TSUNAMI HAZARD SIMULATION MAPPING OF NORTHEAST JAPAN USING SRTM DATA

Jose Edgardo L. ABAN

Senior Lecturer, Geography and Development and Environmental Studies and Tourism Programme
Faculty of Arts and Social Sciences, Universiti Brunei Darussalam,

Jalan Tungku Link BE 1410 Gadong, Brunei Darussalam;
Tel: +673 – 2461528 #1420
E-mail: edgardo.aban@ubd.edu.bn

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Abstract: Abstract: The 2011 Tōhoku earthquake, also known as the "Great East Japan Earthquake", (Japanese: Higashi Nihon Daishinsai) was a magnitude 9.0 (Mw) undersea megathrust earthquake off the coast of Japan that occurred at 14:46 JST (05:46 UTC) on Friday, 11 March 2011. Simulations of the inundated and devastated areas of the tsunami were conducted using data from Shuttle Radar Topography Mission (SRTM; 90m-3 arc second resolution). Digital elevation models (DEM) draped with Landsat TM (pre-disaster) images were produced, onto which tsunami/sea-level heights were simulated at scenarios of 1-meter, 3-meters, 5-meters, 7-meters, 10-meters, 12-meters, 15-meters, 17-meters and 20-meters, along coastal towns of northeastern Japan. Validation and accuracy assessment of resulting coastal (simulated) inundations were done and were visually compared with the post-disaster images of the actual tsunami-devastated areas. The simulated inundation scenarios show considerable accuracies. The technique may have promising applications on tsunami/coastal hazard zoning, as well as, forecasting sea-level rise scenarios.

INTRODUCTION

The NASA Shuttle Radar Topographic Mission (SRTM) has provided digital elevation data (DEMs) for over 80% of the globe. The SRTM data is available as 3 arc second (approx. 90m resolution) DEMs. A 1-arc second data product was also produced, but is not available for all countries. The data currently being distributed by NASA/USGS (finished product) contains "no-data" holes where water or heavy shadow prevented the quantification of elevation. These are generally small holes, which nevertheless render the data less useful, especially in fields of hydrological modeling.

This study aims to simply compare the viability of using SRTM 90m data in modeling and delineating highly-prone coastal communities in the eastern coasts of Japan and how the technique compares with the actual post tsunami-devastated areas, based on the satellite images gathered immediately after the disaster.

METHODS

Derivation of Digital Terrain Models

Shuttle Radar Topography Mission (SRTM) datasets were acquired, which covered the prefectures of Northeastern Japan, to wit, Chiba, Fukushima, Miyagi. The SRTM was then draped with the raw false color LANDSAT TM 2010 image of the area. This process was necessary to provide reference pixel information about the built-up areas, human settlements and other infrastructures near or along the coasts.

Tsunami Height Simulation

Tsunami/Sea-level heights were simulated using tools under the ERDAS Virtual World GIS. For this study WGS 84 datum was used to simulate tsunami sea-level height scenarios of 1-meter, 3-meters, 5-meters, 7-meters, 10-meters, 12-meters, 15-meters, 17-meters and 20-meters. Image-to-image accuracy assessment was done between the post-tsunami images (WorldView) derived and processed by the International Charter Space and Major Disasters, with the simulated tsunami wave height images. Several of these tsunami inundation scenario maps are shown in Figures 2 and 3.

Accuracy Assessment

Image accuracy assessment is a general term for comparing the image with geographical data that are assumed to be true, to determine the accuracy and quality of the image modeling or classification process. Usually, the assumed true data are derived from ground truth, and in this case, the post-tsunami WorldView satellite images. One hundred ground control points were identified in both the post-disaster and modeled SRTM images. In doing the accuracy assessment, the actual post-disaster satellite image was used as the reference "master" image, while the SRTM simulated image was used as "slave" image. The post-disaster area used for this particular accuracy assessment was that of Minamisoma, Fukushima area (Figure 1) .

RESULTS AND DISCUSSION

In order to assess the accuracy of the modeling procedure, a *Confusion matrix* was constructed. *Table 1*, shows a typical Confusion Matrix/ Accuracy Assessment Matrix, which compares the ground control points identified in the reference/master (WorldView) image, and the modeled SRTM-derived inundated areas image.

The results of the accuracy assessment of the SRTM-derived inundated areas in Minamisoma district is shown below.

Table 1: *Confusion Matrix/Error Matrix for Accuracy Assessment*

REFERENCE ACTUAL POST- DISASTER IMAGE
(WorldView image taken March 12, 2011)

		INUNDATED	NOT INUNDATED	TOTALS/ PERCENT
SRTM	INUNDATED	63 (63.00%)	7 (7.00%)	70 (70.00%)
	NOT INUNDATED	6 (6.00%)	24 (24.00%)	30 (30%)
	TOTALS/PERCENT	69 (69.00%)	31(31.00%)	100 (100%)

Kappa = (observed agreement-chance agreement)/(1-chance agreement)
Observed agreement = (63 + 24)/ 100 = **0.87**
Chance agreement = (0.69) X (0.70) + (0.31) X (0.30) = **0.483+ 0.093 = 0.576**

Kappa= (0.483 – 0.093)/(1- 0.093) = **0.39/ 0.907 = 0.43**

Overall Map Accuracy = (observed agreement X 100) + kappa statistic = **87 $\pm$ 0.43**

The overall accuracy of the simulated tsunami inundation map is estimated at **87%** with a *kappa statistic* of **0.43**. The accuracy of the SRTM-derived tsunami inundation map is highly acceptable.

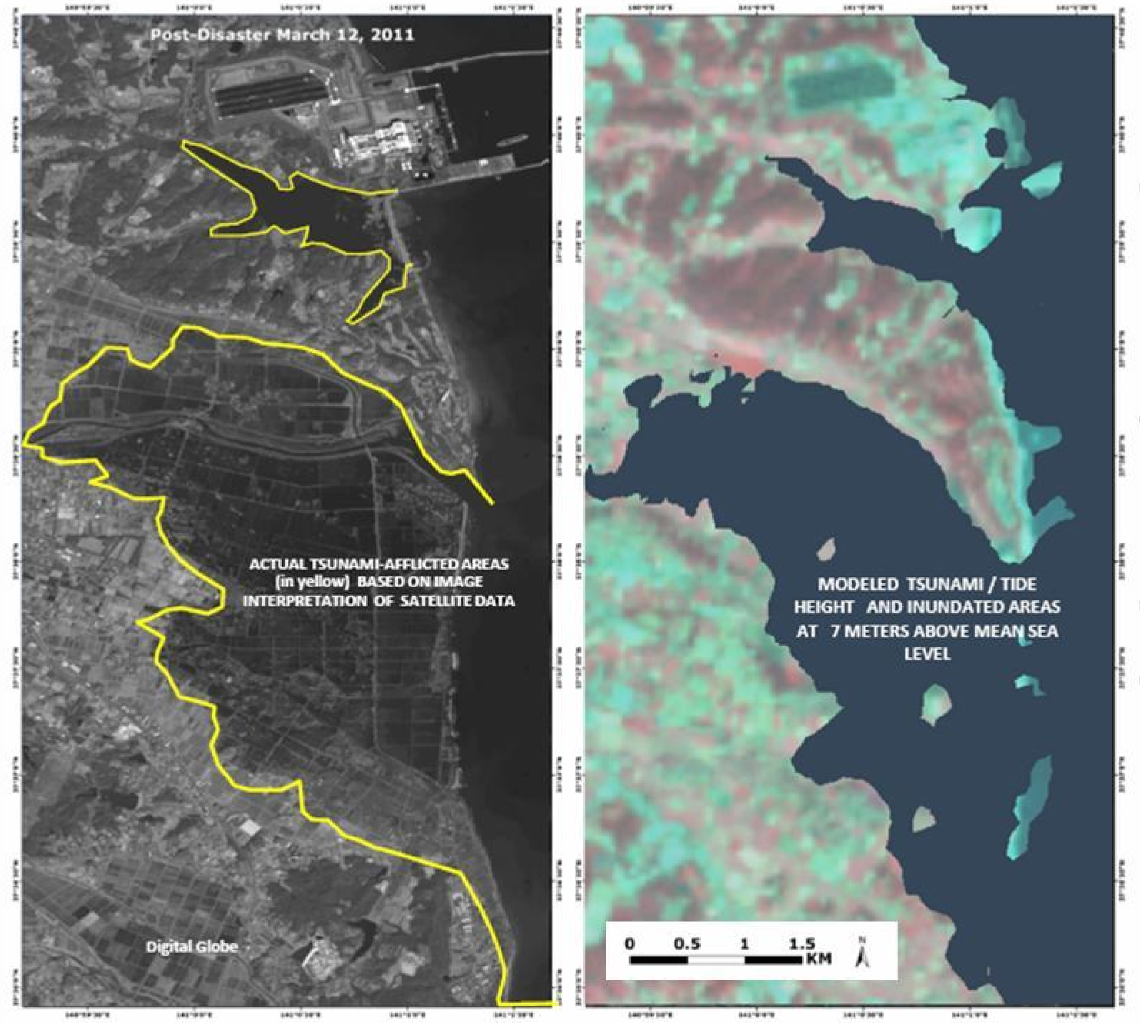

Figure 1: Comparison between tsunami-affected areas over Minamisoma, Fukushima, Japan (left), observed 12 March 2011 Local Projection Geographic Coordinate System; Datum: WGS84. Post-Disaster Image: WorldView by DigitalGlobe; and SRTM-derived inundations at 7 meters above mean sea level (right). Estimated map accuracy for the latter is at 87% ± 0.43.

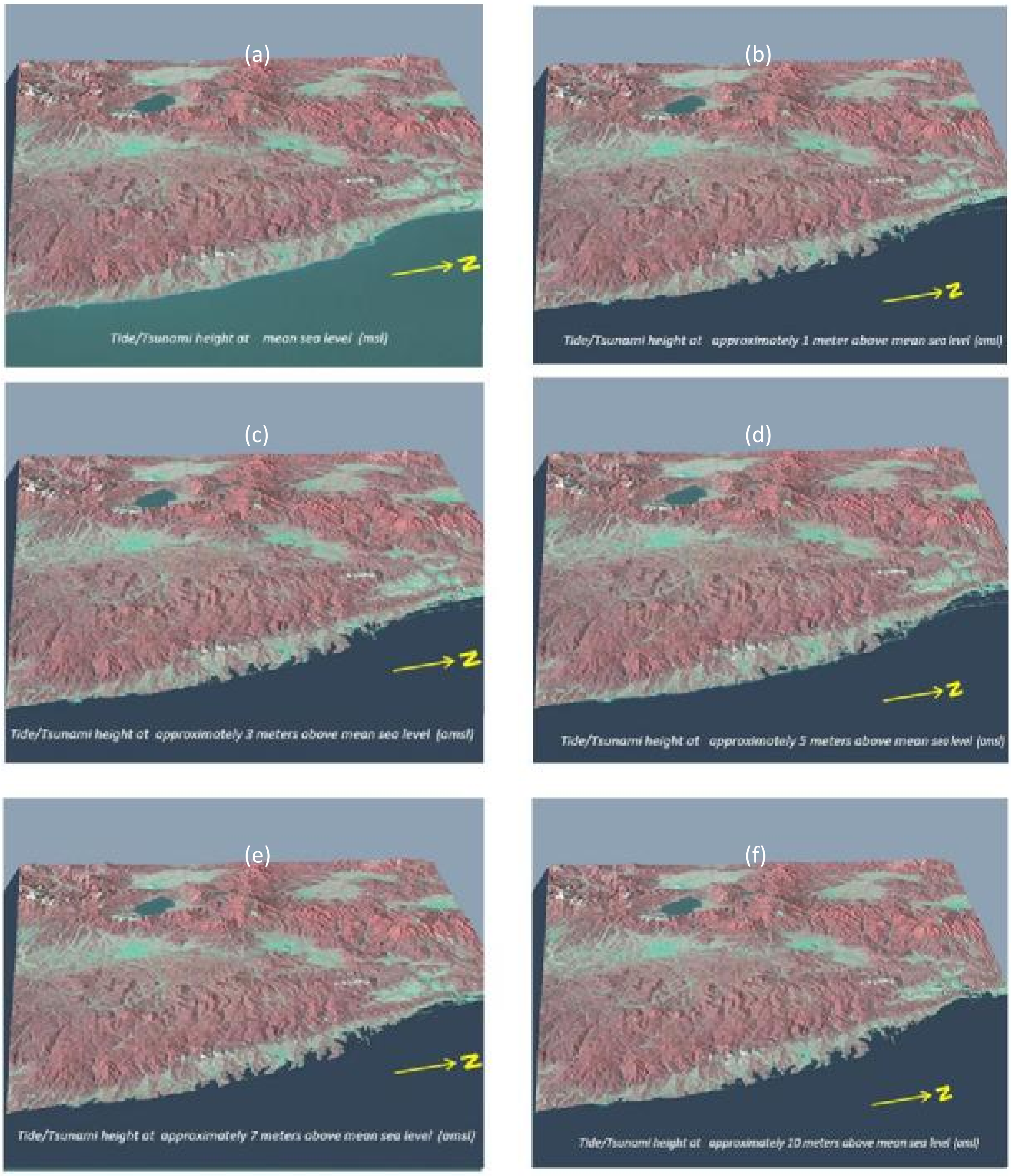

Figure 2: Modeled tsunami heights/inundated areas in the vicinity of coastal Fukushima prefecture: (a) mean sea level; (b) 1 meter above mean sea level (amsl); (c) 3 meters amsl; (d) 5 meters amsl; (e) 7 meters amsl; and (f) 10 meters amsl.

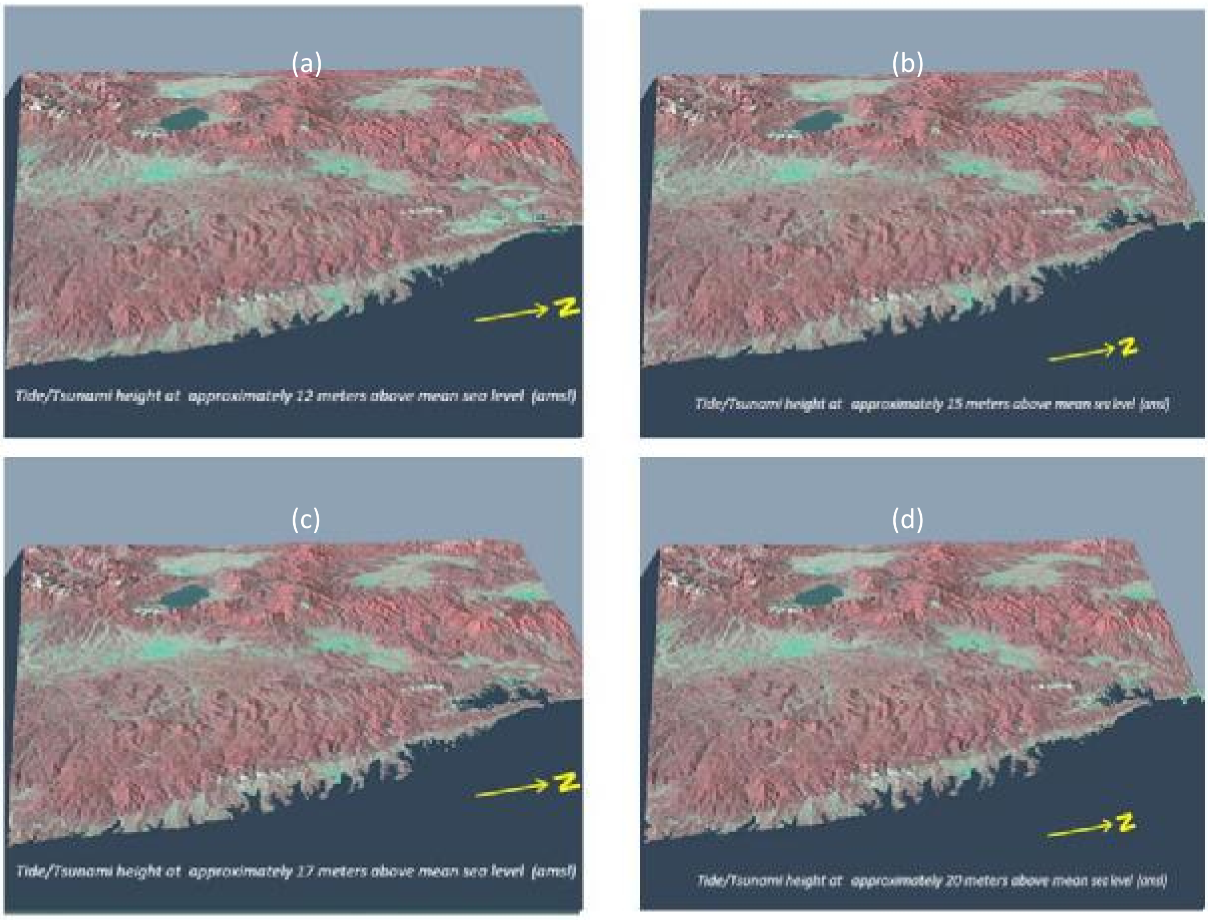

Figure 3: Modeled tsunami heights/inundated areas in the vicinity of coastal Fukushima prefecture: (a) 12 meters amsl; (b) 15 meters above mean sea level (amsl); (c) 17 meters amsl; (d) and 20 meters amsl.

CONCLUSIONS & RECOMMENDATIONS

Assessment of tsunami susceptibility on a local scale, SRTM elevation data can give acceptable results of tsunami vulnerability areas, and could therefore be used to develop vulnerability/hazard maps for coastal communities that are under immediate threat of tsunamis.

The merging of SRTM elevation data with multispectral satellite images like Landsat ETM is suitable for a tsunami susceptibility classification on a local scale. From the previous accuracy assessment exercise, the 7-meter elevation contour fits quite well with the maximum extent of the actual inundation and devastation over Minamisoma district.

The technique may have promising applications on tsunami/coastal hazard zoning, as well as, forecasting sea-level rise scenarios.

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