Developments at the Old Inlet Breach and Great South Bay during 2015

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With the end of 2015 and three years after the formation of the breach near Old Inlet, it is timely to review the past year and how it was similar and different from the preceding years. We start by reviewing the alterations in the breach morphology over the past year using the series of aerial photo mosaics shown in Figure 1. Experience over previous years has shown that there tends to be an accumulation of sand in the breach during the late spring and summer that is eroded in the fall and winter as the nor'easters arrive. And in general that pattern repeated itself during 2015 even though the accumulation of sand seemed to greatly exceed that of the previous two years.

We can describe the inlet in terms of the positions of its western and eastern edges that are aligned with the core of the barrier island and in terms of the seasonal spits that are observed both within the inlet and extending into the bay. A significant observation from the breach monitoring is that the retreat of the western edge of the breach has stopped or at least greatly slowed during the past year. The eastern-most tip of the western shore has stayed within ~50meters of 72.900°W longitude for the past year while the profile from the air of the scrub trees has remained constant. As resolvable by the aerial photos the line of brush along the western shore in February and late October of 2015, are all but identical. These observations suggest that the inlet was quite stable in terms of size and location.

The seasonal spit that formed off the western shore was substantially larger in 2015 than in previous years. This year the spit was nearly twice as long as earlier versions and extended all the way north to Pelican Island. However in the end, the spit was just as ephemeral as in past years and disappeared in early October as a result of a 5-day period of high offshore winds, ~35 kts, and waves, ~15ft, from the southeast and east. As a result of that storm, the sand that had formed the spit was pushed to the northwest forming a broad shoal area while reforming a small version of the earlier west channel.

For most of the year the eastern shoreline remained close to where it has been since the fall of 2013. Then as a result of the October storm that washed away the western spit, the eastern shore formed its own version of a spit that extended more than 100 m into the breach. The spit did not last long and was gone by early December. This eastern spit of sand was formed as a result of an extended period, ~7days, of easterly winds and waves which in addition to breaching the western spit, seems to have brought sand in from the east. This process of moving sand alongshore and into the breach through wave action forming spits is also responsible for the development of the western spit. During the late spring and summer when the mean winds shift from northwest to southwest they produce smaller but near constant wave action from the west and reverse the usual westward littoral drift of sand along the Fire Island shoreline. In the absence of nor'easters during the spring and summer the western spit is given time to accumulate sand. So this is the first time we have clearly seen how wave action for an extended period from either alongshore direction can alter the shape of the breach.

Several prominent bars or spits formed in the offshore area immediately to the east of the inlet in October through December, 2015. The bars are possibly formed from sand being placed on the beach at Smith Point which lies east of the inlet. The offshore area immediately to the west of the breach experienced significant erosion in late 2014 but the eroded area was largely filled in during the spring of 2015. The erosion which is most evident in the Dec 2014 photos suggested the formation of a small clockwise eddy that either caused or was caused by the development of a small offshore-oriented shoal inside the outer ebb shoal. This little sand-island was often dry at low-tide and was over 250 m long in

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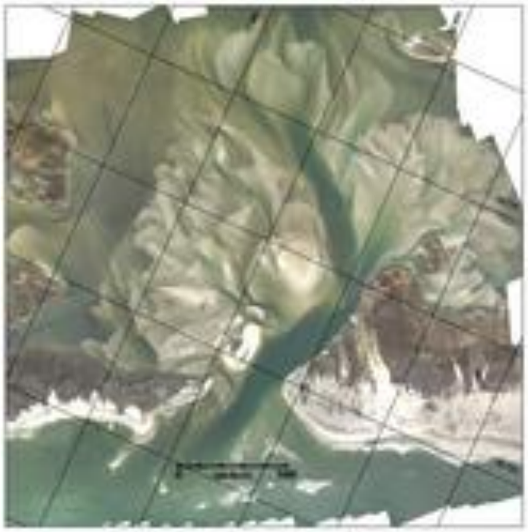	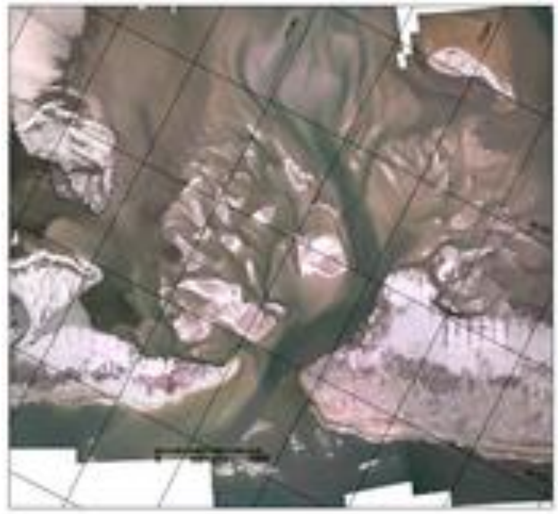
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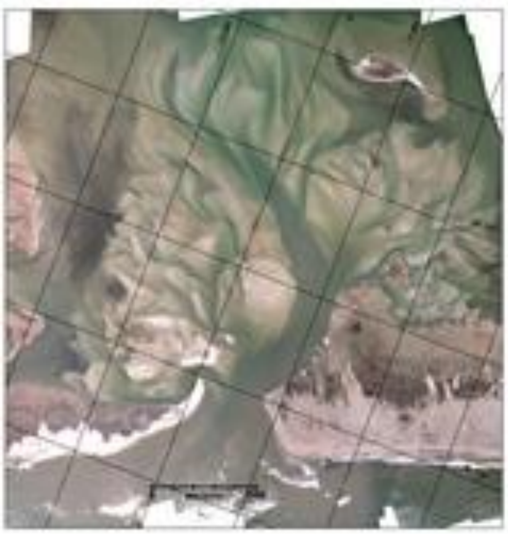	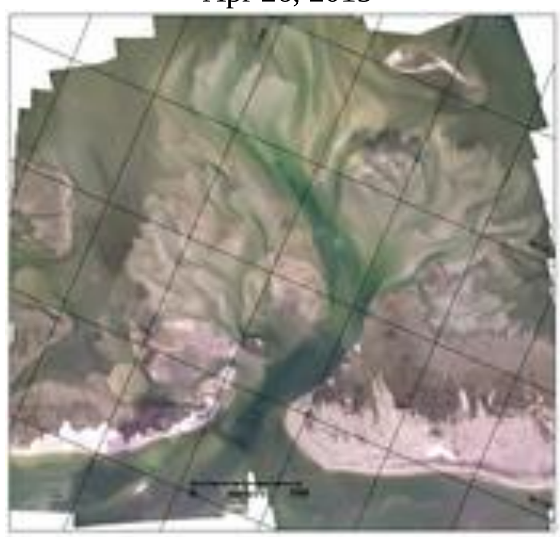
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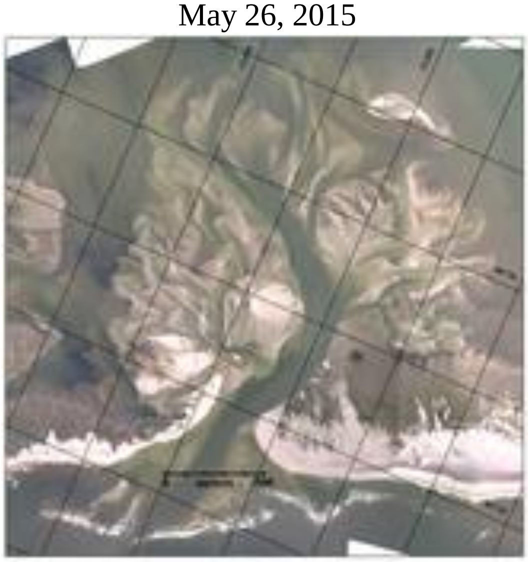	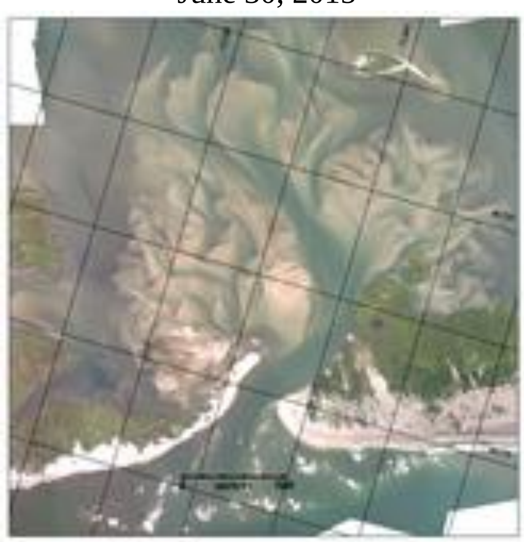

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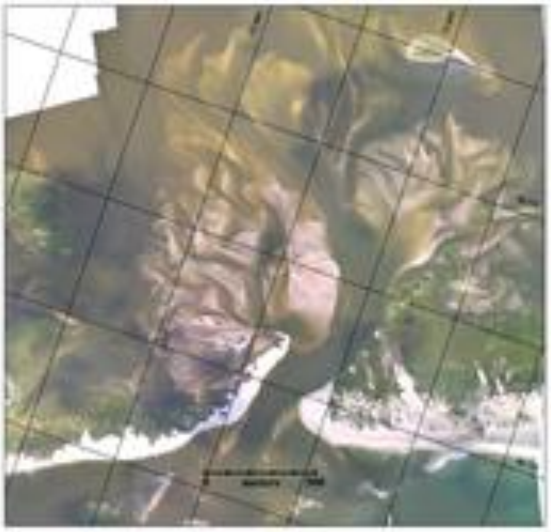	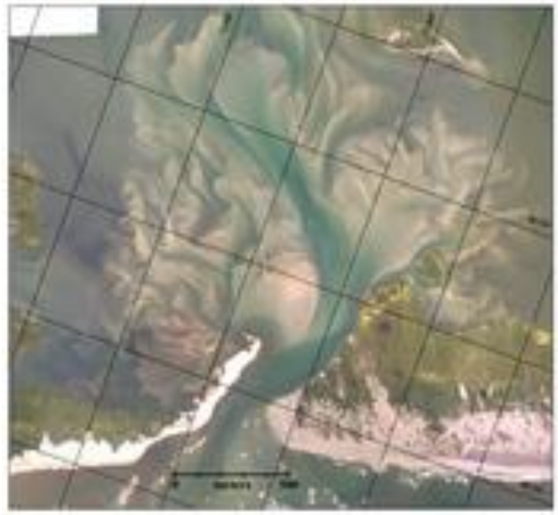
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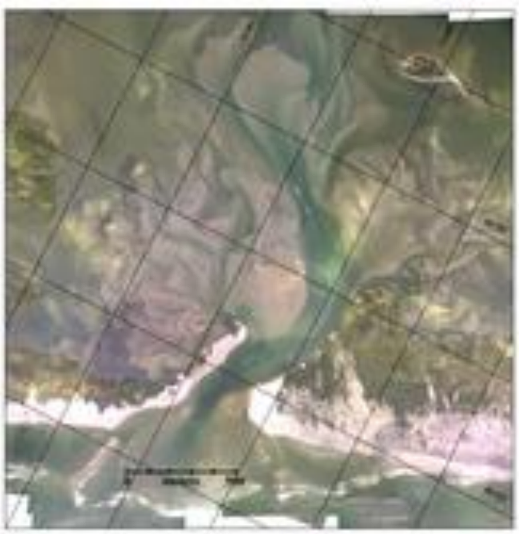
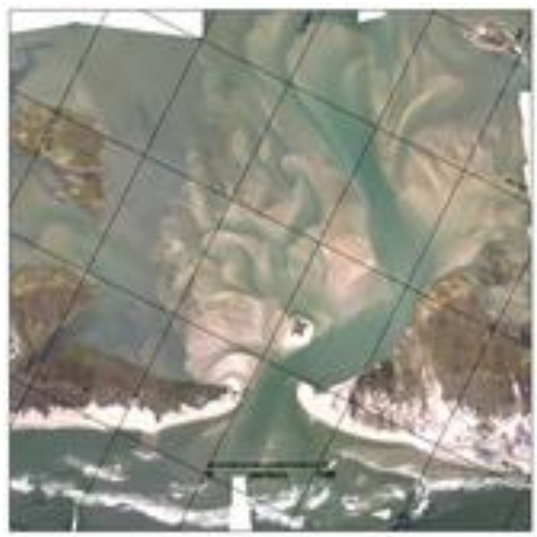
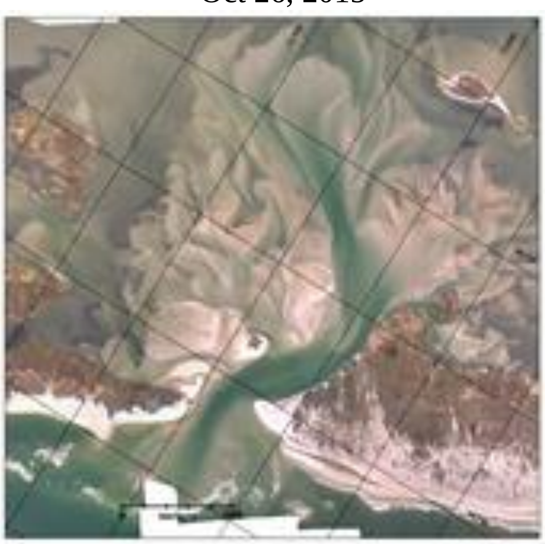
	
Oct 26, 2015	Dec 5, 2015
	

Figure 1. Aerial photo mosaics for 2015.

the August 28th photo. Images such as that taken on July 23rd suggests that the shoal may in part be a result of sand being transported out of the inlet during strong ebb currents. The westward movement of these sand shoals, also observed on the eastern side of the inlet on December 5th, may play a role in the westward transport of sand across the inlet. This offshore shoal lasted throughout 2015 only to be cleared out in the January 2016 storms. It will be interesting to see if this shoal reforms in the future.

Water levels and the potential for additional flooding is a major concern for those living along the Great South Bays shoreline. As part of the project's observatory we have water level recording devices at a few locations including Bellport while the USGS has maintained a tide gauge at Lindenhurst since 2007. We have used the records from these sensors to examine the tides (Figure 2) and responses to winds and storms (Figure 3). As described in earlier reports the changes in tides in the Bay have been relatively minor. At Bellport there has been essentially no change in tidal amplitude whereas high tide has advanced by about 15 minutes relative to conditions prior to Sandy. The high tide had advanced by as much as 20 minutes during the summer of 2014 but has since retreated a bit. At the western end of the Bay at Lindenhurst, the amplitude of the primary semi-diurnal tidal constituent has increased by ~2 cm which means an increase in tidal range of about 4 cm, or 1.5 inches. However, the arrival time of the high tide at Lindenhurst has not changed appreciably. The tidal record at the Fire Island Coast Guard station is not expected to be sensitive to the breach but it is sensitive to dredging activity in Fire Island Inlet. However, overall there has not been much change at the station: the amplitude is within a couple of centimeters prior to Sandy while the phase is nearly the same.

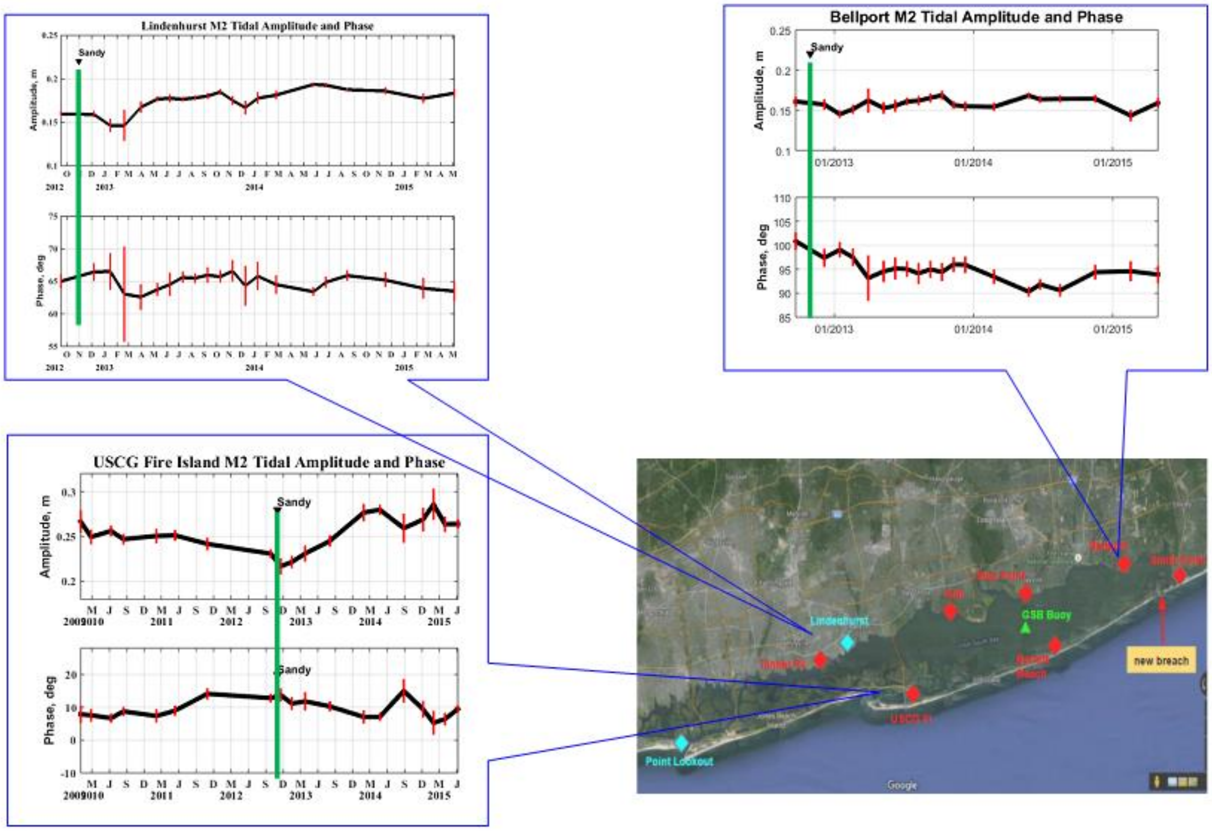


Figure 2. These plots show the evolution of the amplitude and phase of the major semi-diurnal tidal constituent, M_2, through the evolution of the breach. The data from Lindenhurst comes from the USGS tide gauge while the records from Barrett Beach and Bellport are from the Great South Bay Observatory.

If you are interested in tides, check out the discussion from Virginia Institute of Marine Science (http://web.vims.edu/physical/research/TCTutorial/tideanalysis.htm).

Wind driven water level fluctuations in the Great South Bay come in two flavors, a purely local fast-acting event in which the water sets up downwind, and a much slower response as the ocean reacts to a large-scale storm. The short-term set-up and set-down events are the result of along-bay winds in which within an hour or so the wind acting on the water is balanced by the slope of the sea surface. Wind events such as nor'easters, hurricanes or cold-air outbreaks cover a large portion of the Middle Atlantic Bight and cause water levels all along the shore to rise or fall over several hours. When this happens, those changes in coastal sea level filter into the bays through the inlets raising or lowering the water levels throughout the bay. The short-term response to wind plus the longer term oceanic response plus the tides all contribute to the water levels in the bay. Thus, prolonged winds from the east cause a fast set-up of waters in the western Bay and high water along the Fire Island coast that flows into the bay raising sea level more or less uniformly everywhere. When this coincides with high tides, especially spring high tides, flooding can be quite severe. The opposite also happens when winds are out of the west. Under those conditions water levels quickly rise in the eastern bay but ocean water levels fall and eventually water levels in the bay also drop and the danger of flooding is much less.

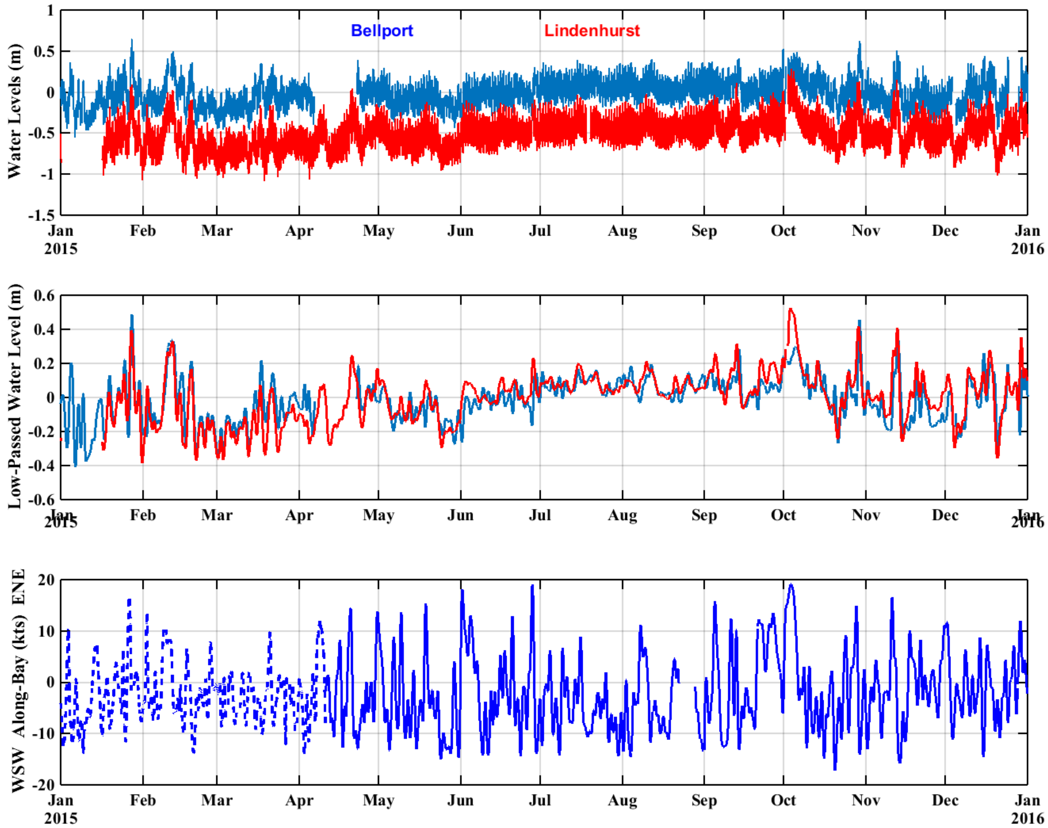


Figure 3. Water level data from Lindenhurst and Bellport and along-bay wind from MacArthur Airport (dashed) and the GSB1 buoy. In the top panel the Lindenhurst water level record was offset by 0.5 meters. The middle panel shows the lowpass filtered water level records which removes the tides. The lower panel shows the along-bay winds.

Figure 3 shows the water levels at Bellport and Lindenhurst for 2015 together with along-bay component of the wind. One can see how the Bay responds to wind events and under what conditions there are differing responses at either end of the Bay. Tidal range is typically around 0.4 meters on top of which is the longer term rise and fall due to wind events. The middle panel shows the two records with the tides removed. The most important point to note is that at the slower sea level fluctuations the entire bay goes up and down more or less together. The local set-up and set-down when Lindenhurst is higher than Bellport, or the reverse happens, also shows up and is clearly related to the direction of the winds shown in the third panel. Another point about the water levels is that there is a clear rise in sea level during the warmer months. This seasonal rise is about 15 cm (~6 inches) and is caused by the seasonal heating and expansion of the ocean off the edge of the continental shelf down to a depth of ~200 meters.

Figure 4 shows the de-tided water levels from the USGS gauge at Lindenhurst from 2007 to the present. The storm surge from hurricane/tropical storm Sandy is clearly visible as it is twice the size of any of the other storm surge events. Aside from Sandy there are many events during which water levels rise between 0.5 and 0.75 meters above the mean, but only one of which during this time period resulted from a hurricane and that was Irene during August of 2011. The other large events are the result of nor'easters. Note also that there are quite a few events during which water level fell by 0.5 meters or more. Lastly, the figure shows that there is a clear seasonality to the water level fluctuations with the largest positive and negative fluctuations ocurring in the months of November through April.

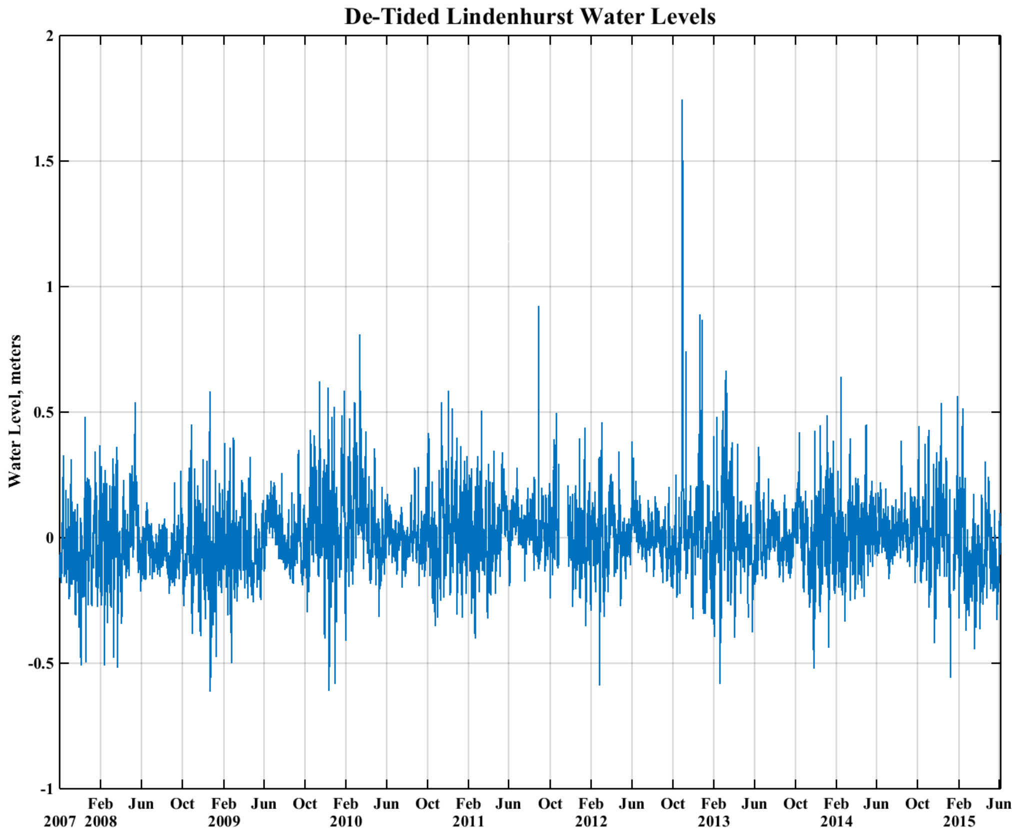


Figure 4. This figure shows the Lindenhurst water levels with the tides removed for nearly 8 years in order to show the numerous incidences of storm surge in the western Great South Bay.

While potential changes in sea level as a result of the breach have been the focus of much of the attention, the change in water properties as a result of the increased ocean-bay exchange has been one of the important mitigating factors in evaluating the impact of the breach. Prior to the breach there was a east-west gradient in the concentration of nutrient contamination. Summer total nitrogen values east of Connetquot River, including Bellport Bay, were almost twice what they were to the west and nearer Fire Island Inlet (from Suffolk County Dept. Health Services survey data). After the breach nitrogen and other nutrient values in the eastern Great South Bay are lower and clearly associated with the higher salinities now found throughout the eastern bay, Figure 5. The impact of the lower nutrients in Bellport Bay is illustrated in the fluoresence record of the Brown Tide bloom that occurred in Great South Bay starting in June 2015. (Fluoresence measures the amount of chlorophyll in the water which is directly related to the amount of phytoplankton or algae in the water.) The Brown Tide bloom in Bellport Bay started around June 10 and lasted until the end of June. The bloom recorded at the buoy in the middle of the of the bay started a little earlier, was more intense and lasted longer, Figure 6. Brown tide blooms typically last a month or so and this one ended in early July to be replaced by the more usual green algae that remained through the rest of the summer.

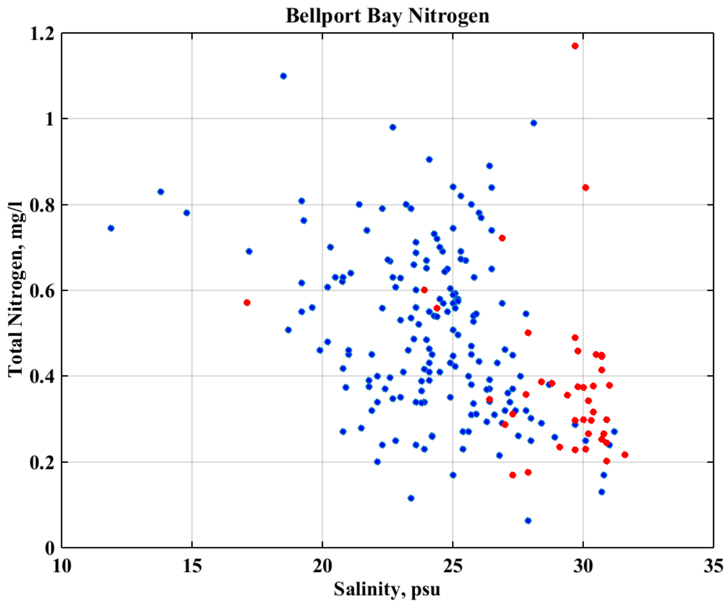


Figure 5. This figure shows the total nitrogen vs salinity in Bellport Bay from the Suffolk County Department of Health Services ~monthly surveys of Great South Bay, station 090110. The blue dots are those from samples obtained prior to Sandy, the red dots are those taken after the breach was formed.

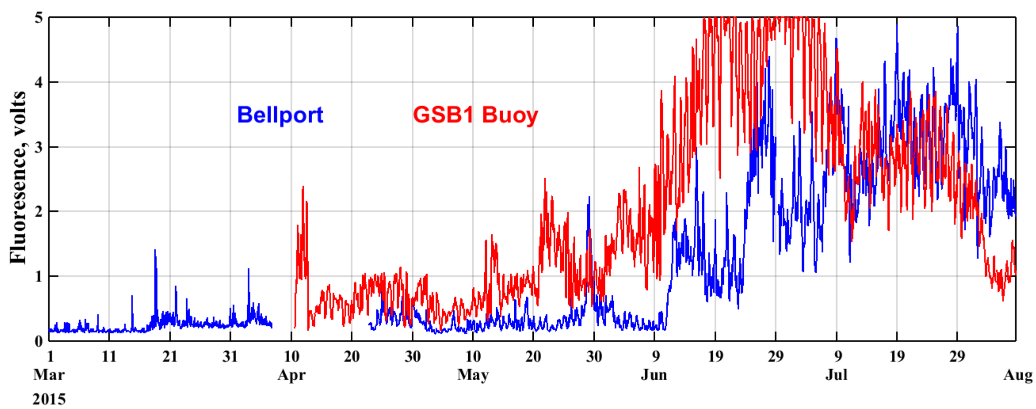


Figure 6. This figure shows the florescence records from Bellport and the GSB1 buoy located in the middle of the bay south of West Sayville. Fluorescence is proportional to the amount of chlorophyll in the water.

Salinity jumped nearly 6 practical salinity units (psu) to around 30 psu in Bellport Bay as the newly formed breach allowed an inrush of ocean waters. Typical ocean salinities south of Long Island are around 32 psu. Since the breach formed, salinity in the eastern bay has generally remained between 28 and 30 psu although the area has been subject occasionally to the effect of rain storms and local runoff. The salinity sensor deployed on the GSB1 buoy in the central bay south of West Sayville showed that the higher salinities began showing up there some 5 to 6 months after the breach and since then have pretty well tracked the salinity changes at Bellport. The potential role of the breach in the arrival of more saline waters in the middle of the bay is supported by our circulation modeling results. The numerical models include realistic bathymetry, with and without the breach, fresh water sources from streams and groundwater, and ocean temperatures and salinities. Under just steady ocean tidal forcing, without winds, the model shows that there has been a clear change in the mean water currents in the bay. Prior to the breach the whole bay was characterised by small-scale eddies. After the breach, the tidal forcing results in a mean flow out of Bellport Bay along the north shore into Patchogue Bay to Blue Point. This change is illustrated in Figure 7 showing the tidal-mean streamlines from the model prior to the breach as compared to the model that includes the breach.

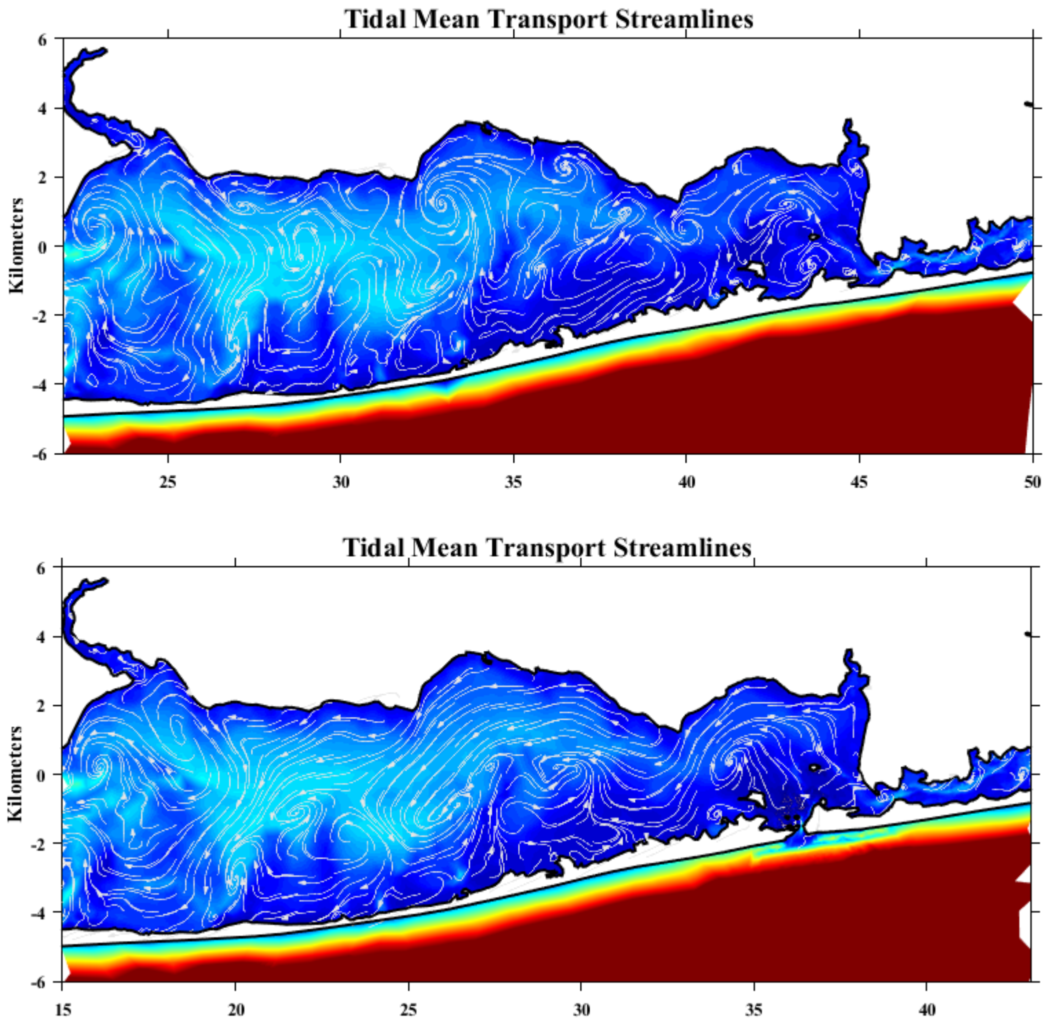


Figure 7. These figures show the tidal-mean streamlines from our numerical model simulations. The top panel shows the streamlines that existed prior to the breach while the lower panel shows those from after the breach.

Despite these model results the role of the breach for the increase in salinity in the middle of the bay is still unclear. The model uses a Fire Island Inlet bathymetry from before Sandy but dredging projects in Fire Island Inlet started in March of 2013. So the relative roles of the breach and Fire Island Inlet in the ocean-bay exchange have yet to be resolved. And as the salinity record from the GSB1 buoy shows,, Figure 8, there are times when the salinity in the middle of the bay is higher than in Bellport Bay. In addition, despite the increased salinity in the central bay there has not been the same degree of nutrient reduction that Bellport Bay has experienced since the breach. Since the nutrient load in the central bay was already lower than in the areas to the east, it suggests that the central area was and may still be dominated by ocean-bay exchange through Fire Island Inlet which, after all, is some ten times larger than the breach.

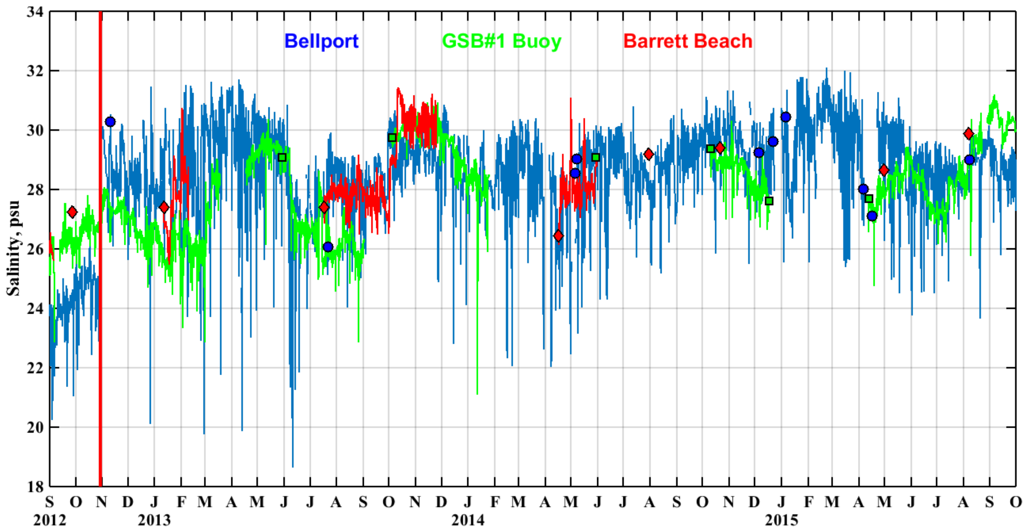


Figure 8. This plot shows the salinity records from the Observatory's sensors at Bellport, Barrett Beach along the south shore across from Patchogue, and from the GSB1 in the center of the bay south of West Sayville. The colored symbols indicate the times and values of calibration samples.

Since the end of 2015 the configuration of the breach has remained fairly stationary despite some significant storms. The spit off the western shore remains in essentially the same location it was late in December while the shoals to the northwest have spread out some more. The distance between the east and west shorelines is now about 500 meters but the main deep channel through the breach is noticeably narrower than in the past and is on the order of 75 meters wide. There is a large shoal extending into the breach from the east and this shoal extends to the north in the main channel reaching all the way to where the main channel bears off to the northwest. A result of this shoaling is a movement of the main channel into the flood delta off to the west, passing close to Pelican Island. The westward displacement of the main channel is a process that has gradually happened over the past four months or so. And the osprey nest on Pelican Island is still hanging on.

This spring we will continue to maintain the observatory while conducting bathymetric and velocity surveys of the breach as it continues to evolve. The numerical circulation modeling will be used to further examine the changes in the flow field of the bay, the impact of winds and storms, and changes in the residence time of the waters in different parts of the bay.

March 16, 2016