Comparing permanent deformation and seismic asperities in the 2015 Illapel earthquake rupture zone

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Abstract:

Giant subduction earthquakes (MW 8 to 9) are usually characterized by heterogeneous slip distributions, including regions of very pronounced slip that are commonly known as asperities. However, it is a matter of ongoing debate whether asperities constitute persistent geologic features or if they rather represent transient features related to the release of elastic strain accumulated in areas of seismic gaps. Recent giant earthquakes along the coast of north-central Chile, such as the 2010 Maule (M8.8), 2015 Illapel (M8.3), and 2014 Iquique (M8.2) events, were all associated with the rupture of single or multiple seismic asperities. Here we compare permanent deformation and seismic-cycle deformation patterns and rates along the 2015 Illapel earthquake rupture zone (~30° to 32°S) spanning orbital to decadal time scales. To decipher permanent deformation features manifested in the upper plate of the subduction system we identified and correlated the elevations of Late Pleistocene marine terraces using TanDEM-X digital topography and previously published terrace ages. We focused on terraces related to the Marine Isotope Stages (MIS) 5 and 9 (~124 ka and ~320 ka) due to their excellent preservation and lateral continuity. We furthermore compared deformation rates based on these uplifted terraces and compared them with published co-seismic slip and interseismic locking models of the Illapel earthquake. Uplift rates derived from the MIS-5 marine terraces range between 0.08 and 0.35 m/ka, while uplift rates based on MIS-9 terraces range between 0.38 to 0.96 m/ka. The higher uplift rates are found at the northern part of the Illapel rupture and these areas correlate to crustal structures (e.g. Puerto Aldea Fault). We observed a direct correlation between MIS-5 and MIS-9 uplift rates and co-seismic slip in the northern parts of the rupture while there was no clear correlation in the south at the central and southern parts of the rupture zone. The comparison between the spatial distribution of locked areas and uplift rates provided only a weak correlation for the MIS-9 terraces at the southern part of the rupture. Our results suggest that the northern part of the Illapel rupture zone may accumulate permanent deformation during megathrust earthquakes. In contrast, accumulation of deformation at the southern part of the rupture may be controlled by activity in the neighboring seismotectonic segment. Broad warping patterns of marine terraces might reflect changes in boundary conditions at interplate depths, such as subduction of seamounts or other oceanic bathymetric features. This analysis highlights the temporal and spatial variability of deformation at convergent plate margins over multiple time
scales.