

The Synthetic Earthquake Waveform Computation using the Direct Solution Method with Anomalous Layers in the Lowermost Mantle Structure



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Abstract

Understanding seismic wave behaviors in the lowermost mantle is crucial for interpreting Earth's deep structure. This region exhibits complex seismic properties, including variations in wave velocities that affect wave propagation through mechanisms such as reflection, refraction, and scattering. This study investigates how seismic S-wave phases (S, ScS, and SKS) interact with anomalous layers located 0–100 km and 300–400 km above the core-mantle boundary (CMB). By using the Direct Solution Method (DSM) and the Preliminary Reference Earth Model (PREM), synthetic waveforms were generated to analyze amplitude variations caused by these anomalous layers. A synthetic earthquake with a normal fault focal mechanism was modeled at a depth of 350 km. Seismic waves were examined at station distance angles of -75, -85, -95, 75, 85, and 95 degrees across a frequency range of 0.005 to 0.1 Hz. Velocity anomalies ranging from -3% to 3% were introduced into the lowermost mantle to assess their effect on wave behavior. The results reveal that S-wave phases exhibit significant amplitude increases when interacting with anomalous layers, particularly in the transverse and radial seismic components. In contrast, when the lowermost mantle is homogeneous, the amplitude and velocity of seismic waves remain unchanged. Note that the ScS phase, which reflects off the CMB, exhibits the most pronounced amplitude variations. The anomalous layers at 0–100 km above the CMB generate stronger amplitude responses than those at 300–400 km depth, influenced by factors such as the distance angle from the earthquake focus to the seismic receiver and the reflection energy of each seismic phase. This study reveals the role of velocity anomalies in shaping seismic wave characteristics, providing deeper insights into wave propagation through the lowermost mantle that contributes to a better understanding of the structural complexity of the Earth's deep interior.

Introduction

This research explores how anomalous layers in the lowermost mantle affect seismic wave propagation. Using DSM by Geller and Takeuchi (1995), we simulate synthetic waveforms to study S-wave behavior. We focus on S, ScS, and SKS phases and their interaction with anomalous layers above the CMB, aiming to understand wave travel time and behavior.

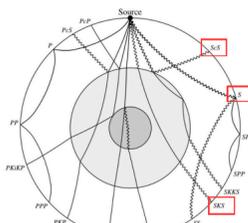


Figure 1 Global seismic ray paths and phase names of the seismic wave phases that pass in the interior earth structure (Shearer, et al., 2009) red frame is the focus phases.

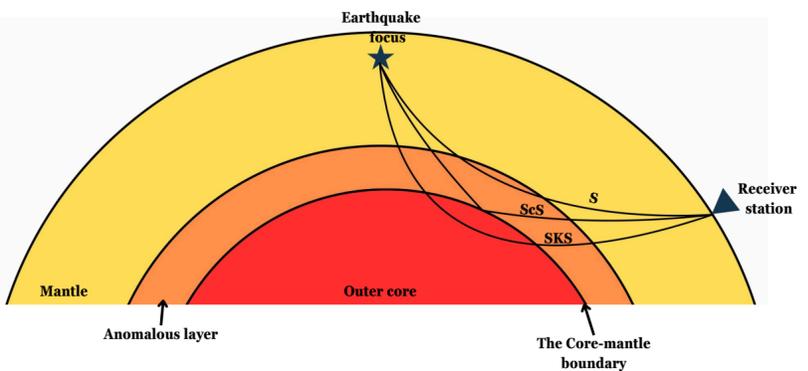


Figure 2 The motion behavior of the S, ScS, and SKS phases when path through an anomalous layer in the lowermost mantle

Objectives

- To construct the synthetic waveforms of S, ScS, and SKS phases on a seismograph using the Direct Solution Method (DSM).
- To analyze the distinct waveforms of each computed phase in the presence of anomalous layers in the lowermost mantle.
- To investigate the motion behavior of the 3 phases of the s wave that travels through the lowermost mantle when adding the anomalous layers in the lowermost mantle.

Methodology

Parameters use in this study use the coordinate earthquake location is in Latitude 0, Longitude 0, with a focus at 350 km depth. Frequency Range is 0.005 to 0.1 Hz. The anomalous Layers at Depths of 0-100 km and 300-400 km above the CMB with velocity anomalies of -3% to +3%. Waveform generating in three components of shaking direction: radial (R), transverse (T), and vertical (Z) components of the distance epicentral angle are -95, -85, -75, 75, 85, and 95 degrees.

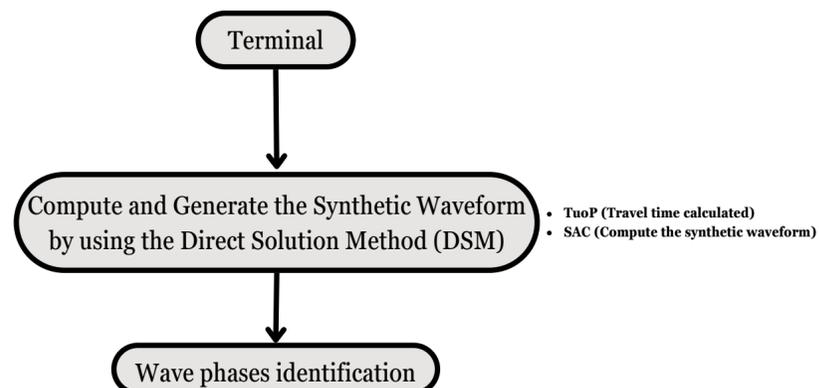
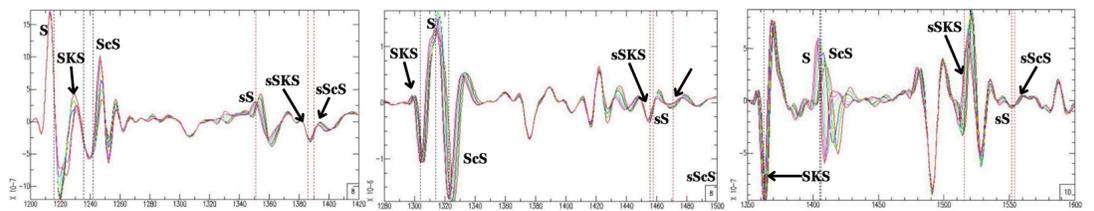


Figure 3 Flow chart represent the progress of the methodology part to compute the synthetic waveform

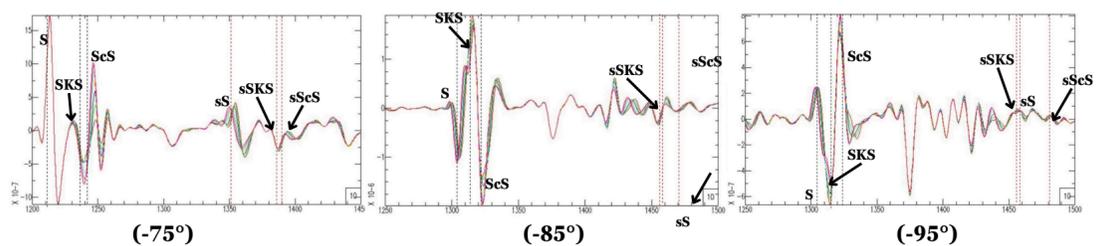
Results

- The results of the radial component (R) at a depth of 300-400 km depth compare to 0-100 km depth above the core-mantle boundary when added anomalous velocity of -3 to 3 percent.

At 300-400 km depth above the core-mantle boundary

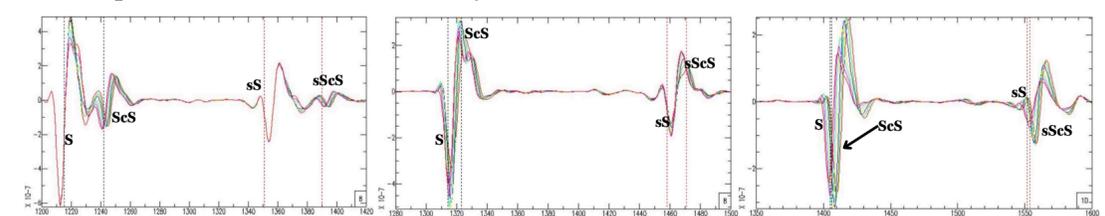


At 0-100 km depth above the core-mantle boundary

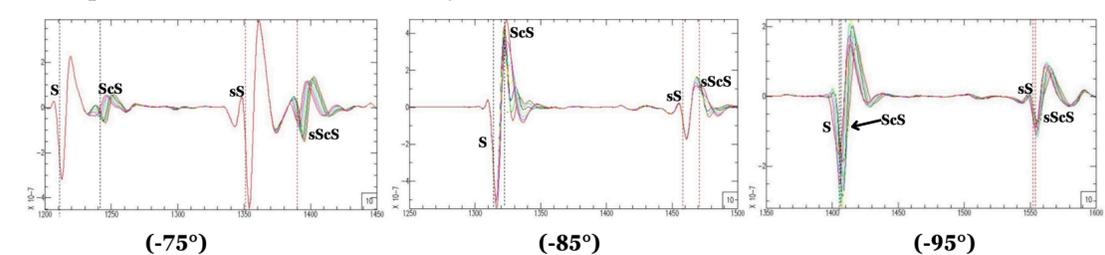


- The results of the transverse component (T) at a depth of 300-400 km depth compare to 0-100 km depth above the core-mantle boundary when added anomalous velocity of -3 to 3 percent.

At 300-400 km depth above the core-mantle boundary



At 0-100 km depth above the core-mantle boundary



Conclusions

- Anomalous layers at 0-100 km and 300-400 km above the CMB significantly impact amplitude and travel time of seismic waves.
- Radial and transverse components show higher amplitudes in anomalous layers.
- Velocity and amplitude changes are due to velocity contrasts.

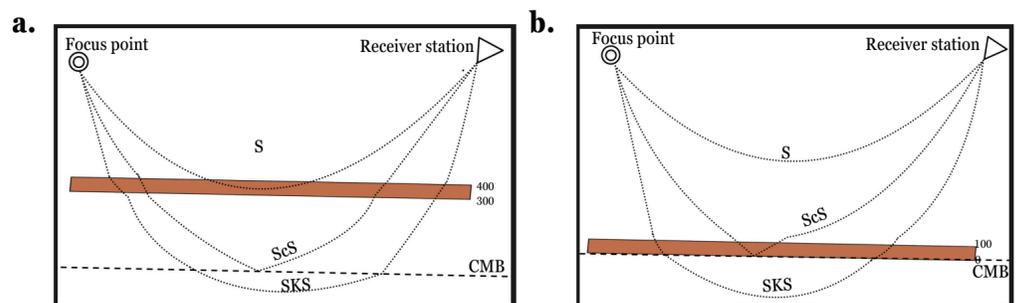


Figure 4 a. and b. The model of seismic motion behavior of the three seismic wave phases: S, ScS, and SKS propagating through an anomalous layer overlying the core-mantle boundary (CMB) (a.) at 300-400 km (b.) at 0-100 km.

References

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Acknowledgement

I thank Kenji Kawai, Dr. Natchanai Doungkaew, Asst. Prof. Dr. Suwimon Udphuy, Mentor Keisuke Otsuru, Adul Yawichai, the 50th Anniversary Geology Fund, Chiang Mai University, the Department of Geological Sciences, Chiang Mai University.