UNCERTAINTY OF BATHYMETRY MODELS AND EFFECTS ON TSUNAMI MODELS

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INTRODUCTION

We describe the uncertainties of altimetry-predicted bathymetry models and then quantify the impact of this uncertainty in tsunami hazard assessments. The study consists of three stages. First, we study the errors of altimetry-predicted bathymetry estimates, which cover ~80% of the earth oceans in massively used models, such as GEBCO and SRTM+. By employing bathymetry surveys, we estimate statistics of the satellite-based bathymetry errors. Second, we employ these statistics to propose a model for the uncertainty anywhere, using a random field conditional to ship measurements, which are assumed to be certain. We also propose a methodology to generate bathymetry error samples. Third, we use the bathymetry samples to conduct a Monte Carlo simulation to quantify the tsunami response uncertainty.

MODELING BATHYMETRY ERRORS

We collected 15 existing bathymetry surveys with sizes as great as 75x75 km^2 with high resolution and accuracy to compare them with satellite-based bathymetry estimates. We noted that one of the main errors of satellite-based models are related with the absence of high-wavenumber content (e.g. Fig. 1b is a blurry version of Fig.1a), consistent with Smith & Sandwell (1994). We describe the errors statistically. As identified previously (e.g. Goff et al.,1989), we show that errors and bathymetry high-wavenumber content exhibit a fractal behavior. We found the associated power spectral density (i.e. Fourier transform of autocorrelation) can be approximately modeled as a universal Von Karman function (Fig. 1c). The histograms also exhibit a general function closer to a Laplacian (Fig.1d). The standard deviation of the error, though, varies regionally. Thus, we propose a scaling law which estimates the error standard deviation based on the satellite-based model.

BATHYMETRY SAMPLES

We model the bathymetry error and uncertainty as a random field, which is conditional to accurate surveys (i.e. ship surveys). We consider a sampling method which combines a Karhunen-Loeve expansion and a translation model (see standard deviation in Fig.1e). We note the random field is associated with a large number of significant random dimensions (i.e. >4000).

UNCERTAINTY IN TSUNAMI HAZARD ASSESSMENT

We use a Monte Carlo simulation for the uncertainty propagation. We propagate uncertainty for a tsunami assessment in Chile using three nested bathymetry grids, the tsunami model COMCOT and the 2014 Chile tsunami. Using several control points, we show that ~1000 samples are required to get accurate estimations of the tsunami response uncertainty for this case.

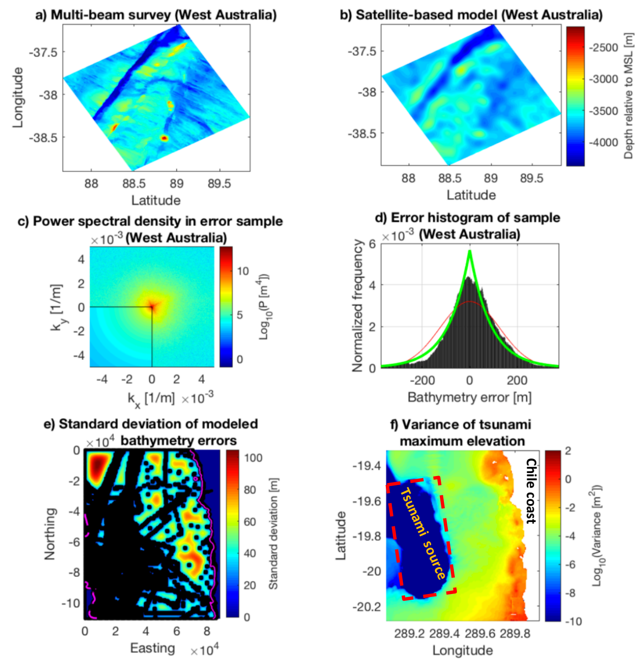

Figure 1: Example of Bathymetry survey (a) and altimetry model (b). (c) Power spectral density of the satellite-based model error and modeled spectrum on left-bottom corner. (d) Histogram of errors (bars), Gaussian distribution (red) and Laplacian distribution (green). (e) Modeled standard deviation of bathymetry uncertainty in North Chile. Black dots are ship surveys. (f) Modeled variance of the maximum tsunami elevation in logarithmic scale.

RESULTS

Bathymetry errors and uncertainty can be estimated anywhere using the proposed functions and scaling law. Local deviations of the bathymetry errors from our model are small but still significant and must be studied further. Fig. 1f show that bathymetry uncertainties have a greater effect in shallow areas. We also noted that tsunami leading waves are less affected by uncertainties.

REFERENCES

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