

Supplements for: Triggered Shallow Megathrust Slip following the 2020 M_w 7.6 Sand Point (Alaska) Strike-Slip Earthquake Explains its Tsunami

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The supplementary materials consist of Supplementary Texts 1-2, and Figures S1-S26.

Supplementary Text 1 – Tectonic Background

The Alaska Peninsula is characterized by nearly trench-normal subduction of the Pacific plate (Fig. 1). The lithosphere of the overriding plate moves in the long-term relative to North America (Cross and Freymueller, 2008; Fournier and Freymueller, 2007), and the long-term motion of the Alaska Peninsula has been described as westerly, nearly arc-parallel motion relative to North America (Li and Freymueller, 2018; Elliott and Freymueller, 2020). The slip behavior of the megathrust varies substantially along-strike, with a wide region of high slip deficit found to the northeast, near Kodiak Island, and a stepwise reduction in slip deficit to the southwest (Fournier and Freymueller, 2007; Li and Freymueller, 2018; Drooff and Freymueller, 2021; Xiao et al., 2021). Near the western tip of the Alaska Peninsula, the plate interface is inferred to be entirely creeping, or nearly so (Drooff and Freymueller, 2021; Freymueller and Beavan, 1999), although a narrow band of moderate slip deficit could exist near the trench without being detected by the on-land GNSS stations (Elliott et al., 2024). Herman and Furlong (2021), among

others, demonstrated that this along-strike gradient in slip deficit produces an interseismic stress field that would increase the stress on a fault oriented in the direction that ultimately ruptured in the Sand Point earthquake.

Supplementary Text 2 – Long-period seismograms

The model that best fits the geodetic and tsunami data features a dominantly strike-slip source followed by a delayed, slow megathrust slip event near the trench, ~ 400 - 480 s later. We assume 420 s for simplicity here. To seek evidence of this late, slow rupture at very long periods, we compare long period vertical-component seismograms (periods $100 - 500$ s) for the Global Seismic Network (GSN), generating predicted seismograms for a variety of sources. Instrument responses are deconvolved to displacement, $0.1 - 200$ mHz, for all active GSN stations for the Sand Point earthquake; signals from the 2020 Simeonof ($M_w 7.8$) earthquake were also compared as a test.

To evaluate the signals, they are compared to full-waveform synthetic seismograms generated using the Syngine seismogram synthesis system (Krischer et al., 2017), for propagation in PREM (Dziewonski and Anderson, 1981). First, seismograms are generated for the strike-slip event using the GCMT solution (Ekström et al., 2012; www.globalcmt.org). Then, a second source is added that matches the megathrust event used for the two-source tsunami modeling (strike = 237.5° , dip = 14.5° , depth = 12 km, moment $M_0 = 6.3 \times 10^{19}$ Nm), lagged by 420 s after the first event. Fig. S24 shows these comparisons at 100 - 400 s periods. Observed seismograms are well-matched by the single GCMT source, while the two-event model predicts a second Rayleigh wave (arrows) that is not observed. The same phenomenon is observed at shorter periods (50 - 100 s) and at most other global stations.

However, the comparison assumes fast rupture. As an alternative we repeat the exercise but assume the second subevent has slow rupture consistent with other tsunami earthquakes. Specifically, the seismograms are convolved with a far-field moment-rate function often used for tsunami events as $M_0/\tau e^{-t/\tau}$ equivalent displacement scaling as $(1 - e^{-t/\tau})$ (Ide et al., 1993; Kanamori, 1972). The characteristic time τ is set to 60 s, comparable to the 50-150 s durations common to many tsunami earthquakes (Bilek and Lay, 2002). For a tsunami-earthquake-type second rupture, the model no longer predicts an unobserved phase (Fig. S25).

Local station signals

High frequencies show no evidence for an event near the 420 s delay modeled for the second tsunami source. Fig. S23 shows seismograms for a handful of the closest stations at high frequencies (2-16 Hz), amplified to show coda clearly. While an obvious aftershock can be seen at 700 s after the mainshock, nothing systematic is seen earlier (arrows point to predicted P arrival). At the closest station, AK.CHN at 0.225° distance, a series of energy bursts, likely small events, can be seen starting about 250 s lag. It is possible that these represent a sequence of very early aftershocks or other events transitory to the tsunami event, not captured in routine catalogs.

Supplementary Figures

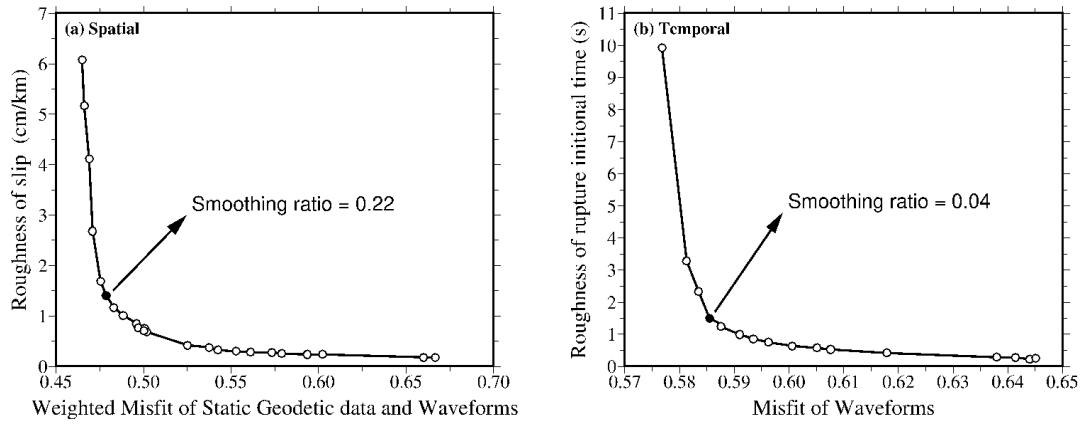


Figure S1. Preferred spatial and temporal smoothing parameters for strike-slip only model, according to the L curve between misfit and roughness.

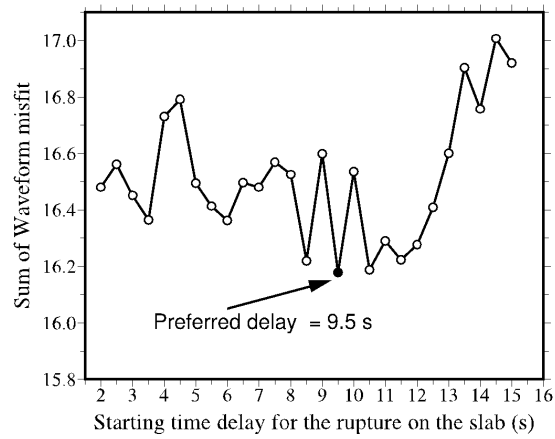


Figure S2. The curve between starting time delay after mainshock initiation for the rupture on the slab and waveforms misfit.

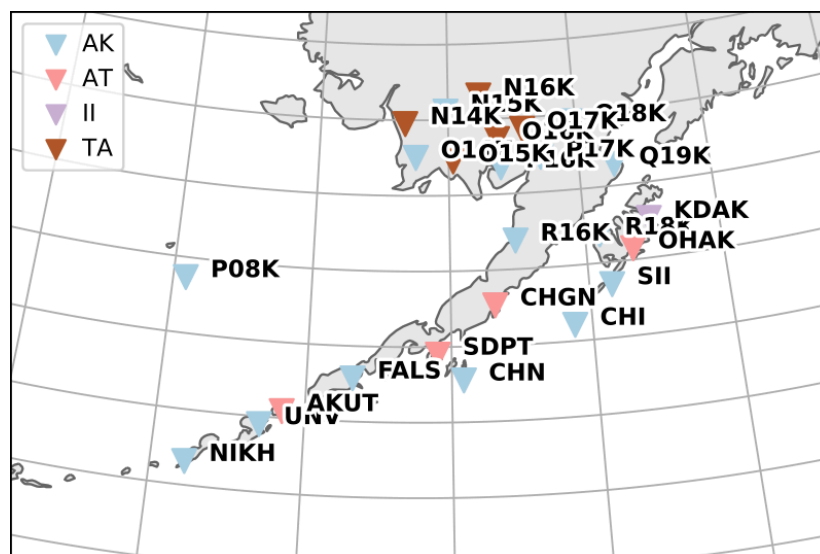


Figure S3. Seismic stations within 600 km of 2020 M7.6 Sand Point earthquake epicenter.

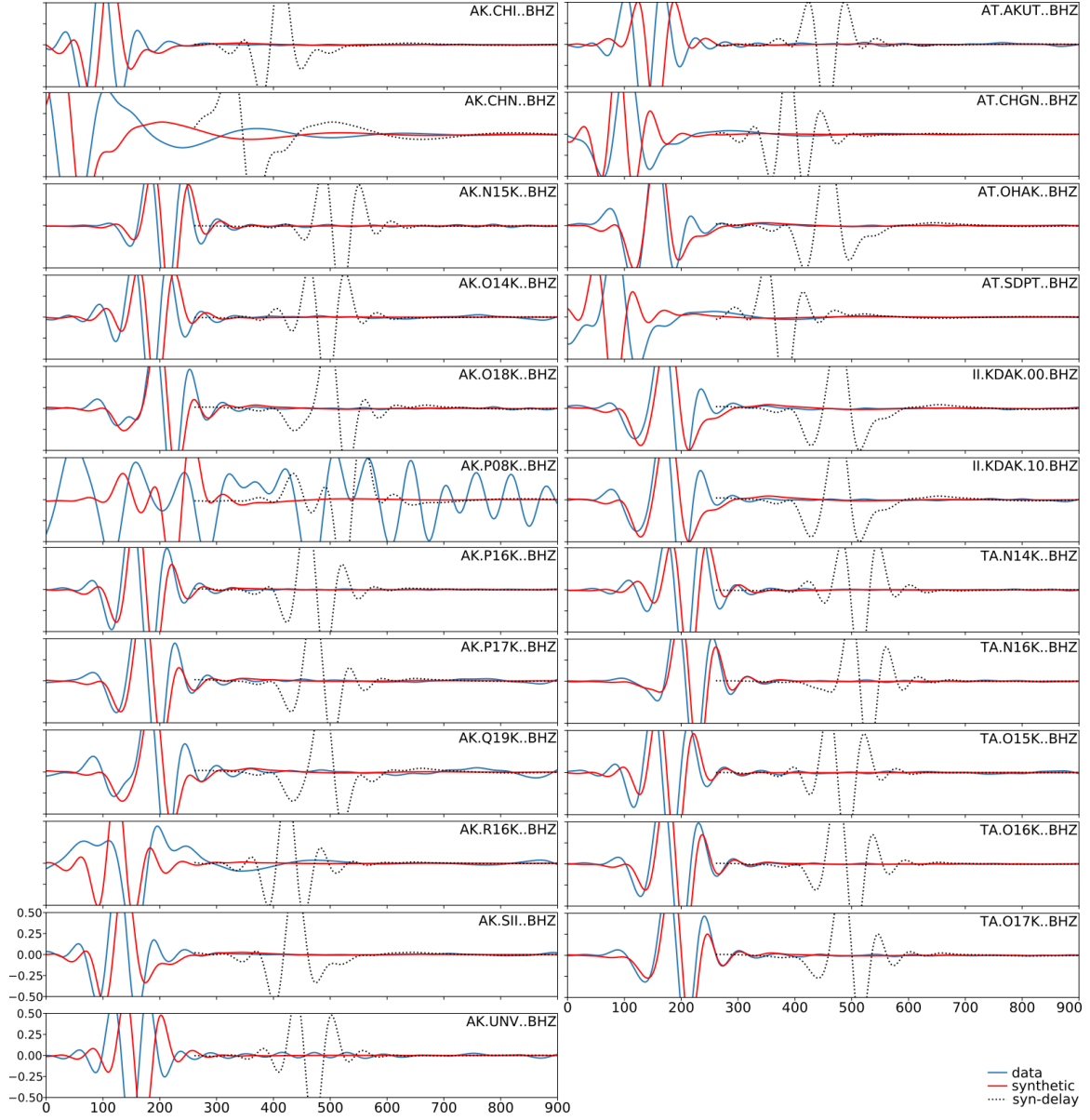


Figure S4. Band-pass filtered (50-300 s period) vertical component seismograms for stations shown in Figure S3 (blue), PREM model synthetics (red), PREM model synthetics shifted by 5 minutes (dotted).

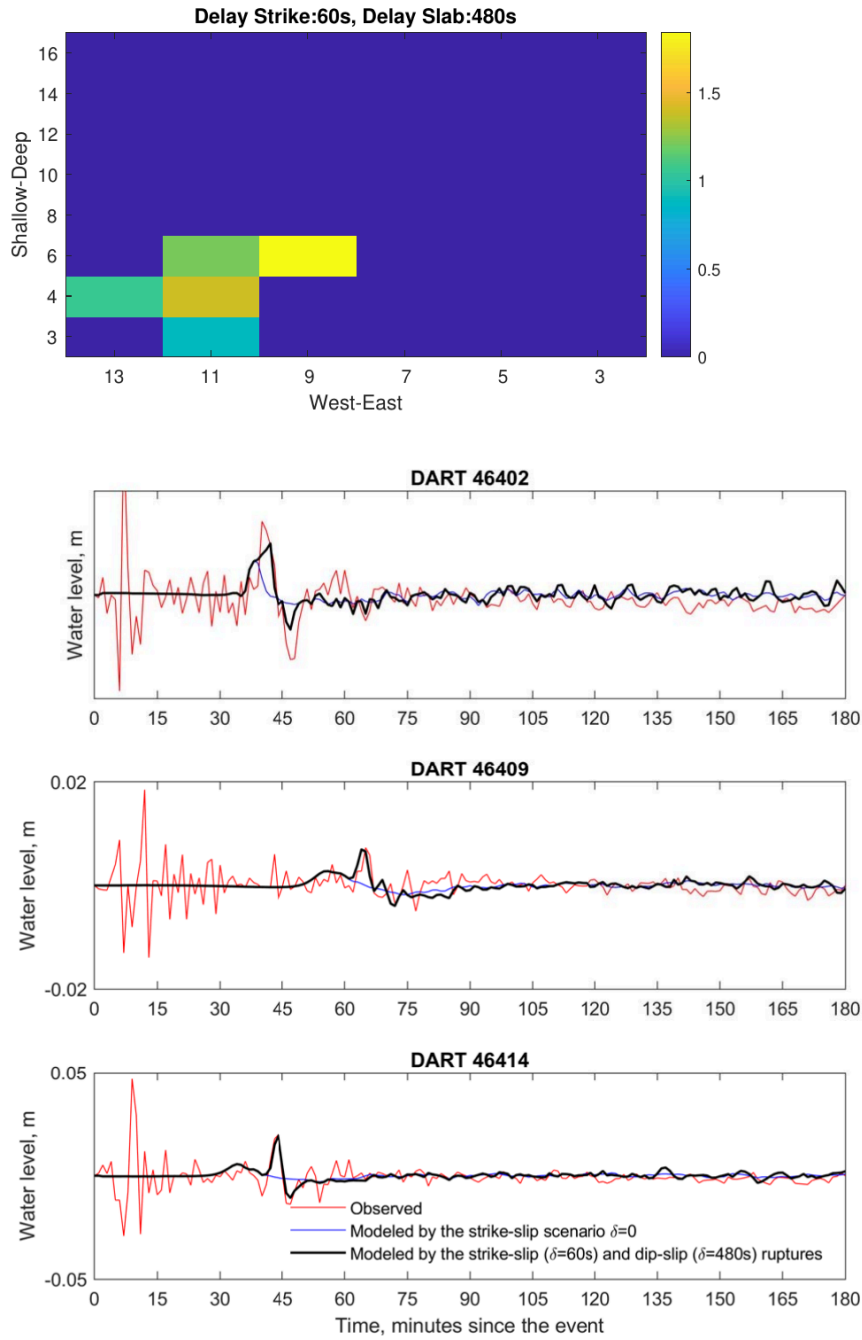


Figure S5. Scaled unit source model candidate and tsunami predictions. **Top:** Pure thrust slip in meters on the fault patches (up-dip end is at the bottom). Patches are indexed via row and column. Shallowest two rows (0-2.5 km) have not been included in tsunami modeling, as they created high frequency artifacts. **Bottom:** Similar to Fig. 8; tsunami observations (red), modeled tsunami from 60 s delayed strike-slip only slip (blue) and combined 60 s delayed strike-slip and 480 s delayed unit source model slip (black) predicted tsunami at the three DART buoys.

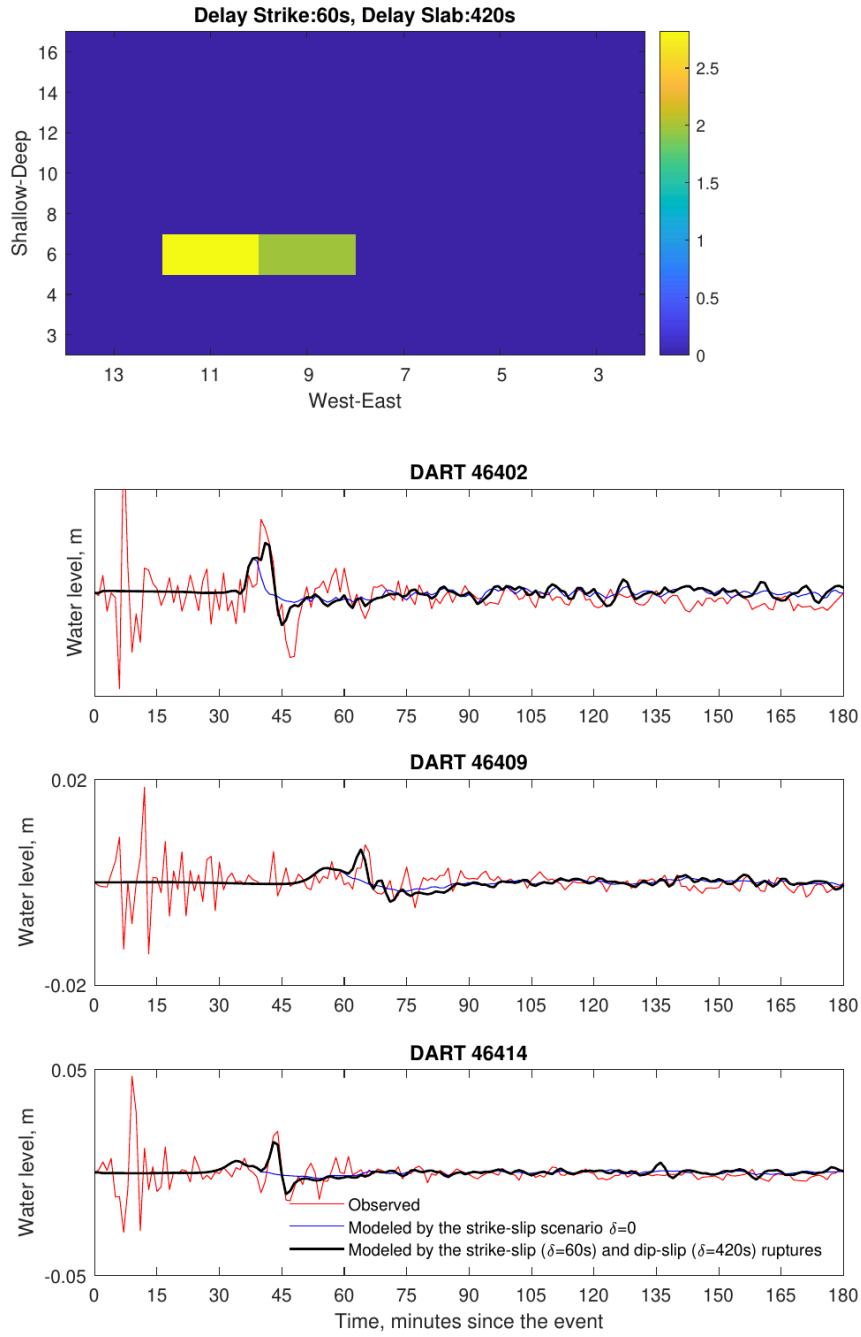


Figure S6 Like Fig. S5, but for strike-slip delay of 60 s and megathrust delay of 420 s.

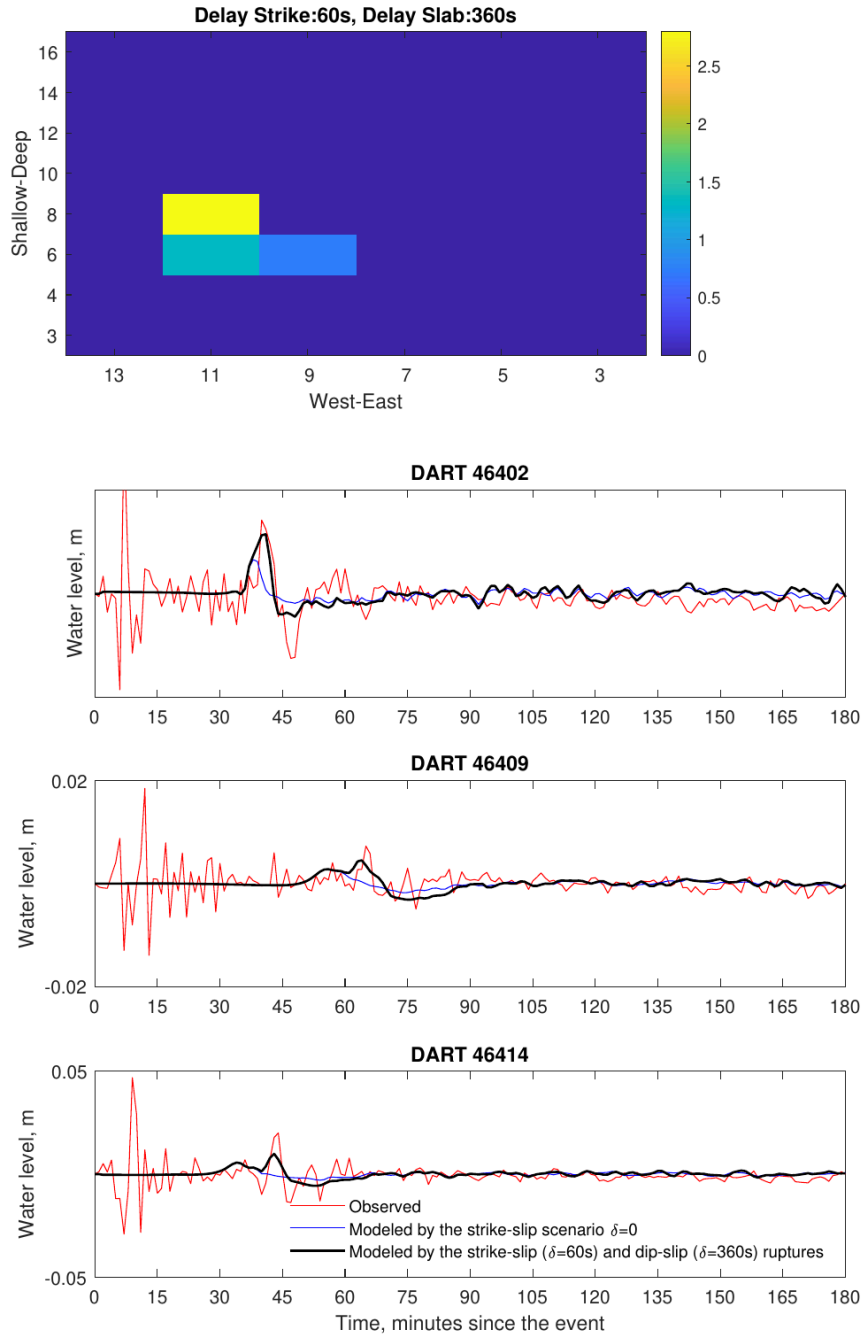


Figure S7. Like Fig. S5, but for strike-slip delay of 60 s and megathrust delay of 360 s.

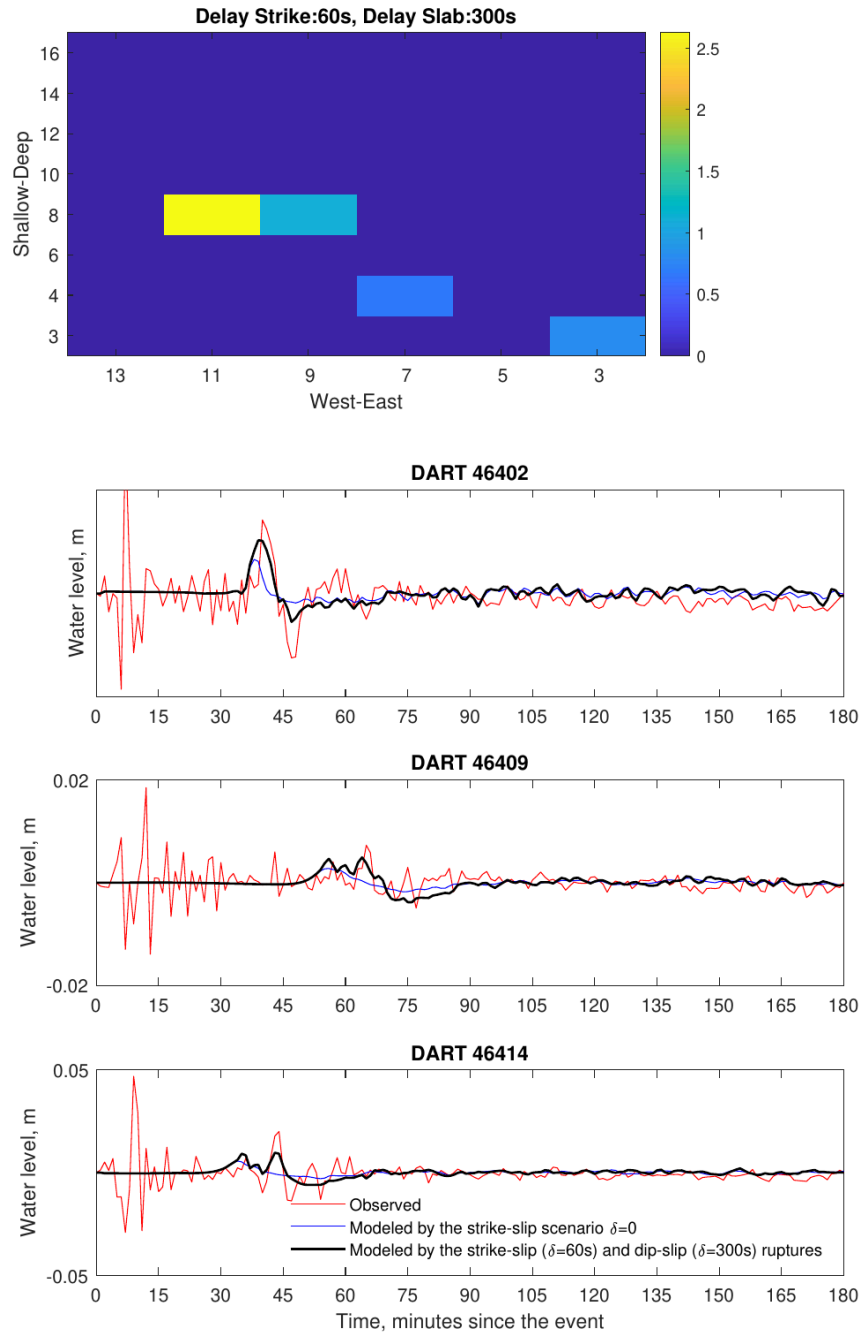


Figure S8. Like Fig. S5, but for strike-slip delay of 60 s and megathrust delay of 300 s.

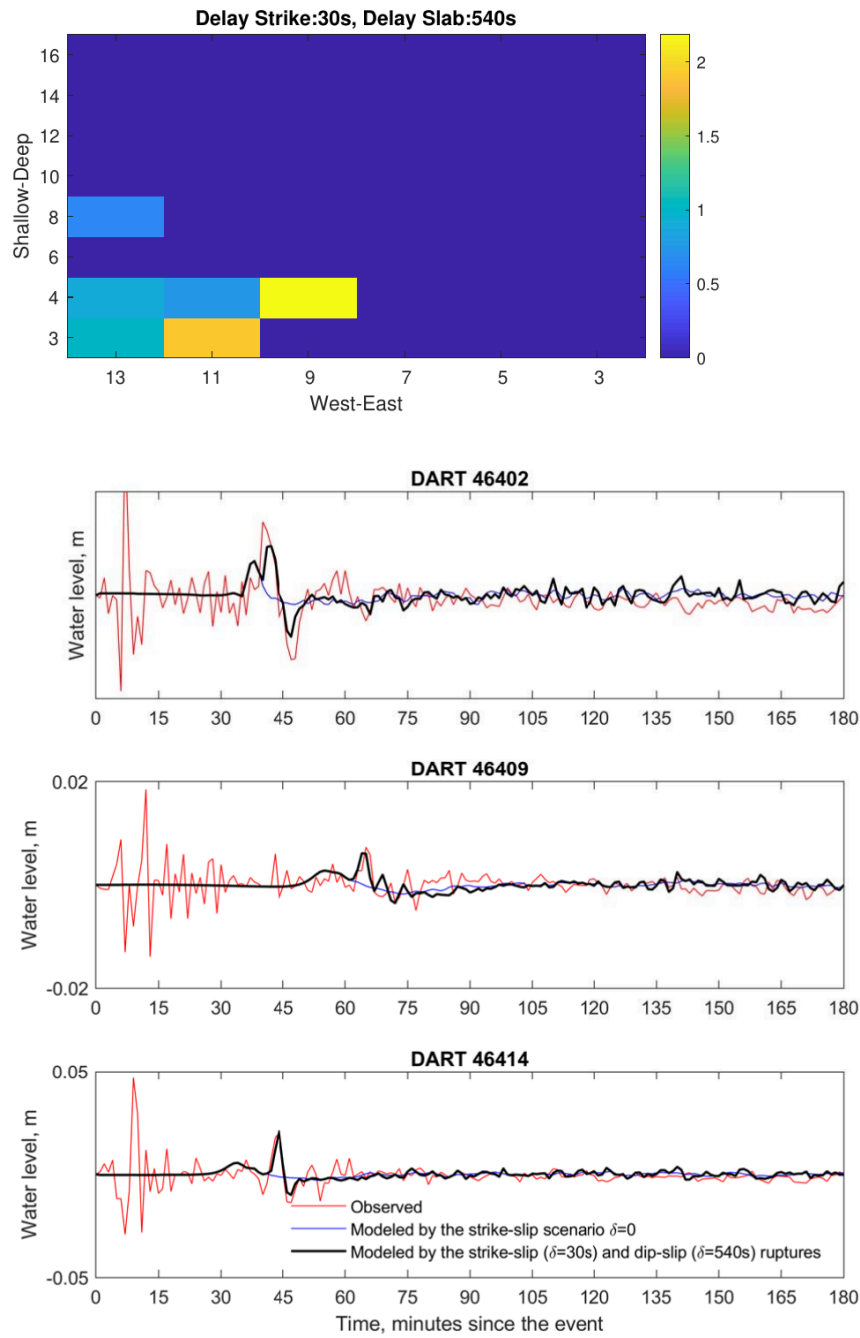


Figure S9. Like Fig. S5, but for strike-slip delay of 30 s and megathrust delay of 540 s.

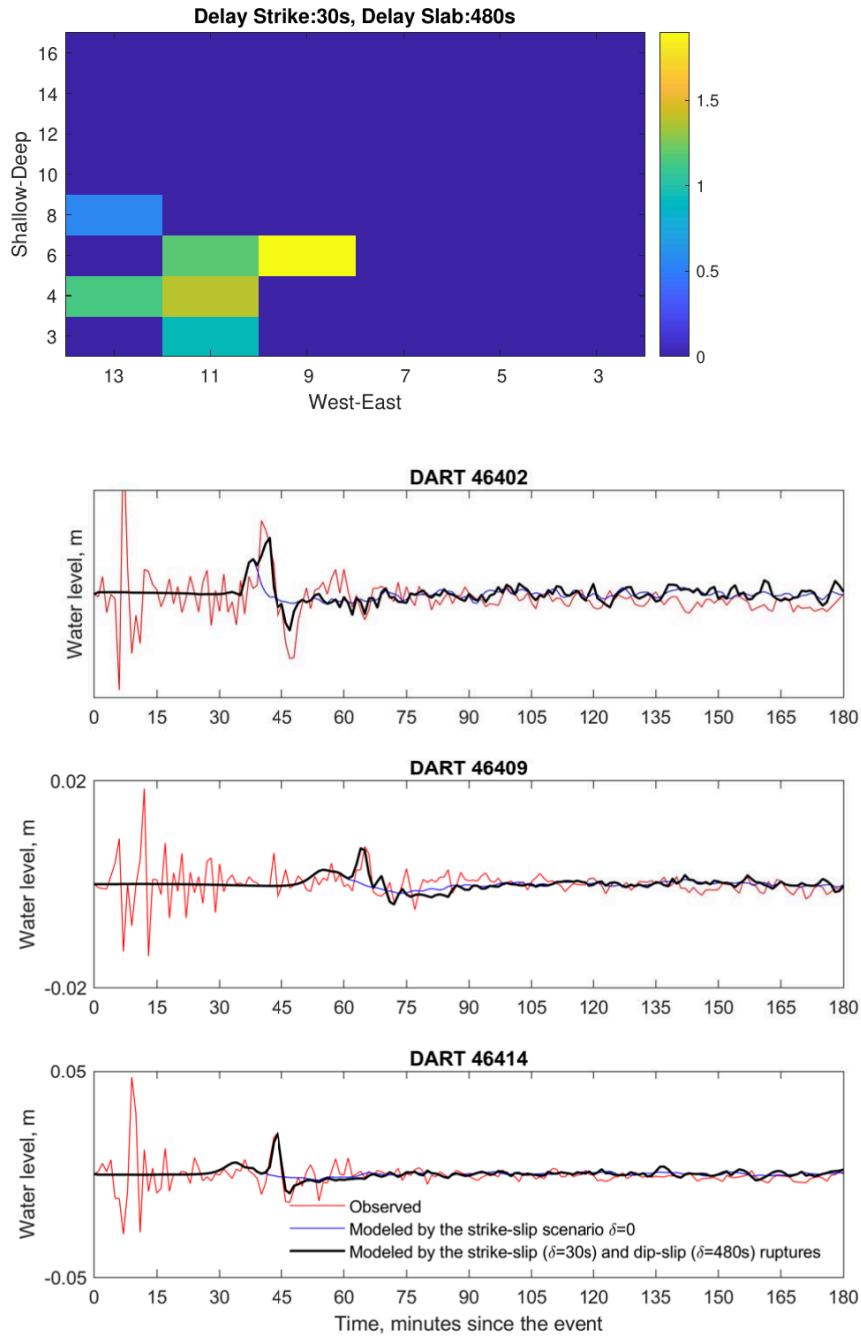


Figure S10. Like Fig. S5, but for strike-slip delay of 30 s and megathrust delay of 480 s.

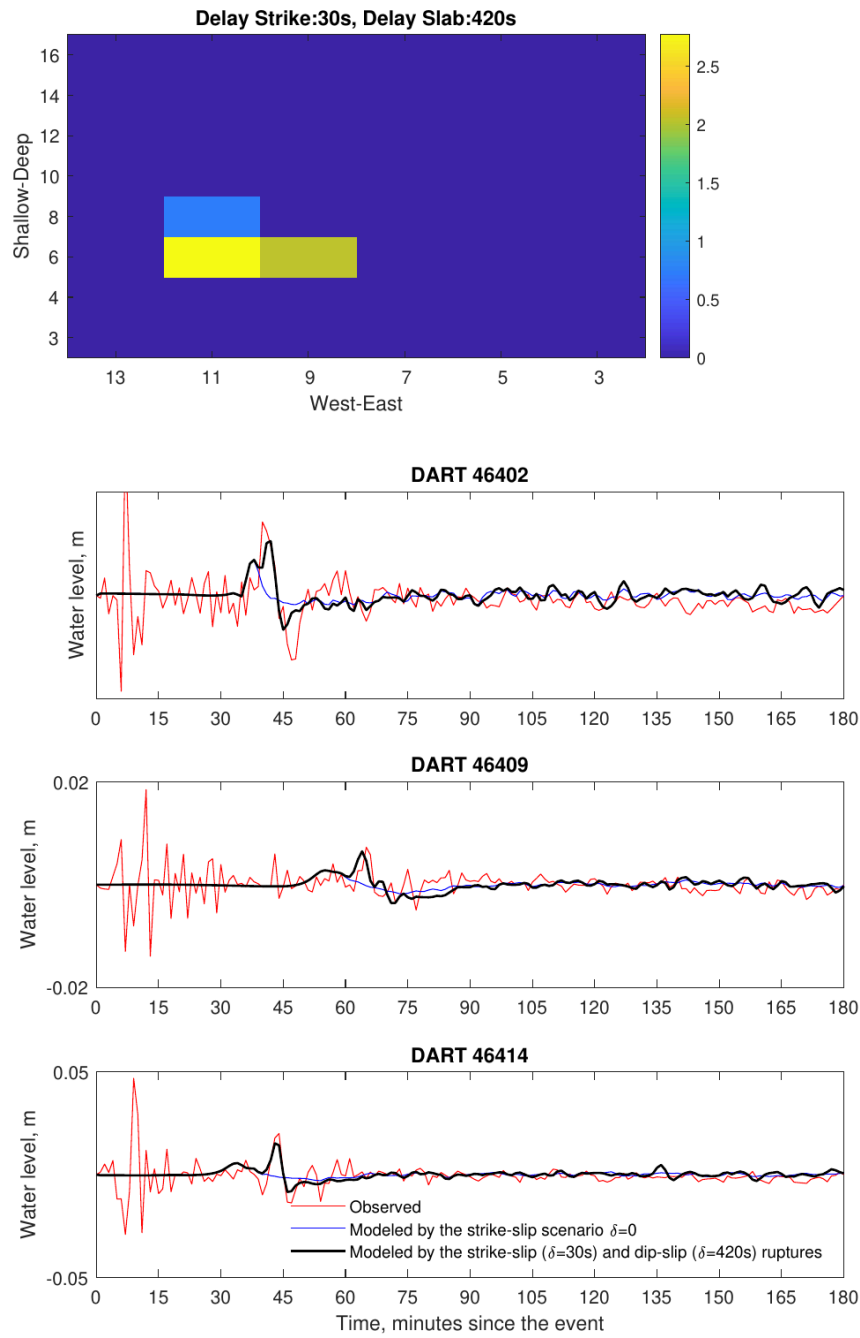


Figure S11. Like Fig. S5, but for strike-slip delay of 30 s and megathrust delay of 420 s.

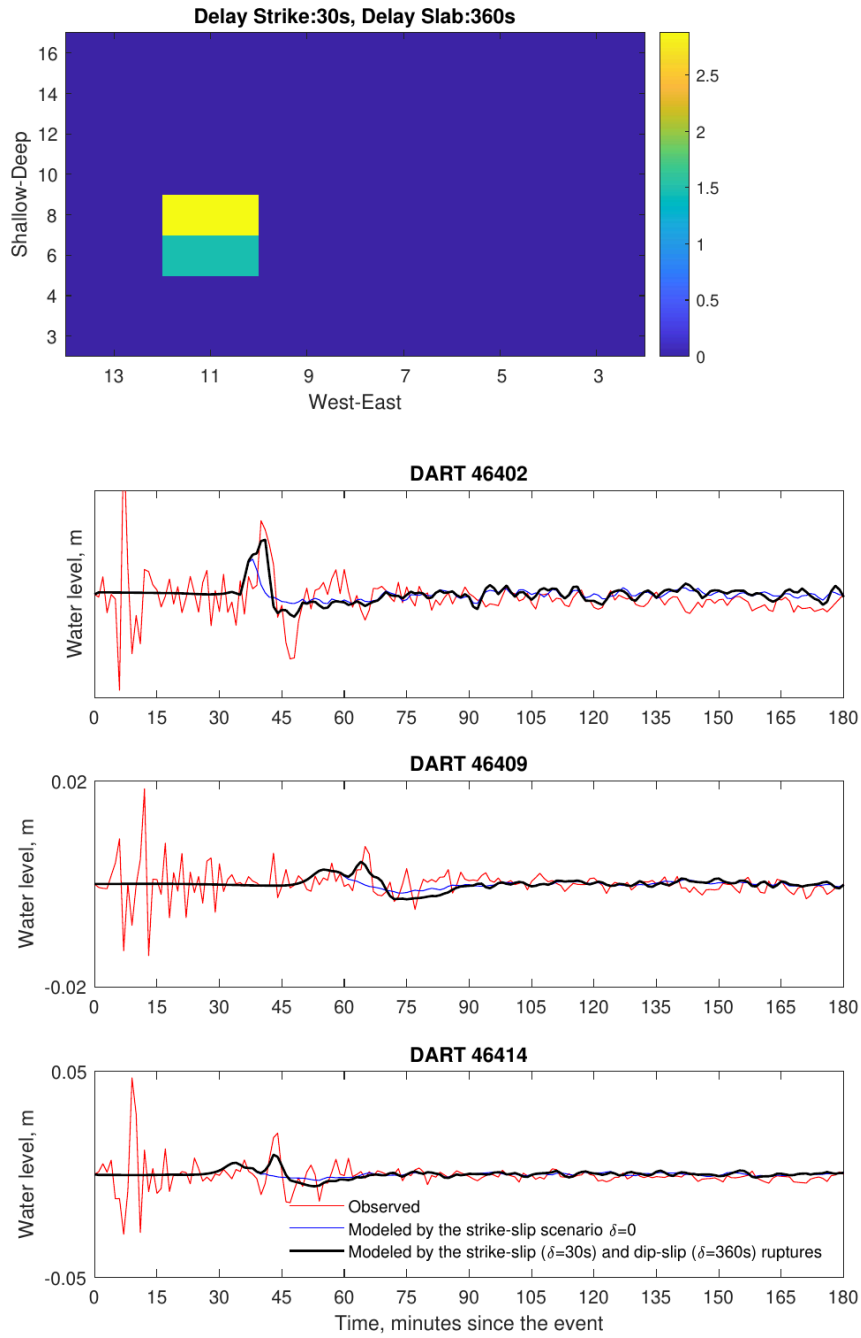


Figure S12. Like Fig. S5, but for strike-slip delay of 30 s and megathrust delay of 360 s.

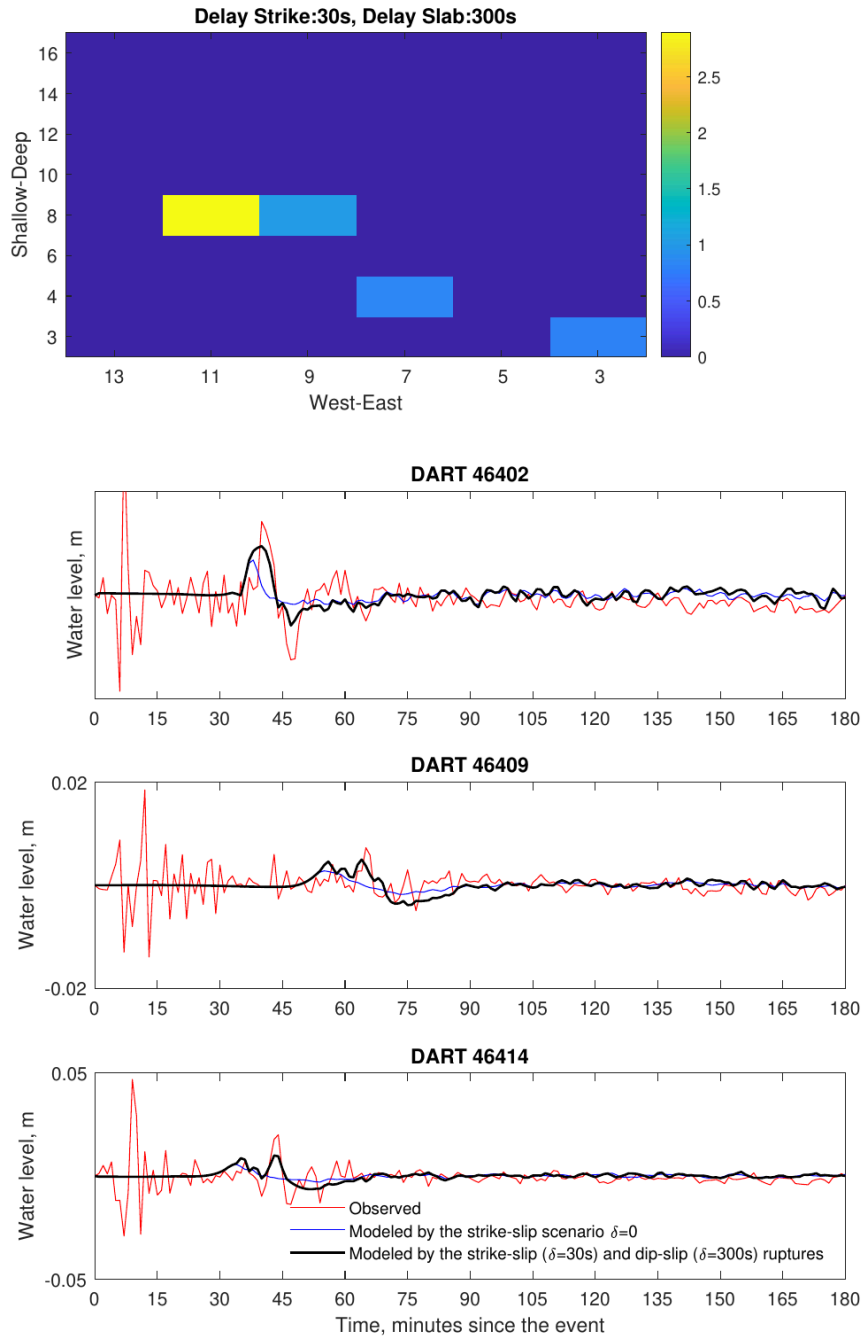


Figure S13. Like Fig. S5, but for strike-slip delay of 30 s and megathrust delay of 300 s.

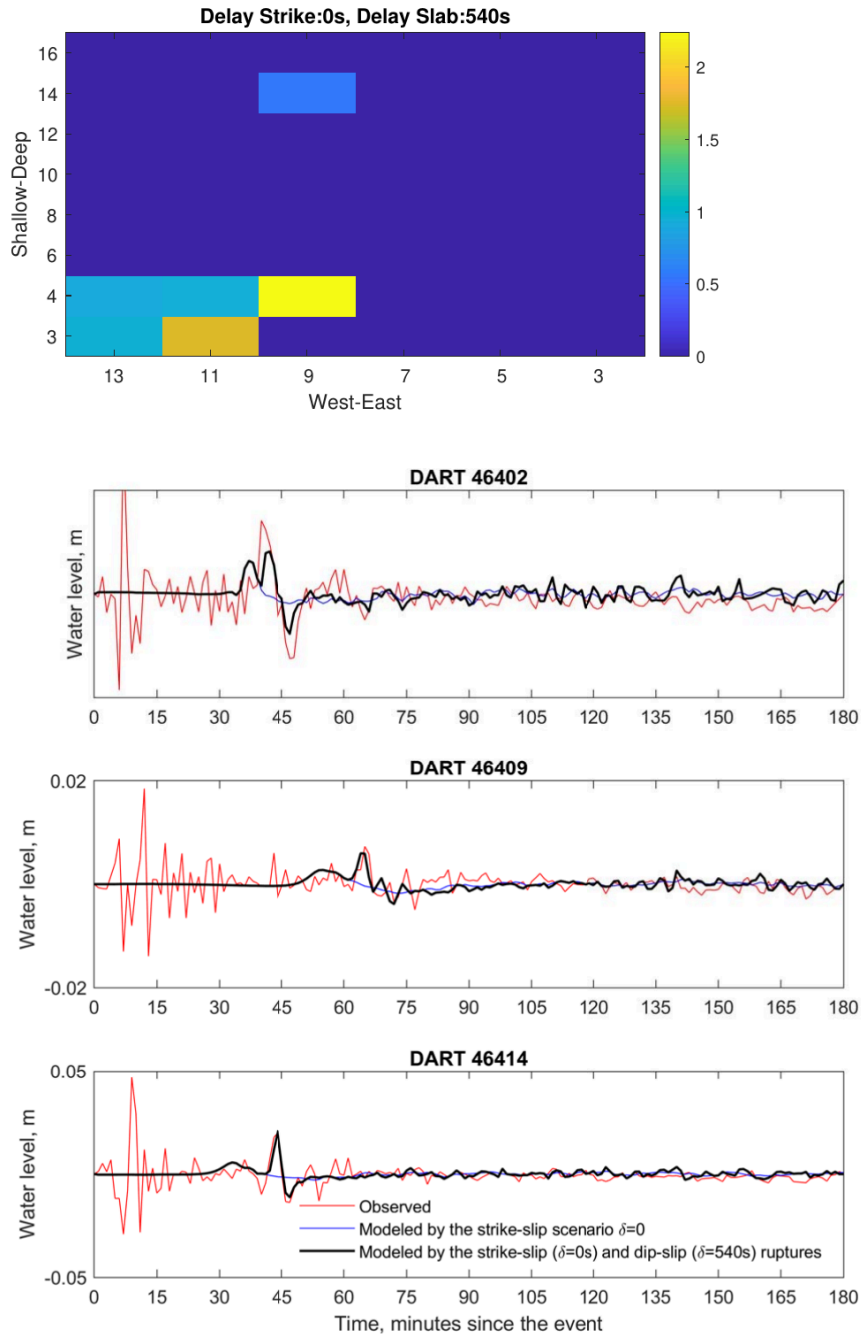


Figure S14. Like Fig. S5, but for strike-slip delay of 0 s and megathrust delay of 540 s.

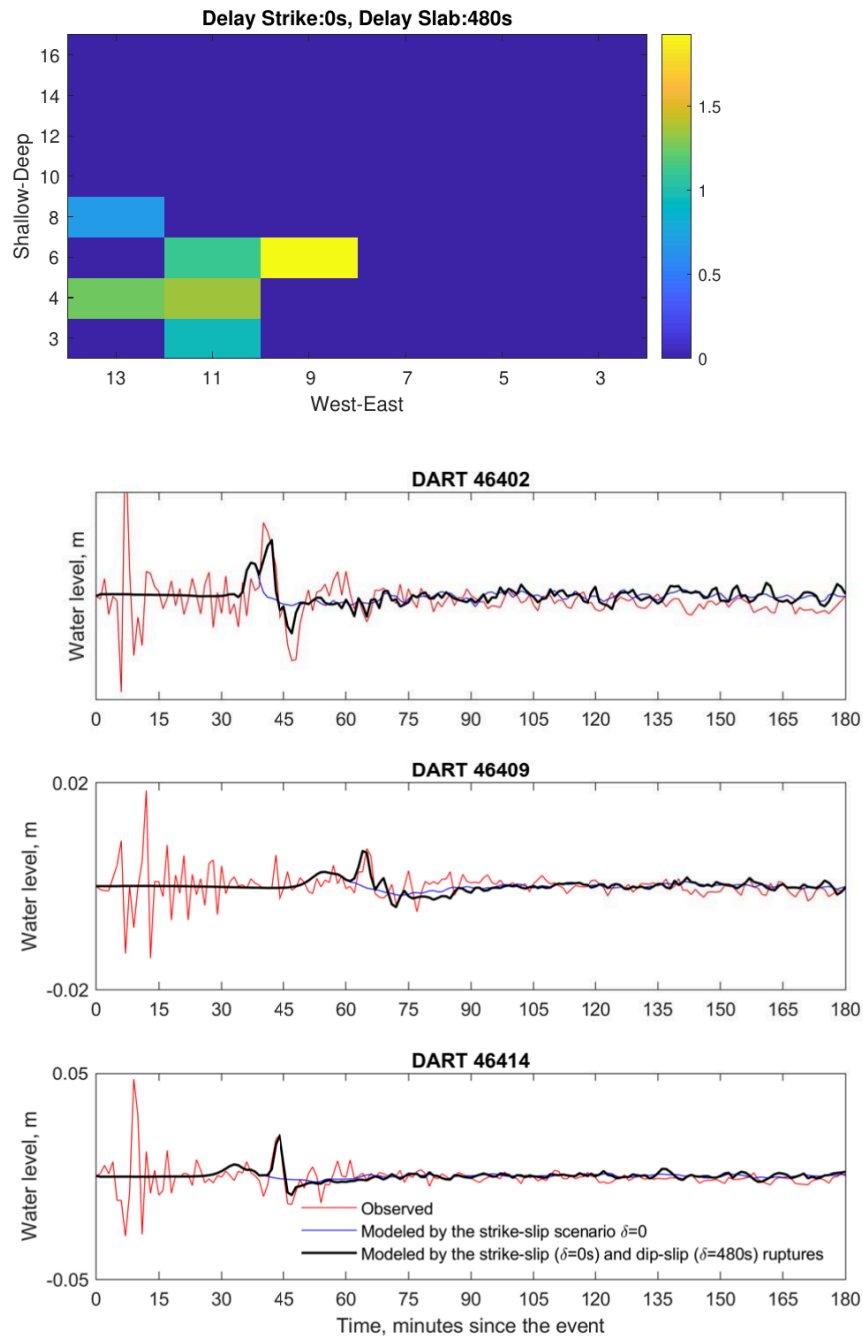


Figure S15. Like Fig. S5, but for strike-slip delay of 0 s and megathrust delay of 480 s.

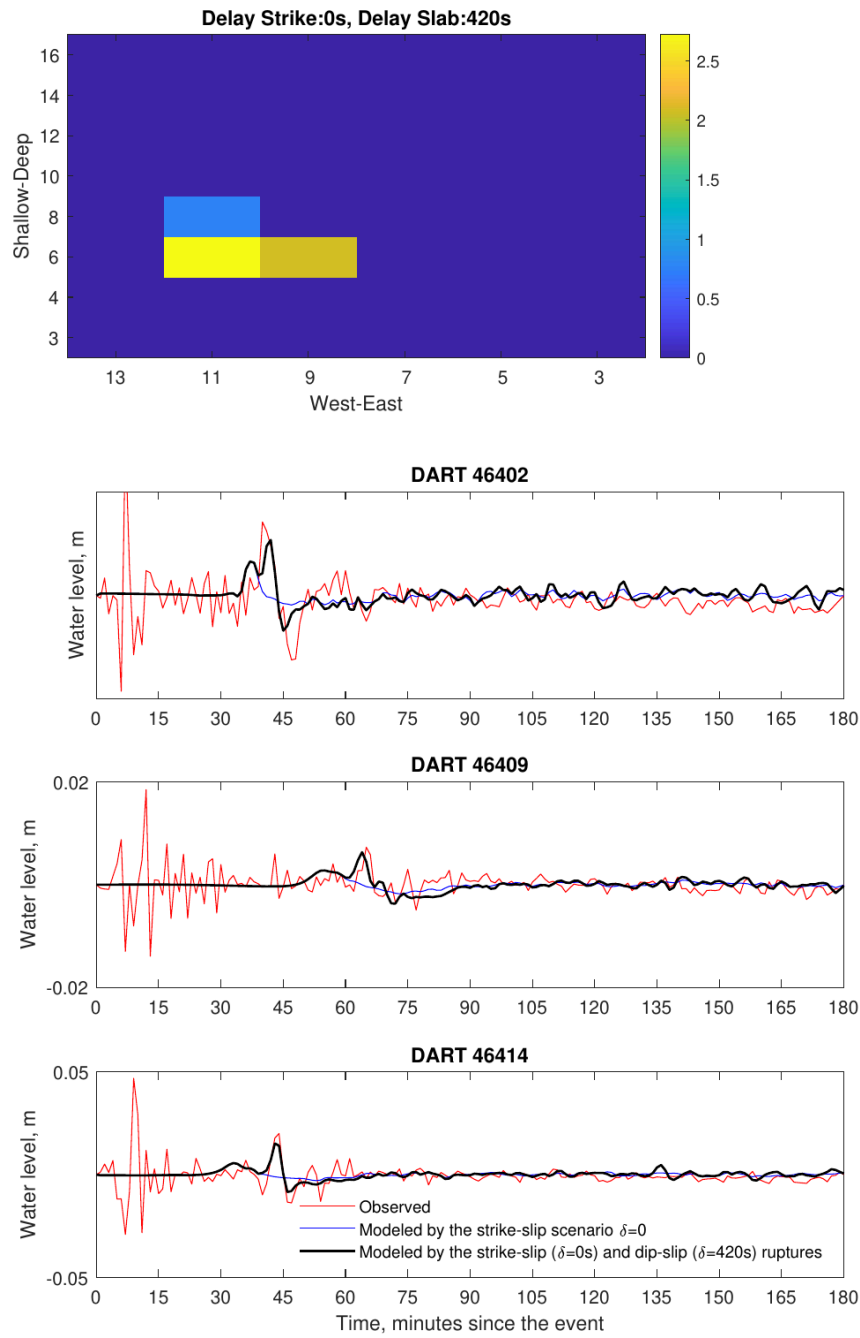


Figure S16. Like Fig. S5, but for strike-slip delay of 0 s and megathrust delay of 420 s.

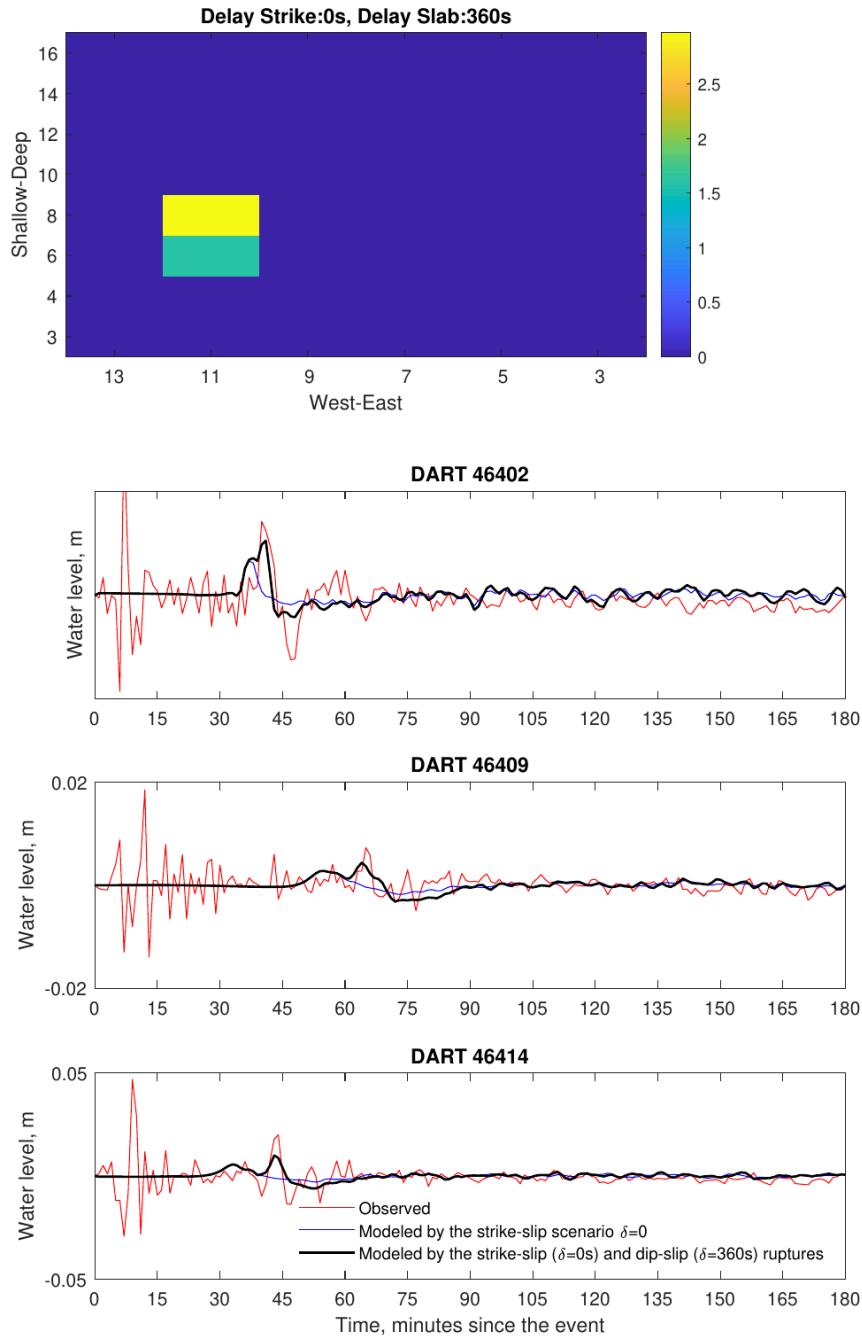


Figure S17. Like Fig. S5, but for strike-slip delay of 0 s and megathrust delay of 360 s.

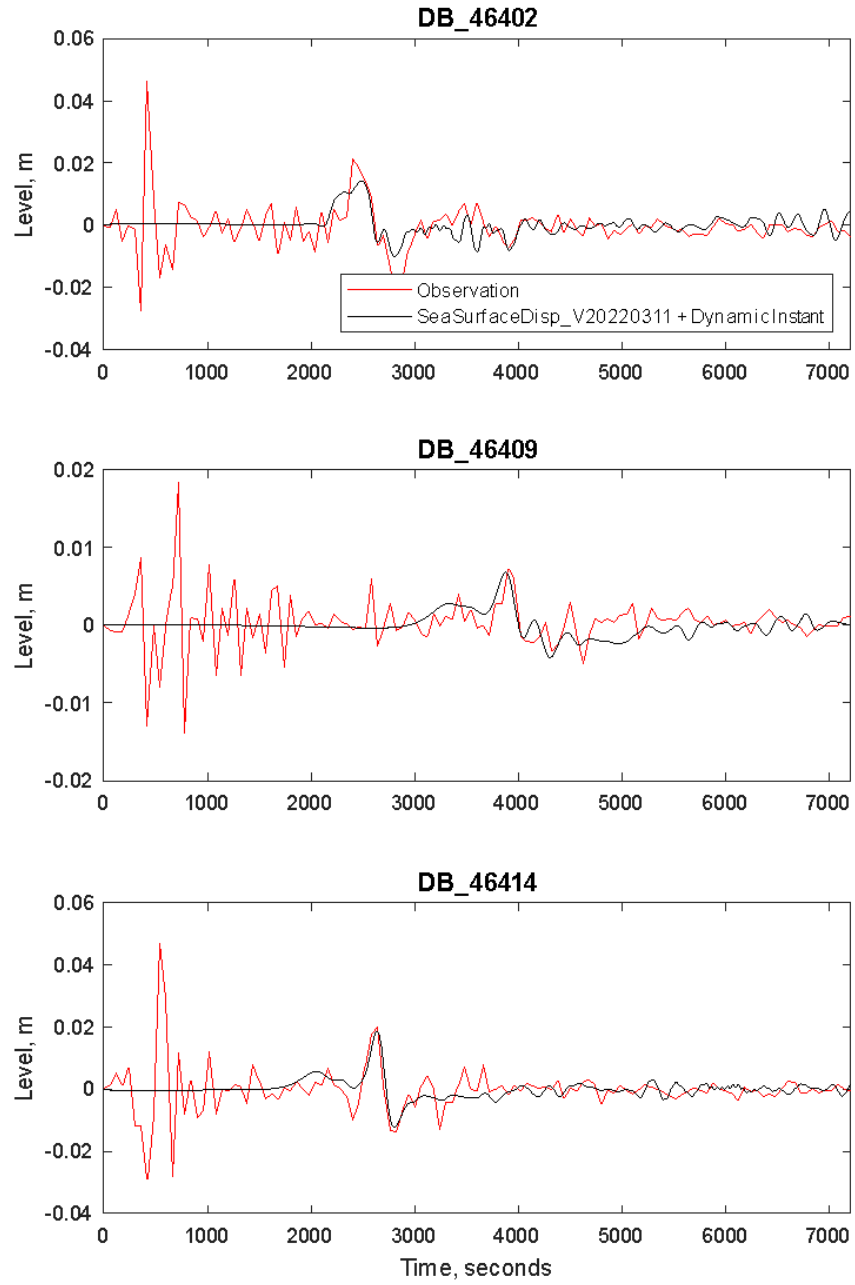


Figure S18. Dynamic rupture model result for tsunami prediction. Same as model shown in Fig. S5, instant rupture no rise time. Scale 1, maximum slip is 1.7 m.

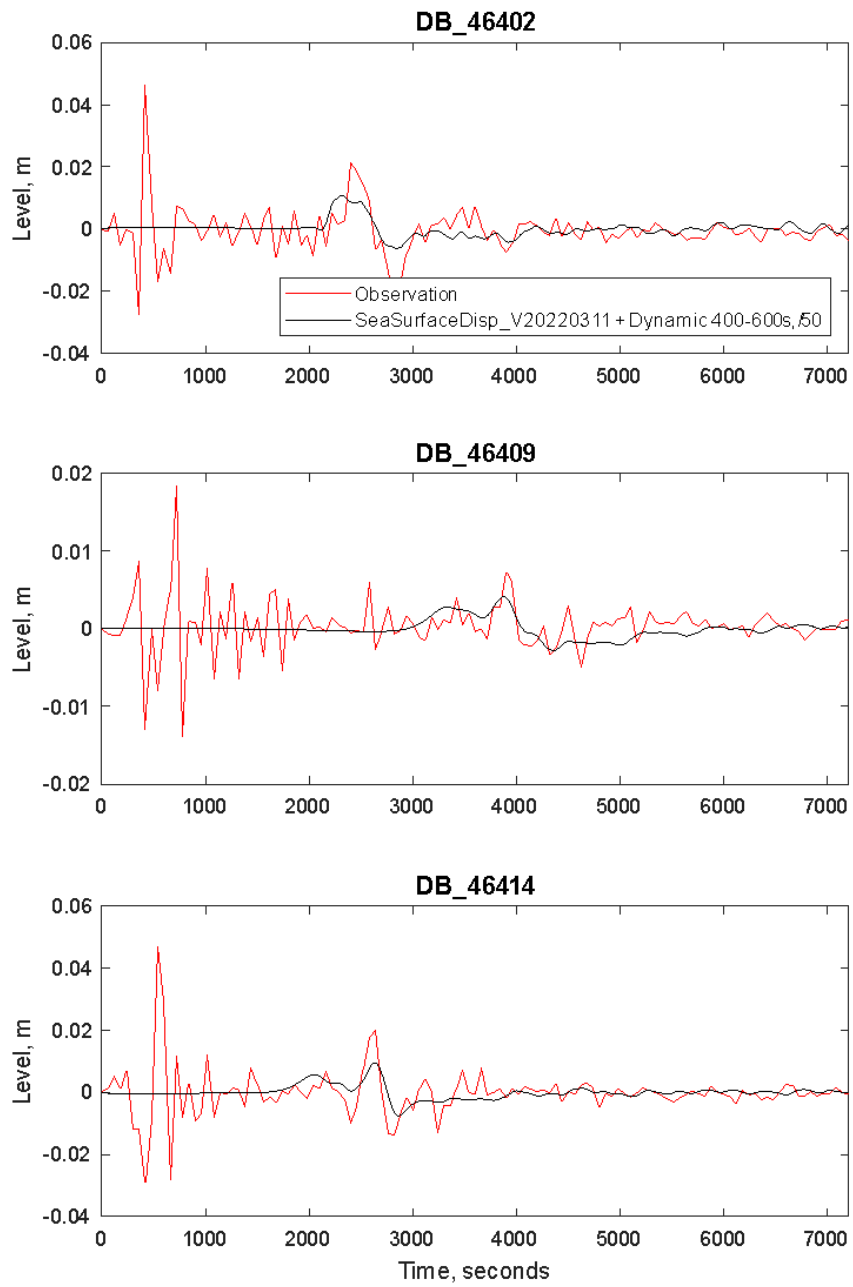


Figure S19. Same as Fig. S18 with 200 s rise time and slip release from 400-600 s after mainshock. Scale 1/50 and maximum slip is 6.8 m.

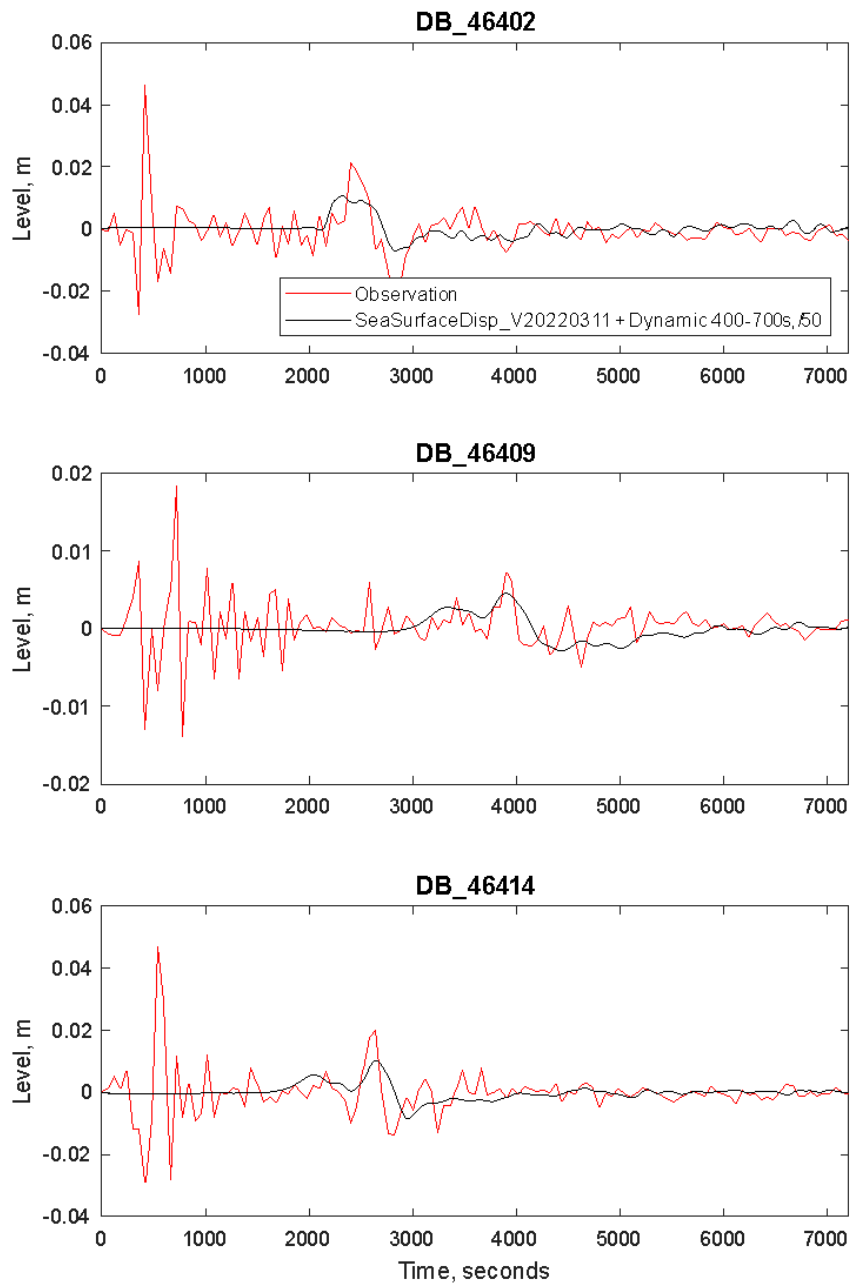


Figure S20. Same as Fig. S18 with 300 s rise time and slip release from 400-600 s after mainshock. Scale 1/50 and maximum slip is 10.2 m.

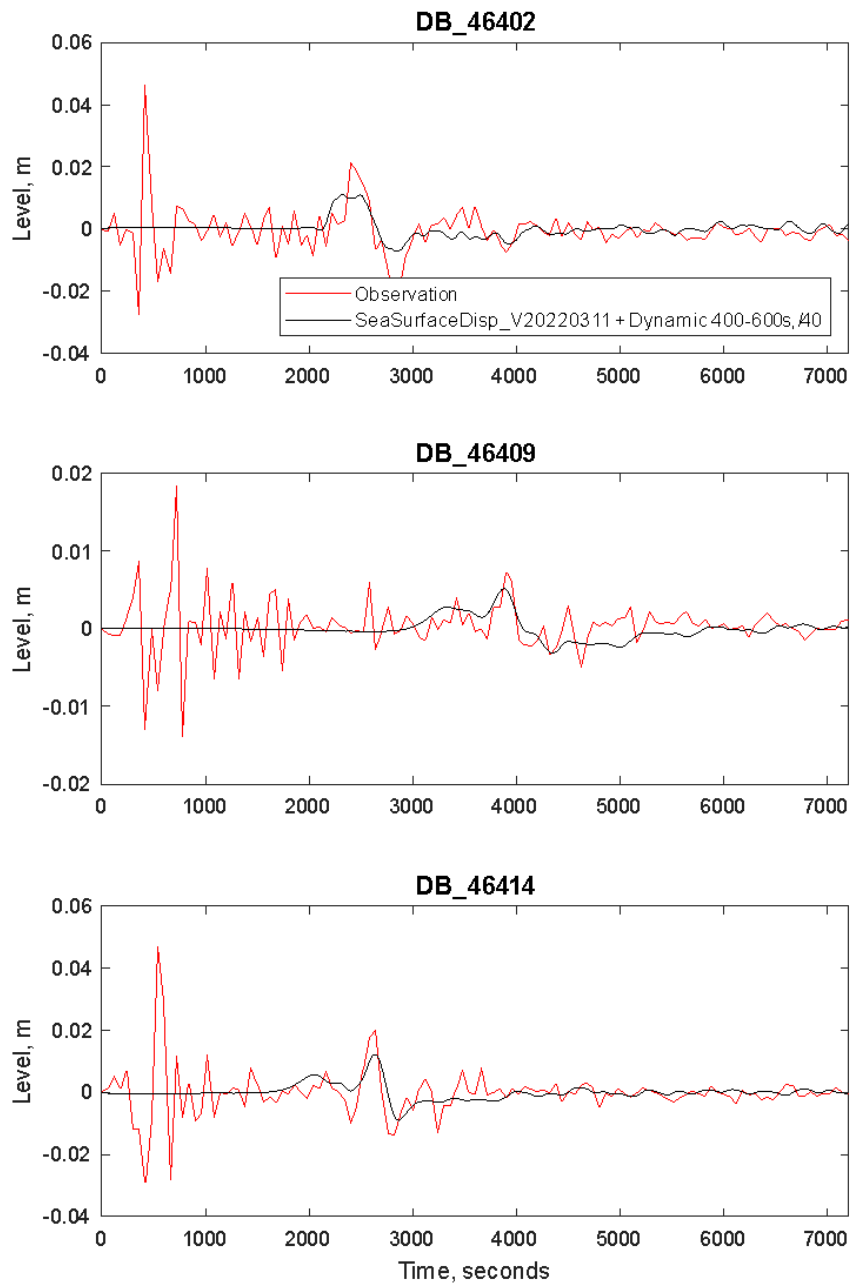


Figure S21. Same as Fig. S18 with 300 s rise time and slip release from 400-600 s after mainshock. Scale 1/40 and maximum slip is 8.5 m.

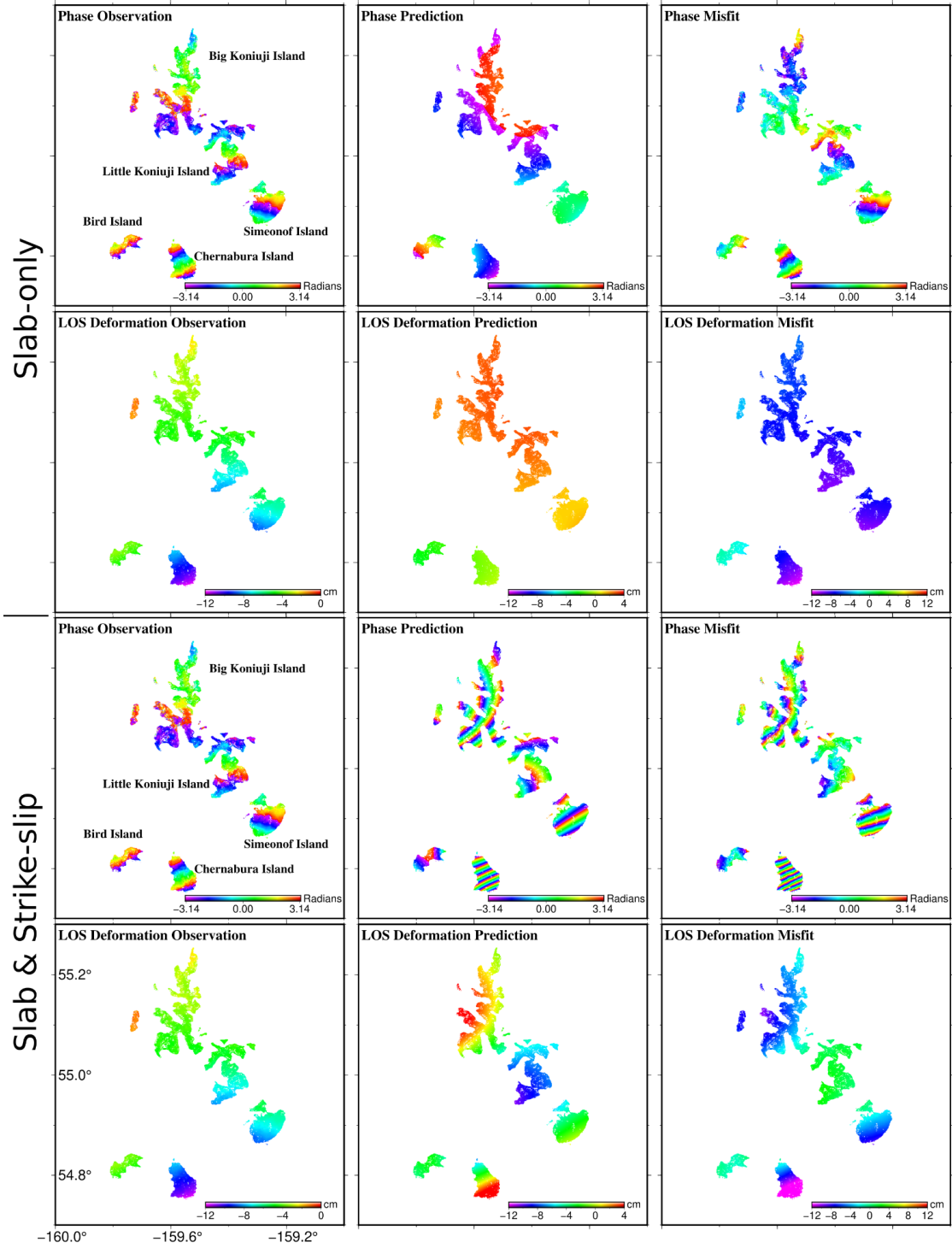


Figure S22. InSAR observations (left column) compared to the *Santallanes et al. (2025)* model (inferred from their figures, according to *Aki and Richards (2009)* geometry) predictions for megathrust component (top two rows) and strike-slip component (bottom two rows) in phase (rows 1 and 3) and LOS (rows 2 and 4) space. Right column shows model misfit. Note that their slab and strike-slip model predicts large LOS deformation for all islands that has not been observed.

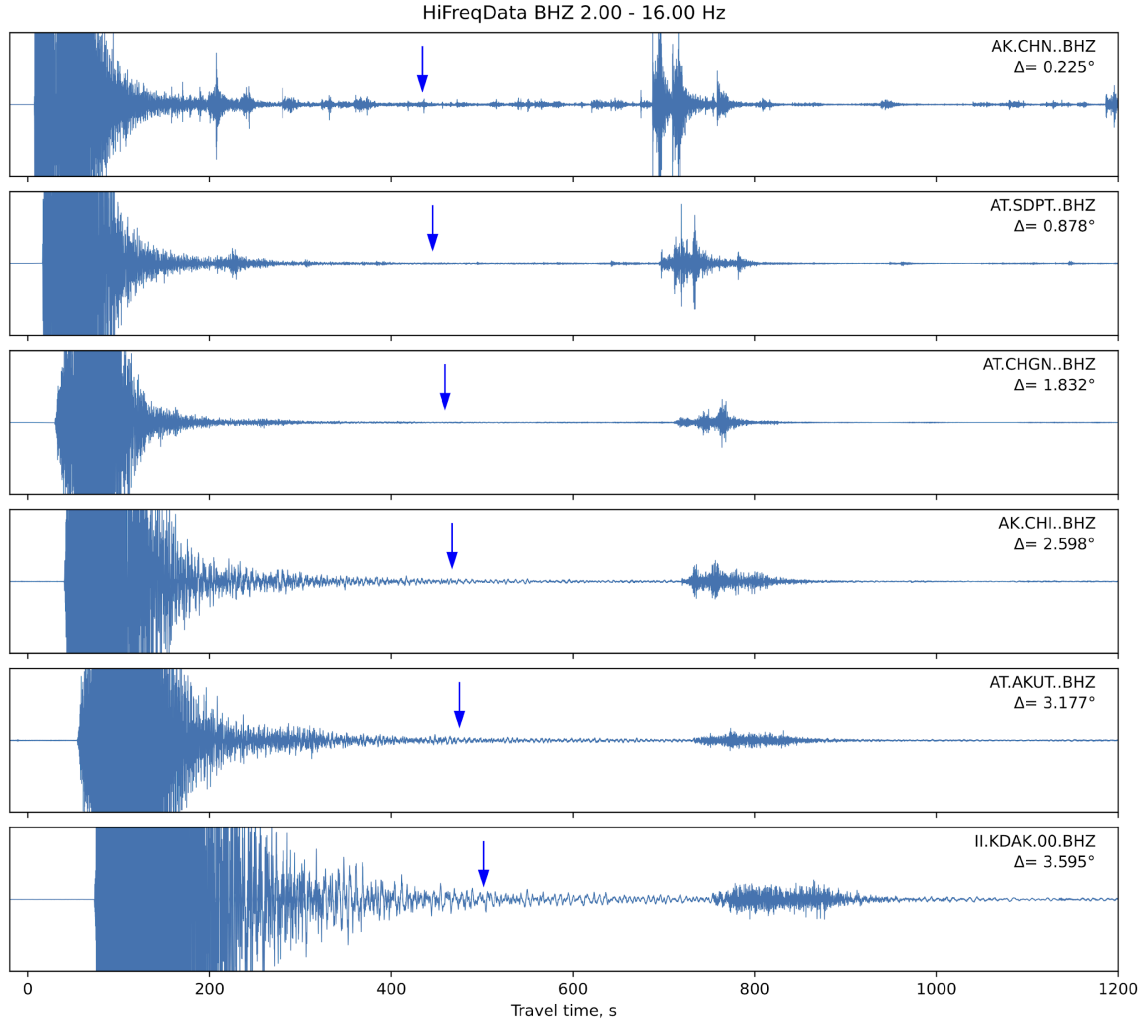


Figure S23. High-frequency seismograms for select stations within 400 km of the mainshock. Seismograms are vertical-component, filtered 2-16 Hz, and enlarged so that peak amplitudes are 10x the largest shown to enhance small events in coda. Seismograms labeled, right, by FDSN network and station code (<https://www.fdsn.org/networks/>) and distance to mainshock epicenter in degrees. Arrows point to predicted P arrival time for secondary tsunami source delayed 420 s and shifted as described in text. The two M5.7 aftershocks are visible at about 700 s.

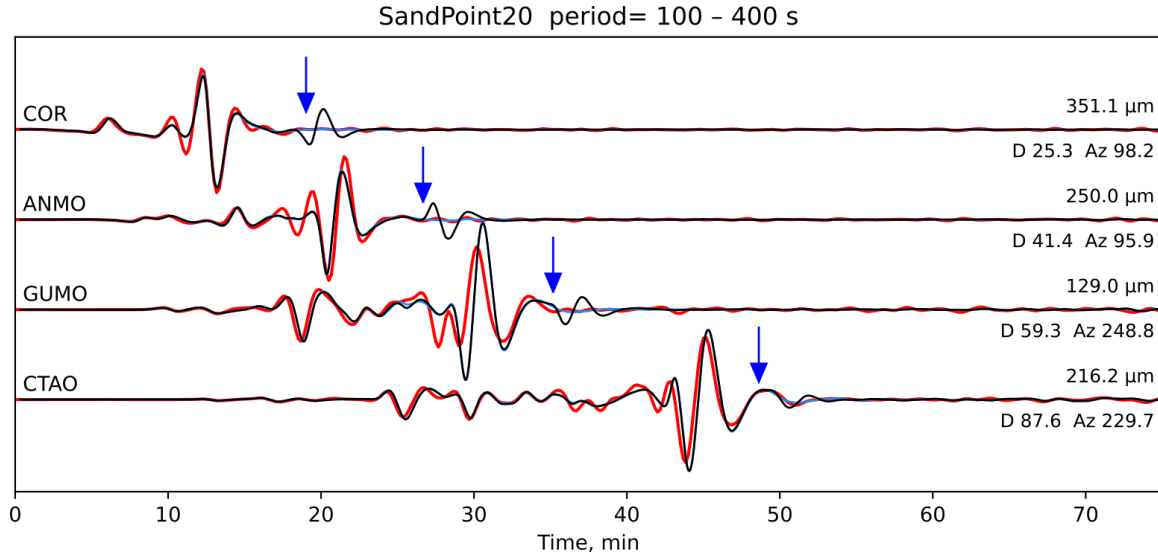


Figure S24. Observed and calculated seismograms for four GSN stations recording the 2020 M7.6 Sand Point earthquake, ordered by distance. Red: observed seismogram; blue line: one-source synthetic excited by the GCMT mechanism; black: two-source seismogram where first source is GCMT source and second is shallow megathrust event. Seismograms are vertical component displacement records, filtered to 100-400 s period, with amplitude in μm labeled to right above each record. Station codes labeled to left, and distance and azimuth to station labeled as D and Az respectively to right, both in degrees. Blue arrows denote a nominal 3.9 km/s group velocity for the second event lagged 420 s, highlighting a modeled phase that is not observed.

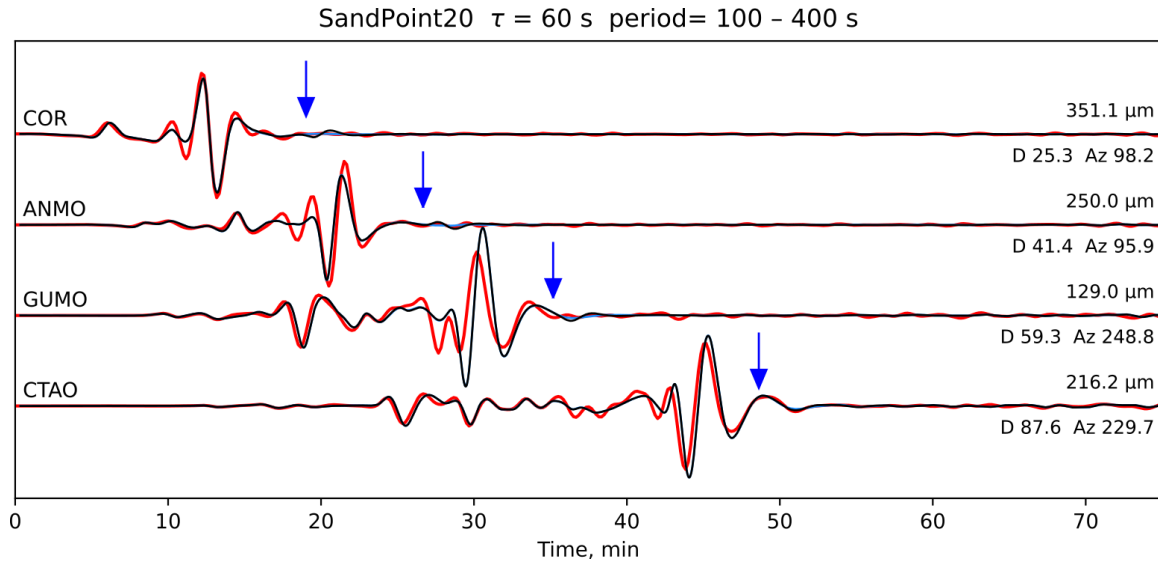


Figure S25. Comparison of observed and calculated seismograms where the two-source synthetic (black) is calculated for $\tau = 60$ s as described in text. Format same as Fig. S24.

