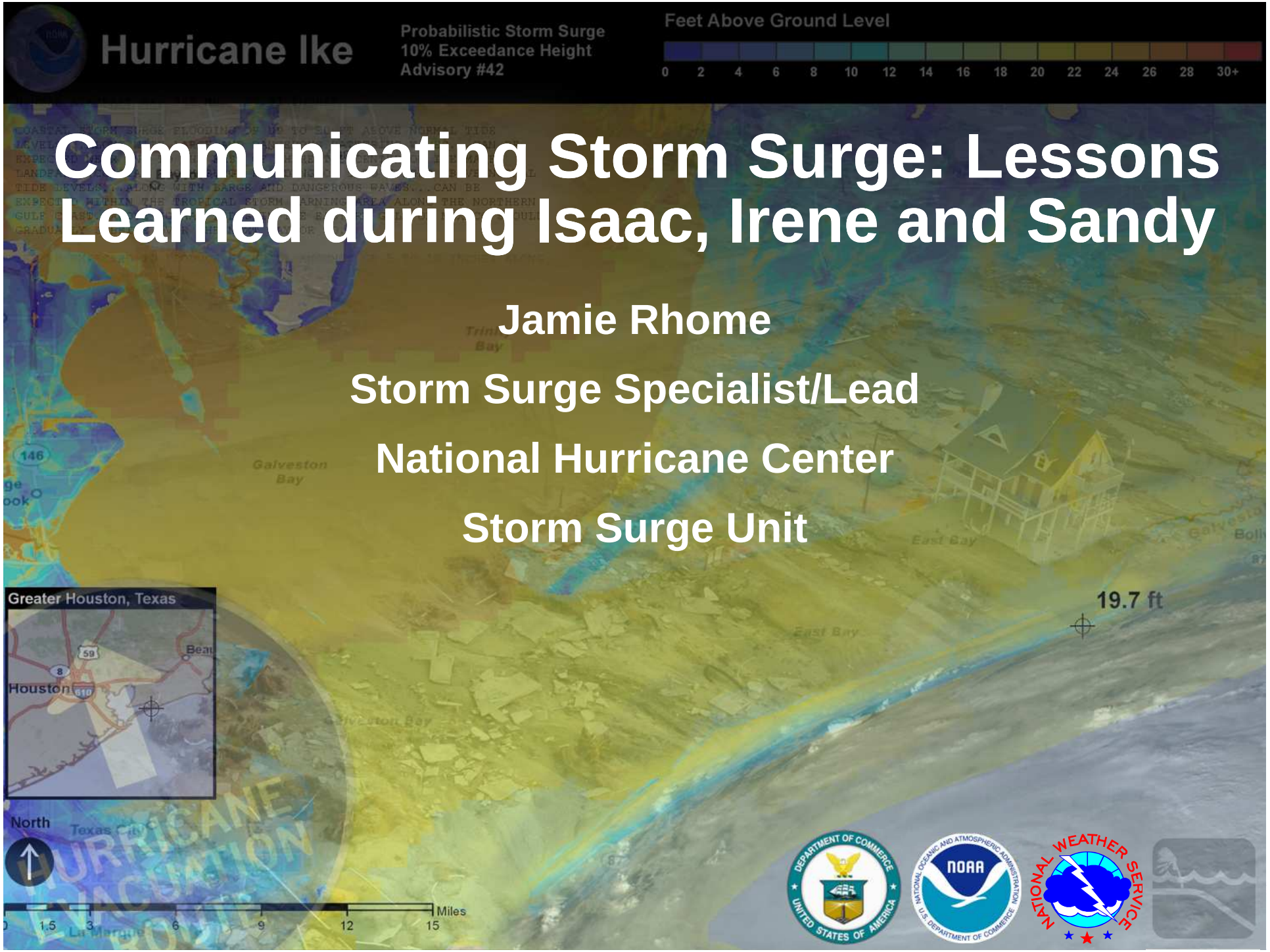


Communicating Storm Surge: Lessons Learned during Isaac, Irene and Sandy

Jamie Rhome

Storm Surge Specialist/Lead

National Hurricane Center

Storm Surge Unit

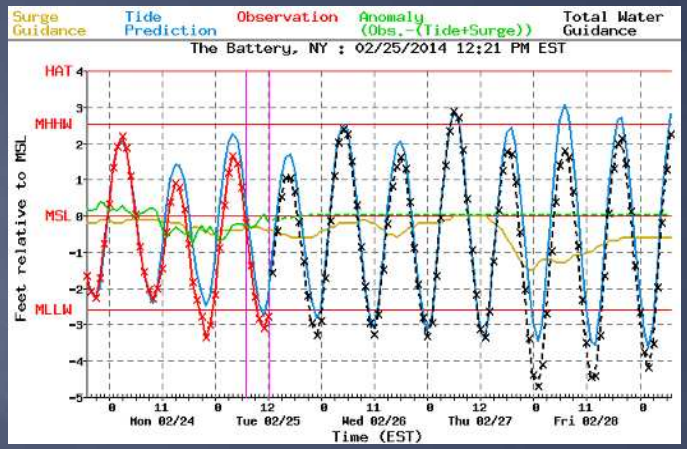
The Surge Team

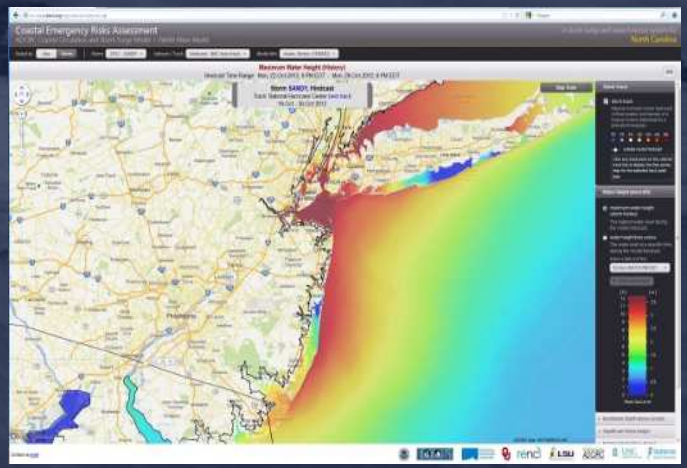
National Hurricane Center Mission

- Provide accurate real-time storm surge forecasts during tropical cyclone events
  - Lead National Weather Service official forecast process
  - Briefings and decision support
- Support coastal community preparedness and resiliency through storm surge vulnerability and risk analysis
  - Drives U.S. hurricane evacuation zones and planning
- Increase awareness through outreach and education

Lessons Learned

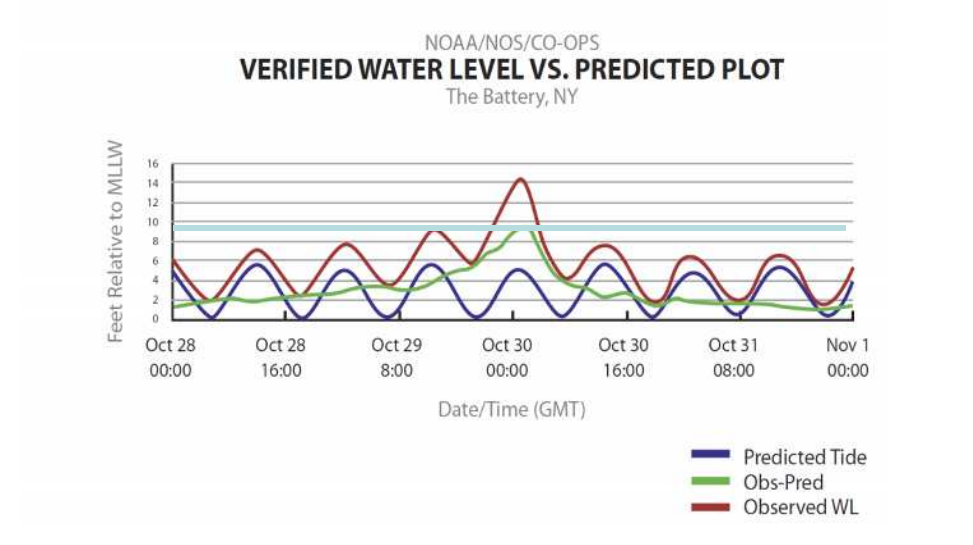
- Consistency/Communication
  - Communicating consistent information is absolutely critical for the proper response
  - Distinction must be made between model guidance and official forecast
- Know Your Audience
  - Local versus regional
  - Technical versus non-technical
    - Different needs and language
- Vertical datums
  - Inconsistent reference levels can cause considerable variation in forecast information
  - Not well understood

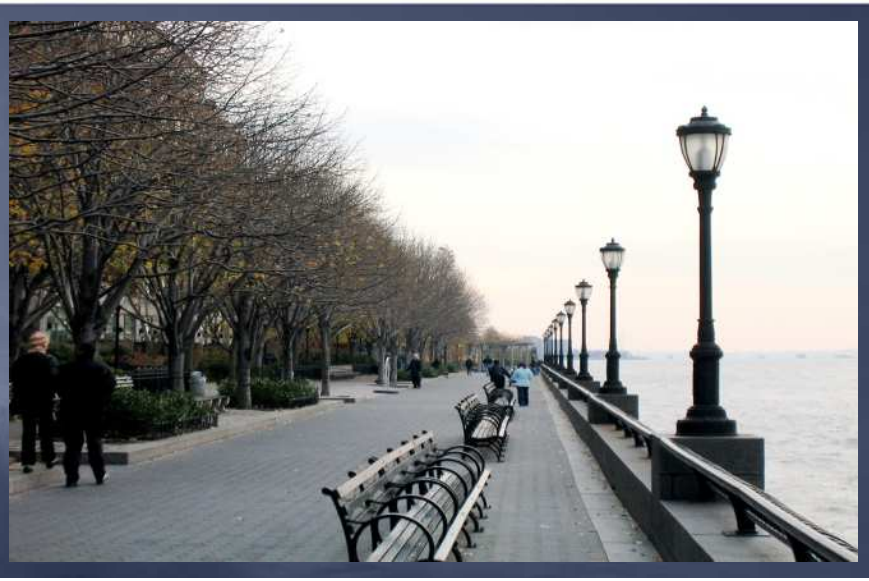




Technical versus Non-Technical: Make the Distinction

Deconstructing Sandy



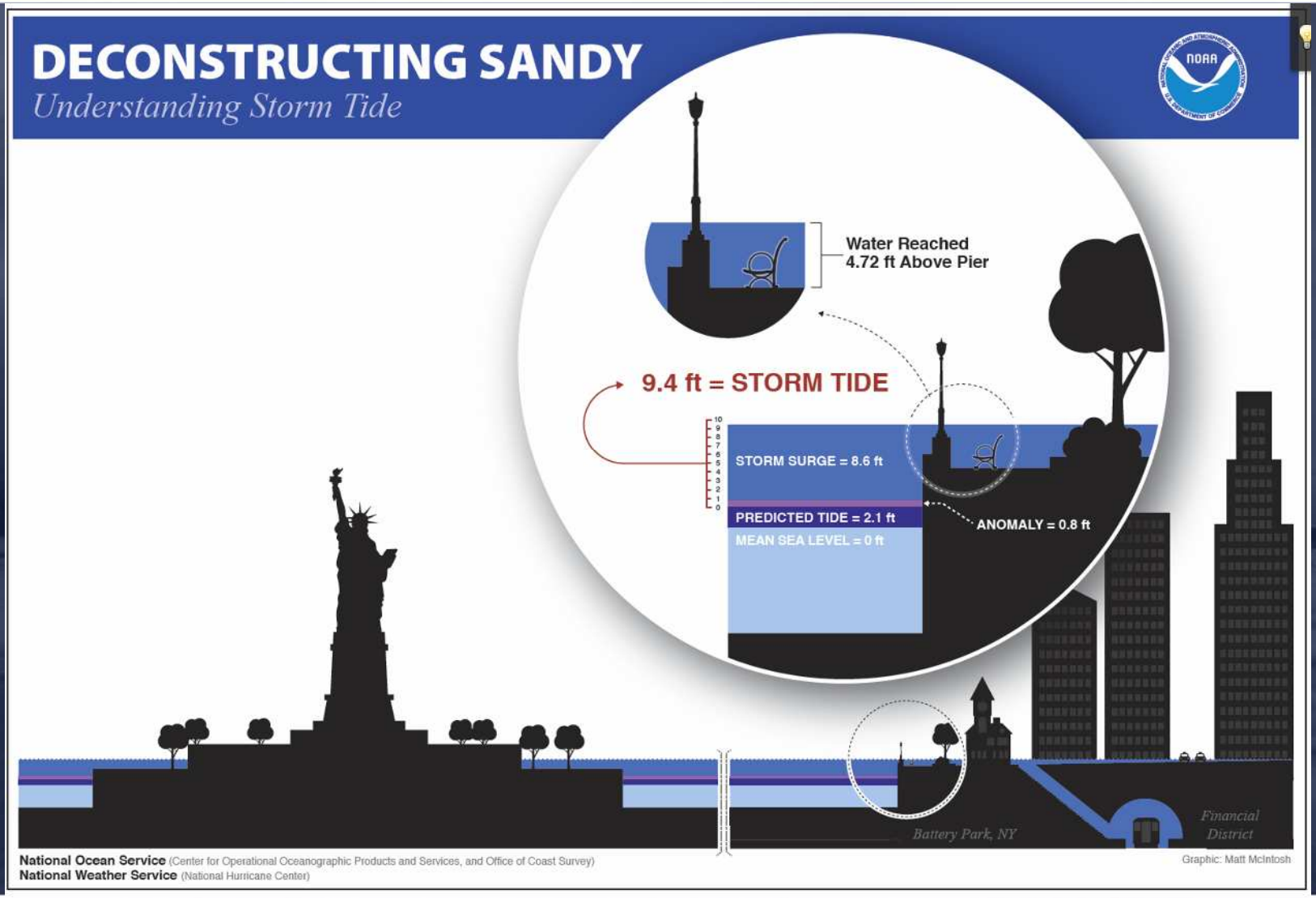


DEMYSTIFYING DATUMS

(Measurement in Feet)

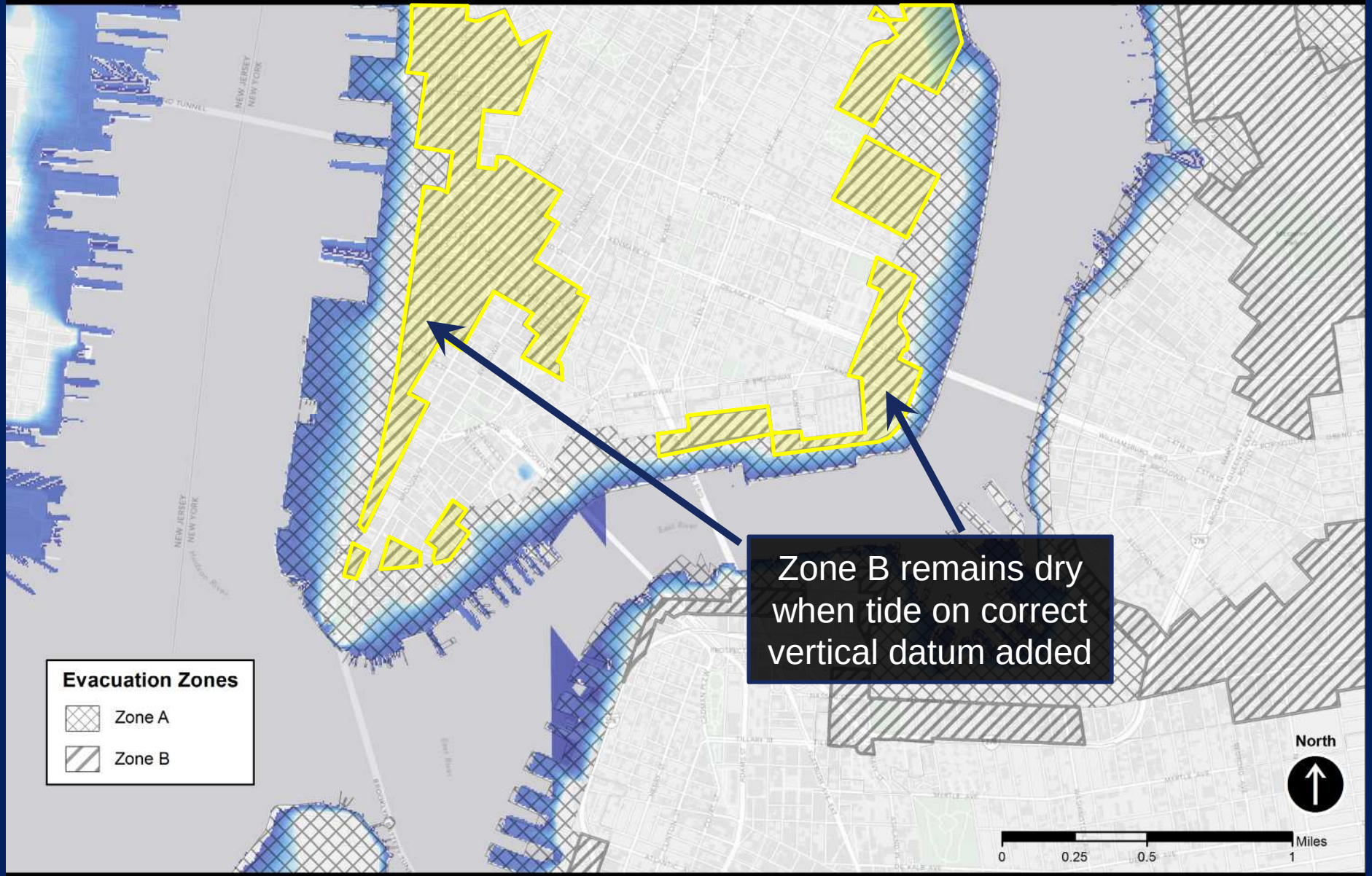
	Ground Level	Mean Higher High Water	Mean Sea Level	Mean Lower Low Water
Storm Tide (total Inundation)	4.72	9.01	11.49	14.06
Surge	8.56	8.56	8.56	8.56
Anomaly	0.85	0.85	0.85	0.85
Predicted Tide	- 4.69	- 0.40	2.08	4.65

Deconstructing Sandy



Hurricane Irene, Advisory #27

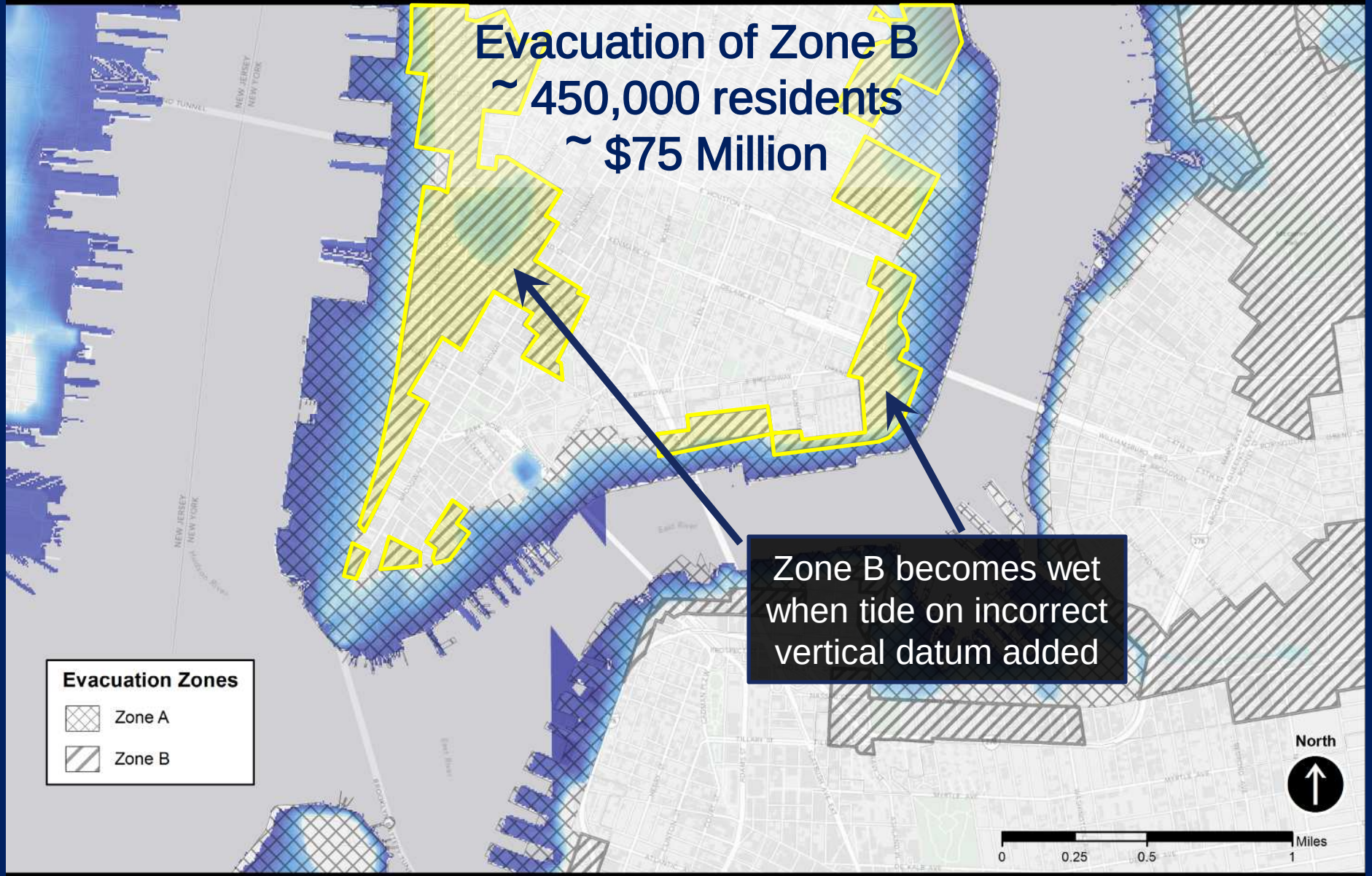
Potential Storm Tide Inundation, Correct Datum



National Hurricane Center
Storm Surge Unit

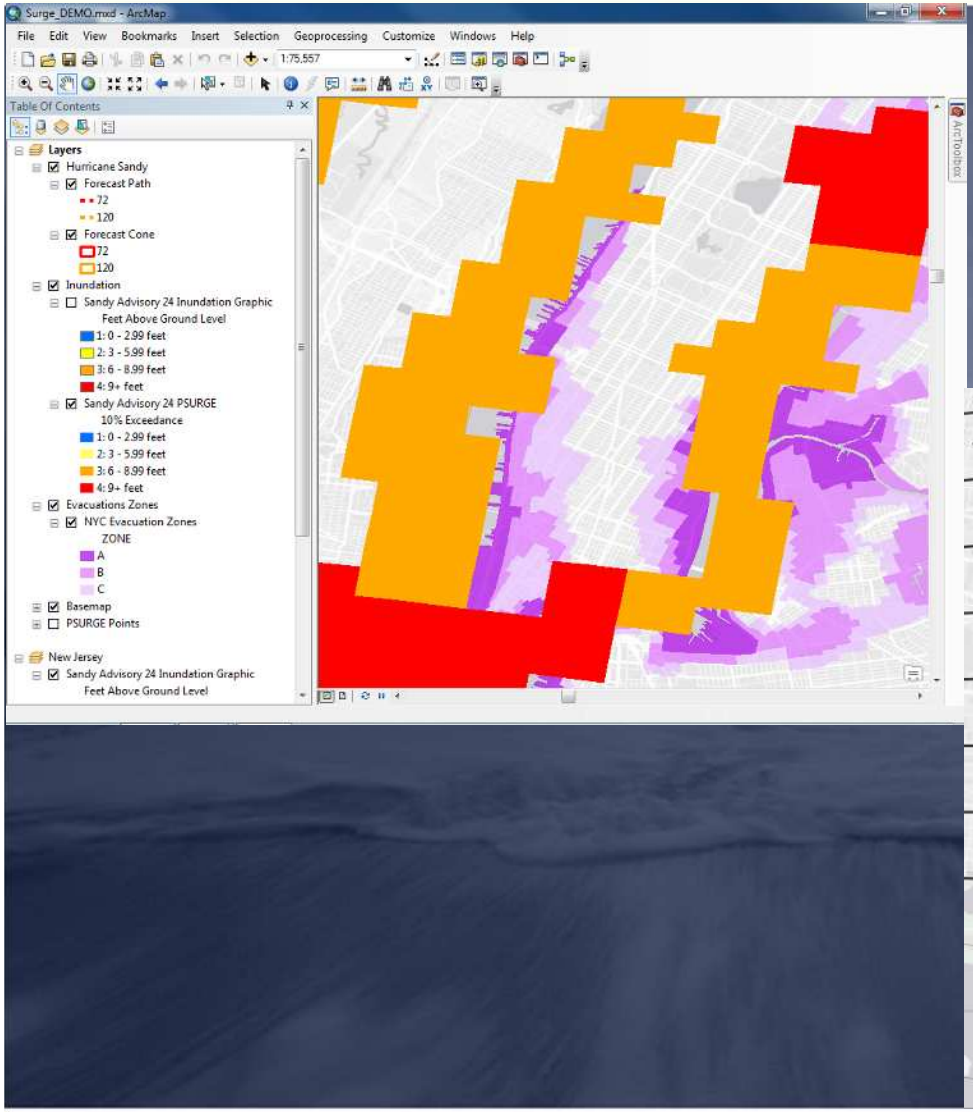
Hurricane Irene, Advisory #27

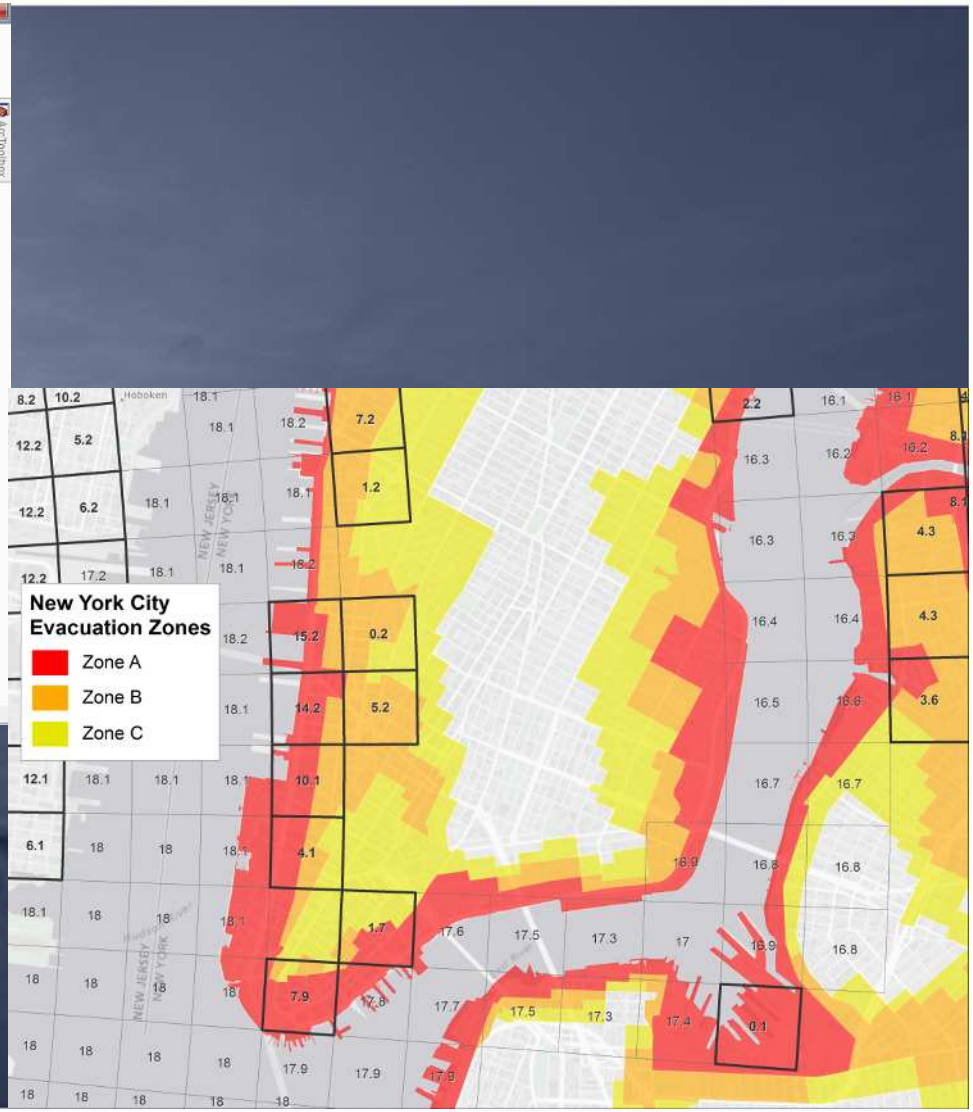
Potential Storm Tide Inundation, Incorrect Datum



National Hurricane Center
Storm Surge Unit

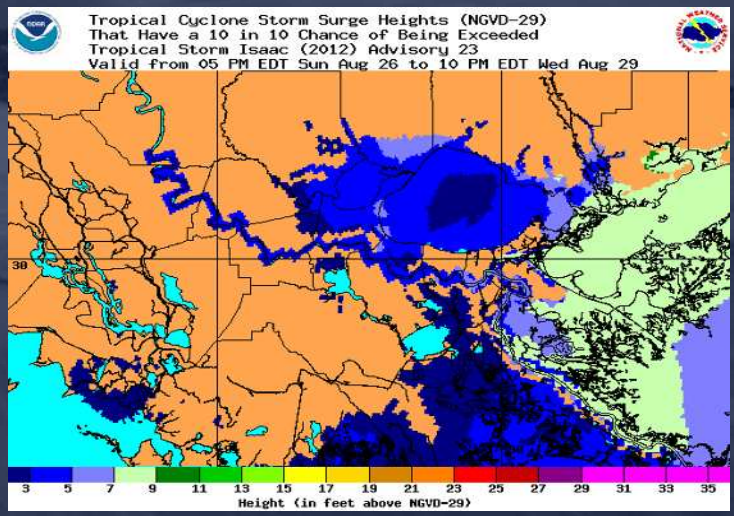
Resolution is Critical

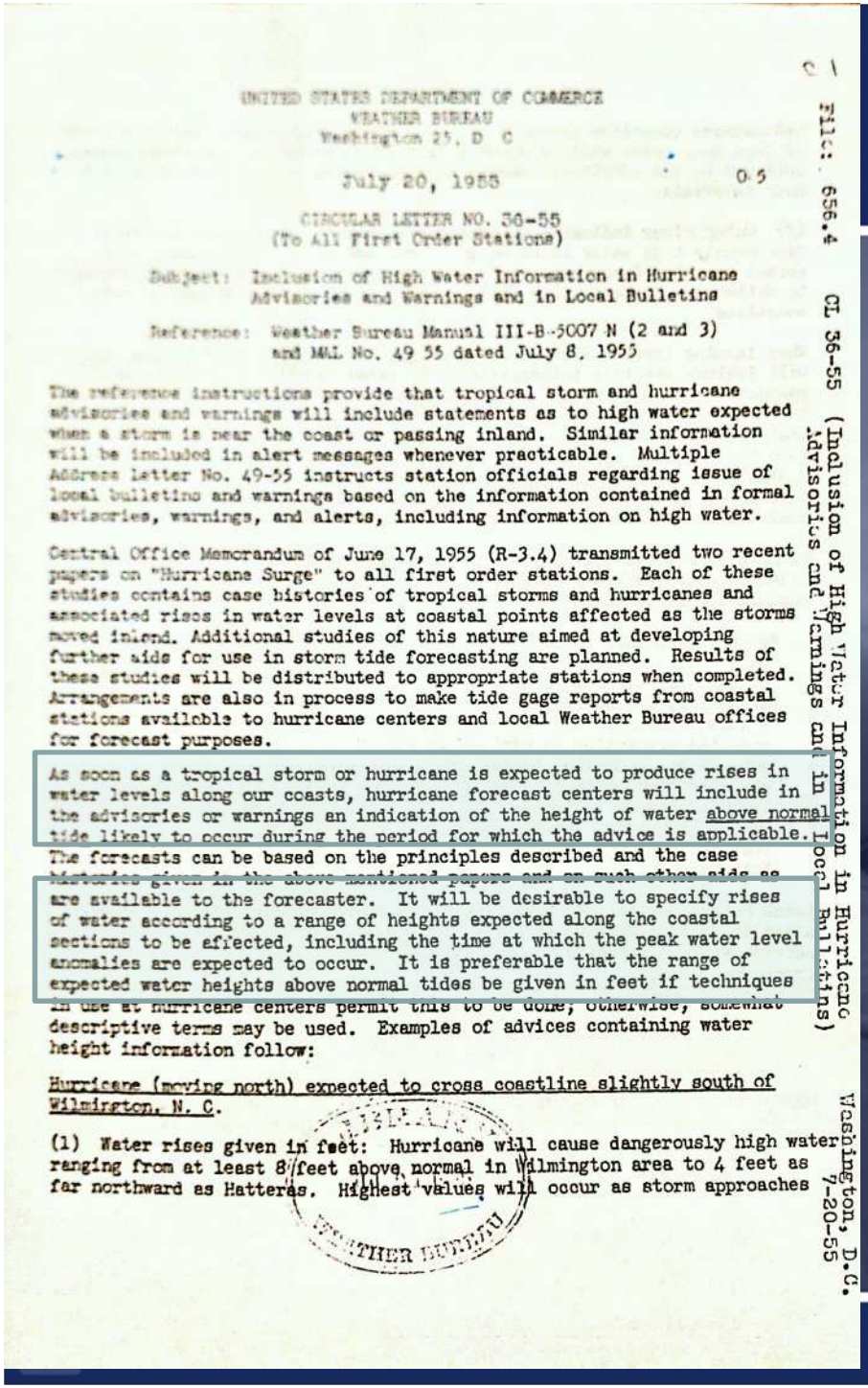




Proper Use of Model Guidance

- Deterministic Versus Probabilistic
  - Deterministic guidance does not properly account for forecast uncertainty
    - Timing uncertainty/tide
    - Meteorological uncertainty
    - Hydrodynamics
    - Run to run changes
- Research Versus Operational Models
  - Research models often contain numerical instability or haven't been properly vetted for operational application
  - Unknown performance/biases and lack of forecaster familiarity





UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
Washington 25, D. C.

July 20, 1955

CIRCULAR LETTER NO. 36-55
(To All First Order Stations)

Subject: Inclusion of High Water Information in Hurricane Advisories and Warnings and in Local Bulletins

Reference: Weather Bureau Manual III-B-5007 N (2 and 3) and MAL No. 49 55 dated July 8, 1955

The reference instructions provide that tropical storm and hurricane advisories and warnings will include statements as to high water expected when a storm is near the coast or passing inland. Similar information will be included in alert messages whenever practicable. Multiple Address Letter No. 49-55 instructs station officials regarding issue of local bulletins and warnings based on the information contained in formal advisories, warnings, and alerts, including information on high water.

Central Office Memorandum of June 17, 1955 (R-3.4) transmitted two recent papers on "Hurricane Surge" to all first order stations. Each of these studies contains case histories of tropical storms and hurricanes and associated rises in water levels at coastal points affected as the storms moved inland. Additional studies of this nature aimed at developing further aids for use in storm tide forecasting are planned. Results of these studies will be distributed to appropriate stations when completed. Arrangements are also in process to make tide gage reports from coastal stations available to hurricane centers and local Weather Bureau offices for forecast purposes.

As soon as a tropical storm or hurricane is expected to produce rises in water levels along our coasts, hurricane forecast centers will include in the advisories or warnings an indication of the height of water above normal tide likely to occur during the period for which the advice is applicable. The forecasts can be based on the principles described and the case histories given in the above mentioned papers and on such other aids as are available to the forecaster. It will be desirable to specify rises of water according to a range of heights expected along the coastal sections to be effected, including the time at which the peak water level anomalies are expected to occur. It is preferable that the range of expected water heights above normal tides be given in feet if techniques in use at hurricane centers permit this to be done; otherwise, somewhat descriptive terms may be used. Examples of advices containing water height information follow:

Hurricane (moving north) expected to cross coastline slightly south of Wilmington, N. C.

(1) Water rises given in feet: Hurricane will cause dangerously high water ranging from at least 8 feet above normal in Wilmington area to 4 feet as far northward as Hatteras. Highest values will occur as storm approaches

WEATHER BUREAU

File: 656.4 CL 36-55 (Inclusion of High Water Information in Hurricane Advisories and Warnings and in Local Bulletins)

Washington, D.C. 7-20-55

Where We Started

COASTAL STORM SURGE FLOODING OF UP TO 20 FEET...WITH A FEW SPOTS TO NEAR 25 FEET...ABOVE NORMAL TIDES ALONG WITH LARGE AND DANGEROUS BATTERING WAVES...CAN BE EXPECTED NEAR AND TO THE EAST OF WHERE THE CENTER OF IKE MAKES LANDFALL. THE SURGE EXTENDS A GREATER THAN USUAL DISTANCE FROM THE CENTER DUE TO THE LARGE SIZE OF THE CYCLONE. WATER LEVELS HAVE ALREADY RISEN BY MORE THAN 5 FEET ALONG MUCH OF THE NORTHWESTERN GULF COAST.

Same language and dissemination vehicle (text) as was used over 50 years ago!

The NOAA/NWS Vision

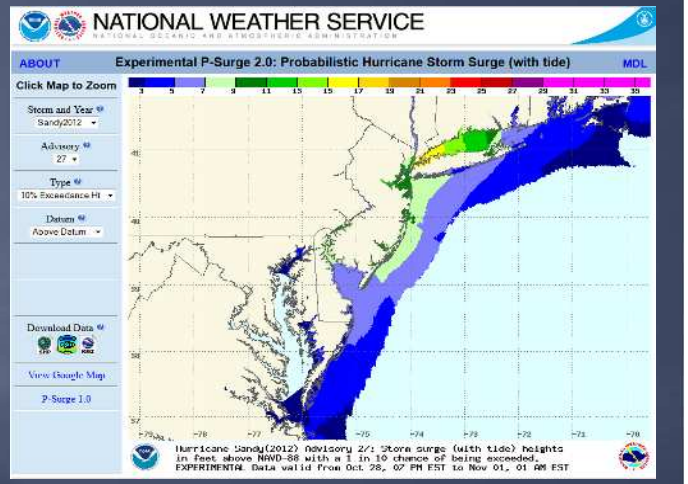
- Improve Storm Surge Guidance
  - Produce water level analyses and forecasts that include all contributions to total water level rise
  - Surge, tides, waves, fresh water, background anomaly
- Transition from deterministic to probabilistic approaches
  - Multi-model ensemble
- Inundation Products
  - Provide information about the water depth over the land (inundation) above ground level (AGL)
- Communicating Actionable Information
  - Provide information that people can act on

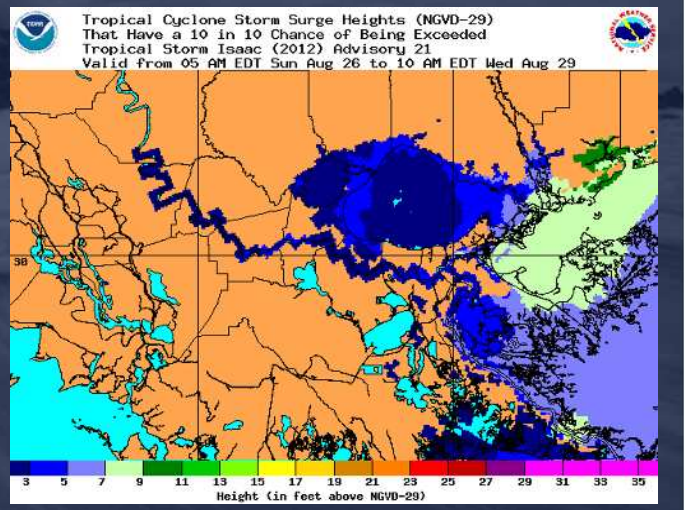
Customer Engagement

Interviews Lee County, FL Citizens Emergency Mangers National Weather Service	FEMA Discussions Emergency Managers National Weather Service Interviews Television	Booths, Exhibits, Polling Emergency Mangers Television Citizens	6 Surveys Emergency Managers Television National Weather Service Public	18 Focus Groups Emergency Mangers Television National Weather Service Community Groups	Product Review Emergency Managers Television 2 Focus Groups Community Members

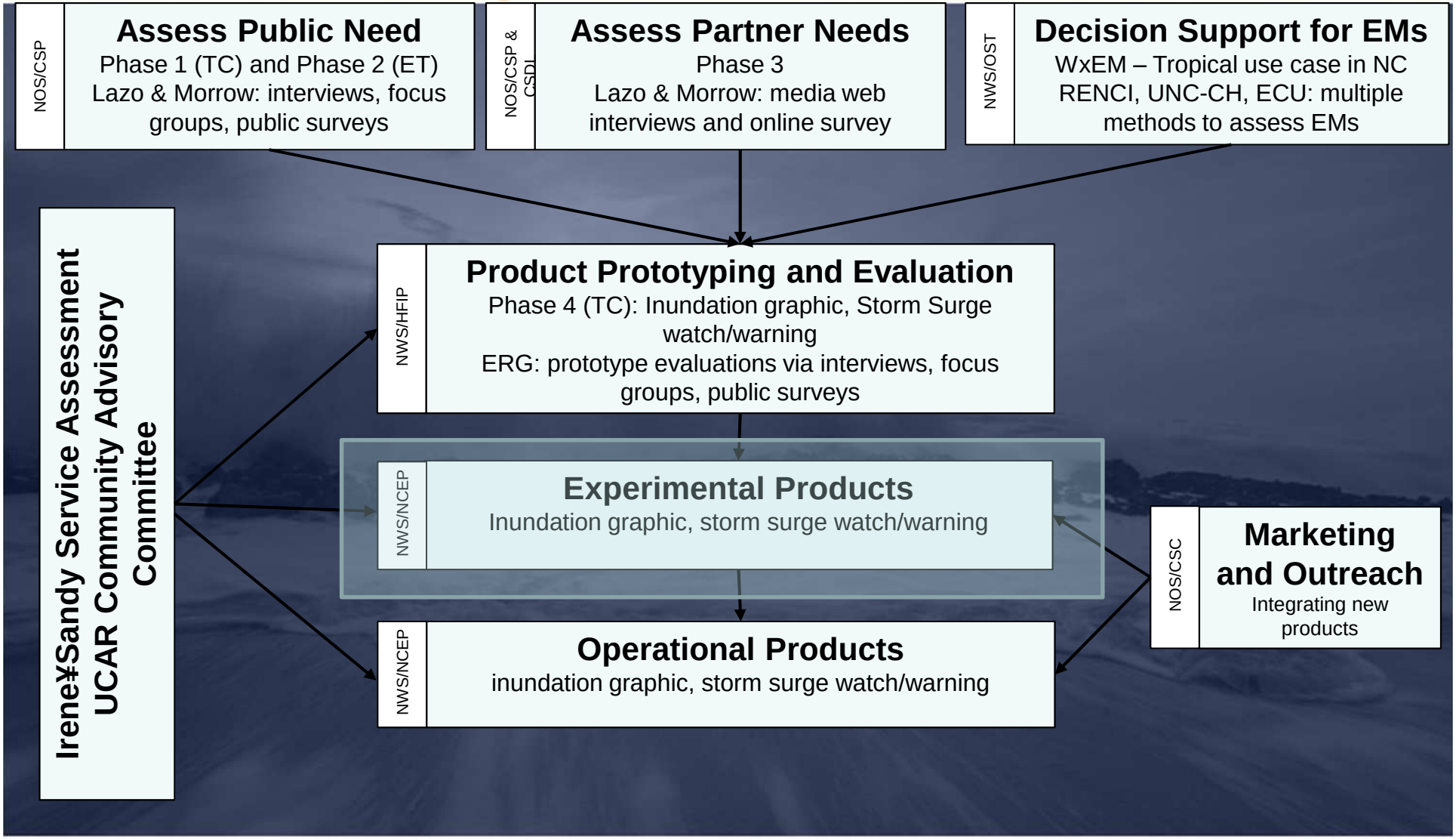
Modeling Upgrades

- Deterministic Versus Probabilistic
  - Eliminated dissemination of deterministic information
  - Official forecasts now based on probabilistic guidance
- Total Water Level
  - Tidal constituents added to probabilistic guidance
  - Background (i.e. steric) anomaly initialized via an initial water level
  - Loose ocean/riverine coupling
  - Addition of near-shore waves (setup) still under research and development
- Vertical Datums
  - Upgraded from NGVD29 to NAVD88
  - Additional vertical datums added for increased versatility





Increased Customer Engagement and Integration of Social Science

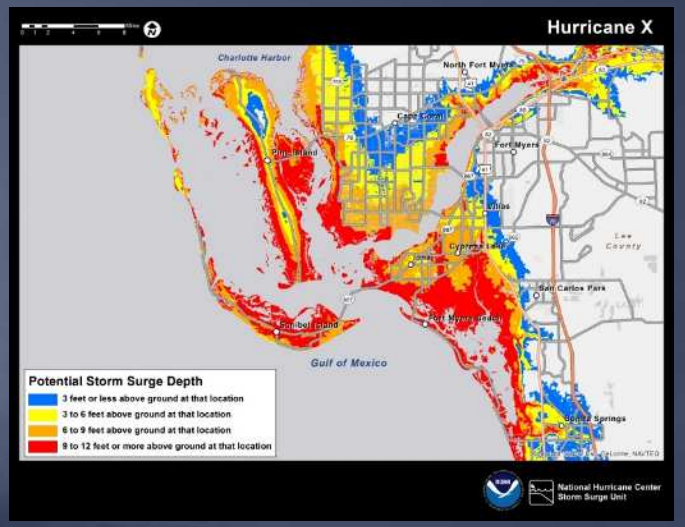


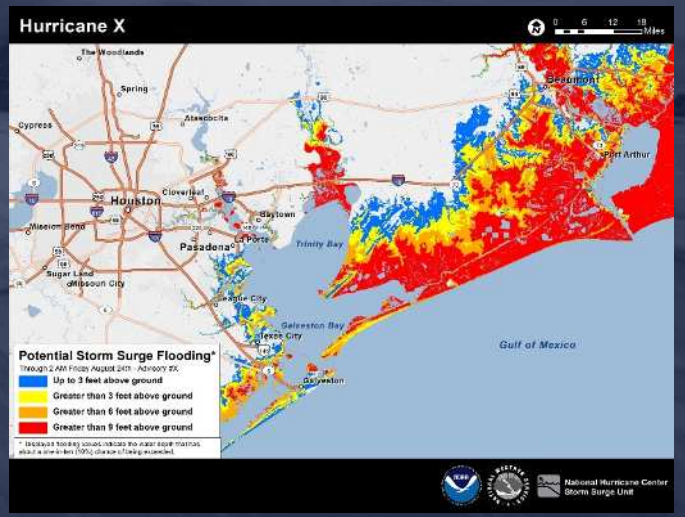
New Product Timeline

- NHC Advisory Text/Format
  - Completed 2012
- Storm surge inundation graphic
  - Experimental in 2014
- Storm surge watch/warning
  - Experimental in 2015

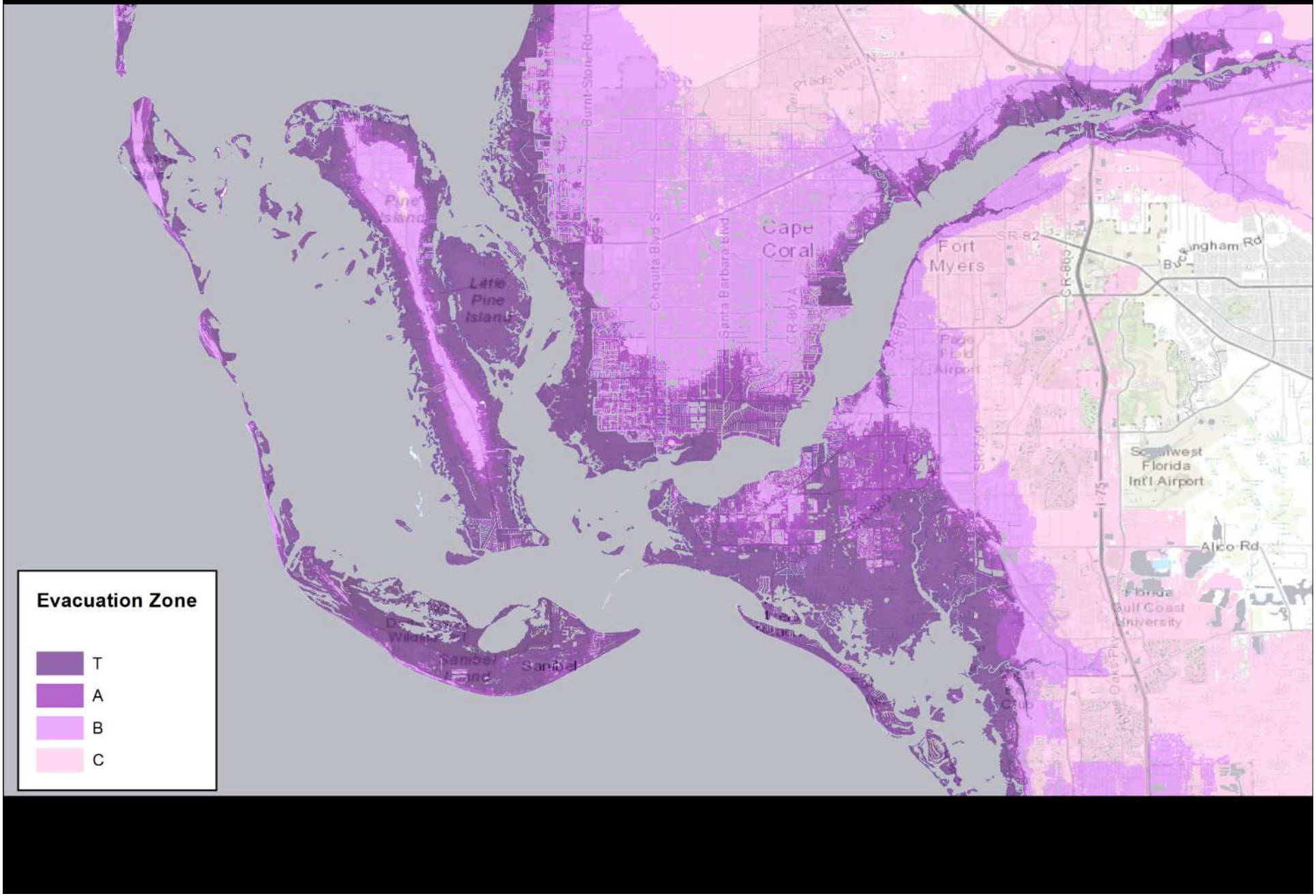
Storm Surge Inundation Graphic

- The entire graphic including colors, labels, thresholds, wording - was tested extensively by social scientists with focus groups
- Implementation of experimental tropical cyclone inundation graphic in 2014
- Lays the foundation for extra-tropical inundation graphic

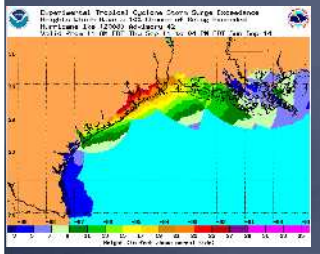


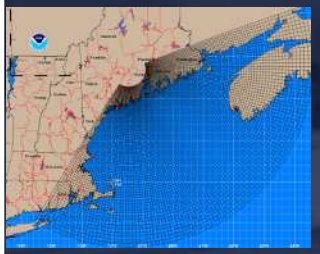


Southwest Florida Evacuation Zones - T, A, B, C



NHC Experimental Inundation Graphic



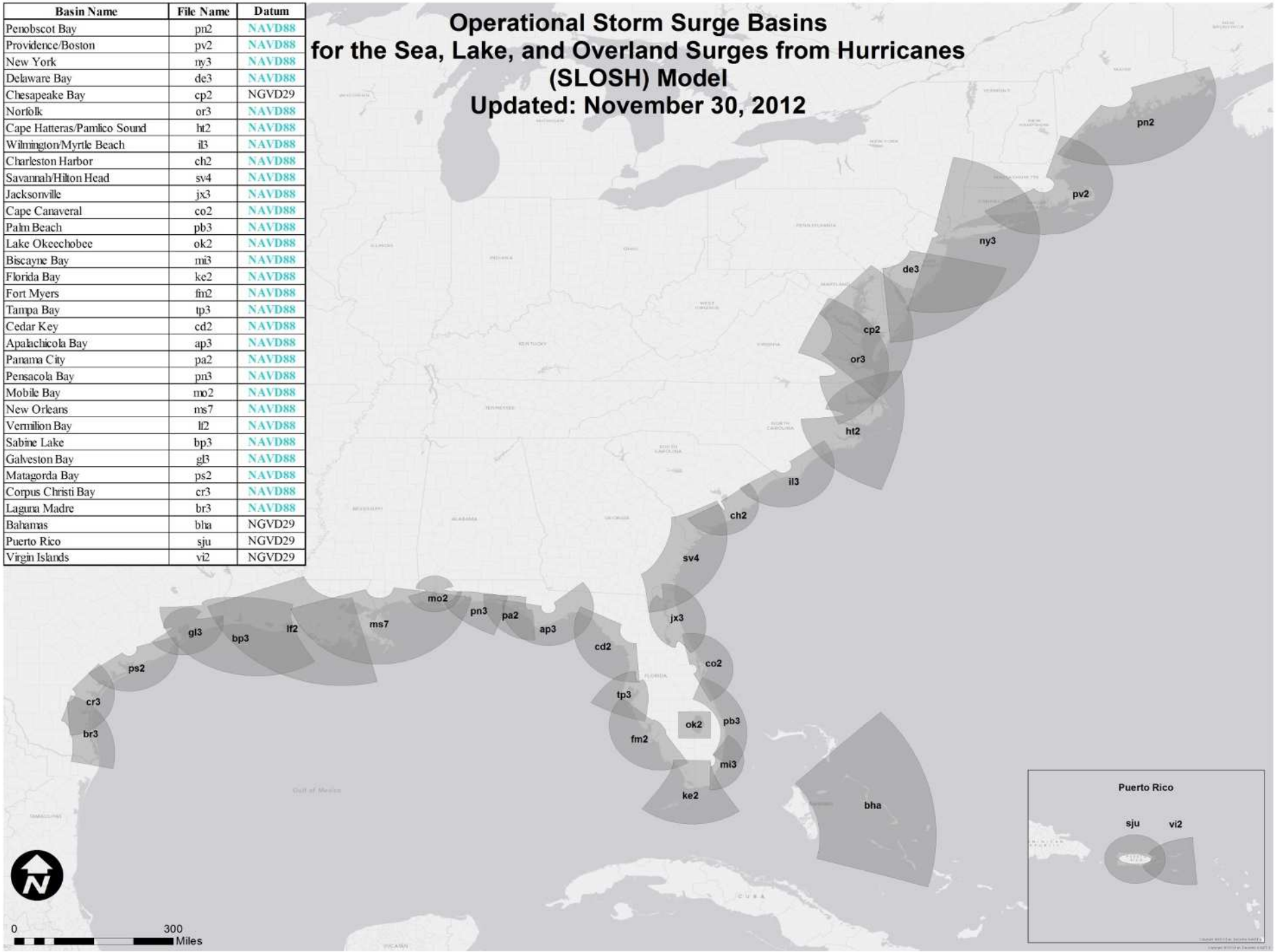


- Which product will drive inundation?
  - Experimental psurge2.0 (includes tides)
  - 10% Exceedance
- Grids
  - Latest SLOSH basins updated to NAVD88
- Topography/DEMs
  - NOAA CSC Sea-level rise DEM
    - Resampled to smoother resolution
  - Augmented with USGS NED
- Processing
  - Locally using ArcGIS for Server and Desktop
  - Working toward automation for 2014 season

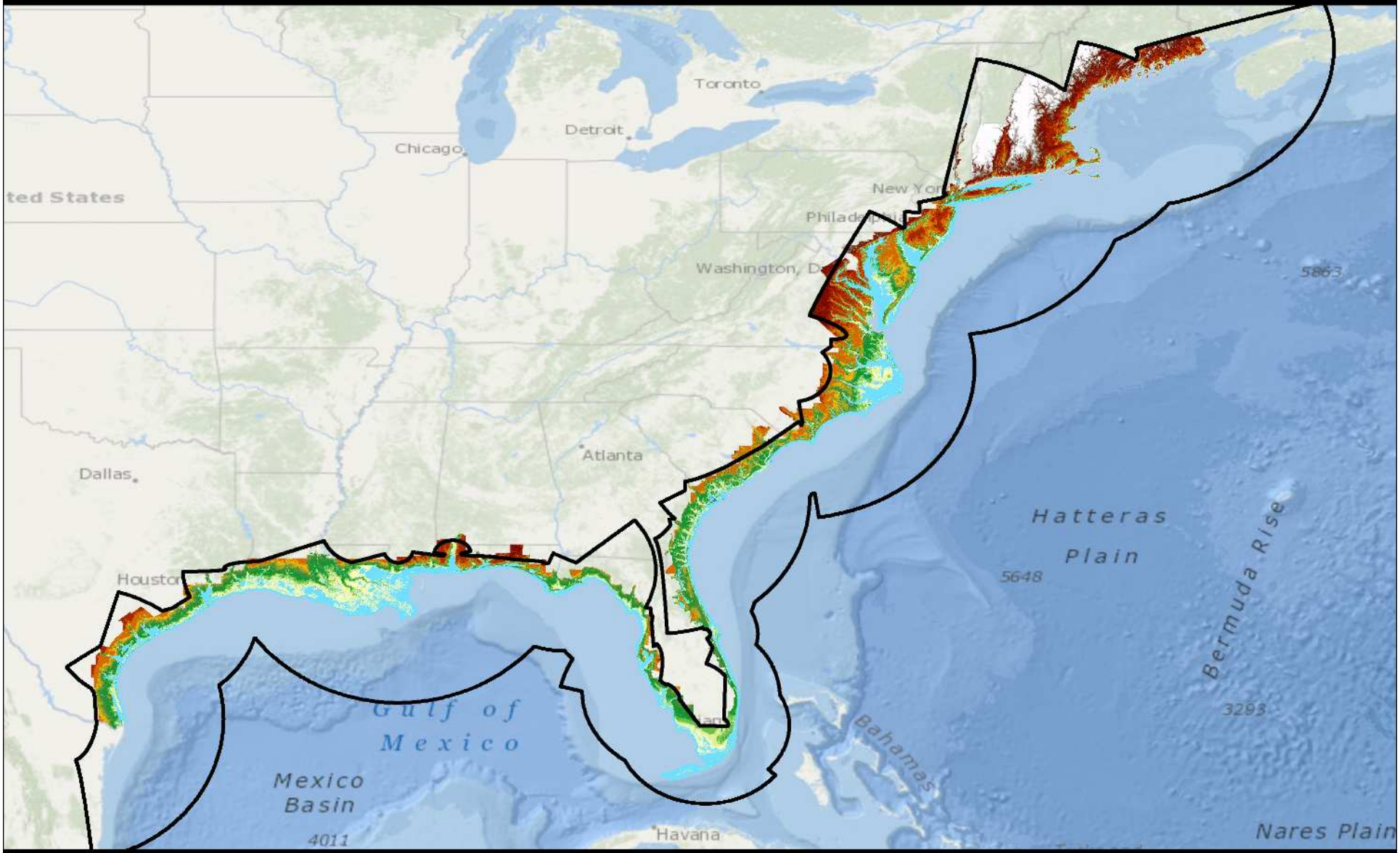
Operational Storm Surge Basins for the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) Model

Updated: November 30, 2012

Basin Name	File Name	Datum
Penobscot Bay	pn2	NAVD88
Providence/Boston	pv2	NAVD88
New York	ny3	NAVD88
Delaware Bay	de3	NAVD88
Chesapeake Bay	cp2	NGVD29
Norfolk	or3	NAVD88
Cape Hatteras/Pamlico Sound	ht2	NAVD88
Wilmington/Myrtle Beach	il3	NAVD88
Charleston Harbor	ch2	NAVD88
Savannah/Hilton Head	sv4	NAVD88
Jacksonville	jx3	NAVD88
Cape Canaveral	co2	NAVD88
Palm Beach	pb3	NAVD88
Lake Okeechobee	ok2	NAVD88
Biscayne Bay	mi3	NAVD88
Florida Bay	ke2	NAVD88
Fort Myers	fm2	NAVD88
Tampa Bay	tp3	NAVD88
Cedar Key	cd2	NAVD88
Apalachicola Bay	ap3	NAVD88
Panama City	pa2	NAVD88
Pensacola Bay	pn3	NAVD88
Mobile Bay	mo2	NAVD88
New Orleans	ms7	NAVD88
Vermilion Bay	lf2	NAVD88
Sabine Lake	bp3	NAVD88
Galveston Bay	gl3	NAVD88
Matagorda Bay	ps2	NAVD88
Corpus Christi Bay	cr3	NAVD88
Laguna Madre	br3	NAVD88
Bahamas	bha	NGVD29
Puerto Rico	sju	NGVD29
Virgin Islands	vi2	NGVD29

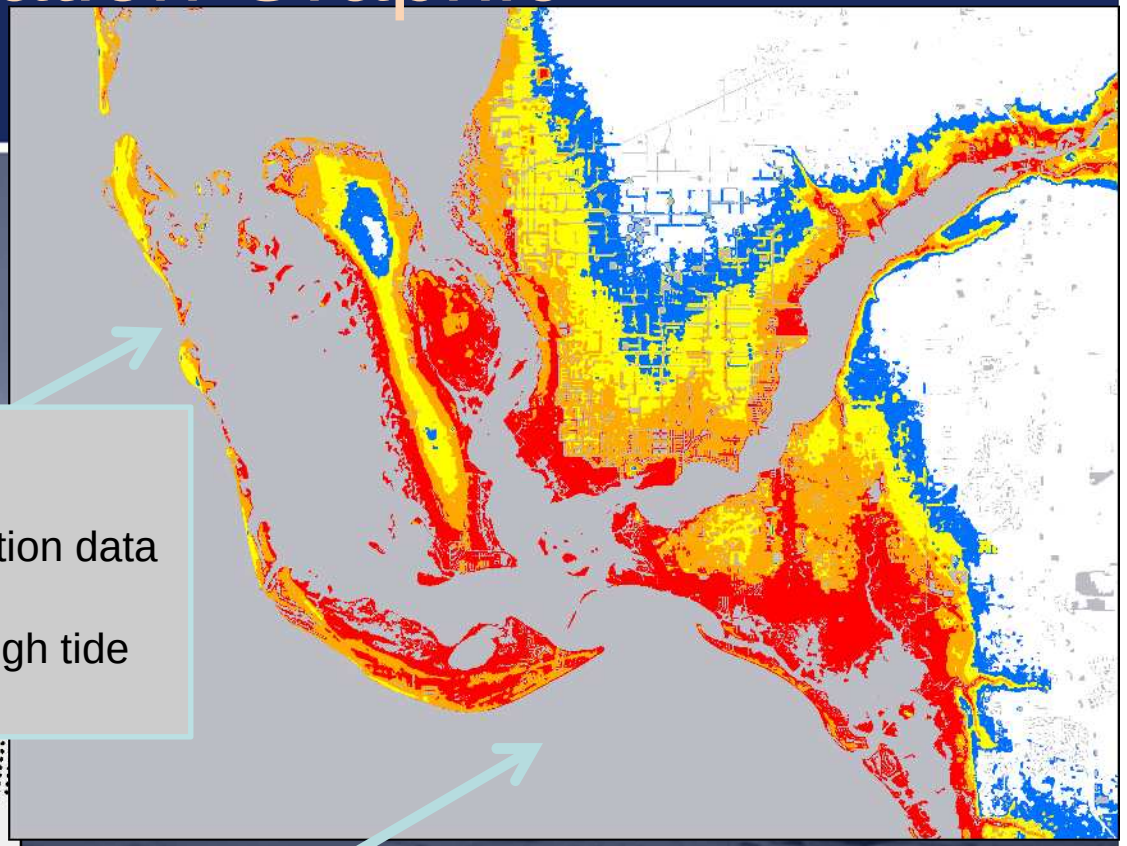


SLOSH Basins and DEMs



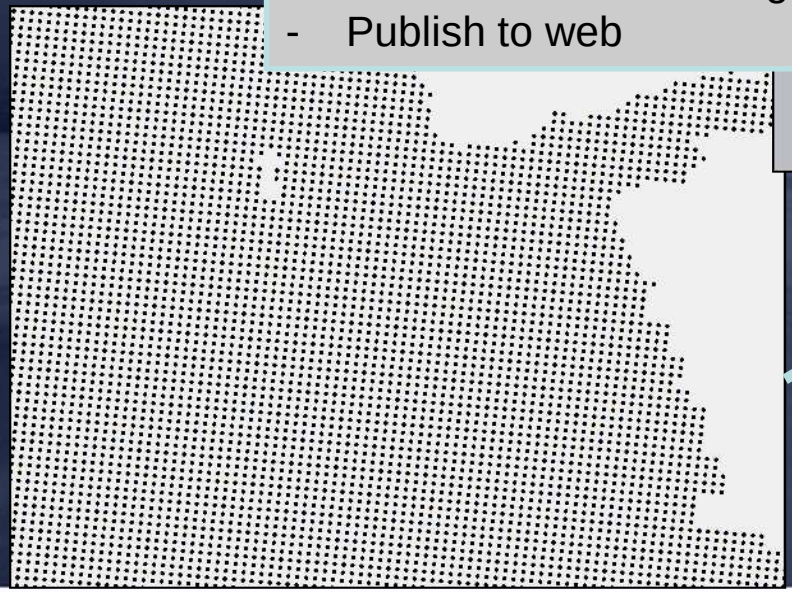
National Hurricane Center
Storm Surge Unit

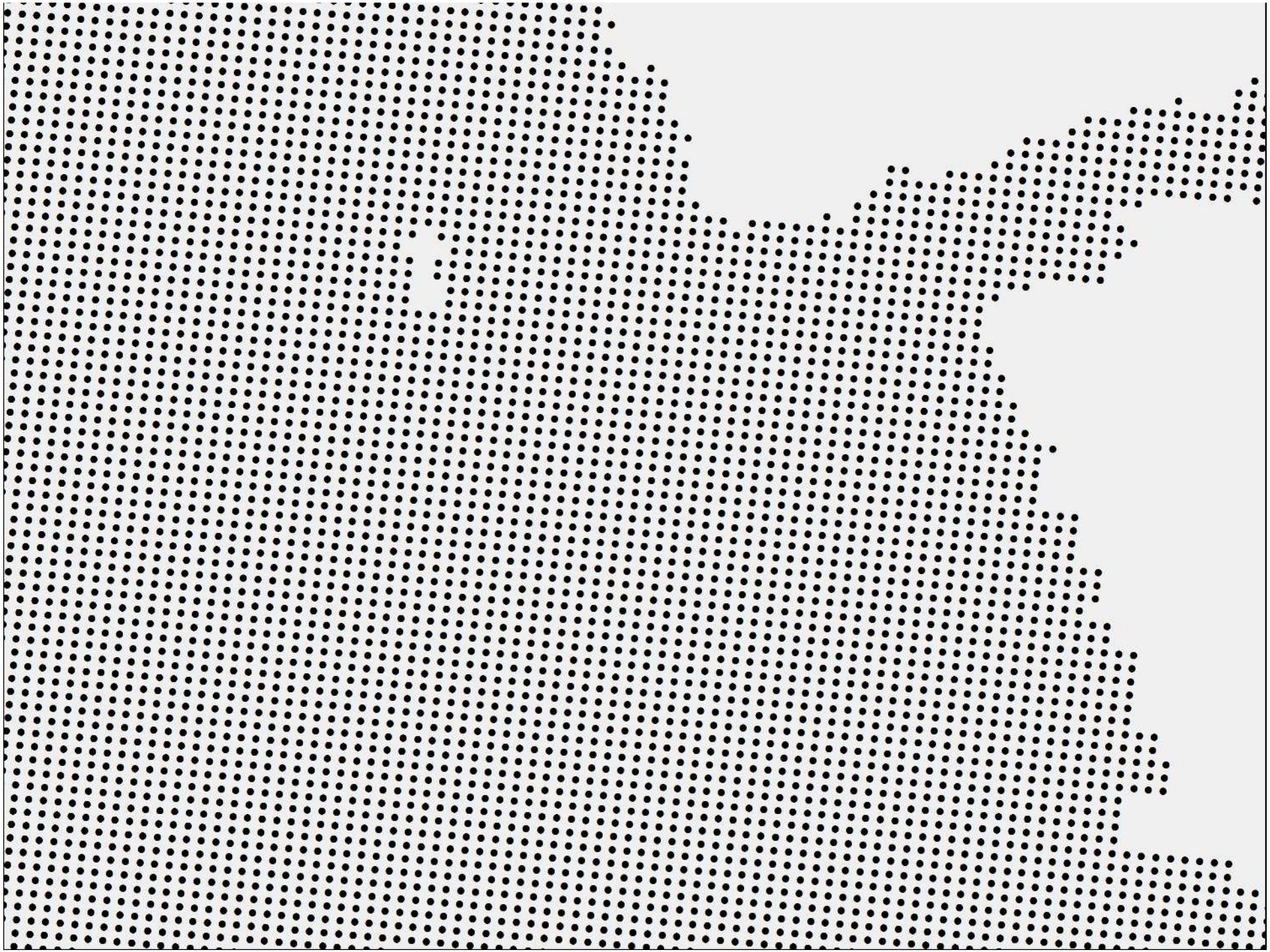
Inundation Graphic



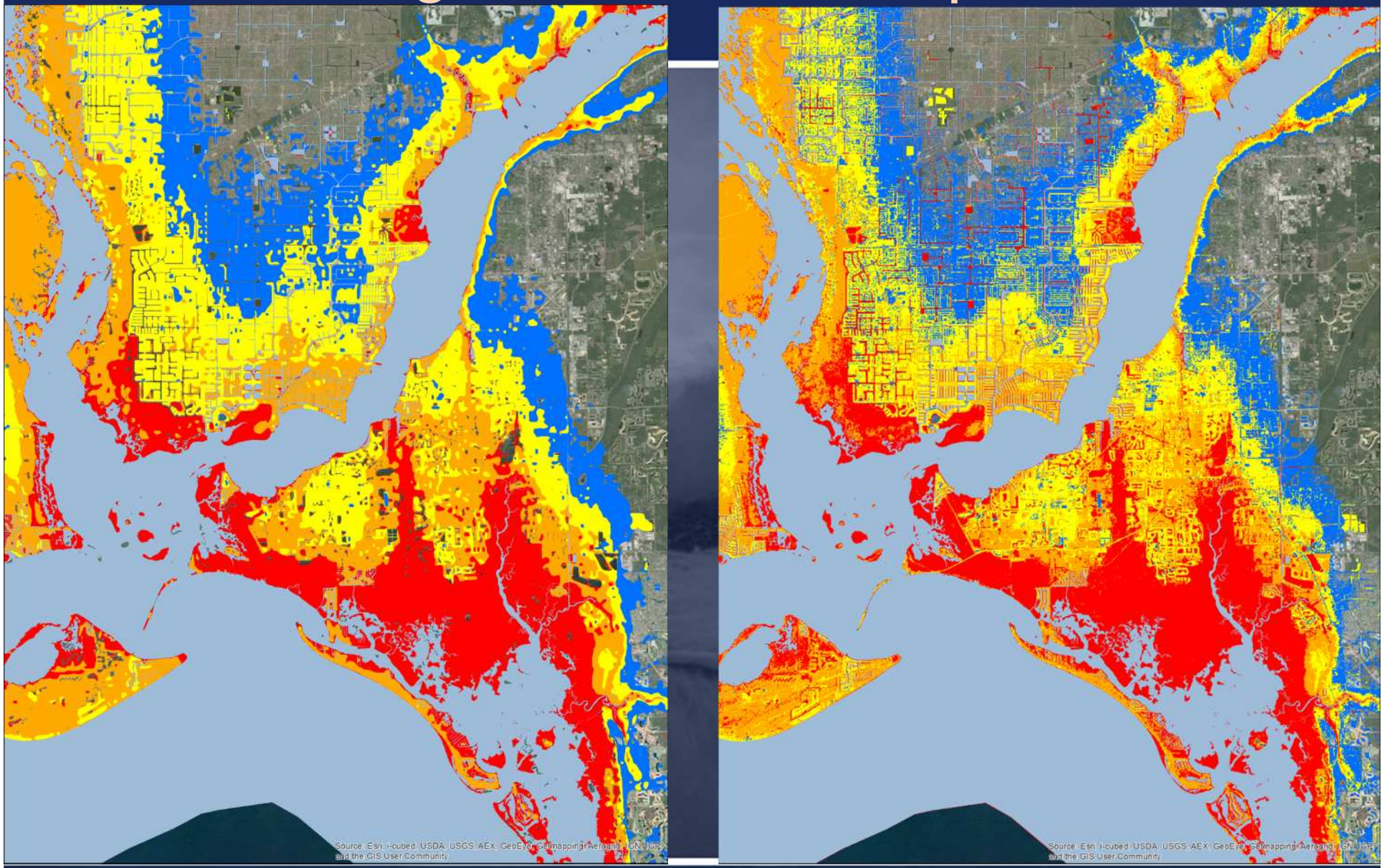
Geoprocessing
- Interpolation
- Processing with elevation data
- Smoothing
- Consider Shoreline/ high tide
- Publish to web

Guidance



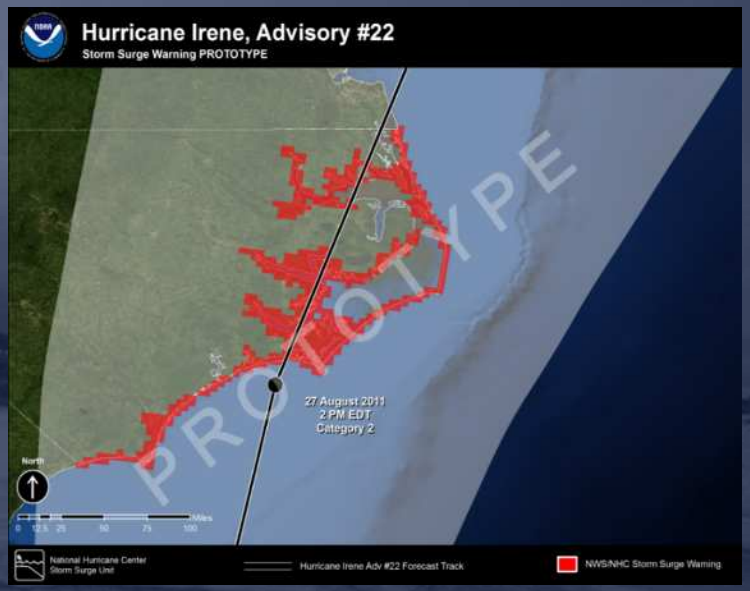


Smoothing Versus Raw Depth Raster



Storm Surge Watch/Warning

- Developing a collaborative process between the National Hurricane Center and local forecast offices to issue tropical cyclone storm surge watches and warnings
  - Collaborative process ensures consistency across all dissemination platforms and offices
  - Incorporates expertise from local offices and the NHC
- Experimental tropical cyclone storm surge watches and warnings in 2015
  - Expanded to include extra-tropical storms (2016/2017)



Takeaways

- Physical science alone will not holistically address storm surge challenges
  - Social sciences must be incorporated
- Clear/consistent communication is critical
- Language/words matter
  - Consistent definitions and frames of reference
  - Use of technical language for a non-technical audience causes confusion

NHC's Storm Surge Unit

Jamie Rhome, Team Lead
Dr. Cristina Forbes
Dr. Brian Zachry
Tarah Sharon
James Brinkley
William Booth
Nathan Hardin
Ethan Gibney

ncep.nhc.ssmia@noaa.gov
(305) 229-4448
hurricanes.gov/surge
@NHC_Surge

Storm Surge Key Milestones

Date	Action	Status
Apr 2013	Storm Surge Inundation Graphic approved by Social Scientists	Complete
Feb 2014	New HLS/TCV examples approved by social scientists	In Progress
May 2014	Develop HLS/TCV requirements	On Track
Jun 2014	Implement P-Surge 2.0	On Track
Jun 2014	Implement experimental tropical inundation graphic	On Track
Jul 2014	Issue Public Information Statement (PNS) announcing experimental test of new TCV	On Track
Aug - Nov 2014	OT&E of experimental TCV at Operations Proving Ground	On Track
Jun 2015	Implement experimental tropical Storm Surge Watch & Warning	On Track
Jun 2015	Implement operational WFO TCV & updated HLS	On Track
Jun 2015	Implement operational TCIG – *approved by social scientists*	On Track
Jun 2016	Implement interactive tropical cyclone web portal	On Track
2016/2017	Implement operational tropical Storm Surge Watch/Warning and inundation graphic	On Track

Interpreting Surge Forecasts

- What does 20 feet of storm surge mean?

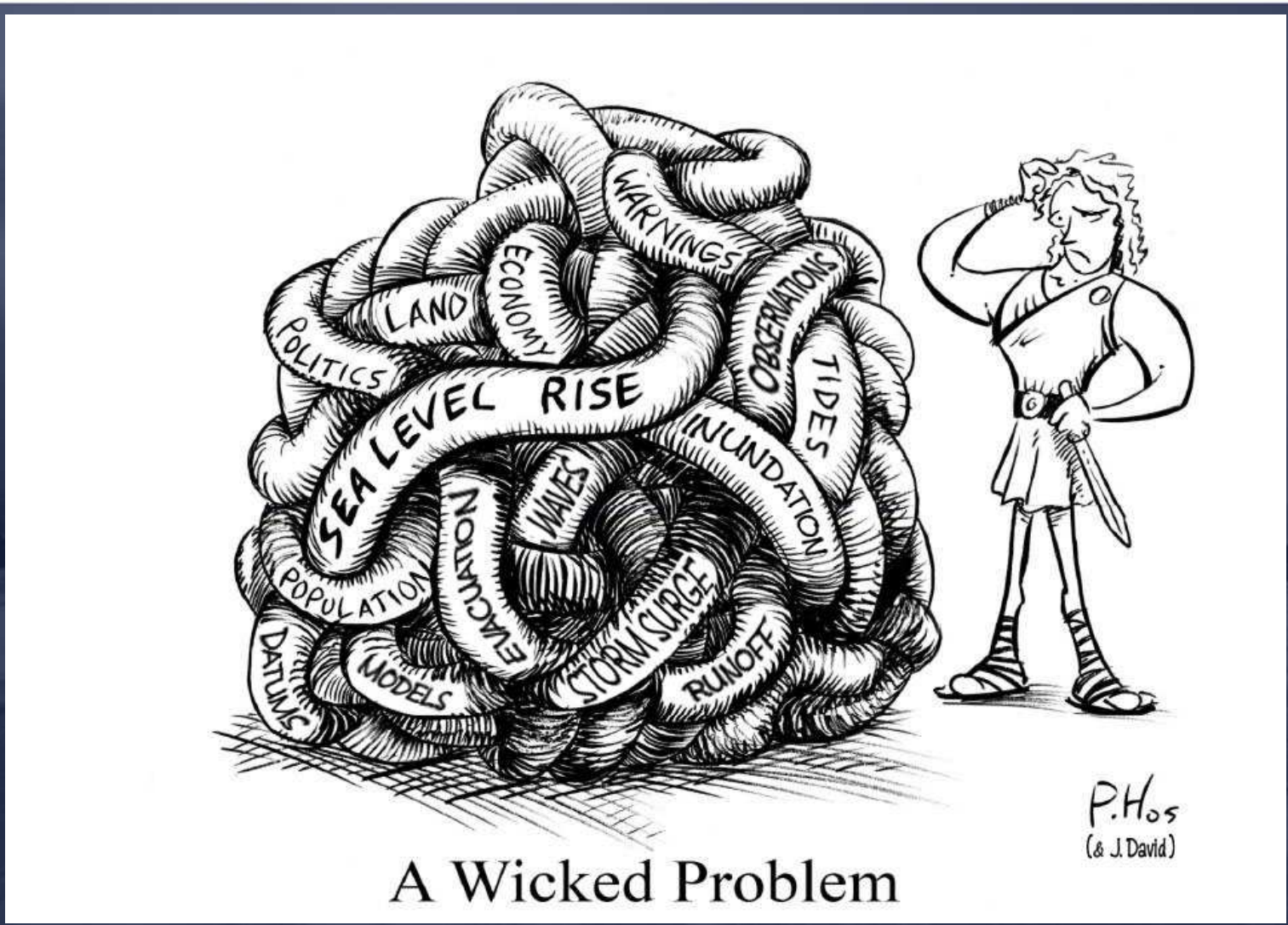
  20 feet of storm surge above ground?
  20 feet of storm surge above mean sea level?

  What is mean sea level?

- All water level observations and models referenced as height above a vertical datum

- A vertical datum is simply a reference level, a zero surface to which storm surge heights are referred

It’s Complicated: Don’t Go it Alone



Probabilistic Versus Deterministic