Tampa Bay Storm Surge & Wave Vulnerability, Response to Hurricane Irma and Tools for Future Use

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with

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iCAR
10/30/18

Hurricane-related Papers by Weisberg's USF-CMS Group

Weisberg, R.H. and L. Zheng (2006). A simulation of the hurricane Charley storm surge and its breach of North Captiva Island, *Florida Scientist*, 69, 152-165.

Weisberg, R.H. and L. Zheng (2006). Hurricane storm surge simulations for Tampa Bay. *Estuaries and Coasts*, 29, 899-913.

Virmani, J. I., and R. H. Weisberg (2006), The 2005 hurricane season: An echo of the past or a harbinger of the future?, *Geophys. Res. Lett*., 33, L05707, doi:10.1029/2005GL025517.

Weisberg, R. H., and L. Zheng (2008), Hurricane storm surge simulations comparing three-dimensional with two-dimensional formulations based on an Ivan-like storm over the Tampa Bay, Florida region, *J. Geophys. Res*., 113, C12001, doi:10.1029/2008JC005115.

Huang, Y., R. H. Weisberg, and L. Zheng (2010). The coupling of surge and waves for an Ivan-like hurricane impacting the Tampa Bay, Florida region, *J. Geophys. Res*., 115, C12009, doi:10.1029/2009JC006090.

Huang, Y., R. H. Weisberg, and L. Zheng (2013), Gulf of Mexico hurricane wave simulations using SWAN: Bulk formula based drag coefficient sensitivity for Hurricane Ike. *J. Geophys. Res*., 118, 1–23, doi:10.1002/jgrc.20283.

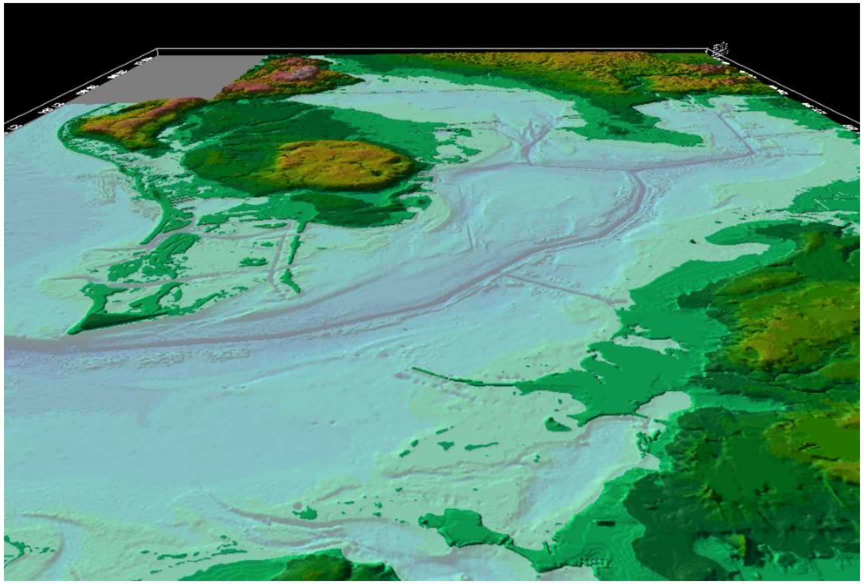
Zheng, L., R.H. Weisberg, Y. Huang, et al., (2013), Implication from the comparisons between two- and three-dimensional model simulations of the Hurricane Ike storm surge. *J. Geophys. Res*., 118, 3350-3369, doi:10.1002/jgrc.20248.

Kerr, P.C., A.S. Donahue, J.J. Westerink, R.A. Luettich Jr., L.Y. Zheng, R.H. Weisberg, Y. Huang, H.V. Wang, Y. Teng, D.R. Forrest, A. Roland, A.T. Haase, A.W. Kramer, A.A. Taylor, J.R. Rhome, J.C. Feyen, R.P. Signell, J.L. Hanson, M.E. Hope, R.M. Estes, R.A. Dominguez, R.P. Dunbar, L. N. Semeraro, H.J. Westerink, A.B. Kennedy, J.M. Smith, M.D. Powell, V.J. Cardone, and A.T. Cox. (2013) U.S. IOOS coastal and ocean modeling testbed: Inter-model evaluation of tides, waves, and hurricane surge in the Gulf of Mexico. *J. Geophys. Res.,* 118, 5129–5172, doi:10.1002/jgrc.20376.

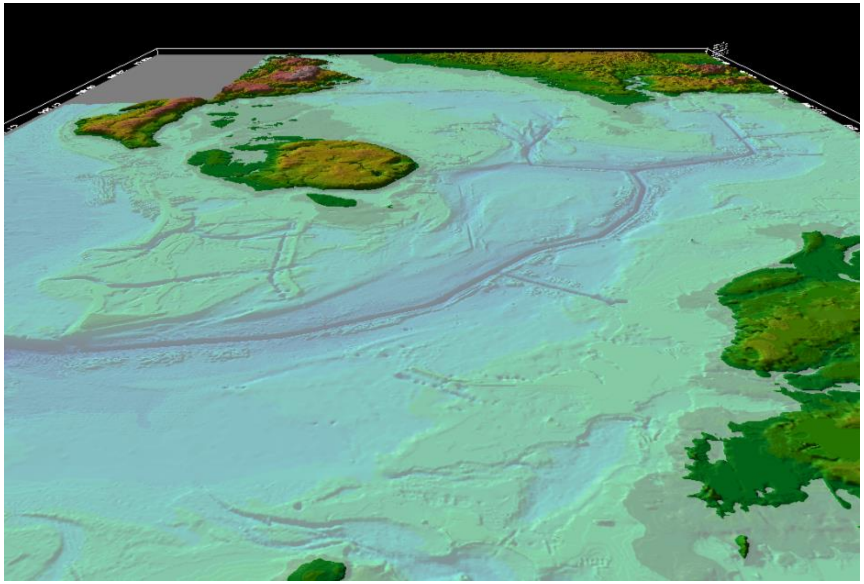
Chen, J, R.H. Weisberg, Y. Liu and L. Zheng (2018), The Tampa Bay Coastal Ocean Model Performance for Hurricane Irma, *Mar. Tech. Soc. Jour*., 52, 33-42.

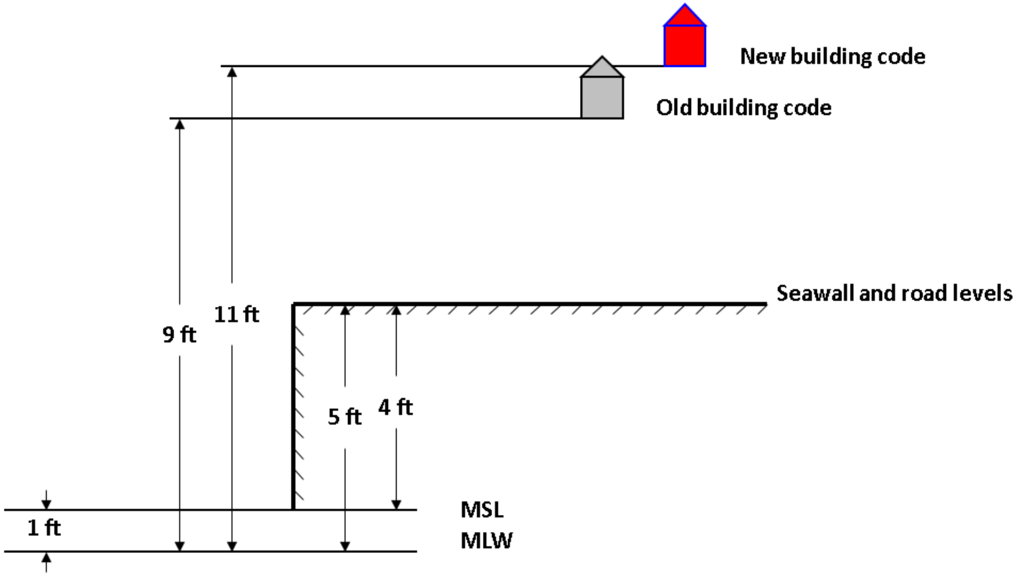
Tampa Bay is Vulnerable due to Low Elevations and Building Codes

Inundation based on a 5-foot uniform sea level rise



Inundation based on a 20-foot uniform sea level rise





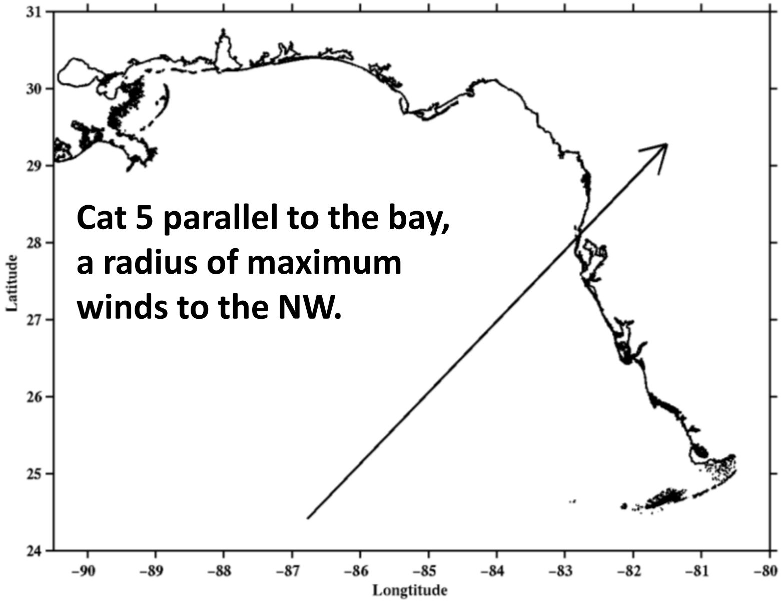
Finished floor levels are relative to Mean Low Water (MLW), not leaving much room in the event of a storm surge. If a typical high tide is 1 ft above MSL (2 ft above MLW), then old or new code homes would be flooded by storm surges of 7 ft or 9 ft, respectively. Storm surge is only part of the problem. Waves are much more important because while surge will flood a house, waves will destroy it and kill its occupants! That lesson was made very clear in Mississippi by Katrina and recently in Florida by Michael.

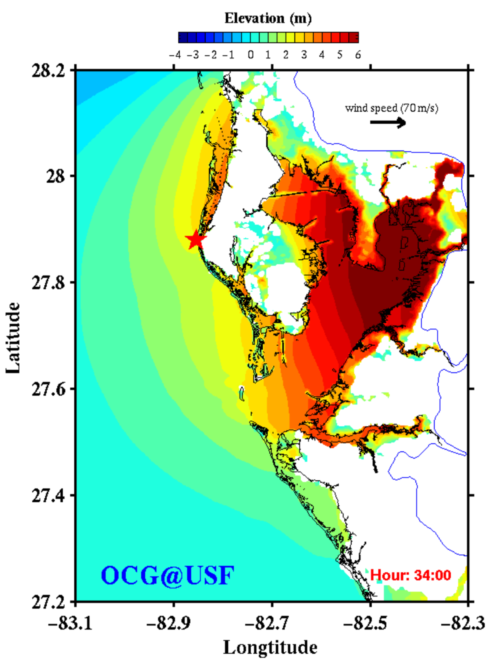
Katrina Damage at Long Beach, MS

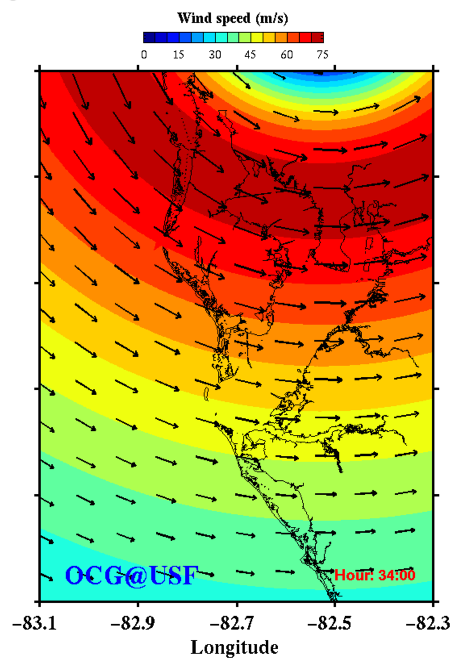
Surge was ~ 20 ft & waves were ~ 6 ft. Houses at elevations less than ~ 16 ft were destroyed. The wrack line (debris from all of the wave-destroyed homes) provided a barrier beyond which waves did not penetrate.

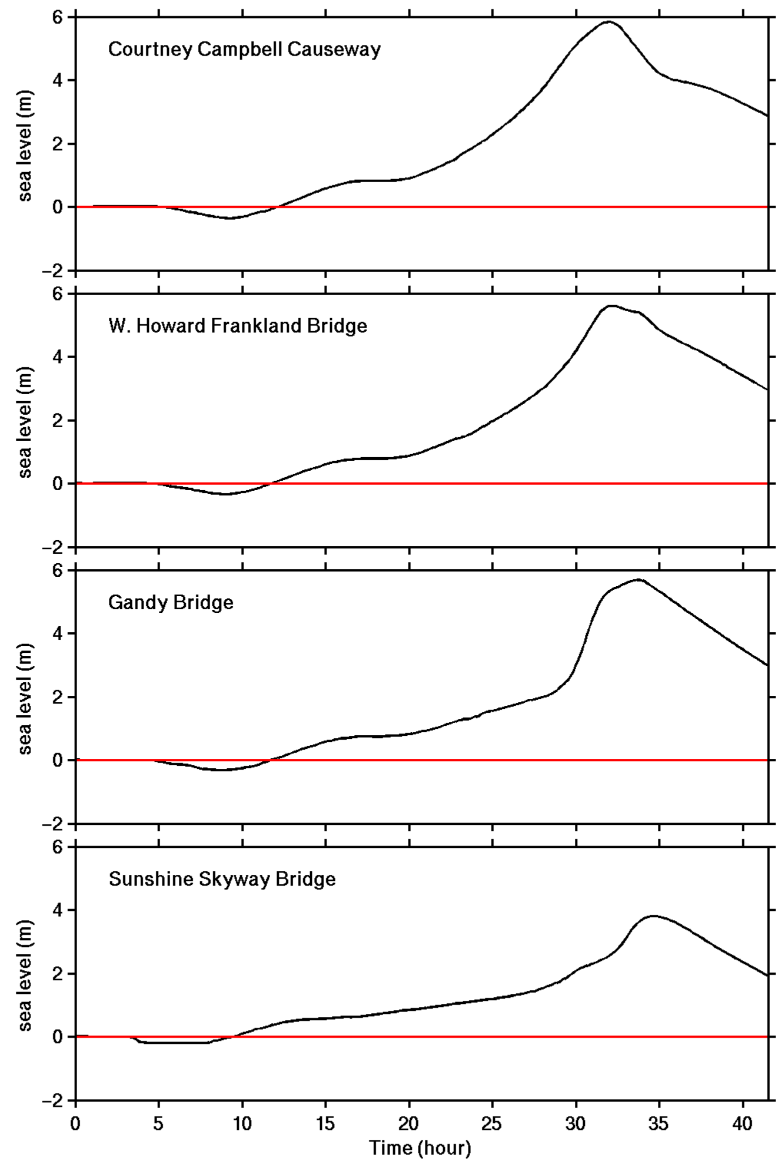
My Worst Case Scenario for Tampa Bay

Presented as the WFCAMS annual banquet invited talk on June 6th 2006.



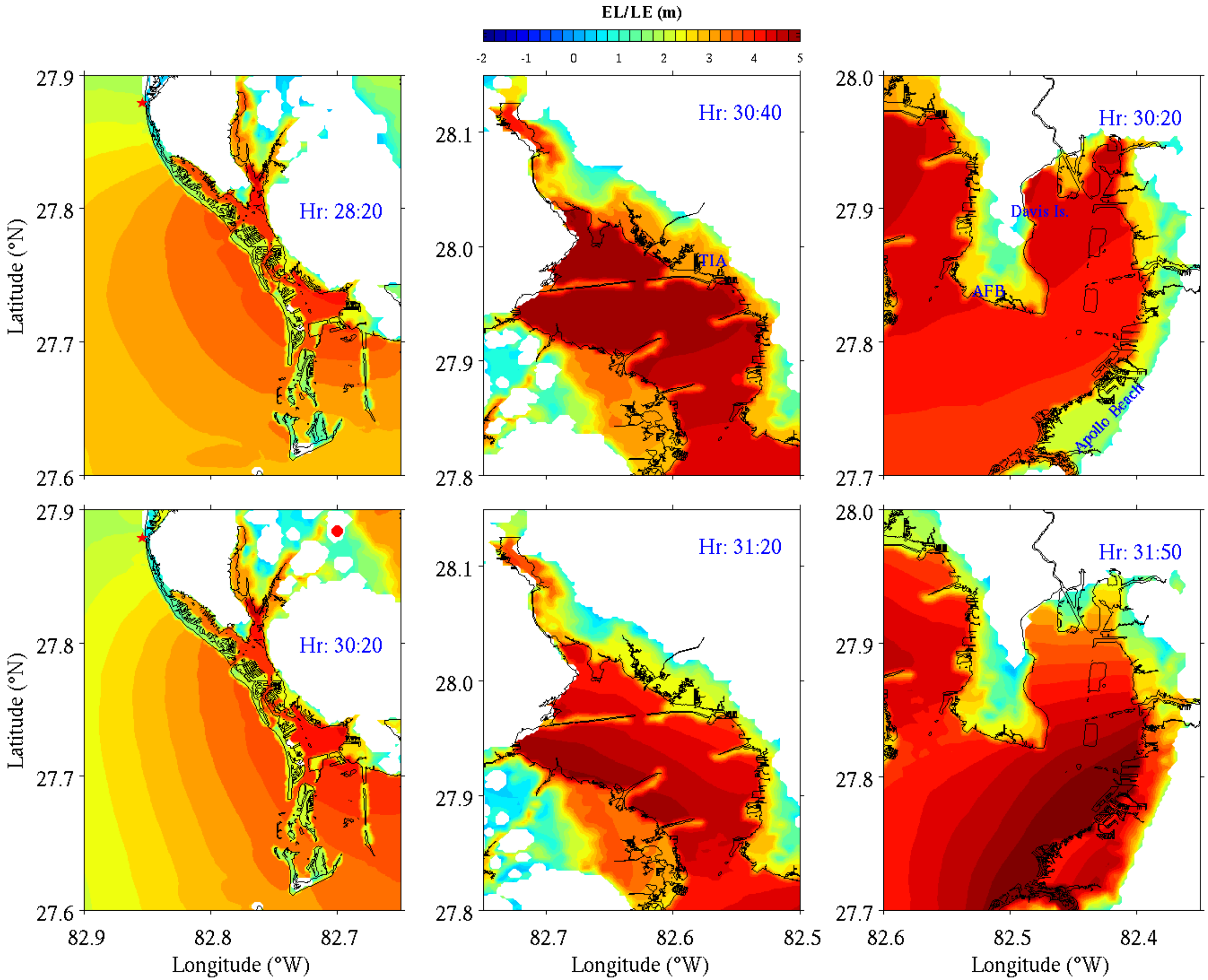






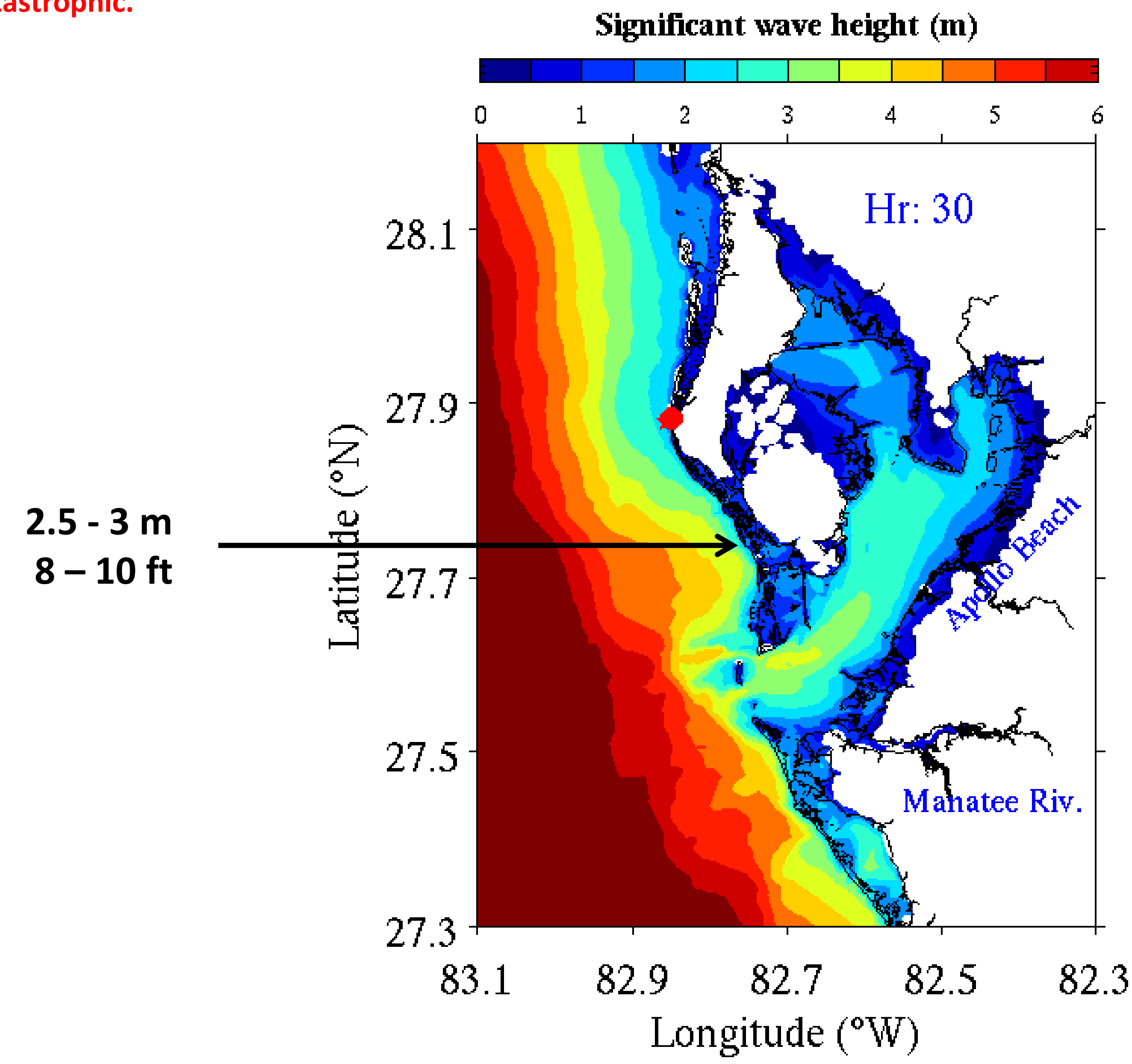
What if a Storm like Hurricane Ivan (Cat 3) Were to Visit Tampa Bay?

Maximum surge heights relative to ground level show just how bad inundation could. We knew this in 2006; yet, construction continued for the next decade and beyond in the most vulnerable regions. **This begs the question: Are we serious about sustainability?**



Now Consider the Waves as Modeled for an Ivan-like Storm.

The entire bay periphery could have significant wave heights exceeding 1 m over what had been land. Significant wave height is the average of the 1/3rd highest waves; it is common to have some waves of twice that height. Destruction could be catastrophic.

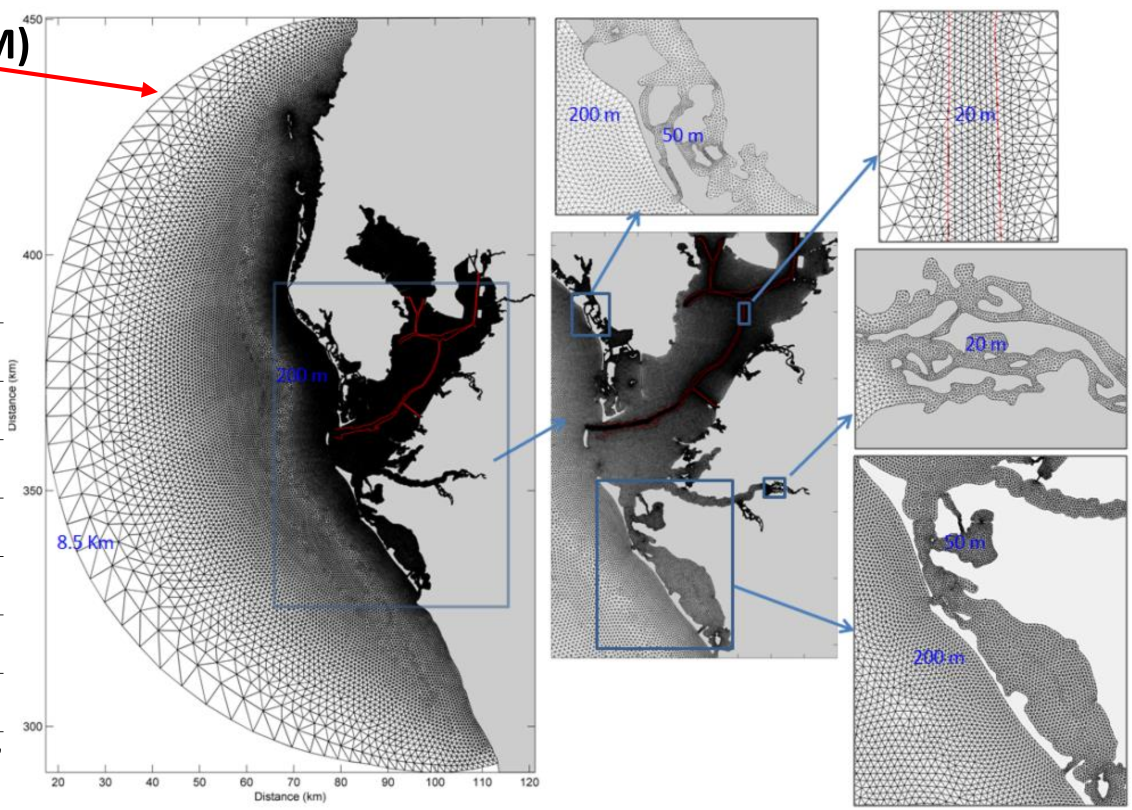


What Are We Doing Now?

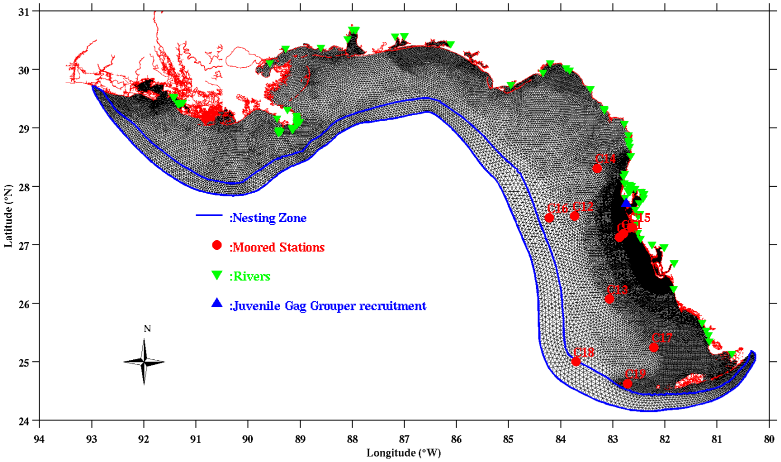
- **The Tampa Bay Coastal Ocean Model (TBCOM) uniquely includes Tampa Bay, Sarasota Bay, the Intra-coastal Waterway and all of the inlets connecting these with the Gulf of Mexico.**
- **TBCOM derives its open boundary values from WFCOM, thereby downscaling from the deep-ocean, across the shelf and into the bay.**
- **TBCOM provides daily nowcasts & forecasts, and Hurricane Irma was its first test.**

Tampa Bay Coastal Ocean Model (TBCOM)
FVCOM nested in WFCOM

219,337 triangle elements; 115,369 nodes;
11 σ layers

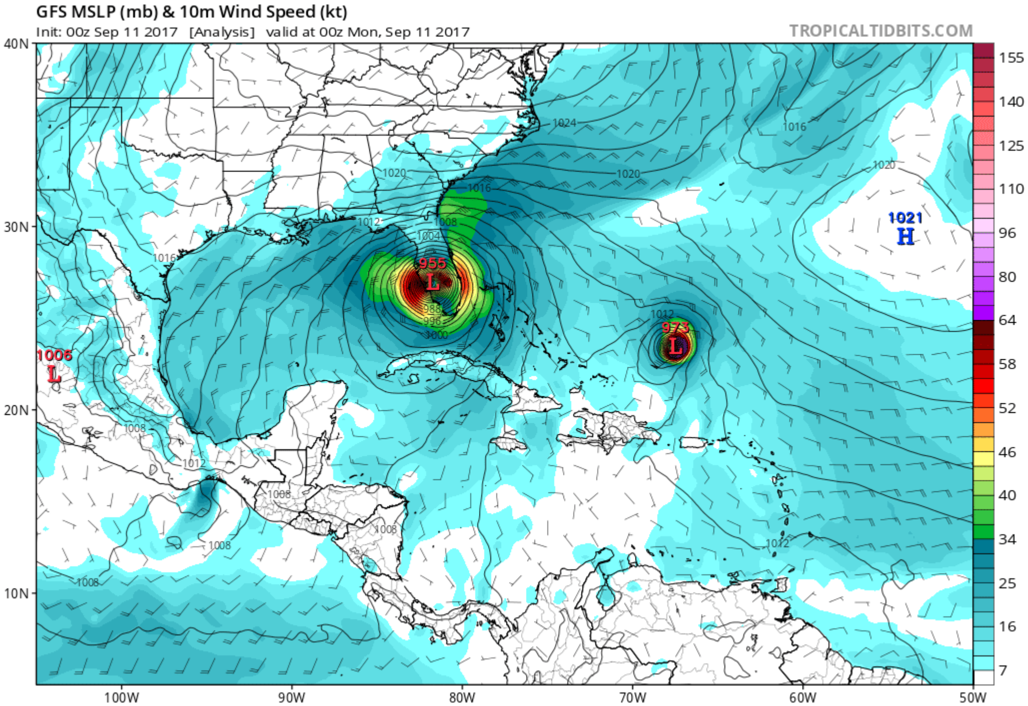


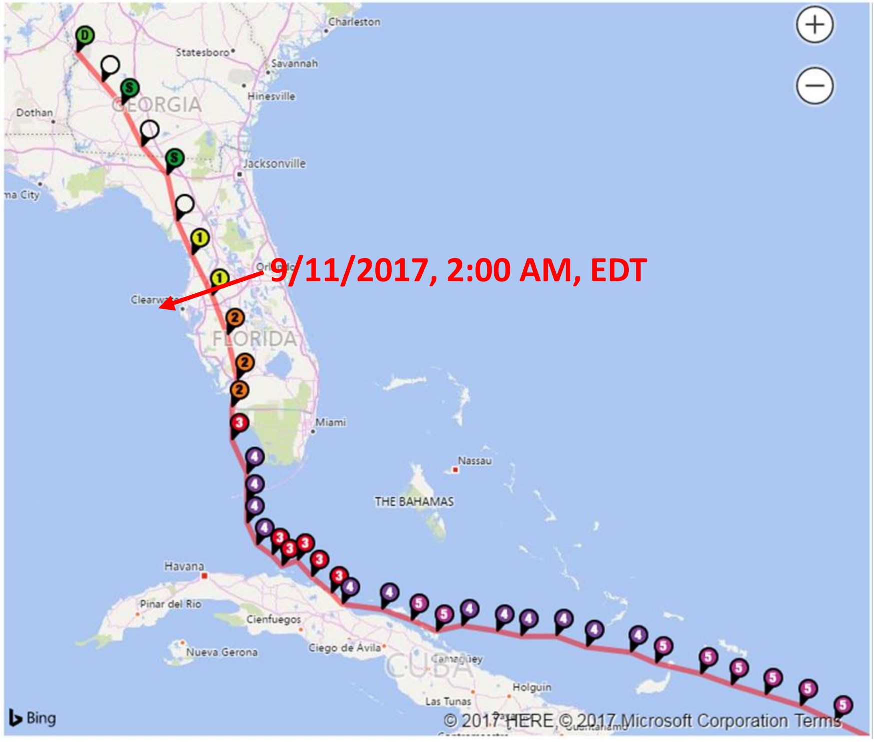
West Florida Coastal Ocean Model
FVCOM nested in GOM HYCOM



Hurricane Irma Application

GFS Analysis at 0000 UT 9/11/17



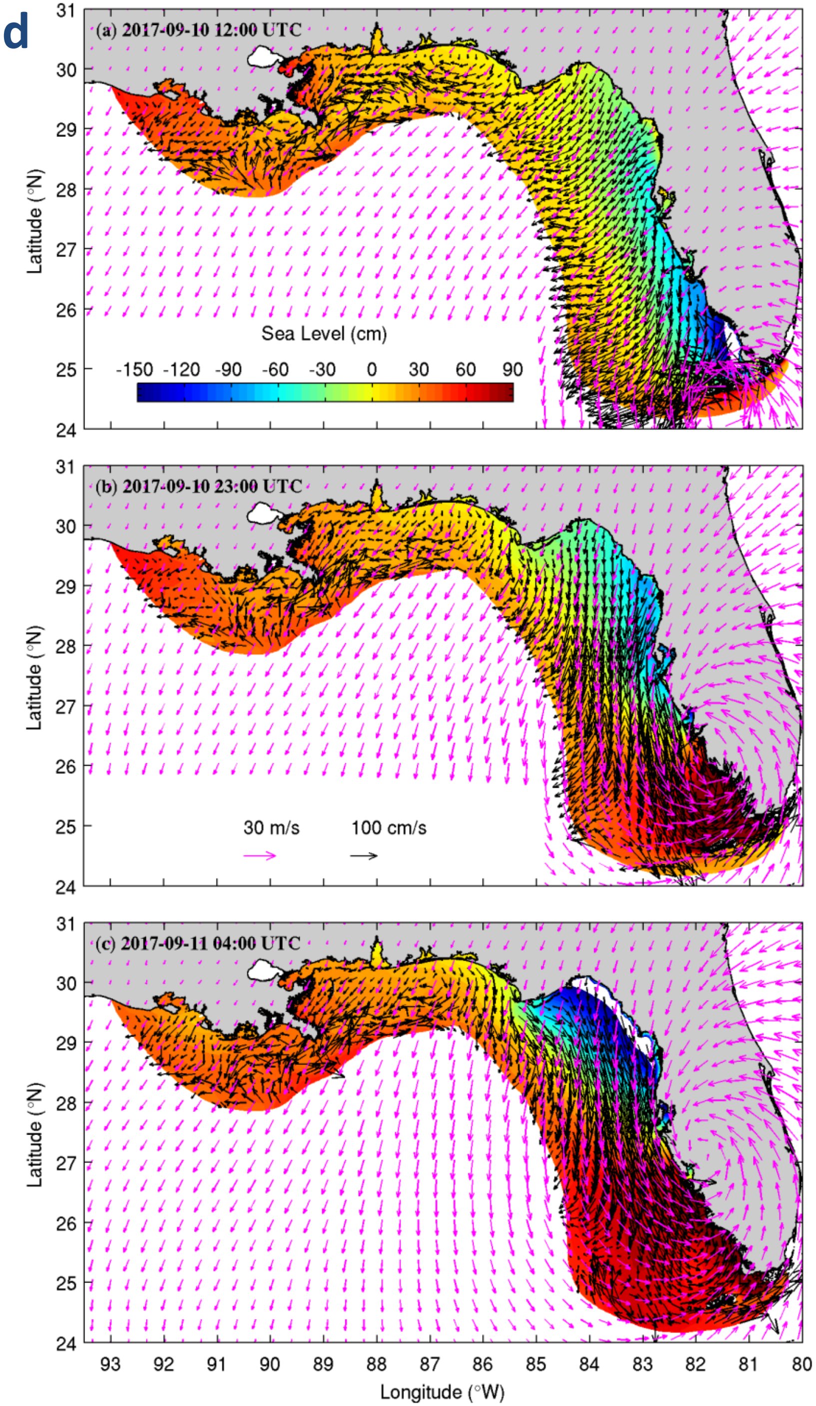


Surface Winds and WFCOM Simulated Surface Currents and Sea Level (September 10 & 11, 2017)

Landfall at the Florida Keys

Second Landfall at Naples

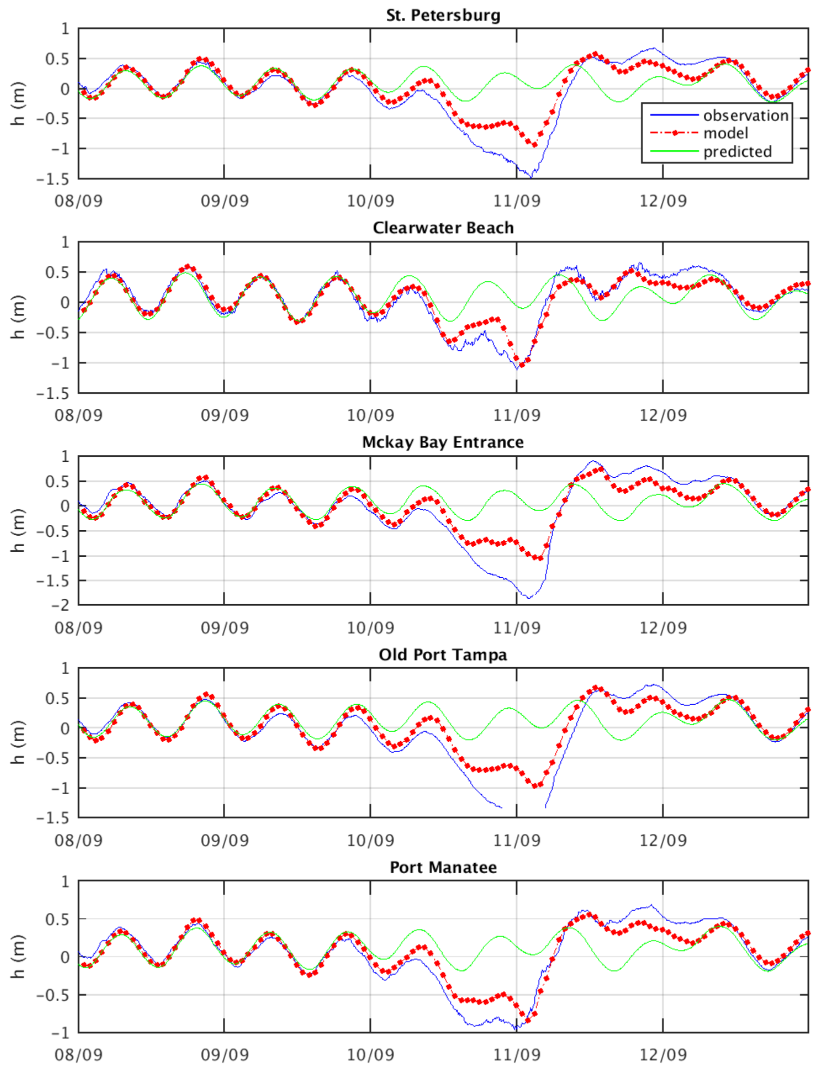
Approach to Tampa Bay latitude



The Initial Hurricane Irma Sea Level Comparisons

From top to bottom are comparisons between sea levels predicted by tides, observed and modeled for stations at St. Petersburg, Clearwater Beach, Mackay Bay, Old Port Tampa and Port Manatee (all relative to mean sea level).

Note: As shown on the next slide, the discrepancies between observed and modeled sea levels during the storm are due to the underestimated winds used to initially force the model.

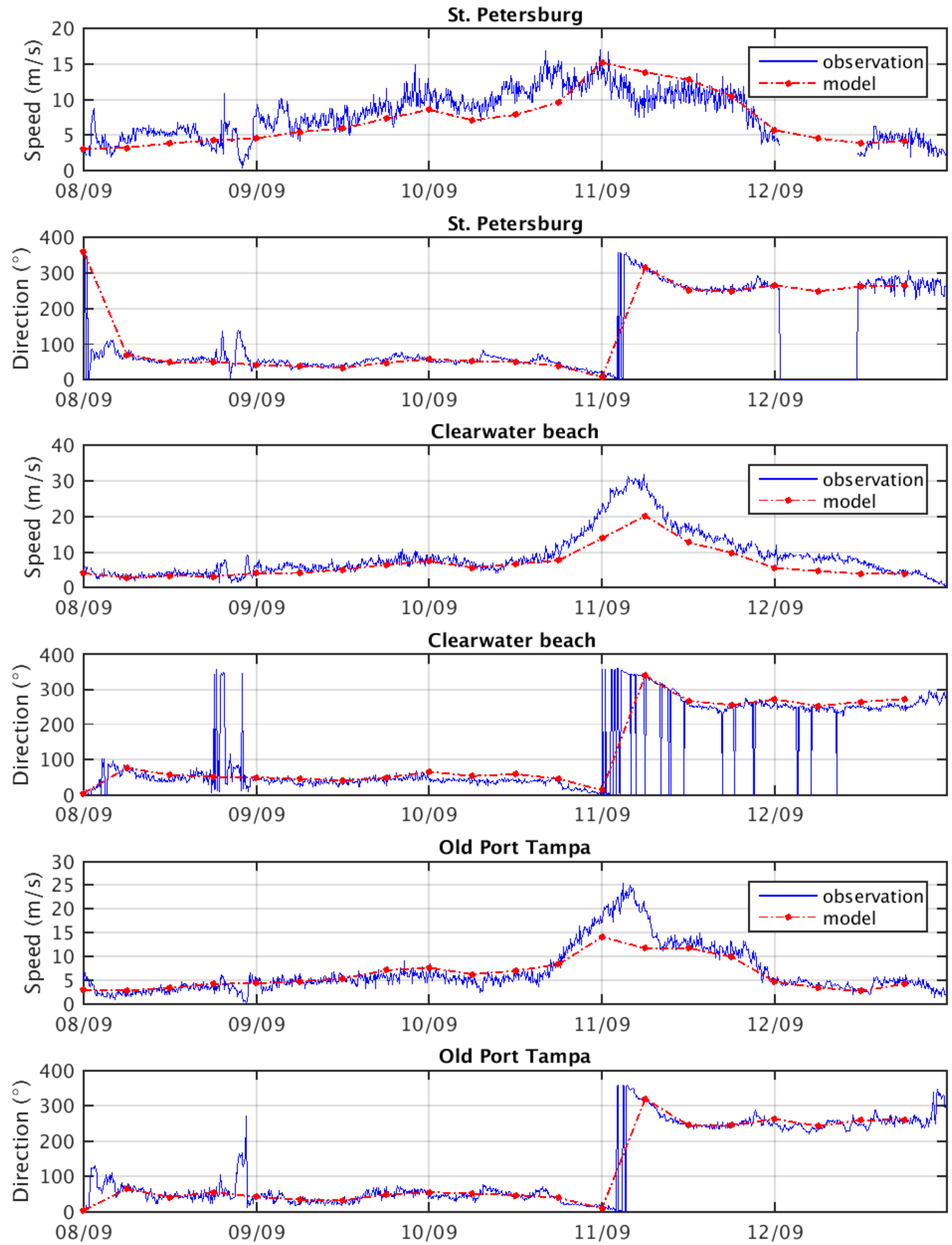


Hurricane Irma Wind Comparisons

From top to bottom are wind speeds and directions observed and modeled (by NOAA) for stations at St. Petersburg, Clearwater Beach and Old Port Tampa.

Note that:

The NOAA modeled winds used to force the TBCOM underestimated the Irma observed winds by a factor of 1.6. This, plus the available six hourly sampling of the modeled winds, reduced the TBCOM response.
The winds were adjusted by a factor of 1.6, and the model was rerun in hindcast.

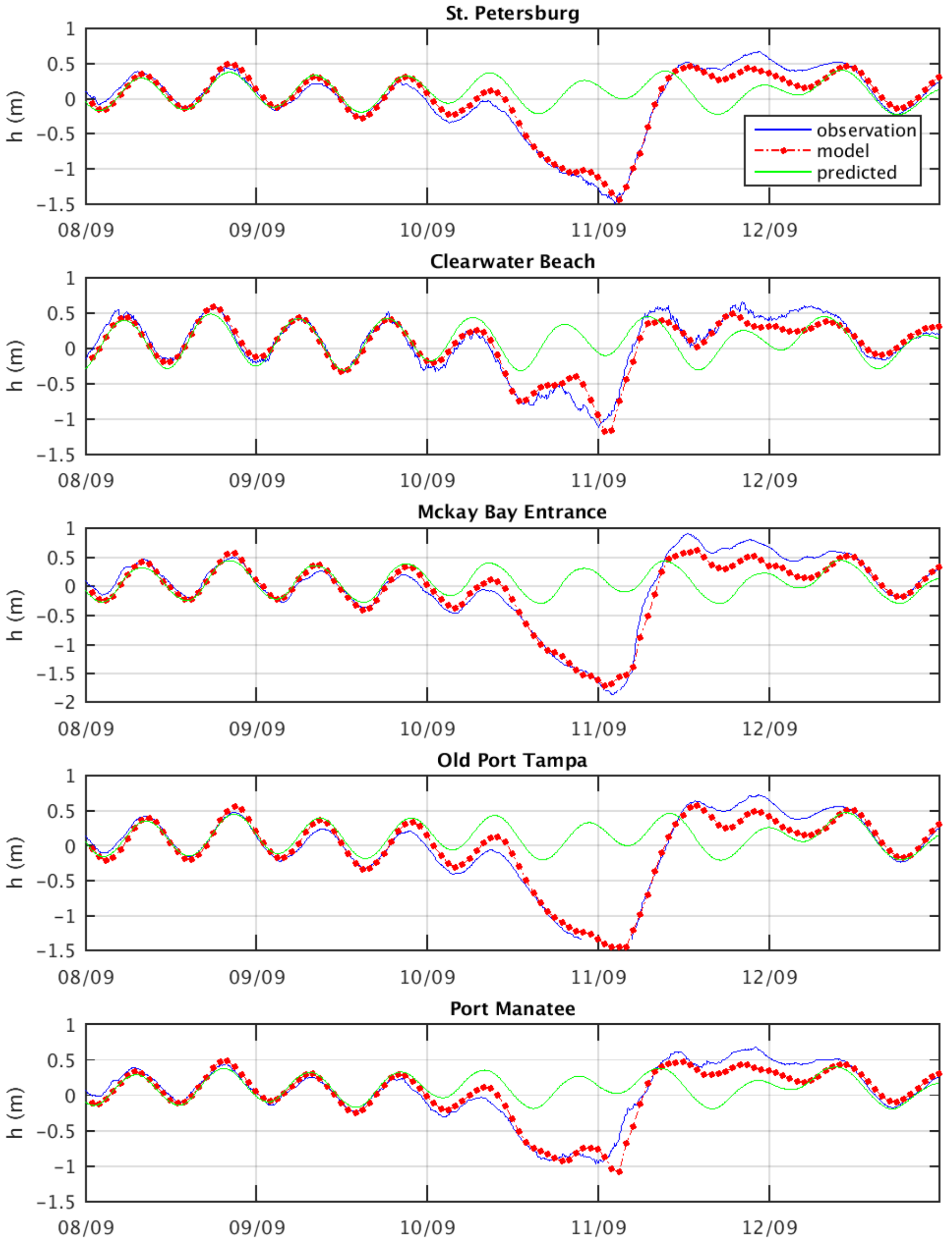


Hurricane Irma Sea Level Results

(Comparisons with wind speed increased by a factor of 1.6)

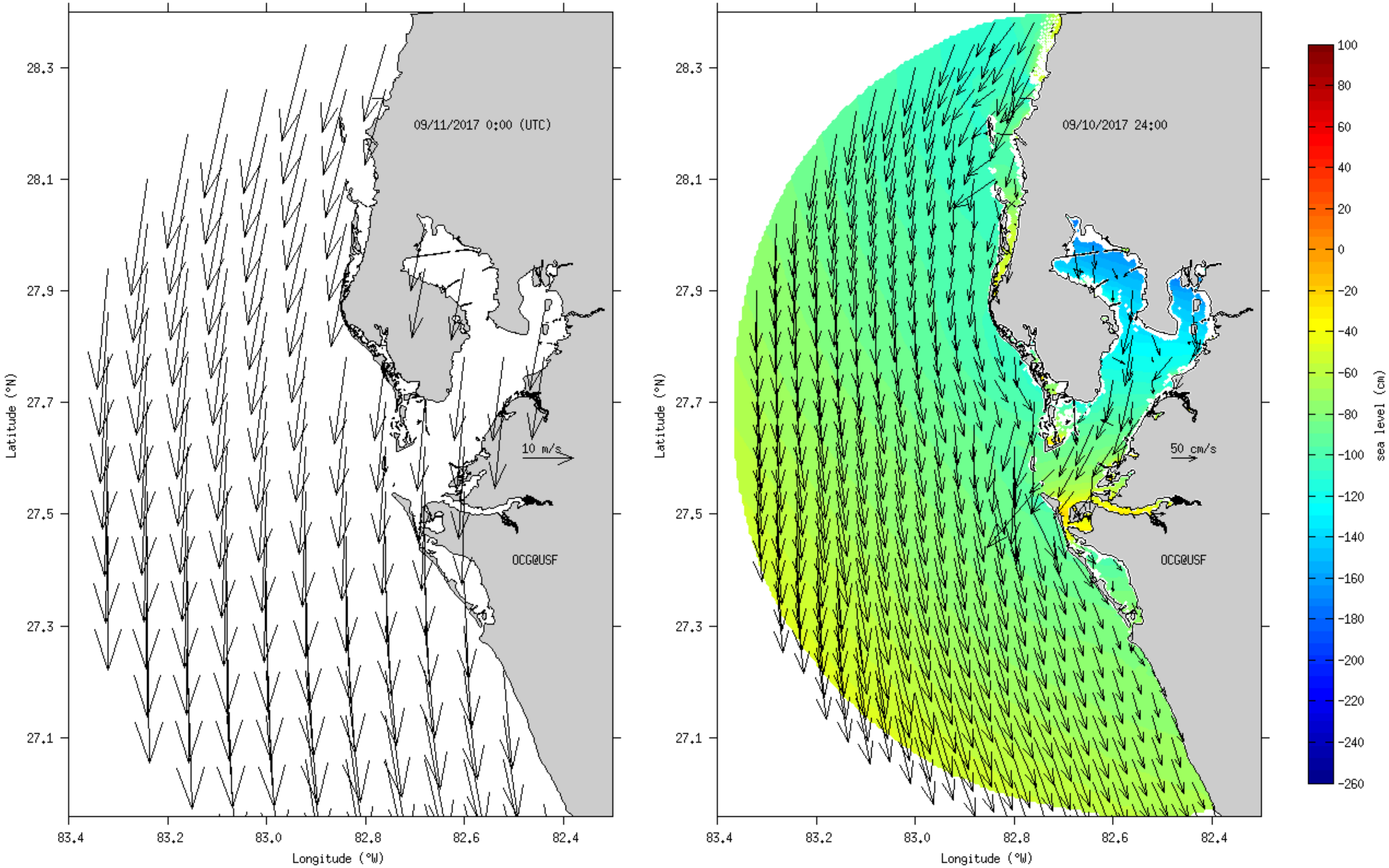
From top to bottom are the sea levels predicted by tides alone, observed and modeled by TBCOM for stations at St. Petersburg, Clearwater Beach, Mackay Bay, Old Port Tampa and Port Manatee (all relative to mean sea level).

TBCOM sea level is now seen to be in excellent agreement with the observations.



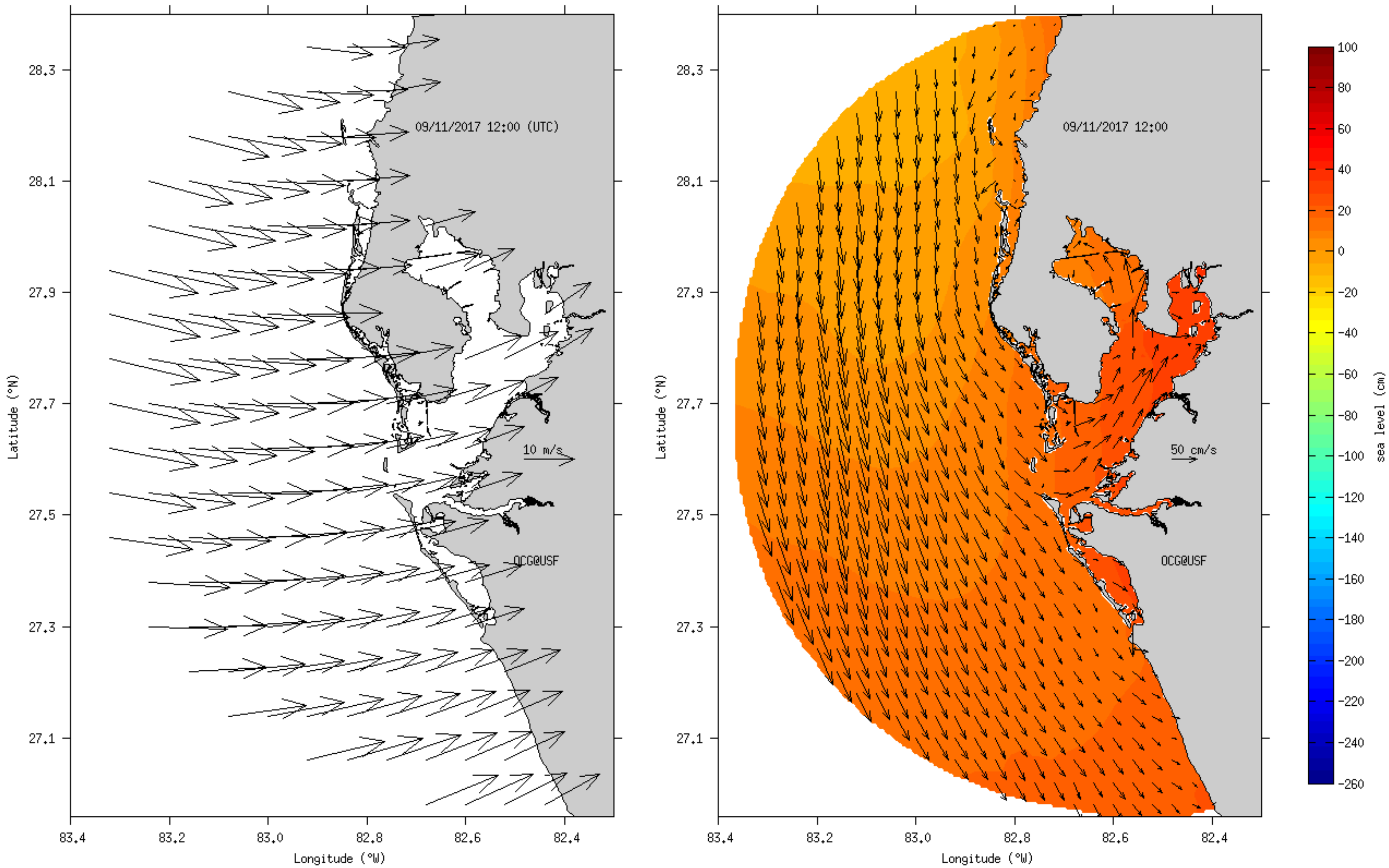
TBCOM Winds, Surface Currents and Sea Level at 2400 UT (2000 DST) on 9/10/17

Sea level dropped in response to strong northerly winds in advance of Irma. The white areas are where the bay went dry.



TBCOM Winds, Surface Currents and Sea Level at 1200 UT (0800 DST) on 9/11/17

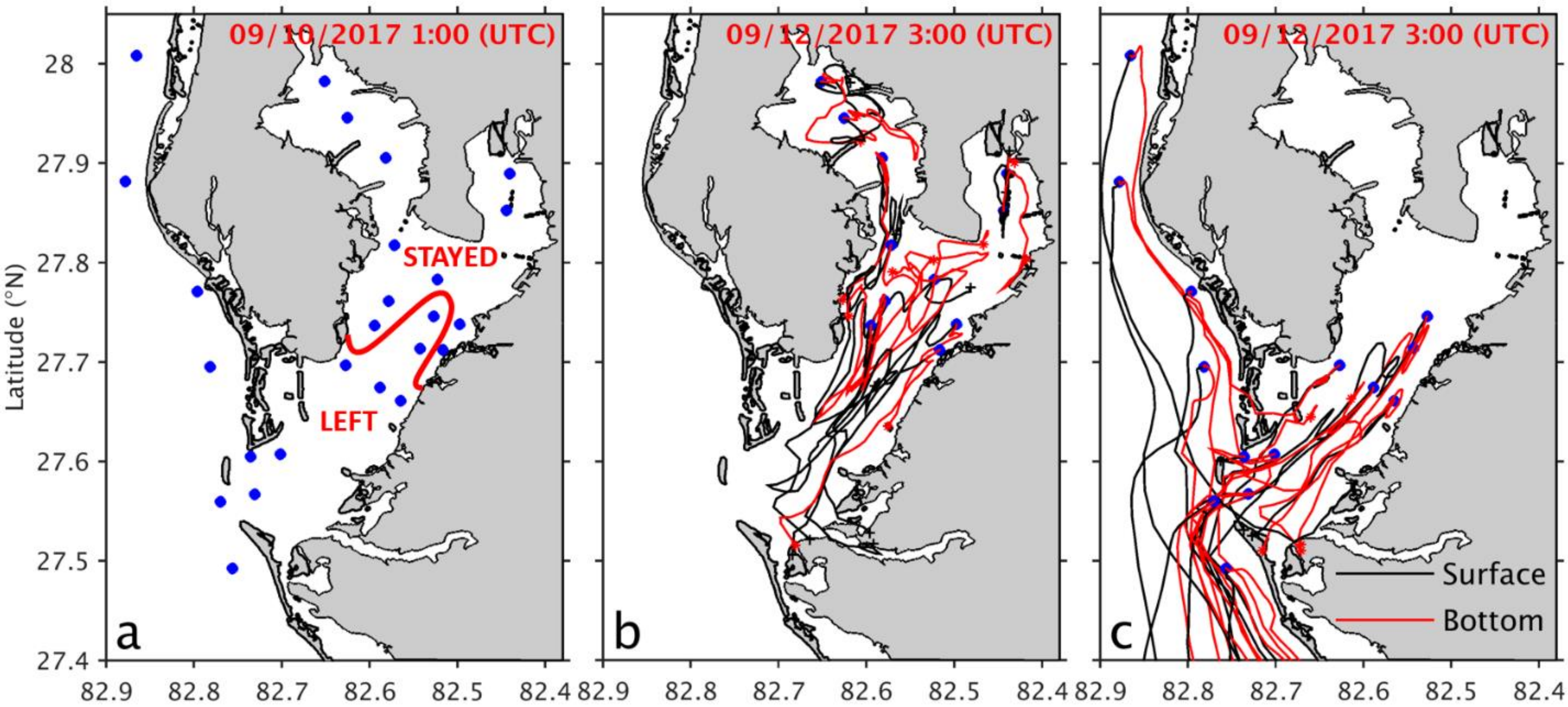
Sea level increased in response to westerly winds in the wake of Irma.



Simulated Lagrangian Drifter Trajectories

From where did water leave the bay?

Answer: From the lower portion of Tampa Bay.

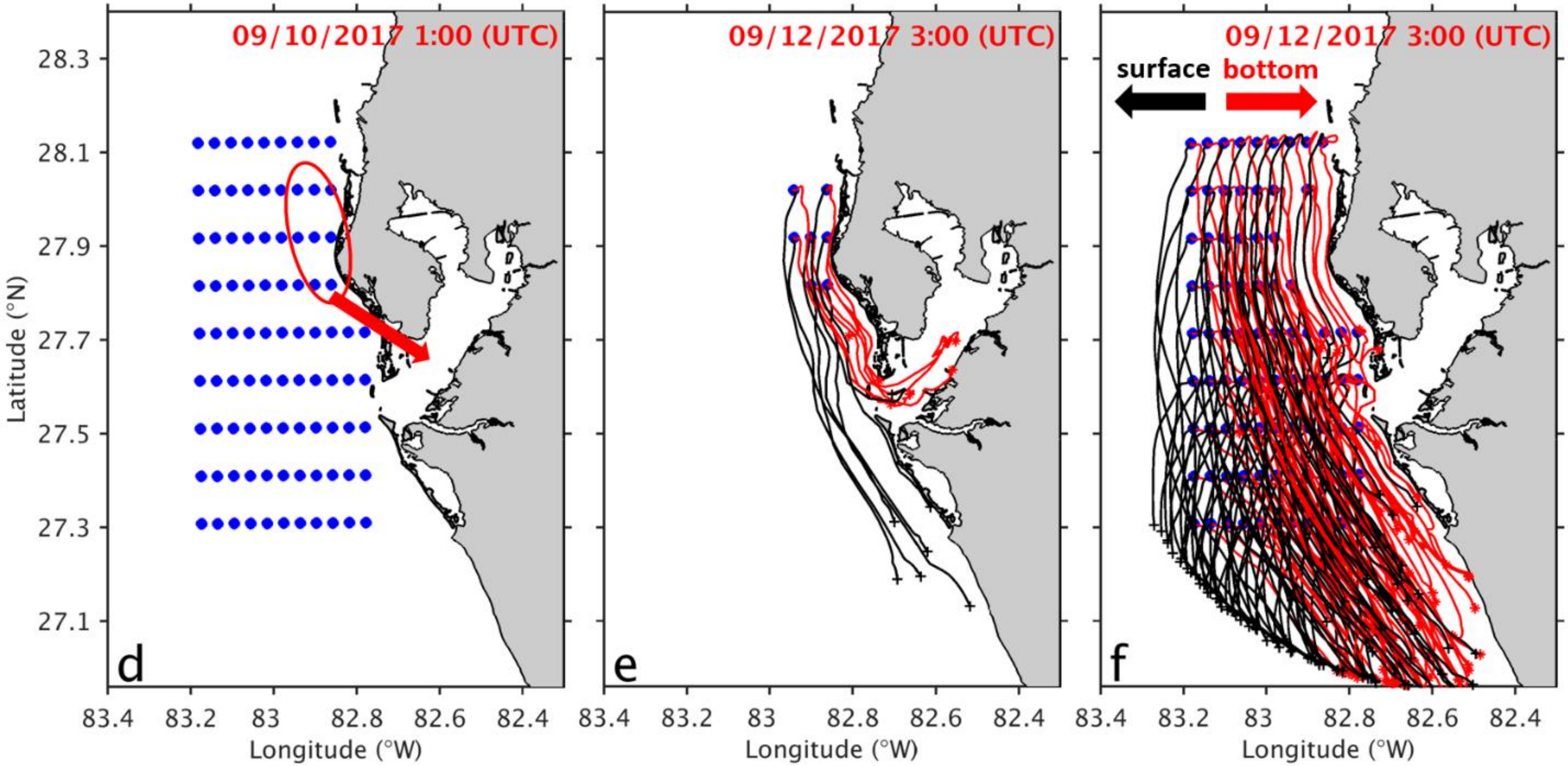


Corollary: We now have an effective tool for tracking red tide, sewage and oil spills, search and rescue and for both engineering and forensics studies.

Simulated Lagrangian Drifter Trajectories

From where did the new water enter the bay?

Answer: From nearshore of Indian Rocks Be. and Clearwater and primarily from the bottom, versus the surface.



Conclusions

- **Tampa Bay is highly vulnerable to hurricane storm surge and waves.**
- **Storm surge results in flooding; waves result in destruction and death.**
- **Certain regions of Tampa Bay are more at risk than others;**
  - **past development has not considered this,**
  - **future development should.**
- **TBCOM, a very high resolution circulation model for Tampa Bay, Sarasota Bay, the ICWW and the adjacent Gulf of Mexico, provides a new and unique tool for planning, research and applications.**
- **Hurricane Irma provided a first test of TBCOM for which it performed excellently.**
- **Given TBCOM and its WFCOM partner, we now have the capability to downscale from the deep ocean, across the continental shelf and into the estuaries, providing opportunity for interdisciplinary studies of the shelf and its estuaries.**
- **TBCOM applications also include recreational and commercial boating, fishing, search and rescue, tracking of sewage and oil spills, engineering and forensics studies and red tide tracking (http://ocgweb.marine.usf.edu/hab_tracking/).**