Supporting Information for

The 2018 $M_w$ 7.9 Gulf of Alaska Earthquake: Multiple Fault Rupture in the Pacific Plate

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Supporting information includes text describing the 4-fault model, 10 figures and 2 animations that support the analysis in the main text.

Movie S1. Animation of the back-projections of high frequency (0.5-3.0 Hz) network data in (left) Asia (CEA stations in China), (middle) Europe, and (right) North America. The upper trace is the time varying peak power in the back-projection for each data set and the red markers move along with time during the animation. All movies are on a common time scale. The NEIC catalog seismicity after the mainshock through 20 February 2018 is shown as a reference in each map. The relative power scale from zero (white) to unity (magenta), normalized by the peak power in the sequence for each event. The position of the Alaska trench is shown by the barbed line.

Movie S2. The tsunami generated by the 4-fault slip model shown in Figures 1, 3 and S8 for the 23 January 2018 Gulf of Alaska earthquake. Small circles indicate the position of DART buoys.
Text S1.

The procedure used in the modeling is to specify one or more target fault geometries based on the overall moment tensor best double-couples, aftershock lineations, and/or back-projection locations of high-frequency subevents. Fault intersections are allowed to overlap spatially somewhat to allow the inversion to place slip where it fits best. For the specified geometries, the teleseismic data are inverted for a slip model, and the predicted displacements at GPS stations are computed and qualitatively compared with the observations. We do not make quantitative measurements of the GPS fit, as the modeling is performed for an Okada (1985) half-space solution and the data are at quite large distance. We focus on alignment and matching of length of large displacement vectors on Kodiak Island, which are most diagnostic. Models that we judge to provide acceptable fit to the GPS data are then used to compute synthetic tsunami waveform, which are compared with the DART observations. The assessment of fits to the tsunami data is based on qualitative assessment, as time alignment and small precursor polarity mismatches are best assessed visually rather than by some integral metric. For parameters such as the relative start-time of ruptures in multiple fault models, we start by assuming continuous rupture from one segment to the next at the specified kinematic rupture front expansion velocity, but we then explore time shifts relative to that start time. The seismic and GPS sensitivity is typically inadequate to differentiate between models, so the full procedure is performed for a range of start-time time shifts with the tsunami waveform comparisons providing a basis for the preferred choice of start times.

The 4-fault model shown in the text is one possible realization of complex faulting for the 23 January 2018 rupture process. Each of the four faults initiates at 25 km depth and rupture expansion velocities are 3 km/s in each case. The rupture expansion velocity is consistent with the back-projections, but the inversion uses multiple subevents for each subfault, so variation in actual rupture velocity is allowed. The rupture initiates on a fault (F1) with strike 155° and dip 72° (Figure 3, S8) at 56.004°N, 149.323°W (slightly west of the current NEIC hypocenter). After 12 s rupture initiates on a fault (F2) with strike 255° and dip 70° at the same hypocenter. A similarly oriented third fault (F3) initiates 36 km northward (56.297°N, 149.568°W) along the first fault at 12 s lapse time, and the model extends eastward along a seismicity trend. The fourth rupture is on a fault (F4) with the same geometry as the first fault that begins to rupture 22 s after the initial failure at 56.466°N, 148.911°W, with the model extending southward from the third fault along a seismicity trend. The largest slip, 15.6 m, is on the first fault, which has a seismic moment of 5.22 x 10^20 Nm, with the slip centroid depth being 16 m and very little slip more than 20 km south of the hypocenter. The second fault has peak slip of 3.0 m, and total moment of 1.30 x 10^20 Nm. Slip near the fault intersection is large and but slip is consistently deeper on this fault, with a centroid depth of 23 km. Shallow slip of up to 2.9 m is found on the third fault, which has a seismic moment of
6.54 \times 10^{19} \text{Nm}, and the fourth fault has slip <0.7 \text{ m}, mostly concentrated near the intersection with the third fault. Details are shown in Figure S8. The normalized residual waveform power is 0.35, about the same as for long single-fault models, and the teleseismic waveform matches (Figure S9) are reasonable for such a complex fault system.
Figure S1. Map locations of the broadband stations recording P waves filtered in the 0.5 – 3.0 Hz passband and used in back-projections for the 23 January 2018 earthquake for the Asia (CEA) (a, b), Europe (c, d), and North America (e, f) large-aperture networks. Travel time residuals for each station from multi-station correlation alignment are shown in (a, c, e), while correlation coefficients with the network mean are shown in (b, d, f).
Figure S2. High-frequency (0.5-3.0 Hz) P waves from Chinese Earthquake Administration (CEA) broadband stations in Asia (China) for the 23 January 2018 earthquake aligned by multi-station correlation and plotted as a function of azimuth from the source.
Figure S3. High-frequency (0.5-3.0 Hz) $P$ waves from European broadband stations for the 23 January 2018 earthquake aligned by multi-station correlation and plotted as a function of azimuth from the source.
Figure S4. High-frequency (0.5-3.0 Hz) $P$ waves from North American broadband stations for the 23 January 2018 earthquake aligned by multi-station correlation and plotted as a function of azimuth from the source.
**Figure S5.** Single-fault model with a strike = 259°, dip = 70°, hypocentral depth 22 km, and rupture expansion speed of 3 km/s and its associated tsunami signals in comparison to measurements at five DART stations. The finite-fault inversion of teleseismic body waves has a seismic moment of $9.7 \times 10^{20}$ Nm. (a) The inverted slip distribution in map view. The red dot denotes the hypocenter. (b) The computed seafloor displacement for the model in (a). The approximated maximum of uplift and downdrop are specified. (c) Comparison of observed (black lines) and computed (red lines) tsunami waveforms (left) and spectra (right).
Figure S6. Single-fault model with a strike = 165°, dip = 81°, hypocentral depth 22 km, and rupture expansion speed of 3 km/s and its associated tsunami signals in comparison to measurements at five DART stations. The finite-fault inversion of teleseismic body waves has a seismic moment of $9.7 \times 10^{20}$ Nm. (a) The inverted slip distribution in map view. The red dot denotes the hypocenter. (b) The computed seafloor displacement for the model in (a). The approximated maximum of uplift and downdrop are specified. (c) Comparison of observed (black lines) and computed (red lines) tsunami waveforms (left) and spectra (right).
Figure S7. Comparison of water-level record at DART 46410 (black lines) with computed waveforms and spectra (red lines) for the 4-fault model shown in Figures 1, 3, and S8 at buoy 46410 (red traces) and at virtual station locations shown in the map (green traces). Red dots in the map locate DART buoys 46410 and 46409 and green dots locate virtual stations. Note how the amplitude of the initial downswing of the waveform relative to the second downswing decreases as the artificial station location is displaced southward.
Figure S8. Slip distributions on the four faults (F1–F4) in the model presented in Figures 1 and 3, along with the individual and composite moment rate functions at the top and the P (upper mechanism) and SH (lower mechanism focal mechanisms for each fault with the cyan circles indicating the teleseismic data distribution for the finite-fault inversion. The strike (\(\phi\)), dip (\(\delta\)), and average rake (\(r\)), peak slip value, subfault source time functions (parameterized with 10 2.5-s rise time triangles shifted by 2.5-s for all cases), rupture expansion velocity (3 km/s in all cases) and centroid depths (Hc) each fault are shown above the slip distributions. Rupture expansion contours are shown with 5 s intervals with white dashed lines. The subfault source time functions are shown inset in each subfault, with the arrows indicating the rake on the fault plane and slip relative to the peak value for that fault. The subfault total slip is also color-coded. The moments for each subfault are listed at the top, color-coded relative to each fault’s moment rate function. The normalized residual waveform power is given by Var. The onset time of each fault is indicated by the relative timing of the moment rate functions. The stars indicate the hypocenter of each fault rupture initiation.
Figure S9. Comparison of observed (black lines) and computed (red lines) $P$ wave ground displacement and $SH$ wave ground velocity waveforms for the 4-fault rupture model in Figures 1, 3, and S8.
Figure S10. Maximum surface elevation of the tsunami generated by the 4-fault slip model shown in Figures 1, 3, and S8.
**Movie S1.** Animation of the back-projections of high frequency (0.5-3.0 Hz) network data in (left) Asia (CEA stations in China), (middle) Europe, and (right) North America. The upper trace is the time varying peak power in the back-projection for each data set and the red markers move along with time during the animation. All movies are on a common time scale. The NEIC catalog seismicity after the mainshock through 20 February 2018 is shown as a reference in each map. The relative power scale from zero (white) to unity (magenta), normalized by the peak power in the sequence for each event. The position of the Alaska trench is shown by the barbed line.
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