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Bayesian uncertainty analysis for advanced seismic imaging - Application to the Mentelle Basin, Australia

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Quantifying the depths of target horizons from seismic reflection data is among the most important aspects of exploration geophysics. In order to constrain these depths we need a reliable and accurate velocity model. Here, we apply Bayesian methods, such as Gaussian process emulators, to estimate the uncertainties of the depths of key horizons near the well DSDP-258 located in the Mentelle Basin, south west of Australia, and compared the results with the drilled core extracted from that well. Eventually, this method will be applied to identify the drilling targets for the International Ocean Discovery Program (IODP), leg 369.

The Mentelle Basin is a sparsely explored, deep water sedimentary basin, located between the Naturaliste Plateau and the southern part of the Western Australian Shelf. Its main depocenter, is believed to contain sediments that span from Cretaceous to Holecene, but most importantly it hosts a continuous shale sequence that it is over a kilometer thick, the study of which, is crucial for the correlation between the paleoclimate conditions and the tectonic history of the region.

Using two 2D multichannel seismic reflection profiles around the drill site, we generate detailed anisotropic velocity models for the well location in order to construct initially the optimum Pre – stack time (PSTM) and eventually the Pre - stack depth migrated (PSDM) subsurface images. Moreover, in order to enhance the sub - basalt imaging of the region of interest with the goal to constrain the tectonic models of the area, we apply deterministic deconvolution filters using the source function extracted from our seismic data.

The best velocity model created from the initial processing serves as the prior information to the Bayesian model. The final goal is to try to build a multi-layered model of n layers and estimate the zero offset two way time, t_0, and the interval velocities,V_i, both for isotropic ($V_{x_i} \approx V_{z_i}$) and anisotropic ($V_{x_i} \neq V_{z_i}$) cases, in terms of a multivariate posterior distribution.

The novelty of our approach and the major difference compared to the traditional semblance spectrum velocity analysis procedure is the calculation of uncertainty of the output model. As the model is able to estimate the credibility intervals of the corresponding interval velocities, we can produce the most probable PSDM images in an iterative manner. The depths extracted using our statistical algorithm are in very good agreement with the key horizons retrieved from the drilled core DSDP-258, showing that the Bayesian model is able to control the depth migration of the seismic data and estimate the uncertainty to the drilling targets.