Response to comments of the anonymous reviewer on the manuscript "Forearc density structure of the overriding plate in the northern area of the giant 1960 Valdivia earthquake" (se-2021-53)

First, we gratefully thank the comments on our work from the anonymous reviewer (https://doi.org/10.5194/se-2021-53-RC1). In this document we write responses in blue after the reviewer's comments (black). The corresponding changes in the text were included in the new submitted version of the manuscript.

Sincerely

The authors

Review for "Forearc density structure of the overriding plate in the northern

area of the giant 1960 Valdivia earthquake"

In this study, the authors have explored the continental fore-arc density structure of the Nazca-South America subduction zone. They compile a gravimetric data base combining public databases and lots of new measurements. They perform 2D and 3D inversion for a detailed density structure both onshore and offshore and further calibrated the results with 1D electrical resistivity models from MT and TEM measurements. The authors show the spatial distribution of the mantle wedge and the Coastal Cordillera domain resolved from this density structure. They propose a model for the current stress and friction evolution on the subduction plate which may relate to the high slip patch distribution of the giant 1960 Mw9.6 Valdivia earthquake. The study provides the density structure along the coast in detail and a geophysical perspective to understand the subduction process.

This study covers an activate region where huge megathrust earthquakes have taken place. The results are significant for understanding the environment of megathrust earthquakes and thus important for future hazard assessment. The manuscript is well written. However, I found some missing references for the method and data process, see comments below. Thus I recommend it to be published in Solid Earth with minor revision.

Minor comments:

Figure 1a. This is a very nice figure but with too many colors. I suggest to use gray scale for elevation.

R.- In the new version of the manuscript use a gray scale for elevation in Figure 1a.

Line 71: This is an old reference. Maybe use MORVEL.

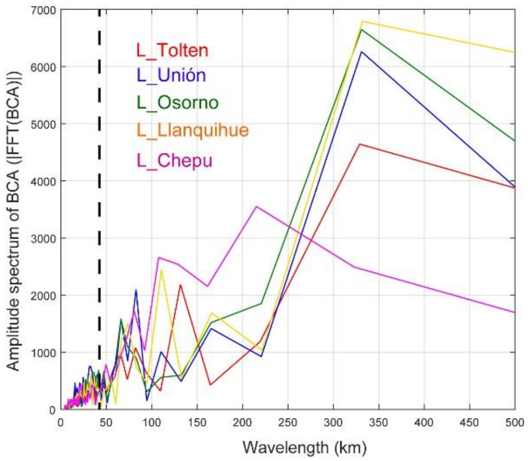
R.- In the new version we referenced to Kendrik et al. (2003) and Vigny et al. (2009). According to DeMets et al. (2010), MORVEL have differences with GPS observations (it gives ~7.4 cm/yr in comparison to ~6.6 cm/yr).

Line 140: it is not clear how is this reference density used.

R.- We replace "reference density" by "reduction density" for more clarity. Both are referring to the constant density used in the standard gravity reduction process to obtain the complete bouguer anomalies.

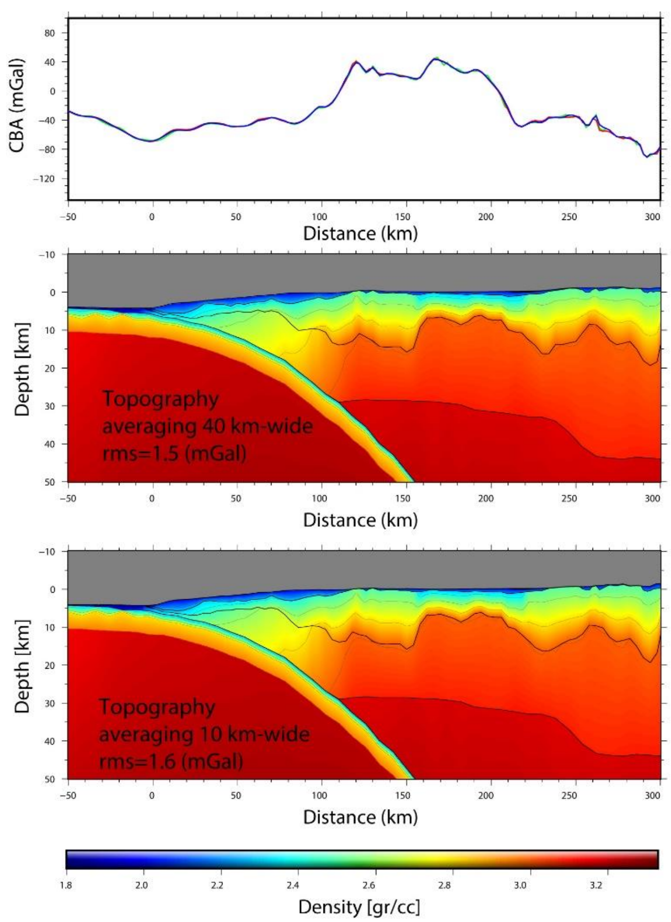
Line 150: why use 40 km-wide band? Any test on this?

R.- In order to represent the regional density structure in a 2D model, some assumptions should be done. In particular, the infinite extension of the model in the direction perpendicular to profile overestimates the effect of local topographic features located exactly in the profile track. To avoid this problem, we averaged the topography (in the direction perpendicular to profile) in a 40 km-wide band (i.e., 20 km to both sides of the line). A 40 km-wide band is a reasonable assumption considering that the wavelengths of the CBA gravity anomalies along the profiles are mostly larger than ~40-50 km as is showed in the amplitude spectrum (see figure below). Then, the averaging of topography at this scale is an appropriate option.



Amplitude spectrum of BCA signal along the 5 gravity profiles used to generate 2D forward models. Dotted vertical line highlights the wavelength equal to 40 km.

On the other hand, the direct comparison of the results obtained with completely different value (10 km-wide, i.e. 5 km to both sides of the line) can be considered with minor modification on the resulting density model, which indicates that this "wide" is not a critical value for our modeling scale (see figure below for Profile Osorno).



Comparison between 2D forward models obtained with different bands of topography-averaging in the Osorno profile. Central panel corresponds to model obtained with a band 40km-wide of topography averaging (corresponding modeled gravity is presented in blue at the upper panel). Lower panel corresponds to model obtained with a band 10km-wide of topography averaging (corresponding modeled gravity is presented in red at the upper panel. Observed data corresponds to green line in the upper panel).

This analysis was mentioned in the new version of the manuscript and the figures were included in the supplementary material.

Line 172: why does the cell size change along depth?

R.- Due to the progressive sensitivity decrease of the Gravity inversion to sources in depth, UBC-GIF developers recommend using smaller cells near the surface and increase the cell thickness with the model depth (https://www.eoas.ubc.ca/ubcgif/iag/sftwrdocs/technotes/faq.htm). Accordingly, the cell size gradually grows from 100 to 1500 m in our model.

Line 176: why choose 6000 m by 6000 m by 3000 m? Additional information is needed to support this.

R.- In UBC-GIF software, length scale parameters define the horizontal and vertical smoothness of the solution (https://www.eoas.ubc.ca/ubcgif/iag/index.htm). We preferred values of LE =6000 m, LN =6000m and Lz =3000m, which is the double of the horizontal and vertical cell size (maximum vertical cell size=1500 m) used to discretize the media. This criterion is one of the recommended in the software manual (https://www.eoas.ubc.ca/ubcgif/iag/index.htm), but also it is important to highlight that sensitivity tests show that, under a strong variation these parameters, the obtained solution of density structure shows similar features. This point was included in the new version of the text supported by figures in the new version of supplementary material.

Line 216: more explanations for WinGLink.

R.- WinGLink is a commercial software developed by Schlumberger, widely used in the industry and scientific community as well, with different modules to process, model and interpret electromagnetic data. Here we used the 1-D inversion module, based on Occam and Bostick procedures, described in the references given in the manuscript.

Figure 4, 5,6,7: I feel some labels are too small. Please use consistent font size.

R.- In the new version of the figures we changed the font labels.

Line 323: how is this initial input model chosen?

R.- As is explained in the text, the inverted input data is the Residual Bouguer Anomaly obtaining by removing a regional (linear) trend from CBA data.

Line 365: how is the dashed line of the incline of H1 determined? Here some explanations are

needed. I am also wondering if the angle H1 has some implication of the subduction structure.

R.- We note in the that the western limit of this anomaly suggests an inclination to the east as is observed in the 3D model (Fig. 7), and then we include segmented lines to highlight this interpretation. In order to clarify this, we write the following description in the figure caption:

“The interpretation of the approximate borders of the D1 anomaly is highlighted with dotted black lines”

On the other hand, regarding a possible relation between the shape of D1 and subduction angle it is in interesting to note that deep seismic reflectors located by Maksymowicz et at. (2021) below the Coastal Cordillera (i.e., westward from D1 at deep crustal levels) present, in general, east dipping angles. Then, we can interpret that the western border of D1 have a shape consistent with the structure of the Metamorphic complexes (WS/ES) at depth. However, the resolution of gravity model is not enough to calculate the precise inclination angle, and this structural relation is only suggested by the results. This idea was included in the new version of the manuscript.

Note that H1 and H2 density anomalies are named as D1 and D2 in the new version

Line 386: is this compact process supported by other studies? Geological or geochemical?

R.- Currently, the structure, lithology and fracturing of the continental wedge is interpreted mainly from geophysical studies. Unfortunately, the few available drills in Chilean Margin reach only the upper portion of the crust (generally the first kilometer below the seafloor), and then, lateral variation of properties as compaction and/or fracturing is not confirmed by direct observations.

Line 390: what is the physical meaning of this low horizontal gravity gradient?

R.- We use the concept of “horizontal density gradient” as the variations of density along the profile at a specific depth. This variation highlights the lateral changes in elastic properties that can be related with lithology, compaction and/or fracturing.

Line 404: how well is the depth (30 km) of WS/ES constrained?

R.- As is mentioned in the text, the interpretation of the seismic reflection data (Krawczyk et al., 2006; Ramos et al, 2018) supports the continuity of WS/ES to depth, which is expected for units that were formed and exhumated by basal accretion. Seismic data locate the depth of reflectors with precisions at the order of few kilometers, but clearly the lithology of deep portion of the crust cannot be univocally determined from geophysical data.

Line 410: it is interesting that the depth limit is related to seismicity. Is this observed in other

subduction fault?

R.- In the text we discuss the published earthquake catalogs in the study zone, but there are some examples of a correlation between the upper plate seismicity and changes in the seismic velocities and/or density along the continental wedge. Between others, Contrereas-Reyes et al., (2015) and Comte et al., (2019) shows similar correlations in Central Chile and Petersen et al. (2021) at northern Chile.

Line 460: Normally the fluid migration can be associated with high Vp/Vs ratio in subduction

zone. Is there Vp/Vs ratio variation that is associated with the fluid migration here?

R.- We agree, in this paragraph we should highlight the Vp/Vs model. Variations in Vp/Vs are associated to variations in rigidity, which can be related to fluid content of the rocks, but also with porosity/fracturing and lithology. In this case the model of Dzierma et al (2012) shows a low Vp/Vs (and High Vp) region correlated with H1 at the northern profile P1_Toltén. Then, we interpret this anomaly as a more rigid zone (and maybe less fractured/hydrated) compared to the surrounding crust.