CAYMAN: Characterizing the crust using 2D & 3D seismic tomographic methods

A-211

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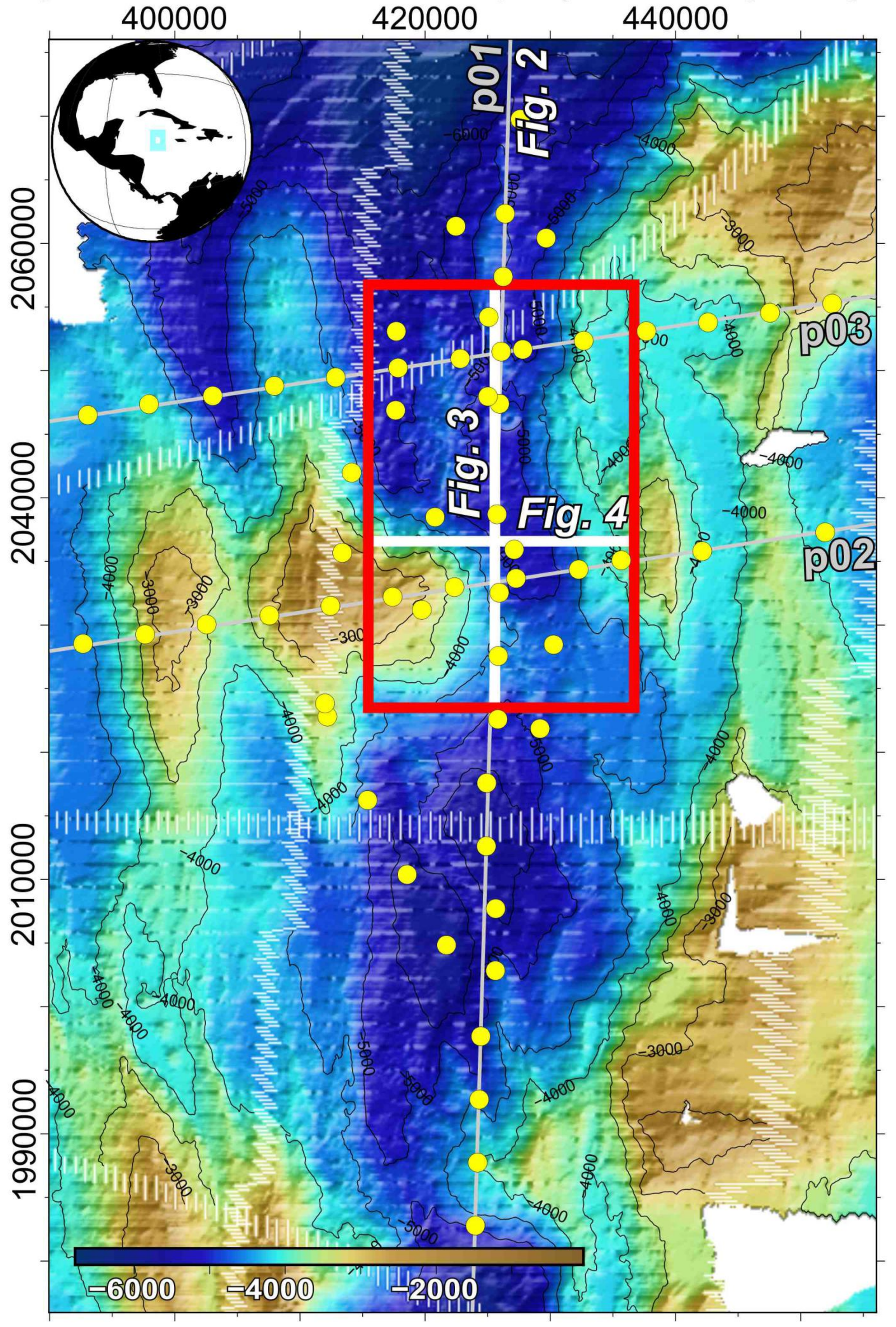
Introduction & Motivation

About 25% of the Earth's mid-ocean ridges spread at ultraslow rates of less than 20 mm/yr. However, most of these ultraslow spreading ridges are located in geographically remote areas, which hamper investigation. Consequently, how the crust forms and ages at such spreading centres, which traditional models predict to be magma-starved and cold, remains poorly understood. One of the most accessible ultra-slow spreading centres is the Mid Cayman Spreading Centre (MCSC), in the Caribbean Sea, with spreading rates of ~15-17 mm/yr. Understanding the sub-seabed geophysical structure of the MCSC is key to understanding not only the lithologies and structures exposed at the seabed, but more fundamentally, how they are related at depth and what role hydrothermal fluid flow plays in the geodynamics of ultraslow spreading.



Data: The CAYSEIS seismic experiment. CAYSEIS project was proposed to survey the Cayman Trough area in order to obtain new data that constraints the nature of the crust, tectonic structures, lithologies outcropping and hydrothermal processes taking place in this area. CAYSEIS was a joint and multidisciplinary programme of German, British and US American top tier scientists designed for the obtaining of a new high-quality dataset, including 3D Wide-Angle Seismic (WAS), magnetic, gravimetric and seismological data.

Figure 1: Bathymetric map of the Cayman Trough (UTM zone 17N projection). The location of the WAS profiles and the OBH/S is shown (gray lines and yellow circles, respectively). The red rectangle shows the area tested in 3D (Figs. 3 and 4).

The 'CAYMAN' project: In CAYMAN project, we are using the CAYSEIS dataset to invert a 3D tomographic model of the Cayman Trough lithosphere using the Tomo3D code (Meléndez et al., 2019). The results of this experiment will show not only the lithospheric structure along and across the MSCS, including the exhumed Ocean Core Complexes, but the 3D lithospheric configuration of the region which is important to understand the crustal formation processes and the evolution of ultra-slow spreading settings.

Testing the code: Using Tomo3D for 2D Inversion

This is one of the first times that the Tomo3D code is used for 3D inversion of real datasets. Thus, we are checking our results comparing them with tomographic inversions of 2D lines and testing the different parameters to obtain the more accurate and higher resolution model as possible.

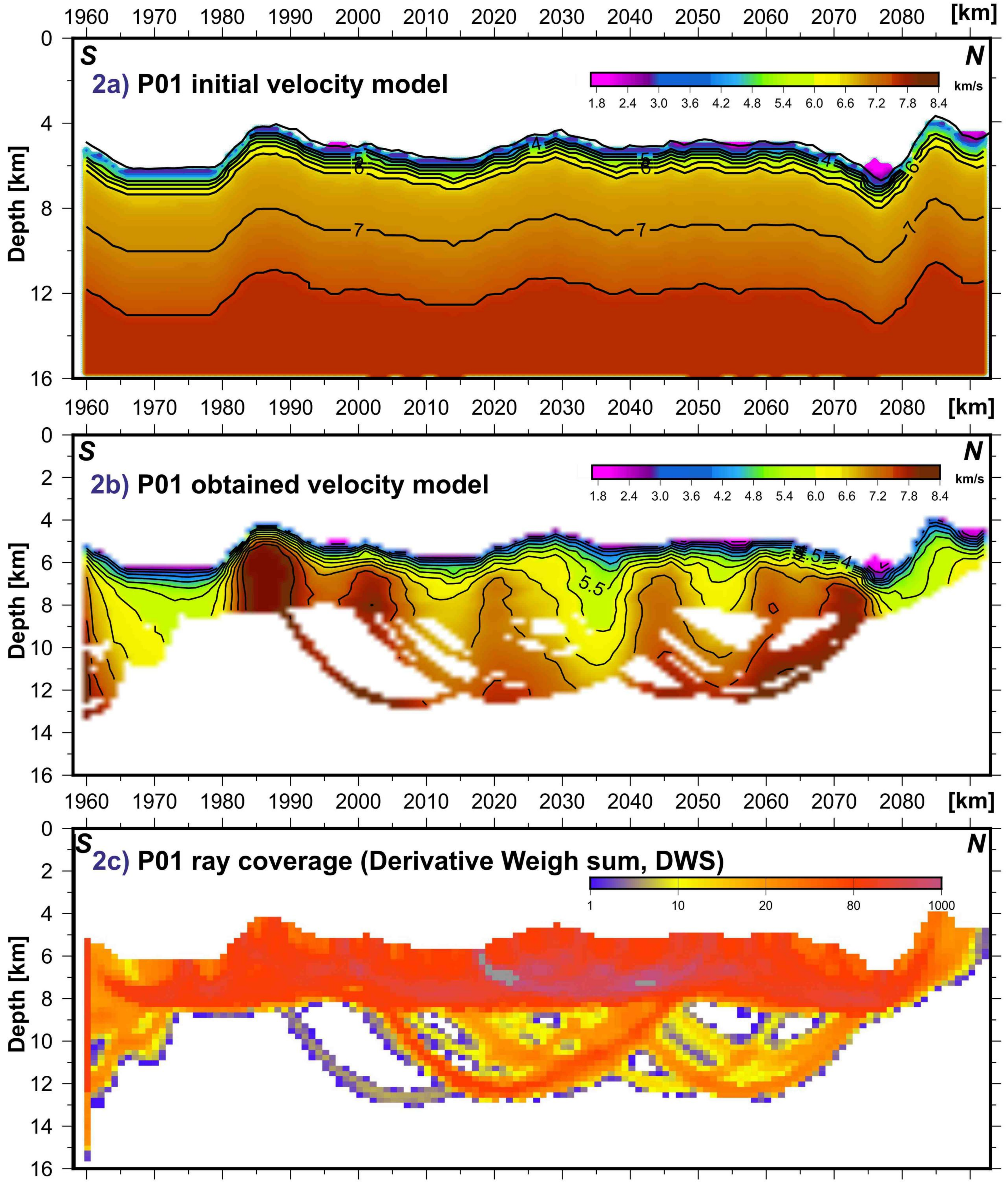


Figure 2: Results of the 2D velocity modelling along P01 using the tomo 3D code. The obtained velocity model is able to image the velocity variations in depth (e.g. Van Avendonk et al., 2017; Grevemeyer et al., 2019).

3D velocity model: first results

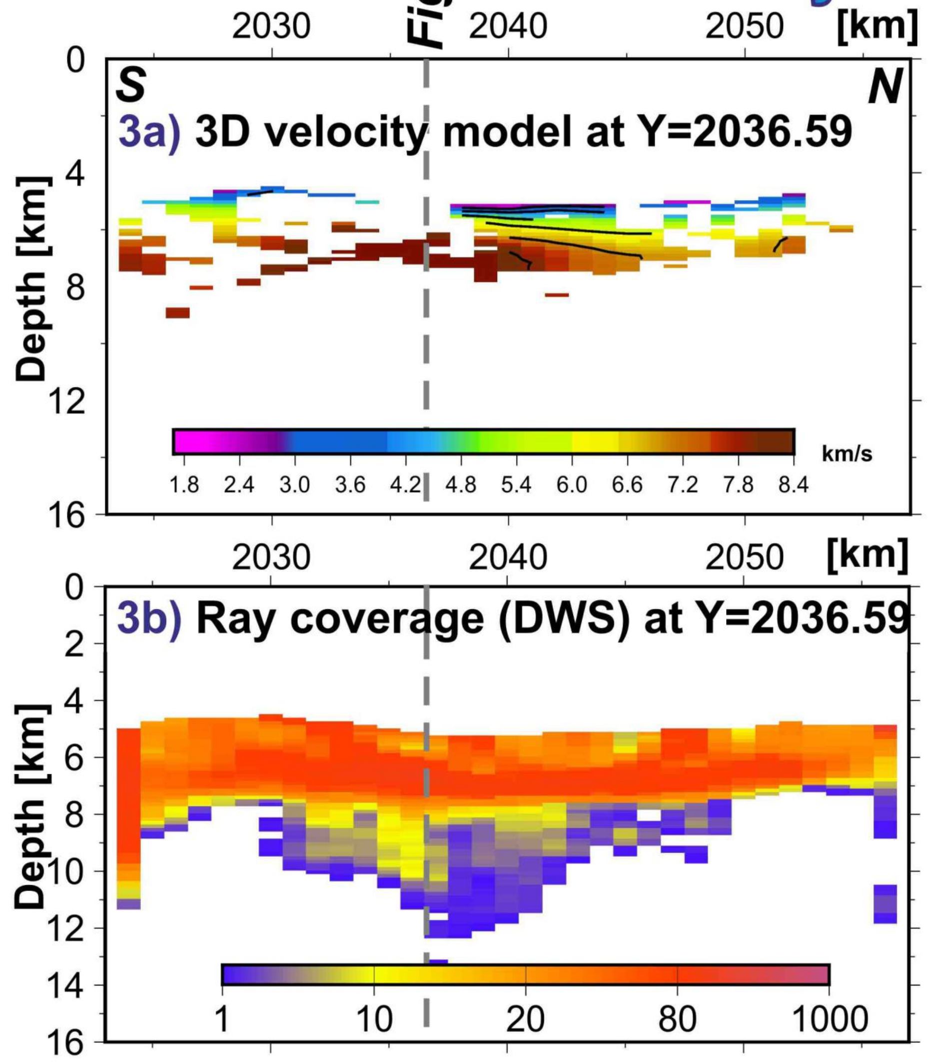


Figure 3: Results of the 3D velocity modelling across a transect at Y=2036.59 (Fig. 1). The gray line shows the crossing point with Fig. 4.

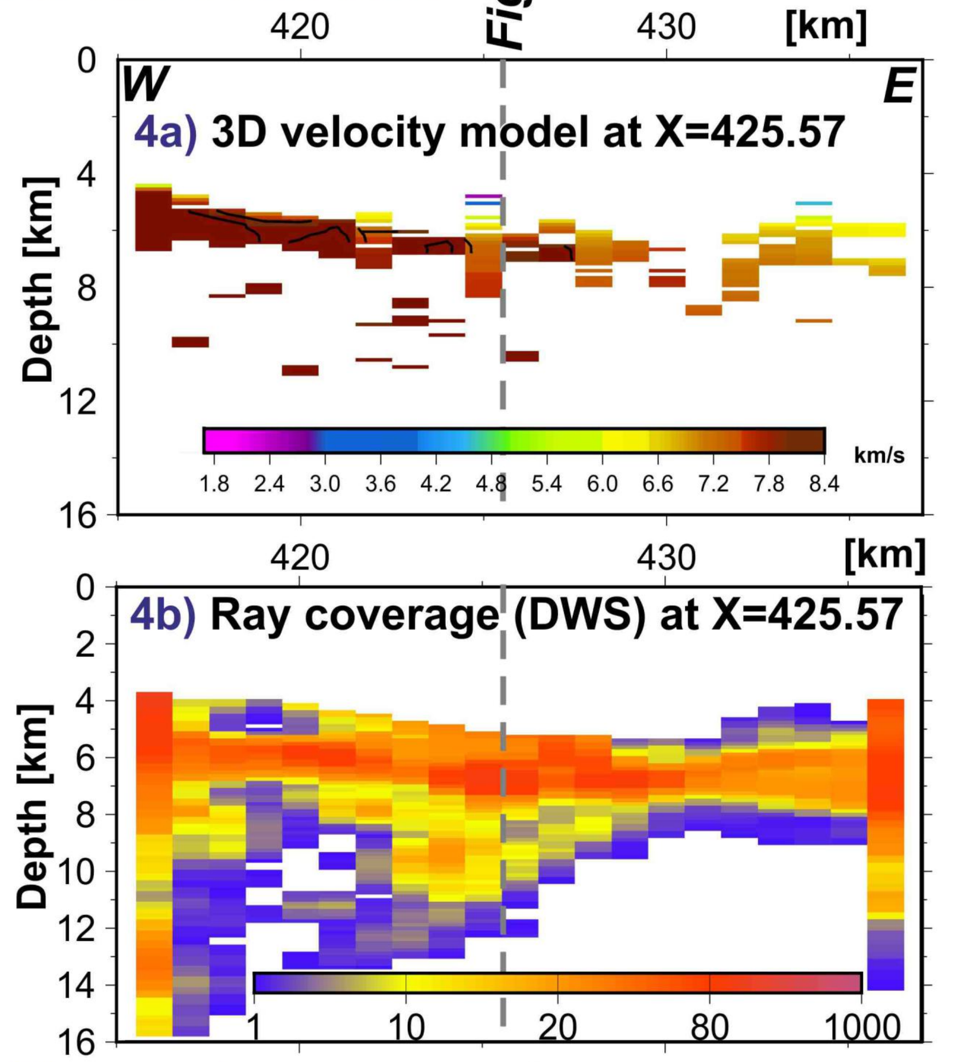


Figure 4: Results of the 3D velocity modelling across a transect at X=425.57 (Fig. 1). The gray line shows the crossing point with Fig. 3.

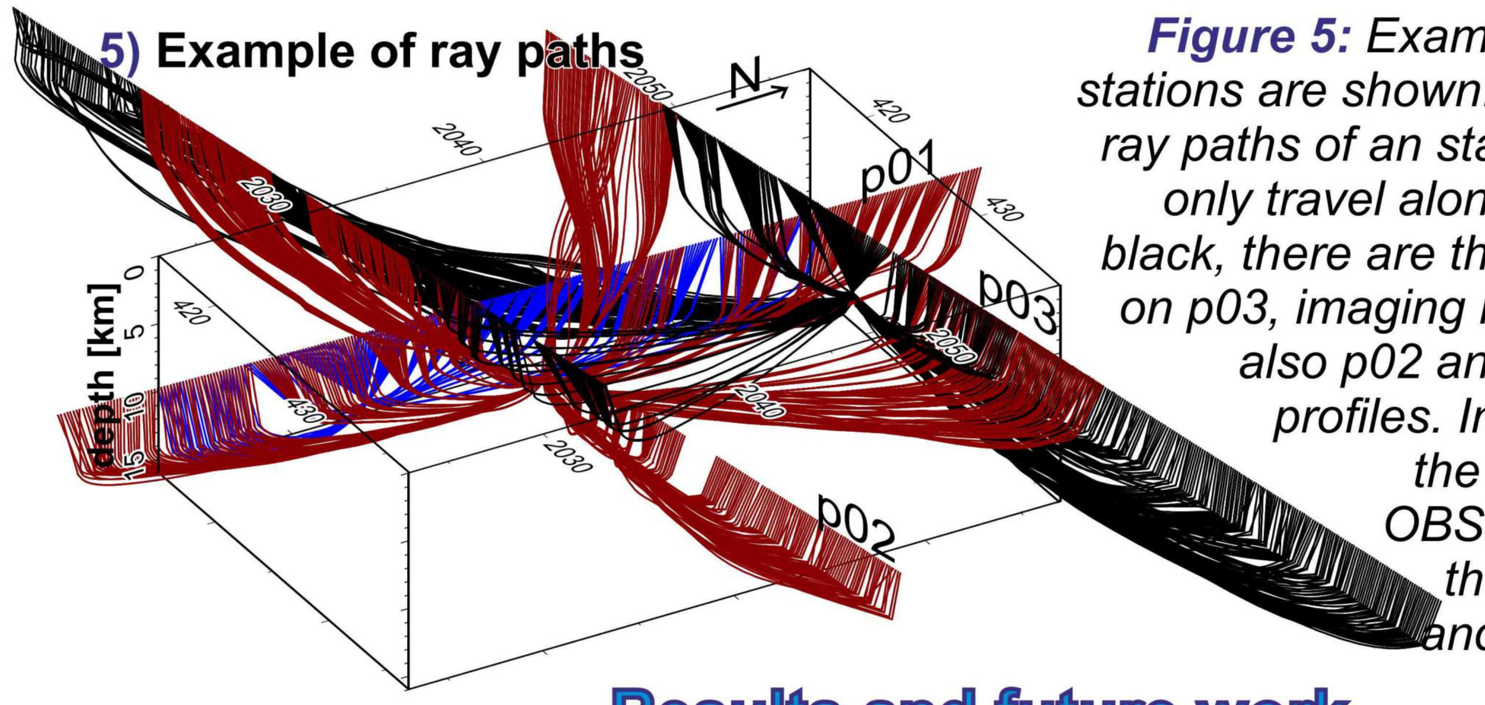


Figure 5: *Example of the ray paths. 3 stations are shown. In blue, there are the ray paths of an station on p01. The rays only travel along the p01 direction. In black, there are the rays from an station on p03, imaging not only along p03 but also p02 and the area in between profiles. In red, there are shown the ray paths of an offline OBS. These rays recorded the shots along profiles, and also travelled across the area in between.*

Results and future work

- First results have been obtained running the 3D inversion using a subset of the data.
- These results image the crustal variation along and across (Figs. 3, 4) the ridge axis.
- The number of OBH/S included in the inversion should be increased in order to improve the coverage and the resolution of the 3D model.

References: Grevemeyer, I. et al.: Maximum depth of brittle deformation at ultra-slow spreading ridges constrained by micro-seismicity. Geology, 47 (11), 1069–1073. (2019); Meléndez, A.: Anisotropic P-wave traveltime tomography implementing Thomsen's weak approximation in TOMO3D. Solid Earth. 10, 1857–1876 (2019); Van Avendonk, H.J.A. et al. Seismic structure and segmentation of the axial valley of the Mid-Cayman Spreading Center. G3 1–35 (2017).

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