Assured Industry Study

May, 2015

Our Annual Update of Hurricane Statistics

A light year predicted, we add 100 years of historical context

One-hundred years may not be a long period on a meteorological scale, and we don't suggest that hurricane statistics presented in this Industry Study can supplant the valuable output of hurricane models. They can, however, supplement what insurance professionals have learned from hurricane models. In this, our second annual presentation of hurricane statistics, we use 100 years of hurricane statistics to reveal:

- The number of annual hurricanes is steadily rising, offset by the declining percentage striking the U.S. Consequently, the number of hurricanes making land fall has been reasonably constant over successive ten-year rolling periods.

- Category 1 hurricanes are the most frequent, but Categories 2-4 storms are equally probable based on data from the past 100 years. The percentage of annual storms reaching intense status (categories 3-5) is stable over time, but cyclical over shorter periods.

- The low hurricane forecasts for 2015 are because of the expected presence of El Niño. Forecasts for 3-5 hurricanes with one intense storm might be compared to 5-6 hurricanes and 2-3 intense storms in a 'normal' year. We also show hurricane probabilities by state (Figure 15).

- We delve into data on Florida. 44% of all land-striking hurricanes have hit that state with the west coast bearing the majority of the impacts. Interestingly, the intensity of storms making land fall in Florida is about the same as those impacting other states.

- The Assured Research team of dart-throwers takes on the experts. Our predictions are inside.

About Assured Research

Assured Research is a research and advisory firm dedicated to the property/casualty insurance industry.

Contact us to learn more; please visit www.assuredresearch.com

June 1 is the official start of the Atlantic hurricane season and even though the potential for major catastrophes usually doesn't begin until the mid-August we always find this a good time of the year to review historical hurricane statistics and to provide some thoughts about the upcoming season.

In this report, after we present the updated historical data, we focus on three specific topics:

- The expected presence of El Niño and why 2015 is forecast to be a light hurricane year,
- A review of the historical data to show how lucky Florida has been not to have been hit by a hurricane for the last nine years, and
- A discussion of the land strike probabilities since that is more important from an insurance industry perspective than the number of hurricanes.

The impact on reinsurance pricing.

We doubt many readers will remember what we said last year about the potential impact of the storm season on reinsurance pricing. Still, in the interest of transparency we'll acknowledge that the following thoughts are exactly the same as we shared last year. The reason – our thinking has not changed!

Conventional logic suggests:

- *If there are no significant land-falling hurricanes, prices probably continue to weaken and traditional (re)insurers accelerate their return of capital to shareholders.*
    - *We'll add that talk of catastrophe reinsurance pricing nearing technical levels seems credible, so perhaps the rate of price declines will slow irrespective of the activity this storm season.*
- *If it is a moderate or even a bad season, but one where storms are deemed to be in line with modeled scenarios, convention might suggest that prices stabilize, or at least the pace of deceleration slows.*
- *If it is a bad season and one that reveals more flaws in the catastrophe models, in turn leading to hand-wringing over non-modeled risks – then maybe prices stabilize and turn (slightly) higher.*

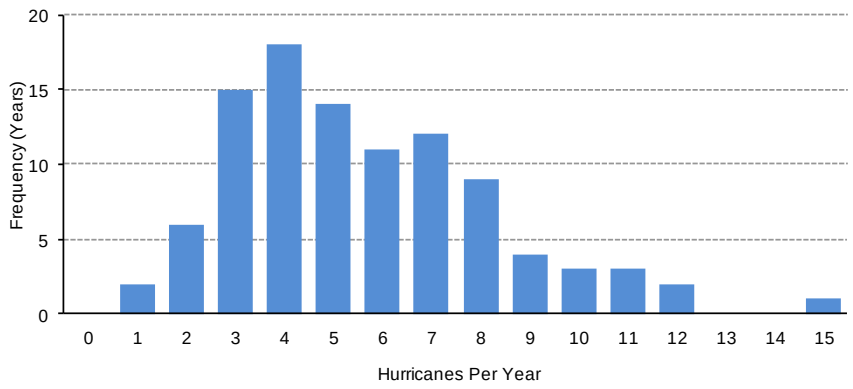
Yet, new capital continues to come into the business at such a pace that it is hard to see anything seriously turning the market around short of some event that is even above extreme tail-risk comprehension.

Statistical Round Up: Frequency

There have been 561 Atlantic hurricanes in the last 100 years. The most frequent number of storms has been four (18 years) and the range has been from one (1919 and 1925) to 15 (2005, of course). See Figure 1.

The trend in the number of hurricanes has generally been increasing, with recent stabilization, as shown in the 10-year average line in Figure 2

Figure 1 Annual Hurricane Frequency

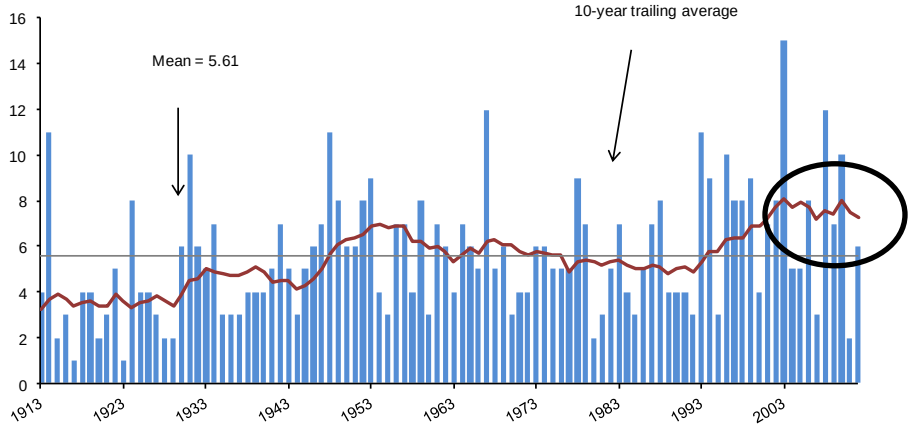


Every year in the past 100 has had at least one hurricane!

The range has been 1 to 15.

Source: Unisys Weather, Assured Research

Figure 2 Annual numbers of hurricanes



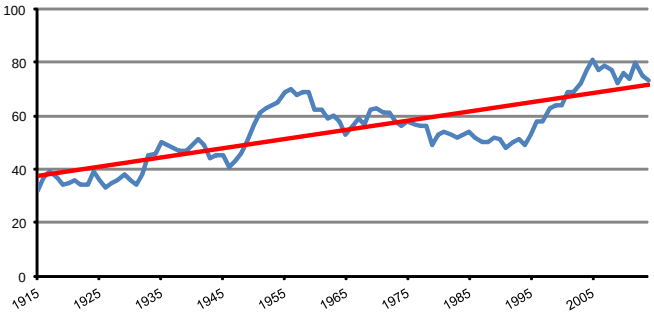
Recent stabilization, albeit at a level that is elevated from the period including the 1970s through early 1990s.

Source: Unisys Weather, Assured Research

Of the 561 hurricanes, 193 (34%) have struck the US mainland; of these, 73 have hit the Atlantic Coast and 120 the Gulf of Mexico. The percentage of land strikes has been trending down but because the number of hurricanes has been increasing the number of land strikes has been fairly constant. This can be seen in Figure 3.

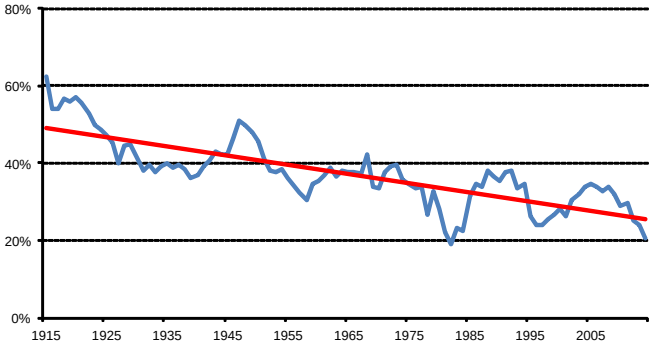
Figure 3 Hurricane land strike trends

Number of US hurricanes 10-year total



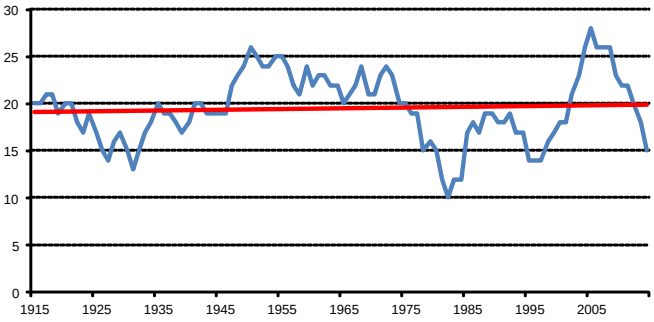
The annual number of hurricanes has risen over the past 100 years…

% of US Land Strikes 10-year Average



…but land strikes are down. Why? Are the incremental hurricanes forming in new locations where they are less likely to make US landfall? This may be an area ripe for research.

Number of US land strikes 10-year total



The number of land strikes has remained fairly constant over the past 100 years.

Source: Unisys Weather, Assured Research

Statistical Round Up: Intensity

When looking at hurricanes by category, 238, or 42% of the hurricanes have been classified as "intense" which is Category 3 and above on the 1-5 Saffir-Simpson scale. See Figure 4. There has no discernible pattern in the percentage of intense storms as the 10-year average shows in Figure 5.

Figure 4 Hurricane frequencies by category

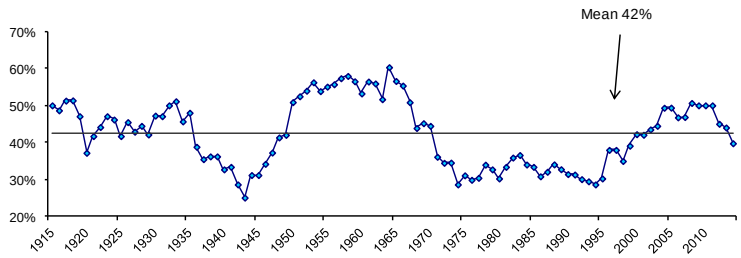
Ranking Criteria: Saffir-Simpson Scale

	Pressure	Winds	Last 100 years	
Category	**(MB)**	**(MPH)**	**Number**	**%**
Hurricane 1	>980	74-95	204	36%
Hurricane 2	965-980	96-110	119	21%
Intense				
Hurricane 3	945-965	111-130	114	20%
Hurricane 4	920-945	131-155	94	17%
Hurricane 5	<920	>155	30	5%
Total			561	100%

When a hurricane forms, category 2-4 storms are equally probable, based on data from the past 100 years. Category 1 remains the most likely, and 5 is still a rare occurrence – thankfully.

Source: Unisys Weather, Assured Research

Figure 5 Intense hurricanes (based on 10-year averages)



The annual percentage of hurricanes reaching "intense" status is cyclical, with no underlying trend over the past 100 years.

Source: Unisys Weather, Assured Research

Statistical Round Up: Timing

Beware August-September (and occasionally October)

While June 1 is the official start of the Atlantic hurricane season, historically June and July have not been particularly troublesome months for hurricanes but the real action (and therefore the risk) typically begins around the middle of August and continues into September and October.

To document this point, **Figure 6 shows that only 65 of the hurricanes in the last hundred years (12%) occurred in June and July and that the average intensity on the storms was much less than those that occurred later in the season**. For example, the table shows that the average intensity for the early-season storms was 1.7 compared to 2.5 for those hurricanes occurring in August and September. As further proof regarding the lack of intensity for early season storms, **only 25% of the hurricanes in June and July were in the intense category compared to 50% percent intense storms in August and September**.

Figures 7 and 8 show the same data as Figure 6, but in graph form.

Figure 6 Hurricanes by date of formation

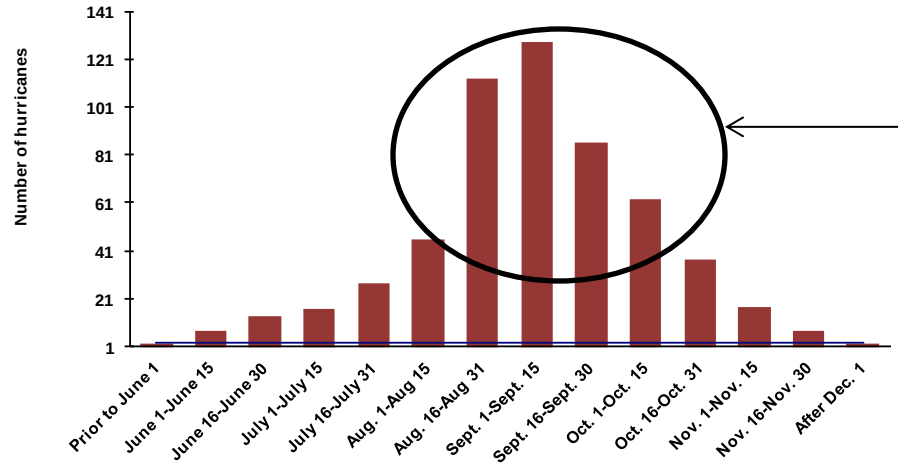
Dates	No of Hurricanes	Category 1	2	3	4	5	Intense
Prior to June 1	2	1	0	1	0	0	1
June 1-June 15	7	5	1	1	0	0	1
June 16-June 30	13	7	3	2	1	0	3
July 1-July 15	16	10	2	2	2	0	4
July 16-July 31	27	17	3	5	1	1	7
Aug. 1-Aug 15	45	16	10	8	8	3	19
Aug. 16-Aug 31	112	25	26	29	23	9	61
Sept. 1-Sept. 15	128	36	22	34	24	12	70
Sept. 16-Sept. 30	86	29	20	16	19	2	37
Oct. 1-Oct. 15	62	23	16	13	9	1	23
Oct. 16-Oct. 31	37	18	10	2	5	2	9
Nov. 1-Nov. 15	17	9	5	1	2	0	3
Nov. 16-Nov. 30	7	6	1	0	0	0	0
After Dec. 1	2	2	0	0	0	0	0
Total	**561**	**204**	**119**	**114**	**94**	**30**	**238**

Not updated

	Hurricanes #	% of total	Average Intensity	Category 1	2	3	4	5	Intense	% Intense
Prior July 31	65	12%	1.7	40	9	11	4	1	16	25%
August-Sept	371	66%	2.5	106	78	87	74	26	187	50%
After Sept	125	22%	2.1	58	32	16	16	3	35	28%
Total	561	100%	2.3	204	119	114	94	30	238	42%

Source: Unisys Weather, Assured Research

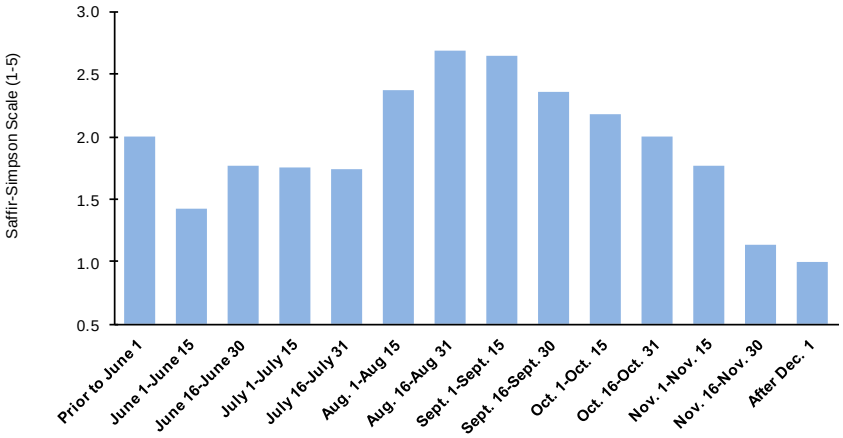
Figure 7 Number of hurricanes by date of formation



The greatest threat arrives in mid-August and stays through mid-October…

Source: Unisys Weather, Assured Research

Figure 8 Hurricane intensity by date of formation



…both because hurricane formation is more probable during those months and because storms are more intense.

Source: Unisys Weather, Assured Research

Here comes El Niño

For this year, every prediction we've seen is for a light hurricane year. (See Figure 9) As an example the April forecast from Colorado State calls for only three hurricanes, while the National Oceanic and Atmospheric Administration (NOAA) has a less precise 3-to-6 storm forecast. Most other forecasts are looking for six, or less. The CSU forecast, in particular, usually receives considerable attention since it comes out in early April in the midst of the June/July renewal negotiations, and thus, has the potential to influence reinsurance buying and pricing decisions.

Figure 9 2015 hurricane forecasts

	Hurricanes	
	Total	**Intense**
Colorado State	3	1
Weather Channel	5	1
AccuWeather	4	1
Tropical Storm Risk	6	2
WeatherBELL Analytics	3 to 5	1 to 2
NOAA	3 to 6	0 to 2

Using our earlier data, the 100-year average would imply 5-6 hurricanes, of which 2-3 were intense.

The recent average would suggest 6-8 hurricanes of which 2-4 were intense.

Source: Specific forecasts, Assured Research

The chief reason for the low forecasts is the expected presence of El Niño later this year.

Without going into extreme detail, El Niño is a warming of water temperatures in the equatorial Pacific which influences weather patterns across the globe; more rain in some places, less in others, and warmer or cooler temperatures in various parts of the world. As an example of the unusual patterns, in El Niño years there is usually drought in Australia and more rain in South America and the Southern United States. Also, the jet stream changes and the trade winds which usually blow toward the West reverse and move eastward.

Typically, El Niño occurs every 3-7 years and lasts for about a year. If there is any generalization it is that no two are alike.

For this discussion**, the important point is that in El Niño years there have generally been fewer Atlantic hurricanes**. For example, NOAA classifies El Niño years into three categories, weak, moderate and strong. We combined that data together with annual hurricane statistics and as Figure 10 shows, in **the years when there have been moderate or strong El Niño's there have been fewer hurricanes compared to the years when there were weak or no El Niños**.

While there is never any guarantee that El Niño will occur, the odds seem high because in the last three weeks three of the meteorological groups that track weather patterns, the US Climate Prediction Center, the Australian Bureau of Meteorology and the Japan Meteorological Agency all raised their probability forecasts.

Figure 10 Number of hurricanes per El Nino years: 1951-2014

	# of years	Hurricanes	Average	Range High	Range Low
Weak or none	50	338	6.8	15	2
Moderate	9	41	4.6	8	3
Strong	5	15	3.0	4	2
Total	64	394	6.2		

Source: National Weather Service re El Nino, Unisys Weather re hurricane statistics, Assured Research calculations

Florida: How lucky can you get

Think about this:

Of the 193 hurricanes that have struck land in the last 100 years, 84 (44%) have hit Florida, which makes it the most storm-prone state in the US. And, hurricanes have hit the state in 54 of the last 100 years. But, now it's been nine years since a hurricane hit (Wilma 2005). That's the longest non-active stretch in the last 100 years.

Talk about lucky; the odds of a nine year non-activity period given the history is less than 1%

Considering all the attention paid to the evolution of the Florida insurance and reinsurance markets, as well as the capital flowing to the state, it seems useful to review the history of hurricanes there.

- As previously noted, there have been 561 Atlantic hurricanes in the last 100 years and 193 have struck the US mainland**. Florida has been the state with the most hurricane strikes, accounting for 84 of the 193, or 44% of all land strikes**. Of those, 31 have hit the state's East Coast and 53 the West Coast.

- Figure 11 shows the details of the land strikes by state. Texas has been the second-most heavily struck state while Louisiana and North Carolina rank third and fourth, respectively.

Figure 11 Hurricane land strikes by state

Atlantic Coast	Total	% Strikes	% Hurricanes
Florida (East Coast)	31	16%	6%
North Carolina	21	11%	4%
South Carolina	8	4%	1%
New York	6	3%	1%
Massachusetts	4	2%	1%
Georgia	1	1%	0%
New Jersey	1	1%	0%
Virginia	1	1%	0%
Total Atlantic Coast	**73**	**38%**	**13%**
Gulf Coast			
Florida (West Coast)	53	27%	9%
Texas	34	18%	6%
Louisiana	29	15%	5%
Mississippi	3	2%	1%
Alabama	1	1%	0%
Total Gulf Coast	**120**	**62%**	**21%**
Total US	**193**	**100%**	**34%**

Source: Unisys Weather, Assured Research

Florida is the state with the most hurricane strikes – 44% of all land strikes have hit the Sunshine state.

The west coast of Florida has borne the brunt of Florida land strikes. Just over 60% of Florida-striking hurricanes first impact the west coast.

- Hurricanes have struck Florida in 54 of the last 100 years. Figure 12 shows the frequency of the number of storms striking the state; the most in any year has been four and that has occurred three times.

Figure 12 Florida land strikes; number of storms per year

# of Strikes	Years
0	46
1	34
2	13
3	4
4	3
Total	100

Data from the past 100 years suggests there is about a 20% chance that Florida will experience more than one landfall. Are ILS-investors ready for that possibility?

Source: Unisys Weather, Assured Research

- **Nine years without a hurricane is the longest non-storm stretch in the last 100 years**. Previously, the longest non-active period was the five years from 1954 to 1958. During this nine year stretch there have been 10 US land strikes, six of which have hit the Gulf and four on the Atlantic side. Of the states, Texas, Louisiana, and North Carolina each have three.

- Considering that Florida has had 46 years out of 100 with no hurricanes, **the probability of going nine years with no storms is less than 1%**. And, if you think of Florida having zero land strikes

when there were 10 in the US from 2006-2014, the probability of that happening is also less than 1%

- Generally, **the intensity of storms that hit Florida has been about the same as those that strike other states**. As Figure 13 shows, 52% of the Florida hurricanes were in the intense category, the same percentage as for all US land strikes.

Figure 13 Florida hurricanes by intensity

Category	Strike US	% Strike US	Strike Florida	% Strike Florida
1	68	35%	33	39%
2	25	13%	7	8%
3	37	19%	17	20%
4	42	22%	18	21%
5	21	11%	9	11%
Total	193	100%	84	100%
% Intense		52%		52%

The intensity of storms that hit Florida has been about the same as those that strike other states.

Source: Unisys Weather, Assured Research

Historically, there have been 10 storms to hit Florida over the years which at one point in their lifecycle reached Category 5; although like most hurricanes, with few exceptions, they were not Category 5 when they struck land. Hurricane Andrew (1992) was the most intense to hit the state and it is the second-most intense to hit the US mainland, after Camille (1969) which struck Louisiana and Mississippi.

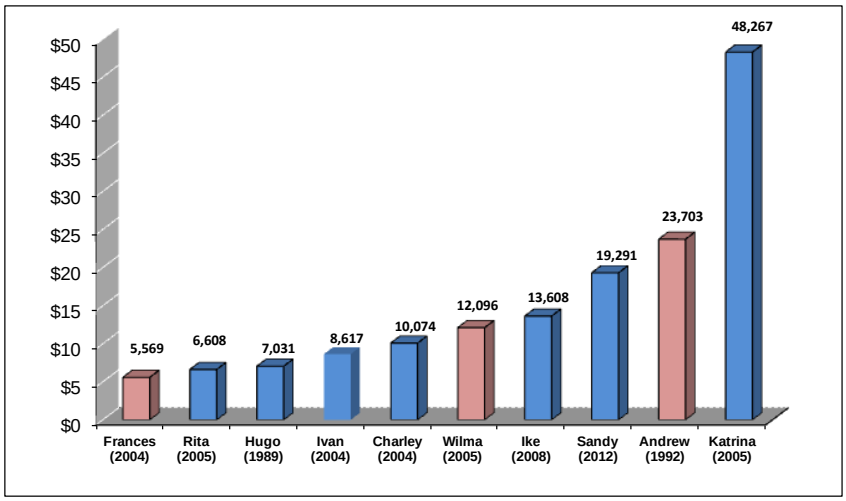
Andrew was the costliest hurricane to hit Florida. Based on Insurance Information Institute data we estimate that in 2015 dollars the cost of that storm would be $23.7 billion, although with a more developed coastline AIR Worldwide's latest estimate is that the same storm would result in $57 billion of damage.[1]

However, Andrew was not a direct hit on Miami Beach. Instead, it made landfall in Homestead which is about 30 miles south of Miami. By **comparison Hurricane #4 in 1926 (which has been labeled the "Great Miami Hurricane") struck closer to downtown hitting between Coral Gables and South Miami. Most observers who have tried to quantify the potential damage of that storm given today's development in Miami put the losses at around $125 billion.**

Figure 14 shows the 10 most costly US hurricane losses, with the Florida hurricanes shaded differently.

[1] AIR Worldwide, *Twenty Years After Andrew-How Far Have We Come?*, August 23, 2012

Figure 14 Ten most costly insured US hurricane losses



Source: Insurance Information Institute, Assured Research

It only takes one

It's all about landfall - not frequency

Even if the number of hurricanes could be forecast with accuracy, that is not necessarily the most critical issue for the industry. Instead, **the number of storms making landfall and their locations are far more important for the industry**, as events in 2011 and 2012 demonstrated. In 2011, there was only one hurricane that made US landfall (Irene) and in 2012 there were only two landfalls (Isaac and Sandy). Yet, because of the strike locations of Irene and Sandy, these were big storm loss years (and remember Sandy was only a tropical storm when it made landfall in New Jersey).

Because of the importance of the number of land strikes and the location of the storms, the Colorado State staff and others have been spending more time analyzing the patterns to try to project landfalls. To date the analyses are not seasoned enough to assess their accuracy, but they do offer some perspective.

Dr. Gray giving up active hurricane research.

Dr. William Gray of Colorado State University, who started researching hurricanes in 1984 and has been participating in the field for 31 years, has announced that he is giving up an active role in the forecasts to devote more of his time to researching climate change and global warming.

Dr. Gray has been a pioneer in the hurricane forecast field and all of us who do research on the insurance industry owe him a debt of thanks. As a bit of nostalgia I still remember reading his early reports when they were without a doubt the state of the art.

The CSU projections for 2015 compared to 2014 and the historic probabilities are in Figure 15, which shows the probability that at least one hurricane will strike each of the selected states. In all cases, the projection for this year is below both the2014 forecast and the historical probability.

For the US overall, they project a 57% probability that at least one hurricane will make landfall. In the last 100 years there has been at least one land strike in 88 years. (For the years that the CSU staff is using the historical probability is 84%).

Figure 15 Probability of at least one hurricane reaching land

State	Historic Probability	2015 Probability	2014 Probability	2015 versus Historic	2015 versus 2014
Florida	51%	21%	35%	-30%	-14%
Texas	33%	12%	21%	-21%	-10%
Louisiana	30%	12%	19%	-19%	-8%
North Carolina	28%	8%	18%	-21%	-11%
South Carolina	17%	4%	11%	-13%	-7%
Alabama	16%	3%	10%	-13%	-7%
Georgia	11%	1%	7%	-10%	-6%
Mississippi	11%	4%	6%	-6%	-2%
New York	8%	3%	5%	-4%	-1%
Connecticut	7%	2%	4%	-5%	-2%
Massachusetts	7%	2%	4%	-5%	-2%
Virginia	6%	1%	4%	-6%	-3%
Rhode Island	6%	3%	3%	-3%	-1%
Maine	4%	<1%	2%	-3%	-1%
Delaware	1%	<1%	1% <	0%	0%
Maryland	1%	<1%	1% <	0%	0%
New Hampshire	1%	<1%	1% <	0%	0%
New Jersey	1%	<1%	1% <	0%	0%
Entire US	**84%**	**57%**	**67%**	**-27%**	**-10%**
Gulf Coast	**60%**	**34%**	**42%**	**-26%**	**-8%**
Florida plus East Coast	**61%**	**35%**	**43%**	**-26%**	**-8%**

< equals less than 1%

Source: Colorado State University, Assured Research

When thinking about land strikes it is important to recognize that **there is very little correlation (R^2 =21%) between the number of land strikes and the number of hurricanes**. For example in 1985, the year with the most land strikes (six), there were only seven hurricanes overall. By contrast in 2010 there were 12 hurricanes and none struck land.

It's not easy to predict hurricanes

Being a predictor of hurricanes is a perilous occupation as more often than not the early (and even the late) season forecasts are off the mark.

For example, looking at the forecasts of the Colorado State team shows how difficult the forecasting task is. Figure 16 shows their 1996-2015 forecasts, and, as the table indicates, the correlations versus actual are quite low as even the late-August R_2 is still only 29%. That doesn't necessarily negate the value of early season forecasts because the research can set the tone for the season and describe conditions that exist that could influence the actual experience.

Figure 16 Colorado State historical projections

	December	April	June	August	Actual	Forecast
1996	5	7	6	7	**9**	2
1997	7	7	7	6	**3**	-4
1998	5	6	6	6	**10**	4
1999	9	9	9	9	**8**	-1
2000	7	7	8	7	**8**	1
2001	5	6	7	7	**9**	3
2002	8	7	6	4	**4**	-3
2003	8	8	8	8	**7**	-1
2004	7	8	8	7	**9**	1
2005	6	7	8	10	**15**	8
2006	9	9	9	7	**5**	-4
2007	7	9	9	8	**6**	-3
2008	7	8	8	9	**8**	0
2009	7	6	5	4	**3**	-3
2010	6-8	8	10	10	**12**	4
2011	9	9	9	9	**7**	-2
2012	(a)	4	5	6	**10**	6
2013	(a)	9	9	8	**2**	-7
2014	(a)	3	4	4	**6**	-3
2015	(a)	3				

Correlation Actual vs Forecast (R_2)

1.9%	0.8%	28.7%

Actual>forecast	8
Even	1
Actual<forecast	10
Total years	19

(a) The December forecast has been discontinued

Source: Colorado State, Assured Research

NOAA and CSU forecasts are generally similar

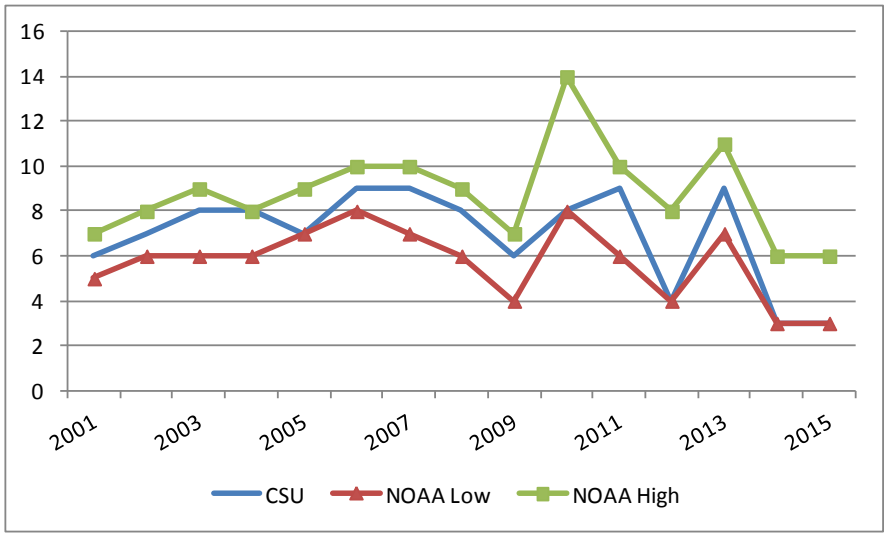
The National Oceanic and Atmospheric Administration (NOAA) through its National Hurricane Center (NHC) also makes forecasts although they project in ranges rather than single number forecasts**. For**

the most part, the projections from CSU and NOAA tend to be similar in direction. This is is to be expected since they are largely looking at the same data.

To demonstrate the similarity, Figure 17 shows the CSU April forecasts compared to the ranges projected by NOAA in their annual May forecast.

Comparing the projections to actual shows that the NOAA forecasts are similar to CSU; while the April CSU comparison to actual showed a 1.9% correlation to actual (per Figure 16 above) the NOAA mean correlation to actual was 3.4% further demonstrating that forecasting hurricanes is difficult.

Figure 17 Colorado State NOAA comparative projections



The CSU and NOAA forecasts generally are in the same direction

Source: CSU, NOAA, , Assured Research

The fearless Assured Research forecast

Many readers will recall the *Wall St. Journal's* long-running column that challenged the stock-picking prowess of professional investors against a handful of inexpertly thrown darts. We don't remember who won more frequently, but in the spirit of trying something equally inane we wanted to add our own projection to the mix. **We'll call for six hurricanes this year of which we forecast two will fall into the intense category**.

Did we use much scientific data in this forecast (or even real darts)? No. What we did is program the historical odds and then we used a random number generator to run numerous tests and we then took the mean of the results. As you would expect from this approach the projections are close to the mean.

We'll check back in November to see how our approach worked versus detailed analyses the other forecasters.