

IRENE: Visitor from the Extratidal World

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Hurricane Irene did not come to Hampton Roads from outer space but if she had, we'd call her an 'extraterrestrial' visitor. Instead she belongs to the *extratidal* world, a rare place and time where tides – predicted ones anyway - do not go. A place and time where extratidal water finds its way into our yards and driveways and other places higher up where we would rather it didn't go. It requires a storm like Irene to take it there.

Perhaps not so rare – the times at least. We experience extratidal water fairly often in minor amounts but in much bigger doses during events like the so-called 'Storm of the Century' in Chesapeake Bay, the August 1933 hurricane (8.02 feet above MLLW at Sewells Point). In more recent times several storms have produced similar extremes in water level: Isabel in September 2003, Ernesto in September 2006, Nor'Ida in November 2009 and now Irene in August 2011. About one every three years entering the second decade of the millennium.

An extratidal water level is one that exceeds highest astronomic tide (HAT) or falls below lowest astronomic tide (LAT). In between is the intertidal zone. The National Oceanic and Atmospheric Administration (NOAA) has defined HAT as the highest predicted tide over the National Tidal Datum Epoch (NTDE), a specific 19-year period that currently includes the years 1983 through 2001. LAT is similarly defined as the lowest predicted tide over the NTDE. Both HAT and LAT are tidal datums; their elevations are given relative to other tidal datums such as mean sea level (MSL) defined as the average water level over the NTDE and two other 'offsets' from MSL, mean higher high water (MHHW) and mean lower low water (MLLW). Their elevations above tide gauge 'zero' can now be found on NOAA's Tides and Currents web site: <http://www.tidesandcurrents.noaa.gov/> under Products >Datums.

NOAA does not change the NTDE very often; only once every twenty years or so depending on sea level trends measured at tide stations it maintains around the country. Until the time comes to pick another

19-year epoch, all of the tidal datums, including HAT, will remain fixed relative to the land. As the most extreme tidal datum in the upward direction (higher than MHHW, the next most extreme datum), HAT is the natural choice for marking the beginning of extreme water levels. Only when water levels rise above HAT and become extratidal do we have reason to be concerned about flooding in the areas surrounding our tidal waterways.

Disclaimer: The data presented below include peak water levels from six-minute observations at NOAA stations, both verified and unverified (Irene), available at <http://www.tidesandcurrents.noaa.gov/>. Additional data include peak water levels from unverified six-minute water level observations at VIMS-owned tide stations in Jamestown, VA (N. Ferry Pier) and Back River (Dandy Haven). Data and graphics for these stations are available at <http://www.vims.edu/tidewatch>. Note also that VIMS has independently determined HAT and LAT relative to MSL over the 1983-2001 NTDE at nine stations in lower Chesapeake Bay; These offsets are similar, but not identical, to those NOAA has determined more recently for its active stations in Chesapeake Bay (not including Jamestown and Back River). HAT referenced data are new and should be used with due caution.

How high did the water rise during Irene? How high compared with previous storms for the last decade in lower Chesapeake Bay? Answers for eight active water level stations in the region are provided in tables below (see <http://www.vims.edu/tidewatch> for station locations).

Table 1. Peak Water Levels in feet above MLLW*

Station	Isabel	Ernesto	Nor'Ida	Irene	Datum
Money Point	8.34	5.74	8.59	8.48	MLLW
Sewells Point	7.89	5.53	7.74	7.55	MLLW
Jamestown**	no data	no data	6.88	6.05	MLLW
Back River**	no data	no data	7.42	7.08	MLLW
CBBT	7.54	5.56	7.61	7.38	MLLW
Kiptopeke	6.51	5.81	6.96	6.49	MLLW
Yorktown	no data	6.01	6.86	6.60	MLLW
Windmill Point	no data	5.23	4.62	4.73	MLLW

* NOAA data verified for all storms except Irene (unverified)

** VIMS water level station (unverified data – use with caution)

Table 2. Peak Water Levels in feet above HAT*

Station	Isabel	Ernesto	Nor'Ida	Irene	Datum
Money Point	4.26	1.66	4.69	4.40	HAT
Sewells Point	4.36	2.00	4.21	4.02	HAT
Jamestown**	no data	no data	4.16	3.31	HAT
Back River**	no data	no data	4.22	3.81	HAT
CBBT	3.72	1.74	3.80	3.56	HAT
Kiptopeke	2.74	2.04	3.12	2.72	HAT
Yorktown	no data	2.67	3.62	3.26	HAT
Windmill Point	no data	3.27	2.63	2.77	HAT

* HAT as determined by VIMS analysis – use with caution

** VIMS water level station (unverified data – use with caution)

Table 1 contains peak water levels referenced to MLLW, the *chart datum* (datum used to reference depths on NOAA's nautical charts). Table 2 shows the same information referenced to the extratidal datum, HAT. A pair of problems come up when using MLLW as the reference: one, numbers between 7 and 8 appear often and have been mistakenly reported in the media and elsewhere as *storm surge*, ignoring the contribution by astronomic tides and other forms of sea level change; two, there is nothing in Table 1 telling us where normal tides end and extreme water levels begin – in other words there is no information about the range of tide at the place in question.

For example, the *diurnal tide range* (vertical interval between MHHW and MLLW) is 3.22 feet at Money Point on the southern branch of the Elizabeth River and 1.39 feet at Windmill Point near the Rappahannock River entrance. During Ernesto, peak water levels for these stations were 5.74 feet and 5.23 feet above MLLW, respectively. Think Money Point got the worst of it? Not really. Table 2 shows that Windmill Point had water 3.27 feet above the level where its tides are predicted to go whereas Money Point had only 1.66 feet of unusual water on its shores. During Irene, Windmill Point got about the same amount of water above HAT as did Kiptopeke near the Bay entrance but its peak is almost two feet lower than Kiptopeke's when referenced to MLLW.

Unlike Hurricane Isabel which impacted mostly the NC-VA coast, Irene managed to visit several other east coast states along the way and we did not lack for Jim Cantore media moments bringing that to our attention. At the Battery in New York City, for example, some very

high water levels were expected after Irene had finished with us in Chesapeake Bay. The National Weather Service's Meteorological Development Laboratory publishes a very useful water level forecast on its site at <http://www.weather.gov/mdl/etsurge/>. Most of the later MDL forecasts for the Battery came close to the actual water level peak of about 8.4 feet above MLLW that occurred after Irene arrived on the morning of August 28 (Figure 1).

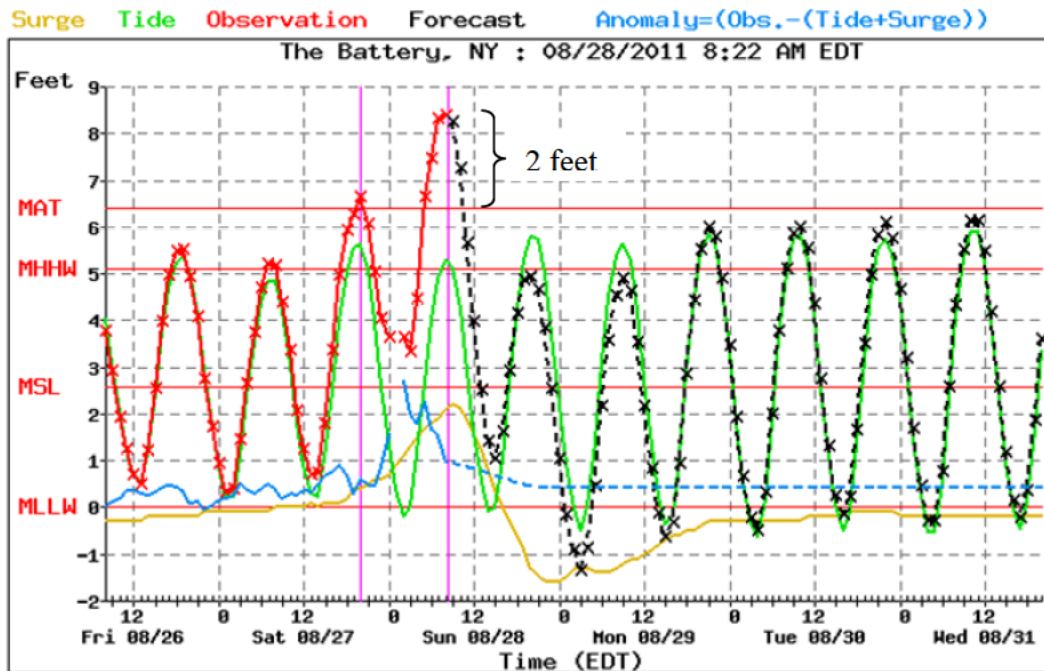


Figure 1. Storm tide forecast for the Battery, NY courtesy of NOAA/NWS/MDL. The diurnal tide range here is 5.01 feet; the peak surge was about 2.1 feet.

Figure 1 does a nice job of breaking the observed peak in water level, called a *storm tide*, into its basic parts. The forecast storm surge (yellow line) adds to the tide (green line) and the 'anomaly' (blue line) to get both the observed water level (red line) and the forecast water level (black line) going forward in time. Note MAT stands for maximum astronomic tide which is approximately the same as HAT.

It's interesting that the storm tide peak at New York came in at about the same height above MLLW (8.4 feet, Fig. 1) as the storm tide peak at Money Point (8.48 feet, Table 1) here in Virginia. Same flood potential? Not really. As shown in Fig. 2, Money Point had an extratidal high of about 4.3 feet whereas the Battery had only a 2 foot extratidal high. To be sure, areas around Manhattan exposed to waters 2 feet above HAT or less will have been flooded. Ground contours may indeed run that low in many places but was it then reasonable, given the flood potential, to build valuable infrastructure on such land?

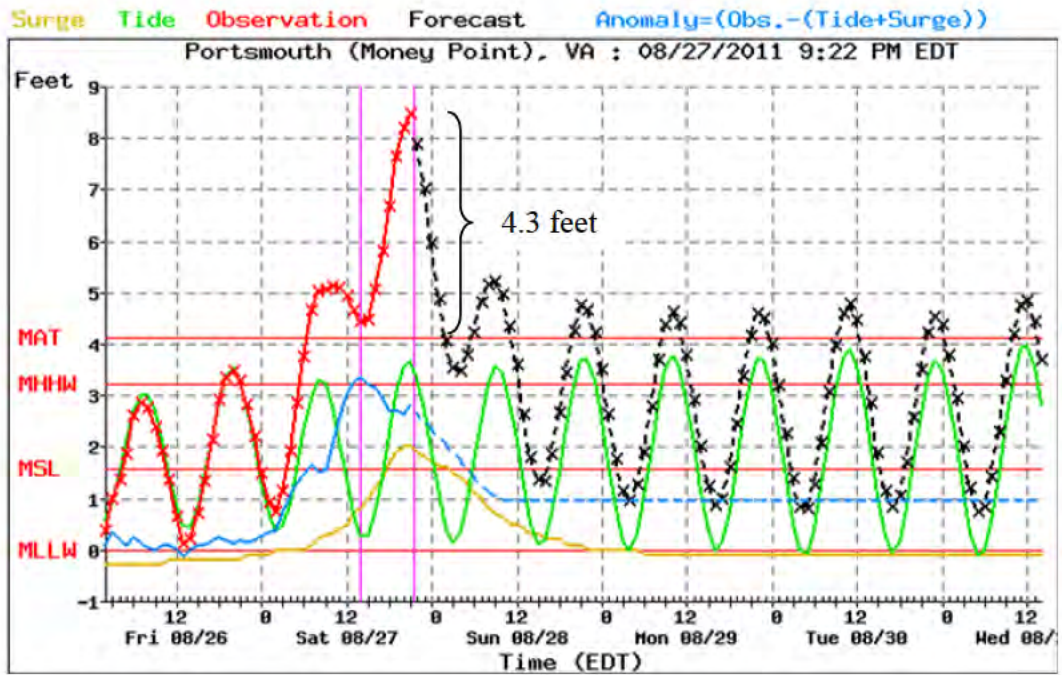


Figure 2. Storm tide forecast for Money Point, VA courtesy of NOAA/NWS/MDL. The diurnal tide range here is 3.22 feet; the peak surge was about 2.0 feet.