Initial Report for the Evaluation of Wilderness Breach, Fire Island National Seashore

Charles Flagg, School of Marine and Atmospheric Sciences, Stony Brook University

Super storm Sandy crashed into the New York/New Jersey area on October 29, 2012 and caused major damage all along the coast. The storm surge and high waves also caused breaches across eastern Fire Island and one on the Westhampton barrier beach just east of Moriches Inlet. Two of the breaches have been closed by USACE whereas the one having the greatest impact on the back bay areas of Great South Bay is the one at Old Inlet. The Old Inlet portion of Fire Island is narrow and has a long history of breaches and inlets. The strand at Old Inlet was overwashed in the memorable nor-easter of 1992 but an actual inlet was last documented near this location in 1825. How this recent breach will evolve and what attendant impact it will have on the back bay and mainland of Long Island are the over-riding questions facing the National Park Service and nearby residents on the mainland.

The Great South Bay Observatory Project has maintained a SeaBird Electronics SeaCat measuring temperature and salinity at the Bellport marina since 2004, Figure 1. The Bellport marina is directly across Great South Bay from the new breach in the Old Inlet area of Fire Island. In 2010 the instrument was updated to an SBE 16Plus which expanded the parameters to include sub-surface pressure, chlorophyll fluorescence and turbidity. This is one of nine shore-based and one buoy-based (GSB1) sensors that have been maintained as part of Stony Brook's Great South Bay Observatory. The existence of the observatory is important in the context of super storm Sandy because it allows us to document the impact that the breach has had on the physical conditions in Great South Bay. This report describes the meteorological, sea level and water property data needed to reconstruct the response of the Bay to Sandy and its immediate and subsequent responses to the breach.

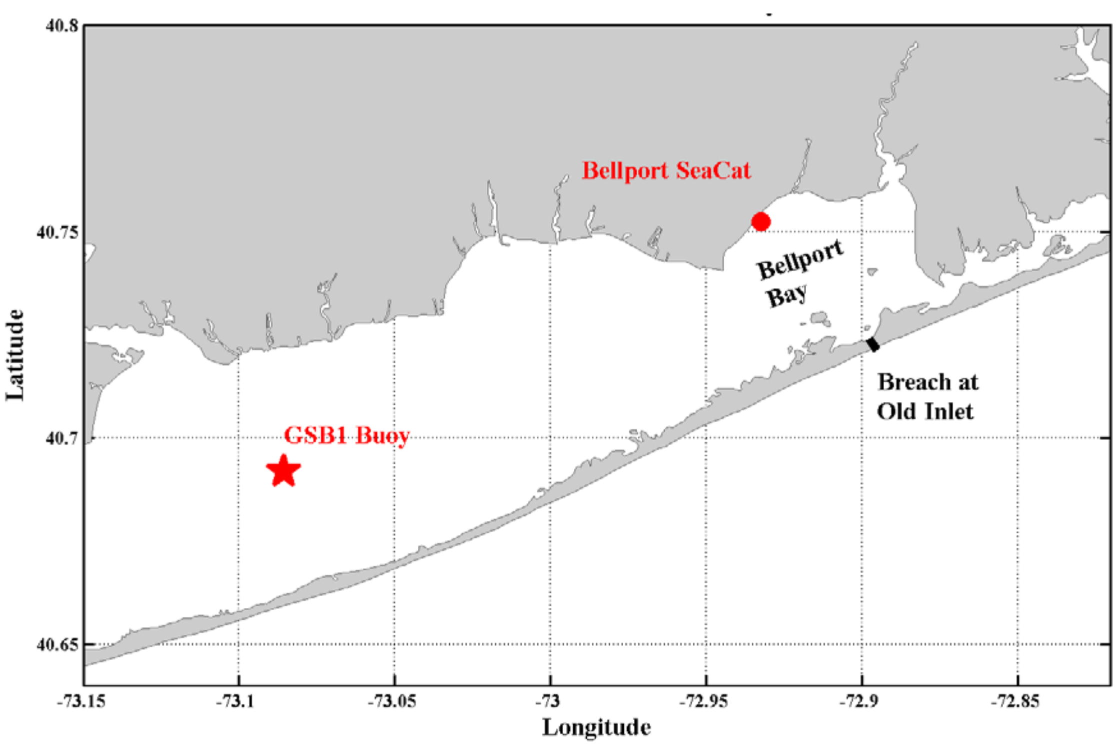

Figure 1. Map of the eastern Great South Bay showing the relative locations of the breach at Old Inlet, the SeaCat at Bellport and the GSB1 buoy south of Sayville.

December 14, 2012

Figure 2 shows the barometric pressure, wind speed and direction from two nearby airports and the GSB1 buoy from the onset of super storm Sandy through a week of fairly calm weather followed by a nor'easter that blew through the area eight days later. Minimum barometric pressure during the hurricane recorded at the airports was about 974 mbars and this occurred just as the winds in the middle of the Bay reached a maximum of about 37 kts (gusts were up to 48 kts). As the hurricane approached the area the winds blew steadily from the northeast. But as the hurricane passed the local area the winds rotated quickly to the east-southeast, the barometric pressure started to increase and the winds began to subside. During the subsequent week the barometric pressure gradually increased to normal levels, winds speeds averaged around12 kts while the wind direction rotated from south, to west, to north, and air temperature dropped. Then on November 7 and 8 the area was hit by a nor'easter of significant magnitude during which the winds were again out of the northeast at 25 kts, gusting to 35 kts, which then rotated slowly to the north and northwest as the storm passed to the east.

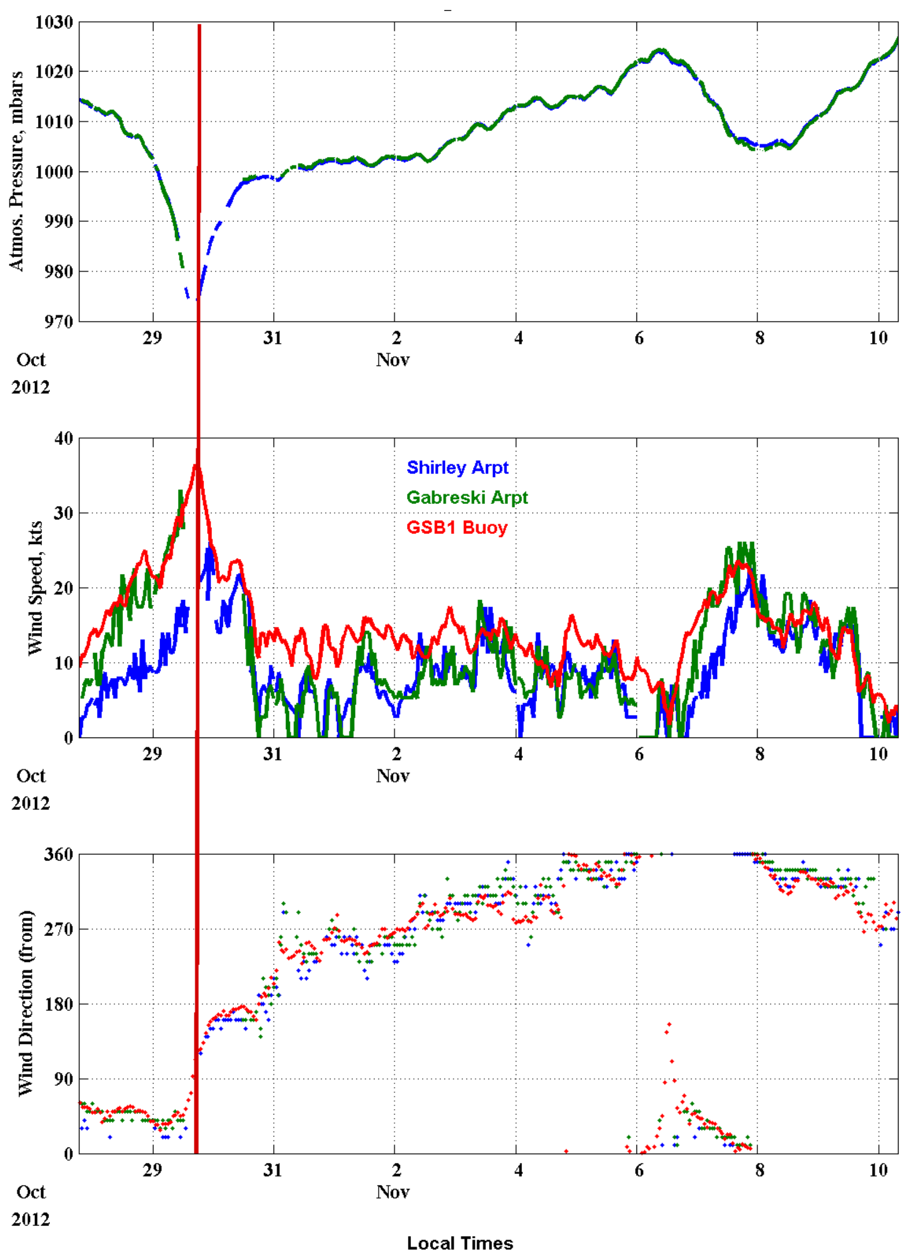

Figure 2. Meteorological observations during hurricane Sandy and the subsequent nor'easter.

December 14, 2012

Figure 3 focuses on the record from the Bellport marina during and after the hurricane. The vertical red line marks the peak winds and shows the temporal coincidence of a sudden rise in sea level and salinity in Bellport Bay that is associated with the opening of the breach. The top panel repeats the wind record from Figure 2. The response of Great South Bay during the initial phase of the hurricane followed a well known historical pattern. As usually has happened when there was a strong wind from the east, the sea level at the eastern end of Great South Bay initially dropped and in the process drew low salinity out from two upwind fresh water streams, Carmans River and Beaverdam Creek. This initially caused the salinity at Bellport to drop by about 2 psu. Right at or shortly after the peak in the wind speed, which occurred on October 29th at 1700 EST, the breach in Fire Island opened and ocean water flooded into the Bay raising sea level by 1.8m and salinity by nearly 8 psu. The peak surge at Bellport closely followed the local high tide at Bellport which added about 0.2m to the sea level relative to the mean water level.

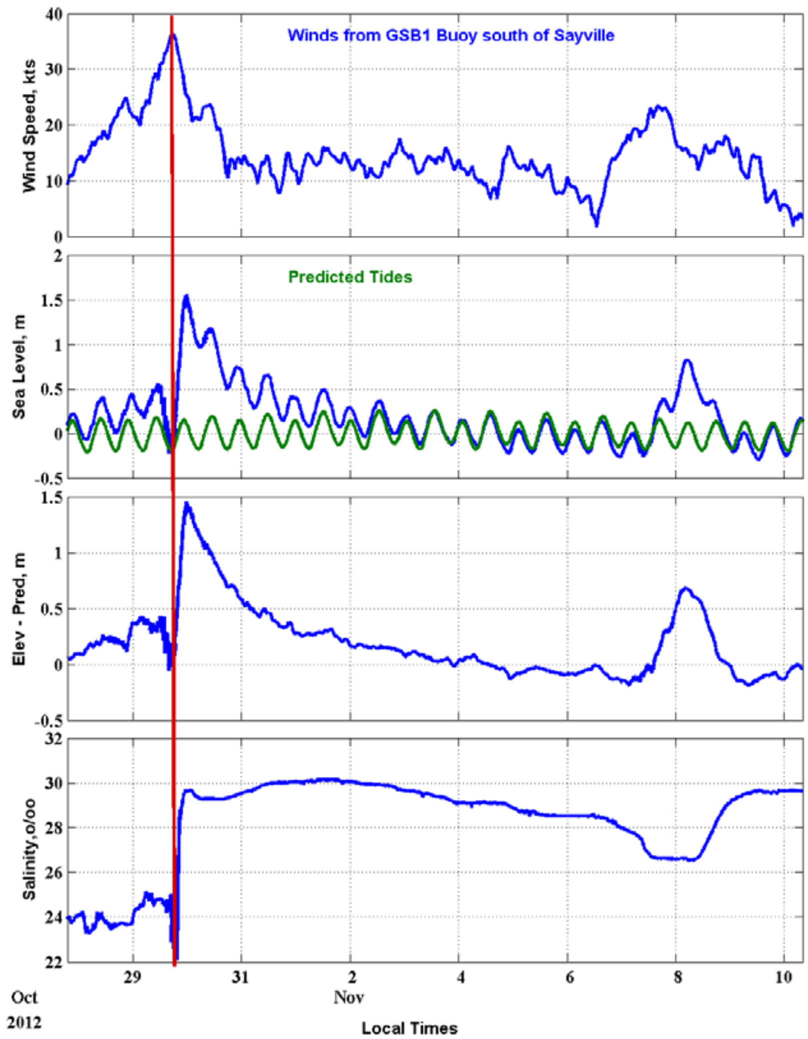

Figure 3. Wind speed from the GSB1 buoy, waterlevel and salinity from the Bellport SeaCat. The green line in the second panel is the predicted tides based upon the first 62.5 days of the record.

The only record available for contemporaneous water levels in the ocean during the hurricane comes from the Pt Lookout gauge maintained by the USGS and the town of Hempstead, Figure 4. The degree to which this record faithfully represents the ocean is uncertain as there may be some attenuation and phase lag relative to the ocean. However, the record does show good agreement with the Bellport water level record. The Pt Lookout record indicates that the ocean setup against Fire Island started 24 to 36 hours before the peak of the storm and that the maximum setup up was almost 1.5 m, augmented by a high tide of another 1m, for a total ocean water level rise of ~2.6m, relative to mean sea level at the peak of the storm. Thus, the strong winds from the east and southeast caused a substantial setup against the Fire Island shore which allowed the storm driven waves to over-top the low dunes in the Old Inlet area and erode a stream for ocean water to enter the Bay. Once the flow started the reduced initial sea level in the Bay and the higher than normal sea level offshore was enough to carry the island's sand into the Bay and open a breach. Notice that the Bellport water level continued to rise until the ocean waters retreated to the same height as the Bay after which both the ocean and Bay water levels decreased through the tidal cycle.

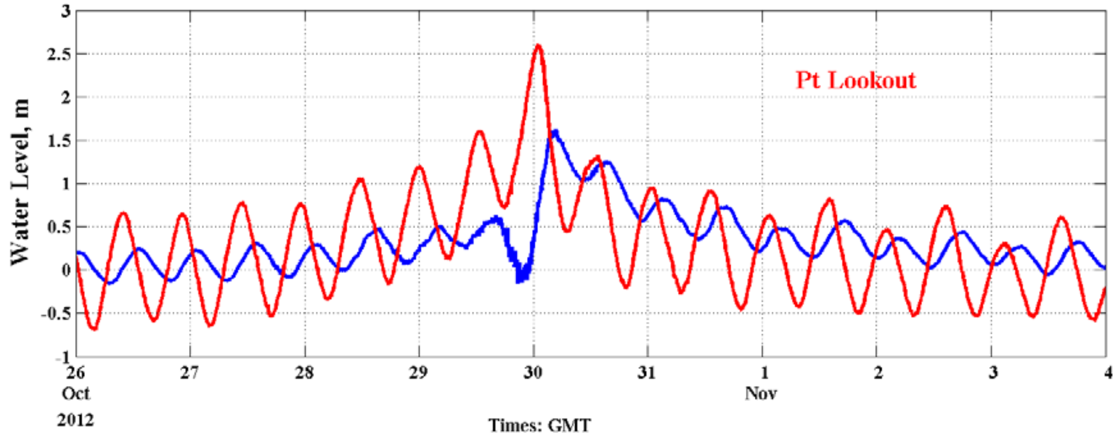

Figure 4. This plot shows the water level records from Bellport (blue) and the USGS guage at Pt Lookout (red) which is just inside Jones Inlet.

On November 3rd a series of aerial photos of the Old Inlet breach showed the overall configuration of the breach. The photos showed that the breach occurred just to the west of the Old Inlet board walk across the dune and well east of the historic Old Inlet. The new channel from the ocean entered in from the east, hugging the east side of the breach before most of the flow turned west, south of several new sand islands. From the appearance of the breach and the location of the new sand islands, it is clear that the water broke through from the ocean into the bay. Thus, the evidence is that super storm Sandy's strong winds, predominantly from the east, caused a large setup against Fire Island so that the sea level on the ocean side of the island was higher than that in the bay. When the waves eroded the dunes and finally over-topped the island, the sea level difference was enough to drive the ocean water into the bay and carry the sand with it.

Over the next three days the storm surge gradually subsided. This seemingly slow return to more normal sea levels undoubtedly reflects what was happening in the ocean as well as the dynamics of Bay's circulation. Of particular note is that the tidal range and phase also returned to normal after the storm despite the added opening to the ocean, Figure 5. Tidal range at the eastern end of the Bay has typically been about 0.4m and the delay in high tide in that area relative to Fire Island Inlet was about 3.5 hours. As the lower panel in Figure 5 illustrates, aside from relatively small water level variations caused by local winds, the amplitude and phase of the tides differ little from the predicted tides based upon the 62.5 days prior to the hurricane. That there was little, if any, change in the tidal amplitude or phase indicates that the volume of water entering the Bay is small relative to both the flow through Fire Island Inlet and the overall tidal prism. This results because the presence of extra water introduced by the inlet is communicated to the rest of Great South Bay at essentially the shallow water wave speed, about 5 m/s, which allows the entire Bay to respond minimizing the impact in the vicinity of the inlet.

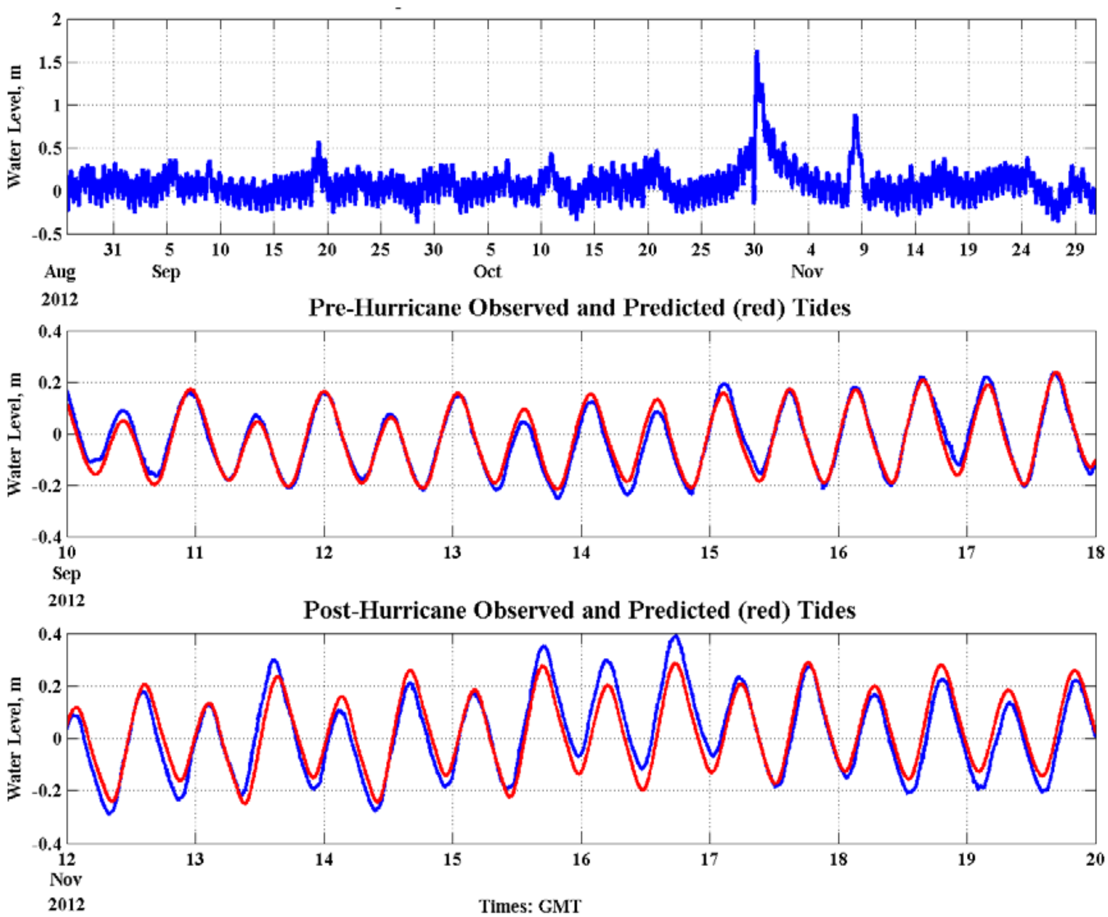

Figure 5. Water level record from Bellport before, during and after hurricane Sandy. The middle and bottom panels show 8 day records from before and after the hurricane, respectively. In the bottom two panels the observed water levels are in blue and the predicted tides are in red.

However, the same cannot be said for the influence that the inlet has on the salinity of the eastern end of the Bay, Figure 6. This figure contains data from two SeaCat deployments at Bellport, the first from August through November 10 and the second from the 10th through November 29. The salinities from these records have not been calibrated against water samples as those are awaiting repairs to the salinometer. So for the purpose of this discussion the records have been adjusted to agree where they join. As a result of the hurricane and the opening of the breach, the water level at Bellport started to increase about an hour before salinity increased. The initial jump in salinity to ~30 psu remained for the first 5 days, before gradually decreasing to about 28.5 psu. This lower salinity is still some 4 psu above normal for this area and indicates that the residence times of waters in this area is fairly long. The salinity record from the GSB1 buoy deployed 15 km to the west also showed the effect of the high salinity water, increasing initially by about 1 psu before settling down to a level that might be 0.5 psu above the previous mean. The difference in post storm response between water level and salinity reflects the different dynamics governing water volume and salt. Water level communicates with the rest of the Bay at shallow water wave speeds while salinity is governed by dispersion and the residence times of the waters at the eastern end of the Bay. In addition, of course, there is a continual supply of saline ocean waters entering the Bay through the new inlet. After the super storm, a nor-easter came through the area on the 7th and 8th, and then a strong westerly event occurred on the 24th and 25th of November. With the advent of the inlet, the salinity record becomes harder to interpret and it appears that there are large boluses of high and low salinity waters being advected around the eastern Bay.

Nevertheless, it is fairly clear that the salinity in the eastern Bay remains elevated 3 to 4 psu relative to pre-inlet times and that the center of the Bay, represented by the GSB1 data, also has elevated salinities by about 0.5 psu.

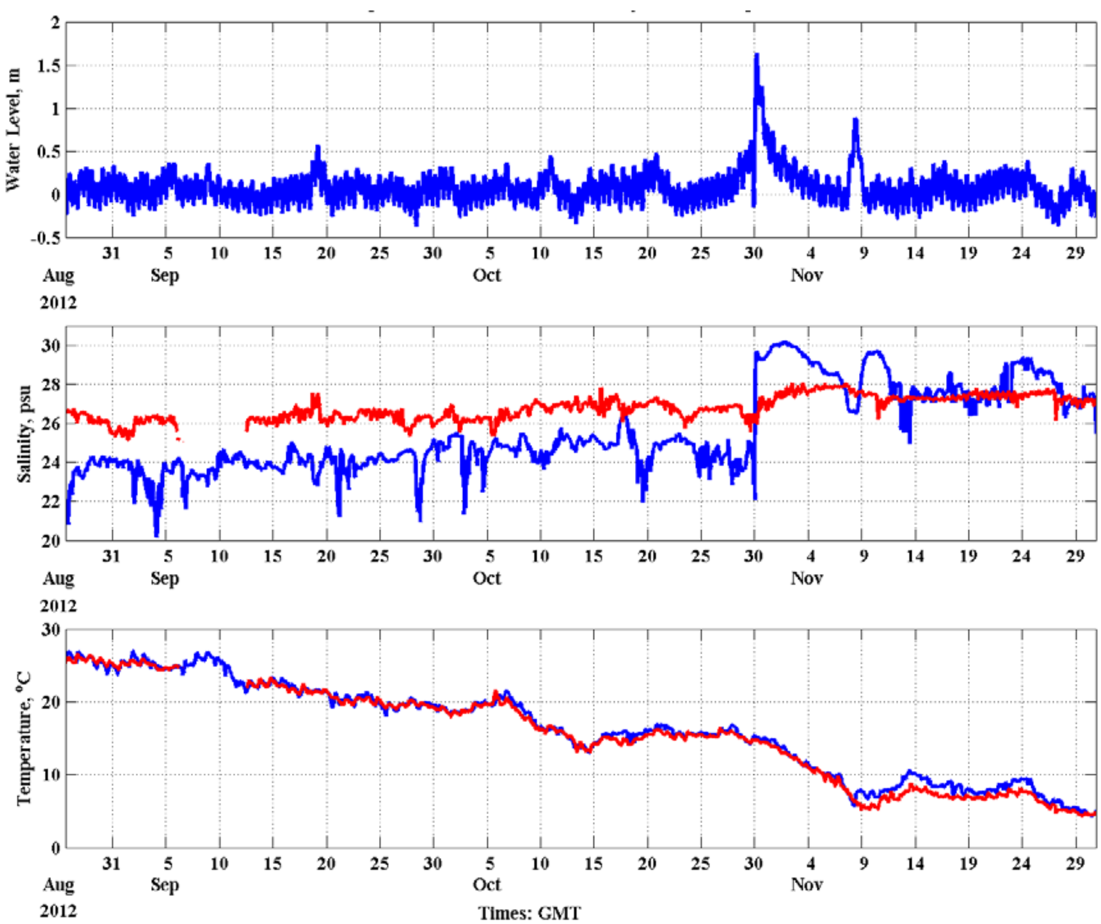

Figure 6. This shows an extended record through November 30, 2012 of water level salinity and temperature at Bellport and the salinity (red) and temperature (red) at the GSB1 buoy.

As shown in Figure 3, a week after the hurricane, a nor'easter went through with some of the same characteristics as the hurricane but shorter with less wind. The nor'easter lasted about a day, and as Figure 3 shows, there was an initial small drop in sea level at Bellport followed by a sea level rise of about 0.8 m. About two weeks later on November 25 and 26 there was a sustained period of strong west winds and Figure 6 shows that there was continual decrease in water level at Bellport during this period.

The record from both the nor'easter and the period of west winds suggest that the presence of the inlet has fundamentally changed the response character of the eastern end of the Bay to wind events. This change is illustrated in the diagrams of Figure 7. Traditionally, winds with a strong easterly component blew the waters of Bellport Bay toward the west lowering water levels and drawing fresh water out of the nearby Carmans River and Beaverdam Creek. The signature of those fairly frequent events shows up in the short periods of low salinity in the salinity record in Figure 6. The salinity often rebounded as more saline waters from Moriches Bay reached Bellport Bay through Smith Point channel. If the east winds persisted long enough the setup against Fire Island would eventually flow in through the inlets and water levels would rise throughout the Bay. Because of the restricted access to the Bay through the existing inlets, hurricanes sometimes produced less flooding than the longer lasting nor'easters. Conversely, strong westerly winds traditionally had the opposite effect pushing Bay water into Bellport Bay and sometimes causing significant flooding in the area. These responses are illustrated in the left panel of Figure 7.

With the development of the breach at Old Inlet the situation now appears to have changed significantly. The response to the nor'easter with its strong alongshore winds towards the west still causes a set up against Fire Island as before but the presence of the inlet appears to minimize the usual set down in the Bay as ocean waters flow into the area to make up for the waters blown to the west. This influx of ocean waters also brings in a large slug of saline ocean water causing local salinity levels to increase. Because of a faster response to nor'east wind the inlet now probably increases the chance of localized flooding. On the other hand the new inlet may reduce the impact of strong winds from the west which in the past raised water levels in Bellport Bay. This is because winds from the west cause a set down of the ocean along Fire Island so that the usual water level rise experienced in Bellport Bay finds an easy outlet through the inlet and the water level there continues to decrease to match the ocean's set down. So the new inlet probably decreases the chances of localized flooding under strong winds from the west. These new responses are illustrated in the right panel in Figure 7. The net result, which will need to be confirmed through continued observations, is that if areas in the eastern Great South Bay flooded before, they are likely to be flooded again but the wind directions leading to the flooding will have reversed.

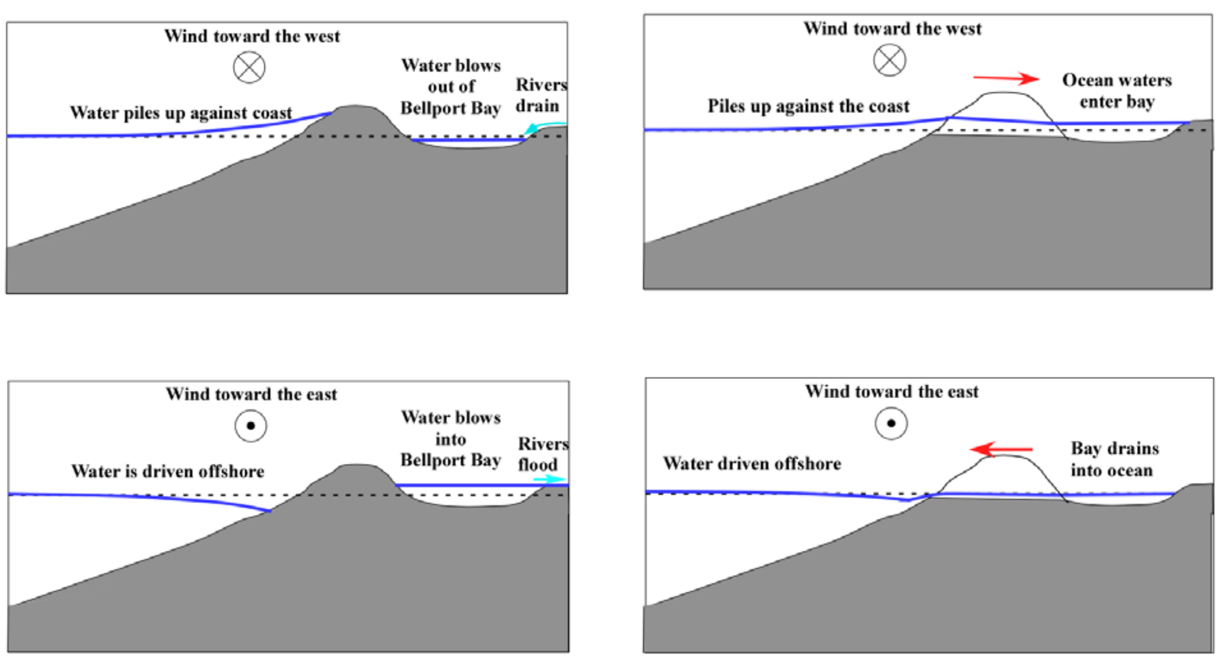

Figure 7. Illustration of the differing responses in the Bay with, left panel, and without, right panel, the inlet under strong east and west winds.