IMPROVED COASTAL FLOOD RISK ESTIMATES THROUGH INTEGRATED JPM AND COUPLED PHYSICS APPROACH

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INTRODUCTION

Large scale flood risk computation has enjoyed a metamorphosis since Hurricane Katrina. Improved characterization of risk is the result of improved computational capabilities due to super computer capacity combined with coupled regional hydrodynamic models, improved local hydrodynamic models, improved joint probability models, inclusion of the most important uncertainties, metamodels and increased computational capacity for stochastic simulation. Improvements in our understanding of, and the ability to model, the coupled hydrodynamics of surge and waves has been well documented as has been improvements in the joint probability method with optimal sampling (JPM-OS) for synthesizing synthetic tropical cyclones (TC) that correctly span the practical hazard probability space. However, maintaining the coupled physics and multivariate probability integrity through the entire flood risk computation while incorporating epistemic uncertainty has had relatively little attention. This paper addresses this latter topic within the context of the Sabine Pass to Galveston Bay, TX Pre-Construction, Engineering and Design (PED): Hurricane Coastal Storm Surge and Wave Hazard Assessment (S2G). In this study, flood hazards are being assessed for over 100 km of levee/floodwall/gate coastal storm risk management systems.

APPROACH

The S2G approach consisted of the following tasks: 1. Gather TC data from HURDAT II database (1938-2017); 2. Construct JPM of TC parameters $\hat{x} = (x_o$=reference location, ΔP=central pressure deficit, R_{max}=radius of maximum winds, V_f=forward speed, θ=heading direction); 3. Optimally sample JPM to construct 660 TCs that map practical probability space and construct synthetic storm suite; 4. Validate numerical models, quantify uncertainties; 5. Construct wind and pressure fields using PBL model; 6. Model offshore waves with WAM and surge and nearshore/inland waves with CSTORM (coupled ADCIRC and STWAVE) for 660 TCs; 7. Create efficient subsample of 660 TC that best matches the hazard and update storm relative probabilities (sample consisted of 189 storms).; 8. Model surge and nearshore/inland waves with CSTORM for with- and without-project and three relative sea level scenarios for 189 synthetic TCs; 9. Sample storms stochastically, extract peak SWL, H_{m0}, T_p, mean wave direction and incorporate uncertainty, integrate JPM to compute hazard curves for SWL, H_{m0}, and response (e.g. $R_{2\%}$ wave runup and q overtopping rate). Compute confidence limits. For USACE projects, q is computed at 50% and 90% upper confidence limits and compared to overtopping limit states corresponding to start of damage and incipient failure. The flood risk assessment methodology employed methods to maintain the nonlinear physics between flood water levels, waves and currents and the complex multivariate statistics including both aleatory and epistemic uncertainties.

SOME RESULTS

Figure 1 shows the matching hazard curves of the original 600 storms and genetic algorithm optimized reduced set of 189 TCs at a single point near the levee toe. Figure 2 shows overtopping rate hazard curves for event-based (traditional AEP-based) and response-based (storm stochastic simulation) approaches.

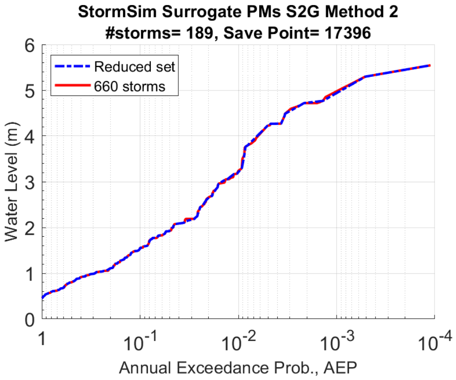

Figure 1. Full set and metamodel hazard curves for SWL

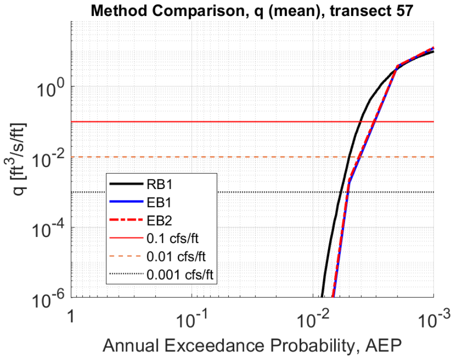

Figure 2. q hazard curve for example levee transect. RB=response-based and EB=event-based.