Imaging Crustal Structure of Southeast Asia from Seismic Noise

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Overview and Motivation

- Southeast Asia hosts one of the most complex tectonic process on Earth such as tsunamis, earthquakes, volcanoes etc.
- We apply full waveform seismic noise tomography across different domains of Australia and Indonesia to image crust and upper mantle.
- Various features some with high wavespeeds in Australia and largely with low wavespeeds in Indonesia were imaged.
- More data has been currently acquired in basin scale from recent campaigns in Indonesia to improve the model.
Dataset

- Large broadband seismic dataset (over 400 stations) from national networks of Indonesia, Australia and temporary deployments from the region.
Seismic Noise Cross-Correlations

- We use simultaneously recorded **seismic noise** at different seismic stations mainly originated from ocean and local noise.
- After applying a cross-correlation type operation, **Green’s Function**—$GF(t)$ between any two-stations can be retrieved, as if one station was acting as an impulsive source—$\delta(t)$ and other as source.
- We use these signals to probe the Earth.
Example Green’s Functions
Dispersion Measurements

We apply FTAN analysis for estimating traveltimes for all of the possible interstation pairs, and picked every dispersion curve manually.
Ray Path Velocities

AuSREM (Mantle) vs. Group velocities at 48 s

- Ray path velocities at 48 s show considerable similarity with AuSREM mantle (Kennett et al., 2013) velocities for events from 40°.
Travel Time Tomographic Imaging

Forward Part

- We use Rawlinson & Sambridge (2004) **Fast Marching Method** (FMM)
- FMM can track wavefronts propagating in a heterogeneous media.

\[ T = 20 \text{ s} \]
Group Velocity-Period Images

20 s

40 s
1-Compute the synthetic seismograms for given sources and receivers with 3D full elastic method.

2-Compare observed and synthetic waveforms for many source receiver pairs.

3-Apply Perturbations with Adjoint Fields to model then follow step 1-2 to reduce misfit.

4-After many iterations of steps 1-3, obtain Final Model.
Full Waveform Tomography-Example
Fichtner et al., 2013a & 2013b
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Computational Setup

- We use 3D simulations of elastic waves with spectral code of Fichtner et al., 2009. The computations are run in parallel utilizing 384 cores.
- Each simulation (forward part) takes about 6.5 hours.
- Starting model is based on Comprehensive Earth Model (Fichtner, 2012).
- The inversion is based on conjugate gradient method, where optimum step length is found via testing multiple lengths.
- Model pertubations are computed via Adjoint method.
- Data processing is handled via LASIF (Krischner et al., 2015).
Inversion
Starting Model

40 km

60 km

50 km

80 km
Model from $5^{th}$ Iteration

40 km

60 km

50 km

80 km
Model from 10\textsuperscript{th} Iteration

40 km

60 km

50 km

80 km
Current Model

40 km

60 km

50 km

80 km
First vs. Last

40 km

First

Last

80 km

First

Last
Interpretation
Many features have been imaged via 3D Full Waveform inversion of Green’s Functions retrieved from cross-correlations of seismic noise. More inversion steps will be conducted by increasing the bandwidth to image the shallow crust. The final model will be utilized in creating a definitive velocity model of the region.
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