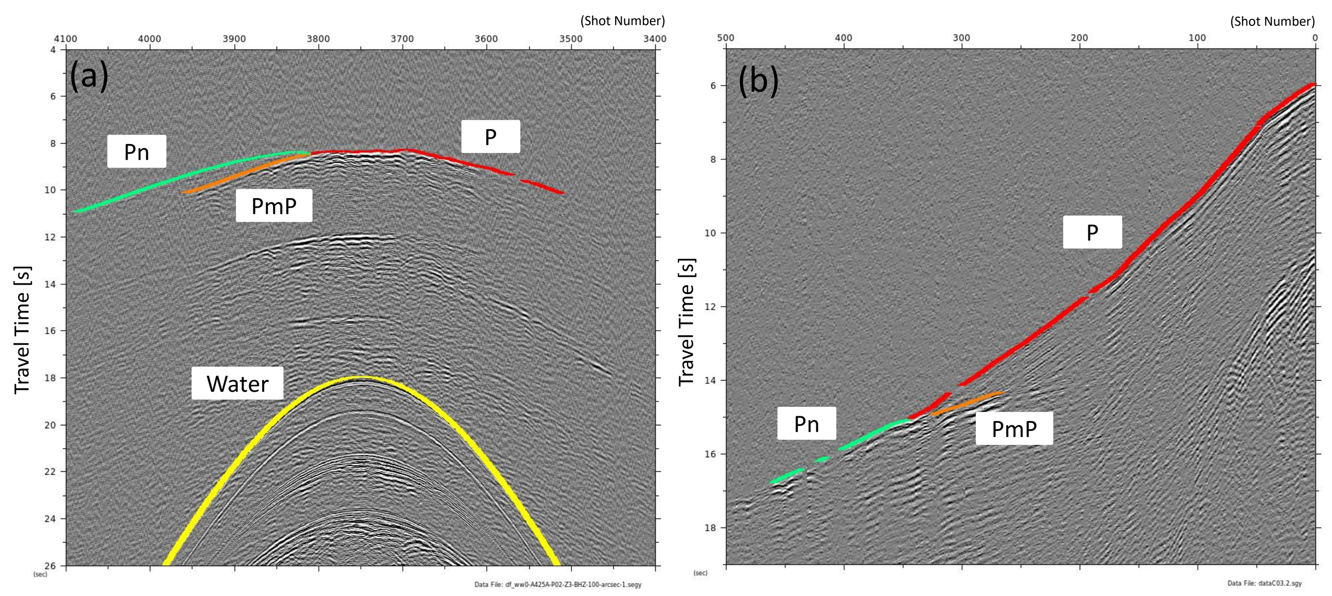

Figure 3: Data examples from (a) an OBS in the basin (OBS425), and (b) a land station on Corsica (C03). Figures made in PasteUp [Fujie, 2008]

- P and Pn arrivals were picked manually in PasteUp [Fujie, 2008]
- Data from OBS and surrounding land stations from permanent and AlpArray networks were used [Hetényi, 2018]
- The data were converted from mseed to segy format using GIPPtool
- The segy files were then deconvolved and bandpass filtered between 1 and 30 Hz
- Additional data has now been added from the 2008 GROSMarin project [Dessa, 2011]
- The travel times and station and shot locations were passed to the tomographic inversion code TOMO3D [Meléndez, 2019]
- A 1D velocity model was used as a starting model, the velocity model was based on tomographic studies by Dannowski et al. 2020, and Thorwart et al. 2021

Summary & Outlook

- The first attempt at a 3D tomographic model has not provided sensible results, but this is likely mainly due to poor ray coverage and a low number of crossing rays
- The ray coverage has been increased by adding shot profiles from the GROSMarin project
- The ray coverage will be further increased by adding local seismicity travel times [Thorwart, 2021]
- The starting model will also be adjusted as the area spans from the basin onto the shore, but the current starting model is based only on studies of the basin

By improving the ray coverage, we hope to improve the resolution and robustness of the model. Once a more robust model is reached, we plan to extend the study to the region's anisotropy. This could also be accomplished with TOMO3D which has the capacity to estimate Thomsen's anisotropy parameters. However, the first step is of course, to reach a stable, plausible, and robust model of the P-Wave velocity in the Ligurian Basin.

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