MODELING TSUNAMI INUNDATION AND ASSESSING TSUNAMI HAZARDS FOR THE U.S. EAST COAST

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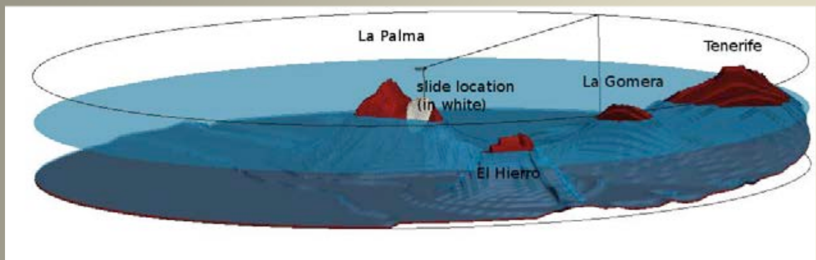
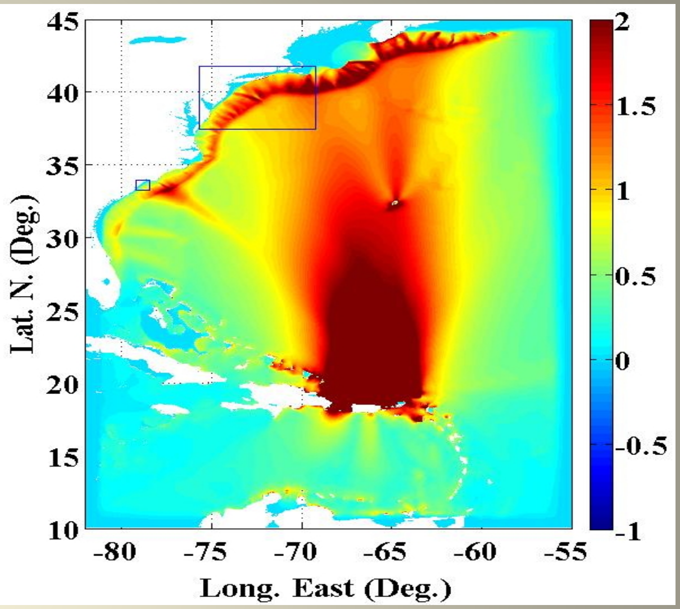
Sources for East Coast modeling documented in technical reports available at http://chinacat.coastal.udel.edu/nthmp.html

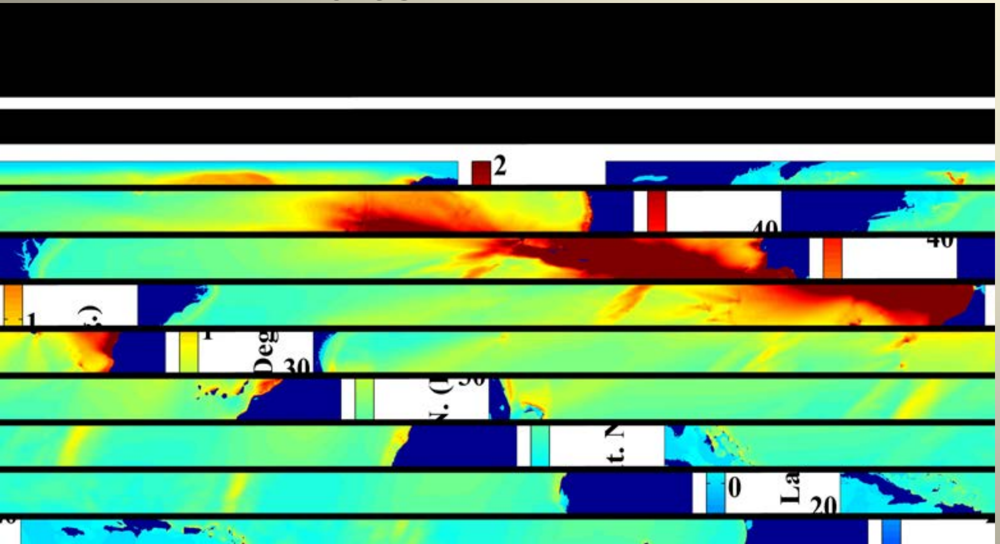


Cumbre Vieja

Puerto Rico

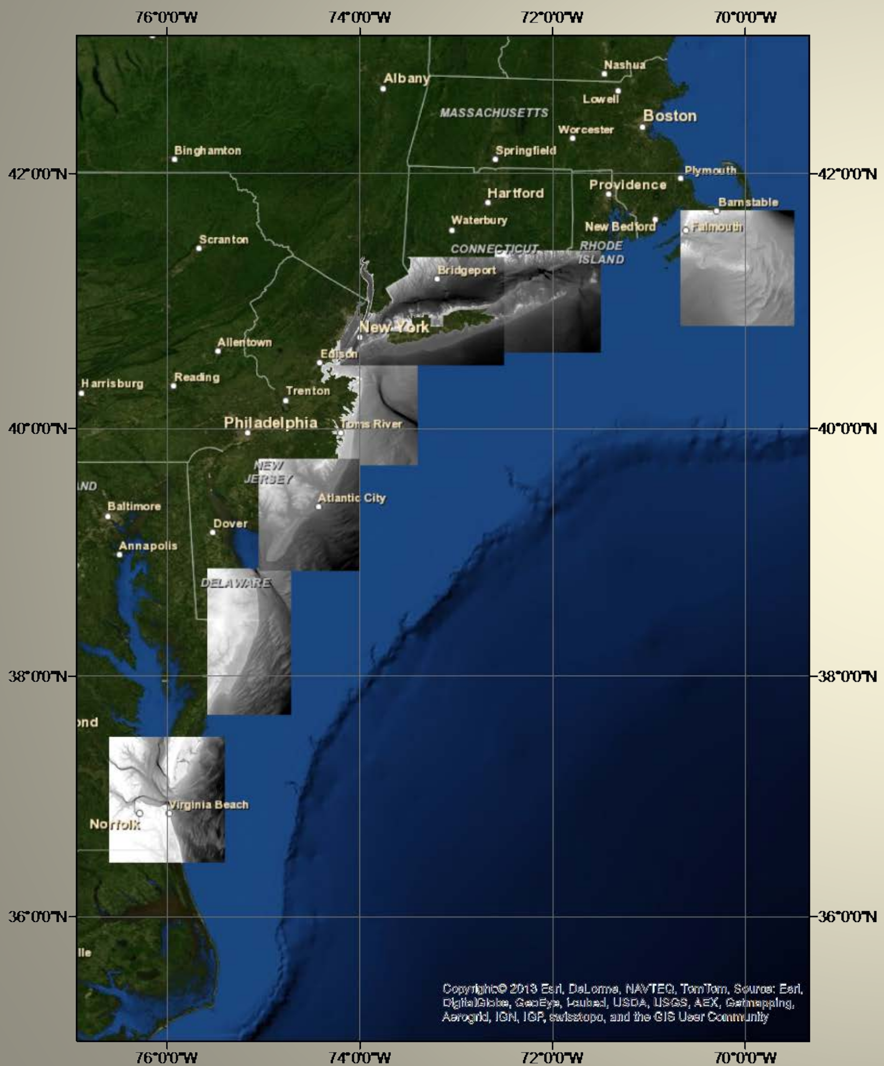


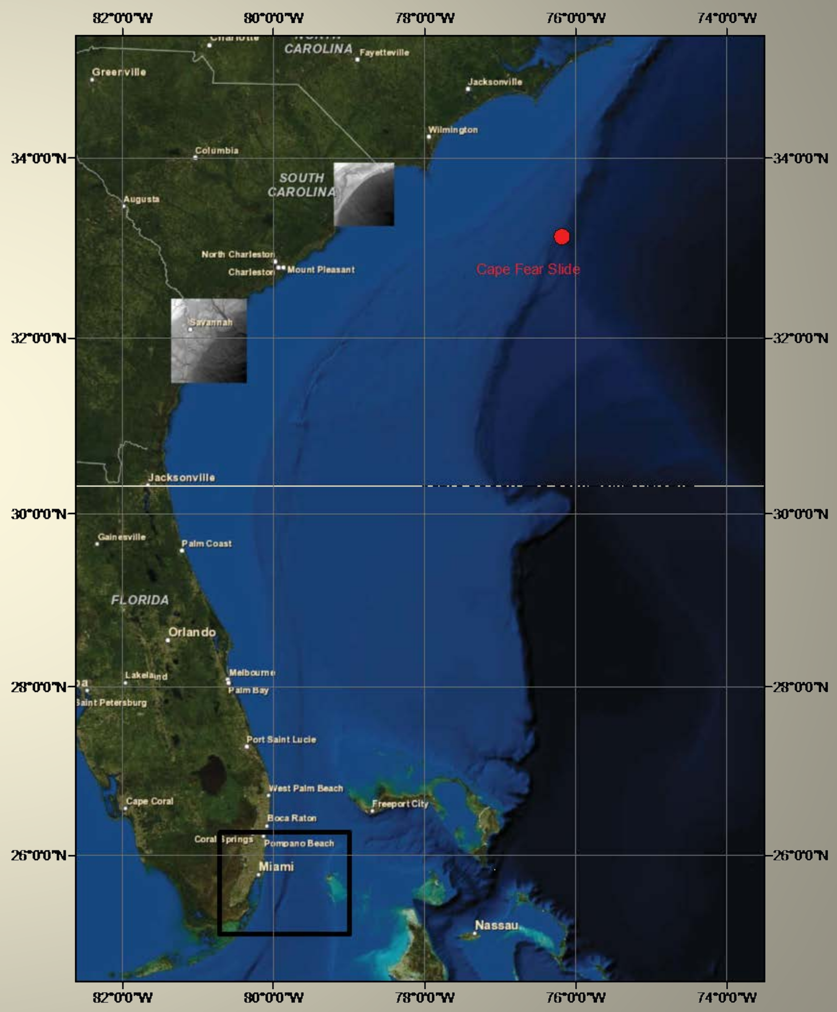
Azores



SMF sources

FY10-12 and FY 13 DEM coverage





Florida Straits SMF of Grand Bahama Bank carbonate platform

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potential for
tsunami generation by submarine slope failures
along the western Great Bahama Bank

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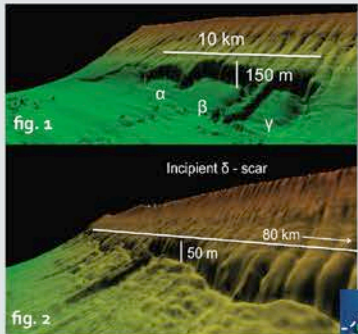
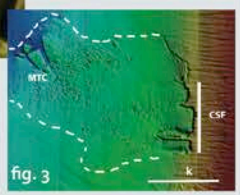
slope failures



The western slope of Great Bahama Bank shows slope failures at various scales (fig. 1). Three landslides were identified; i.e. alpha-, beta-, and gamma-landslide.

In addition, creeping and incipient slump scars indicate slope instabilities that will lead to large-scale failures in the near future (fig. 2).

Bathymetry and hydroacoustic data was used to identify the volume and nature of past large mass movements within this area and the mass transport complexes (MTC) in the basin (fig. 3).



failure scenarios

Three possible failure scenarios were designed based on estimated volume and nature of the failure mechanisms (tab. 1).

Single Slope Failure (SSF)
An isolated collapse of the beta-failure mass is simulated (fig. 1).

Combined Slope Failure (CSF)
The failure of alpha-, beta-, and gamma-mass simultaneously is simulated and approximated as single landslide mass (fig. 2).

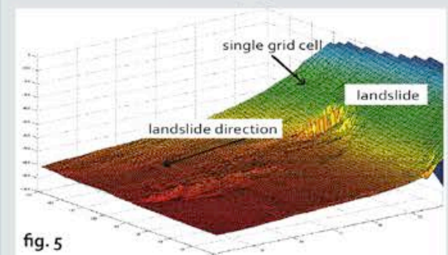
Potential Major Slope Failure (pMSF)
The failure of an over 80 km long scar is simulated (fig. 3).

tab. 1

Parameters	Landslide Names				Failure Scenarios		
	α	β	γ	δ	SSF	CSF	pMSF
Thickness [m]	150	150	150	50 (visible)	150	150	150
Length [km]	1.4	3.2	3.0	2	3.2	3.8	2
Width [km]	2.2	3.7	1.6	80	3.7	10	80
Water depth [m]	600	500	570	300	500	550	300
Slope angle [degree]	2.9	3.2	3.3	3	3.2	3.2	3

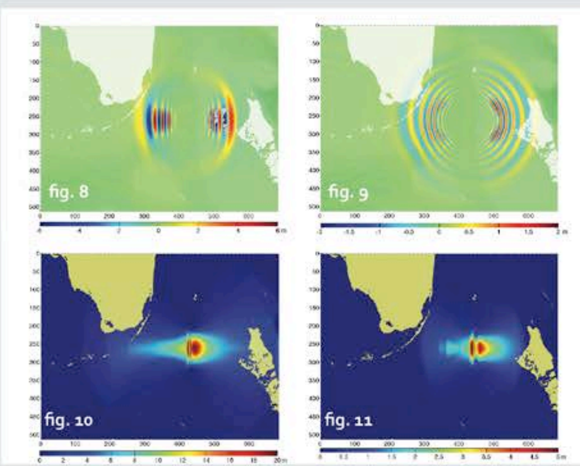
numerical domain

Two bathymetric grids were used for the simulations (fig. 4).
(1) is a 30 x 30 m grid based on multibeam data acquired during CARAMBAR cruise (Mulder et al. 2012). The grid was used for landslide and tsunami initiation.
(2) is the general bathymetric chart of the oceans, GEBCO-grid, in a 700 x 700 m resolution and was used for the propagation simulations.



The 30 x 30 m resolution bathymetric grid was converted into UTM and re-gridded in MATLAB (fig. 5).

tsunami wave propagation



Sea surface elevation for 15 min propagation time of CSF scenario for 240 s landslide duration (fig. 8) and 10 min propagation time of pMSF scenario for 240 s landslide duration (fig. 9).

Maximum wave elevation computed with FUNWAVE-TVD in Cartesian grid for the pMSF source with 50 ms^{-1} terminal landslide velocity and 120 s outrun time (fig. 10) and with 100 ms^{-1} terminal landslide velocity and 240 s outrun time (fig. 11).

All simulations ending in a considerable wave impact on the coastline show arrival times of less than 20 min between landslide initiation and wave impact. For bigger waves, the propagation velocity is larger.

tsunami wave initiation

fig. 6 **landslide duration**

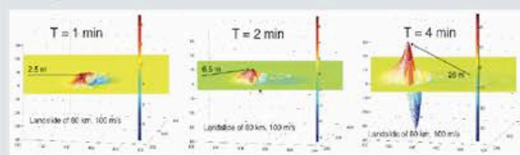
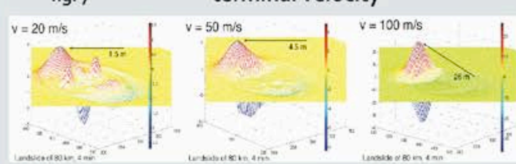


fig. 7 **terminal velocity**



For the simulations we chose landslide durations of 1, 2, 3, and 4 minutes. Terminal velocities of 20, 50 and 100 ms^{-1} were used. Landslide outrun direction was assumed to be westwards.

numerical models

The tsunami wave generated by a landslide was modeled using the non-hydrostatic wave model NHWAVE (Ma et al., 2012). The model was developed for submarine landslide induced tsunami wave simulation and simulates fully dispersive surface wave processes.

The resulting wave from these first simulations, then was reinterpolated as input into the fully nonlinear and dispersive Boussinesq model FUNWAVE-TVD to simulate the wave propagation and estimate an impact with the coastline (Shi et al., 2012).

conclusions

Our simulations show that the submarine landslides along Western Great Bahama Bank have the potential to create hazardous tsunami waves.
First order predictions show local wave crests can build up to 26 m height for a worst-case scenario and result in a 6 m run-up on the coastline.
The shallow waves dissipate quickly during propagation through the ocean. More conservative estimates result in 5 m crest height and 1 m run-up.
However, the fast moving run-up can create dangerous currents in surf zone, inlets, and river entrances.
The governing factor for a disastrous event is the terminal velocity of the landslide and the duration of the slide event (fig. 6&7).
An over 80 km extending incipient scar indicates a large-scale failure in the near future.
These are low probability but high impact events.

references

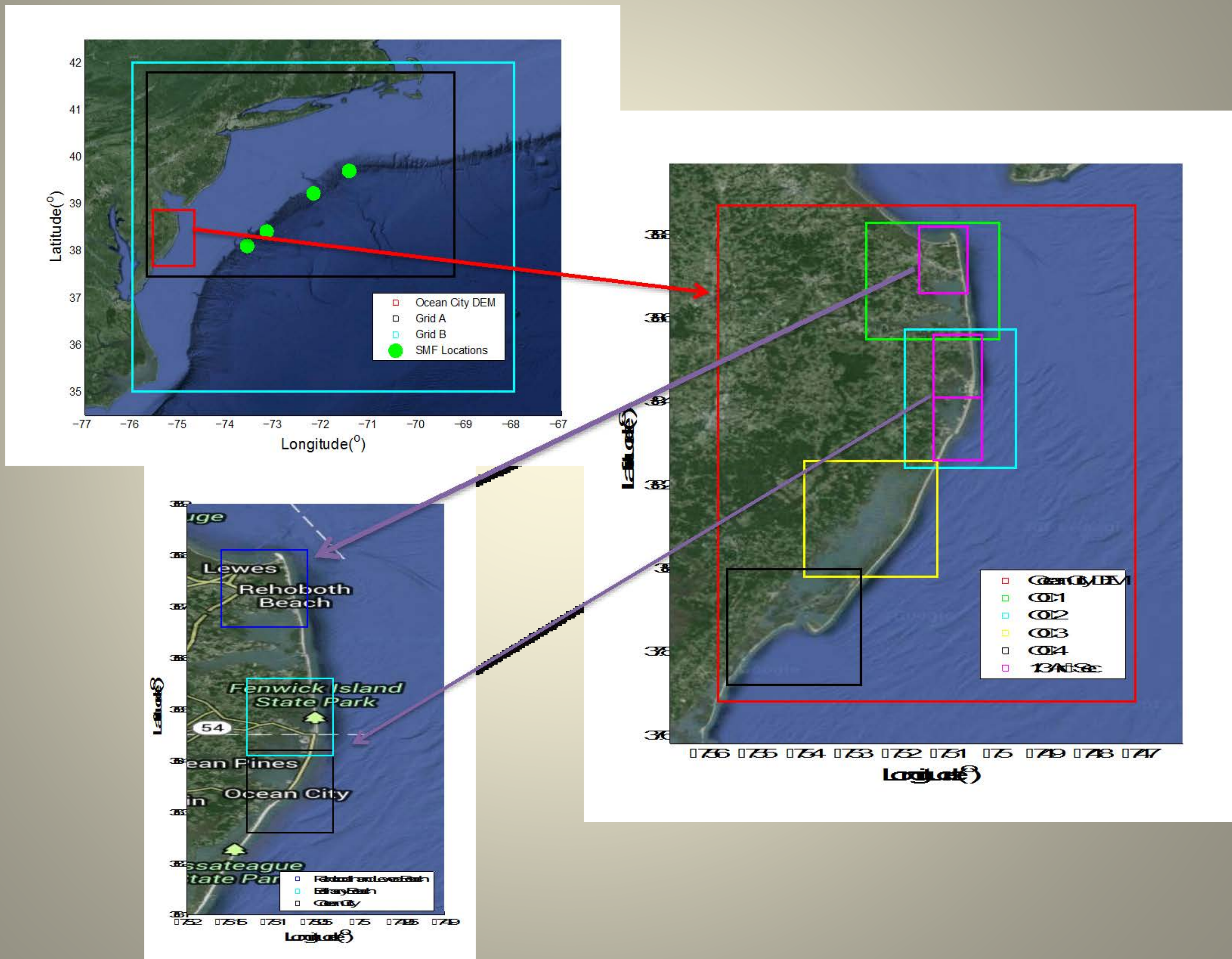
Ma, Gangfeng, Fengyan Shi, and James T. Kirby. "Shock-capturing non-hydrostatic model for fully dispersive surface wave processes." Ocean Modelling 43 (2012): 22-35.
Mulder, T., E. Ducassou, G. P. Eberli, V. Hanquiez, E. Gonthier, P. Kindler, M. Principaud et al. "New insights into the morphology and sedimentary processes along the western slope of Great Bahama Bank." Geology 40, no. 7 (2012): 603-606.
Shi, Fengyan, James T. Kirby, Jeffrey C. Harris, Joseph D. Geiman, and Stephan T. Grilli. "A high-order adaptive time-stepping TVD solver for Boussinesq modeling of breaking waves and coastal inundation." Ocean Modelling 43 (2012): 36-51.

Inundation "mapping"

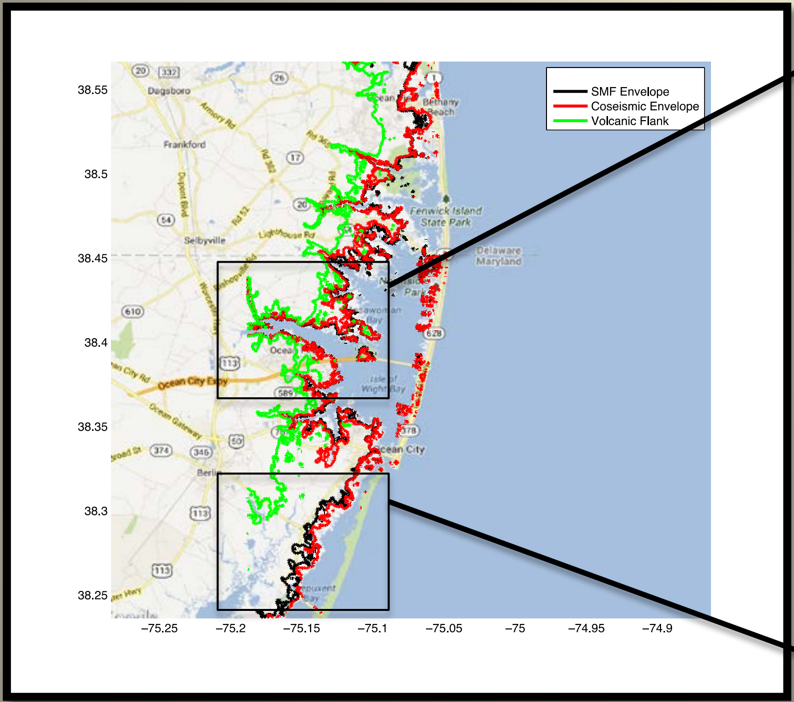
- Mapping for each DEM is being documented in individual reports and accompanying data sets.
- Data provided as ArcGIS raster or vector files.
- Reported data include
  1. In inundated (initially dry) areas:
     a. Maximum inundation depth during event (raster)
     b. Maximum velocity during event (raster)
     c. Maximum momentum flux during event (raster)
     d. Location of inundation line (vector)

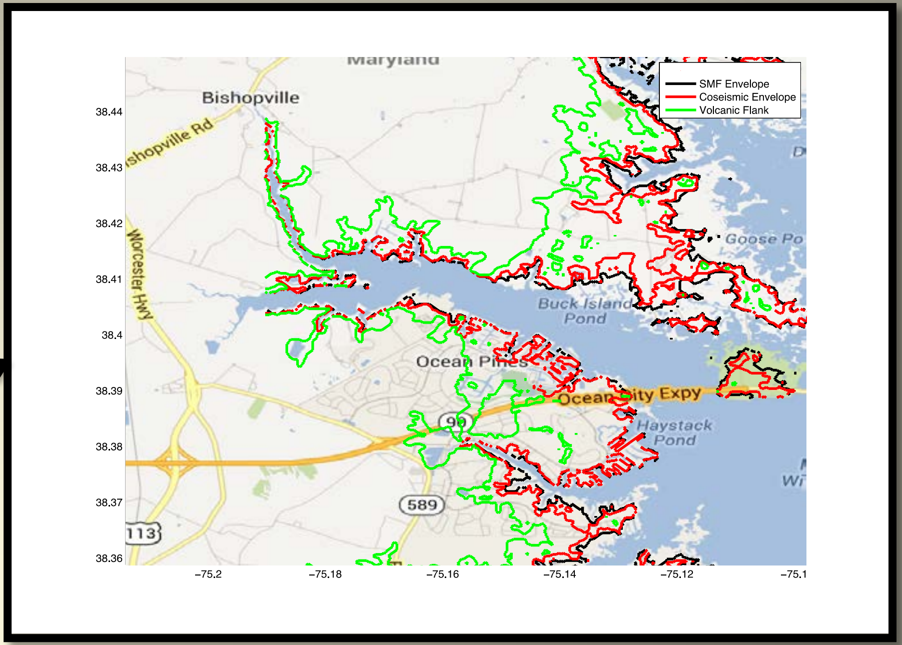
  2. In initially wet areas:
     a. Maximum surface displacement during event
     b. Maximum velocity during event

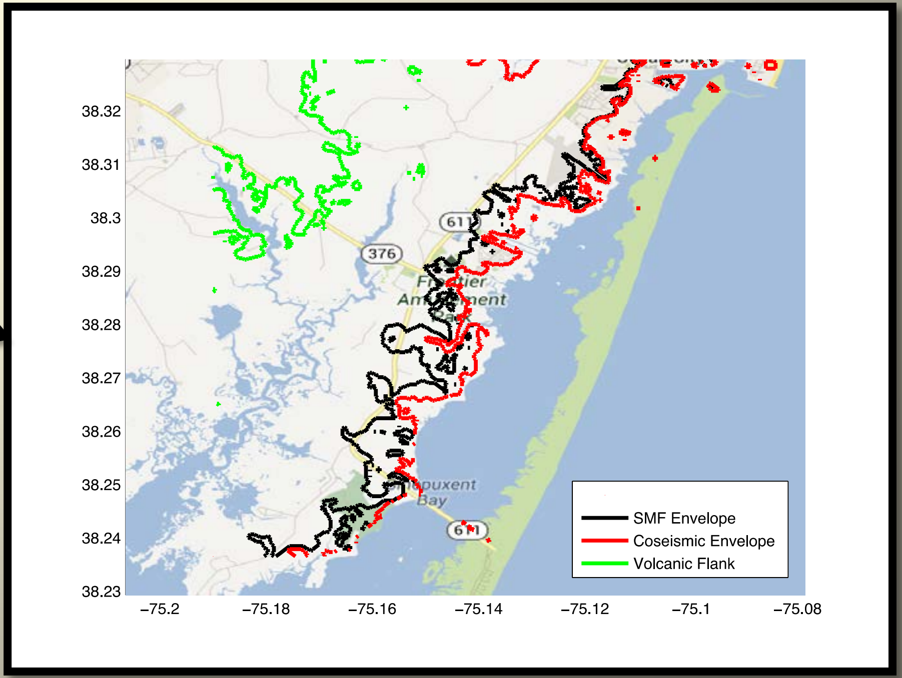
Grid nesting from ocean to DEM and DEM to local 1 arc second



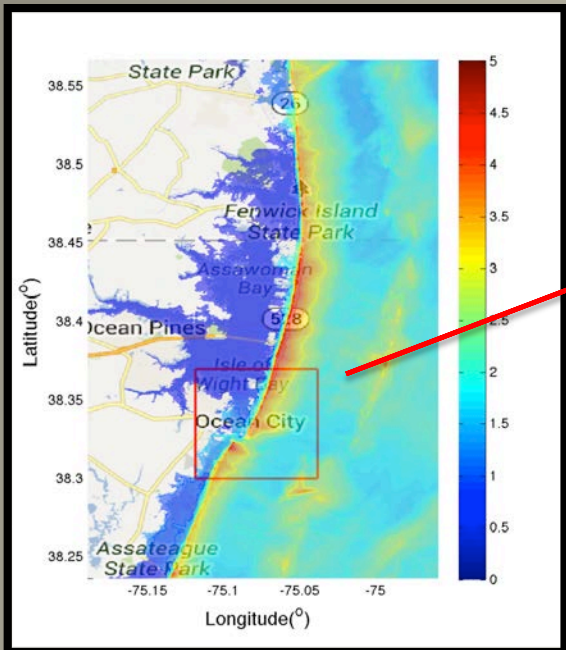
Inundation Lines

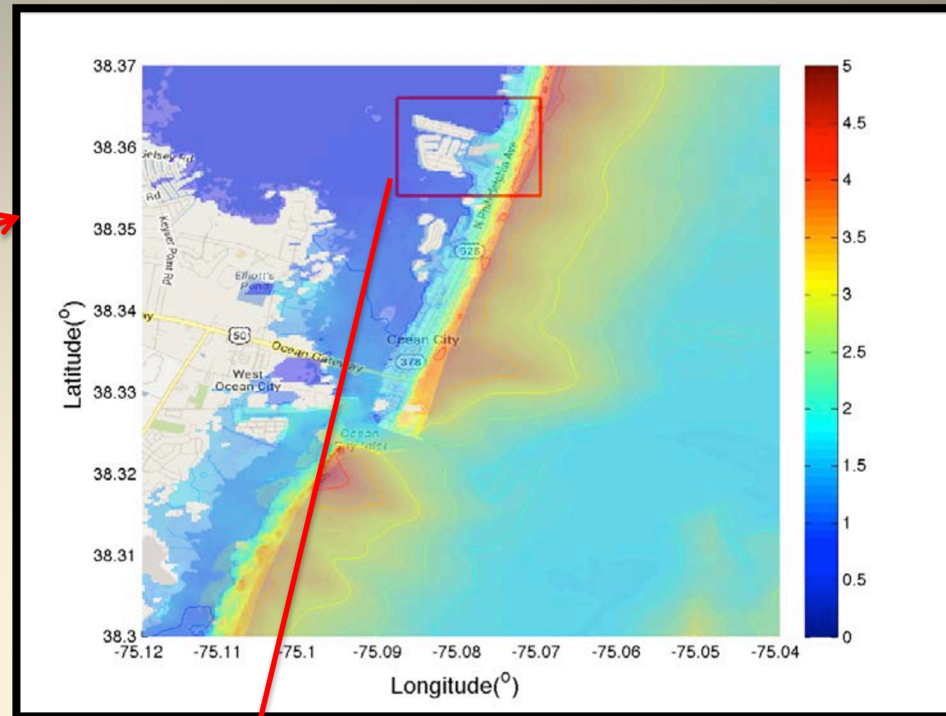




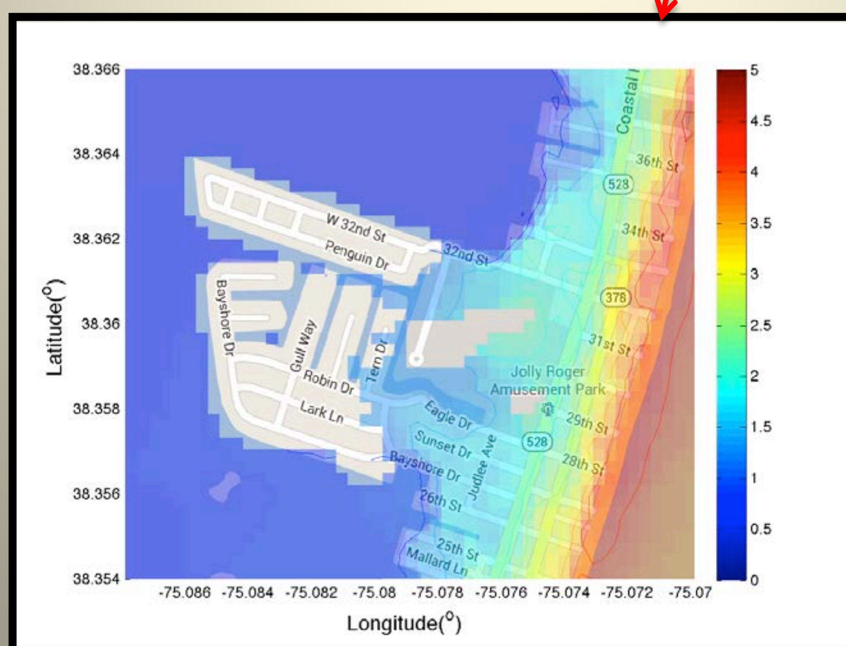


Lines shown here for individual event categories: CVV, coseismic and east coast SMF

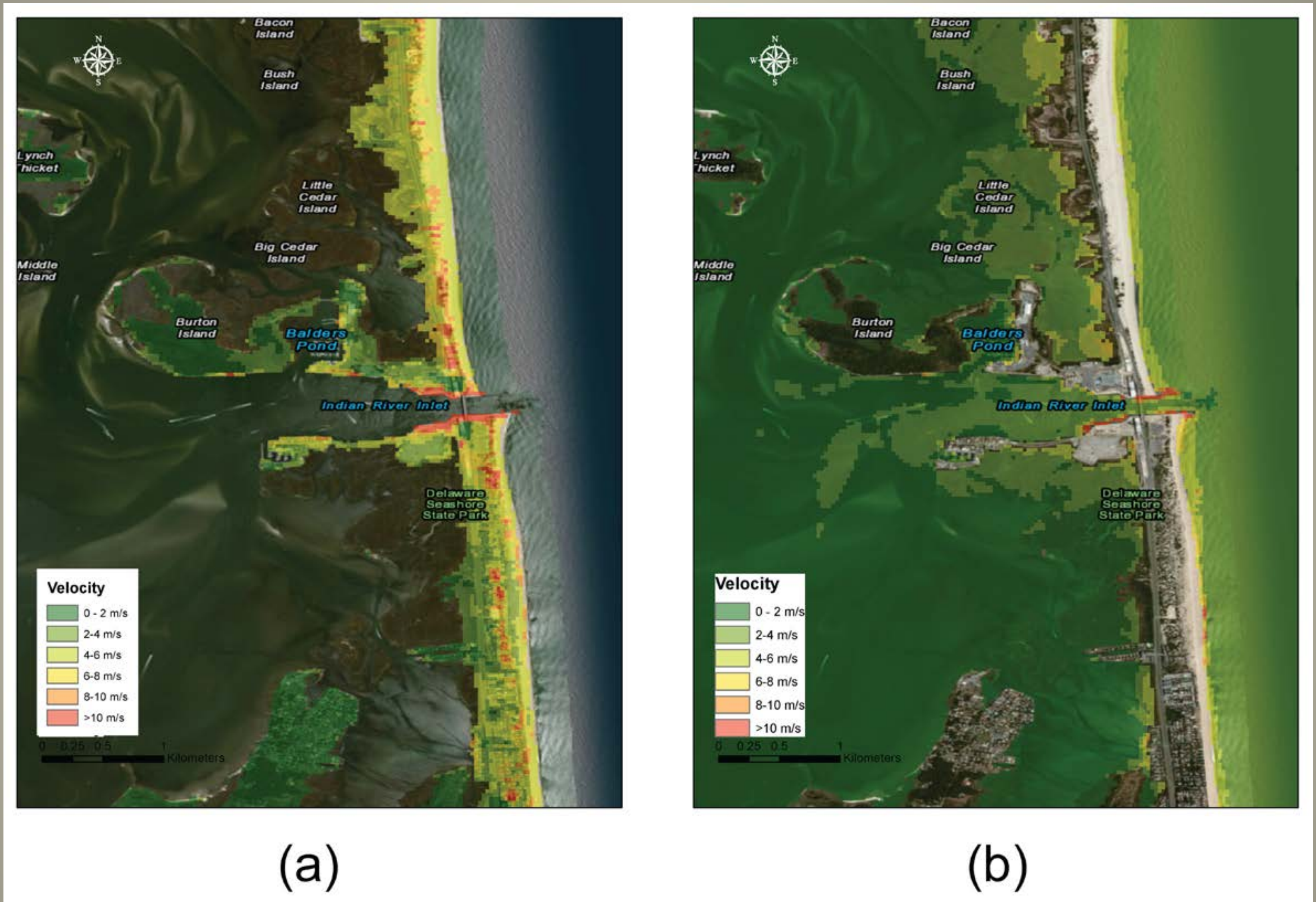




Inundation depths



Maximum occuring velocities



"Dry" areas

"Wet" areas