SEARCHING TSUNAMI AFFECTED AREA BY INTEGRATING NUMERICAL MODELING AND REMOTE SENSING

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ABSTRACT

The present paper reports a preliminary result of searching tsunami-affected area using recent advances of GIS analysis and remote sensing combined with a numerical modeling of tsunami propagation/inundation and world population database. Applying the method of searching tsunami affected area to the 2009 Samoa earthquake tsunami and the 2010 Chilean earthquake tsunami, the potential tsunami affected area have been detected at some coastal cities/communities. The results are utilized to detecting tsunami impacted area for conducting disaster relief activities.

Index Terms— Tsunami model, Remote sensing, GIS, The 2009 Samoa earthquake tsunami, The 2010 Chile earthquake tsunami

1. INTRODUCTION

The 2004 Indian Ocean tsunami, which caused more than 237,000 fatalities, propagated entire Indian Ocean and caused extensive damage to 12 countries. Because of the devastating damage on infrastructure and local/regional/international communication network and the failure of the disaster response activities, the tsunami-affected areas and overall damage could not be addressed for months. As one of the lessons from this event, the importance of developing technologies to search tsunami-affected area has been raised. However, the extensive scale of catastrophic tsunami makes it difficult to search the impacted area in the aftermath of the event.

A project is under way to search tsunami-affected area using recent advances of remote sensing technologies combined with a numerical modeling of tsunami propagation/inundation. In the present study, the authors propose a framework in developing a method to search and detect the impact of tsunami disaster by integrating numerical modeling, remote sensing, and GIS. Part of the method is implemented to recent tsunami events including the 2009 tsunami in American Samoa to search the tsunami-affected area and detect the structural damage, using the numerical modeling and the analysis of high-resolution optical satellite images.

2. METHODS

The structure of our method consists of several damage mapping efforts. The first phase is the regional hazard mapping. Mapping the potential tsunami hazard in regional scale is based on the numerical modeling of tsunami propagation and bathymetry/topography database. The numerical model for regional scale is based on the finite difference method of shallow-water theories in spherical or cartesian co-ordinate systems[1].

In the second phase, to identify the potential tsunami impact along the coast, the authors incorporate PTE (the Potential Tsunami Exposure)[2] as the number of population exposed against the potential tsunami hazard. PTE is obtained by the GIS analysis integrating the numerical model results and the world population database, such as LandScan[3].

In the third phase, after the potential tsunami-affected areas are estimated, the analysis gets focused and moves on to the “ detection ” phase using remote sensing. Recent advances of remote sensing technologies expand capabilities of detecting spatial extent of tsunami affected area and structural damage. To detect the impacted area in regional and local scales, the authors use the capability of SAR (Synthetic Aperture Radar) image analysis[4] and interpretation of high-resolution optical satellite images, such as QuickBird, IKONOS and WorldView.

3. PRELIMINARY RESULTS

3.1. The 2009 tsunami in American Samoa

The method has been implemented and verified in recent tsunami events. Here, an example is shown from the most recent tsunami, which was generated by an earthquake of magnitude 8.0 on 29 September 2009 (UTC) in Samoa. The tsunami caused more than 120 fatalities in Samoa, Am. Samoa and Tonga[5]. Fig.1 is the result of our analysis searching the potential tsunami-affected area of the 2009

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tsunami in American Samoa. The result indicates the possibilities that the tsunami attacked densely populated areas along the central and western coasts of Tutuila island, American Samoa. This estimation suggests that the disaster response should focus on these areas to investigate its impact using emergency satellite observation.

Fortunately in this event, Digital Globe Inc. succeeded to take the image in the central Tutuila island by QuickBird satellite. Fig. 2 is the result of visual interpretation and field inspection of pre and post-tsunami QuickBird images, which were acquired on 24 and 29 September 2009 (UTC) in Tutuila island, American Samoa. Especially, the post-tsunami image was acquired approximately four hours after the earthquake occurred. As estimated in the tsunami numerical modeling with population data, Pago Pago which locates at the central coast of the island was severely affected.

3.2. The 2010 tsunami in Chile

Another implementation is conducted in Chile to search potential impacted area by the 2010 27 February tsunami.

On 27 February, 2010, a great earthquake of magnitude 8.8 is occurred off the Pacific coast of Chile. The tsunami accompanied this earthquake caused extensive damage along the coast of Chile. Fig.3 (a) and (b) indicate the result of tsunami numerical model (longshore tsunami height) and exposed population. Applying the threshold (4 m as tsunami height and 1000 as population in the coastal region), we search the potential tsunami impacted area as shown in Fig.3 (c). As a result, 14 coastal communities are detected that were potentially impacted by the tsunami.

4. SUMMARY AND FUTURE PERSPECTIVE

Integrating the numerical model of tsunami, GIS analysis combined with population data, and the remote sensing technologies with use of modern computing power increases possibility searching and detecting the impact of tsunami disaster. We are now developing the capability to search and detect the tsunami-affected area within 24 hours after a tsunami event occurs so that emergency response and disaster management efforts make use of it. The present research is still underway in developing automatic damage detection algorithms, real-time tsunami inundation modeling to estimate the structural damage in a quantitative manner[6], developing house and structure inventory database, and preparation of high-resolution merged bathymetry and topography data.

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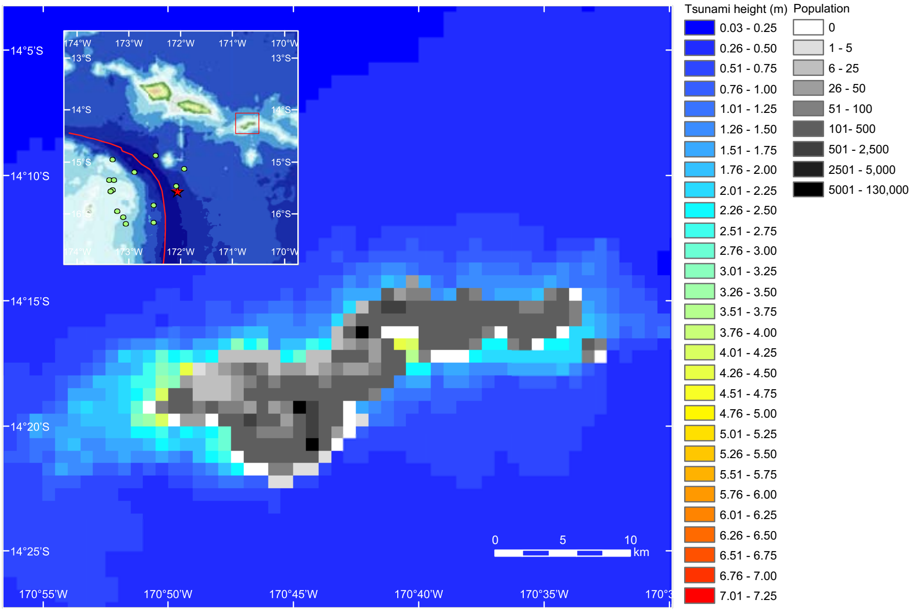

Fig. 1. The estimated tsunami height of the 2009 tsunami in American Samoa and distribution of exposed population.

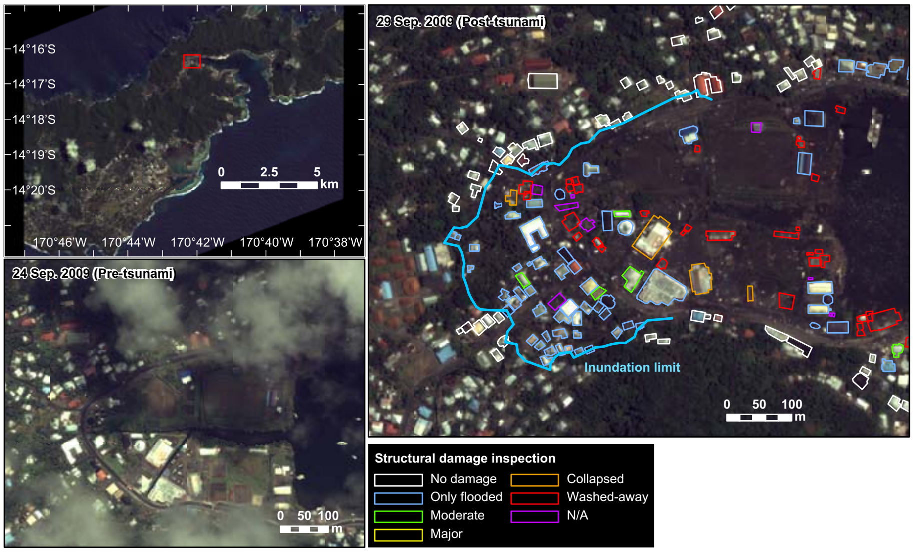

Fig. 2. Interpretation of structural damage in Pago Pago, Tutuila island, American Samoa, combined with the field inspection.

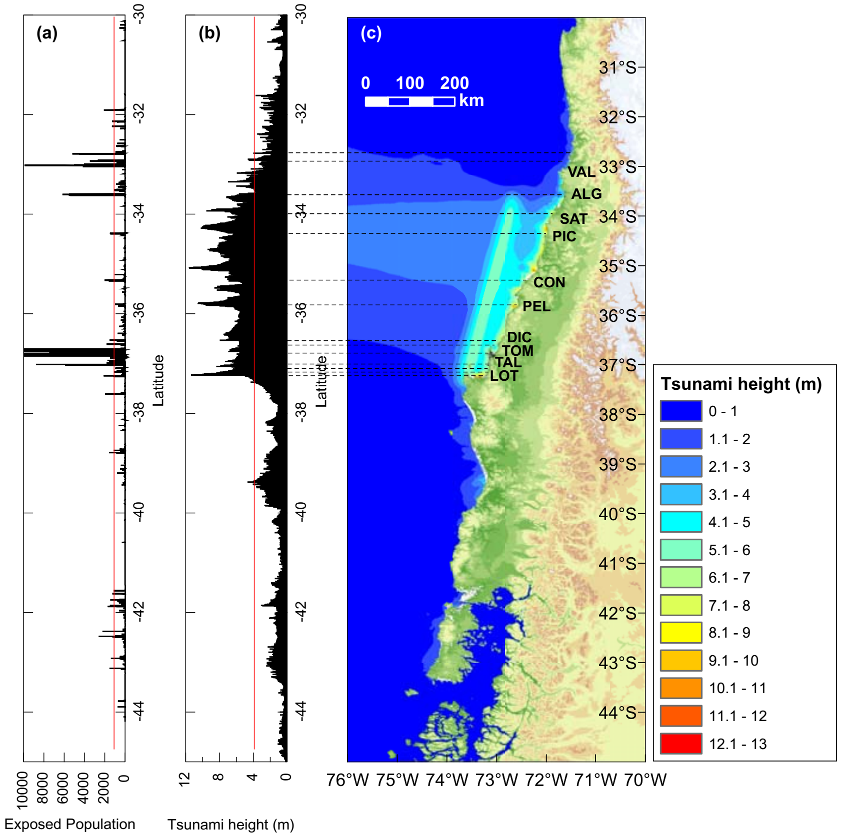

Fig. 3. The estimated tsunami height of the 2010 tsunami in Chile, distribution of exposed population, and the potential impacted area searched by the threshold of 4 m as tsunami height and 1000 .Abbreviations as follows ; **VAL**:Valparaiso, **ALG**: Algarrobo, **SAT**: San Antonio, **PIC**: Pichilemu, **CON**:Constitucion, **PEL**:Pelluhue, **DIC**:Dichato, **TOM**:Tome, **TAL**:Talcahuano, **LOT**:Lota)

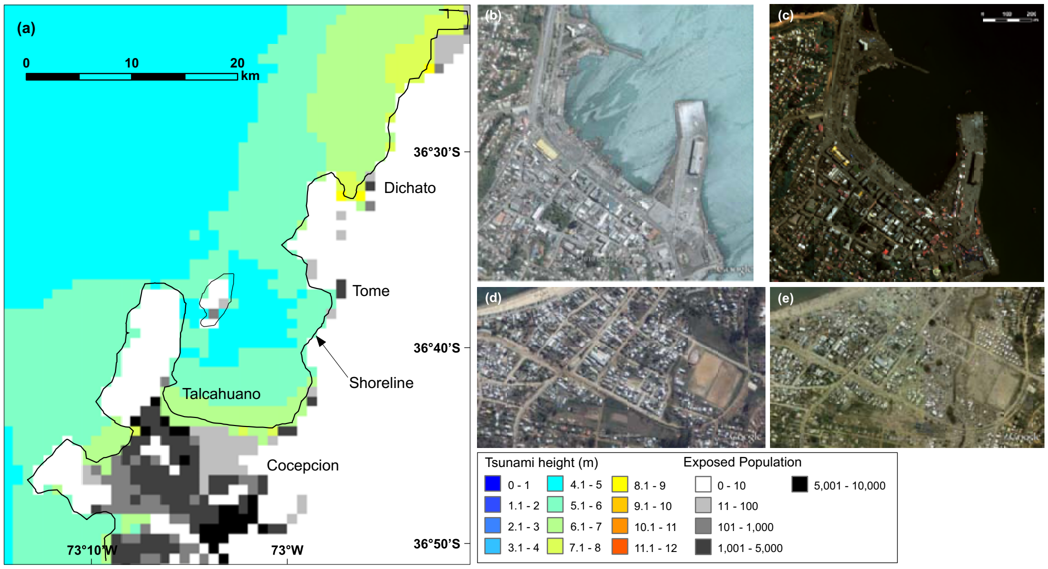

Fig. 4. (a) Tsunami inundation model results and exposed population in BioBio, Chile, (b and c) Pre and post tsunami satellite images in Talcahuano (13 January 2006 (GoogleEarth) and 6 March 2010 (WorldView)), (d and e) in Dichato (26 April 2006 and 5 March 2010, both from GoogleEarth).