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Effect of lateral heterogeneity of the earth on earthquake rupture imaging and 3D model based back projection

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ABSTRACT

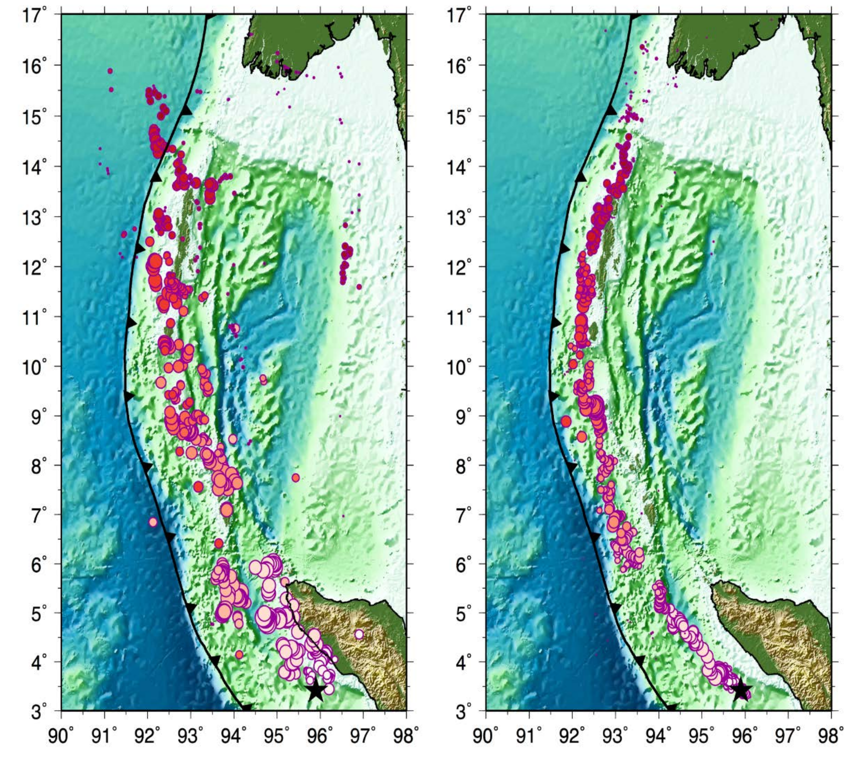
Conventional back-projection (BP) method uses 1-D earth model to image rupture process of earthquakes. This may result in discrepancies while using data from arrays with different azimuths. In our study, we integrate a 3-D earth model into BP method to obtain more consistent results when data from different arrays are used for a given earthquake.

MOTIVATION

For aligned data, the beamforming amplitude should be

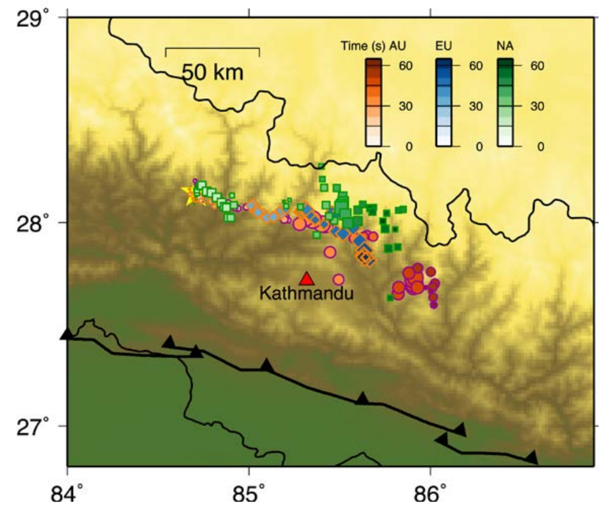
$$BP_m(t)=\sum_n(t+t_{mn}^{cal}-t_{0n}^{cal}+\delta t_{mn}-\delta t_{0n})$$

Here, m is the index of the m^{th} sub-source; n is the index of the n^{th} station.When the medium ray paths go through is homogeneous, the error term is zero.
If not, we have to figure out a method to minimize the error term, which means the predicted travel time difference term should be more accurate.



EU data HINET data

2004 Sumatra EQ



Meng et al(2015)

2015 Nepal EQ

Fig 1. Results of arrays with different azimuths show inconsistency.

METHOD

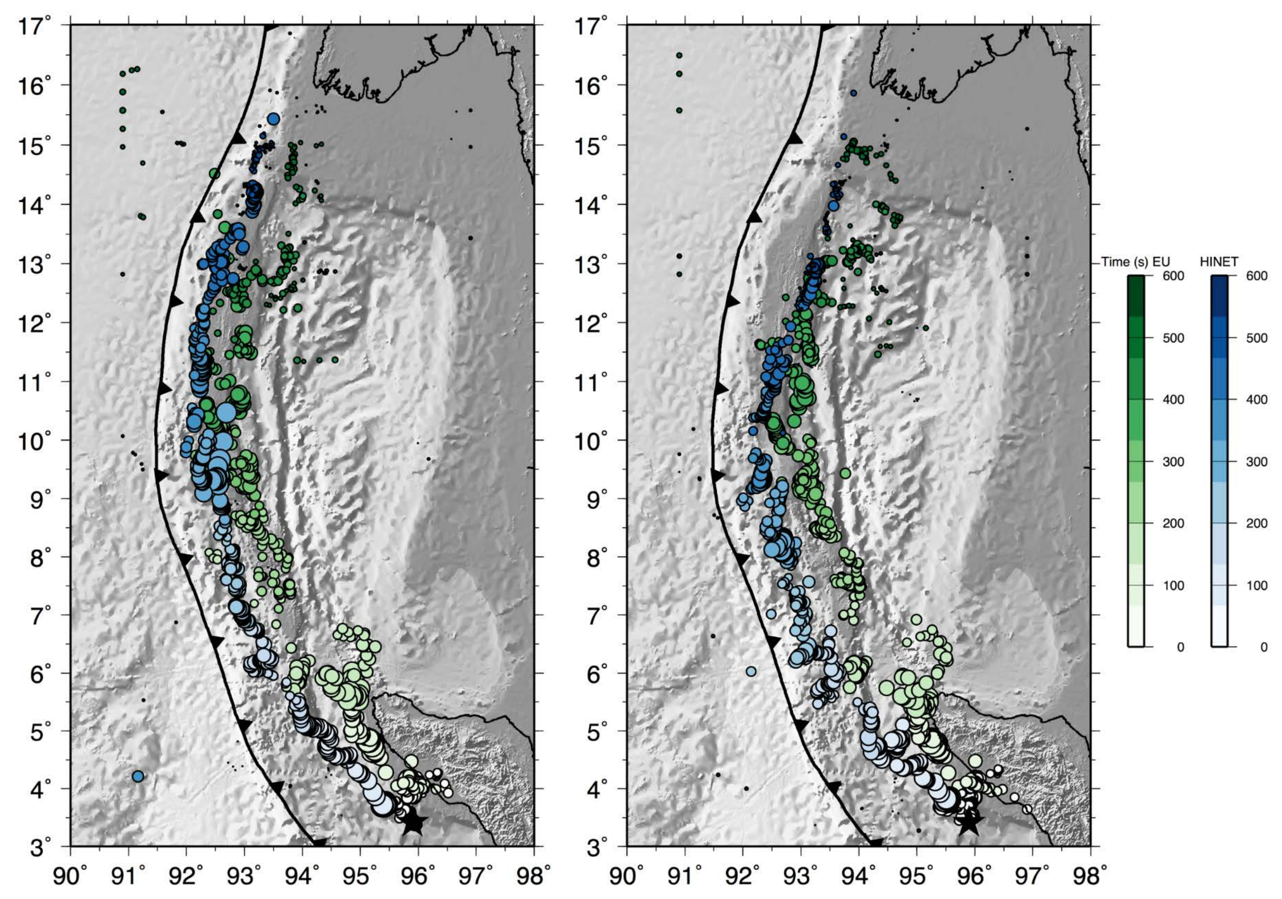
Previous methods: Using aftershocks to calibrate.

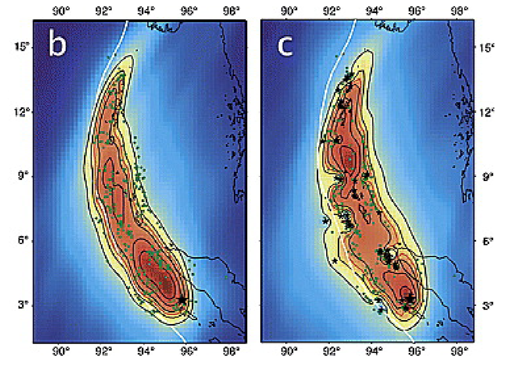
Meng et al. (2015) and Ishii et al. (2007)

Weaknesses:

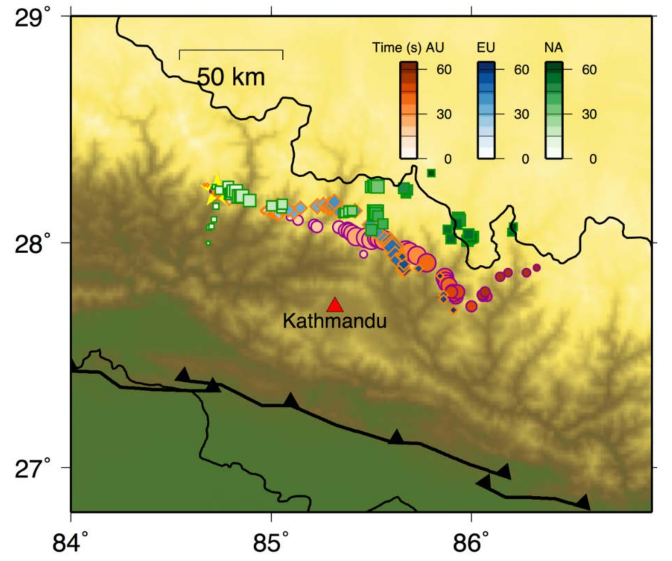
A. It relies on locations of aftershocks, which may not be accurate enough.
B. It always takes days or months to obtain sufficient aftershocks.
C. The area of a large coseismic zone is generally depleted of aftershocks large enough for BP analysis.

In our study, we use the LLNL-G3Dv3 model (Simmons, et al. 2012), a global 3-D seismic tomography, as our known earth model, to predict travel time.

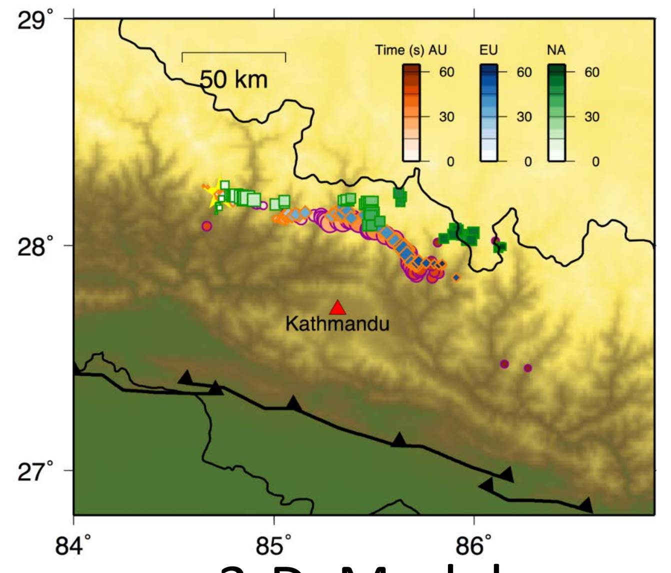




Ishii et al(2007)



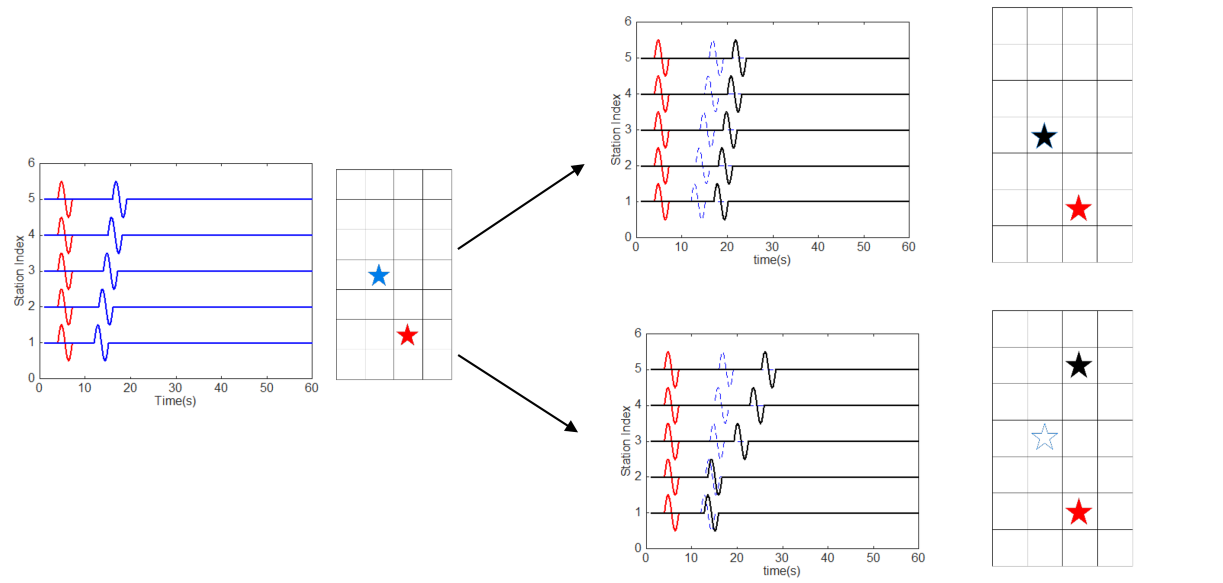
1-D Model

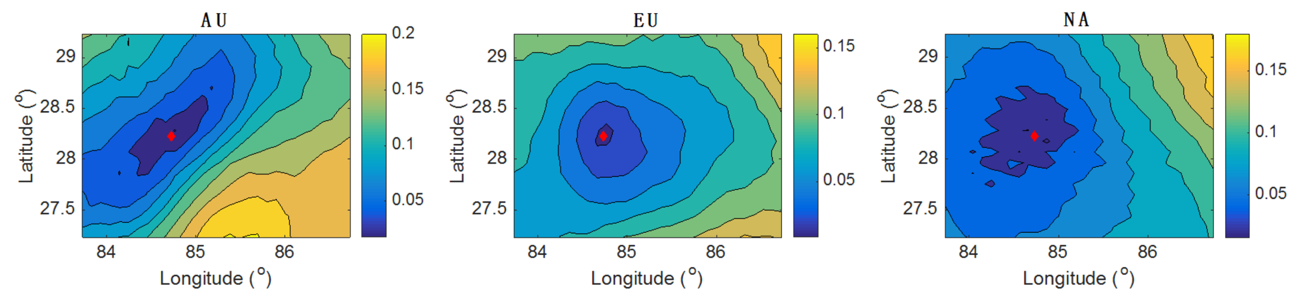


3-D Model

Fig 2. For these two cases respectively, after the calibration with 3-D earth model, results of different arrays are more consistent with each other.

DISCUSSION





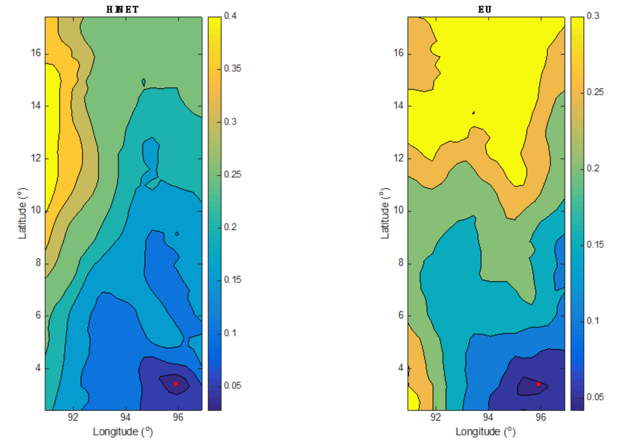
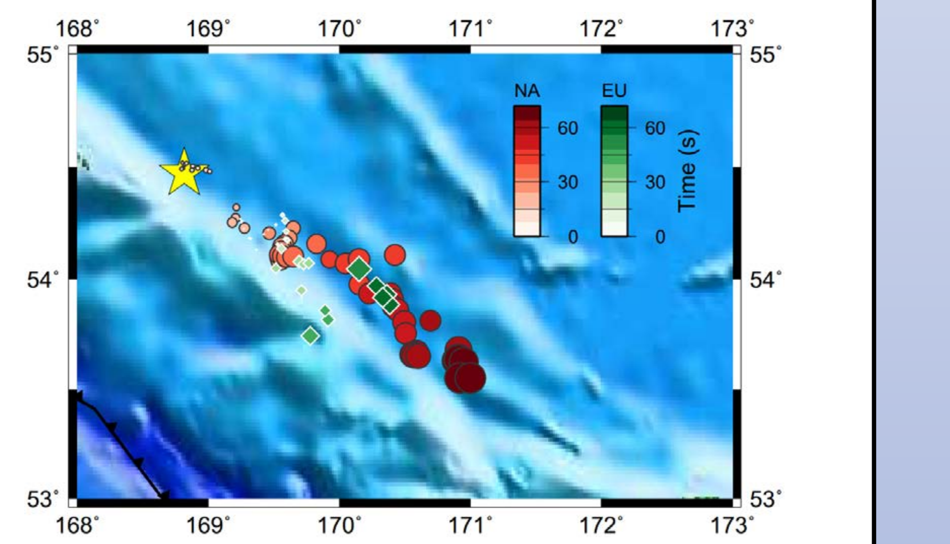


Fig. 3 Standard deviation of $(t_{mn}^{3d}-t_{0n}^{3d})-(t_{mn}^{1d}-t_{0n}^{1d})$,

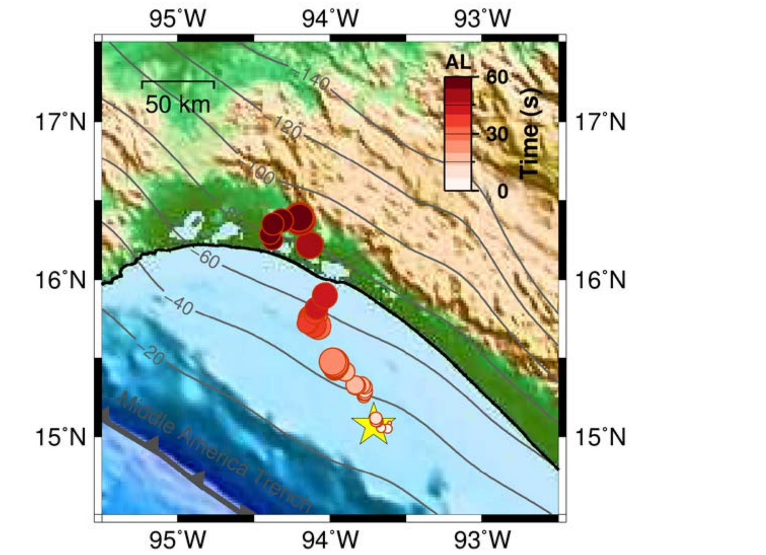
CONCLUSION

1. We obtain more consistent results with data from different azimuths by using 3-D model.
2. No need to use information of aftershocks. Calibrate rupture process quickly.
3. For better results, we could integrate a much finer earth velocity model for travel time.

APPLICATION



2017 Russia Earthquake



2017 Mexico Earthquake

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