GREENSURGE: AN EFFICIENT ADDITIVE MODEL TO ASSESS STORM SURGE INDUCED BY TROPICAL CYCLONES

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INTRODUCTION

Storm surge is one of the main components of coastal flooding induced by tropical cyclones (TCs), a big concern for Pacific Island Countries (PICs). It is well-known that storm surge levels can be accurately estimated using numerical models capable of considering both the inverse barometer effect and wind set-up. Therefore, dynamic simulations of a shallow water (SW) numerical model can be forced with the corresponding dynamic pressure and wind fields to accurately assess the storm surge induced by any TC at any spatial scale. However, this kind of dynamic simulations are a very computationally expensive task to be implemented in an operational inundation forecasting system, particularly for Small Island Developing States (SIDS) where computational resources are often limited. For this reason, in order to rapidly assess storm surge levels under the threat of occurrence of any TC, an additive model based on a library of pre-run cases has been developed.

METHODOLOGY

The additive model, suitable both for the regional (10-100 km) and the local (100-200 m) scale where a linear dynamics framework can be assumed, assesses the inverse barometer effect and the wind setup independently. Thus, the inverse barometer effect is directly calculated by turning pressure differences into sea level rises and falls, while the wind setup is estimated using GreenSurge, a newly developed methodology based on the linear summation of Green's functions (Xu 2007). This methodology consists of two main stages (Figure 1). The first stage deals with the compilation of the Green's functions database for the study area, which applied to the wind setup component, corresponds to the database of sea level response to unitary wind-sources from any direction over pre-defined regions (hereafter, cells); the second stage deals with the scaling and ensembled of the corresponding "pieces" of the previous database to reconstruct any given TC event and finally obtain an approximation of the induced storm surge conditions due to wind setup.

The first stage corresponding to the compilation of the empirical Green's Functions Database (GFD) includes:

i. Definition of the cells for the application of the unitary winds covering all possible directions,
ii. Definition of the unit wind magnitude and the direction discretization of wind sources, as well as the drag coefficient function (function of wind magnitude).
iii. Time definition of each independent simulation corresponding to each Green's function both for the length of the sustained unit wind and for the numerical simulation time after the wind forcing ends.
iv. Computation of the GFD with a SW numerical model.

The second stage for any TC event study includes:

i. Division of TC-induced wind fields taking into account the spatial and temporal resolutions defined in stage1.
ii. Search for analogues of the above wind forcing partition for each cell and time step in the corresponding GFD pre-computed in stage1.
iii. Re-scaling of the corresponding wind setup according to the real wind magnitude taking into account the quadratic expression of the wind shear stress used at the free surface boundary condition for the momentum equations.
iv. Ensemble of the re-scaled wind setup corresponding to the Green's Functions selected by directional analogy for each time step.

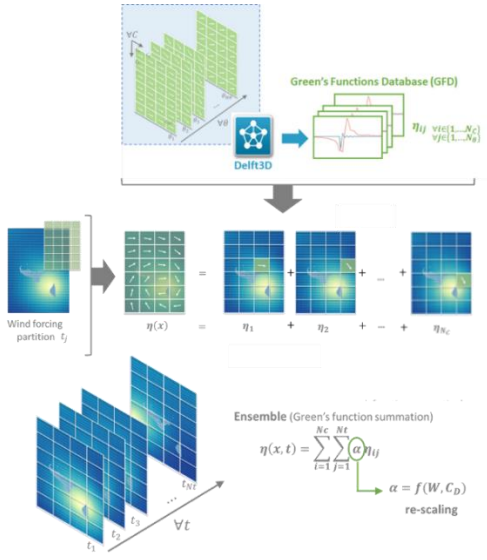

Figure 1 - Conceptual methodology of GreenSurge

RESULTS

The additive model proposed allows to generate accurate estimates of TC-induced storm surge for any event in a matter of seconds at a very low computational effort. This efficient model can be integrated not only within warning systems and short-term inundation forecast systems, but also to assess risk and future climate change scenarios in a probabilistic way. The demonstration and validation of the model has been set up in the Pacific Islands of Samoa and Tonga.

REFERENCES

Xu Zhigang (2007): The all-source Green's function and its applications to tsunami.. Sci Tsunami Haz 26(1):59-69

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