Seismic Tomography of Peninsular Malaysia Inferred from Teleseismic Earthquake

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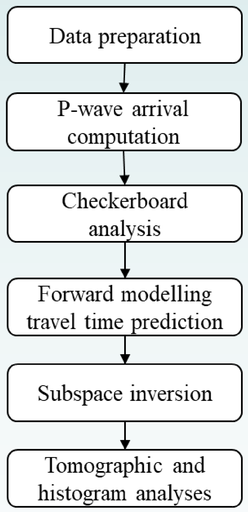
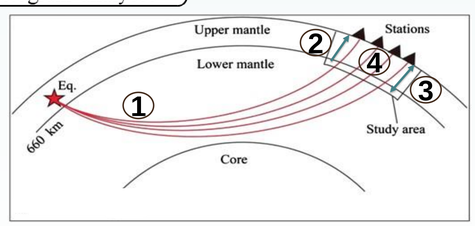
Introduction

- 3-D seismic tomography analysis is used for the study of the velocity characteristic up to crustal-mantle boundary layer.
- 3-D approach using teleseismic tomography analysis used the information obtained from earthquakes occurred at 30° to 90° away from the determined receiver in Peninsular Malaysia
- Tomography approach deals with P and S-waves arrival time residuals, instead of P and S-waves arrival times differences.
- From the arrival time residuals obtained, the subsurface image is determined as a result of P or S wave speed variations in the upper mantle beneath a particular seismic station.
- The integration of multiple stations produces a full 3-D image of the studied region, with respect to the wave speed variation in the depth domain.
- Throughout the tomography analysis, the 1-D ak135 global velocity model is used for computing the travel times from the earthquake source to the edge of the 3-D model

Methodology



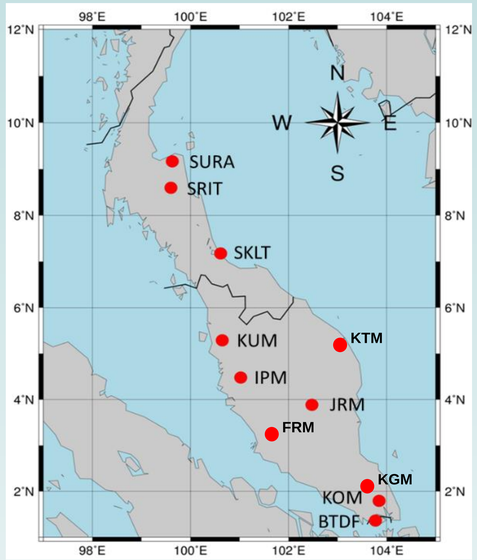
1) Compute P-waves travel-times from tele-seismic earthquake to the base of study area using ak135 velocity predictions
2) Compute travel-times from the base of model area to the receivers within the study region through Fast Marching Method (FMM).
3) Perform iterative linearized travel-time inversion until the model satisfy the data.
4) Output produced shows the P-wavespeed perturbation from a reference velocity model of a particular studied region.



Acknowledgements

I would like to thank FMTT Fortran 96 package (Rawlinson, 2008), UTP and USM for the permission to present and publish this research. The work conducted is supported by YUTP Fund (015LC0-309). I welcome any feedback and discussion on the topic. Main author can be contacted at **abdulhalim.alatiff@utp.edu.my**

Location Map

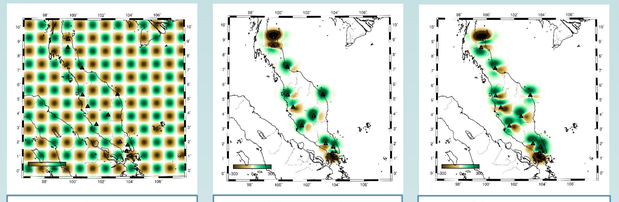


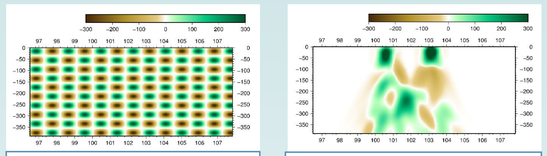
Phase 1: Data Acquisition

Station	Recorded Earthquakes (2005 - 2016)	Exceed SNR Criterion (ratio > 5.0)
IPM	889	421
KUM	937	440
BTDF	691	69
SRIT	278	28
KOM	894	308
JRM	109	43
SKLT	317	146
SURA	314	16
FRM	32	32
KTM	39	39
KGM	40	40

- Data acquired for this tomography analysis downloaded from ISC real-time sharing database, with the additional data obtained for JRM, KGM, KTM and FRM station were obtained with the permission of MMD.
- There were 1598 teleseismic earthquakes events recorded in between 2005 to 2016 which satisfy the criteria of 6.0 M_W or larger.
- In ensuring higher arrival time accuracy, the SNR larger than five criteria was applied which effectively eliminate almost half of the dataset. The remaining waveforms were qualitatively analysed and consequently picked for P-wave arrival using the SEISAN software

Phase 2: Checkerboard Test

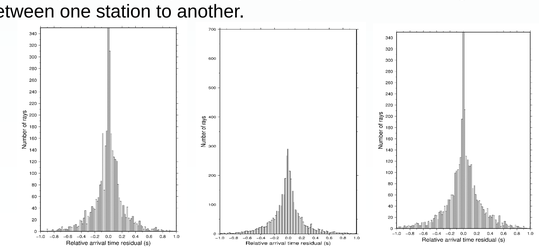




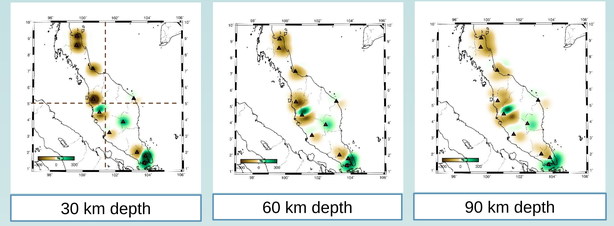
- To check model's sensitivity and reliability towards the external changes via a seven cycles of forward 7 inverse modelling iterations.
- Alternate high and low-velocity anomaly was set on the interval of 25 km (latitude) x 25 km (longitude) x 10 km (depth) initial velocity grid
- Synthetic reconstruction images show pattern of the checkerboard anomaly is properly recovered at depth of 30 km, 60 km and 90km with corresponding high and low wave speed
- Amplitudes for different depth levels are retrievable and is slightly underestimated, as a result of damped least squares solution effect.
- Relatively poor performance of the checkerboard attributed to the different path coverage between source and receiver, which is a function of the significant wave speed anomalies.

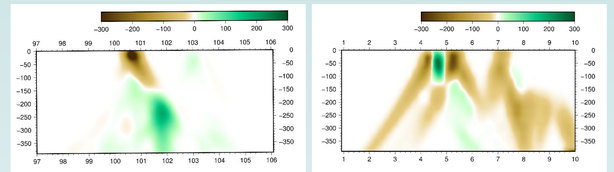
Phase 3: Subspace Inversion

- 3580 P-wave arrival time residuals used for the forward and inversion using FMTOMO iterative scheme
- Ak135 chosen as initial velocity model, ensure consistency with the checkerboard resolution analysis
- Inversion procedure conducted using seven iteration cycles of 20-dimensional subspace inversion scheme with damping and smoothing constants were fixed at ε=5.0 and η=10.0, respectively.
- 2 Velocity grids are tested: 50km x 50km x 10km & 25km x 25km x 10km grid.
- 50 km x 50 km grid yield a fewer comprehensive details and poor resolution result although significantly faster,
- Smaller grid spacing (<25km) is not possible due to large distance between one station to another.



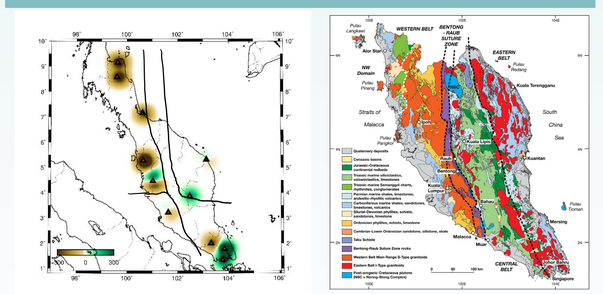
Tomography Maps





- Variation from fast to slow wave speed in Northwards trend.
- Earth's structure beneath the SRIT, SKLT, SURA, IPM and KUM stations are experiencing negative wave speed perturbation.
- Positive wave speed perturbation is recorded beneath JRM, KOM and BTDF stations.
- Pattern of faster velocity in the Southern region carried through to the uppermost mantle structure, i.e. > 70 km depth
- Significant changes of wave speed from faster to slower perturbation in the central region of the Malay Peninsula.
- Seismic velocity pattern changes at the central region of the Malay Peninsula (> 150 km), indicate the suture zone.

Conclusion



- Clear separation between Sibumasu and Indochina blocks.
- North-Western domain has specific velocity features.
- Slower P-wave speed deviation in North-Western domain of Malay Peninsula.
  - → Sedimentation of Semanggol formation consist of carboniferous marine shales that lower the seismic velocity.
- High velocity in Southern Peninsula due to granitoids blocks.
- This findings confirm on the surface geological study on Peninsula belts separation model.
- Significant geological differences in term of seismic wave velocity speed has been demonstrated.