The Ust'-Kamchatsk "Tsunami Earthquake" of 13 April 1923: A Slow Event and a Probable Landslide

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AGU FALL MEETING
San Francisco | 12–16 December 2016

NH43B-1864

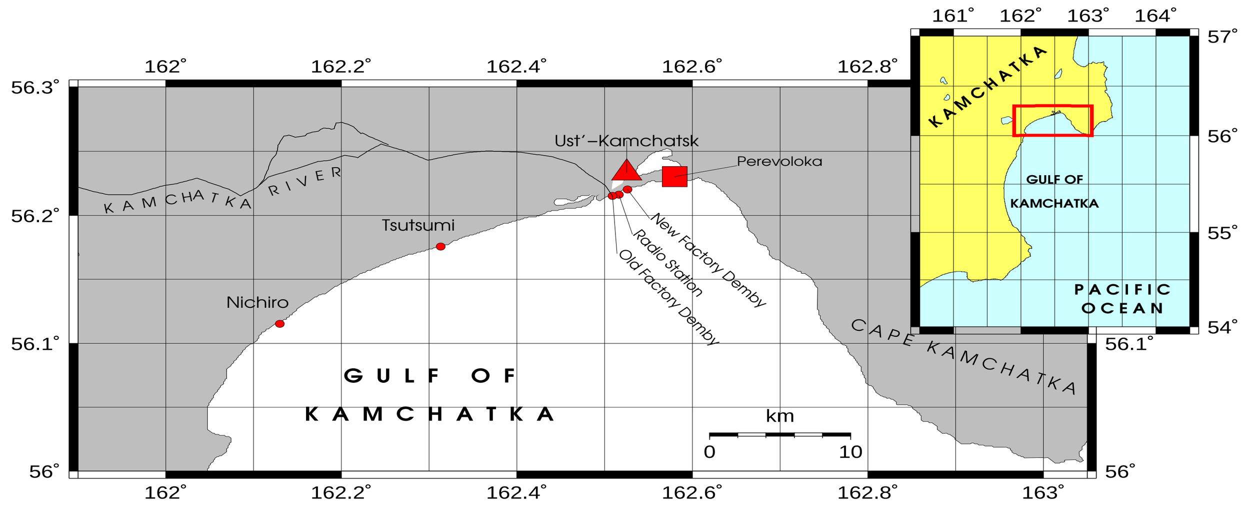
Background

The 13 April 1923 tsunami occurred in the Gulf of Kamchatka as an aftermath of a $M \sim 7.6$ earthquake in the region. This earthquake itself was an aftershock of a larger event $M \sim 8$.

Evidence

Detailed reports of the 13 April 1923 tsunami include two waves with run-up values as high as ~ 11 m at the Kamchatka river delta and Ust'-Kamchatsk (e.g., Troshin & Diâgilev, 1926). According to these reports, Tsutsumi and Nichiro canneries were demolished.

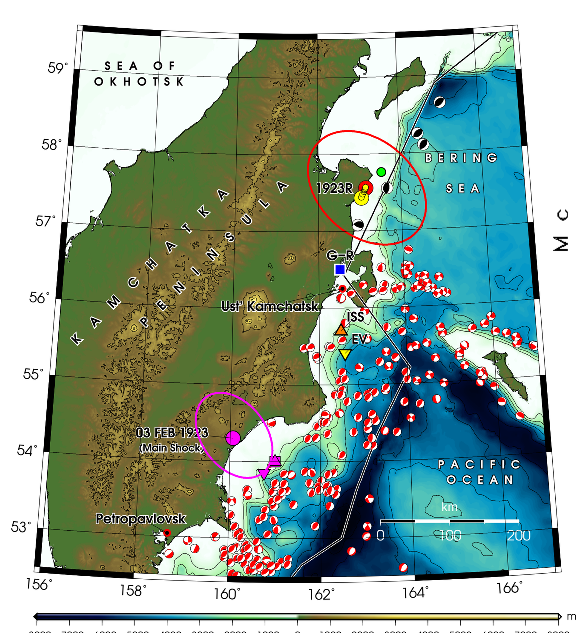
The generated tsunami for this event was twice as big as that of the main shock.

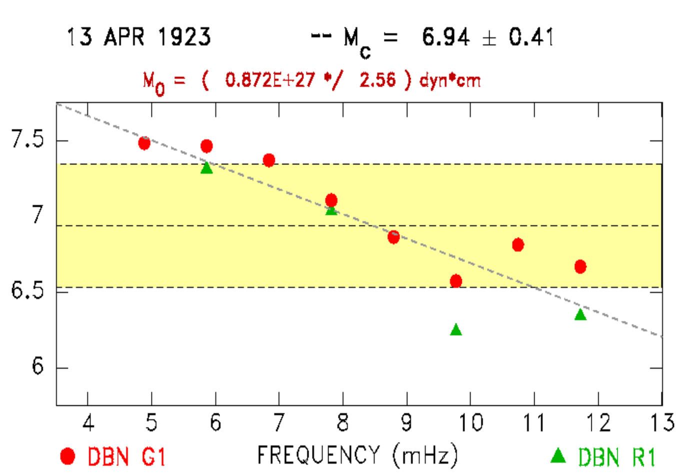


Seismological Assessment of the Source

The residual times from the ISS catalog were used to relocate the earthquake. Records from station DeBilt (DBN) were used to obtain a long-period estimate of the seismic moment.

$M_0 \approx 3.2 \times 10^{27}$ dyn-cm.





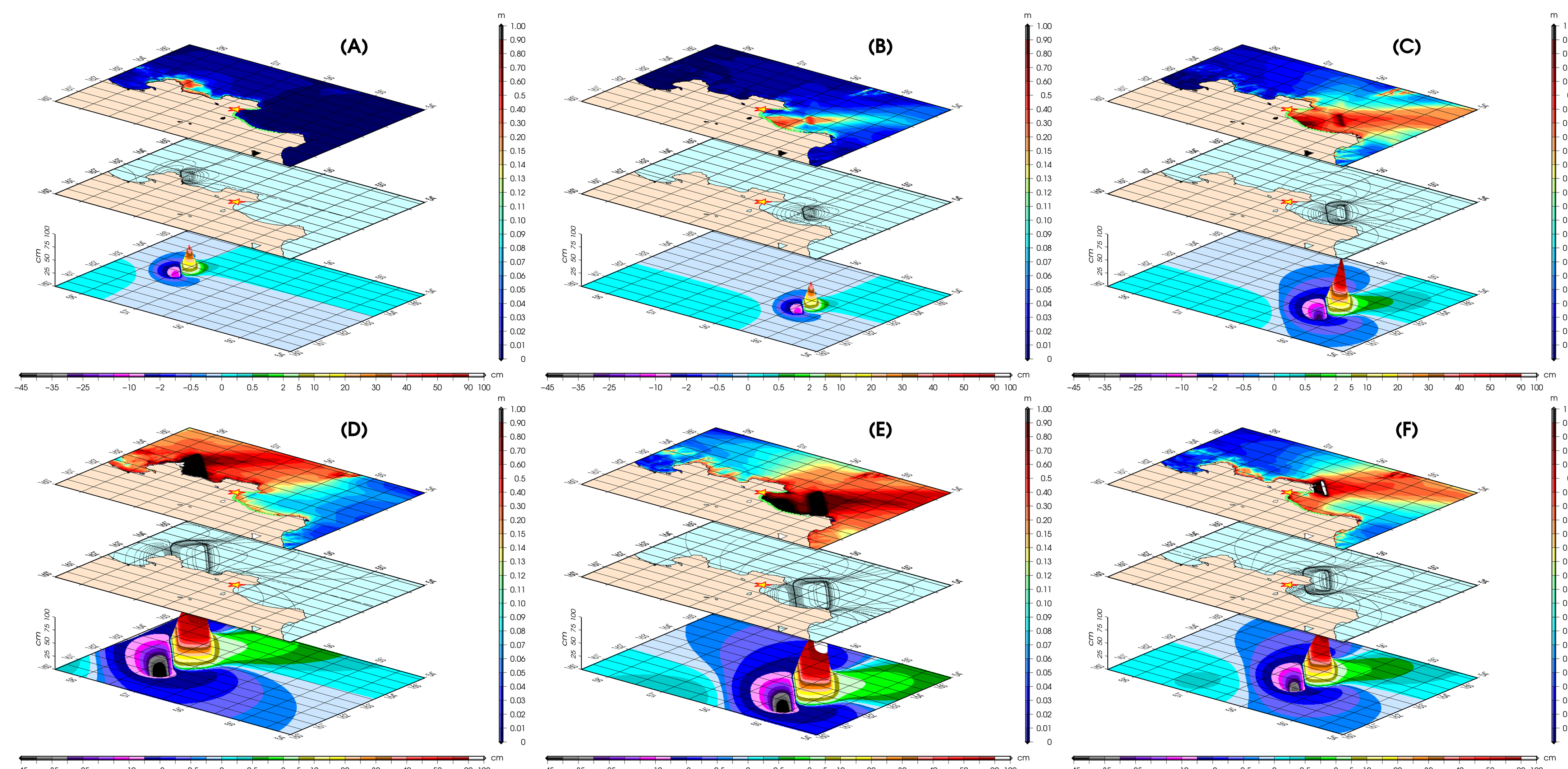
NOTE: Strong increase of moment with period

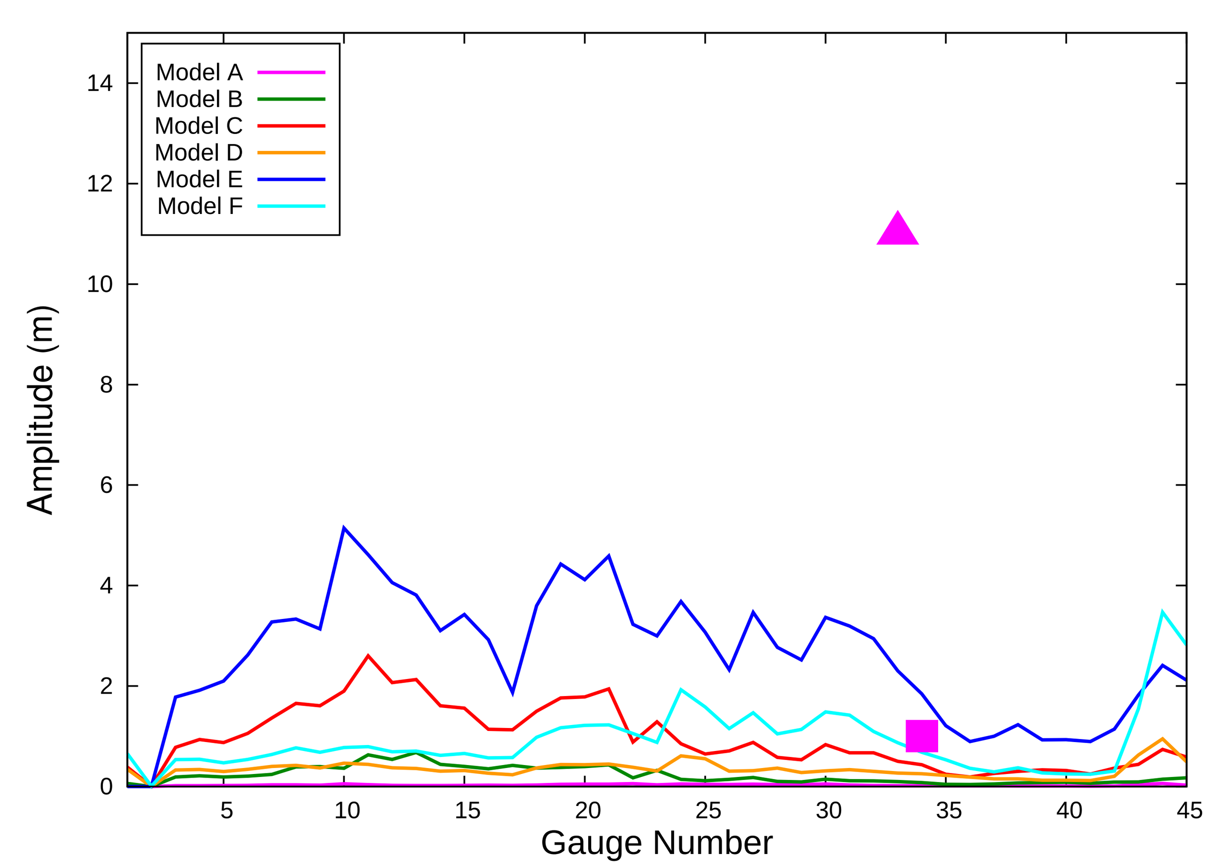
Relocation ⟶ To ~ 200 km north of the ISS epicenter
Source Mechanism ⟶ Remains Elusive
The well-constrained 1969 mechanism is assumed for the 1923 event

Earthquake Source

Several scenarios were considered due to the uncertainty in the seismological assessments. Considering the location uncertainty ellipse for the 1923 event, we have tested our relocated epicenter, the ISS epicenter as well as an intermediary case at the tip of Cape Kamchatka. As the initial condition to the equations of hydrodynamics, and in the case of earthquake sources, MOST (e.g., Titov & Synolakis, 1995) uses the field of static deformations of the epicentral area resulting from the dislocation, as computed for example through the algorithm of Mansinha and Smylie (1971).

We have simulated the tsunami for three locations and two seismic moments ($M = 7$ and $M = 8$) with the mechanism from the 1969 event as shown in the figures below. The simulations were done on a bathymetry grid from both GEBCO and digitized Russian maps for the Gulf of Kamchatka (Anonymous, 2001).



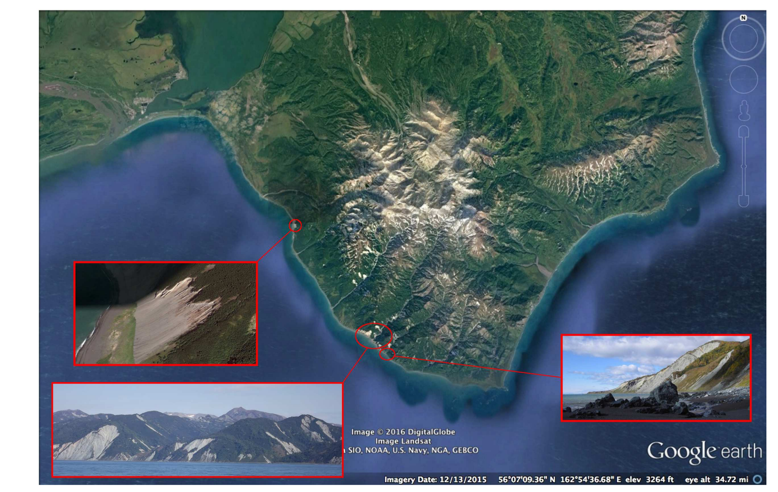


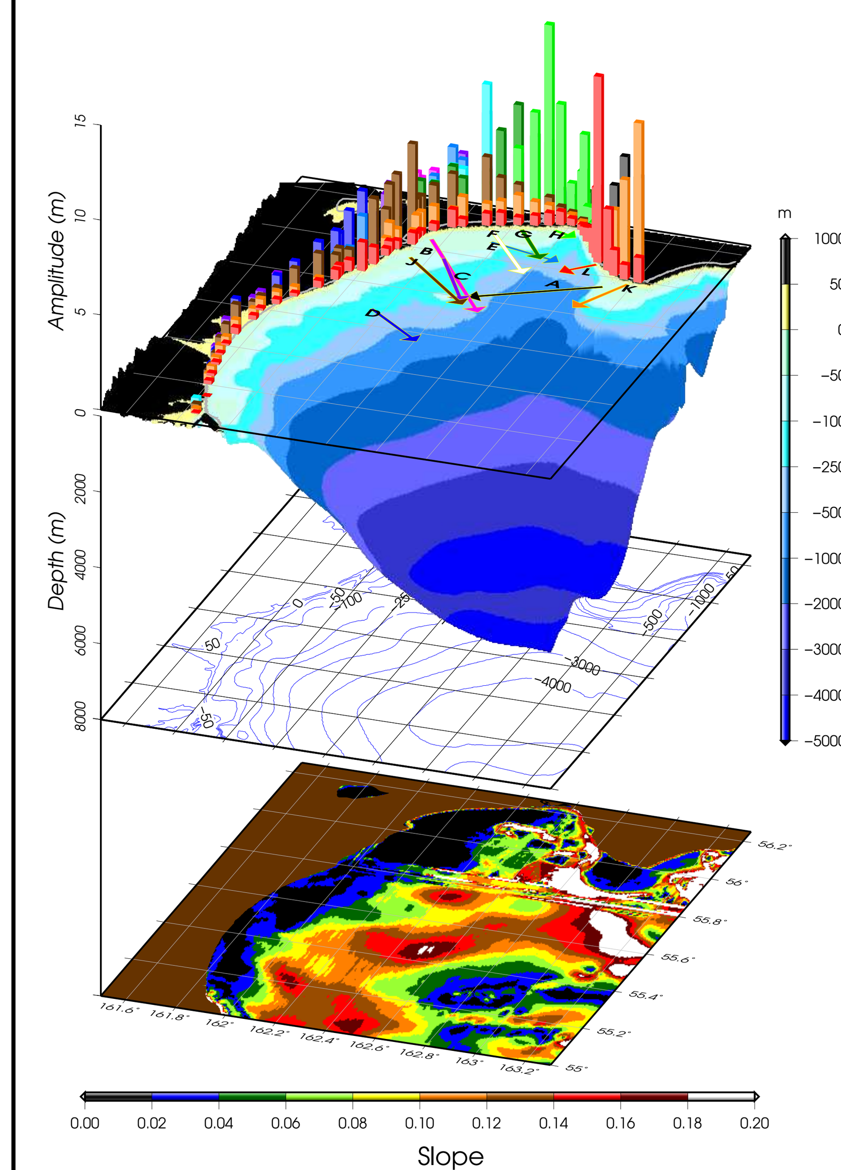
Even though models **E** and **F** reproduce higher amplitudes close to the shorelines at Nichiro, Tsutsumi and the tip of Cape Kamchatka, they fail to generate high amplitudes at Ust'-Kamchatsk as well as the run-up distribution as described in the reports.

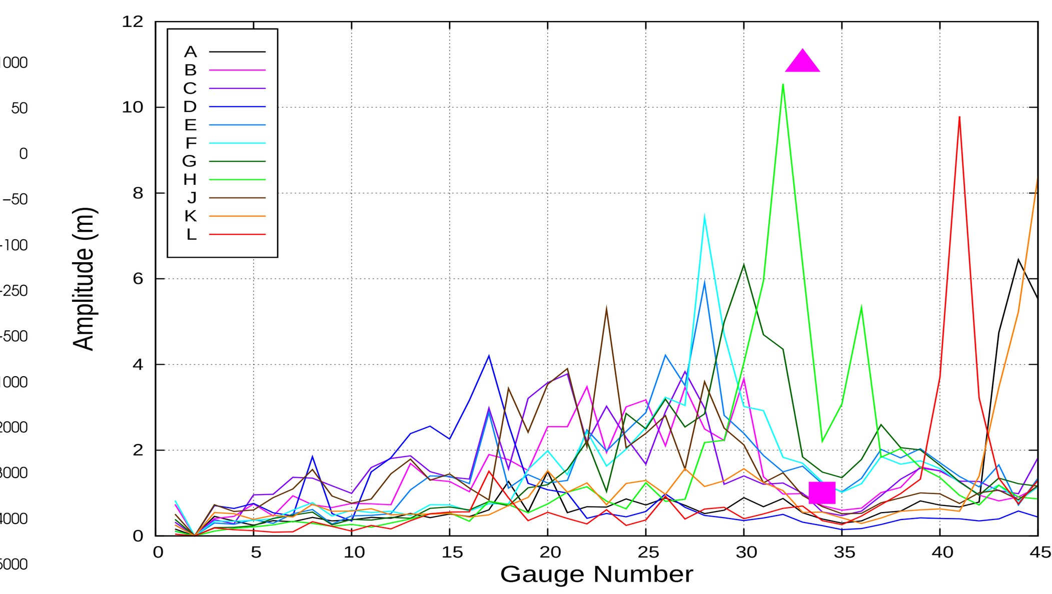
THE EARTHQUAKE SOURCE CANNOT MODEL TSUNAMI REPORTS

Landslide Source

A landslide source for the 1923 tsunami is strongly suggested by the geomorphological evidence in Cape Kamchatka. Satellite images of the coastal areas, especially to the east of the Gulf of Kamchatka, reveal numerous aerial slides (Figure on the right).







We used the method proposed by Okal & Synolakis (2003) to model slumps with initial and final states approximated as a dipole considered as static deformation.

11 different scenarios were simulated to reproduce the reported amplitudes following the directions of local slopes of 3 – 6% best represented by the gradient of the bathymetry field (e.g., Salaree & Okal, 2015).

Conclusion

Even though we document source slowness, we fail to identify a legitimate seismic source for the 13 April 1923 tsunami. Rather, landslide models can reproduce amplitudes reaching 11 m close to the sites reported by Diâgilev (1926). Furthermore, a concentration of the inundation over a $\sim$50-km stretch of coastline is suggestive of a source with shorter wavelength as expected from landslides. Our model (H) of a landslide, presumably triggered by the earthquake, originating around 55.95°N, 162.90°E, and extending 20 km in a 100° azimuth manages to match the general profile of the reported tsunami along the coast. It should also be noted that the reported much smaller first wave could be suggestive of a small tsunami generated by the earthquake as shown by our tectonic dislocation models.

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ACKNOWLEDGMENT This study was supported by NSF (Grant OCE-1331463).