TROPICAL CYCLONE MODELING

UNIT 5

RMS® CCRA® Training Program

CCRA™
Certified Catastrophe Risk Analyst

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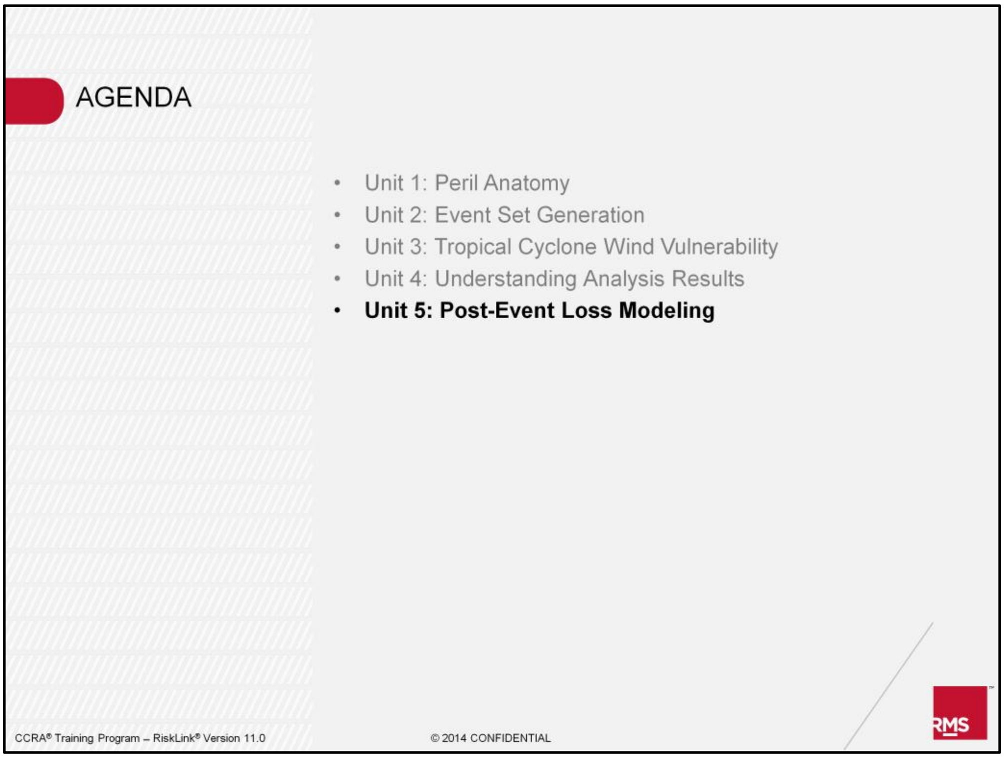
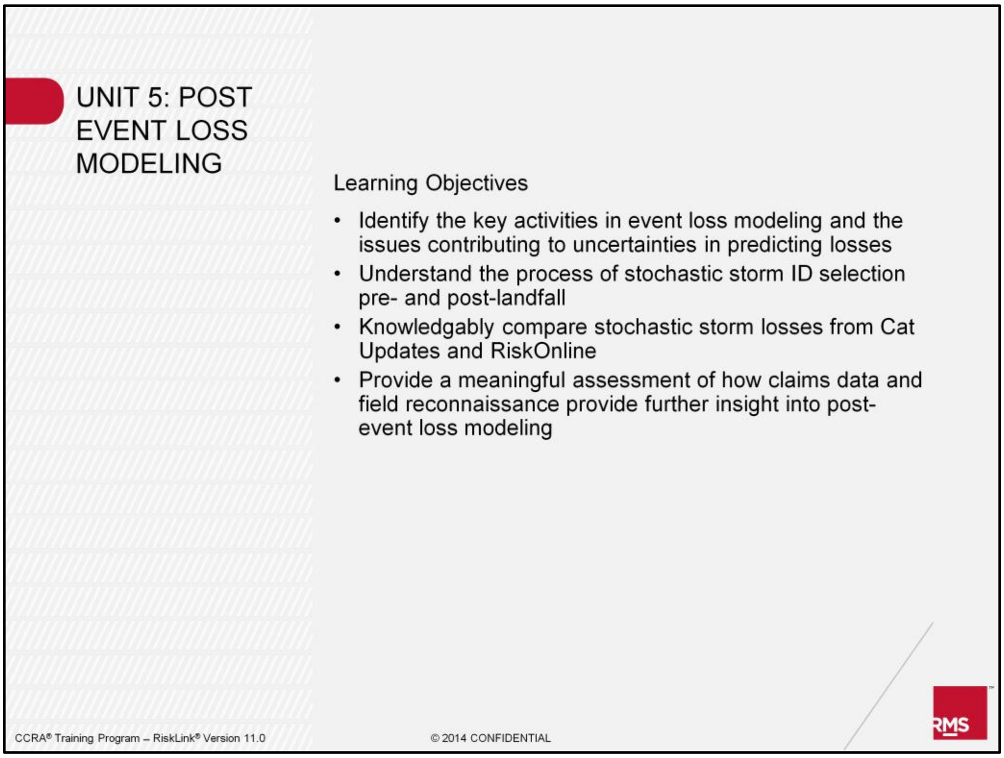


This is the last of five presentation units in the Tropical Cyclone Modeling course. It covers catastrophe modeling applications before and after a tropical cyclone makes landfall. Topics related to the implementation of real-time information, as well as post-event information, are discussed.

This unit includes the following sections:

- Real-time event information
- Pre-landfall loss modeling
- Post-landfall loss modeling
- Post-landfall field reconnaissance
- Modeled vs. actual loss comparison



At the end of this unit you should have a good understanding of each of the six learning objectives listed on this slide.

TYPICAL EVENT RESPONSE ACTIVITIES

- Daily monitoring (starting with notice of tropical depression or Cat 1 status)
- Storm tracking information via online providers and media
- Periodic updates for modeling parameters pre- and post-landfall (usually starting at 48 hours prior for probable U.S. landfall)
- Analyzing industry and portfolio specific probabilistic loss estimates
- Post-event reconnaissance
- Post-event reports and retrospectives

We first take a look at the typical activities that RMS conducts when faced with an impending tropical storm.

We are constantly monitoring tropical cyclone activity around the world, and we are notified by an automatic alert system whenever a storm forms. If the storm strengthens and develops and moves towards land in one of our modeled regions, we then start issuing information via our website behind the log-in for clients. We update this information every 24 hours and provide perspective on the storm characteristics and assessments of the latest forecasts, as well as modeling parameters for clients to assess potential losses to their books. We also provide industry loss estimates.

For major storms making landfall, we will send reconnaissance teams as soon as possible to assess the damage and supplement our other sources of information. For example, we sent teams to each of the hurricanes of 2004 and 2005 that made landfall, as well as for Hurricane Ike in 2008. For Hurricanes Katrina and Ike, we had a team in the region (far enough away so they were not in danger) the day the storms made landfall. For Katrina, we had both a ground and an aerial survey team assess the worst affected coastal regions as well as New Orleans during the following five days. We followed this up with another ground team two months and six months after the event.

Longer term, we produce summary reports on the key lessons learned from the events for unusual aspects, such as having four landfalling hurricanes in one season, as we did in 2004. In addition, we produce retrospective reports on historical events that were of great significance. Not only can lessons be learned from significant historical events, these lessons have often ultimately been trigger points for changes in the industry itself.

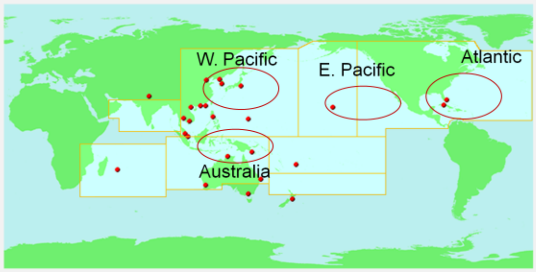
EVENT RESPONSE TOPICS

- Storm monitoring
- Event loss modeling and loss estimation
  - Probabilistic model estimates – two different methods
  - Pre-landfall stochastic storm selection
  - Post-landfall stochastic storm selection
- Post-landfall field reconnaissance and claims comparisons
  - Role of reconnaissance and claims in model calibration
  - Understanding uncertainty in modeled loss estimates
  - Non-wind related damage considerations

We are going to be talking about three main topics. The first one concerns storm monitoring and response in different oceanic basins of the world. The second is real-time loss modeling and all perspectives and ways we have of doing this, along with the advantages and disadvantages for different clients. Finally, we will look at field aspects, such as the reconnaissance work, assessing non-modeled losses, and how we build a full picture of the whole event.

REAL TIME TROPICAL CYCLONE MONITORING AND RESPONSE: KEY AREAS OF INTEREST

- Atlantic Hurricane Season: June 1 – November 30
- Eastern Pacific Hurricane Season: May 15 - November 30
- Western Pacific Typhoon Season: April - November
    - Most active region worldwide
- Australia Tropical Cyclone Season: November 1 to April 30



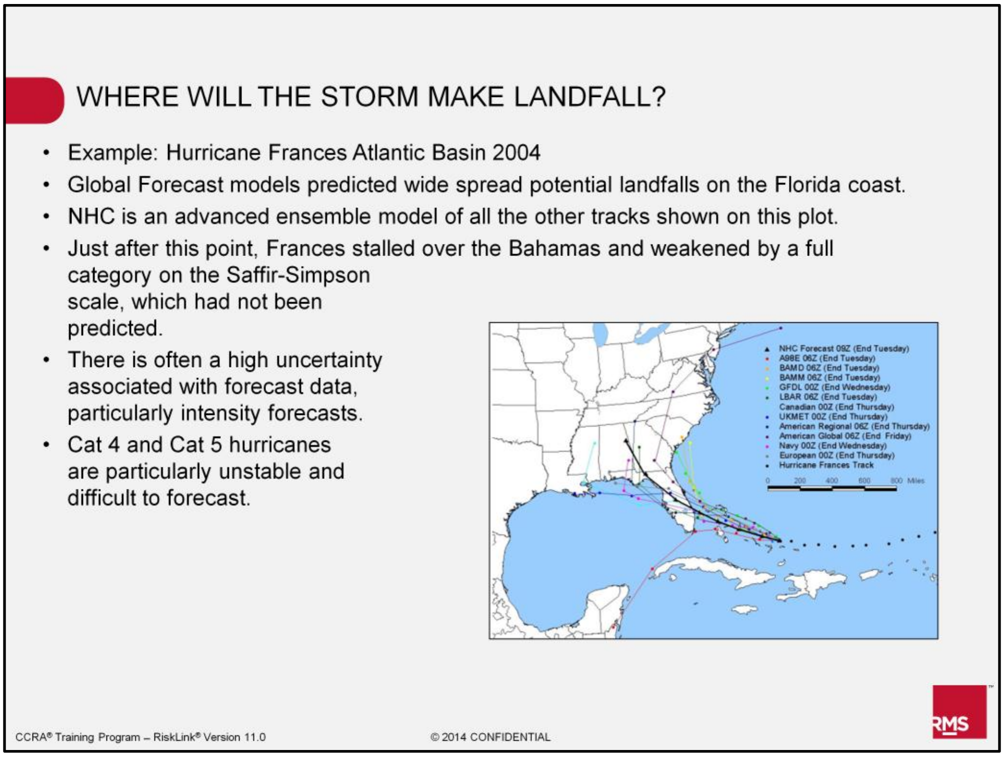
First we will take a look at the key areas at risk from tropical storm activity. There are several key areas that have a combination of high tropical activity and high insured exposure, as indicated on this map. We are highlighting here the four tropical cyclone model regions for which RMS currently has models. The geographic periods of interest for each of these regions are different. Three of the four coincide in the northern hemisphere summer and the fourth, in Australia, is active from November to April with the highest activity occurring between January and February.

FORECAST DATA IN THE ATLANTIC BASIN

- Aircraft reconnaissance data combined with ship, buoy, and satellite data help determine initial conditions of Atlantic storms.
- NHC "official" forecast issued every 6 hours.
  - The center position, maximum one-minute surface wind speed (intensity), and radii of the 34 knot (39 mph, 63 kph), 50 knot (58 mph, 92 kph), and 64 knot (74 mph, 117 kph) wind speeds in four quadrants surrounding the cyclone.
- NHC takes into account the operational track and intensity guidance models.
- Greater variety of global track forecasting models compared to intensity forecast models
- Post landfall modeling available for modeled North Atlantic hurricane countries
  - Includes U.S., offshore platform, Canada, Mexico, Caribbean, Central America
  - Suite of stochastic events
  - Ensemble Footprints (event reconstructions) for U.S. and offshore platform only

A wide range of forecast data is available for the U.S., allowing RMS to obtain a reasonable projection of a hurricane's track and intensity. The NHC is the main provider of forecast information in the U.S and provides "official" forecasts of the cyclone's center position and maximum one-minute sustained wind speed. The forecasts are issued every six hours and contain forecasts for every 12 hours, up to 120 hours ahead. There are several individual models that produce dozens of potential tracks and various model ensemble members, therefore it becomes difficult to decide which model to follow. RMS uses the NHC "official" track and intensity forecasts that take account of the numerous guidance models. Most of the operational track guidance models require output from global forecast models. There are eight operational track guidance models: CLIPER, NHC90, BAM, NCEP Aviation and MRF, UKMET, and NOGAPS. Despite the variety of hurricane track forecast models, there are only a few models that forecast intensity change for the Atlantic Basin; SHIFOR, SHIPS, GFDL, and The RI scheme.

The Hurricane Research Division is also a valuable source of real-time data.



Some storms remain very difficult to predict, depending on the atmospheric conditions. An example is Hurricane Emily, whose forecasted track changed considerably with each update, which occurred every six hours.

The map on this slide shows the output from the three global forecast models for Hurricane Frances in 2004, produced by a range of meteorological organizations, and it indicates the range of possibilities for Hurricane Frances several days before it made landfall.

The National Hurricane Center, which is the U.S. body tasked with public forecasting and safety, produced a forecast which is an ensemble of many of these. It takes a very scientific approach to weighting these models to produce the NHC forecast, indicated by the black line.

By looking at a range of forecast models and knowing their inputs and the potential biases, it helps us to assess the most likely course. In this example, Frances weakened over the Bahamas by a full category on the Saffir-Simpson, which had not been predicted by the models.

Intensity forecasts are much more uncertain than directional forecasts. There is still much unknown about the processes that sustain and that can also disrupt hurricane systems, especially once they reach very intense status. In particular, Category 4 and 5 hurricanes are very unstable systems in many ways. They can change intensity dramatically and very rapidly. This is not only a challenge for the forecasters at the NHC but also for the RMS Cat Response team. A change in intensity shortly before landfall could have a massive impact on loss projections.

With modern technology and air reconnaissance, the uncertainty is being reduced and we have added considerably to the amount of data that was collected in 2004. However, uncertainty in intensity predictions remains high in every basin.

In the U.S., a large amount of money is invested in real-time aircraft observations, such as the hurricane hunters who fly several times a day. Such aerial reconnaissance missions do not occur in any other basins, so we have considerably less information to work with elsewhere.

FORECAST DATA IN THE NORTHWEST PACIFIC BASIN

- Most active basin in the world – with an average of 16 typhoons each year, compared to an average of 5.4 in the Atlantic
- Track behavior is highly uncertain
- Forecast data obtained from the Joint Typhoon Warning Center and the Japan Meteorological Agency
- Forecast data often associated with high uncertainty due to:
  - Limited techniques available to define initial conditions
  - Many complex contributing factors that remain poorly understood
- Post-landfall modeling, Japan
  - Preliminary suite of weighted stochastic tracks issued that represent the storm in question based on intensity and landfall location
  - Updated suite of stochastic tracks selected using a reconstruction of the storm's wind field.
- Post-landfall modeling, China
  - Preliminary suite of post-landfall stochastic tracks issued that represent the storm in question based on intensity and landfall location
  - Updated suite of stochastic tracks selected based on wind and flood observations

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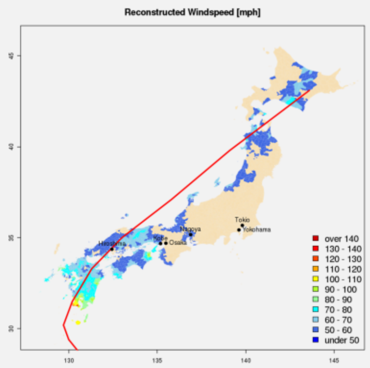
The Northwest Pacific Basin is the most active basin in the world. The season runs from April to November and typhoons regularly strike the Philippines, east China, Taiwan, Vietnam, and Japan. Unfortunately the ability to predict losses in the Northwest Pacific is much lower than that in the Atlantic. This is due to the high uncertainty associated with track and intensity forecasts issued by the Joint Typhoon Warning Center (JTWC) and the Japan Meteorology Agency (JMA). The high uncertainties stem from limited techniques available to monitor the current intensity and location of a storm. The problems associated with identifying the initial position and intensity of a tropical cyclone can lead to major errors in forecasting. It is not uncommon for the JTWC and JMA to issue very different forecast advisories with even their analysis conditions varying. The lack of wind speed recordings also presents problems in post-landfall analysis. RMS strives to collect all available data and make an assessment of which data source is likely to be most reliable – this may vary from storm to storm.

For typhoons that make landfall in Japan, we use available landfall meteorological parameters, notably minimum central pressure and the landfall location, to identify a preliminary suite of stochastic tracks that will represent the uncertainty associated with the landfall parameters. Each stochastic event will be weighted according to the similarity to the actual storm. These weighted stochastic events are issued to clients so they can obtain a range of possible losses using the Stochastic EP (STEP) Tool that represents the uncertainty in the landfall parameters.

After the storm has ceased impacting Japan, a reconstruction of the wind field is created, and a 'best' suite of stochastic events are selected and weighted according to their similarity to the reconstructed wind field of the event.

JAPAN TYPHOON WIND FIELD RECONSTRUCTION

- New in 2011
- Event Wind Field Reconstruction
  - A best set of modeling parameters
  - Targets geography and distribution of loss to reduce uncertainty
  - Weighted according to best fit
  - Closer match to historical event losses
- Deliverables based on reconstructed wind field
  - Updated suite of stochastic events based on match of stochastic wind field to event wind field
  - Accumulation footprints
  - Banded wind field GIS mapping files
  - Industry loss estimate



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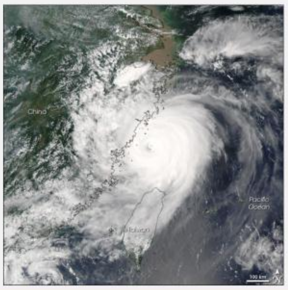
In 2011, RMS is introducing a “best” set of post-landfall deliverables 3-7 days after the storm has ceased impacting Japan. These deliverables are based on a reconstruction of the storm’s wind field at landfall, and leverages the RMS methodology developed for U.S. hurricane wind field reconstruction developed in 2009.

Development of the wind field reconstruction, or the target best representation of the event loss, is intended to give equivalent perspective on the event loss, geography, and uncertainty associated with the storm. Stochastic track selections are weighted based on the match of their stochastic wind field with that of the reconstruction.

In the future, RMS will also provide Ensemble Footprints for Japan typhoon events, similar to what is currently available for U.S. Hurricane; however, this methodology is still under development.

CHINA TYPHOON CAT RESPONSE DELIVERABLES

- Following the landfall of a large typhoon in China, two sets of modeling deliverables are produced:
  - Post-landfall (within 48 hours)
  - 3-5 days after the storm has dissipated



Deliverable	Description
RiskLink® modeling parameters	Suite of stochastic matches for use in the STEP tool
Accumulation footprint	Contains all affected counties
RiskManager report file	Based on accumulation footprint
Miu risk profile	Based on the weighted suite of stochastic events
GIS mapping files	Based on accumulation footprint

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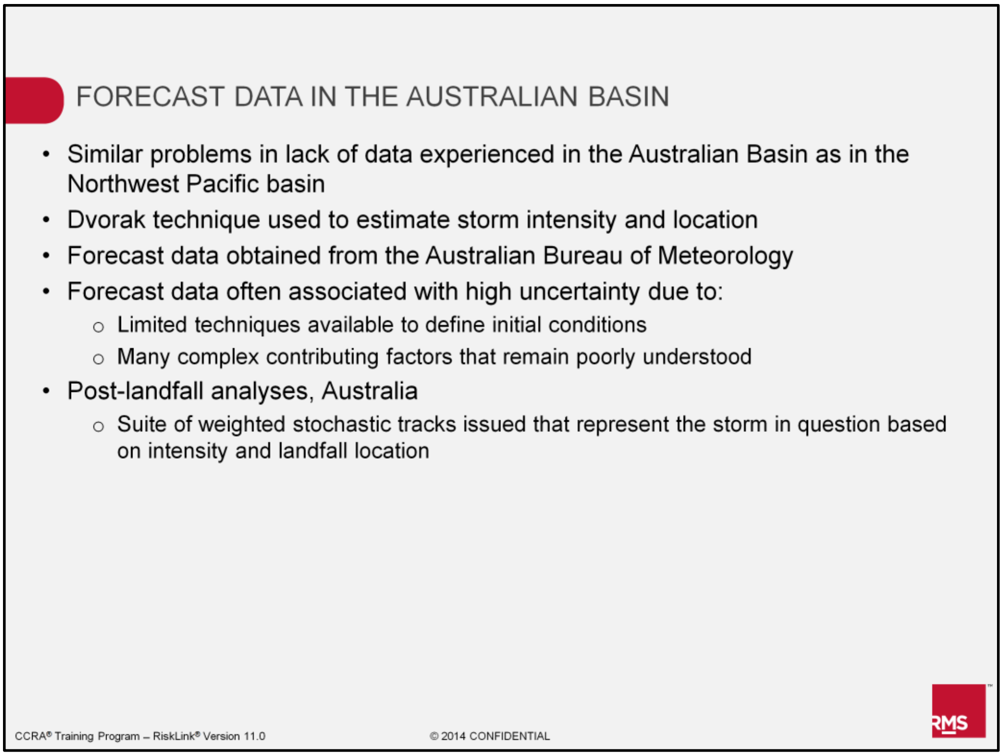
With the release of the RMS China Typhoon model in 2011, RMS has implemented a new event response procedure for China typhoons.

Following a significant typhoon impacting China (including Hong Kong), a Cat Update report is posted in the Cat Updates section of www.rms.com, and several deliverables are provided to clients.

A preliminary set of modeling deliverables are issued with the first Cat Update, issued within 48 hours post-landfall. This preliminary set includes a suite of stochastic events for use in the STEP Tool. This set of tracks is based on the wind parameters of the storm at or just before landfall. Accumulation footprints, RiskManager, and Miu files, as well as associated GIS mapping files are also provided.

A second set of modeling deliverables will be issued 3-5 days after the storm has dissipated. This second set of stochastic track selections incorporates flood observations to allow for a more complete picture of the area impacted by the typhoon. The other deliverables are updated based on these new selected stochastic tracks.



The Australian Basin tropical cyclone season runs from November to April. As with the Northwest Pacific basin, there is a notable lack of land and sea observations. The Dvorak technique (discussed in detail on the next slide) is used to estimate storm intensity and satellite imagery is used to estimate the location of the storm. These techniques can lead to errors when initializing forecast models. Forecasts are issued by the Australian Bureau of Meteorology and, as with the Northwest Pacific, forecasters are faced with many challenges. The unpredictable nature of the tropical cyclone track and intensity makes it very difficult to predict losses in this basin.

For Cyclones that make landfall in Australia, we use available landfall meteorological parameters, notably maximum sustained winds, minimum central pressure, and the landfall location, to identify a suite of stochastic tracks that will ultimately represent the uncertainty associated with the landfall parameters. Each stochastic event will be weighted according to the similarity to the actual storm. These weighted stochastic events are issued to clients so they can obtain a range of possible losses using the STEP Tool that represents the uncertainty in the landfall parameters.

THE DVORAK TECHNIQUE

- In the absence of aircraft reconnaissance and reliable ship and buoy data in other basins around the world, the Dvorak technique is used to estimate the intensity of a tropical cyclone.
- Infrared satellite imagery is used to analyze the difference between the warm eye and surrounding cold cloud tops.
- Uses patterns and measurements as seen on satellite imagery to assign a number (T number) representative of the cyclone's strength.
- The T number scale runs from 0 to 8 in increments of 0.5.
- Satellite imagery is also used to determine location of a tropical cyclone.

T Number	Winds (Knots)	Minimum Pressure (mb)	
		Atlantic	NW Pacific
1.0-1.5	25	-	-
2.0	30	1009	1000
2.5	35	1005	997
3.0	45	1000	991
3.5	55	994	984
4.0	65	987	976
4.5	77	979	966
5.0	90	970	954
5.5	102	960	941
6.0	115	948	927
6.5	127	935	914
7.0	140	921	898
7.5	155	906	879
9.0	170	890	858

Note: The Northwest Pacific has lower pressure because it has a lower background sea level pressure gradient field. Therefore, to sustain a given pressure gradient and thus the winds, the central pressure must accordingly be smaller in this basin.

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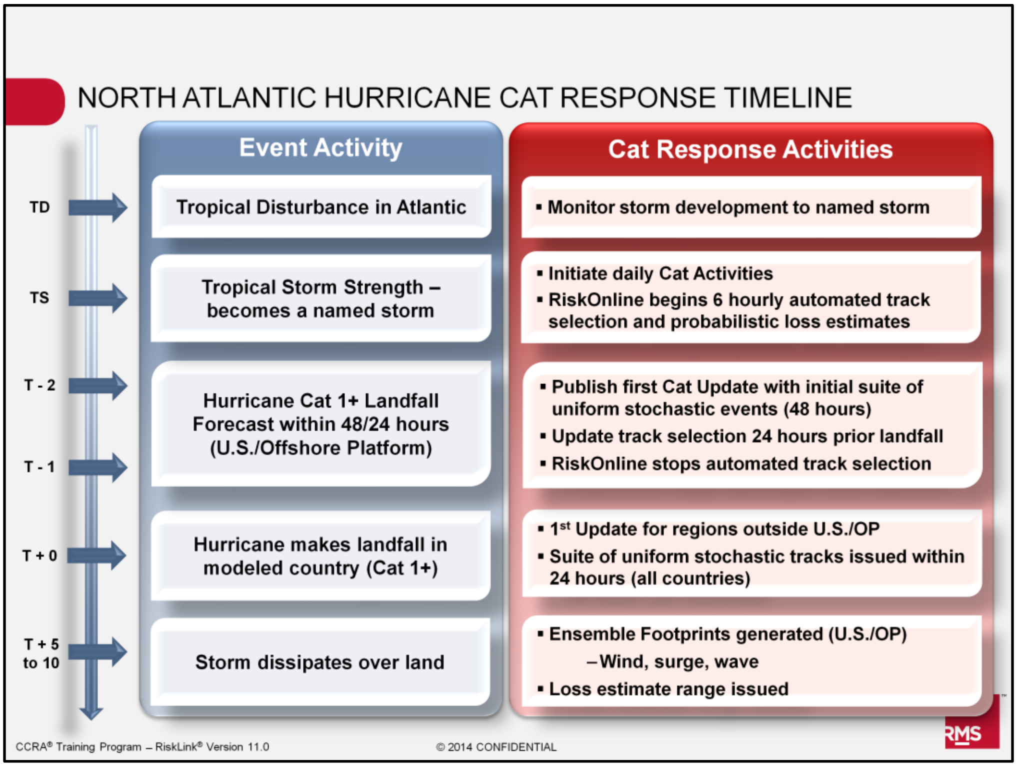
In 1987, aircraft reconnaissance over the Northwest Pacific was terminated, cutting off an important source of information. Aircraft reconnaissance operations are also rare in other basins around the world – except for the Atlantic. The observation network in the Northwest Pacific and Australia basins are very poor and reliable ship and buoy data are very rare – all important sources of information. This means that meteorologists must use alternative methods to estimate the intensity and location of tropical cyclones.

The intensity is estimated by using satellite imagery, a technique known as the Dvorak technique. If infrared satellite imagery is available for eye patterns, then meteorologists can analyze the difference between the warm eye and the surrounding cold cloud tops; the larger the difference, the more intense the tropical cyclone is estimated to be. In each case a "T-number" and a Current Intensity (CI) value are assigned to the storm. The numbers range between one (minimum intensity) and eight (maximum intensity). The estimation of both maximum winds and central pressure assumes that the winds and pressures are always consistent. However, this is not always the case, particularly in small tropical cyclones which may have stronger winds for a given central pressure than a larger tropical cyclone with the same central pressure. If an eye is not visible, then satellite imagery is used to determine the "pattern" of a cyclone. Possible pattern types include curved band pattern, shear pattern, central dense overcast pattern, and banding eye pattern. Once a pattern is identified, the storm features can be analyzed and a T-number can be assigned to a storm.

Research has revealed that the errors when using the Dvorak technique in comparison to aircraft measurements average 10 mb with a standard deviation of 9 mb. In the absence of aircraft reconnaissance data in regions outside the Atlantic Basin, this method provides the best estimate of storm intensity.

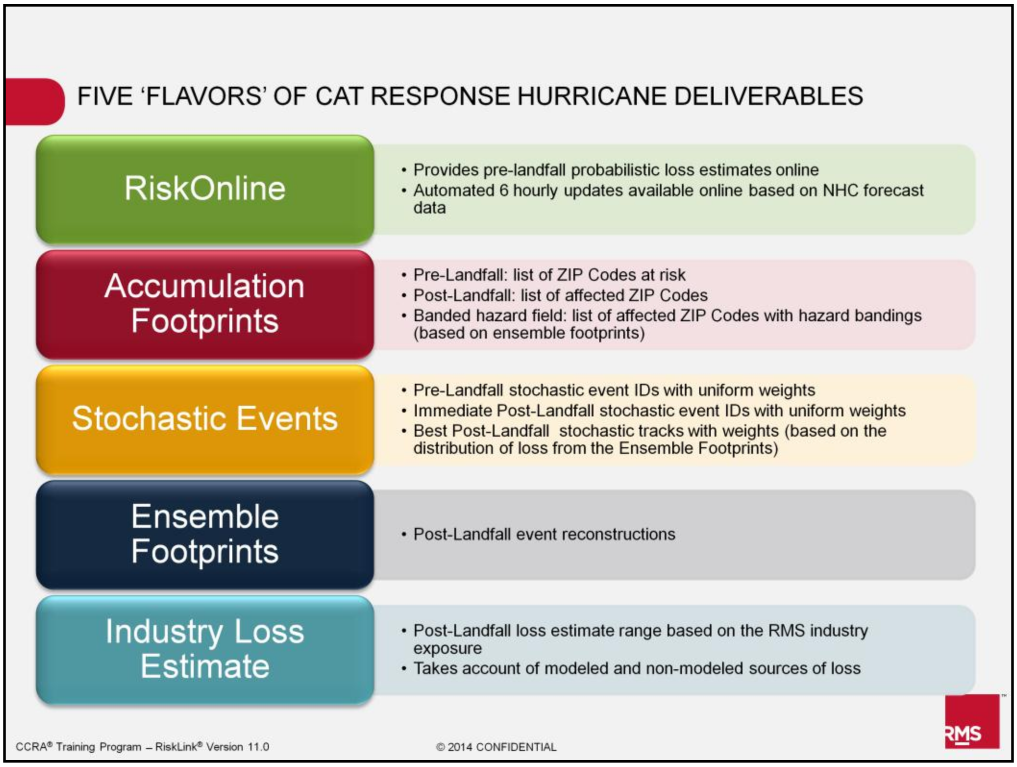
Satellite imagery is also used to estimate the location of a storm; however, in the absence of a well-formed eye, estimating the center of the storm can be difficult.



As soon as a storm develops in the Atlantic Ocean, the RMS Cat Response team begin monitoring the storm. When the storm intensifies to tropical storm strength and is named, daily Cat Activities are initiated.

For hurricanes forecasted to make landfall in the U.S. and/or the Offshore Platforms as a category 1 storm or higher on the Saffir-Simpson Hurricane Scale, Cat Update reports begin 48 hours prior to the forecast landfall.

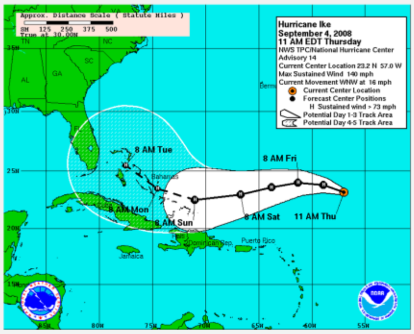
For all other modeled North Atlantic hurricane countries, (including Canada, Mexico, the Caribbean, Belize, Costa Rica, Guatemala, Honduras, and Nicaragua), Cat Update reports begin post-landfall, generally within 24 hours.



The five deliverables for hurricane Cat Response are listed on this slide. Maps and GIS files will supplement all of these products to provide visual representations.

PREDICTING LOSSES PRE-LANDFALL: THE ATLANTIC

- Ability to predict insured losses is greatest in Atlantic Basin
- Track behavior is more predictable than in other tropical basins
  - Stable and predictable climatology
  - More scientific research and understanding of storm behavior
- National Hurricane Center has more publicly available information
  - Heavily funded by government to protect public life
  - Other regions do not have as much data so have to purchase data or technology to collect the data



NHC forecast for Hurricane Ike in 2008: NHC forecasts give indication of uncertainty of forecast track and intensity based on historical storms

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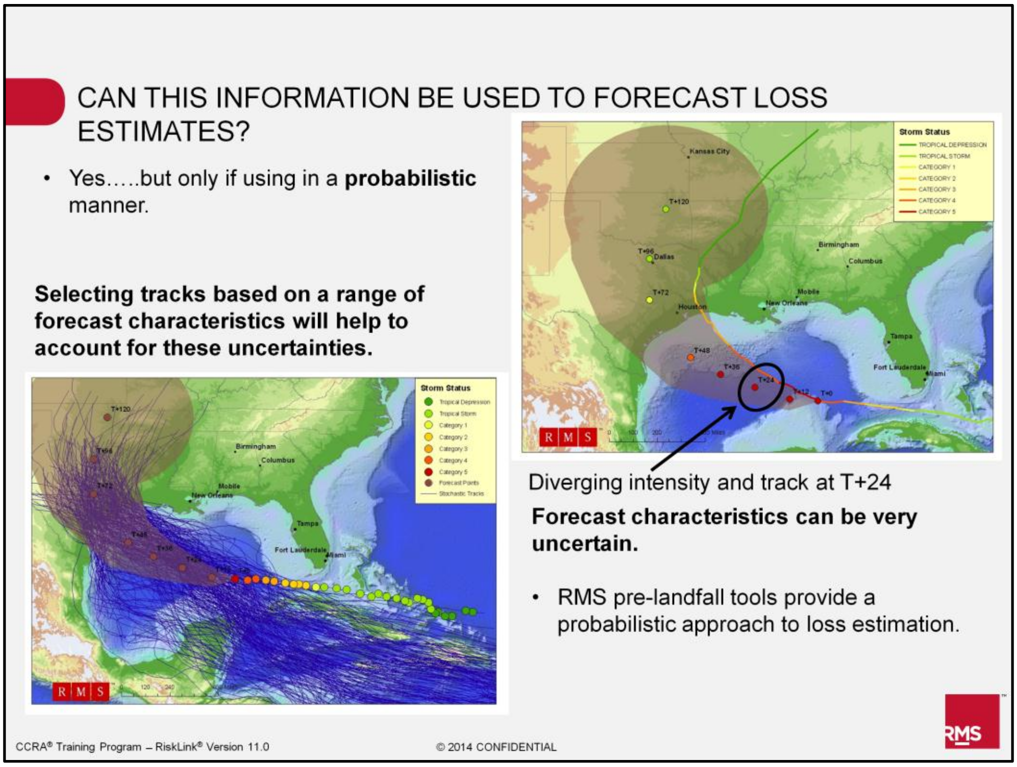
Our ability to predict losses ahead of landfall is different in each of these basins, and so our offering varies. The most studied basin and the one that behaves most predictably in many ways is the Atlantic Basin, although there can still be a substantial amount of uncertainty at times. Storm behavior is very well researched. The National Hurricane Center (NHC) is a well-funded public body that collects and distributes information freely, both on the storm characteristics ahead of landfall as well as post-landfall wind speed measurements.

There is also significant interest from the scientific and academic community in the U.S. and significant research funding of different aspects of hurricane formation and intensification, track prediction methodologies, and so on. There is also a lot of private interest, with which RMS has some collaboration.

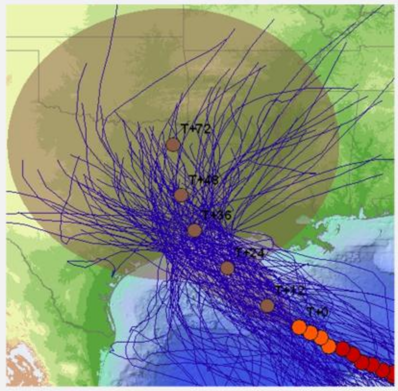
In the Western Pacific, storms tend to be more unpredictable and, therefore, predictions are less accurate and public updates are less frequent than in the U.S. Frequently, cyclones heading for Japan have defied forecasts and changed intensity or direction dramatically before landfall. This is in contrast to many storms in the Atlantic basin where the forecast skill levels are generally higher. For example, Hurricane Dennis' landfall point, which was forecast five days beforehand, and its actual landfall point were within a couple hundred miles of each other. Despite the potential to more accurately forecast a hurricane, there are still many uncertainties that exist and these need to be taken into account when trying to estimate the potential impact a storm will have after landfall.



Given the uncertainties associated with the forecasts, it is impossible to provide one single stochastic storm that will capture what will happen at landfall. For example, the map on the top right shows the forecasted track of hurricane Rita in 2005 (shown by the points). Rita's actual track is shown by the solid line. The forecast was made at T+0 and you can see that from T+24 the forecasted track and intensity starts to diverge and at the point when the forecast was made, which is about 72 hours before landfall, the landfall location and intensity is very different to what actually happened. In this pre-landfall phase, we take into account all possible outcomes, within reason, and we can, therefore, select tracks based on a range of storm characteristics forecast, rather than single values of parameters. This will result in a probabilistic loss estimate.

SELECTING STOCHASTIC TRACKS PRE-LANDFALL

- For the U.S. mainland and offshore platform region, pre-landfall stochastic tracks will be issued from 48 hours prior to landfall.
  - Key parameters to determine: forecast location, maximum sustained winds, and direction.
  - Size of suite will reduce each day as the uncertainty in landfall parameters falls.
  - Will be based on the 9 a.m. UTC advisories issued by the NHC
- Each track is equally weighted.
- Range of losses and EP curve can be obtained using the STEP tool.



Suite of pre-landfall stochastic tracks

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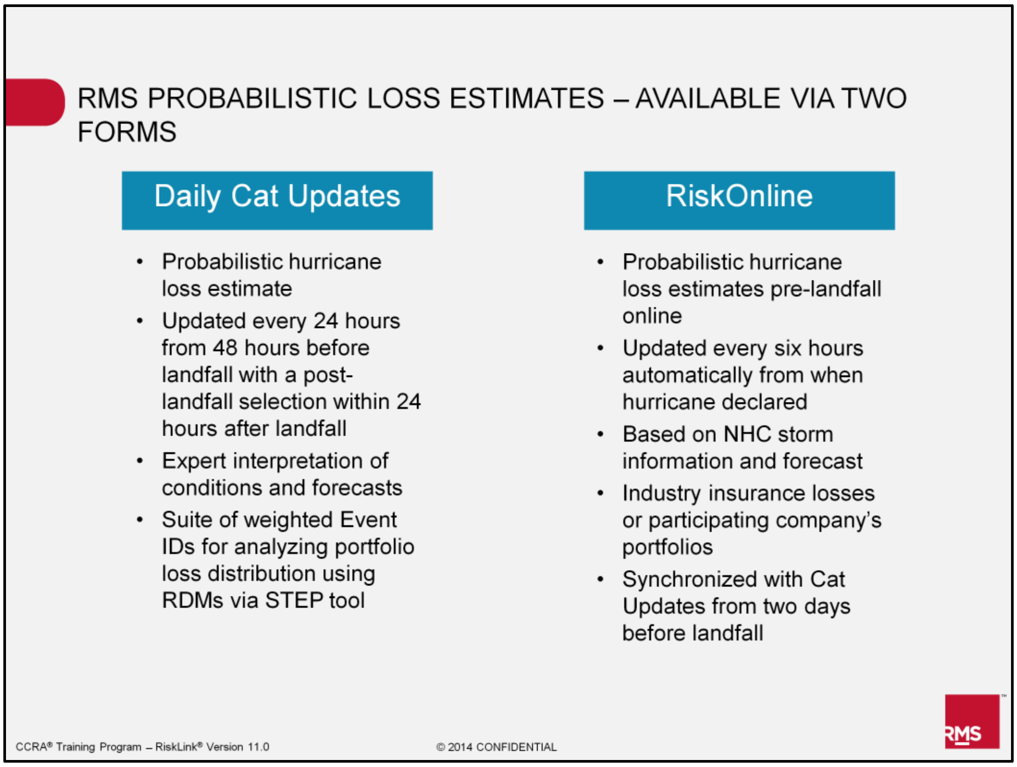
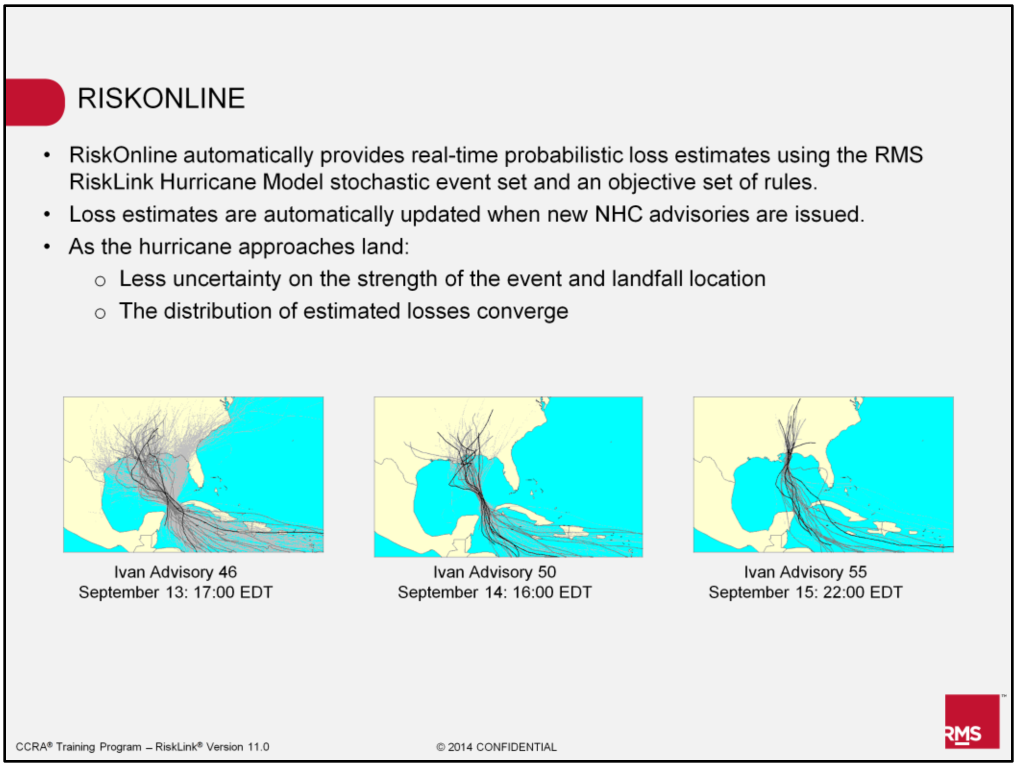
Suites of tracks are released through the RMS Cat Updates service from 48 hours before landfall. The information is posted to the RMS website and clients receive an email notification each day when we have updated the information. The full hurricane model event set is filtered to identify all the stochastic events with similar meteorological parameters as the storm in question. All the events dissimilar to the event in question will be zeroed out and those events remaining will be equally weighted. Several sources of data are used to help us assess the forecast parameters but the National Hurricane Center data is the most reliable and is the only ‘official’ forecast for Atlantic Hurricanes. The key parameters used for track selection include the forecast landfall location, bearing, and maximum sustained winds. The methodology used to select the suite of stochastic tracks takes into account the range of uncertainty in the strength and location of the storm in question at landfall. Typically, the greatest amount of uncertainty is associated with the intensity forecasts as the understanding of tropical cyclone intensity is not nearly that of track knowledge. Processes such as rapid intensification are rarely forecast well. Hurricanes Dean and Felix in 2007 are prime examples where none of the forecasts predicted that the hurricanes would intensify as much as they did and as quickly. There have also been several examples of storms making landfall on the U.S. Gulf of Mexico coast where the forecasts have not picked up the reduction in intensity as the storm moves over the shallower waters of the shelf. This was seen with Hurricane Rita in 2005 and Hurricane Gustav in 2008.

The IDs of the suite of tracks, along with their weights, are released to clients on a daily basis. The number of tracks within the suite will typically reduce each day as the storm approaches landfall and the uncertainty in storm landfall strength and location reduces. Due to the high uncertainty involved at 72 hours before landfall, tracks are only issued from 48 hours prior to landfall. Clients can obtain a probabilistic loss estimate from each suite of tracks and an EP curve from the STEP Tool. This tool provides functionality to extract loss information from RDM databases and give a range of losses based on the weighted tracks.



Our perspective on loss is based on using our hurricane model event set in two different ways. One perspective on loss is derived by using our expert assessment of the storm data either pre- or post-landfall and filtering storms from the entire hurricane stochastic event set that have similar characteristics in terms of strength, location, and size. RMS clients can then use these filtered events to model losses to their portfolios. These are particularly useful for clients who have access only to RDM data sets, or for ALM users; they can pull the relevant event losses from the event loss table by looking at the source ID number. These events are also used in conjunction with the RMS Industry Exposure Database to help define the impact on the industry as a whole. The Stochastic EP (STEP) Tool is an easy to use tool that can be launched in Microsoft Excel to assist clients in analyzing the portfolio loss distribution and will be discussed later in the presentation.

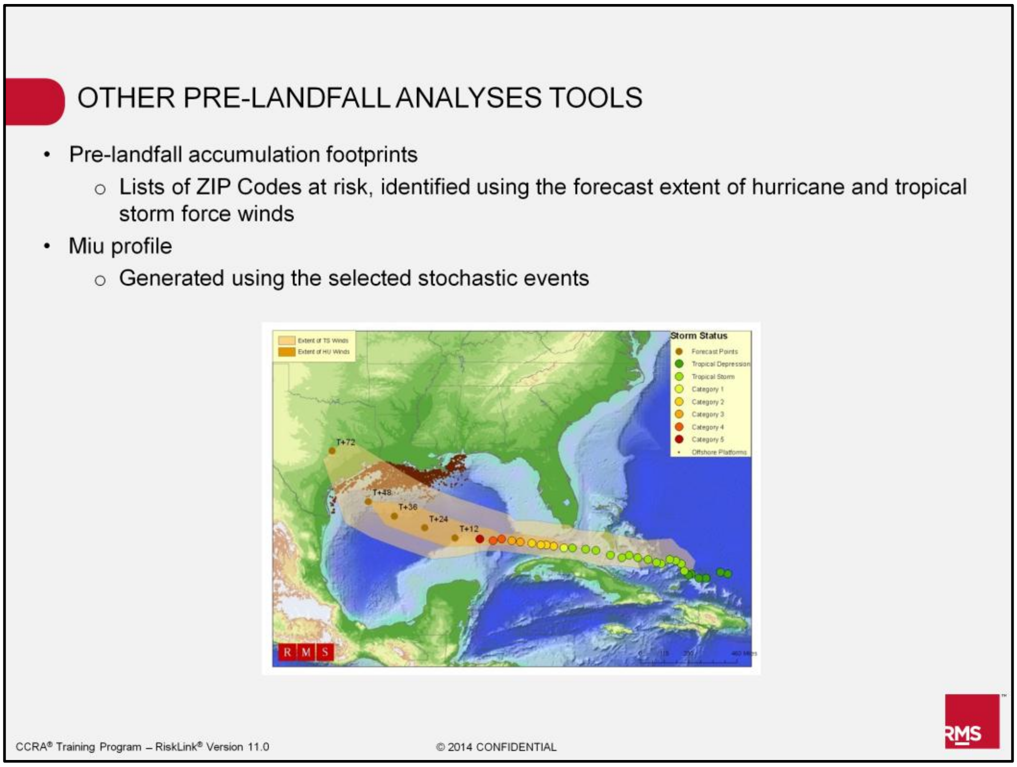
The other perspective comes from reassigning probabilities to the whole of the hurricane event set based on their similarity to the actual storm. This is done automatically using an objective set of rules and is available online for an industry perspective or for a participating company's own portfolio. The loss associated with each storm is weighted by its probability to give a probabilistic loss distribution. This product is known as RiskOnline.



The RiskOnline service uses the hurricane’s current parameters, including the wind speed of the storm, location, bearing, forward velocity, radius to the maximum winds, previous track, and the National Hurricane Center's forecast. It automatically performs a selection of RMS' model tracks, re-assigning probabilities of each, and provides probabilistic loss distribution with updated EP curves.

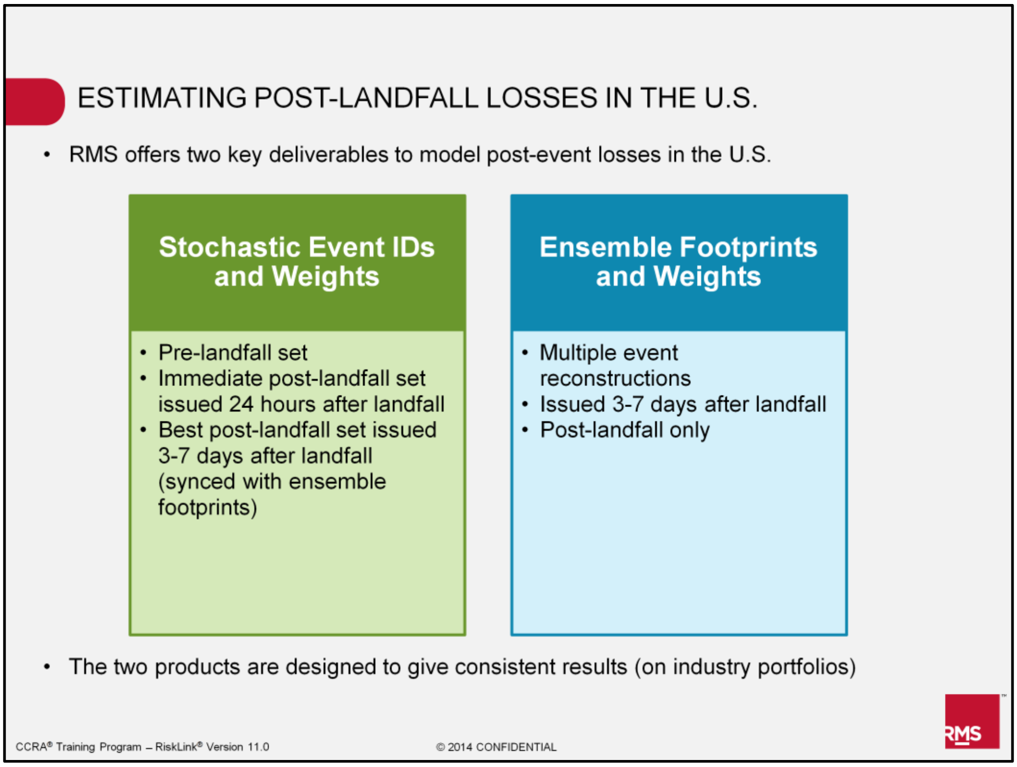
You can see this in the time series of Hurricane Ivan in 2004 at the bottom of the slide. This time series shows how the selection of possible tracks narrows the closer the storm gets to landfall. The dark lines represent the tracks with the highest probability and the light lines represent all of the storms that are being selected by RiskOnline. You can see as the storm approaches land, the selection gets narrowed down geographically to where the storm actually came on shore.

An important distinction to make for users of both the Cat Updates service and the estimates by RiskOnline is that the loss estimates will vary between the two. This is mainly due to timing and differences in methodology. The Cat Updates service takes into account RMS’ meteorologists’ considered view of the stochastic tracks most likely to represent an actual landfall and is produced every 24 hours; whereas RiskOnline is completely automatic and updates itself every six hours. To align the Cat Updates and RiskOnline estimate, the considered view will be dropped into RiskOnline on a daily basis based on the 4 a.m. UTC NHC advisory.

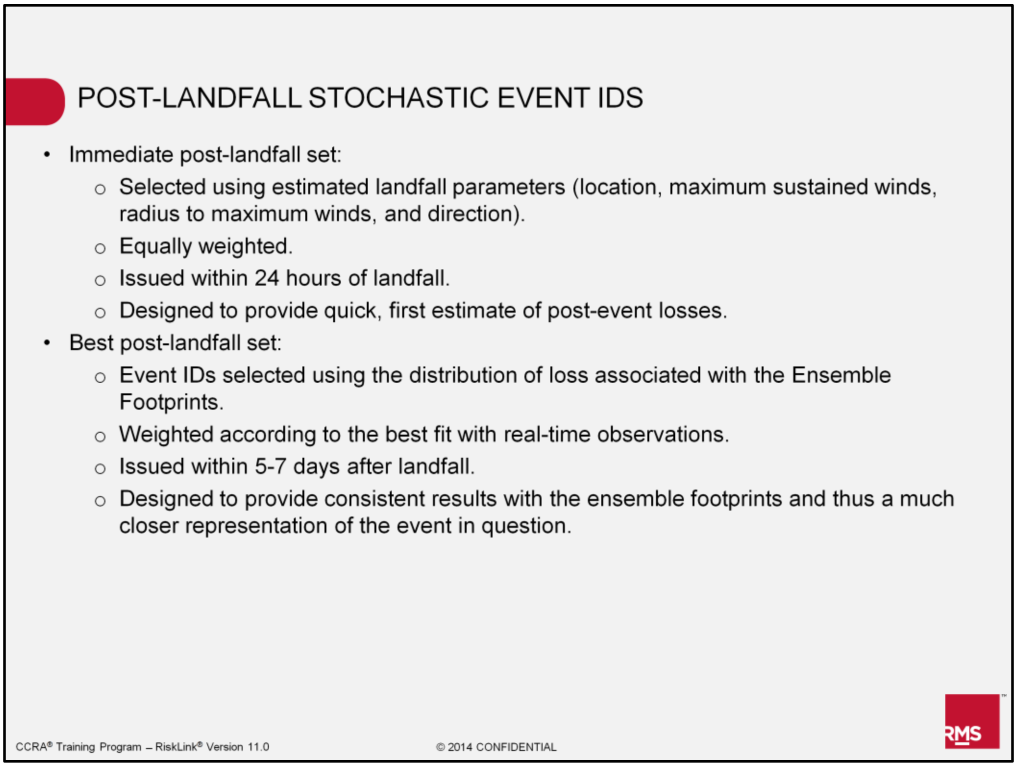


In addition to providing the pre-landfall stochastic tracks, RMS can help clients understand the geographic areas at risk by providing pre-landfall accumulation footprints for the U.S. This is done by using the National Hurricane Center's forecast extent of hurricane and tropical storm force winds and identifying which ZIP Codes will be impacted. This may be useful to clients in helping to determine to which areas they need to deploy claims adjusters ahead of landfall as well as identifying all their accounts that could potentially be impacted. Accumulation footprints are issued in several formats; an xml file for use in RiskLink 10.0 and 11.0, an excel file consisting of a list of ZIP Codes and associated counties/states, and a RiskManager file for those clients who license RiskManager.

Additionally, RMS also provides a Miu profile that can be used to estimate the impact an event will have on a portfolio by clients who use Miu.



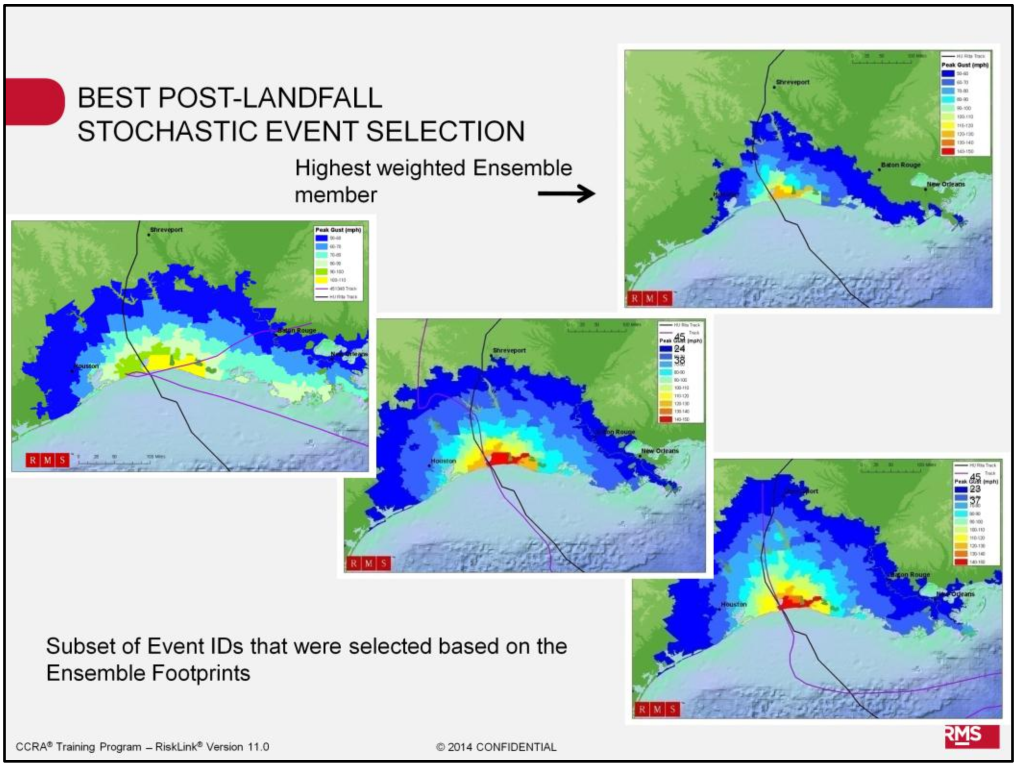
After a hurricane has made landfall in the U.S., RMS provides a range of deliverables to help clients estimate their losses. Two key deliverables include the post-landfall stochastic event selections and the Ensemble Footprints. On the next few slides we will examine these deliverables in more detail and look at the tools that RMS makes available for clients to obtain portfolio specific losses.



Immediately after a hurricane makes landfall there will be estimates available about the hurricane's landfall location and intensity. There is generally a degree of uncertainty associated with the landfall parameters and this may be reflected by differing estimates from different agencies. For example, it is often the case that the National Hurricane Center will have different estimates of the maximum sustained winds at landfall than that estimated by the Hurricane Research Division. These uncertainties are often associated with a lack of real-time observations. In order to take these uncertainties into account, RMS selects the first set of post-landfall stochastic events, known as the Immediate Post-landfall set, using a similar methodology as that used before landfall (i.e., using the landfall location, maximum sustained winds, radius to maximum winds, and bearing). This set of tracks will be issued within the first 24 hours after landfall and are designed to give a first pass estimate of potential losses.

As we learn more about an event after landfall, having gathered meteorological observations from available weather stations and damage information from the media and the RMS reconnaissance teams, we can update and refine our initial event selections. RMS does this by using the Ensemble Footprint event reconstructions (discussed in more detail later) as a basis for the selection, focusing on the distribution of loss associated with the hazard.

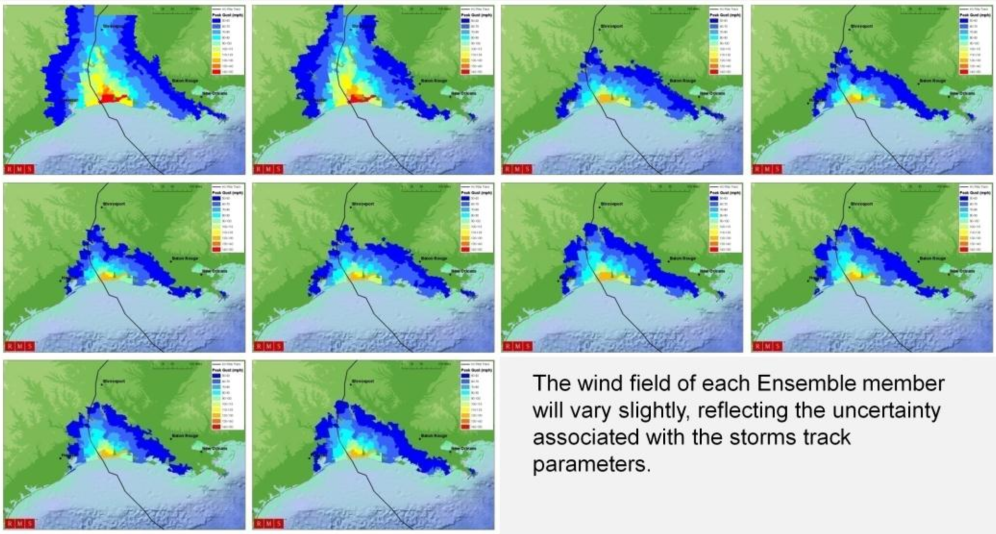
The next slide shows a visual example of matching some stochastic tracks to one Ensemble Footprint member.



The wind field in the top right corner of the page is an example of one ensemble member, in this case, the highest weighted member. The other three wind fields are Event IDs that have been selected to match the Ensemble Footprints. Notice how the wind fields all represent a relatively good match to the ensemble member shown, but the forecasted tracks (the purple line) is very different to the actual hurricane track (the black line).

The next slide shows a visual representation of the full ensemble, which consists of 10 ensemble members.

VISUAL EXAMPLE OF THE ENSEMBLE FOOTPRINTS



The wind field of each Ensemble member will vary slightly, reflecting the uncertainty associated with the storms track parameters.

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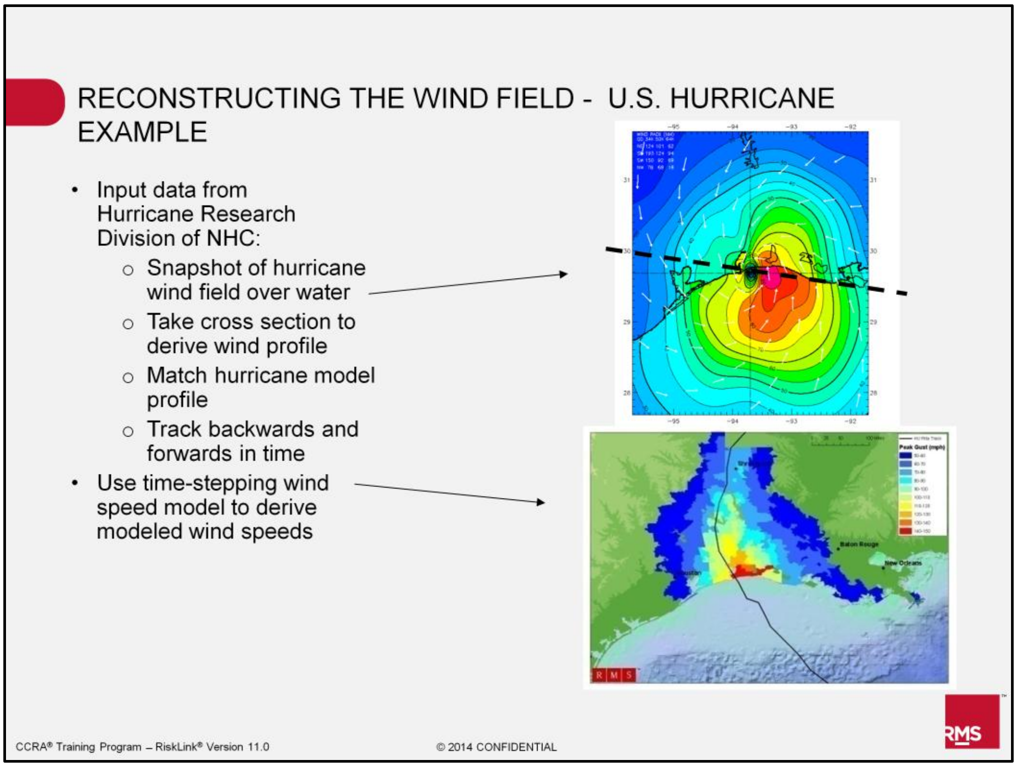
Here you can see how each wind field is unique and varies slightly from the others. Unlike using one single wind field footprint, these Ensemble Footprints take into account the uncertainty associated with the parameters along a storm's track.

To understand how RMS generates the Ensemble Footprints, let's first think about the process that we go through to generate one single wind field.



We take input parameters up to the landfall time using data from the Hurricane Research Division (HRD) as well as the National Hurricane Center and any observations.

On the right of this slide you see an example of an over-water representation of a storm, which is known as a Mark Powell Wind Field. This is produced by the Hurricane Research Division, part of the National Oceanic and Atmospheric Administration.

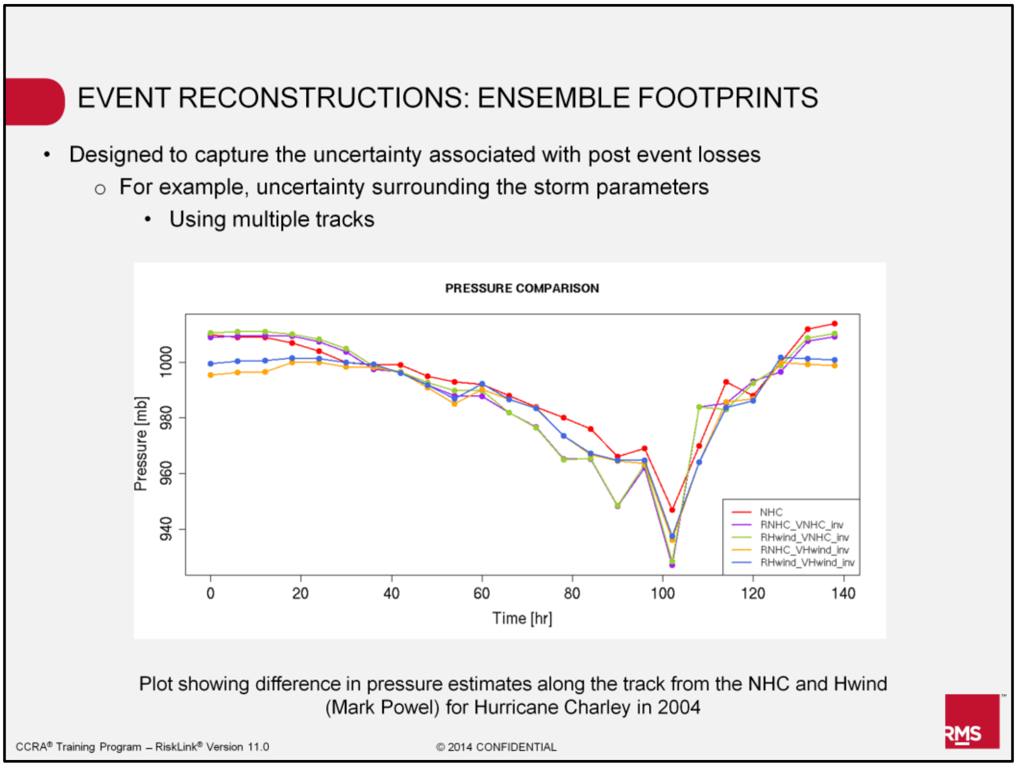
We have very close contact with the team, headed by Mark Powell, that produces this wind field. We will often be in conversation with them about the storm's parameters. Because there are few actual measurements of a full wind field, this picture is built up by using a model. The Hurricane Research Division can only model wind fields over water; they cannot take them on land. So that is where RMS comes in.

We take their input at landfall, which includes their view of the hurricane size, its intensity, and the shape of its wind field. We then run it through our own model to output the winds on land, taking into account roughness factors, etc.

We can take a cross-section through the storm, as indicated by the black dotted line, and from that we can determine the shape of the wind field profile. As you move away from the center of the storm, where wind speeds tend to be zero, the winds increase sharply to a maximum on both the left-hand side and the right-hand side. The maximum is always higher on the right-hand side than on the left-hand side of the storm because of the rotation of the storm. Winds tail off again as you move further away from the center of the storm. This profile is always different for every hurricane, and this is what we define to enable us to model how the wind field then tracks inland.

The inputs taken from the Mark Powell Wind Field are fed into our time-stepping wind field model, which outputs surface winds inland, taking the impact of terrain roughness and topography on wind speeds into account as the storm passes by. The model computes the maximum wind speeds at each location at each time step as the storm moves inland and then takes the maximum at each location over the entire history of the storm to build a footprint of the peak gusts over the VRG grid experienced at any point during the storm.

We know that some uncertainty exists when estimating the storm's parameters, not just at landfall but along its entire track. This uncertainty is often highlighted when the NHC and HRD estimate different parameters for the same storm at the same point in time – seen in the example on the next slide.

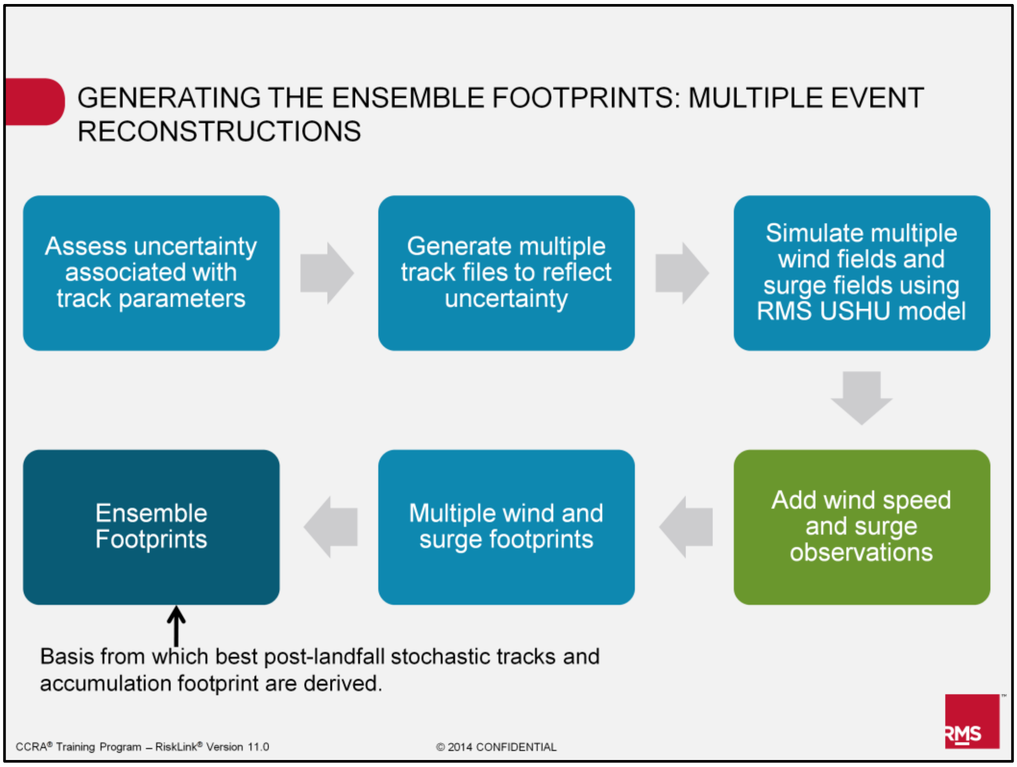


Instead of using one set of inputs taken from the HRD, which would generate one single wind field, we use all the available parameter estimates to input into our model and generate multiple wind fields in order to account for this uncertainty in our post-event modeling.

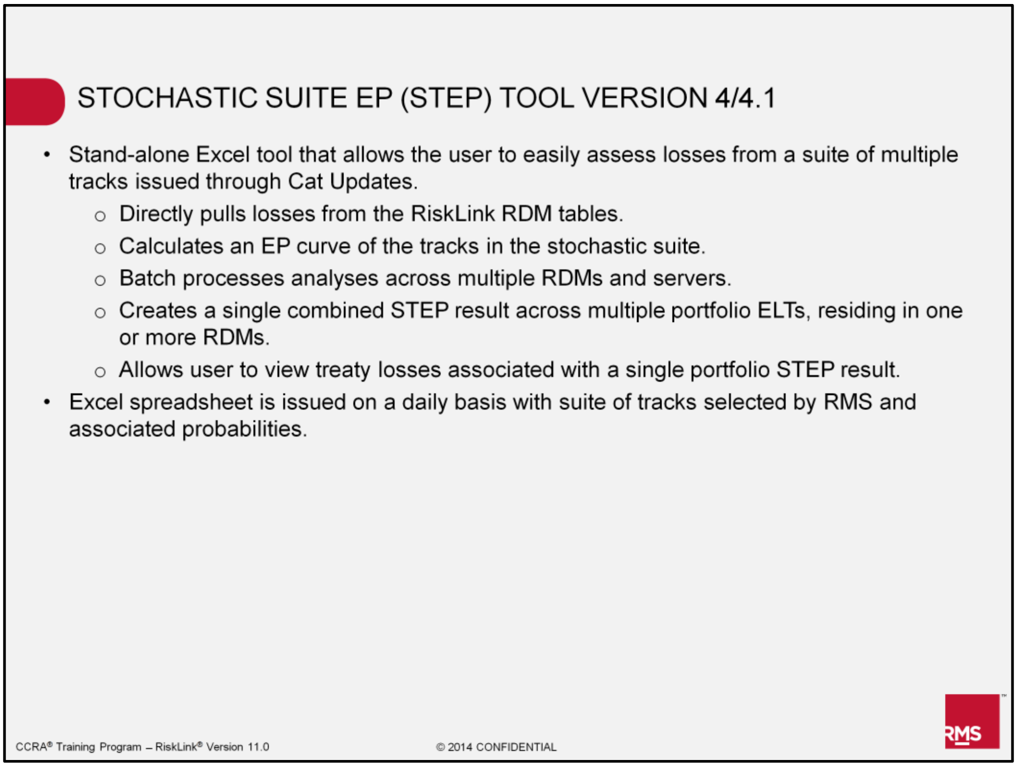
The model output is then compared with ground observations and each ensemble member is weighted according to the best fit to the observations. However, before we begin comparing the ensemble footprints to the observations, a significant amount of QA is carried out on each meteorological recording.

Observations are sometimes incomplete due to power outages. Power outages are one of the biggest problems for data quality. Wind speed stations are rarely destroyed by strong winds, but power failures do mean that we get gaps in the record. We can identify whether a station has a full record of observations by analyzing the time series of recordings, and, therefore, whether the recorded peak is likely to have been the actual peak, or whether a power outage means the peak was missed.

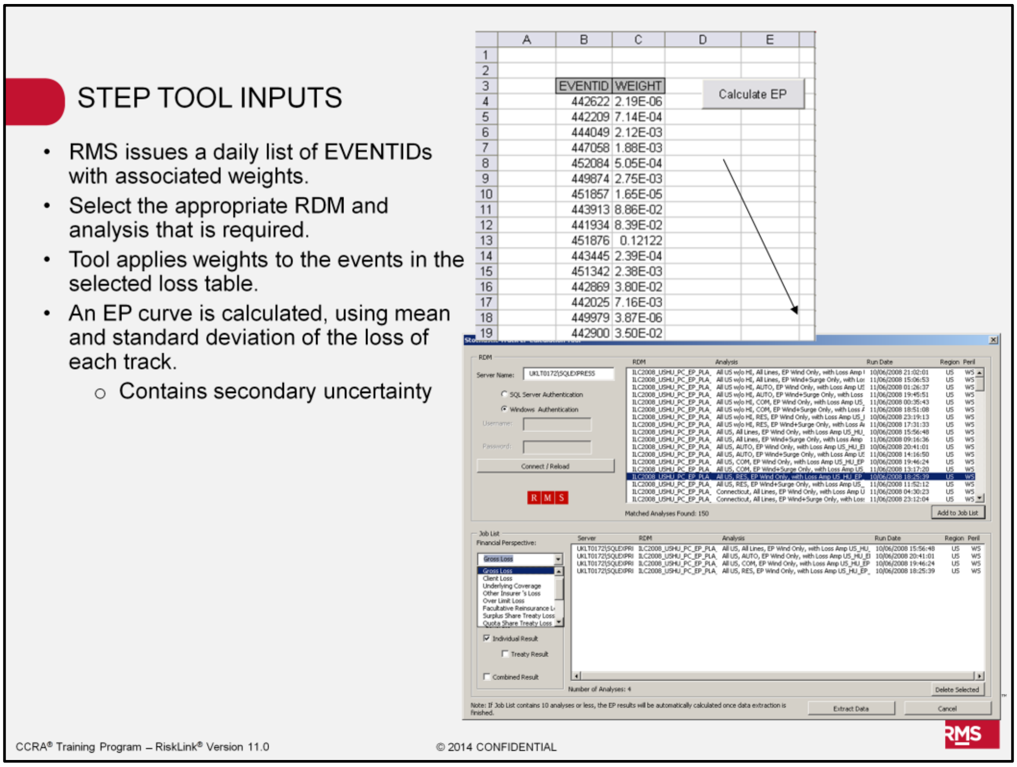
We also use ground observations from our reconnaissance teams who are our vulnerability experts. They can backtrack estimated wind speeds on the ground from the type of damage they see. They go out into the field and drive around the damaged region taking photographs, notes, and GPS locations, and compare that with our wind field footprint to validate each wind speed band in terms of its intensity as well as its lateral extent. What the team is doing is similar to the approach that is used to determine wind speeds in tornadoes, which are based on the Fujita Scale.



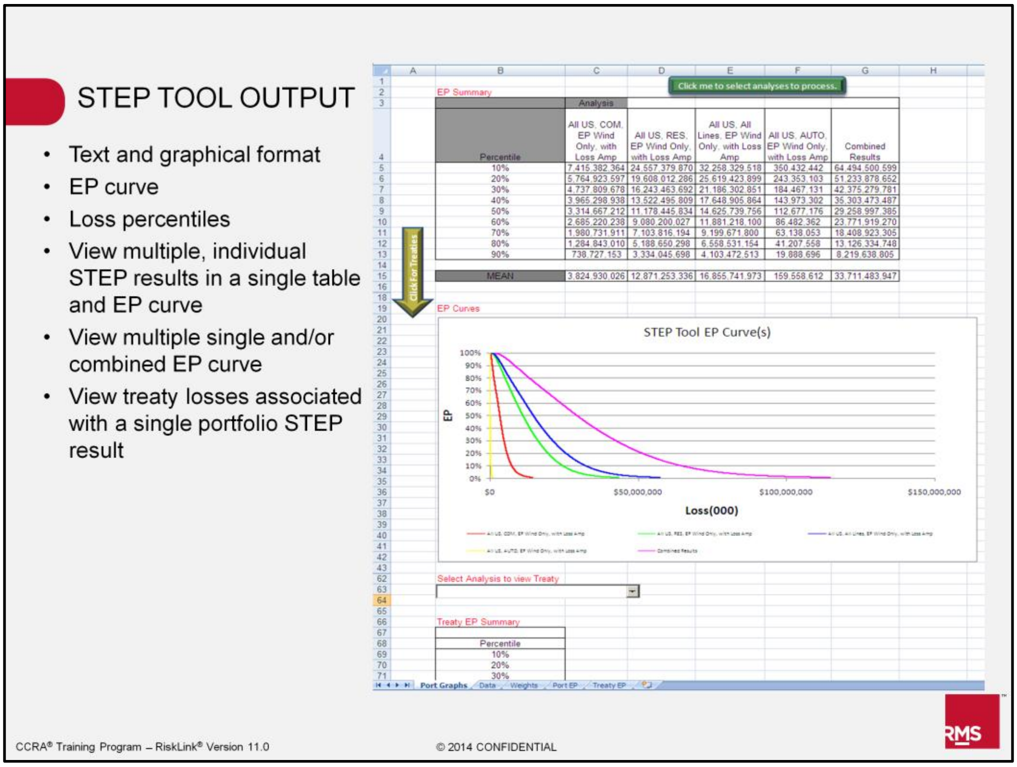
This is a summary of what was discussed in the previous slides, outlining the process by which the Ensemble Footprints are generated.



The Stochastic EP (STEP) Tool is easy to use and can be launched in Microsoft Excel. It has been designed to assist client catastrophe response and allows clients to extract information from RDM databases. When stochastic tracks are issued before or after a U.S. hurricane landfall, the tool can be used to calculate an event-specific loss EP curve by using the track's expected losses and standard deviations. STEP Tool version 4 (released in August 2009) and 4.1 (released in May 2011), provide the user with much more functionality than available prior to version 4. Users can now batch process analyses across multiple RDMs and servers, and create and view single or multiple EP curves.

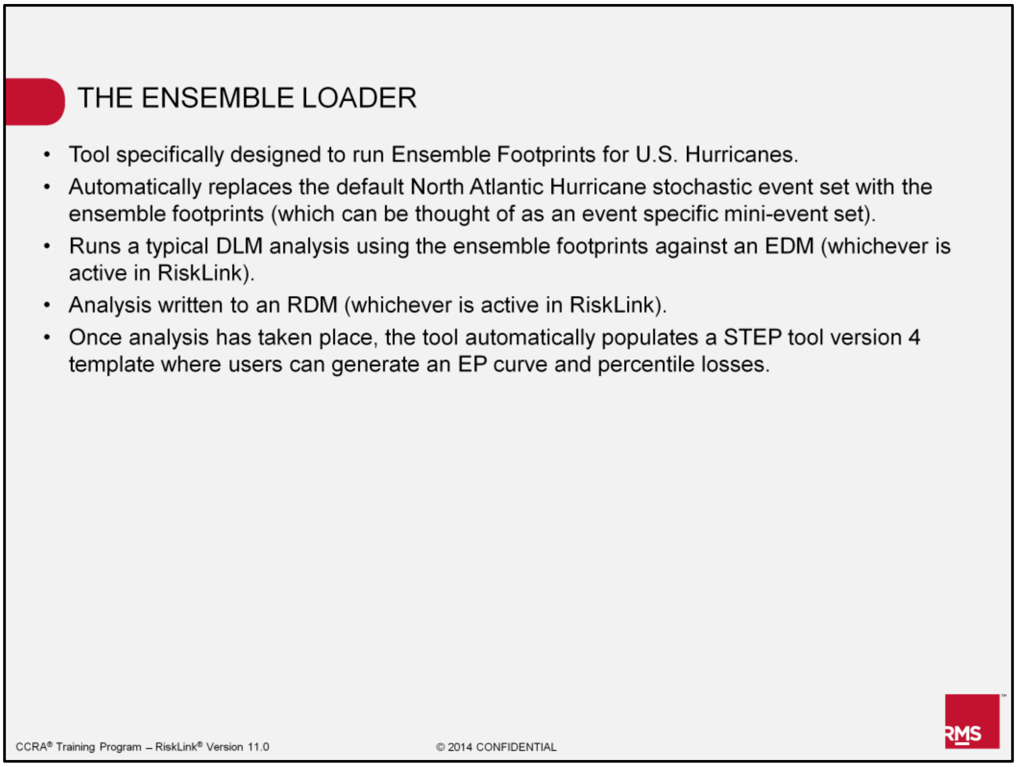


To provide a bit more clarity on how the STEP Tool is used, let's think about the inputs required for the tool. Whenever RMS issues a suite of weighted stochastic Event IDs, they are issued in a STEP Tool template, which is an Excel file containing the Event IDs and associated weights. Once the Tool has been activated using Ctrl+shift_T, the STEP Tool User Interface will appear allowing the user to select the appropriate analysis in the relevant RDM. The tool then applies the weights to the event and associated losses to calculate an EP curve. This method uses the mean and standard deviation of the loss for each track, and, therefore, includes secondary uncertainty.

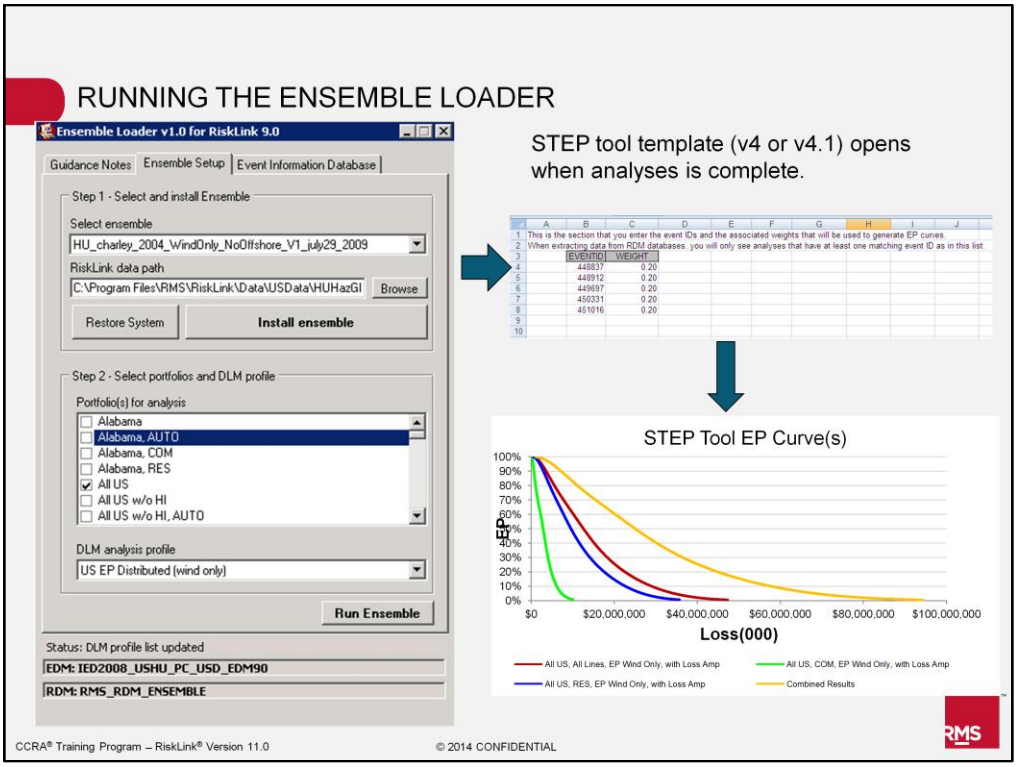


	Analysis				
Percentile	All US, COM, EP Wind Only, with Loss Amp	All US, RES, EP Wind Only, with Loss Amp	All US, All Lines, EP Wind Only, with Loss Amp	All US, AUTO, EP Wind Only, with Loss Amp	Combined Results
10%	7,415,382,364	24,557,379,870	32,258,329,518	350,432,442	64,494,500,599
20%	5,764,923,597	19,608,012,286	25,619,423,899	243,353,103	51,233,878,652
30%	4,737,809,678	16,243,463,692	21,186,302,851	184,467,131	42,375,279,781
40%	3,965,298,938	13,522,495,809	17,648,905,864	143,973,302	35,303,473,487
50%	3,314,667,212	11,178,445,834	14,625,739,756	112,677,176	29,258,997,385
60%	2,685,220,238	9,080,200,027	11,881,218,100	86,482,362	23,771,919,270
70%	1,980,731,911	7,103,816,194	9,199,671,800	63,138,053	18,408,923,305
80%	1,284,843,010	5,188,650,298	6,558,531,154	41,207,558	13,126,334,748
90%	738,727,153	3,334,045,698	4,103,472,513	19,888,696	8,219,638,805
MEAN	3,824,930,026	12,871,253,336	16,855,741,973	159,558,612	33,711,483,947

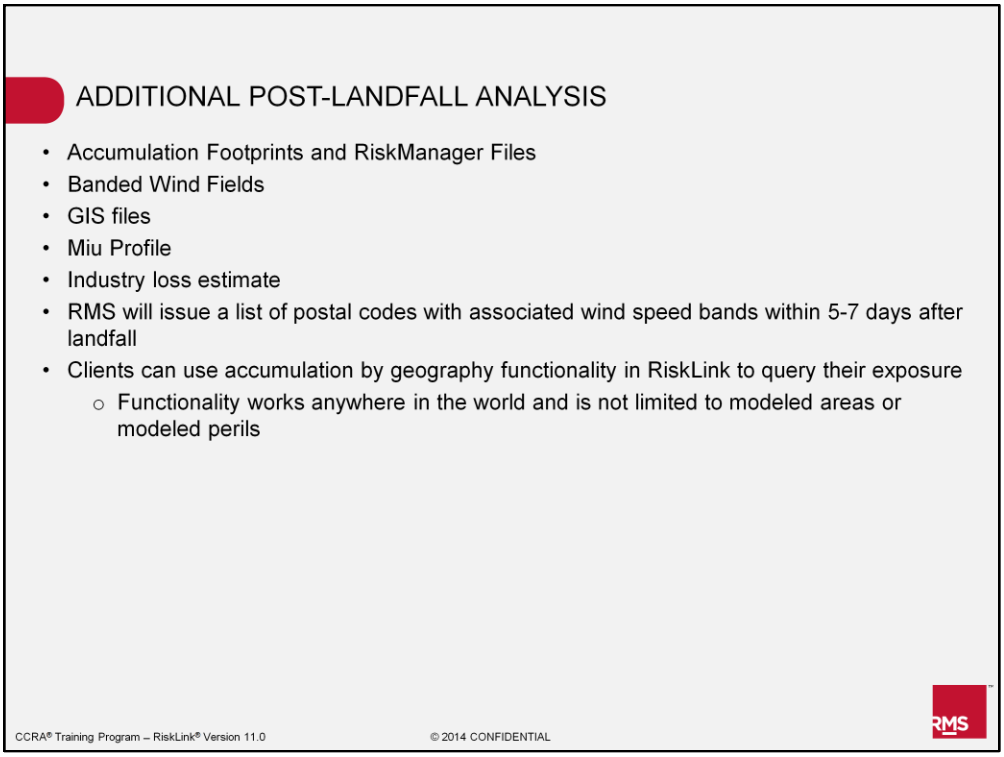
Results are presented as an event loss EP curve(s), mean loss, and loss deviations for the event, as well as the “raw” EP data used to produce the curve.



To run the Ensemble Footprints for U.S. hurricanes, RMS has built a tool called the Ensemble Loader. The tool automatically replaces the default North Atlantic Hurricane stochastic event set with the Ensemble Footprints issued for a particular event. The tool runs a typical DLM analysis against the active EDM in RiskLink and results are written to whichever RDM is active. The Ensemble Loader will automatically populate a STEP Tool template, which allows users to generate an EP curve and percentile losses.



This slide shows the setup of the Ensemble Loader and the output that is created once it is finished running.



In addition, RMS provides accumulation footprints (list of affected ZIP Codes) to enable a “worst case” analysis (assumes 100% loss) in combination with the probabilistic loss estimate, and the capability to identify by account what exposure lies within the affected region.

Following a U.S. hurricane landfall, RMS will aim to reconstruct the wind field over land associated with the hurricane within 5-7 days after landfall. We assign a wind speed banding to each affected postal code. This information enables clients to query their exposure using the accumulation by geography function in RiskLink. Accumulation management allows users to identify, monitor, and manage pockets of risk in a portfolio, and is a class of analytical functionality that is included in RiskLink DLM .

RMS INDUSTRY LOSS ESTIMATE

- RMS will typically issue an industry loss estimate within 7-10 days of landfall, although this may vary depending on the magnitude and severity of an event.
- Loss estimate typically a range
- Based on the RMS Industry Exposure Database (IED)
- Also takes into account non-modeled losses:
  - Flooding
  - Localized Super Cat conditions
  - Losses outside the hurricane states

This slide discusses the RMS industry loss estimate.

RMS RECONNAISSANCE

- Use available real-time satellite data
- Deploy ground teams within 48 hours of an event
- Deploy aerial photography plane for two to three days
- Obtain high-resolution satellite data to map areas of damage and flood extents with storm surge

Beginning in 2004 and into 2005, RMS developed the use of aerial reconnaissance teams. The team flies the coast taking aerial video and photography, which can also be completely geo-referenced. This enables us to much more quickly get a broad view of the amount of damage to roofs. For example, when combined with the detailed building vulnerability assessments from the teams on the ground, it enables us to supplement the wind speed observations. This is also important in order to obtain significant information about building performance that we can use in later model updates. We also use more satellite imagery as resolution and quality increases, this was particularly helpful for assessing flood extents in New Orleans after Hurricane Katrina.

INSIGHTS FROM RECONNAISSANCE TEAMS

- Ground and aerial surveys corroborate site damage reports quickly and help refine modeling parameters and loss estimates.
- Focus on specific issues in the field such as storm surge damage in Ivan

Hurricane Ivan storm surge impact: Pine Beach, AL

Reconnaissance is used to verify loss predictions produced by our models as well as longer-term calibration of the models themselves through updates in the future.

In addition to collecting information from all our contacts in the research and private industry and using online sources, we send reconnaissance teams into the field immediately following an event. Most of the time we have people on the ground within 24 hours. We will have one or two teams of between two and four people collecting geo-referenced information and property damage, as well as the magnitudes of some of the non-wind-related damage, as shown by these pictures of storm surge impacts in Alabama after Hurricane Ivan.

USING CLAIMS INFORMATION

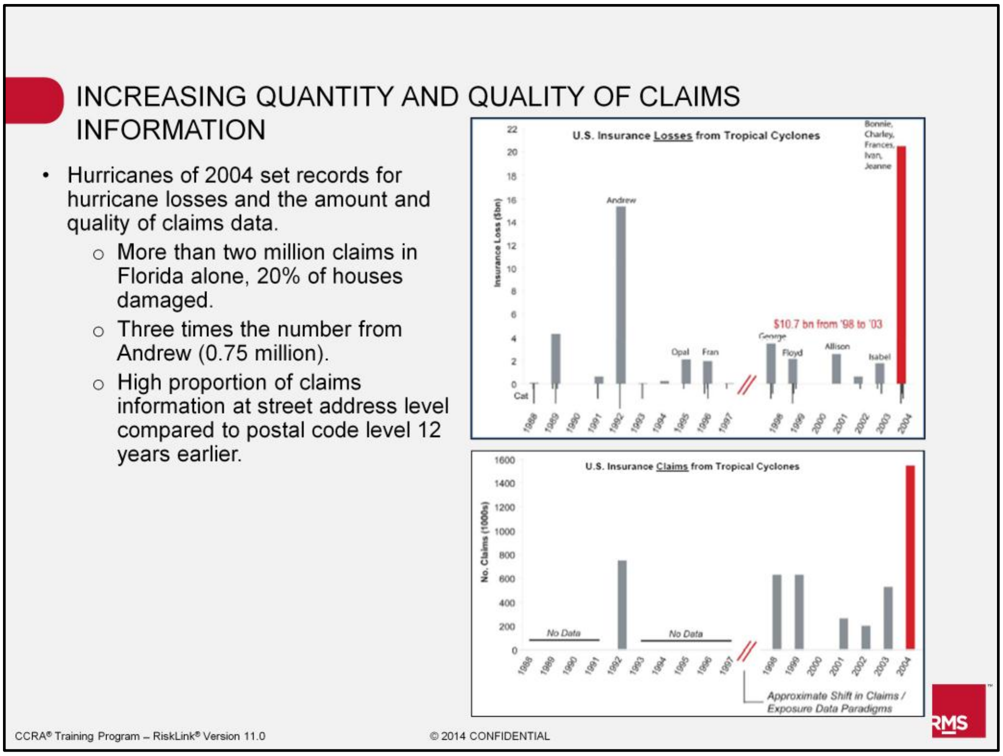
- Client claims data is applied to a wide variety of model development uses that improve accuracy of modeled loss.
  - Calibration of vulnerability functions
  - Calibration of hazard gradient where detailed data is provided
  - Calibration of event losses and calculation of average annual loss
  - Examination of currently non-modeled loss drivers such as inland flooding, tree damage, etc.

Our vulnerability experts will always make considerable effort to collect claims data in conjunction with many of our clients to help with future model enhancements. We undertook a major initiative after the 2004 hurricanes, and extended that for the 2005 hurricanes, and again after Hurricane Ike in 2008.

The 2004 hurricanes produced a record number of claims. The number of claims that have been filed in total for the four land-falling hurricanes is considerably more than was recorded for Hurricane Andrew in 1992.

Real-time events are relatively rare, despite what happened in 2004 and 2005, and therefore extremely valuable to understand in the long-term.

Upgrades to building codes put in place after Hurricane Andrew were first tested in Florida with Hurricanes Charley and Frances in 2004, and sometimes behaved differently than how they were predicted. They also help us define the additional contribution of non-wind related losses, as we saw on the previous slide.



As well as having significantly more claims data, we have significantly higher quality claims data than we have ever seen before.

As has already been said, the hurricanes of 2004 were completely unprecedented in both the total loss from the four events together as well as the number of claims. The extent of damage means a far wider area was impacted than in previous hurricane seasons. A very large area of Florida was hit by at least one hurricane, if not two, or in some cases, three hurricanes. The four storms together acted as one particularly important effect, and that is the creation of demand surge. This is the elevation of market prices for building materials and labor above normal conditions. We saw a much bigger impact after the 2004 hurricanes on this factor than ever before, primarily because of the vast number of properties that were affected. We also see that a much larger proportion of the claims data is at much higher resolution than in previous events, and this reflects the industry's move towards much better quality exposure information. This will help us refine to spatial aspects of our model considerably in the future, having concentrated previously on overall loss number calibrations.

ADDITIONAL PERSPECTIVES ON DAMAGE

- Looking beyond the model predictions
- Share damage reports and expert opinion on unique storm characteristics
  - Example: Additive or multiplicative effects of multiple hurricanes affecting the same structures in Florida in 2004
- Special topics examples
  - Storm clustering analysis based on 2004 hurricane season
  - Impact of moving to seasonal deductibles from event deductibles, which has now been legislated in Florida

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So far we have mainly talked about how we at RMS provide perspectives on direct property insured losses for real events.

In addition to the products being released by Cat Updates in terms of storm characteristics, modeling parameters, industry loss estimates, and briefing presentations, we also produce special whitepaper reports after events that focus on any unique aspects of the storm and how it might impact the industry as a whole. This forms part of our longer-term response to an event, as it does not start within a few days of a storm making landfall. We were developing these perspectives for several months after the end of the 2004 hurricane season.

We did this by going back into the model and studying how to appropriately model the occurrence of the four hurricanes so close together, a phenomenon that we have since identified on several historic occasions, as well as the impact of moving towards a seasonal deductible compared to event deductibles and the impact of that on our average annual losses. These studies are published to clients and available on our website.

By doing these studies, we can help the industry quantify the changes in their risk that occur as a direct consequence of real events.

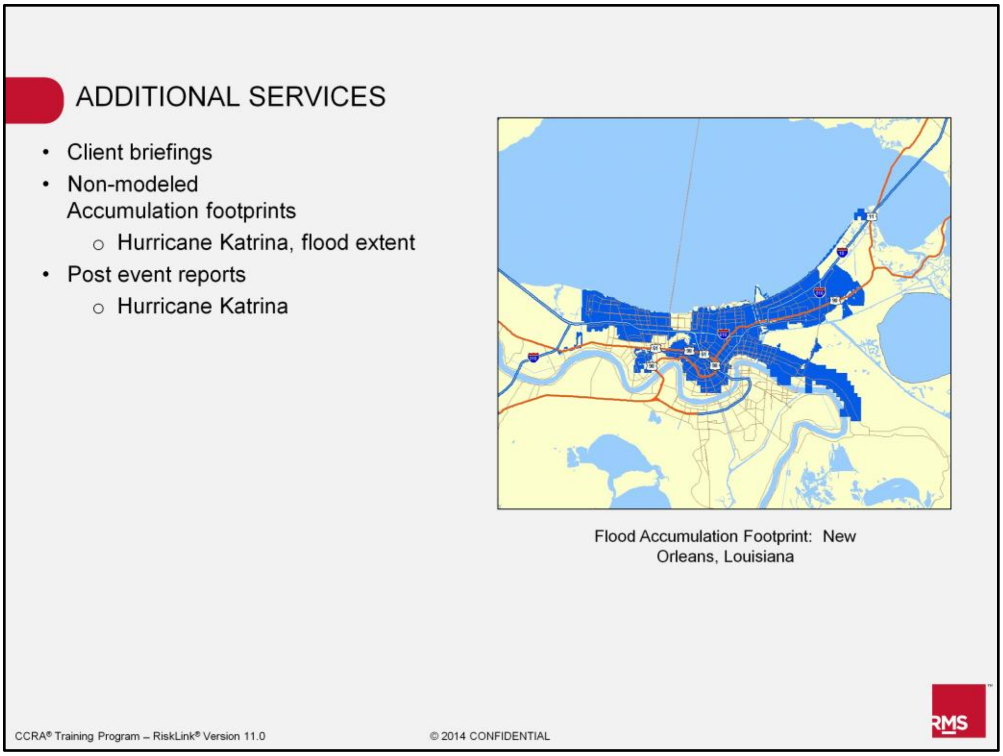
LONGER TERM BENEFITS OF EVENT RESPONSE

- Claims collection helps validate current model assumptions and provides information for future model upgrades
- Real events test building performance and building codes
- New phenomena can be revealed during real events
- Limited amount of historical claims information means each new event is valuable

Hurricane Ivan wind and surge damage: Perdido Key, FL

As we mentioned already, the event response process is not confined to the time around landfall but extends to incorporate all the lessons from a whole range of issues, both from our perspective and that of clients. In particular, the use of claims data to validate model assumptions or to reveal a new phenomena that needs to be included in the future.

For example, antecedent conditions before Hurricane Isabel made landfall in 2003 made trees much more susceptible to falling on property than we typically have seen before. We now also provide information on similar risks for this above-normal level of tree fall within our Cat Updates service.



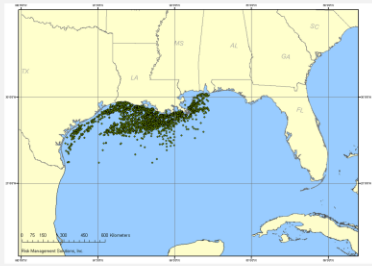
During a large event, RMS will conduct client briefings approximately two hours after the Cat Update is released. These are designed to give clients updated and detailed information from what was released in the Cat Update. Clients also have the opportunity to ask questions of RMS specialists.

In events where non-modeled losses become significant, RMS has the ability to construct accumulation footprints, enabling clients to identify their exposure in the affected areas. Following satellite and aerial reconnaissance after the flooding from Hurricane Katrina in New Orleans, a footprint was constructed consisting of VRG cells that defined the flood boundary. This allowed clients to assess their total exposure within the flood extent, regardless of line of business or coverage.

Following large events, RMS will compile Post Event Reports, which are typically released a few months after the event. For example, a post event report was released several months after Hurricane Katrina. The research that went into this report gave rise to RMS's new view of loss amplification, which was ultimately embedded into the model update done in 2006.

NON-U.S. CAT RESPONSE DELIVERABLES

- Mexico, Canada, Caribbean, Central America
- Suite of stochastic tracks will be issued within 48 hours after landfall.
  - Represents uncertainty in landfall parameters; e.g., landfall location, maximum sustained winds, and Rmax.
- Multiple landfalls:
  - Individual track sets will be issued for each affected country/region/platforms.
  - Where possible, an additional single combined track set will be issued for the whole region.
- Accumulation Footprints and RiskManager Files
- Banded Wind Fields (where applicable)
- GIS files
- Miu Profile
- Industry loss estimate (where applicable)



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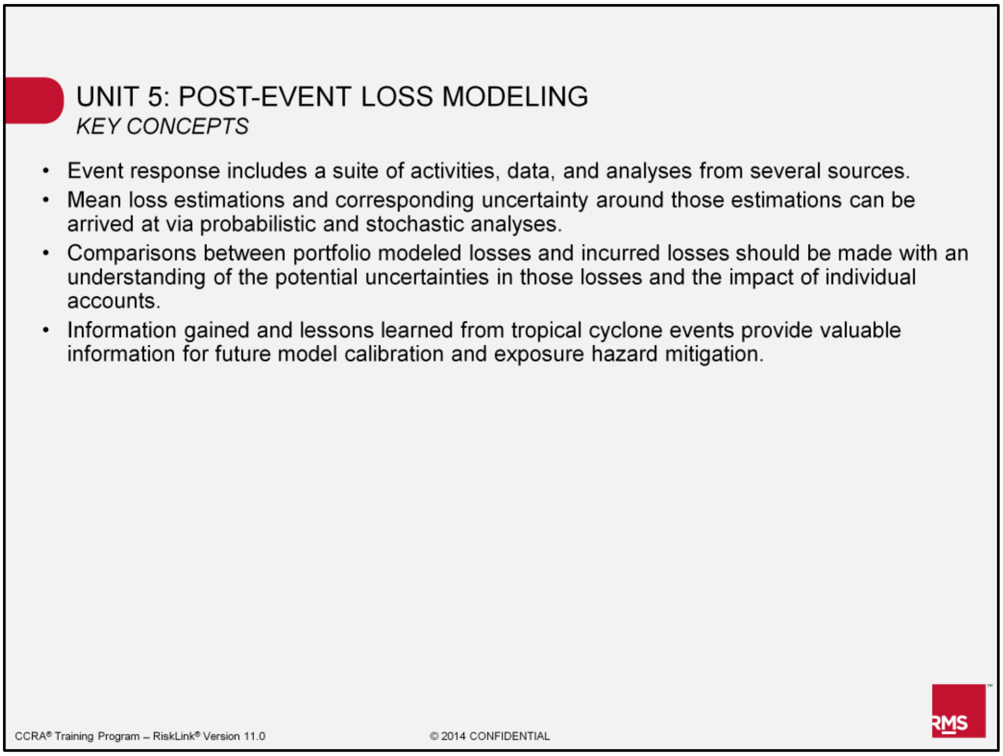
For hurricanes that track across any of the other modeled North Atlantic hurricane countries/regions, suites of weighted stochastic tracks are generally issued within 48 hours after landfall. Tracks are selected based on the uncertainty in the landfall location, maximum sustained winds, and radius to maximum winds. As with all other regions, data is collected and analyzed from many different sources, with the NHC being a major source of meteorological data.

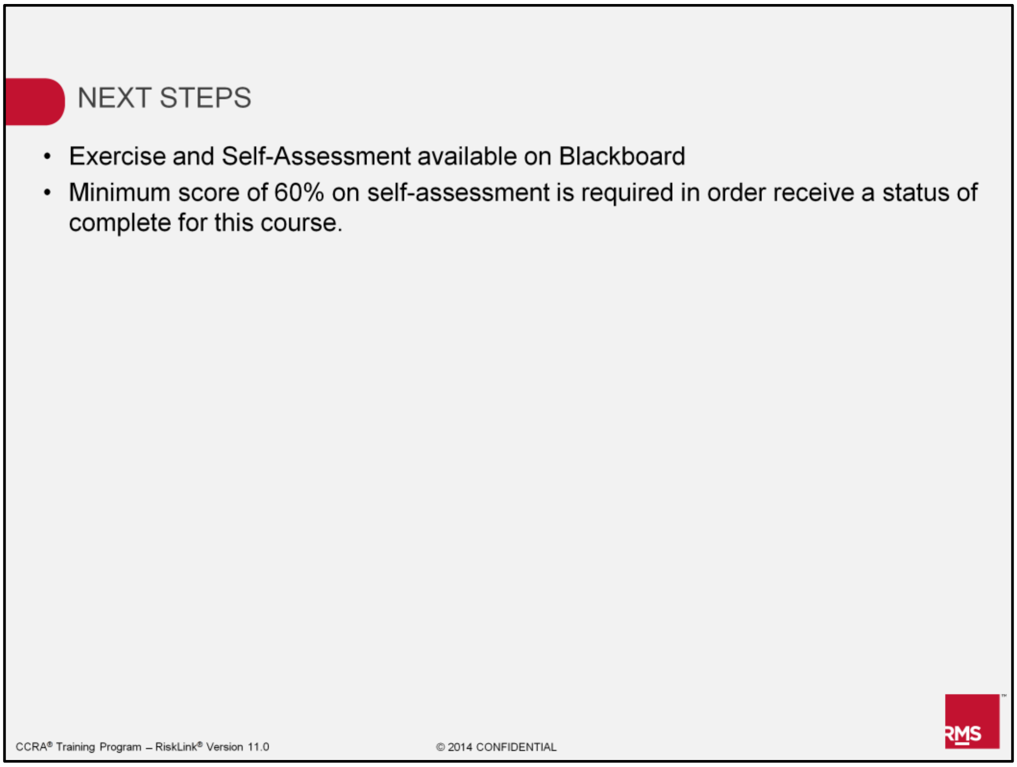
In cases where multiple landfalls occur (e.g., Caribbean + Offshore Platform + U.S. or Mexico + U.S.), RMS will release individual track sets for all affected countries/regions. With the basin-wide stochastic event set released in 2011, RMS will also endeavor to select a single combined stochastic track set that represents all landfalls; however, finding a suite of representative tracks in the stochastic event set may not be possible due to the wide range of possible tracks of storms with multiple landfalls.

Other deliverables released for these countries/regions (where appropriate) include accumulation footprints and RiskManager files, banded wind fields, GIS mapping files, a Miu profile, and an industry loss estimate. Timing for the release of these deliverables is consistent with the post-landfall U.S. hurricane deliverables.



To summarize, we have seen how event response spans the whole spectrum of activities and products, focused on providing real-time estimates of the likely loss and the associated uncertainty. We have learned about some of the sources of uncertainty, along with how you can assess losses using either a deterministic approach or the probabilistic approach of RiskOnline.

Finally, each new event teaches the industry as a whole, as well as modelers, a significant amount in terms of how the real world reacts. Events, as well as the models that represent them, are often catalysts for change in the insurance industry.



In order to fully complete the course work for this peril, complete the exercise and self-assessment available on the Blackboard. You must score a minimum of 60% on the self-assessment in order to receive credit for completing this course.

Completion of three peril model courses is mandatory in order to be eligible to sit for the CCRA® exam.