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The 2015 Illapel earthquake: a comprehensive assessment

Frederik Tilmann (1,2), Yong Zhang (3), Maros Moreno (1), Joachim Saul (1), Felix Eckelmann (1), Mauro Palo (1), Zhiguo Deng (1), Andrey Babeyko (1), Kejie Chen (1), Juan-Carlos Baez (4), Bernd Schurr (1), Rongjiang Wang (1), Torsten Dahm (1,5)

(1) Deutsches GeoForschungsZentrum, GFZ Potsdam, Seismology, Potsdam, Germany (tilmann@gfz-potsdam.de), (2) Freie Universität Berlin, Berlin, Germany, (3) Peking University, Beijing, China, (4) Centro Sismológico Nacional, Universidad de Chile, Santiago-de-Chile, Chile, (5) Universität Potsdam, Potsdam, Germany

On September 16, 2015, the convergent Chilean margin again experienced a great subduction megathrust earthquake. The MW=8.2 Illapel earthquake occurred in the Metropolitan segment north of where the Juan-Fernandez ridge meets the Chile trench and subduction style and geometry change over a short distance. Combining GPS displacement measurements, InSAR interferograms, strong motion data, broadband seismological waveforms and backprojection of high frequency teleseismic signals we derive a comprehensive description of the coseismic rupture. Further, we determine accurate depths for the mostly offshore aftershock sequence by careful observations of teleseismic depth phases and derive moment tensors for the larger earthquakes from waveform modelling of body- and surface waves. The rupture nucleated near the coast but then propagated to the north and updip. The resulting simple rupture geometry is approximately circular with a peak slip of 6 m, and a diameter of approximately 100 km, centered below the middle slope of the forearc. Forward modelling of tsunami propagation for this model successfully predicts approximate tsunami wave heights measured at 3 tide gauges along the North Central Chile coast, confirming that the rupture diminished towards the trench. Similar to previous observations, high frequency seismic radiation is mostly emitted downdip of the region of most intense slip, but unlike in most previous events, the high frequency emitters do not track the whole rupture along-strike but are confined to a small region within $\sim$ 50 km of the epicenter. The time evolution of high frequency seismic radiation also peaks earlier than the long period rupture evolution, indicating that the final phase of the rupture progressed smoothly. The aftershocks extend significantly beyond the limits of the main rupture in both north and south direction; their pattern of propagation suggests triggering by coseismic changes to the Coulomb failure stress. Plate interface events dominate the aftershock sequence but there are also some thrust events in the forearc crust and some shallow normal faulting events in the oceanic crust below the trench. In 1943, an earthquake of comparable along-strike extent occurred in the Illapel area. The similar extent of the aftershock zone and tsunami heights therefore make this part of the margin a candidate site for generating characteristic earthquakes, in particular as the 1943 event was itself preceded by an event in 1880, again with apparently the same part of the margin affected. The approximate match of peak slip and accumulated slip deficit in the 72 years since the 1943 event also support this interpretation. However, the 1943 Illapel event appears to have had a shorter source time function and probably a smaller magnitude than the 2015 event, pointing to differences in the detailed rupture evolution. The coupling is mostly close to fully locked in this area at least along the coast line but nevertheless the coseismic rupture is associated with a local peak in the locking pattern, whereas a distinct narrow partially interseismically creeping area is found just to the south of the main rupture. The northern transition to lower locking is more gradual but also here the rupture can be said to have terminated against a zone of reduced locking. Although locally the recent Illapel earthquake has relieved much of the accumulated stress, the segment immediately adjacent to the north remains unbroken since 1922, and presents a serious earthquake and tsunami hazard.