EXTERNAL CATASTROPHE MODEL VALIDATION
ILLUSTRATIVE VALIDATION DOCUMENT NO. 1
US WINDSTORM, HIGH MATERIALITY

Region/peril:	US Windstorm
Materiality:	Very high
Model:	RMS RiskLink v11 U.S. Windstorm

The scope of this document is restricted to the Solvency II requirements as they apply to using an external cat-model within an Internal Model.

THIS DOCUMENT IS AN ILLUSTRATIVE EXAMPLE, NOT AN ACTUAL VALIDATION. The materials we have used are only examples of the kind of thing you may want to use. There are no "must-do" items, because your materiality will drive everything that you do.

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v1.83 – 6th July 2012

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INTRODUCTION

The purpose of this document is to provide an example of validating an external cat-model for use in an Internal Model under Solvency II.

The document is not a template or a checklist, but an illustration of how the principles of model-validation may be applied in practice.

The principles themselves are explained in the Lloyd's and LMA paper "External Catastrophe Model Validation: Conceptual Framework" published on 3rd May 2012. Further guidance on the principles, and some useful suggestions for implementing them, can be found in chapter 7 of "Industry Good Practice for Catastrophe Modelling" published in December 2011 by the Association of British Insurers.

REGION/PERIL

To make the example as realistic and relevant as possible, we have chosen to use vendor source materials for an actual catastrophe model for a specific region/peril - **RMS RiskLink v11.0 U.S. Windstorm**.

We have taken this approach for two reasons. Firstly, using an actual cat model allows us to reference real documentation and other vendor material, rather than inventing hypothetical examples. Secondly, Atlantic Hurricane is a region/peril that is especially relevant to much of the Lloyd's market.

<u>However, this illustrative example document should not be taken as an endorsement or actual validation of RMS v11 U.S.Windstorm</u>. Indeed, we could equally well have chosen the equivalent models from AIR or EQECAT. The principles illustrated here can be applied to any catastrophe model, from any provider (including an in-house team or a broker), for any region/peril.

MATERIALITY

The single most common question about catastrophe model validation is "How much validation should I actually do?". It is difficult to overstate the significance of materiality in assessing the appropriate level of validation. As discussed in the Conceptual Framework document, the requirement for validation is determined primarily by the materiality of a company's catastrophe-risk within its overall risk.

<u>This illustrative example document assumes a very high level of materiality for U.S. Windstorm for your company</u>.

PRE-VALIDATION PROCESS

Please see the Conceptual Framework document for a discussion about assessing materiality, sensitivity-testing of the Internal Model to changes in the cat-model, and levels of validation.

DOCUMENTATION AS EVIDENCE

As evidence of your model validation process, it may be helpful to distinguish between two types of documentation. They can be combined in a single document, but even so you should understand the distinction.

Firstly, you will need a *process document* which describes – probably in quite abstract terms – how your company goes about validating an external cat-model. It should include descriptions of how the process is evidenced, what are the necessary sign-offs, and how the process itself can be revised and updated.

As always, materiality and proportionality are key. The process document need not be of encyclopaedic length and detail if your cat-risk is not very material (although it should certainly describe how you assess that this is the case). Similarly, the sign-off procedure may require anything from a lengthy assessment by a risk-committee to a short discussion with the Chief Risk Officer. In either case, what matters is the existence of a document which states what the process is.

Secondly, there needs to be an actual *validation document*, of which this document is intended to be an illustrative example. This describes what has actually been done, and why, and what adjustments (if any) are recommended to the cat-model inputs or outputs to better reflect your company's actual catastrophe risk. It will be this document which is signed-off as the final step in your validation, and forms the evidence that your process has been followed.

HOW THIS DOCUMENT IS STRUCTURED

The process of validating a catastrophe-model can be thought of in two separate steps:-

- understanding the model; and
- relating it to your portfolio.

As always, the question you are trying to answer is "*does this model provide a valid representation of catastrophe risk for my portfolio, taking into account proportionality and materiality?*" You are not expected to reach an opinion about the cat-model in isolation from your portfolio.

We suggest that there should also be a third step, which is the formal recommendation to your company that the external catastrophe model provides a valid representation of the risk, subject to whatever qualifications and adjustments are indicated by your validation process.

We have therefore divided this document into three parts:-

1. UNDERSTANDING the cat-model itself

2. RELATING it to your portfolio

3. RECOMMENDING how it should be used (adjustments, run-time options, etc)

Throughout, we have commented on what your documentation is intended to demonstrate, what approaches you may take to validation, and how you may best describe them.

CONSIDERATIONS FOR SENIOR MANAGEMENT

There is a lot of material in this document, much of which is highly technical. The average reader – assuming an average person would want to read a document like this – may find the content hard-going.

This is an example of validating a catastrophe model, and is therefore by definition a technical document. It is not necessarily addressed to Chief Risk Officers or Board Members, who can expect to see a high-level summary of this material that presents only the conclusions.

Finally, please remember the document assumes that exposure to catastrophic losses from U.S. Windstorm is very material in relation to your company's overall risk. Companies for which U.S.Windstorm is much less material are not expected to perform this level of validation. Proportionality is key.

1. UNDERSTANDING THE CATASTROPHE MODEL

This section is about the cat-model itself, and should demonstrate an appropriate level of factual understanding about it.

The validation process should focus on the user's understanding and assessment of the cat model. As in this illustrative example, the language and structure should clearly distinguish what is information provided by the vendor and what is the opinion and interpretation of that information by the user. In the case of analysis conducted by the user, they should reference their own credentials and expertise, any scientific published papers they have used to support their analysis, and whether they have had their own work reviewed and signed off by others.

It will also be helpful to separate what you know about the model from your opinion about it. For example:-

FACT – the vendor has taken [such-and-such] approach to near-term rates

OPINION – this approach seems very conservative/optimistic, but is supported by [such-and-such]

We have therefore taken the approach of listing all the facts first, then having a separate section for commentary.

1.1 FACTS ABOUT THE PERIL AND THE MODEL – VENDOR MATERIAL

The first, easiest and most accessible source of understanding will be material that the vendor provides, which may come in the form of documentation, seminar presentations, meetings, technical discussions etc.

Your document should include an assessment of the vendor material, showing that it has been read/seen/heard, understood and (where appropriate) commented upon. Information about the vendor's own validation, derived from documentation etc., belongs here.

1.1.1 QUALITY OF VENDOR MATERIAL

This section should comment on the quality of material available from the vendor, including whether it provides enough information for you to understand the model.

The vendor has published copious information about their U.S. hurricane model, which provides a sound base for understanding and further investigation.

We have also taken advantage of discussions with them to provide detailed information and insight on particular technical points.

1.1.2 BACKGROUND FACTS ABOUT THE MODEL

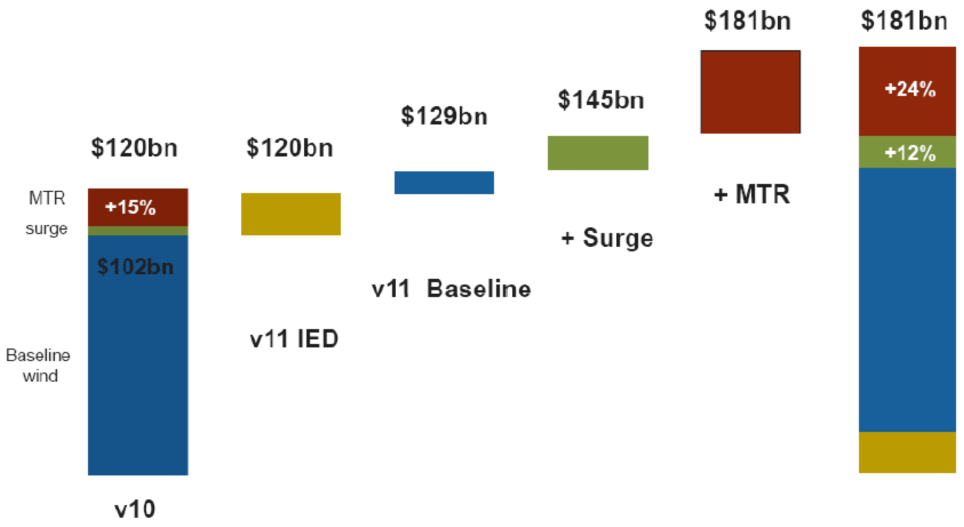
In February 2011, RMS updated their U.S. hurricane model from v10 to v11. The last major upgrade of U.S. hurricane hazard was in 2003, while a 2006 release focused primarily on vulnerability, and the introduction of the medium-term rates.

RMS describe the v11 update as including the following major changes:

- Country coverage extended to new territories in the Atlantic Basin. This validation report focuses only on the mainland U.S.
- A rebuild of the wind hazard model, including changes to vulnerability curves
- Changes to the inland filling methodology (in the hurricane wind speeds degrade less rapidly over land, thus causing damage further inland)
- Adoption of a new storm surge model
- Medium-term event frequencies

In addition to working with independent academics and engineers in the building of the model, RMS has published peer-reviewed papers on key assumptions, and had the entire hazard model independently peer-reviewed by hurricane expert Dr Bob Hart, Associate Professor, Meteorology Department Florida State University, who published a summary of his review. The baseline wind model was also reviewed and passed by the Florida Commission on Hurricane Loss Projection Methodology (FCHLPM), which employs a team of experts to verify the technical credibility of the science, engineering, actuarial methodology, and software that the model is based upon (FCHLPM does not review surge or medium-term rates).

The following gives a brief summary of the key changes from v10 to v11 using the RMS industry exposure data, at the 1 in 100 year return period:



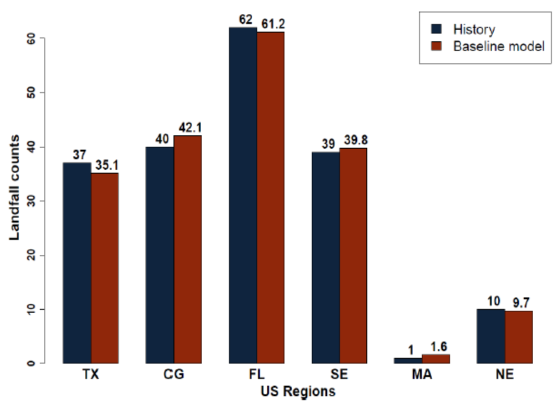
Using this reference data set, the Medium Term Rate (MTR) change is the single largest driver of the model change, being responsible for circa 59% of the total change to the industry 1 in 100 year loss, and will thus form a core part of this validation report. The changes to the Storm Surge model are also significant, with the vulnerability and hazard components (within the v11 Baseline change above) being somewhat less significant.

Source: "2011 RMS North Atlantic Hurricane Models Highlights"

1.1.3 VENDOR'S VALIDATION OF EVENT FREQUENCY

a) Long Term

RMS believe that the most important validation metric for event frequencies of the baseline model (long term rates) is to compare stochastic landfall rates to observed landfall rates, overall for the U.S., and for coastal segments (called gates). RMS has published these comparisons, which they state can be verified independently. The following figure from RMS shows the all-U.S. comparison of Historical and Stochastic (baseline model) landfall counts in 6 US regions (109 years). Regional breakdowns are available, which show a similar picture.



RMS also have provided a comparison of the stochastic model losses (using the baseline model) with that derived only from historical storms. Publicly available data from the FCHLPM allows benchmarking relative to other generally available models. On an AAL basis, all the cat models stochastic derived AAL are slightly above the historical-generated AAL, on a wind only basis. RMS states that this is because 110 years of history is insufficient to capture the full distribution of possible hurricanes, which the stochastic model represents.

Residential AAL reported in Form S-5 of modeller submissions per the FCHLPM 2009 standards

	Historical-AAL ($bn)	Stochastic-AAL ($bn) – using long-term rates	Ratio Stochastic/Historical
RMS v11	2.67	3.47	1.3
RMS v10	2.80	3.26	1.16
AIR	2.84	3.62	1.27
EQE	3.26	3.99	1.22
ARA	4.13	5.28	1.28

RMS state that the gap between stochastic and historical losses is wider when storm surge is included. RMS believe that it is reasonable to assume that for catastrophe storm surge events in particular, which are even rarer than the most severe wind events (due to the combination of factors which need to be in place), 110 years of history is insufficient to represent all possible event occurrences.

b) Near/Medium Term rates forecast - forward looking view of risk

In addition to the baseline model (long term rates) RMS provides a medium term (also referred to as the near term) perspective of hurricane event rates. This is a currently inflated set of event rates to take account of the medium term, enhanced activity projection of the next 5 years, and represents hurricane activity in terms of annual average landfall probabilities over the next 5 years.

To create the medium term rates, RMS builds a range of forecast activity rate models using different techniques. RMS states that its philosophy is not to rely on just one method, nor solely on SST changes, given the uncertainties, but to use a variety of indicators and variables and predictors. These rate models do not make any assumptions in themselves whether the Atlantic basin is in a relatively warm SST phase, or cool SST phase, but will "automatically" adjust according to the conditions. If this method was applied during relatively low periods of activity, and cooler SSTs than average, the medium-term rates would be lower than the long-term rates. RMS has tested these activity rate models relative to historical activity (both basin wide and landfalling) - by "hindcasting".

The individual rate models are then weighted to give the blended medium term rates implemented in RiskLink.

In version 11, RMS no longer utilise their previous "expert elicitation" approach to do this weighting, but use a statistical weighting approach, based on back testing each individual model's ability to "forecast" historical activity rates over the course of the last 50 years (known as hindcasting). The hindcasting results of the models have been published by RMS within their whitepapers. Following this, regionalisation adjustments are made by RMS to account for the changes in the geographical distribution of hurricanes seen with changes in sea surface temperature patterns. RMS's policy is to review the medium-term rates annually, and to conduct more research, and will provide updates if warranted. Their method, and the details of the individual models and the weighting mechanism and the regionalisation method is all published by RMS.

The overall rate increase across all hurricanes (cat 1-5) relative to the baseline model is similar to previous model versions, but with a very significant increase in major storms (cat 3-5) compared to prior years, which has a considerable impact on modelled loss.

The overall difference between long-term and near-term rates for all U.S. landfalls is very consistent between model versions, at an overall difference of ~20%. However, the increase in major hurricane landfalls (category 3-5) for the near-term rates relative to long-term in the 2011 model is greater than in the 2010 model (39% compared to 22%) while the relative increase for. the less damaging but much more common category 1-2 storms is smaller in version 11 (11% compared to 16%).

This change, and the regionalisation of it, are shown in the table below, which shows the % difference between the long-term and medium-term rates in both the v10 model and v11 model:

	All Hurricanes		Cat 1-2 Hurricanes		Cat 3-5 Hurricanes	
	V10	V11	V10	V11	V10	V11
All U.S.	19%	21%	16%	11%	22%	39%
West Gulf of Mexico Coast	16%	19%	15%	14%	18%	26%
East Gulf of Mexico Coast	16%	22%	15%	14%	17%	41%
Fl Gulf Coast	8%	24%	9%	18%	8%	33%
FL Atlantic Coast	27%	37%	28%	17%	31%	61%
Southeast and Mid-Atlantic	27%	19%	24%	14%	31%	55%
Northeast	23%	19%	27%	18%	15%	25%

The impact of the increase to major category hurricanes is a significant change to the near term event rates, and has a very material impact on modelled losses. In addition, for certain portfolios that are regionally concentrated, the significant change to landfall rates from v10 to v11 may cause even more dramatic changes.

In addition, for certain portfolios that are regionally concentrated in Florida and Gulf states, the significant change to landfall medium-term rates from v10 to v11 may cause even more dramatic changes.

Sources:

“North Atlantic Hurricane Model v11 Activity Rates: The Medium-Term Perspective”

“FAQ: North Atlantic Hurricane Medium-Term Rates FAQ – Sensitivity of Loss Results”

“North Atlantic Hurricane Model v11 Activity Rates: The Medium-Term Perspective (RMS Technical White Paper)”

“Background and scope of the RMS-RPI meeting on Atlantic Hurricane Medium Term Rates, March 21st 2012 Presentation by Robert Muir-Wood”

1.1.4 VENDOR’S VALIDATION OF HAZARD

a) Windspeed at landfall, storm pressure and filling rate

Shortly after landfall, storms are removed from their primary energy source and their central pressure increases and the eye fills. This phenomenon is referred to as inland filling, and it is responsible for the large scale weakening of hurricanes as they move over land.

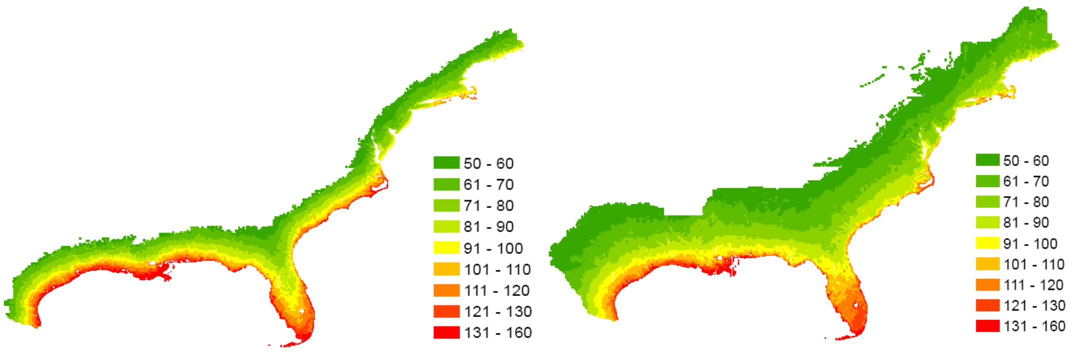
At the time of the previous update to the hazard model in 2003, the RMS inland filling model used a single distribution for filling rates across all stochastic storms across the U.S., based on the available data and research at the time (Kaplan and DeMaria). It did not use predictors, other than time since landfall (so in effect, the storm would degrade using a uniform distribution, as it moved further inland, and would vary only with how rapidly the storm moves inland).

There is a paucity of historical observational data on hurricane decay, as there are only a few storms for which there is reliable data on the filling rate, so with the new model RMS utilised a numerical modelling approach to simulate over 1,000 years of hurricane landfall at 12km resolution. These simulated storms were compared to the historical record for consistency, and after validation by RMS were added to the small amount of observed data on infill, and new relationships between multiple storm parameters and the rate of inland filling were established.

RMS state that they partnered with one of the world's leading experts in numerical modelling, Dr David Nolan Associate Professor, Meteorology & Physical Oceanography, University of Miami to conduct this research, and had the research accepted through peer-review and publication. RMS further state that this research was verified as having "more skill at predicting tropical cyclone intensity over land than similar models".

The result of the new inland filling approach is a net increase on the reach of certain types of storms further inland than the previous version, with more variability by each individual storm. In our opinion, the failure of the previous model to penetrate deep inland was a known limitation, and we find the new model an improvement in this regard.

The images below show the peak gust 100 year return period maps (3 second peak gust, mph) between v10 (left) and v11 (right):



In addition to the inland hazard increases, there are also some decreases in the coastal hazard resulting from other changes to the hazard model, but not consistently. The impact of this change will thus vary greatly by portfolio.

RMS has validated the new inland filing rate against historical hurricanes, and shown an improved agreement over the previous version of the model. In addition, RMS has compared the wind-hazard model output to other accepted views of the hazard to sense-check the output. An independent validation check of the latest wind-hazard map underlying the latest wind speed design standards for the U.S., as published by the American Society of Engineers in May 2010 shows that the two are in good agreement. These comparisons have been published.

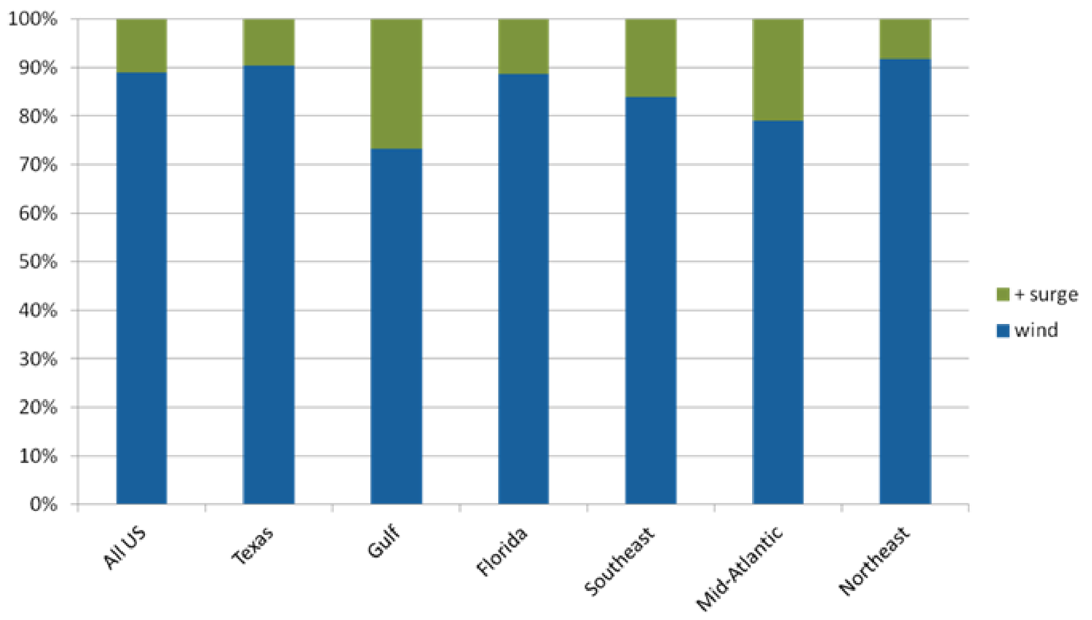
RMS has also compared the modelled wind fields of historical hurricanes with windspeed recordings wherever possible, and found a good agreement spatially and with time during the duration of a hurricane, showing that the wind field model can recreate a wide range of types of hurricane wind fields. RMS has published all of these exhibits to their clients.

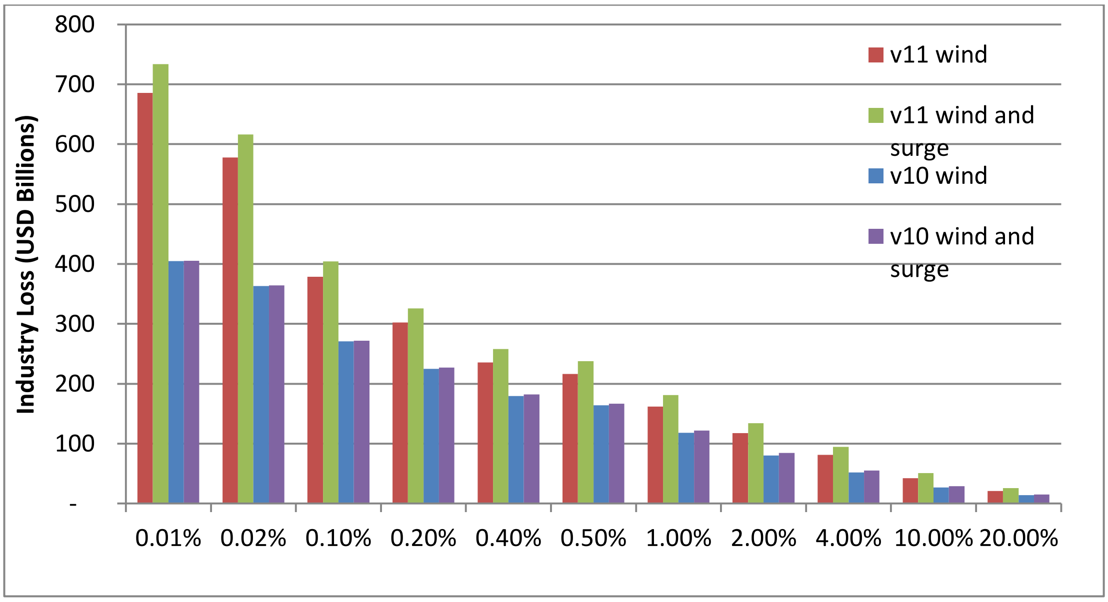
Source: "Hurricane Inland Filling, RMS Technical White Paper"

b) Storm Surge

The table below shows the impact of the storm surge component relative to wind on the RMS industry loss data (for all US, all Lines), by region. At the 1 in 100 year level the impact is 12%

in v11 (compared to 3% in v10). On an annual average loss basis the impact is 18% in v11 (compared to 7% in v10):





So from the above we can ascertain that for many portfolios the change to the storm surge model may have a material impact. There have been significant changes to the approach utilised by RMS to estimate the storm surge component:

- Prior versions included a simple, parametric storm surge model
    - Losses generally muted, did not produce scenarios of catastrophic surge
- New model couples tracks, analytical wind model and hydrodynamic surge models
- Detailed mesh for resolving shoreline
- Simulated 1M individual storm scenarios
- Risklink includes several analysis features

- Option to modify flood "leakage" – payment of surge claims under a wind policy
- Ability to determine base flood elevation from geocode, or enter elevation directly
- Ability to modify NFIP take-up rates
- Ability to scale losses directly

Sources:

"Hurricane Inland Filling (RMS Technical White Paper)"

"Hurricane Storm Surge Modelling (RMS Technical White Paper)"

"U.S. Hurricane Model Validation and Calibration: Florida"

"U.S. Hurricane Model Validation and Calibration: Gulf Region and Texas"

"U.S. Hurricane Model Validation and Calibration: Southeast, Mid-Atlantic, and Northeast Regions"

1.1.5 VENDOR'S VALIDATION OF VULNERABILITY

RMS are using the following validation approach for Hurricane Vulnerability:

- Development of specific vulnerability curves where RMS has enough location level data (e.g., single family dwelling, low rise masonry);
- Develop other curves (by LOB) where there is not much data using analytical models, judgment and engineering principles e.g. comparisons of building codes and application of knowledge of building code compliance, expertise developed from post-event engineering studies etc. In this process, RMS consulted with known engineering consultants – particularly on construction quality and standards in different regions, and for different construction types, and building code compliance;
- When all curves are developed, validate the entire suite of curves (by LOB) by comparing model and actual losses across multiple portfolios for multiple storms, iterating if necessary. This step ensures that the commercial curves produce reasonable losses in aggregate;
- RMS has provided information about how much claims data they have for which lines of business and which regions, and thus where there is more uncertainty in vulnerability than and where there is relatively less uncertainty, and provided guidance via sensitivity tests and exhibits.
- RMS has also published model versus actual losses for individual client portfolios (anonym zed) and by line of business for historical storms to show how well the model captures the losses.

a) "Education" Vulnerability

RMS made significant changes to the vulnerability function for buildings in educational facilities, leading to very large increases in modelled losses on these accounts. Driven by claims data from Hurricane Ike and re-analysis of previous claims data, primary education buildings have higher vulnerability in v11.0, due to specific design features such as gym facilities, large windows, and outdoor playing fields.

The impact of the new educational curve is very significant for risks coded with that occupancy type. RMS recommended that the coding be applied on a blanket basis across all buildings coded as educational facilities. RMS recommended that University buildings use ATC 8 (professional services), or ATC 54 (university, released in service pack 1) as the "default" occupancy for universities, but would not discourage users from using other occupancy types, if they are more relevant (e.g. a parking garage on a university campus can be coded as ATC 1).

1.1.6 COMMENTARY BASED ON VENDOR MATERIAL

This section contains illustrative examples of subjective opinions about the model as it has been as described in the vendor documentation. As everywhere throughout this document, these opinions should not be taken as actually evaluating or validating the vendor's material.

a) Number of Years of Historical Data RMS used

Considering the large amount of test stations in the US, we can assume today's measurements for pressure to be quite accurate but before the late 1980s only the central pressure in 6 hours intervals was available. Hence the data quantity is again very small.

For the filling rate curve, there is a paucity of storms to compare the tail of the curve with. (This is the reason that RMS state they used the numerical modelling study to build the new filling rate curve.)

In our opinion, the filling rate curve [does/does not] agree well with Andrew and Charley, and we [are/are not] comfortable that RMS has applied due diligence through its peer-review process of the research underlying this part of the model.

b) Wind-speed observations

The RMS v11 wind field model has been developed with access to 10 times more wind-speed observations than the previous model version. This is due in part to the large number of hurricanes since 2005, giving an 80% increase in the number of windspeed observations, as well as additions and updates to the HURDAT database of historical hurricanes back to the mid-1800s. The newer observational data is of better quality and measuring stations do not fail so frequently at peak wind speeds. Radar advances and hurricane hunter aircraft readings have also improved the quantity and quality of data.

c) Vendor's validation

Comment on the vendor validation – as evidenced by the vendor's own documentation and material – can include statements about its completeness, appropriateness, etc.

The detailed validation and calibration documents provided around each region, as well as around the core changes (inland fill, storm surge, medium term rates), seem to be of a high quality and have helped to enable a more comprehensive model review to be undertaken.

d) Storm surge

The storm surge changes are material, and while the white paper provided very detailed information on the modelling approach, there was a paucity of data around the sensitivity of the assumptions, or of the increases in modelled losses by class that this new approach to storm surge modelling would make. The vendor documentation at time of release could have been strengthened here by providing a suite of sensitivity testing around the various user-definable parameters, with, of course, the default recommended approach as the baseline.

RMS state that this has now been provided, via a presentation and recorded WebEx released in May 2012 available on their website. We are assessing the information provided, and conducting our own sensitivity tests.

Conceptually, overall approach appears sound:

- Coupled wind+surge models have been used operationally for many years
- Latest vintage of surge models (MIKE21) are robust
- Options provide user with good amount of flexibility

e) Medium term rates

The reliance of the Medium Term Rates on a linear assumption between basin activity and landfall is a very significant element that was not clearly articulated. In addition, we are considering the weighting of a variety of models to achieve the MTR as discussed in the RPI review. There is a lot of uncertainty around the MTR in v11, and this is both the single most material change in terms of loss impact, and also perhaps the most dramatic change in terms of methodology utilised in v11. There is very little data on landfall for category 3-5 storms, and even when using basin-wide data for these storms, the parameters ultimately chosen by RMS appear somewhat [conservative/optimistic].

References:

“North Atlantic Hurricane Models—Scope of Models Update”

1.2 FACTS ABOUT THE PERIL AND THE MODEL – INDEPENDENT MATERIAL

This section shows a sample of the sort of independent work that can be undertaken to review a component of the model. In this case the same data sets as utilised by the model vendor are freely available and have been utilised to provide some basic-level sense checks of the long-term hurricane event rates.

The following material is illustrative only, and should under no circumstances be taken as a coherent presentation of actual facts, theories, research or ideas. Furthermore, this is just one example for illustrative purposes only, and does not represent a comprehensive independent review of all parts of the RMS model.

We have also created a fictional dialogue with the vendor around why the long-term view was or was not more conservative than the pure-historical view. The "vendor comments" should not be taken as necessarily realistic, either.

1.2.1 THE IMPACT OF SEA SURFACE TEMPERATURES ON HURRICANE ACTIVITY

The following analyses was conducted for own verification of the state of hurricane activity. The RMS model does not assume that SSTs are the only driver of changes in hurricane frequency, nor does it contain any built-in assumption that the next five years activity will be higher than average, rather the MTR forecast "automatically" adjusts to the physical state of the system, whether high, low or average. However, we wanted to form our own opinion on trends in HU activity, and links to SSTs. Utilising the HURDAT SST data and the historical hurricane data set (basin-wide and land-falling), we wanted to produce a simple sense check around statistical trends in the frequency of storms to support the model view of risk (this data was obtained from the National Oceanic and Atmospheric Administration).

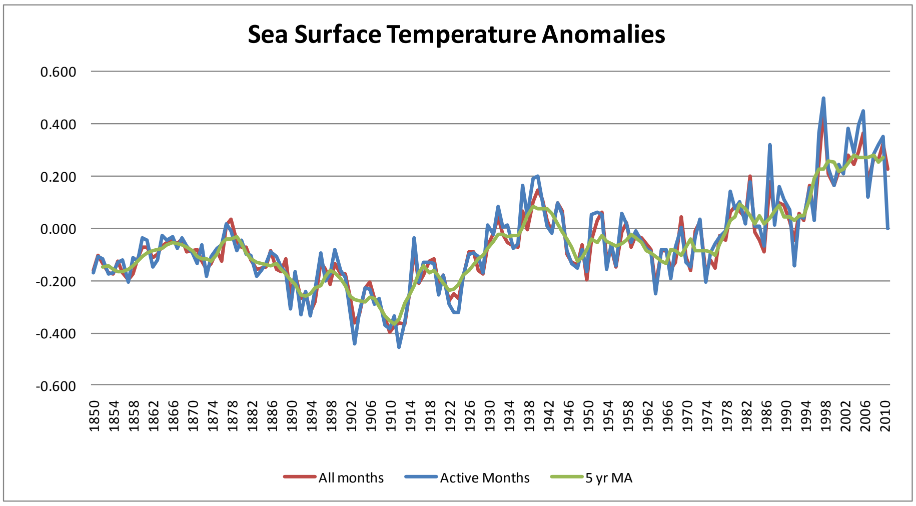
In order to come to our own view on the impact of SSTs , we analysed:

- The trend in SSTs for all months (Jan-Dec) as well as for active hurricane periods only (Jul-Oct)
- The relationships between higher SSTs and tropical storm frequency in the Atlantic basin
- The correlation of SSTs with hurricane landfall.

The data used in our analysis included:

- The Hadley timeseries database of sea surface temperatures containing monthly temperature anomalies (diversions from the average SST as measured between 1961 and 1990) grouped into 10 degree latitude and longitude regions
- The HURDAT dataset containing entries for all known tropical storms in the North Atlantic basin since 1850. It should be noted that the quality of data have increased significantly around 1950. Very early entries would not include all tropical storms that did not make US landfall and might also not have accurate wind speed measurements at or before landfall.
- RMS event tables containing the history of tropical storms making landfall, the expected frequency of these storms and expected insured losses in current monetary terms.

The graph below shows the SST anomalies over the period from 1850 to 2010:

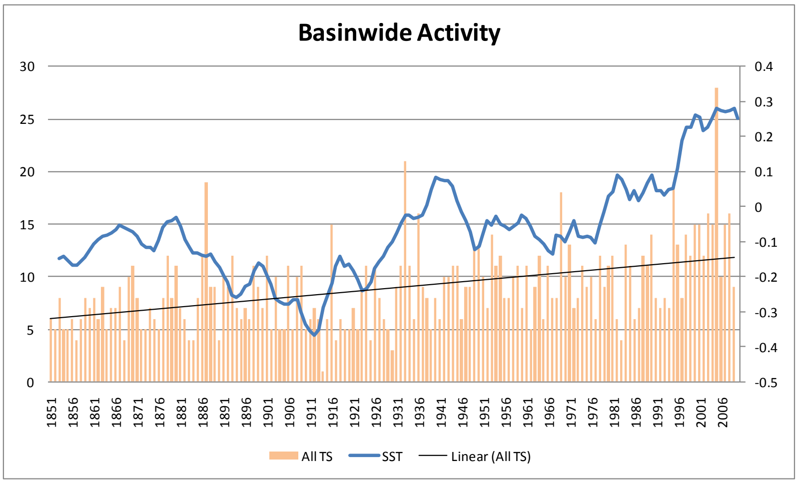


The main observations can be summarised as:

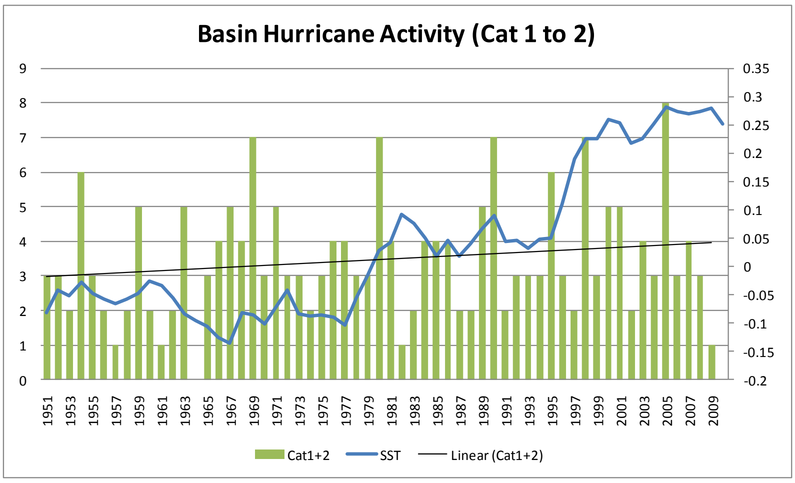
- SSTs appear to oscillate along the long term average, referred to as the North Atlantic oscillation.
- There is an observable increase in the long term trend in SSTs, with current levels higher than any previous period in the historic data set. This phenomenon has been attributed to climate change, where the levels of greenhouse gasses have increased significantly since the mid-20th century

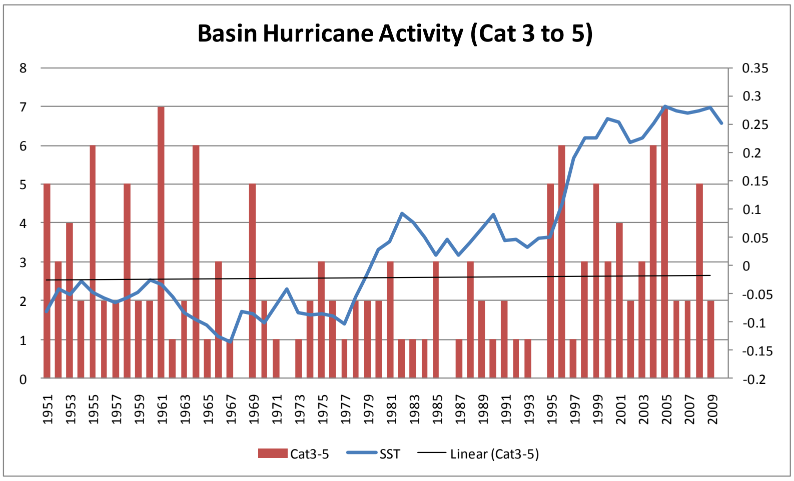
f) Hurricane activity in the North Atlantic Basin

Reviewing the number of tropical storms by year in the Atlantic basin over the same period, it seems like the number of storms are increasing in line with the increasing SSTs:



Considering data from 1950 onwards (as shown below), it seems that while the number of tropical storms have increased in line with SSTs, the number of storms reaching hurricane status have not increased to the same extent. The number of category 1 and 2 hurricanes forming in the basin has only increased slightly, with no observable upward trend in the number of category 3 to 5 hurricanes over the course of the last 60 years:





What is interesting to us is that there seem to be an oscillation in the observed frequencies of category 3 to 5 storms, with a period of high activity followed by a period of low activity. However, this does not seem to correspond exactly with the North Atlantic oscillation in SSTs.

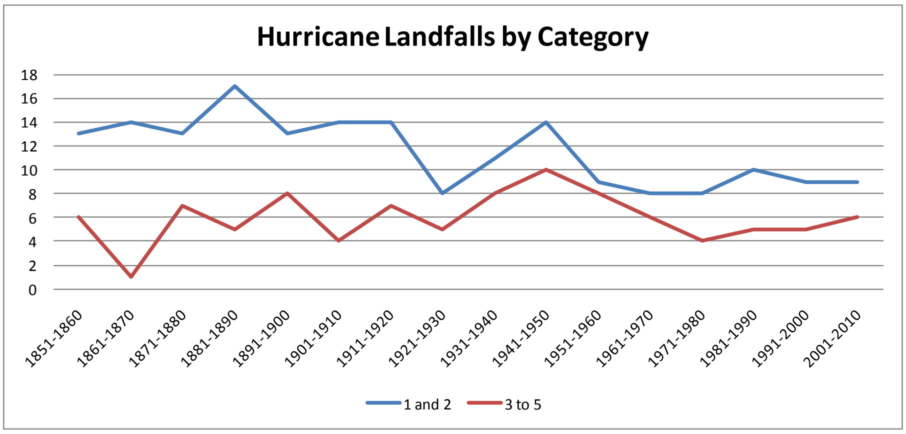
g) Hurricane landfalls

The next question is whether the increase in storm activity in the basin implies an increase in hurricanes making landfall. It is not the number of storms in the basin that is of interest here, but rather the number of storms actually making US landfall. The v11 hurricane model assumes a linear relationship between storms in the basin and storms making landfall.

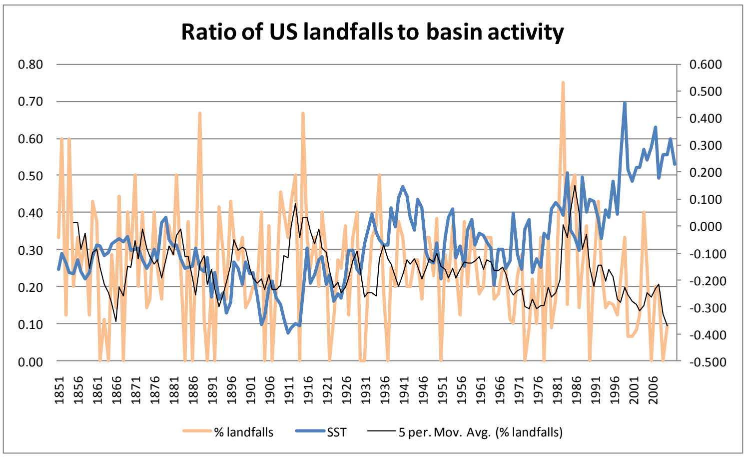
RMS have told us that, within their suite of forecast models used to create its medium-term rates, some forecast basin activity, and then use an assumption of what proportion of those make landfall (so called “indirect” models), and others make a direct forecast of landfalling hurricanes. For the indirect models, RMS assumes a constant relationship between storms in the basin and storms making landfall, based on published research. RMS state that they are unaware of any published evidence that the proportion of storms that make landfall, relative to the total that form in the basin, has changed with time.

The graphs below show the annual number of tropical storm landfalls since 1851. The number is of course relatively low, especially compared to the total forming in the basin. Considering the whole time period, the number of tropical storms making landfalls appears to have increased slightly. However, if we consider the time period since 1930 (graph below shows since 1950), there seem to be no trend present in the data. The observed trend over the full period might be attributable to better data capture rather than a true underlying increase in landfall activity.

When only actual hurricanes are considered (rather than all tropical storms), there is no indication from the observed data that the landfall frequencies are increasing in line with SSTs.



Looking at the ratio of landfalls to activity, it is interesting to note that since the early 1980's there appears to be an inverse relationship between the number of named storms and US landfalls. RMS have told us that they are unaware of any scientifically-published papers to verify that this is a trend, versus coincidence.



This trend fitting is, of course, a simplistic method, and one should not draw too strong a conclusion from it. The RMS-RPI review (see below) does highlight several potential explanations, but one of the strongest may be that before 1948 there was a lot less data on basin-activity, and thus much more observed data relied upon landfall. However, in our opinion this does not explain the lack of change in the trend since 1948, or the possible decoupling as SSTs rise from the 1970s.

1.2.2 HISTORICAL AAL VS. MODEL

In continuing to review, and working with RMS, the following summary table was produced showing the historical annual average loss (for 111 years of historical loss data), compared to the long-term modelled annual average loss (wind plus surge). For the modelled losses we compare 2 sets of results, the first showing those events with return periods of <111 years (to align with the historical data set), and another to show all events, including the infrequent but damaging storms that sit outside of the historically observed data set:

Historical as % Stochastic < 111yr RP
82.87%
Historical as % Stochastic < xxxyr RP

72.89%

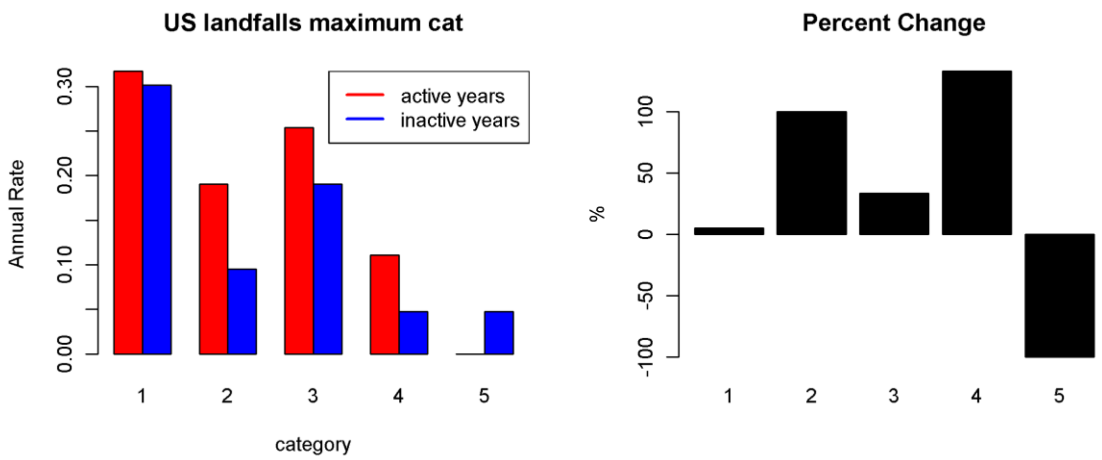
Based on publicly available information from the FCHLPM, all available cat models from other vendors (EQE, AIR, ARA) show a similar relationship between historical and stochastic AALs, with the stochastic being higher than historical by between 15 and 30% (see table earlier in this document), and accepted by the independent review conducted by the FCHLPM. RMS have commented: “This difference can be explained because the historical record is not long enough to capture all extreme events which could occur, and due to the skewedness of loss distributions – for example see the see the paper by Fleming in 2009 (Fleming, K., " Yep, We’re Skewed ", Variance: Advancing the Science of Risk. Casualty Actuarial Society, Volume 2 / Issue 2, page 179-183. 2009.)   this paper explains that the most likely estimate for a sampled average (i.e. 100 years of history) from a skewed distribution will below the average of the parent population (i.e. Model AAL)” .. This needs to be the subject of further investigation by us.

1.2.3 NEAR TERM EVENT REVIEW

We tried to isolate the impact of this change by taking the general commercial industry data from the RMS Industry Loss Curve, and looking at the annual average loss in v10 and v11 for both the long-term and near-term event sets. As an initial test we looked at the magnitude of change in the AAL in v10 moving from long-term to near-term and found that this was around 25% for the entire US. The same impact in v11 is 41%.

There are differences in the industry exposure data, but if we ignore that for the time being we find that roughly 35% of the change in losses from v10 to v11 was attributable to the new event rate methodology (meaning that if one was to build a bespoke version of v11 that used the v10 uplift from long-term to near term and applied that to the v11 long-term view the result would be around 35% lower than the actual v11 near term view).

This additional conservatism does not necessarily mean that the new methodology is wrong. We sought additional data from RMS to support their new near term rates, and to supplement the RMS white paper. One diagram that RMS sent through is shown below:



There is limited landfalling data on which to make conclusions, which is why trends that can be seen in the basin-activity levels are more visible than in landfalling statistics (as there are so many more data points). Based on our visual analysis, cat 1-2 visually appears to go from 0.4 to 0.5 annual probability. Cat 3-5 visually appears to go from 0.3 to 0.35. This seems insignificant increases to us, though we have not yet produced any statistical tests.

RMS provided the following explanation for the above:

"The SST changes affect the strongest storms the most, both theoretically (Elsner et al. 2008, Webster et al. 2005) and in the near-term rate set. The attached document shows a comparison between average annual rate during the active years (1948-1962 and 1995-2010) and inactive years (1963-1994) both for the basin and US landfalls.

"It can be seen that the largest increases in the active years (that is, warm MDR SST years) are the intense storms, and in the category 4 storms more than the category 3s."

RMS utilised research by Elsner when setting their view of medium term risk. In the abstract of his paper ("On The Increasing Intensity of the Strongest Atlantic Hurricanes) with Thomas H. Jagger it is stated:

"The past three decades have seen a significant upward trend in the intensity of the strongest hurricanes worldwide that is most pronounced over the North Atlantic […]This might help explain why, despite the increasing intensity of basin-wide hurricanes, there is no detectable upward trend in damage costs in the United States."

This ties back to the data produced earlier around landfall proportions. Even with data gaps (so using only data post 1960, for example), there is not a clear linear relationship between the increase in basin activity and an increase in land fall. The Risk Prediction Initiative conference paper stated that "The Atlantic Multidecadal Oscillation, which mirrors the increase in Cat 3-5 storms in the Atlantic Basin, has been traditionally referenced to support phases of activity. Much uncertainty continues to exist in the precise mechanism of the change in sea surface temperatures (SSTs) and related increase in tropical storm activity."

In conclusion, our opinion is that there remains significant uncertainty as to how the AMO works (assuming it exists), how increases in basin activity correlate with landfall, and how the regionality of the landfall is affected.

1.2.4 RPI CONFERENCE RESPONSE

In February 2012, RMS presented their MTR methodology to a group of leading hurricane experts within the Bermuda based Risk Prediction Initiative. The RMS material presented is available on their website ("Background and scope of the RMS-RPI meeting on Atlantic Hurricane Medium Term Rates"), as is a confidential memorandum on the outcome ("Risk prediction Initiative Conference on RMS Version 11.0 Medium Term Rates").

The overall response of the visiting scientists was to affirm the thorough and scientifically-grounded RMS medium rate methodology, although all the participants expressed a desire to see greater exploration of the Medium Term Rate model

There were however, several areas of improvement noted by the RPI, and suggestions for further research:-

- the uncertainty around the proportion of hurricanes which make landfall was highlighted, and all parties agreed that a physically based study would help to improve knowledge on this topic;
- the regionalisation approach was highlighted as an area which could be made more robust with the addition of more approaches;
- it was noted that weighting multiple models differentially may not add much skill, but could add uncertainty.

Our understanding is that RMS is incorporating feedback from the RPI initiative into its annual review process during 2012. In our opinion, the RMS medium-term forecast is [conservative/optimistic].

1.2.5 VALIDATION AGAINST INDUSTRY LOSSES

RMS's own view of the performance against historical losses is given in the below:

0.97 Ratio of Modeled to Actual Since 1989 (Trended)

Year	Storm	Region	PCS Incurred	PCS Trended	Major Surge	v11 Wind	v11 Wind + Surge	Ratio Wind+ Surge
2008	IKE	TX	14*	15.5	Y	10.9	16.4	1.1
2005	WILMA	FL	10.3	15.3		22.0	22.6	1.5
2005	RITA	TX, LA	5.6	7.5	Y	3.2	4.5	0.6
2005	KATRINA	LA, MS	41	55	Y	14.0	36.3	0.7
2004	JEANNE+ FRANCES**	FL	8.2**	14.2		15.4	16.1	1.1
2004	IVAN	AL, FL	7.1	11.9	Y	4.5	6.0	0.5
2004	CHARLEY	FL	7.5	13		12.0	12.0	0.9
2003	ISABEL	Mid Atl	1.7	3	Y	3.2	4.2	1.4
1996	FRAN	SE	1.6	4.4		5.1	5.6	1.3
1995	OPAL	FL	2.1	6.3	Y	3.0	3.4	0.5
1992	ANDREW	FL	15.5	57.4		61.0	62.1	1.1
1991	BOB	NE	0.6	1.7		1.1	1.1	0.7
1989	HUGO	SC	3	12.2		14.3	15.0	1.2
Total				**218**		**170**	**205**	**0.97*** **

*PCS for Ike in Texas is $11b, widely considered to be too low. $14b is consistent with other credible estimates of loss within Texas (excluding Offshore and others states).
**Given overlapping impacts of Jeanne and Frances, incurred and actual losses for these two storms have been combined
***The ratio 0.97 is the mean of the individual storm ratios

We have performed independent industry loss validation tests as follows.

a) Industry Losses

We licence RMS's Industry Loss Curve Databases, which include the estimated Industry EP curves and Event Losses for all common model settings. To extract modelled losses we use SQL Server and the backend tables from RiskLink. All Model Settings are the same as used in our standard process, hence Storm Surge and Loss Amplifications are enabled and the Near Term Hurricane rates are used.

The Rates have obviously no impact on the event losses but are important when we use EP curve comparisons.

We use both PCS and Swiss Re sigma as sources of independent estimates of the actual insured losses.

b) PCS Industry Loss Data

When a catastrophe occurs, PCS generates estimates of industry wide insured property losses for buildings, contents, business interruption, vehicle and inland marine coverages. Initial estimates are formed informally through interviews and surveys of public officials, insurers, adjusters, agents and others on the ground in the catastrophe zone. Modelling and analysis of its proprietary database, which contains the number and types of structures in all 50 states on a ZIP code level, allows PCS to further refine estimates.

For each catastrophe, the PCS loss estimate represents anticipated industry wide insurance payments for property lines of insurance covering:

- fixed property
- building contents
- time-element losses
- vehicles
- inland marine (diverse goods and properties)

PCS loss estimates only include marine losses to the extent they would be included in personal lines policies. No commercial marine or offshore losses are included in PCS estimates. It's also important to note that PCS estimates will not include storm surge or flood losses.

The RMS model does not include Flood but includes Storm Surge, which would at first indicate the model should return slightly more conservative values. However, we recognise that in reality, a lot of surge losses will be claimed for under a Hurricane Policy in the aftermath of an event and the expected difference between PCS and the RMS model including Surge should be reasonably small.

Year	Event	Estimated Loss (US$bn)
2005	Katrina	41,1
2008	Ike	12,5
2005	Wilma	10,3
2004	Charley	7,5
2004	Ivan	7,1
2005	Rita	5,6
2004	Frances	4,6
2004	Jeanne	3,7

c) Swiss Re sigma Industry Loss Data

The regular Swiss Re sigma study attempts to revalue losses to today's values, but will include energy losses that are not included the RMS model values.

Table 8
The 40 most costly insurance losses 1970–2010

Insured loss[7] (in USD m, indexed to 2010)	Victims[8]	Date (start)	Event	Country
72 302	1 836	25.08.2005	Hurricane Katrina: floods, dams burst, damage to oil rigs	US, Gulf of Mexico, Bahamas, North Atlantic
24 870	43	23.08.1992	Hurricane Andrew: floods	US, Bahamas
23 131	2 982	11.09.2001	Terror attack on WTC, Pentagon and other buildings	US
20 601	61	17.01.1994	Northridge earthquake (M 6.6)	US
20 483	136	06.09.2008	Hurricane Ike: floods, offshore damage	US, Caribbean: Gulf of Mexico et al
14 876	124	02.09.2004	Hurricane Ivan: damage to oil rigs	US, Caribbean: Barbados et al
14 028	35	19.10.2005	Hurricane Wilma: floods	US, Mexico, Jamaica, Haiti et al
11 266	34	20.09.2005	Hurricane Rita: floods, damage to oil rigs	US, Gulf of Mexico, Cuba
9 295	24	11.08.2004	Hurricane Charley: floods	US, Cuba, Jamaica et al
9 041	51	27.09.1991	Typhoon Mireille/No 19	Japan
8 043	71	15.09.1989	Hurricane Hugo	US, Puerto Rico et al
8 000	562	27.02.2010	Earthquake (M_w 8.8) triggers tsunami	Chile
7 794	95	25.01.1990	Winter storm Daria	France, UK, Belgium, NL et al
7 594	110	25.12.1999	Winter storm Lothar	Switzerland, UK, France et al
6 410	54	18.01.2007	Winter storm Kyrill: floods	Germany, UK, NL, Belgium et al
5 951	22	15.10.1987	Storm and floods in Europe	France, UK, Netherlands et al
5 941	38	26.08.2004	Hurricane Frances	US, Bahamas
5 326	64	25.02.1990	Winter storm Vivian	Europe
5 290	26	22.09.1999	Typhoon Bart/No 18	Japan
4 723	600	20.09.1998	Hurricane Georges: floods	US, Caribbean
4 453	–	04.09.2010	Earthquake (M_w 7.0)	New Zealand
4 439	41	05.06.2001	Tropical storm Allison: floods	US
4 390	3 034	13.09.2004	Hurricane Jeanne: floods, landslides	US, Caribbean: Haiti et al
4 139	45	06.09.2004	Typhoon Songda/No 18	Japan, South Korea
3 800	45	02.05.2003	Thunderstorms, tornadoes, hail	US
3 695	70	10.09.1999	Hurricane Floyd: floods	US, Bahamas, Columbia
3 586	59	01.10.1995	Hurricane Opal: floods	US, Mexico, Gulf of Mexico
3 538	6 425	17.01.1995	Great Hanshin earthquake (M 7.2) in Kobe	Japan
3 315	25	24.01.2009	Winter storm Klaus	France, Spain
3 142	45	27.12.1999	Winter storm Martin	Spain, France, Switzerland

d) Trending of Industry Losses from actual loss date to present day values

One major issue when comparing Actual versus modelled losses for the insurance industry is the estimation of changes in Exposure values between the date of loss and the current date. We have used the 2011 RMS Exposure Database to estimate today's industry losses. At the same time PCS data is based on the actual losses at the time of occurrence.

One commonly quoted paper for the normalisation of Hurricane losses is Normalized Hurricane Damage in the United States: 1900-2005 by Roger A. Pielke Jr, Joel Gratz, Christopher W.

Landsea, Douglas Collins, Mark A. Saunders and Rade Musulin. The paper states that losses for the same event occurring again would double every 10 years. This is the same assumption used in a study from the Association of British Insurers in 2005. In addition using the RMS Validation paper for Florida also suggests in average a doubling in losses every 10 years.

But we also believe that the simple rule, which might have worked for a long period of time, is overly conservative for the past decade up to 2012. The general economy in the hurricane exposed areas of the US has seen low inflation, replacement values have barely risen, and building has stopped for a long period.

1.3 SUMMARY OF OUR UNDERSTANDING OF THE CATASTROPHE MODEL

This section should provide enough information for a Chief Risk Officer, or equivalent Committee, to assess the level of understanding about the model achieved by your validation process.

Since the purpose of this document is to provide an example of the <u>process</u>, rather than an actual validation, our comments here are generic, and not related to the RMS v11 U.S. Windstorm (or any other) model.

1.3.1 MODEL BASIC CHARACTERISTICS

age, last major revision, etc

1.3.2 STRENGTHS

"representation of landfall rates for FLA appear to be correlated with latest [such and such]"

"very robust approach to [such and such]"

1.3.3 WEAKNESSES

"representation of landfall rates for FLA appear <u>not</u> to be correlated with latest [such and such]"

"Seems to be very heavily skewed towards [such and such] class of business"

"The IED used for validation has not been updated for such-and-such years"

1.3.4 LIMITATIONS

"Preceding conditions are not incorporated. For example, if a major disaster has already occurred, there would likely be an increase in the demand surge component of loss, but the model is not updated on a live basis to handle preceding conditions of this nature. On the aggregate loss basis, a subsequent modelled event impacting the same region has the severity calculated on the basis of no existing damage to the structures and as such could over- or under-estimate the loss"

"For extreme events, the event frequencies are the subject of very significant uncertainty due to the paucity of observed data"

"individual vulnerability functions are often based upon very small amounts of supporting data, or are extrapolations from related vulnerability functions for which data was available. Thus greater uncertainty exists around commercial vulnerability functions due to less detailed individual claims data being available"

1.3.5 CONCLUSION

"The […] model [offers/does not offer] a significant update on the previous version. It includes substantial additional claims data from 2004 to 2010 (some of which had been utilised to offer an updated view of vulnerability in [….]), a heavily revised approach to setting the MTR and regionalising storms, expanded reach of damaging winds further inland and changes to coastal vulnerability due to a heavily revised inland filling model, a completely new storm surge model, and further changes to vulnerability based upon lessons from Ike.

"Overall we believe [the vendor's] method to be sound and in line with current scientific knowledge."

2. RELATING THE CATASTROPHE MODEL TO OUR PORTFOLIO

This section describes the relationship of the cat-model, as you have described your understanding of it in Section 1, to the catastrophe-risk in your portfolio.

Readers should note that, in the interests of readability, we have abbreviated the descriptions of testing against historical experience and other tests of fit to the fictional portfolio. For example, both the "exposure movements" and the comparisons against hurricane losses are abbreviated to avoid repetition. Section 2 therefore appears much shorter in this document than it will for an actual validation process.

2.1 MATERIAL DRIVERS FOR OUR RISK

2.1.1 DESCRIPTION OF OUR PORTFOLIO

The company writes a mixed portfolio of U.S. hurricane exposed business. The mid-sized D&F portfolio is composed of a broad range of commercial occupancies, but with particularly heavy exposure to retail trade and professional services. In addition the company writes a significant number of educational facilities across the Texas, Gulf and Florida regions, and as such the change to the education vulnerability function is of some importance to the company.

The binding authorities book includes heavy North East residential exposure, as well as a small but spread book of residential and small commercial across the U.S.

The property reinsurance portfolio covers domestic U.S. insurers, with no particular regional focus. It does, however, tend towards the reinsurance of commercial insurance books.

2.1.2 MATERIALITY OF THE PERIL

U.S. hurricane has been defined as a high materiality peril for us. The materiality test consists of the following elements:

- Frequency and severity of the peril
    - U.S. hurricane deemed to be of high frequency, and with significant modelled loss severity to the company at the 1 in 200 year loss return period.
- Historical losses to the market and business from the peril
    - The company suffered significant loss activity in 2004 and 2005. 2005 (Katrina, Rita, Wilma) caused the company to make reinsurance recoveries and to report an overall loss ratio of greater than 100%. Loss activity from Ike in 2008 was somewhat below market share would suggest. Hurricane Irene in 2011 was a near-miss, with low loss levels to the company.
- Business exposure to the peril
    - The company writes significant U.S. property business, including Direct & Facultative, Binding Authorities, and Property Reinsurance. These classes cover the entire mainland U.S., but with peaks of exposure in Florida and in the North-East. The exposure is broadly equal (in terms of modelled loss at the 1 in 200 year return period) across all three books.

The categorisation of risk is undertaken annually, and in addition, at any stage that the risk monitoring framework in place highlights a change in risk (e.g. through a material increase in exposure, or through a material change in the understanding of the severity or frequency of a peril). The last categorisation took place in early 2012, but the high materiality of U.S. hurricane risk to the company is not expected to change significantly over the next few years.

2.2 COMPARISON OF MODEL CHARACTERISTICS TO PORTFOLIO

2.2.1 OVERVIEW

The mid-sized D&F portfolio is composed of a broad range of commercial occupancies; the binding authorities book includes heavy North East residential exposure, as well as a small but spread book of residential and small commercial across the U.S., and the reinsurance portfolio is predominantly covering commercial insurance books.

There is no material industrial or agricultural exposure in the portfolio, and as such we have not validated these occupancy types.

The model's ability to represent our specialty portfolio of education facilities requires investigation.

2.2.2 REGIONAL SPREAD

The portfolio is relatively well spread geographically, equating to around a 0.5% market share of residential and commercial business, except in the North East (circa 1% market share of residential business, 0.5% commercial business), based on the vendor supplied industry loss curves.

The regional distribution of exposures in the RMS Industry Exposure Database is reasonable match to our portfolio. Based on our understanding of the model, we have no reason to suppose that the it has been developed with a significantly different geographical emphasis.

2.2.3 SPECIAL FACTORS - EDUCATION

RMS made significant changes to the education vulnerability function (see section 1.1.5), leading to very large increases in modelled losses on these accounts. As noted, the impact of the new educational curve is very significant for risks coded with that occupancy type. The default RMS recommendation is to code all buildings on K-12 campuses as ATC 25 (education), but to capture differences in their construction class, number of stories and year of construction.

For the D&F portfolio, in the previous version of the model, K-12 educational facilities contributed around 18% of the 1 in 200 year modelled loss, and around 14% of the annual average loss. Moving to the new version of the model led to these facilities contributing 23% of the 1 in 200 year loss, and 18% to the annual average loss.

Our next approach was to code each element of the facilities separately under the more relevant occupancy coding for the various buildings on the site (rather than block-coding the entire risk as ATC 25). For example, if we have the sports hall designated separately, we coded that as ATC 10 (entertainment, encompassing sports facilities), school board administration buildings were coded as office buildings (ATC 8), maintenance yards as ATC 7, etc. Rerunning our portfolio in this way produced losses more in line with our historical loss experience (19% of the 1 in 200 year loss, 15% of the annual average loss).

2.2.4 SETTINGS

"A 'setting' is defined as a choice provided by the vendor modelling company that allows users to decide how a model is run, for example ticking certain boxes in the analysis options at the time when the model is run." (from Chapter 6 of the ABI document)

When running the model several options are available with regards to how the model should be executed, and hence the produced loss estimates. We have tested these options as investigation steps into the appropriateness of RMS to our business.

By comparing the results to similar tests done by RMS we are able to understand:-

- whether RMS's own validation processes are appropraite and sufficent for us;
- the extent to which our books are similar to the RMS portfolios used during testing and validation;
- more about the inner workings of the model;
- the most appropriate settings for our day to day running of the model.

SETTINGS TESTED

We used the DLM modules with the following major options switched on or off:-

- Primary & secondary modifiers
- Post-loss amplification
- Historical rates
- Secondary perils (storm surge)

The choice of option was based on presentations and documentation released by RMS, focusing on the areas where the model strengths and weaknesses should become most obvious.

Primary modifiers – the primary characteristics required by the model in order to produce a loss. The primary modifiers are as follows: Occupancy, Construction, Year built, Number of stories, Floor area, Floors occupied.

Secondary modifiers – additional information that alters the vulnerability curves, such as roof modifiers, or the depth of a basement.

Post Loss Amplification (PLA) – in the aftermath of large events, the cost of replacing and repairing property can increase and even exceed the replacement cost because of economic demand surge and increased repair/waiting time.

Historic Rates – also known as the long-term view of risk (event rates) in the model. The historical event rates are calibrated over the historical records from the HURDAT database which date back to 1900. This database is managed by NOAA, who collate detailed weather information in the United States.

'Low' and 'High' Vulnerability - in areas with limited claims data, there is greater uncertainty in the quality of the building stock and the vulnerability functions used to estimate losses. To characterize this uncertainty, in version 11.0, two sets of alternate vulnerability functions are provided in addition to the default set that represents RMS' view of risk. The range is narrowest in Florida where hurricane claims is available to guide the derivation of the wind vulnerability functions and widest in the Northeast where historical claims data is scarce or non-existent. Alternate sets of vulnerability functions are provided for all regions of the U.S. but they are not implemented in any other region.

Storm Surge – the secondary peril for Hurricane, this is the increased water height due to wind driven water pushing inland an causing coastal flooding.

PORTFOLIOS TESTED, AND RESULTS

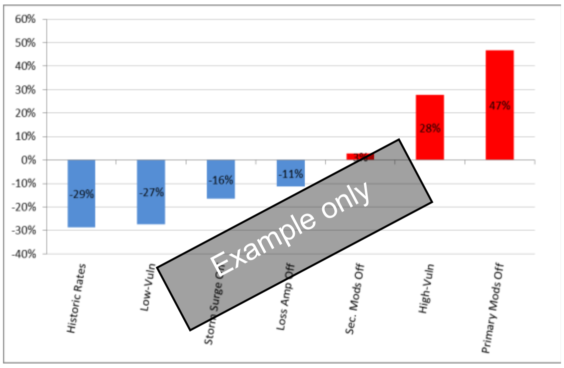
The"results" text and all graphics are illustrative only, and do not reflect any real testing of an actual portfolio.

We have tested the following portfolios, as being broadly representive of our wind-exposed US account:-

- November 2011 Binders Portfolio

- December 2011 Open Market Portfolio
- July 2011 Treaty Portfolio

The single biggest impact is disabling **Primary Modifiers**. This shows the importance of collecting the right amount of data and is one of the reasons why completeness of data is very important.



It is encouraging however to see that if the model receives less detailed information, then it reacts with more conservative estimates.

The second highest impact is created by switching to the **Historical Landfall Rates**. This is again no surprise as RMS in the medium-term forecastassumes a higher number of hurricanes making landfall then happened in average over the last 50 year. This is especially true for high loss events, Cat 4 or 5, where the assumed frequency is significantly higher than historically measured.

Storm Surge and Loss Amplification are also significant.

The table below illustrates the impact of storm surge on the wind only losses for all three portfolios underwritten by the company, as well as the changes to the industry loss data. Please note that this does not account for changes in industry exposure data between models, and shows the impact on the MTR view of risk, hence the lack of alignment with the figures illustrated above.

		v9	v11	v9	v11	v9	v11
Storm Surge Increase	Key Metric	D&F		Binders		Treaty	
	AAL	4%	13%	9%	19%	5%	11%
	10	4%	13%	9%	18%	5%	11%
	50	3%	9%	11%	22%	5%	11%
	100	3%	8%	11%	23%	5%	11%
	250	2%	6%	10%	21%	5%	10%
	500	1%	5%	9%	18%	4%	8%
	1000	1%	4%	7%	16%	3%	7%

Example only

As can be seen, the three portfolios respond differently to the changes in surge, but when grouped together the combined impact is broadly in line with the industry data provided by the vendor in their IED and ILC databases.

As such, the validation work of the vendor documentation should be broadly transferrable to the portfolios underwritten by the company.

Surprisingly, setting all **secondary modifiers** to unknown makes a reasonably small impact. But given that the portfolio is not using many of the secondary modifiers, and when used are collected on a consistent basis throughout the portoflio, the net impact can be expected to be relatively neutral and small.

The chart below shows a similar study, presented by RMS during the Version 11 release.

[other graphics]

In this graph we see an impact of Storm Surge of 12.4% and for the Near Term Rates of 24.8%. This is slightly lower than for our portfolio.

But we know that our Binder's book is more coastal then the industry portfolio and also slightly more Florida weighted, hence this would be expected.

Open Market reacts slightly different but the behaviour regarding Historic Rates is the same. Frequency changes simply result in fewer events happening and hence the losses reduce by the same amount.

A notable difference is that both Surge and Loss Amp, and with it the test Vulnerabilities, show smaller movements than they did for the Binders Book.

2.3 COMPARISON OF MODEL RESULTS TO EXPERIENCE

The following material is illustrative only, and should under no circumstances be taken as a coherent presentation of actual facts, theories, research or ideas.

The“results“ text and graphics are also illustrative only, and do not reflect any real testing of an actual portfolio.

Comparing model results to our own historical experience is not straightforward, despite an unbroken record of [xx] years continuous underwriting in the USA.

We used a mid-2011 Exposure database for both Property and Reinsurance Divisions to extract the modelled losses. In comparison we reviewed the Ultimate Claims from our Reserving team. All tests where run on a Gross loss basis.

a) Exposure Movements since the actual losses took place

When we looked into detail at some of the events, it became clear that the underlying exposure for us has changed significantly, even since Ike which was the last major event to happen.

When we looked at Rita, the model shows the following Accounts as producing the largest potential losses today:

Reference	Assured	Loss ($)
xxxxxxxxxxxx	Little Ins Co	0
Xxxxxxxxxxxx	Bo Reinsurance	0
Xxxxxxxxxxxx	Peep Re	0
Xxxxxxxxxxxx	Has Ins	0
Xxxxxxxxxxxx	Lost Inc.	0
Xxxxxxxxxxxx	Her Ins Inc	0
xxxxxxxxxxxx	Sheep Ltd	0
Xxxxxxxxxxxx	Baabaa & Others Synd 1	0
Xxxxxxxxxxxx	Black C Re	0
Xxxxxxxxxxxx	Sheep Ltd	0

If we then look at the actual top 10 losses occurred during Rita in 2005 we get the following results:

Reference	Assured	Loss ($)		In 2011 portfolio?
YYYYYYYY	Please Ins Co	0		N
YYYYYYYY	Baabaa & Others Synd 1	0		Y
YYYYYYYY	Hard Inc.	0		N
YYYYYYYY	Sale Re	0		N
YYYYYYYY	Sheep Ltd	0		Y
YYYYYYYY	Black C Re	0		Y
YYYYYYYY	Chump & Sons	0		N
YYYYYYYY	Change Inc	0		N
YYYYYYYY	With Holding Insco	0		N
YYYYYYYY	Has Ins	0		Y

The picture is completely different. In fact, 6 out of 10 of the major loss contributors during Rita are not part of our book today.

b) Changes in our underwriting approach since the actual losses took place

There have been significant changes in our underwriting approach since 2005:

- Pulled massively back from the beach.
- Changed deductibles.
- Better management of Coverholder portfolios, i.e. changed where coverholders allowed to write.
- Reduced the participation on Hotel and Casinos or increased deductibles significantly

2.3.1 HURRICANE KATRINA

Our top 10 actual losses by client 2005:-

Client	Sum of Claim Incurred GBP	Underwriter Comments on re-underwriting
[redacted]		

Our top 10 modelled losses by client 2005:-

Account Number	Account Name	Average Mean Loss
[redacted]		

Differences in account include:

- not writing surge exposed contracts: now, every account has no business within 2 miles of the coast.
- previously, moral hazard of if someone bought flood policy or not; now:
    - warrant flood policy in place
    - ISO wording “not covered by flood”
    - even so, still turn on storm surge setting for coverage leakage within RMS modelling

Top 7 contracts in 2005 produced approx. 50% of the loss, now would be less than a quarter. Of the rest, many non-renewed, all substantially re-written.

2.3.2 HURRICANE [...]

[…other loss comparisons for major events…]

2.3.3 CONCLUSION

Results from this test indicate that it is difficult to use directly our historical Exposure in conjunction with past Event Losses to evaluate the performance of RiskLink effectively.

The reason is that our historical Exposure has changed significantly over the past decade due to more stringent Underwriting practices and better understanding and management of exposures. It is therefore not appropriate to extrapolate our past losses directly to estimate today's losses.

The size of catastrophic events in recent years have been too low on the Exceedance Probability curve in order to review the model performance in areas of high or material exposure.

When comparing RMS RiskLink v11 to actual historic losses at industry level, the model shows some overestimation and underestimation. However we would expect this behaviour. Due to the uncertainty in the Vulnerability Curve, every event loss in the model has a range around the mean. Therefore across many events we will see the model to be lower and higher than the historical losses.

Over a very large number of events the model will regress towards the historical mean.

We therefore conclude that the model works well for the Industry, while we can reproduce similar, close results for portions of our book which haven't changed. We have however difficulties finding a close fit for the whole book due to major changes over the last years.

We have also shown that on an Exceedance Probability basis, RiskLink is conservative compared to historical loss data.

2.4 SUMMARY OF MODEL REPRESENTATION OF OUR PORTFOLIO

This section should provide enough information for a Chief Risk Officer, or equivalent Committee, to understand broadly how well the cat-model represents the cat-risk in your portfolio.

As in section 1.3, the purpose of this document is to provide an example of the process, rather than an actual validation. Our comments here are therefore once again generic and imaginary, and not related to the RMS v11 U.S. Windstorm (or any other) model.

2.4.1 MODEL CHARACTERISTICS RELATIVE TO OUR PORTFOLIO

"The geographical spread of our portfolio is mainly concentrated in […], which are well covered by the model"

"Classes of business […] are represented"

"There are no elements of our portfolio which are idiosyncratic compared to what we know about the vendor's Industry Exposure Database, which was used during the model's development."

2.4.2 WEAKNESSES

"Levee failure burst is not included in the storm surge component outside of New Orleans and the Galveston Sea Wall (which are modelled explicitly)"

"Inland flooding from rainfall, often a major contributor to our portfolio on small events, is not modelled"

"Wind and flood losses in non-coastal states to which we have significant exposure (e.g. […], […], […]) are not included in the model"

"The small amount of observed data for North-Eastern and Mid-Atlantic storms means that changes to the model in these regions are based upon the extrapolation of observed data from other regions, and thus there is greater uncertainty around both the frequency and severity components in these regions"

2.4.3 LIMITATIONS

"Contingent business interruption losses are not modelled"

"Time element losses are connected to the physical damage to a building, and no business interruption losses will be calculated where there has been no physical damage loss"

"[classes of business A, B and C] are not explicitly modelled. The model can be adapted in certain cases to try to estimate losses for these types of coverages using adjusted parameters/assumptions"

"Residual market loss is not explicitly included (although this can be estimated and loss curves for the various pools typically can be obtained)"

3. RECOMMENDING

This section summarises the fit between the cat-model and your portfolio, describes how it should be used (including run-time settings, adjustments to inputs or outputs, etc.), and makes a formal recommendation to the approving group/person/office.

As in section 1.3, the purpose of this document is to provide an example of the process, rather than an actual validation. Our comments here are therefore once again generic and imaginary, and not related to the RMS v11 U.S. Windstorm (or any other) model.

3.1 SUMMARY OF FINDINGS

Following the analysis undertaken, including an extensive review of the vendor documentation, sensitivity testing to understand the key drivers for our portfolio and their sensitivity to parameter adjustments, and a review of the suitability of the various decisions the vendor made in developing their model in reference to our own portfolio of risk, we have come to the following conclusion:

- The […] model is a comprehensive development on the previous model versions, with many significant enhancements. The ratio of modelled to actual losses since 1989 does offer relatively strong support for the view that the model is broadly representative of the risk.
- The new storm surge component utilises a much more advanced modelling methodology, and while the losses look conservative, it is very difficult to isolate this component of loss from historical claims data and thus it is difficult to firmly accept or refute the adjusted view of risk. We agree with the approach taken, and accept that it is an advancement from the prior simplistic method of adjusting for storm surge damage, but we remain somewhat concerned about the large contribution of storm surge to the annual average loss.
- The inland filling changes are also predicated upon much more advanced techniques being applied, and clearly address a previously significant weakness with the prior models (lack of damaging winds inland). However, the changes to the hazard in certain coastal and close-inland regions is also significant. This has led to both large positive and large negative movements on accounts, with some Florida coastal risks seeing material reductions in the hazard, and some mainland accounts seeing very material increases in the hazard. The inland component does not tend to drive the overall losses generated from the peril, due to the overall lower wind-speeds.
- The increase in claims data from 2004 through 2010 has helped to refine the fit with our particular portfolio, as most of the collected data is residential and commercial, similar to our portfolio. The changes to roof-type vulnerability are extrapolated regionally from quite small samples of claims data, but this is a common problem with the models. The education curve changes are probably of immaterial impact to most companies, but for our specific portfolio they have an outside impact. Upon review we do not believe that they are fully reflective of our experience of the risk nationwide, and will thus be adjusting our approach to coding K-12 educational facilities to reduce the impact of this change.
- . Our own analysis of data appears to suggest that warmer SSTs lead to more storm activity in the basin. However, the MTR forecast depends upon the core assumption of a linear relationship between basin activity and land-fall. Our own research suggested that the available data did not provide strong support for this assumption, but there are considerable uncertainties around this element, and the scientific community is still actively debating this. In light of the uncertainty, we can understand why [the vendor] have elected to assume that an increase in basin activity will correlate strongly with an increase in landfall activity. It would only take a few more active seasons to either provide stronger support for this view, or to provide further evidence that some counteracting element is at play.
- The MTR (Medium Term Rate) view of risk is the single largest driver of portfolio modelled loss increases. This has been a very contentious element of this release, and the approaches taken in the market vary considerably. It is also important to note that the approach taken by [the vendor] is substantially different to the approach taken by one of their

major competitors, whose U.S. hurricane model applies roughly a [x%] uplift in rates, albeit with some regionalisation and category adjustments taken into account

3.2 ADJUSTMENTS

The following small adjustments will be made:

[…] facilities will be coded with each individual component of the site matched to the most appropriate occupancy code to avoid taking the full conservative adjustment to the relevant occupancy curve. [….] will be coded using the new coding, although at present that does not provide a bespoke view of risk.

3.3 LIMITATIONS

Preceding conditions are not incorporated. For example, if a major disaster has already occurred, there would likely be an increase in the demand surge component of loss, but the model is not updated on a live basis to handle preceding conditions of this nature. Similarly preceding wave heights / tide is not incorporated and a mean is utilised. On the aggregate loss basis, a subsequent modelled event impacting the same region has the severity calculated on the basis of no existing damage to the structures and as such could over or under-estimate the loss

For extreme events, the event frequencies are the subject of very significant uncertainty due to the paucity of observed data

Contingent business interruption losses are not modelled

Time element losses are connected to the physical damage to a building, and no business interruption losses will be calculated where there has been no physical damage loss

Loss (Claims) adjustment expenses are not included

[classes of business A, B and C] are not explicitly modelled. The model can be adapted in certain cases to try to estimate losses for these types of coverages using adjusted parameters/assumptions.

Residual market loss is not explicitly included (although this can be estimated and loss curves for the various pools typically can be obtained)

3.4 RECOMMENDATION

To adopt the […]model, using the Medium Term Rate view of risk, with the default storm surge parameters and storm surge turned on by default, with Demand Surge turned on.

We recommend the adoption of this approach, despite the caveats we have outlined in this report. However, we will be carefully monitoring the outcome of further research by [the vendor] and by independent agencies (including further testing by ourselves as more data becomes available), and reserve the ability to alter our view of risk (e.g. by scaling the MTR frequencies, or adjusting our storm surge parameters). It is our feeling that despite the very large uncertainties, at this point in time we are better served by erring on the side of caution while continuing to review our options. As we write a very mixed book of natural catastrophe exposed business worldwide, as well as non-natural catastrophe business, the impact of the changes to our view of risk on this one peril will not have a material impact on our diversified capital.

3.5 PROCESS OF APPROVAL

The recommendation above shall be formally considered by the [.....] Committee, as described in the relevant Model Validation Process Document. Such consideration shall provide the opportunity for challenge and/or rebuttal of any of the findings herein.