The supporting information provides 5 additional figures, and a description of how the smoothed SKS map (Fig. 3b) was derived.

Calculating the smoothed SKS field

The surface wave model has limited resolution and is additionally constrained to be smooth by the a priori correlation length, whereas SKS splitting measurements are sensitive to the local structure below each station, with sometimes abrupt changes in direction. In order to be
able to quantitatively compare both measurements, it is thus necessary to smooth the SKS measurements to the scale seen by the surface waves. We follow this procedure:

1. Clean up splitting database by removing duplicates and measurements based on individual earthquakes to only retain station averages. Where different references derived differing splitting estimates for the same station both were retained, unless it was immediately obvious that one estimate is far superior, for example, because a much larger number of events have contributed.

2. Transform fast direction ($\phi$) and splitting delay ($\delta T$) of each measurement

$$S=\delta T \sin(2\phi), \quad C=\delta T \cos(2\phi).$$

The multiplication by 2 maps the inherent 180° periodicity of fast directions to the 360° periodicity of the trigonometric functions.

3. For each 1x1° block, average the $S$ and $C$ values of all splitting measurements within the block, and grid them (using GMT commands blockmean and nearneighbor)

4. Apply a Gaussian smoothing filter of 500 km diameter to the gridded data; this also serves to interpolate between measurements (using GMT command grdfilter)

Although we do not know in detail the frequencies at which the SKS measurements in the database were derived, it is likely that most of them were derived at periods more than 5 s, i.e., significantly longer than the splitting delays. We therefore prefer to use the method of Montagner et al. [2000] to generate predictions of SKS splitting from the surface wave model (see Fig. 3a of main text). However, in some special circumstances the shallow layer can dominate the splitting parameters inferred from SKS [Rümpker and Silver, 1998]. Fig. S5 therefore compares the SKS measurements to the anisotropy of the shallow layer of the surface wave model. The overall level of agreement is quite similar to the comparison of the SKS observations with the Montagner predictions, which include the deeper layers (Fig. 3b in the main text). In the east of the map, both comparisons are quite similar but fast directions agree somewhat better for the Montagner predictions in Fig. 3b. In southern West Tibet the shallow layer predictions show large E-W FPD, which is inconsistent with small splitting measurements there. Along the southern Altyn Tagh and northern West Tibet the fit of the shallow model is better, though.

We prefer to use the Montagner predictions to compare the surface wave results with the SKS measurements, although some of the misfit might be attributable to its shortcomings, as discussed in the main text.
Figure S1. Map of SKS splitting measurements (blue bars) and station distribution (red triangles) in the study area. The SKS splitting data are taken from modified version of the SplitLab database [Wüstefeld et al., 2010], Eken et al. [2013] and Zhao et al. [2010]. SKS measurements with null splitting or smaller splitting times (<0.3 s) are indicated by white circles. Major tectonic features [from Zhang et al., 2011; Pandey et al., 2014] are marked by solid lines with main tectonic units labeled. Black dashed lines indicate plate boundaries of Eurasia with Pacific/Philippine Sea and Indian plates. Orange dashed lines are slab contours of oceanic subduction zones [Gudmundsson and Sambridge, 1998]. Abbreviations: IP, Indian Plate; TP, Tibetan Plateau; EHS, Eastern Himalaya Syntaxis; TB, Tarim Basin; YC, Yangtze Craton; NCC, North China Craton; QB, Quaidam Basin; SB, Sichuan Basin; OB, Ordos Block.
Figure S2. Global map showing the distribution of stations (yellow triangles) and teleseismic events (red circles) used in this study.
Figure S3. Optimized Voronoi diagram showing the coverage of 2° by 2° areas for which at least three distinct azimuths are sampled. It is built from the actual ray coverage, using a scheme defined by Debayle and Sambridge [2004]. This diagram confirms that our ray coverage would be sufficient to resolve the 2θ azimuthal variation of surface waves on a 2° by 2° grid over the area under study.
Figure S4. Resolution test for depths of 75 km (a), 125 km (b) and 175 km (c). Input models are shown on the left, output on the right. The input model contains two anisotropic layers (50-100 km and >150 km depths) with 5% azimuthal anisotropy and fast speed directions reversing every 20°. The two layers are separated by an isotropic layer (100-150 km depth). Color in the output models indicates small velocity perturbations induced by tradeoff with anisotropy (<0.5% in most areas).
Figure S5. Comparison of the shallow anisotropy structure in the surface wave model with the SKS splitting measurements (depth = 75 km). The percentage anisotropy values were arbitrarily scaled by a factor of 1/4 to convert them into pseudo-predicted splitting delays. The maximum percentage anomaly in the map region of 8.2% is thus equivalent to a splitting delay of 2.1 s, and the threshold for insignificant splitting is 1.2%. Otherwise, processing and figure format follow Fig. 3b in the main text.


