Issue Brief: Weathering Hurricane Variability in a Warm Atlantic

AIR

Executive Summary

After the catalytic 2004 and 2005 hurricane seasons in the United States, the insurance industry wondered if a "new normal" was establishing itself in the Atlantic basin. In 2006, risk modelers began offering alternative views of risk that purported to capture elevated risk in seasons with warm ocean temperatures, including methods based on forward-looking projections, or forecasts, of sea surface temperatures over the near term.

AIR quickly abandoned early efforts to use sea surface temperature (SST) forecasts to project hurricane activity and insured losses, realizing that the scientific basis for such an approach was precarious at best. Not only is there very limited skill in predicting SSTs beyond a few months, but there is also very high uncertainty in translating SSTs in the Atlantic basin to the risk of landfalling hurricanes along the U.S. coast. Instead, AIR began offering a climate-conditioned catalog as an alternative view of risk, one that is stable, transparent, and scientifically defensible. Other modelers forged ahead with SST forecasting, resulting in projected losses that were sometimes up to 40% higher than the long-term average.

In the decade that followed, actual hurricane losses were lower than the long-term average, and in fact some even used the term "hurricane drought" to describe the absence of U.S. landfalls at major hurricane strength. That drought was finally broken by the catastrophic 2017 hurricane season.

Not surprisingly, the track record for near-term (also called medium-term) *forecasting* of hurricane risk has been poor. This was underscored in 2017 when, after one modeling company lowered their near-term landfall rates and losses below the long-term rate, we saw in excess of USD 60 billion in insured losses from hurricanes Harvey, Irma, Maria, and Nate.

The past 12 years have reaffirmed that high variability in year-to-year hurricane losses should be expected. Any promise of superior results using near-term forecasting is not supported by science, and the volatility it introduces is a disservice to model users. Indeed, the promise of catastrophe models was to eliminate the volatility in pricing, capital management, and risk transfer that is the inevitable outcome of recency bias—reliance on the recent past to estimate what the future holds. Short-term "trends"—such as consecutive high loss years of 2004 and 2005 or the run of zero-loss years from 2013 to 2015—are more likely to be a manifestation of natural variability rather than a change in hurricane climatology. Catastrophe models were created with the long view in mind, to help companies weather the short-term ups and downs.

Introduction to Alternative Views of Risk

For several decades, researchers have understood that there is a correlation between sea surface temperatures (SSTs) in the Atlantic Ocean and basinwide hurricane activity. Because tropical cyclones derive their energy from warm ocean water, increased heat content provides more fuel for both the formation of storms and their intensification.

Some believe that SSTs oscillate between extended warm and cool periods according to an ocean circulation pattern called the Atlantic Multidecadal Oscillation (AMO, see Figure 1). 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 sulfate aerosols. Indeed, the ambivalence around the cause of the signature illustrated in Figure 1 has led some scientists to prefer the term Atlantic Multidecadal Variability, or AMV.

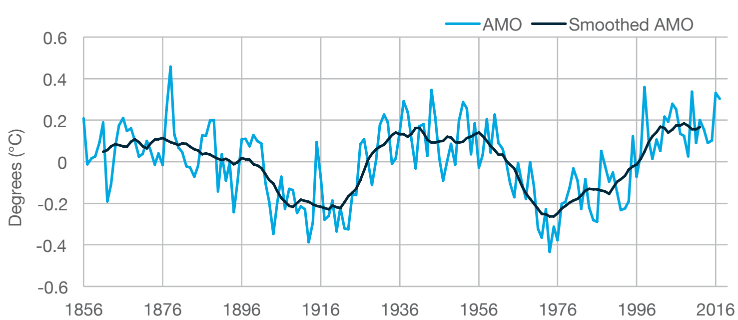

Figure 1. Annual average and smoothed average of the Atlantic Multidecadal Oscillation (Data Source: NOAA Earth System Research Laboratory)

Regardless of the underlying mechanism, during the current warm period, which is generally cited as beginning in 1995, an average of 15 named storms have formed per season, compared to a long-term (1950–2017) average of about 11. After tremendous losses from consecutive hurricane seasons in 2004 and 2005—seasons that saw the likes of Charley, Jeanne, Katrina, and Wilma—risk modelers, including AIR Worldwide, created alternative catalogs to reflect the elevated risk during seasons with warm SSTs.

In 2006, all three major catastrophe model vendors at the time began to offer "near-term" catalogs 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. AIR scientists applied statistical modeling techniques to forecast SSTs for a five-year window. Yet even in 2006, AIR recognized the significant uncertainty in using SST forecasts and other climate signals to forecast hurricane activity for a *single* upcoming season, let alone on a five-year horizon.

Not only was there limited skill in forecasting SSTs, but also the influence of basinwide oceanic warmth on tropical cyclone *landfalls* is small relative to the overall variability in landfall numbers across years of any temperature. 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, and in 2007, abandoned near-term forecasting entirely, choosing instead to offer an alternative long-term view of risk conditioned on historical years with elevated SSTs.

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 were preferred over the long-term model.

The Track Record After One Decade

It has been more than a decade since alternative views of risk were first introduced, and it is clear that the dramatic increase in hurricane landfalls and losses called for in the near-term models released in 2006 did not materialize (see Table 1). In fact, during this period, the average annual count of *loss-causing* storms and average annual insured loss came in significantly below the long-term average of 1.7 landfalling events and USD 12.5 billion in modeled average annual insured loss based on AIR's standard catalog. U.S. hurricane losses during this period were much lower than the near-term models called for, even with some models revised downward in the later years given their poor performance after the first five-year period.

Year	Storm Count	Total Estimated Loss (USD Millions)	Trended Loss (USD Millions)
2006	-	-	-
2007	1*	-	-
2008	3	15,175	22,222
2009	-	-	-
2010	-	-	-
2011	1	4,300	5,441
2012	2**	19,680	23,944
2013	-	-	-
2014	1*	-	-
2015	-	-	-
2016	2	2,861	2,975
2006 - 2016 Average	0.9		4,962
Long-Term Modeled Average, AIR Standard Catalog	1.7		12,486

* 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.

2016 and Beyond

In 2015, several researchers speculated that the AMO was shifting (or had shifted) into the next cool phase. Klotzbach, Gray, and Fogarty from Colorado State University published a paper (summarized here) hypothesizing that starting in 2013, localized drops in temperature in the North Atlantic near Greenland, combined with higher-than-normal sea-level pressure in the tropical Atlantic, may have signaled a phase shift in the AMO that suppressed hurricane activity in the 2013–2015 seasons. McCarthy et al. pointed to changes in ocean circulation (which drives ocean heat content and is believed to have a major role in the AMO) as a sign that the AMO may be shifting to a negative phase.

After three years of zero hurricane losses in the U.S. (by PCS's catastrophe threshold) between 2013 and 2015, one near-term modeler embraced the new research to again adjust its catalogs, this time in advance of the 2017 season. Rates of hurricane activity and modeled losses were brought below the long-term average, based in part on the possible "missed signal shift" in the AMO that Klotzbach et al. believed to have occurred in 2013. For the five-year period between 2017 and 2021, the model calculated a landfall frequency 1% below the long-term rate for all hurricanes and 6% below the long-term rate for major hurricanes, resulting in average annual losses that were 16% lower on a national basis compared to the previous five-year forecast.

Even without the hindsight of knowing what ultimately transpired during the Atlantic hurricane season in 2017, the decision to alter modeled losses once again was highly questionable. Despite occasional dips, basinwide SSTs have remained warm in the past two years, and in 2017 were even higher than they were during the 2004 and 2005 seasons. SSTs are expected to remain elevated in 2018. Indeed, Klotzbach and Bell's first qualitative discussion of the 2018 season acknowledges that the continued positive AMO "clouds the AMO phase issue considerably."

The point is further driven home by the devastating 2017 season, which saw four landfalling hurricanes in the United States for a cumulative insured loss exceeding USD 60 billion. While a single season cannot be used to judge a model's performance, 2017 further demonstrates the futility of near-term forecasting given the current state of the science.

The Fundamental Fallacy

The fundamental problem with near-term forecasting is twofold. First: there are well-understood theoretical bounds on climate predictability stemming from the nonlinear and chaotic nature of the climate system. Second, the link between any climatic forces and what ultimately concerns risk managers—hurricane landfalls in highly exposed locales—has a low signal-to-noise ratio. In other words, the predictable influence of various climatic phases on U.S. hurricane landfalls is overwhelmed by the much larger underlying randomness of these catastrophes.

While warm SSTs may increase the odds of greater basinwide activity substantially, the influence on landfall activity is much less clear-cut. In fact, AIR has found that Atlantic SST anomalies 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. Another signal that forecasters watch closely is the index measuring the phase of the coupled phenomena El Niño and the Southern Oscillation (ENSO), which can be even more challenging to predict than SSTs. During the El Niño phase of ENSO, wind shear tends to be higher over the Atlantic, inhibiting storm development.

Furthermore, there is some evidence that when SSTs are anomalously warm, the region of storm genesis shifts to the east in the tropical Atlantic, which means that 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.

Even when climate conditions create favorable (or unfavorable) environments for tropical cyclone formation and intensification, hurricane seasons can unfold in ways that are contrary to expectations. It's easy to find counterintuitive examples from the historical record: Camille '69 and Andrew '92 both occurred when the AMO was negative; Charley, Frances, Ivan, and Jeanne all occurred in 2004 during a weak El Niño event. And the large amount of inherent randomness also reconciles the apparent paradox between the positive SSTs we've been experiencing for the last two-plus decades and the 10-year Florida hurricane landfall "drought" that only came to an end in 2016.

Stable Views of Risk

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.

This approach is not based on attempts to forecast either SSTs or hurricane activity for an upcoming season or seasons. Rather, the catalog implicitly captures variability in ocean and atmospheric patterns that have occurred under warm ocean conditions to allow probabilistic estimates of landfall risk for a typical warm Atlantic season. Offering two stochastic catalogs, both long-term, allows users to assess the sensitivity of their portfolios to a warm ocean climate.

Figure 2 shows the observed cumulative count of storms producing AIR modeled losses in the U.S. 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

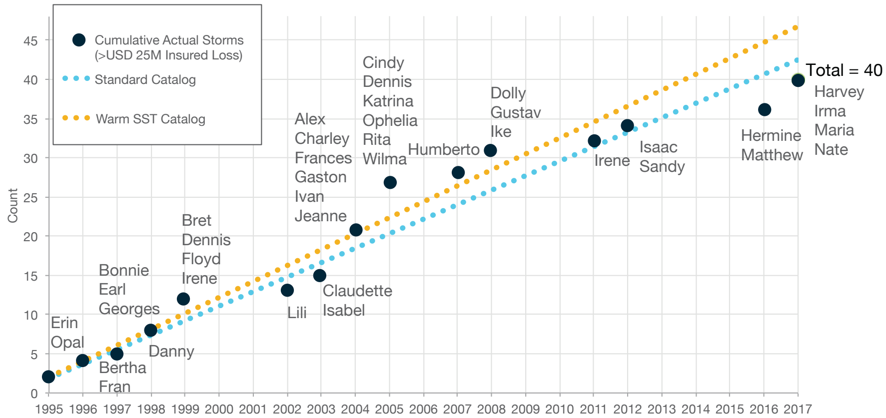

Figure 2. Observed cumulative count of loss-causing storms (>USD 25 million insured loss) from 1995 to the present, shown with the cumulative frequency of these storms implemented in AIR's standard and WSST catalogs. Note that both landfalling and bypassing storms are included in this analysis, and modeled historical losses are based on today's exposures. (Source: AIR)

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.

Catastrophe models were introduced to better prepare the (re)insurance industry not only for extreme losses, but also for high year-over-year variability in losses. Instability in the models hurts (re) insurers by making their solvency requirements a moving target, making reinsurance costs fluctuate unnecessarily, forcing frequent changes in rates that must be explained to regulators and rating agencies, and causing consumers to distrust their insurer. A stable, long-term view of risk that is only updated when there are scientifically credible advances is a basic standard that catastrophe modelers should be expected to uphold.

Closing Thoughts

At AIR, we have learned through our ongoing climatological research that although the approaches implemented in 2006 were informative, the uncertainty was (and is) too great for near-term forecasting models to be of real value.

There is no clear consensus as to whether the current regime of anomalously warm SSTs is a manifestation of climate change, part of a naturally occurring cycle, or a combination of both. Scientists do widely agree that anthropogenic warming is occurring, and the scientific community is moving toward a consensus that, for a variety of reasons, warming is likely to produce fewer but more intense hurricanes globally, more intense tropical cyclone–induced rainfall, and continued rise in mean sea level (see our white paper for a more in-depth discussion). However, there is no clear consensus as to whether 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 should be expected and may indeed increase as the climate warms. Still, while streaks of active and inactive landfall years are statistically interesting, neither consecutive high loss years (such as 2004 and 2005) nor runs of zero-loss years (2013–2015) can be construed as a fundamental shift in hurricane climatology with any degree of statistical robustness. The decision by near-term modelers to dramatically alter modeled hurricane activity and losses in either case is unjustified and, in our opinion, a disservice. After all, the promise of catastrophe modeling is to offer a stable, long-term view of risk to help companies weather the short-term ups and downs.

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.

AIR will continue to resist the temptation to issue near-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) provides risk modeling solutions that make individuals, businesses, and society more resilient to extreme events. In 1987, AIR Worldwide founded the catastrophe modeling industry and today models the risk from natural catastrophes, terrorism, pandemics, casualty catastrophes, and cyber incidents, globally. Insurance, reinsurance, financial, corporate, and government clients rely on AIR's advanced science, software, and consulting services for catastrophe risk management, insurance-linked securities, site-specific engineering analyses, and agricultural risk management. AIR Worldwide, a Verisk (Nasdaq:VRSK) business, is headquartered in Boston with additional offices in North America, Europe, and Asia. For more information, please visit www.air-worldwide.com.

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