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Localization of seismicity prior to large earthquakes

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We present results aimed at understanding preparation processes of large earthquakes by tracking progressive localization of earthquake deformation with three complementary analyses: (i) estimated production of rock damage by background events, (ii) spatial localization of background seismicity within damaged areas, and (iii) progressive coalescence of individual earthquakes into clusters. Techniques (i) and (ii) employ declustered catalogs to avoid the occasional strong fluctuations associated with aftershock sequences, while technique (iii) examines developing clusters in entire catalog data. The different techniques provide information on different time scales and on the spatial extent of weakened damaged regions. The analyses reveal generation of earthquake-induced rock damage on a decadal timescale around eventual rupture zones, and progressive localization of background seismicity on a 2-3 yr timescale before several M > 7 earthquakes in southern and Baja California and M7.9 events in Alaska. This is followed by coalescence of earthquakes into growing clusters that precede the mainshocks. Corresponding analysis around the 2004 M6 Parkfield earthquake in the creeping section of the San Andreas fault shows contrasting tendencies to those associated with the large seismogenic faults. The results are consistent with observations from laboratory experiments and physics-based models with heterogeneous materials not dominated by a pre-existing failure zone. Continuing studies with these techniques, combined with analysis of geodetic data and insights from laboratory experiments and model simulations, may allow developing an integrated multi-signal procedure to estimate the approaching time and size of large earthquakes.