Final Report for Period: 02/2010 - 01/2011 **Submitted on:** 04/19/2011
Principal Investigator: Newman, Andrew V. **Award ID:** 1020239
Organization: GA Tech Res Corp - GIT
Submitted By:
Newman, Andrew - Principal Investigator

Title:
RAPID: Near-trench Deformation and Tsunami Runup from the Jan 3, 2010 Solomon Islands Earthquake

Project Participants

Senior Personnel

Name: Newman, Andrew
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Fritz, Hermann
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Wei, Yong
Worked for more than 160 Hours: Yes
Contribution to Project:
Performed necessary tsunami modeling to confirm results. Yong also wrote the tsunami modeling portion of the submitted manuscript.

Post-doc

Graduate Student

Name: Lifton, Zachery
Worked for more than 160 Hours: Yes
Contribution to Project:
Contributed to the field deployment of GPS in the Solomon Islands and presented first results at the Western Pacific Geophysics Meeting in Taiwan.

Name: Feng, Lujia
Worked for more than 160 Hours: Yes
Contribution to Project:
Performed modeling of geodetic deformation and provided detailed comments on the submitted manuscript.

Name: Kalligeris, Nikos
Worked for more than 160 Hours: Yes
Contribution to Project:
Performed field experiment and offered numerous comments on submitted manuscript.

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

Technical University of Crete

Graduate student, Nikos Kalligeris, provided additional field support for this project.

NOAA Pacific Marine Environmental Laboratory

Collaborated with Yong Wei in order to perform necessary tsunami modeling to confirm results.

Other Collaborators or Contacts

Activities and Findings

Research and Education Activities:

With RAPID funding we:

1) Performed a 2 week long field study of the geodetic deformation and tsunami impact along some of the Solomon Islands following the 3 January 2010 magnitude 7.1 earthquake.

2) Processed GPS and subsidence measurements in order to determine the level of GPS-observed postseismic deformation and coseismic coastal subsidence.

3) We ordered and processed available ALOS InSAR data in an attempt to observed deformational field using remote sensing techniques.

4) We developed coseismic deformation models that describe the observed field. These results were subsequently tested with tsunami models and data from ocean-bottom pressure sensors.

5) The results of this work were presented at the 2010 Western Pacific Geophysics Meeting and the 2010 Fall AGU meeting.

6) The results have been submitted to the Geophysical Journal International. We've recently received very minor comments on the manuscript, and expect it to be accepted for publication shortly.

Findings:

This project was incredibly successful. Most findings are detailed in the attached submitted manuscript, however they will be repeated below:

The 3 January 2010 magnitude 7.1 earthquake in the Solomon Islands was a rare, and possibly first-of-its-kind observed energetic tsunami earthquake. There are several findings that support this:
1) The earthquake generated a tsunami (7 m runup) comparable to a previous regional earthquake that was one unit magnitude larger.
2) The earthquake ruptured the shallow megathrust with slip occurring entirely within the 20km closest to the trench.
3) Slip on this event was massive for its size (6-8 m), which caused the locally large

tsunami, similar to other tsunami earthquakes.
4) Event radiated seismic energy comparable to other magnitude 7.1 earthquakes. This is in contrast to other known tsunami earthquakes which radiate far less energy (usually an order of magnitude less). It is not yet clear why this is the case, but it is suspected to be at least partially due to the rapid convergence of extremely young crust in the region.

Training and Development:

This project trained graduate student, Zach Lifton, to use campaign GPS equipment--a tool that he again used later last year in an unrelated NSF-funded field project. The project contributed to the training of another graduate student, Lujia Feng, in modeling GPS and non-traditional coastal subsidence measurements for understanding earthquake slip. Zach Lifton also gained valuable communication experience presenting this science at the Western Pacific Geophysics Meeting.

Outreach Activities:

While performing our field campaign, we discussed the tsunami hazards with local tribal chiefs, and a volenteer doctor. While our instruction of the doctor was useful, it was quite clear that the local villages knew precisely what to do in the event of an earthquake (this is why no one was killed in this event!!).

Journal Publications

Newman, A. V; Feng, L; Fritz, H.M; Lifton, Z; Kalligeris, N; Wei, Y, "The Energetic 2010 MW 7.1 Solomon Islands Tsunami Earthquake", Geophysical Journal International, p. , vol. , (2011). Submitted,

Books or Other One-time Publications

N. Kalligeris; H. Fritz; A. V. Newman; L. Feng; Z. M. Lifton, "Tsunami Generation of the 3 January 2010 Mw 7.1 Solomon Islands Earthquake", (2010). Conference Proceeding, Published Bibliography: Presented at 2010 Fall Meeting, AGU, San Francisco, Calif., Dec. 13-17, 2010.

Lujia Feng; Andrew Newma;, Zach Lifton; Hermann Fritz; Nikos Kalligeris , "Geodetic Constraints of the Anomalously Tsunamigenic 2010 MW 7.1 Solomon Islands Earthquake", (2010). Book, Published Bibliography: Presented at the Western Pacific Geophysics Meeting, Eos Trans. AGU, 91(26), Suppl., Abstract T31B-06

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

This project largely used techniques that we've already developed.

Contributions to Other Disciplines:

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

This event serves as a warning to tsunami warning centers. That is, even when applying techniques commonly used to observe tsunami earthquakes, events like this one may be mischaracterized and its tsunami potential underestimated.

Contributions Beyond Science and Engineering:

(see last comment)

Conference Proceedings

Categories for which nothing is reported:

Any Web/Internet Site
Any Product
Contributions: To Any Other Disciplines
Contributions: To Any Human Resource Development
Any Conference

The Energetic 2010 M_W 7.1 Solomon Islands Tsunami Earthquake

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Submitted to: *Geophysical Journal International,* 8 – Feb, 2011.

Summary:

On 3 January 2010 a moment magnitude M_W 7.1 earthquake struck the Solomon Islands very near the San Cristobal trench, causing extensive landslides and surprisingly large tsunami waves. Because of the unique proximity of islands to the trench (<20 km) and earthquake, a post-seismic survey successfully identified unexpected widespread coseismic subsidence toward the trench (up to 80 cm), with no discernable postseismic deformation. Approximately 1000 km from the earthquake ocean-bottom pressure sensors measured 1-2 cm open-ocean tsunami waves. Though spatially limited, the local tsunami wave heights up to 7 m were comparable to the much larger adjacent 2007 M_W 8.1 earthquake. The seismically determined focal mechanism, broad-scale subsidence, tsunami amplitude and open ocean wave heights are all explained by an extremely shallow low-angle thrust adjacent to the impinging subduction of the two seamounts near the trench. This event belongs to a new class of shallow "tsunami earthquakes" that is not identified as deficient in radiated seismic energy.

Introduction:

The Solomon Islands lie within one of the most active seismogenic zones globally due to the rapid and complicated convergence of the Pacific plate with the Australian plate and numerous microplates at approximately 10 mm yr^{-1} (Phinney, *et al.*, 2004; Miura *et al.*, 2004; Taira *et al.*, 2004)(**Fig. 1a**). This activity creates a unique environment that both: causes large and tsunamigenic earthquakes with sufficient frequency to self-sustain an oral tradition of tsunami preparedness within the indigenous populations (Fritz & Kalligeris, 2008; McAdoo *et al.,* 2009); and allows for detailed land-based studies of shallow subduction processes due to the development of land from permanent collisional deformation and volcanism very near the trench. In the area of the 2010 M_W 7.1 earthquake, young bathymetrically elevated microplate boundaries and seamounts are subducted along the San Cristobal trench causing the development of several islands, including Rendova and Tetepare (**Fig. 1b**), within 10-20 km of the trench (Mann *et al.*, 1998, Taylor *et al.*, 2005; Taylor *et al.*, 2008). A complex recent history of uplift is associated with the subduction of a ridge system (270-130 ka), followed by subsidence, and recent return to very rapid uplift (~50 ka – present) due to the initiation of Coleman and Kana Keoki Seamount subduction (Mann *et al.,* 1998, Taylor *et al.,* 2005). Currently, geologic uplift rates are observed to rapidly increase from near zero at the northeastern end of Rendova to maximum values (5-7 mm yr^{-1}) on the southwestern (near-trench) edges of Rendova and Tetepare Islands (Mann *et al.*, 1998, Taylor *et al.*, 2005).

Past earthquakes in the Solomon Islands were highly tsunamigenic. While the 2007 M_W 8.1 event is the largest instrumentally recorded local earthquake, other notable tsunamigenic earthquakes occurred over the past century. A series of earthquakes between 1925 and 1926 excited at least two tsunamis. Following a magnitude M 7.2 event near Guadalcanal on 12 April

1926, a similarly sized *M* 7.3 event on 16 Sept. 1926 caused a tsunami that flooded western Guadalcanal and Kokomaruki islands (Soloviev & Go, 1984; Engdahl & Villaseñor, 2002). Both events are comparable, but estimated to be slightly larger than the 2010 event. Interestingly, with the exception of the 2007 event, the other tsunamigenic earthquakes were low-*M*7; normally considered too small for significant tsunami generation. While it is possible that some of these events were classic slow-source "Tsunami Earthquakes" (TsE), such events identified to date have a very limited magnitude range (between M_W 7.5 and 8.1) (Kanamori, 1972; Newman & Okal, 1998; Ammon *et al.*, 2006; Newman *et al.,* 2011). Thus, while the 2010 earthquake may indeed have ruptured the near-trench environment, as suggested by gCMT depth (12 km) and location, and position relative to the observed shallow slip localization of the 2007 event (**Fig. 1b**), its magnitude is smaller than known slow-source TsE.

Earthquake Energy and Duration:

Other recent TsE events are well-observed to be deficient in radiated seismic energy, *E*, when compared to seismic moment, M_0, such that the TsE discriminant $\Theta=\mathrm{Log}_{10}(E/M_0)$ is below -5.7, as compared to the global thrust average, Θ=-4.74 (Newman & Okal, 1998; Convers & Newman, 2011). Analysis of the TsE discriminant using 68 vertical broadband seismograms from global stations for the 2010 Solomon Islands earthquake define Θ=-4.8, comparable to the global average for thrusting mechanism earthquakes, and unlike observed slow-source TsE (**Fig. 2**). Hence, if the earthquake is to be classified as a TsE, it is unique in that it is comparatively energetic in nature.

To evaluate the rupture duration T_R of the 2010 event we identified the energy minimum from the envelop of stacked seismograms, aligned by the *P*-wave arrival. However, because observational duration estimates include both near-source surface reflections and can include later scattered energy after the termination of rupture, the estimated rupture duration is a maximum. Unlike the recent larger TsE events ($M_W \geq 7.7$), with rupture durations T_R in excess of 100 s, the M_W 7.1 2010 event has $T_R \leq 33$ s, comparable to another regional M_W 7.1 earthquake in the Celebes Sea on 11 Feb. 2009 (**Fig. 2**). However, given the spatial extent of the 2010 Solomon Islands event, the event may have been slow (>1-1.5 km/s dependent on point of nucleation for a 50 km long rupture). If the event is indeed slow rupturing, it remains to explain why it does not exhibit the deficiency in radiated seismic energy observed in larger slow-source TsE.

Tsunami and Subsidence Observations:

The 2007 M_W 8.1 megathrust earthquake nucleated just west of Rendova Island and ruptured northwest for approximately 300 km (Taylor *et al.*, 2008; Furlong *et al.*, 2009; Chen *et al.*, 2009). The earthquake created prevalent tsunami waves across the islands, with focused run-up in excess of 12 m in some locations (Fritz & Kalligeris, 2008). Though tsunami waves were widespread, only 52 deaths were reported due to the rich ancestral recitation of past events, whereby the need to run to high ground immediately after shaking was understood and practiced (Fritz & Kalligeris, 2008). In the 2007 event massive slip (20+ m) occurred in patches very near the trench, and within 20 km of the source region of the 2010 event near Rendova Island (Chen *et al.*, 2009), suggesting the recent event was triggered (**Fig. 1**). The boundary between the events is concurrent with a projected break in a subducted transform fault and ridge system along the megathrust interface (Mann *et al.*, 1998), likely inhibiting rupture of the 2007 event to the southeast. However, the large 20+ m slip from the 2007 event caused a stress perturbation that likely enhanced the Coulomb failure criteria (Stein, 1999), and positively influenced the occurrence of the adjacent 2010 earthquake, similar to the stress induced by the M_W 9.1 2004 Sumatra-Andaman earthquake, on the M_W 8.7 2005 earthquake in Sumatra; forecasted by McCloskey *et al.* (2005).

Though far smaller than the expected magnitude for significant regional tsunami excitation, the M_W 7.1 2010 event created a local tsunami run-up that was only moderately smaller than the much larger M_W 8.1 2007 event (**Fig. 3**). Based on initial reports of villages inundated by tsunami waves and identification of tsunami waves on two ocean-bottom pressure sensors termed DART buoys (or Deep-Ocean Assessment and Reporting of Tsunamis) nearly 1000 km away (NOAA, 2010), we investigated the extent of tsunami inundation and coseismic and early postseismic deformation. Between 12 and 19 January we surveyed tsunami inundation, run-up, and coastal land-level changes, and established a rapid postseismic deployment of five Global Positioning System (GPS) stations in the area. Tsunami and land level surveys were made at 21 sites surrounding Rendova, Tetepare, South (Marovo Lagoon) and Simbo Islands (**Figs. 1, 3**). No tsunami measurements were made on Ranongga Island, however local individuals described some small waves similar to a “fast tide”, but since the island was uplifted by 3 m in 2007, villages are now far from beaches and tsunami effects are difficult to observe. The opposite is true for Simbo Island, which subsided 2 m in the 2007 event and recorded 1.2 m tsunami run-up in 2010. GPS measurements were focused on 4 stations in the near-source region of Tetepare and Rendova Islands for determination of early postseismic deformation relative to a base station established on Lola Island (**Fig. S1**).

The survey team documented tsunami land-level changes as well as tsunami run-up, flow depth and inundation; identifying wave induced deposition or erosion, structural damage and interviewed eyewitnesses following established protocols (Synolakis & Bernard, 2006). The tsunami arrived at mean sea levels during a rising tide, and all survey measurements were corrected for tide based on predictions (UHKO, 2010). Significant variations in tsunami impact was observed across Rendova and Tetepare Islands, with a maximum flow depth (7.5 m) and run-up (7 m) on the southern shores of Rendova (**Fig. 3**). Fortunately only two villages, Mbaniata and Retavo (299 and 10 inhabitants, respectively), were significantly inundated (up to 150 m from the coast), and only two minor injuries occurred while villagers were evacuating because of strong ground shaking. In Mbaniata 16 houses (compared to only 4 in 2007) and the entire village of Retavo were destroyed (**Fig. S2**). Tsunami wave heights from the 2010 event exceeded those from 2007 across most of the two islands. Further away, tsunami run-up over 1 m was documented at South Island (50 km east) and at Simbo Island (90 km west). Smaller tsunami waves (<1 m) were observed throughout the New Georgia group including the south shores of Ranongga and Ghizo Islands.

Throughout the affected area, eyewitnesses reported one to five main waves usually with an initial recession, which could correspond to a leading depression N-wave (Tadepalli & Synolakis, 1994). At most locations, the first wave arrived within 10 minutes of the earthquake. A second smaller wave shortly followed within another 10 minutes along the south coast of Rendova. (*See supplementary information for further tsunami survey details.*)

Coastal subsidence was measured at boat launches, and navigation and port infrastructure using pre- and post-event high tide water lines and eyewitness accounts. At several locations subsidence measurements where made both in 2007 (Fritz & Kalligeris, 2008), and 2010 along identical transects based on GPS waypoints and photographic documentation. At some locations such as Rendova Harbor identical eyewitnesses were interviewed in 2007 and 2010.

Though substantial afterslip was observed in the shallow megathrust following large earthquakes including the 2005 Sumatra (Hsu *et al.*, 2006), and likely the 2007 Solomon Islands earthquakes (Chen *et al.*, 2009), GPS observations here revealed no discernible afterslip at our survey locations (**Fig. S3**). However, the observation of no uplift and widespread sub-meter subsidence with maximum values nearest the trench are intriguing (**Fig. 3c**), as they are opposite in sense from both the expected hanging wall motion of a megathrust rupture, and the rapid short-term geologic uplift across the islands (Mann *et al.,* 1998; Taylor *et al*. 2005).

Deformation Modeling:

The gCMT focal mechanism for this event suggests shallow thrusting along the plate interface downdip of the San Cristobal trench (Ekström *et al.*, 2005). However, a shortcoming of far-field seismic techniques, as is used for gCMT determinations, is the inability to distinguish between the true fault and auxiliary planes. With near-field deformation measurements such an ambiguity may be resolved. Thus, we tested models with the observed regional subsidence for both low-angle slip (dip = 22°) along the megathrust and high-angle slip along an orthogonal intraslab plane. For slip along the megathrust, in order to explain the observed increasing subsidence of sites nearer the trench it is necessary to allow slip only along a narrow strip between the southern shore of the nearby islands and the trench (downdip width = 13 km). This is because substantial slip further downdip would require uplift rather than subsidence of the trenchward component of Rendova and Tetepare islands.

We inverted for variable thrust along the shallow megathrust using smoothed Okada (1992) dislocation model, similar to that described in Chen *et al.* (2009) for the 2007 event. Our optimal rupture model requires 6+ m of thrust along a 30 km segment in the upper half of the modeled fault. Assuming average crustal rigidity (30 GPa), the extent and magnitude of slip corresponds to an M_W 7.2 earthquake that yields the proper direction, shape, and magnitude of motion, with RMS misfit (0.18 m) comparable to error in subsidence measurements (**Fig. 4**; *see supplementary information for details*). The slight increase in magnitude over the seismically resolved M_W 7.1 may be due to either early afterslip occurring in the week prior to our arrival, or an un-modeled reduction in the local shallow rigidity allowing increased slip for the same seismically observed moment release (Bilek & Lay, 1999).

An alternative high-angle thrust model requires larger slips, but with comparable RMS misfit (0.18 m). Given the teleseismic mechanism and the locations of the one-sided geodetic observations, the high-angle intraslab result is not distinguishable from the shallow megathrust model.

Tsunami Modeling:

To distinguish between these two models we compare the predicted tsunami runup and open-ocean tsunami wave height time series as recorded by DART sensors. Because tsunami excitation from earthquakes is predominantly controlled by the amplitude and spatial extent of vertical seafloor deformation, the high-angle intraslab and low-angle megathrust models can be differentiated due to the larger amplitude and shorter wavelength deformation produced by the high-angle thrust model.

Using the vertical predicted seafloor deformation from the two distributed slip models, we estimated the tsunami wave time series at the DART stations as well as coastal runup around Tetepare and Rendova Islands using the MOST tsunami model (Titov & Synolakis, 1998). MOST computes tsunami propagation and inundation using multi-scale grids of increased resolution nearest the coast (in this case moving from 36” in open ocean to 3” nearest the shore). The shallow thrusting TsE model produced surprisingly accurate predictions of the observed runup and open-ocean DART wave heights (**Figs. 5)**, while the high-angle model consistently over-predicted tsunami heights by a factor of 2 or more (**Fig. S7)**. Modest local differences in runup can occur due to inaccuracies in the near-shore bathymetry. Of particular note, the DART wave heights accurately predict the first wave-heights in both amplitudes and frequencies. Shifts of 1 to 2 minutes in the model are necessary to match the timing, and can be attributed to finite source duration (~30 s; see **Fig. 2**) that is not considered in the tsunami model, and small inaccuracies in the absolute open-ocean bathymetry (1-2%). Though splay faults have been observed in the shallow trench, and proposed to cause increased tsunami excitation in TsE (Moore *et al.*, 2007), such a high-angle vertical fault was unnecessary to explain the observed tsunami field.

The very large tsunami runup commensurate with an earthquake an order of magnitude larger clearly identifies this event clearly as a tsunami earthquake given its original definition (Kanamori, 1972). Like other TsE events, the earthquake occurred in the shallowest trench environment (Polet & Kanamori, 2000; Ammon *et al.*, 2006). However because the radiated seismic energy is comparable to other earthquakes of its size, its was not identified as a TsE using the current E/M_0 discriminant (Newman & Okal, 1998). It is unclear why the earthquake energetically ruptured the shallow TsE region. However, the likely recent subduction of an active ridge (Mann *et al.* 1998), and the onset of subduction of the geologically young Coleman and Kana Keoki seamounts are likely contributors (**Figs. 3, S8**). Given the history of frequent tsunamis from low *M*7 events in the early 20th century, it is possible that TsE’s are a common feature in this region, however a lack of digital broad-band seismic data would make the energy determinations of earlier events difficult or impossible.

Conclusion:

Utilizing the near-trench deformation, tsunami runup, and open-ocean wave height data, we identified the 3 January 2010 Solomon Islands earthquake as a shallow low-angle earthquake occurring along the megathrust along the front of the impinging seamounts. Due to the recent development of seafloor pressure sensors, and the unique occurrence of land (and hence geodetic observation) very near the trench, we were able to constrain the broad-scale coseismic subsidence and the shape of the observed open-ocean tsunami wave field. These data were instrumental in identifying the extensive shallow thrusting TsE. Without such data, the event would have likely been attributed to undocumented underwater landslides. This event belongs to a previously undocumented class of shallow energetic tsunami earthquakes.

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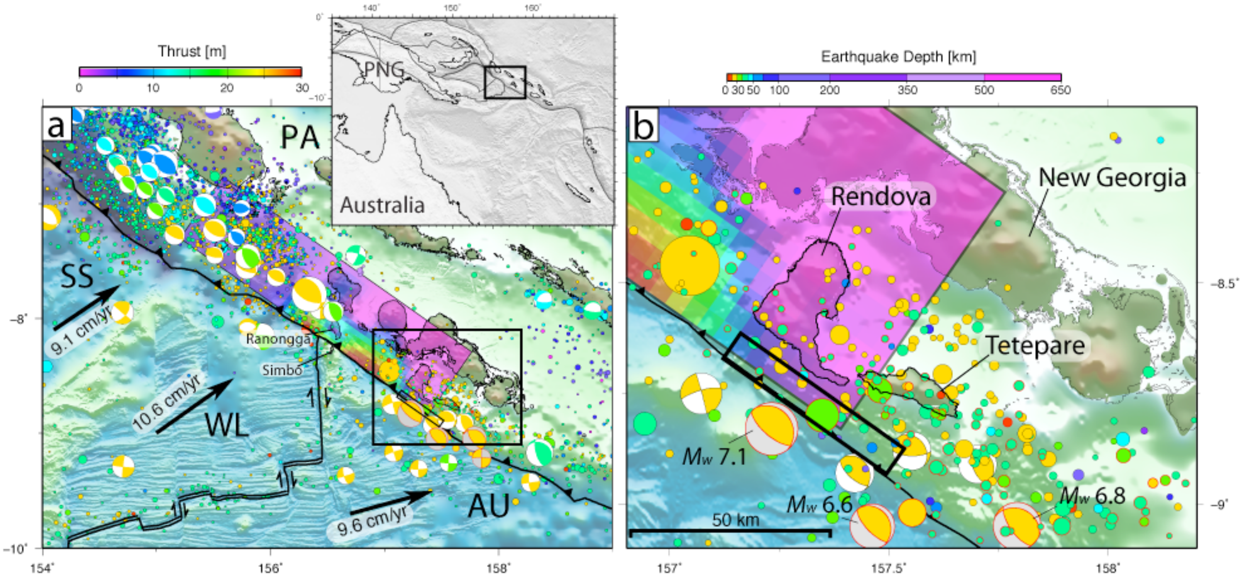

Figure 1: [a] Regional hypocentral earthquake locations since 1962 ($M_W \geq 4$), centroid focal mechanisms since 1976 ($M_W \geq 6$) (Ekström *et al.*, 2005), and regional plate boundaries and motions (Goodliffe *et al.*, 1999; Bird, 2003). Plate motions (arrows) are shown for the Australian (AU), Woodlark (WL), and Solomon Sea (SS) microplates relative to stable Pacific plate (PA). The modeled slip from Chen *et al*. (2009) is shown for the 1 April 2007 M_W 8.1 event (diagonal rectangle). Location of [a] is shown in gray shaded-relief (box). [b] Detailed view of box in [a] illustrates the 3 January 2010 M_W 7.1 event adjacent to the high slip zone of the larger 2007 earthquake. Diagonal box is the outline of the preferred megathrust model of this study. Seismicity occurring in January 2010, including two events with $M_W \geq 6.6$ is outlined in red.

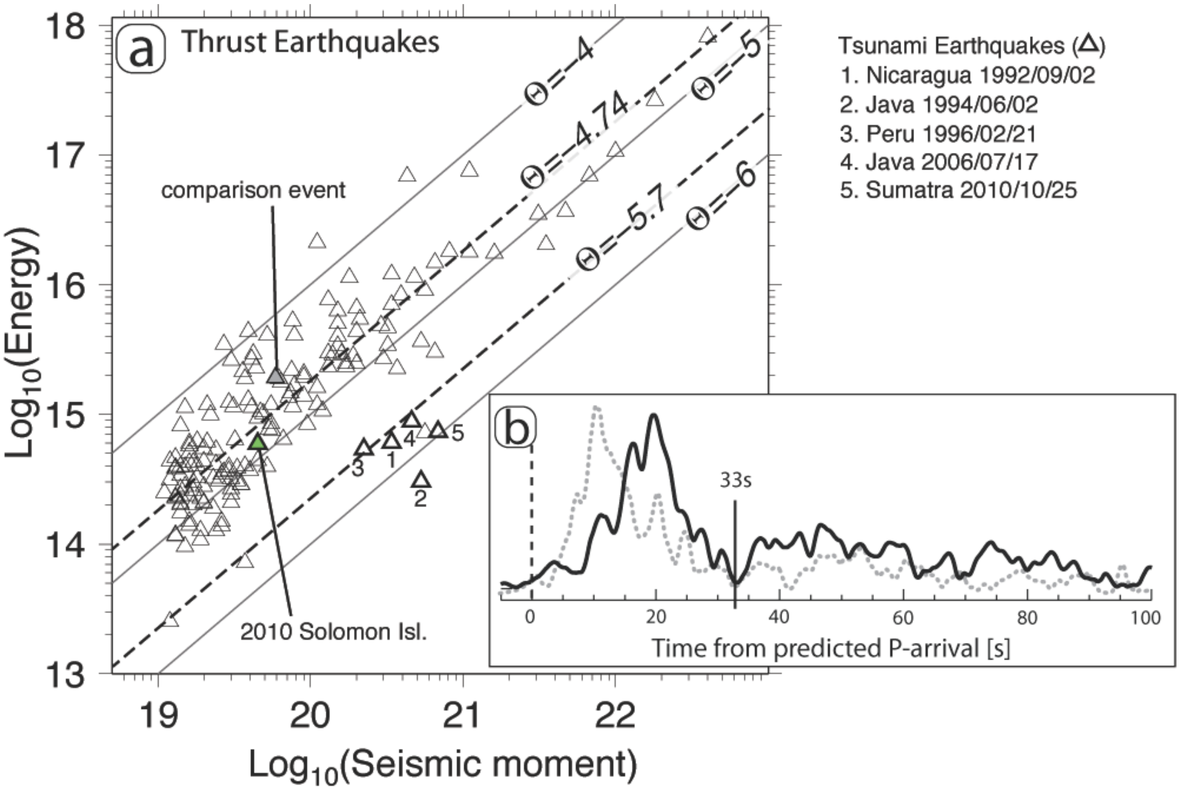

Figure 2: [a] Shown is a comparison of energy-to-moment ratios for global thrust earthquakes between 1997 and mid-2010, including known tsunami earthquakes since 1992 and the 2010 Solomon Islands earthquake (Newman & Okal, 1998; Convers & Newman, 2011; Newman *et al.,* 2011). Unlike other known tsunami earthquakes that consistently report very low radiated seismic energy, the 2010 Solomon Islands earthquake generated normal radiated seismic energy (Θ = -4.8±0.3, using 68 stations 25° ≤ Δ ≤ 80°). [b] The envelope of the stacked vertical broadband seismograms reveals an estimate of the rupture duration (33 s) for the 2010 Solomon Islands earthquake, significantly shorter than the 5 observed slow-source tsunami earthquakes (duration > 100 s), and comparable to another recent regional M_W 7.1 event used for comparison; a shallow (depth = 23 km) megathrust event in the Celebes Sea on 11 Feb. 2009 (gray dashed line in [b] and gray triangle in [a]). The stacked envelopes show that while the more energetic comparison event peaks earlier its approximate duration is similar.

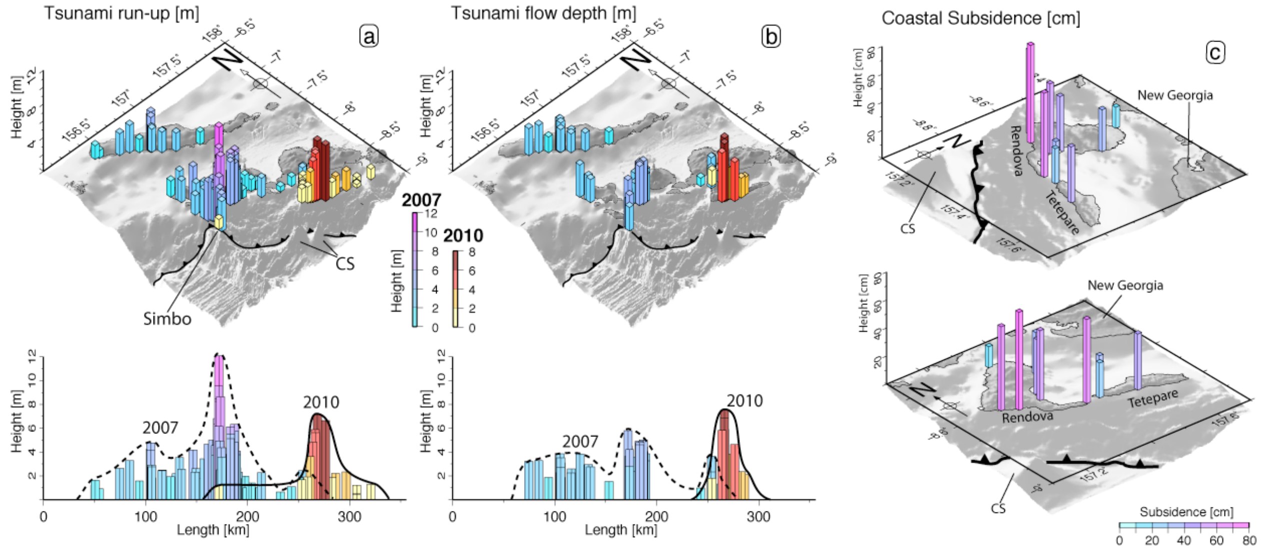

Figure 3: Tsunami [a] run-ups and [b] flow depths are shown for both the 2007 M_W 8.1 (cool colors) from Fritz & Kalligeris (2008) and the 2010 M_W 7.1 (hot colors) Solomon Islands earthquakes. Maximal tsunami impact in the 2010 earthquake is near the now subducting double-peaked Coleman Seamount (CS) structures. Flow depths, though harder to measure, yield a more precise estimate of tsunami height. The order of magnitude smaller 2010 earthquake caused larger localized flow depths, and only moderately smaller run-ups. No significant tsunami impact occurred in the western 30% of the 2007 earthquake zone (area not shown). [c] Two views of land-level change observed across Tetepare and Rendova Islands from the M_W 7.1 earthquake. Though uplift was expected from megathrust rupture, only subsidence was found, with a maximum (-80 cm) in the near-trench region. Data were collected over a 5-day period beginning nine days after the mainshock, and consisted primarily of submerged natural and anthropogenic markers. White diamonds represent 4 points where land-level changes were not discernible.

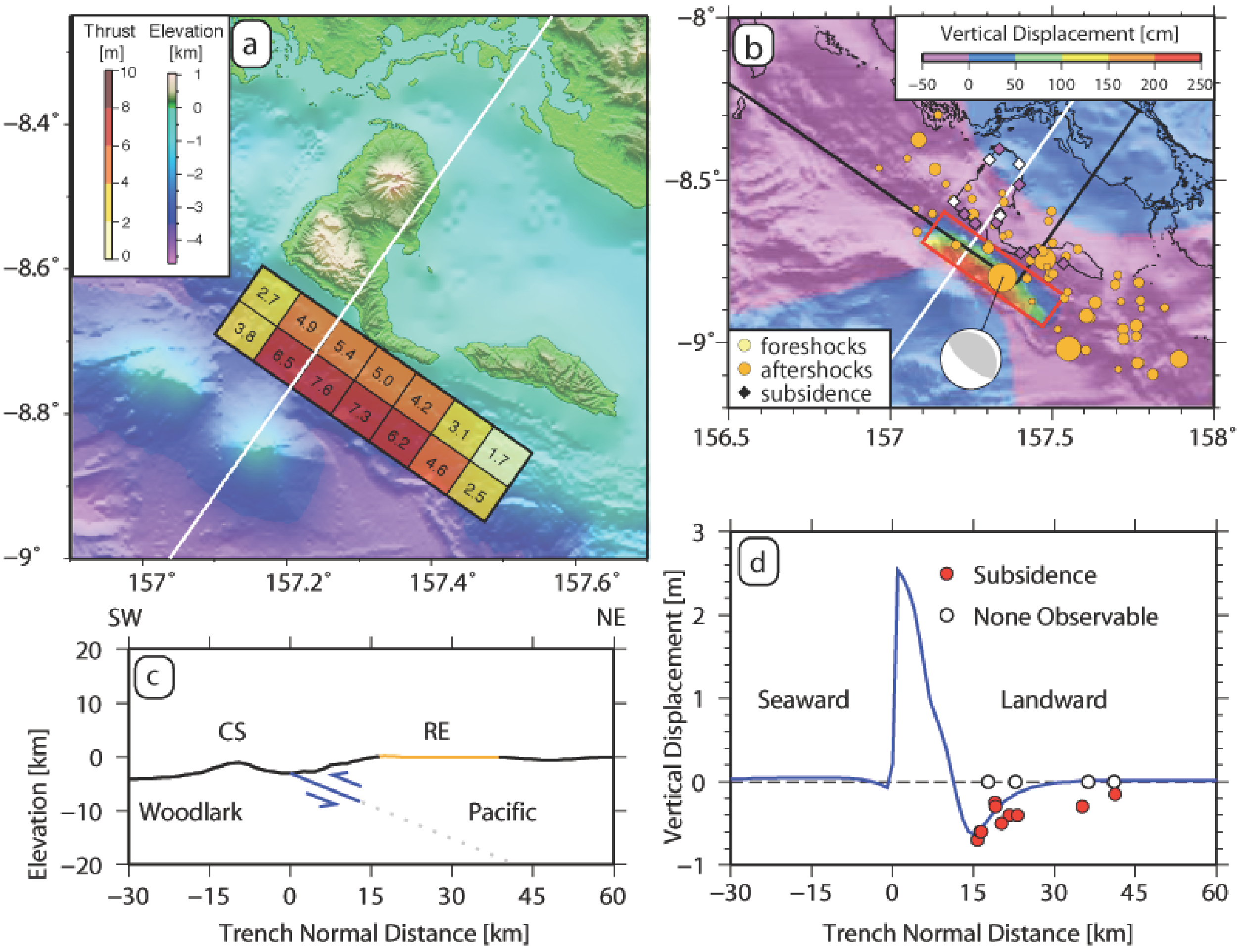

Figure 4: [a] The optimal distributed shallow megathrust slip model is shown for the [b] measured subsidence (diamonds) and predicted vertical deformation (red box highlights model in [a]). [c] Subduction zone profile along the white line in [a] shows the down-dip extent of the TsE model predicted by the gCMT mechanism. Rendova Island (RE) is shown in orange. [d] Projected subsidence measurements (circles) along the modeled vertical deformation (blue line) are shown for the profile in [b]. A high angle intraslab event also fits observed subsidence data but not the observed tsunami (Figures **S3**, **S7**).

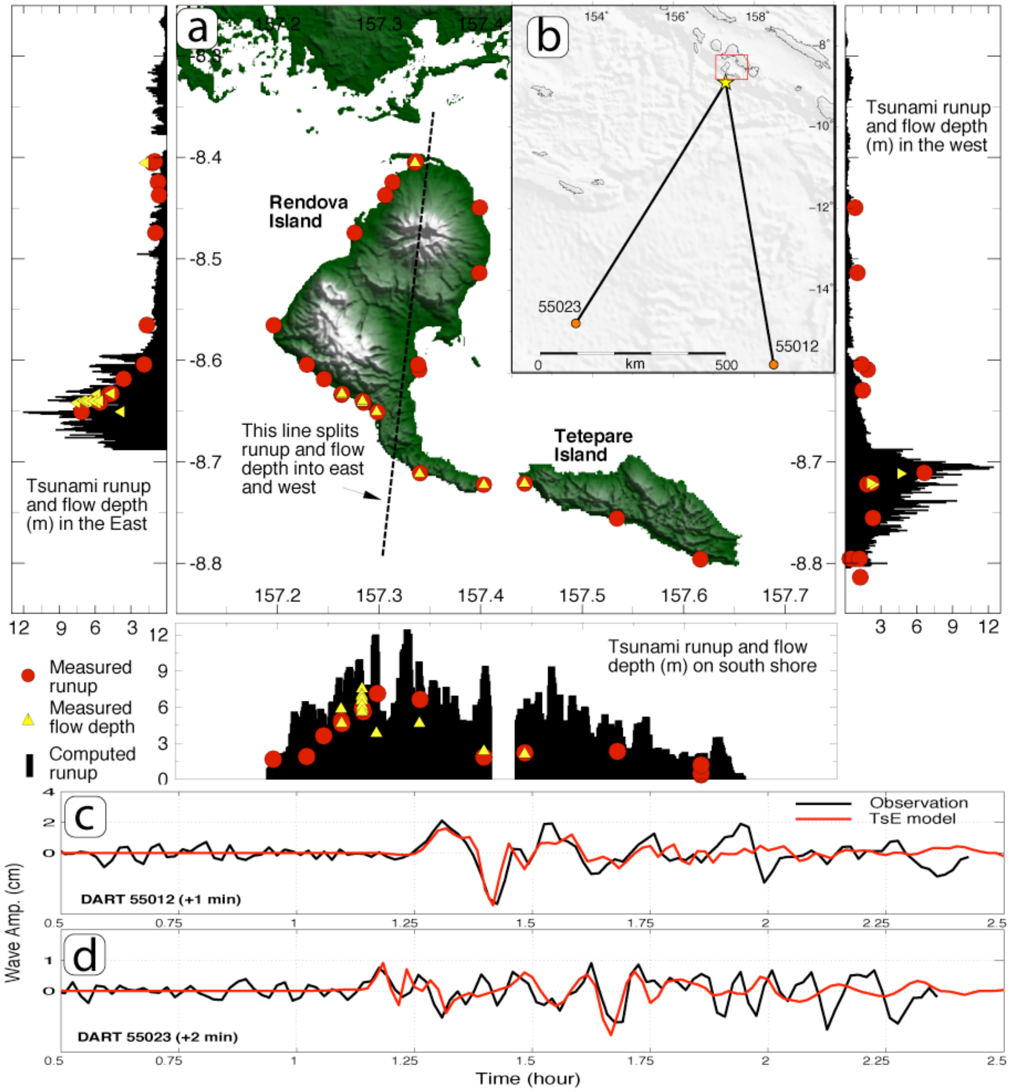

Figure 5: Comparison of observed tsunami data and model predictions using seafloor displacements estimated from the earthquake slip model in **Fig. 4**. [a] The spatial distribution of predicted (black bars) and observed tsunami runup and flow depths (red circles and yellow triangles) are projected along the south shore, and along the eastern and western sides of the islands (separated by dashed black line). [b] Two ocean-bottom pressure sensors approximately 1000 km south of the event [c,d] measured cm-level open-ocean tsunami heights, which are well predicted by the tsunami model.