FEMA Employs New State-of-the-art Technology to Predict Losses from Hurricane Isabel

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Background

As Isabel threatened the east coast of the U.S., FEMA got a chance to test out the newest innovation in predicting losses from natural disasters. In mid-September, FEMA's Mitigation Division (MT) was performing acceptance testing on the latest version of HAZUS-MH® (Hazards-US-Multihazard), its state-of-the-art Geographic Information System (GIS) loss estimation software. HAZUS-MH is the latest in a series of HAZUS releases. Since FEMA was in possession of a fully operational version of HAZUS-MH, FEMA elected to utilize HAZUS-MH in preparing for the landfall of Hurricane Isabel.

FEMA successfully employed the HAZUS-MH Hurricane Wind Module to develop loss estimates based on the projected track and intensity of Hurricane Isabel. On Friday, September 13, 2003, the National Hurricane Center's models indicated that a Hurricane Isabel landfall along the east coast of the U.S. was quite possible. That same day, in response to this growing likelihood that a major hurricane would make landfall in the U.S., FEMA began mobilizing its response resources and consulting with its state emergency management counterparts. To get a sense of the potential impacts from such a major hurricane event, senior officials of FEMA's Response Division requested that MT begin assessing these potential impacts.

As Hurricane Isabel moved towards the east coast of the U.S., MT employed a number of approaches to estimating potential losses. These approaches included using:

- For long-range estimates (>5 days before expected landfall), historic hurricane data, combined with data on today's built environment to estimate potential losses today from these historical events;
- Using mid-range (3-5 days before expected landfall) hurricane forecasts from the National Hurricane Center (NHC)
- Using short-range (1-3 days before expected landfall) hurricane forecasts from the National Hurricane Center (NHC)
- Using real time (day of landfall) hurricane forecasts from the National Hurricane Center (NHC)

As demonstrated in Figure #1, as Hurricane Isabel approached the North Carolina coast, the estimates of the intensity at landfall trended downward. As this reduced intensity was incorporated in the HAZUS-MH meteorological input data, subsequent HAZUS-MH runs produced an expected corresponding reduction in estimated losses.

To support FEMA in providing loss estimate during this emergency, FEMA issued a task order to Applied Research Associates (ARA) of Raleigh, N.C. for modeling and technical

support. ARA is the HAZUS-MH hurricane module developer and was therefore uniquely qualified to support FEMA during this event. ARA performed several important roles that included:

- Providing expert advice to FEMA on the proper meteorological input data for HAZUS hurricane scenarios
- Conducting peer review of the HAZUS runs completed by FEMA, including duplicating the FEMA model runs to ensure the reliability of the output.
- Running a number of alternative wind field simulation models in an attempt to understand the range of possible outcomes and produce a best estimate of the on land wind field.
- Providing important data sets for the overall performance evaluation of the HAZUS-MH hurricane module as part of the product acceptance testing.

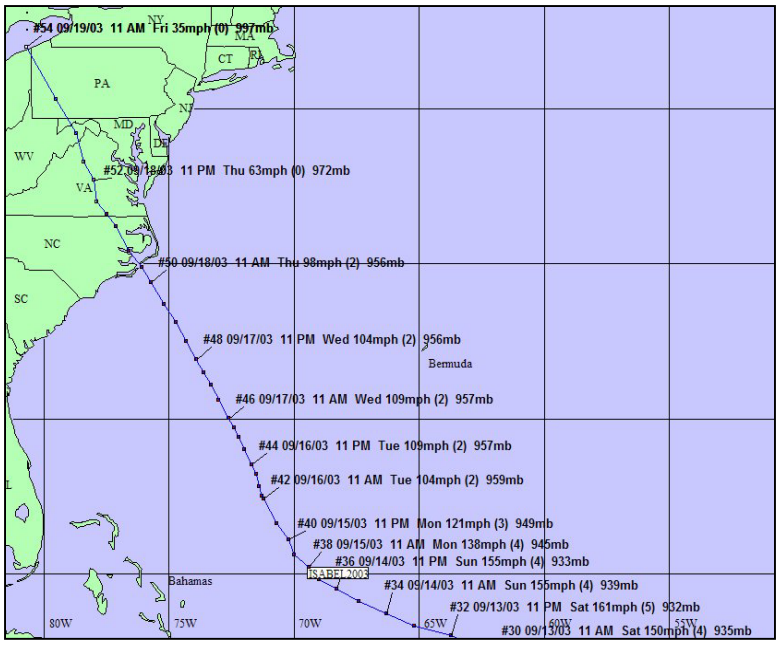


Figure #1: Hurricane Isabel Track Showing Advisory Number, Date, Time, Day, Maximum Sustained Wind Speed, Saffir-Simpson Scale Category (in parenthesis), and Central

Long Range Loss Estimation (>5 days before landfall)

The first discussions regarding the use of HAZUS-MH to support the Response Directorate began on Friday, September 13, 2003. At that time, Hurricane Isabel was more than 5 days from making landfall and was a category 5 Hurricane. Although the National Hurricane Center (NHC) began issuing five-day forecasts for the first time during the 2003 hurricane season, the storm was still too far off shore to project either the intensity or the precise location of the storm at landfall. However, the projected five-day track indicated that Hurricane Isabel might make landfall near the border of South Carolina and North Carolina. Since landfall was beyond the limits of the NHC forecast, both in terms of track and intensity, FEMA looked to the historical hurricane library within HAZUS-MH for hurricanes that might reasonably approximate the potential losses from Hurricane Isabel.

In reviewing the HAZUS historical hurricane library, it appeared that Hurricane Hazel (1954) and Hurricane Hugo (1989) presented characteristics similar to those that Hurricane Isabel might exhibit if and when it made landfall. Therefore, to produce the first estimates of potential losses from Isabel, the characteristics of Hurricanes Hazel and Hugo, including track, size, and intensity, and the present built environment in North Carolina and South Carolina (as defined in the national datasets in HAZUS-MH) were utilized to build the HAZUS run.

As Figure #2 indicates, Hurricane Hazel tracked in a northerly direction through North Carolina into Virginia generating peak gust winds (3-second average) in the 155-170 mph range near the point of landfall. As Figure #3 indicates, Hurricane Hugo tracked in a northwesterly direction through South Carolina into western North Carolina generating peak gust winds of in the 125-140 mph range near the point of landfall.

Based on Hurricane Hazel's track, size and intensity, HAZUS estimated several tens of billion of dollars in wind damage would occur given today's built environment and about 140,000 people would seek temporary public shelter as a result of wind damage to their residences. Based on Hurricane Hugo's track, size and intensity, HAZUS estimated approximately 5 billion dollars in direct economic losses from wind damage would occur and about 3,000 people would seek temporary public shelter as a result of wind damage to their residences.

Midrange Loss Estimation (3-5 days before landfall)

As the 5-day Isabel forecasted track projection reached the coast of the U.S., FEMA moved from using historic hurricanes to building hurricane scenarios based on forecast information provided by the National Hurricane Center. The data required by HAZUS-MH to generate a hurricane scenario from an NHC Forecast/Advisory are the time, position, (latitude and longitude), maximum sustained wind speed (1-minute average), maximum radius to hurricane winds, and central pressure at each point along the predicted track.

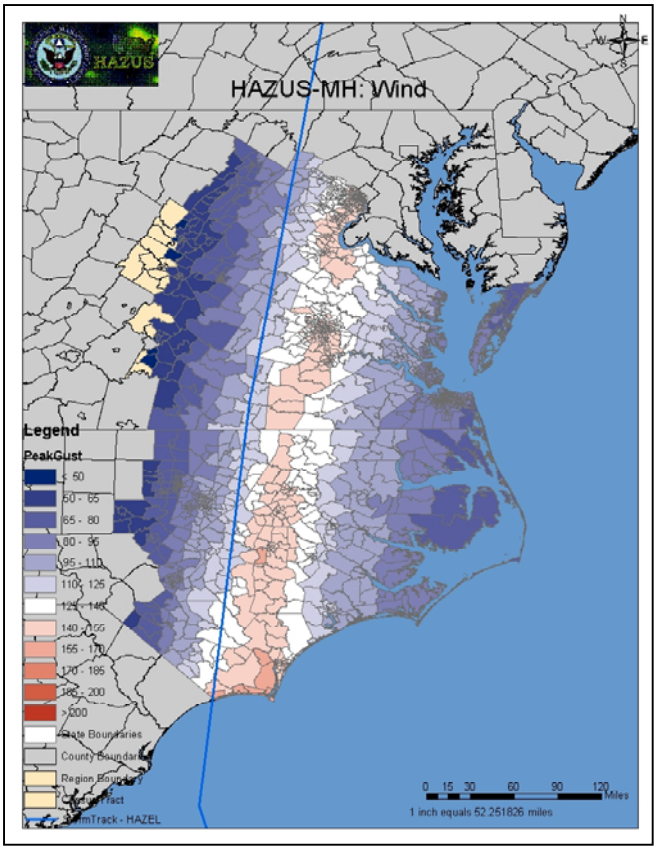


Figure #2: Peak Gusts Wind Field From Hurricane Hazel in 1954, Taken From the HAZUS Historic Hurricane Library

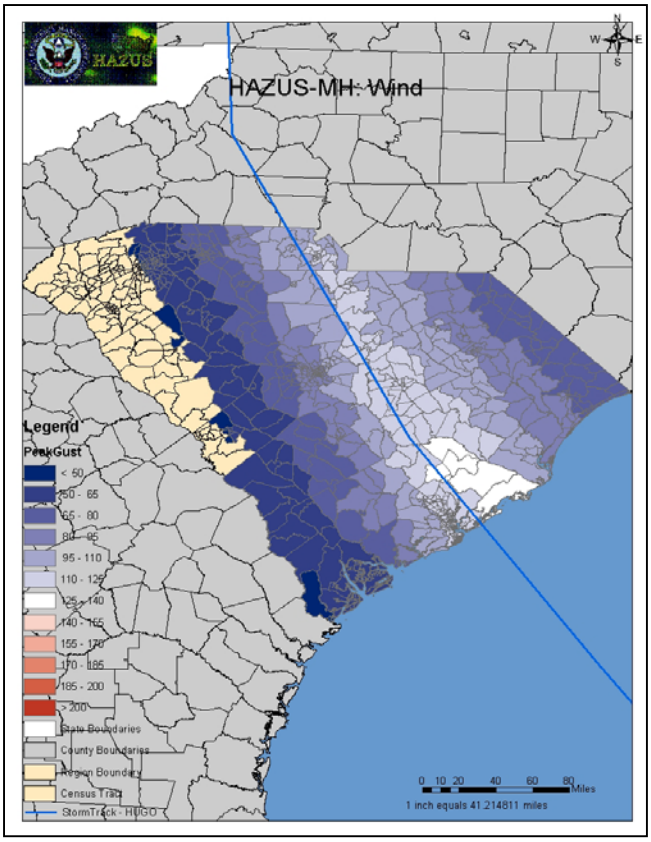


Figure #3: Peak Gusts Wind Field From Hurricane Hugo in 1989, Taken From the HAZUS Historic Hurricane Library

Based on Advisory #37, issued at 0500 EDT on Monday, September 15, 2003, Hurricane Isabel was forecast to come ashore as a Category 3 hurricane with maximum peak wind gusts of 125-140 mph (see Figure #4). Based on Hurricane Isabel's forecasted track, size and intensity, HAZUS estimated 8 billion dollars in direct economic losses from wind damage would occur and about 4,000 people would seek temporary public shelter as a result of wind damage to their residences. These estimates appeared reasonable considering the high peak gust wind speeds forecasted for the Norfolk area.

As Isabel approached the coast, MT was able to further refine potential loss estimates for use by

Short-range Loss Estimation (1-3 days before landfall to landfall)

senior government officials who needed to gain an understanding of the potential scale of the event and take necessary actions to minimize deaths, injuries, and economic losses, as well as speed the response and recovery process. During the 3-day period before Isabel made landfall, the predicted track did not vary significantly, but the loss estimates for Virginia did vary significantly as the forecasted track moved towards or away from the heavily populated areas of Norfolk and Richmond. During Monday and Tuesday, however, the overall intensity of the storm weakened substantially, as the estimated maximum sustained wind speeds offshore decreased from 150 mph (Advisory #37) to 104 mph on (Advisory #42). This weakening was partially offset by an increase in the maximum radius to hurricane winds from 115 miles (Advisory #37) to 144 miles (Advisory #45).

Based on Advisory #45, issued at 0500 EDT on Wednesday, September 17, 2003, Hurricane Isabel was forecast to come ashore as a Category 2 hurricane with maximum peak wind gusts of 110-125 mph (see Figure #5). Based on

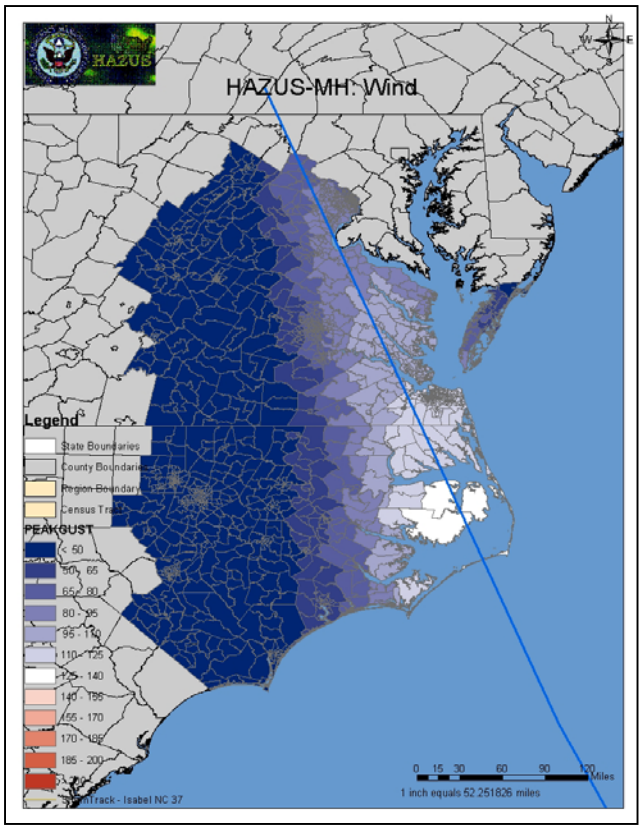


Figure #4: Forecasted Peak Gusts Wind Field For Hurricane Isabel, Based on NHC Advisory #37

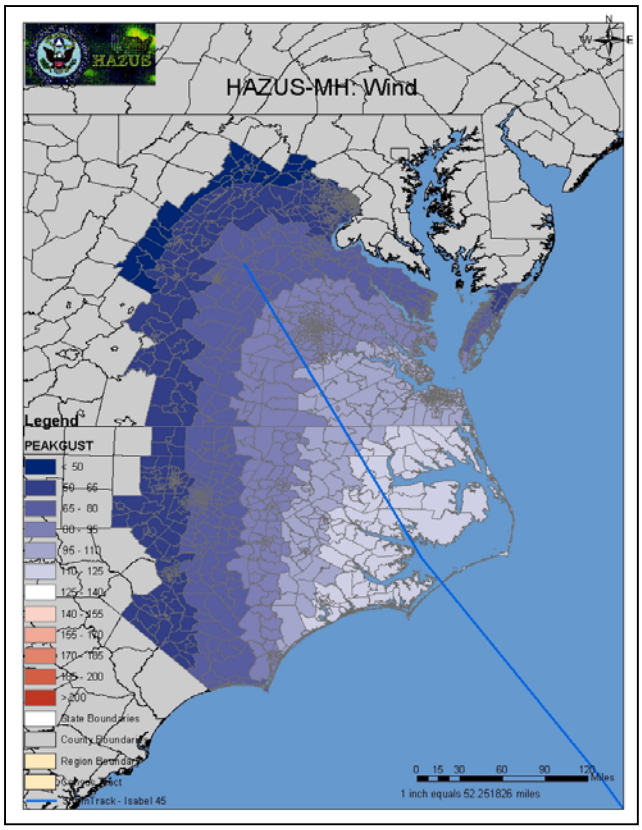


Figure #5: Forecasted Peak Gusts Wind Field For Hurricane Isabel, Based on NHC Advisory #45

this forecast, HAZUS estimated 7 billion dollars in direct economic losses from wind damage would occur and about 4,000 people would seek temporary public shelter as a result of wind damage to their residences. This track still showed a significant impact of damaging winds in the southern portions of the greater Washington, D.C. metropolitan area.

As Hurricane Isabel approached the coast of North Carolina, another HAZUS run was completed. Based on Advisory #49, issued at 0500 EDT on Thursday, September 18, 2003, Hurricane Isabel was continuing to weaken. Although the forecast still resulted in peak gusts of 110-125 mph at the coast, the inland swath of strong winds was shrinking (see Figure #6). Additionally, the storm track was forecast to move slightly more to the west, further moving the highest winds away from the Richmond and Norfolk metropolitan areas. Based on the more westerly track and reduced intensity, HAZUS estimated 2 billion dollars in direct economic losses from wind damage would occur and about 500 people would seek temporary public shelter as a result of wind damage to their residences. This was a significant reduction from the forecast from Advisory #45, issued just 24 hours before.

As Hurricane Isabel made landfall, the final HAZUS run, based on NHC predicted track and intensity, was completed. Based on Advisories #50, 50A and 50B, issued at 0500, 1300, and 1500 EDT, respectively, on Thursday, September 18, 2003, the intensity of Hurricane Isabel was forecast to continue weakening to a Category 2 hurricane with maximum peak wind gusts of 95-110 mph (see Figures #7and #8). Based on Hurricane Isabel's lessened forecasted intensity, HAZUS estimated 1.3 billion dollars in direct economic losses from wind damage would occur and about 200 people would seek

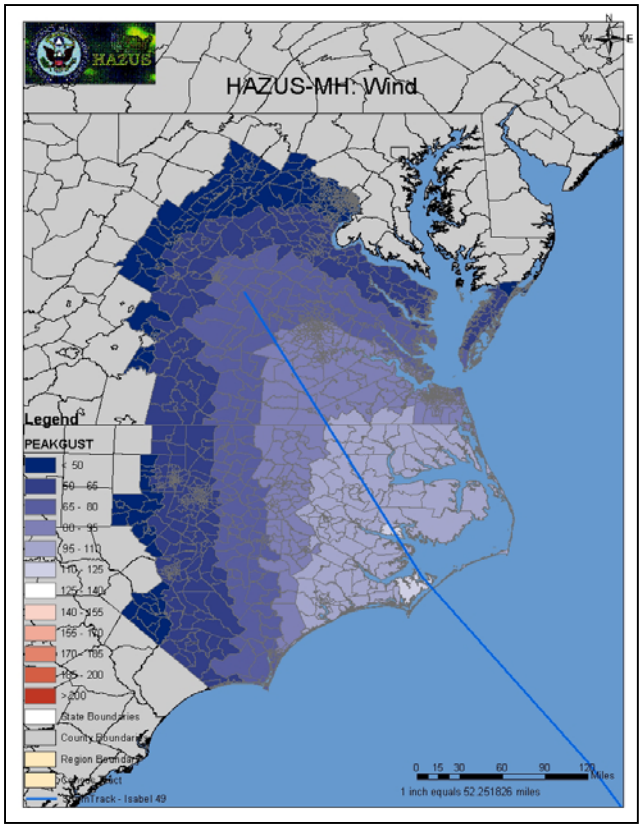


Figure #6: Forecasted Peak Gusts Wind Field For Hurricane Isabel, Based on NHC Advisory #49

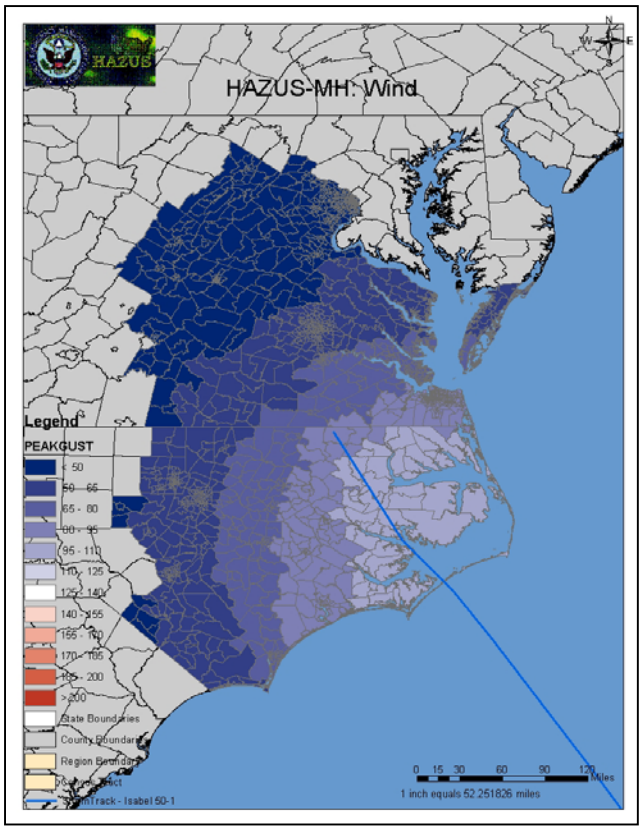


Figure #7: Forecasted Peak Gusts Wind Field For Hurricane Isabel, Based on NHC Advisories #50, 50A, and 50B

temporary public shelter as a result of wind damage to their residences.

In addition to supporting FEMA's HAZUS runs based on the official NHC Advisories, the modeling team at ARA was concurrently collecting and analyzing additional sources of data to develop a best estimate of the entire hurricane windfield.

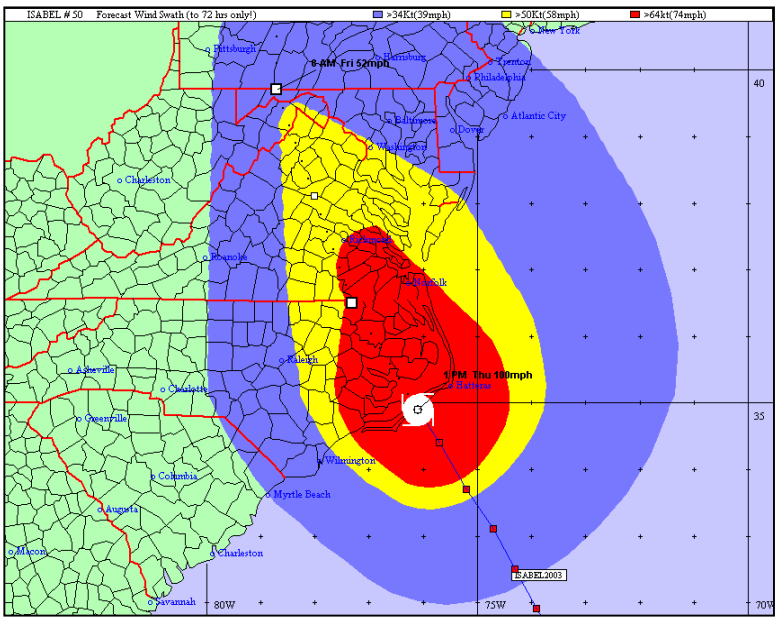


Figure #8: Estimated Wind Field from Hurrevac Software, Based on NHC Advisory #50

The best estimate tracks were defined using radius to maximum winds (R_{max}) and pressure profile parameter (B) instead of radius to hurricane winds and maximum sustained wind speed. R_{max} and B are fundamental inputs to the HAZUS hurricane windfield model, but they are not available in the official NHC Advisories. To estimate these parameters, the

Real-Time Loss Estimation

ARA team relied heavily on NHC's H*Wind product. H*Wind is an experimental product that uses flight level data, surface observations, dropsonde data, remote sensing inputs, and expert knowledge of hurricane windfield characteristics to develop a snapshot of the entire surface level windfield.

Using the projected track coordinates from the NHC Advisories, together with estimates of R_{max} and B derived from NHC's H*Wind model and projections of inland central pressures based on the HAZUS inland decay model, the ARA team began generating best estimate loss projections in parallel with the purely Advisory-based loss projections described in the previous sections.

As Isabel crossed the Outer Banks, real-time anemometer readings from offshore buoys and several onshore locations were used to further refine the best estimate wind field. Figure #9 shows a sample comparison of the best estimate wind trace to observations recorded at the Cape Lookout C-MAN station.

The final best estimate maximum peak gust windfield, generated within 24 hours of landfall, is shown in Figure #10. Using the best estimate windfield, HAZUS estimated 1.0 billion dollars in direct economic losses from wind damage would occur and about

100 people would seek temporary public shelter as a result of wind damage to their residences.

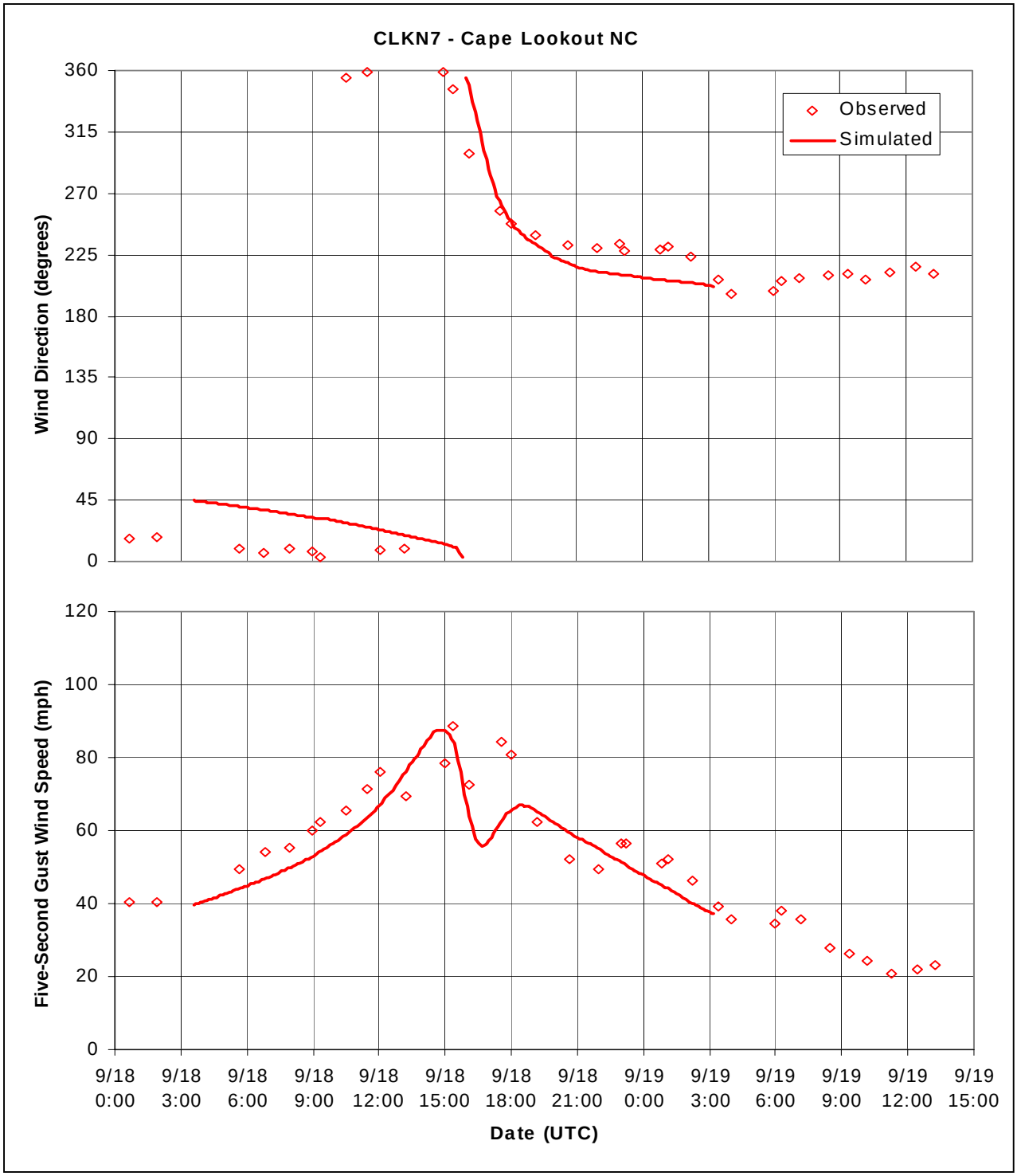


Figure #9: Comparison of Best Estimate Wind Trace to Observations Recorded at the Cape Lookout C-MAN Station

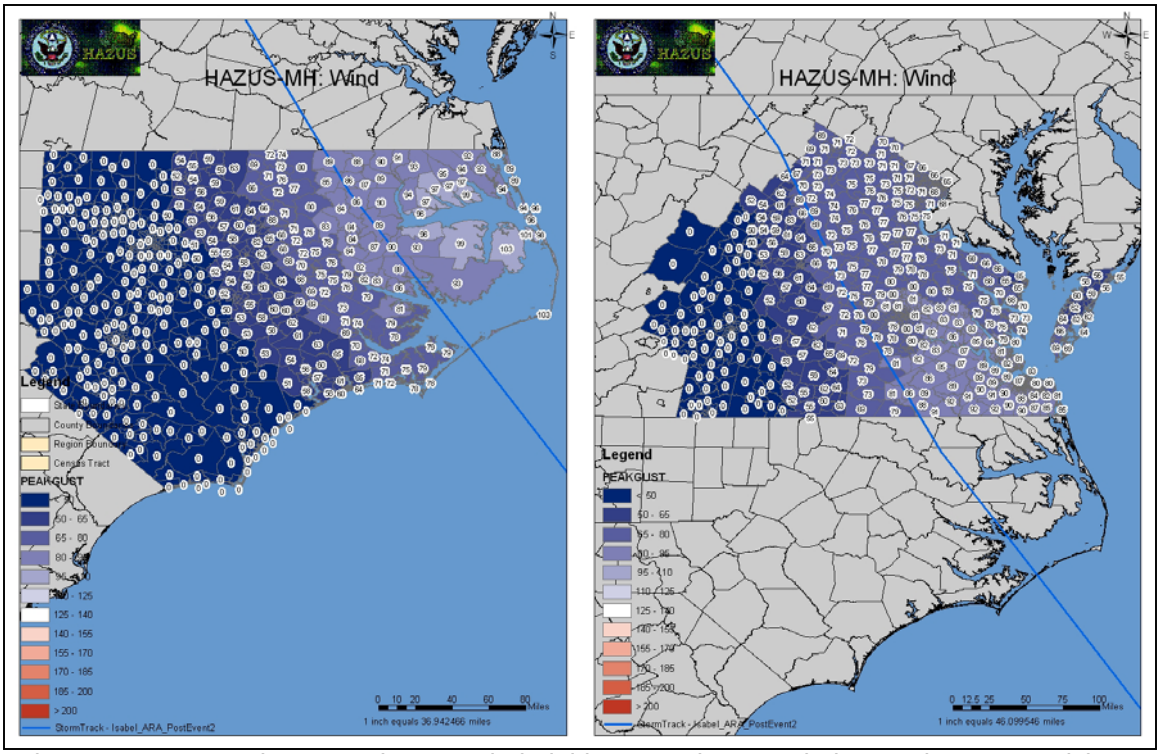


Figure #10: Best Estimate Peak Gust Wind Field For Hurricane Isabel, Based on NHC Advisory #54, H*Wind, HAZUS Inland Decay Model, and Real-Time Anemometer Observations. *(Note: The "0" wind speed values are shown in census tracks where the maximum peak gust winds were less than 50 mph.)*

Within 24 hours of landfall, the H*Wind research team at NHC, led by Dr. Mark Powell, also provided an estimate of the peak gust wind swath. Due to differences in inland decay models, the inland winds in the H*Wind swath were generally lower than the ARA best estimate windfield. Based on the H*Wind swaths, HAZUS estimated 460 million dollars in direct economic losses from wind damage would occur and less than 100 people would seek temporary public shelter as a result of wind damage to their residences. A subsequent update to the H*Wind swath was issued by the NHC research team on September 23, 2003. Using the updated swath, HAZUS estimated 960 million dollars in direct economic losses from wind damage would occur and about 100 people would seek temporary public shelter as a result of wind damage to their residences.

Assessing the Accuracy of HAZUS-MH Wind Loss Estimates for Hurricane Isabel

Upon landfall of Hurricane Isabel, FEMA directed ARA to immediately conduct a validate survey of damage to further assess the accuracy of HAZUS-MH wind loss estimates. The preliminary results of this survey indicate that wind thrown trees were a major contributor to wind-induced property damage. As expected, direct wind damage to roofs, windows, and walls was generally light. A preliminary sensitivity study conducted with HAZUS-MH prior to landfall indicated that tree damage to houses would account for over 40% of the total estimated losses in North Carolina. Detailed comparisons of actual damage observations to HAZUS-MH predictions are underway for several locations in northeastern North Carolina.

On October 2, 2003 the Property Claim Services (PCS) unit of Insurance Services Office, Inc. (ISO), a leading source of information, products and services related to property and liability risk, issued a press release stating that insurers are expected to pay $450 million in losses in Virginia and $170 million in North Carolina to homeowners and businesses for insured property losses from Hurricane Isabel.

Figure #11: Hurricane Isabel
HAZUS Wind Loss Estimates for NC and VA
(In millions)

State	H*Wind (9/23/03)	ARA Best Track (9/19/03)	ISO Estimated Insured Losses (10/2/03)
NC	$360	$250	$170
VA	$600	$750	$450
Total	$960	$1000	$620

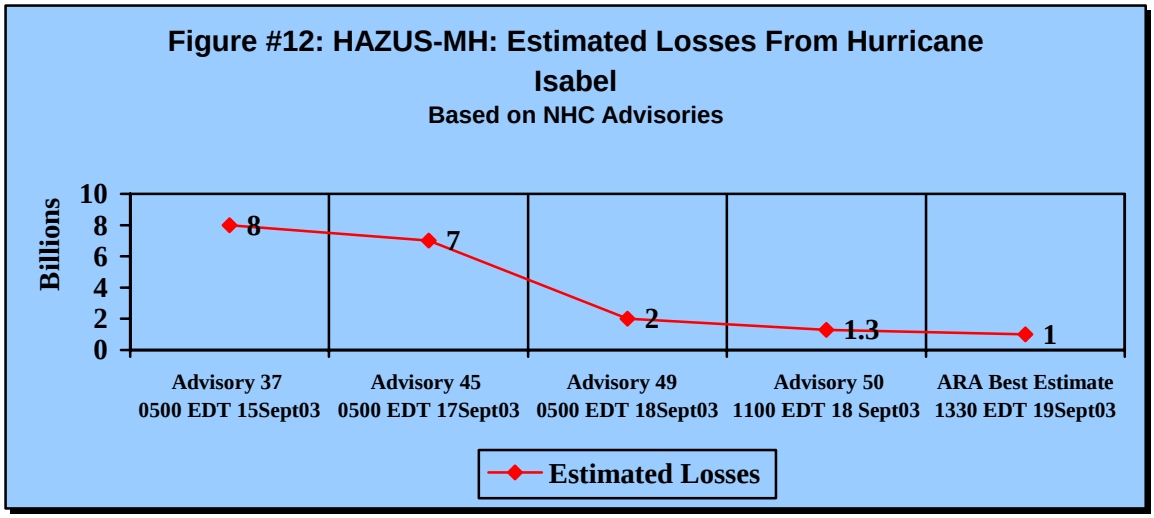
PCS states that it developed its preliminary insured property loss estimates from actual claims reported to insurers by homeowners and commercial policyholders. They further stated that nearly 458,000 residential and commercial claims are anticipated from Isabel's victims, said PCS (this includes losses in all impacted areas).

PCS estimates represent anticipated insured loss on an industry wide basis arising from catastrophes, reflecting the total net insurance payment for personal and commercial property lines of insurance covering fixed property, personal property, vehicles, boats, related property items and business-interruption losses. The estimates exclude losses insured by the National Flood Insurance Program as well as all loss-adjustment expenses.

Lessons Learned From Hurricane Isabel

Much was learned in this first use of HAZUS to predict potential losses from an impending disaster from a hurricane. Some lessons learned include:

- Predicting potential losses from a landfalling hurricane, prior to landfalling remains an imprecise science. Figure #12 clearly shows how sensitive loss estimates are to forecasted storm track, size, and intensity.



- Predicting potential losses from a landfalling hurricane more than 5 days before forecasted landfall is speculative at best.
- Predicting potential losses from a landfalling hurricane more than 3 days, but less than 5 days before forecasted landfall, can provide a sense of the magnitude of the impending event. This information can be used to get a sense of the potential scale of the emergency response and to begin making preparations at the state or regional level.
- Predicting potential losses from a landfalling hurricane less than 3 days before forecasted landfall can provide valuable information to federal, state, and local emergency managers, including a sense of the magnitude of the impending event and where damages might be concentrated.
- As Hurricane Isabel approached the east coast of the U.S., the forecast models used by the National Hurricane Center produced unusually high agreement on storm track and intensity. This convergence resulted in forecasts in which the NHC expressed a high level of confidence. Future, less predictable hurricanes could result in additional uncertainties and complicate producing accurate loss estimates using HAZUS.
- Using HAZUS to predict loss from a landfalling hurricane requires expert skills in meteorology to validate the input data used to develop the hurricane scenario and expert skills in wind and forensic engineering to evaluate and efficacy and accuracy of the model output.

History of HAZUS

FEMA's Mitigation Division (MT) began developing HAZUS in the mid 1990's as the advent of GIS made such a loss estimation model possible. In 1997, MT released the first version of HAZUS that estimated the losses from earthquakes. This was followed, in 1999, by a release that further improved the accuracy of earthquake loss estimations and improvements in software reduced the processing time from hours to minutes. Since the 1999 release, MT has been working to expand HAZUS to include the affects of high winds and flooding. When Hurricane Isabel struck, MT was in the process of conducting acceptance testing on the latest release, HAZUS-MH, and was able to utilize the hurricane wind module to estimate wind losses. For more information on HAZUS, go to http://www.fema.gov/hazus/.

HAZUS-MH, to be released in late 2003**,** is a nationally applicable standardized methodology and software program that will contain models for estimating potential losses from earthquakes, floods, and hurricanes. HAZUS-MH is developed under contract with the National Institute of Building Sciences (NIBS) for the Federal Emergency Management Agency (FEMA). NIBS maintains committees of wind, flood, earthquake and software experts to provide technical oversight and guidance to HAZUS-MH development. Loss estimates produced by HAZUS-MH will be based on current scientific and engineering knowledge of the effects of hurricanes, floods and earthquakes. Estimating losses is essential to decision-making at all levels of government, providing a basis for developing mitigation plans and policies, emergency preparedness, and response and recovery planning.

HAZUS-MH utilizes state-of-the-art geographic information system (GIS) software to map and display hazard data, and the results of damage and economic loss estimates for buildings and infrastructure. It also allows users to estimate the impacts of hurricanes, floods and earthquakes to populations. HAZUS-MH runs faster than HAZUS-99 to facilitate use in real time to support response and recovery following a natural disaster.