A RETROSPECTIVE ON 10 YEARS OF MODELING HURRICANE RISK IN A WARM OCEAN CLIMATE

After tremendous losses from consecutive hurricane seasons in 2004 and 2005—seasons that saw the likes of Charley, Jeanne, Katrina, and Wilma—the insurance industry wondered if a new normal was establishing itself in the Atlantic basin. Did we need to radically adjust our expectations regarding hurricane activity and insured losses? Risk modelers, including AIR Worldwide, tried to make sense of how elevated sea surface temperatures (SSTs) would affect tropical cyclone activity.

This issue brief takes a look back at efforts to quantify this impact in U.S. hurricane models, reviews what we've learned in the 10 years since the catalytic events of 2004 and 2005, and examines how "near-term" catalogs and other alternative approaches, like AIR's climate-conditioned catalog, have performed.

THE LINK BETWEEN A WARM OCEAN AND HURRICANE ACTIVITY

Following the active and quite costly 2004 and 2005 hurricane seasons—which occurred about 10 years into a period of elevated Atlantic SSTs—meteorologists, climate scientists, and researchers at AIR and other modeling companies began to look more closely at Atlantic hurricane risk in an environment of warm SSTs. Fifteen named storms had formed in 2004 and a record-breaking 27 named storms had formed in 2005 (six of which took the names of Greek letters, after the 21 English alphabet letters used for naming storms were exhausted).

Historical data show that warm SSTs correlate with greater storm activity (Figure 1), as well as with a greater percentage of storms reaching hurricane strength. However, scientists do not agree why the North Atlantic has been warmer than the long-term average since 1995. Some scientists attribute warm SSTs to a warm phase of the Atlantic Multidecadal Oscillation (AMO), a naturally occurring climate signal with an irregular periodicity that spans decades. Other experts believe that SSTs are elevated primarily because of the accumulation of greenhouse gases in the atmosphere and that variability in SSTs is caused by episodic events, such as volcanic activity, sunspots, and the industrial release (and subsequent decay) of aerosol sulfates.

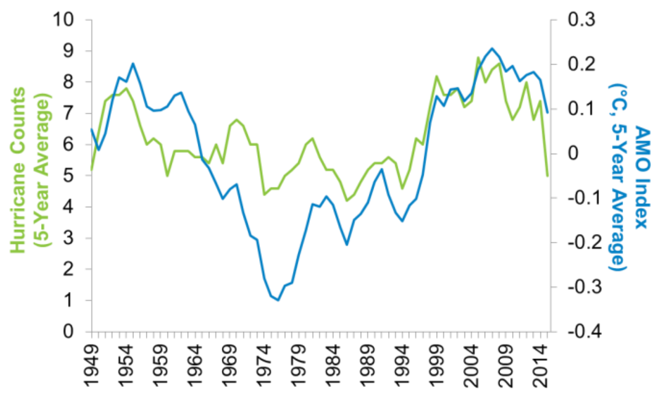

Figure 1. AMO correlation to Atlantic hurricane activity, 1949–2015. (Data Source: National Hurricane Center)

Regardless of what was making the ocean warmer, insurance and reinsurance companies, as well as regulators, had expected catastrophe modelers to better anticipate losses from years like 2004 and 2005. Concerned that the Atlantic Basin had entered a period of increased hurricane activity, there was pressure for modelers to forecast risk on a near-term horizon.

THE BEGINNING OF NEAR-TERM FORECASTING

In 2006, all three major catastrophe model vendors began to offer models that purported to capture the impact of warmer-than-average SSTs on the next five years of hurricane activity. The new forecast models were a radical departure from the established approach of using long-term historical storm data. The departure was a philosophical one as well. After all, the promise of catastrophe models had been that by taking the long-term view, insurers and reinsurers would *not* be caught by surprise, as they were by Hurricane Hugo in 1989 and Andrew in 1992, both of which came at the end of a period of below-normal tropical cyclone activity.

Nevertheless, the pressure to respond was palpable. To develop AIR's near-term catalog, AIR scientists collaborated with outside researchers to apply statistical modeling techniques to forecast SSTs for a five-year window. Yet even in 2006, AIR recognized the significant uncertainty in using forecasts of SSTs and other climate signals to forecast hurricane activity even for a single upcoming season (see Figure 2), let alone on a five-year horizon.

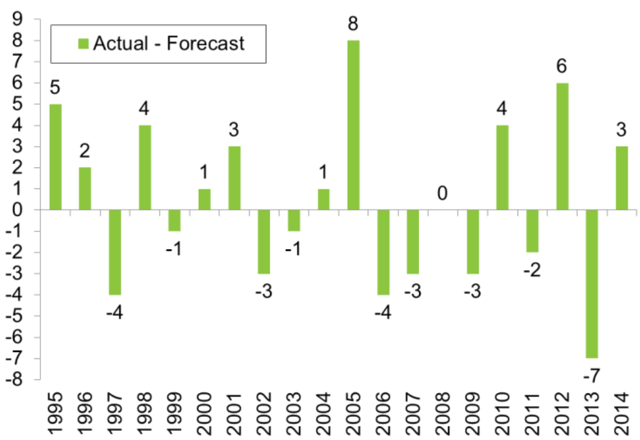

Figure 2. Difference between number of observed storms and NOAA forecast storms, 1995–2014. (Data Source: NOAA)

Not only was there limited skill in forecasting SSTs, but translating what elevated SSTs meant for landfall risk was mired in uncertainty. The statistical models developed by AIR suggested a correlation between SSTs and hurricane landfalls, but not a strong one and certainly not a correlation suitable for projecting regional insured losses. For the 2006 hurricane season, AIR told clients that the standard catalog was the most credible view.

"…**the standard model** based on over 100 years of historical data and over 20 years of research and development is still the most credible model to use given the uncertainty arising from the sparse data available for projecting the next five years."

–*Understanding Climatological Influences on Hurricane Activity: The AIR Near-Term Sensitivity Catalog*

Other modelers implemented their own unique methodologies to develop near-term catalogs in 2006, including one based on "expert elicitation," which involved asking a select set of climate scientists for their forecasts of hurricane activity over the next five years. Unlike AIR, other modelers were adamant that their near-term catalogs—which projected a 35%–40% increase in the frequency of landfalling hurricanes over the long-term average, with a similar increase in insured losses—were preferred over the long-term model.

The 2006 season saw no U.S. hurricane landfalls or losses—the first such season since 2001. While this offered no definitive proof that the first generation of near-term models were significantly overestimating the risk, AIR—unique among major modeling companies—moved on from attempting to forecast hurricane activity.

THE FUNDAMENTAL FALLACY

The fundamental problem with near-term forecasting is two-fold: not only is climate forecasting in itself highly uncertain, but the link between these climate factors and what ultimately concerns risk managers—hurricane landfall in highly exposed locales—is tenuous at best.

Greater storm activity with warm SSTs may be a given, but not necessarily an increased frequency of major hurricanes or a higher landfall rate of damaging storms. In fact, Atlantic SST anomalies **have been found** to account for less than 1% of the variability in U.S. hurricane landfalls. Instead, mid-level steering currents—which are highly variable and unpredictable beyond a few days—are responsible for some 80% of the variation in storm tracks.

Furthermore, there is some **evidence** that when SSTs are anomalously warm, the region of storm genesis shifts to the east in the tropical Atlantic, and that such storms are more likely to curve northward before reaching the U.S. coastline. In addition, while storm genesis in warm SST years may increase in the Gulf of Mexico, there is little time for them to intensify to hurricane strength before landfall; the Gulf Coast therefore may experience more frequent landfalls at tropical storm strength but little increase in hurricane landfalls. In short, warm SSTs could actually result in a lower *proportion* of hurricanes making landfall in the United States, as compared to the long-term average.

Ongoing climatological research tells us that although the approaches implemented in 2006 were informative, the uncertainty of the data used for forecasts was (and is) too great for near-term forecasting models to be of real value, regardless of forecasting methodology. However, while the expert elicitation approach has been broadly abandoned, other modeling companies continue to use SST forecasts to inform their views of hurricane risk.

A STABLE, CLIMATE-CONDITIONED CATALOG

In 2007, AIR abandoned near-term forecasting and introduced the warm sea surface temperature (WSST) stochastic catalog to complement the standard catalog. (Both have been offered in the ensuing years.) Like the standard catalog, the WSST catalog is a long-term view of risk, but conditioned on data from the seasons since 1900 when the Atlantic Ocean has been warmer than average.

The catalog does not attempt to forecast either SSTs or hurricane activity for an upcoming season or seasons. Rather, it implicitly captures the myriad of complex interactions and shifting ocean and atmospheric patterns that have manifested under warm conditions to allow probabilistic estimates of landfall risk for a typical warm Atlantic season. Offering two long-term catalogs promotes a multimodel, or ensemble, approach to catastrophe risk management by allowing users to assess the sensitivity of their portfolios to a warm ocean climate.

MODEL PERFORMANCE

Beyond the academic discussion of alternative catalogs, the real test is how well they've performed in light of actual hurricane experience. While 10 years are not sufficient to draw any absolute conclusions, it is clear that the dramatic increase in hurricane landfalls and losses called for in the near-term models released in 2006 has not materialized. As shown in the table below, in the first five-year forecast period from 2006–2010, four hurricanes made landfall in the United States, three of which produced insured losses of at least USD 25 million according to Property Claim Services® (PCS®), for a total loss of almost USD 18 billion when trended to today's exposures and values. Since 2010, three more hurricanes have made landfall in the United States, for an additional trended insured loss of about USD 25 billion.

Year	Number of U.S. Landfalling Hurricanes	PCS Insured Loss, Trended to Current Values and Exposures (USD Billions)
2006	0	0
2007	1*	0
2008	3	17.7
2009	0	0
2010	0	0
Average 2006–2010	*0.8*	*3.5*
2011	1	4.5
2012	2**	20.2
2013	0	0
2014	1*	0
Average 2006–2014	*0.89*	*4.7*
Long-Term Modeled Average, AIR Standard Catalog	**1.7**	**13.7**

*Humberto in 2007 and Arthur in 2014 made landfall at hurricane strength, but did not meet PCS's loss threshold for a catastrophe event.

**Includes Sandy, which was categorized as a post-tropical cyclone when it made landfall in New Jersey.

The reality is that U.S. hurricane losses since 2005 have been much lower than the near-term models have called for, even with some models revised downward in more recent years given their poor performance after the first five-year period and the abandonment of the expert elicitation approach. In fact, hurricane activity is lower than even the long-term annual average of 1.7 landfalling events and losses are far short of the USD 13.7 billion in modeled average annual insured loss based on AIR's standard catalog. While modeling companies have not used these past few years of experience as evidence that we are currently in a low loss regime (and rightly so), these numbers do suggest that the rush to produce an elevated near-term view of risk after the 2004 and 2005 seasons was an overreaction—ironically, a reaction that catastrophe models were meant to avoid.

Since 2005 and as of publication, no hurricane has made landfall in Florida, and no major hurricane (Category 3 or higher) has made landfall anywhere in the United States (the last one, on both counts, was Hurricane Wilma in 2005). Of course, storms that do not make landfall as major hurricanes can still cause extensive damage, as demonstrated by Ike in 2008 and Sandy in 2012.

Figure 3 shows the observed cumulative count of storms producing AIR modeled losses greater than USD 25 million since 1995—the beginning of the current warm ocean period—as well the cumulative frequencies of these storms implemented in the AIR standard and WSST stochastic catalogs. The actual storm count has tracked near or between the standard and WSST views, dipping below the standard view some years and rising above the WSST view in others. The WSST view of risk is about 10% higher in hurricane counts nationwide than the standard view, a proportion that varies by region. AIR's measured approach to the uncertainties of warm SSTs has delivered scientifically defensible and consistently high-performing results.

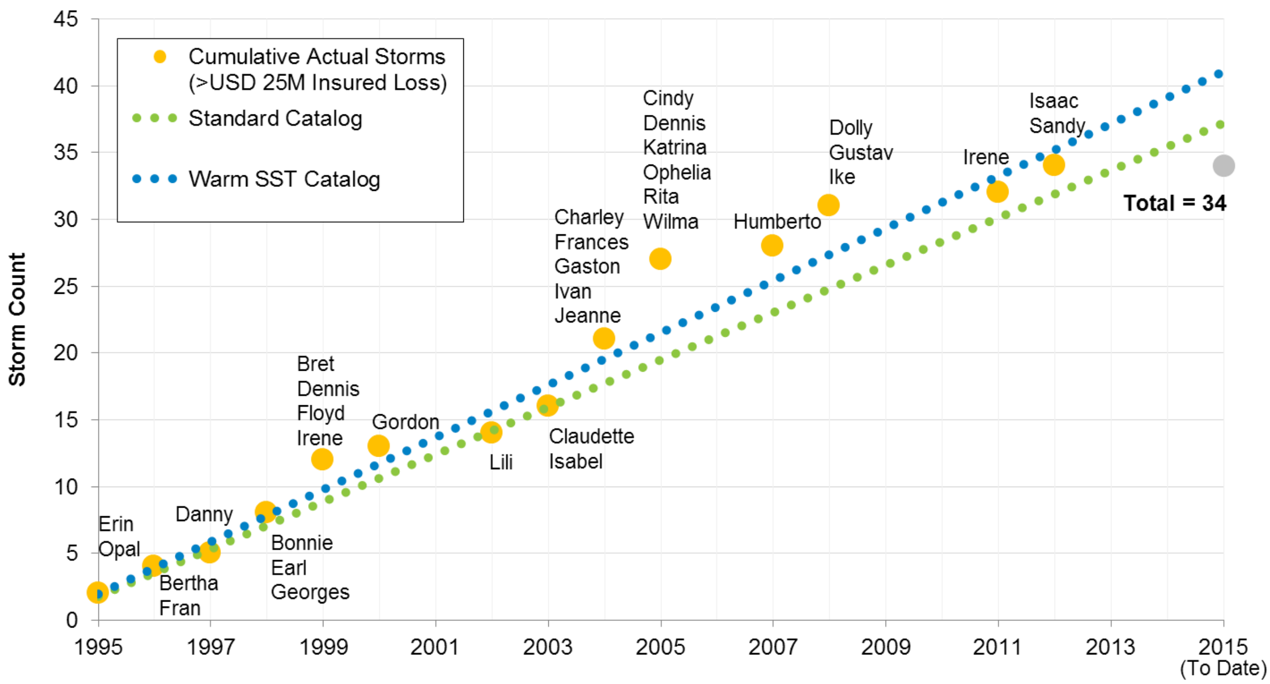

Figure 3. Observed cumulative count of loss-causing storms (>USD 25 million modeled insured loss) from 1995 to the present, shown with the cumulative frequency of these storms implemented in AIR's standard and WSST catalogs. Note that both landfalling and bypassing storms are included in this analysis, and modeled historical losses are based on today's exposures. (Source: AIR)

CONCLUSION

There is no clear consensus as to whether the current regime of anomalously warm SSTs is a manifestation of climate change or part of a naturally occurring cycle. Scientists do widely agree that anthropogenic warming is occurring, and the latest projections show that it will likely result in fewer (but more intense) hurricanes globally. However, there is no concrete evidence that climate change has already influenced Atlantic hurricane activity, or that near-term activity should be expected to significantly deviate from what has been observed in the past. High year-to-year variability is expected, and the fact that two very high loss years occurred in succession—2004 and 2005—is of interest from a statistical point of view, but not indicative of a fundamental shift in hurricane climatology.

Significant differences exist among catastrophe modeling companies, as well as among their respective models. Disagreement about the validity of using near-term weather forecasting is one such difference, as are disagreements over the correlation of warm SSTs and hurricane development, landfall, and loss estimates.

Ultimately model users must understand and evaluate the different approaches to truly "own their risk." Real-world conditions are complex and rife with uncertainty. Accurate forecasts—even for next week's weather—can be elusive, let alone forecasts five years out. Even perfectly accurate SST forecasts would not make landfall risk more predictable given the current state of knowledge.

While the elevated risk of hurricane landfalls that had been expected has not materialized, we should be equally cautious about making predictions of lower-than-average activity because the skill in such predictions is very limited, particularly when it comes to assessing the risk along various parts of the U.S. coastline. AIR will continue to resist the temptation to issue near-term, or even medium-term, predictions when the science and data are not there to support them. Offering a standard view and alternative WSST catalog has enabled insurance and reinsurance companies to assess the sensitivity of their portfolios to a warm ocean climate and decide how best to use the information to manage their risk.

ABOUT AIR WORLDWIDE

AIR Worldwide (AIR) is the scientific leader and most respected provider of risk modeling software and consulting services. AIR founded the catastrophe modeling industry in 1987 and today models the risk from natural catastrophes and terrorism in more than 90 countries. More than 400 insurance, reinsurance, financial, corporate, and government clients rely on AIR software and services for catastrophe risk management, insurance-linked securities, detailed site-specific wind and seismic engineering analyses, and agricultural risk management. AIR, a **Verisk Analytics** (Nasdaq:VRSK) business, is headquartered in Boston with additional offices in North America, Europe, and Asia.