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Earthquake nucleation under heterogeneous friction : aseimic slip and foreshocks interaction

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Large earthquakes are often preceded by slow slip and foreshock sequences. These precursory phenomena activate the hypocentral region of the main shock fault. However, slow slip events and earthquake swarms do not systematically lead to large earthquakes and can not be considered for short-term prediction. Understanding what controls the occurrence and the dynamics of precursors on tectonic faults is of critical importance to improve seismic hazard assessment. This study shows how frictional heterogeneity on a finite planar fault can explain the different fault behaviours preceding a large earthquake in a unified manner. It is demonstrated that under heterogeneous conditions, four different regimes of earthquake nucleation occur. All of them are characterised by slow slip acceleration, but only one involves a growing foreshock activity. The transitions between the different regimes, and the fault slip history preceding the main shock are in the four regimes controlled by effective friction parameters, and by a fracture mechanics criterion involving the characteristic wavelength of heterogeneity. The effective friction theory developed here for earthquake nucleation may have major implications in the understanding of other fault processes under heterogeneous conditions, such as dynamic rupture or episodic slow slip events.