FEMA

FEMA's Coastal Flood Hazard Analyses in the Atlantic Ocean and Gulf of Mexico

Probabilistic Flood Hazard Assessment – Panel 7

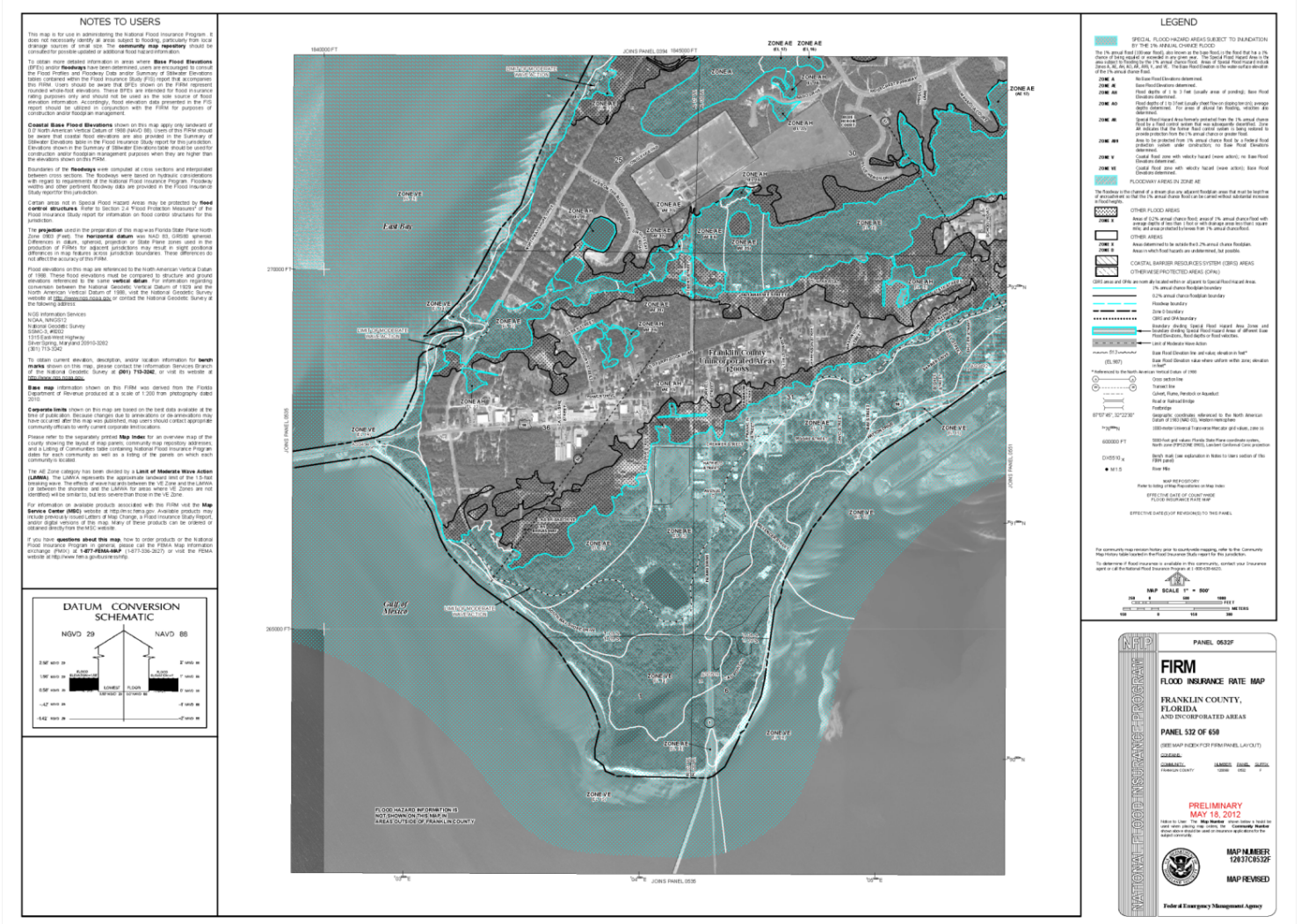
January 31, 2013

RiskMAP
Increasing Resilience Together

Agenda

- Introduction to FEMA's Mission & Coastal Flood Hazard Mapping
- JPM-OS for Storm Surge Modeling in the Atlantic Ocean & Gulf of Mexico
- Areas for Collaboration & Improvement

FEMA & Flood Hazard Mapping



NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Florida State Plane North Zone (FIPS 0903 (Feet). The **horizontal datum** was NAD 83, GRS80 spheroid. Differences in datum, spheroid, projection or State Plane zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, NINGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713-3242**, or visit its website at http://www.ngs.noaa.gov.

Base map information shown on this FIRM was derived from the Florida Department of Revenue produced at a scale of 1:200 from photography dated 2010.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels, community map repository addresses, and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

The AE Zone category has been divided by a **Limit of Moderate Wave Action (LiMWA)**. The LiMWA represents the approximate landward limit of the 1.5-foot breaking wave. The effects of wave hazards between the VE Zone and the LiMWA (or between the shoreline and the LiMWA for areas where VE Zones are not identified) will be similar to, but less severe than those in the VE Zone.

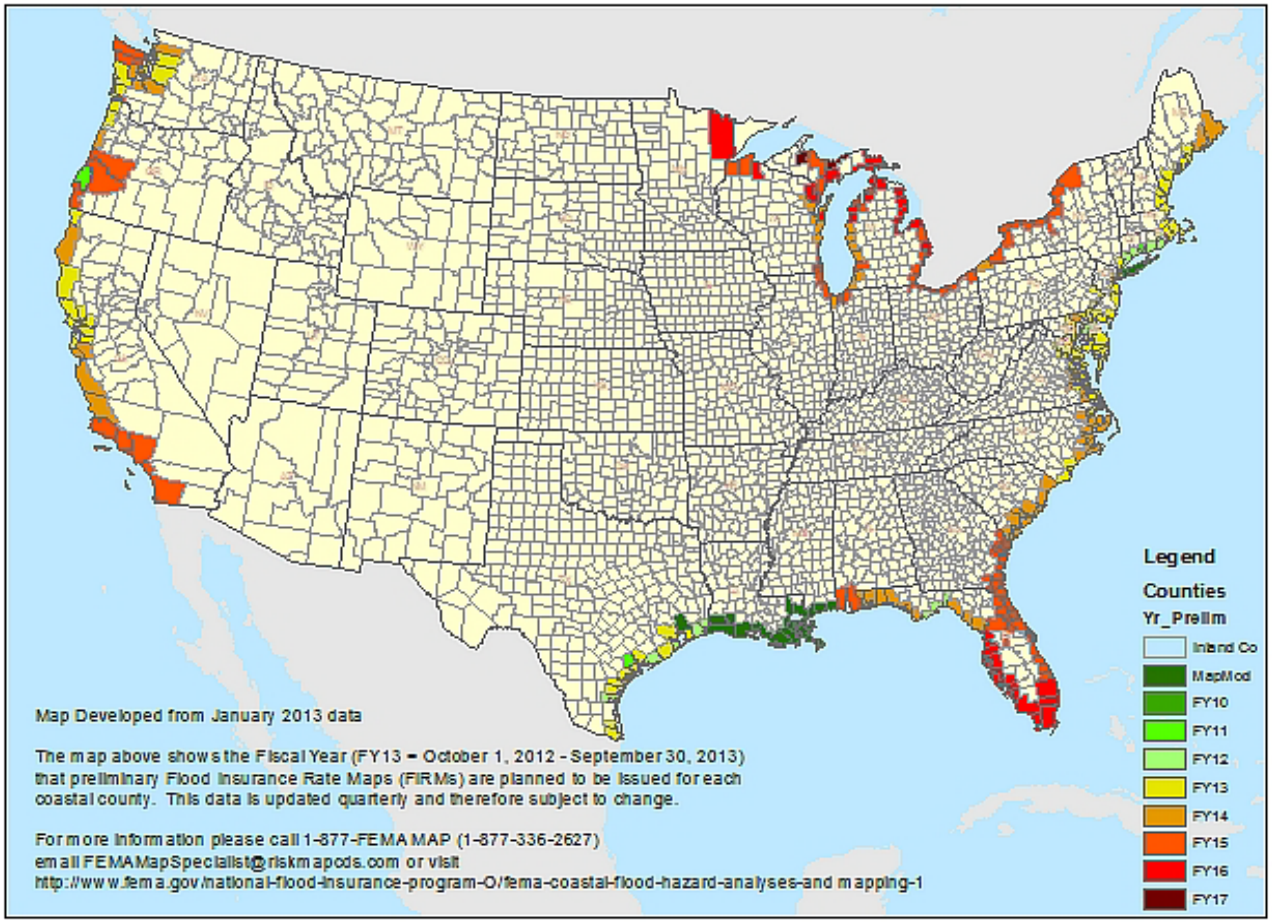
For information on available products associated with this FIRM visit the **Map Service Center (MSC)** website at http://msc.fema.gov. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the MSC website.

If you have **questions about this map**, how to order products or the National Flood Insurance Program in general, please call the FEMA Map Information eXchange (FMIX) at **1-877-FEMA-MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/business/nfip.

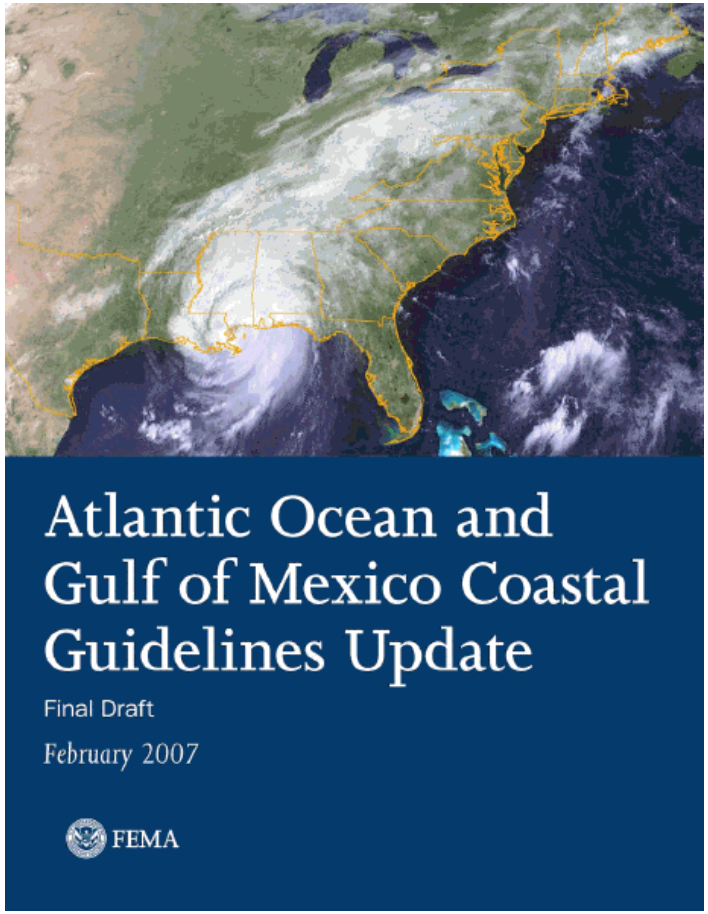
DATUM CONVERSION SCHEMATIC

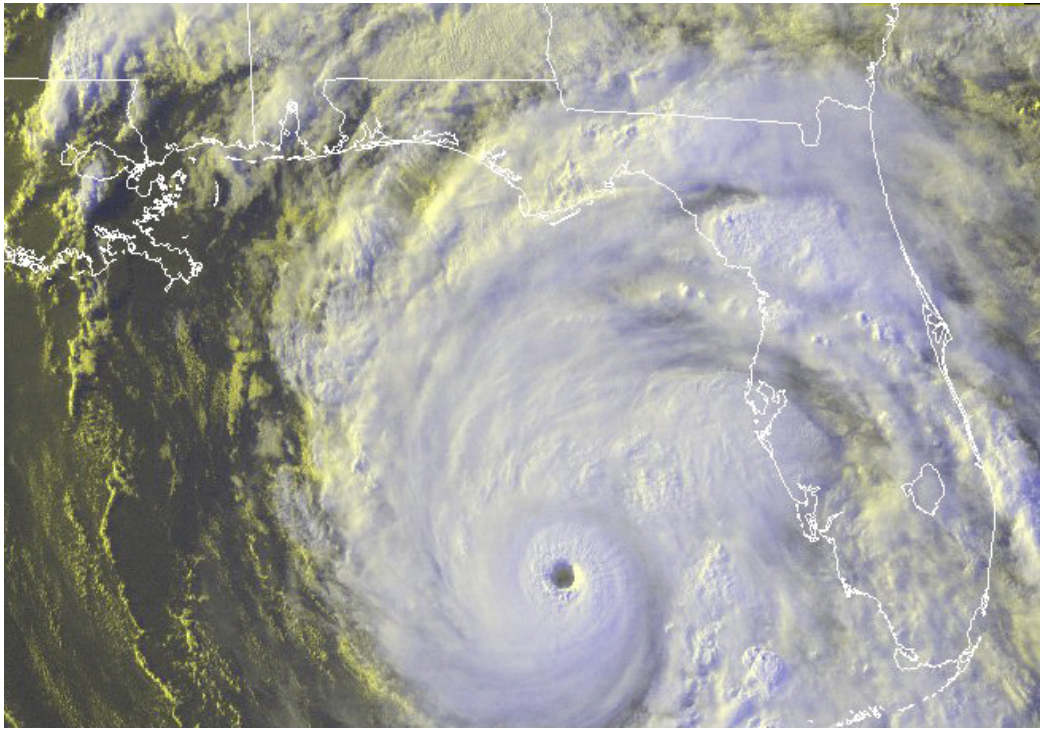
LEGEND

FEMA & Flood Hazard Mapping

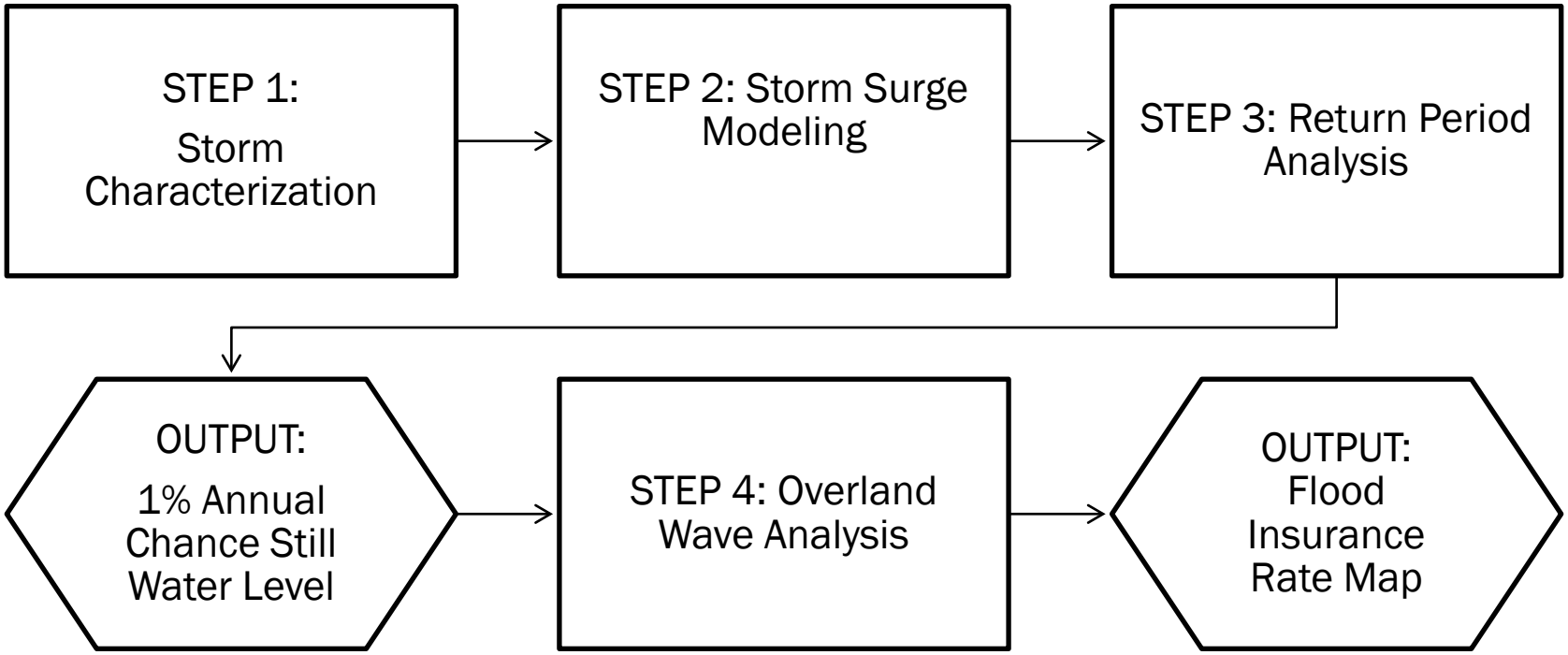


Atlantic Ocean & Gulf of Mexico





Numerical Modeling Framework

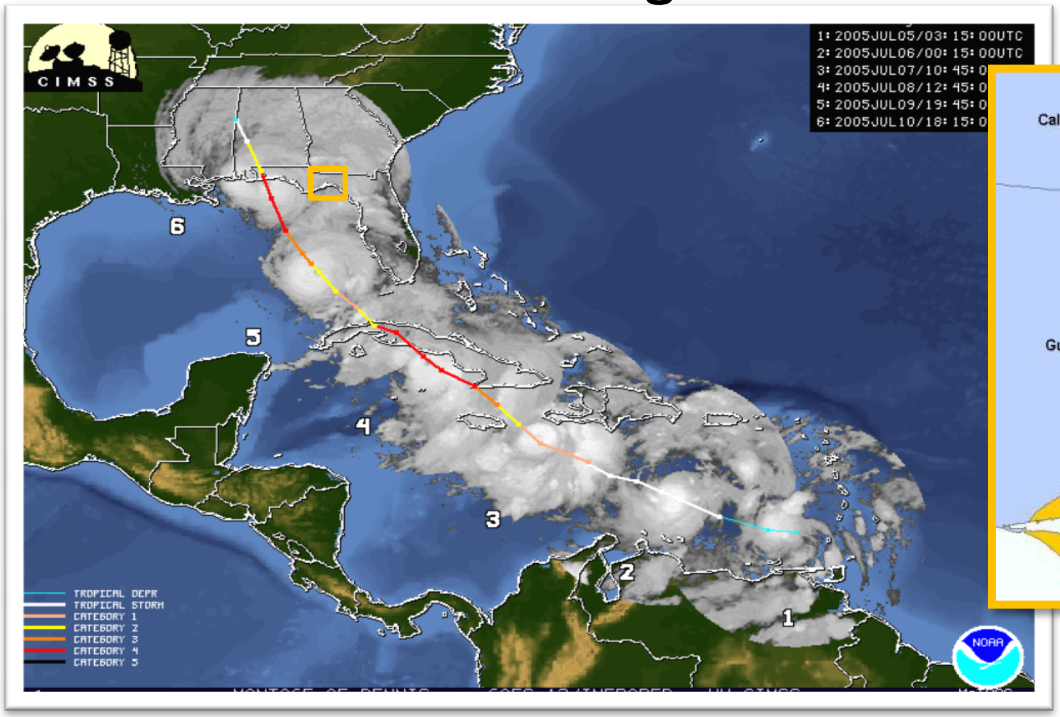


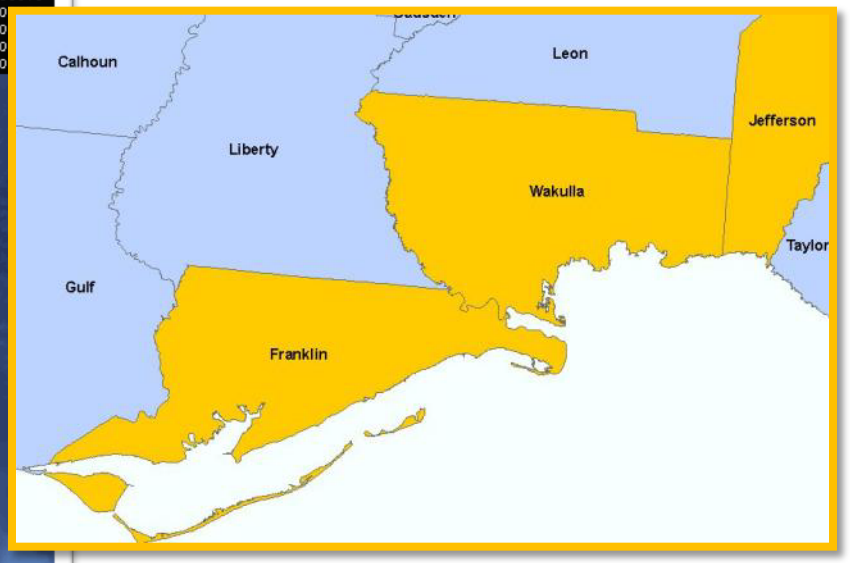
Step 1: Storm Forcing

A. Storm Rate and Storm Characterization

B. JPM-OS and Representative Synthetic Storms

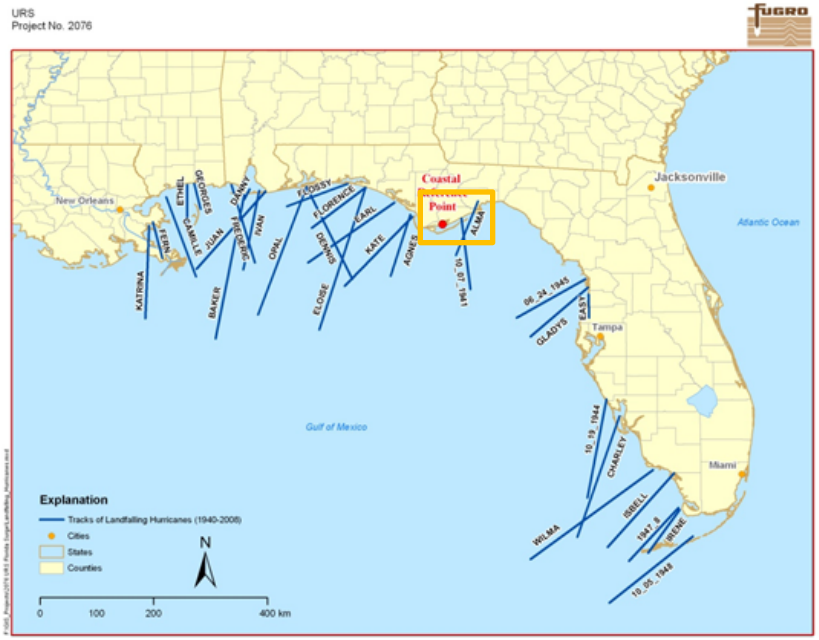
C. Validation of "OS" using SLOSH or a coarse ADCIRC mesh



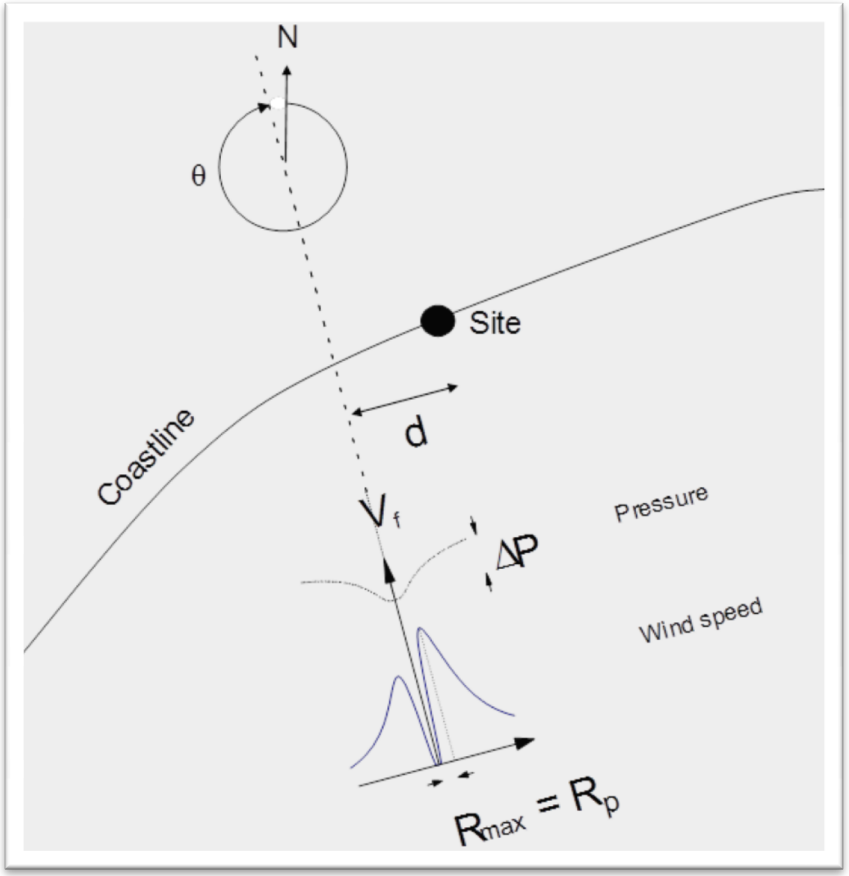


Step 1A: Storm Characterization

- storm occurrence rate λ
- pressure deficit ΔP
- radius of the exponential pressure profile R_{max}
- forward velocity V_f
- storm heading θ
- landfall location d

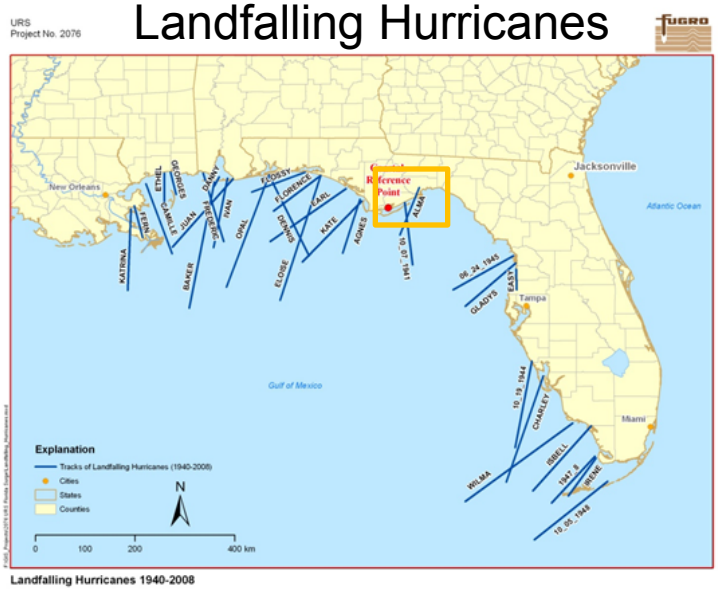


Landfalling Hurricanes 1940-2008



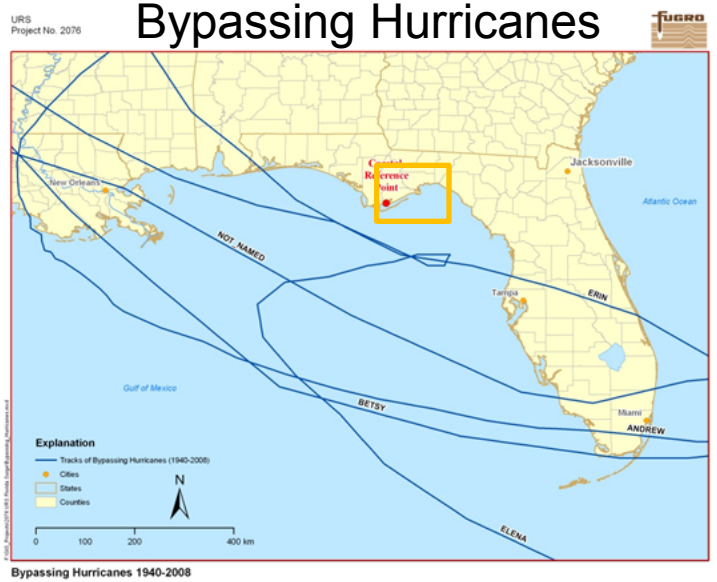
Step 1A: Establishing Storm Rate (storms/year/km)

Landfalling Hurricanes



Landfalling Hurricanes 1940-2008

Bypassing Hurricanes



Bypassing Hurricanes 1940-2008

$$\lambda = \frac{1}{T} \sum_{i \text{ (all storms)}} k(d_i)$$

$$k(d_i) = \frac{1}{\sqrt{2\pi}\,h_d} \exp\left[-\frac{1}{2}\left(\frac{d_i}{h_d}\right)^2\right]$$

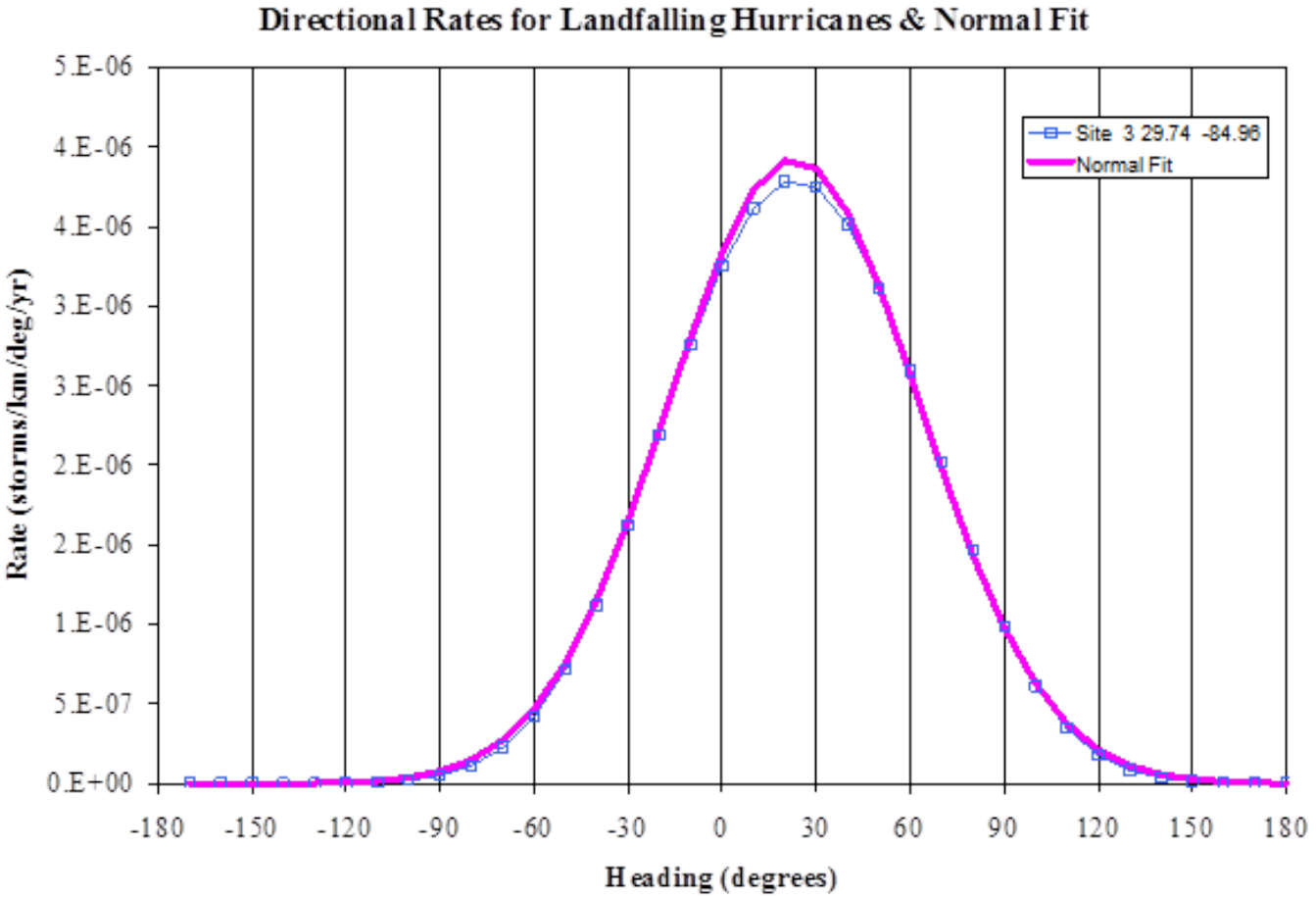
h_d ~ 200 km

$$\lambda(\theta) = \frac{1}{T} \sum_{i \text{ (all storms)}} k(d_i)\,k(\theta_i - \theta)$$

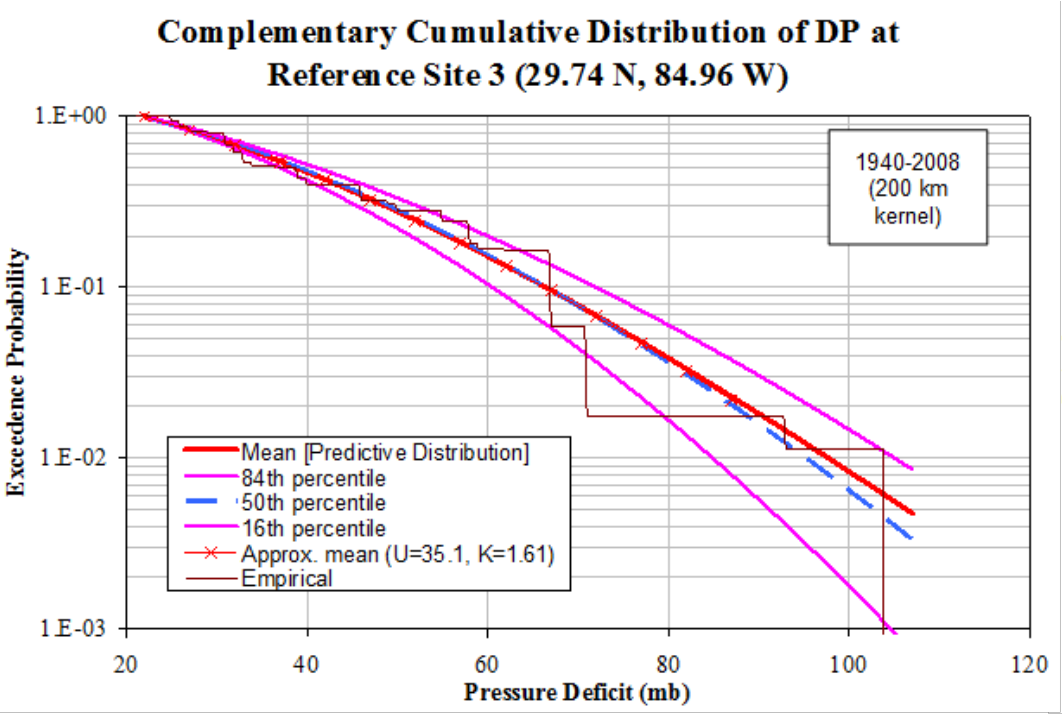
$$k(\theta_i - \theta) = \frac{1}{\sqrt{2\pi}\,h_\theta} \exp\left[-\frac{1}{2}\left(\frac{\theta_i - \theta}{h_\theta}\right)^2\right]$$

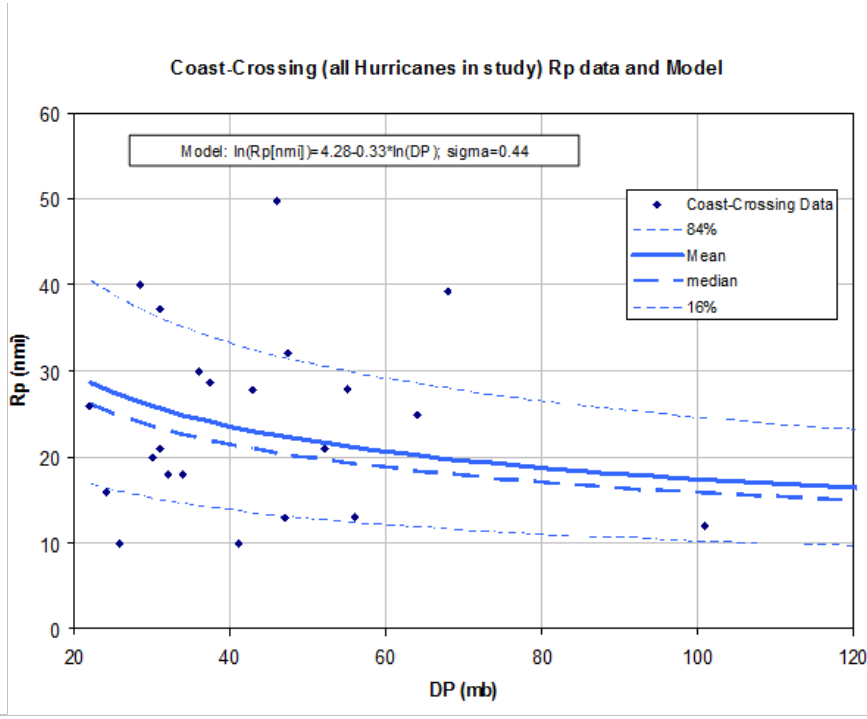
h_θ ~ 30°

Step 1A: Establishing Storm Heading



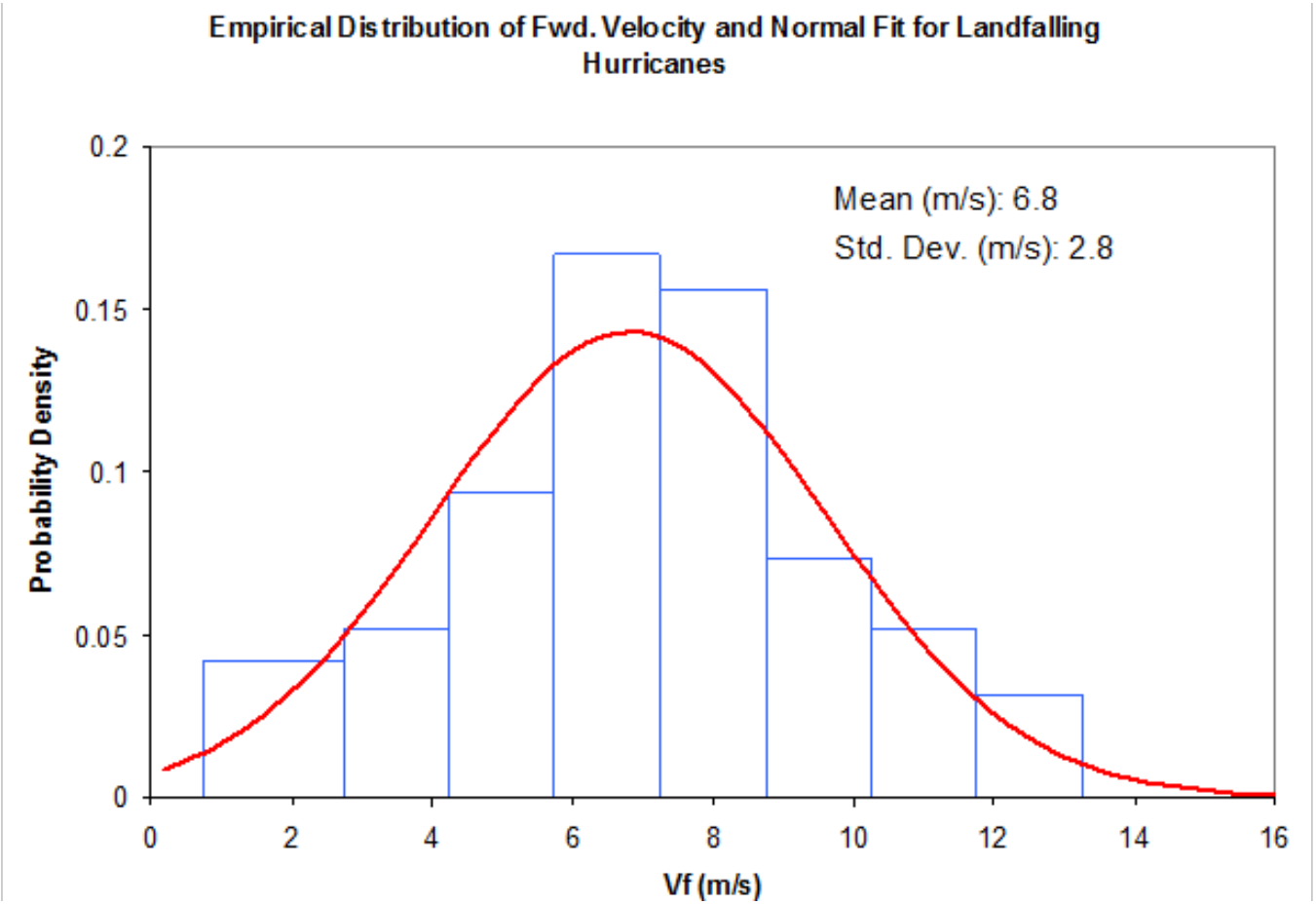
Step 1A: Characterization of Storm Parameters





$$P[\Delta P > x] = \exp[-(x/u)^k + (\Delta P_0/u)^k] \qquad x > \Delta P_0$$

Step 1A: Characterization of Storm Parameters



Step 1B: Storm Tracks

1. **The geometry of the tracks is defined based on:**
   a) Similar work performed by USACE for probabilistic storm surge studies for MS & LA
   b) Historical tracks for the regions (as performed in NC, SC)

2. **Storm parameters, R_p, ΔP, and B are specified for each point along the track, based on the specified conditions at landfall from the probabilistic analysis.**

Step 1B: JPM Development

Joint Probability Distribution of Storm Characteristics

Annual rate for synthetic storm *i*

Numerical model estimate of storm surge elevation

$$P[\eta_{\max(1\,yr)} > \eta] = \lambda \int \ldots \int_{\underline{x}} f_{\underline{X}}(\underline{x}) P[\eta_m(\underline{x}) + \varepsilon > \eta]\, d\underline{x} \approx \sum_{i=1}^{n} \lambda_i P[\eta_m(\underline{x}_i) + \varepsilon > \eta]$$

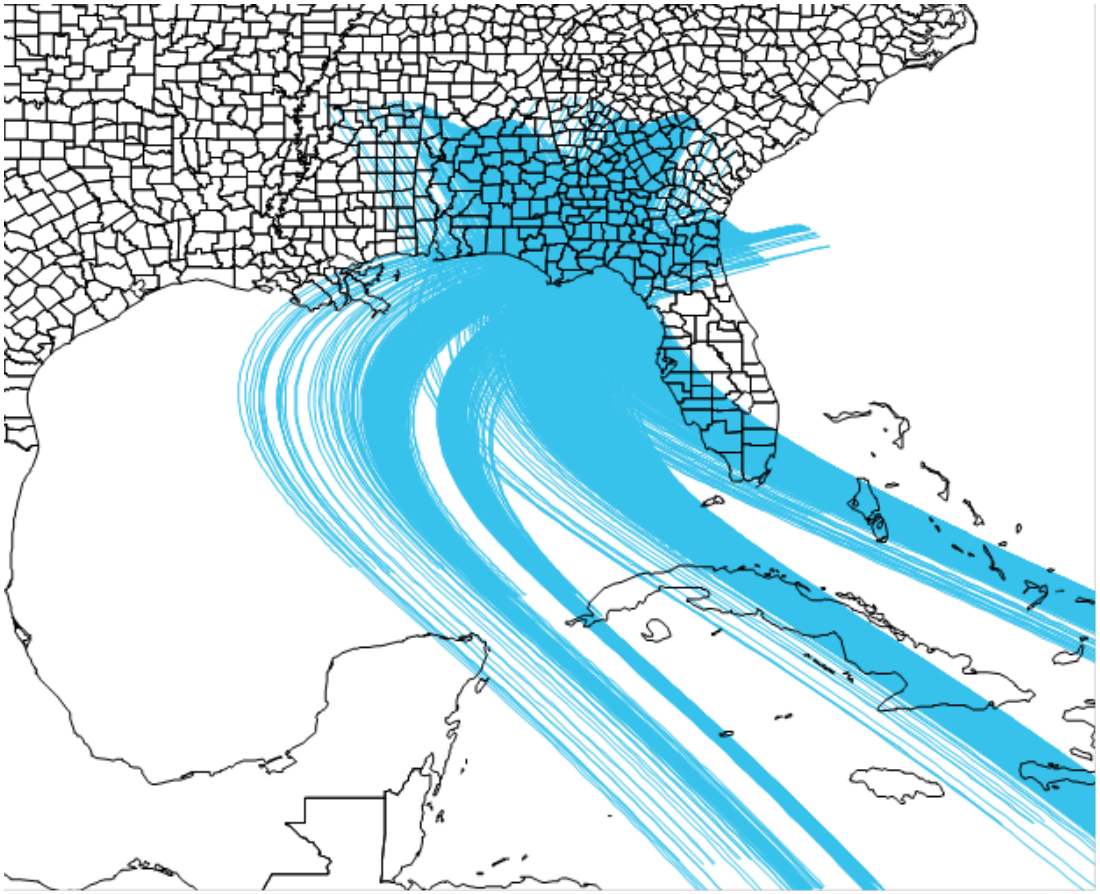
Annual rate (storms/km/yr)

Storm generated surge

$$\underline{x}_i = (\Delta P_i, Rp_i, V_{f,i,} \text{landfall location}_i, \theta_i)$$

1. Discretize ΔP into multiple broad slices
2. Within each slice, discretize the joint probability distribution of ΔP , R_p, V_f and θ using Bayesian Quadrature.
3. Discretize landfall location by offsetting each synthetic storm by R_p, as measured perpendicular to the track.
4. Compute the probability, pi, assigned to each synthetic storm as the product of the probabilities from the first 3 steps.

Step 1B: Reference Synthetic Storms



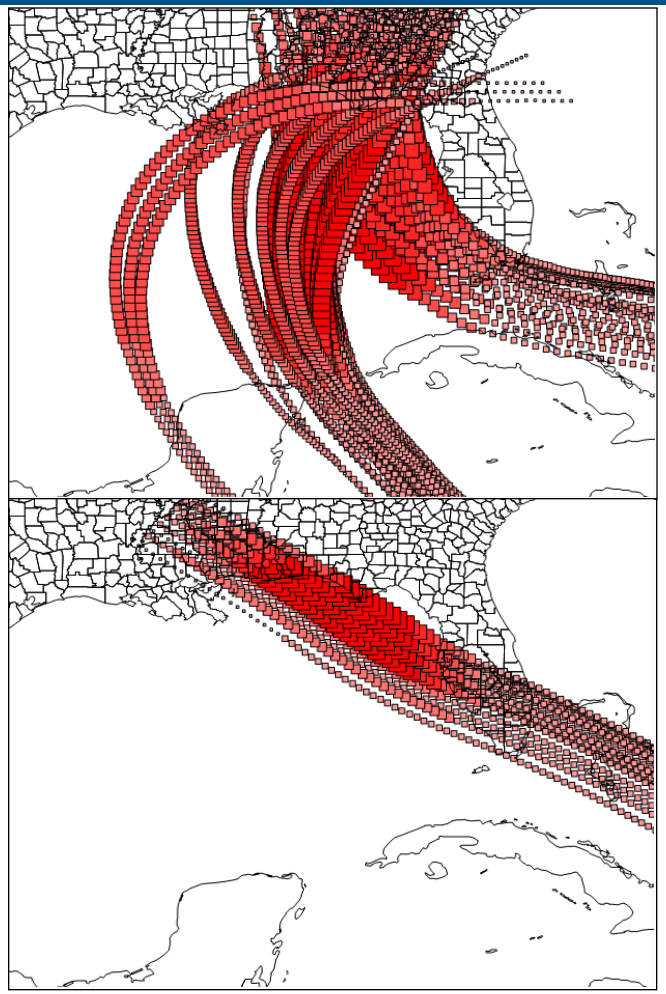
Step 1B: JPM-OS Development

Example: JPM-OS representation of joint probability distribution of storm characteristics for landfalling hurricanes

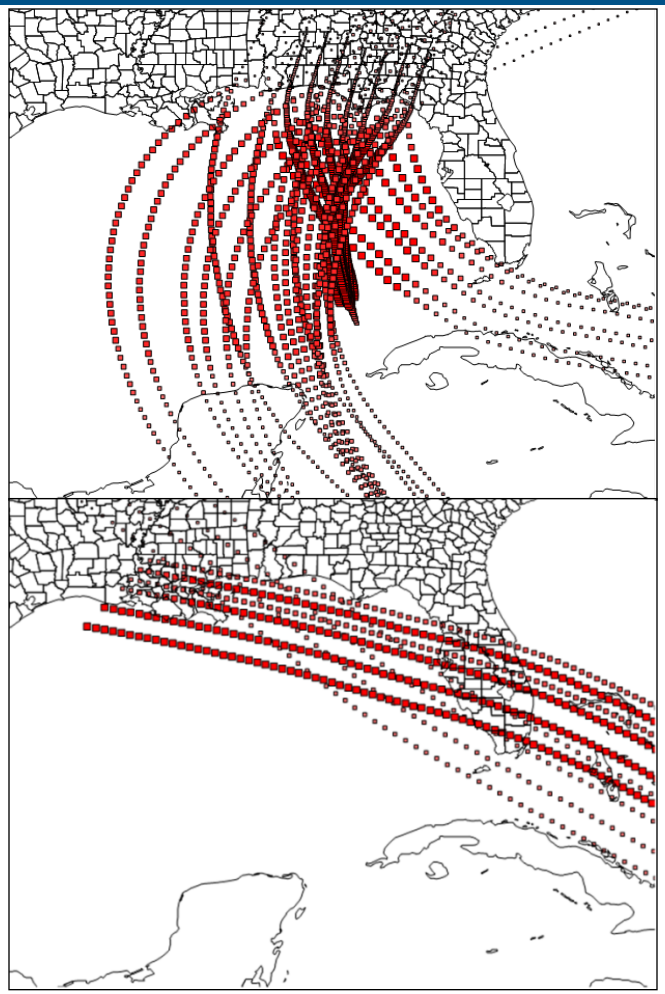
Probability	ΔP (mb)	Rp (nmi)	Vf (m/s)	Theta (deg)
0.248	26.0	36.6	6.8	23.0
0.209	35.3	16.3	6.8	23.0
0.139	42.0	33.2	6.8	23.0
0.094	46.8	14.9	6.8	23.0
0.049	48.9	10.3	5.9	26.6
0.033	56.5	36.4	4.2	61.1
0.057	57.8	19.2	3.9	-12.7
0.046	58.8	17.5	7.1	86.8
0.035	61.7	14.4	11.3	-8.0
0.030	63.4	34.0	9.5	-10.9
0.026	80.4	9.5	5.5	23.7
0.034	87.0	20.2	6.8	28.3

Step 1B: JPM-OS Synthetic Storms

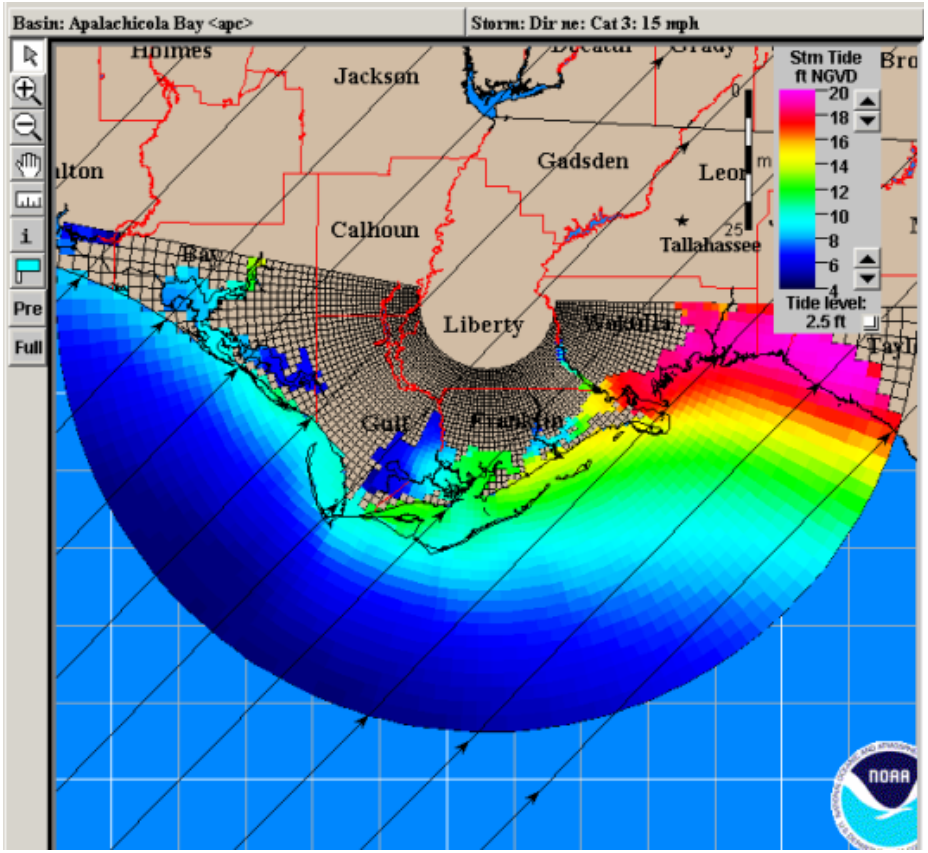
Hurricanes – Landfalling and Bypassing

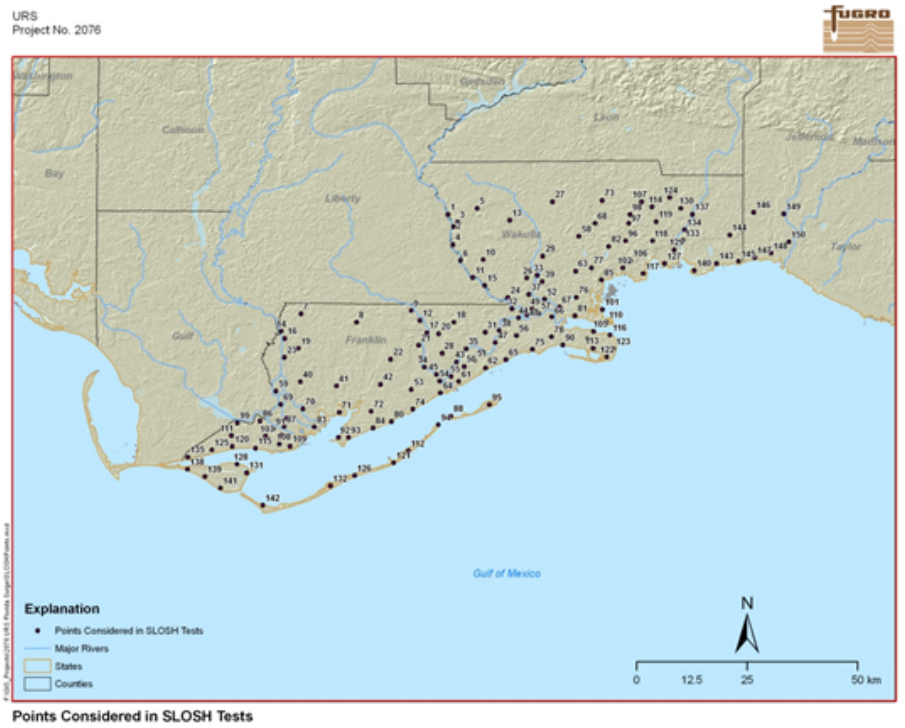


Tropical Storms – Landfalling and Bypassing



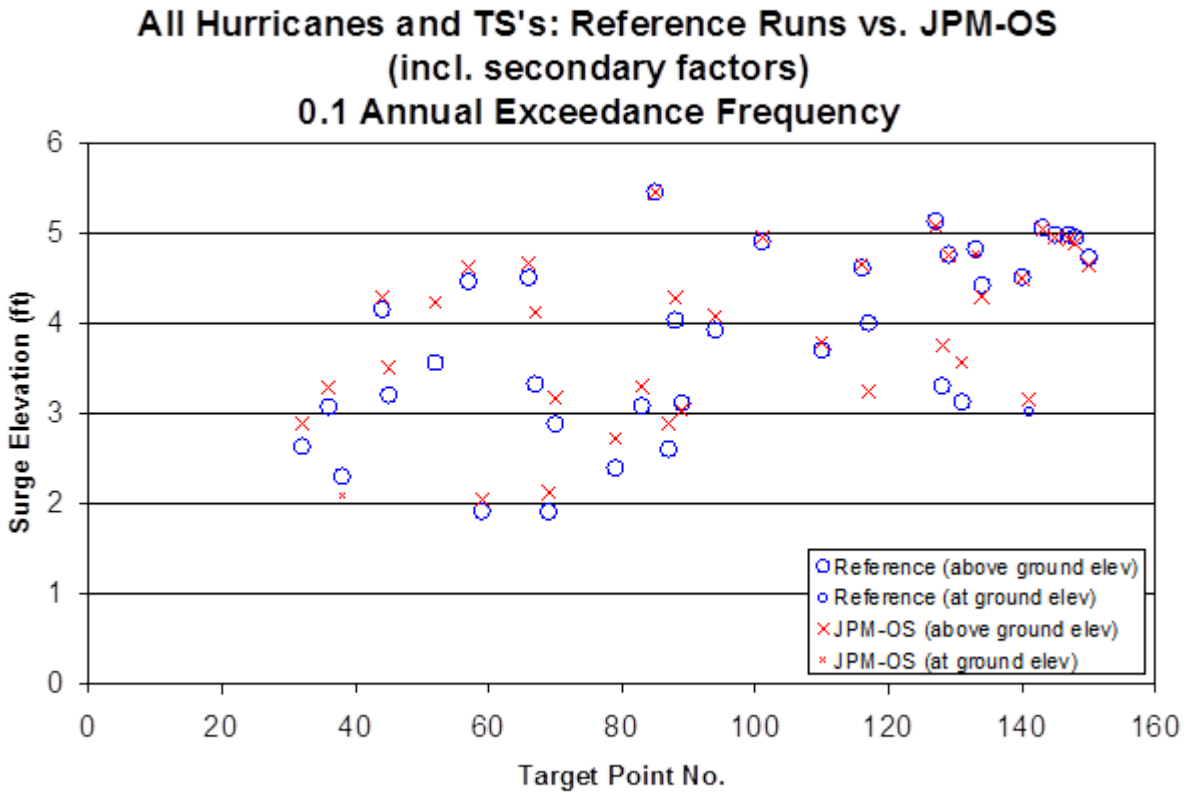
Step 1C: Comparing Reference and JPM-OS Synthetic Storm Suites



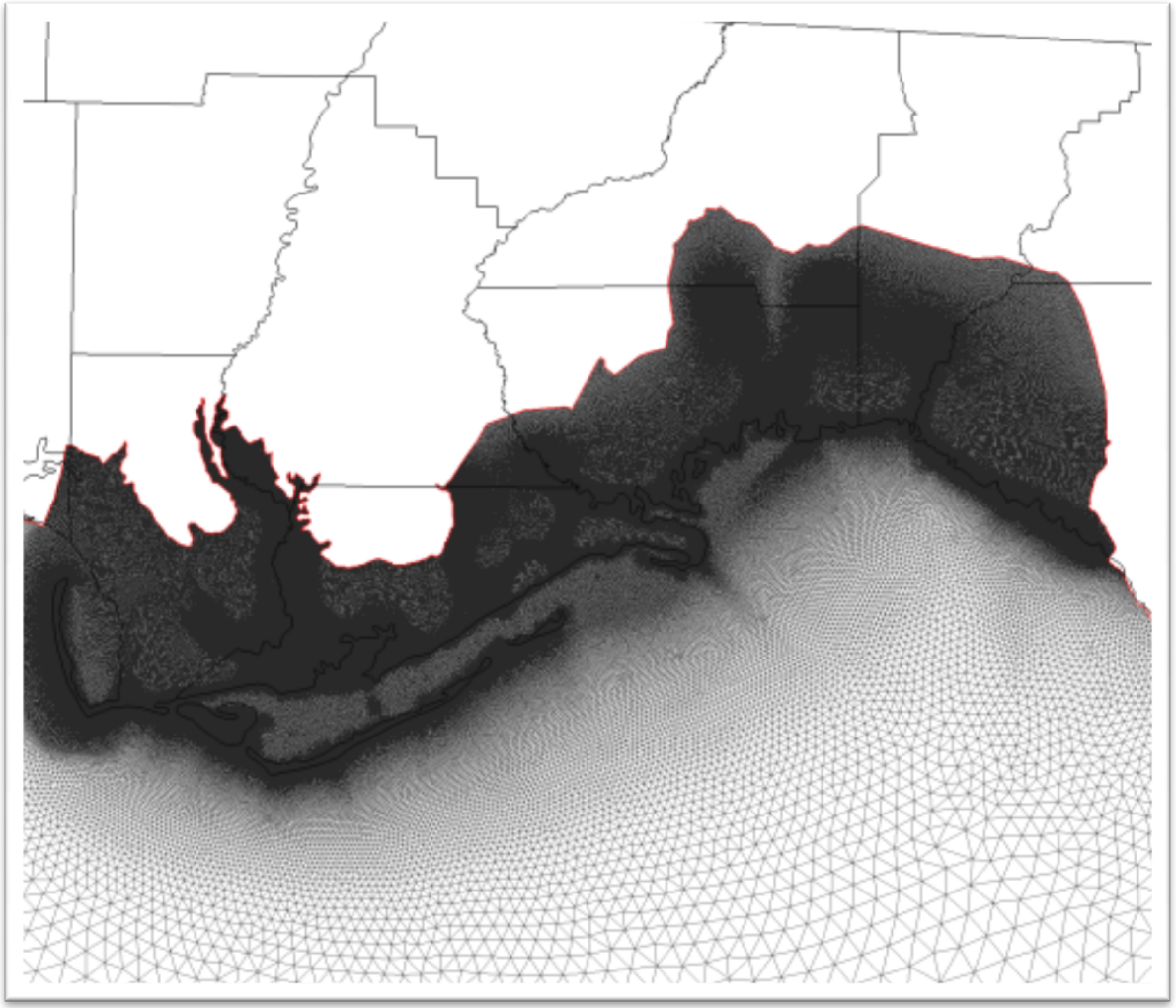


Points Considered in SLOSH Tests

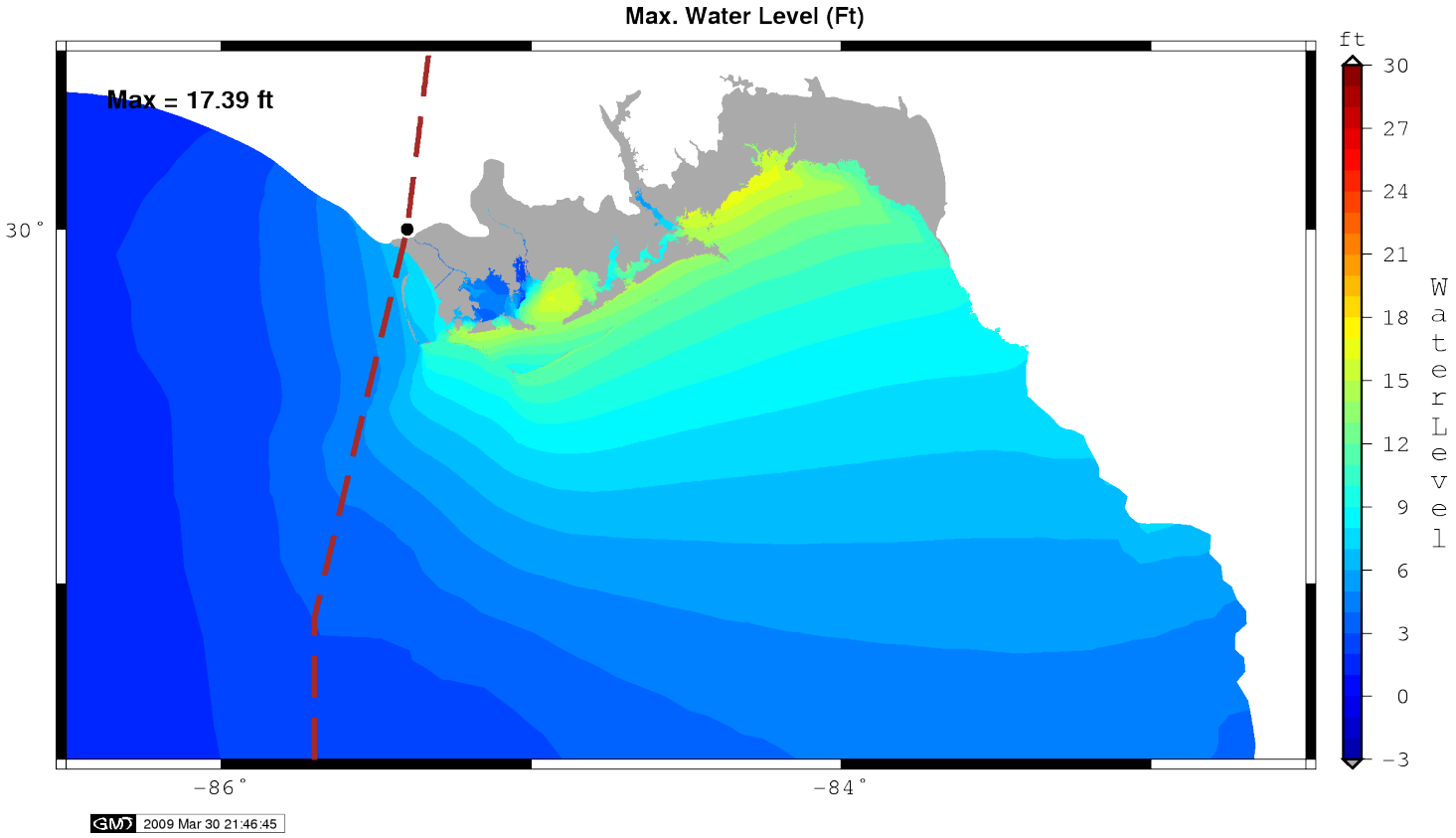
Step 1C: Comparing JPM and JPM-OS



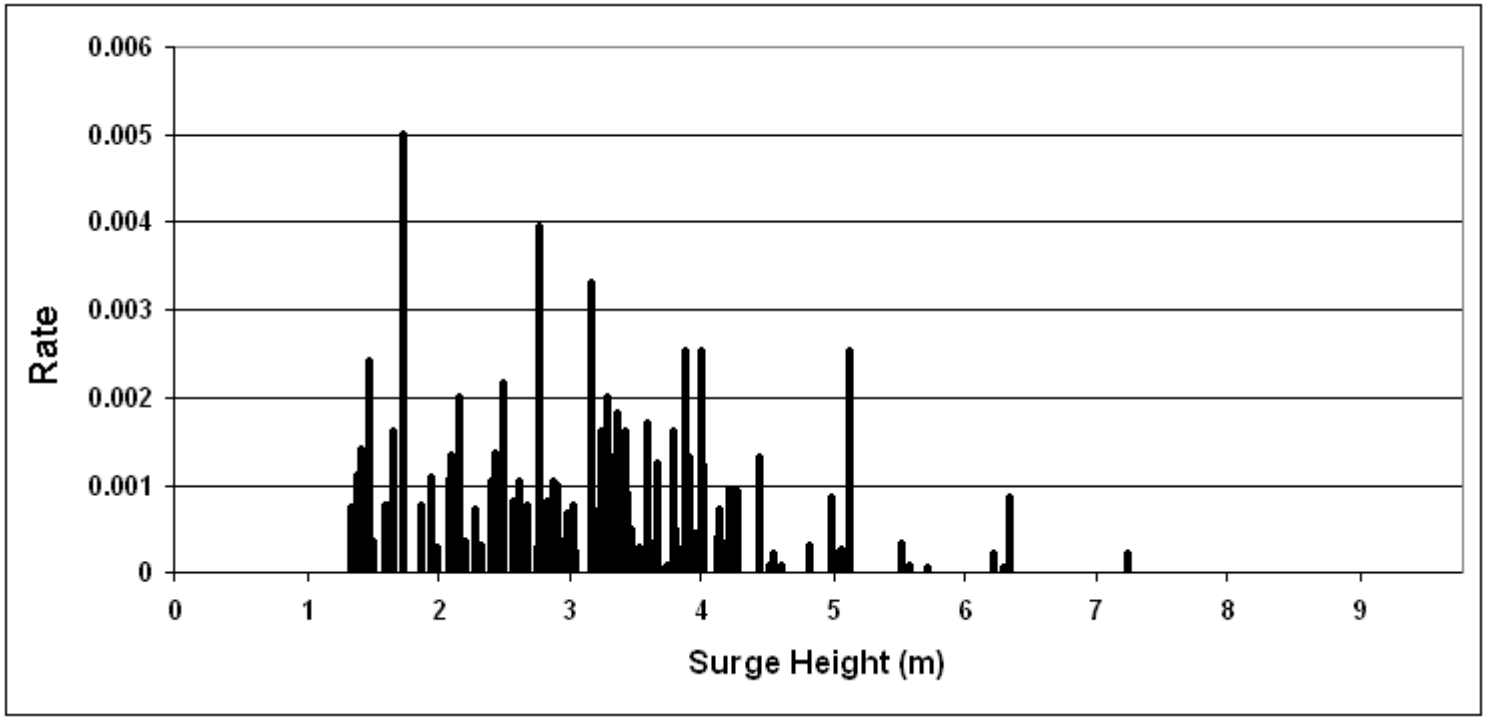
Step 2: Hydrodynamic & Wave Modeling



Step 2: Single Storm SWL Result

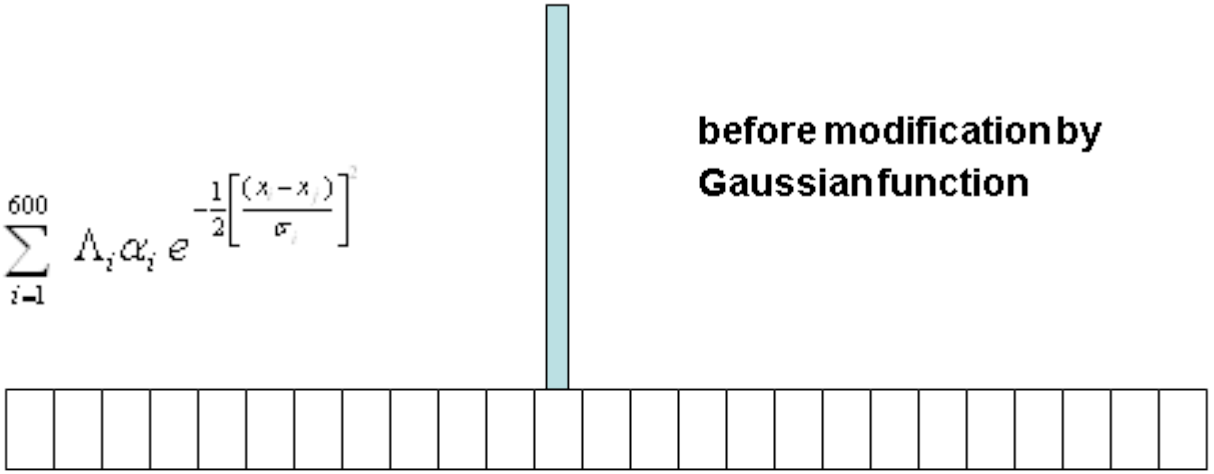


Step 3: JPM-OS SWL Results

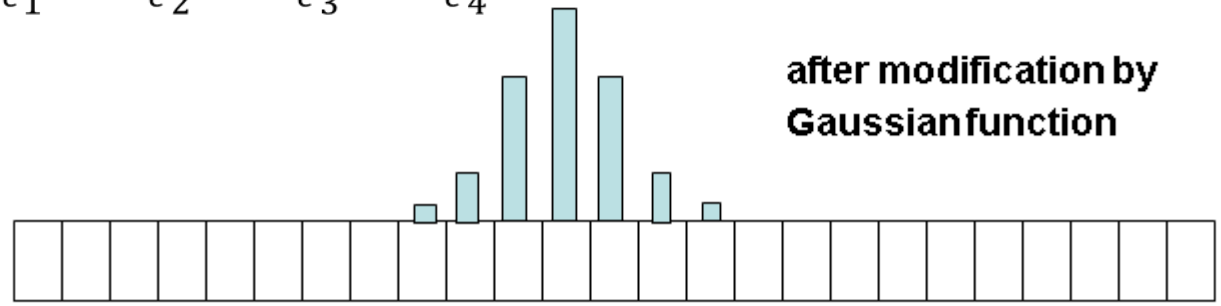


Step 3: Accounting for Uncertainty

$$\Lambda_j^{new} = \sum_{i=1}^{600} \Lambda_i \alpha_i \, e^{-\frac{1}{2}\left[\frac{(x_i - x_j)}{\sigma_i}\right]^2}$$



$$\sigma = \sqrt{{\sigma_{\epsilon_1}}^2 + {\sigma_{\epsilon_2}}^2 + {\sigma_{\epsilon_3}}^2 + {\sigma_{\epsilon_4}}^2}$$

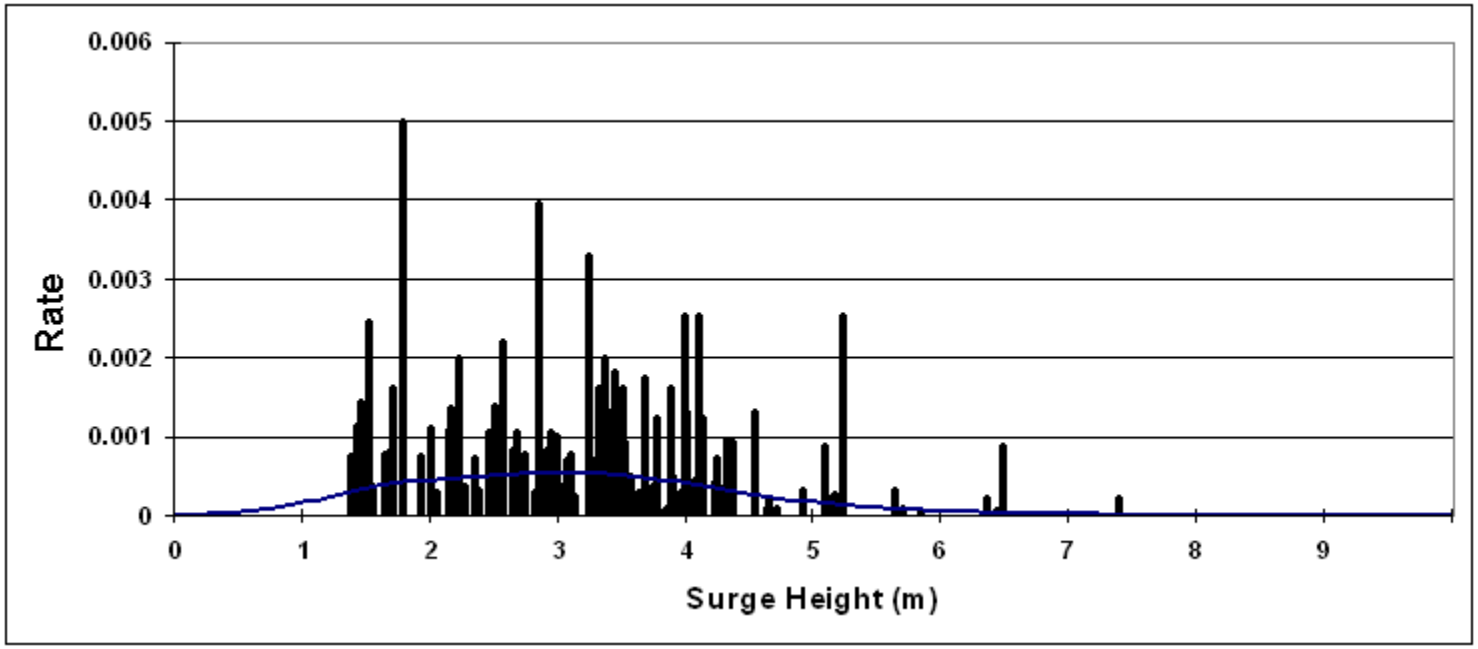


Step 3: Accounting for Uncertainty

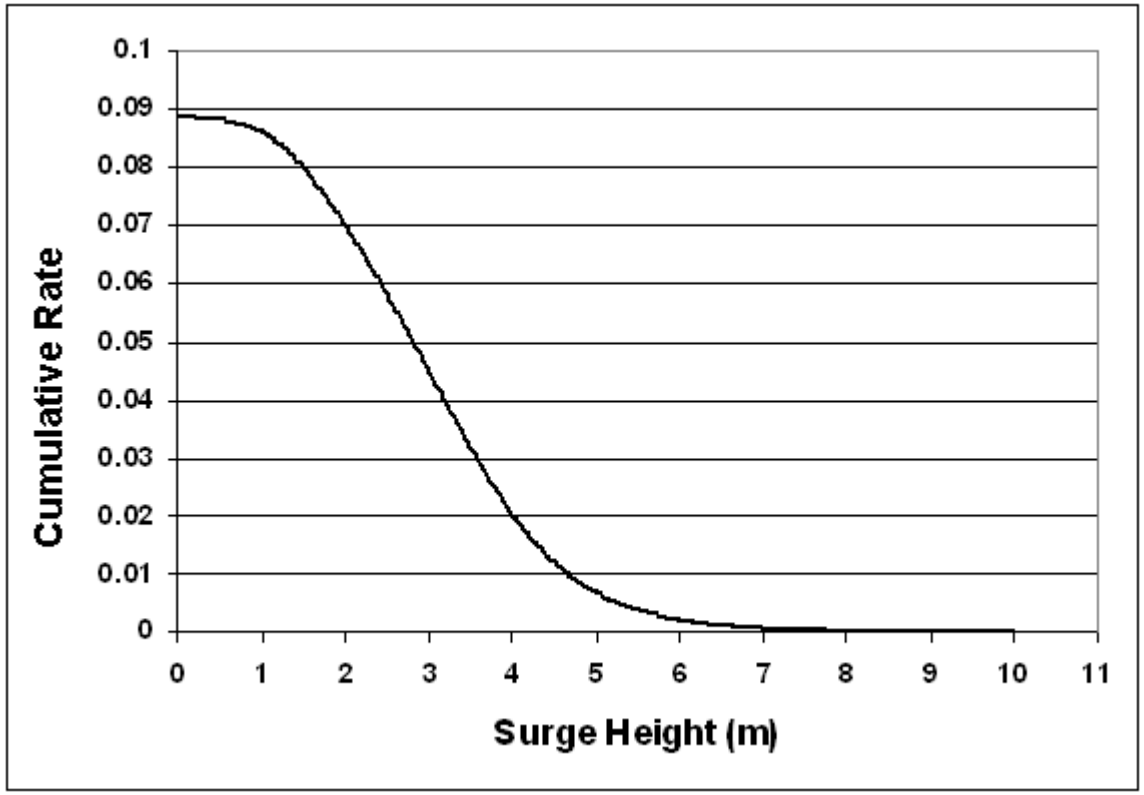
- ε_1 This is the contribution from the astronomical tide. A storm can make landfall at any phase of the tide. This epsilon term is used to represent the effect of random phasing of the maximum storm surge and the astronomical tide.
- ε_2 This epsilon term represents the changes in surge heights due to unaccounted variability in the value of Holland B. This parameter is used in the PBL numerical model of hurricane winds and pressures to account for the radial gradients.
- ε_3 This epsilon term represents the departures between modeled and measured surge levels and is used to express variations in the surge heights due to lack of accuracy in the modeling results.
- ε_4 This epsilon term represents the uncertainty associated with using idealized wind fields for the surge simulations, instead of the "best" or measured wind fields.

Step 3: Accounting for Uncertainty

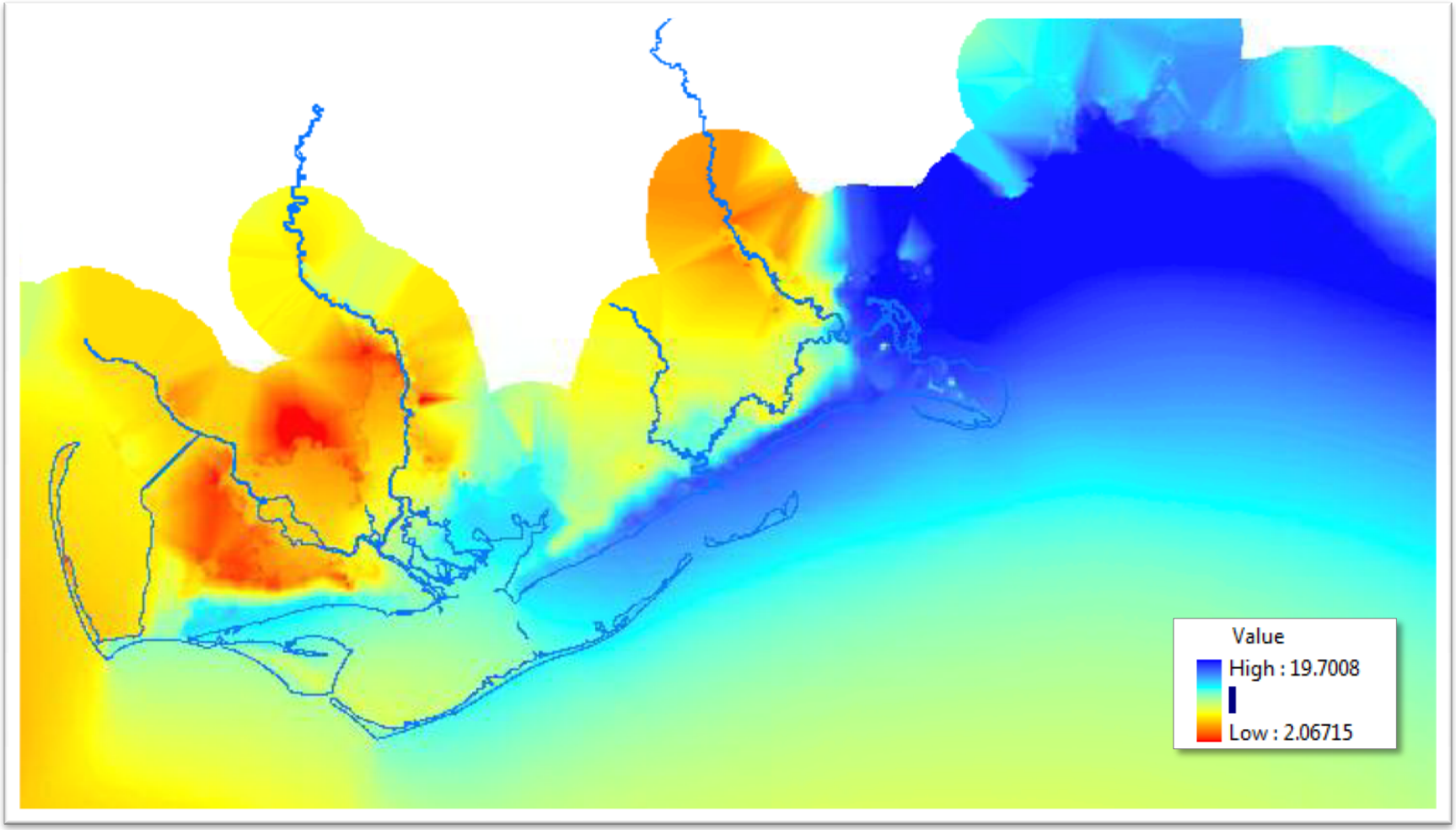
- The effect of the inclusion of the uncertainty term is shown by the blue line in the figure below



Step 3: Final SWL Results



Step 3: Final SWL Results



What can we share with Partners?

- **2D storm surge modeling**
  - Seamless Digital Elevation Model
  - Model mesh
  - Model choice
  - Overland wave modeling
- **Storm characterization & tropical system behavior**
  - Progress in understanding
  - Knowledge transfer needed
  - Area for plentiful future research
- **Treatment of Uncertainty**

Questions?

Thank you to Chris Reed (URS), Alan Niedoroda (URS), Chris Jones, Mark Osler (Baker), Darryl Hatheway (AECOM) & Cheryl Johnson (Accenture) for their shared expertise in this presentation.

Thank you to all FEMA mapping partners, who are the reason this substantial program has been so successful.

Contact information:
Tucker Mahoney
tucker.mahoney@fema.dhs.gov
770-220-5626