info@twelvecapital.com
www.twelvecapital.com

For professional/qualified investors only

Twelve Capital Research Spotlight | April 2019

Hurricane risk: Modelling versus forecasting for Insurance-Linked portfolios – towards machine learning

The evolution of hurricane modelling

- Hurricane Andrew making landfall in Florida in 1992 became one of the costliest insurance events in history. The impact of this event on the (re-)insurance market for property exposed to natural catastrophe led to the advent of scientific modelling of natural catastrophe risk, as well as the beginning of securitisation of natural catastrophe risks and with it the opportunities to invest in Insurance-Linked Securities ('ILS').
- The modelling of tropical cyclones requires assessing both the frequency and severity of this peril, given certain scientific dynamics and long-term meteorological conditions. To estimate the risk to insured values, a view of a storm's landfall probability, location and landfall angle is also required, as well as the distribution of insured values and the vulnerability of such values to corresponding wind forces.
- One of the main uses of models' output is to help assess the relative attractiveness of a single investment opportunity versus other opportunities in the market and, with that, the pricing of a potential investment. The other main use of natural catastrophe models focuses on aggregating the modelled natural catastrophe risks of single investments to derive a risk and return profile of an ILS portfolio. The aggregate portfolio model, therefore, allows for the assessment of the potential portfolio drawdown and its corresponding probability.
- While still in its early stages, the initial results from the use of machine-learning and automated pattern recognition methods for forecasting hurricane systems seem promising. Twelve Capital is currently exploring how such information may be used in the tactical optimisation of portfolios across the various ILS strategies it manages.

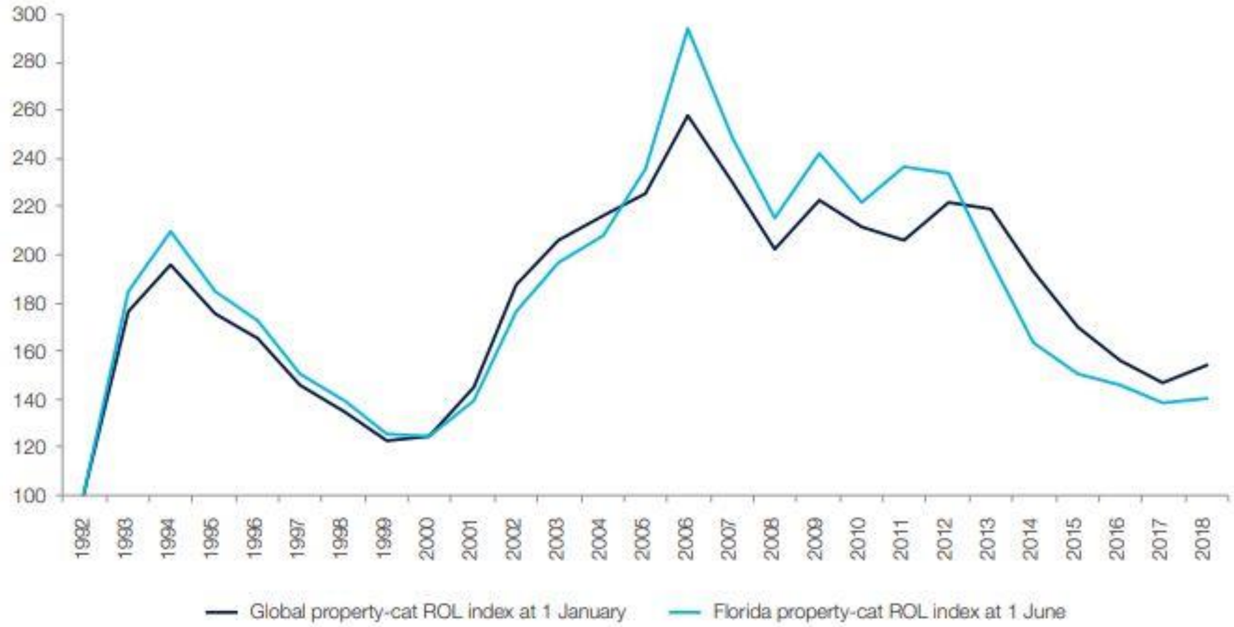
Modelling hurricane risk

Historical background

The natural catastrophe models ('NatCat' models) used in the (re-)insurance industry have developed significantly, with a breakthrough in terms of acceptance and subsequent use, as a consequence of Hurricane Andrew in 1992. The reinsurance industry subsequently moved from loss experience-based modelling to a scientifically derived scenario-based modelling approach. The latter approach consists of simulating a representative set of possible scenarios reflecting various possible investment outcomes over the duration of a risk period, typically one year.

The change of assessment of the underlying risks, in combination with the high level of costs caused by Hurricane Andrew, also led to a global repricing of property catastrophe risk in the (re-)insurance market and even more so for Florida-specific risks, as shown in Figure 1 below.

Figure 1: JLT Re's Global and Florida-specific property-catastrophe ROL Index – 1992 to 2019. This index is risk-adjusted, meaning changes to exposures, as well as premiums, are incorporated.



Source: JLT Re, JLT Re VIEWPOINT, August 2018.

With the benefit of hindsight, the lessons learned from Andrew seemed rather obvious as they were related to the appropriate assessment of the general loss potential of hurricane risk. In other words, only considering the loss experience in the past is not sufficient for deriving an appropriate and fair representation of the actual and inherent loss potential for the future. On one side, changes in the underlying exposure - such as evolving demographics and construction regulations - would likely not be appropriately reflected. On the other side, the occurrence of hurricanes making landfall in the more recent past would not necessarily be an appropriate reflection of the inherent hurricane risk.

Typical use of the natural NatCat models in the (re-)insurance industry

Today, a handful of companies with extensive insurance, engineering, meteorological and earth-scientific modelling expertise have specialised in providing third party modelling software and, with it, modelling platforms and services for scenario-based modelling of natural catastrophe risk. These companies have established themselves in the (re-)insurance industry as a third party modelling provider allowing investors to derive their own assessment of the risk based on key modelling assumptions that are independent from the protection buyers' view of the risk.

The key design principle of scenario-based modelling is based upon the separation between the scientific modelling of the peril in a given region, e.g. tropical cyclones in the US, from the underlying exposure, i.e. the set of property assets which would be exposed to the corresponding peril. Such a modelling approach allows for various statistical analyses on the likelihood, frequency and loss potential of single insured event occurrences of the modelled peril in a specific region, taking into account the current or even future planned exposure levels. These should appropriately reflect current exposure values, given that new scientific research outcomes and updated market developments on building codes and construction requirements are regularly added to new model releases.

The NatCat model standard outputs are:

- **Event loss tables:** an extensive list of modelled events, with expected occurrence frequency and expected modelled loss in case of occurrence.
- **Year loss tables:** an extensive list of equally-likely modelled investment outcomes, so-called 'scenarios', possibly consisting of the occurrence of several events.
- **Occurrence and annual exceedance probability curves:** aggregated probability distribution referring to the portfolio's likelihood of experiencing a profit/ loss outcome exceeding a certain monetary amount, in consideration of the largest modelled event and all modelled events occurring over the time period of one investment year, respectively.

Main uses of the NatCat model output:

- **Pricing:** model the underlying natural catastrophe risk and assess the relative attractiveness of a single investment opportunity versus other opportunities.
- **Portfolio risk/return management**: aggregate the modelled natural catastrophe risks of single investments to derive a risk and return profile for an ILS portfolio.
- **Portfolio optimisation and reporting**: manage the full distribution of the modelled risk and return outcomes within the corresponding risk limits set and report corresponding relevant key risk figures.
- **Scenario/event impact analysis**: given the occurrence of an insurance event, assess the expected impact of the specific event on the property catastrophe (re-)insurance market or on specific ILS portfolios.

However, it is important to note that scenario-based NatCat models are by no means prediction or forecasting tools, even though they allow for assessing the expected impact on a portfolio given the occurrence of an event.

Current challenges in modelling hurricane risk

Most recently, the ongoing developing loss impact on the reinsurance industry from Hurricane Irma, in particular, strongly indicates that the ultimate modelled output should more appropriately account for human (or social)-driven claims' inflation, which has come to the fore in certain geographical regions such as Florida, given specific and local legislation.

Furthermore, certain recent events highlighted weaknesses in the models in accurately assessing the impact of the catastrophic hurricane-type of events on larger-scale infrastructures (e.g. airports and ports) and, with that, the consequences due to disruption in the (industrial) production chains and claims that were made relating to these losses.[1] This was particularly the case for Hurricane Maria in Puerto Rico in 2017 as well as for Typhoon Jebi in Japan in 2018.

Given the most recent experience, the event-active years of 2017 and 2018, and the lessons learned earlier, the industry is expected to more closely follow the new model updates and their rationale. An impact on the general premium rate environment over the coming renewal cycles in the reinsurance industry cannot be excluded.

[1] Catastrophe models: In the eye of the storm, JLT Re viewpoint, July 2018.

info@twelvecapital.com
www.twelvecapital.com

For professional/qualified investors only

Forecasting hurricane risk: The principles

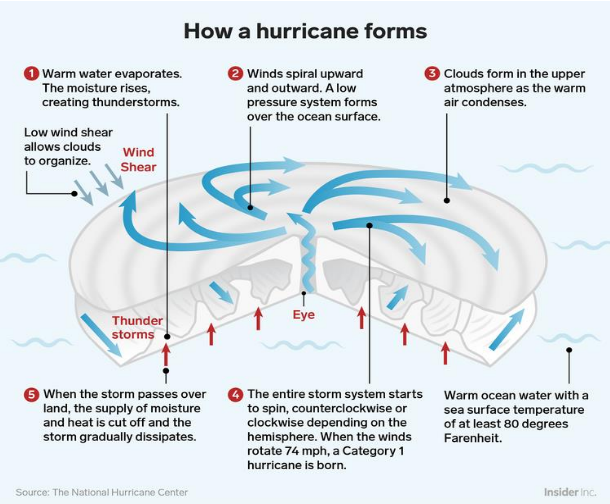
Key meteorological aspects

Hurricanes are a sub-set of the tropical cyclones that form over the Atlantic and the North-Eastern Pacific and require warm water to form. Typhoons, meanwhile, are tropical cyclones that form over the North-Western Pacific Ocean. More generally, the term cyclone refers to winds moving in a circle around a central eye, with winds blowing counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere

How a tropical cyclone is formed

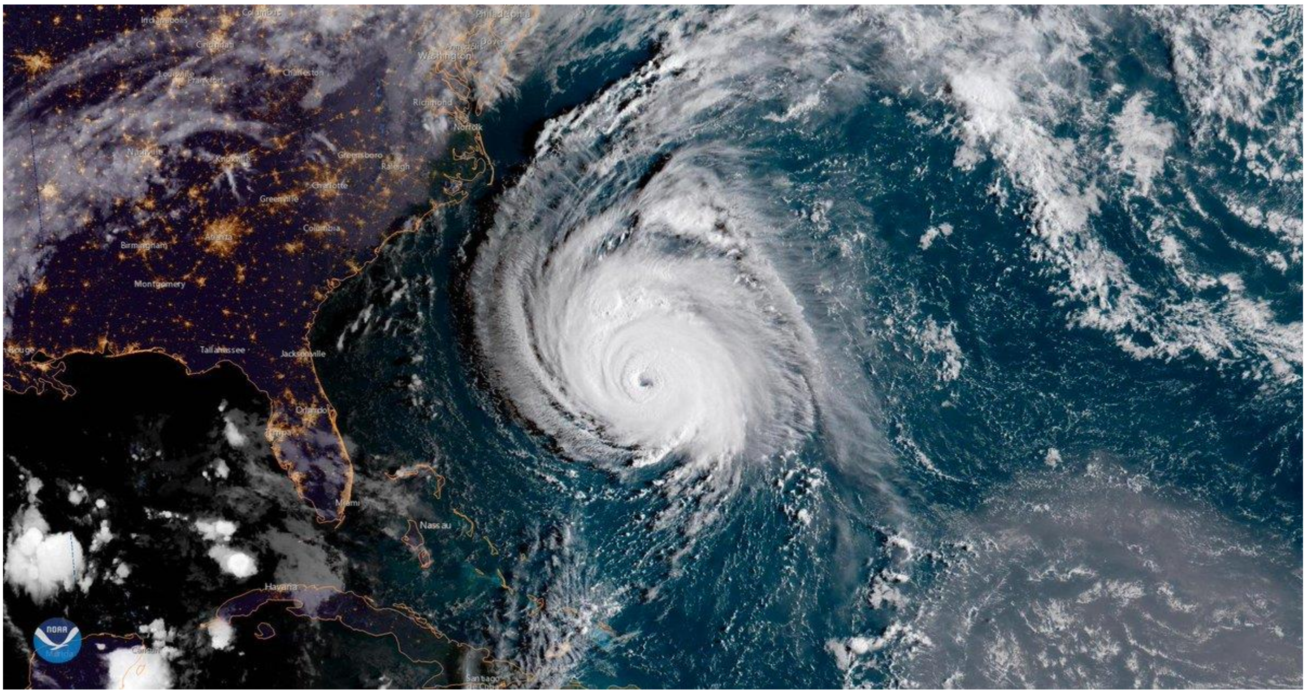
- Pre-existing low pressure area moves over moisture-rich tropical waters.
- System draws up humid air from beneath.
- Air rises then cools down so clouds and eventually thunderstorms form. Subsequently, in the upper atmosphere, water condenses and forms droplets, releasing even more heat to power the storm further
- 'Wind shear', i.e. a large difference in wind speed and direction at different atmospheric altitudes, may tear apart a cyclone[2]. If not, it becomes a hurricane[3].

Figure 2: How a hurricane forms.



Source: NHC, picture from Business Insider: https://www.businessinsider.com/how-hurricanes-form-2018-9?r=US&IR=T.

Figure 3: Hurricane Florence, 2018.



Source: National Hurricane Center (US), NOAA.

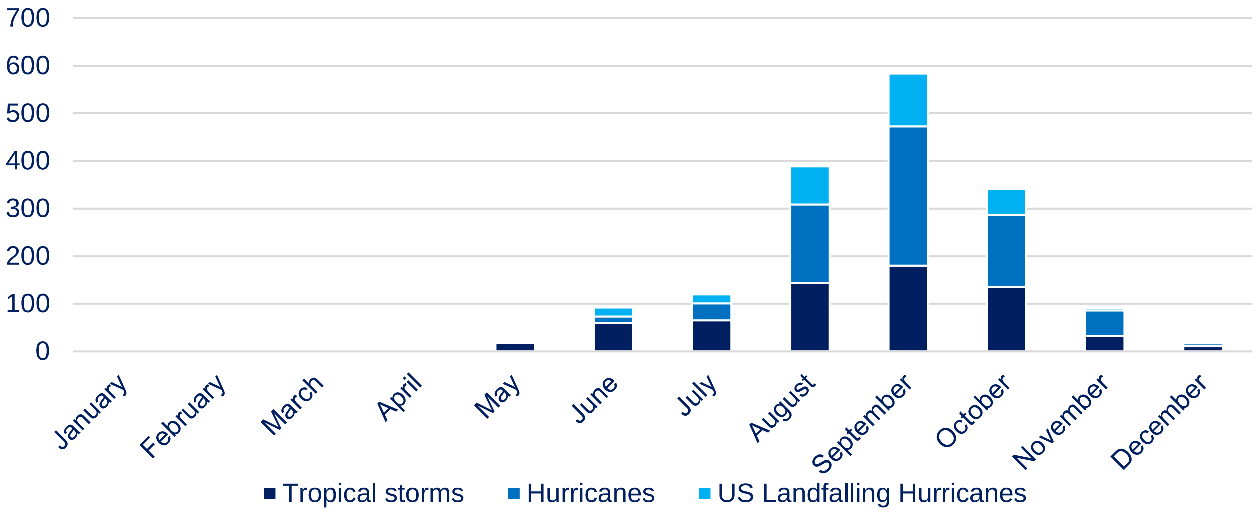
[2] The actual level of wind shear is the atmosphere is heavily influenced by the state of the El Nino-Southern Oscillation ('ENSO'), by which El Niño seasons in the Atlantic basin tend to come with stronger wind shear.

[3] https://www.nhc.noaa.gov/aboutsshws.php

The Atlantic Hurricane 'Season'

The official hurricane season for the Atlantic basin runs from 1 June to 30 November. As seen in Figure 4 below, the peak of the season is from mid-August to late October.

Figure 4: Tropical cyclones by month 1851-2017.

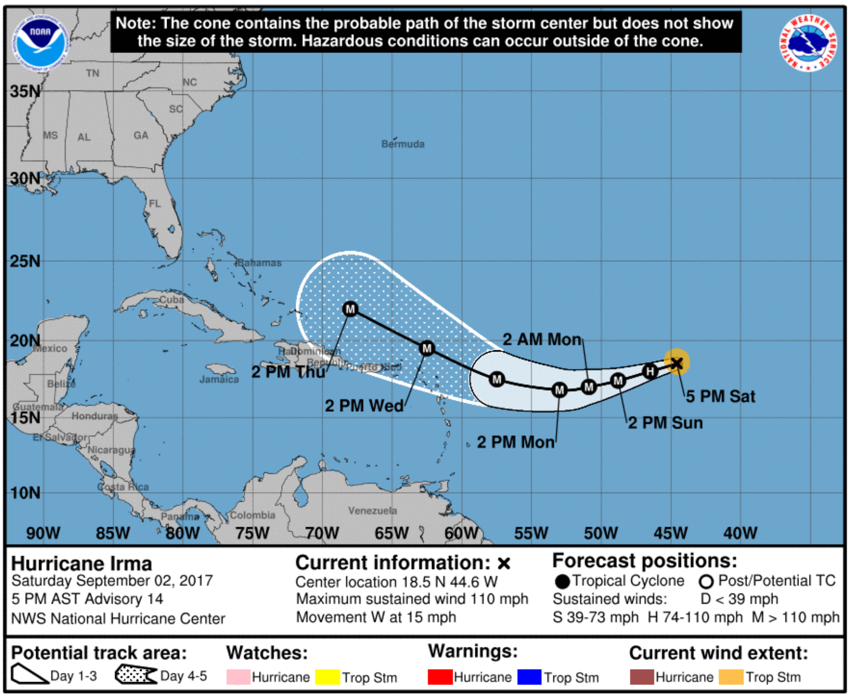


Source: National Hurricane Center (US), NOAA.

A variety of climatological research centres and departments of universities have specialised in the business of forecasting expected hurricane activity for the Atlantic in a given calendar year. Generally, in April, a forecast is published which gives the actual status of certain key meteorological predictors (such as the sea surface temperatures and wind shear) which aims to forecast the expected number of storms, hurricanes and major hurricanes likely to be formed in the Atlantic Basin for that year. This forecast is subsequently updated in June. To Twelve Capital's knowledge, only a very few institutes, such as the Colorado State University ('CSU') and the Climate Forecast Applications Network ('CFAN'), actually attempt to assess landfall potential.

Having said that, the potential material economic impact of hurricanes has expanded to the extent that, over the last two decades, interest and funding have increased and, correspondingly, research has advanced considerably. Improved data information as well as greater computational power has improved the reliability of forecasting materially. Today's usage of parallel computing in the insurance industry in combination with machine-learning algorithms are now propelling this field of science and weather forecasting one step further forward.

Figure 5: Hurricane Irma, September 2, 2017, track and intensity forecast.



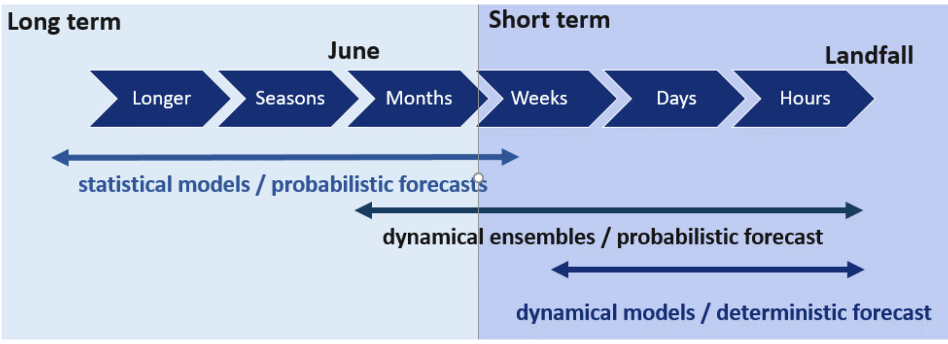
Source: National Hurricane Center (US), NOAA.

Note that the modelling of tropical cyclones differs from forecasting track and wind speed forces of an actual hurricane once it is underway. The so-called dynamic (forecasting) models are used for the short-term forecast of hurricanes' track and intensity once a storm is on the water. The dynamic forecast models aim at forecasting the hurricane's tracks and intensity by solving the mathematical equations describing the physical laws governing the meteorological behaviour in the atmosphere. These models, therefore, base the forecast on actual atmospheric values measured, typically, over a 3D virtual grid defined across (part of) the globe, and are updated every 3 to 6 hours.

As an example, the National Hurricane Center ('NHC'), with headquarters in Florida, publishes a track forecast which represents the probable track of the centre of a tropical cyclone up to 120 hours ahead, of which Figure 5 is an example. However, the level of inherent uncertainty, especially with regards to the ultimate track for a period greater than five days ahead remains considerable. This uncertainty is reflected by the so-called cone of uncertainty, see the shaded (3 days ahead) and dotted area (5 days ahead) in Figure 5.

In Figure 6, the different types of models used for the various aspects of assessing hurricane risk are outlined. Their typical use within different time frames relative to a hurricane making landfall is also shown.

Figure 6: The landscape scenario-based and forecasting models for hurricane.



Source: Twelve Capital AG.

Machine-learning for hurricane forecasting: Refining the risk view

In order to drive research forward and to mitigate the challenges surrounding the assessment of hurricane risk, as described above, Twelve Capital has recently started to work with Reask, a specialist in the fields of catastrophe risk management, modelling and forecasting.

This climate technology firm applies state-of-the-art methods derived from artificial intelligence (AI) as pattern recognition systems without the need for explicit human input, as well as image processing, in order to forecast hurricane risk. Pattern recognition is combined with a 'smart' selection of what physically drives hurricane risk.

These methods allow for the exploration of far more scientific and meteorological-relevant information in an effective manner. The machine learning approach recognises in an automated way any meteoroidal pattern which repeats itself and may therefore be relevant for the formation and persistence of hurricanes in the Atlantic basin. Furthermore, the approach this company follows is not only aimed at providing reliable predictions on the number of hurricanes expected to form in a single year, but, more importantly, aims at predicting landfall potential in geographical areas considered most at risk. This approach further focuses on assessing the risk of clustering of such hurricane systems within a certain hurricane season.

Twelve Capital is closely involved in the progress achieved in this area and is actively contributing to the debate to further improve and tailor the application of these methods for the optimisation and tactical adjustments of its ILS portfolios with regards to the risk arising from hurricanes formed in the Atlantic basin.

Conclusions: Investment in technology to drive ILS portfolio performance

As a manager of elemental insurance risks, Twelve Capital has incorporated human and computational powers to enable it to understand key aspects of investing in ILS. Modelling the impact of tropical cyclones brings with it a number of positives. Clients who invest in ILS with Twelve Capital therefore gain an improved perspective of the riskiness of their assets. Nonetheless, Twelve Capital believes a model, no matter how sophisticated, will always contain certain assumptions and simplifications assumed when compared to the 'real world'. Therefore, it is important to understand the strengths as well as the weaknesses of a model in order to derive conclusions with the appropriate level of confidence, while remaining conscious of its inherent level of uncertainty which ultimately drives the price to be asked of the protection buyer.

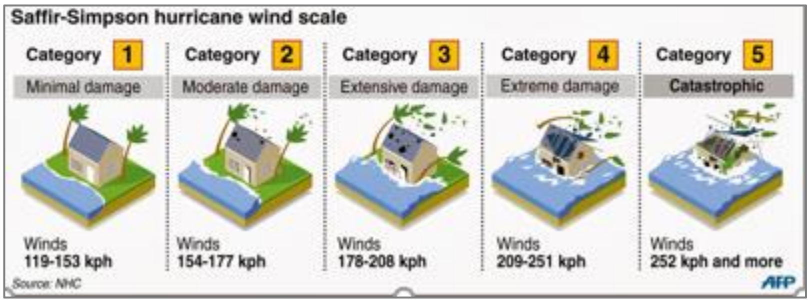
Twelve Capital is involved in further developing and supporting the research and evolution of hurricane forecasting methods in order to better inform and service clients' needs and expectations. While still in its early stages, initial results of using machine-learning and automated pattern recognition methods for forecasting hurricane systems look promising. Twelve Capital is currently exploring how such information may be taken into consideration in the tactical optimisation of the portfolios across the various strategies in the insurance sector it manages.

info@twelvecapital.com
www.twelvecapital.com

Appendix – The genesis of the ILS market coincided with the use of scenario-based modelling

Hurricane Andrew made landfall in Homestead in Florida on 24 August 1992, hitting Florida as a Category 5 hurricane, the highest level on the Saffir-Simpson scale[4]. The Saffir–Simpson hurricane wind scale classifies the hurricanes according to their general impact and damage potential, see below figure 7 illustrating the different level of classifications.

Figure 7: Illustration of the hurricane damage potential according to the Saffir- Simpson scale



Source: NHC: picture form http://geomodderfied.weebly.com/hurricanes.html.

Hurricane Andrew caught the insurance industry by surprise as insured losses of USD 27bn were not thought to be possible for a natural event. Its impact was well above expectations and evidenced the deficiencies of the modelling approaches used at that time. Swiss Re referred to this as a 'watershed' event[5].

First, hurricane Andrew resulted in the costliest insurance event to date and, second, this event highlighted the need for diversification, even for a multinational reinsurance company. This subsequently led to the advent of scientific so-called scenario based modelling, as well as the origination of securitisation, both of which changed investment in ILS.

[4] The Saffir–Simpson hurricane wind scale (SSHWS) classifies hurricanes – Western Hemisphere tropical cyclones that exceed the intensities of tropical depressions and tropical storms – into five categories distinguished by the intensities of their sustained winds. The scale was developed in 1971 by civil engineer Herbert Saffir and meteorologist Robert Simpson, who at the time was director of the U.S. National Hurricane Center (NHC). Hurricanes reaching Category 3 and higher, i.e. sustained wind speed in excess of 178 km/h, are considered major hurricanes because of their potential for significant life- threatening impact and economic damage.

[5] Sigma No.1/ 2018: 'Natural catastrophes and man-made disasters in 2017: a year of record-breaking losses'.

Twelve Capital AG
Dufourstrasse 101
8008 Zurich, Switzerland
Phone: +41 (0)44 5000 120

Twelve Capital (UK) Ltd
Moss House, 15-16 Brook's Mews
London W1K 4DS, United Kingdom
Phone: +44 (0)203 856 6760

info@twelvecapital.com
www.twelvecapital.com

About Twelve Capital

Twelve Capital is an independent investment manager specialising in insurance investments for institutional clients. Its investment expertise covers the entire balance sheet, including Insurance Bonds, Insurance Private Debt, Catastrophe Bonds, Private Insurance-Linked Securities and Insurance Equity. It also composes portfolios of its Best Ideas. Its capital solutions are drawing the world of insurance and reinsurance into a closer, more productive relationship with capital markets. It was founded in October 2010 and is majority-owned by its employees. It has offices in Zurich and London.