T51F-0358

Investigation of Phase-Converted Seismic Waves at the Hikurangi Plate Interface, New Zealand

Mel Zhang[1,2] (melody.zhang@colorado.edu), Anne F. Sheehan[1,2], Jefferson Yarce[1,2]

[1]Department of Geological Sciences, University of Colorado, Boulder [2]Cooperative Institute for Research in Environmental Sciences (CIRES)

1. Project Goals

- Use local earthquakes recorded on HOBITSS and Geonet stations to identify seismic waves converted from S to P phases at the slab interface from local earthquakes at the Hikurangi subduction margin.
- Use **S-to-P (referred to hereafter as Sp)** arrivals to infer characteristics of the subducting slab, such as whether conversions correlate with high Vp/Vs gradients across the slab interface.
- Investigate the relationship between regions of slow slip (defined in **Section 2**), regions where Sp conversions prevail, and the corresponding Vp/Vs values of the slab interface.

2. Introduction

In the northern Hikurangi subduction margin, aseismic slip events known as **slow slip events (SSEs)** occur approximately every 18-24 months with a long duration (weeks to months), and have been shown to cause several centimeters of displacement both onshore and offshore. SSEs constitute the elastic rebound portion of slip behavior, but are in "slow motion" relative to fast slip, and do not produce earthquakes (*Wallace et al., 2014*).

The one-year-long Hikurangi Ocean Bottom Investigation of Tremor and Slow Slip (HOBITSS) was a deployment of 25 ocean bottom seismometers and pressure gauges offshore New Zealand from May 2014 – June 2015. In our work we combine earthquake data from New Zealand's permanent GeoNet on-land seismic network as well as **ocean-bottom seismometers (OBSs).**

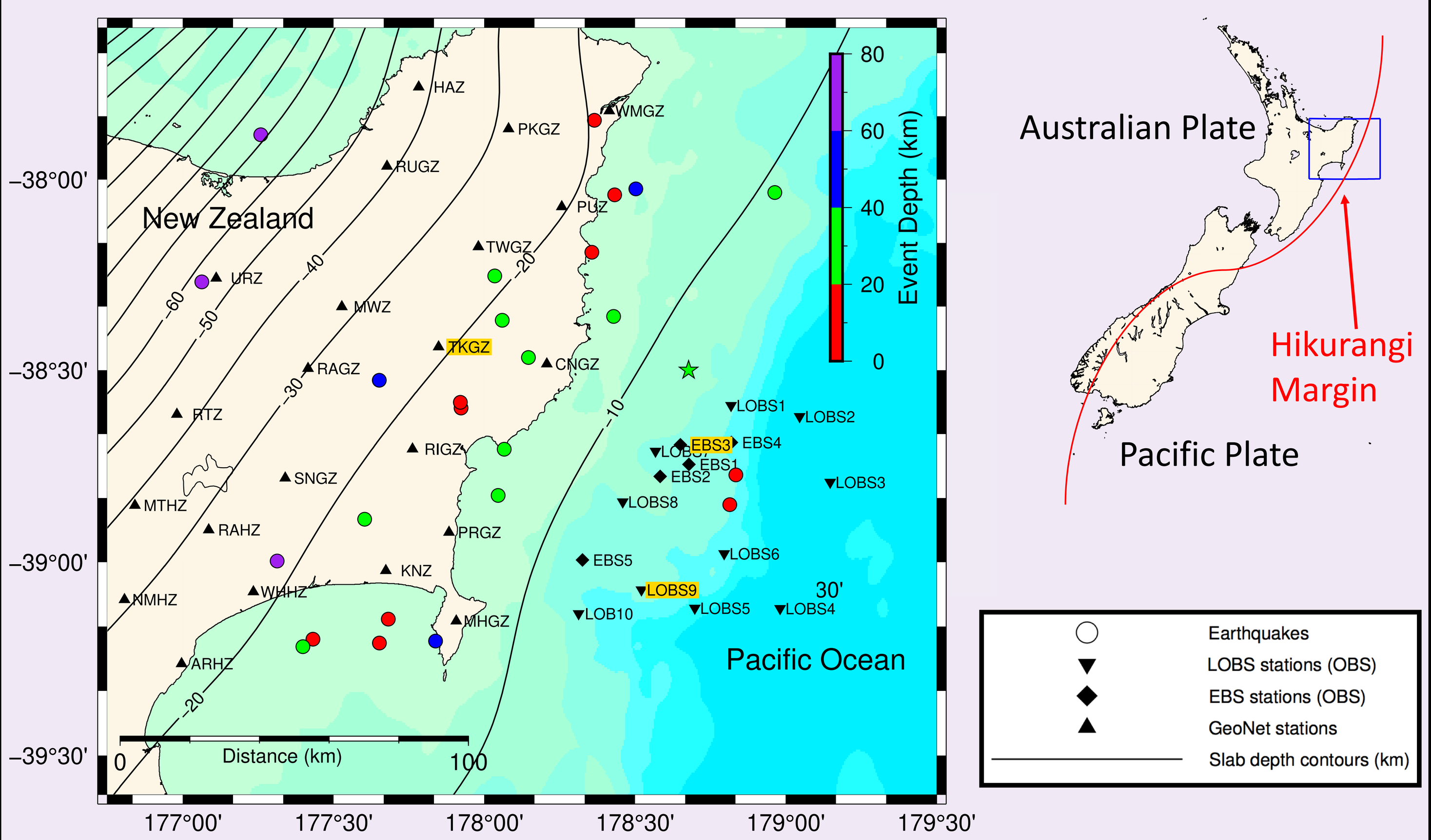


Figure 1. Study area offshore New Zealand's north island. Blue box on subset map indicates study area in main map. Highlighted stations are referenced in **Sections 5 & 6**. Magnitude 3.1-4.7 earthquakes used in this study shown by circles and color-coded by depth. Land and ocean seismometers denoted by station name and symbol. Green star is a 2010 pre-HOBITSS event referenced in **Section 6.**

Dozens of SSEs have been observed in the area offshore the North Island of New Zealand in the past twenty years (*Yarce et al., 2019*).

- SSEs have expanded our scientific understanding of subduction zones beyond earthquake-producing slip events. However, there is not yet a consensus opinion to explain the mechanisms that lead to slow slip behavior.
- Sp conversions found to correlate with high Vp/Vs gradients may suggest that presence of fluids plays a role in slow slip.

3. Data and Methods

Seismic Waveform Data

- 25 local slab earthquakes ranging from M 3.1-4.7 recorded on HOBITSS instruments (error margin of 2 km horizontally; 5 km for depth (*Yarce et al., 2019*))
- GeoNet local earthquake data obtained from land stations operating pre- and post-HOBITSS time frame

Data Processing

- Seismograms bandpass-filtered between 2-8 Hz
- Visual comparison of three-component seismometer data from events within as well as outside of HOBITSS project timeline
- Multiple events recorded at one station were plotted by epicentral distance from receiver to identify possible Sp arrival patterns (**Sections 5 & 6**).

4. Sp Wave Conversion

- Body waves may be converted to different phases when encountering a boundary across which there is a difference in Vp, Vs or density.
- Sp phases arrive between the P and S arrivals and are polarized in the P-SV plane, typically showing up best on the vertical components.
- In our study of Sp arrivals from local earthquakes, the most discernible converting boundary is the slab interface of the subducting oceanic plate.

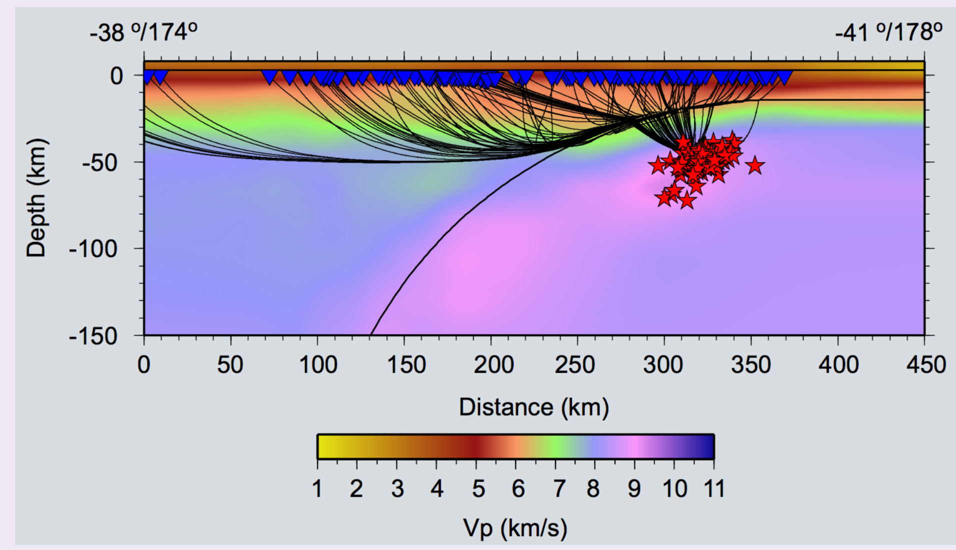


***Figure 2**, from Bourguignon et al., 2013.* Cross-section through Eberhart-Phillips (2017) velocity model showing slab interface, hypocenters for earthquakes (red stars) and possible Sp raypaths to stations (blue triangles).

5. Ocean-Bottom Seismometers (OBSs)

The HOBITSS experiment included 15 total OBS with records obtained across both the continental and oceanic sections of the subducting slab.

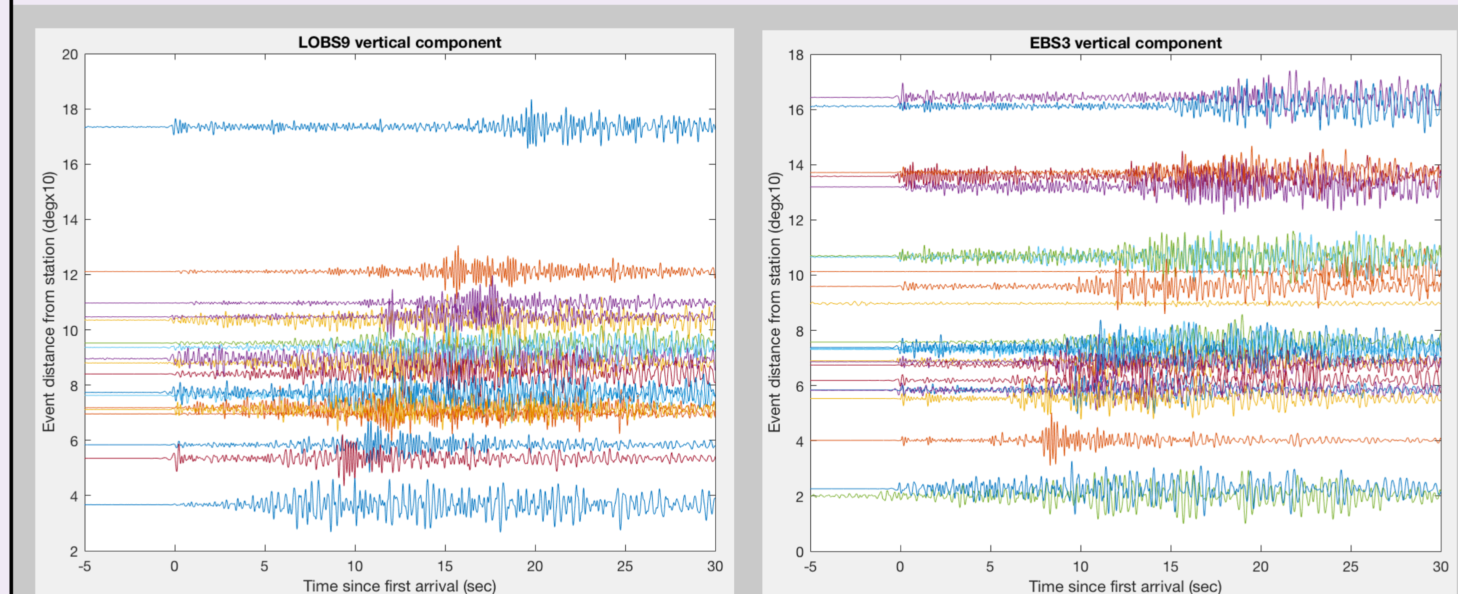
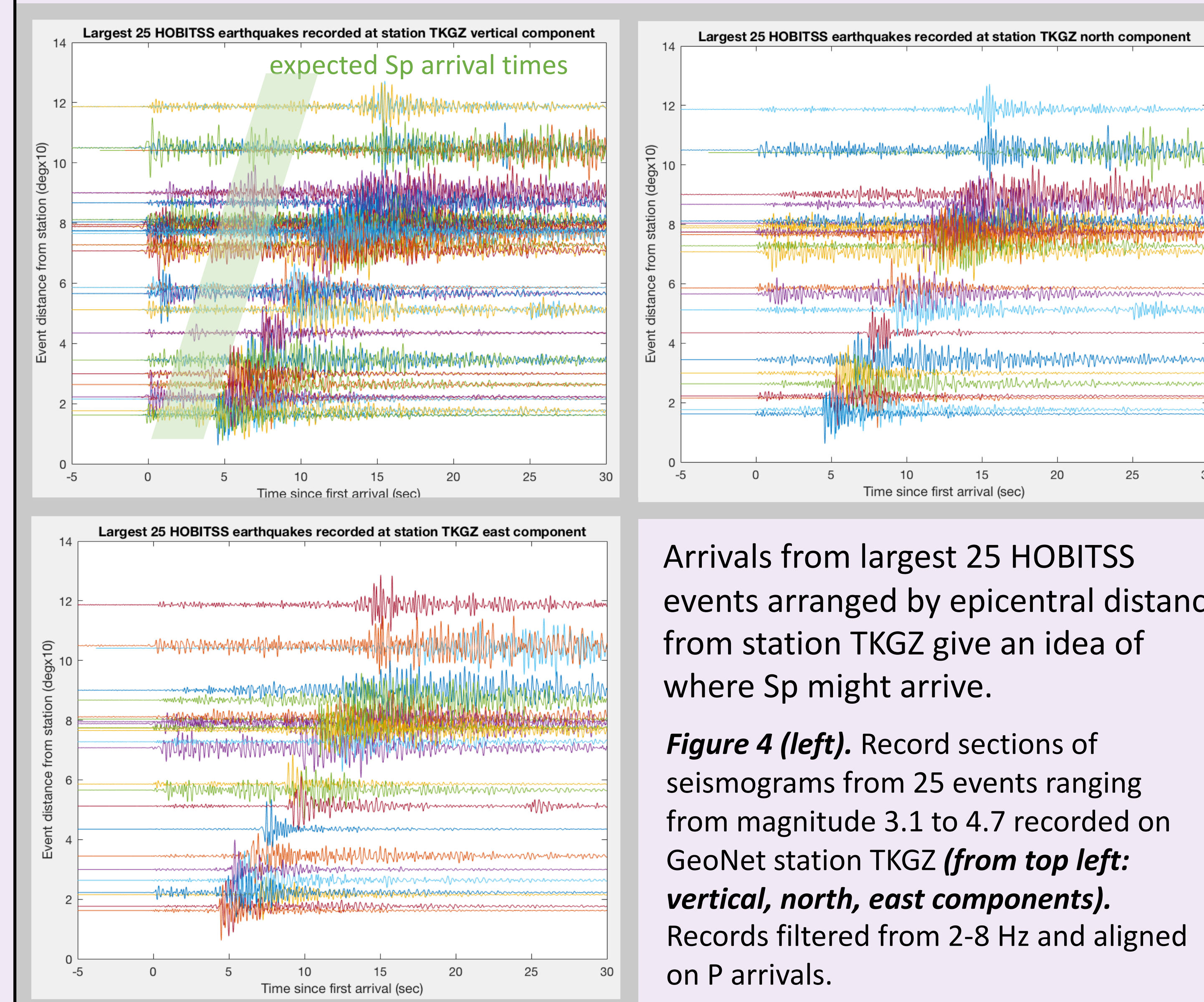


Figure 3. (left) Vertical record section from HOBITSS Lamont broadband OBS station LOBS9. ***(right)*** Vertical record section from HOBITSS ERI (Earthquake Research Institute, Univ. Tokyo) short-period OBS station EBS3. Waveforms filtered from 2-8 Hz and aligned on direct P arrival. OBS locations as indicated in ***Fig. 1.***

- On the OBSs we have not yet positively identified Sp arrivals based on visual inspection. Envelope methods such as those employed by Eberhart-Phillips & Reyners (1999) and Bourguignon et al. (2013) may help enhance these small arrivals.
- The use of OBSs give us a unique opportunity to better resolve the oceanic section of the subducting slab.

6. Results

As most events occur beneath the slab interface rather than above it (***Figs. 1, 2***), we hypothesize that the slab interface itself would be the cause of any recorded converted signals. Preliminary results from 1-D modeling in Tau-P suggests this as well. 3-D modeling is expected to yield further results.



Arrivals from largest 25 HOBITSS events arranged by epicentral distance from station TKGZ give an idea of where Sp might arrive.

Figure 4 (left). Record sections of seismograms from 25 events ranging from magnitude 3.1 to 4.7 recorded on GeoNet station TKGZ ***(from top left: vertical, north, east components).*** Records filtered from 2-8 Hz and aligned on P arrivals.

Pre-HOBITSS Land Station Data

- Visual inspection of pre-HOBITSS seismograms obtained from GeoNet land stations reveal Sp arrivals on vertical components.
- We plan to further explore data from pre- and post-HOBITSS to expand the dataset of Sp arrivals.

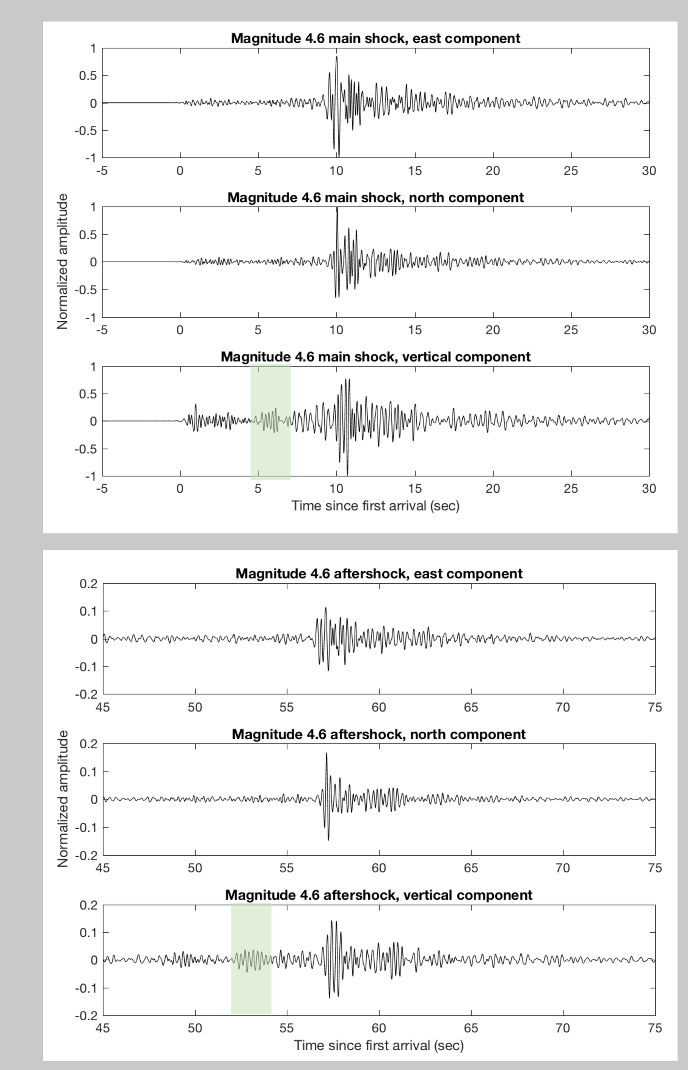


Figure 5 (right). Normalized GeoNet seismograms from a pre-HOBITSS local M 4.6 event (marked by green star in ***Fig. 1***). ***(top)*** Main event; ***(bottom)*** Aftershock. Identifiable Sp arrivals on vertical component marked by vertical shaded green lines. Records filtered from 2-8 Hz and aligned on P arrivals.

7. Future Work

- Use of FMTOMO (fast marching method) and the 2017 Eberhart-Phillips velocity model for 3D modeling of converted waves in the northern Hikurangi region to output expected Sp arrival times from the slab interface
- Use stacking and envelope functions to enhance small arrivals
- Calculate synthetic seismograms to compare with observations
- Identify regions of the plate margin which have stronger degrees of wave conversion relative to others
- Identify whether a relationship exists between locations of slow slip, Sp conversion, and change in Vp/Vs across the slab interface

Acknowledgments: We thank Hongda Wang, Kyren Bogolub, and Steven Plescia of University of Colorado, Boulder for their contributions of code for use in data analysis; the PI team of HOBITSS for making their ocean bottom seismic waveform data available via the IRIS DMC; GeoNet and its sponsors EQC, GNS Science, and LINZ that provided the land seismic data in this study. This work was supported by NSF Award 1551922.

References

- **Bourguignon, S.,** Bannister, S., Reyners, M. (2013). Heterogeneity of the Hikurangi plate interface from seismic S-to-P converted phases. In: Reid, C.M and Wandres, A. (eds). Abstracts, Geosciences 2013 Conference, Christchurch, New Zealand. *Geoscience Society of New Zealand Miscellaneous Publication 136A.*
- **Eberhart-Phillips, D., & Reyners, M.** (1999). Plate interface properties in the northeast Hikurangi subduction zone, New Zealand, from converted seismic waves. *Geophysical Research Letters, 26*(16), 2565-2568.
- **Eberhart-Phillips, D.,** Bannister, S., & Reyners, M. (2017). New Zealand-wide model 2.1, seismic velocity model for New Zealand (Version 2.1) [Data set]. Zenodo.org.
- **Helffrich, G., & Abers, G. A.** (1997). Slab low-velocity layer in the eastern Aleutian subduction zone. *Geophysical Journal International, 130*(3), 640-648.
- **Wallace, L. M.,** Webb, S. C., Ito, Y., Mochizuki, K., Hino, R., Henrys, S.A., Schwartz, S.Y., Sheehan, A. F. (2016). Slow slip near the trench at the Hikurangi subduction zone, New Zealand. *Science, 352*(6286), 701-704.
- **Williams, C.A.,** Eberhart-Phillips, D., Bannister, S., Barker, D., Henrys, S., Reyners, M., Sutherland, R. (2013). Revised interface geometry for the Hikurangi subduction zone, New Zealand. *Geophysical Research Letters*, 84, 1066-1073
- **Yarce, J.,** Sheehan, A.F., Nakai, J.S., Schwartz, S.Y., Mochizuki, K., Savage, M.K., Wallace, L.M., Henrys, S.A., Webb, S.C., Ito, Y., Abercrombie, R.E., Fry, B., Shaddox, H., Todd, E.K. (2019). Seismicity at the northern Hikurangi Margin, New Zealand, and investigation of the potential spatial and temporal relationships with a shallow slow slip event. *Journal of Geophys. Res.: Solid Earth*, 124, 4751– 4766.