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Geodetic Evidence for Weak Mantle Beneath the Sumatran Backarc and Its Influence on Regional Sea-Level

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Postseismic deformation in the far field following large earthquakes is increasingly recognised as a key factor contributing to regional land height and relative sea-level (RSL) changes. The Sumatran subduction zone provides a unique setting to study this deformation owing to the availability of far-field (600 – 1000 km from the trench) and long-term (>20 years) Global Navigation Satellite System (GNSS) observations. In this study, we model the GNSS-constrained postseismic deformation of multiple great ($M_w \geq 8.0$) regional earthquakes using a layered and self-gravitating spherical Earth model. Our results reveal a weak asthenosphere beneath the continental lithosphere in explaining the far-field GNSS observations. We estimated an asthenosphere Maxwell viscosity as low as η_m = 1.5 – 3e18 Pa s. Even assuming the presence of a weaker lithosphere-asthenosphere boundary layer (η_m = 1.3 – 2.8e17 Pa s) of 5-10 km thickness, the asthenospheric Maxwell viscosity remains less than 1e19 Pa s. Using these mantle viscosities, we estimated horizontal and vertical postseismic viscoelastic surface deformation over a broader region beyond where GNSS observations are available. We show that a weak backarc asthenosphere leads to relatively large, fast, and extensive postseismic deformation, a conclusion that likely applies to many other subduction zones. The great Sumatran megathrust earthquakes, namely the 2004 Sumatra-Andaman, 2005 Nias-Simeulue, and 2007 Bengkulu events, caused continuous far-field postseismic land subsidence over two decades. The 2012 M_w 8.6 and M_w 8.2 Wharton Basin strike-slip earthquake sequences in the Indian Ocean produced postseismic uplift in the far field, slowing down but not offsetting the ongoing subsidence caused by the great megathrust earthquakes. Our results highlight a critical concern for Southeast Asia's coastal population, as the regional VLM and RSL rise due to large earthquakes compounds the impacts of climate-driven sea-level changes.