SLOSH Planning and Mitigation

WMO WORKSHOP 2019

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)**

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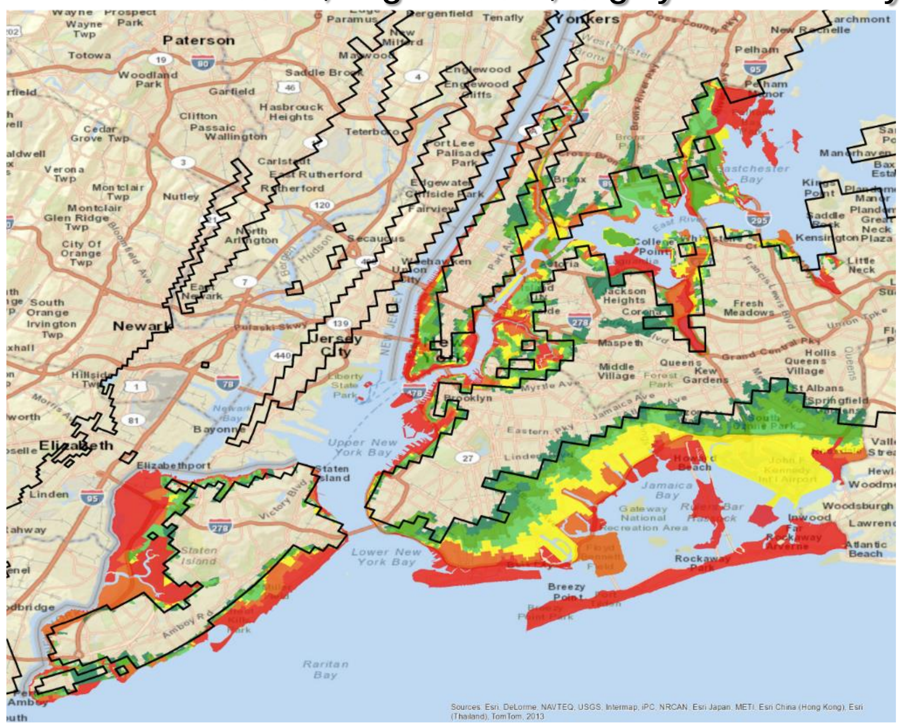
Evacuation Planning

NYC Evacuation Zones / Cat 4, High Tide Anomaly



- Zone 1
- Zone 2
- Zone 3
- Zone 4
- Zone 5
- Zone 6

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

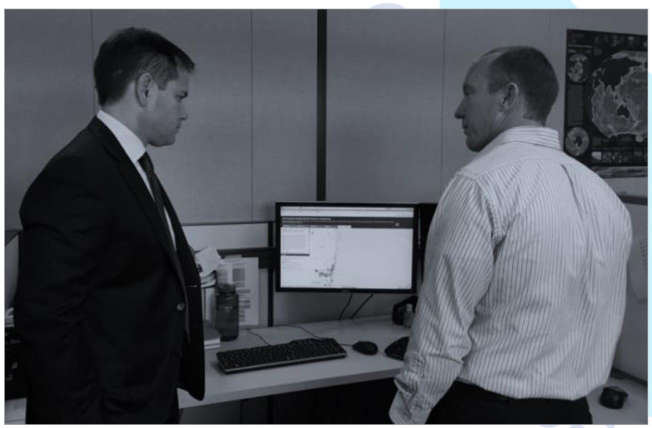
Storm Surge Hazard Maps

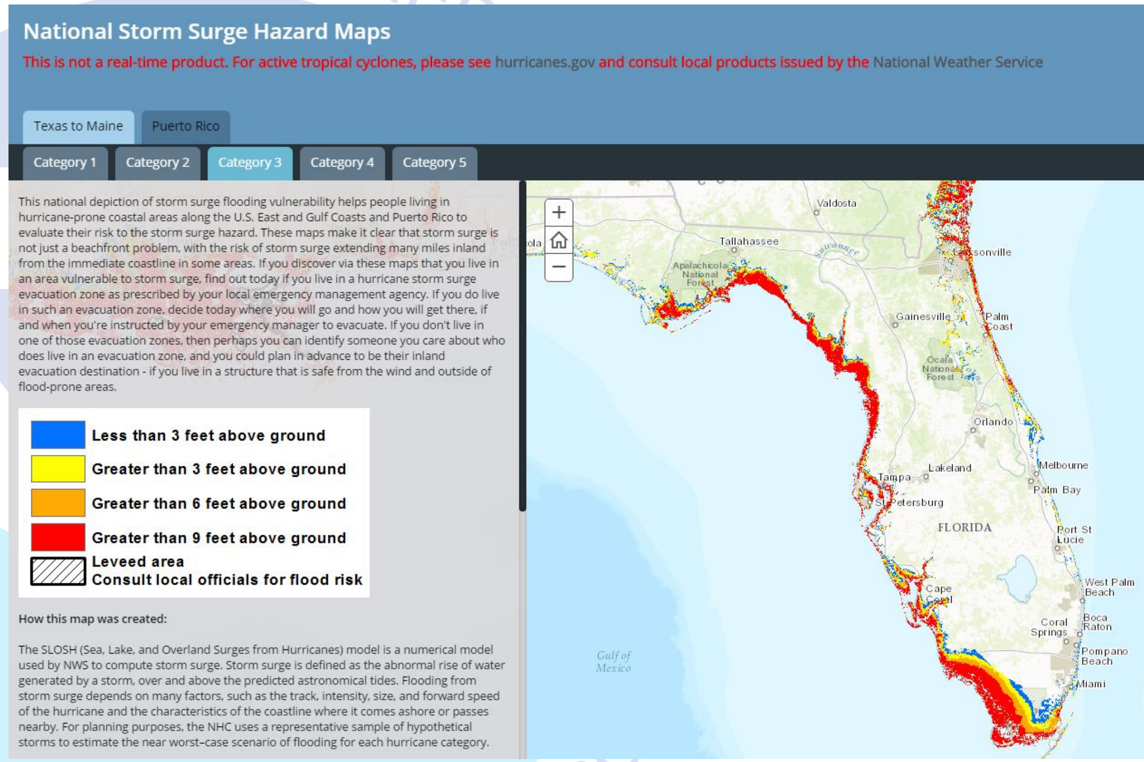
Motivation

- High-demand for a seamless view of storm surge inundation using the SLOSH products
- A new product to increase awareness of storm surge hazard through education and outreach to reduce loss of life and property
- Eliminate confusion for our partners about SLOSH basin overlap for planning purposes/analyses
- Numerous benefits for federal, private, academic, and public organizations

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





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

SLOSH Model MOMs and MEOWs

- Fundamental data that is used by the National Hurricane Program to create hurricane evacuation zones from Texas to Maine

- Based on climatology, tens of thousands of hypothetical hurricanes are simulated in SLOSH each basin, and the storm surges are calculated

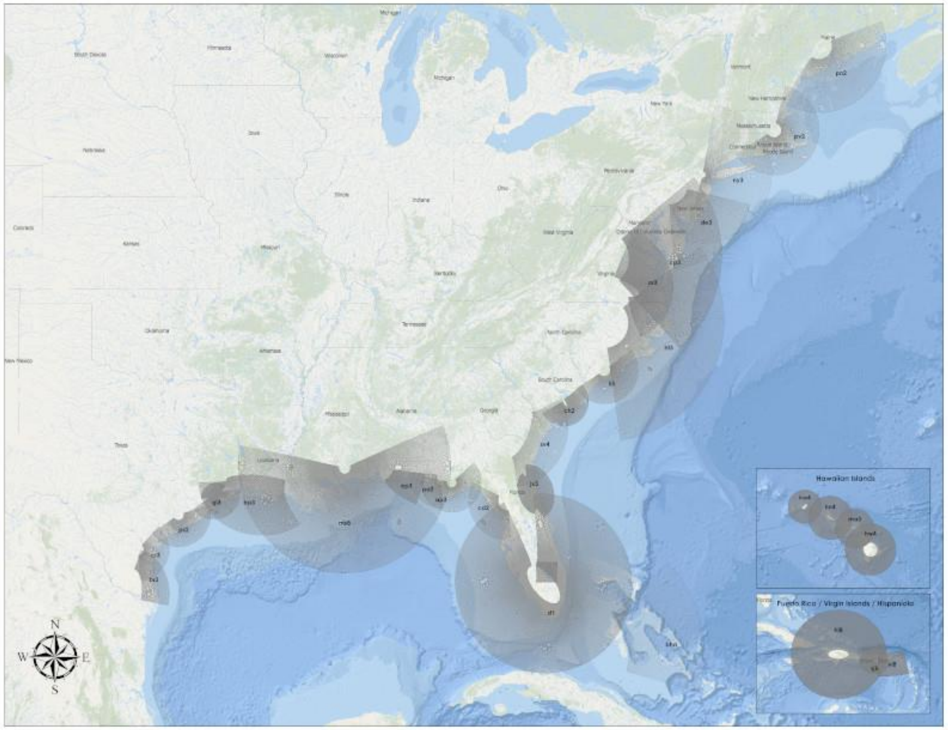
- **MEOWs** — represent the maximum storm surge resulting from hypothetical storms of varying forward speed, radius of maximum wind (RMW), intensity (categories 1–5), landfall location, initial water level, and storm direction

- **MOMs** — are an ensemble product of maximum storm surge heights and are created by compositing all the MEOWs, separated by category and initial water level anomaly, and retaining maximum value in each grid cell

Storm Surge Hazard Maps

- Seamless high-resolution storm surge inundation maps:
  - Texas to Maine
  - Puerto Rico
  - U.S. Virgin Islands
  - Hawaiian Islands
  - **Hispaniola**
- Updated DEM (new LIDAR)
- Improved inundation mapping techniques (same as potential storm surge flooding map)
- GIS data available for download

SLOSH Grids Used



New NHC Webpage and Data Download

- New NHC webpage is currently being developed along with ArcGIS online map services
- Comprehensive metadata will be provided to describe the data and its limitations
- Data will be available on NHC website in GeoTIFF format in 8-bit unsigned integer raster (most likely 1 ft inundation bins)

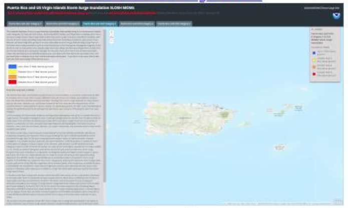
What's New with November 2018 update to Version 2

- Reprocessed Puerto Rico at an improved grid cell size
- Added USVI, Hawaii, and Hispaniola to Story Maps and data download
- No updates at this time for U.S. East and Gulf Coasts storm surge hazard data

Interactive Map Viewer

Texas to Maine

Puerto Rico/US Virgin Islands



Hawaii

Hispaniola

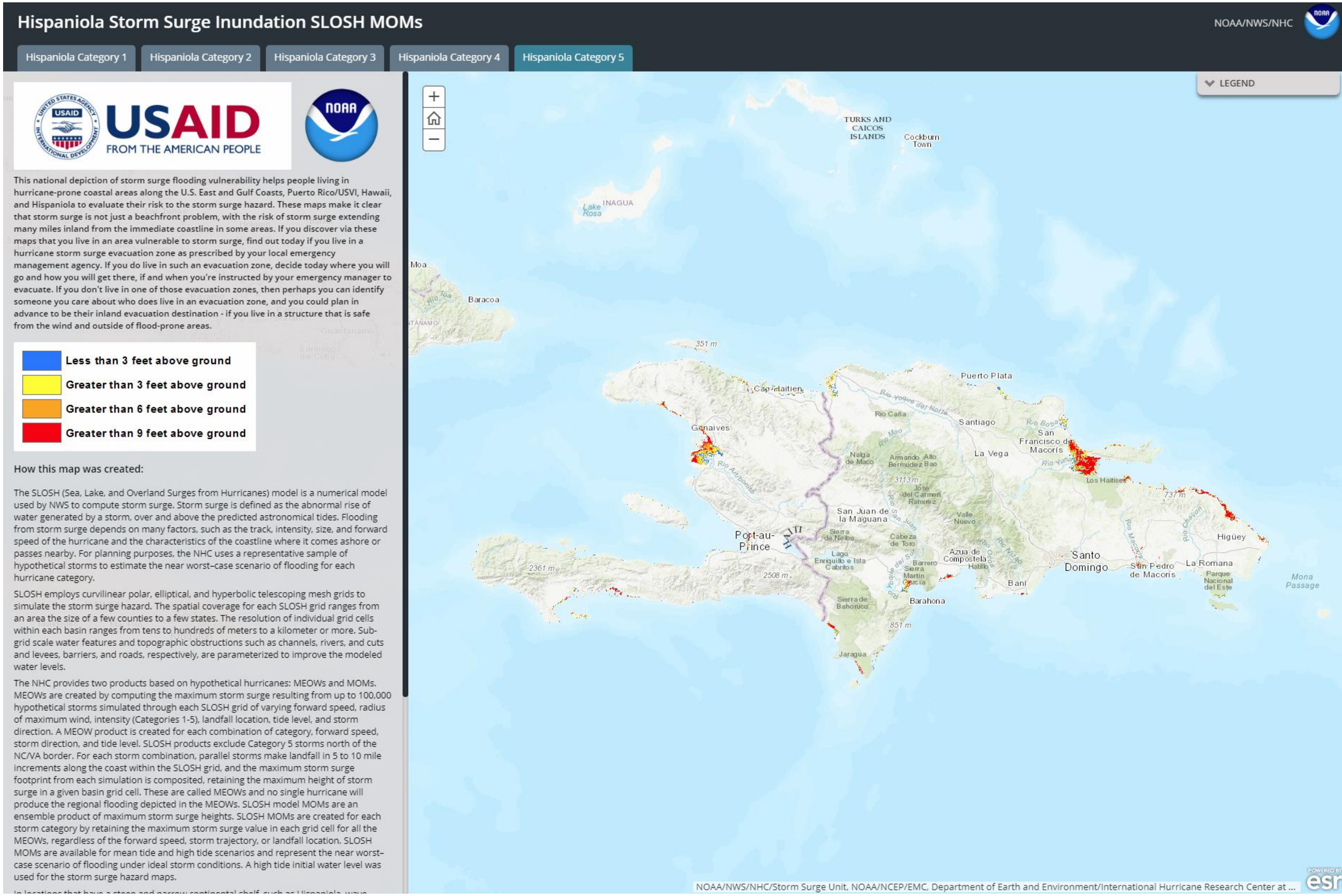
Technical Description

Introduction

The National Oceanic and Atmospheric Administration (NOAA), specifically the National Weather Service's (NWS) National Hurricane Center (NHC), utilizes the hydrodynamic Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model to simulate storm surge from tropical cyclones. Storm surge information is provided to federal, state, and local partners to assist in a range of planning processes, risk assessment studies, and operational decision-making. In regards to the former, tens of thousands of climatology-based hypothetical tropical cyclones are simulated in each SLOSH basin (or grid), and the potential storm surges are calculated. Storm surge composites – Maximum Envelopes of Water (MEOWs) and Maximum of MEOWs (MOMs) – are created to assess and visualize storm surge risk under varying conditions. While MEOWs and MOMs provide a local assessment of storm surge risk, they do not provide a seamless perspective of the hazard owing to the many discrete SLOSH grids. This section briefly describes the scientific techniques used to create the seamless inundation maps for Category 1-5 hurricanes using the SLOSH MOM product as well as a description of the datasets and map viewer available to the public.

Hispaniola

Hispaniola Storm Surge Inundation



CIFDP-C

Hispaniola Demonstration Project Overview

WMO CIFDP-C

- Coastal Inundation Forecasting Demonstration Project (CIFDP) initiated by Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM)

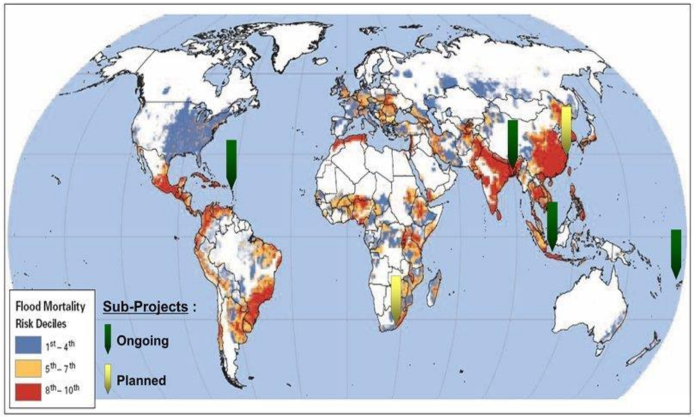
- At the 5th meeting of the CIFDP Program Steering Group (May 2014, Geneva), the previous Sub-Project for Dominican Republic (CIFDP-DR) was re-scoped for a Caribbean/regional approach and denoted CIFDP-C

- CIFDP-C will be initially demonstrated and tested for the Dominican Republic and Haiti

- Developed 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

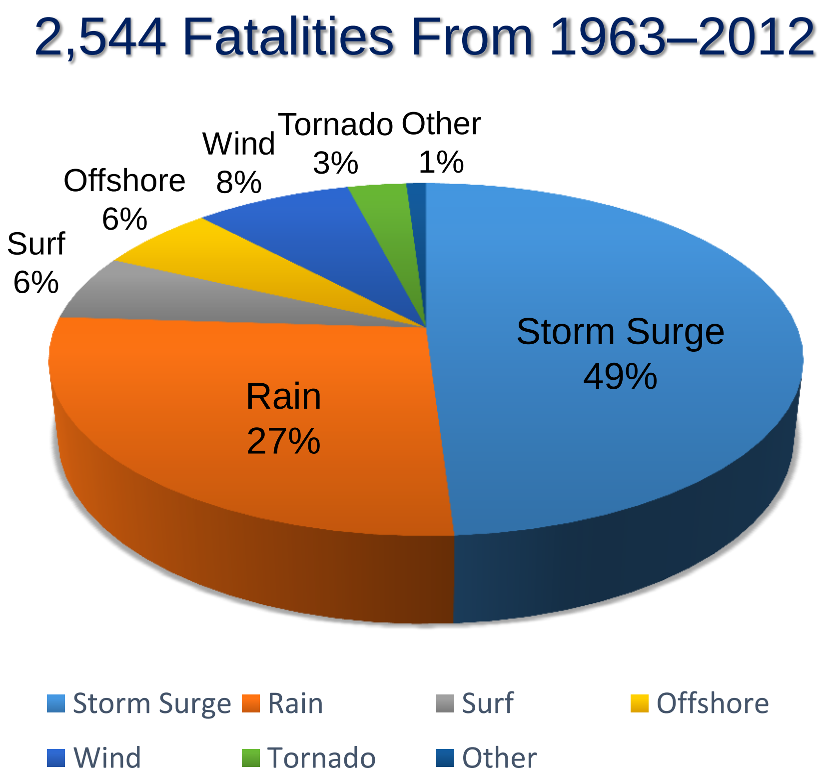
NWS Environmental Modeling Center

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

Project Scoping and Preparation:

Definitive National Agreement (DNA), training, and initial data inventory

Project Planning and Design:

Stakeholder workshop, establish National Coordination Team (NCT), regional buy-in, initial project design/setup (Mexico demo)

System Development:

Digital elevation model (DEM), SLOSH/wave grid creation and quality control, and model development

Develop Training modules

System Validation:

MOMs/MEOW creation, QA/QC, and model validation

Deploy online training modules

System Integration and Training:

System implementation, project evaluation, specialized training workshop

Project evaluation and recommended application to region (RA-IV)

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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

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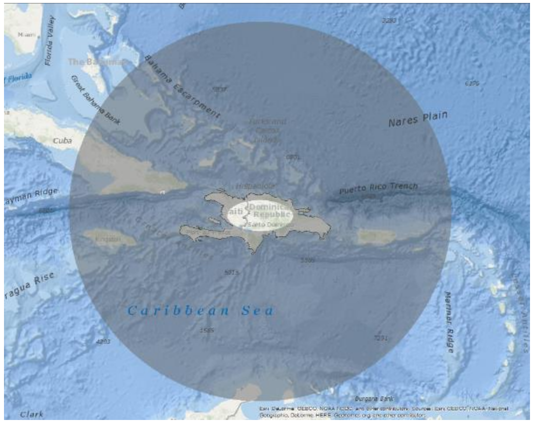
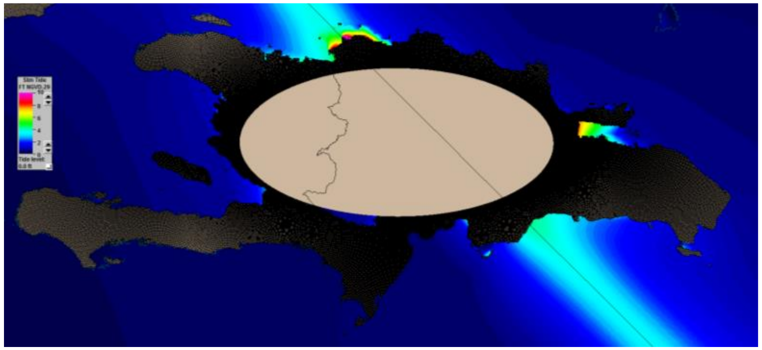
SLOSH + Waves Development

Coastal Inundation Forecasting Demonstration Project

- Fully funded by USAID (1.2 Million U.S.)
- Implement a coupled storm surge and wave modeling system
  - SLOSH hydrodynamic model
  - Wave model recommended by IOOS modeling testbed (parametric)
- 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
  - Project completed in 2018





2^{nd} Gen (Parametric) Wave Model

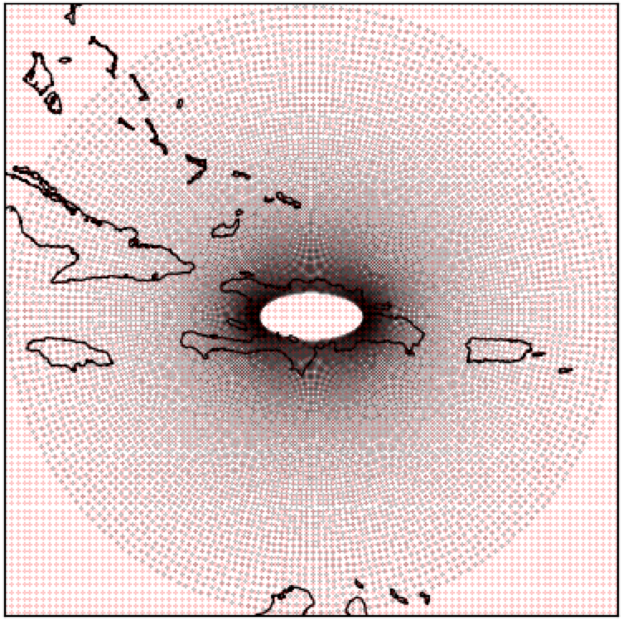
- An efficient parametric wave model to couple with SLOSH (within P-Surge)
- Parametric models that reduce full solution space N(t,x,y,σ,θ), to e.g. M(t,x,y) (Schwab et al. 1984).

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

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

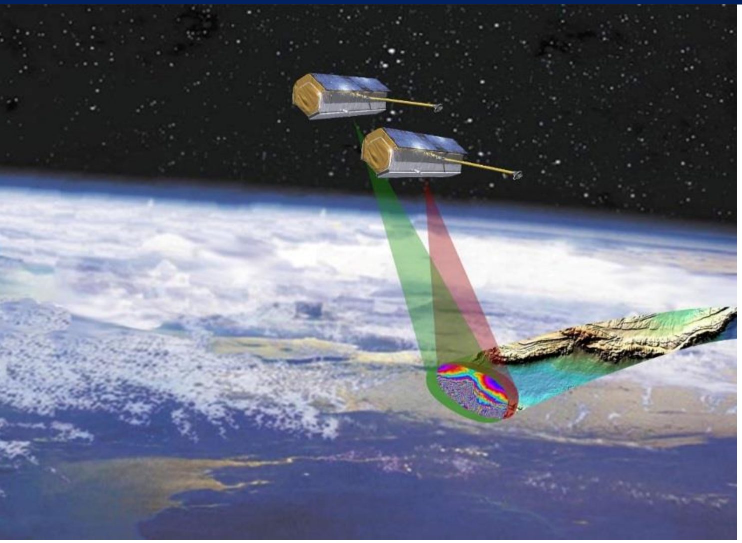
$$\sigma^2 = 6.23 \times 10^{-6} \left(\frac{f_p U}{g} \right)^{-10/3} \frac{U^4}{g^2}$$

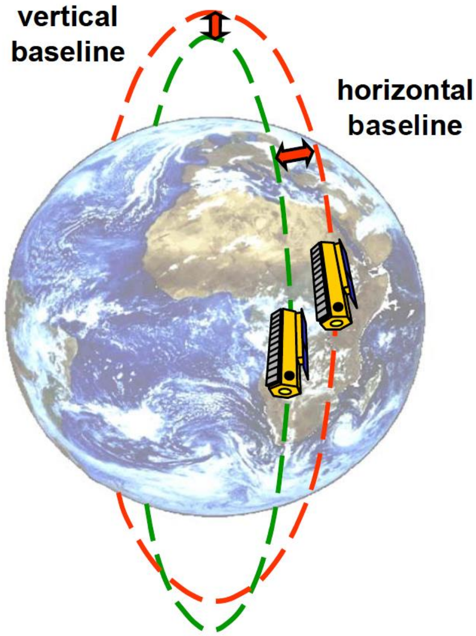
- Simplified physics, but significantly cheaper than SWAN or WW3
- More suitable to couple with SLOSH



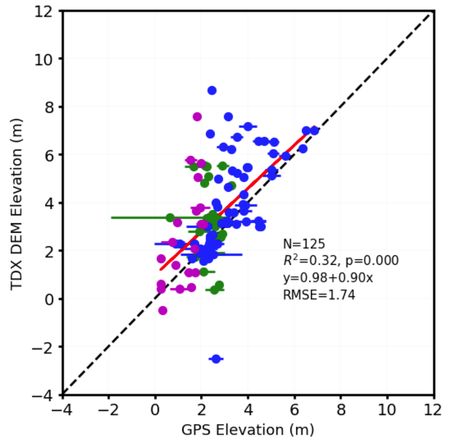
SLOSH basin and wave model grid mesh

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

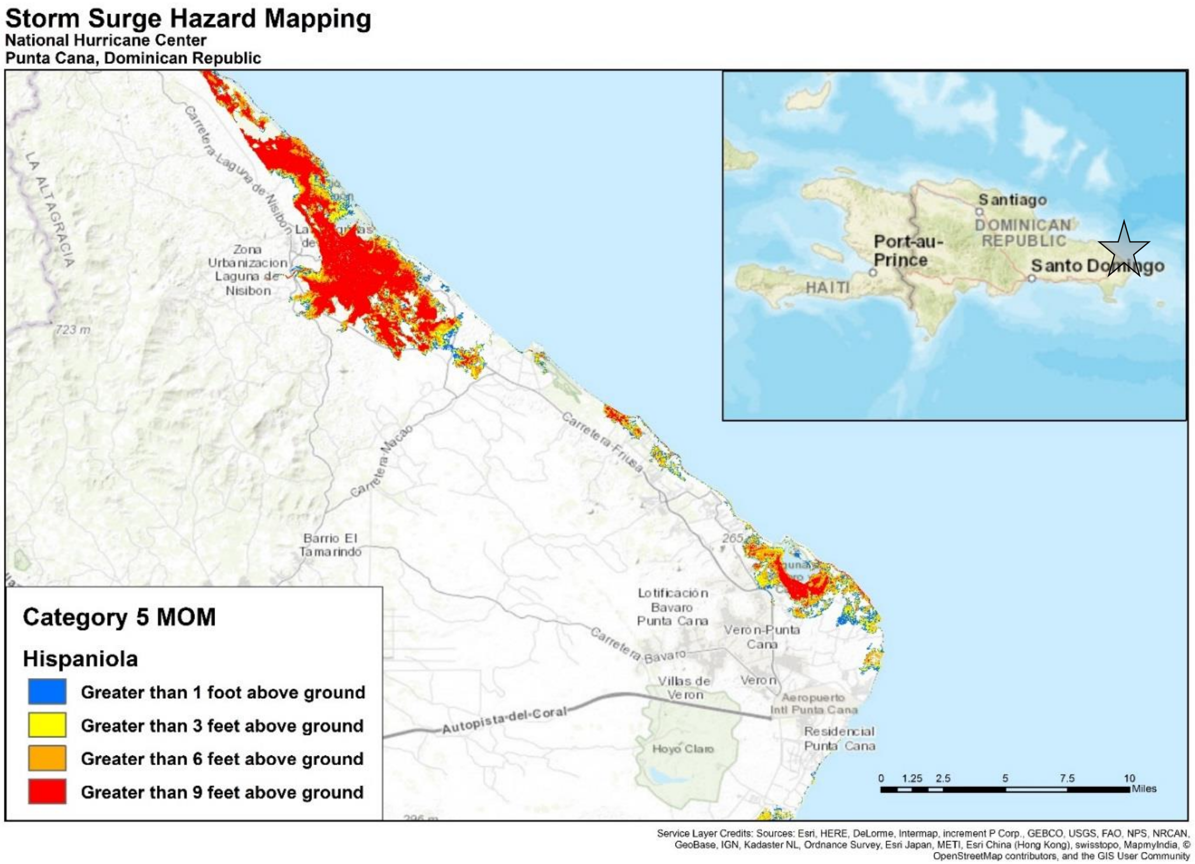


Scatter plot of TDX DEM vs GPS measurements at Pedernales, Samana, and Sanchez in The Republic of Dominica (Zhang et al. 2018 – *under review*)

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

Funded by USAID

Hispaniola Demonstration Project



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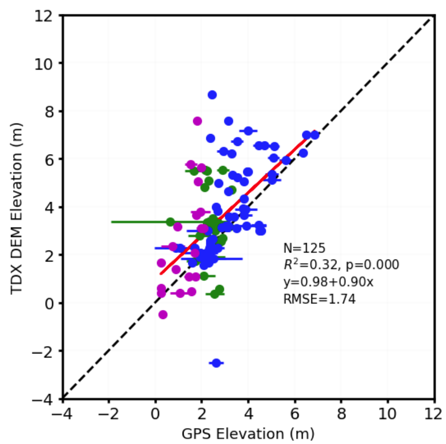

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