Inferring the Evolution of a Large Earthquake from its Acoustic Impacts on the Ionosphere

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The details of forward seismic wave simulation method

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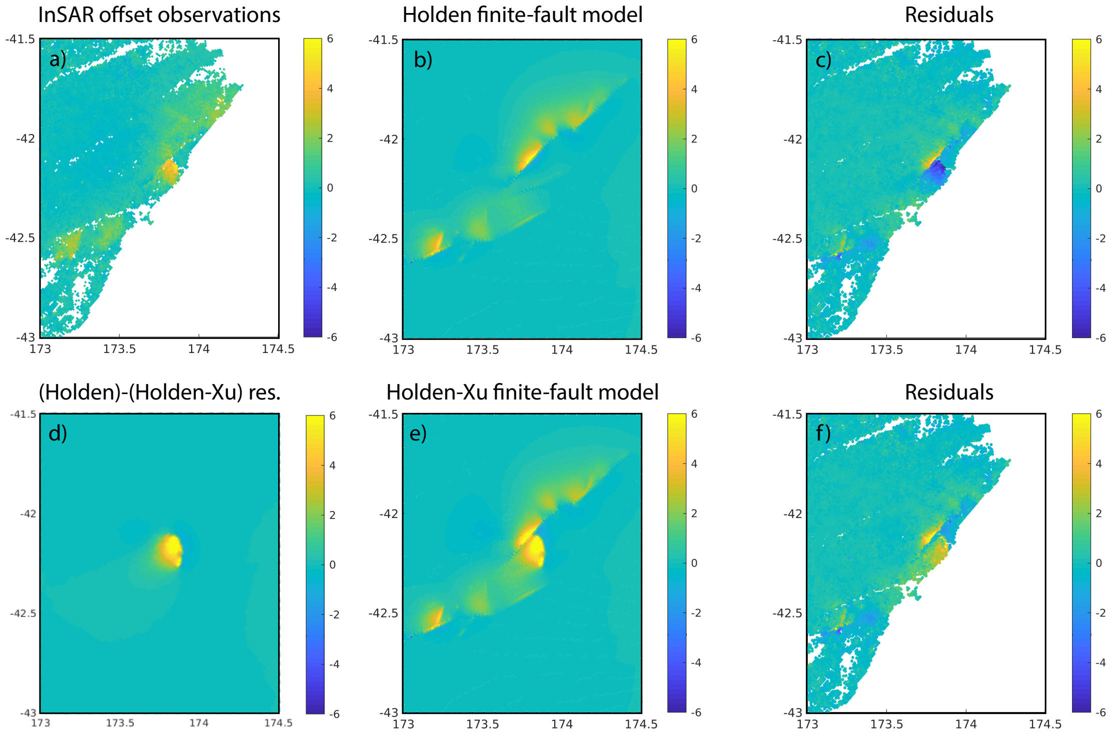
Detail of forward seismic wave simulation method

We simulate seismic wave propagation resulting from the Kaikoura earthquake using open-source seismic wave propagation software SPECFEM3D (Komatitsch & Vilotte, 1998; Komatitsch & Tromp, 2002). The computational domain is 1200 km by 600 km at the Earth surface, extends to 400 km depth and includes local topography and bathymetry. The mesh contains 4.7 million spectral elements with the average spacing between Gauss-Lobatto-Legendre node points at the Earth surface is 250 m. The minimum values of Vp, Vs and density are 1.7 km/s, 0.98 km/s and 1.7 g/cm^3, respectively. The seismic waves are numerically resolved down to a period of 2.5 s. Topography and bathymetry are interpolated from SRTM-30P (Becker *et al.* 2009). All the seismic stations are placed on the Earth's surface (i.e., on the topography). To compute time-dependent surface displacement used as an input for the IAW propagation code, a grid of receivers with a spatial resolution of 1.0 km is additionally placed on the Earth's surface. A water layer is not included in this mesh. A mesh depth of 400 km is chosen to mitigate the effect of artificial wave reflections from the bottom boundary.

We compare simulated surface velocities to 3 component velocity waveform data from a total of 17 regional stations comprised of 14 strong motion stations and 3 high-rate GPS sites from the New Zealand GeoNet network (e.g., Figure 2). The acceleration waveforms are integrated into velocity and filtered using a Butterworth bandpass filter from 0.01 to 0.3333 Hz (a period band of 3 to 100 s). The GPS velocity waveforms are derived from the time derivative of displacement waveforms, which are then bandpass-filtered at the same frequency range.

Becker, J., *et al.*, 2009. Global bathymetry and elevation data at 30 arc seconds resolution: SRTM30 PLUS, *Mar. Geod.,* **32**(4), 355–371.



Comparison between (a) observed and (b, d) simulated vertical displacement field for the original Holden model and Holden-Xu model and (c, d) their residuals. The overall residual in the region around the Papatea fault (indicated by the black rectangle) is smaller in the Holden-Xu model (root-mean-square misfit of 2.39) than the original Holden model (root-mean-square misfit of 2.67). Note that, in both of these models, the deformation is slightly overestimated in general, because the final slip distributions were previously obtained assuming a homogeneous elastic halfspace (Clark et al., 2017; Xu et al., 2018) as opposed to a 3D velocity model accounting for lower rigidity rocks at shallow depths assumed in our simulations.