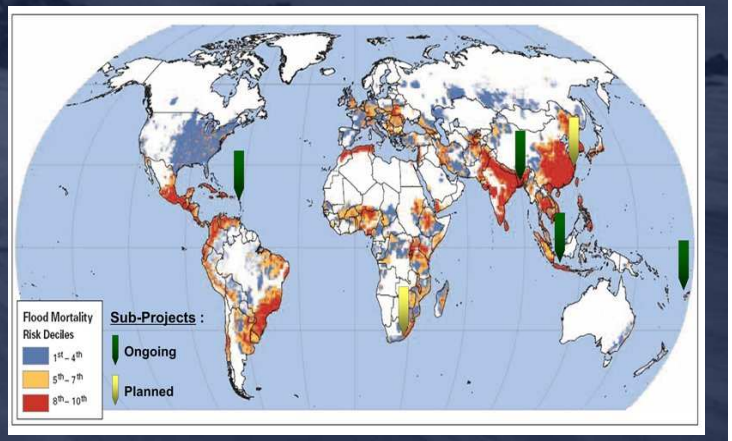
International Storm Surge Activities at RSMC Miami

Cody Fritz and Jamie Rhome

WMO RA-IV RSMC/CIFDP-C System Developer

WMO CIFDP-C

- Coastal Inundation Forecasting Demonstration Project (CIFDP) initiated by Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM)
- At the 5th meeting of the CIFDP Program Steering Group (May 2014, Geneva), the previous Sub-Project for Dominican Republic (CIFDP-DR) was re-scoped for a Caribbean/regional approach and denoted CIFDP-C
- CIFDP-C will be initially demonstrated and tested for the Dominican Republic and Haiti
- Develop SLOSH products for planning, preparedness, and forecasting
- RSMC Miami will provide the leading technical contribution, in collaboration with the PSG and other partners
- Fully funded by USAID (1.2 Million U.S. Dollars)



WMO CIFDP-C Participants

RSMC Miami

Jamie Rhome CIFDP-C System Developer/Project Manager

Ethan Gibney CIFDP-C Grid Builder

NWS Environmental Modeling Center

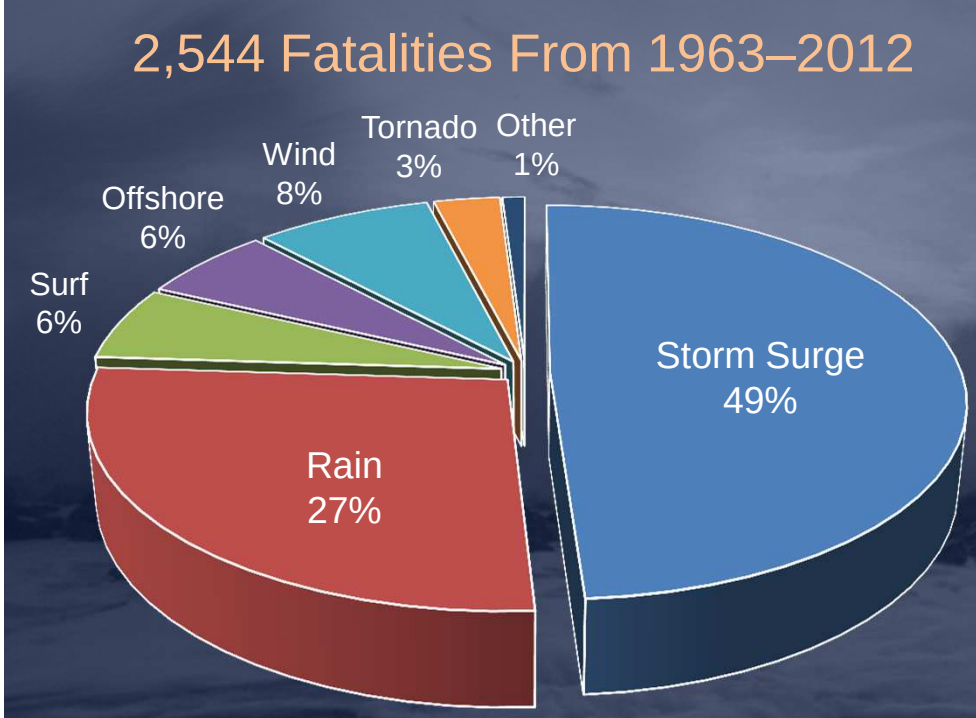
Andre Van der Westhuysen and Dongming Yang

CIFDP-C Modelers

Florida International University

Keqi Zhang CIFDP-C DEM and Grid Builder

Why the Need for a Demonstration Project



- Almost 50% the deaths are due to storm surge
- Over 80% of deaths are due to water
- Wind causes less than 10% of deaths

Edward N. Rappaport, 2014: Fatalities in the United States from Atlantic Tropical Cyclones: New Data and Interpretation. Bull. Amer. Meteor. Soc., 95, 341–346.

CIFDP-C Demonstration Project Plan

Specialized Storm Surge Training

- First-ever international storm surge modeling workshop held at NHC/FIU in January 2015, funded by the WMO
- Students consisted of various Nations from the WMO RA-IV region plus participants from the Philippines (PAGASA) and JMA
- Specialized training focused on setting up, running, and analyzing SLOSH model results and required data sets necessary for properly setting up and validating a storm surge modeling system
- NHC gathered feedback from workshop participants to lay foundation for CIFDP-C system design and implementation in member Nations

CIFDP-C Project Kickoff and NCT Meeting in Dominican Republic

Hispaniola Demonstration Project Phases

MEXICO DEMONSTRATION PROJECT

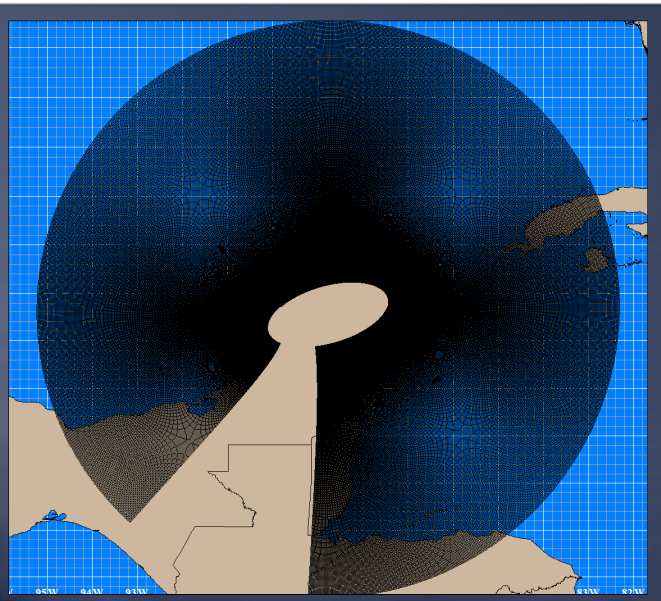
Mexico Storm Surge Demonstration Project

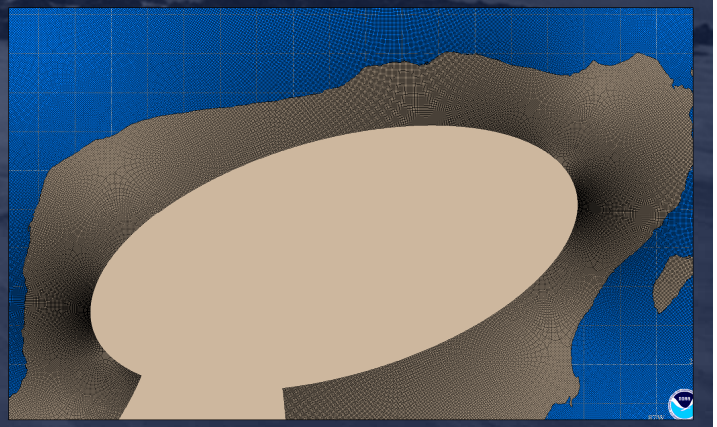
- Collaboration between RSMC-Miami, Florida International University, and the Coastal Processes and Engineering Laboratory of the Sisal Academic Unit of the Engineering Institute of the UNAM

- Explore the feasibility of using SLOSH within WMO RA-IV:
  - Initial scoping project in the Yucatan Peninsula due to data availability

- Establish a technical foundation for the CIFDP-C

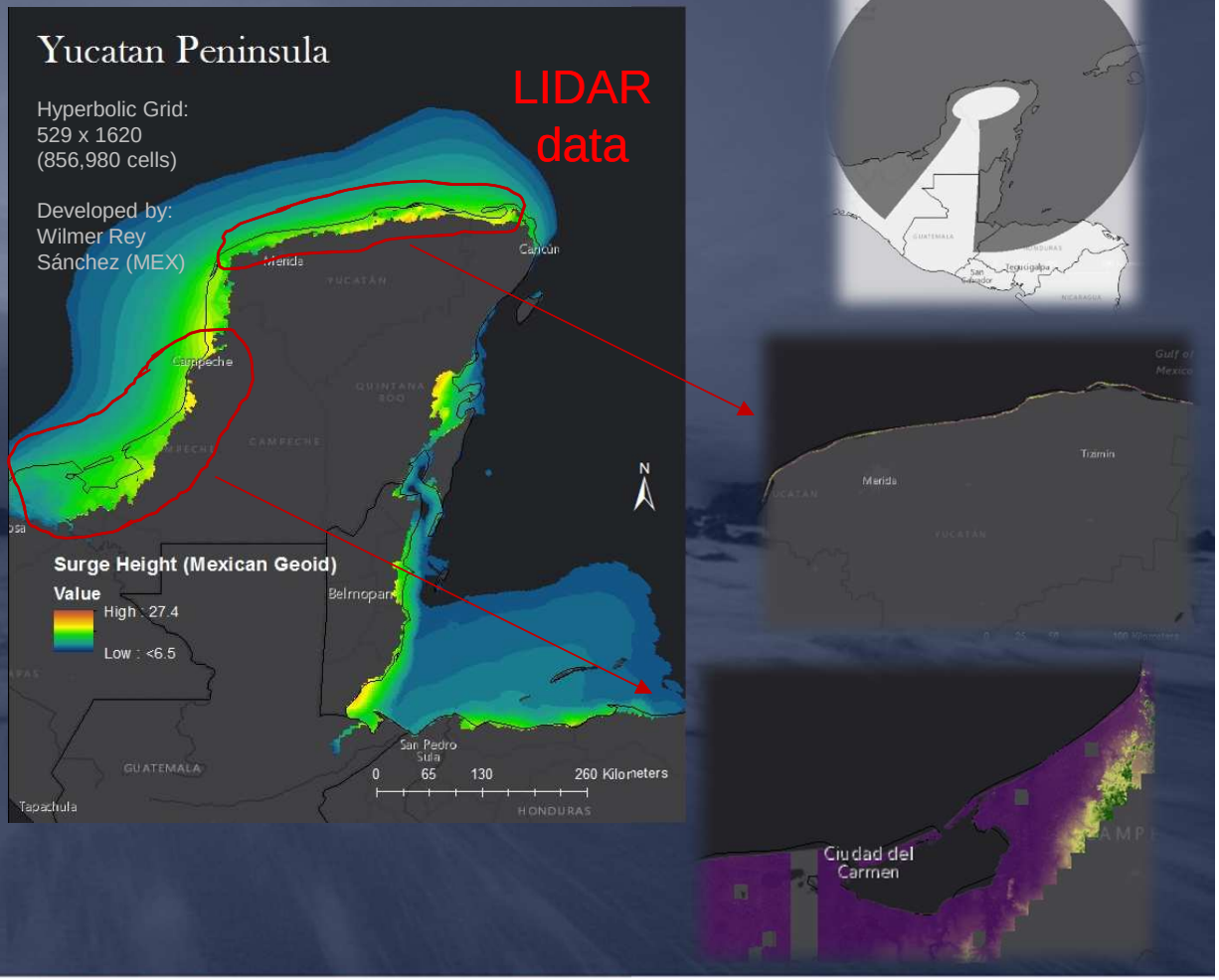
- Establish a framework for sharing storm surge modeling expertise and data between RSMC Miami and RA-IV member nations

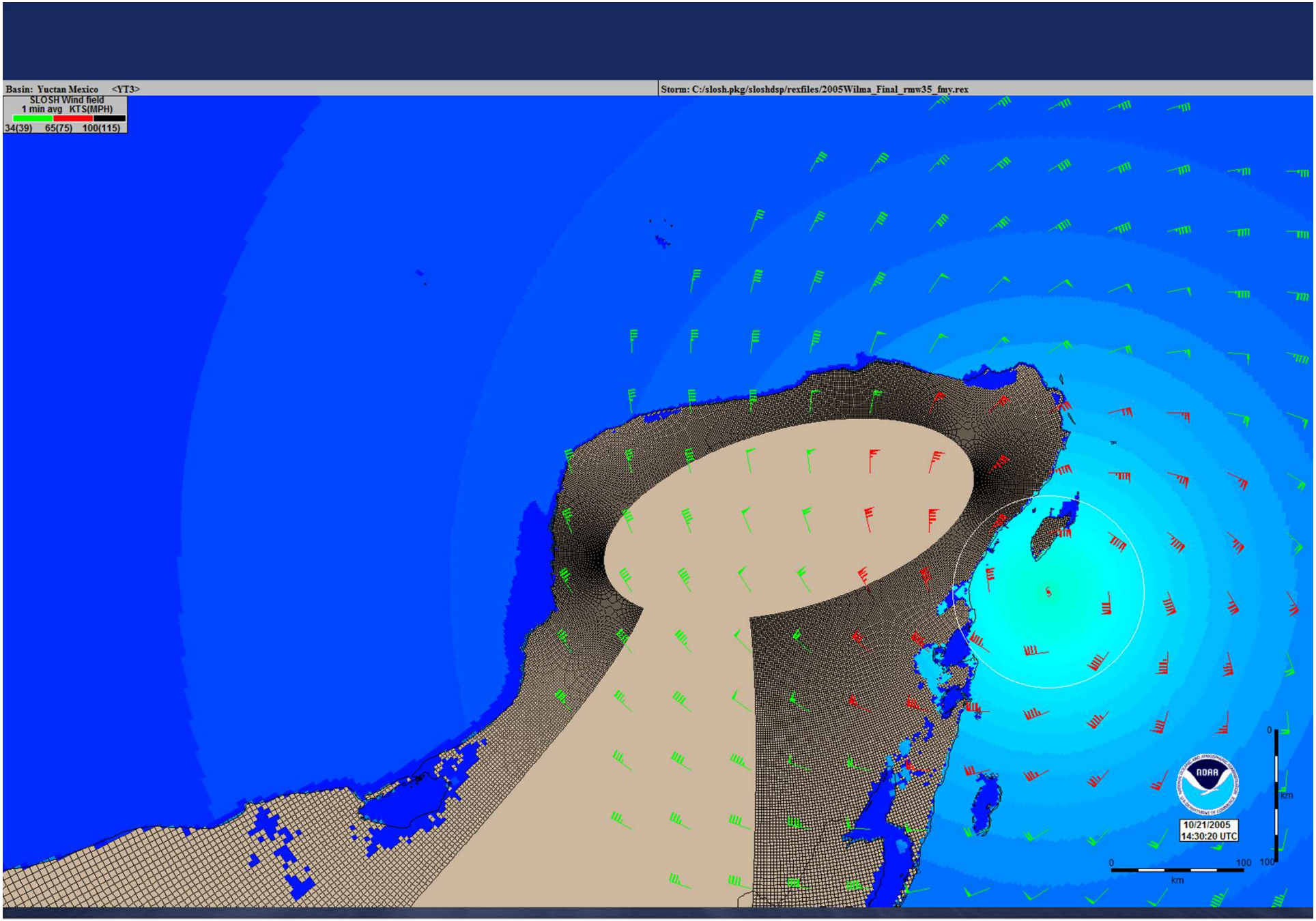




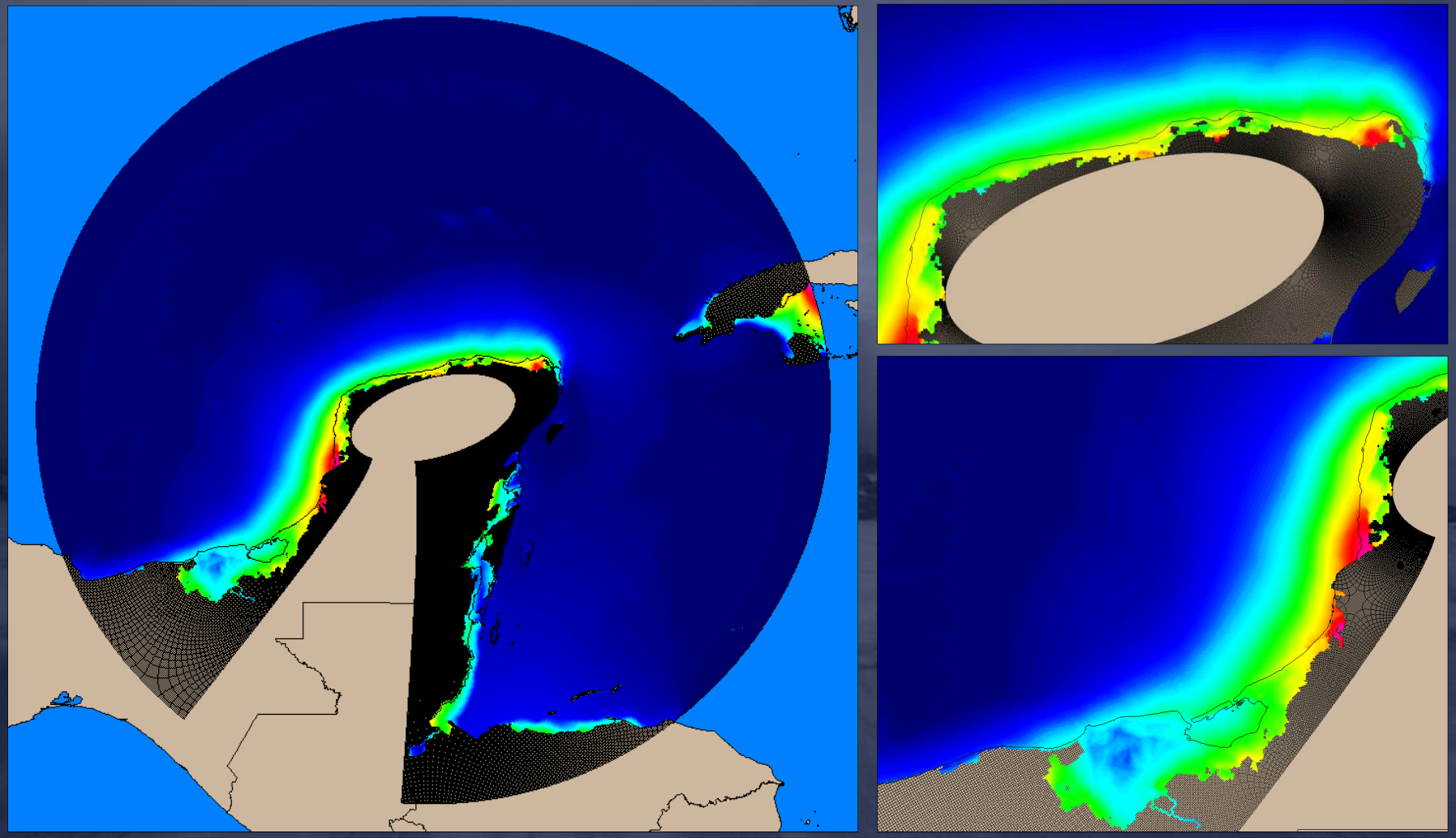
SLOSH Basin for Yucatan Peninsula

- First ever SLOSH basin for the Yucatan Peninsula
- Working to understand IT requirements and data necessary to develop SLOSH within Mexico
- LIDAR data supplemented with ETOPO1 (1.8 km) global relief model for topography and bathymetry data



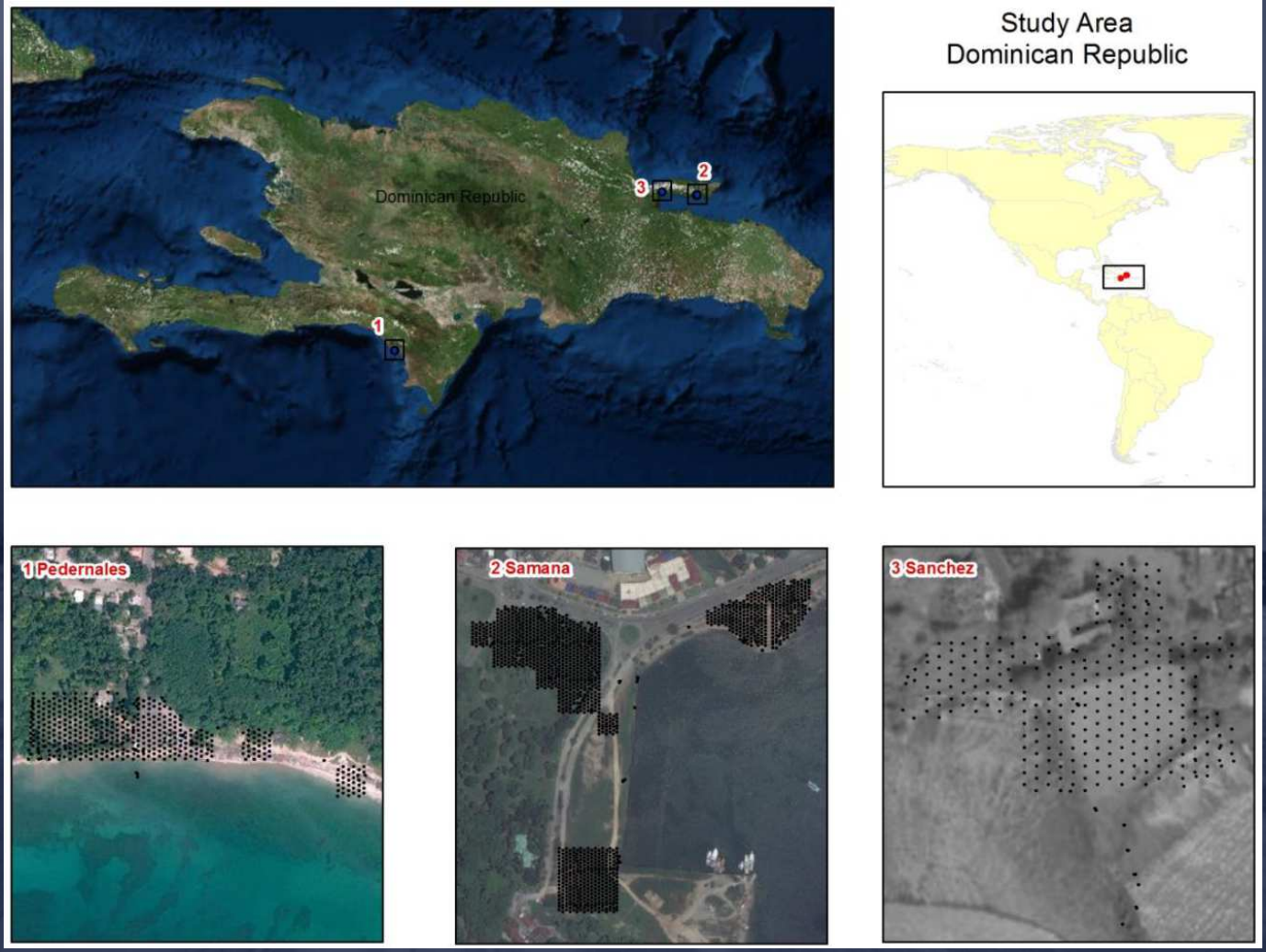

Basin: Yuctan Mexico <YT3>
Storm: C:/slosh.pkg/sloshdsp/rexfiles/2005Wilma_Final_rmw35_fmy.rex
SLOSH Wind field
1 min avg KTS(MPH)
34(39) 65(75) 100(115)
NOAA
10/21/2005
14:30:20 UTC
0
100
km
0
100
km

Mexico Storm Surge Demonstration Project
Category 3 MOM (Mean Tide)

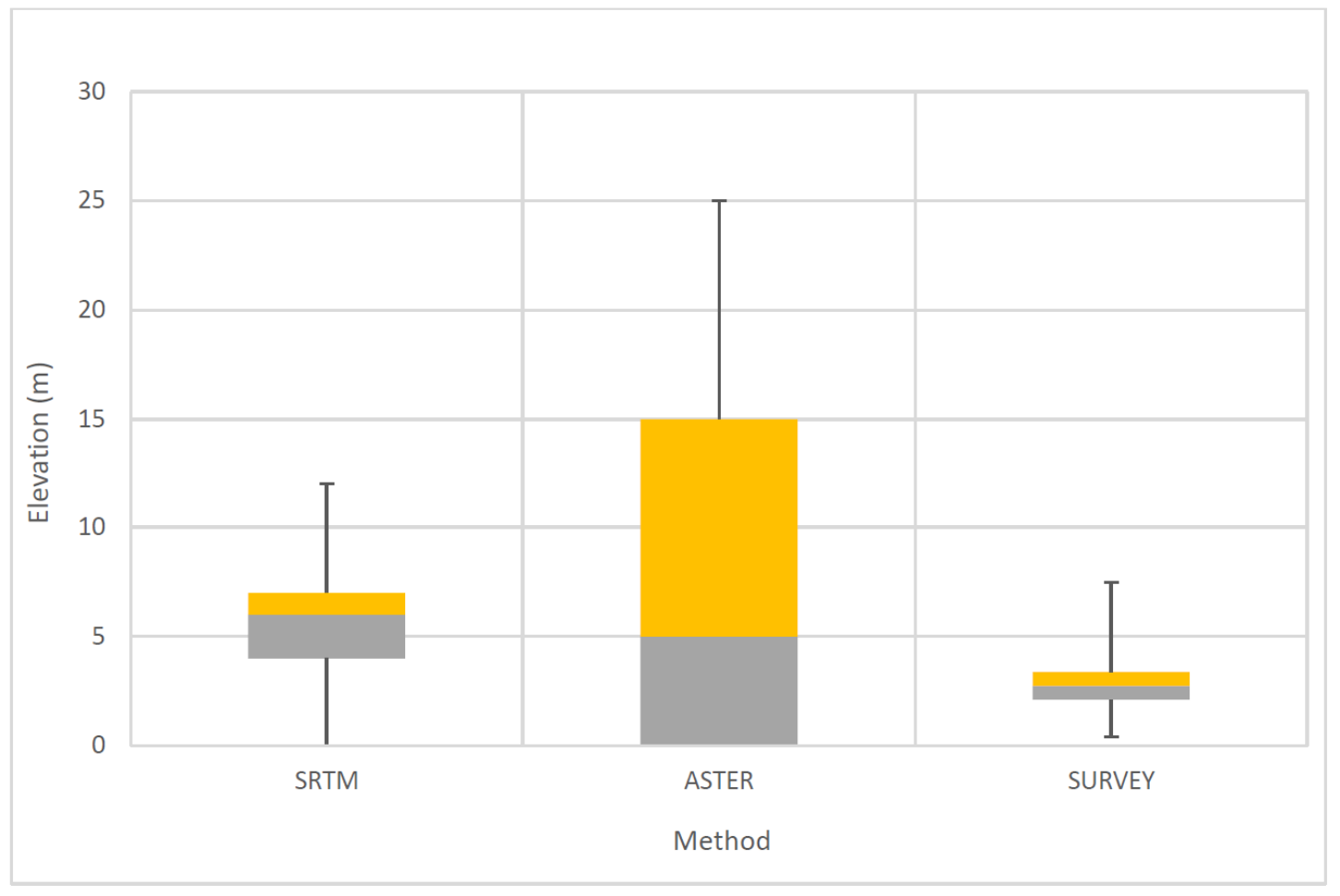


CIFDP-C DATA COLLECTION AND DATA ASSESSMENT

FIU Surveyed Areas in Dominican Republic

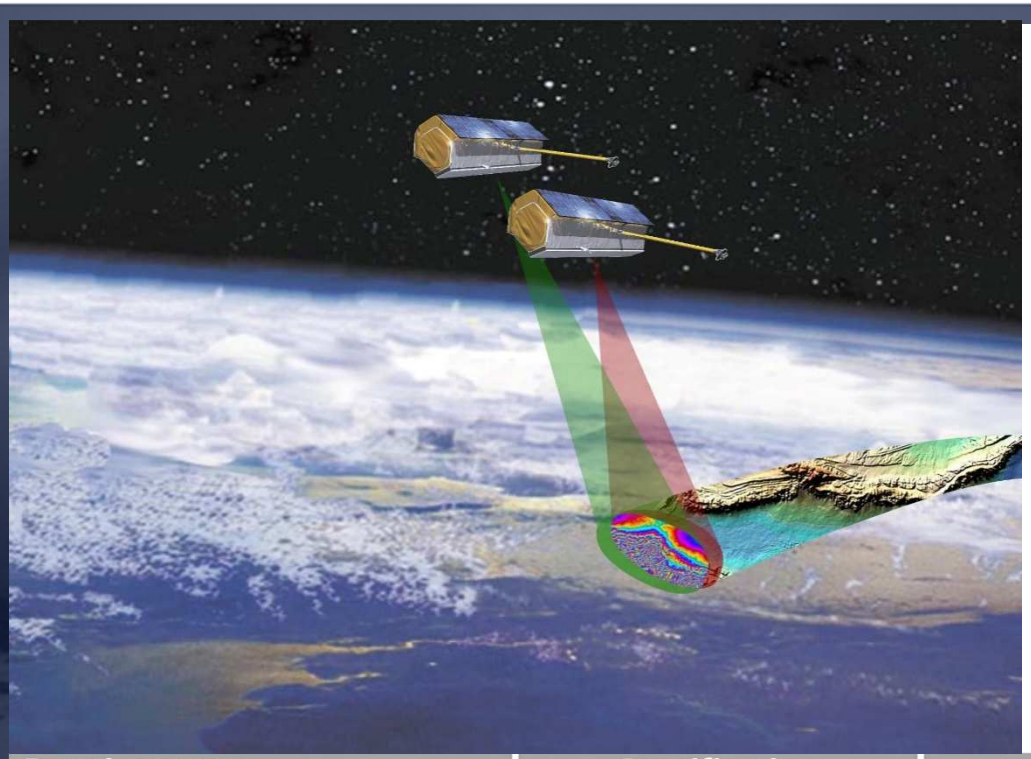


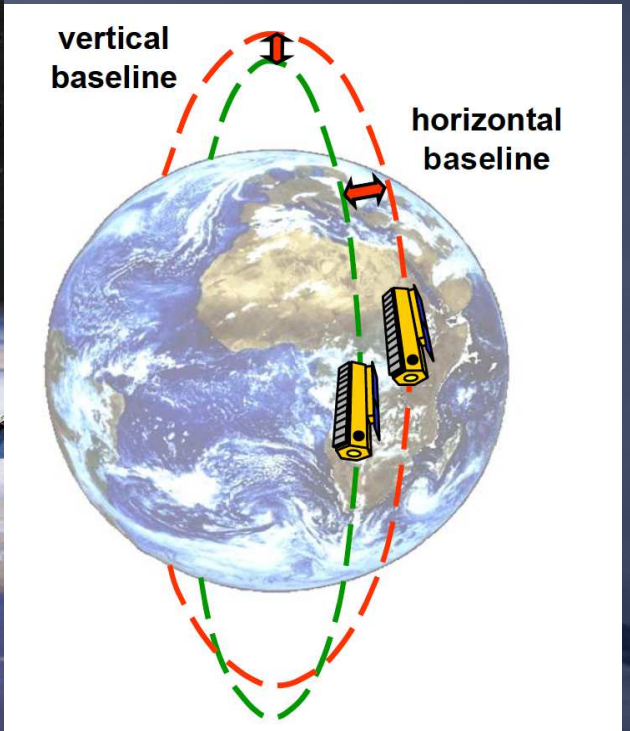
Boxplots for Grid Elevations and Survey Elevations for all Sites



Grey area represents the 25th to 50th percentiles; yellow 50th to 75th

TanDEM-X



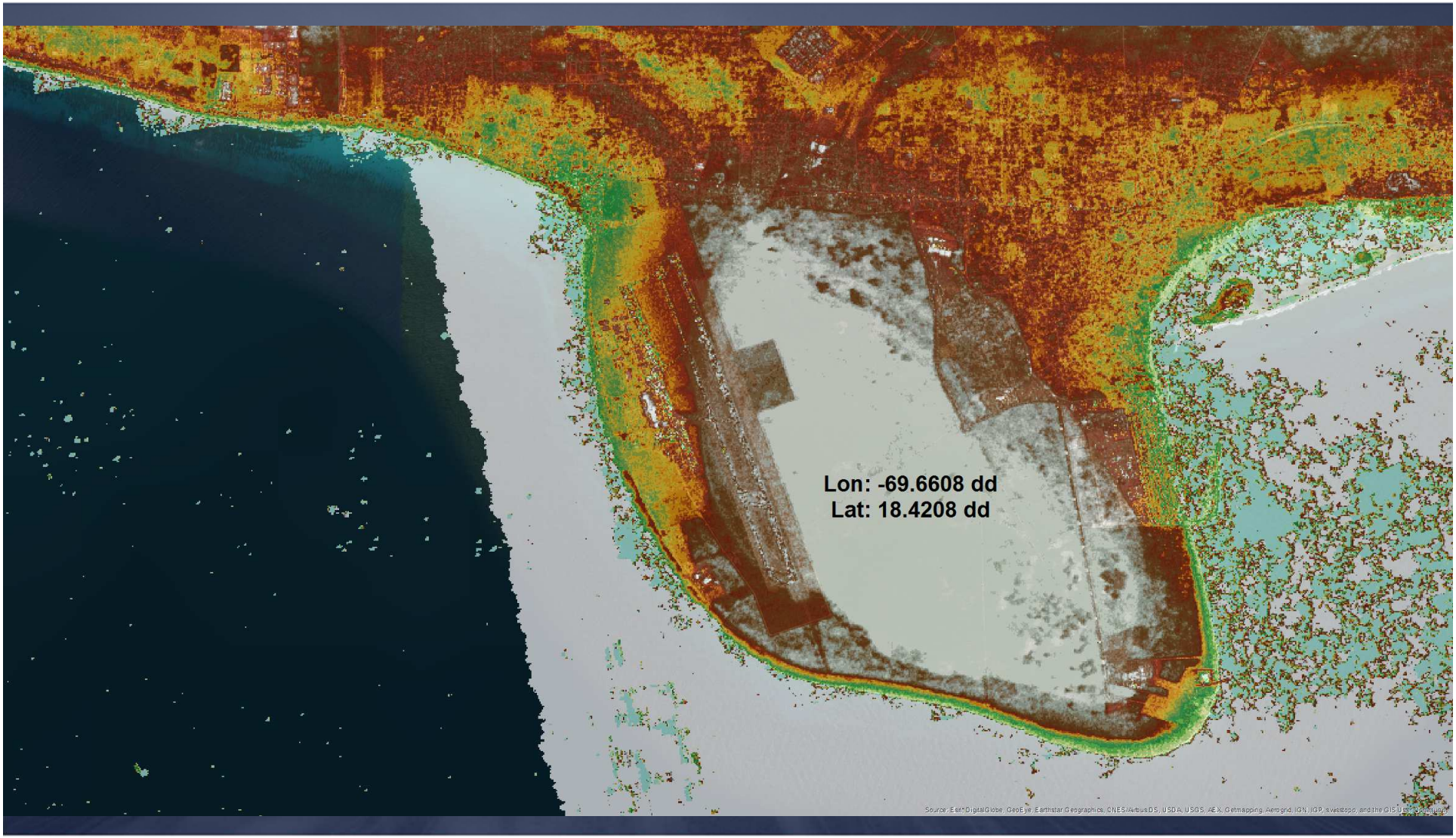


Requirements	Specification	DTED-2	TanDEM-X DEM
Relative Vertical Accuracy	90 % linear point-to-point error over a 1° by 1° cell	12 m (slope < 20 %) 15 m (slope > 20 %)	2 m (slope < 20 %) 4 m (slope > 20 %)
Absolute Vertical Accuracy	90 % linear error	18 m	10 m
Relative Horizontal Accuracy	90 % circular error	15 m	3 m
Absolute Horizontal Accuracy	90 % circular error	23 m	10 m
Spatial Resolution	Independent pixels	30 m (1 arc sec @ equator)	12 m (0,4 arc sec @ equator)

TanDEM-X Data Availability

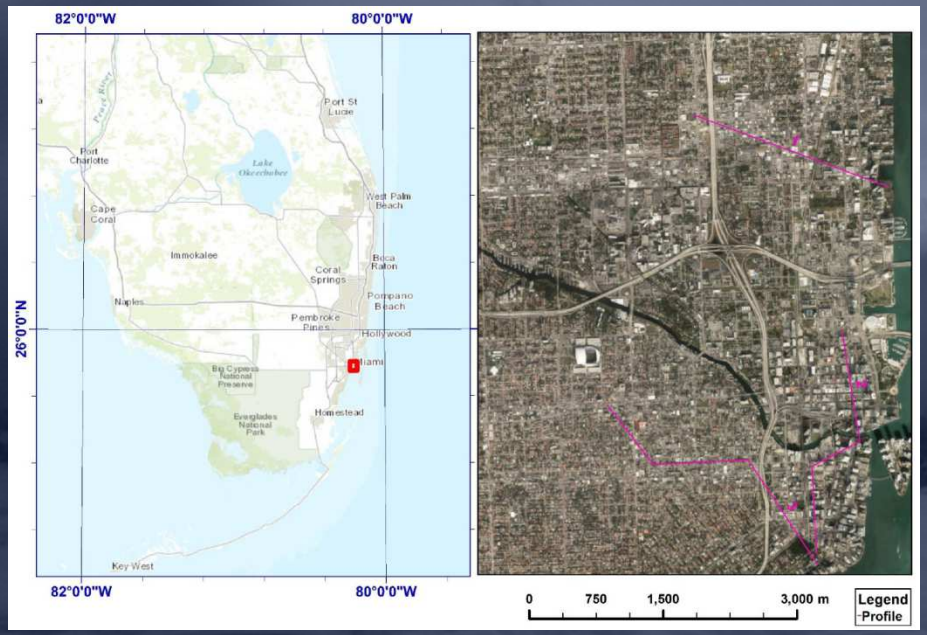
- Availability as of March 2016
- Estimated cost: ~100K U.S. dollars for study area
- Working with NWS International Affairs and FIU to establish an agreement regarding data sharing and savings for CIFDP-C

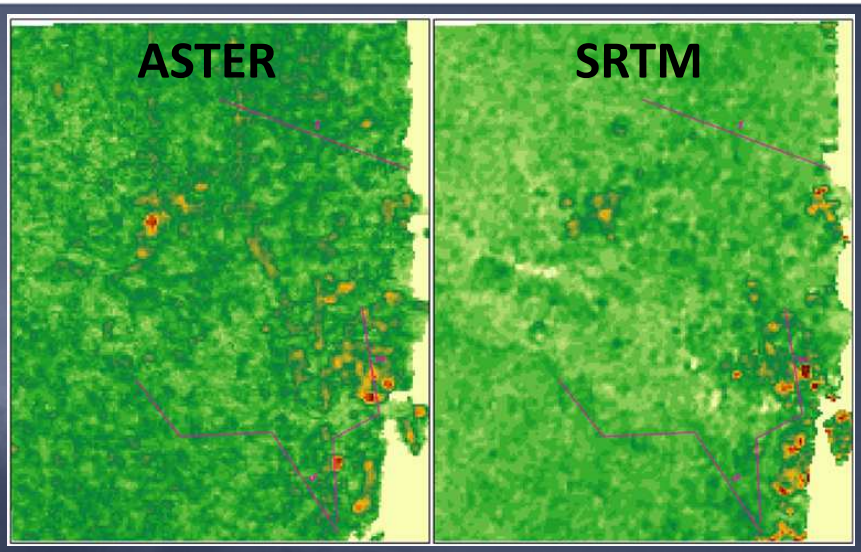
Raw TanDEM-X: Santo Domingo Airport

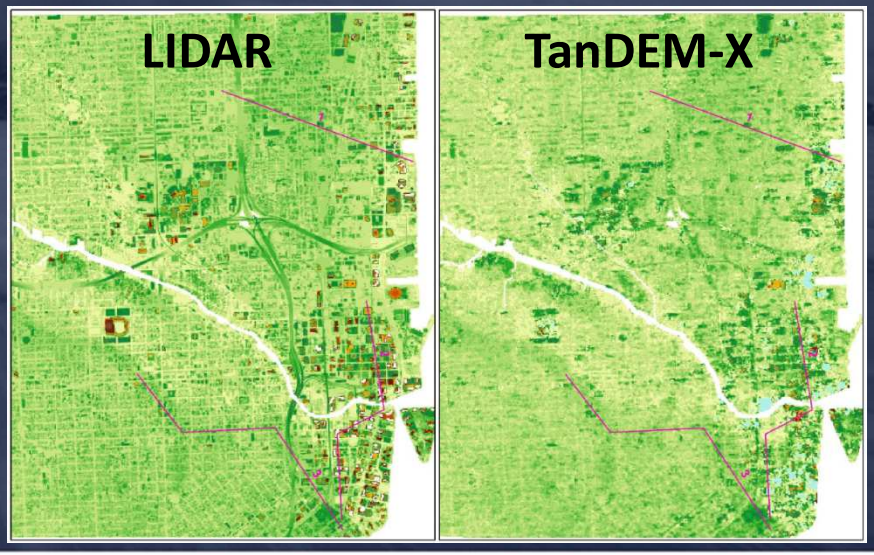


Topography Data Comparison: Miami, FL

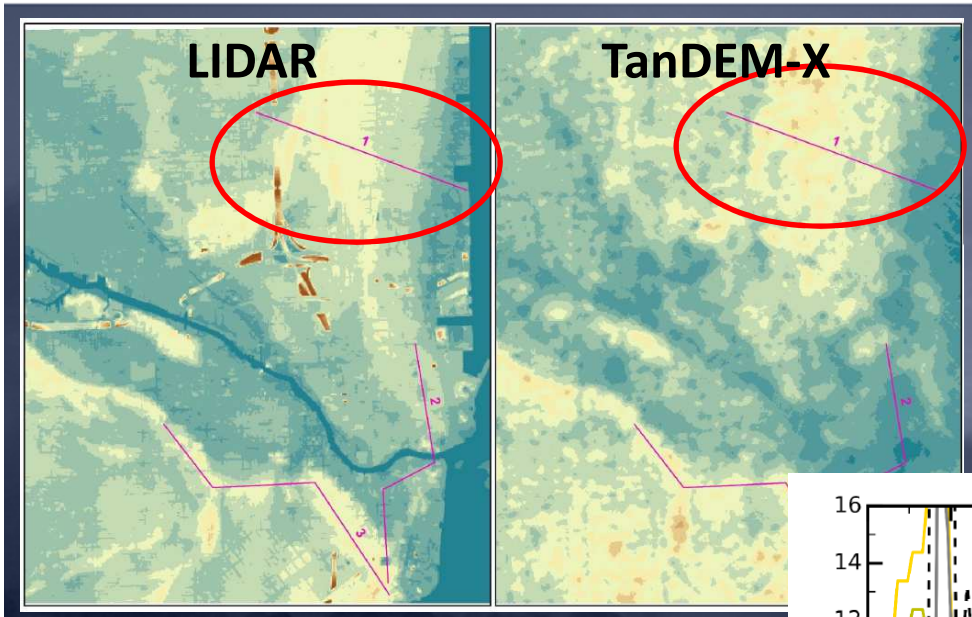
Downtown Miami, FL



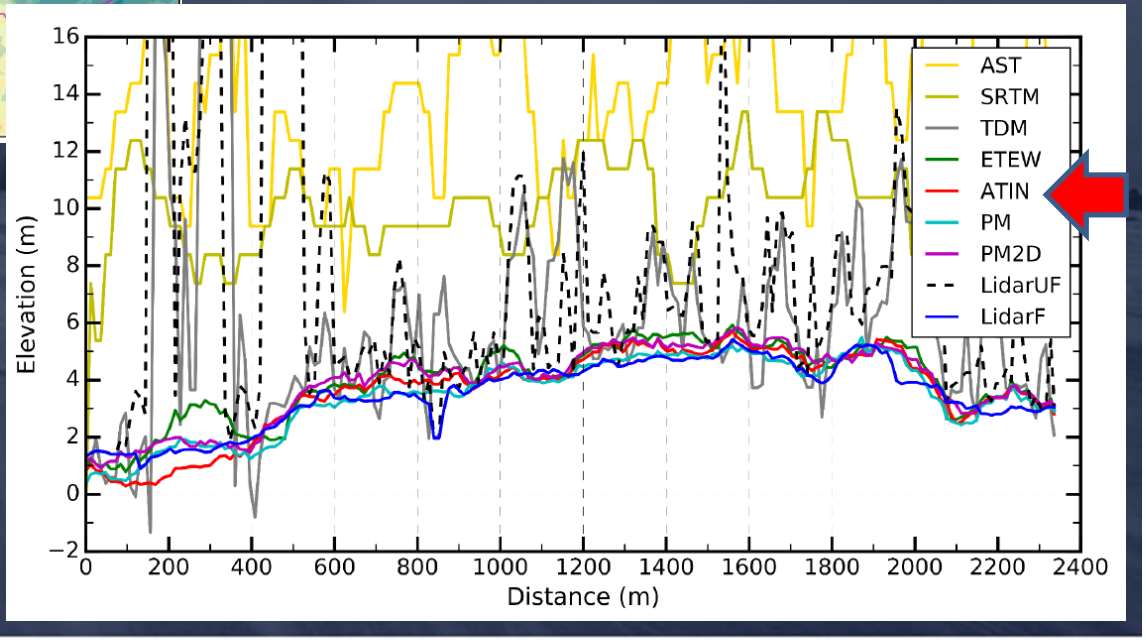




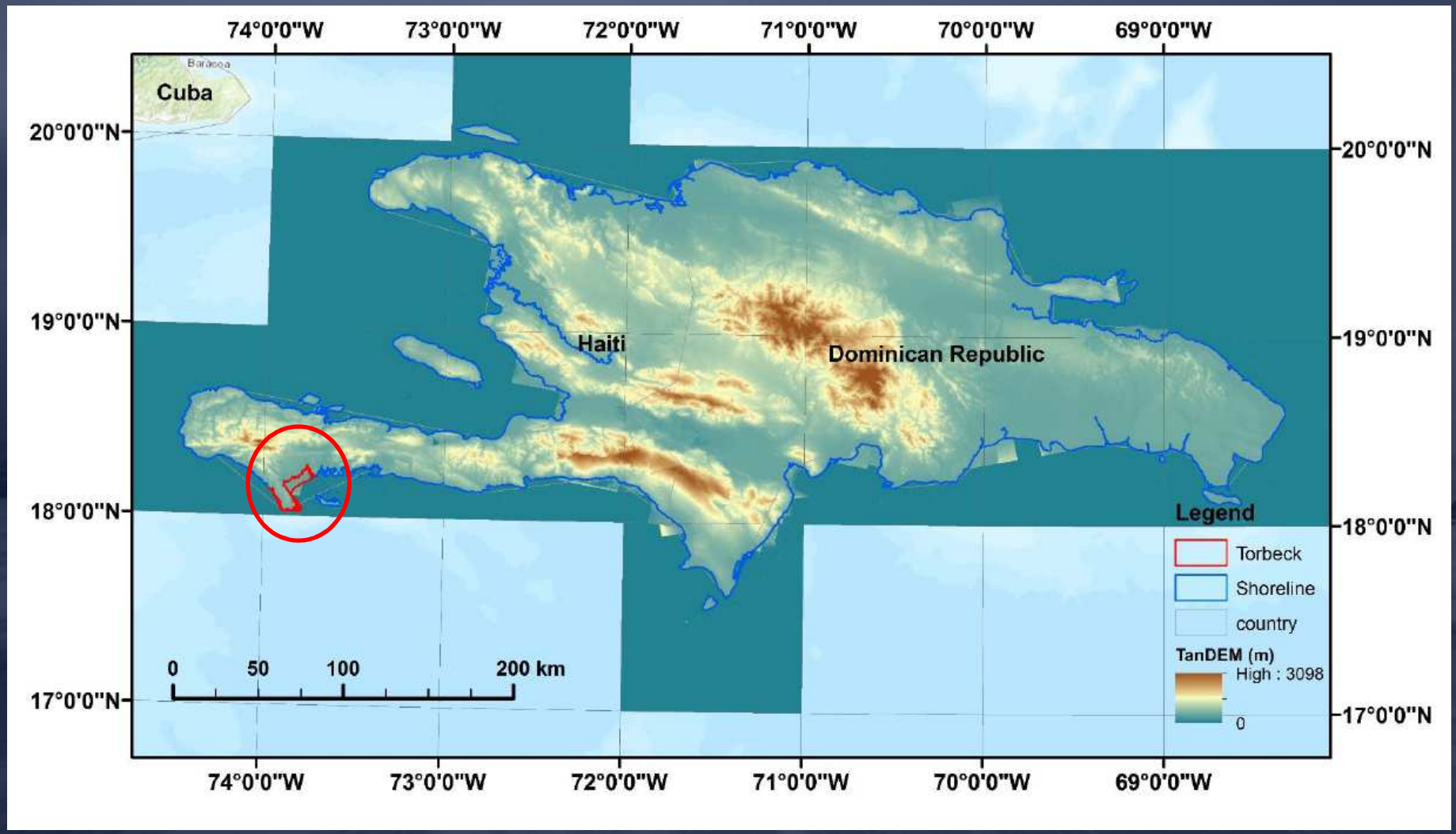
Topography Data Comparison: Miami, FL



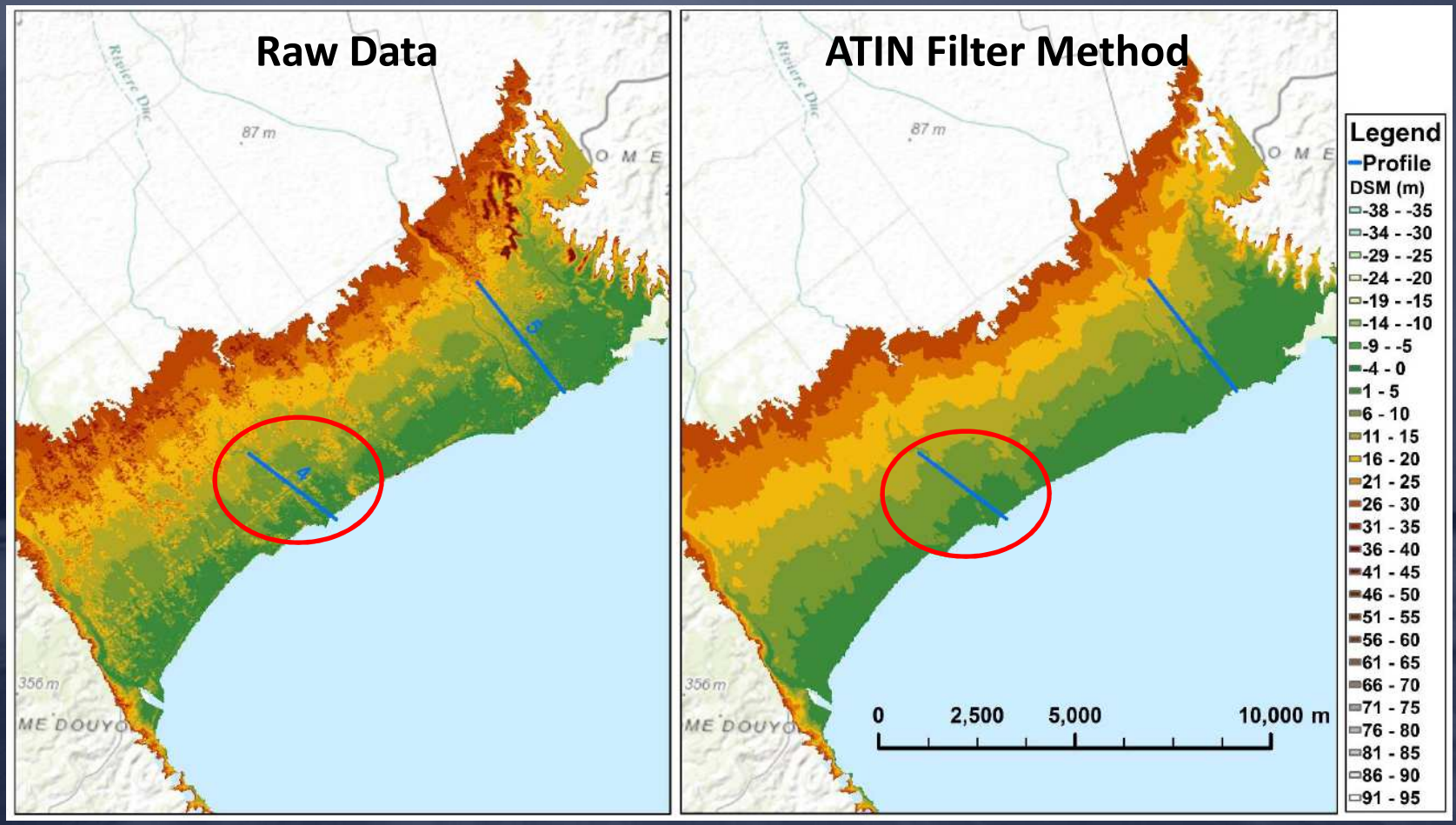
Filtering Methods to create DTM



TanDEM-X Data for Hispaniola

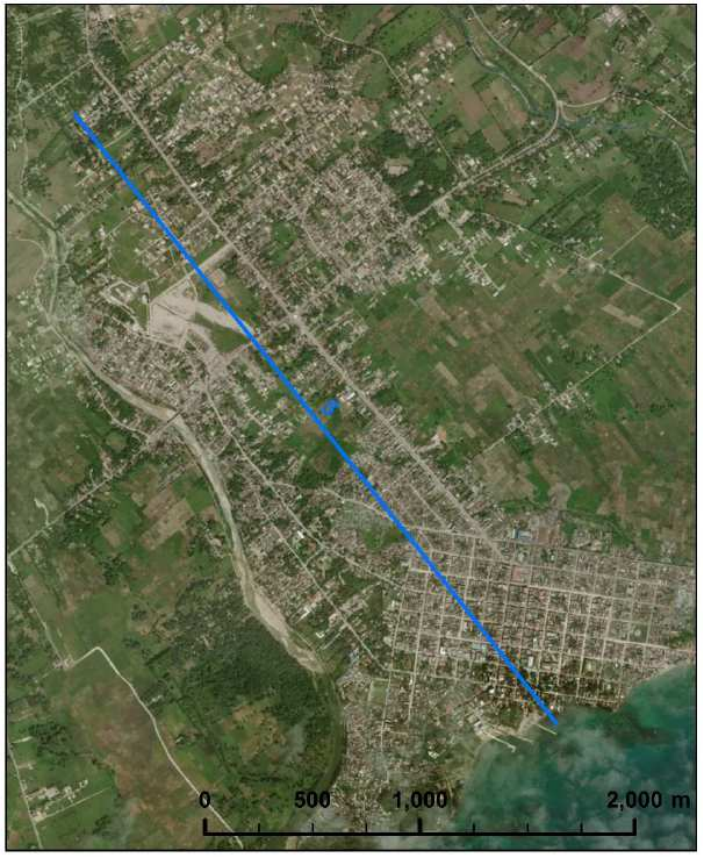


DTM Creation: Torbeck, Haiti

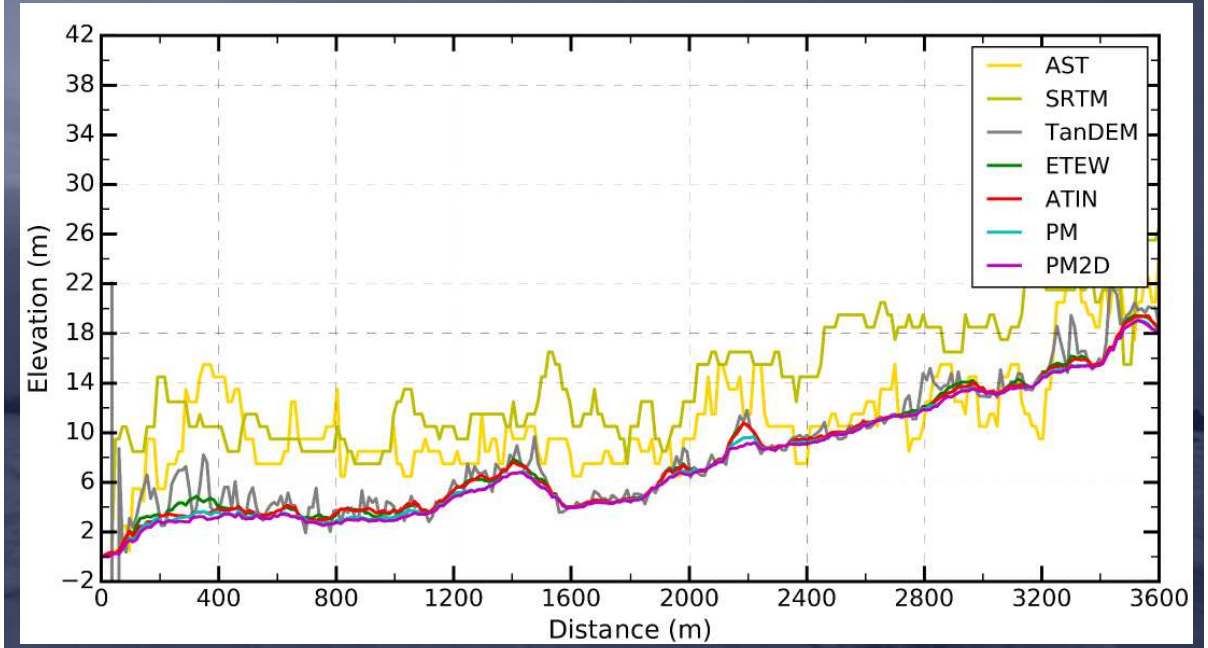


DTM Comparison: Torbeck, Haiti

Profile Location



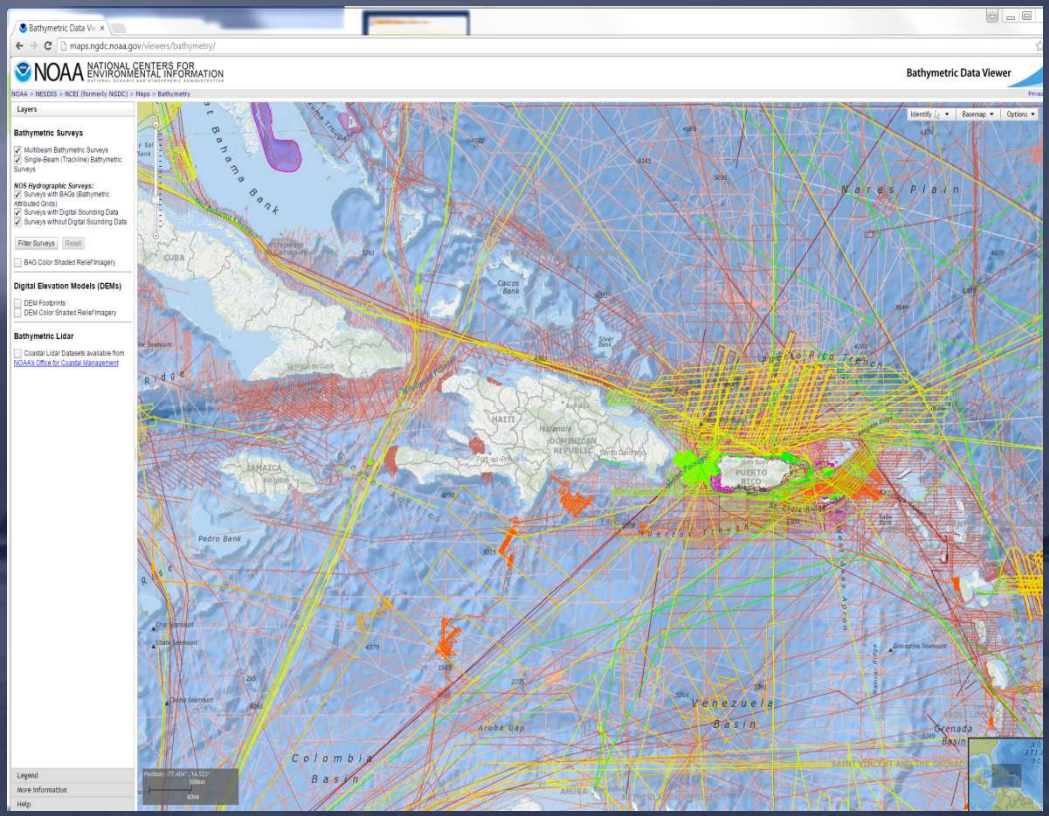
DTM Comparison: ASTER, SRTM, TanDEM-X



Bathymetric Data

- NOAA single and multi-beam sounding surveys
- NOAA Tsunami program
- CIFDP-C NCT data collection
- IOC bathymetry

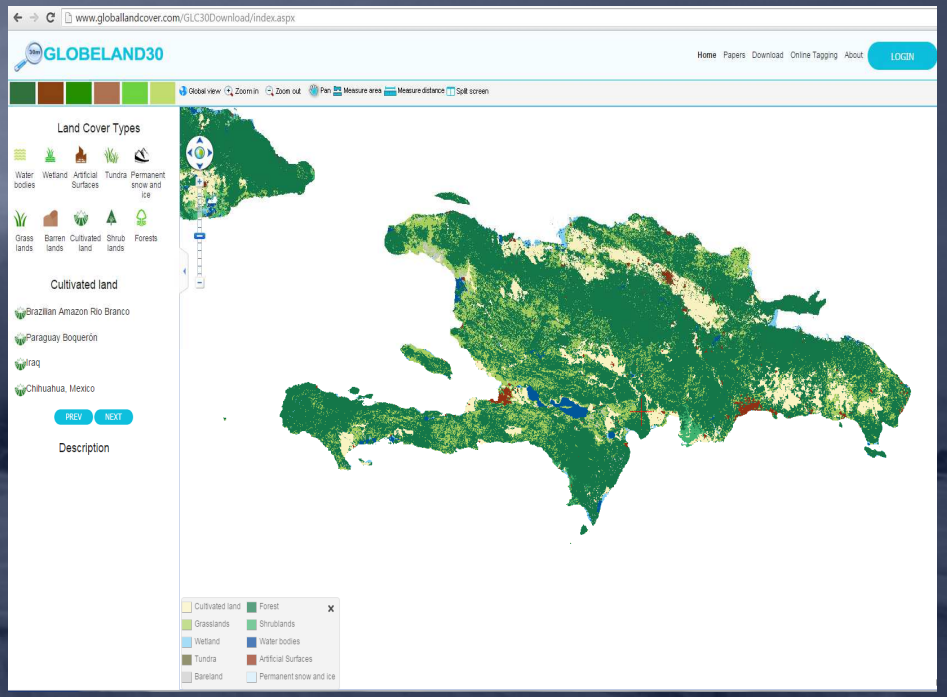
- Already incorporated into model grids



Supplemental Information

NOAA Global Shoreline

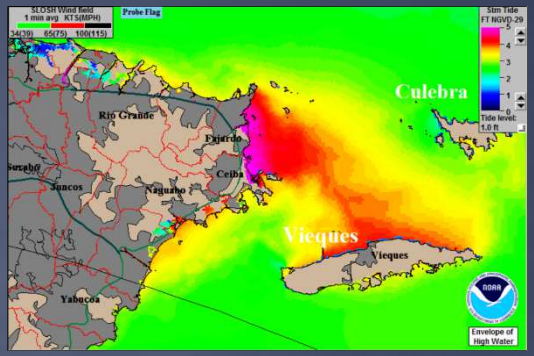
Global 30m Land Cover from China

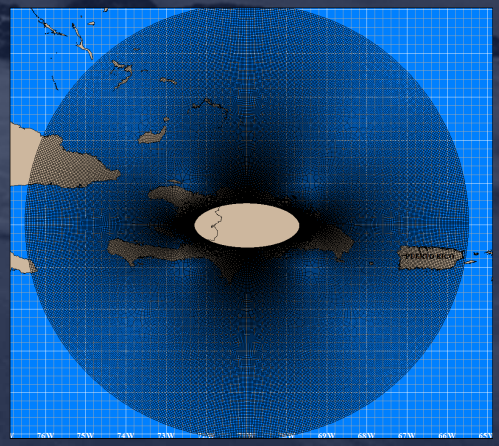


CIFDP-C SYSTEM DEVELOPMENT

CIFDP-C System Development

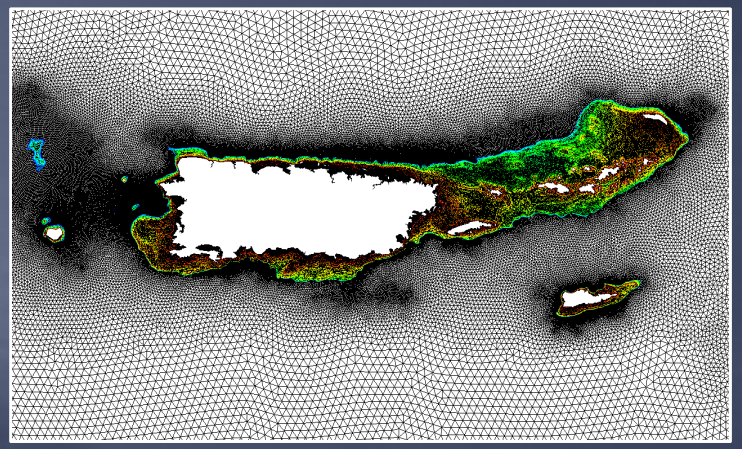
- Implement a coupled storm surge and wave modeling system
  - SLOSH hydrodynamic model
  - Wave model recommended by IOOS modeling testbed
- Develop products for planning, preparedness, and forecasting
  - SLOSH MOMs and MEOWs
  - Same display system as employed by RSMC-Miami (SLOSH Display Program)
- Provide specialized training programs on how to use the storm surge products for planning and preparedness

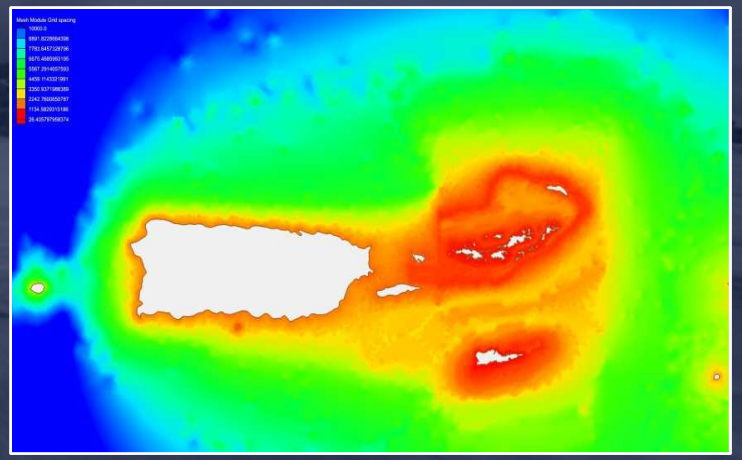




Leveraging U.S. Modeling Testbed for Puerto Rico and the Virgin Islands

- Evaluate wave/surge operational modeling/forecasting in steep-sloped regions such as the Caribbean
- Features regional-scale and nearshore-scale field cases using SWAN wave model
- Broad participation from academic and operational communities with a wide range of surge and wave models
- Conclude with recommendations for operational environment and facilitate the transition to NOAA's National Hurricane Center





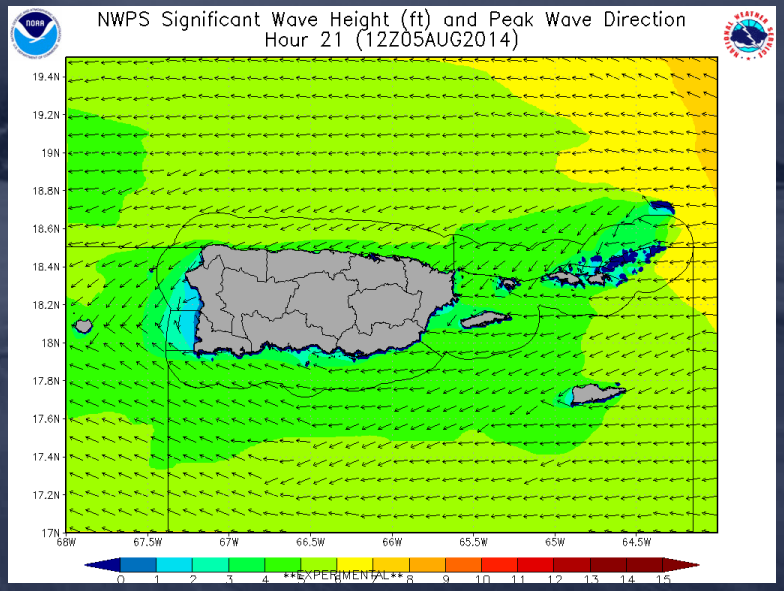
2nd Generation Wave Model for SLOSH

- Initial model development and evaluation of a 2nd generation wave model to couple with SLOSH
- Selected the Great Lakes Wave Model and began adding wave physics parameterizations
- Model uses simplified physics, but is cheaper computationally than SWAN or WW3
- More suitable to couple with SLOSH than SWAN

$$\frac{\partial \vec{M}}{\partial t} + \vec{v} \cdot \nabla_{x,y} \vec{M} = \vec{\tau}_w$$

$$\vec{\tau}_w = 0.028 \rho_a D_f \left| \vec{U} - 0.83 C_p \right| \left(\vec{U} - 0.83 C_p \right)$$

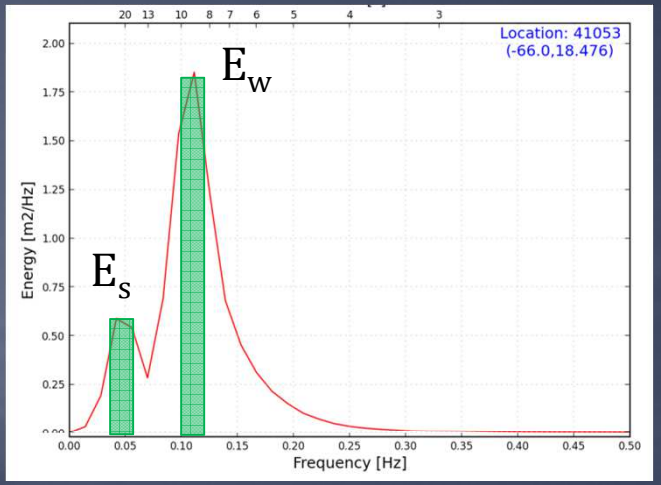
$$\sigma^2 = 6.23 \times 10^{-6} \left(\frac{f_p U}{g} \right)^{-10/3} \frac{U^4}{g^2}$$



Wave Model Discretization

Wind Sea: $$\frac{\partial E_W}{\partial t} + \frac{\partial C_g \cdot E_W}{\partial x} = S_{wind} + S_{diss}$$

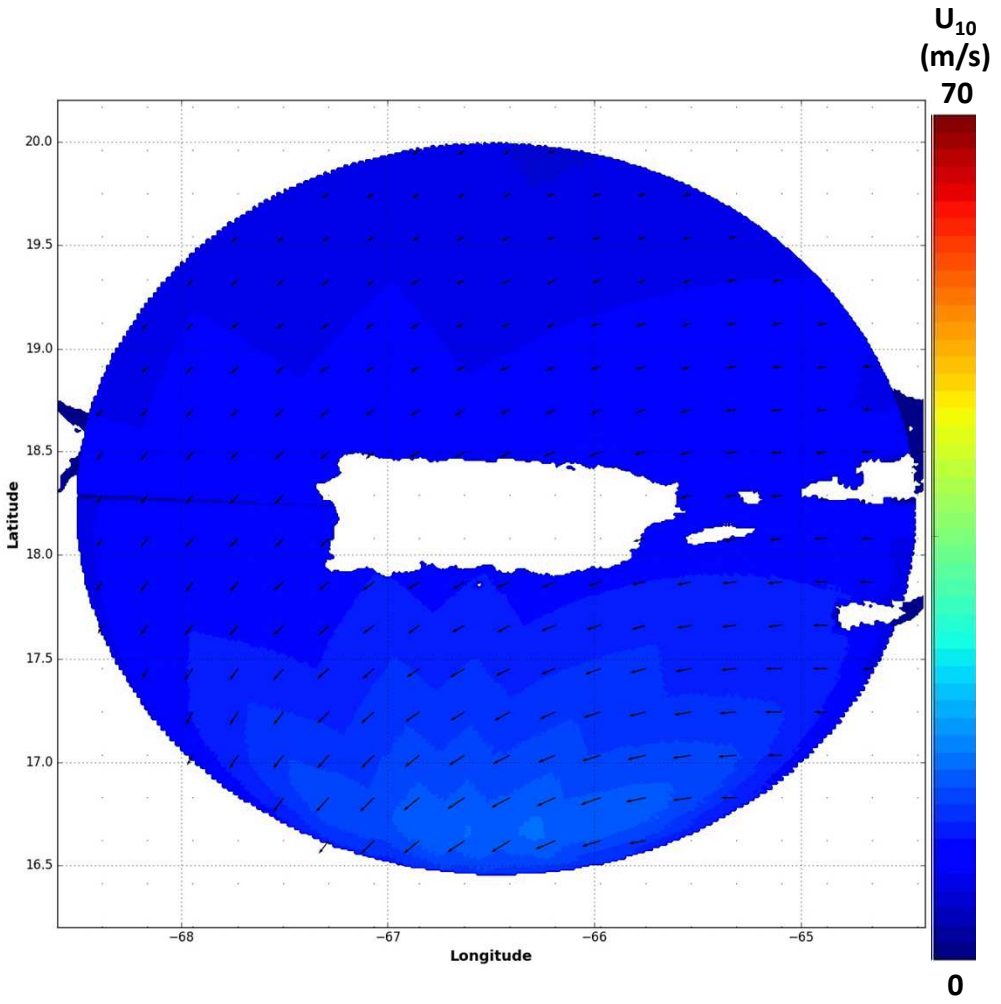
Swell: $$\frac{\partial E_s}{\partial t} + \frac{\partial C_g \cdot E_s}{\partial x} = S_{diss}$$



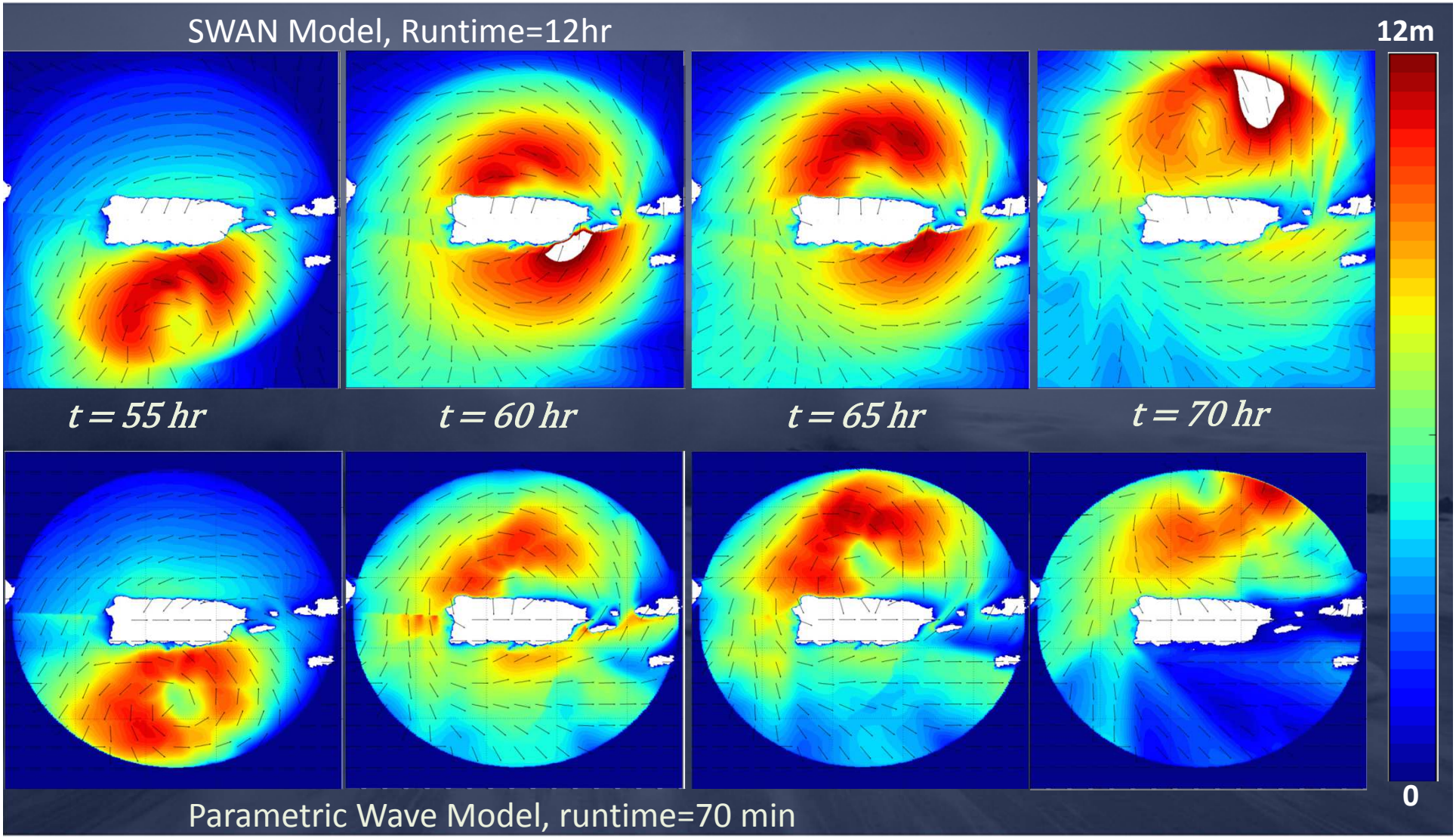
- Wind seas (E_w): grows when angle between wave direction and wind direction is < 90°, and wind velocity is larger than phase velocity
- Swell transition: associated wind sea wave energy now propagates without further generation and is treated as swell energy (E_s)
- Swell frequency: equals corresponding wind sea frequency at the point when the wave growth ends
- Total variance: adding E_w and E_s for each wave direction and integrating through all directions

Parametric Wave Model Test Case

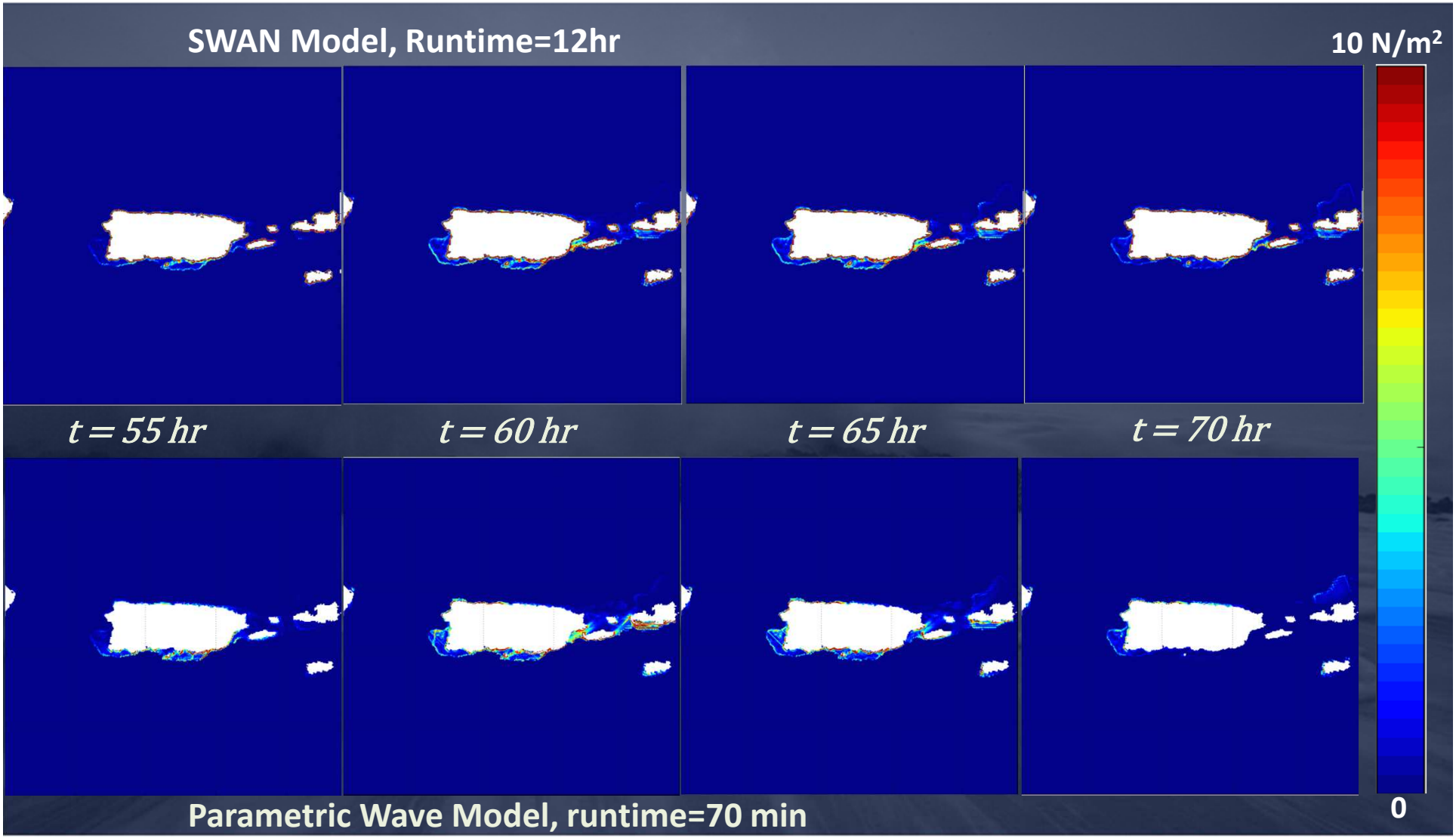
- Hypothetical Category 5 Hurricane
- Storm center crosses Puerto Rico from the South to the North
- Maximum wind speed around 65 m/s



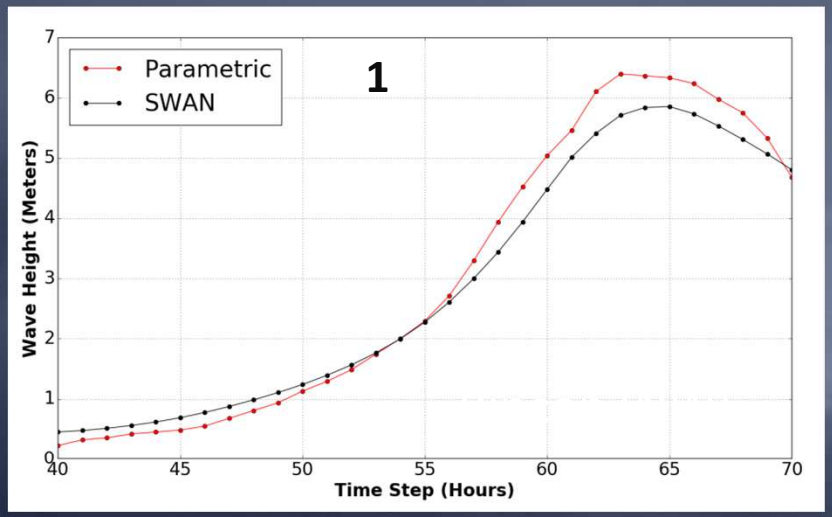
Wave Height Comparison

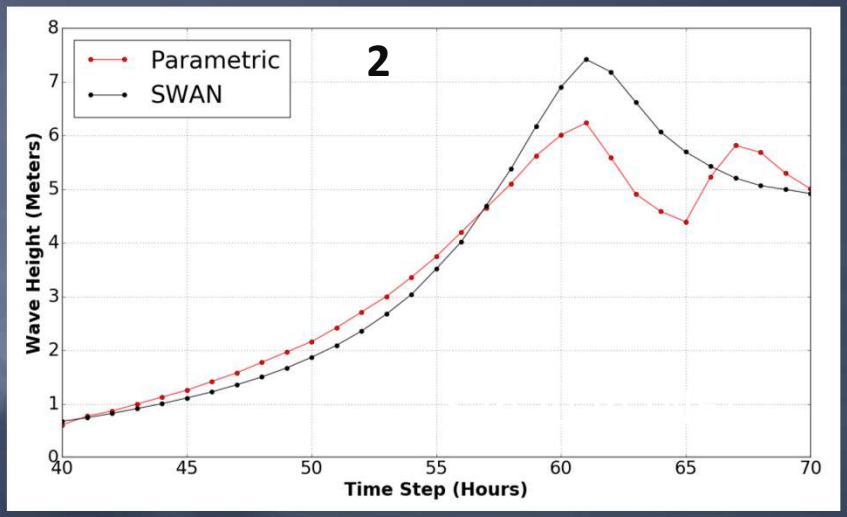


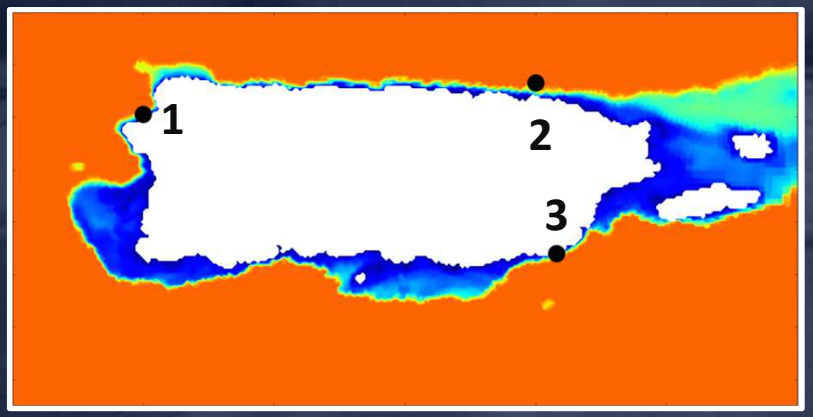
Wave Radiation Stress Comparison

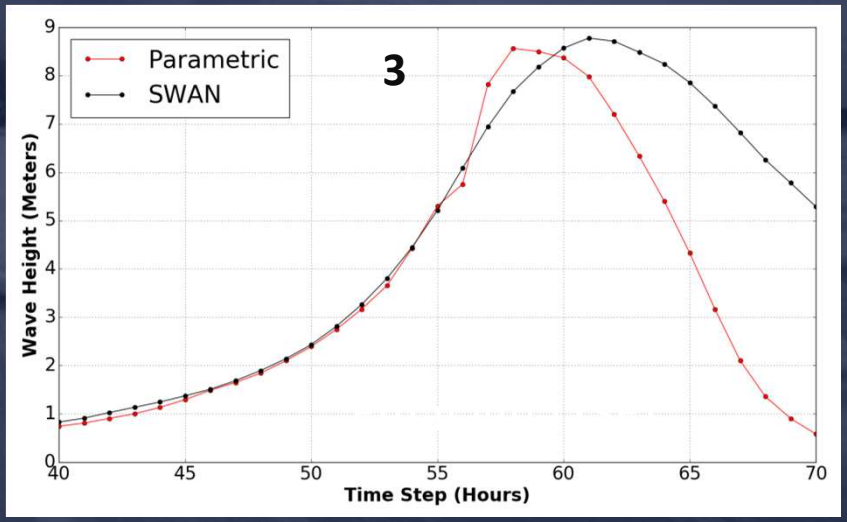


Wave Height Comparison

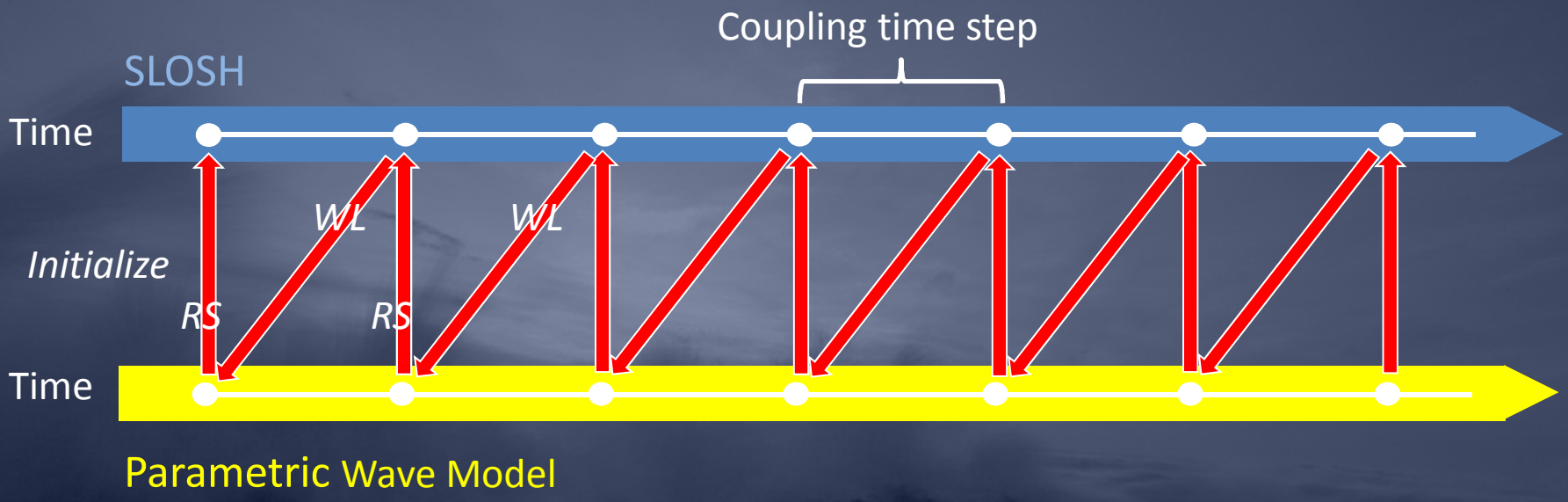








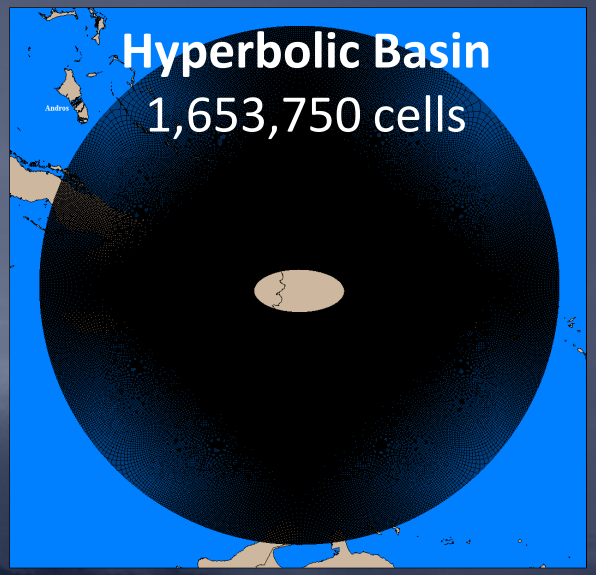
Wave Model Coupling to SLOSH

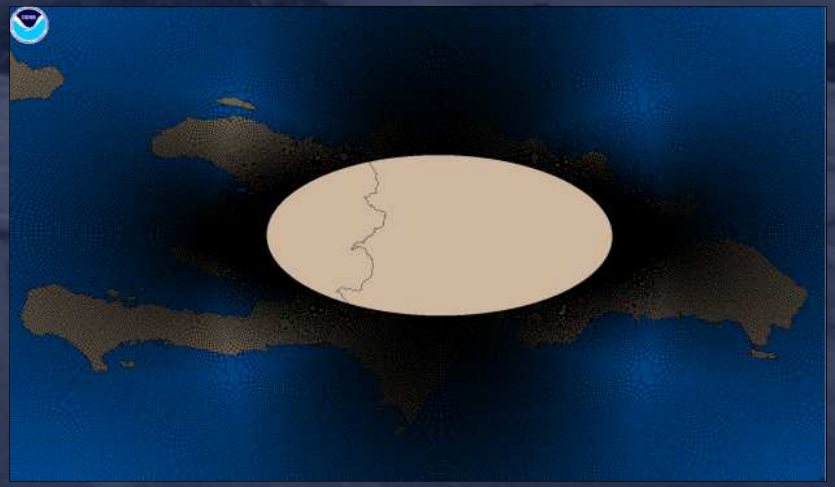


- SLOSH is driver, with parametric wave model as a subroutine
- Compiled into single, efficient executable
- To be used for computation of MEOW surge/inundation envelopes

SLOSH Grid Development

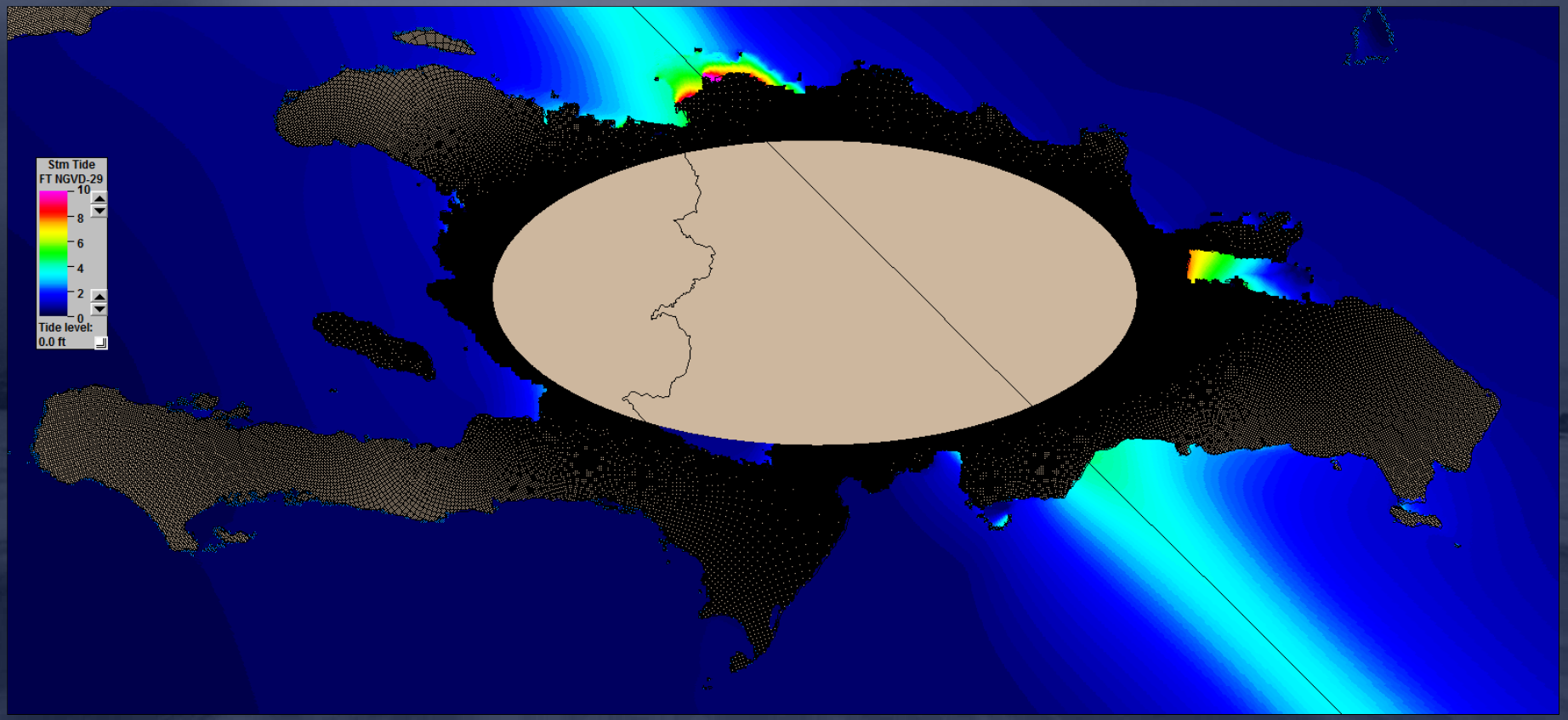
- Tested different SLOSH basin configurations for optimal grid resolutions in main areas of interest
- Developed an initial SLOSH basin for testing and evaluation of run times and stability analysis
- Evaluated current data requirements, data availability, and data gaps



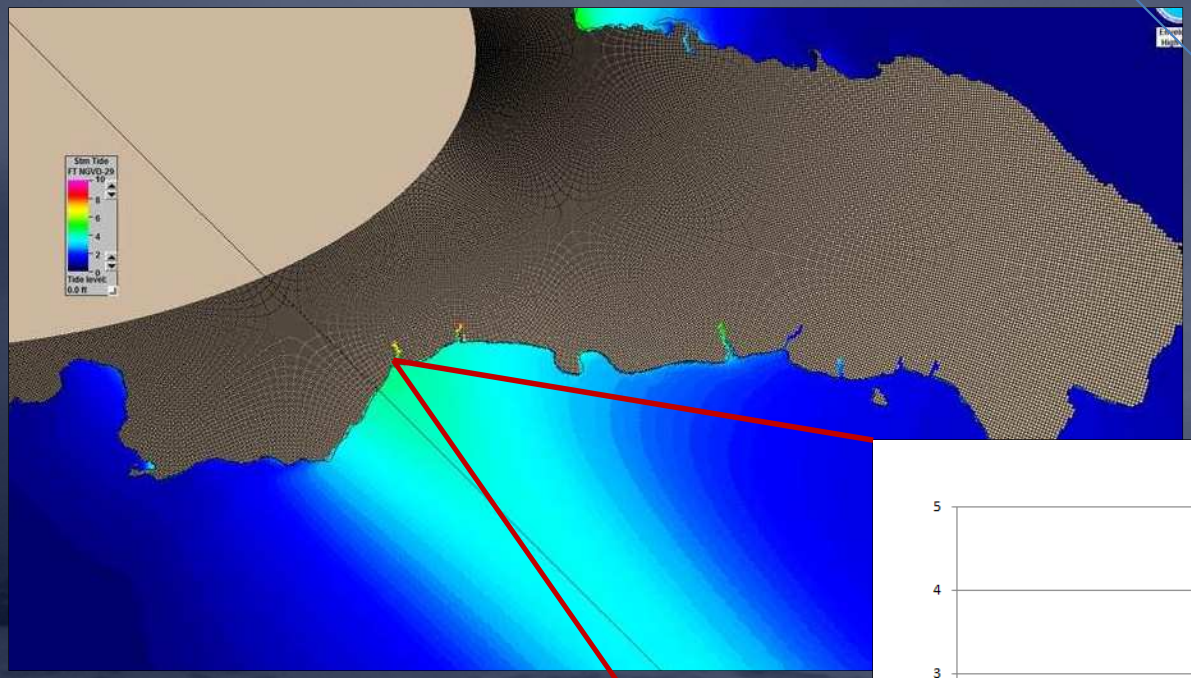


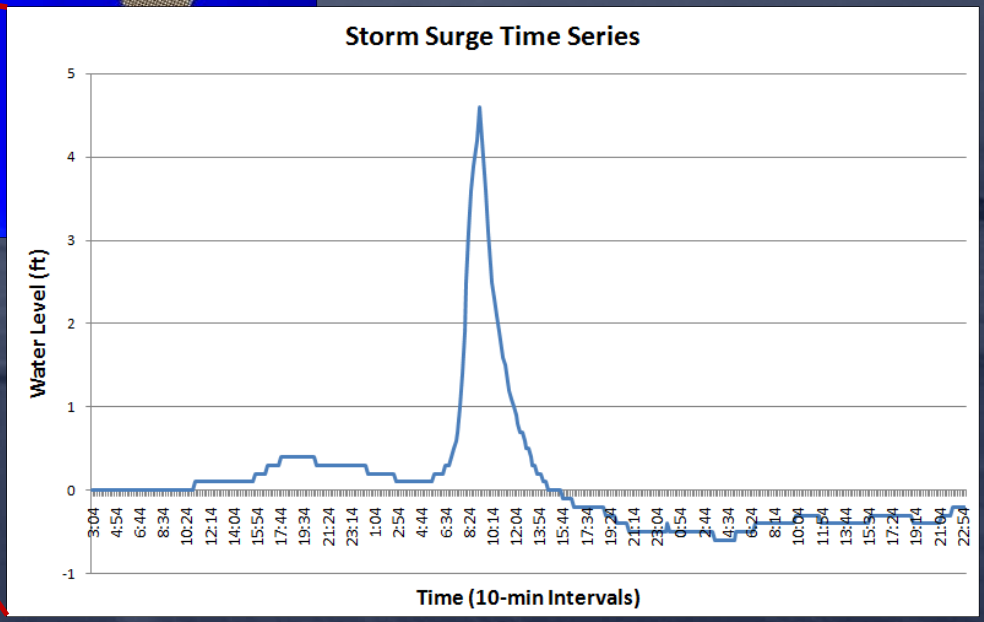
SLOSH Model Results

SLOSH Category 5 Hurricane Moving NW at 20 mph



River Coupling Methodology: Ozama River



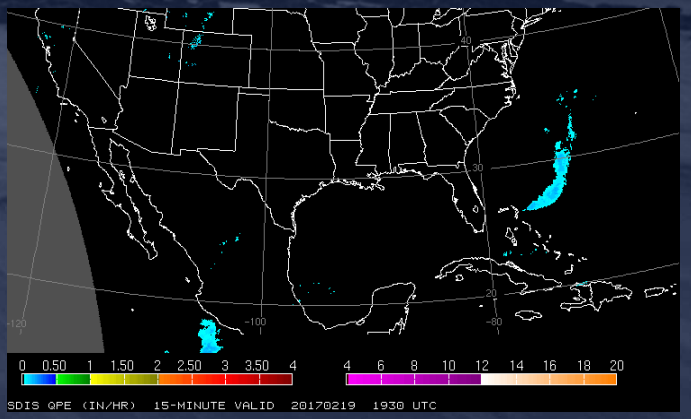


Accurate and Timely QPE for CIFDP-C?

- Many countries in Latin America, including DR, lack timely and accurate Quantitative Precipitation Estimates (QPE)

- While QPE products are available from GOES satellites, accuracy typically suffers in tropical environments and areas of complex terrain.
  - Dissemination is a challenge

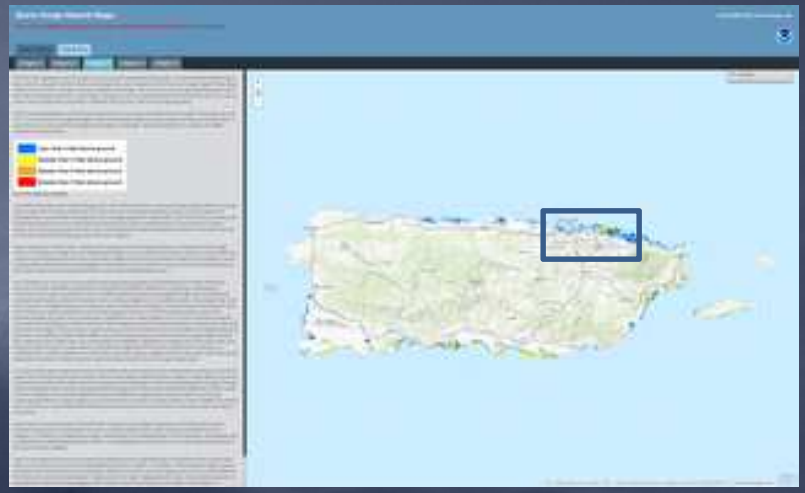
- GOES-R will provide improved QPE
  - Baseline rainfall rate product from ABI IR brightness temperatures will be calibrated in real time against microwave-derived rain rates to enhance accuracy.



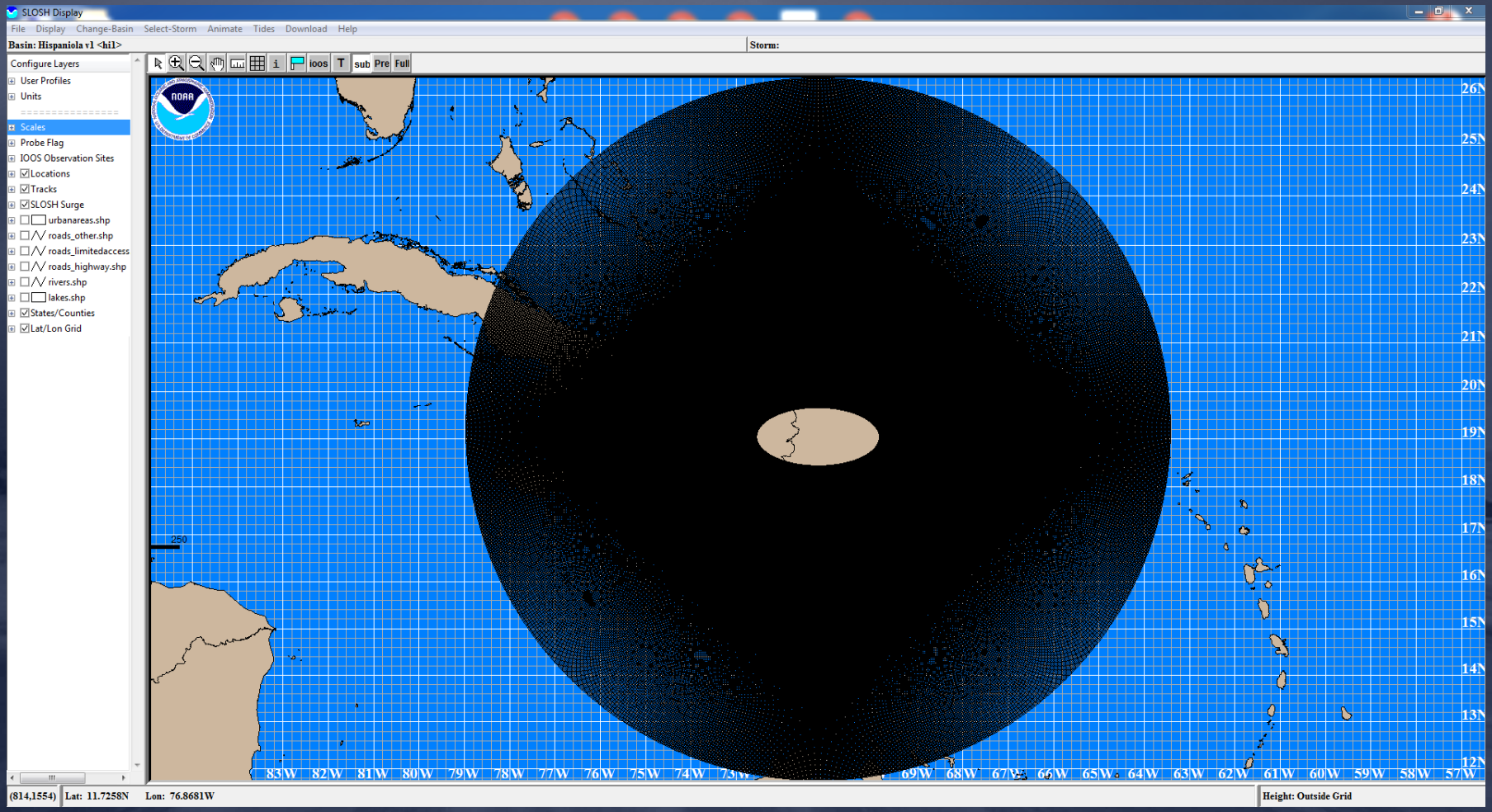
TRAINING MODULES AND OUTREACH MATERIAL

Dissemination and Data Availability

- NHC will host the CIFDP-C MOMs on an online web portal for high-resolution inundation mapping
- Provide GIS data
- Map services



SLOSH Display Program

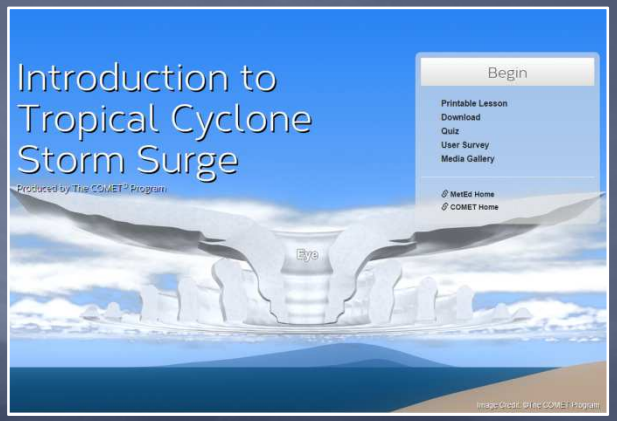


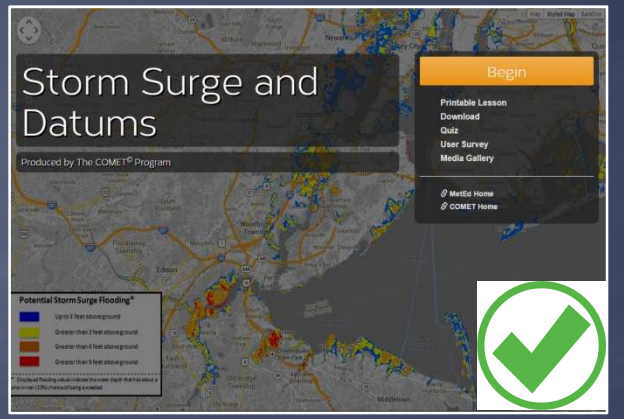
Demo

Translation of Outreach Material

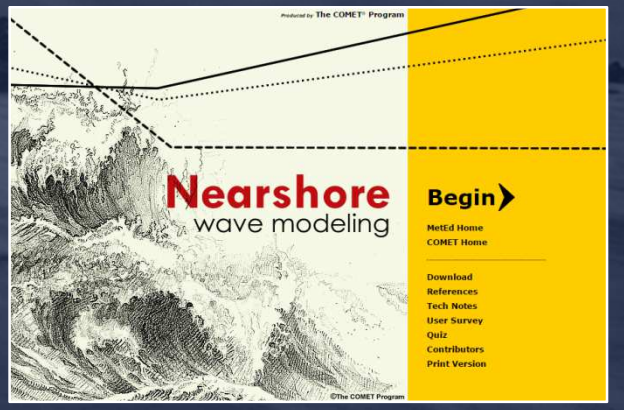
Translation of Existing COMET Modules to Spanish and French

Tropical Cyclone Forecast Uncertainty





Storm Surge Forecasting



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