PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Simulation Confidence in Tsunami-Driven Overland Flow

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ABSTRACT

Numerical models are a key component for methodologies used to estimate tsunami risk, and model predictions are essential for the development of Tsunami Hazard Assessments (THAs). By better understanding model bias and uncertainties and, if possible, minimizing them, a more reliable THA will result. This study compares the run-up height, inundation lines, and flow-velocity field measurements between GeoClaw and the Method of Splitting Tsunami (MOST) model predictions in the Sendai Plain. In general, run-up elevation and average inundation distance are overpredicted by the models. However, both models agree relatively well with each other when predicting maximum sea surface elevation and maximum flow velocities. To explore the variability and uncertainties in the numerical models, the MOST model is used to compare predictions from four different grid resolutions (30 m, 20 m, 15 m, and 10m). Our work shows that predictions of statistically stable products (run-up, inundation lines, and flow velocities) do not require use of high-resolution (less than 30 m) Digital Elevation Maps (DEMs) at this particular location. In addition, the Froude number variation in overland flow is presented. The results provided in this paper will help understand the uncertainties in model predictions and locate possible sources of errors within a model.

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1 Introduction

1.1 BACKGROUND

On March 11, 2011, a M_w = 9.0 earthquake generated a tsunami 130 km off the coast of Sendai, Japan [Mori et al. 2011]. This event was one of the worst in Japanese history, killing more than 15,000 people and causing more than $200 billion (USD) in damage. Available data shows that in some areas run-up elevations reached 40 m, and flow velocities reached more than 14 m/sec [Mori et al. 2011; Koshimura and Hayashi 2012]. This event raised the safety concerns of many coastal communities. Along the Sendai Plain, the tsunami traveled more than 5 km inland, with a maximum measured run-up of approximately 9.4 m and an average of 2.5 m above Mean Sea Level (MSL) [Mori et al. 2011]. The tsunami velocities measured by Koshimura and Hayashi [2012] at different locations on the Sendai Plain ranged from 2–8 m/sec. The measurements collected during and after the Tohoku event provided researchers with a great opportunity to model, study, and understand the nearshore and onshore hydrodynamics of tsunamis.

Numerical model predictions are important for the development of probabilistic and deterministic methods that are used for Tsunami Hazard Assessments (THA). Generally, methodologies for Probabilistic Tsunami Hazard Assessment (PTHA) use numerical models to predict various parameters (run-up, inundation, and flow velocity), which are then used to perform a statistical analysis to compute recurrence interval rates at a given location [Geist and Parsons 2006; González et al. 2009, Thio et al. 2012; and González et al. 2013]. In a deterministic approach, worst-case scenarios are modeled by considering physical limitations of the natural occurrences [Gonzalez et al. 2007]. Better understanding of model bias and uncertainties will result in more accurate and reliable THAs and PTHAs, thus leading to improved risk assessment and hazard mitigation in coastal areas susceptible to tsunamis and better evacuation, maritime, land-use, and construction planning.

Previous decades saw the development of numerical models that can accurately predict tsunami run-up, inundation, and flow velocity. Despite the surge of “state-of-the-art” numerical models and their widespread use in this field, there remains a need for more robust models for better evacuation and construction planning. The study reported herein compared measured field data with run-up and flow-velocity results obtained from two tsunami models: the Method of Splitting Tsunami (MOST) [Titov and Synolakis 1995; 1998] and GeoClaw [LeVeque 1997; 2002]. Available field-survey data and video footage analysis measurements are used to compare model run-up and flow-velocity predictions. Possible sources of error and uncertainty in their predictions are analyzed and discussed. This study includes detailed comparisons between observations and numerical simulations in Sendai, focusing on the Sendai Plain area.

2 Methodology

2.1 FIELD MEASUREMENTS AND OBSERVATIONS

The field-survey data published in Mori et al. [2011] and the flow-velocity measurements obtained from Koshimura and Hayashi [2012] were used to compare the accuracy and reliability of numerical model predictions. More than 5300 measurements were recorded by a large group of scientists and researchers. A total of 63 universities and 297 people were involved in this project, which covered 2000 km of the Japanese coast. The maximum measured run-up elevation in Sendai was 9.4 m [The 2011 Tohoku Earthquake Tsunami Joint Survey Group 2011]. Only 10% of the run-up measurements were greater than 5 m. This study focused on the Sendai Plain (particularly from 38.10° N to 38.28° N), where the wave front reached more than 5 km inland from the shoreline (with the average being 4.2 km).

Flow-velocity estimates measured by Koshimura and Hayashi [2012] were obtained from a two-dimensional (2D) projective transformation video analysis. One of the two locations where measurement estimates were made was the Sendai Plain. The video used in the analysis was taken by a Japanese broadcasting company. Flow-velocity estimates were made at four different locations within the Sendai Plain. These locations are at a distance of 1000–3000 m from the coastline. The maximum measured flow velocity was 8.0 m/sec.

The grids used in this study are from the M7000 digital contoured bathymetric data and the GSI 10-m digital elevation models (*http://fgd.gsi.go.jp/download/*). Five nested grids were used in the numerical models. The propagation grid, or grid A, was the coarsest grid at 3 arc-minutes. Four additional nested grids (1 arc-min, 20 arc-sec, 4 arc-sec, and 1 arc-sec) were used covering the area of interest. Also, three additional grids were created (0.67 arc-sec, 0.50 arc-sec, and 0.33 arc-sec) by interpolating the 1 arc-sec grid. These grids were used to analyze convergence and variability within the MOST model predictions. All the grids were referenced to Mean Sea Level (MSL) vertical datum and the World Geodetic System [ICAO 1984] horizontal datum.

2.2 TSUNAMI MODELING

The Method of Splitting Tsunami (MOST) model was developed as part of the Early Detection and Forecast of Tsunami (EDFT) project, and introduced by Titov and Synolakis [1995; 1998]. This model is currently used by U.S. National Oceanic and Atmospheric Administration for propagation and inundation forecasting [Titov 2009]. The MOST model has been validated and successfully tested in various studies [Titov and González 1997; Titov and Synolakis 1998; and Synolakis et al. 2007]. Wei et al. [2011] modeled the 2011 Tohoku tsunami by using MOST to perform a detailed analysis of run-up height and inundation along the Japanese coast. MOST solves the 2+1 nonlinear shallow water equations:

$$ht + (uh)_x + (vh)_y = 0 \tag{2.1}$$

$$u_t + uu_x + vu_y + gh_x = gd_x - Du \tag{2.2}$$

$$v_t + uv_x + vv_y + gh_y = gd_y - Dv \tag{2.3}$$

where $\eta(x, y, t)$ equal wave amplitude, d is the water depth, $h(x, y, t) = \eta(x, y, t) + d(x, y, t)$, $u(x, y, t)$, and $v(x, y, t)$ are the depth-averaged velocities, and $D(h, u, v)$ is the drag coefficient computed by Equation (2.4):

$$D(h, u, v) = n^2 g h^{-4/3} \sqrt{u^2 + v^2} \tag{2.4}$$

Run-up and inundation were only performed in the higher resolution grids (1 arc-sec, 0.67 arc-sec, 0.5 arc-sec, and 0.4 arc-sec, or approximately 30 m, 20 m, 15 m, and 10 m, respectively). A Manning coefficient of n = 0.025 was used in all simulations. For a detailed description of the MOST model, see Titov and Synolakis [1995; 1998].

GeoClaw, developed by LeVeque [1997; 2002], is an open-source tsunami model approved by the U.S. National Tsunami Hazard Mitigation Program (NTHMP). It has been validated by comparing real and artificial data (run-up, inundation, and flow velocity) with model results [LeVeque and George 2006; George 2008; González et al. 2011, Berger et al. 2011; LeVeque et al. 2011; and Arcos and LeVeque 2015]. GeoClaw uses the finite volume to solve the 2D nonlinear shallow water equations in conservative form:

$$h_t + (uh)_x + (vh)_y = 0 \tag{2.5}$$

$$(hu)_t + \left(hu^2 + \frac{1}{2}gh^2\right)_x + (huv)_y = -ghB_x - Dhu \tag{2.6}$$

$$(hv)_t + (huv)_x + \left(hv^2 + \frac{1}{2}gh^2\right)_y = -ghB_y - Dhv \tag{2.7}$$

where $h(x, y, t)$ is the fluid depth, $u(x, y, t)$ and $v(x, y, t)$ are the depth-averaged velocities, $B(x, y, t)$ is the topography or bathymetry, and $D(h, u, v)$ is the drag coefficient computed by Equation (2.4), with the Manning coefficient, n = 0.025 constant throughout the grid. For a detailed description of GeoClaw, see LeVeque [2002] and the other references provided above.

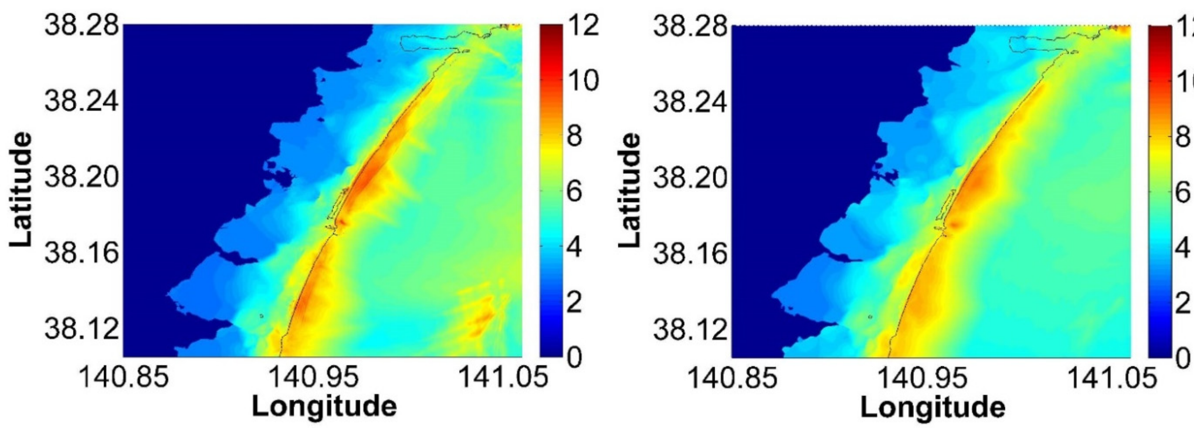
The initial condition used in both models is an initial sea-surface deformation based on Yokota et al. [2011]. This source model was created by carrying out a quadruple joint inversion of the strong-motion, teleseismic, geodetic, and tsunami datasets. The resulting model has a maximum co-seismic slip of approximately 35 m and a seismic moment of $4.2 * 10^{22}\, Nm$, which yields M_w = 9.0.

3 RESULTS AND DISCUSSION

3.1 INTER-MODEL COMPARISON

A 30-m resolution grid was used for the inter-model comparison analysis. Figure 3.1 shows the maximum free-surface elevation during the Tohoku tsunami event for the MOST and GeoClaw models. Both models predict that higher free-surface elevations occur at the central part of the Sendai Plain, around 38.20° N 140.975° E, with maximum wave amplitudes ranging from 8–12 m. Both models agree relatively well with each other when predicting sea surface elevation near the shoreline, with the MOST model yielding slightly higher predictions.

For consistency purposes, seven run-up measurements from the field data were removed from the analysis; see Table 3.1. These run-up measurements were located very close to the shoreline and led to an irregular inundation line when combined with the other run-up points. This analysis used a total of 46 run-up measurements from the Sendai Plain. Table 3.2 presents some statistics from field data and model predictions. The predicted average distance for the wave front as it traveled inland was 4460 m and 4740 m from the MOST and GeoClaw models, respectively, compared to 4450 m calculated from field data. Table 3.2 presents the average absolute difference between the field data and the two models. The GeoClaw model overestimated the inundation distance by 18% more than the MOST model.



(a) (b)

Figure 3.1 Predictions of the maximum tsunami amplitudes (m) in the Sendai Plain by the (a) MOST and (b) GeoClaw models.

Table 3.1 **Field-data measurements not used in this study.**

Lat. (ºN)	Lon. (ºE)
38.1725	140.9538
38.1822	140.9583
38.2394	140.9533
38.2718	140.9981
38.2724	140.9980
38.2799	141.0506
38.2799	141.0484

Table 3.2 **Average inundation distance from field measurements and models.**

	MOST model	GeoClaw model	Field data
Avg. (m)	4460.5	4739.3	4451.5
Max. (m)	6246.4	6562.4	5947.0
Min. (m)	1993.3	2746.9	2107.3
Avg. Abs. Diff. (m)*	525.2	644.3	N.A.

*Average absolute difference between field data and model predictions.

Figure 3.2a shows field data run-up measurements and the predicted run-up by both models. The average run-up from the 44 field-data measurements is 1.89 m, with a standard deviation of 0.70 m, while the average run-up calculated by MOST and GeoClaw is 3.01 m and 3.34 m, respectively. Thus, much of the model run-up results lay approximately two to three standard deviations away from the mean of the field data. The run-up standard deviation for both models is 0.16 m and 0.33 m for the MOST and GeoClaw models, respectively. Figure 3.2b shows the inundation line predicted by both models and the field data run-up height measurements at the Sendai Plain (38.10° N to 38.28° N). Both models provide a reasonably accurate prediction of the inundation line, thus indicating an inconsistency, i.e., the inundation line is well predicted, but the run-up elevation is not. This will be addressed later.

Figure 3.3 shows the probability density function (pdf) of the run-up height obtained from field data and the models. This pdf, and all pdfs presented in this paper, were generated using all relevant field or modeled data between 38.10° N to 38.28° N along the Sendai Plain. Although the model distributions have a similar shape, with means within 10% of each other, clearly they overestimate the observed run-up. To further analyze the run-up predicted by both models, the field data run-up height measurements were compared with the elevation from the numerical topographic grid at the location of the run-up measurements using the Sendai 30-m resolution topography.

Figure 3.4 presents a histogram of the estimated differences, which shows that most of the differences range between (-3 m) to (-1 m), indicating that there is an error in the topography. Due to the spread of the histogram, this error cannot be simply attributed to a datum inconsistency. The differences between run-up elevations and topographic grid elevations would also indicate that it should not be possible for a model to agree with both the inundation line and the run-up elevation when using this GSI topography data. Such errors are particularly significant for flat coastal areas such as the Sendai Plain.

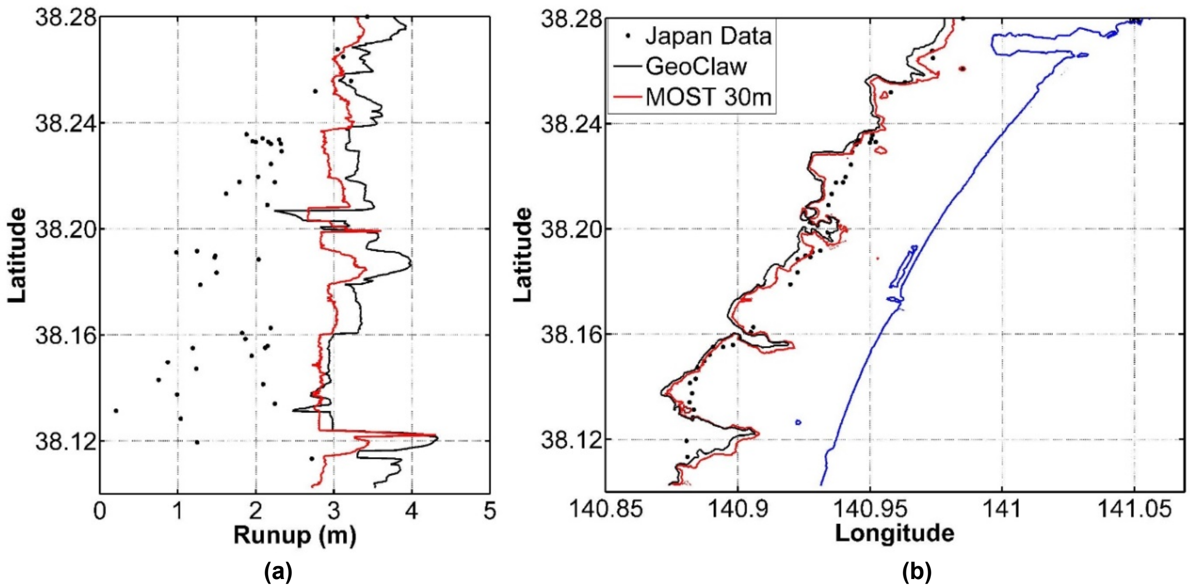


Figure 3.2 **Comparison of run-up height measurements and inundation line among field data, the MOST model, and the GeoClaw model during the 2011 Tohoku event in the Sendai Plain.**

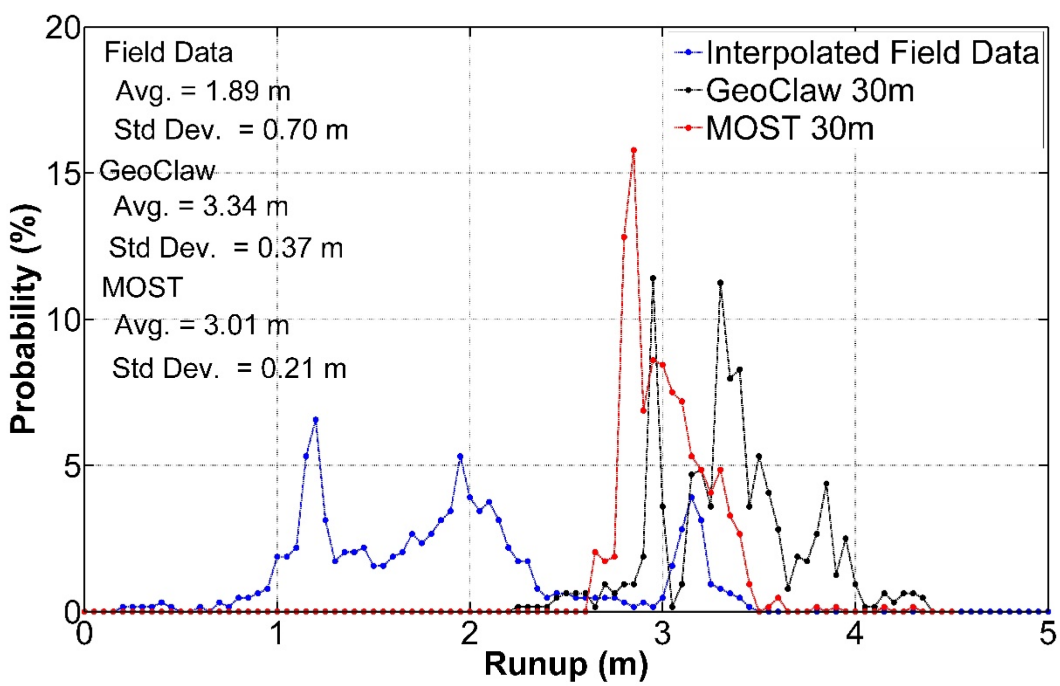


Figure 3.3 **Comparison of the run-up heights probability density functions among the interpolated field data, the MOST model, and GeoClaw model.**

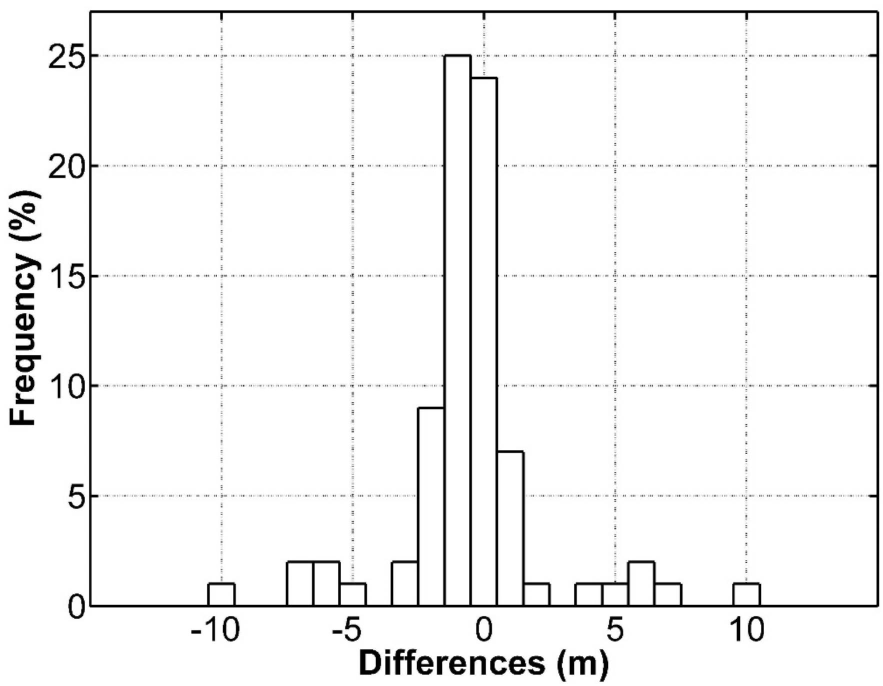
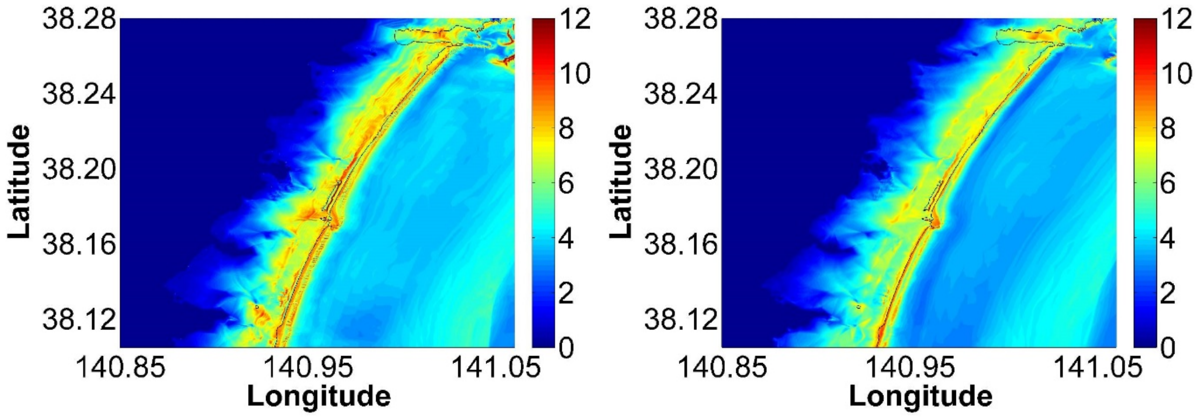


Figure 3.4 Estimated differences between field data run-up heights and the topographic elevations from the numerical grid at the location of the run-up measurements.

In addition to flow depths, tsunami flow velocities were analyzed to understand the tsunami hazard at a particular location, e.g., currents are more destructive than wave height amplitudes during many tsunami events [Synolakis 2004; Lynett et al. 2012; and Lynett et al. 2014]. Figure 3.5 presents the maximum flow velocities in the Sendai Plain predicted by the MOST and GeoClaw models, respectively. Both models are in agreement predicting the locations of high-flow velocities. In addition, both models show a rather complex profile of overland flow velocity, with a number of local maxima. These local maxima are due to topographic features and properties of the incident wave form.

Koshimura and Hayashi [2012] measured the tsunami flow velocities at four different locations in the Sendai Plain. Figure 3.6 shows the modeled tsunami flow velocities and field measurements at these locations. Both models underpredicted the flow velocity at F1, which is close to the coastline and overpredicted at Y1 and K3, which are further inland. At F2, GeoClaw overpredicted the two data measurements, while the MOST model underestimated them. There are several reasons why a numerical model might over- or underestimates flow-velocity measurements: complex and unresolved bathymetry/topography, improper friction coefficients, no inclusion of tides, and numerical dispersion and dissipation errors. A higher friction coefficient, perhaps more appropriate to rice paddies (e.g., n = 0.035), would likely decrease flow speeds further inland, which is the area with largest model–data discrepancy.



(a) (b)

Figure 3.5 **Maximum flow velocities predicted by the (a) MOST and (b) GeoClaw models.**

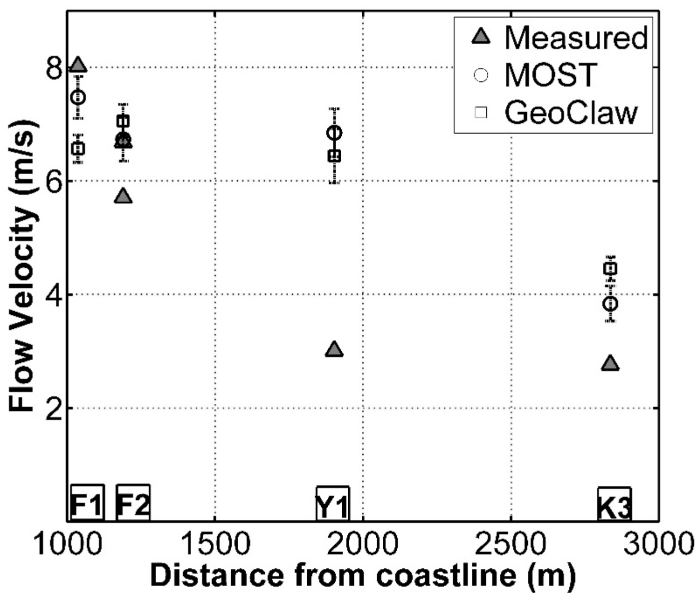


Figure 3.6 **Comparison of maximum flow velocities at the Sendai Plain between Koshimura and Hayashi [2012] measurements (gray triangles), MOST model predictions (circles), and GeoClaw model predictions (squares). The vertical bars on the model data provide the standard deviation of the predictions in the measurement window. Two measurements were taken at F2.**

Figure 3.7 compares the pdfs of modeled maximum shoreline flow velocity and flow velocity at the 1-m inland flow depth. These two locations are meant to represent limits of the overland flow area; one comparison was performed at the shoreline and another near the inundation limit, but still at a significant flow depth. Since there is no available data at these locations, it is very difficult to assess accuracy of the models. Many of the model velocity predictions at the shoreline are between 5–9 m/sec, with means of 7.30 and 7.34 m/sec for GeoClaw and MOST models, respectively. The shapes of the shoreline flow-velocity pdfs tend to agree well with small differences in their means. Figure 3.7b shows that both models agree well when predicting the maximum flow velocities at the 1-m flow depth. The peak of the

GeoClaw distribution is located around 1.63 m/sec, with an average of 1.60 m/sec, while the peak for MOST is located around 1.20 m/sec, with an average of 1.63 m/sec.

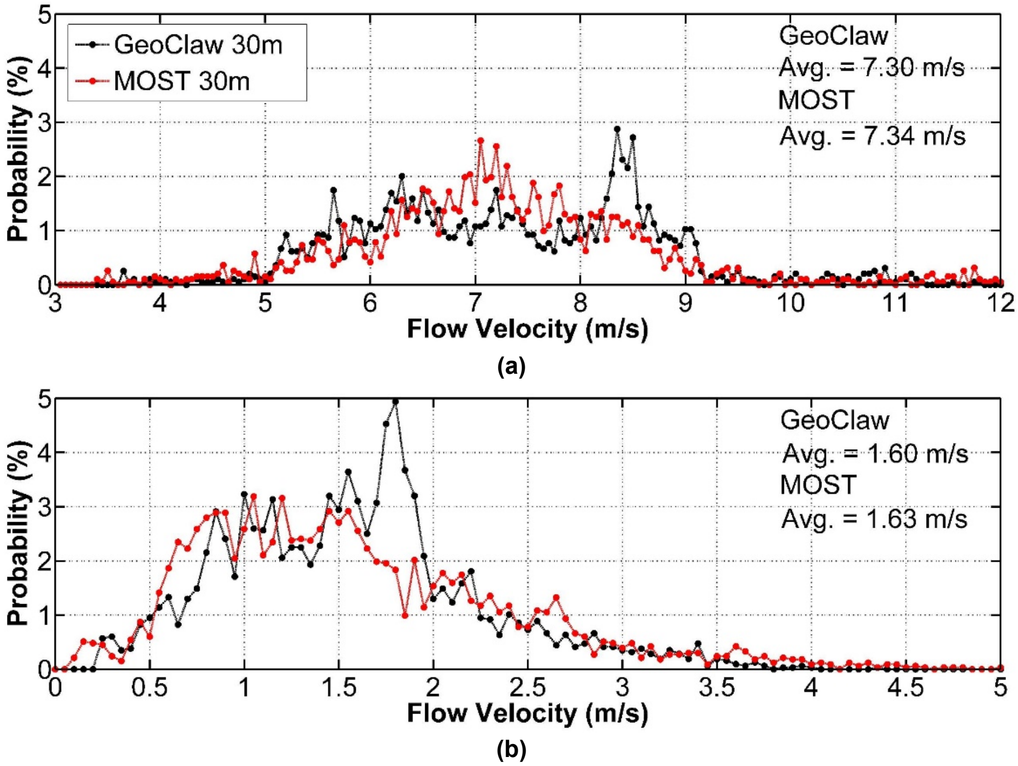


Figure 3.7 **Comparisons between GeoClaw and MOST models: (a) probability density functions of maximum shoreline flow velocities; and (b) 1-m depth maximum flow velocities at the Sendai Plain.**

3.2 VARIABILITY AND UNCERTAINTIES: THE MOST MODEL

Unquantified uncertainties and variabilities within a model can lead to unknown errors in a THA. This section uses the MOST model to further explore and understand possible sources of error within a model. For this part of the analysis, four inundation grids (1 arc-sec, 0.67 arc-sec, 0.50 arc-sec, and 0.33 arc-sec) were used to compare inundation, run-up, and velocity predictions made by the MOST model. As was previously mentioned, finer grids were created by interpolating the 1 arc-sec topography data. Figure 3.8 shows a pdf of the run-up height calculations from the different grids. Both run-up and inundation line predictions numerically converge within the tested grid sizes. There are small deviations in the inundation line and run-up calculations when using different grid resolutions (30 m–10 m). In this case, it seems reasonable to conclude that there is no need to use inundation grids finer than 30 m when calculating run-up and inundation lines.

Figure 3.9 shows a comparison of maximum shoreline flow velocity pdfs and 1-m flow depth maximum velocity pdfs for the different grid resolutions. Averages for shoreline velocities are around 7.50 m/sec, and for 1-m flow depth velocities are around 1.70 m/sec. Initially, there appears to be numerical convergence between the 30 m, 20 m, and 15 m resolution simulations at the shoreline; however, the 10-m resolution grid diverges, with an average maximum velocity of 8.03 m/sec. While this divergence is relatively small with a change of 7% in mean values between the 15 m and 10 m results, this difference is not easy to reconcile. Further study reveals that this variance between the 15-m and 10-m results appears to be driven by a difference in the prediction of the steep front of the incoming bore, with the understanding that breaking in this model is controlled through numerical dissipation. However, it is difficult to assess whether this variance is physical (i.e., a better resolution of the process) or numerical (i.e., resulting from different numerical errors). Stable numerical results were not achievable for grid sizes less than 10 m. Such a divergence with finer resolutions is not found at the inland location.

Figure 3.10 shows the calculated mean flow velocity at six different flow depths (where 6 m corresponds approximately to the shoreline): note that the means seem to converge at lower flow depths. Also, the greatest increase in flow velocity between flow depths was found to be from 2–3 m, with an average increase of 2.69 m/sec for the tested grids. It is commonly assumed that the Froude number (Fr) is near 1 at the shoreline and decreases inland, but Figure 3.10 shows an irregular Fr profile. The Fr is very near 1 at the shoreline, greater than 1 (supercritical flow) at flow depths of 3–5 m, and less than 1 (subcritical flow) at flow depths of 1–2 m.

It is reasonable to expect a steady decrease in velocity if assuming a simple beach as the wave front makes its way inland; however, the simulation results provided in Figure 3.11a show otherwise. Between 400–1200-m inland, maximum velocities (again the mean of the maximum velocities across the studied Sendia Plain) appear to be constant. Analysis of numerical output demonstrates that small bathymetry/topography features can cause large changes in predicted flow velocities, producing secondary peaks. Further inland, results from the MOST model show a steady decline in velocity from 1200–2800 m, with a negative slope of about 0.002 for all grid resolutions. Peak-flow velocities fluctuate from 6–17 m/sec and standard deviations from 0.9–1.7 m/sec.

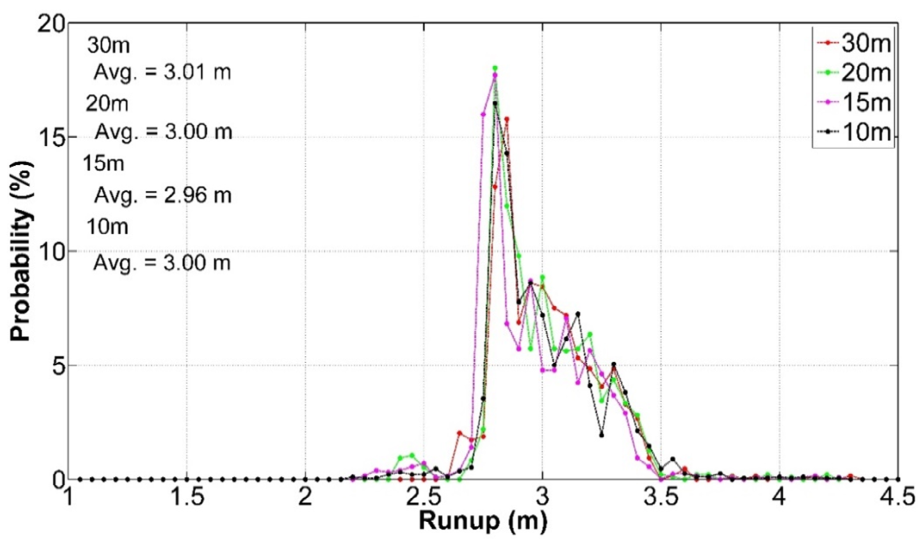


Figure 3.8 **Comparison of the run-up heights probability density functions between the four different grid resolutions using the MOST model.**

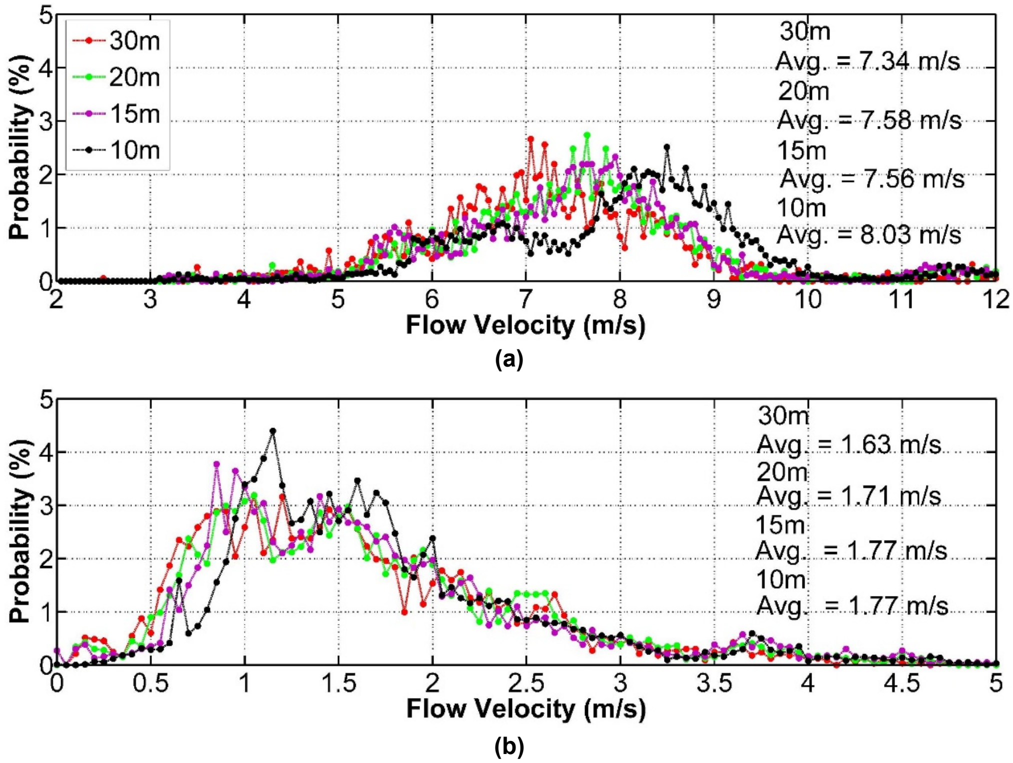


Figure 3.9 (a) Comparison of the maximum shoreline flow velocities probability density functions; and (b) 1-m depth maximum flow velocities probability density functions between the four different grid resolutions using MOST.

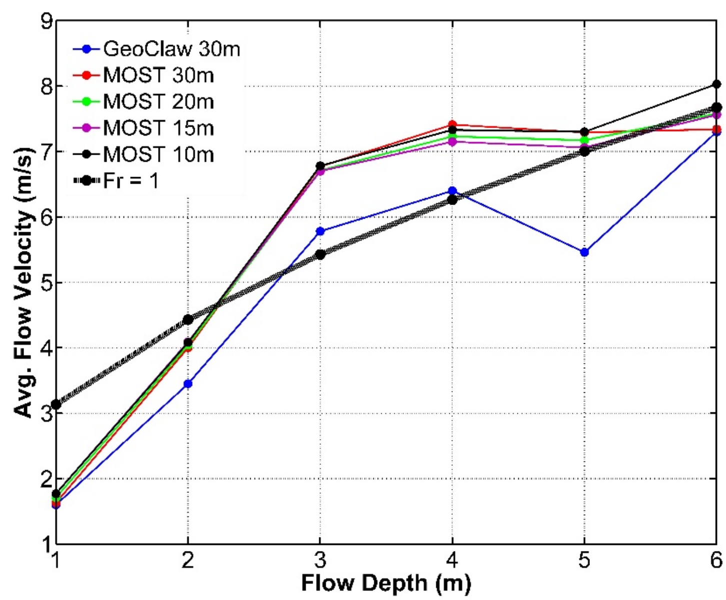


Figure 3.10 Mean flow velocity at different flow depths. The 6-meter flow depth corresponds approximately to the shoreline. The thick black line represents the calculated mean flow velocities using a Froude number of 1.

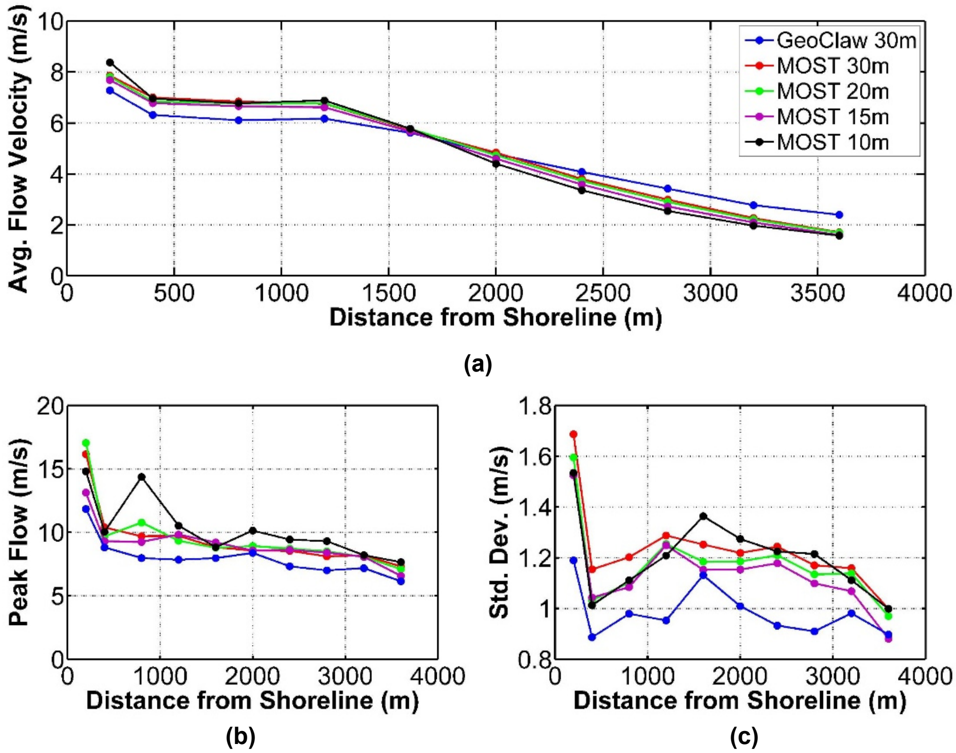


Figure 3.11 **Inland maximum flow velocities across shore in the Sendai Plain: (a) comparison of the average flow velocities between GeoClaw model and the four different grid resolutions using the MOST model; (b) comparison of peak-flow velocities; and (c) comparison of standard deviations.**

4 CONCLUSIONS

This study compares the results from field data obtained from the 2011 Tohoku tsunami with predictions obtained from two numerical models: the MOST and GeoClaw model. In general, both models overpredicted the run-up elevation. On the other hand, the inundation line predicted by both models was in good agreement with field data observations; this inconsistency can be attributed to errors in the topographical data. By comparing observed run-up elevation measurements to DEM elevations at the same location, the topography bias ranged from (- 3m) to (-1 m). This bias is very significant for this particular location since the Sendai Plain is relatively flat. Given this topography, it should prove impossible to obtain acceptable agreement for both the run-up elevation and inundation line. For inter-model agreement, both numerical models agree relatively well with each other when predicting maximum sea surface elevation and maximum velocities, with MOST model yielding slightly higher predictions for both. Note that both models predict similar maximum velocity at the shoreline—see Figure 3.7—a key metric.

When predicting run-up heights and inundation lines using the MOST model, numerical convergence was achieved using the 30-m resolution inundation grid, suggesting that grids finer than 30-m resolution are not necessary when calculating these parameters at this particular location. Generally, when trying to simulate velocities, it is recommended to use higher-resolution topography, as small local changes in bathymetry/topography can cause similarly large local changes in the speed. Predictions of overland flow showed that the Froude number varies at different flow depths, which is contrary to what is commonly assumed. At flow depths of 3–5 m, the flow is considered supercritical, indicating that speed would increase in the presence of buildings or structures. Finally, it was expected that the maximum flow velocity would decrease as the wave makes its way inland, but this pattern was not obvious between the 400-m and 1200-m contour lines, as complexities in the topography and flooding waves obscured this idealized expectation.

REFERENCES

Arcos M.E.M., LeVeque R.J. (2015). Validating velocities in the GeoClaw tsunami model using observations near Hawaii from the 2011 Tohoku tsunami. *Pure Appl. Geophys*., 172: (3–4), doi:10.1007/s00024-014-0980-y.

Berger M.J., George D.L., LeVeque R.J., Mandli K.T., (2011). The GeoClaw software for depth-averaged flows with adaptive refinement, *Adv. Water Res*., 34: 1195–1206.

Geist E.L., Parsons T. (2006). Probabilistic analysis of tsunami hazards, *Natural Hazards*, 37: 277–314.

George D.L. (2008). Augmented Riemann solvers for the shallow water equations over variable topography with steady states and inundation, *J. Comput. Phys*., 227: 3089–3113.

George D.L., LeVeque R.J. (2006). Finite volume methods and adaptive refinement for global tsunami propagation and local inundation, *Sci. Tsunami Hazards,* 24: 319–328.

González F.I., et al. (2007), Scientific and technical issues in tsunami hazard assessment of nuclear power plant sites, *NOAA Tech. Memo*. *OAR PMEL-136, NTIS: PB2008-101460*, Pacific Marine Environmental Laboratory, Seattle, Wash., 125 pgs. + appendices on CD.

González F.I., Geist E.L., Jaffe B., Kanoglu U., Nofjeld H., Synolakis C.E., and fifteen others, (2009). Probabilistic tsunami hazard assessment at Seaside, Oregon, for near- and far-field seismic sources, *J. Geophys. Res. Oceans*, 114: C11023, doi: 10.1029/2008JC005132.

González F.I., LeVeque R.J., Adams L.M. (2013). Probabilistic tsunami hazard assessment (PTHA) for Crescent City, CA, *Final Report on Phase I, January 31, 2013*, University of Washington, 70 pgs.

González F.I., LeVeque R.J., Chamberlain P., Hirai B., Varkovitzky J., George D.L. (2011). GeoClaw results for the NTHMP tsunami benchmark problems, [NTHMP] National Tsunami Hazard Mitigation Program. 2012. *Proceedings and Results of the 2011 NTHMP Model Benchmarking Workshop*. Boulder, CO, *U.S. Department of Commerce/NOAA/NTHMP*; (NOAA Special Report). 436 pgs.

ICAO (1984). *World Geodetic System—1984 Manual*, Doc 9674, AN/946, International Civil Aviation Organization, Montreal, Quebec, Canada.

Koshimura S.; Hayashi S. (2012), Tsunami flow measurement using the video recorded during the 2011 Tohoku tsunami attack*, Proceedings, Geoscience and Remote Sensing Symposium (IGARSS)*, 2012 IEEE International, pp. 6693–6696: doi: 10.1109/IGARSS.2012.6352063.

LeVeque R.J. (1997). Wave propagation algorithms for multi-dimensional hyperbolic systems, *J. Comput. Phys*., 131: 327–353.

LeVeque R.J. (2002). *Finite Volume Methods for Hyperbolic Problems*, Cambridge University Press, U.K.

LeVeque R.J., George D.L. (2008). High-resolution finite volume methods for the shallow water equations with bathymetry and dry states, in *Advances in Coastal and Ocean Engineering*, P.L. Liu, C. Synolakis, and H. Yeh, eds., World Scientific, 10: 43–73.

LeVeque R.J., George D.L, Berger M. (2011). Tsunami modeling with adaptively refined finite volume methods, *Acta Numerica*, 20: 211–289.

Lynett P., Borrero J., Son S., Wilson R., Miller K. (2014). Assessment of the tsunami-induced current hazard, *Geophys. Res. Lett*., 41: 2048–2055, doi:10.1002/2013GL058680.

Lynett P., Borrero J., Weiss R., Son S., Greer D., Renteria W. (2012). Observations and modeling of tsunami-induced currents in harbors and ports, *Earth Planet Sci. Lett.*, 327–328: 68–74.

Mori N., Takahashi T., Yasuda T., Yanagisawa H. (2011). Survey of 2011 Tohoku earthquake tsunami inundation and run-up, *Geophys. Res. Lett*., 38(7): doi:10.1029/2011GL049210.

Okal E.A, Synolakis C.E. (2004). Source discriminants for near-field tsunamis, *Geophys. J. Int*., 159(3): 899–912.

Synolakis C.E., Bernard E.N., Titov V.V., Kanoglu U., González F.I. (2007). Standards, criteria, and procedures for NOAA evaluation of tsunami numerical models. *NOAA Tech. Memo*. *OAR PMEL-135*, NOAA/Pacific Marine Environmental Laboratory, Seattle, WA, 55 pgs.

The 2011 Tohoku Earthquake Tsunami Joint Survey Group (2011). Field survey of 2011 Tohoku earthquake tsunami by the Nationwide Tsunami Survey, *Japan. Soc. of Civ. Eng*., Tokyo.

Thio H.K., Somerville P., Polet J. (2012). Probabilistic tsunami hazard analysis, *Proceedings, 15th World Conference on Earthquake Engineering*, Lisbon, Portugal.

Titov V.V. (2009). Tsunami forecasting. Chapter 12 in *The Sea*, Vol. 15: Tsunamis, Harvard University Press, Cambridge, MA, and London, England, pp. 371–400.

Titov V.V., González F.I. (1997). Implementation and testing of the Method of Splitting Tsunami (MOST) model. *Technical Report NOAA Tech. Memo*. *ERLPMEL-112 (PB98-122773*), NOAA/Pacific Marine Environmental Laboratory, Seattle, WA.

Titov V.V., Synolakis C.E. (1995). Modeling of breaking and nonbreaking long wave evolution and run-up using VTSC-2, *J. Water. Port Coast Ocean Eng*., 121: 308–316.

Titov V.V., Synolakis C.E. (1998). Numerical modeling of tidal wave run-up. *J. Water. Port Coast Ocean Eng*., 124: 157–171: doi:10.1061/(ASCE)0733-950X(1998)124:4(157).

Wei Y., Chamberlin C., Titov V.V., Tang L., Bernard E.N. (2013). Modeling of the 2011 Japan tsunami: Lessons for near-field forecast, *Pure Appl. Geophys*., 170: 1309–1331.

Yokota Y., Koketsu K., Fujii Y., Satake K., Sakai S., Shinohara M., Kanazawa T. (2011). Joint inversion of strong motion, teleseismic, geodetic, and tsunami datasets for the rupture process of the 2011 Tohoku earthquake*,* *Geophys. Res. Lett.*, 38(7).

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