ERL visit summary

"Retrieving localized reflections and imaging the mantle transition zone below Japan"

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The mantle transition zone (MTZ) is bounded by two pronounced seismic markers related to mineral phase changes: the 410- and 660-km discontinuities. Topography of these markers could be used to derive the thermal and / or compositional state of the MTZ. Below Japan, knowledge of the MTZ topography is mostly derived from receiver functions (e.g., Tonegawa et al., 2006), underside reflections from distant seismicity (*SS* and *PP* precursors) and *ScS* reverberations (Kato et al., 2001). We are developing an alternative technique, that would image the MTZ with primary reflections from (virtual) sources and receivers in Japan. This would lead to a higher resolution image. The challenge is to obtain the required primary reflections off the MTZ. During the ERI visit we worked out two strategies to extract these reflections: 1) by integrating crosscorrelations over regional seismicity (i.e., seismic interferometry: SI), 2) by integrating crosscorrelations over a receiver array (i.e., receiver-pair seismic interferometry: RPSI). Here we report a proof of principle of the second approach.

With RPSI (Ruigrok, 2014) reflections are extracted from free-surface reflected phases. Fig. 1 depicts one possibility to retrieve *Sv660S* (the phase depicted on the right-hand side) at one offset by applying RPSI to the recordings of *s* and *sSv660S* (the phases depicted on the left-hand side) over the array. From the same recordings, *Sv660S* could be retrieved for a range of offsets.

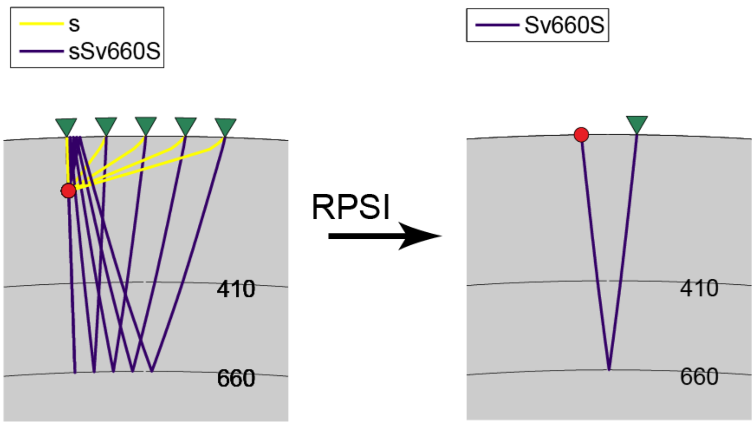

Figure 1: (left) From a deep earthquake (red dot) upgoing s (yellow rays) and the depth phase of the 660 reflection (purple rays) are recorded over an array of stations (green triangles). (right) By the application of receiver-pair seismic interferometry (RPSI) the response is extracted as if there were a source and receiver at the Earth's surface and the upside 660 reflection (purple ray) were measured.

Fig, 2(a) shows the configuration of the Hi-net (Okada et al., 2004) tiltmeter stations. This network contains both the required spacing and low-frequency sensitivity for retrieving mantle reflections with RPSI. From a large database of seismicity near Japan we select one earthquake (blue dot on Fig. 2a) for which MTZ depth phases could be observed on the recordings. Only one line of stations (purple triangles on Fig. 2a) is selected and their transverse-component recordings are plotted in Fig. 2b. On this panel, the upgoing *s* phase can clearly be distinguished, but not the 410 and 660 depth-phase reflections. These are hidden behind (near-surface) S-wave reverberations. Only after band-pass filtering, whitening and time-domain running-absolute mean normalization, the MTZ reverberations become apparent (Fig. 2c).

We derived a phase correction required for applying RPSI with a line (rather than a grid) of receivers. This phase correction is tested with numerical data with almost the same configuration as the field data. For the numerical data, however, only the upgoing *s* and *sSv660S* phase are forward modelled, whereas the field data contains all possible reverberations.

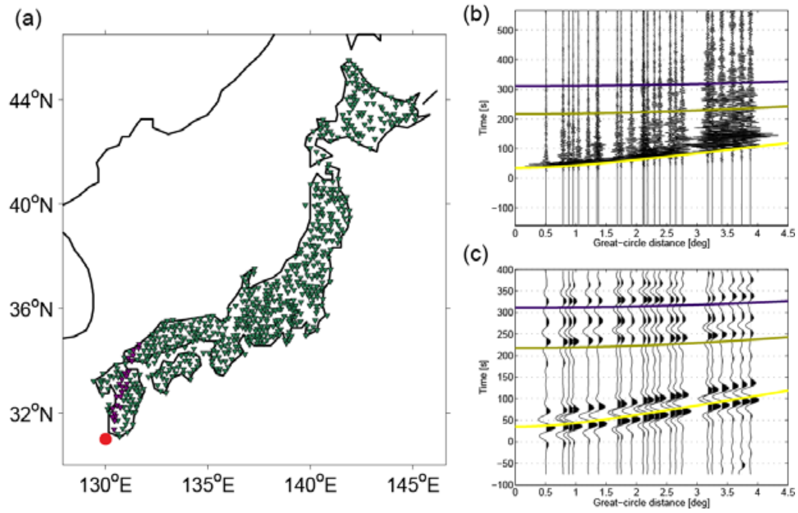

Figure 2: Configuration and data for the application of receiver-pair seismic interferometry. (a) a deep earthquake (red dot) and the tiltmeter network (green triangles) detecting the response. (b) The response measured by the purple receivers in (a). (c) The same response after filtering (see text). The yellow, olive and purple lines denote the expected timing of the upgoing s, sSv410S and sSv410S phase, respectively (Fig. 1).

RPSI is applied by first crosscorrelating the data for an offset of 1.4 degrees (or half offset h=0.7 degrees), yielding Fig. 3(a) and by subsequently stacking the crosscorrelations and by applying a phase correction, yielding the black trace in Fig. 3(b). The black trace is compared with the red trace, which is the actual Sh-wave point-source response as if there were a source and receiver at the Earth's surface and *Sv660S* were recorded (Fig. 1; right). The overlap of the negative peaks of the black and red traces (at ~280 s) confirms the kinematic correctness of the RPSI approach. The black wiggle near t=0s is an artefact due to crosscorrelations of the direct wave. Next, RPSI is applied for the same offset (1.4 degrees) to the field data (Fig. 2c), yielding the panel in Fig. 3(c) after the crosscorrelation step and the trace in Fig. 3(d) after stacking and phase correction. For the field data, besides *Sv660S*, also *Sv410S* and *Sv520S* are retrieved. Due to the low frequency of the retrieved phases, there is likely some interference between the 410, 520 and 660 reflections, which needs to be taken into account when extracting kinematic information for building topographic maps of the MTZ.

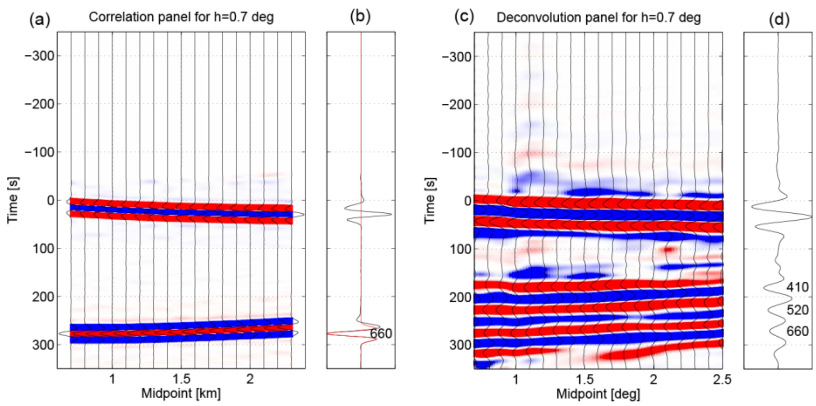

Figure 3: Results for applying RPSI on (a&b) numerical data and (c&d) field data, for a configuration as depicted in Figs. 1&2. The panels (a&c) show the results after the crosscorrelating step. The black traces (b&d) show the results after RPSI. For the numerical data also a reference trace is provided (red trace in b).

The stay at the ERI served as a good kick-off of the project. With help of NIED (National Research Institute for Earth Science and Disaster Prevention) we gathered all the necessary data and made a numerical and field-data proof of principle for retrieving MTZ reflections with RPSI. Inspired by Kato et al. (2001) and the excellent Hi-net data quality, our next focus will be on retrieving MTZ reflections from receiver-side *ScS* reverberations.

References

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Okada, Y., Kasahara, K., Hori, S., Obara, K., Sekiguchi, S., Fujiwara, H., & Yamamoto, A. (2004). Recent progress of seismic observation networks in Japan-Hi-net, F-net, K-NET and KiK-net. *Earth Planets and Space*, *56*(8), xv-xxviii.
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