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Assessment of statistical uncertainty analysis of joint refraction and reflection travel-time tomographic models applied to real data off the Nicaraguan margin.

M. Prada (1), V. Sallarés (1), A. Meléndez (2), C.R. Ranero (3), and K. McIntosh (4)

(1) Barcelona Center for Subsurface Imaging-Unitat de Tecnologia Marina-CSIC, Barcelona, Spain (mprada@cmima.csic.es), (2) Barcelona Center for Subsurface Imaging-Institut de Ciéncies del Mar-CSIC,Barcelona,Spain, (3) Barcelona Center for Subsurface Imaging-Institució Catalana de Recerca i Estudis avançats at CSIC,Barcelona,Spain, (4) University of Texas Institute for Geophisycs- Austin,Texas

The wide-angle seismic modeling of crust and mantle is key to understand the structure and physical properties of the Earth's interior. However, a reliable interpretation of the obtained models requires having constraints on the model parameter uncertainties. For that reason, we analyze here the potential and limits of most common, Monte-Carlo-based, statistical uncertainty analysis schemes of velocity and reflector geometry models obtained by travel-time tomography of wide-angle seismic data.

We have used a wide-angle seismic data set acquired off the Nicaragua convergent margin. The data correspond to a profile that runs parallel to the trench axis along the continental slope. It is 190 km long and includes 12 Ocean Bottom Hydrophones located 10-15 km apart. The data have been modeled following a joint refraction and reflection travel-time tomographic inversion to obtain a 2-D velocity field of the overriding plate as well as the location and geometry of the inter-plate boundary. The model shows a $\sim$5 km thick sedimentary cover with velocities varying from 2 km/s to 3.5 km/s, overlying a $\sim$12 km thick basement with velocities between 4 km/s and 6.5 km/s.

Ray coverage shows that diving waves concentrate in the upper third of the model, whereas the two bottom thirds are covered only by reflections from the inter-plate boundary zone. This gives an idea of the areas where the model is likely to be better constrained by the data, but the ray coverage alone does not provide a measure of the accuracy of the results nor an idea of the significance of velocity-depth trade-off. To analyze the accuracy of the model we have implemented a Monte Carlo-like uncertainty analysis consisting of randomly varying an 1D velocity model, the depth of the floating reflector, and the picked arrival times, to generate a total of 100 2D reference models and perturbed data sets, to subsequently conduct an inversion for each model-data set pair. Theory states that, under certain conditions, the mean and other statistical measures such as mean deviation can be estimated from the velocity models. By taking a range of variation that covers all the region of possible solutions, the mean deviation of the Monte Carlo realizations give a measure of model parameters uncertainty. It is therefore important to select the appropriate range of variation of the different model parameters, so we have performed different tests changing the range of variation of velocities, depth of reflector, and time perturbation to see its influence in the obtained results. The objective is to assess the required conditions to interpret the mean deviation of the model parameters as a reliable measure of uncertainty.

Our results show that the improvement, or reduction, of mean deviation before and after the inversion depends on different factors. The reduction of mean deviation is much larger at the zones covered by diving waves (sediments and uppermost basement) than at those controlled only by reflections (mid and lower basement). The relationship between the mean deviation of the initial models (σi) and the mean deviation of the final ones (σf) is linear below a critical σi value (σ0) and converges to a constant σf (σref) above σ0, in areas covered by diving waves. This means that we must select σi> σ0 to be able to interpret σf (σref) as a measure of model parameters uncertainty. The reduction of mean deviation of the floating reflector depth is significant regardless of the significant velocity uncertainty. This means that even if single velocity nodes are poorly resolved, the average of all velocity values makes that the travel time to the floating reflector is not dramatically affected.