Backprojection Imaging Based on a 3D Model: Method and Applications on the 2017 $M_{ww}8.1$ Mexico Earthquake and $M_w7.7$ Russia Earthquake

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ABSTRACT

In this study, we carried out a backprojection (BP) analysis to image the rupture process of the newly happened September 8, 2017 Mww8.1 Mexico earthquake based on a global 3D P-wave tomography model, the LLNL-G3Dv3 model.

Limited to epicenter distance and data quality, only waveform observation data from Alaska (AL), USA was utilized finally, with some data from South America (SA) as supplement. First, we compared the HF BP results of 1D and 3D model to illustrate the higher resolution and reliability of the 3D one. Then we discussed the consistency among the overall rupture pattern, the main event focal mechanism and aftershocks distribution, and further inferred the possible fault geometry. After that, we explained the rationality of the setting for rupture duration based on beamforming energy pattern, normalized power variation and other previous works. We then seriously examined the creditability of stage 2 and explained why speed in stage 2 is much bigger than in 1. Finally, we obtained the coulomb stress change imparted on the faults of the subsequent September 19 Mww7.1 event and September 23 Mww6.1 event to find out if they are positively triggered by this main event.

From our current research, the complete ~53s rupture process of this earthquake can be divided into two stages. In stage 1, which lasted for ~37s, the rupture propagated from the epicenter towards the NW direction (~330° measured from north clockwise) with a speed of ~2.8 km/s, and extended to a length of ~89 km. Then it made a right turn and shortly after, it continued to propagate to near N (~3°) with a higher speed of ~5.3 km/s and a scale of ~75 km. Our study intended to believe that the Mww8.1 event has almost nothing to do with the Mww7.1 event while it strongly triggered the occurrence of the latter Mww6.1 event.

DATA and METHOD

Many previous works has greatly contributed to the improvement of BP, including multi-array and image deconvolution to weaken the disturbance between phases, aftershock calibration to reduce the travel time difference between conventional 1-D model and complex underground structure along the ray path.

With abundant data received by worldwide stations and development of computer capabilities, we can build more precise 3-D models. They could solve the problem mentioned above by giving accurate travel time indicating lateral heterogeneity. Without waiting for the aftershocks, it is suitable for quick responses.

Here we still employ the LLNL-G3Dv3 model (Simmons et al., 2012), a global 3-D P-wave tomography model to compute the travel time. Liu et al. (2017) has proved the validity of this model and method, and apply it successfully on the case of 2015 Mw7.8 Nepal earthquake.

REFERENCE

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2. Liu, Z., Song, C., Meng, L., Ge, Z., Huang, Q., & Wu, Q. (2017). Utilizing a 3D Global P-Wave Tomography Model to Improve Backprojection Imaging: A Case Study of the 2015 Nepal Earthquake. *Bulletin of the Seismological Society of America*, *107*(5), 2459-2466.
3. Bruhat, L., Fang, Z., & Dunham, E. M. (2016). Rupture complexity and the supershear transition on rough faults. *Journal of Geophysical Research: Solid Earth*, *121*(1), 210-224.

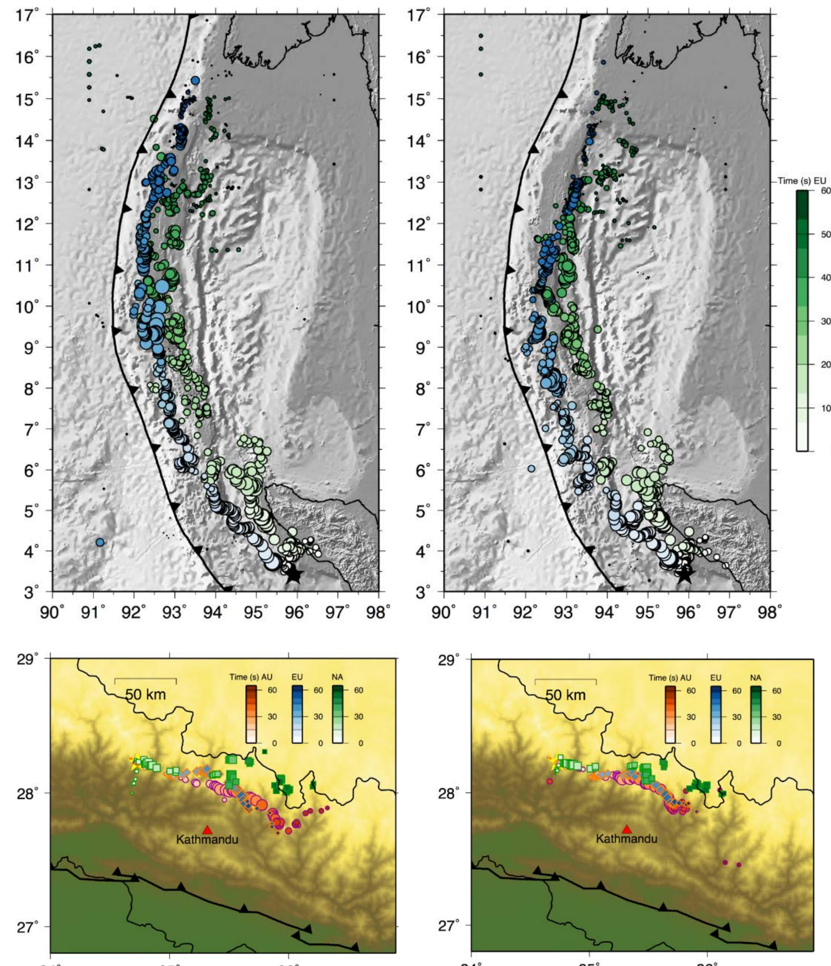

Fig.1 Validity test, 1-D vs. 3-D (Liu et al., 2017)

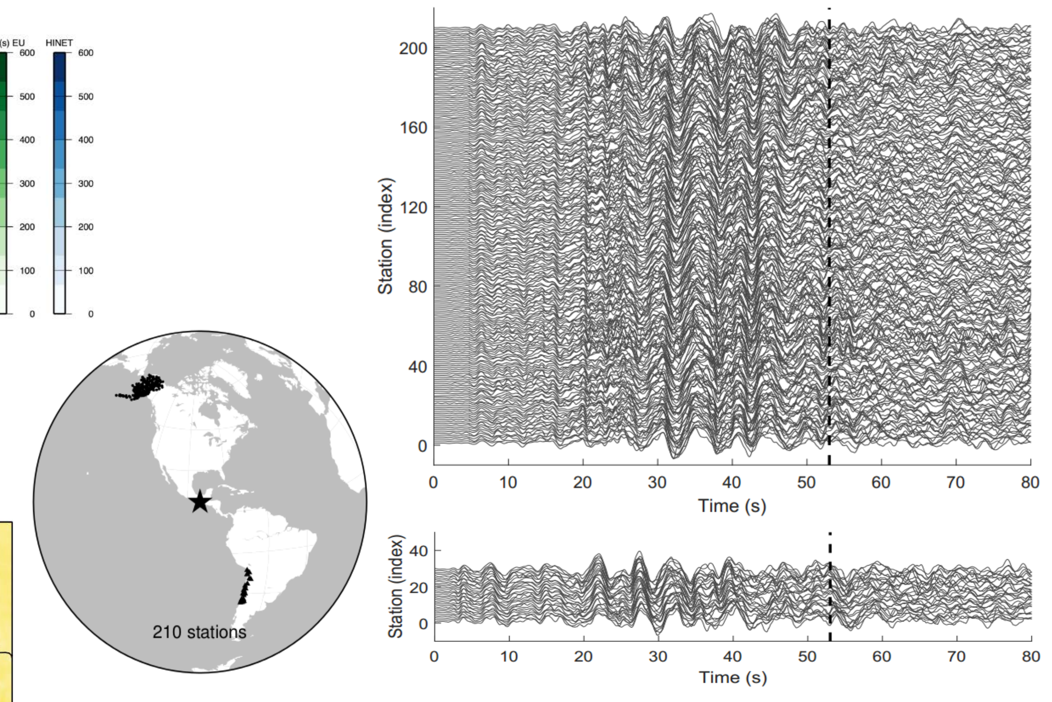

Fig. 2 Station distribution and aligned data

RESULTS

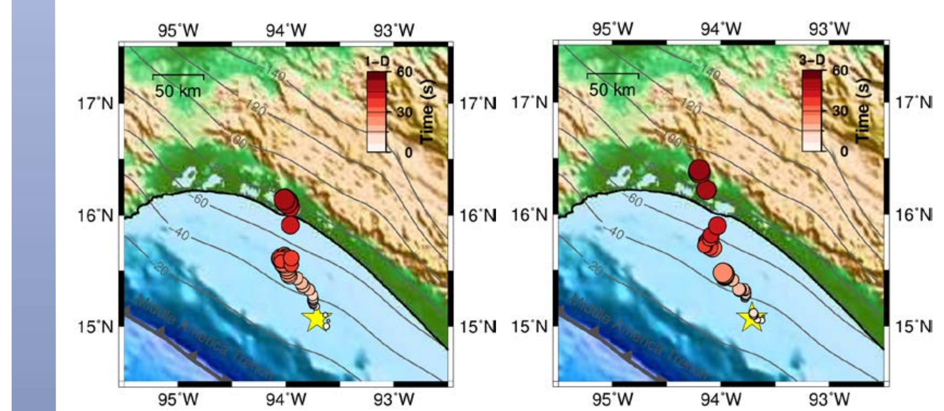

Fig. 3 BP HF radiation distribution

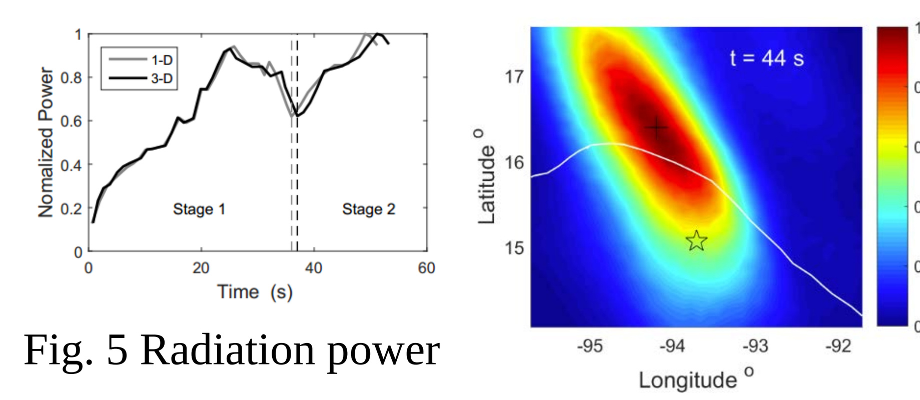

Fig. 5 Radiation power

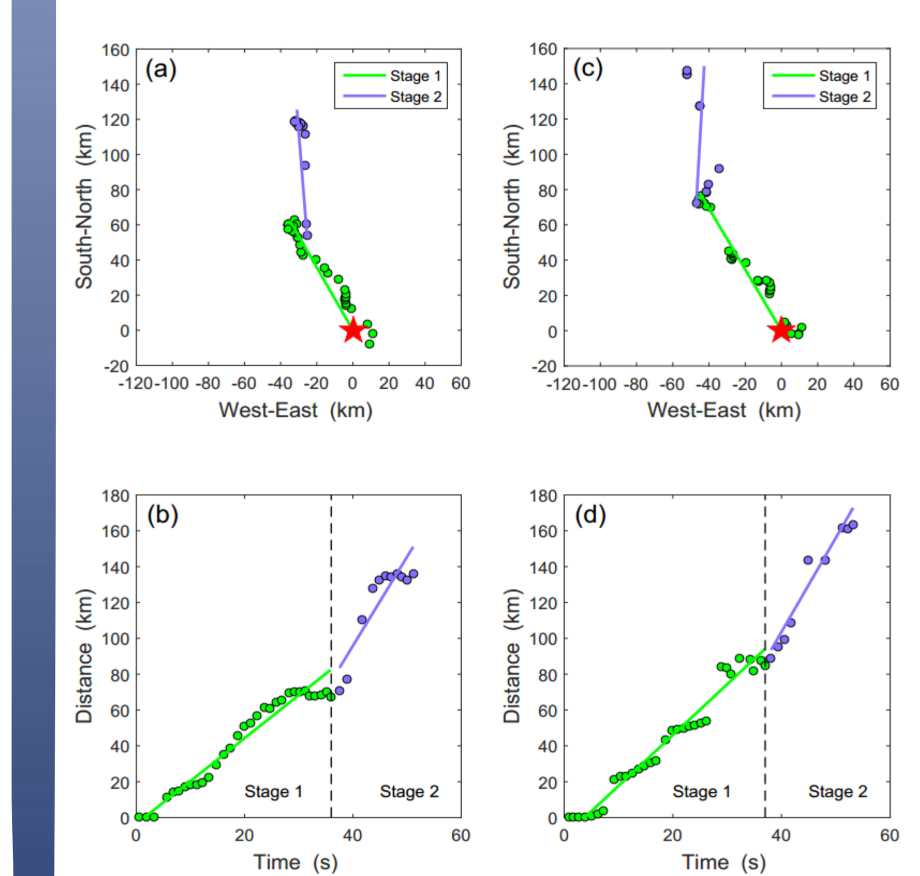

Fig. 4 Rupture direction, length and speed

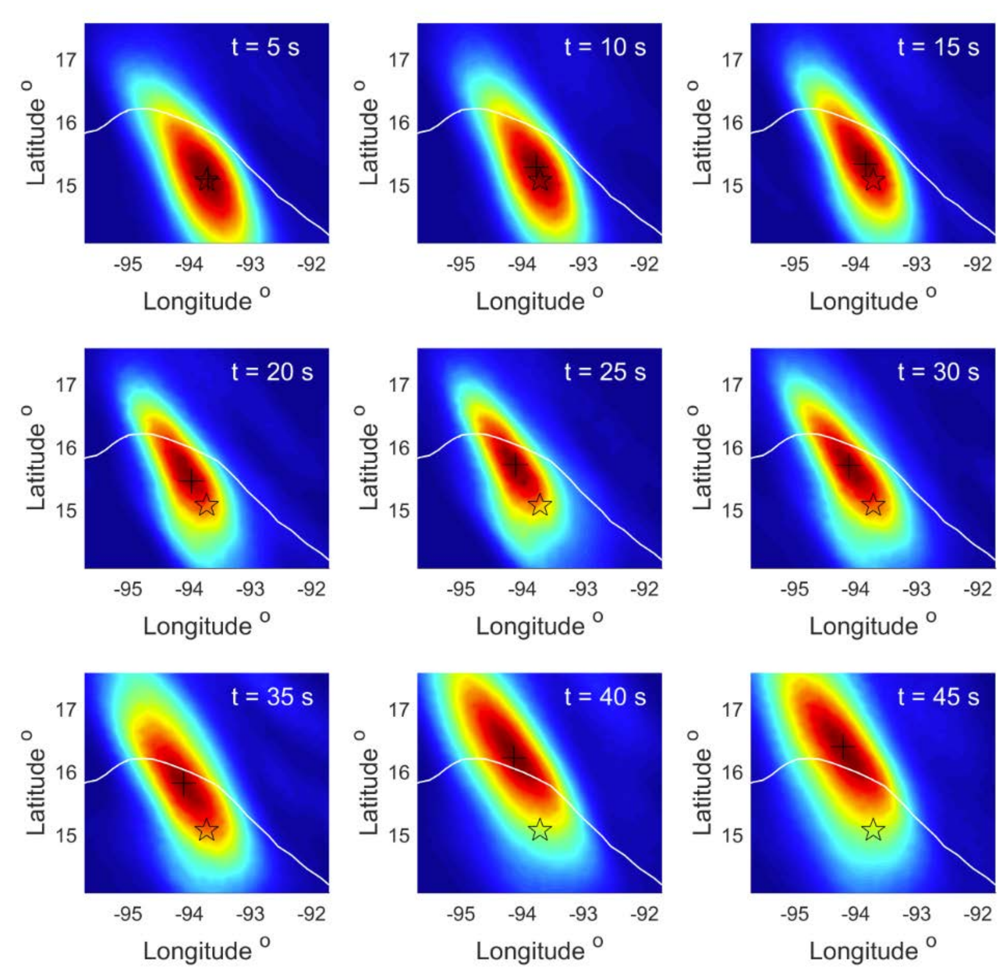

Fig. 6 Beam-forming snapshot (no time correction)

DICUSSION

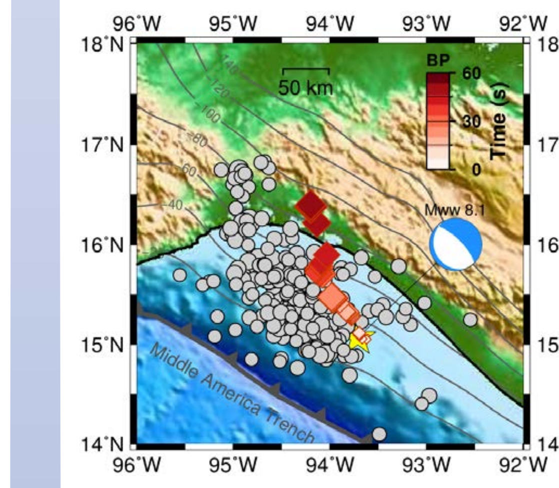

Fig. 7 Rupture direction consistency

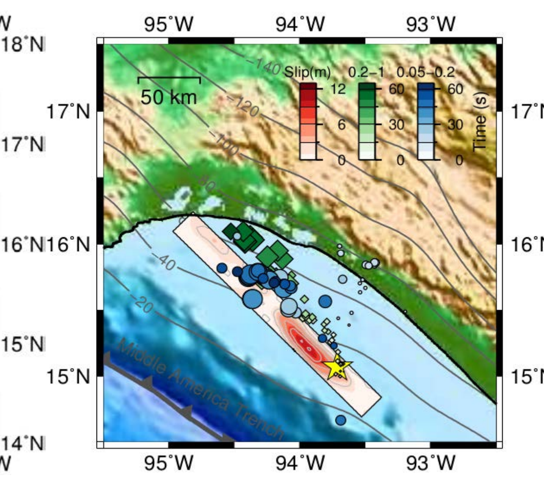

Fig. 8 Frequency characteristics

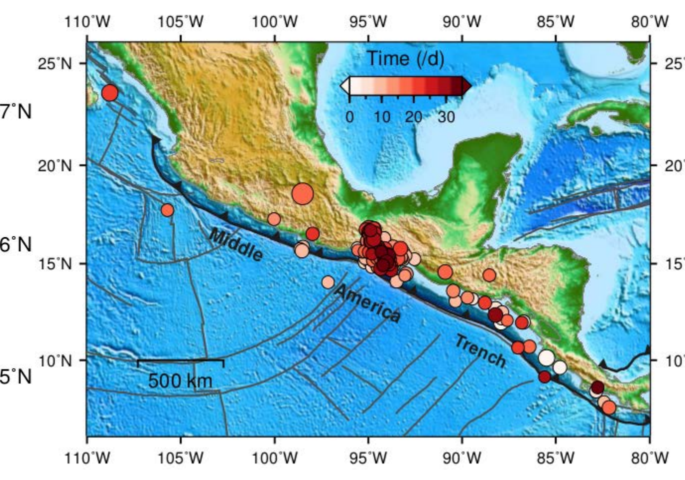

Fig. 9 Seismicity migration towards NW?

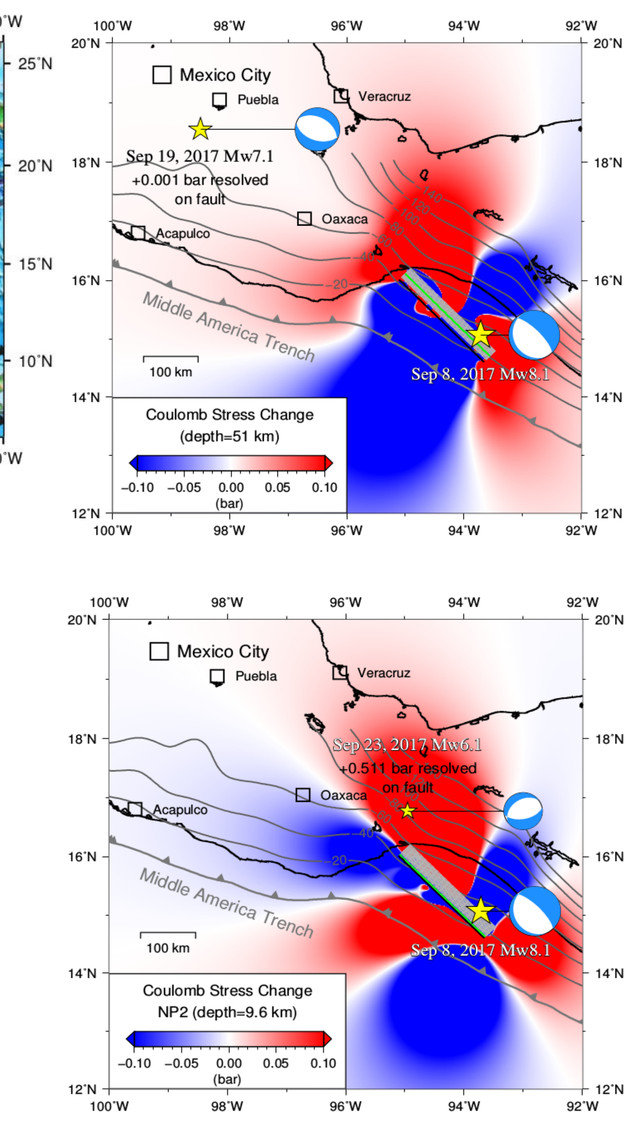

Fig. 12 Triggering effects

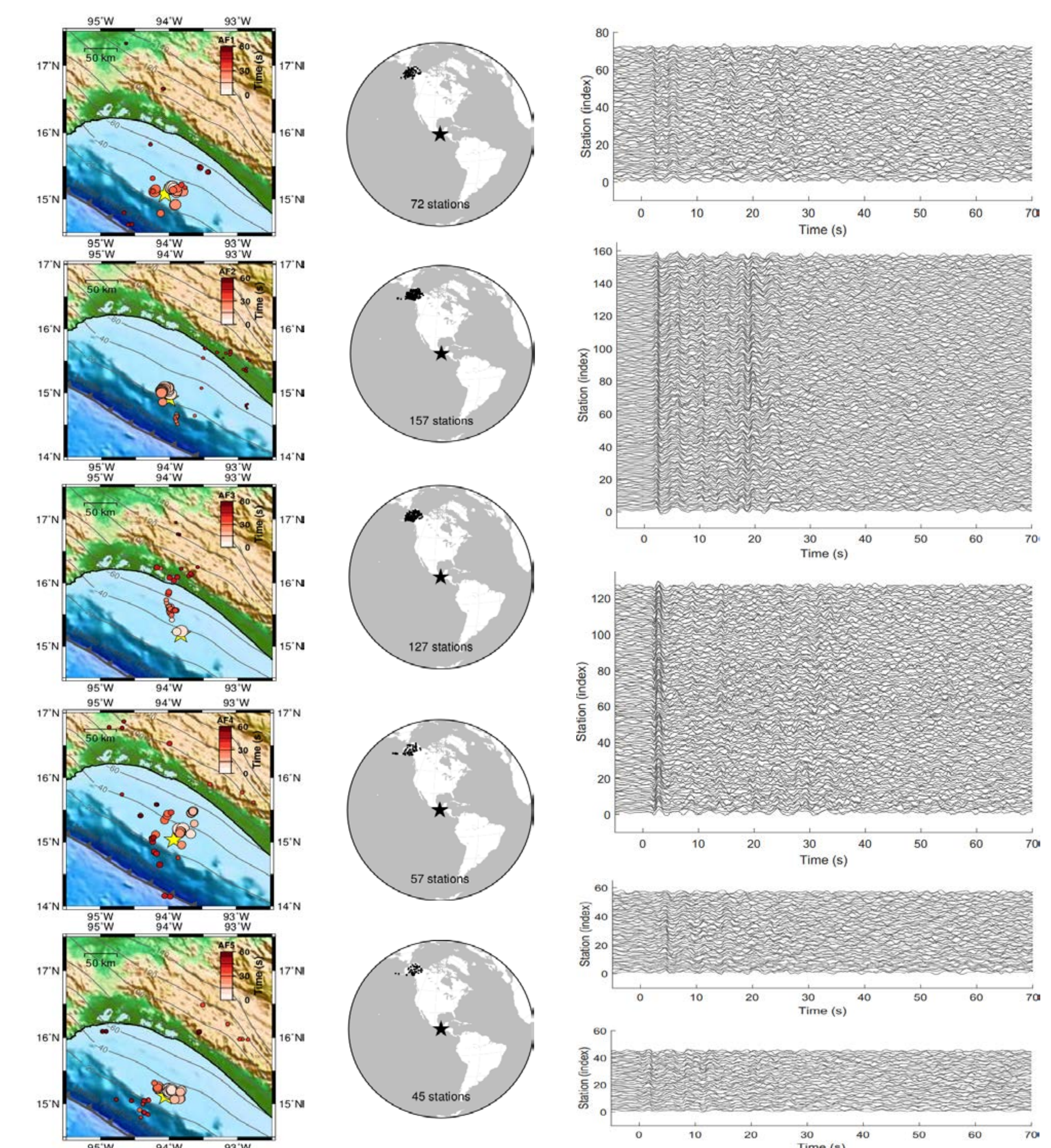

Fig. 10 Stage 2 was caused by depth phase or other reflection?

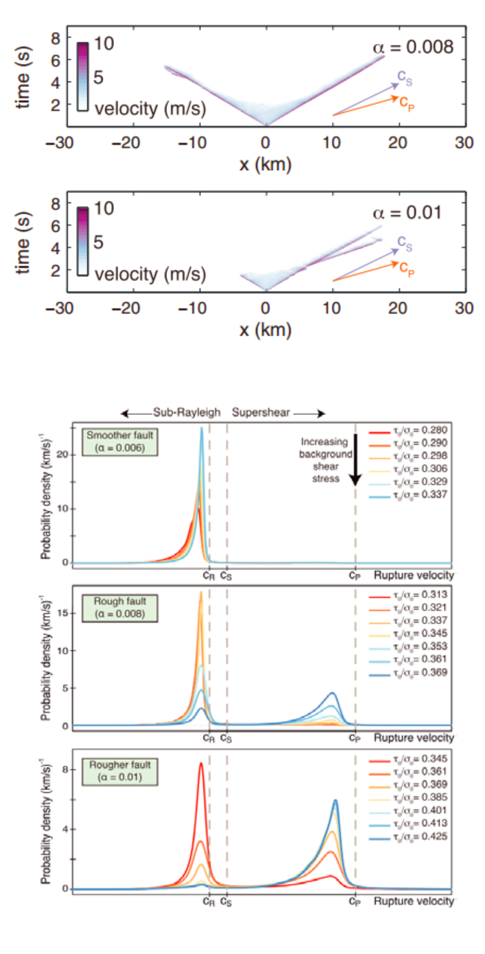

Fig. 11 Supershear with roughness and background stress level (Bruhat et al., 2016)

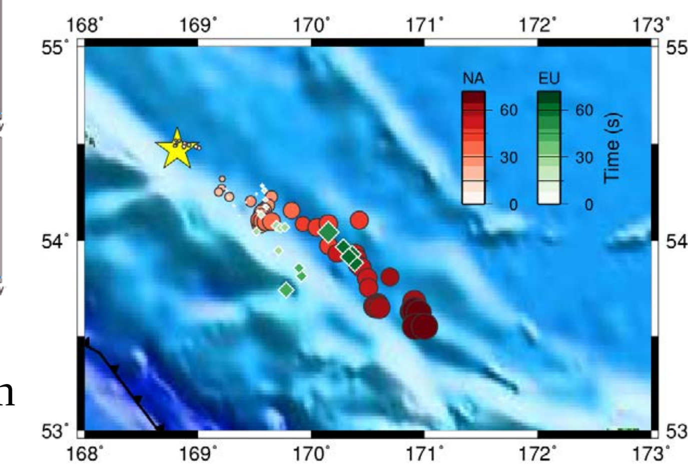

Fig. 13 Preliminary results on Russia event

CONCLUSION

1. Backprojection with traveltime tracing based on the 3-D model, LLNL-G3Dv3, can improve the results by higher resolution and more rupture details than 1-D model.
2. It is revealed that the complete ~53s unilateral rupture process of this earthquake can be divided into two stages. During stage 1 for ~37s, the rupture propagated from the epicenter towards NW (~330°) with a speed of ~2.8 km/s, extending to a length of ~89 km. Then it made a right turn and shortly after, it continued to propagate to near N (~3°) with a speed of ~5.3 km/s and a scale of ~75 km. The long axis of mechanism and aftershocks distribution also corresponded well with the rupture direction.
3. We believe that the September 8 Mww8.1 event strongly triggered the occurrence of the latter Mww6.1 event, but not to the consequent Mww7.1 event. The reason why the Mww7.1 event seems unusually isolated from other quakes remains unknown.