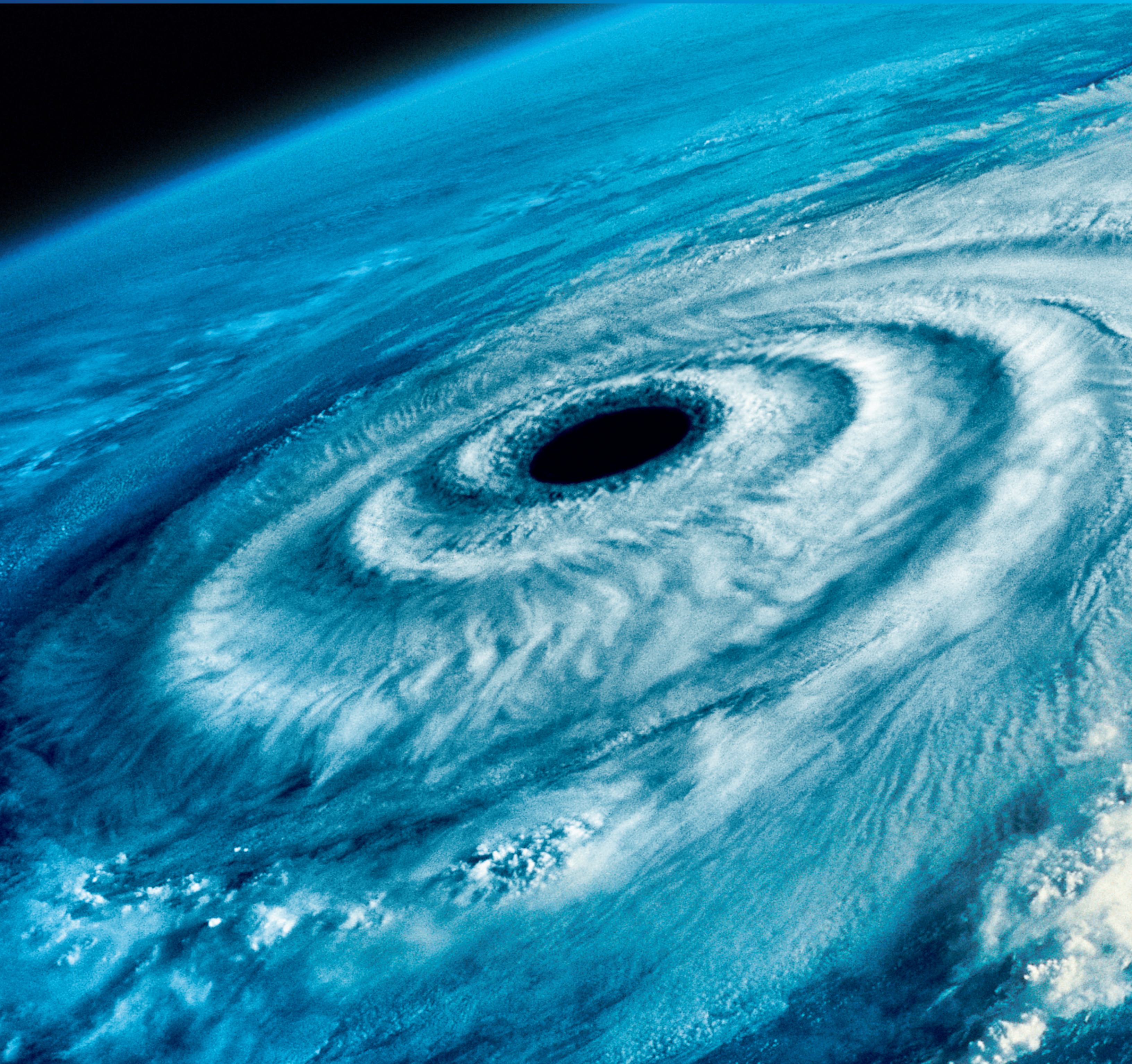
# The big one: The East Coast's USD 100 billion hurricane event



# Foreword

It's been two years since Hurricane Sandy reminded us that the Northeast United States is vulnerable to hurricanes, and for those still recovering from the storm's aftermath, the trauma of the hurricane continues. Yet despite Sandy being the third largest hurricane loss on record, the majority of New York, New Jersey, and other Northeast residents did not experience how devastating a hurricane could be. For many of us Sandy is little more than a distant memory of a temporary inconvenience.

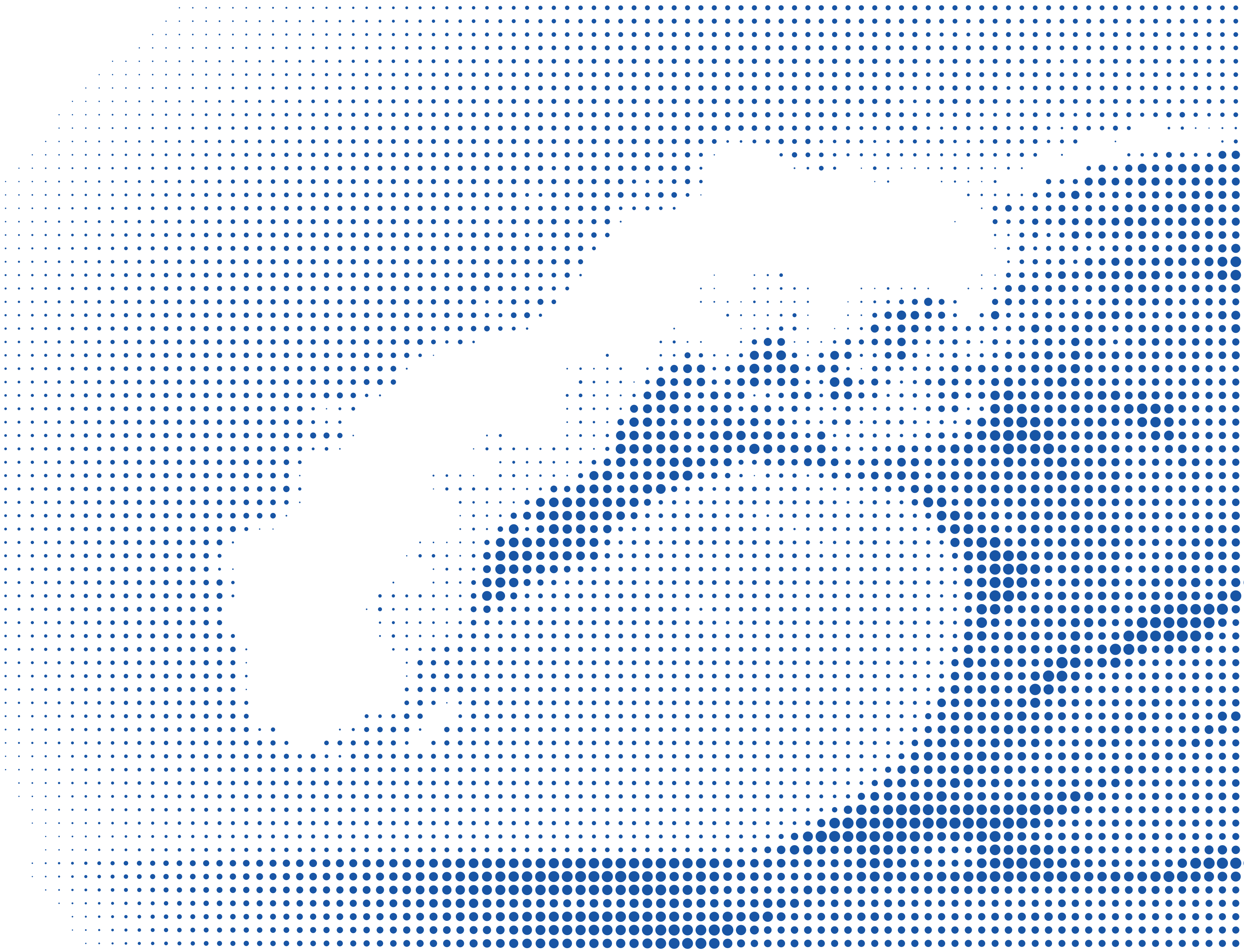
In the months following Sandy many experts told us that Hurricane Sandy was a very unusual event. It was unusual in terms of its westward storm track, its interaction with the jet stream, the high tide, and how it intermingled with the continental weather systems. They tell us that the probability of a similar storm taking the same perpendicular track as Sandy is at least one in 500 years.

Once in 500 years is misleading. Although Sandy was unusual in a meteorological sense, it wasn't a particularly intense storm and lacked the widespread high winds and rainfall that can occur with a Northeast hurricane. It's highly unlikely that we will see a hurricane with the same characteristics as Sandy. However it's very likely (1 in 50 years) that we will see, and in fact, have seen, other hurricanes in the Northeast that would have caused economic damages equal to or greater than those caused by Hurricane Sandy if they were to occur today. Sandy is a harsh reminder of what greater event potentially awaits us.

Over the last decade we've seen an alarming rise in the insured and economic damages due to natural disasters. The largest portion of this increase is due to the ever-growing amount of exposed values in areas of higher risk. Underestimating the true risk within these regions can lead to a false sense of security, promote more building in areas of higher risk areas, and understate the need for investing in resiliency.

Furthermore, we must continue to be mindful that our coastal risk landscape is going to shift upwards due to climate change and sea level rise. Since the 1850s, the sea level has risen by a foot and a half at the Battery in New York City. This additional 18 inches of sea level exacerbated Sandy's tremendous storm surge. If this trend continues, as it's expected to, hurricanes much smaller and weaker than Sandy will be capable of generating storm surge and damages comparable to or exceeding that of Sandy.

Swiss Re Natural Hazards Expert Megan Linkin evaluated a handful of major historical events that have impacted the Northeast. A few of these events, when recreated with today's exposures, produced insured damages in the tens of billions, much like Hurricane Sandy. One of the more interesting storms reviewed was the 1821 Hurricane that moved along the Mid-Atlantic coastline before striking the New York/New Jersey coastline. The following report looks into this event as if it were to occur today. The story is a compelling reminder that Sandy, or at least the loss caused by Sandy, was not that unusual.



# Introduction

Nearly 200 years ago, a powerful hurricane decimated the Mid-Atlantic and Northeast United States. Packing wind gusts of over 156 miles per hour, the Norfolk Long Island Hurricane of 1821 surged up the Eastern Seaboard creating chaos and wreaking havoc from the Outer Banks of North Carolina all the way up to the Boston metropolitan area. If this hurricane was measured by today's standards, it would be a strong Category 4 storm — unlike anything the Mid-Atlantic and Northeast have recently seen or experienced.

In comparison, Hurricane Sandy, with its unique track, 1,000-mile-wide wind field, and low central pressure, pushed record-breaking storm surge into the New York and New Jersey coasts, destroying businesses, homes, and lives in a short 24-hour period. But for all the devastation and damage that Hurricane Sandy brought, its intensity at landfall, measured by 1-minute maximum sustained winds, was equivalent to a weak Category 1 hurricane. Other events in recent years (Irene, Isabel, Gloria, and Bob), while significant, weakened prior to landfall, coming onshore as either Category 1 or Category 2 hurricanes, and not the major hurricanes originally anticipated and feared.

If the 1821 Hurricane were to happen today, it would cause 50% more damage than Sandy and potentially cause more than $100 billion in property losses stemming from storm surge and wind damage.

At the time, the combined population of New York City and Washington, DC was 136,000 people, and radar, satellites, even the National Weather Service (founded as the US Weather Bureau in 1870) didn't exist. There were no meteorologists or observation networks to provide centralized weather information. Weather events arrived, with little to no warning unless you were an experienced sailor who knew how to interpret the sky.

The 1821 Hurricane roared through the Mid-Atlantic and Northeastern United States in early September, passing over or near major cities and tourism regions such as the Outer Banks, North Carolina; Norfolk, Virginia; Cape May, New Jersey; and New York City. In fact, the storm made landfall on September 3, which would have been Labor Day, had the holiday been recognized at the time. Ludlum (1963) provides the most comprehensive archive of information regarding the storm; reports regarding timing, weather conditions, and damage are meticulously recorded.

Coastal communities in North Carolina were washed away, ships in Norfolk were pushed ashore, and the Delaware Bay flooded Cape May. On eastern Long Island, the aftermath was described by locals as, "the most awful and desolating ever experienced." The hurricane was a devastating event for the expanse of Northeast United States, with communities, farms, and churches laid in ruins from North Carolina to New Hampshire. The storm's wind field was immense with hurricane force winds recorded as far north as Maine.

The hurricane is notable not only for its strength, but its contribution to science; it's the storm that led to the discovery that in the Northern Hemisphere, these weather systems rotate in a counterclockwise direction (Redfield 1831).

All the existing documentation around the 1821 Hurricane refers to it as a catastrophic, devastating event. With today's models, we can reconstruct a track for this hurricane to illustrate how it moved up the coast, along with its wind field and storm surge field to determine what the loss potential would be if the 1821 Hurricane recurred today.

# Reconstruction of the 1821 Norfolk Long Island Hurricane track

While population density and meteorological networks in the Mid-Atlantic and Northeast were far less than they are today, the East Coast was the first area to be settled by Europeans, and by the time of the hurricane, some communities were approaching 200 years old. Thus, some valid qualitative observations of wind direction and wind severity during the storm do exist. As previously mentioned, Ludlum (1963) collected and organized much of the information regarding the 1821 Hurricane, and the archives from Ludlum and others are available from the Historical Hurricane Information Tool (HHIT; Bossack and Elsner 2003).

Weather observations, including wind direction and qualitative descriptions of the wind speeds, are available from the Outer Banks through New Hampshire (Ludlum 1963, Bossack and Elsner 2003, Coleman and LaVoie 2012). Although the exact hours and minutes of the observations are unknown due to a lack of a standardized time-keeping system in the United States in 1821, estimates of times could be made based on the description of the time of day (morning, afternoon, evening, and so on). Figure 1 shows many of the stations where weather information was available during the 1821 storm and Table 1 gives the timeline of weather observations in the affected area.

Figure 1:
**Map showing many of the locations where weather information was available in September 1821.**

Table 1:
**Wind observations available September 3-4, 1821.**

| Date | Time | Wind Direction | Wind Speed | City |
|---|---|---|---|---|
| 3-Sep | 800 | NE | Gale | Norfolk |
| 3-Sep | 800 | NE | Gale | Edenton |
| 3-Sep | 900 | NW | Hurricane | Edenton |
| 3-Sep | 900 | SE | | Cape May |
| 3-Sep | 1130 | ESE | | Cape Henlopen |
| 3-Sep | 1130 | NW | Hurricane | Edenton |
| 3-Sep | 1130 | NE | Hurricane | Norfolk |
| 3-Sep | 1150 | ENE | | Cape Henlopen |
| 3-Sep | 1200 | NW | | Norfolk |
| 3-Sep | 1200 | SE | | New Haven |
| 3-Sep | 1230 | Calm | Calm | Norfolk |
| 3-Sep | 1300 | Calm | Calm | Edenton |
| 3-Sep | 1400 | SE | Hurricane | Cape May |
| 3-Sep | 1400 | SE | Violent | Tuckerton |
| 3-Sep | 1430 | Calm | Calm | Cape May |
| 3-Sep | 1450 | ENE | | Cape Henlopen |
| 3-Sep | 1520 | WNW | | Cape Henlopen |
| 3-Sep | 1600 | N | | Poplar Island |
| 3-Sep | 1700 | NE | Violent | Newark |
| 3-Sep | 1700 | SE | | Hartford |
| 3-Sep | 1730 | NW | | Cape May |
| 3-Sep | 1800 | NW | | Cape May |
| 3-Sep | 1800 | SE | Violent | Williamstown |
| 3-Sep | 1800 | SE | | Litchfield |
| 3-Sep | 1800 | SE | Increasing | New Haven |
| 3-Sep | 1800 | SE | Increasing | Bridgeport |
| 3-Sep | 1800 | E | Low pressure | New York |
| 3-Sep | 1800 | NE | Hurricane | Newark |
| 3-Sep | 1800 | NW | Violent | Philadelphia |
| 3-Sep | 1800 | NW | Decreasing | Poplar Island |
| 3-Sep | 1900 | SE | | Litchfield |
| 3-Sep | 1900 | SE | | Middletown |
| 3-Sep | 1930 | NW | Decreasing | Newark |
| 3-Sep | 2000 | S | Violent | Ellington |
| 3-Sep | 2200 | SE | Gale | Epping |
| 4-Sep | 0 | SW | | New Haven |

Several conclusions about the Norfolk Long Island Hurricane can be drawn from the weather observations. First, the storm made landfall and quickly moved through North Carolina. Indeed, Edenton's observations show a shift in wind direction, with winds from the northeast at 8 AM and northwest by 9 AM, indicating that the center of the storm passed to the east sometime in the early morning hours. The storm then moved to the northeast, slowing slightly, with northeast winds reported consistently in Norfolk until 11:30 AM. The storm passed Norfolk around noon.

Several historical accounts report the eye passing directly over Cape Henlopen, Delaware and Cape May, New Jersey approximately between 2 and 3 PM (Ludlum 1963, Savadove and Buchholz 1993). By 3:30 PM, the storm had moved north, with Cape Henlopen reporting winds from the west-northwest.

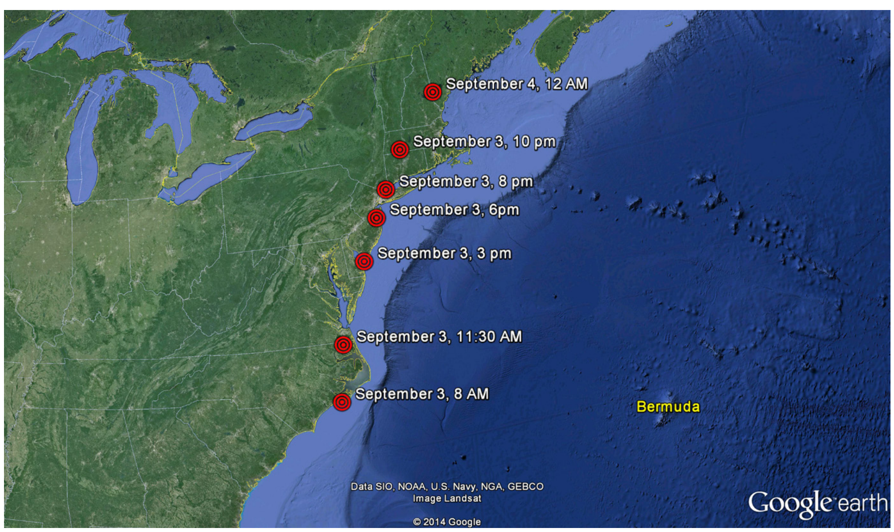
In the evening hours, the storm was approaching New York City; at 6 PM, much of southern New England was reporting winds from the east-southeast and southeast, and New York (Manhattan) and Newark were reporting winds out of the east to northeast. By 7:30 PM, the winds in Newark shifted to the northwest; around the same time, New York was reporting its lowest central pressure. Nearby, the storm was making landfall in Jamaica Bay, within the present-day boundaries of New York City. As the storm continued north, the density of observations decrease, however, there's enough information regarding the timing and duration of the east to southeast winds to conclude that the storm tracked to the northeast through New England throughout the evening into the midnight hour. Southeast to south winds were reported in much of eastern Connecticut and eastern New Hampshire, implying storm passage to the west.

Furthermore, based upon the accounts of William Redfield, later summarized by his great-grandson after the 1938 Long Island Express, the winds in Cromwell and Middleton, Connecticut were from the southeast at 9 PM, and from the northeast in Stockbridge, Massachusetts at the same time (Redfield 1939). The storm center passed between these two locations (Figure 2) during the night of September 3. While no observations of storm structure exist, by this time, the hurricane was likely undergoing or had undergone extratropical transition, broadening its destructive wind field.

Figure 2:
**Map showing the locations of Middleton, Connecticut and Stockbridge, Massachusetts.**

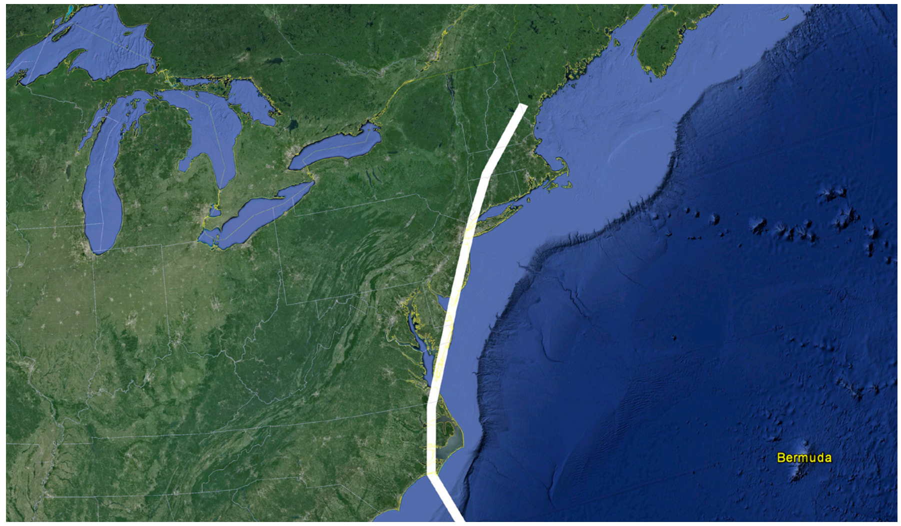

The conclusions drawn from the historical anecdotes and wind observations led to the assignment of the storm center location between the morning of September 3 and midnight of September 4 in the map below (Figure 3).

Figure 3:
**Approximate storm center positions for the 1821 Norfolk Long Island Hurricane.**



The track of the hurricane is derived by essentially connecting the dots, and is plotted in Figure 4 below.

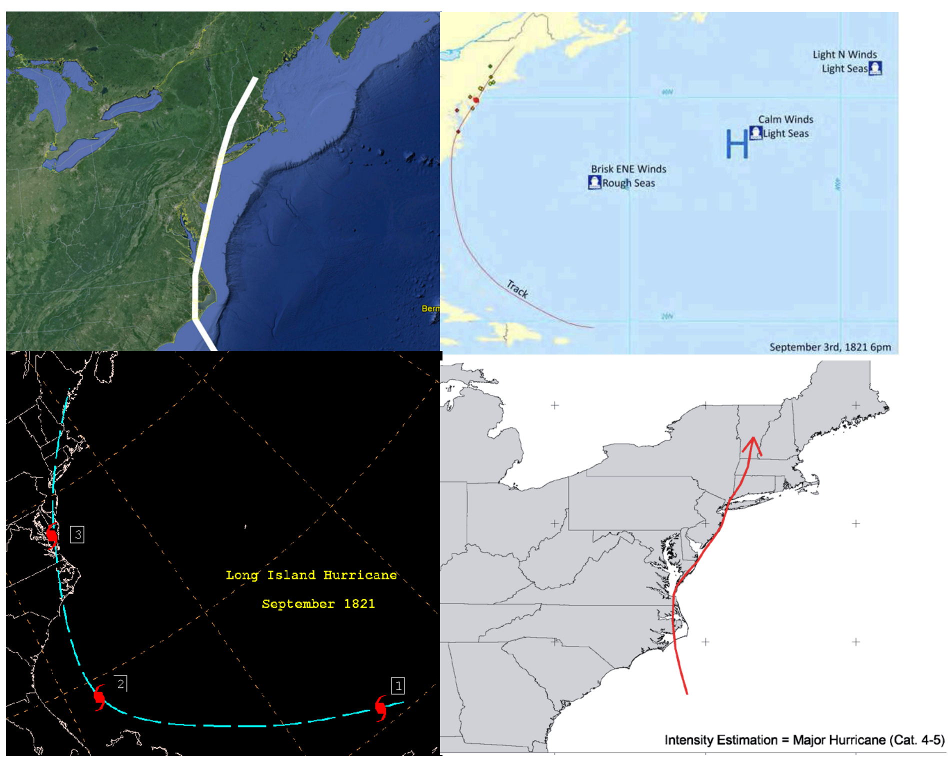
Figure 4:
**The projected path of the 1821 Hurricane.**




A comparison of the Swiss Re track with other published tracks shows that our conclusions and the track derived from these conclusions is in line with other peer-reviewed publications (Figure 5). The track is also consistent with the proposed track published in Ludlum (1963), and the discovery of significant tree damage during the creation of the Garden State Parkway in New Jersey (Savadove and Buchholz 1993).

The Swiss Re track places many heavily developed areas, such as coastal New Jersey, Long Island, and Connecticut, in the right front quadrant of the hurricane. Since hurricanes in the northeast United States move rapidly due to their interaction with the jet stream, the winds on the right side of the storm were undoubtedly enhanced by the storm's motion, resulting in many of these areas likely experiencing the worst of the storm.

Figure 5:
**Comparison between the Swiss Re 1821 Hurricane track (top left) and other proposed tracks, clockwise, from top left, published by Coleman and LaVoie (2012), FSU, and NOAA.**



# Wind field of the 1821 Hurricane

Once the track and track nodes were finalized, a wind field for the 1821 Hurricane was developed using Swiss Re's proprietary tropical cyclone model. Our tropical cyclone model relies on the scientific concepts set forth in Holland (1980, updated 2008) and Vickery (1995, 2005) coupled with a land use model to account for surface roughness.

Since the Holland model generates the gradient wind, thus requiring information on the pressure gradient, the pressure of the storm at landfall and all subsequent points was calculated based on information from Ho (1989) and methodology from Vickery (2005). Ho (1989) estimates that at the time of approach and landfall in Jamaica Bay, the hurricane had a central pressure of approximately 965 mb. This information and the calibrated exponential pressure-decay coefficients for the Mid-Atlantic and Northeast regions developed by Swiss Re, based on the work of Vickery (2005), allows for the calculation of the storm central pressure at each track node. Central pressure at the time of first landfall in North Carolina is calculated to be approximately 927 mb; this is comparable to a very strong Category 4 hurricane on the Saffir-Simpson Scale. The returned intensity is similar to the intensity calculated by Bossack and Elsner (2003).

The central pressure of the storm at each track node is shown in Table 2 below.

Table 2:
**The central pressure of the 1821 Hurricane at various points along the track. The green highlighted row is the report from Ho (1989).**

| Date | Time | Pressure |
|---|---|---|
| 3-Sep | 8:00:00 AM | 927.10 |
| 3-Sep | 11:30:00 AM | 943.46 |
| 3-Sep | 3:00:00 PM | 956.25 |
| 3-Sep | 6:00:00 PM | 965.00 |
| 3-Sep | 8:00:00 PM | 969.92 |
| 3-Sep | 10:00:00 PM | 974.24 |
| 4-Sep | 12:00:00 AM | 978.02 |

Once the central pressure, and thus, pressure gradient, associated with the storm is known, the wind field can be calculated. The model calculates both 3-second peak gusts and 1-minute sustained winds; variables such as forward motion and friction are considered. The wind field at the Swiss Re grid points is plotted in Figures 6 and 7.

Figure 6:
**The 3-second peak gust wind footprint of the 1821 Norfolk Long Island Hurricane. Cooler colors represent stronger wind speeds.**

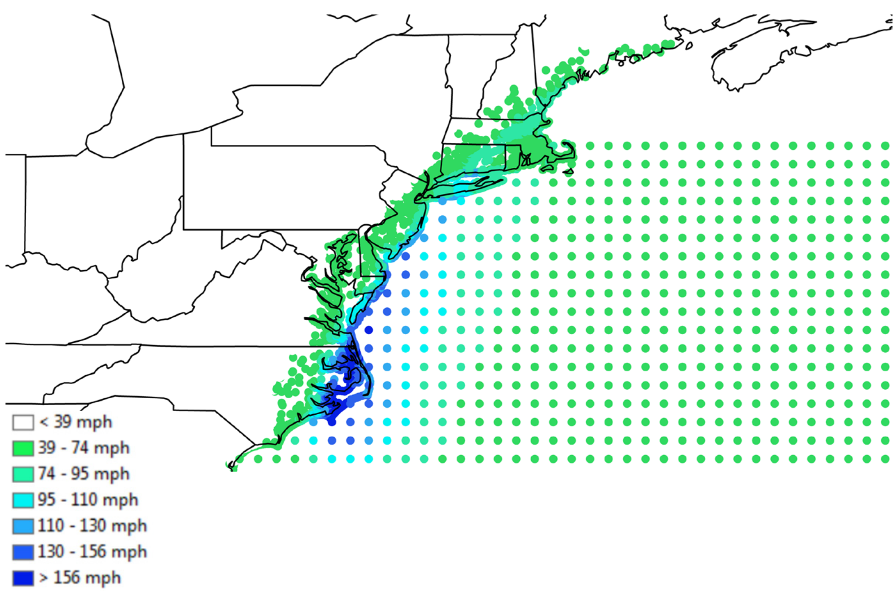
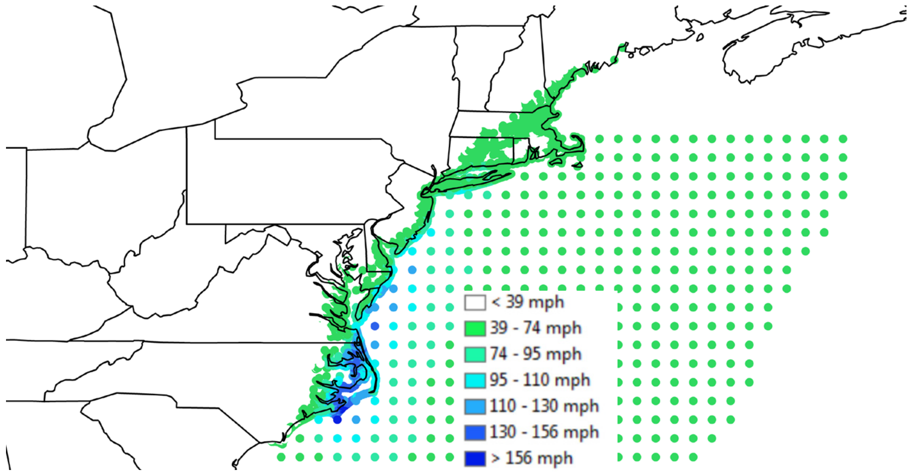


Figure 7:
**The 1-minute sustained wind footprint of the 1821 Norfolk Long Island Hurricane. Cooler colors represent stronger wind speeds.**




The wind footprint is in line with the historical description available. The footprint shows a powerful hurricane making landfall in North Carolina; the coastal region of North Carolina experiences 3-second gusts in excess of 130 mph, and along the Outer Banks, the gusts are estimated to be above 156 mph. As the storm moves up the coast and weakens, it still produces hurricane force sustained winds and wind gusts, with the New Jersey, New York, and Delaware coasts experiencing wind gusts over 100 mph.

In an effort to ascertain a clearer picture of the sustained winds and wind gusts, the maximum of both are plotted by county in Figures 8 and 9.

Figure 8:
**Maximum 3-second peak gusts by county. Cooler colors represent stronger wind speeds.**

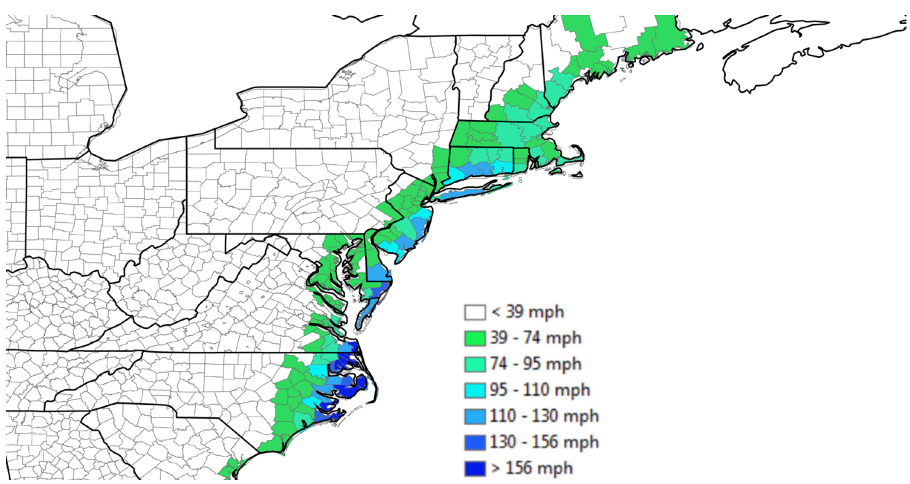
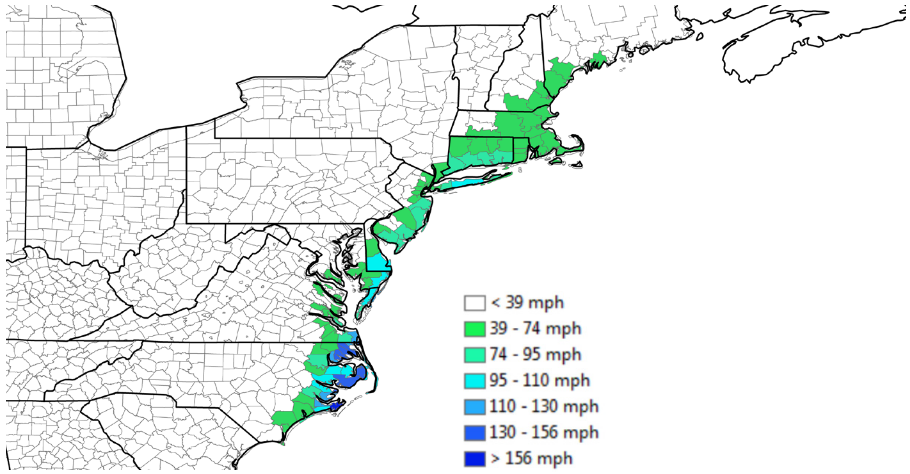


Figure 9:
**Maximum 1-minute sustained wind by county. Cooler colors represent stronger wind speeds.**




The county plots also show the strength and intensity of the 1821 Hurricane, and the wide area that powerful winds affected. The coastal regions of North Carolina, Virginia, Maryland, Delaware, New Jersey, New York, and Connecticut all experience wind gusts in well excess of 100 mph, and in some areas, 150 mph. The storm produces hurricane force wind gusts as far north as Maine.

Such a large area of powerful winds striking the highly developed counties today would be disastrous, especially considering the area hasn't experienced a powerful wind storm in years, and much of the building stock is old.

# Storm surge from the 1821 Hurricane

Unfortunately, significantly less information regarding the storm surge from the 1821 Hurricane exists in the observations. The few reports regarding storm surge are listed in Table 3. Additionally, sediment cores in southern New Jersey clearly show an overwash layer from the 1821 Hurricane. While detailed storm surge heights aren't determinable from such paleotempestology analysis, Donnelly (2001) points out that with most of the southern New Jersey coast being approximately 3 meters (10 feet) above sea level, the storm surge has to be at least that high to cause the overwash layer.

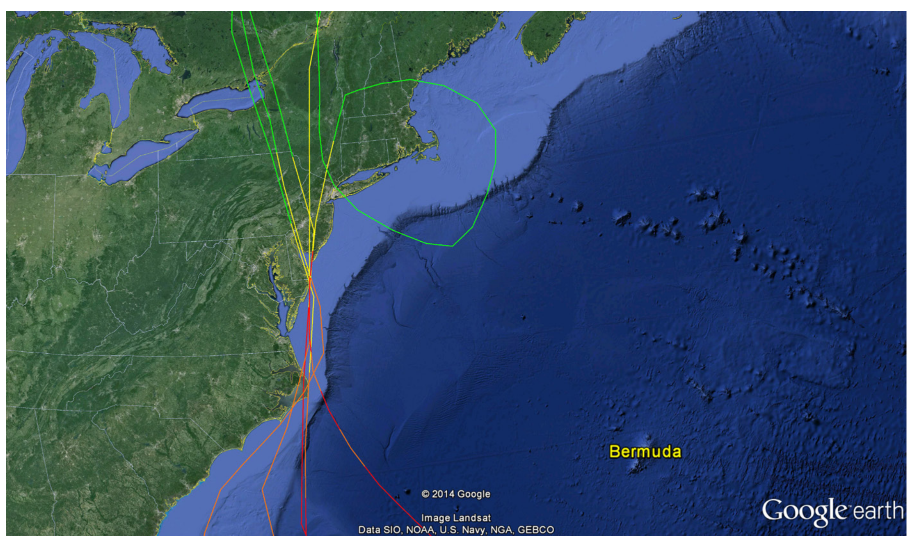
Table 3:
**Historical storm surge reports for the 1821 Norfolk Long Island Hurricane.**

| Location | Source | Description |
|---|---|---|
| Chesapeake Bay | Ludlum (1963) and Roth and Cobb (2001) | 10 foot storm surge |
| Cape May, NJ | Ludlum (1963) | 5 foot storm surge in the Delaware Bay |
| The Battery, NYC | Mayor's Office - New York City | 11-13 foot storm surge at the Battery led to the convergence of the East River and the Hudson River along present-day Canal St. The record was only recently broken by Hurricane Sandy. |

Swiss Re's proprietary storm surge model, which combines the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model and a high-resolution digital elevation model, generates storm surge footprints for hurricanes. Given the dearth of information regarding the hurricane storm surge, and the sensitivity of storm surge to the final track, analog storms which produce storm surge values comparable to the few storm surge reports from the 1821 Hurricane are used to estimate the storm surge loss potential from the 1821 Norfolk Long Island Hurricane.

The analog tracks are shown in Figure 10 below; while the tracks aren't identical to the 1821 Hurricane, all are powerful storms impacting the East Coast, capable of generating large storm surges along much of the Eastern Seaboard.

Figure 10:
**Hurricane tracks of the storm surge analogs from Swiss Re's probabilistic tropical cyclone model. Warmer colors indicate higher intensity.**



# Loss estimation for the 1821 Norfolk Long Island Hurricane

To determine the loss potential from the 1821 Norfolk Long Island Hurricane, wind and storm surge scenarios are run through Swiss Re's tropical cyclone model using the Swiss Re market portfolio for US hurricane. Both ground up, to assess total property damage, and gross, to assess the impact of such an event on the insurance industry, losses are calculated. The analysis is performed for a subset of the market portfolio, which contains the states of North Carolina to Maine.

The eastern part of the United States is heavily developed, particularly along the coast (Figures 11-13). Across all three lines of business (residential, commercial, and auto), there is USD 34 trillion in total insured values from the states of Texas to Maine; residential properties make up the largest portion, with USD 19 trillion in total insured value. Many counties affected by the 1821 Hurricane have TIVs across all lines of business in excess of USD 100 billion dollars.

Figure 11:
**Residential TIV per county from the Swiss Re market portfolio. Cooler colors indicate areas of higher TIV.**

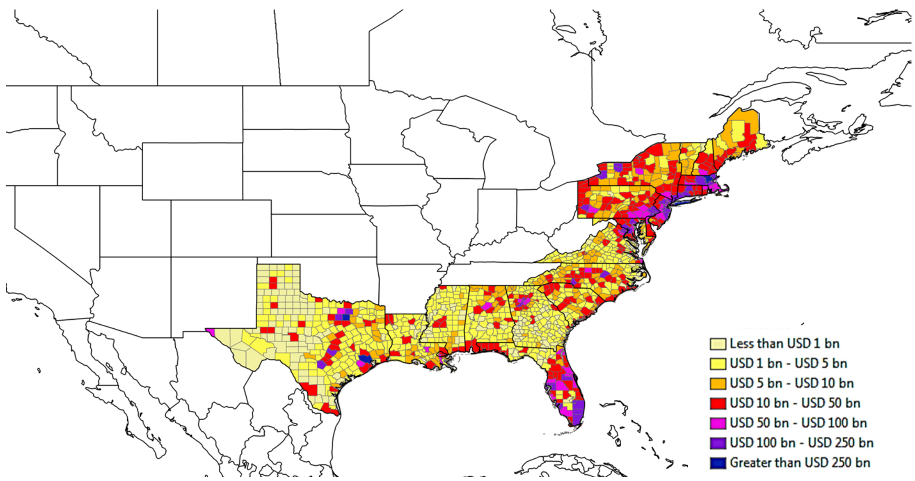



Figure 12:
**Commercial TIV per county from the Swiss Re market portfolio. Cooler colors indicate areas of higher TIV.**

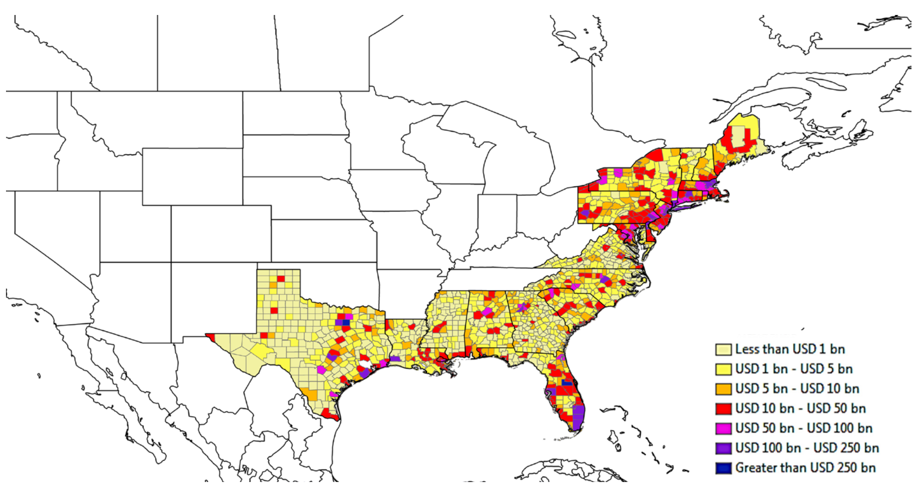
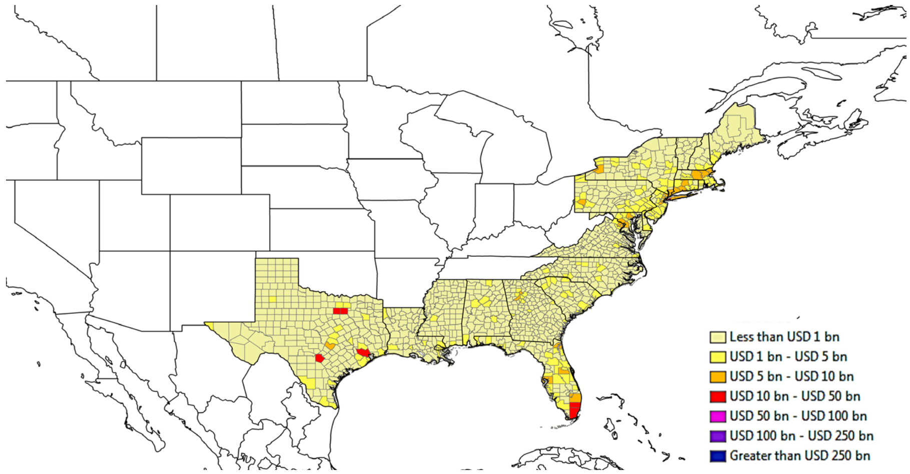


Figure 13:
**Automotive TIV per county from the Swiss Re market portfolio. Cooler colors indicate areas of higher TIV.**




## Wind losses

The ground up loss from the 1821 Norfolk Long Island Hurricane is USD 38.7 billion; application of primary deductibles decreases the loss to USD 35 billion. On the loss frequency curve for only North Carolina to Maine, the return period of the 1821 Norfolk Long Island Hurricane is 55 years for wind only.

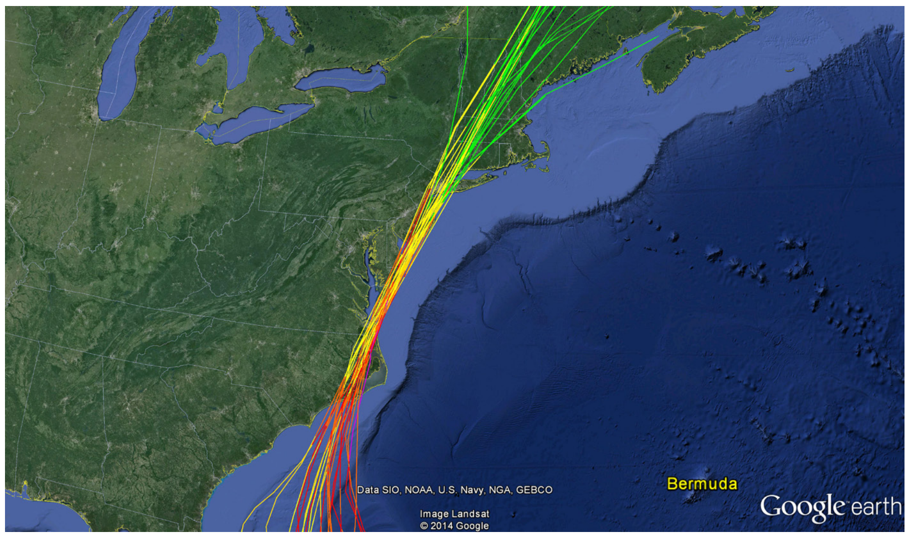
To place the losses in context, wind losses from other notable historical storms and wind losses from analog storms within the Swiss Re event set are calculated. When compared with other events historically, there is no storm in the late 19th, 20th, or early 21st century which would have caused wind losses comparable to the 1821 Norfolk Long Island Hurricane. Even the 1938 Long Island Express, the benchmark to which all New England hurricanes are held, only generates USD 29 billion of ground up wind loss, with a gross wind loss of 27 billion (Table 4).

Table 4:
**The ground up and gross wind losses from the 1821 Norfolk Long Island Hurricane compared with other notable Mid-Atlantic and Northeast hurricanes.**

| Event Name | Ground Up Loss | Gross Loss |
|---|---|---|
| 1821 Norfolk Long Island Hurricane | 38,655,161,733 | 35,075,197,597 |
| 1858 New England Hurricane | 5,031,440,374 | 4,499,594,148 |
| 1869 Eastern New England Hurricane | 6,425,151,499 | 5,817,321,170 |
| 1869 Saxby's Gale | 715,209,914 | 649,747,665 |
| 1878 Gale of 1878 | 19,028,043,995 | 17,087,346,380 |
| 1879 Great Beaufort Hurricane | 474,521,551 | 430,041,286 |
| 1893 Hog Island Hurricane | 8,508,641,242 | 7,737,821,787 |
| 1903 Vagabond Hurricane | 28,222,265 | 17,414,398 |
| 1933 Chesapeake Potomac Hurricane | 4,339,369,007 | 3,845,697,259 |
| 1938 Long Island Express | 29,501,966,186 | 26,815,910,931 |
| 1944 Great Atlantic Hurricane | 3,288,411,857 | 3,022,532,438 |
| 1954 Carol | 5,821,885,232 | 5,295,940,357 |
| 1954 Edna | 590,004,952 | 556,594,205 |
| 1954 Hazel | 20,195,353,050 | 18,607,245,957 |
| 1960 Donna | 8,580,525,474 | 7,858,961,586 |
| 1972 Agnes | 2,511,274,439 | 2,207,493,179 |
| 1985 Gloria | 4,910,634,706 | 4,308,052,313 |
| 1989 Hugo | 8,142,112,152 | 7,332,630,646 |
| 1991 Bob | 1,401,879,512 | 1,295,867,401 |
| 1999 Floyd | 3,573,426,675 | 3,122,117,581 |
| 2011 Irene | 7,822,436,938 | 6,307,956,066 |
| 2012 Sandy | 15,073,912,970 | 13,436,697,496 |

One benefit of a probabilistic model is the ability to generate storms which are within the physical realms of possibility, but aren't necessarily in the historical record. With the official Atlantic best track database, HURDAT (Neumann 1984, updated Landsea et al., 2013), starting in 1851, the 1821 Norfolk Long Island Express isn't included in the historical record. Furthermore, the dearth of wind events in the Northeast in the last century or so renders a historical comparison somewhat insufficient. However, the Swiss Re model, which contains over 200,000 Atlantic hurricanes, does contain storms which take a comparable track and have a comparable intensity to the 1821 Hurricane. A plot of the 22 tracks identified as analog tracks are plotted in Figure 14 below.

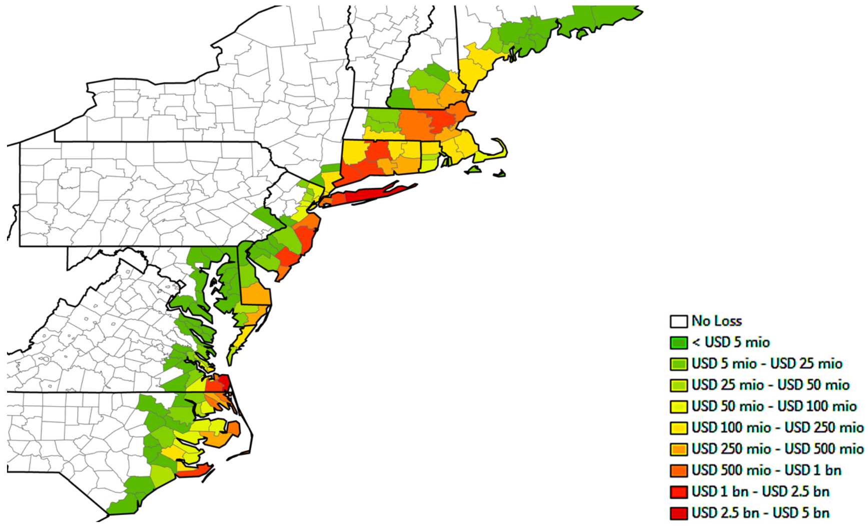
Figure 14:
**The 22 analog wind tracks from Swiss Re's proprietary tropical cyclone model. Warmer colors indicate more intense simulated hurricanes.**




Since the intensities and tracks of the analog storms vary, the ground up losses from the analog tracks range from USD 2.3 billion to USD 227 billion and the gross losses range from USD 2 billion to USD 217 billion. The average ground up (gross) loss across all analogs is USD 41 billion (USD 38 billion), placing the 1821 Norfolk Long Island Hurricane right in the middle of the loss range, and demonstrating that as severe as the storm was, it's still not the worst-case wind scenario for the East Coast.

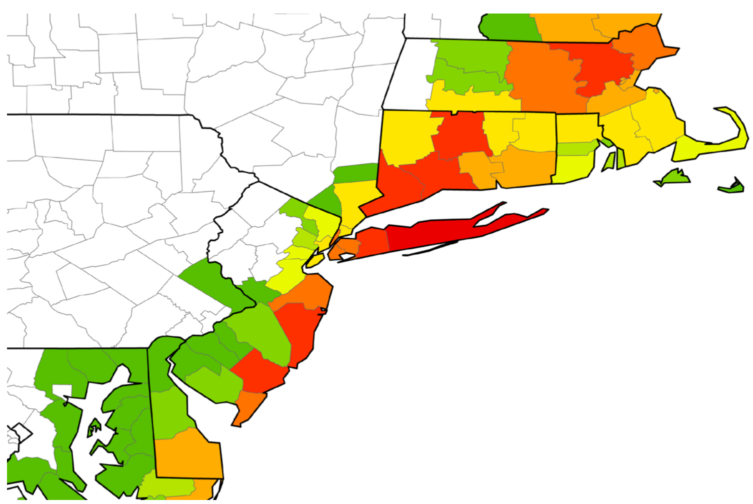
Ground up losses by county are shown in Figure 15; along the heavily developed area between Washington, DC and Boston, Massachusetts, numerous counties have losses in excess of USD 500 million. In 11 counties, the losses are in excess of USD 1 billion.

Figure 15:
**Ground up losses from the 1821 Norfolk Long Island Hurricane by county. Warmer colors indicate larger losses.**




Focusing in on the Tri-State area, an area that was significantly impacted by Hurricane Sandy, shows that many of the counties would experience property damage in excess of USD 250 million (Figure 16). Property damage in Atlantic and Ocean Counties in New Jersey and Fairfield, New Haven, and Hartford Counties in Connecticut is more than USD 1 billion. In the two Long Island counties (Nassau and Suffolk) and Fairfield County, the losses are in excess of USD 2 billion.

Figure 16:
**Ground up losses from the 1821 Norfolk Long Island Hurricane by county, focusing on the Tri-State area. Warmer colors indicate larger losses.**



Clearly, the exact final losses are sensitive to the final track, and although the track was reconstructed using the best available information, it does contain uncertainty. Therefore, if the storm tracked further west, through Vermont, losses in parts of New England could be less. However, regardless of the final track, a recurrence of the 1821 Norfolk

Long Island Hurricane would be an unprecedented and devastating wind event for the Eastern Seaboard of the United States, far exceeding the impact of any hurricane that's been experienced in the last 125 years.

## Storm surge losses

Regarding storm surge analysis, an identical market portfolio is used, however, the gross loss analysis accounts for the lack of a personal lines private flood insurance market in the United States. Site level deductibles for all residential properties are set to 100% of the total TIV. A USD 300,000 per site deductible is applied for commercial exposure, and a 2.5% deductible for automobile exposure is used.

As discussed earlier, a single deterministic loss estimate for the 1821 Hurricane isn't produced; rather analog storms are used. The storm surge for the analog events at several locations throughout the Northeast United States are in Table 5 below; the storm surge at The Battery ranges from 11 to 13 feet, while in Atlantic City, the storm surge is between 16 and 26 feet.

Table 5:
**Storm surge values for the analog probabilistic hurricanes at various locations throughout New York and New Jersey.**

| Event ID | The Battery | Cape May | Long Beach | Atlantic City |
|---|---|---|---|---|
| 2189309103 | 11.8250 | 11.7668 | 5.2075 | 24.6152 |
| 2192804050 | 12.3834 | 11.0863 | 4.9282 | 19.7440 |
| 2195409060 | 11.8250 | 12.7990 | 5.2075 | 15.8166 |
| 2195409159 | 12.3834 | 11.0863 | 5.4867 | 25.9452 |
| 2196105132 | 11.8250 | 11.5087 | 5.2075 | 22.3984 |

The calculated ground up loss range if the 1821 Norfolk Long Island Hurricane recurred today is between USD 49 billion and USD 83 billion with an average of USD 69 billion. To place this context, the modeled storm surge loss estimate for Hurricane Sandy is USD 55 billion, and the modeled storm surge loss estimate for the Long Island Express is USD 43 billion. From an insurance industry perspective, the loss for a recurrence of the 1821 Norfolk Long Island Hurricane ranges from USD 28 billion to USD 54 billion (Table 6). More than 1,000 miles of coastline, from North Carolina to Massachusetts, would be susceptible to storm surge and storm surge losses from the 1821 Hurricane.

Table 6:
**Storm surge losses from the 1821 storm surge analogs identified in the Swiss Re probabilistic tropical cyclone model.**

| Event ID | Ground Up Loss | Gross Loss |
|---|---|---|
| 2189309103 | 82,641,324,411 | 54,535,411,460 |
| 2192804050 | 82,647,153,938 | 54,156,039,974 |
| 2195409060 | 60,292,865,182 | 39,358,058,227 |
| 2195409159 | 72,031,895,228 | 47,224,428,537 |
| 2196105132 | 48,613,674,242 | 27,618,995,514 |
| Average | 69,245,382,600 | 44,578,586,742 |

## Combined losses

Using the average storm surge loss from the 1821 analogs and the wind loss calculated from the deterministic analysis, the total loss from a recurrence of the 1821 Norfolk Long Island Hurricane today would be over USD 107 billion. Currently, loss estimates for Hurricane Sandy stand at USD 68 billion. Therefore, today, the 1821 Norfolk Long Island Hurricane would cause 50% more damage than Hurricane Sandy. Even assuming a "best-case" storm surge scenario, with losses of USD 49 billion, the loss potential from the 1821 Hurricane is still in excess of Hurricane Sandy (USD 87 billion versus USD 68 billion). Losses to the insurance industry are USD 75 billion, using the average of the storm surge analog losses and the deterministic wind analysis.

The ground up loss analysis represents tangible economic losses, or physical damage. Actual economic loss would be much greater, after factoring in lost tax revenue due to destroyed homes and businesses, lower real estate values, and other economic aspects. A general rule of thumb is that the final economic loss is twice the insured loss; thus, the total economic impact from the 1821 Norfolk Long Island Hurricane recurrence would be USD 150 billion.

# Conclusion

Hurricane Sandy was a devastating event for the eastern United States, particularly the states of New York and New Jersey. Storm surge, caused by the storm's exceptional size, perpendicular track into the coast, and record-breaking low pressure, decimated the coastline, closing businesses which had been open for over 100 years and destroying homes which had been standing for eight or nine decades. Although shattering from a surge perspective, Sandy was a relatively light wind event, with only a few reports of wind gusts above hurricane strength. The combination of an intense wind and storm surge event in the Northeast United States isn't a hypothetical; historical archives and anecdotes report that the 1821 Norfolk Long Island Hurricane brought both powerful winds and tremendous storm surge up and down the East Coast.

An analysis of the 1821 Norfolk Long Island Hurricane is performed based on historical information available from anecdotes, archives, and other sources. Wind observations and timing suggest that the storm took a track which impacted much of the Eastern Seaboard, with landfalls occurring in North Carolina, Maryland, New Jersey, and New York. The weather reports available from September 1821 suggest that the storm didn't significantly weaken as it moved north along the coast. Widespread wind and storm surge damage was reported in North Carolina, Virginia, New Jersey, New York, and Connecticut. Newspaper archives weave a tale of a monster storm, with so many homes, businesses, and communities upended or destroyed.

Combining this historical information with methodologies developed in-house, a wind field and storm surge analogs are developed for the hurricane to understand both the intensity and breadth of the storm. Much of the coastal region experienced wind gusts in excess of 100 miles per hour; in parts of North Carolina, the wind gusts are calculated to be in excess of 150 miles per hour. The storm surge is extensive as well; in parts of New York and New Jersey, the storm surge ranges from 5 to 13 feet.

The loss estimates for a recurrence of the 1821 storm are in the range of USD 100 billion, which would be in excess of all storms which recently impacted the Eastern Seaboard, including Hurricane Sandy. Hurricanes Irene and Sandy served as harsh reminders that the Eastern Seaboard, particularly the Northeast United States, isn't immune to hurricane strikes. A recurrence of the 1821 Norfolk Long Island Hurricane would be a paradigm shifter, severely and negatively impacting the economy and altering the culture going forward of the oldest part of the United States.

## References


Bossack, B.H. and J.B. Elsner (2003). *Use of GIS in plotting early 19th century hurricane information (part 2)*. Tallahassee, FL: Florida State University.

Coleman, J.S.M. and S.A. LaVoie (2012). Paleotempestology: Reconstructing Atlantic tropical cyclone tracks in the pre-HURDAT era. In S. Wang and R.R. Gillies (Eds.), *Modern Climatology*. Croatia: InTech

Donnelly, J.P., S. Roll, M. Wengren, J. Butler, R. Lederer, and T. Webb III (2001). Sedimentary evidence of intense hurricane strikes from New Jersey. *Geology, 29*(7), 615-618.

Ho, F.P., (1989) Extreme hurricanes in the nineteenth century. *NOAA Technical Memorandum*, NWS Hydro 43. Silver Spring, MD: United States National Oceanic and Atmospheric Administration's National Weather Service.

Holland, G.J. (1980). An analytic model of the wind and pressure profiles in hurricanes. *Mon. Wea. Rev., 108*, 1212-1218.

Holland, G.J. (2008). A revised hurricane pressure-wind model. *Mon. Wea. Rev., 136(9)*, 3432-3445.

Landsea, C.W. and J.L. Franklin (2013). Atlantic hurricane database uncertainty and presentation of a new database format. *Mon. Wea. Rev., 141(10)*, 3576-3592.

Ludlum, D. M. (1963). *Early American hurricanes, 1492-1870*. Boston, MA: American Meteorological Society.

Neumann, C.J. (1984). A tropical cyclone data tape for the North Atlantic Basin, 1886-1983; Contents, limitations, and uses. *NOAA Technical Memorandum*, NWS NHC 22. Silver Spring, MD: United States National Oceanic and Atmospheric Administration's National Weather Service.

Redfield, W. C. (1831). Remarks on the prevailing storms of the Atlantic Coast, of the North American States. *Amer. J. Sci and the Arts, 20*, 17-51.

Redfield, A. C. (1939). This hurricane and others. *Collecting Net, March 1939*, 10-14.

Savadove, L. and M.T. Buchholz (1997). *Great storms of the Jersey Shore*. Harvey Cedars, NJ: Down the Shore Publishing.

Vickery, P.J. and L.A. Twisdale (1995). Wind-field and filling models for hurricane wind-speed predictions. *J. Struct. Engin., 121(11)*, 1700-1709.

Vickery, P.J. (2005). Simple empirical models for estimating the increase in the central pressure of tropical cyclones after landfall along the coastline of the United States. *J. Applied Meteorol. 44(12)*, 1807-1826.

Title:
The big one: The East Coast's USD 100 billion
hurricane event

Author:
Megan Linkin, Swiss Re

Editor:
Jennifer Themel

Graphic design and production:
Juan Pertuz
Corporate Real Estate & Logistics/
Media Production, Armonk

Swiss Re publications can also be downloaded
from www.swissre.com



9/14, 250 en

Swiss Re America Holding Corporation
175 King Street
Armonk, NY 10504

Telephone +1 914 828 8000
Toll Free +1 877 SWISS RE
www.swissre.com