Tomography of Chile

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Chile is known to be one of the most seismically active country of the world. It is the place of the largest instrumentally recorded earthquake of the 20th century (1960, Southern Chile) and every year, several thousands of M3+ events are catalogued by the National Seismological Center (CSN, Univ. de Chile). More recently, in 2010, the M8.8 Maule earthquake triggered a tsunami resulting in 181 casualties. Although the seismic code and its enforcement together with emergency response protocols have proven valuable, earthquake characterization (location, magnitude, shake map, etc.) remains crucial for both the population and the authorities.

Locating earthquakes in Chile can be quite challenging for two main reasons. Firstly, the station coverage is strongly limited in the east-west direction due to geography of the country and the Andean topography. Secondly, as velocities are very heterogeneous, conventional 1-D models are inadequate and the numerous tomographic studies available are generally too local or present too poor resolution in the lithosphere to be an effective option.

Efforts were made in recent years to extend the seismic network to the East by incorporating data from 8 Argentinian stations of the Instituto Nacional de Prevención Sísmica (INPRES) and 43 stations from the Red Nacional de Vigilancia Volcánica administered by the Servicio Nacional de Geología y Minería (Sernageomin). Unfortunately, offshore information, when exist, remains unavailable in real time.

Regarding the velocity structure of Chile, we propose a new velocity model for the most seismically active area of Chile (18ºS to 46ºS) for the first 300 km depth. This model is a combination of six tomographic models determined in separated inversion processes. The dataset consists mainly in the data of the CSN between 1980 and mid-2018 to which we added data from about forty temporary networks. The resulting dataset is made of 2,527,000 P- and 1,852,000 S-wave arrival-times corresponding to 250,000 local earthquakes. The tomography was managed using the Insight code. The model consists of vP and vP/vS values given at each node of a 6x6x3 km grid, which constitute the inversion grid. Forward computation of propagation times is determined by slowness integration along ray-paths, which are obtained by the Podvin-Lecomte algorithm (finite difference resolution of Eikonal equation). The inversion is carried out by a non-linear least-squares approach based on a stochastic description of both data and model. In order to manage such large models and datasets, several mechanisms are used to filter outliers and stabilize the inversion.

The resulting model presents an interesting overview of the crust and the upper mantle of Chile. The fine localization of the seismicity leads to several new observations, such as a triple seismic pattern along the slab in the Mejillones region of northern Chile or an ambiguous deep slab beneath the flat slab zone in central Chile. The model was successfully incorporated to the CSN routine systems and improves daily locations, especially offshore where 1D models cannot provide realistic depths.