異常強地動分布與隱沒帶導波效應之關係 High frequency waves guided by the subducted plates underneath Taiwan and their association with seismic intensity anomalies



陳卉瑄

Kate Huihsuan Chen

Department of Earth Sciences, National Taiwan Normal Univ., Taipei, Taiwan 台灣師大地球科學系

Brian Kennett²

2. Research School of Earth Sciences, The Australian National Univ., Canberra, Australia



3. Earthquake Research Institute, Univ. of Tokyo, Japan



隱沒帶地震具有複雜的波場特徵...



Mantle

日本北邊隱沒帶的異常震度圖





日本南邊隱沒帶的異常震度圖





在日本,震度異常與(1)地震波振幅的放大(2) 持續很久的高頻成分高度相關。 這種"挾帶隱沒板塊訊息"的地震波,同時亦告 訴我們隱沒帶的連續性與空間形貌。 Seismic events with guided wave characteristics can explain the anomalous ground shaking. They also provide useful information on the plate configuration.

弧前區域的特殊震波 – 隱沒帶導波

In Japan, such seismic waves guided by the high wave velocity and high Q plate lead to surprisingly large intensity in the forearc area, even if the events are not felt near the epicenter.

back arc stations

fore arc stations



如何解釋隱沒帶導波?



Utsu [1966]: dipping plate with high Q and high V gives the efficient propagation in the plate.

Abers [2000], Martin et al.[2003]: waveguide effect of high-f signals in the thin, low-V zone of former oceanic crust at the top of the plate.

Furumura and Kennett [2005]:

Multiple forward scattering of high-frequency signals in the heterogeneous plate is the main cause of the guiding of highfrequency signals with very long coda







The anomalous seismic intensity from intermediate-depth earthquakes should happen in Taiwan, if the subducted plates are acting as an efficient waveguide for high-frequency seismic waves.



Questions

• What are the characteristics of guided waves in Taiwan subduction zones?

台灣隱沒帶導波的特徵是甚麼?

• Under which conditions the guiding effect would cause anomalous seismic intensity?

這些特徵是否造成地表加速度異常?而其關係為何?



Guiding effect of subducted PSP vs. EP?



- 2. Patterns of PGA for events with apparent guiding
- The relation between the characteristics of the guided waves and subduction zone properties
- Continuity of subducted materials



PSP event

P event

24



DATA: 1991-2010 M>5 earthquakes



PSP events

Waveform characteristics: (1) low frequency precursor



Low-f P wave forerunner is clearly recognized in the radial and vertical motions with an offset of < 1 s prior to the high-f arrivals. But there is no clear low-f precursor in tangential motion.

Direct propagation of P waves from the source to the station along the great circle path

High frequency with long coda

Strong internal scattering of high-f signals due to heterogeneities in the plate

Waveform characteristics: (2) spectral ratio



Waveform characteristics: (2) spectral ratio

The elevated high frequency energy at some other stations is also found, which confirms the association with wave guide effect of the subducting slab instead of the localized site amplification effect.







Waveform characteristics: (4) low-frequency precursors

Time separation behaves differently at different stations.



(km)

focal depth

(5) Spatial distribution of guiding effect



(6) PGA pattern

Comparison of PGA pattern and the seismic characteristics implies that the abnormal intensity from intermediate-depth event is likely a result of excitation of high-frequency signals while propagating along the slab.



• Anomalous pattern occurred for the events deeper than ~60 km

EP events

Waveform characteristics: (1) low frequency precursor?



No clear low frequency precursor for deep events

The geometric path does not allow the low-f forerunner

High frequency with long coda Strong internal scattering of high-f signals due to heterogeneities in the plate

Waveform characteristics: (2) spectral ratio

The contrast between shallow and deep events is less striking compared with the PSP events



Waveform characteristics:(3) depth-frequent high-frequency content



(4) Spatial distribution of guiding effect





PGA patterns

• Anomalous pattern occurred for the events deeper than ~90 km



Comparison of PGA pattern and the seismic characteristics implies that the abnormal intensity from intermediate-depth event is likely a result of excitation of high-frequency signals while propagating along the slab.

Discussion: Characteristics of guided waves in Taiwan subduction zones?



4. guiding effects for the high-f signals are more striking



 4. guiding effects for the high-f signals are less striking



Under which conditions the guiding effect would cause anomalous seismic intensity?



How do they reflect the plate configurations?



Summary

- We demonstrate the presence of frequency selective wave propagation effect from the intermediate-depth earthquakes in PSP and EP.
- The higher frequency signal (4-10 Hz) can be amplified by a factor of a few hundred with longer than 10-s shaking due to guiding effect, which provides important information for hazard mitigation planning.
- Comparison of the PGA patterns and the seismic characteristics suggests that the abnormal intensity from intermediate-depth events is likely to be a result of excitation of high-frequency signals while propagating along the PSP/EP.
- The different guiding behavior from PSP and EP events seems to reflect the stronger scattering property in the PSP and different source-to-receiver geometry.
- By detection and quantification of the subduction zone guided waves, the geometry, thickness, velocity gradient, and heterogeneities of the plates can be further inferred through 2D and 3D finite-difference modeling and comparison with other subduction zones.