Estimating Extreme Coastal Flooding Conditions for the Maine Coast

Nathan Dill, PE
What is the Hazard?

Rising water at a range of time scales

**Hours**  
**Storm Surge:**  
A increase sea level, above the normal tide, caused by wind stress and changes in barometric pressure during a storm event. AKA “Wind Setup”.

**Seconds**  
**Storm Waves:**  
Highly energetic fluctuations in the water surface caused by local winds (seas) and/or generated from distant winds (swell).

**Decades**  
**Relative Sea Level Rise:**  
Gradual increase in the mean water level due to increased volume of ocean water, subsidence, changing large scale ocean currents.
"The flood in Bangor was due to a combination of strong, prolonged, south-southeasterly winds and high astronomical tides. Storm rainfall, ice jams, and streamflow were not major factors causing the flood."

"Water surface elevation in downtown Bangor reached 17.46 feet (5.32 m) (NGVD), approximately 10.5 feet (3.2 m) above predicted astronomical tide."

“Waves caused by high winds can be more of a factor in flooding and damage than the combination of surge and tide. Flooding from wave action can take many forms. The storm surge may not reach the height of a seawall, but waves may overtop it. Water passing over (overwash) a barrier can damage structures behind it.”

Sea Level Rise

A gradual increase in the mean water level due to increased volume of ocean water, subsidence, changing large scale ocean currents, etc.

The magnitude of sea level change over the past century has been very small compared to sea level change experienced on a twice daily basis in Maine.
Sea Level Rise

Sea Level rise impacts will almost certainly manifest through discrete extreme events, rather than a gradual “flat” increase in the mean high water.

Although interesting, tools such as this have limited utility since they cannot take into account the highly dynamic nature of actual coastal flooding.

The flooding they portrait is an unlikely future reality.
Storm Surge – Gauge Data Analysis

For FEMA FIS purposes

Gives the Still Water Elevation (SWEL)

5 stations in Maine

Strategic Alliance for Risk Reduction. (2012). *Updated Tidal Profiles for the New England Coastline*
Storm Surge – Gauge Data Analysis

L-Moment Analysis
Annual Maximum Series
Wakeby Distribution

Strategic Alliance for Risk Reduction. (2012). *Updated Tidal Profiles for the New England Coastline*
Storm Surge – Gauge Data Analysis

Gives the Still Water Elevation (SWEL) for FIS purposes

Strategic Alliance for Risk Reduction. (2012). *Updated Tidal Profiles for the New England Coastline*
Storm Surge – Single Event Numerical Modeling

FEMA used the RMA2 model to simulate a single “100-year” storm, recognizing that the gage analysis does not necessarily give accurate results for the complex Maine coastline.
Storm Surge – Single Event Numerical Modeling

Results give a spatially variable estimate for the still water level associated with a 100-year storm.

- No waves
- No direct wind forcing
- Only a single high tide adjusted peak at the 100-year SWEL at the model boundary

Strategic Alliance for Risk Reduction. (undated). Coastal Hydraulics and Hydrology.
Storm Surge – Probabilistic Modeling
SLOSH

- Dynamic modeling of Storm Surge including important meteorological forcing (Wind and Atmospheric Pressure)
- Hurricane Inundation maps by Saffir-Simpson Category
- Used for Evacuation Planning
- MEOWs and MOMS
- National Hurricane Center Forecasts

- Saffir-Simpson Category does not easily translate to any risk level
- Does not include Extratropical storms
- Does not include Wave processes
Storm Surge – ADvanced CIRCulation Modeling
ADCIRC + STWAVE/SWAN

• State of the practice for storm surge modeling
• Includes all pertinent physical processes (including wave setup)
• High spatial resolution
• Requires high performance computing

• Applied by FEMA for Flood insurance studies in all East Coast and Gulf Coast Regions except Region I (New England)

• Determine the 100-year storm surge and associated wave conditions rather than the surge and waves from a single example of a 100-year storm.
Storm Surge – Probabilistic Modeling
Joint Probability Methods (JPM)

- Simulate hundreds to thousands of storms that **could** occur as well as many that have.
- Based on Joint probability of storm size, intensity, speed, approach angle, landfall location.

  e.g. North Atlantic Coast Comprehensive Study (NACCS).

Simulate Sea Level Rise cases to assess one aspect of climate change

---

Storm Surge – Probabilistic Modeling
Statistical-Deterministic approach

- Simulate a large set of hypothetical tropical storms that could occur and simulate hundreds to thousands of them.
- Storm set based on statistical-deterministic model of storm generation and evolution.

- WindRiskTech model allows for generation of storm sets based on future climate scenarios by downscaling from global climate models
- Simulate Sea Level Rise cases.
- For example, applied in the recent Boston Harbor Flood Risk Model (BH-FRM) effort

Figure 4-19. Example of the tropical storm track lines associated with one of the global climate model storm sets from WindRiskTech, Inc.
Storm Surge – Storm Set Optimal Sampling Methods

• Reduce computational requirements by selecting an “optimal” sample of storms for high fidelity modeling.

Response Surface Method

Bayesian Quadrature Method


Storm Surge – Incorporating Uncertainty
The Epsilon Term

If uncertainty can be quantified in terms of its probability, (i.e. you need to estimate a probability distribution for the uncertainty), it can be accounted for mathematically when determining recurrence intervals associated with the coastal flood hazard. For example:

Storm Surge – Incorporating Uncertainty
The Epsilon Term

If uncertainty can be quantified in terms of its probability, (i.e. you need to estimate a probability distribution for the uncertainty), it can be accounted for mathematically when determining recurrence intervals associated with the coastal flood hazard. For example:

Storm Surge – Advanced Analysis for Maine
Based on NACCS study

NACCS grid In New York City
Storm Surge – Advanced Analysis for Maine
Based on NACCS study

NACCS grid In Portland
Storm Surge – Advanced Analysis for Maine
Based on NACCS study

• Best Use of NACCS Data for Maine will use nested modeling for storm surge and waves to downscale NACCS results to the local scale
• E.g. a model for Scarborough Marsh