Dear Dr Cottaar,

We have reached a decision regarding your submission to Seismica, "The root to the Galápagos mantle plume on the core-mantle boundary ". Based on reviews received, your manuscript may be suitable for publication after some revisions.

Please find the reviews appended below. Both reviewers agree that this work is an important contribution for the deep Earth community's understanding of ultra low velocity zones, and have recommended minor revisions. Specifically, the reviewers have requested additional figures, references, and discussion, as well as clarifications of methodology.

We look forward to receiving a revised manuscript, along with point-by-point responses to the reviews.

Best wishes,

Lauren

Thanks for managing the review process. Responses to the individual points raised by reviewers can be found below.

Reviewer A:

The manuscript by Cottaar et al. presents a nice study of ultra low velocity zone (ULVZ) near the Galápagos hotspot using shear-diffracted waves. The authors performed forward modeling to constrain the width, height and velocity variations of the ULVZ. They found this mega-ULVZ is comparable to other broad ULVZs on the core-mantle boundary near Hawaii, Iceland and Samoa. They further associated the isotope signatures observed in the ocean island basalts nearby with this mega-ULVZ. At last, several possible mechanism for the origin of the ULVZ are proposed.

Their analysis is well organized and technically sound. This paper would be a good addition to the mega-ULVZ patches on the CMB and contribute an important finding for the deep Earth community in understanding the origin of ULVZs. I have some comments/suggestions and questions below.

Thanks for the review. Individual comments are addressed below. Line numbers refer to those in the 'tracked changes' file.

1. I suggest the authors plot a cartoon figure to demonstrate the possible mechanisms for the ULVZ origin.

Although I am generally a fan of cartoons, there are several good ones available in studies that introduce potential origin scenarios (e.g. Labrosse et al. 2007). While our study provides new insights to the presence and dimensions of one particular ULVZ and links to geochemical signatures, it does not provide new insights in the geodynamics of the ULVZ origin (we can imagine several different cases). Hence, we have not taken on board this suggestion by the reviewer.

2. How would the velocity profile/gradient in the lowermost 300 km of the mantle affect the results, considering these profiles are different among various 1D reference models.

The slight differences in 1D profiles (without the presence of a ULVZ) affect the main arrival time of Sdiff, but do not create the postcursors we attempt to fit here. We do not attempt to fit the absolute arrival time of Sdiff in this study.

3. Since the mega-ULVZ is close to the LLVP boundary, how would such a boundary affect the Sdiff postcursors?

LLVP boundaries can create postcursors (e.g. To et al. 2005), although these are less delayed and not observed over a wide array like the observation here. When the initial postcursors were discovered in event A, I attempted to fit it with the fact that the coverage for this event runs parallel to the LLVP but could not recreate the postcursor with a sharp LLVP boundary. Since then, the subsequent finding of the postcursors in other events, led to a need for a ULVZ, and so the LLVP scenario is not further discussed or explored in this paper.

Otherwise, the presence of LLVP or not does affect the arrival timing of the main phase and postcursors. Whilst there is undoubtedly constraints on the sharpness of the LLVP boundary in this data set (events A and B), this is not the focus of this study.

4. Please discuss more about why the mega-ULVZ cannot be attributed to partial melting of the deepest mantle material in the discussion section.

Further clarification is now added in lines 76-77 - 'as the melt is dense due to enriched in Fe and drains to the core-mantle boundary'.

5. I notice that the mentioned filter band is 10-30s in the manuscript, but in the supplementary the synthetic waveforms are filtered between 30-50s. What is the reason for the inconsistency?

Figure S1, S2, and S4 show further data examples. For some of these a filter between 12-30s was chosen as this reduced the noise in the data. Figures S6-S9 use a filter band of 10-30s, which can be directly compared to the main manuscript. Figures S10-S12 do indeed use 30-50s. These are showing the particular tests for the height of the ULVZ. At these longer periods, postcursors are weak or non-observable in the data, but still persist in the synthetics for the thicker models. There is less variation between the synthetic models at periods of 10-30s. This was somewhat discussed in the text, but now further clarified:

'To evaluate the height, we assess the data at longer periods between 30 to 50, as the synthetics for models of different heights show more variations in postcursor amplitudes at longer periods.'

6. The Figure 6b is not quite informative and a little bit confused. Please present it in a better way.

We have now used the dashed/solid lines to indicate what we identify as a main phase (arriving before 35 s) or a postcursor (arriving after 35 s). We hope this better shows the difference in direction between these two types (previously this was only shown by the transparency of the lines). We hope this makes the figure more informative to the reviewer. We have adapted Figure S14 as well to follow the same plotting convention.

7. In Table 1, the numbers in the Long. column are not well aligned.

Fixed. Thanks.

8. Line 114, 116: By good and low SNR, what are the criteria values? Which time window did the authors choose for calculating the SNR?

We haven't taken a quantitative approach to this, data quality is judged by eye. This information is now added in line 121.

9. Line 304: How did the authors estimate the uncertainties of the ULVZ parameters?

Again, this isn't quantified, but based on our judgment of our resolution on the parameters based the waveform tests presented in the supplementary material. This is further clarified with the text: 'Based on these tests, estimated uncertainties…' in lines 317.

Recommendation: Revisions Required

Reviewer B:

This paper analyzes Sdiff arrivals recorded by North American stations, including USArray data, in search of Sdiff post-cursors, which have been used successfully in several previous studies to detect and image ULVZs at the CMB. Finding such post-cursors this study focuses on four high-quality events with crossing coverage on the CMB and performs 3D waveform modeling to constrain possible ULVZ dimensions and S-wave velocity decrease. Ultimately, the authors conclude that this ULVZ, located to the west of the Galapagos hot spot is potentially linked as the source of this hot spot volcano and suggest that the largest "mega"-scale ULVZs are all linked with common isotopic signatures at their respective hot spot volcanoes.

Overall, I found this paper well-written and the data presented and modeling results quite compelling for this ULVZ. The discovery of a large ULVZ in this location is an excellent contribution to our knowledge of ULVZs. I have only a few minor comments that I discuss below, and suggest this paper be accepted for publication with only minor revisions.

Thanks for the review. Individual comments are addressed below. Line numbers refer to those in the 'tracked changes' file.

- From lines approximately 360 to 375, this paper discusses the possible connection of a Galapagos plume to this ULVZ on the CMB in tomography models. I think it would strengthen the paper if some cross-sections through the tomography models (SEMUCB at the very least, which is used for the CMB slices and shows the best connections between ULVZs and hot spots at present) were shown. This would definitely aid the discussions in this part of the manuscript.

  Yes, we added cross-sections for SEMUCB and DETOX models to illustrate this part of the discussion (see Figure 8).

- At around lines 335, the authors discuss ULVZ imaging by Ma and Thomas to the south of Galapagos. But, do not mention other ULVZ studies that have previously demonstrated evidence for ULVZ presence in the vicinity of Galapagos. Namely the studies of [*Vanacore and Niu*, 2011] and [*Thorne et al.*, 2020] have also shown ULVZ evidence linked to Galapagos, however these studies do not appear to show the same ULVZ uncovered in the present study, or nearly as large. Nevertheless, it seems that it would be more complete if these past studies were referred to as well as the Ma and Thomas study.

  The Vanacore and Niu study conclude their data are better explained by a weak low velocity anomaly across the D'' instead of a ULVZ. I presume for that reason, this study was not included in the compilation by Yu and Garnero 2018, which is presented in our plot. For the probability maps of Thorne et al. [2020, 2021], it is hard what to take at face value. In Thorne et al. 2020, a ULVZ near Galapagos only has moderate probability, and it is discussed that this is only due to a small set of data in one direction that could be contaminated by the Samoan ULVZ. In Thorne et al. 2021, the probability is even smaller (at 0.125). We don't include this on our map, but based on a comment below, these studies are now included in the introduction.

- This paper refers to the four mega-sized ULVZs uncovered so far as Hawaii, Samoa, Iceland, and now Galapagos. But, this paper does not mention evidence that other large mega-sized ULVZs may exist that are comparable in size to these four [*Thorne et al.*, 2021]. This paper also points out a mega-sized ULVZ beneath the Caroline hot spot. Hence, I think this paper should at least mention that there may be other mega-sized ULVZs in existence, and some of them in regions that are not beneath hot spot volcanoes. But, perhaps you could say that detailed waveform modeling has yet to be done for these regions so the exact size and extent of them is as yet unknown. Nevertheless, initial waveform modeling around the ULVZ beneath Caroline, does suggest this is potentially quite large, comparable to that of Samoa, Hawaii, etc. I am curious how does the isotopic evidence for the Caroline hot spot fit into this picture?

  This is a fair point. We have now acknowledged suggested mega-ULVZs beneath Caroline (Thorne et al. 2021) and Marquesas (Kim et al. 2020) in the introduction (lines 69-71). Caroline hotspot has an anomaly in both helium and tungsten (albeit not as large as the 'big four' discussed here) and the location might also be less explored by isotopic studies. Note, that due to this question we noticed the tungsten anomaly for the Caroline hotspot was plotted in the wrong location in Figure 7, and fixed this.

- Lines 59-60 state “While only a fraction of the core-mantle boundary has been targeted for these anomalies, there is a weak trend that these patches appear within or near the LLVPs (Yu and Garnero, 2018).” Approximately 57% of the CMB has been explored in [*Thorne et al.*, 2021; *Thorne et al.*, 2020] and they show no trend with ULVZs preferentially being located within or near LLVPs.

  We have now extended this discussion with the two papers mentioned here (lines 61-63). The approach of using one data type across a large part of the CMB to address this question is good.

- Line 90. “near the Galapagos”. This is awkward, near the Galapagos Islands?

  Fixed, we found several other occurrences and fixed those as well.

- Line 115. “…that observe the Galapagos ULVZ…” maybe change to “…that sample the Galapagos ULVZ…”

  Changed, thanks.

- Line 331. Samoa is also more recently investigated in [*Krier et al.*, 2021]. Similarly the size extent of the Samoa hot spot shown in Fig. 7 has been updated in the above work, and is significantly larger than shown in this figure.

  We have added the 0.5 probability contour for Samoa from Thorne et al. 2021 to illustrate the potential larger shape. We have also added a sentence to the caption to acknowledge the recent modelling studies for Hawaii and Samoa that we don’t represent on the plot. We have also made sure to cite Krier et al. in other appropriate locations.

Krier, J., M. S. Thorne, K. Leng, and T. Nissen-Meyer (2021), A compositional component to the Samoa ultralow-velocity zone revealed through 2- and 3-D waveform modeling of SKS and SKKS differential travel-times and amplitudes, *Journal of Geophysical Research Solid Earth*, *126*(e2021JB021897), doi:10.1029/2021JB021897.

Thorne, M. S., K. Leng, S. Pachhai, S. Rost, C. W. Wicks, and T. Nissen-Meyer (2021), The most parsimonious ultralow-velocity zone distribution from highly anomalous SPdKS waveforms, *G-cubed*, *22*, doi:10.1029/2020GC009467.

Thorne, M. S., S. Pachhai, K. Leng, J. K. Wicks, and T. Nissen-Meyer (2020), New candidate ultralow-velocity zone locations from highly anomalous SPdKS waveforms, *Minerals*, *10, 211*, 1-26, doi:10.3390/min10030211.

Vanacore, E., and F. Niu (2011), Characterization of the D" beneath the Galapagos Islands using SKKS and SKS waveforms, *Earthquake Science*, *24*, 87-99, doi:10.1007/s11589-011-0772-8.

Recommendation: Revisions Required