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Deep-learning based large-scale automated observation of earthquake surface ruptures

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Rapid and objective mapping of co-seismic surface ruptures is essential for post-earthquake impact assessment and for improving our understanding of fault geometry, stress transfer, and rupture processes that inform longer-term seismic hazard analyses. However, rupture mapping has traditionally relied on manual interpretation of field observations or remote-sensing data, which is time-consuming and difficult to extend consistently to large spatial extents, multiple earthquakes, and diverse data sources. Here we present an automated deep-learning framework—the Deep Rupture Mapping Network (DRMNet)—a convolutional neural network designed for end-to-end, high-precision detection of co-seismic surface ruptures from multi-sensor imagery. DRMNet is applied to four large continental earthquakes: the 2021 Mw 7.4 Maduo, 2022 Mw 6.9 Menyuan, 2001 Mw 7.8 Kokoxili, and 1905 Mw ~8 Bulnay (Mongolia) events. The framework consistently delineates both primary and subsidiary rupture structures across centimetre-scale drone imagery and metre-scale satellite data. Across diverse tectonic settings, image resolutions, and preservation states, DRMNet achieves precisions approaching or exceeding 90%. By enabling consistent rupture recognition across multiple events, sensors, and timescales, the proposed framework overcomes the event-specific and local-scale limitations of previous approaches, supporting both rapid post-earthquake response and retrospective rupture reconstruction, and laying the groundwork for standardized global surface-rupture inventories.

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