Supporting Information

Heightened hurricane surge risk in northwest Florida revealed from climatological-hydrodynamic modeling and paleorecord reconstruction

Ning Lin[1*], Philip Lane[2,3], Kerry A. Emanuel[4], Richard M. Sullivan[2], Jeffrey P. Donnelly[2]

[1]Department of Civil and Environmental Engineering, Princeton University, Princeton, New Jersey, USA
[2]Department of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA
[3]Deceased 11 July 2012
[4]Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA
*Corresponding author: N. Lin, Department of Civil and Environmental Engineering, Princeton University, E328 Engineering Quad, Princeton, New Jersey, 08544, USA (nlin@princeton.edu).

To account for the uncertainty in storm size in the surge estimation, we developed an empirical relationship between the storm radius of maximum wind (Rm) and the outer radius (Ro; see equation (1) in the main article). Fig. S1a shows that the modeled Rm distribution (with a mean of 59.7 km) compares well with the historical statistics in *Demuth et al.*, [2006], which are based on a combination of satellite imagery, aircraft, ship and surface reports of North Atlantic storms occurring between 1988 and 2006. The *Kossin et al.*, [2007] data, which are satellite-based Rm estimates of North Atlantic storms from 1983-2005, have a distribution that exhibits much less variability than either the *Demuth et al.*, [2006] or the modeled distribution. The modeled Rm for the synthetic storms also exhibits a lognormal distribution, with values ranging from 10 to 250 km (Fig. S1b). The observational datasets suggest that more intense storms have, on average, smaller Rm (Fig. S1c). The synthetic dataset shows similar features (Fig. S1d).

To examine the uncertainty associated with the storm size estimation in estimating the surge for individual storms, we carried out 10 Monte Carlo simulations for each of 40 Best-Track extreme storms. In each simulation, Ro is randomly drawn from a lognormal distribution with mean of 400 km, based on the statistics for the Atlantic basin [*Chavas and Emanuel*, 2010]. Once determined, Ro is kept as a constant over the storm lifetime, while Rm is calculated from the developed Ro–Rm relationship for every time step. Fig. S2 shows the ADCIRC-model simulated surge height as a function of Ro for Hurricanes Elena and Kate of 1985. The estimated surge height at Bald Point is about 2.5 m (close to the observation of 2.8 m by Bodge and Kriebel, 1985) when Ro is 400 km and corresponding Rm is about 35 km near landfall (close to the estimation of *Corbosiero et al.*, [2005] for the Rm). The estimate surge height at Bald Point is about 2.6 m (as observed by *Clark*, [1986]) when Ro is about 415 km and corresponding Rm is about 32 km near landfall. For both of these storms, and for most other storms, the surge height increases with Ro monotonically (to some limit when Ro becomes extremely large) and almost linearly, but the increasing rate varies for different locations in the region.

To achieve the efficiency and accuracy of the surge simulations for large storm sets, we applied the SLOSH model with various model configurations to select extreme events for further analysis with the ADCIRC model. Fig. S3 compares the synthetic surges at Bald Point estimated from the SLOSH and ADCIRC simulations. In most cases, a useP (useV) SLOSH-simulated surge is lower (higher) than the ADCIRC estimation, as the SLOSH empirical relationship between the maximum wind and pressure deficit underestimates the maximum wind when pressure data are used and overestimates the pressure deficit when the maximum wind data are used (compared to the estimations by the deterministic hurricane model; figure not shown). This bias becomes larger as the storm size increases (Fig. S3). Therefore, the SLOSH wind-pressure relationship may fail to generate a realistic wind field for large storms [*Jelesnianski et al*., 1992]. However, in this case, it is likely we captured all the large surge events in the synthetic dataset by using both storm intensity parameters to cover the opposite trends. In addition, the EGLL-basin simulations have larger variations relative to the ADCIRC simulations than the APC simulations. Using these two very different basins also ensures the selection of all large surge events. Therefore, we regard the SLOSH simulation with the four configurations as a sufficient event-selection filter.

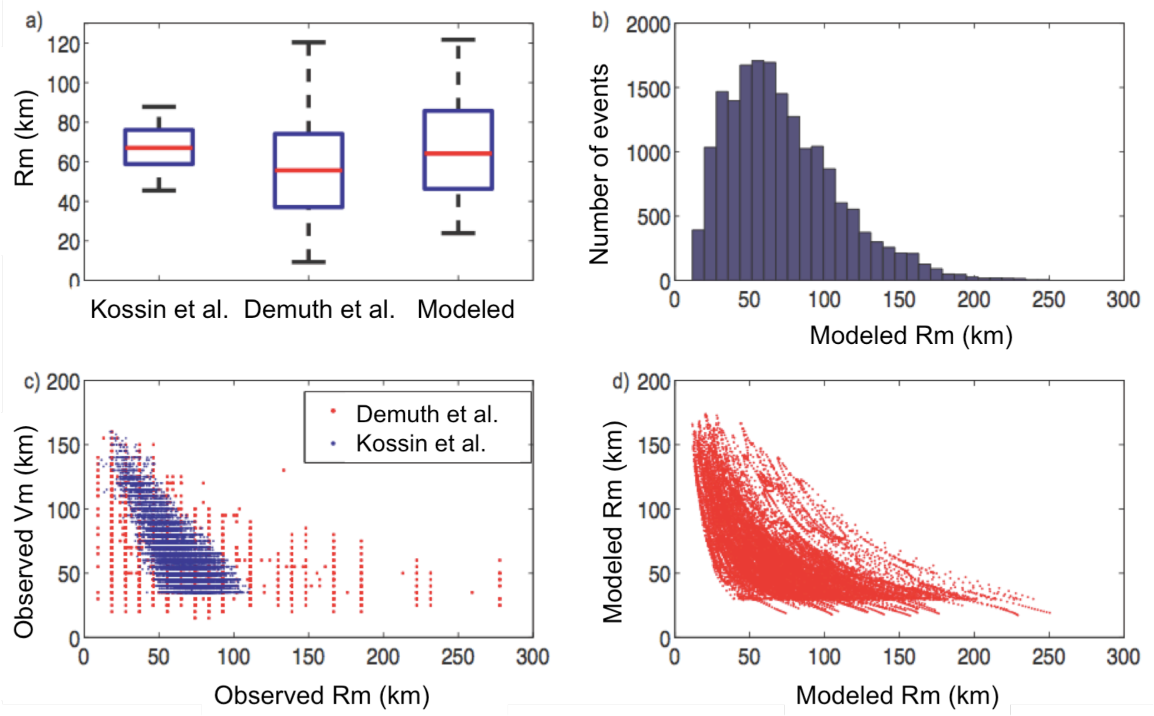

Figure S1. Statistics and modeling of storm radius of maximum wind (Rm): (a) boxplots of observed [*Demuth et al*., 2006; *Kossin et al*., 2007] and modeled distributions of North Atlantic historical hurricanes; (b) Rm distribution for the modeled synthetic storms; (c) observed maximum wind speed (Vm) vs. Rm for North Atlantic historical hurricanes; and (d) same as (c) but for the modeled synthetic storms.

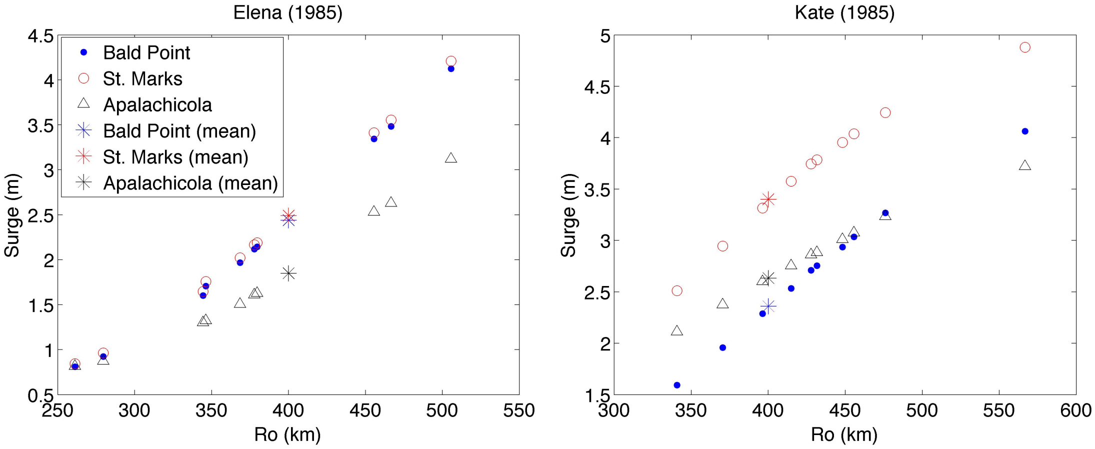

Figure S2. Simulated surge height at Bald Point, St. Marks, and Apalachicola, for Hurricanes Elena (left) and Kate (right) as a function of the storm outer radius.

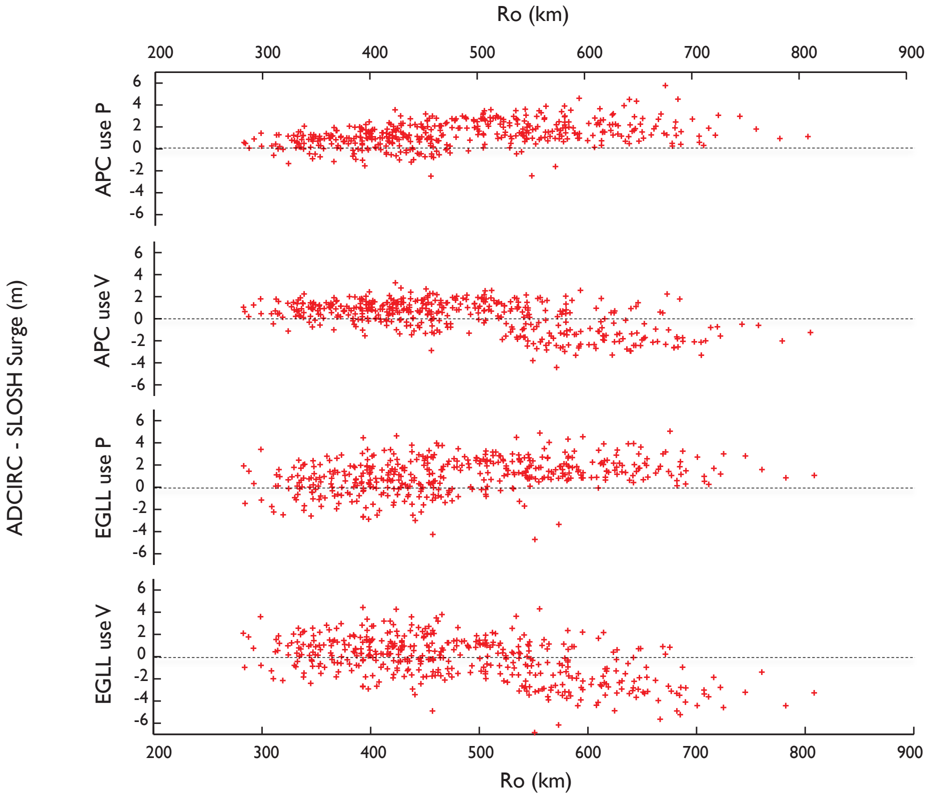

Figure S3. Difference between the ADCIRC-model and SLOSH-model simulated surges at Bald Point for the 451 extreme events, as functions of the storm outer radius. The SLOSH simulation uses four model configurations: using the APC basin with ΔP as the storm intensity input (APC useP), using the APC basin with the Vm as the input (APC useV); using the EGLL basin with ΔP as the input (EGLL useP), and using the EGLL basin with Vm as the input (EGLL useV).

Supplemental Reference

Corbosiero, K. L., Molinari, J., & Black, M. L. (2005). The structure and evolution of Hurricane Elena (1985). Part I: Symmetric intensification. *Monthly weather review*, *133*(10), 2905-2921.