U.S. and Caribbean Hurricane Activity Rates

The New RMS Medium-term Perspective & Implications for Industry Loss

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RMS™
Risk Management Solutions

Executive Summary

In May 2006, RMS will release RiskLink® and RiskBrowser® 6.0 with upgraded hurricane models for the Gulf and Atlantic Coasts of the United States, the Caribbean islands, and offshore energy platforms in the Gulf of Mexico. The scope of this upgrade is significant and reflects the principal lessons learned from the active 2004 and 2005 hurricane seasons, including advancements in vulnerability assessment, refinements to storm surge modeling, a more comprehensive methodology to assess loss amplification, and a new view on hurricane landfall activity rates.

This white paper is solely intended to describe the rationale, methodology, and implications of one single component of these changes—the inclusion of a new understanding of the activity rates of landfalling hurricanes. In making these changes, the RMS model now provides a view of risk consistent with a forward-looking five-year risk horizon, rather than the long-term historical baseline (1900-2005).

Atlantic hurricane activity has remained persistently high since 1995 (except for El Niño years). In 2004 and 2005, the high activity in the basin translated into U.S. landfall and the highest loss years ever experienced by the insurance industry. With strong evidence that higher than average activity rates are likely to persist for at least a decade, it is no longer appropriate to employ a long-term historical baseline for characterizing medium-term activity rates in hurricane catastrophe (Cat) models. Acknowledging that the long-term historical baseline is no longer the best measure of current activity also means it is necessary to be explicit about the intended time horizon of Cat model activity rate projections.

In developing the new medium-term five-year view of risk, RMS has taken counsel from representatives across the insurance industry in determining that future model output will be for a 'medium-term' five-year risk horizon. In October 2005, RMS called an expert meeting of four leading hurricane climatologists to arrive at a consensus forecast for medium-term hurricane activity in the Atlantic basin, at U.S. landfall, and in the Caribbean. For the U.S., the medium-term perspective represents about a 20% increase in Saffir-Simpson category 1-2 hurricanes and over a 30% increase in category 3-5 hurricane landfall rates relative to a 1900-2005 historical baseline. This view of hurricane activity rates has been implemented within the U.S., Caribbean, and Offshore Platform models in RiskLink and RiskBrowser, based on RMS hurricane type, geographical region and Saffir-Simpson category.

The impact of these changes in hurricane activity rates will increase average annual losses (AALs) by approximately 40% on average across the Gulf Coast, Florida, and the Southeast, and by 25-30% in the Mid-Atlantic and Northeast coastal regions. When compared with a pre-2004 historical baseline, as has been previously employed for quantifying insurance risk, the increases in modeled annualized losses are closer to 50% in the Gulf, Florida, and the Southeast.

Introduction

There has been a marked increase in hurricane activity in the Atlantic Basin since 1995. Relative to the average of the low activity period from 1970-1994, the overall number of hurricanes has increased by more than 60% and the number of the more intense category 3-5 storms by more than 150%. While the increase relative to the long-term historical baseline of activity is less than half of these numbers, since 1995 the basin has not only been more active, but a greater proportion of hurricanes are becoming intense. The switch from a low-activity regime to a high-activity regime has previously been considered the result of cyclical, multi-decadal climatological variations, principally driven by sea surface temperatures in the equatorial North Atlantic. There are also emerging views in the scientific literature that these sea surface temperatures are being affected by climate change, so that they may not revert back to the long-term, pre-1990s averages.

While the cause of increased hurricane activity is a source of vigorous scientific debate, for considerations of U.S. and Caribbean risk, the concern is to understand what proportion of Atlantic hurricanes will make landfall and at what intensities. Between 1995 and 2003, in particular for the more intense category 3-5 storms, the higher activity in the basin did not convert into higher U.S. landfall rates. There was speculation that those factors that led to an increase in activity showed some correlation with a climatology that kept storms offshore or weakened them as they advanced towards landfall. The 2004 and 2005 seasons ended the landfalling deficit, and more than 50% of the category 3-5 hurricanes in the basin made landfall at those high intensities.

Background to the Understanding of the Variability in Atlantic, U.S., and Caribbean Hurricane Activity

Hurricane formation in the Atlantic basin varies by seasonal and multi-decadal time scales. A number of established climatological cycles are known to influence this activity. For example, Atlantic hurricane activity is influenced by the phase of the El Niño Southern Oscillation (ENSO). During the warm phase (El Niño), Atlantic activity is generally reduced, as the wind shear (the difference between upper and lower level winds) notably increases in the tropical Atlantic and Gulf of Mexico. During the cold phase (La Niña), lower than average wind shear helps create more favorable conditions for hurricanes to form and intensify. The North Atlantic Oscillation (NAO) has also been discussed in scientific literature for its role on the seasonal distribution of hurricane tracks. In the positive phase of the NAO, a strong Azores High favors hurricane recurvature out to sea before U.S. landfall, while a negative NAO implies a Bermuda High that is more likely to steer storms towards a U.S. landfall in Florida and the Gulf (Elsner, BAMS, 2003). There are limited skills in forecasting the phase and amplitude of those oscillations with more than a few months lead time, therefore making their use difficult for (re)insurance applications.

Hurricane activity has also shown well-established variability on longer time scales. Goldenberg et al. (Science, 2001) provide the best summary of evidence for a multi-decadal oscillation in the activity of Atlantic hurricanes, linked to the phase of the Atlantic multi-decadal oscillation (AMO). The AMO reflects a pattern of Atlantic sea surface temperature (SST) anomalies that has also varied on decadal time scales. The case for a multi-decadal cycle in hurricane activity rests on the equivalence between the current period and the last period of high activity that culminated in the 1950s, as well as the degree to which earlier cycles of high activity and high storm intensity can be detected. The argument of the AMO as a primary cause of the hurricane activity cycle was challenged in 2005 by two studies that focused on the evidence of a trend in activity rates. Research by Emanuel (Nature, 2005) showed that the 'destructiveness' power of Atlantic hurricanes (defined as the cube of the maximum wind speed integrated over the storm lifetime) has increased over the last 30 years, in a manner consistent with the increase in tropical Atlantic SSTs over the same period. Emanuel also showed that the latest period of high activity has broken records for both SSTs and cumulative power dissipation when compared with the 1950s. A parallel study by Webster et al. (Science, 2005) documented a significant global increase in the proportion of tropical cyclones that reached the highest category 4-5 intensities, linked to changes in tropical SSTs. Both studies also referenced that the increase in SSTs appeared to be closely linked with global warming.

Climatologists who give priority to the theory of the AMO as well as those who see evidence of climate trends all agree that the Atlantic basin is likely to continue to remain very active for the next decade or longer. The key issue for U.S. hurricane risk concerns how higher basin activity is expected to convert into landfall activity and intensity. Figure 1 shows a five-year running mean (from 1950-2005) of the basin activity of category 3-5 hurricane and the proportion of those storms that made a U.S. landfall at category 3-5. During that period, category 3-5 activity in the basin has successively gone through an active period (1950s and 60s), then shifted to low activity (1970s and 80s), before a return to high activity since 1995. On average, about 25% of all Atlantic category 3-5 hurricanes make U.S. landfall as a category 3-5. This proportion has become increasingly volatile, with an anomalously low number of category 3-5 storms making intense landfall in the U.S. from 1995-2003, while this number was unusually high in 2004-2005. Between 1995 and 2003, a number of intense storms (Floyd 1999, Isabel 2003 for example) underwent significant weakening as they approached the U.S. coast. RMS expects that averaged over time, the proportion of category 3-5 storms that make a U.S. intense landfall to be in the range of the long-term mean or between 20-30%.

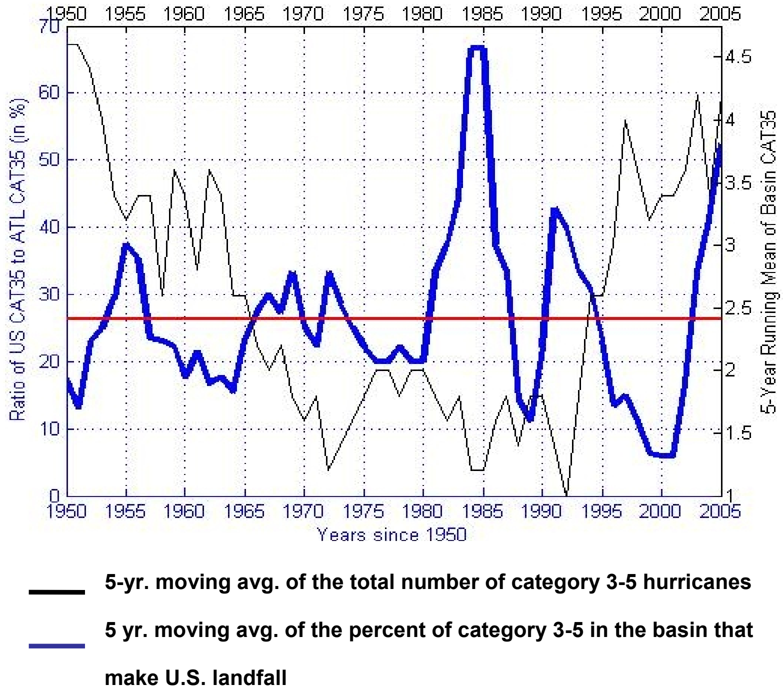

Figure 1: Five-year running average of category 3-5 Atlantic hurricanes (black line) and the ratio of hurricanes making U.S. landfall as a category 3-5 (blue line) since 1950. The red line marks the average ratio of Atlantic Basin to U.S. landfall category 3-5 across this period.

The Shift to a Medium-term Perspective on Activity Rates

Given a constant climatological state (or if annual variations from that state are short lived and unpredictable) the activity rate in a catastrophe model can best be represented as the average of long-term history. In this situation there is no need to characterize the period over which the activity is considered to apply because, with current knowledge, it is expected that rate will continue indefinitely. The assumption that activity remains consistent breaks down, however, where there are either multi-year fluctuations in activity or persistent trends. It then becomes necessary to characterize the time period over which the activity in the Cat model is intended to apply.

To determine what should be the explicit risk horizon of an RMS Cat model, opinions were solicited among the wider insurance industry from those who both use and apply the results of models to find the duration over which they sought to characterize risk. While there are some users concerned with results for a short-term, seasonal (few months) perspective, the majority of risk horizons extend over and beyond the minimum lifetime of an annual contract due to the volatility inherent in a short-term seasonal horizon. A perspective that spans multiple years is best suited for many other purposes, including capital allocation, dealing with investors and rating agencies, long-term management planning, and the issuing, rating and investment in Cat bonds. Additionally, a medium-term five-year perspective is viewed by many companies to allow for stable pricing that helps to maintain strong client relationships over the volatility a seasonal perspective can introduce. For maximum utility, the risk horizon in the model needs to bound the longest time periods for which results are commonly employed. On this basis, a five-year perspective was selected as being the forward-looking time horizon. Starting in May 2006, this will become the explicit time horizon of new and upgraded RMS catastrophe models, where appropriate. Currently, a medium-term perspective is used in the RMS time-dependant methodology of analyzing earthquake slip rates for multiple countries. This summer, RMS will release a Germany Flood Model that incorporates temperature and precipitation trends for a medium-term five-year view of flood risk.

Over the course of the last 18 months, RMS climatologists have conducted extensive research on all aspects of Atlantic, U.S., and Caribbean hurricane activity to develop a foundation of knowledge on how annual and inter-annual activity has varied by intensity and region. Given the critical financial and regulatory impact of the assessment of the medium-term activity rate, RMS decided to build scientific consensus on the question by bringing together four leading experts on hurricane climatology in October 2005.

Expert Elicitation Session

Background on the Process of Elicitation

In every probabilistic risk assessment, as a result of data incompleteness and the existence of alternative scientific theories, some degree of expert judgment is involved in probability assignments. The formal elicitation of subjective judgment from domain experts is standard practice in analyzing earthquake and other geological hazards, but is rare in applied meteorology, which has a long established mathematical pedigree focused around improving weather forecasting. Even though the physics of the atmosphere is better understood than subterranean processes, there remains a sufficient lack of understanding of hurricane hazard characteristics to cause some divergence among expert opinions. Meetings to poll U.S. earthquake hazard experts and develop a consensus on each ingredient of the hazard model are managed by the United States Geological Survey. With no equivalent agency constituted to develop information on medium term hurricane risk, RMS took the lead to establish a transparent procedure to develop consensus climatological forecasts of hurricane activity based on the latest scientific knowledge.

Formal methods have been developed within the decision sciences for eliciting expert judgment in a systematic and auditable way. One effective and efficient method involves the gathering of experts at a special decision conference at which the scientific issues can be presented and differences in individual judgments examined and explored. Even though individuals may arrive at the meeting with divergent views, the opportunity to debate the case, and explain the merits of different data sets, can allow them to arrive at a set of group decisions on risk modeling that reflect the insights and perspectives shared during the discussions.

In the context of assessing the medium term risk of hurricanes at U.S. landfall, there are two main reasons for organizing such an elicitation session:

1. The Atlantic Basin historical record is relatively short and generally considered incomplete before 1945 (even before 1900, the U.S. landfall record appears incomplete for intensity, particularly in underestimating the category of some smaller hurricanes). Approximately 183 category 1-5 storms are known to have made U.S. landfall between 1900 and 2005, of which around 40% were at category 3-5. The data is therefore sparse, particularly to assess the category 3-5 activity and its regional distribution.
2. There are two distinct theories (one cyclical and one trended) to explain the current period of high activity. With insufficient evidence to confirm either theory, and the potential for the reality being a hybrid of both, the theoretical underpinning of what determines current hurricane activity cannot be settled from historical observations alone.

Elicitation Roundtable

The first Hurricane Activity Rate elicitation session was conducted in Bermuda on October 15, 2005. The following experts in tropical cyclone meteorology and climate were present at the meeting:

1. **Professor Jim Elsner (Florida State University)** - Expert in tropical cyclone climatology, well known for his studies of the mechanisms controlling hurricane annual frequencies and their tracks. Professor Elsner has written numerous papers on ENSO, the AMO and the influence of the NAO on hurricane activities and regionalization.

2. **Professor Kerry Emanuel (MIT)** - Expert in tropical cyclone dynamics, thermodynamics, and climatology. Professor Emanuel is best known for his work on the maximum potential intensity of tropical cyclones and his 2005 paper on the evidence for an increase in the destructiveness of hurricanes.
3. **Tom Knutson (NOAA/GFDL)** - Expert in climate modeling and the potential effect of ongoing rises in global greenhouse gas concentrations on the activity, intensity, and rainfall of tropical cyclones. Tom Knutson has written several key papers that are the most widely cited source of information on what kind of changes in hurricane intensities could occur late into the 21st Century.
4. **Professor Mark Saunders (University College London)** - Expert in understanding the mechanisms that drive the seasonal activity of tropical cyclones. He is best known for demonstrating that seasonal forecasting now has sufficient skill to be employed to project the general tendency of financial losses from hurricanes.

Information Presented to the Experts

The experts were provided with exhibits and datasets regarding activity in the Atlantic Basin, at U.S. landfall, and in the Caribbean, including time series of annual and five-year windowed activity for all category 1-5 and category 3-5 storms from 1900-2005. Basic information on the way activity rates were considered in the RMS U.S. Hurricane model was also provided to show the context of the discussions, but the decision-making process around activity rates was kept independent of the specifics of RMS landfall gates and hurricane track types.

The time series and averages for the Atlantic Basin were derived from the HURDAT record, as maintained by the National Hurricane Center (NHC) (http://www.nhc.noaa.gov). Although the data covers the period from 1851-2005, the experts stated that prior to 1946, when reconnaissance flights began, the record should be considered incomplete and therefore could not be employed for inclusion in the activity rate statistics. For the assessment of medium-term activity in the basin, the experts decided to use only data from 1950. Figure 2 shows the time series of Atlantic basin category 3-5 hurricanes from 1900-2005 with a superimposed five-year running mean.

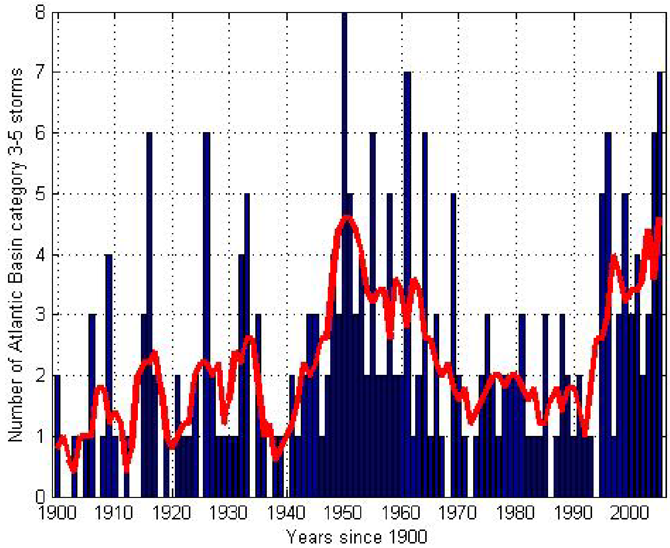

Figure 2: Number of Atlantic category 3-5 hurricanes between 1900 and 2005 and the five-year running mean.

The list of landfalling U.S. storms was also provided. The data is maintained by NOAA/NHC and derived from the HURDAT dataset. It is available through the NHC website or directly at the NOAA Hurricane Research Division (HRD). It provides information about all storms between 1851 and 2005 that affected the U.S. with hurricane strength winds (e.g., includes some grazing storms near Cape Hatteras). The database provides the storm Saffir-Simpson category, based on the 1-minute maximum sustained wind in all U.S. states affected by a storm. Figure 3 shows the time series of category 3-5 U.S. landfalls between 1900 and 2005 with the 5-year running mean superimposed.

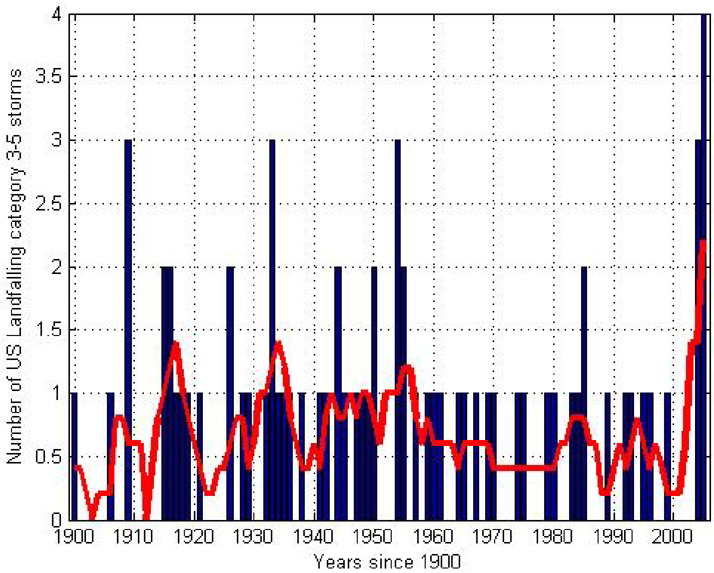

Figure 3: Number of U.S. landfalling category 3-5 hurricanes between 1900 and 2005 and the five-year running mean.

The experts were asked to address and resolve the following questions:

- What is the expected basin activity of category 1-5 and category 3-5 hurricanes in the Atlantic basin over the next five years?
- What is the expected activity for category 1-5 and category 3-5 hurricanes at U.S. landfall over the next five years?
- How much longer can we expect the recent period of high Atlantic hurricane activity to persist?
- What is the expected activity of category 1-5 and category 3-5 hurricanes in the Caribbean over the next five years?

The experts discussed each question for one hour and a consensus opinion was then established for each question. The main conclusions reached by the experts were:

1. Activity in the Atlantic basin for the next five years is expected to be close to the average of the past 11 years. The probability for the activity to return to levels corresponding to the long term baseline is small over the next five years.
2. The experts each provided perspectives on the probability of the five-year U.S. landfalling rates being above or below certain thresholds, with the probability estimates provided by each expert considered interdependent (under a Poisson assumption). Relative to the historic 1900-2005 baseline, the increases in landfalling activity rates averaged across the group convert into about a 20% increase in the rate of category 1-2 storms and a more than 30% increase for category 3-5 storms.
3. The high levels of activity observed over the last 11 years are expected to last for at least another 10-15 years.
4. The medium-term activity in the Caribbean region is expected to be consistent with the perspective of activity developed for the full basin.

RMS then used the information provided by the panel of experts to implement the five-year view of activity rates in both the U.S. and Caribbean Hurricane models.

Annual Updates of Stochastic Event Rates

In order to annually renew the medium-term view of risk, RMS will evaluate and update the expected activities for the next five years at the end of each hurricane season. An expert elicitation session will be convened to solicit a consensus opinion from a panel of leading tropical climatologists and meteorologists, ensuring stability in annual outputs through consistency in the experts serving on the panel and in the Bayesian methodology employed. Following the completion of the development of expected activity rates, if there is a material change in the five-year medium-term view of risk, RMS stochastic event rates will be updated. This could then reflect:

- Change in inputs/outputs of the annual expert elicitation assessment of new scientific research and the activity during the additional season
- Refinement of the implementation by Saffir-Simpson Category, RMS storm type, and regionalization of U.S. and Caribbean landfalls

In parallel with this work, RMS scientists will continue to monitor all aspects of the science related to hurricane climatology and where appropriate provide regular guidance on issues related to hurricane landfall frequency.