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Short-Term Foreshocks and the Prediction of Mainshock in the Aftermath of L' Aquila Earthquake: A Global Review

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The lethal earthquake (M=6.3) of 6 April 2009 in L' Aquila, Central Italy, re-opened the discussion about the earthquake prediction due to the several precursory phenomena described in association to this earthquake. One of the most important precursors that preceded the L' Aquila mainshock was the foreshock activity. Papadopoulos et al. (NHESS, 2010) reported that a foreshock activity was there in the last months before the mainshock but the foreshock signal became very strong in the last 10 days with drastic changes in space-time-size domains of local seismicity. The importance of the short-term foreshocks for the prediction of the mainshock was noted since the 1960's. However, foreshocks appear to precede only some mainshocks and not others, while there are also foreshocks too small to detect by routine seismic analysis. To go further with the foreshocks research a review on the state-of-the-art is needed. To this aim we reviewed a long number of papers relevant to the foreshock activity including laboratory experiments, theoretical modeling, statistical analysis and real seismicity observations with foreshock cases studied around the globe but mainly in Alaska and Aleutian Arc, Central Asia, China, eastern Pacific Ocean, Greece, Italy, Japan, Latin America, New Zealand, Russia, Taiwan, Turkey and western US. It has been found that the percentage of mainshocks reported to be preceded by foreshocks increases with time which is obviously due to improving seismicity monitoring capabilities. Foreshocks are characterized by some distinct properties. In the time domain, it is generally accepted that foreshock event count accelerates towards the mainshock time by following a power-law fit. In the size domain, the G-R b-value usually drops which is a discriminator from swarm activity where parameter b increases drastically with respect to background seismicity. In the space domain foreshocks occur very close to the mainshock epicenter, thus signifying nucleation of the main rupture. However, foreshock energy release does not correlate well with the mainshock magnitude, M. This indicates that foreshock is independent of the total crustal volume which is under deformation for the preparation of the mainshock. On the other hand, there is evidence that foreshock incidence increases with increasing crustal heterogeneity which may be a critical parameter to understand the foreshock process. For the recognition of the foreshocks beforehand statistical properties are of particular importance. However, waveform and spectral characteristics are also of value. Therefore, the real-time close monitoring and analysis is the corner-stone for the foreshock recognition before the occurrence of the mainshock. As for the mechanism driving foreshock activity and its relation to the mainshock, two main assumptions have been introduced. One is that foreshocks occur as a result of a stress change in the region. Initiation of foreshock by remote triggering due to distant strong earthquake is in favour of this model. The other one is that foreshocks cause stress changes and finally trigger the mainshock. This is supported by the acceleration of the foreshock process.