The systematic spatial bias pattern of earthquakes related to tectonic heterogeneity

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Back-projection (BP) is a source imaging approach that combines both time-reversal and grid-search techniques. BP utilize coherent waveforms to image a finite source process without any prior parameterization of the source itself, and the recent development of large dense seismic array has triggered its severe growth. BP can also be used for earthquake detection and location. As aftershocks of one earthquake always occur in the neighboring area, their rays towards a specific teleseismic array will travel along similar paths as that of the mainshock. The travel time errors from the mainshock hypocenter can be derived by cross-correlating its P-arrival waveforms, and if applied right on the waveforms of aftershocks, one can obtain the aftershocks' BP-inferred locations. However, small-scale heterogeneity caused by the real Earth 3-D structure will result in the so called 'spatial bias', which is the spatial offset between the BP-inferred location and the true epicenter locations. Meng et al (2016) has proposed an aftershock-based method to calibrate the travel time errors due to the near source structural heterogeneity. In this study, we take the 2017 July Mw 7.8 Near-Islands Aleutian earthquake as an example to investigate the spatial bias artifact of the source region. We found that in the ~500 km long rupture area, three systematic patterns of spatial biases exist, which correlate to three different structure characteristics. The three segments are the northwestern termination of the Aleutian island (169°-170°E), southeast of Mednyi Island with the Shirshov Ridge in the arc (170°-171°E), and the western segment of the Aleutian arc around Attu Island and northwest of it (171°-172 °E). The spatial bias directions in the three areas can be observed to have a good consistence with the nodal planes of focal mechanisms in the three areas, separately. This phenomena can be attributed to the sudden change in this elongate area brought by the Shirshov Ridge in the arc (170°-171°E). Besides, the coincidence between fault-planes solutions for the earthquakes in this area and the systematic spatial bias patterns also demonstrate that the state of stress experiences a sudden change, which reflects the tectonic heterogeneity in the near-source area, validating the necessity of subarea slowness calibration for this earthquake and providing us insight into the tectonic structure characteristics of this area.

Keywords: BP-projection technique, aftershock-based calibration method, systematic patterns of spatial biases, near source structural heterogeneity

