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The use of direct shear waves in quantifying seismic anisotropy: Reference station technique applied on the Northeastern Tibet

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Using direct shear waves in addition to SKS waves for splitting measurement would be advantageous in splitting measurements since they sample possible anisotropic structures in the upper mantle with an increased range of incidence angles and backazimuths. However, source-side contamination of direct S-waves makes splitting measurements complicated although all shear waves theoretically suitable for splitting analyses as long as the angle of incidence at surface is smaller than 35°. Here we introduce the reference station technique, a direct S wave-based method in the estimation of shear-wave splitting parameters. The method depends on maximizing the correlation between seismic traces with direct-S wave signal at reference and target stations of a station pair after correcting the reference station for the receiver side anisotropy effect using SKS splitting parameters. The procedure effectively assumes the same source side anisotropy affecting the two stations for the same seismic event. Only a few stations with well-constrained SKS splitting results are needed as seeds to determine the splitting parameters of a large array in an iterative manner. Various synthetic tests show that (1) reference station technique is not critically sensitive to varying crustal thicknesses between reference and target stations (2) the use of events with increased angle of incidence will cause deviations in split time delays (STD) with respect to the true value of the STD. Applying the reference station technique to the real data obtained from the INDEPTH IV and ASCENT seismic experiments at the northern margin of Tibet generally resulted in a good agreement between SKS- and direct S-derived splitting parameters. Where differences exist, the resolved shear waves fast polarization directions (FPD) indicate a higher degree of internal consistency for closely spaced stations where we do not expect clear lateral variation. This is probably due to the much larger number of S waves available for splitting measurements compared to SKS. Compared to SKS phases that are strongly restricted to the signal quality and a narrow range of angle of incidences, the use of direct S-waves increases the number of analyzed events by a factor of $\sim$4.