



NATIONAL HURRICANE CENTER STORM SURGE UNIT

State of Operations

Jamie Rhome, Team Lead
LTJG Phil Manougian
Tarah Sharon
Laura Alaka
William Booth
Ethan Gibney
Taylor Trogdon
Cody Fritz

hurricanes.gov/surge
[@NHC_Surge](https://twitter.com/NHC_Surge)

Annual HFIP Meeting
November 7, 2018

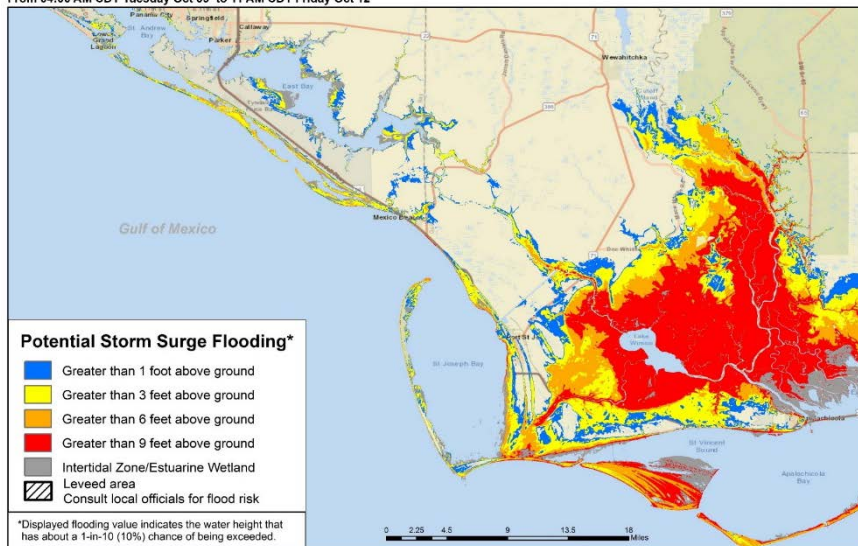


2018 Season Overview Storm Surge

- U.S. Landfalls
 - Subtropical Storm Alberto
 - Hurricane Florence
 - Tropical Storm Gordon
 - Hurricane Michael

HURRICANE MICHAEL (2018)

NHC Potential Storm Surge Flooding Map
Hurricane Michael (2018) Advisory 11
From 04:00 AM CDT Tuesday Oct 09 to 11 AM CDT Friday Oct 12



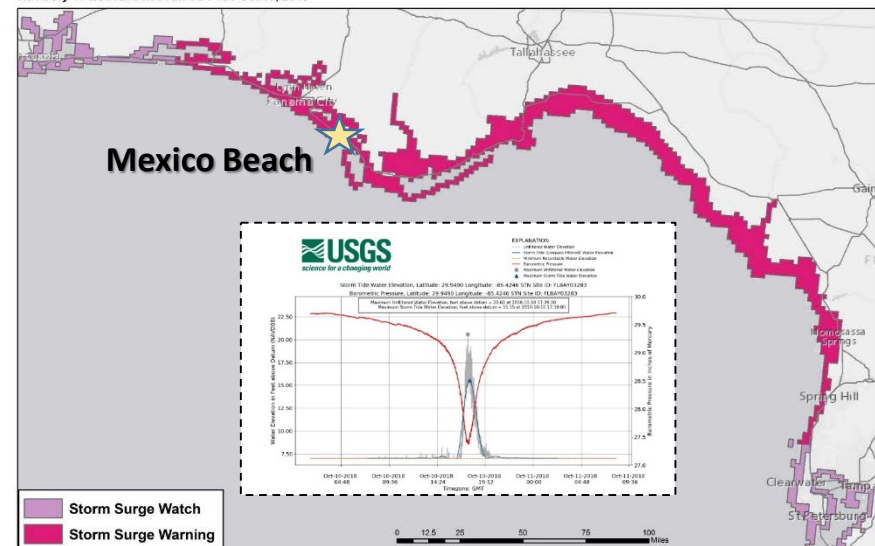
Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Swisstopo, Mapbox, © OpenStreetMap contributors, and the GIS User Community

Cooperative Institute for Meteorological Satellite Studies / University of Wisconsin-Madison



Storm Surge Watch/Warning Graphic

Hurricane Michael
Advisory 11 Issued: 04:00 AM CDT Tue Oct 09, 2018



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National Hurricane Center Mission

- **Support coastal community preparedness and resiliency through storm surge vulnerability and risk analysis (Stafford Act)**
 - National Hurricane Program
 - Evacuation planning, modeling, and mapping
 - Training and technical assistance
- **Provide accurate real-time storm surge forecasts during tropical cyclone events (Weather Service Organic Act)**
- **Support post-landfall response and recovery (Stafford Act and Coastal Act)**

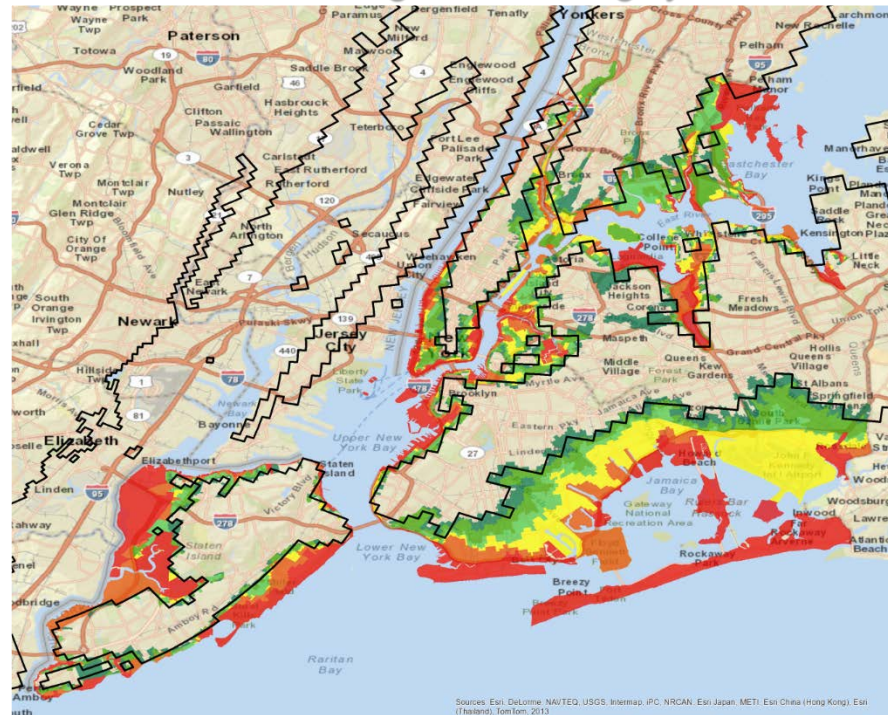


Evacuation Planning

NYC Evacuation Zones for Hurricane Sandy



| 2010 Population | |
|------------------|-----------|
| Zone 1 | 370,000 |
| Zone 1+2 | 620,000 |
| Zone 1+2+3 | 1,020,000 |
| Zone 1+2+3+4 | 1,470,000 |
| Zone 1+2+3+4+5 | 2,230,000 |
| Zone 1+2+3+4+5+6 | 2,990,000 |



Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Taipei), TomTom, 2013

National SLOSH MOM and Risk Analysis

- About 7.4 million people vulnerable to storm surge
- Roughly 4,600 miles of evacuation route becomes inundated or cut off
- Almost 3.9 million housing units vulnerable to surge

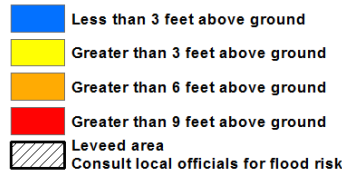
National Storm Surge Hazard Maps

This is not a real-time product. For active tropical cyclones, please see hurricanes.gov and consult local products issued by the National Weather Service

Texas to Maine Puerto Rico

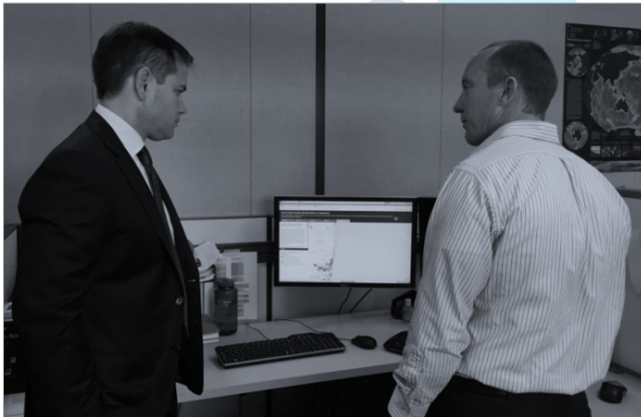
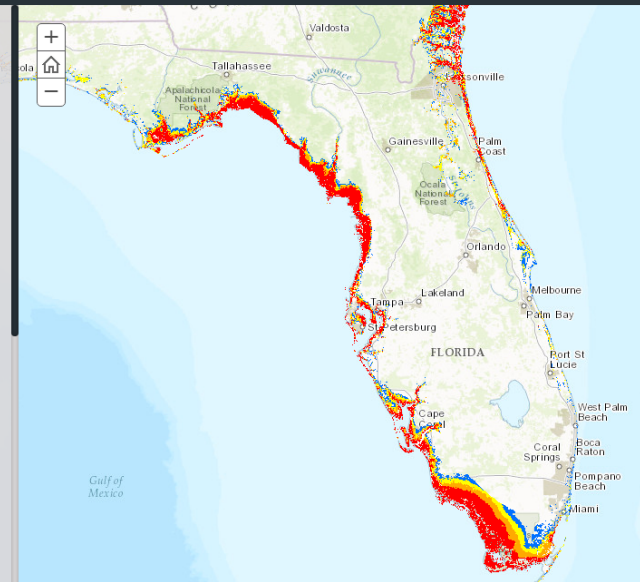
Category 1 Category 2 Category 3 Category 4 Category 5

This national depiction of storm surge flooding vulnerability helps people living in hurricane-prone coastal areas along the U.S. East and Gulf Coasts and Puerto Rico to evaluate their risk to the storm surge hazard. These maps make it clear that storm surge is not just a beachfront problem, with the risk of storm surge extending many miles inland from the immediate coastline in some areas. If you discover via these maps that you live in an area vulnerable to storm surge, find out today if you live in a hurricane storm surge evacuation zone as prescribed by your local emergency management agency. If you do live in such an evacuation zone, decide today where you will go and how you will get there, if and when you're instructed by your emergency manager to evacuate. If you don't live in one of those evacuation zones, then perhaps you can identify someone you care about who does live in an evacuation zone, and you could plan in advance to be their inland evacuation destination - if you live in a structure that is safe from the wind and outside of flood-prone areas.



How this map was created:

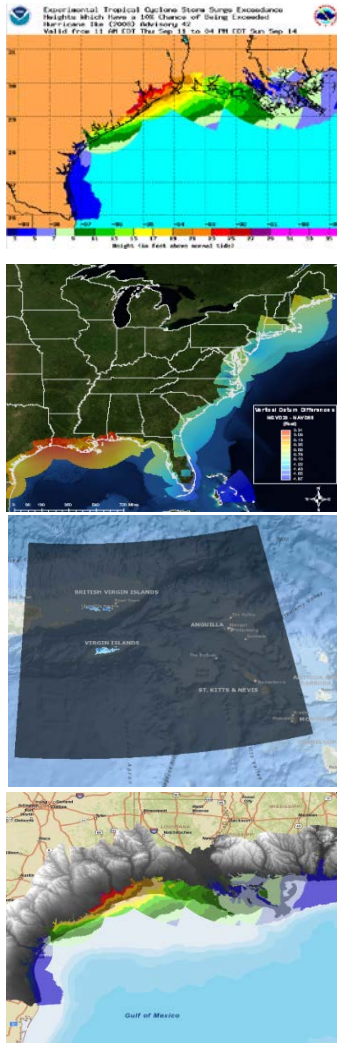
The SLOSH (Sea, Lake, and Overland Surges from Hurricanes) model is a numerical model used by NWS to compute storm surge. Storm surge is defined as the abnormal rise of water generated by a storm, over and above the predicted astronomical tides. Flooding from storm surge depends on many factors, such as the track, intensity, size, and forward speed of the hurricane and the characteristics of the coastline where it comes ashore or passes nearby. For planning purposes, the NHC uses a representative sample of hypothetical storms to estimate the near worst-case scenario of flooding for each hurricane category.



Zachry, B. C., W. J. Booth, J. R. Rhome, and T. M. Sharon, 2015: A National View of Storm Surge Risk and Inundation. *J. Wea. Climate Soc.*, 7(2), 109-117



Outline



- **Real-time Products/Services and CONUS**
 - **P-Surge 2.7 to 2.8**
 - **Storm Surge Watch/Warning**
 - **Grid Updates**
- **OCONUS Activities**
 - **MOMs/MEOWs**
 - **SLOSH Fast Wave**
- **HSOFS**
 - **ADCIRC based ensemble**



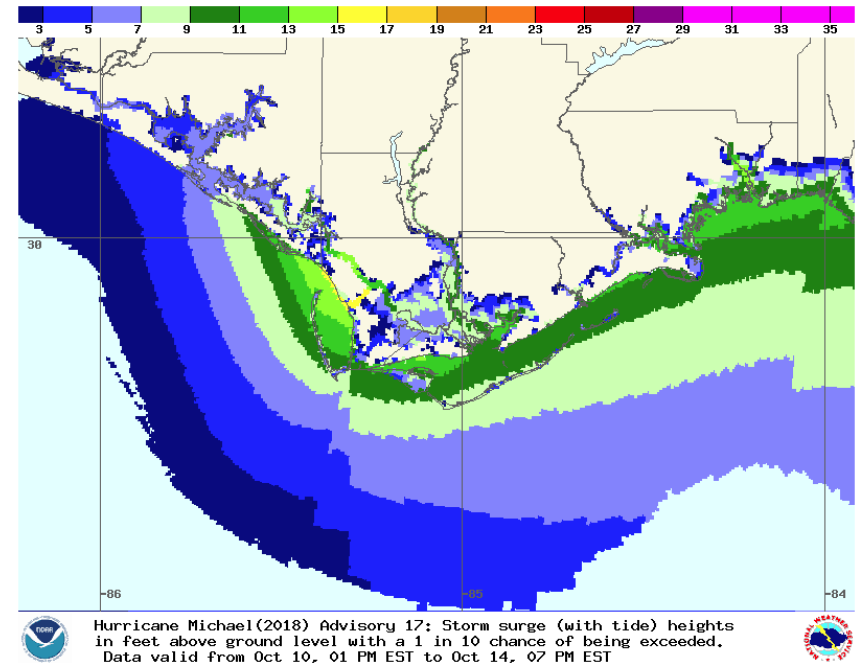


**Real-time Products/Services and
CONUS**



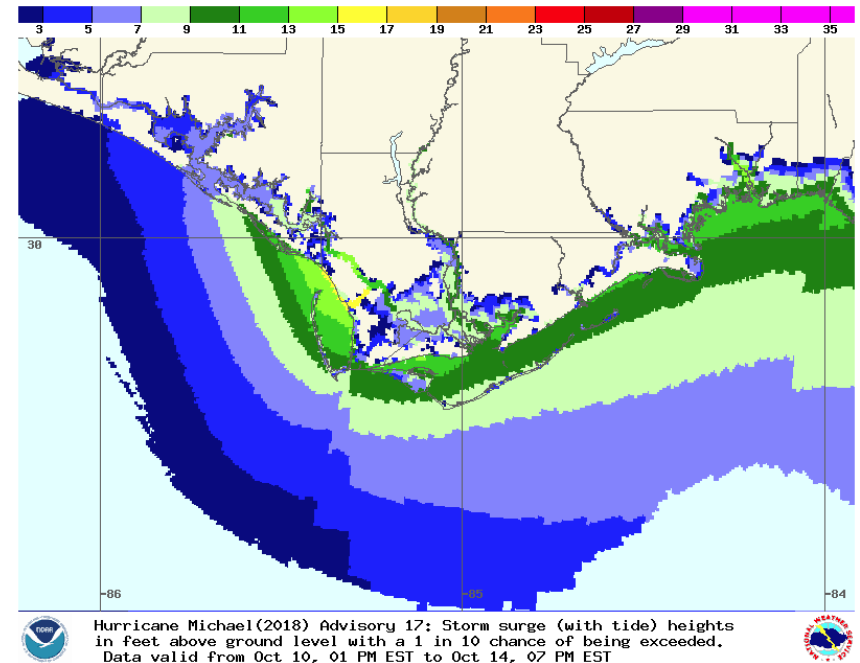
Probabilistic Storm Surge (P-Surge)

- **P-Surge 2.7 implementation (current)**
 - Includes latest NHC error statistics (2013-2017)
 - Minor bug fixes
 - Initialization of dry cells
 - Calculations to friction coefficient
 - Corrections to tide



Probabilistic Storm Surge (P-Surge)

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 - Includes latest NHC error statistics (2013-2017)
 - Minor bug fixes
 - Initialization of dry cells
 - Calculations to friction coefficient
 - Corrections to tide
- **P-Surge 2.8 implementation (projected 2019 hurricane season)**
 - Halo parallelization technique
 - Supports full (grid) HSF1 and HMS8
 - Storm specific error statistics
 - Include 60-hr forecast point

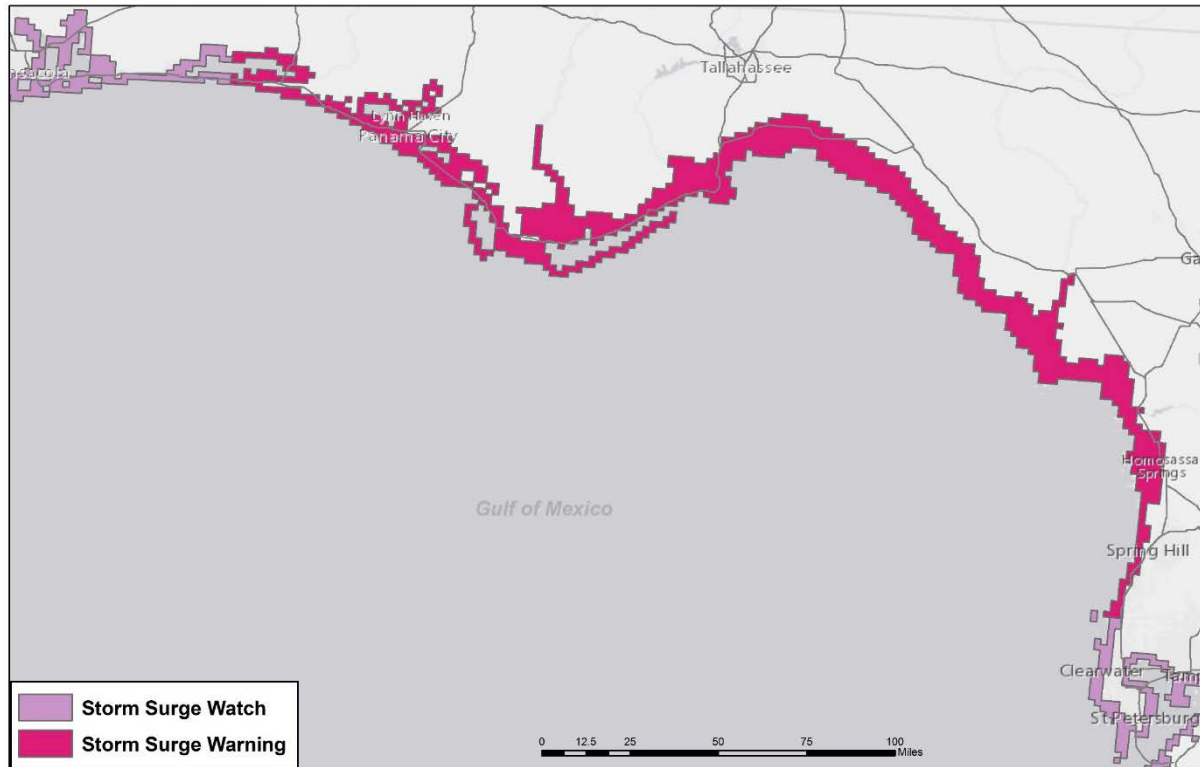


Storm Surge Watch Warning Alerting

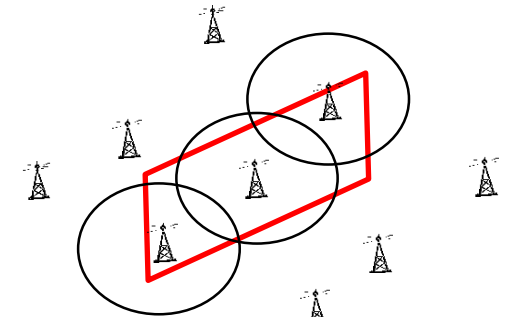
Wireless Emergency Alerts have been implemented by some (not all) carriers

Storm Surge Watch/Warning Graphic

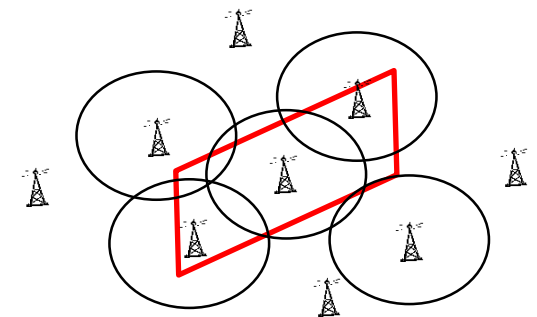
Hurricane Michael
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Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community



Carriers generally broadcast WEA from cell towers within the defined warning area



They may broadcast from towers where signal overlaps the defined warning area

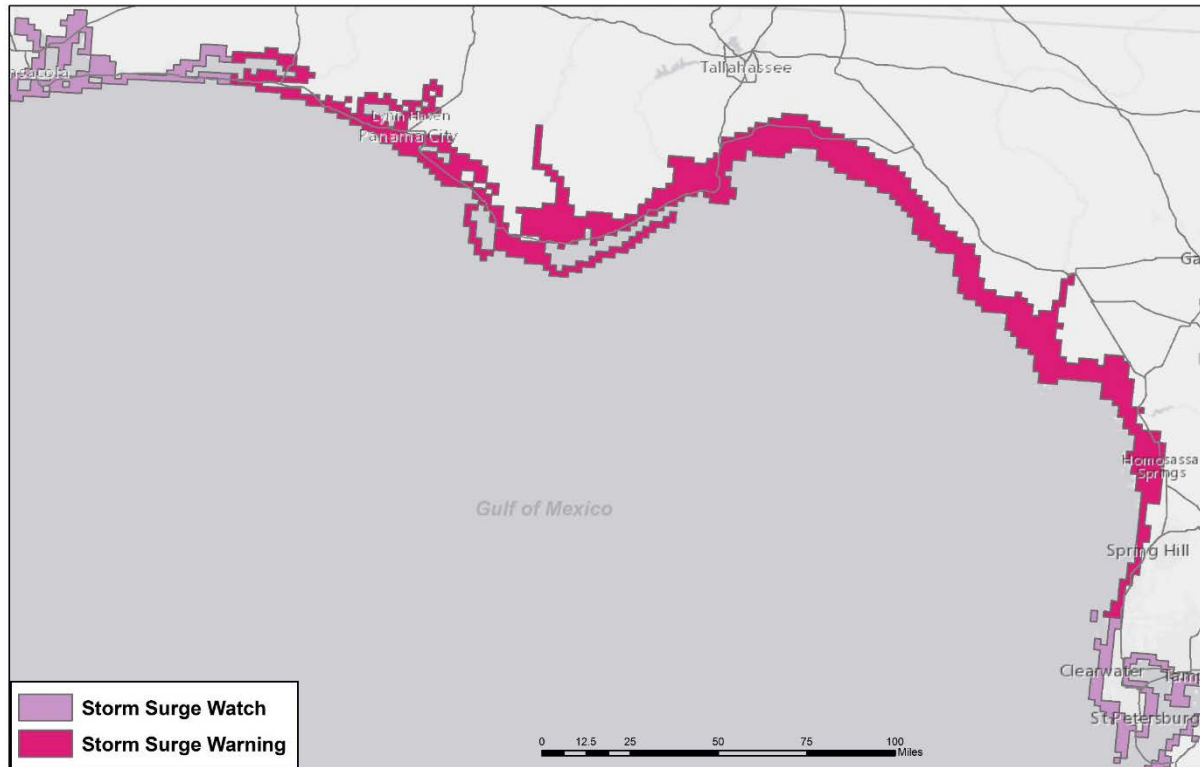


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Watch: The **possibility** of life-threatening inundation from rising water...within 48 hours

Warning: The **danger** of life-threatening inundation from rising water...within 36 hours



SLOSH Basin Upgrades

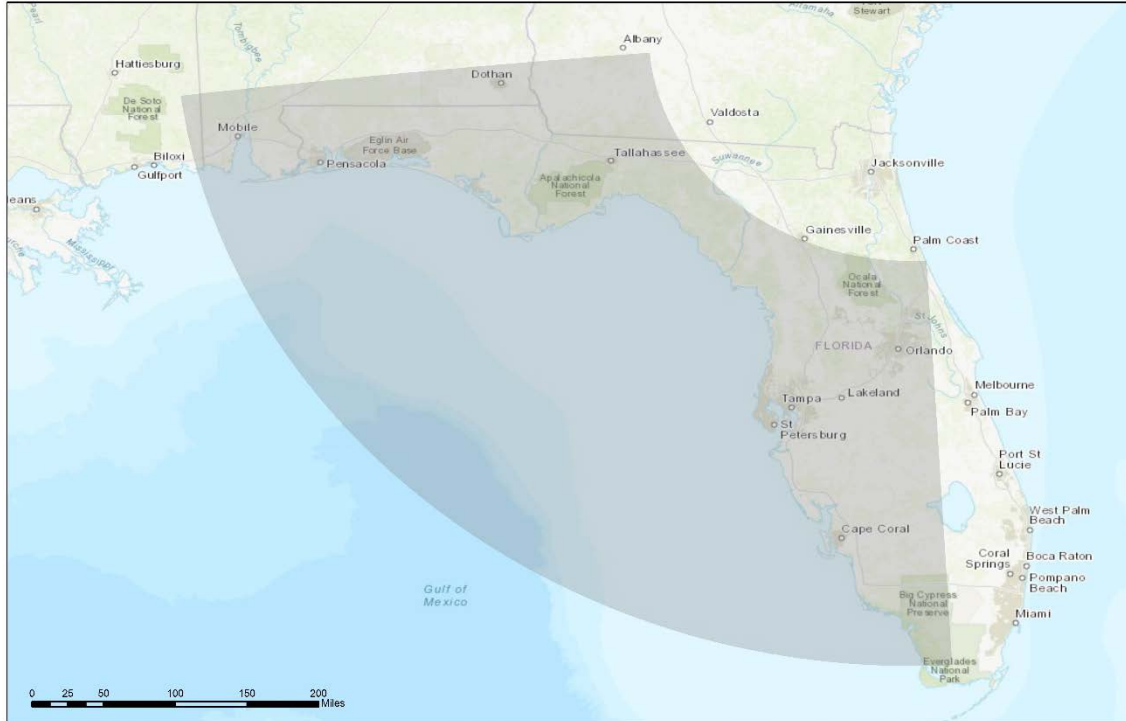
- **Developing larger basins with higher resolution to improve surge representation and accuracy**



SLOSH Basin Upgrades

West Florida SLOSH Basin

National Hurricane Center

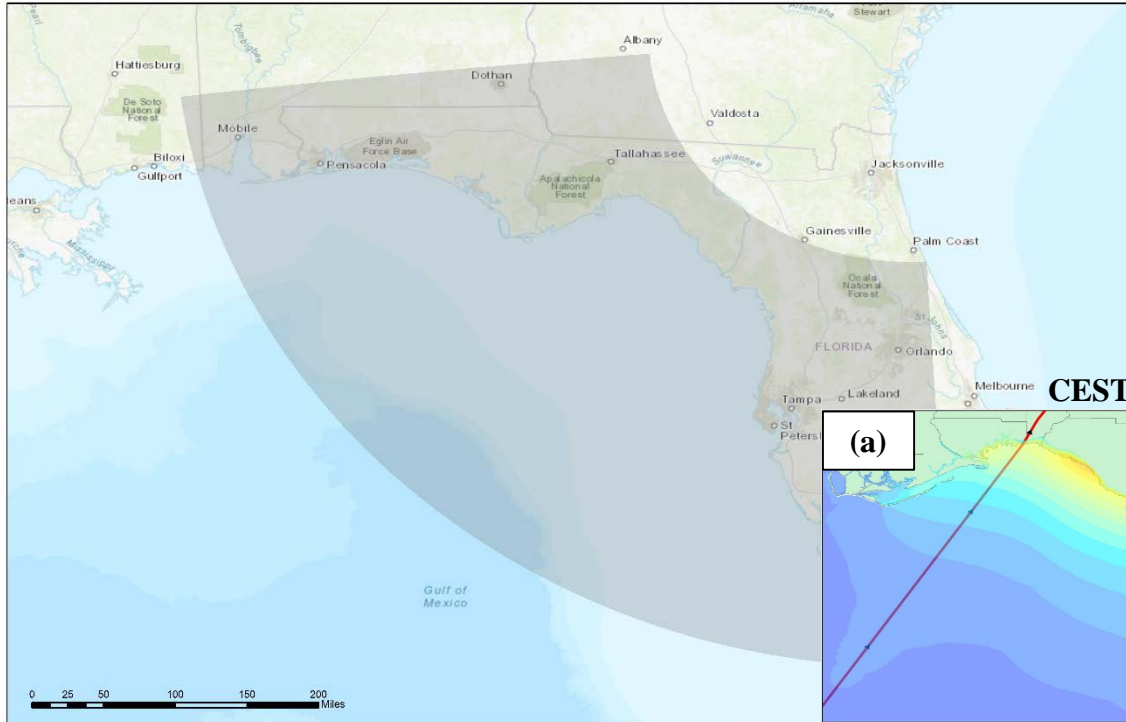


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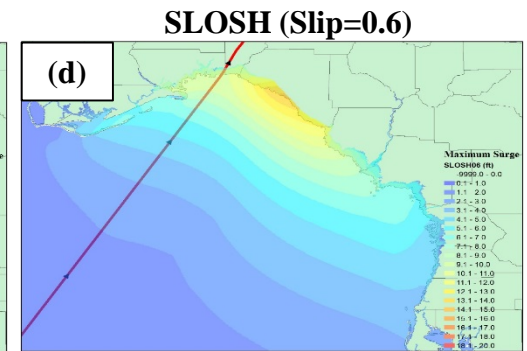
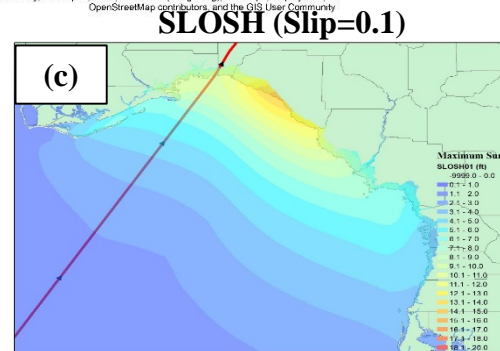
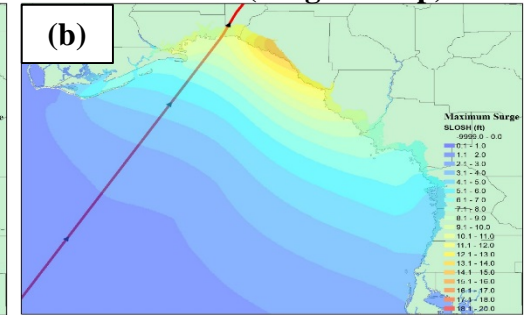
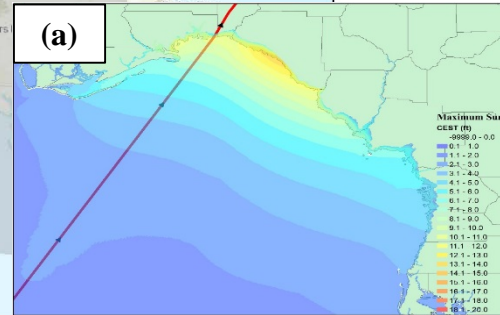
- Developing larger basins with higher resolution to improve surge representation and accuracy
- Curvilinear structured mesh

SLOSH Basin Upgrades

West Florida SLOSH Basin National Hurricane Center



- Developing larger basins with higher resolution to improve surge representation and accuracy
- Curvilinear structured mesh



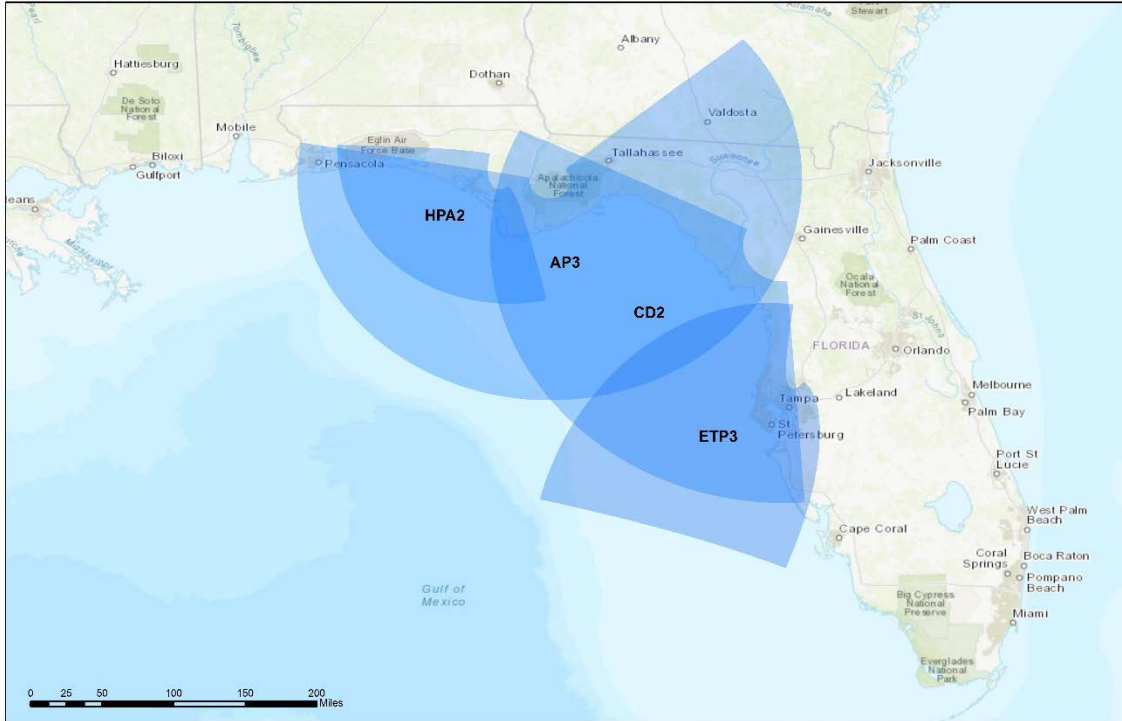
A comparison to CEST is used to evaluate the effects due to bottom friction

Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), Swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



SLOSH Basin Upgrades

West Florida SLOSH Basin National Hurricane Center

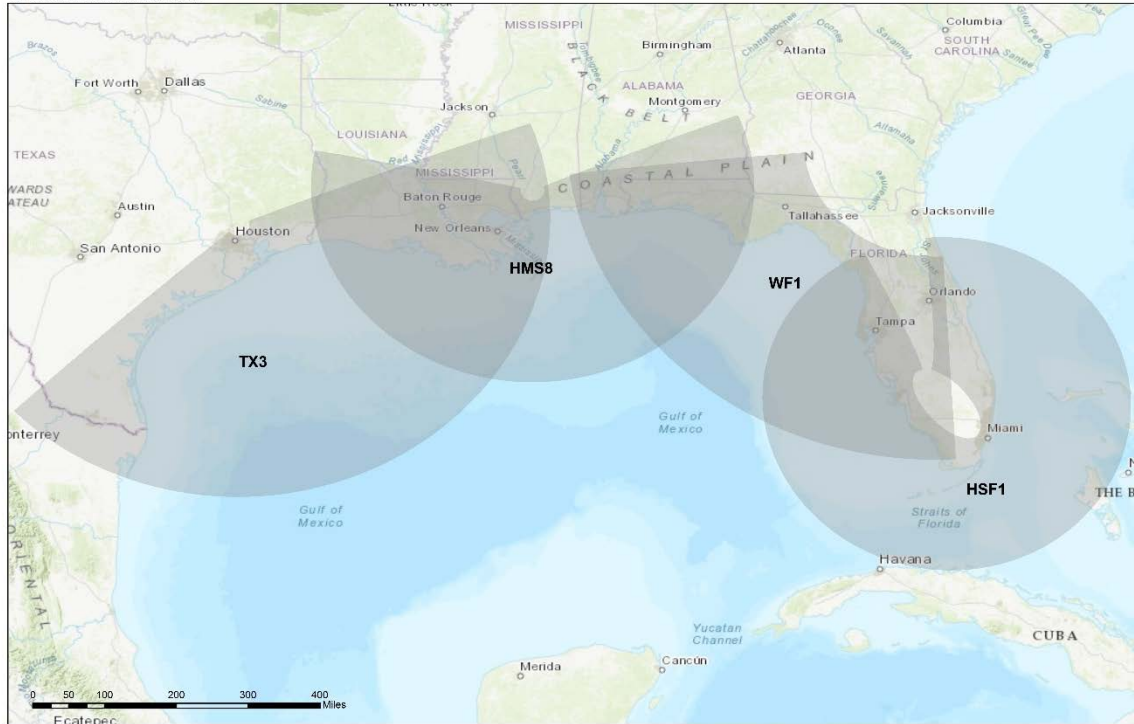


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- Developing larger basins with higher resolution to improve surge representation and accuracy
- Curvilinear structured mesh
- Replaces several existing grids

SLOSH Basin Upgrades

West Florida SLOSH Basin National Hurricane Center



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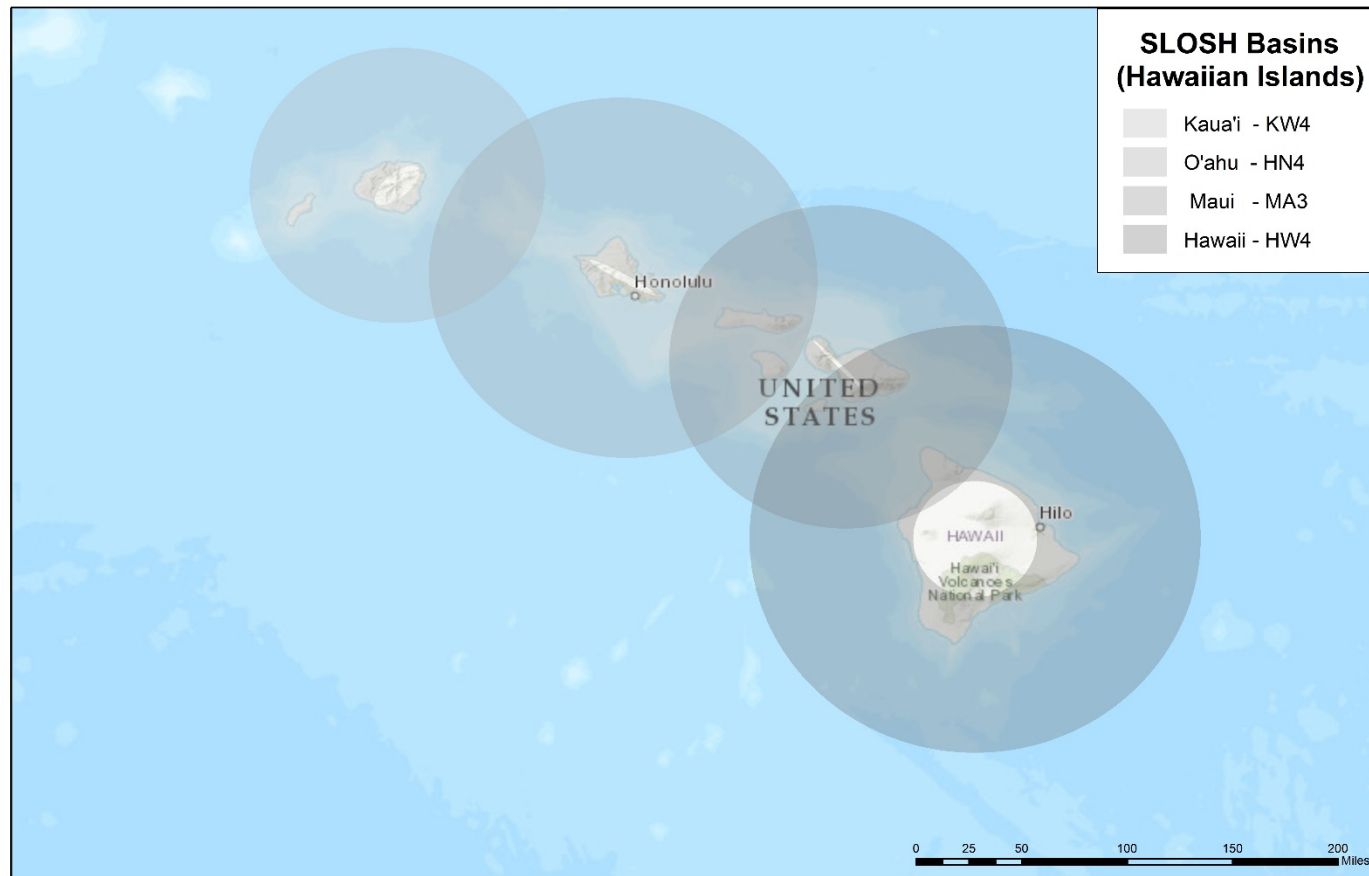
- Developing larger basins with higher resolution to improve surge representation and accuracy
- Curvilinear structured mesh
- Replaces several existing grids
- Gulf Coast will include TX3, HMS8, WF1, and HSF1



OCONUS

Developing MOMs and MEOWS

Storm Surge Hazard Mapping National Hurricane Center



Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

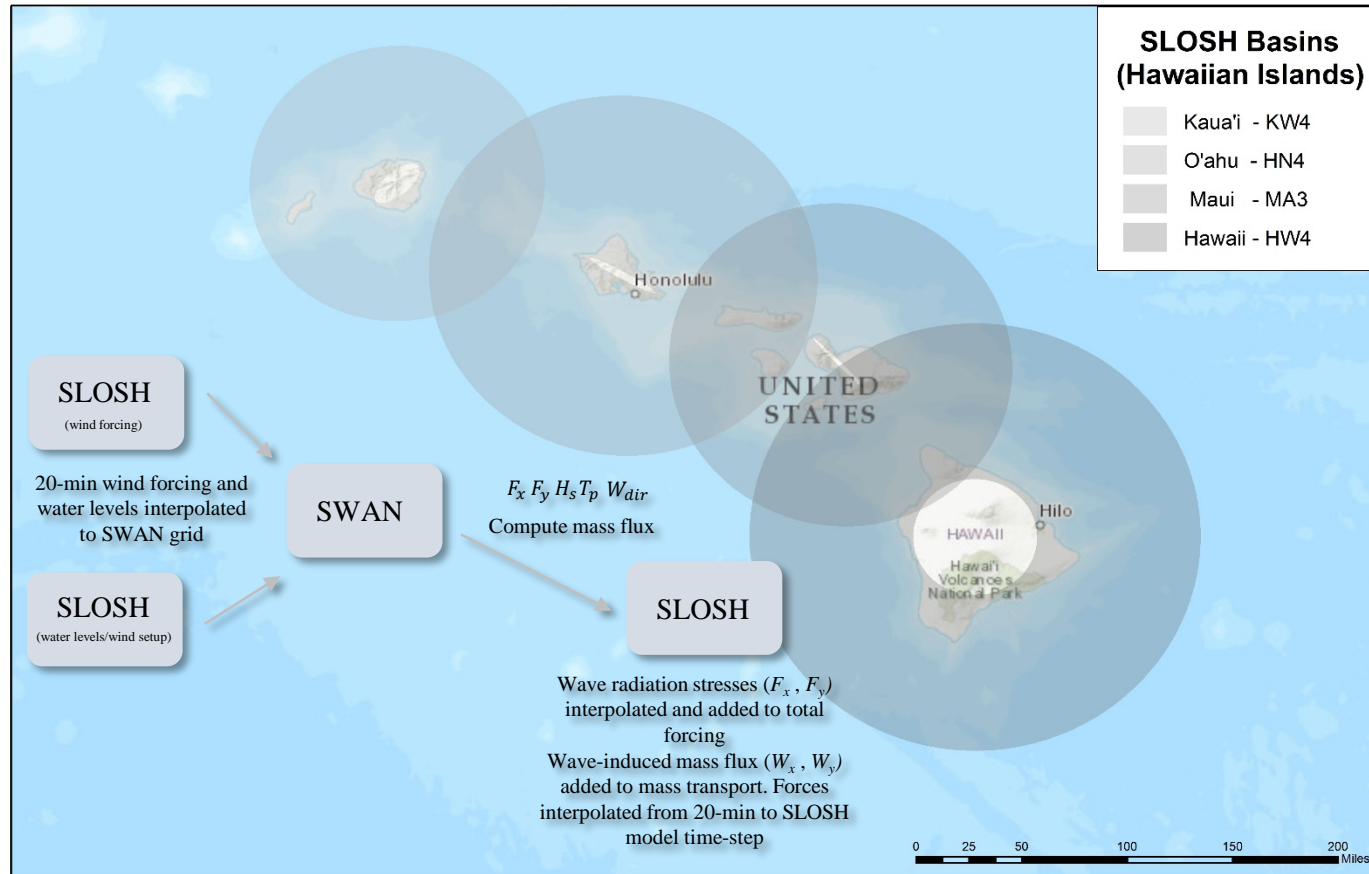
- **High-resolution MEOWs and MOMs Available for:**
 - **Puerto Rico**
 - **U.S. Virgin Islands**
 - **Hawaiian Islands**



OCONUS

Developing MOMs and MEOWS

Storm Surge Hazard Mapping National Hurricane Center



- **High-resolution MEOWs and MOMs Available for:**
 - Puerto Rico
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- **SLOSH coupled to the Simulating Waves Nearshore (SWAN) third-generation wave model**

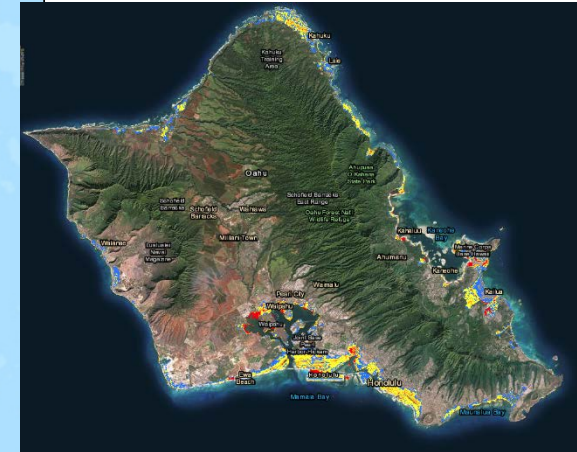
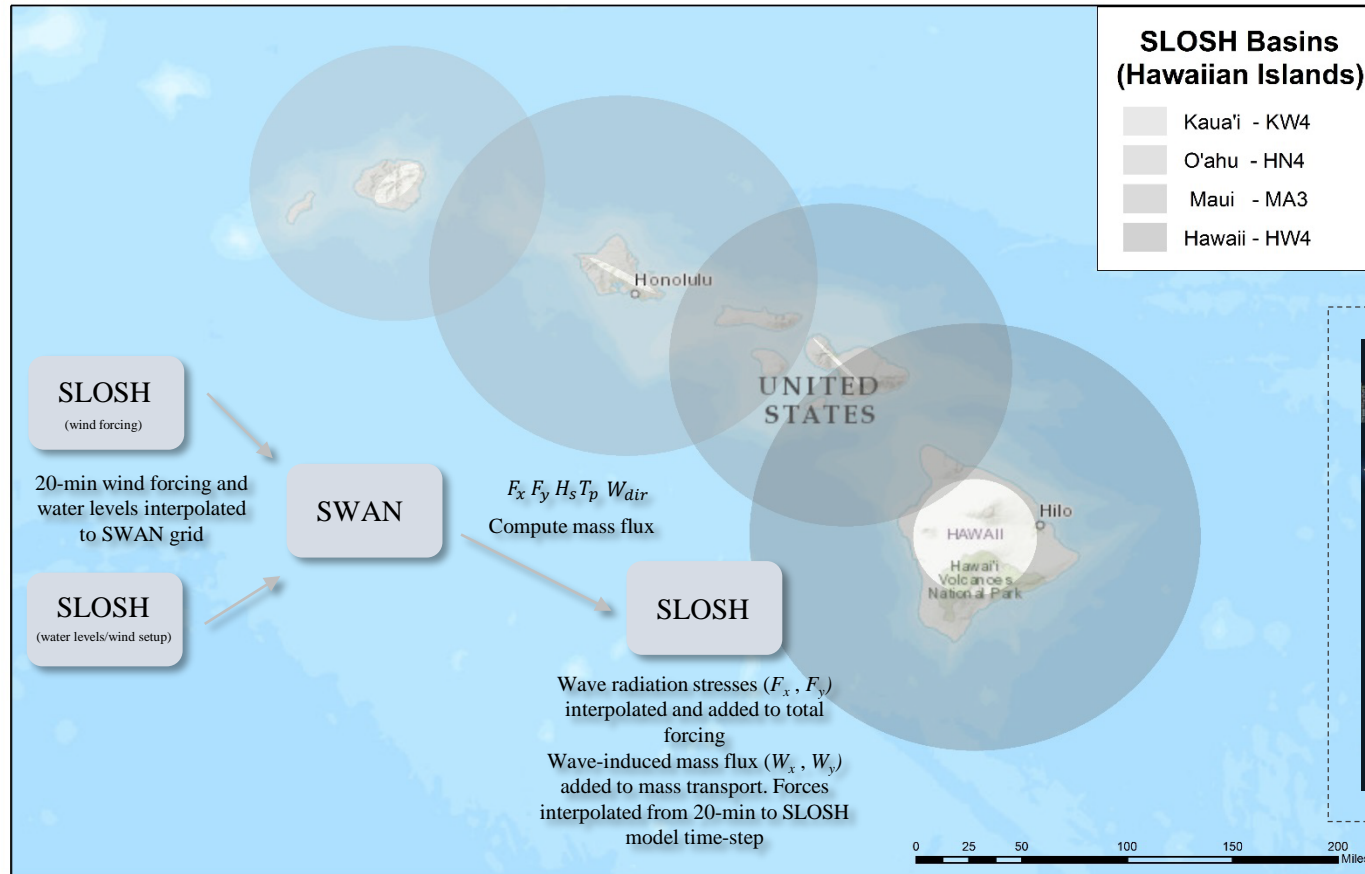
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OCONUS

Developing MOMs and MEOWS

Storm Surge Hazard Mapping National Hurricane Center



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 - Puerto Rico
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 - Hawaiian Islands

- **SLOSH coupled to the Simulating Waves Nearshore (SWAN) third-generation wave model**

- **Inundation resolution 10m**



SLOSH + Waves

- **Waves are a significant contribution to the total water level in island environments**
- **Numerical efficiency and stability are essential in meeting operational requirements.**



SLOSH + Waves

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Coastal and Ocean
Modeling Testbed



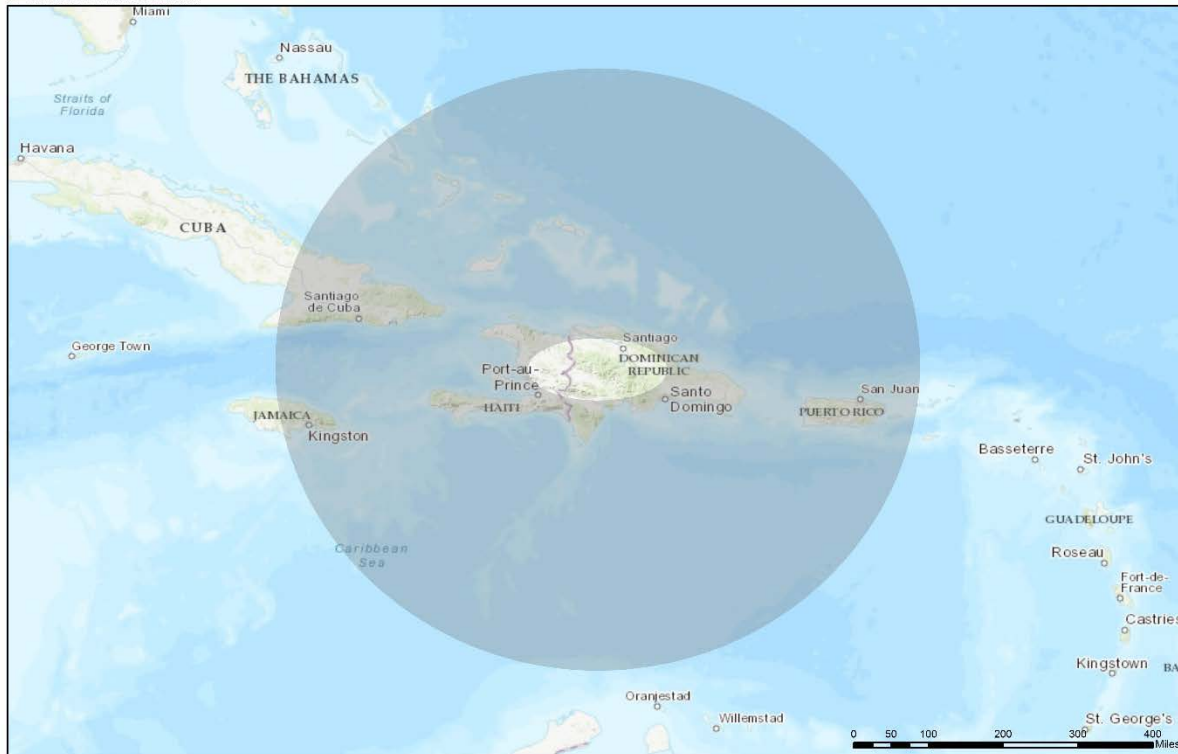
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Coastal and Ocean
Modeling Testbed

Hispaniola Demonstration Project National Hurricane Center SLOSH Fast Wave Model



Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), Swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



hurricanes.gov/surge



@NHC_Surge

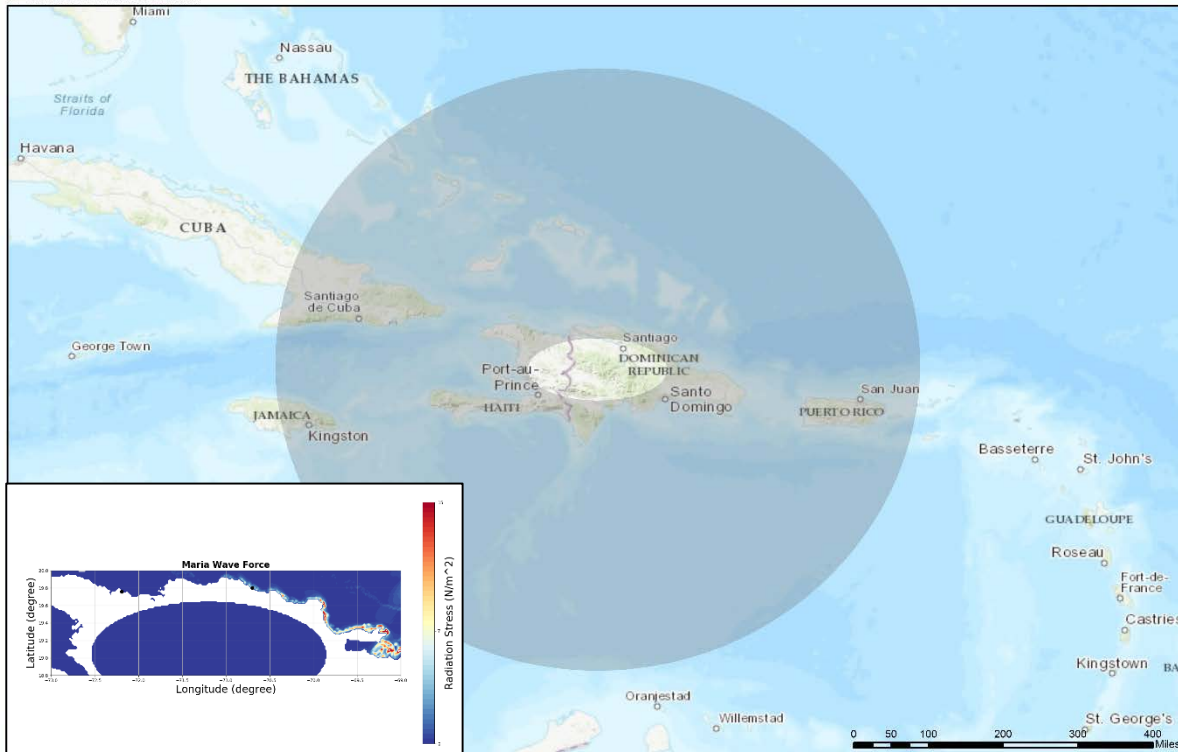
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Coastal and Ocean
Modeling Testbed

Hispaniola Demonstration Project National Hurricane Center SLOSH Fast Wave Model



SLOSH Fast Wave

Environmental Modeling Center

- SLOSH coupled to a parametric wave model (Schwab et al. 1984)
- More computationally efficient
 - 1.66 times increase of wall-time compared to stand-alone SLOSH
- Surge and wave models run on different grid meshes
- Validated both with idealized cases and field cases in Hispaniola.
 - Field cases include:
 - Irene (2011)
 - Matthew (2016)
 - Irma (2017)
 - Maria (2017)

Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, Geobase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), Swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

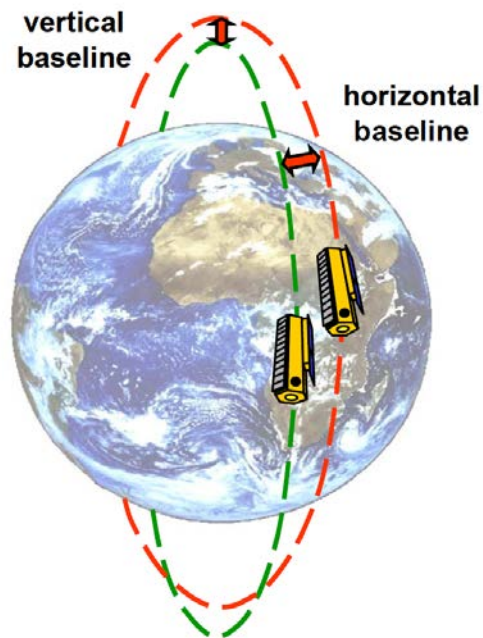
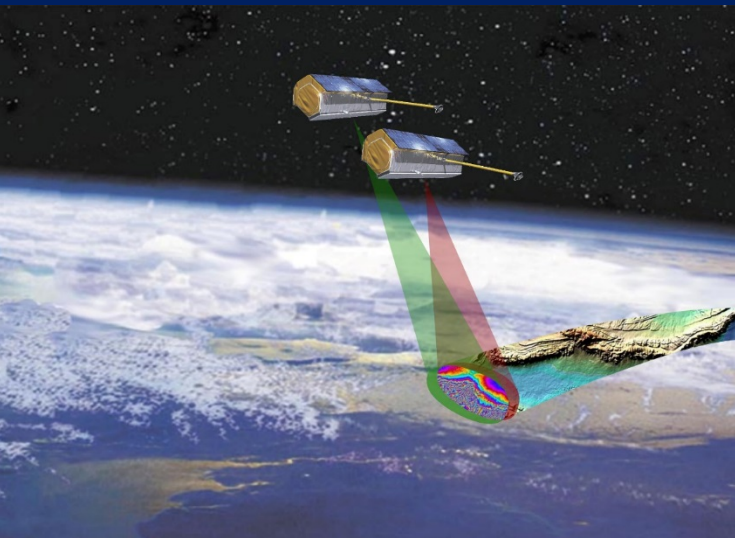


hurricanes.gov/surge



@NHC_Surge

TanDEM-X Project



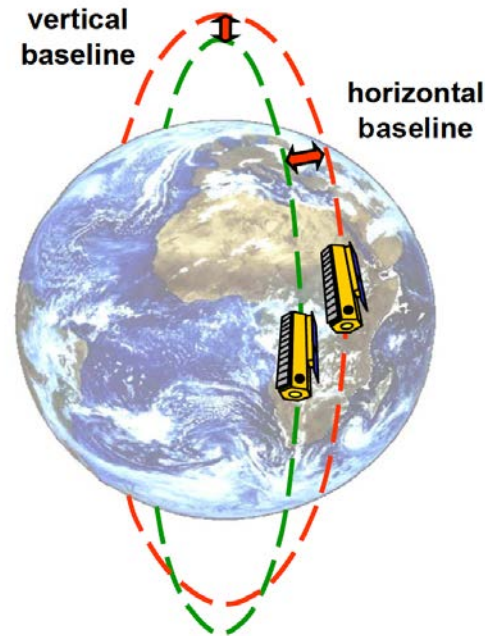
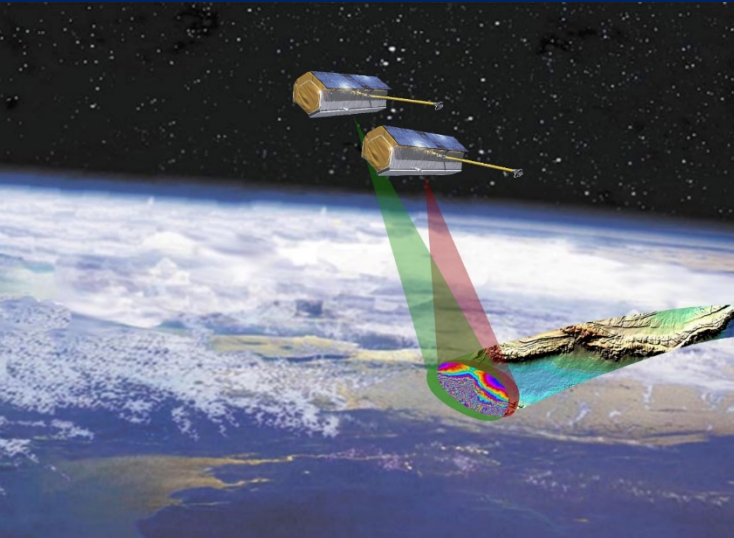
- TDX global DEM developed by German Aerospace Center
 - Relative vertical accuracy (2m slope < 20 %); (4m > 20%)
 - Absolute vertical accuracy (10 m)
 - 0.4 arc second resolution in latitudinal direction (12m)
 - Resolution varies in longitudinal direction (0.4-4 arc seconds)

WMO Coastal Inundation Forecasting Demonstration Project
(CIFDP) – for the Caribbean (C)

Funded by USAID

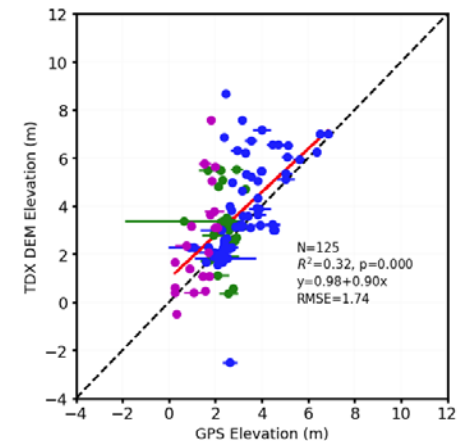


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- Vertical datum – EGM2008 (Pavlis et al. 2012)
- Filtered DEM using the Morph Method

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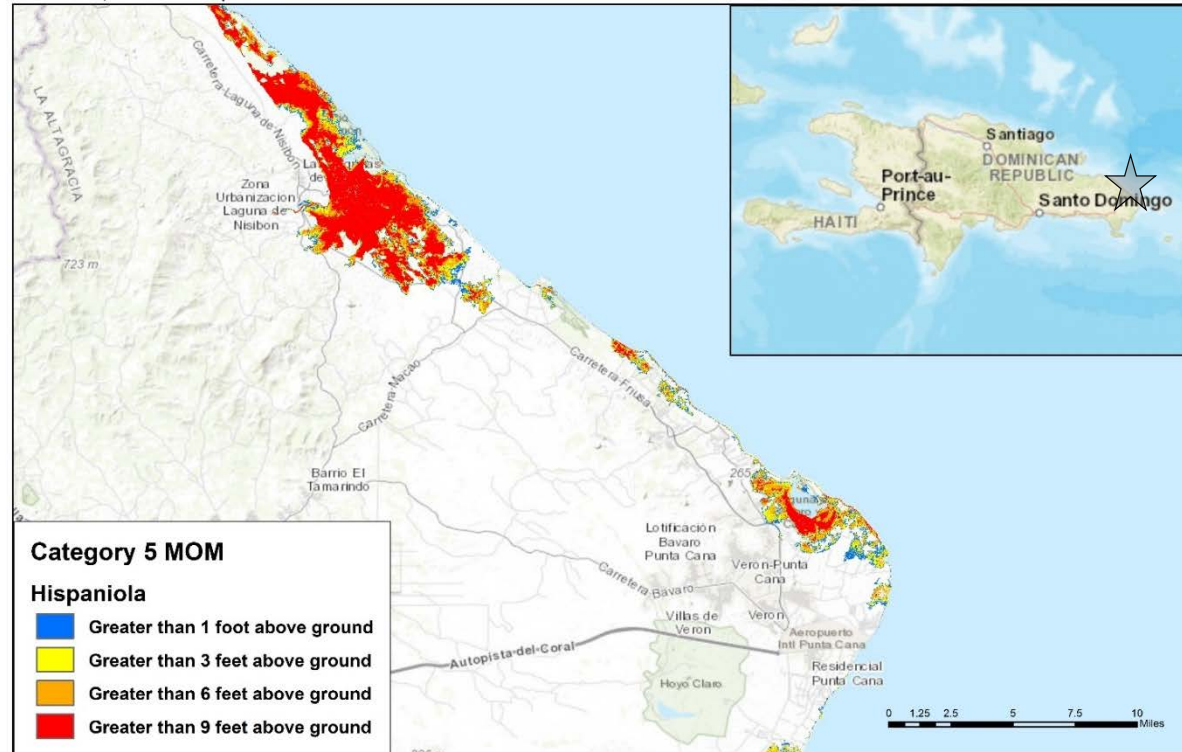


Scatter plot of TDX DEM vs GPS measurements at Pedernales, Samana, and Sanchez in The Republic of Dominica (Zhang et al. 2018 – under review)



Hispaniola Demonstration Project

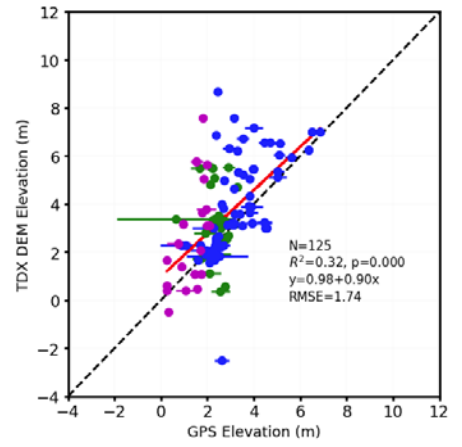
Storm Surge Hazard Mapping National Hurricane Center Punta Cana, Dominican Republic



Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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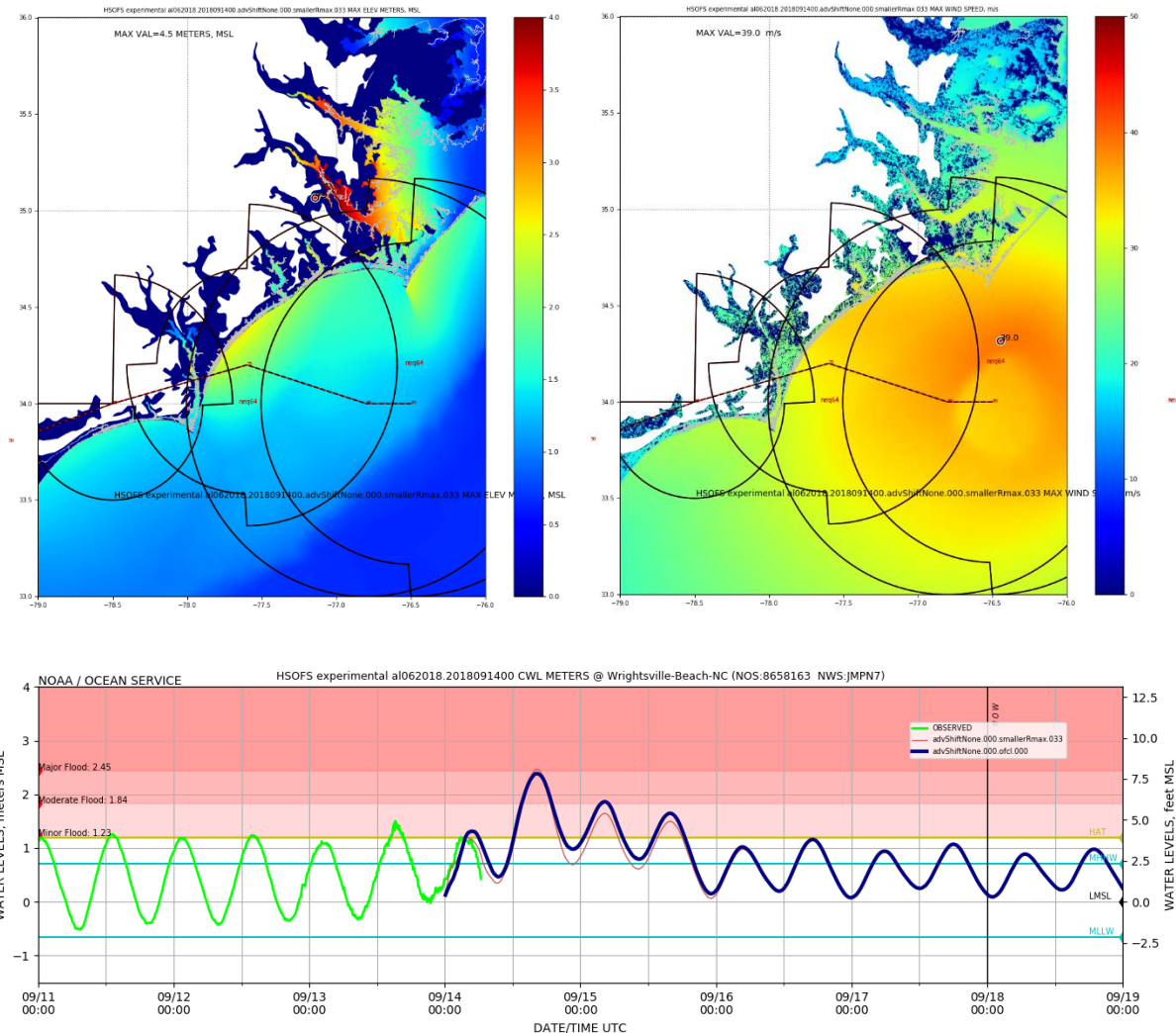
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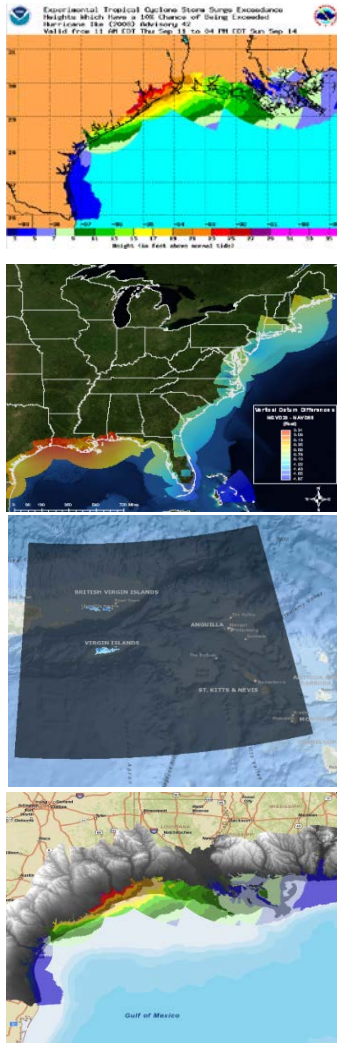
Hurricane Surge On-demand Forecast System (HSOFS)

HURRICANE FLORENCE (2018)

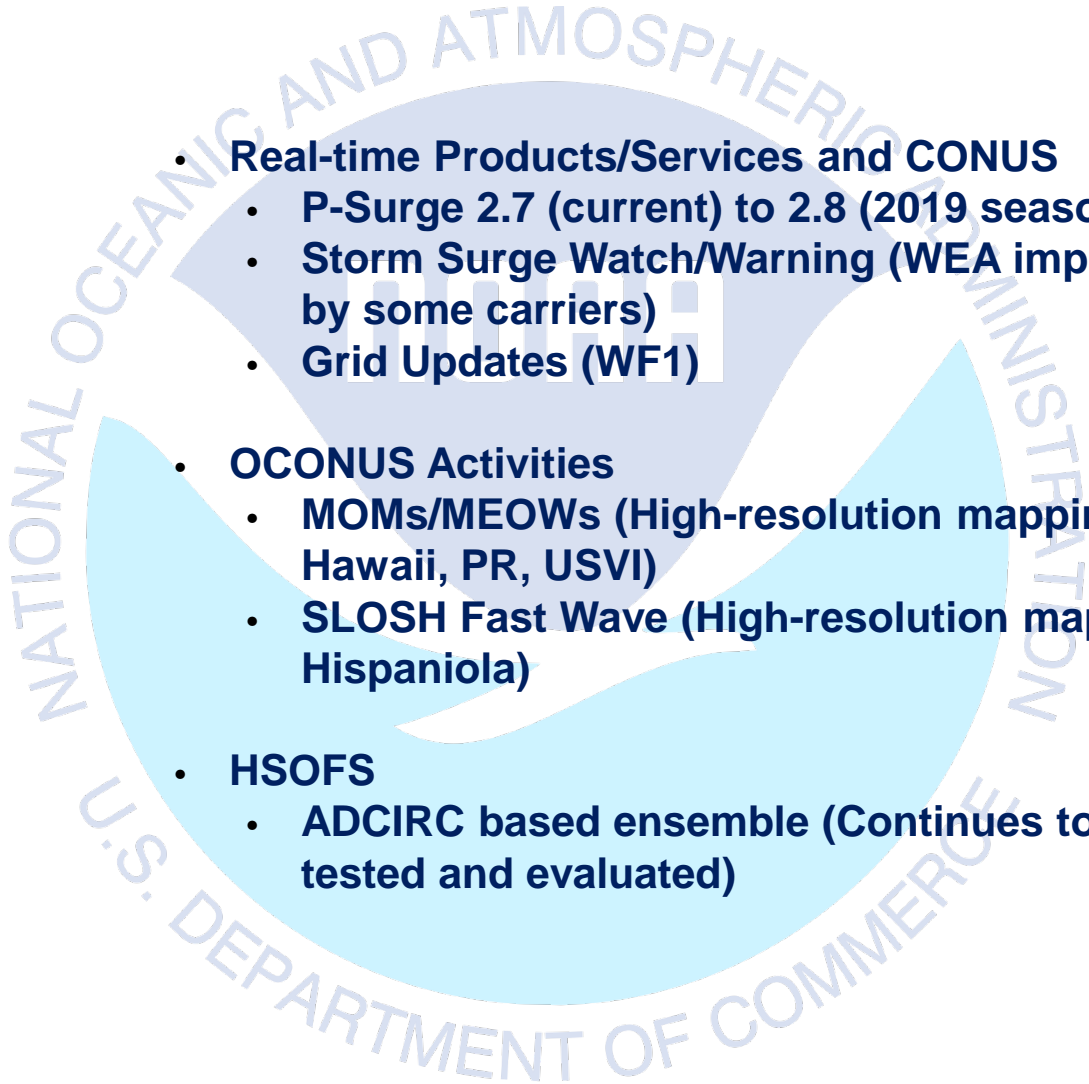
- Meant to supplement existing SLOSH (P-Surge)
- Test and evaluate ADCIRC capabilities in real-time and post-landfall
- Custom set of ensemble members
 - Vary by track direction, storm speed, and RMW



Summary



- **Real-time Products/Services and CONUS**
 - P-Surge 2.7 (current) to 2.8 (2019 season)
 - Storm Surge Watch/Warning (WEA implemented by some carriers)
 - Grid Updates (WF1)
- **OCONUS Activities**
 - MOMs/MEOWs (High-resolution mapping for Hawaii, PR, USVI)
 - SLOSH Fast Wave (High-resolution mapping for Hispaniola)
- **HSOFS**
 - ADCIRC based ensemble (Continues to be tested and evaluated)

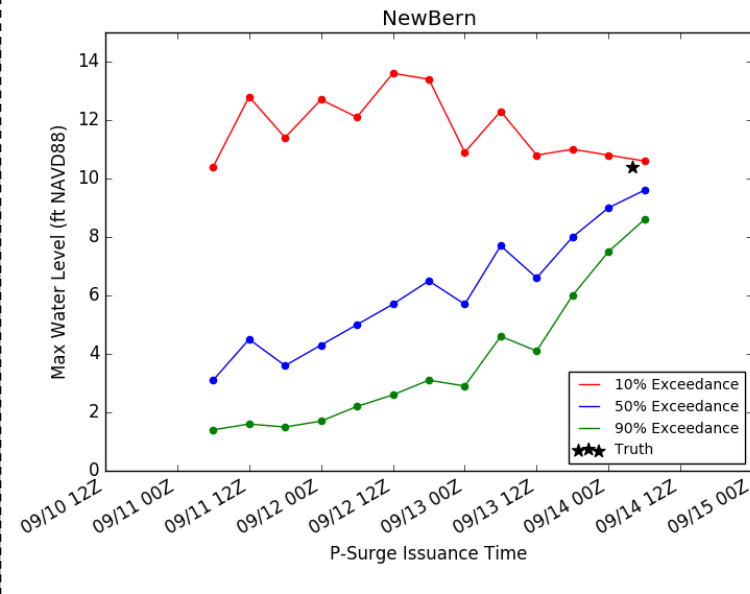
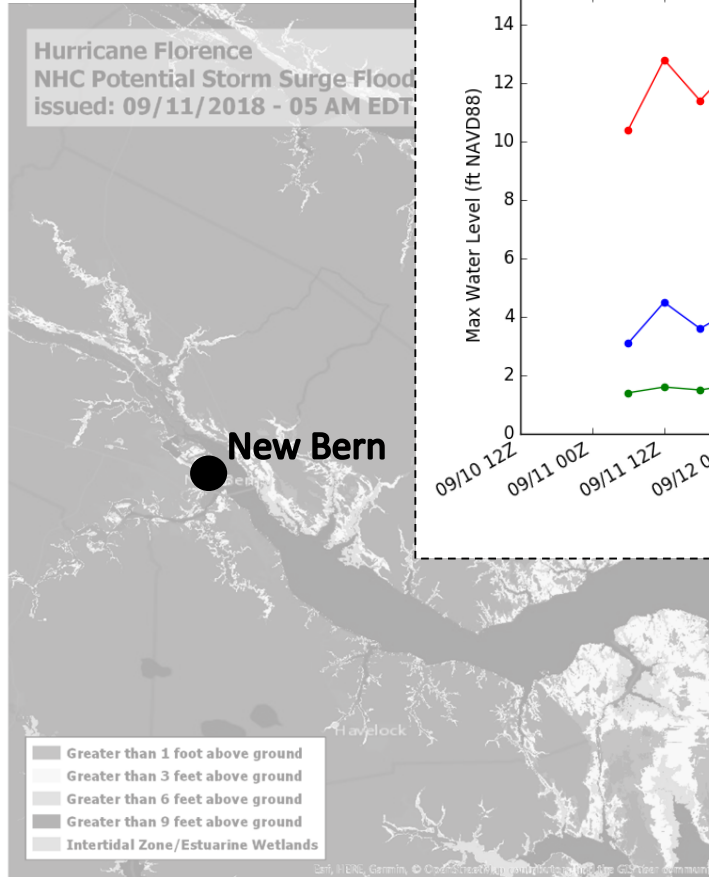
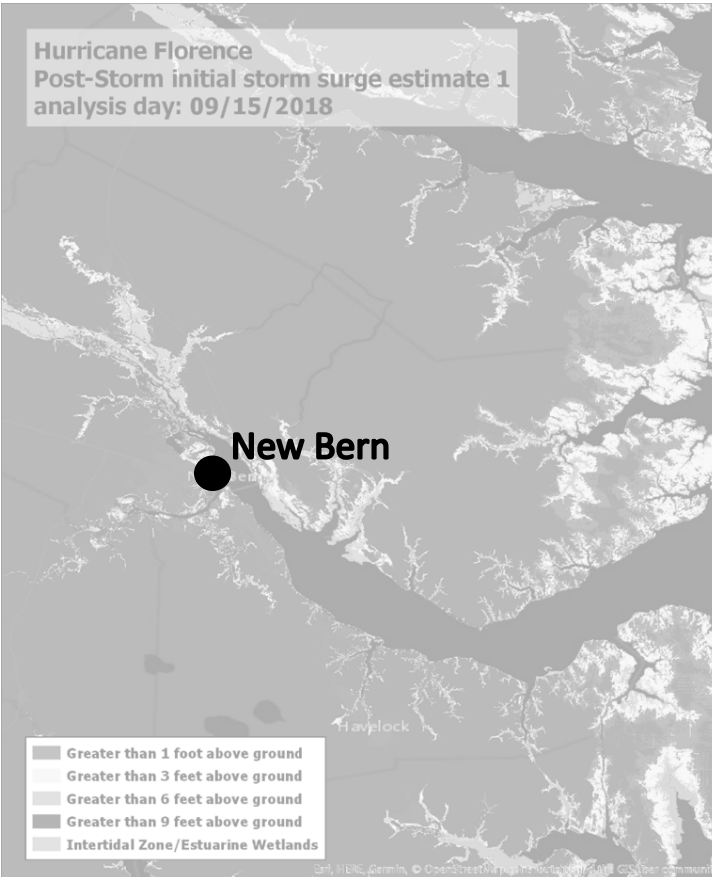


Questions?



HURRICANE FLORENCE (2018)

Why do we use the 10% exceedance (or near worst-case scenario)?



HURRICANE FLORENCE (2018)

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