ERNESTO: ANATOMY OF A STORM TIDE

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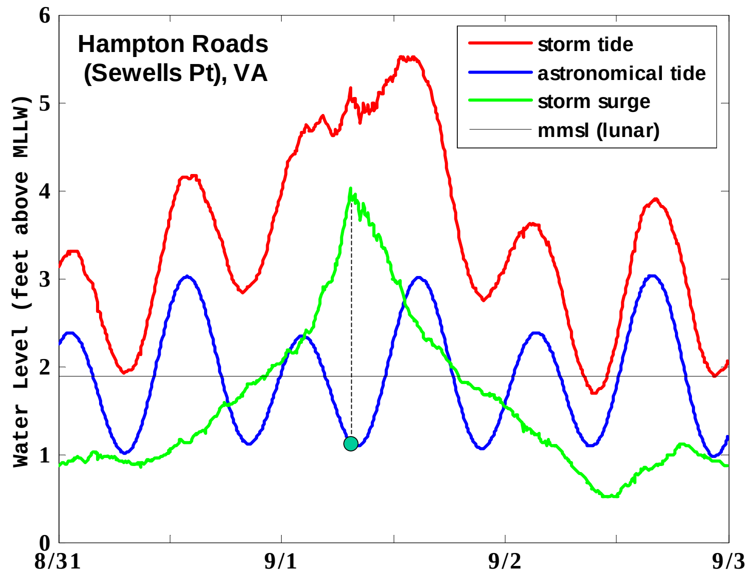
Virginia residents were warned that tropical depression ERNESTO would bring a lot of rain and consequently some flooding from runoff. Although briefly a *hurricane* (sustained winds greater than 74 mph) near the island of Haiti, ERNESTO spent most of its life as a *tropical storm* (winds greater than 58 mph) before crossing into Virginia on September 1, 2006, as a *tropical depression* (winds greater than 39 mph). Little did we know that a mere tropical depression would be packing high winds and a walloping **storm tide** along with the rain.

A storm tide is water level made higher by the combination of a **storm surge**, the change in water level due to the action of the storm, with the **astronomical tide**, the normal rise and fall of the water due to earth's gravitational interaction with the moon and sun. The way these two elements combine with one another makes a big difference in the peak water level reached by the storm tide – a peak that is likely to vary from place to place. ERNESTO has provided some good examples.

As ERNESTO passed through lower Chesapeake Bay, the storm tide it created was recorded at several tide stations operated by the National Oceanic and Atmospheric Administration (NOAA). Using these observations, we can take the storm tide apart and see just what happens when a storm surge and the astronomical tide get together.

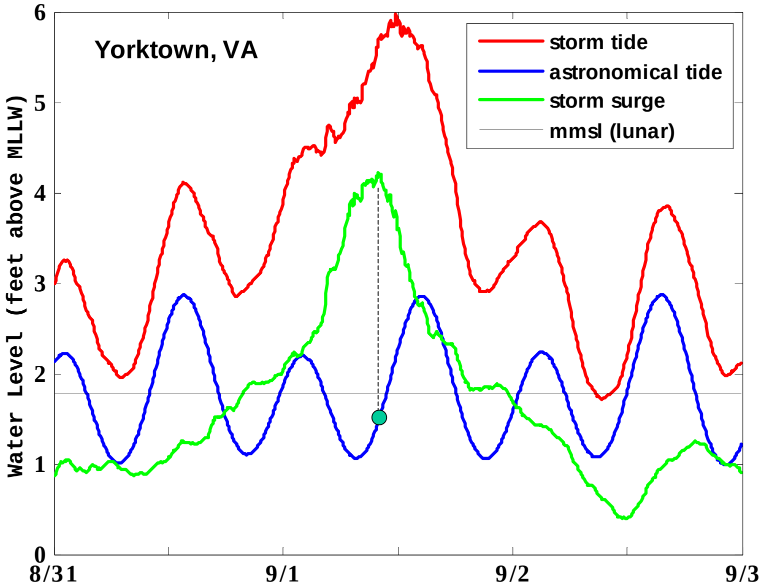


At Sewells Point in Hampton Roads, the storm surge reached a peak of about 4 feet above monthly mean sea level for the lunar month. Fortunately, it did so at low tide as shown in the figure at right. Had the peak storm surge occurred six hours later, it would have then combined with a high tide of about 3 feet to produce a storm tide peak of about 7 feet above the tidal datum of *mean lower low water* (MLLW)[1]. This level is only 0.9 feet below the storm surge peak produced by hurricane ISABEL at Hampton Roads (see my VIMS web article entitled

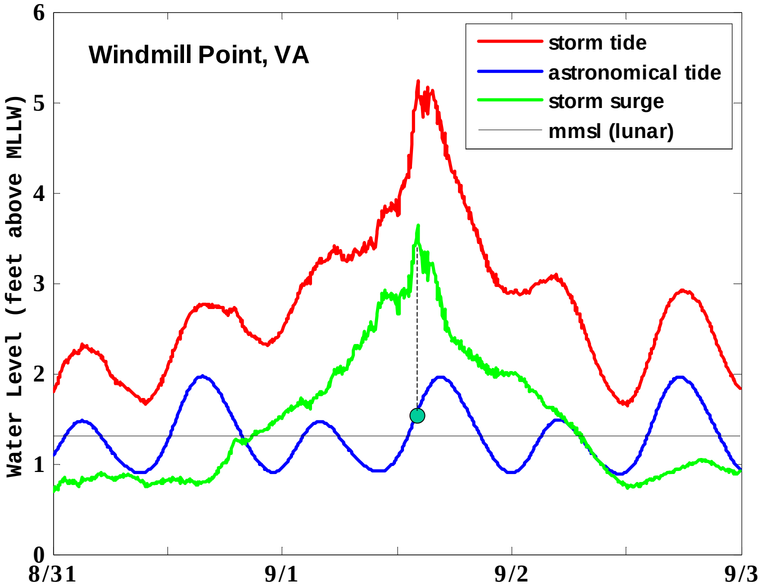
[1] Each point on the storm tide (red) curve is the sum of heights from the storm surge (green) and astronomical tide (blue) curves directly below that point.

“The Three Faces of Isabel”). Even though the peak surge did not occur during the high tide coming up, the surge still retained sufficient height by that time to produce a 5.5-foot storm tide. Some tropical depression! To add to the mix of possibilities, ERNESTO arrived during *tropic tides* which occur when the moon’s declination in orbit around the earth is near the maximum north or south of the earth’s equator. In our region, this condition produces successive high tides (but not low tides) of unequal height. The *mean tide range* at Hampton roads is 2.5 feet.

Proceeding further up the Bay, the next figure shows that the storm surge at Yorktown on the lower York River was slightly elevated compared to Hampton Roads. Its ‘waveform’ seems to have also gained a bit in its position relative to the astronomic tide (both are waves, after all, traveling at different speeds while moving up the Bay). This change contributed to an even greater storm tide peak of about 6 feet above MLLW at Yorktown. But again looking at what might have been, notice that the range of tide on September 1 did not exceed 2 feet whereas the mean range at Yorktown is 2.4 feet. Had ERNESTO arrived on September 10, the storm would have encountered spring tides with a range of 3.5 feet.

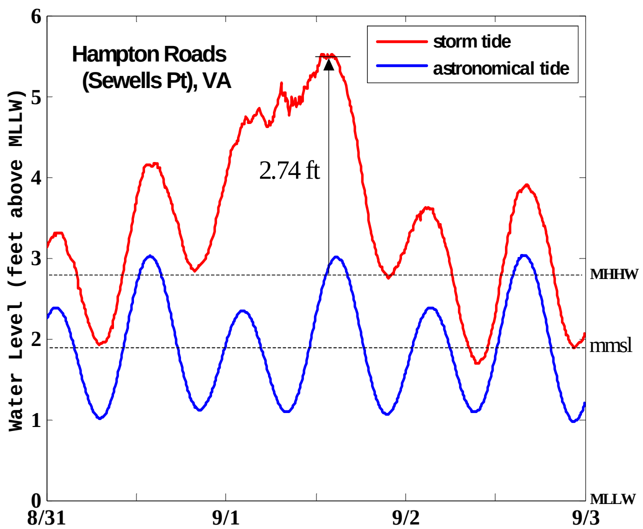


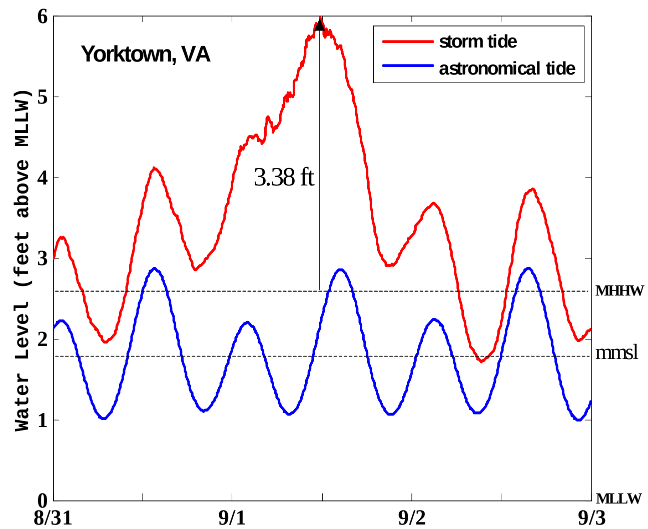
Traveling onward, the next NOAA tide station visited by ERNESTO was Windmill Point just above the entrance to the Rappahannock River. Here the mean range of tide is only 1.2 feet and the range on September 1 did not exceed 1 foot. As shown in the figure at left, the storm surge peak advanced further in time toward the following high tide but also decreased in height to about 3.5 feet, down from the 4.1-foot storm surge seen at Yorktown. Thus, a 5-foot storm tide resulted at Windmill Point. Not as bad as at Yorktown, some might say, except that those accustomed to a lower tide range might find water levels reaching 5 feet above MLLW to be just as unwelcome. Actually, they would have a point.



The three water level graphs presented above use the MLLW tidal datum as determined by NOAA for the 1983-2001 National Tidal Datum Epoch. The MLLW tidal datum is defined by the average of the lowest water level recorded each day during the 19-year period representing the Epoch. It is a convenient vertical reference for water levels because (a) NOAA periodically revises it to keep up with changing sea level; (b) the numbers shown are all positive which makes graphs easier to read. On the other hand, MLLW is not an ideal reference for comparing extreme water levels from point to point because it introduces another variable – the tidal range – into the comparison. Using another tidal datum that NOAA keeps track of and revises periodically - *mean higher high water* (MHHW) – can simplify things by removing the tidal range factor. For example, Eastport, Maine, has a mean tide range of 18.4 feet. Any number expressing the height of an extreme water level there is going to look huge if referred to MLLW. Biloxi, Mississippi, has a daily range of less than two feet so its past extremes don't appear nearly as large as Eastport's when referred to MLLW. But if the extremes at both places are compared using MHHW as the vertical reference, they do.

ERNESTO has provided evidence supporting the use of MHHW to discriminate between a water level that is normal and one that is not. The figure below at left shows that the storm tide peak at Hampton Roads reached a height of approximately 2.7 feet above MHHW. The one on the right

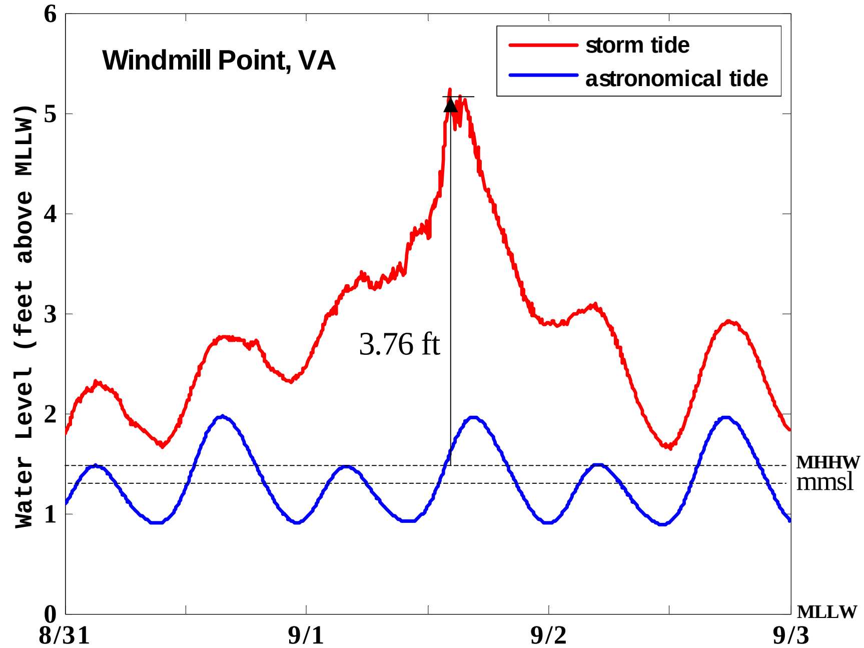




places the storm tide peak at approximately 3.4 feet above MHHW at Yorktown, a difference of about 0.7 feet. The smaller tide range at Yorktown is evidenced by a slight drop in the elevation of the MHHW datum in the figure on the right. The reasons for the higher storm tide at Yorktown have already been discussed but note that mmsl, the base water level that both the astronomical tide and the storm surge have operated from during the current month, has remained the same at both places while MHHW is lower at Yorktown. Using MHHW for the vertical reference adds another tenth of a foot to the difference in storm tide heights at Hampton Roads and Yorktown.

Turning next to Windmill Point, the figure presented on the following page illustrates what happens as the *diurnal tide range* (MHHW-MLLW) continues to decrease. We see that the MHHW reference has drawn closer still to monthly mean sea level and the height of the storm tide peak at Windmill Point is now 3.8 feet above MHHW, more than a foot higher than at Hampton Roads.

Studies conducted at VIMS in the early seventies established a clear relationship between tidal datum elevations contoured on land and the transition zone between tidal marsh and upland plant communities. The ultimate significance of this finding is of more than academic interest to persons living near the water. If you have some of the common transition plants known as the salt bushes (Marsh Elder, Groundsel Tree) on the lower elevations of your waterfront property, they (and you) are not far from the MHHW line.



A final word or two about monthly mean sea level: This is an average sea level that NOAA routinely tabulates as the average of the observed hourly heights for the calendar month at its tide stations. In my programs for tidal analysis, I calculate averages for the lunar month which has a fixed duration of 29 days. Whatever method is used, it is well known that mmsl elevations vary seasonally and that the months of September and October usually produce the highest monthly elevations in lower Chesapeake Bay. Unfortunately, these are also months in which hurricanes and tropical storms are most active - mmsl approximates the mean water level that will be there to greet them as they arrive on our shores.