SeisAndes: A High Resolution Crust and Upper Mantle Seismic Velocity Model beneath the Central Andes from 16° S to 30° S from Full Waveform Inversion

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We present a new seismic tomography model from multi-scale full seismic waveform Inversion for the crustal and upper-mantle structure beneath the Central Andes (16°-30° S), where the oceanic Nazca plate is subducting beneath the South American continent. The Central Andes is characterized by significant along-strike changes in crustal shortening and thickening, arc migration, subduction erosion and catastrophic earthquakes (e.g. the 2014 Iquique M8.1 earthquake). A high resolution seismic velocity model would bring new insights into the geodynamics of this region, especially for the effects on the seismicity and volcanic arc from the serpentinization in the mantle wedge and dehydration effects from the subducting oceanic crust.

Our model is derived from multi-scale full waveform inversion, including multiple time period stages (40-80 s, 30-80 s, 20-80 s, 15-80 s and 12-60 s). In order to avoid the risk of falling into the local minima of optimization, we started our inversion from the lowest frequency signals costing lower computational resources. Specifically, the forward and adjoint simulation based on a 3D model are accomplished with Salvus (Afanasiev et al., 2018), which is a suite of spectral-element method solver of the seismic wave equation. We invert waveforms from 117 events, which are carefully selected for good data coverage of the study region and depth range. We take advantage of the adjoint methodology coupled with conjugate gradients and L-BFGS optimization scheme to update the velocity model. We adopt a time-frequency phase shift as misfit functional with adjoint sources in the first four period-stages, and cross-correlation coefficient in the final stage after most of the phase shifts has been eliminated. The cross-correlation coefficient can capture distorted body wave seismograms, not only the phase shift. We also provide a resolution analysis through the computation of the point-spreading functions and validation dataset with a misfits evolution chart, demonstrating the robustness of our final model.
Through full-waveform inversion, we provide a new higher resolution P and S wave velocity model from the middle crust to the upper mantle around 300 km depth. The subducted Nazca slab in the upper mantle beneath the Central Andes is fully imaged, with dip angle variations from the north to the south. We could also observe a strong low velocity band in the middle crust and uppermost mantle from 80 to 100 km beneath the volcanic arc, correlating with the volcano distributions and recent intermediate depth seismicity relocation results. An offset of this low velocity band between 20°-21°S is conspicuous, both in the middle crust and uppermost mantle, indicating a weak extent of the dehydration from 20°-21°S, resulting in the weak intermediate depth seismicity and absent volcanic activity in the same latitude range. We also imaged strong low velocity anomalies in the middle crust beneath the Altiplano-Puna Volcanic Complex and South Puna, giving strong evidence supporting the magmatic underpinnings and reservoirs. Meanwhile, low velocity beneath Puna tectonic units down to 100 km may represent the lithospheric detachment, resulting in the melting and upwelling fluids from the Nazca plate.