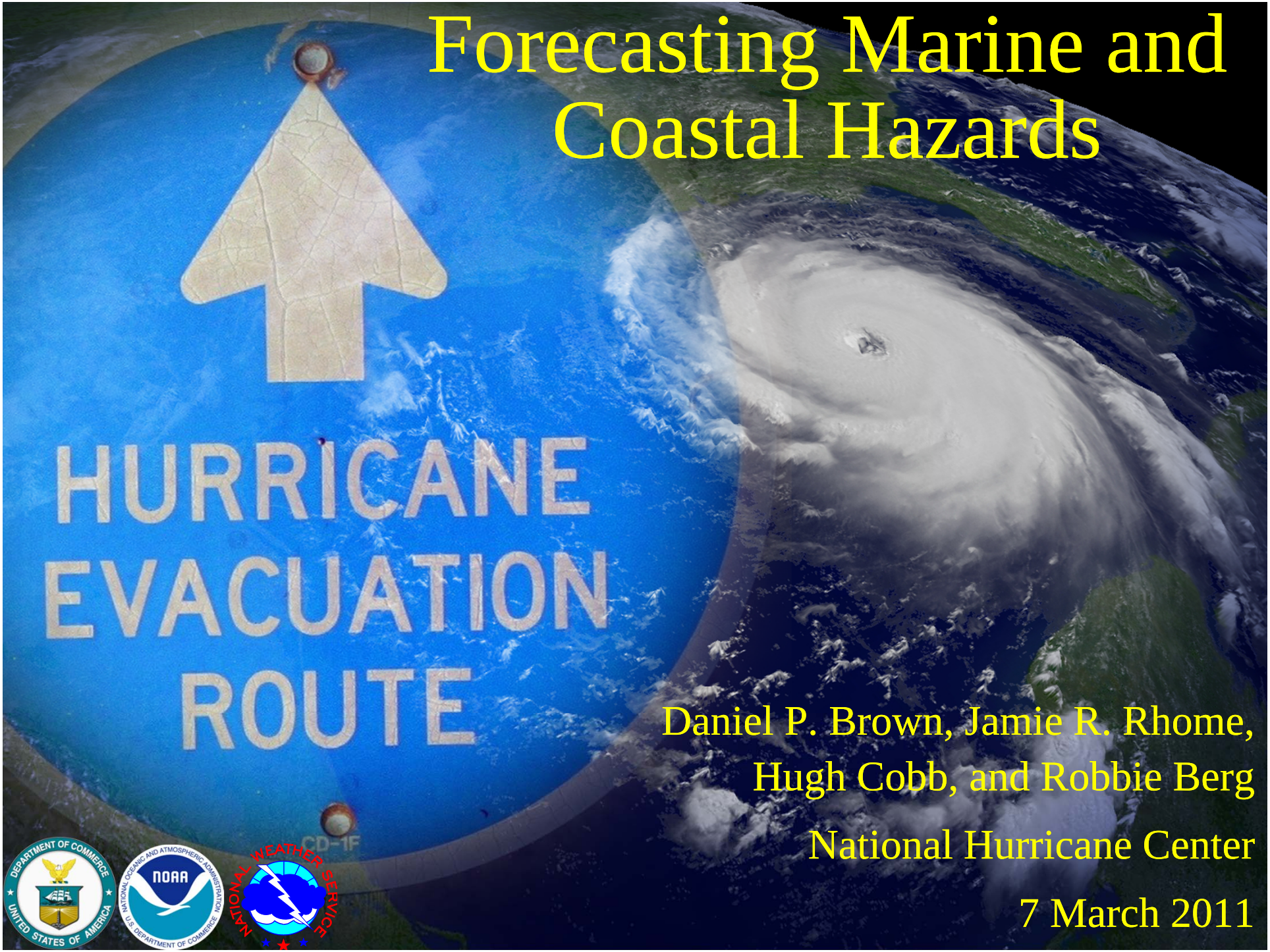
Forecasting Marine and Coastal Hazards



Daniel P. Brown, Jamie R. Rhome,
Hugh Cobb, and Robbie Berg
National Hurricane Center

7 March 2011

National Hurricane Center

Three branches focusing on different hazards

Hurricane Specialist Unit

Develop, coordinate (domestically and abroad), and issue tropical cyclone warnings, forecasts and outlooks in text and graphical formats (~700 full advisory packages/yr)

- Forecasts
- Advisories
- Wind

"Off-season" outreach and public awareness programs

Applied research

Tropical Analysis and Forecast Branch

Marine/ocean and satellite analyses, forecasts and warnings in text and graphical formats 24x7, (~100 products/day)

- Marine hazards

Conduct tropical cyclone (Dvorak) analyses for the hurricane specialists

Augments operational support staffing

Technical Support Branch

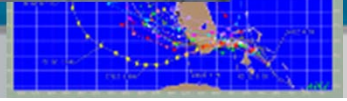
Computer systems support 24x7

Applications development and technology infusion

- Storm Surge

Storm surge guidance (real time; community planning; preparedness)

Emergency operational support staffing



NCEP HPC –Rainfall
NCEP SPC- Tornadoes
NCEP OPC- Marine (north of 31N)

NWS Marine and Coastal Weather Services

Mission

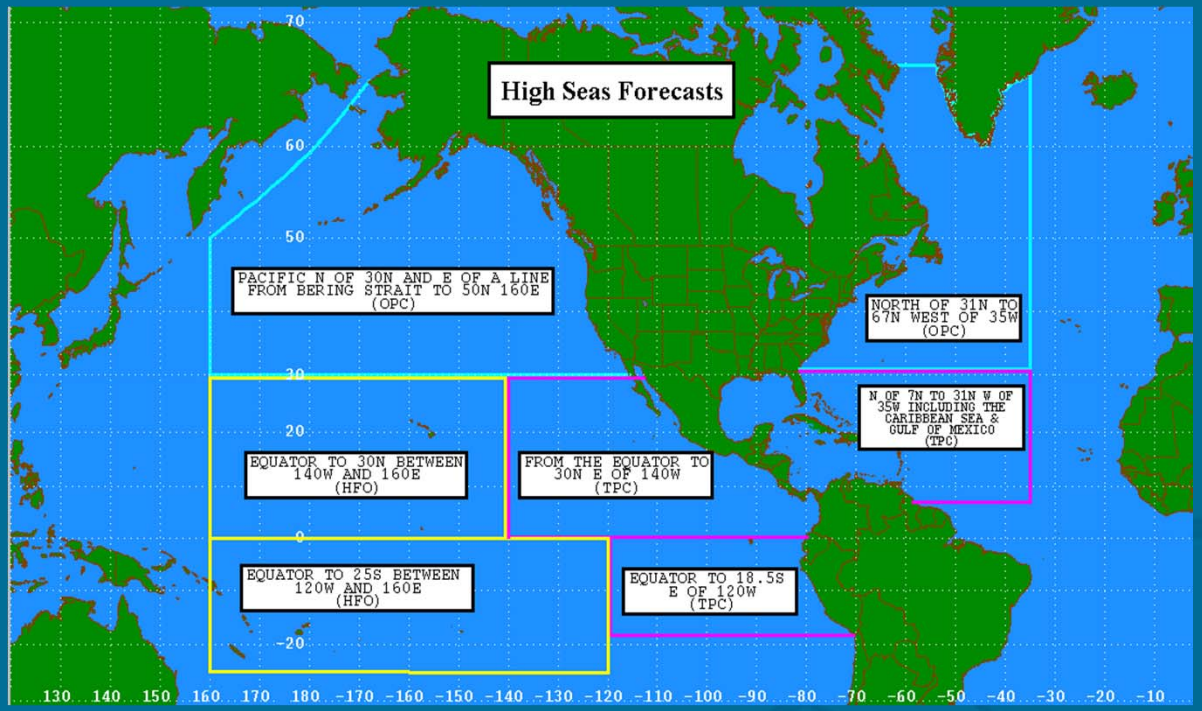
To lead the U.S. coastal and marine weather forecast and warning programs for the protection of life and property, promotion of economic benefits, and the enhancement of quality of life.

Vision

All marine customers meet their safety needs and other concerns through ready access to accurate, timely, easily understood and technologically advanced forecasts, warnings and other products.

High Seas Marine Forecasts and Warnings

- Atlantic, Pacific, Caribbean & Gulf of Mexico
  - NCEP
    - Ocean Prediction Center
    - Tropical Analysis and Forecast Branch



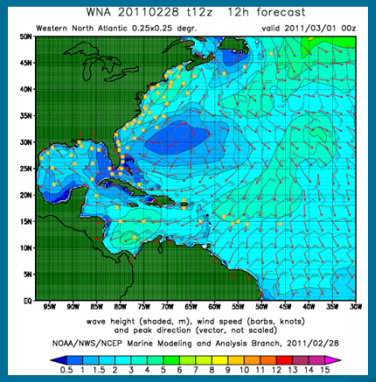
High Seas Graphic Forecasts extend to Europe and Asia

National Hurricane Center
Tropical Analysis Forecast Branch (TAFB)

- Year round (24/7/365) products
  - Marine forecasts (graphical and text) and discussions (MIM)
  - Surface analyses and discussions (TWD)
  - Satellite-derived rainfall estimates
- Hurricane Season – 15 May – 30 November
  - Tropical cyclone intensity estimates using Dvorak technique
  - Media support to NHC (English, Spanish, French)
  - Radar tracking of tropical cyclones
  - Forecast support to Hurricane Specialists

Marine Forecast Tools

- **Surface Observations**
  - METAR, Moored platforms (Buoy/CMAN) and Ships
- **NWP Guidance**
  - Global Models (GFS, ECMWF, UKMET, NOGAPS)
  - Regional Models (NAM, SREF)
  - Global Wave Model (NWW3)
- **Satellite Tools**
  - Geostationary (GOES 11-12-13)
  - Polar Orbiting
    - Microwave (TRMM, AMSR-E, SSM/I)
    - Scatterometer (WindSAT, ASCAT)
    - ***Loss of QuikSCAT Nov 23, 2009 – Big Impact on operations***



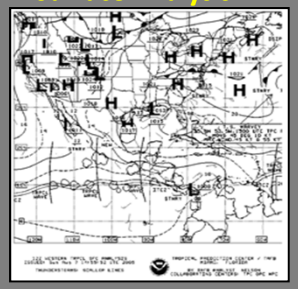
Suite of Marine Radiofax Charts Produced by TAFB

Pt. Reyes and Honolulu Radiofax

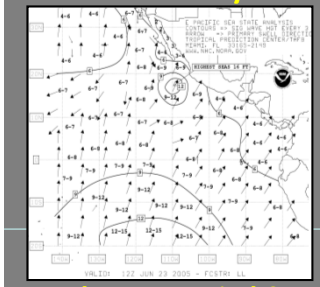
Pt. Reyes Broadcast Frequencies
4346 kHz
8682 kHz
12786 kHz
17151.2 kHz
22527 kHz

Honolulu Broadcast Frequencies
9982.5 kHz
11090 kHz
16135 kHz
23331.5 kHz

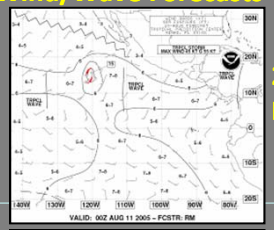
Surface Analysis

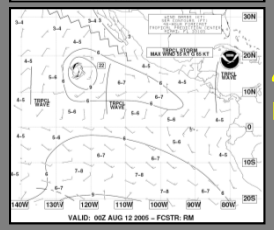


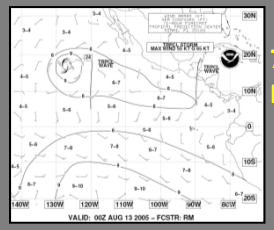
Sea State Analysis



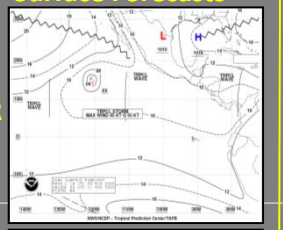
Wind/Wave Forecasts

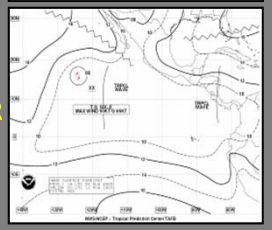


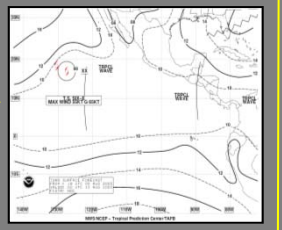




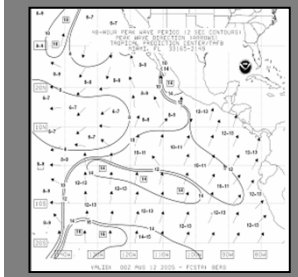
Surface Forecasts

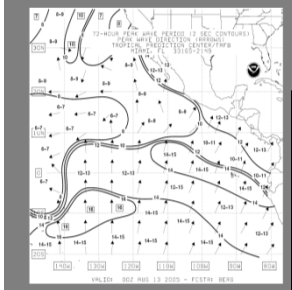




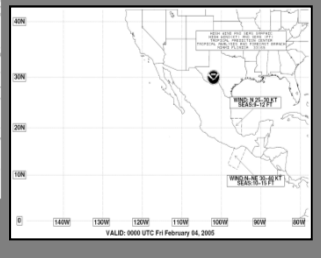


Peak Wave Period & Swell Direction

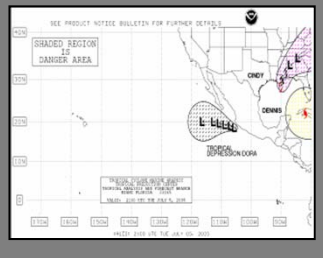




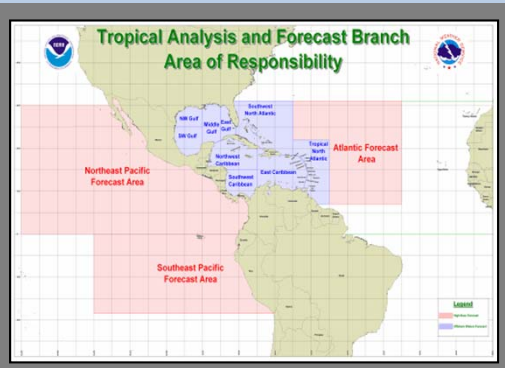
High Wind Graphic



TC Danger Graphic

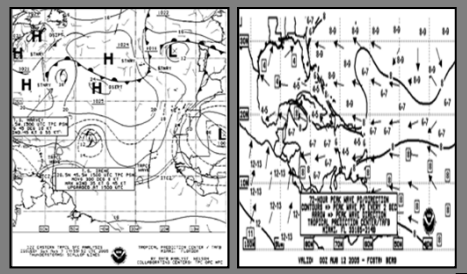


Tropical Analysis and Forecast Branch Area of Responsibility



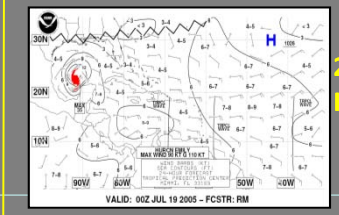
New Orleans Radiofax

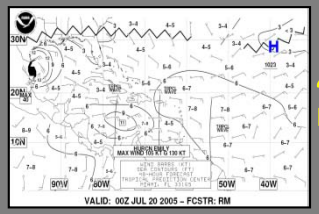
Surface Analysis

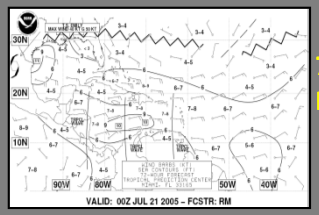


New Orleans Broadcast Frequencies
4317.9 kHz
8503.9 kHz
12789.9 kHz

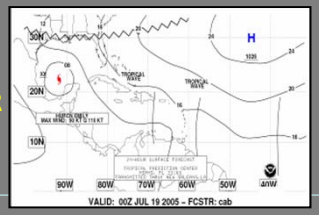
Wind/Wave Forecasts

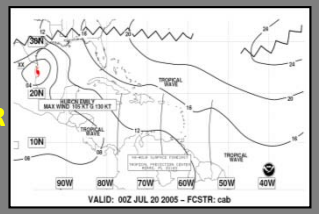


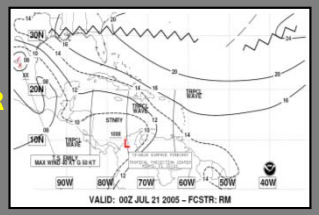




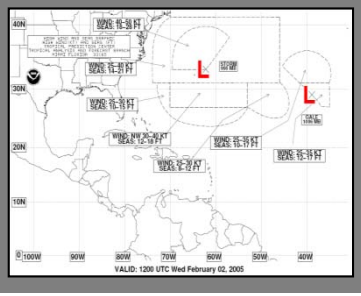
Surface Forecasts



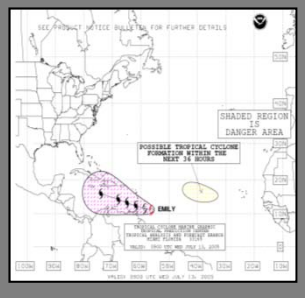


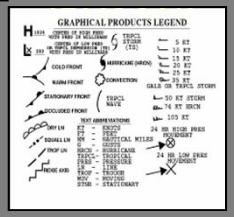


High Wind Graphic

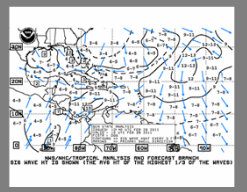


TC Danger Graphic

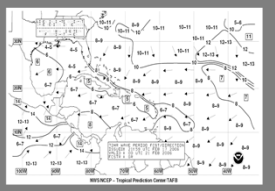




Sea State Analysis

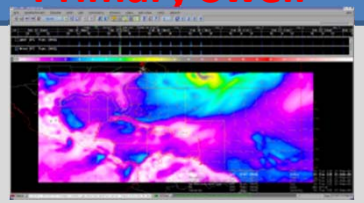


Peak Wave Period & Swell Direction



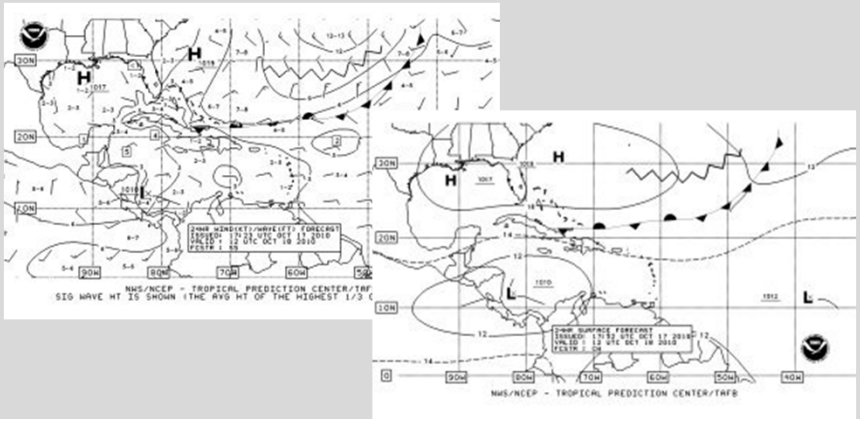
Gridded Marine Forecasts
Graphical Marine Forecasts in GFE

Grids edited in GFE
MSLP
10-M Winds and Gusts
Sig Wave Heights
Primary Swell

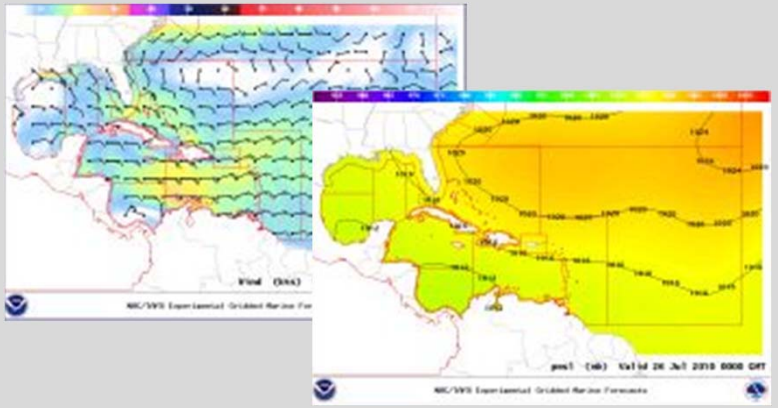


NetCDF to GEMPAK conversion

Populate marine parameter layers in NAWIPS for legacy marine graphics



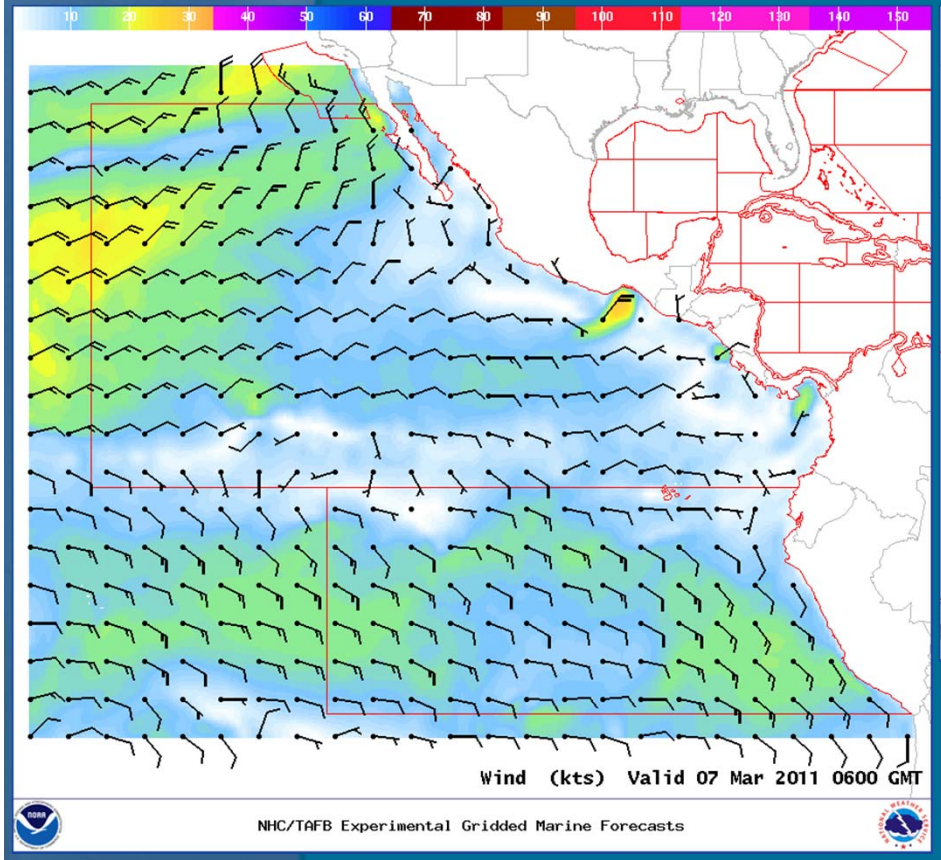
Create experimental gridded marine Forecasts on the web



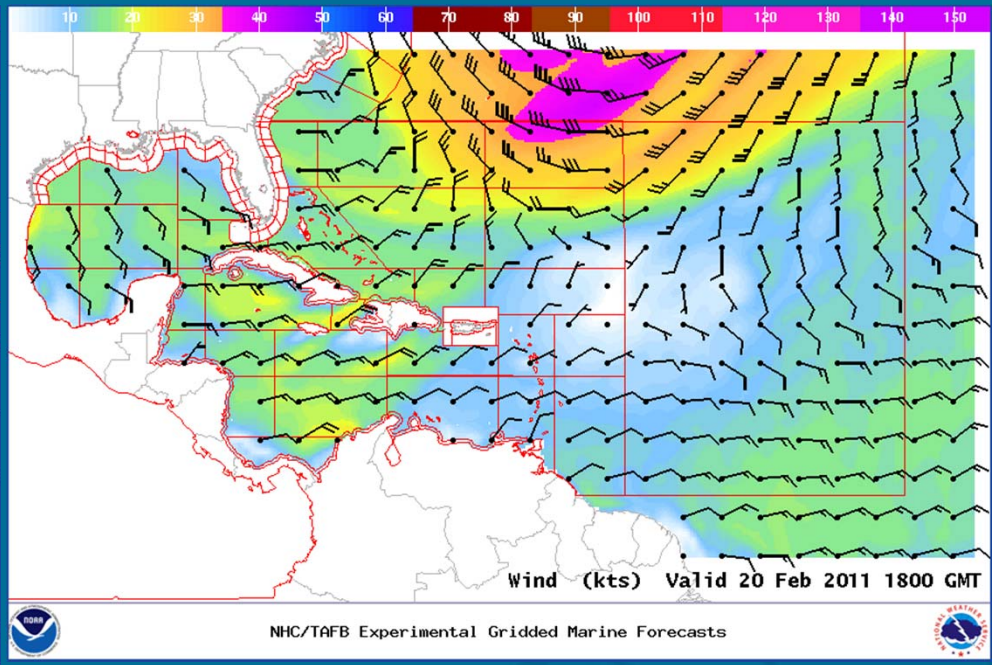
Experimental Gridded Marine Forecasts

www.nhc.noaa.gov/marine_forecasts.shtml

East Pacific

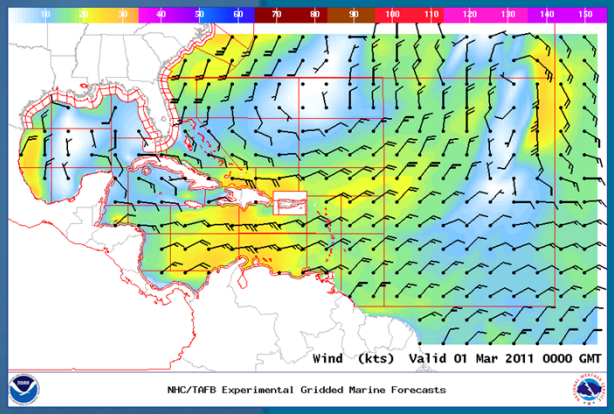


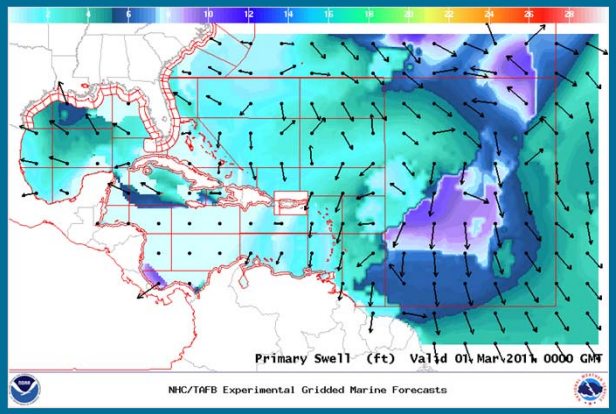
Atlantic

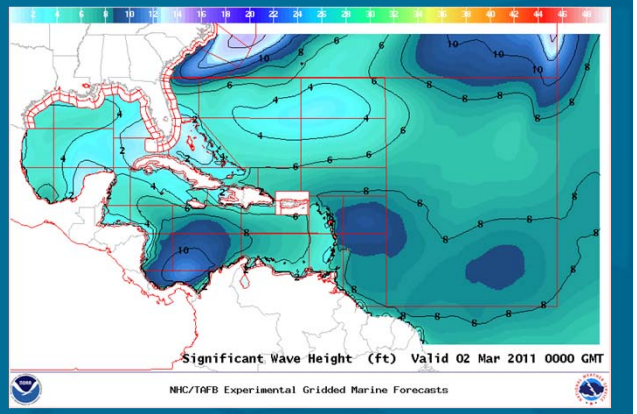


Advantages of Gridded Forecasts

- Model blending tool can be used to create ensemble of NWP solutions
- Tropical cyclone wind tool incorporates wind radii from NHC forecasts (TCM) with forecasters blending radii into the ambient wind field
- Grids used to create legacy charts to ensure forecast consistency

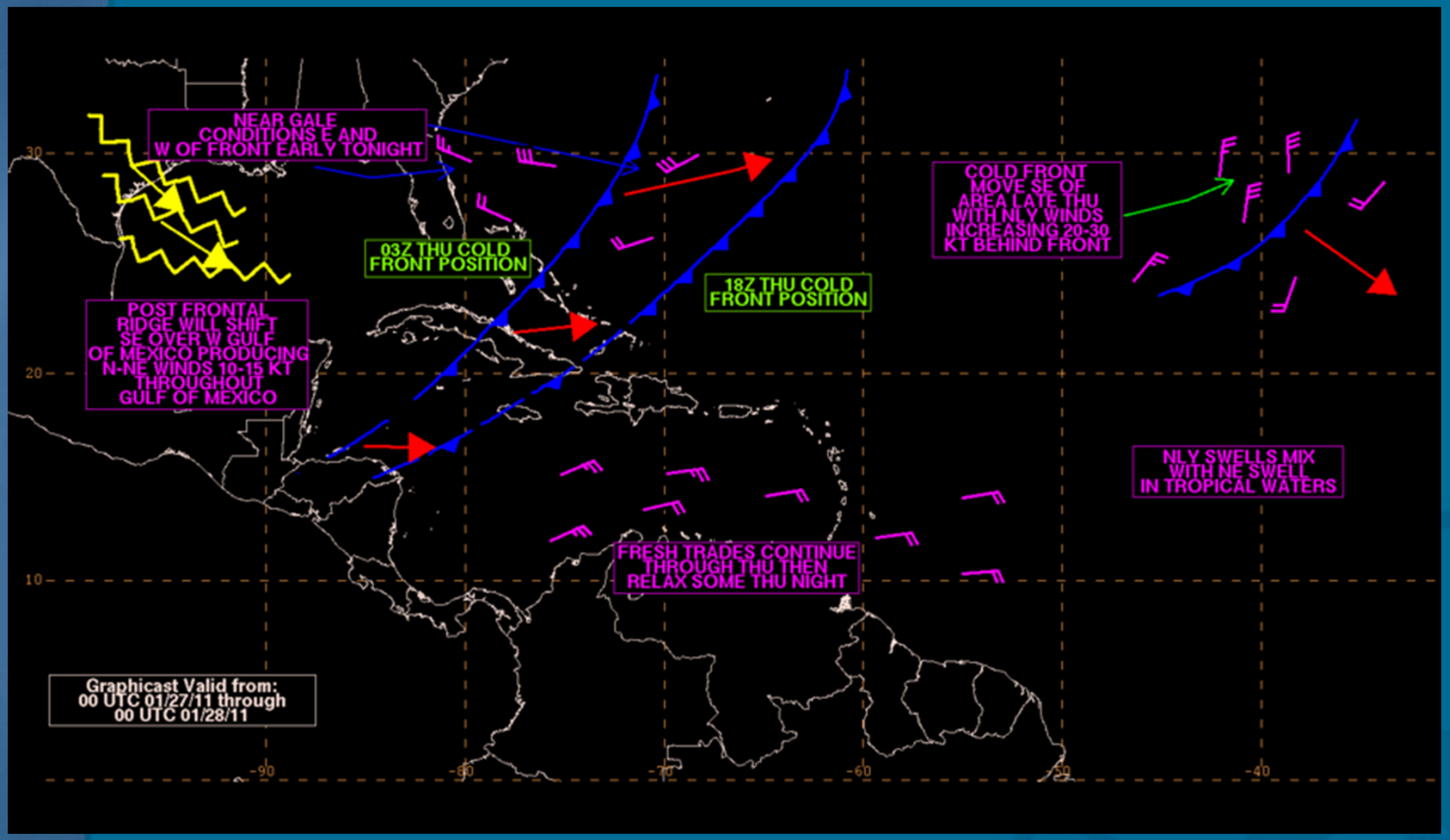




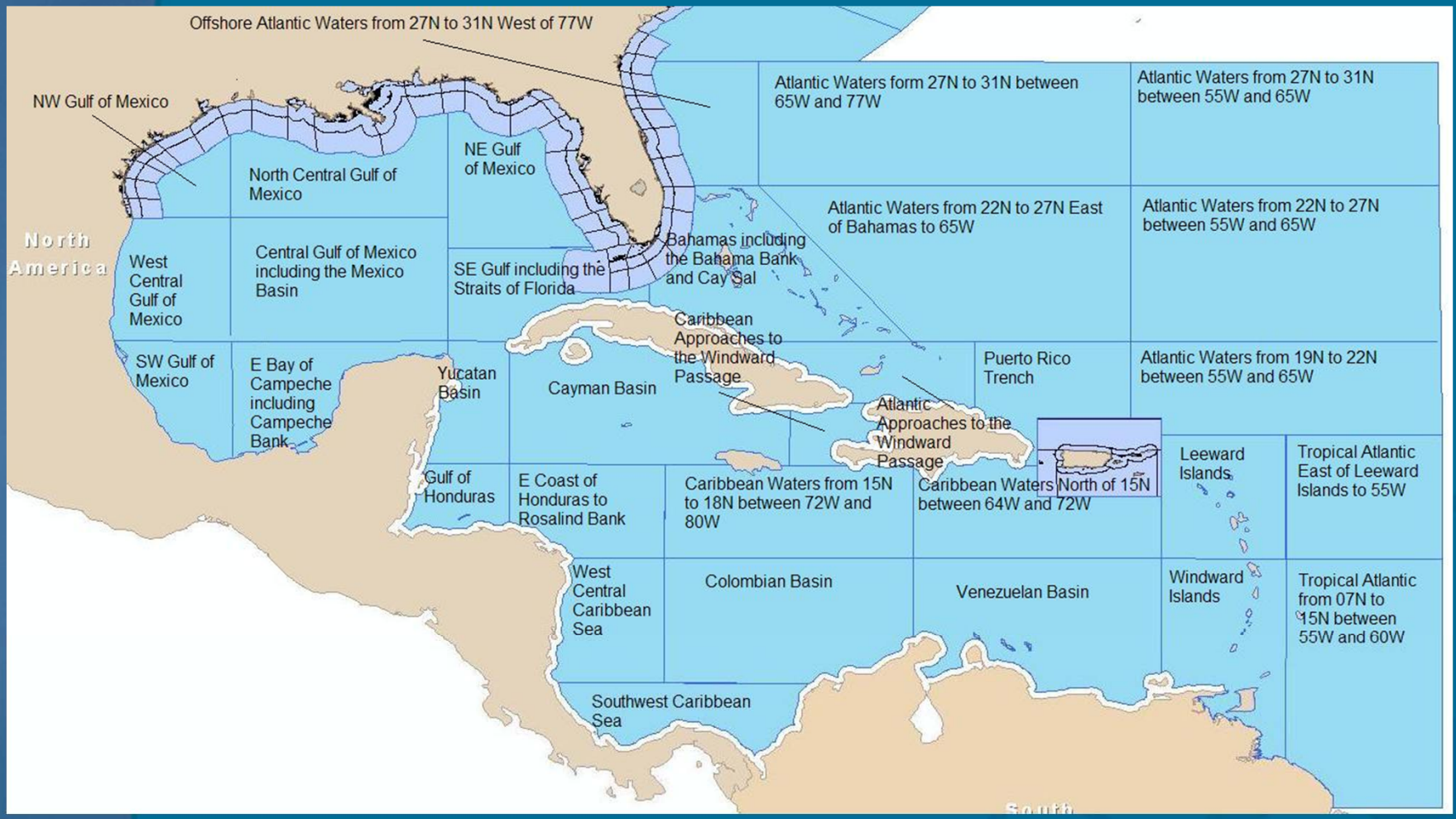


Experimental Decision Support Graphicast

- Highlights current areas of significant marine weather



New, More Detailed Offshore Marine Zones Coming Soon



Future Plans for TAFB Marine Products and Support

- 4X a day issuance of Sea State - Fall 2011
- Locally run WW3 model using NHC tropical cyclone forecasts – JHT project – Fall/Winter 2011-12
- Enhance marine products on the web
  - Point and click forecasts (MFM, Zones)
- Enhanced Decision Support Services (Local high resolution grids)
- Enhanced Ecological Support Services (HAB, Oil Spill)
- Collaborate gridded marine forecasts with International MET services

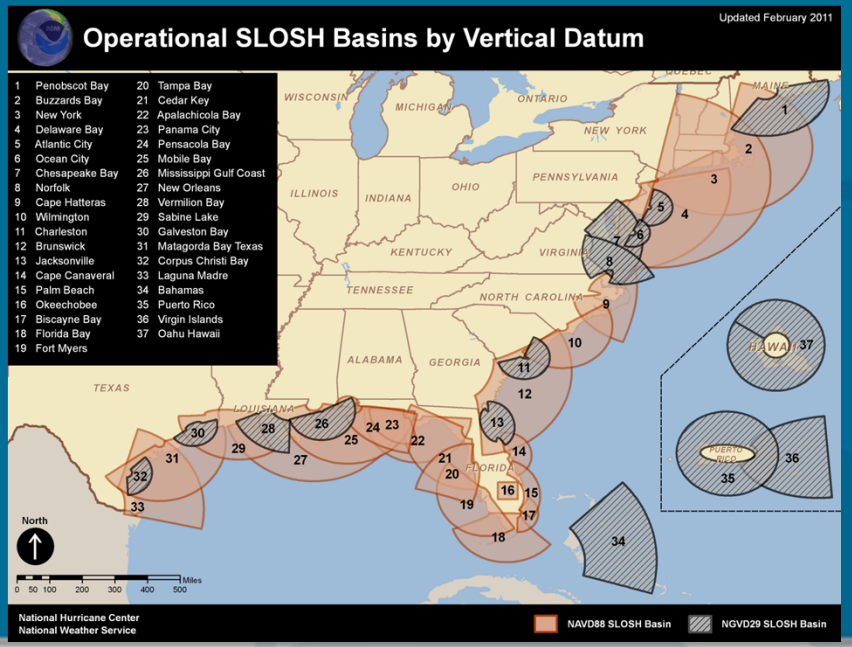
NHC Storm Surge Team
Forecasting Surge

- Storm surge models are HIGHLY dependent on the accuracy of the meteorological input!!!
- Meteorological uncertainty will dominate over storm surge model specifications (physics, resolution, etc)
- Different vertical datums/reference levels
- Storm surge is only one component in the real water level rise.
  - Total water rise = surge + tides + waves + freshwater flow

SLOSH

NWS/NHC Operational Surge Model

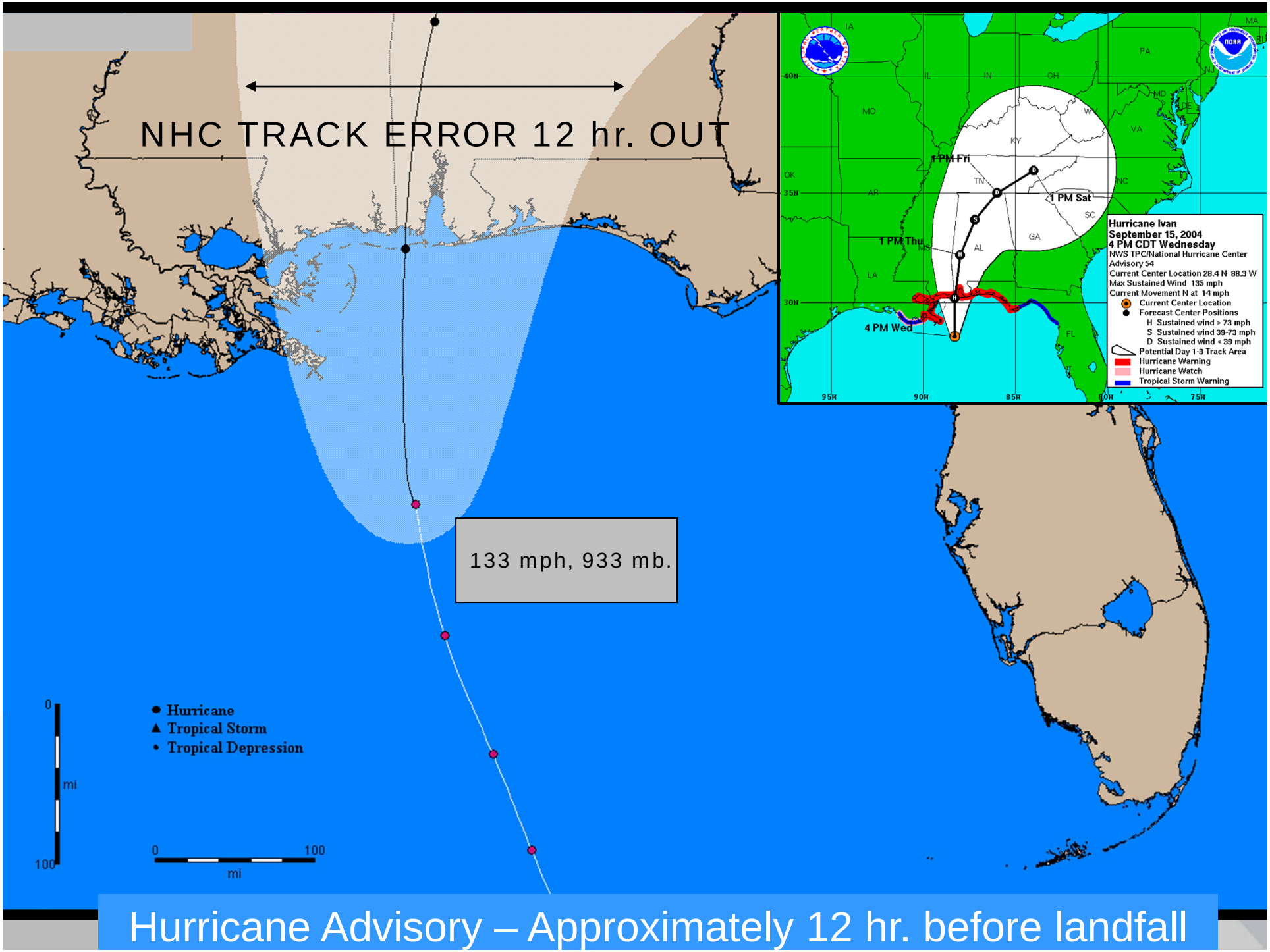
- Sea, Lake, and Overland Surges from Hurricanes
- A computerized numerical model developed by the National Weather Service (NWS) to estimate storm surge heights (and winds) resulting from historical, hypothetical, or predicted hurricanes



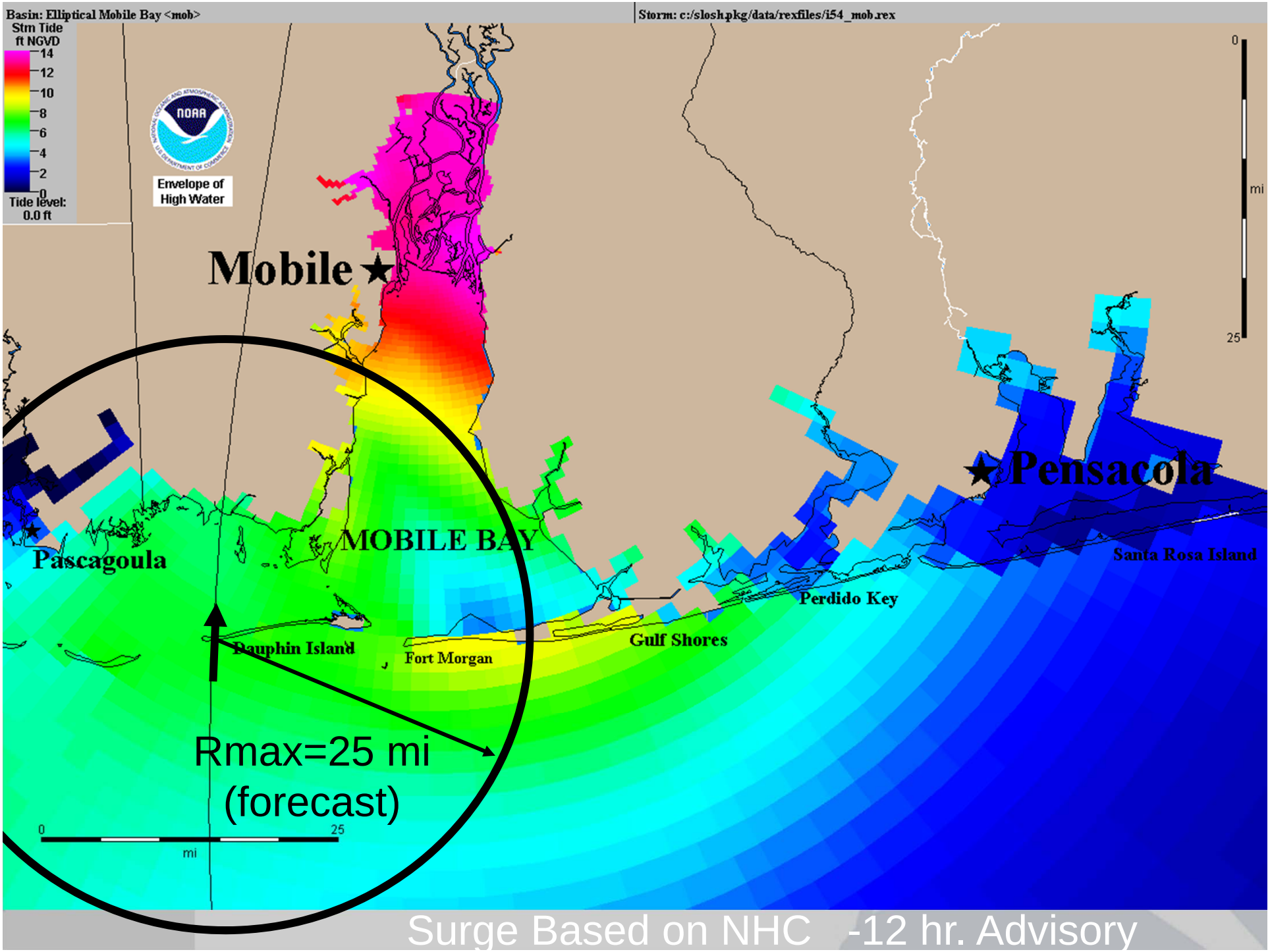
SLOSH

- SLOSH does include:
  - Flow through barriers/gaps/passes
  - Deep passes between bodies of water
  - Inland inundation (wet/dry cell)
  - Overtopping of barrier systems, levees, and roads
  - Coastal reflection (coastally trapped Kelvin waves)

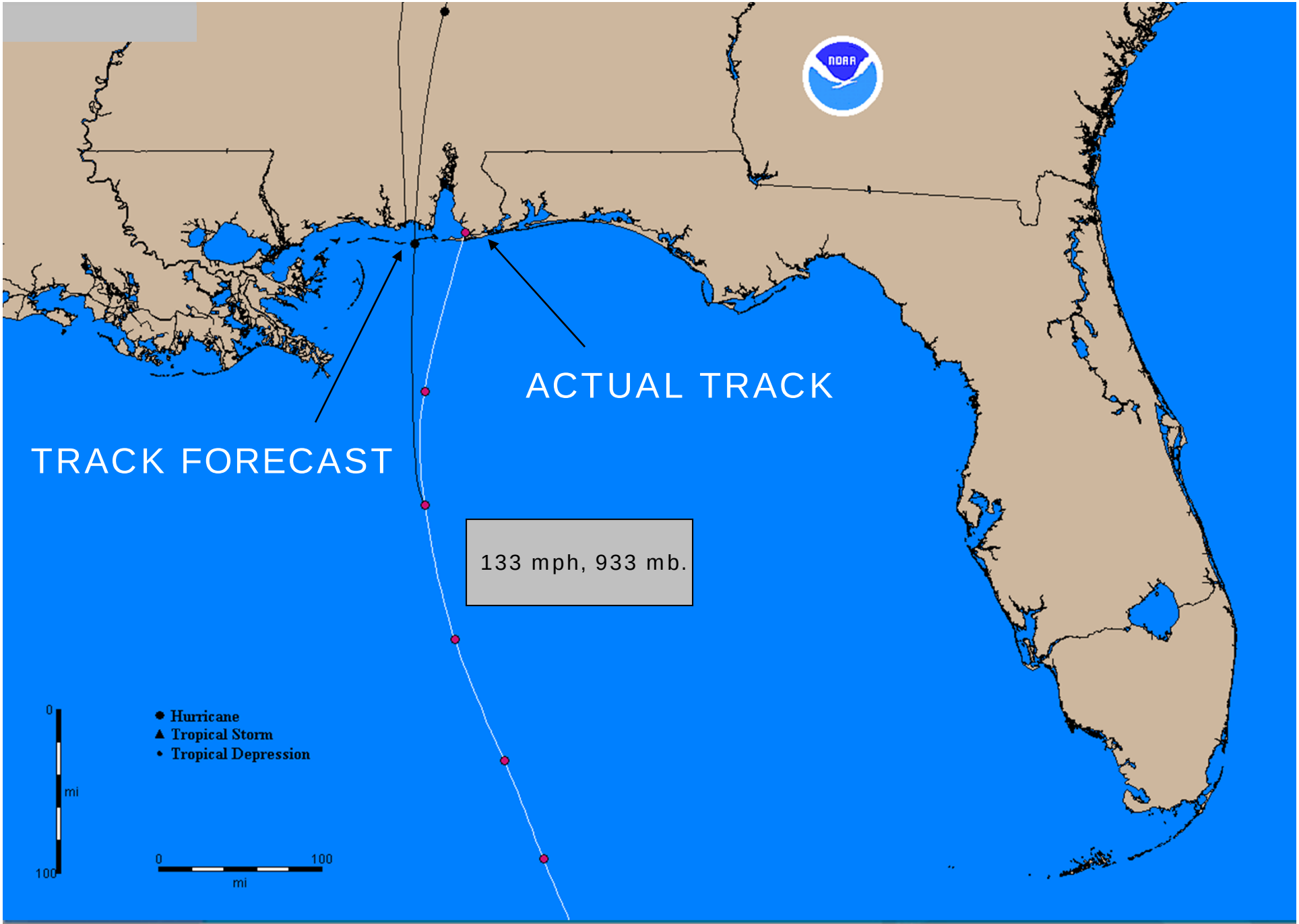
- SLOSH does not include:
  - Breaking waves/wave run-up
  - Astronomical tide
    - Synthetic runs can be initialized at different tide levels via a static initial water level
  - Normal river flow
  - Precipitation



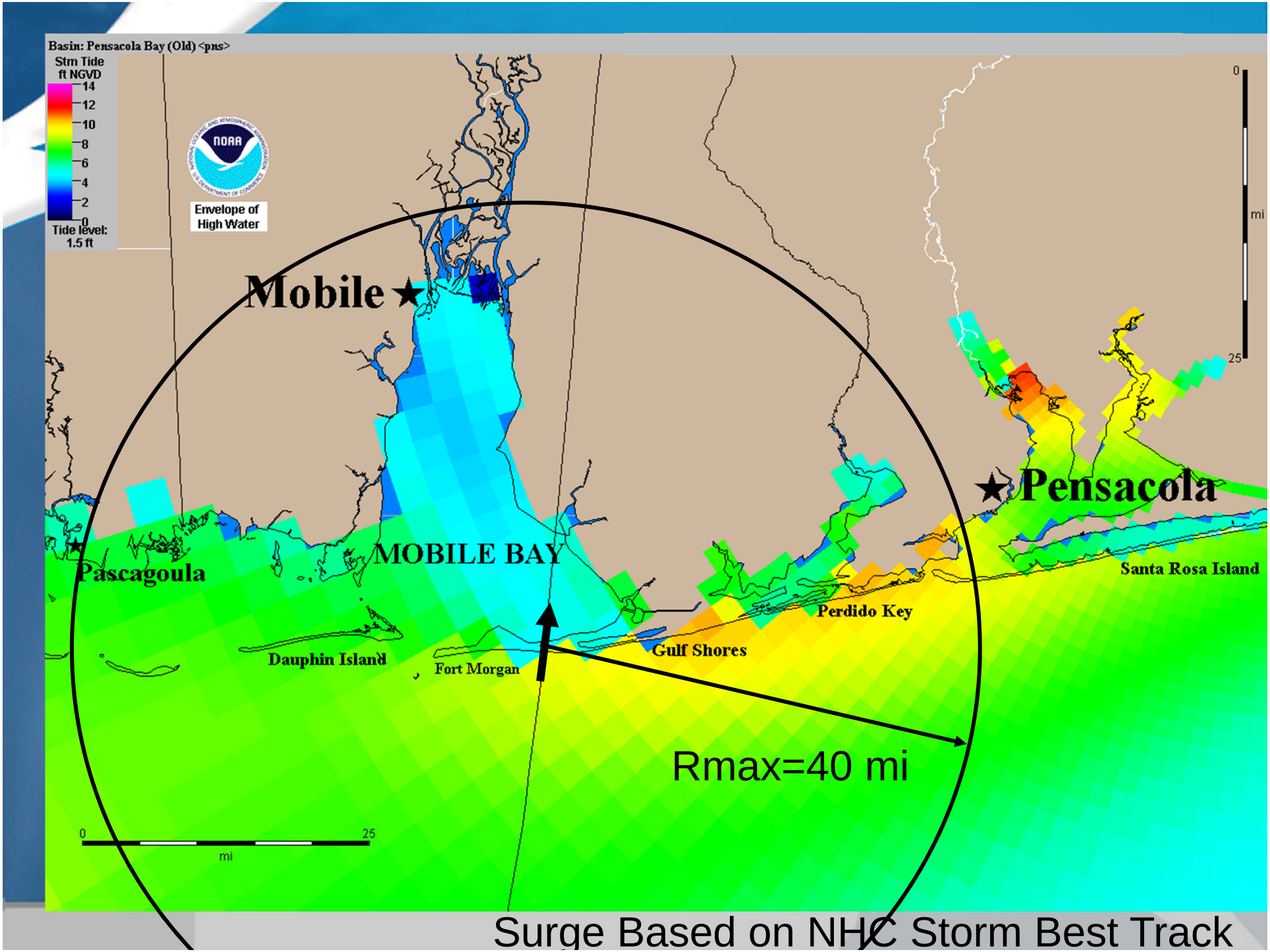
Hurricane Advisory – Approximately 12 hr. before landfall



Surge Based on NHC -12 hr. Advisory



Actual Hurricane Track 30 mi. E of -12 hr. Advisory Forecast Track



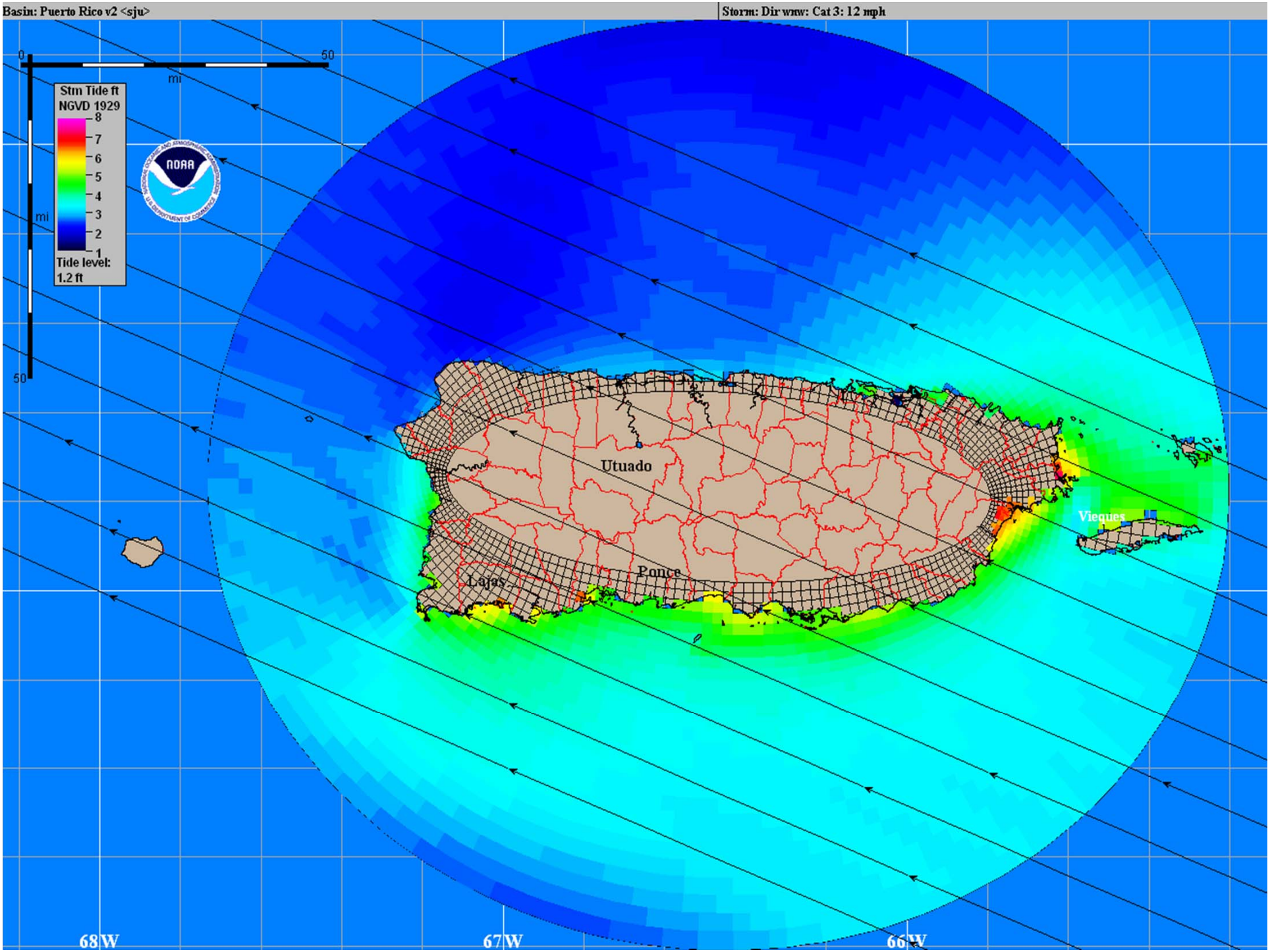
Surge Based on NHC Storm Best Track

Alternative to Single Runs

- Atlas of pre-computed surge maps based on:
  - Different directions of motion
  - Different landfall locations
  - Different intensities
  - Different storm sizes
  - Different forward speeds
- For example, using 3 different directions of tropical cyclone tracks, each direction with 10 parallel equally spaced tracks, 5 different central pressures, 2 different sizes, and 2 different translational speeds, would require 3x10x5x2x2=600 model runs

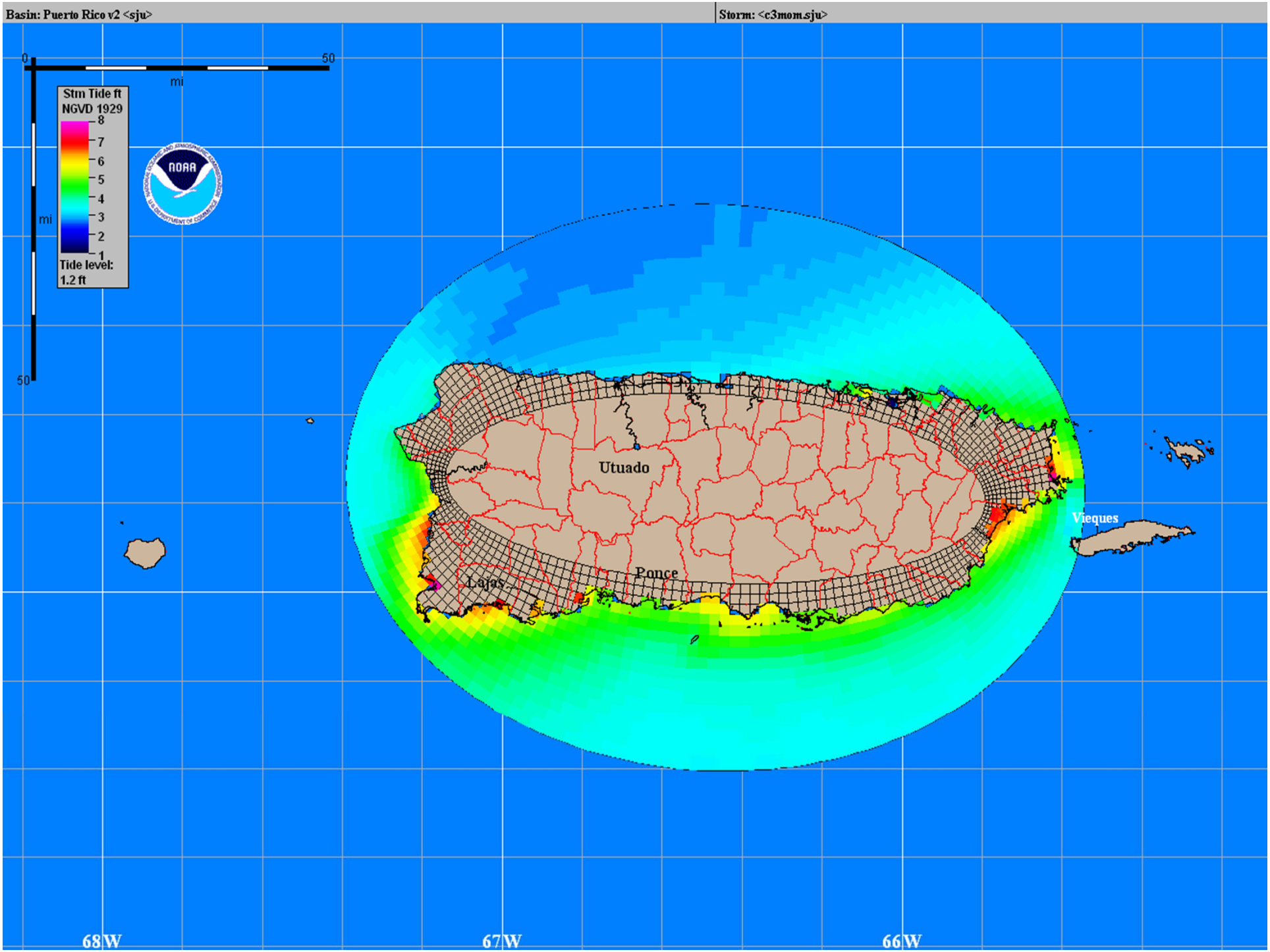
Ensemble Products
MEOW

- Maximum Envelope of Water
- Composite of maximum storm surge heights at each grid cell using hypothetical hurricanes run with the same:
  - Category (Intensity)
  - Forward Speed
  - Landfall Direction
  - Initial Tide Levels
- Composite achieved by reviewing parallel tracks that make landfall at different locations
- Over 80 MEOWs have been generated for some basins


Basin: Puerto Rico v2 <sju>
Storm: Dir wnw: Cat 3: 12 mph
0
50
mi
mi
50
Stm Tide ft
NGVD 1929
8
7
6
5
4
3
2
1
Tide level:
1.2 ft
NOAA
Utuado
Ponce
Lajas
Vieques
68 W
67 W
66 W

Ensemble Products
MOM

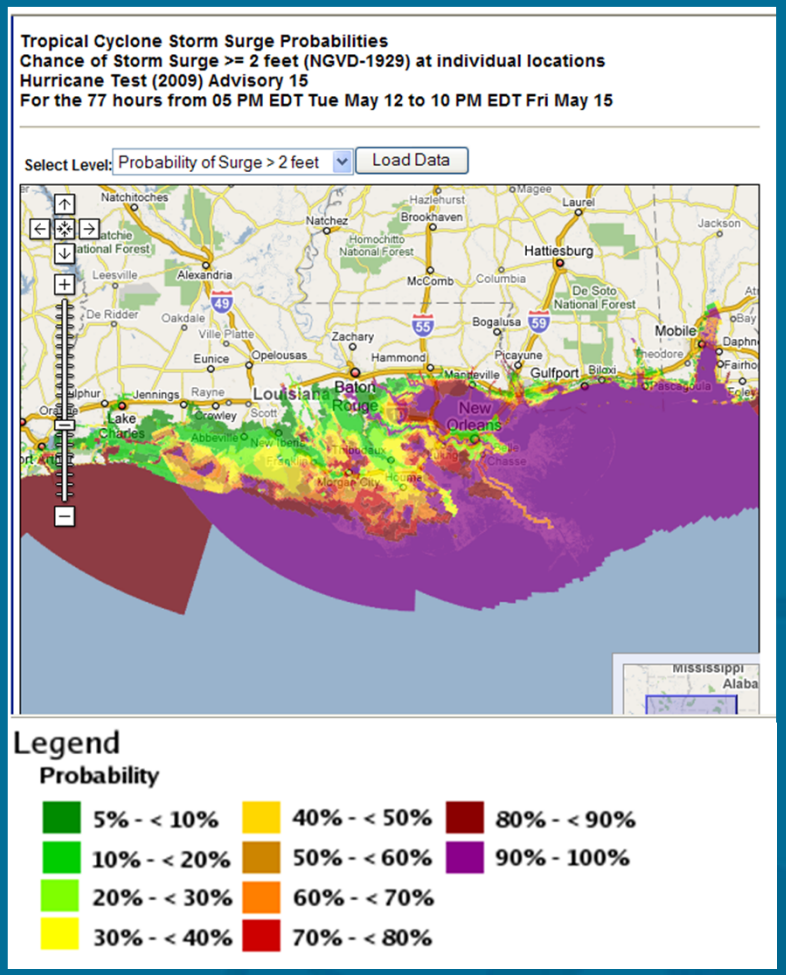
- Maximum of MEOWs
- Composite of the maximum storm surge height for all hurricanes of a given category
- Disregards forward speed, landfall direction, landfall location, etc.
- Only 1 MOM per storm category


Basin: Puerto Rico v2 <sju>
Storm: <c3mom.sju>
0
50
mi
Stm Tide ft
NGVD 1929
8
7
6
5
4
3
2
1
Tide level:
1.2 ft
mi
50
NOAA
Utuado
Ponce
Lajas
Vieques
68 W
67 W
66 W

Ensemble Products
Probabilistic Storm Surge

Use an ensemble of SLOSH runs to create probabilistic storm surge

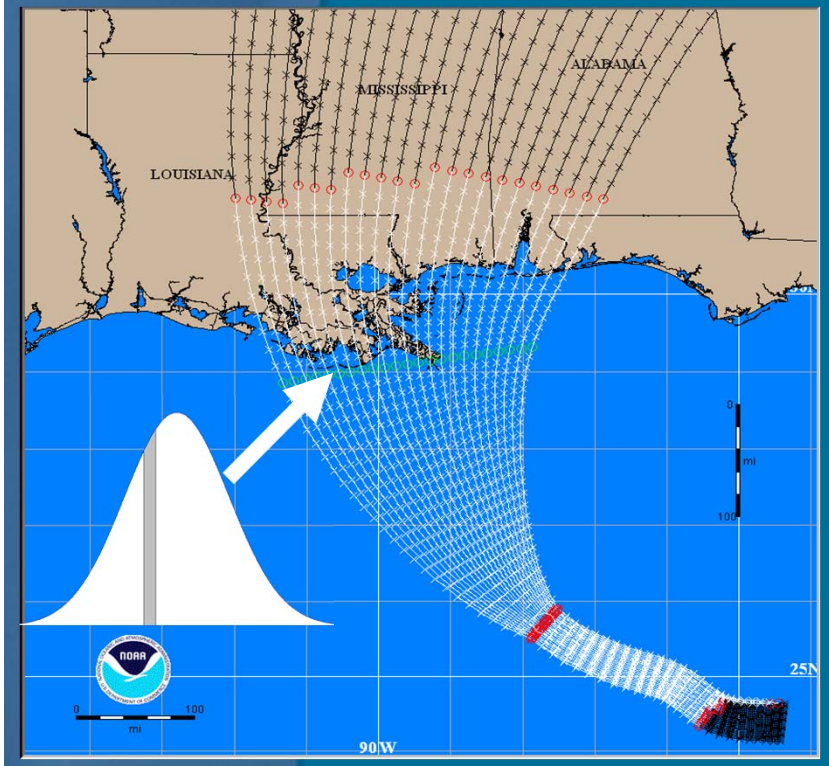
- Intended to be used operationally so it is based on NHC's official advisory
- Perturbations are determined by statistics of past performance of the advisories
- Uses a representative storm for each portion of the error distribution space rather than a random sampling
- Available whenever a hurricane watch or warning is in effect for the U.S.



Probabilistic Storm Surge

Incorporates typical track, intensity, and size errors

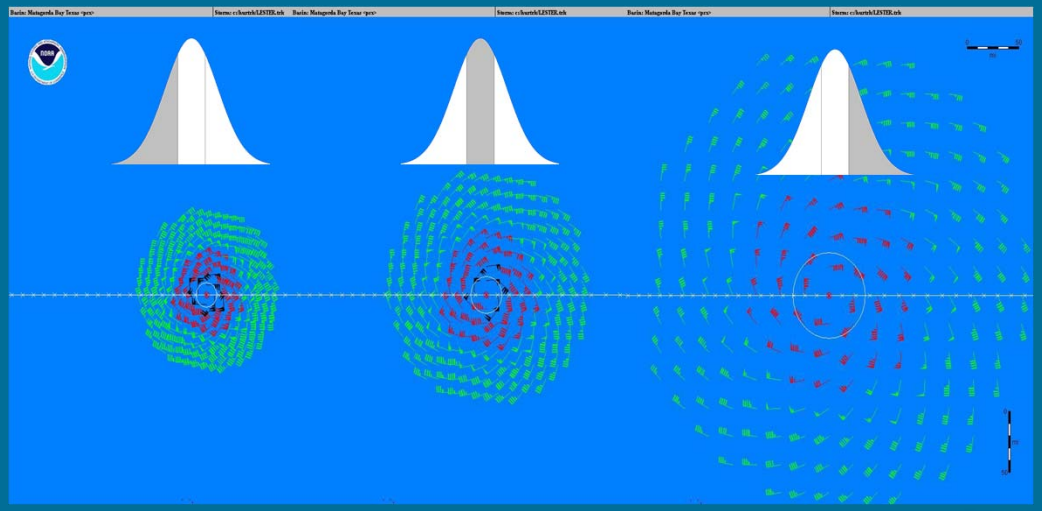
Track Uncertainty



Cross Track- left or right forecast errors

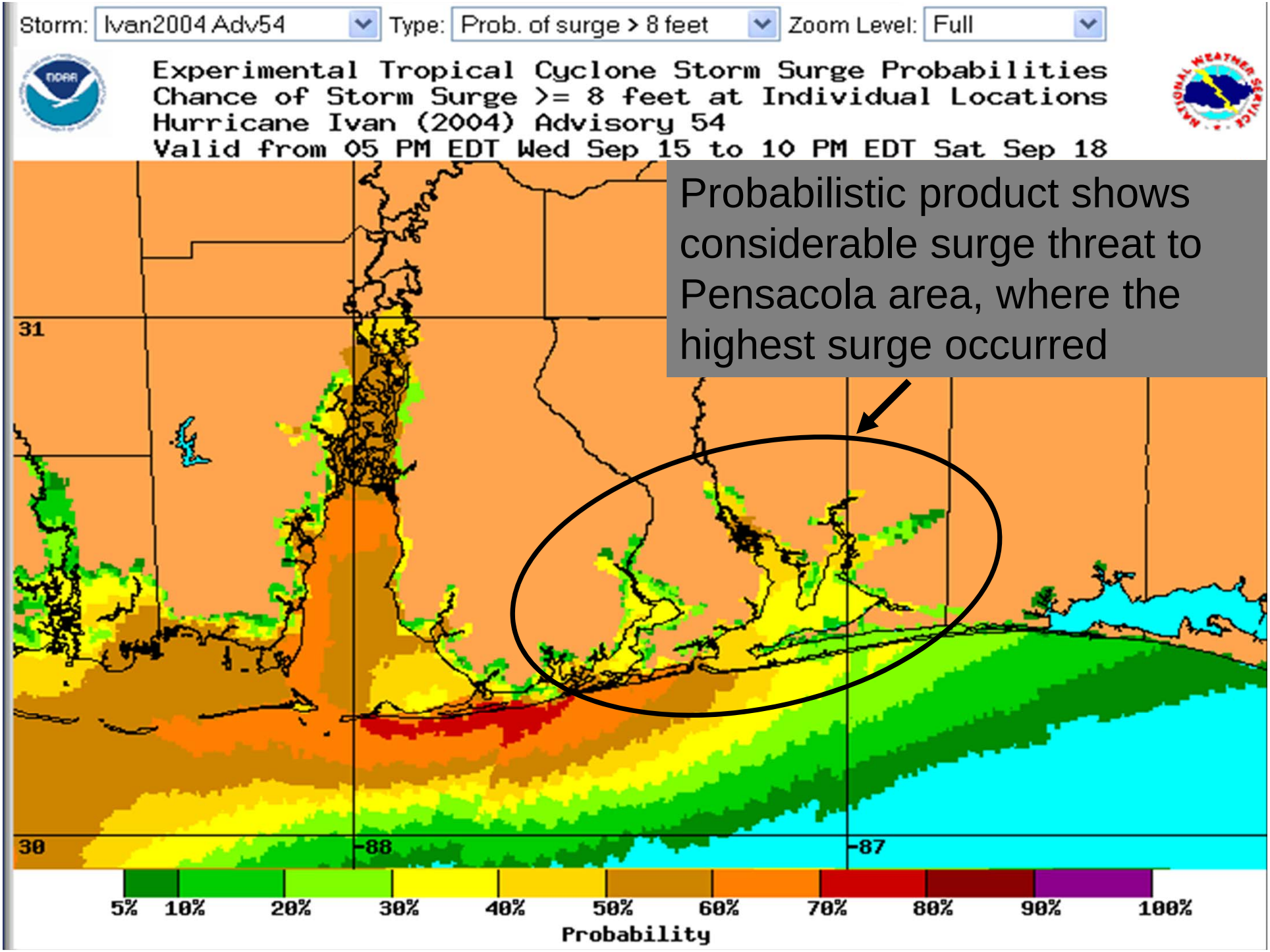
Along Track - Forward Speed: Fast (30%), Medium (40%), Slow (30%)

Intensity & Size Uncertainty

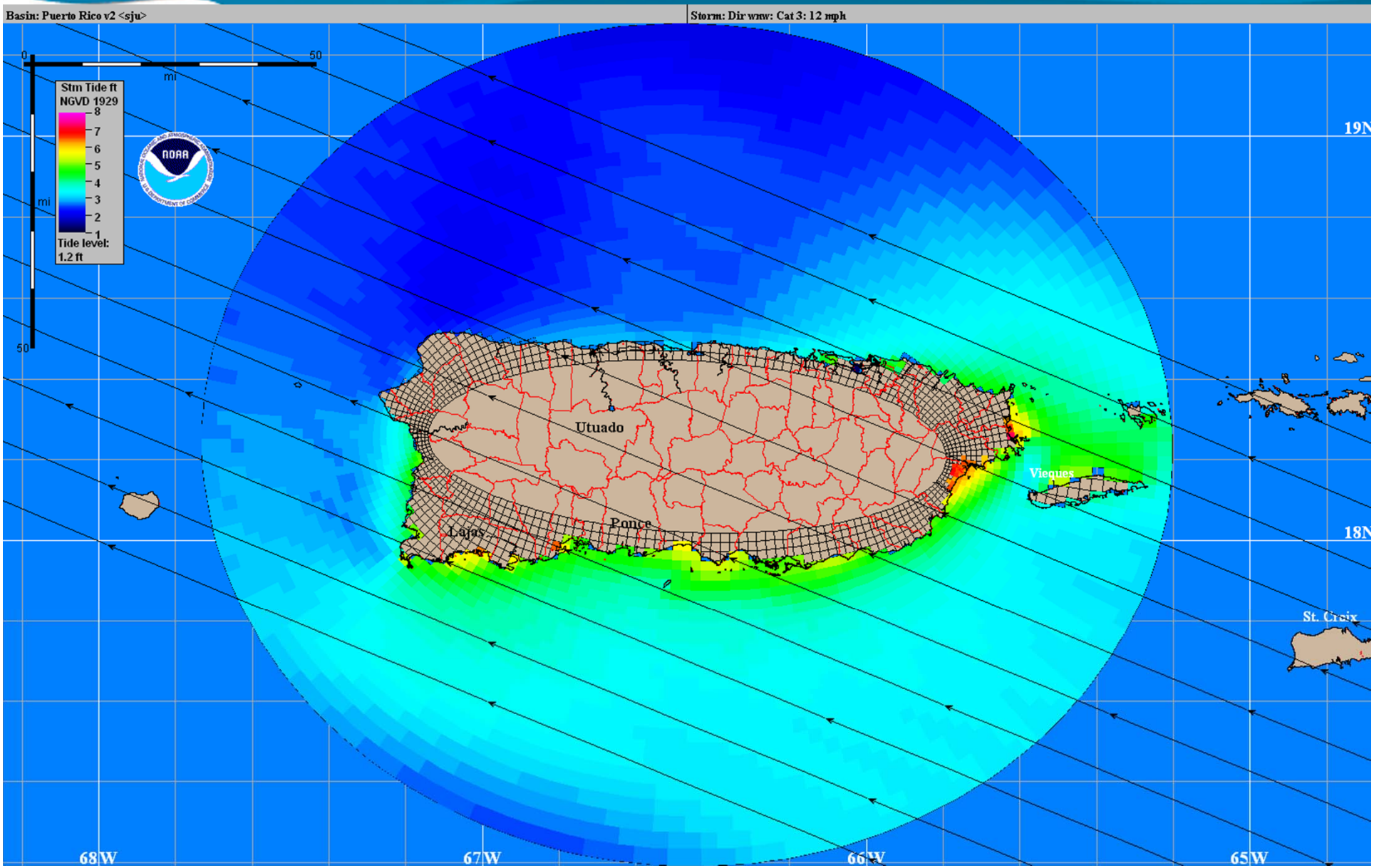


Size: Small (30%), Medium (40%), Large (30%)

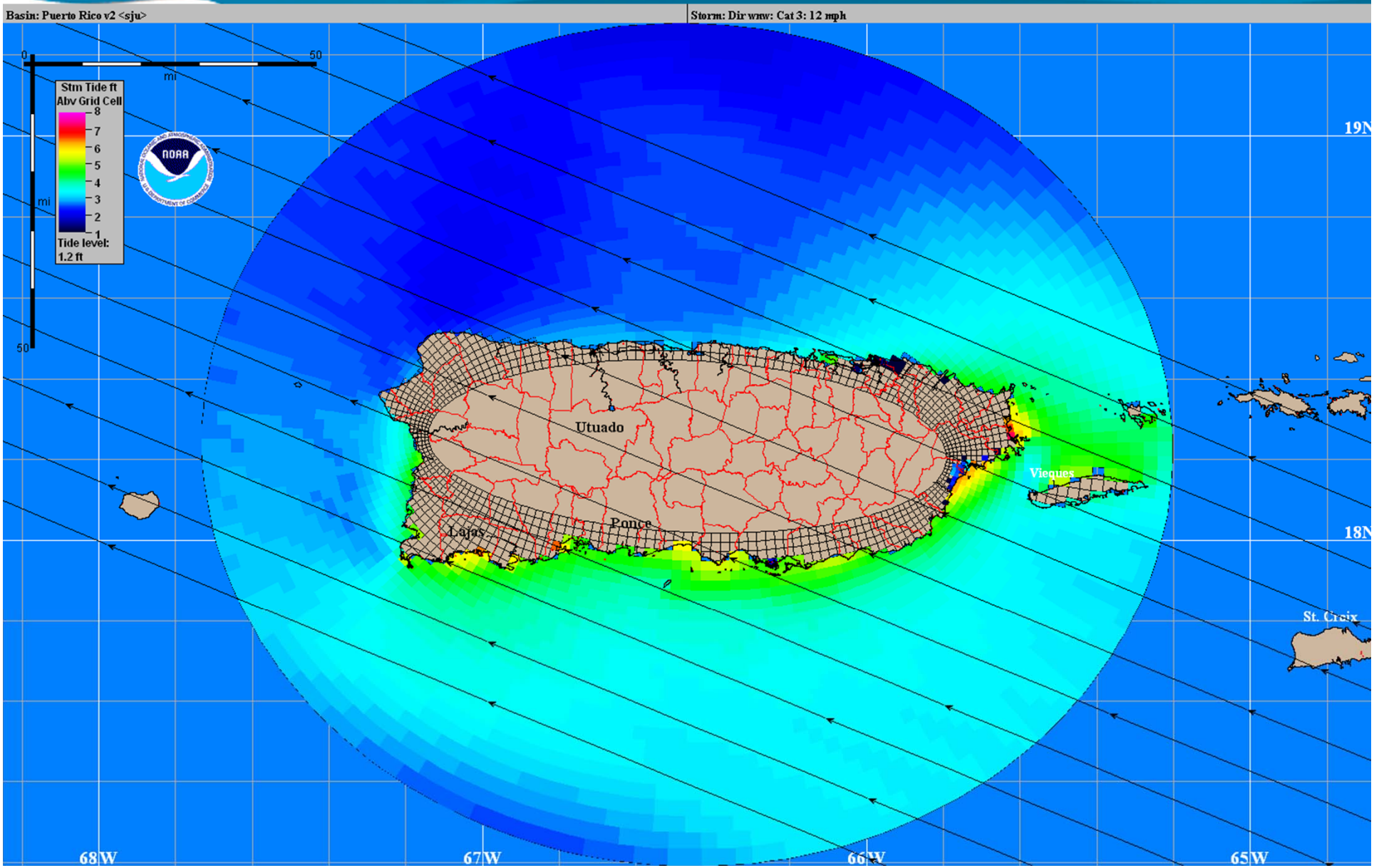
Intensity: Strong (30%), Medium (40%), Weak (30%)


Storm: Ivan2004 Adv54
Type: Prob. of surge > 8 feet
Zoom Level: Full
Experimental Tropical Cyclone Storm Surge Probabilities
Chance of Storm Surge >= 8 feet at Individual Locations
Hurricane Ivan (2004) Advisory 54
Valid from 05 PM EDT Wed Sep 15 to 10 PM EDT Sat Sep 18
Probabilistic product shows considerable surge threat to Pensacola area, where the highest surge occurred
31
30
-88
-87
5%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Probability

Height Above Reference Level

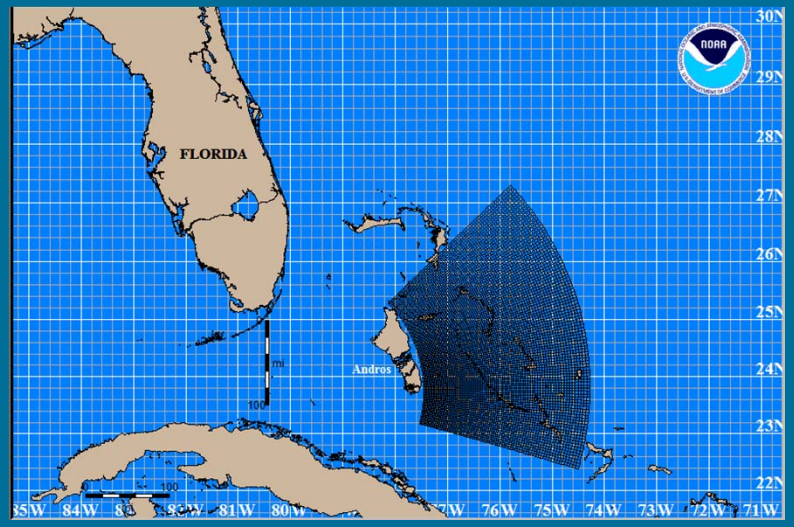


Height Above Ground Level
(Inundation)



SLOSH Basins Outside the USA

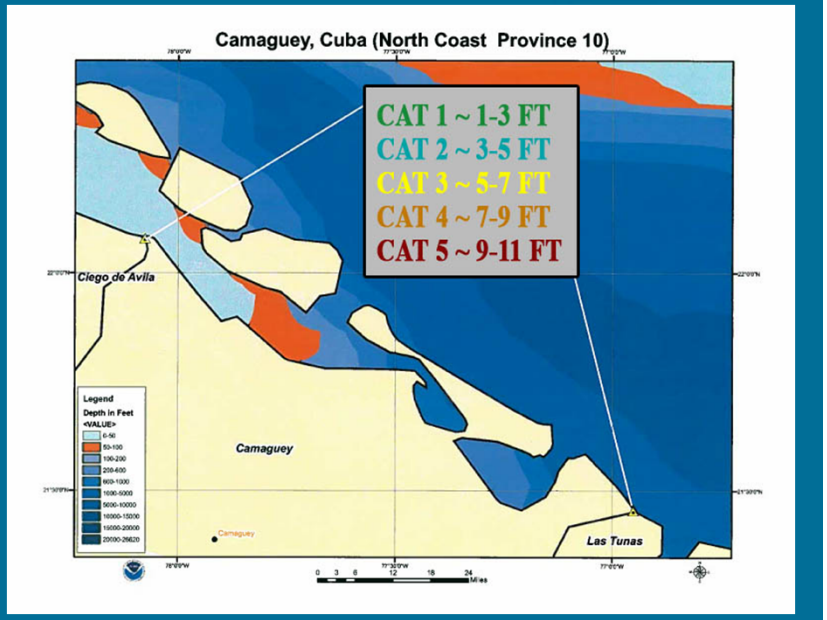
- NHC has partnered with other countries to create basins outside the USA (ex. central Bahamas)
  - Working on new partnership with the Government of the Bahamas to expand SLOSH coverage
- Difficult and expensive multi-year process especially if necessary (elevation) data are not available
- NHC does not currently have staffing to build basins outside the USA without additional resources

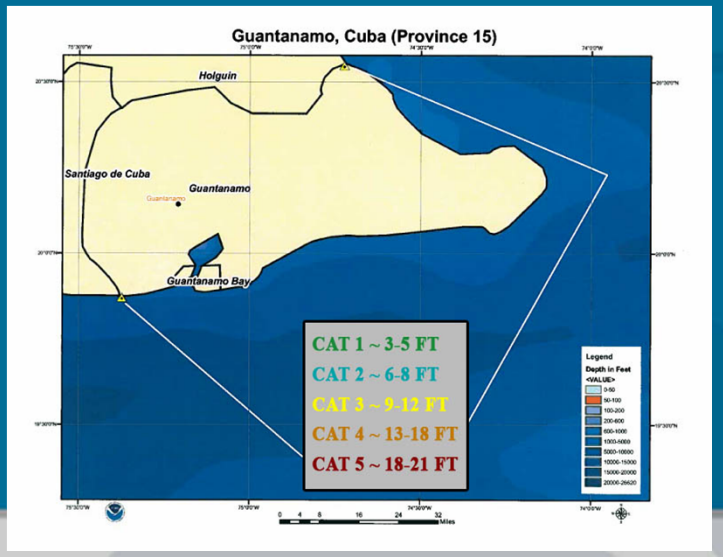


SPLASH

- **Special Program to List Amplitudes of Surges from Hurricanes**

- Predecessor to SLOSH
- Intended for simple storms
  - Didn't allow for sudden changes in track
  - No rapid intensification
- Intended to display surge at the coast – no inundation
- Restricted to rectangular grids





Ongoing Work

- Storm Surge (?) Warning
  - National Hurricane Center is collaborating with the local National Weather Service Offices on the idea of a storm surge warning
  - Current discussions are on the definition and issuance criteria
  - In-house (NHC) experiment likely to take place during the next year or two

Thank You!

Questions-

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Hugh.Cobb@noaa.gov

Storm Surge - Jamie Rhome

Jamie.R.Rhome@noaa.gov