Evidence of a slab of subducted lithosphere beneath central Taiwan from teleseismic S waves

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ABSTRACT

Knowing whether there is a slab of subducted lithosphere beneath central Taiwan is important for our understanding of the regional tectonic evolution. Seismic waves propagating through a slab exhibit earlier arrivals, small amplitudes, and broader waveforms. We investigate the slab signatures of S waves from deep and intermediate-depth earthquakes in the Tonga-Kermadec subduction zone. The Generic Array Processing software package is used to extract S waves from BATS array. The genetic algorithm is applied for cross-correlating the S waveforms to determine the differential residual times for each BATS station. Results show that S waves exhibit stronger travel time reductions than those of P waves for central Taiwan stations. The crustal effects can be proved to be insignificant by the observations of PKPdf.

Introduction

In previous study, Chen et al. (2004) shows that first arrival P waves from Tonga-Kermadec deep and intermediate-depth earthquakes exhibit reduced amplitudes and travel times for central Taiwan stations relative to KMNB, consistent with the effects of an eastern dipping aseismic slab. The tomographic study also finds similar evidence (Wang et al., 2006). In this following-up study, we investigate the slab signatures of S waves for earthquakes from the same subduction zones because S waves are more sensitive than P waves to thermal anomalies caused by slab. As a result, we observed that the travel time reductions of S waves are more significant than those of P waves for central Taiwan stations. We also analyze the differential residual times of PKPdf phase from deep and intermediate-depth earthquakes in the Nazca subduction zone. Results show that the nearly vertical incident PKPdf phases do not show travel time reductions for central Taiwan stations. Therefore, the observations of Tonga-Kermadec earthquakes are caused by mantle heterogeneities.

Methodology

Although several other phases arrive around the time window of S waves, the use of seismic array help us identify S waves without doubt by providing the horizontal slowness constraint (Figure 1). The Generic Array Processing (GAP) software package (Koper, 2005) is a convenient tool to process the SAC format BATS data. The teleseismic signals are often filtered with 0.01 to 0.3 frequency band. For the targeted phase, the theoretic travel times to each BATS station are calculated and corrected using iasp91 model. If there is no differential residual times (DRTS), the phase signals of BATS stations would align in a vertical line at this stage. The slight deviation from a vertical line is the DRTS that we wish to obtain. We apply genetic algorithm (GA) to simultaneously determining the relative time shifts of all stations by minimizing the sum of cross-correlation of all station pairs. The initial population size of GA is 300 and run for 3000 generations. The GA is done a decent job in this respect (Figure 2). Compared with the conventional cross-correlation method, the GA approach avoids the drawback of depending heavily on the reference trace. We referred the method of GA to Chen et al. (2006) and references therein.

Results

We have selected six events from the Tonga-Kermadec subduction zone and five events from the Nazca subduction zone. DRTS of P and S wave are obtained for the former group, while those of PKPdf wave are obtained for the latter group. Figure 3 shows that the travel time reductions of P waves range between from -0.5 to -2.0 secs for central Taiwan stations, consistent with previous study (Chen et al., 2004). Furthermore, those of S waves exhibit even more reductions ranging from -0.5 to -4.5 secs, consistent with the idea that S waves are more sensitive to slab signature. On the other hand, those of PKPdf from the Nazca events do not show travel time reductions, demonstrating that the crustal effects won't cause the reduction in travel times. Future study is to measure the amplitudes of S waves compared with that of KMNB.

References

Chen, P.-F., B. S. Huang and W. T. Liang, 2001: Evidence of a slab of subducted lithosphere beneath central Taiwan from seismic waveforms and travel times, *Earth Planet. Sci. Lett*., 229, 61-71.

Chen, P.-F., L. Y. Chiao, P. H. Huang, Y. J. Yang and L. G. Liu, 2006: Elasticity of magnesite and dolomite from a genetic algorithm for inverting Brillouin spectroscopy measurements, *Phys. Earth Planet. Inter.,* 155 (1-2), pp. 73-86.

Koper, K. D., 2005: The Generic Array Processing (GAP) Software Package, SSA, Lake Tahoe, NV.

Wang, Z., D. P. Zhao, J. Wang and H. Kao, 2006: Tomographic evidence for the Eurasian lithosphere subducting beneath south Taiwan, Geophys. Res. Lett. 33(18), Art. No. L18306.

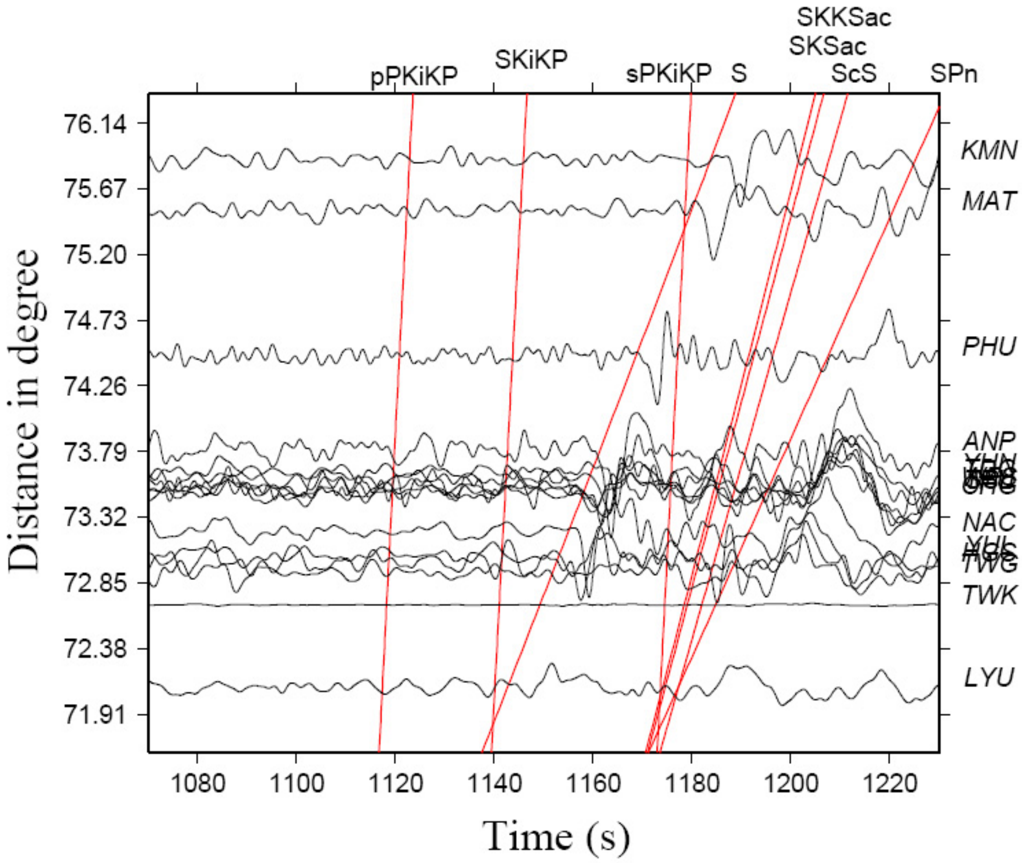

Figure 1. Time window around S waves of a typical Tonga_Kermadec event (radial component). The array data are helpful in identifying certain phases.

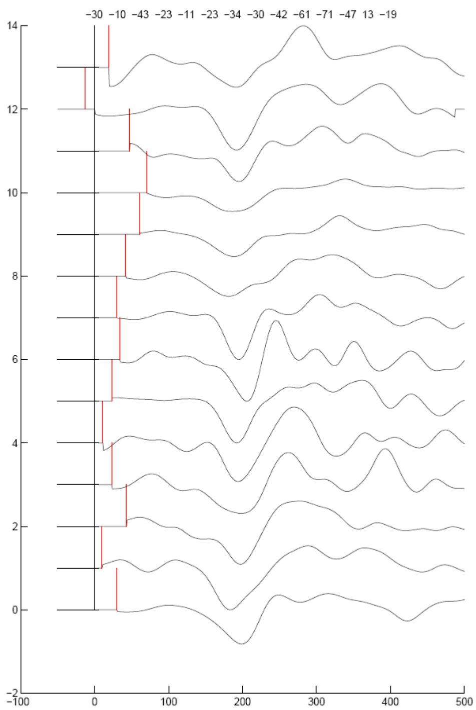

Figure 2. Results of cross-correlation by GA.

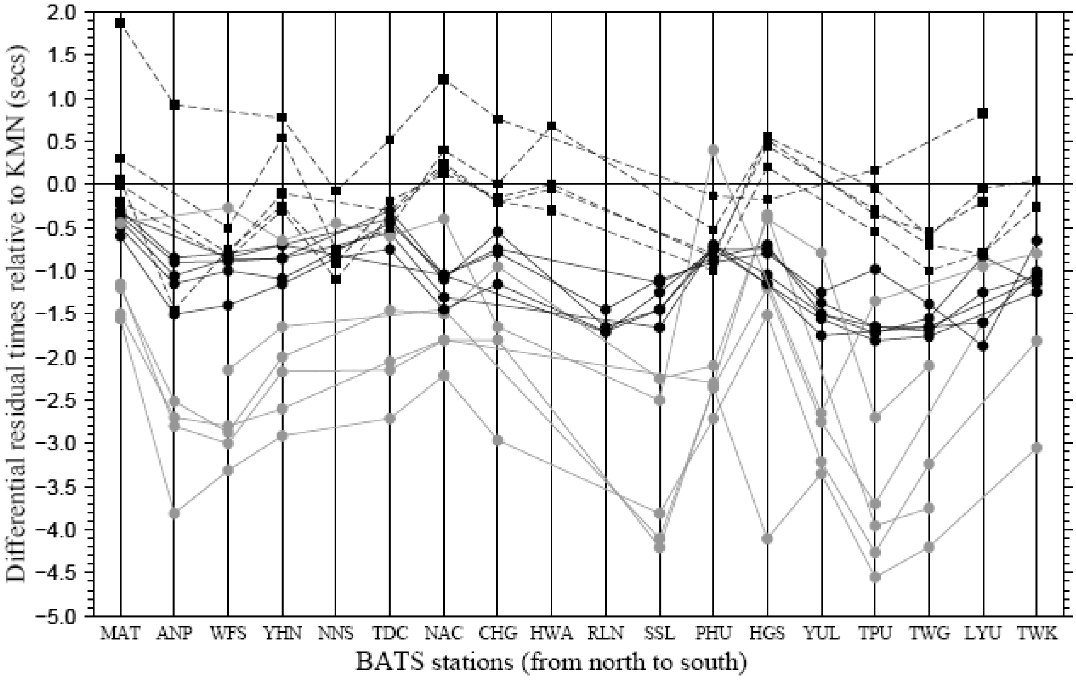

Figure 3. DRTS for three phases. Black circles and gray circles are P and S of the Tonga-Kermadec events, respectively. Black squares are PKPdf of the Nazca event. Data of one phase in the same event are connected.