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Foreshock patterns preceding large earthquakes in the subduction zone of Chile

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Some of the largest earthquakes in the globe occur in the subduction zone of Chile. Therefore, it is of particular interest to investigate foreshock patterns preceding such earthquakes. Foreshocks in Chile were recognized as early as 1960. In fact, the giant (Mw9.5) earthquake of 22 May 1960, which was the largest ever instrumentally recorded, was preceded by 45 foreshocks in a time period of 33h before the mainshock, while 250 aftershocks were recorded in a 33h time period after the mainshock. Four foreshocks were bigger than magnitude 7.0, including a magnitude 7.9 on May 21 that caused severe damage in the Concepcion area. More recently, Brodsky and Lay (2014) and Bedford et al. (2015) reported on foreshock activity before the 1 April 2014 large earthquake (Mw8.2). However, 3-D foreshock patterns in space, time and size were not studied in depth so far. Since such studies require for good seismic catalogues to be available, we have investigated 3-D foreshock patterns only before the recent, very large mainshocks occurring on 27 February 2010 (Mw 8.8), 1 April 2014 (Mw8.2) and 16 September 2015 (Mw8.4). Although our analysis does not depend on a priori definition of short-term foreshocks, our interest focuses in the short-term time frame, that is in the last 5-6 months before the mainshock. The analysis of the 2014 event showed an excellent foreshock sequence consisting by an early-weak foreshock stage lasting for about 1.8 months and by a main-strong precursory foreshock stage that was evolved in the last 18 days before the mainshock. During the strong foreshock period the seismicity concentrated around the mainshock epicenter in a critical area of about 65 km mainly along the trench domain to the south of the mainshock epicenter. At the same time, the activity rate increased dramatically, the b-value dropped and the mean magnitude increased significantly, while the level of seismic energy released also increased. In view of these highly significant seismicity changes we used the 1 April 2014 large earthquake as a reference event when examining the 2015 and 2010 large Chilean earthquakes. This consideration is also justified by that the 3-D patterns revealed before the 2014 earthquake are quite similar to the ones that preceded the M = 6.3 L'Aquila (Italy) mainshock of 6 April 2009. The 2015 large event was preceded only by a weak foreshock sequence while no statistically significant foreshock activity was detected before the 2010 large mainshock. It is not clear so far if these different results are due to geophysical factors or to the fact that the catalogue completeness is much better in the area of the 2014 event than in the areas of 2010 and 2015 events.
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