**Non-Observation of SK(K)S wave splitting in the NW Pacific**

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## 1. Introduction

In the original application for my research stay we proposed to do a comparison study on crust and lithosphere structure derived from receiver function analyses from Japanese ocean bottom seismometer (OBS) data from the Pacific Ocean and German OBS data from the Atlantic Ocean. Since, in the meantime (I arrived two years later as planned due to pandemic restrictions), receiver functions from the Japanese data set NOMan in the NW Pacific was already analysed by a PhD student that was just about to finish her promotion during my early stay. Therefore, we decided to change to topic of my research stay to looking for splitting of SKS and SKKS waves recorded in the NOMan data set (Takeuchi et al. 2017), to get some additional information on seismic anisotropy in the NW Pacific upper mantle.

That dataset was already intensively analysed by Japanese colleagues over the years applying various methods to image the structure of the oceanic crust and upper mantle down to the mantle transition zone (e.g., Takeo et al. 2018).

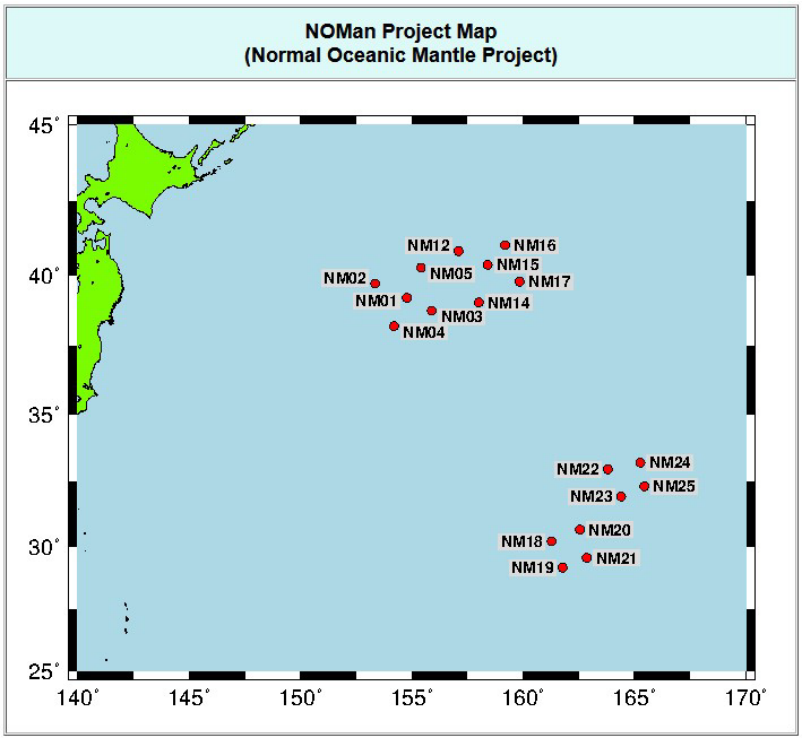


**Fig. 1** Station map of the NOMan Project. Source: http://ohpdmc.eri.u-tokyo.ac.jp/

## 2. Data inspection

SKS and SKKS phases can be used as tool to study anisotropy in the lithosphere and upper mantle (e.g., Savage 1999, Komeazi et al. 2023). In that sense it is complementary to observations from surface wave studies (e.g., Takeo et al. 2018). For data inspection we applied the software Seismic Handler (Stammler 1993).

In a first step, the orientation of the horizontal components had to be determined. This was done by analysis of P and Ps wave polarization of teleseismic events. These “misorientation” angles were then used to rotate the horizontal components 1 and 2 into N and E. Then all events between with an epicentral distance in the range 85°–140° and with a magnitude >6.3 were selected for the polarization analysis of the SKS and SKKS phases.

During the time of stay at ERI it was not possible to check all stations from all three deployments within the NOMan project, but we selected several stations from each deployment to get an idea on the quality and if we can actually observe SK(K)S splitting or not. Since the OBS data is very noisy, especially in the period band of the secondary microseisms, we had to apply filters with corner periods of 50 s (high pass) and 8 s or even 10 s (low pass). And even with that severe filtering, noise could not be always suppressed in a way that a clear analysis of splitting of the SK(K)S phases could be made. Therefore, we only selected events that are not influenced by noise on the horizontal components, and finally these are not many events.

For both NOMan networks we could analyse events from limited backazimuth ranges by exploring the particle motion of SKS and SKKS phases:

NOMan-A: 45°, 60°-65°, 79°, (95°), 119°, 185°, 320°-325°

NOMan-B: 52°, 70-72°, 91°, 316°, 324°-329°

Actually, in none of these backazimuth ranges we could observe a clear splitting, which is in a way unexpected. That means we observe a “null splitting” over all azimuth ranges that could be analysed. For some events and stations, we observe a slight rotation in the RT plane, and sometimes even a slight elliptical moveout, which could indicate a real splitting and therefore anisotropy beneath the station. However, inspecting the waveforms visually, we cannot rule out, that this apparent splitting is caused by noise or scattered phases. The slight elliptical moveout sometimes occurred with a low pass filter of 8 s corner period, but when using a corner period of 10 s the apparent elliptical moveout disappeared, arguing for an origin of the elliptical moveout by either noise or scattering.

**3. Comparison of the findings with results from previous studies**

As written above, the fact of not observing clear SK(K)S splitting for all analysed stations and events is unexpected. A previous study by Takeo et al. (2018) found evidence from surface waves that azimuthal anisotropy should be present. Takeo et al. report a fast direction of ~130° (and a strength of 3.5%) for NOMAN-A, and ~105° for NOMAN-B, respectively, for the sub-Moho mantle. Anisotropy is stronger in the shallow upper mantle (10-40 km) and weaker at larger depths.

There might be two reasons why we do not observe these anisotropic structures with splitted shear waves: (1) the filtering was too severe and actually splitting cannot be observed at NOMan networks due to ocean noise in the period band beneath 10 s, or (2) the anisotropy in the uppermost part (lithosphere: fossil seafloor spreading) and lower part (asthenosphere: present-day absolute plate motion/asthenospheric flow) of the upper mantle cancel each other out for SK(K)S phases. Normally, “null splitting” observations would be normal to be observed close (within ± 20°) to the true direction of anisotropy or perpendicular to it. On the other hand, if the anisotropy in the deeper parts of the upper mantle is actually weak as indicated by early studies of Nishimura & Forsyth (1989), then actually, the ocean noise on the OBS data might actually hinder us from observing that weak anisotropy with long-period (>10s) SK(K)S phases.

The non-Observation of SK(K)S wave splitting in the NW Pacific using NOMan data should be approved by looking at more data, also from nearby deployments to understand if it is a local effect or actually a phenomenon that can be observed also in other parts of the Pacific Ocean.

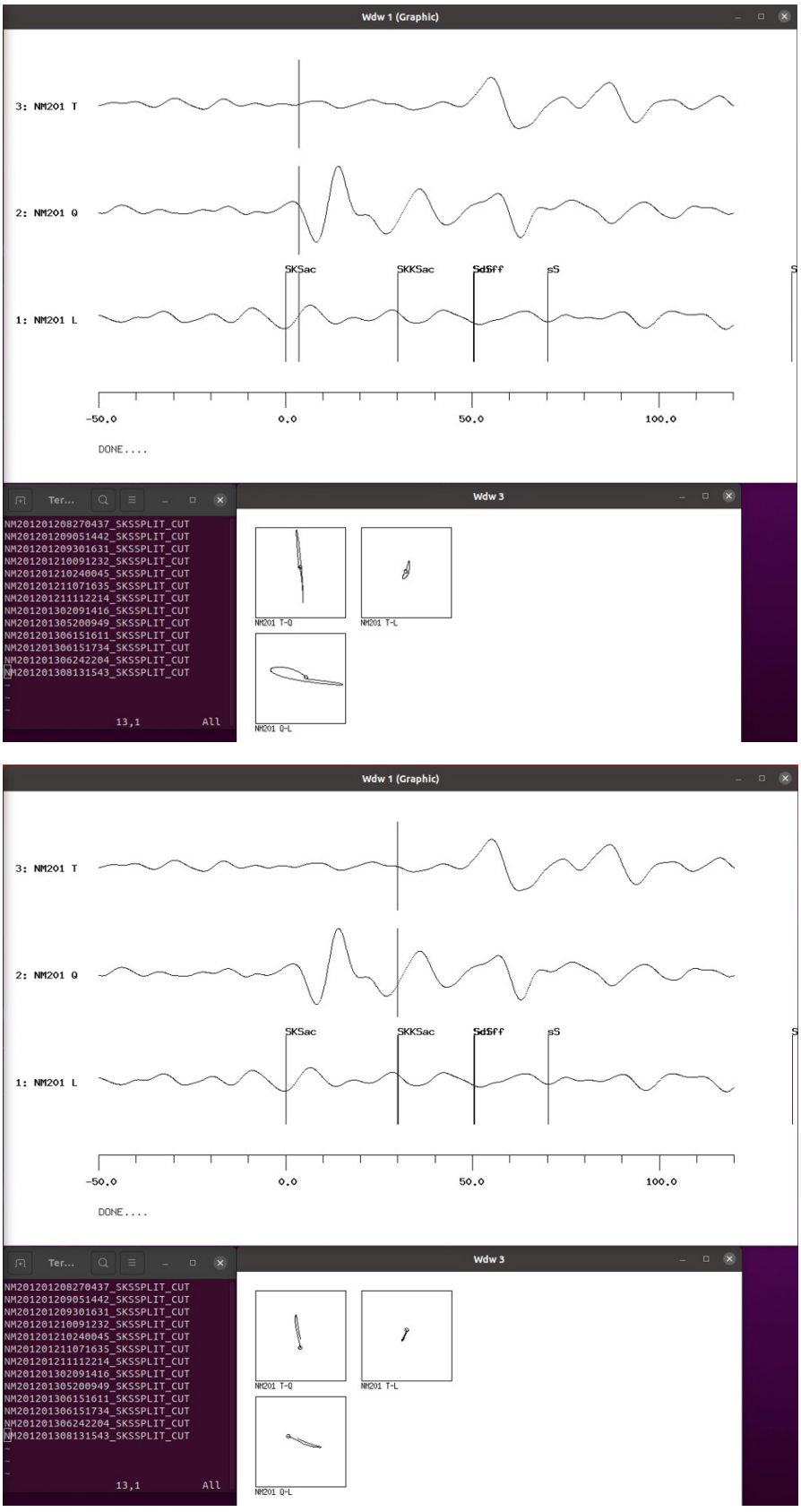





**Fig. 2** Examples of SK(K)S waveforms and particle motions. Station NM01. Event 2012-11-07 16:35, magnitude 7.4, distance 98.1, back azimuth 64.6, depth 18.6 km. The components are actually ZRT (not LQT as indicated on the plots).

**4. Acknowledgement**

I am very grateful to the University of Tokyo, and the Earthquake Research Institute, Professor Baba, and the staff at the International Office for giving me the opportunity to do research in one of the World's leading institutes for seismology.

**Data availability**

All of the waveform data used in this study are publicly available at OHPDMC (http://ohpdmc.eri.u-tokyo.ac.jp).

**References**

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Sincerely,

Wolfram Geissler