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Anisotropic P-wave traveltime tomography implementing Thomsen's weak approximation in tomo3D

Adrià Meléndez (1), Estela Jiménez (1), Valentí Sallarès (1), and César R. Ranero (2)

(1) Barcelona Center for Subsurface Imaging, Institut de Ciències del Mar (CSIC), Barcelona, Spain (melendez@icm.csic.es), (2) Barcelona Center for Subsurface Imaging, ICREA at Institut de Ciències del Mar (CSIC), Barcelona, Spain (melendez@icm.csic.es)

We present the implementation of Thomsen's weak anisotropy approximation for TTI media within tomo3D, our code for 2-D and 3-D joint refraction and reflection traveltime tomographic inversion. In addition to the inversion of seismic P-wave velocity and reflector depth, the code can now retrieve models of the Thomsen's parameters δ and ε. We test this new implementation on a canonical synthetic experiment. First, we study the sensitivity of traveltimes to the presence of a 20% anomaly in each of the parameters. Next, we try inverting for two combinations of parameters, (v||, δ, ε) and (v||, δ, v⊥), following two inversion strategies, simultaneous and sequential, and compare the results to determine whether one of the options is significantly better. In each case we derive the fourth parameter from the relationship between ε, v⊥ and v||. Recovery of v||, ε and v⊥ is satisfactory whereas δ proves to be impossible to recover even in the most favourable scenario. However, this does not hinder the recovery of the other parameters, and we show that it is still possible to obtain a smooth model or at least an average value of δ provided that the other two parameters are well retrieved. The simultaneous inversion of the parameter combination (v||, δ, ε) produces the overall best results.

We apply this new anisotropic code to a real case study that we already modelled with its 2-D isotropic version. The 2-D wide-angle seismic data set was acquired parallel to the subduction trench offshore Nicaragua. The resulting model of the overriding plate displays small lateral velocity variations and a nearly flat interplate reflector. We detected a certain degree of anisotropy by comparing the location of the interplate reflector obtained from traveltime tomographic inversion to that in a coincident seismic reflection image. A $\sim$15% increase in the subhorizontal velocities obtained from the tomographic inversion was able to cancel the misfit between reflectors. The anisotropic inversion of the original refraction and wide-angle reflection data along with newly-added reflection picks from streamer data yields a model of anisotropy for the overriding plate, and a more reliable location of the interplate reflector.