NEAR-FIELD TSUNAMI FORECASTING BASED ON A TSUNAMI RUN-UP RESPONSE FUNCTION

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INTRODUCTION

Since near-field-generated tsunamis can arrive within a few minutes to coastal communities and cause immense damage to life and property, tsunami forecasting systems should provide not only accurate but also rapid tsunami run-up estimates. For this reason, most of the tsunami forecasting systems rely on pre-computed databases, which can forecast tsunamis rapidly by selecting the most closely matched scenario from the databases. However, earthquakes not included in the database can occur, and the resulting error in the tsunami forecast may be large for these earthquakes. In this study, we present a new method that can forecast near-field tsunami run-up estimates for any combination of earthquake fault parameters on a real topography in near real-time, hereafter called the Tsunami Run-up Response Function (TRRF).

TSUNAMI RUN-UP RESPONSE FUNCTION (TRRF)

The basic concept of the TRRF is that the tsunami run-up distribution $R(x)$ can be decomposed into a source run-up $S(x)$--modeled by fault parameters using the Okal and Synolakis (2004) empirical formula--and a normalized topographic run-up $NT(x)$ that is dictated by the local topography. A response surface methodology is used to model the source run-up, where the response surface is developed from a discrete set of numerical simulations. This approach was first introduced in Lee et al. (2018) who showcased the TRRF performance for northern Puerto Rico (mean of normalized root-mean square error for 100 random cases: 7%). The limitation of Lee et al. (2018) was that the rake angle must be fixed to 90 degrees– not the only case that occurs in nature. Lee et al. (2020) expanded this methodology to consider different rake angles by introducing a method to isolate and characterize the influence of the strike angle and the rake angle from other fault parameters. Once the TRRF is developed, the $S(x)$ and the $NT(x)$ can be predicted for any combination of fault parameters. Finally, the $R(x)$ can be predicted by Eq. 1.

$$R(x) = S(x)[1 + NT(x)] \qquad (1)$$

Herein, we will investigate the forecasting performance of TRRF for northern Chile.

CASE STUDY

The TRRF was built based on a 3-level full factorial design (729 simulations) using the Boussinesq model Basilisk (Popinet, 2015) with high resolution bathymetry data (15-arcsecond). To validate the TRRF, we conducted a case study based on the 2014 Iquique, Chile tsunami (Mw 8.2). We compared the TRRF prediction with the Basilisk prediction (not used to develop TRRF) and the measured data (Fig. 1). We assumed a uniform slip distribution, and the results show that the TRRF can predict the tsunami run-up distribution as accurately as the numerical simulation (normalized root-mean square error: 7.4%). Note that the computational time of TRRF is less than a second while the Basilisk simulation took about 5 hours. Additionally, note that the TRRF solution is always stable since it solves a simple algebraic equation while the numerical simulation can have a stability issue-- a critical concern in forecasting.

CONCLUSIONS

A new methodology, called the TRRF, is introduced and the case study shows that the TRRF can accurately predict a run-up distribution in near real-time without any stability problem. We believe that this methodology has the potential to significantly reduce loss of life in coastal communities by supporting rapid and accurate tsunami forecasting.

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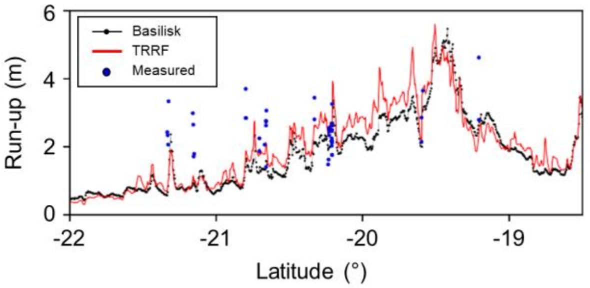

Figure 1 - Comparison of tsunami run-up distribution predicted by numerical model Basilisk (black) and TRRF (red). Blue dots are measured data from Catalán et al. (2015).

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