Using Voronoi diagrams to assess the resolvability of a given seismic parameter

In seismic tomography, our ability to resolve a given parameter at a given location depends strongly on the distribution of rays which is always irregular. We propose a strategy to find a 2D 'optimized' parameterization of the model in which each geographical point belongs to the smallest cell for which a quality criterion, related to the resolution of a given seismic parameter, is satisfied. The resulting 'optimized' parameterization is almost always irregular and the size and shape of each cell parameterization therefore provides information about the way a given seismic parameter can be resolved from the ray coverage.

1. Parameterization using natural neighbours

In 2-D, the Voronoi diagram of an irregular set of nodes divides the plane into a set of regions, one for each node, such that any point in a particular region is closer to that region's node than to any other node (Fig. 4).

3.1 A simple quality criterion for the azimuthal anisotropy of surface waves

A long period SW wave propagating horizontally in a slightly anisotropic medium at depth \( \phi \) experiences an azimuthal variation of the form (see e.g. Montagner and Nataf, 1986; Lévêque et al., 1998):

\[
SV(\phi) = SV(\phi_0) + SV(\phi) \cos(2\theta) + SV(\phi) \sin(2\theta)
\]

where \( \theta \) is the azimuth. A similar relation but with a 40 variation can be obtained for long period SH waves. In most studies, authors concentrate on the 2 azimuthal variation almost everywhere in the Earth. Note however that the actual horizontal azimuthal variation depends on the azimuthal distribution of rays. Here we refine the cellular structure of a starting Voronoi diagram by developing a quality criterion which ensures resolution of azimuthal structure in each of the final cells. The resulting 'optimized' Voronoi diagram provides a measure of our ability to resolve the azimuthal anisotropy of SW waves from the ray coverage.

3.2 Retrieving the 20 azimuthal variation from regional tomography

Current waveform inversion techniques (e.g. Cara and Lévêque, 1987; Nolet 1990) provide a path-average shear velocity model compatible with a multi-modes surface wave seismogram. From a set of path-average models related to paths with different azimuths it is possible to retrieve the azimuthal variation of long period shear waves. Our ability to resolve this azimuthal variation depends on the azimuthal distribution of rays. Here we refine the cellular structure of a starting Voronoi diagram by developing a quality criterion which ensures resolution of anisotropic structure in each of the final cells. The resulting 'optimized' Voronoi diagram provides a measure of our ability to resolve the azimuthal anisotropy of SW waves from the ray coverage.

3.3 Retrieving the 20 azimuthal variation from global tomography (synthetic experiment)

With a coverage comparable to what can be achieved in modern global tomography (here 37320 paths with lengths greater than 1200 km) it is possible to retrieve the 20 azimuthal variation almost everywhere in the Earth. Note however that the actual horizontal resolution achieved in surface wave tomography results from the compromise between what can be geometrically resolved and what can be resolved from the physics of surface waves.

References