



MODELING SANDY: A HIGH-RESOLUTION APPROACH TO STORM SURGE

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¹ Originally released in February 2013, this document reflects updated meteorological observations, industry economic and insured loss estimates, and casualty counts from Superstorm Sandy.





Executive Summary

On October 29, 2012, Superstorm Sandy made landfall along the New Jersey coastline as a post-tropical cyclone, bringing unprecedented coastal flooding to the New York and New Jersey coastlines. RMS' first, and to date only, estimate of insured losses from Sandy is between \$20 and \$25 billion.

Sandy was not a "regular" hurricane. The superstorm's catastrophic impacts were driven by its sharp turn into the New Jersey coastline; its very broad wind field, which rapidly diffused inland after Sandy transitioned into an extratropical storm; and the disproportionately large storm surge that took many by surprise—and will prove responsible for driving insured losses.

In particular, Sandy highlighted how storm surge can drive more insurance loss than hurricane wind. Sandy was not even classified as a hurricane at landfall, according to the National Hurricane Center (NHC), but caused a Category 2 storm surge in New York City. This is not the first time that storm surge has had a dominant effect. It was responsible for more than half of the total loss from 2005's Hurricane Katrina, which was a Category 3 storm at landfall, but had a Category 5 equivalent storm surge.

Sandy has therefore once again emphasized the need for catastrophe models with fully physical coastal flood modeling capability—such as that introduced in version 11.0 of the RMS[®] North Atlantic Hurricane model suite—compared to traditional approaches, which have been shown to underestimate the impacts of surge.

Sandy's impacts are also a reminder of the uncertainty and limitations associated with low-resolution data and aggregate modeling at the ZIP Code-level. High-resolution models are required for accurate flood underwriting, as adjacent properties may have very different levels of flooding and damage. The RMS surge footprint for Sandy revealed the street-by-street pattern of flooding in Manhattan and along the New Jersey coast, where the flooding closely follows small-scale changes in terrain and topography—highlighting the value of very high-resolution and data intensive modeling in accurately assessing flood loss.

Recognizing that the market requires a new level of transparency into model assumptions and uncertainties, as the industry continues to settle claims from Sandy, RMS is committed to supporting an open dialogue around areas of model uncertainty and ongoing learning to better inform long-term insurance strategies.



Sandy's Path

On October 22, 2012, in the western Caribbean Sea, a tropical wave intensified over the course of six hours to become the 18th named storm of the 2012 Atlantic Hurricane Season. Over the next two days, Tropical Storm Sandy tracked northward toward the Greater Antilles, strengthening into the season's 10th hurricane on October 24 (Figure 1). Hurricane Sandy made landfall in Jamaica the same day as a Category 1 storm with sustained winds of 80 mph (130 km/h) before continuing north over the Caribbean, where it strengthened into a Category 2 hurricane with winds reaching 110 mph (175 km/h). Sandy made landfall in Cuba on October 25, weakened to a Category 1 storm, and impacted the Bahamas the following day.

By October 27, Sandy had taken a northwest turn, and briefly weakened to tropical storm status before re-intensifying to a Category 1 hurricane and tracking northeast along the U.S. East Coast, approximately 300 mi (480 km) offshore. On October 28, Sandy curved back toward the U.S., wrapping around an upper-level low situated over the eastern United States. By October 29, Sandy's wind field spanned a diameter of over 1,000 nautical miles (1,150 mi or 1,850 km)—roughly the size of Mongolia—and Sandy became the largest Atlantic hurricane on record as it tracked toward the New Jersey coast. As Sandy reached the mid-latitudes, it began to lose its tropical characteristics and merged with a mid-latitude cyclone in the phenomenon known as extratropical transition, a common process when hurricanes reach the mid-latitudes and the ocean waters become cooler. One hour prior to landfall, having completed its extratropical transition, Hurricane Sandy was reclassified as a post-tropical cyclone by the National Hurricane Center (NHC). Compared to tropical systems, transitioning storms have more irregular wind fields, broader wind swaths, and tend to move much more quickly. Hurricanes undergoing extratropical transition thus require special modeling, accomplished with the transitioning wind field model in the version 11.0 RMS[®] North Atlantic hurricane model suite.



Figure 1: Track of Hurricane Sandy, showing the location and intensity of the storm at 6-hour intervals from October 19–31, 2012. Symbols denote storm status (circle = tropical cyclone; triangle = post-tropical cyclone, remnant low, or tropical disturbance), and colors indicate intensity on the Saffir-Simpson Hurricane Scale (light blue = tropical depression; bright blue = tropical storm; light yellow = Category 1 hurricane; dark yellow = Category 2 hurricane (*Storm track data from the National Hurricane Center; background image from NASA*).



Sandy made landfall on Monday, October 29 at 8:00 p.m. ET (0000 UTC) near Brigantine, New Jersey, just northeast of Atlantic City, with sustained winds of 80 mph (130 km/h). Sandy's large size, in combination with its slow movement offshore, low pressure, and timing of landfall (during a full moon high tide—one of the highest tides of the month) resulted in catastrophic coastal flooding impacts in New York and coastal New Jersey.

In New York City's Lower Manhattan (the Battery), flood elevations reached a record 14.1 ft (4.3 m) the night Sandy made landfall. Here, the high tide drove the flood levels to even greater heights, and the coastal geography (the Long Island and New Jersey coastlines meet New York Bay at a right angle), acted to funnel the bulging sea waters farther inland. The storm was not even classified as a hurricane at landfall, but still caused a Category 2 storm surge impact in New York City. Streets, tunnels, and subway lines flooded extensively throughout the New York metro area, with severe flooding reported throughout Lower Manhattan, New York City's Financial District, Hoboken, Staten Island, Queens, the barrier islands, New Jersey resort towns, and along coastal areas from the Delaware Bay northward to Connecticut.

Superstorm Sandy's unique nature and unprecedented impacts were well characterized by the RMS U.S. Hurricane Model, which incorporated significant advances in the science of modeling extratropical storms in the northeast, and a high-resolution hydrodynamic modeling capability to capture coastal flooding caused by storm surge.

Assessing Sandy's Impacts

Sandy was one of the largest, most destructive events in recent history, in large part due to its catastrophic surge impacts, which accounted for an overwhelming 65% of Sandy's total insured loss. By the time Sandy finally dissipated into a remnant trough over western Pennsylvania on October 31, it had caused over 70 fatalities throughout the U.S., making it the greatest number of U.S. direct fatalities related to a tropical cyclone outside of the southern states since Hurricane Agnes in 1972.² While the most severe damage occurred in New York and New Jersey, Sandy impacted a total of 24 states, including the entire Eastern Seaboard from Florida to Maine, and west across the Appalachian Mountains into Michigan and Wisconsin.

The system brought hurricane-force winds, rain, and coastal flooding to the Mid-Atlantic and Northeast, and significant snowfall to parts of Appalachia and the Midwest. Power outages (in many cases lasting multiple days) were reported in 15 states, impacting nearly 8.5 million customers, and causing severe business interruption (BI) and contingent BI. Sandy currently ranks as the second costliest Atlantic hurricane in U.S. history, behind only Hurricane Katrina, with economic loss estimates exceeding \$65 billion in the U.S. and \$3 billion in the Caribbean.³ It could take months to years for all insurance claims to be settled, and the final loss tallied, and RMS is working with clients to analyze claims data at a detailed level.

The Importance of Coastal Flood Modeling

Similar to 2005's Hurricane Katrina, Sandy highlighted how coastal flood can drive more insurance loss than hurricane wind. Flood damage is highly sensitive to the precise location of the exposure relative to the hazard, emphasizing the need for physically based "numerical" catastrophe models with high-resolution

² http://www.nhc.noaa.gov/data/tcr/AL182012_Sandy.pdf

³ As of June 2013. Hurricane/Post-Tropical Cyclone Sandy, October 22-29, 2012 Service Assessment. United States National Oceanic and Atmospheric Administration's National Weather Service. June 2013.



modeling capability. Numerical models more realistically simulate the storm surge and the resulting coastal flooding and improve model results, as opposed to traditional approaches, which have proven to underestimate coastal flooding losses for major events, as in Katrina's aftermath. RMS hurricane models incorporate the most advanced physical coastal flood modeling technology available, deploying the highly regarded "MIKE 21" model from DHI Water and Environment.⁴ MIKE 21 is one of only two numerical models approved by FEMA as meeting the minimum requirements for modeling for the National Flood Insurance Program.

To represent the timing, location, and severity of coastal flood in the RMS U.S. Hurricane Model, this high-resolution hydrodynamic model is dynamically linked with the hurricane wind field to simulate the storm surge throughout the entire lifecycle of a hurricane. The onshore impacts of surge are modeled using detailed data on topography, land use, land cover, the contours of the coastline, and water depth.

This unique approach to coastal flood modeling captures the localized nature of flooding and damage, enabling clients to assess damage and loss to individual buildings and at street level. RMS is the only catastrophe modeling company to employ such technology in its hurricane model.

Post-Event Modeling and Validation

To support clients in using the RMS U.S. Hurricane Model to assess Sandy's impacts on their business, RMS simulated the entire lifecycle of the storm and issued a range of Catastrophe Response tools as the event unfolded.

Storm tracks from the U.S. Hurricane Model event set provided a credible proxy for Sandy's impacts in the immediate aftermath of the event. In the days that followed, RMS provided high-resolution wind and flood hazard footprints—generated using our hurricane and coastal flood modeling capabilities—the exact same modeling technology that we used to create the RMS stochastic event set, and verified against 300 actual wind and flood observations. These footprints were accompanied by tools allowing clients to examine associated uncertainty in the wind and coastal flood damage. These and other deliverables, including recommendations on how to characterize individual portfolio losses, are standard RMS[®] Catastrophe Response deliverables.

Thus far, the RMS methods used to model Sandy's wind and storm surge impact have been well validated by the high number of recorded wind and flood observations from the storm, giving confidence in the completeness and accuracy of modeling these perils with the U.S. Hurricane Model.

The RMS high-resolution flood footprint revealed the street-by-street pattern of flooding in downtown New York City, along coastal New Jersey, and other dense areas where flooding closely follows small-scale changes in topography that cannot be captured by modeling at the ZIP Code level. The footprint was verified by measurements of flood elevations at the coastline, as well as our reconnaissance team's observations of onshore impacts.

Similarly, the wind field reconstruction, which employed the wind field modeling capabilities for transitioned hurricane wind fields in v11, was verified against 170 unique wind observations from the storm, together with our reconnaissance teams' assessments of the level of property damage, including the contribution of

⁴ <http://www.dhigroup.com/Aboutus/CompanyProfile.aspx>



treefall. Thus far, the data supports RMS' v11 vulnerability curves well. Clients interested in examining vulnerability uncertainty can use the high/low vulnerability functions in the U.S. Hurricane Model to explore the impact of more conservative or less conservative views of northeast vulnerability on overall portfolio losses.

One of the key uncertainties following any hurricane-related coastal flood loss is the degree to which residential writers who have written wind-only policies may be liable for flood losses for properties with no National Flood Insurance Protection (NFIP) cover, known as "coverage leakage." After conducting extensive research into this topic, RMS has found that there is high variability in the amount of coverage leakage from storm to storm, which will be documented more fully in the coming months. To bring more transparency to the impacts of this uncertainty, the RMS hurricane model includes the ability to customize the degree of coverage leakage, allowing clients to input their own experience and policy terms and conditions, and to sensitivity test the impact of different assumptions on resulting loss estimates.

The RMS Industry Loss Estimate

As of the end of July 2013, the Property Claims Services (PCS) industry loss estimate for Sandy is \$18.75 billion—a 70% increase over its initial \$11 billion estimate released on November 21, 2012.⁵ RMS' \$20–25 billion industry loss estimate for Sandy, issued on November 14, 2012, accounts for insured losses that are not captured within the PCS estimate, but its closeness shows that the RMS U.S. Hurricane Model accurately characterized Sandy's impacts and resulting loss—particularly for the coastal flood component.

The RMS-issued storm tracks and footprints, along with RMS post-event field reconnaissance and other key observational data were used to reconstruct the event in the U.S. Hurricane Model. RMS' \$20–25 billion insured loss estimate corresponds to a return period of 50–90 years for the Northeast and Mid-Atlantic regions. This estimate includes residential, commercial, and automobile wind and coastal flood losses.

The RMS industry loss estimate is composed of the following information:

- An industry breakdown of 65% commercial lines and 35% personal lines loss (inclusive of several hundred million in modeled auto losses), which is driven by estimates of insured flood losses to commercial and industrial lines of business
- Coastal flood damage accounts for approximately 65% of the total insured loss, with the remaining 35% attributed to wind-related damage
- Wind damage is responsible for the majority (80%) of modeled personal lines loss, while surge damage accounts for the majority (85%) of modeled commercial lines loss
- RMS estimates that approximately 50% of the insured losses will arise from New Jersey, 40% from New York, and 10% from other states
- The range in the industry loss estimate reflects sensitivity testing around the application of hurricane and wind deductibles.

Sources of non-modeled loss in Sandy, which are not accounted for in the RMS estimate, include, but are not limited to:

- Losses to the National Flood Insurance Program (NFIP), public buildings, or infrastructure

⁵ Source: *Property Casualty 360* <http://www.propertycasualty360.com/2013/01/23/new-insured-loss-estimate-of-1875b-from-sandy-pcs>. Note that further increases are possible in future updates.



- Sectors of the industry not covered explicitly in the RMS Industry Exposure Database, such as inland marine, cargo, watercraft, and aviation lines of business
- Physical phenomena that have not been explicitly modeled, such as inland flooding, snowfall, or environmental liability from water-borne pollutants
- Contingent BI caused by power outages

These sources of non-modeled loss are not expected to have a significant impact on the insurance industry losses presented by RMS. Nevertheless, RMS is striving to reduce the extent of non-modeled phenomena in the future through the development of more comprehensive models.

Lessons for 2013 and Beyond

The latest version of the RMS North Atlantic Hurricane model suite, released on July 31, 2013 as part of RMS RiskLink 13.0, incorporates updates to the coverage leakage assumptions for uninsured flood losses to reflect the latest industry practice, including early insights from Superstorm Sandy. The release also incorporates new high-resolution data and updates to the long-term rates to account for recent changes to HURDAT (the official Atlantic basin hurricane database), as well as a new medium-term rate forecast for the next 5 years, driven by new research and findings on the impacts of climate variability on hurricane activity.

Catastrophe models are highly sophisticated tools that provide a wealth of understanding and insight, yet RMS recognizes that elements of catastrophe risk remain, by their very nature, uncertain and subject to ongoing learning. Sandy showed that one of the biggest sources of uncertainty around hurricane risk continues to be the amount of property that is insured against surge driven flood losses for commercial lines of business, as well as the degree to which residential and commercial flood losses are paid out under wind/fire insurance policies. We will continue to research these issues, and work with our clients to enable better capture of this data.

Thus far, the methods used to model Sandy's wind and storm surge impacts have proven valid in comparisons with actual storm observations, lending confidence to the completeness and accuracy of the U.S. Hurricane Model's wind and surge capabilities. RMS will continue to gather and analyze detailed claims data from Sandy over the coming months and years, adding to our existing claims database. The storm's unique characteristics will provide valuable data points for further model validation and testing in a part of the world with little recent real-world experience.