Contents of this file

Text S1 Details of the Finite-Fault Inversion
Text S2 Discussion of Seismic Moment Estimates
Figures S1 to S6
Table S1 Velocity Model

Additional Supporting Information (File uploaded separately)

Movie S1

Introduction

Supplemental Texts S1 and S2 provide additional information on the finite-fault inversion and the seismic moment estimates. Figures S1 and S2 illustrate the W-phase mechanism and the use of Rayleigh and Love waves to constrain the dip angle. Figures S3, S4, and S5 show
comparisons of the teleseismic waveforms and predictions of the preferred model, the rupture model stress change on the fault and stress drop parameters, and the average source spectrum. Figure S6, along with Figures 3a and 4a, demonstrates convergence of the fault model refinement process using the DART records. Table S1 provides the velocity model used in the finite fault inversion. Movie S1 shows evolution of the modeled tsunami around the Hawaiian Islands.

**Text S1. Details of the Finite-fault Inversion**

The faulting geometry to be used in the finite-fault inversion is determined first. Often, one can rely on long-period moment tensor inversions to give candidate fault planes from the corresponding best-double-couple solutions. For this event, both the GCMT and USGS W-phase inversions indicate thrust-faulting with a northwestward dip of 20°. Because the source is very shallow, the dip is expected to be uncertain. Professor Hiroo Kanamori provided us with a W-phase inversion solution, shown in Figure S1, which has a dip of 10.9° and a centroid depth of 11.5 km. Given that the hypocentral depth of the event as estimated by the NEIC is being even shallower (2.1 km), the dip is not reliably resolved by the long-period full-waveform inversions in this case.

We constrained the dip by analyzing long-period fundamental mode spectra, emphasizing the Love waves, as the excitation and radiation pattern for these waves varies rapidly with dip for shallow sources. This is demonstrated in Figure S2 for group-velocity windowed Rayleigh and Love wave spectra for short-arc \((R1, G1)\) and long-arc \((R2, G2)\) signals with a period of 204.8 s. Scaling the seismic moment so as to give the same peak Rayleigh wave amplitudes, theoretical Love wave spectra for a 6 km depth in the PREM structure are seen to have two of the radiation pattern nodes, which become less pronounced as the dip decreases. For dip less than 2° the Love wave radiation pattern will become two-lobed, rather than quasi-four-lobed. The data clearly show variation in the depth of the Love wave radiation nodes as found for synthetics for models with dip of 2.5° to 7.5°. Because there is always some noise in the spectra at nodal directions, we adopt a preferred dip of 7.5°, although a dip of 3° to 4° is also consistent with the data. This is discussed in detail by "Lay, T., Ye, L., Kanamori, H. & Satake, K. (2018). Constraining the dip of shallow, shallowly-dipping thrust events using long-period Love wave radiation patterns: Applications to the 25 October 2010 Mentawai, Indonesia and 4 May 2018 Hawaii, Island Earthquakes. Geophysical Research Letters, 45, doi: 10.1002/2018GL080042, in press".

An updated first-motion focal mechanism from local observations was provided to us by Paul Okubo, with a westward dipping fault plane of 6°, and a steeply dipping nodal plane with a dip of 87°. This supports our preference for a shallowly-dipping thrust fault plane compatible with the event being located on the offshore décollement fault.

The finite-fault inversion method used is an extensively modified version of the linear least-squares kinematic rupture inversion code introduced by M. Kikuchi and H. Kanamori (available from http://www.eri.u-tokyo.ac.jp/ETAL/KIKUCHI/). This code builds on the basic algorithm suggested by Hartzell & Heaton (1983). Extensive applications of the code that demonstrate the basic properties are shown, for example, by Ye et al. (2016). For the Hawaii Island earthquake, a single planar fault with specified strike and dip is prescribed, along with a hypocentral location on the fault grid. For the preferred model, the strike is 235°, dip is 7.5°,
and hypocentral depth is 6.0 km. Rectangular subfaults are defined along strike and along dip on the planar surface. For the preferred model, there are thirteen 3-km long subfaults along strike and twelve 3-km wide subfaults along dip. Green's functions are computed for orthogonal rake values ± 45° on either side of a reference rake (92.1° for the preferred modeling). A positivity constraint in the inversion ensures that the rake of each subevent for each subfault is within the allowed range. The subfault source time functions are prescribed by a set of overlapping triangular subevents. For the preferred model, we use twelve 2-s duration symmetric triangles staggered by 1-s each, giving maximum possible subfault source time function durations of 13 s. A constant rupture front expansion velocity is specified, the final model uses 1.5 km/s, and subfaults with central points within the expansion front are allowed to have slip through the time duration of the subfault. The Green's functions are computed for the velocity model shown in Table S1.

**Text S2. Discussion of Seismic Moment Estimates**

The preferred finite-fault model has a seismic moment estimate of $M_0 = 8.7 \times 10^{19} \text{Nm}$ ($M_W 7.2$), with the dip being 7.5°. The seismic moment estimates for the long-period moment tensors obtained by GCMT (2.71 x 10^{19} Nm) and USGS W-phase (2.74 x 10^{19} Nm) are both for a best-double-couple dip of 20°. The centroid depths of the GCMT (12 km) and W-phase (11.5 km) inversions are both deeper than the mean slip depth in the finite-fault solution (5.1 km). Difference in centroid depth and source velocity structure will have some effect on seismic moment estimation, but the shallower dip, δ, of the finite-fault solution versus the long-period moment tensors will likely increase the estimated moment relative to the long-period inversions because the excitation is proportional to $M_0 \sin(2\delta)$ for this shallow dip-slip thrust event. Essentially, larger $M_0$ is required for shallower δ. Just scaling the long-period moment estimates of 2.71x10^{19} Nm to 2.74 x 10^{19} Nm to correspond to a 7.5° dip would increase the estimated seismic moment by a factor of ~2.5 to around 6.9 x 10^{19} Nm, slightly smaller than our preferred moment estimate. Increased seismic moment for a shallower centroid depth and some difference in crustal structure likely account for the difference. A finite-fault inversion using the GCMT dip and a hypocentral depth of 5 km gives a moment of 3.2 x 10^{19} Nm, so the approximate scaling with dip is predictive to first order. Because we fit the GPS displacements, which are primarily sensitive to slip, the moment estimate for the finite-fault model is stabilized by those data.
Figure S1. W-phase mechanism from a W-phase inversion (courtesy of H. Kanamori). This solution used 38 stations with 49 channels, and a centroid depth of 11.5 km. The best nodal plane for the northwestward dipping fault has strike 226.3°, dip 10.9° and rake 92.1°. The half duration is 14.7 s and the centroid location is 19.320°N, 155.133°W. The seismic moment is $3.69 \times 10^{19}$ Nm (Mw 6.98).
Figure S2. Observed and predicted Rayleigh wave (top) and Love wave (bottom) source spectral amplitudes for $T = 204.80$ s for the 4 May 2018 Hawaii Island earthquake. Red dots indicate short-arc (R1, G1) observations; cyan dots indicate long-arc (R2, G2) observations. Theoretical amplitudes for point-source models with step-function displacement time histories with $\phi = 235^\circ$, $\lambda = 102^\circ$ and $\delta$ from 2.5° to 12.5° are shown by the color curves. The depth is 6 km in the PREM structure. Seismic moment for each model is adjusted to give the same Rayleigh wave peak amplitude. From Lay, T., Ye, L., Kanamori, H. & Satake, K. (2018). Constraining the dip of shallow, shallowly-dipping thrust events using long-period Love wave radiation patterns: Applications to the 25 October 2010 Mentawai, Indonesia and 4 May 2018 Hawaii, Island Earthquakes. *Geophysical Research Letters*, 45, doi: 10.1002/2018GL080042, in press.
Figure S3. Station distributions and waveform fitting of teleseismic P (left column) and SH (right column) data for the 2018 Hawaii Island earthquake. Azimuthal waveform plots show comparison of the observed (black lines) and predicted (red lines) P wave ground displacements (left) and SH wave ground velocities (right) for the preferred model (Figure 2).
Figure S4. Variation in shear stress change over the fault model surface of the preferred model in Figure 2 for the 4 May 2018 Hawaii Island earthquake. The average static stress drop obtained by the two methods in Ye et al. (2016) is estimated as from 5.2 to 6.3 MPa.
Figure S5. The average source spectrum (computed following the procedure described by Ye et al., 2016) for the preferred model of the 4 May 2018 Hawaii Island earthquake (red) is shown along with the measured radiated energy, $E_r$, and $E_r/M_0$. A reference spectrum for an $\omega$-squared model with a 3 MPa stress factor is shown by the dashed line.

\[ E_r = 4.28 \times 10^{14} \text{ J} \]
\[ E_r/M_0 = 5.42 \times 10^{-6} \]
Figure S6. Examples of initial fault models and corresponding vertical surface displacements and tsunami signals at DART 51407. Comparison between computed (red) and recorded (black) tsunami signals enables inference of generation mechanisms and guides refinement of the fault model. The recorded initial pulse shows superposition of two harmonics with a slight phase lag. The concentrated slip patch of model01 generates a single-harmonic arrival at DART 51407. Increasing the along-strike length of the slip patch in model03 produces two harmonics, but with an overestimated phase lag resulting in a double-peak initial arrival. Iterative refinement of the fault parameters and dimensions in the finite-fault inversion
achieves a slightly oblong slip patch in Figure 3a that can match the recorded initial arrival as shown in Figure 4.

**Table S1. Seismic velocity model used in inverting teleseismic data**

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</table>
Movie S1. Animation of the tsunami generated by the $M_W$ 6.9 Hawaii Island earthquake of 4 May 2018. Circles indicate locations of water-level stations.