SHORELINES – January 2017

As presented to the *Island Review* magazine

The 2016 Hurricane Season Review

"It's not the destination, but the journey." This adage might best summarize the 2016 Hurricane season, which officially runs annually for a 6-month window opening on June 1st and sun-setting on November 30th. Forecasters were predicting a "near normal" hurricane season for 2016 based predominantly on the anticipated transition from the strong 2015-2016 *El Niño* event to that of *La Niña* (or "ENSO neutral") conditions. *El Niño* is actually a component of *El Niño* Southern Oscillation (ENSO) occurring in the Pacific Ocean basin. ENSO "warm phase" or *El Niño* conditions generally produces atmospheric conditions suppressing the formation of tropical cyclones in the Atlantic. Conversely the "cool phase" of ENSO, or *La Niña* tends to produce atmospheric conditions more favorable for tropical cyclone development. And lastly as you might expect, "ENSO Neutral" conditions are somewhere in between.

Couple more favorable *La Niña* and ENSO neutral conditions with Tropical Atlantic sea surface temperatures that were slightly above-normal throughout the hurricane season; and forecasters had two good elements in place to call for a near normal season. The atmospheric conditions were somewhat favorable for cyclone development AND there was fuel available in the form of warm water. The results of the season *per se* are depicted in Figure 1.

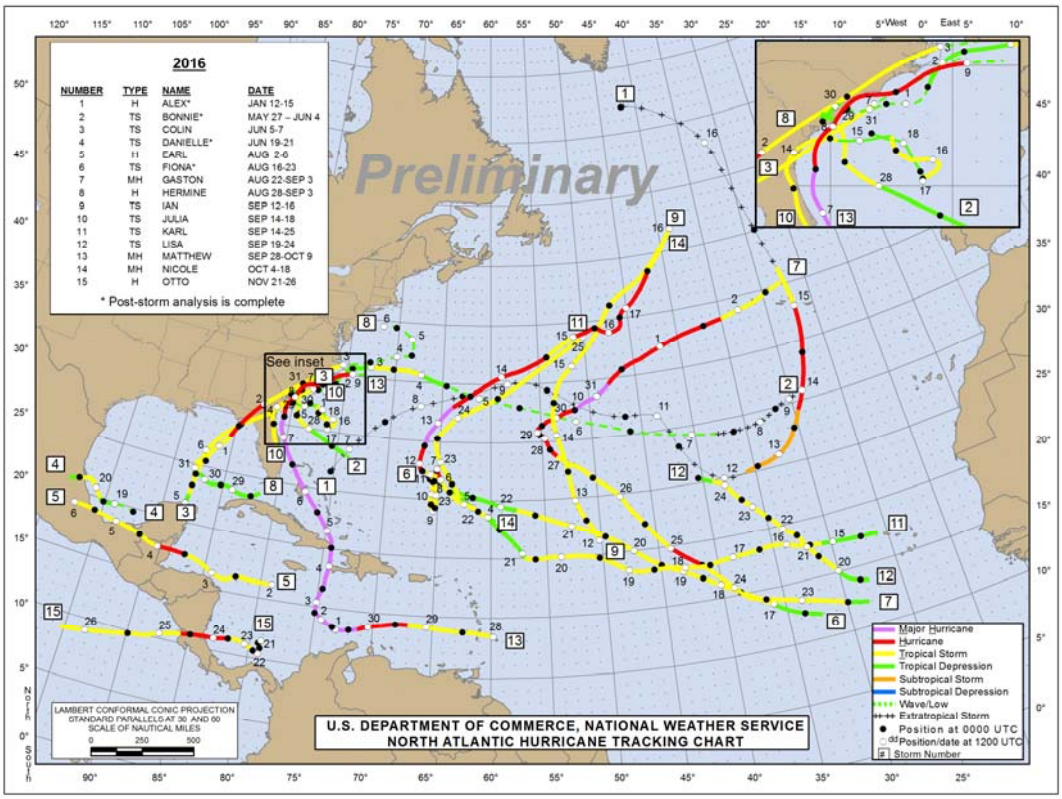

Figure 1 – Graphic prepared by the National Weather Service (NOAA) depicting cyclone tracks and intensities reported for the 2016 hurricane season.

2016 "Preseason" Forecasts Were On Mark

There are a ton of hurricane preseason predictions available each year but we usually focus on those that make not just their prediction public, but verify their prediction skill in the public arena as well. This really leaves us with; **(1)** the Tropical Meteorology Project at Colorado State University, **(2)** the University College London, U.K. for Tropical Storm Risk, and **(3)** our federal voice for climatology/meteorology matters, the National Oceanic & Atmospheric Administration (NOAA). We then take these groups' last prediction just before or near the start of hurricane season on June 1st and compare the predictions to the actual results at the end of the season (November 30th).

The forecasters were on the mark this year without question. As the accompanying prediction summary chart indicates (Table 1), the average prediction included 15 total cyclones (the actual was 15), 7 of which were predicted to generate into hurricanes (the actual was indeed 7), with 3 of these becoming major hurricanes (the actual was 3). This means 8 tropical storms were predicted and the actual number again was 8. "BOOM" - right on target and indeed above the 1981-2010 historical average exactly as they predicted.

	NOAA (median) 5/27/16	Colorado State University, US 6/1/16	University College London, UK 5/27/16	Average of Predictions	ACTUAL 2016	Historical Average (1981-2010)
Total No. of Named Tropical Cyclones	13	14	17	15	15	12
Tropical Storms	7	8	8	8	8	6
Hurricanes / Major	6/3	6/2	9/4	7/3	7/3	6/3
Accumulated Cyclone Energy (ACE) Index	92	94	130	105	134	104

Table 1 - Summary comparing publicly available pre-season predictions for the 2016 Hurricane Season with actual results and average activity.

The only variable that was slightly off is something we haven't discussed yet - the Accumulated Cyclone Energy Index (ACE Index). The ACE Index is simply a measurement taking a storm's wind speed strength for each 6-hour period of its existence into account. The larger the ACE Index value, the more active the season. The ACE Index is actually one of the more revealing parameters we can use and serves as a better barometer of whether or not a hurricane season is truly "active" or not. The longer duration and/or more intense each cyclone (tropical storm or hurricane); the more contribution to the ACE Index value – and *vice versa*. The average forecasted ACE Index for 2016 was 105 - the actual was 134. Significantly more than forecasted, and we can also use this number to determine that we indeed had an "above normal" season. "Below normal" is <68, "near normal" is 68 to 106, "above normal" ranges from 106 to 168, and "hyperactive" is >168). Below (Table 2) is a summary of the past 14 years with respect to the ACE Index – again, it's a great barometer (no pun intended) of hurricane activity.

YEAR	ACE Index	Notes
2016	**134**	Uncommonly prolonged (January 12 to November 25) yet very little activity in the climatological peak of the season as October had a higher ACE Index input (69) than August and September combined. *Matthew* alone had an ACE Index of 49.
2015	**62**	Somewhat surprising near average numbers of tropical storms and hurricanes despite the 2015-16 moderate to strong *El Niño* event. ACE Index higher than forecasted yet still "below normal" and skewed by *Joaquin* which had an ACE Index of 27 alone.
2014	**66**	Fewest amount of total cyclones (8) since 1997 (7). Hurricanes *Edouard* and *Gonzalo* accounted for over 60% of the ACE Index. Hurricane *Arthur* crossed Shackleford Banks.
2013	**33**	6th lowest ACE Index since 1950; 13 cyclones with 2 that developed into hurricanes - fewest number of hurricanes since 1982.
2012	**128**	Third consecutive year with 19 cyclones that ties record for 3rd-most most cyclones ever for a season (2011, 2010, 1995, and 1887 all had 19 cyclones). Eight cyclones formed in August alone, which tied 2004 for the most to form in that particular month, and only 7 seasons had more hurricanes than 2012 (10).
2011	**119**	Tied with 2010, 1995, and 1887 for the 3rd-most most cyclones for a season at 19, but fewer of the cyclones developed into hurricanes (7 hurricanes in 2011 compared to 12 in 2010), yielding a lower ACE value. *Irene* was the first U.S landfalling hurricane since *Ike* in 2008.
2010	**163**	Tied for 3rd-most most cyclones for a season at 19, and tied for 2nd-most hurricanes for a season at 12. *Igor* had an ACE Index of 42 alone - highest since *Ivan* (2004).
2009	**51**	*El Niño* year - 15th lowest ACE Index since 1950, 12 cyclones (most short-lived), 3 hurricanes.
2008	**145**	*Ike* and *Gustav* were two major hurricanes that impacted Tx. and La., *Bertha* was an extremely long-lived cyclone, and collectively accounted for 60% of the total ACE Index for 2008.
2007	**72**	Five more tropical cyclones than average, but most were very short-lived or rather weak, with the exception of two category 5 hurricanes that impacted Central America (*Dean* and *Felix*).
2006	**79**	Ten cyclones total (lowest number since the 1997 season)
2005	**248**	Highest ACE Index on record and included the most cyclones (28), hurricanes (15), and category 5 hurricanes (4) in a single season, and the most intense hurricane on record (*Wilma*).
2004	**225**	4th highest ACE Index value on record, hurricane *Ivan* alone had an ACE Index of 70, 2004 had six major hurricanes.
2003	**175**	Hurricane *Isabel* will long be remembered in Carteret County for Down East flooding, and for the island breach near Hatteras Village in Dare County. *Isabel's* ACE Index alone was 63, one of the highest recorded for an individual cyclone.

Table 2 – ACE Index summary chart (2003 – 2016).

Other Oddities

Although the forecasters were on the mark this year, how we arrived at the final destination however was a wild ride. For instance;

- **Long Duration** - Although the hurricane season begins on June 1st and ends on November 30th; *Alex* (hurricane max.) formed on January 12th and *Bonnie* (tropical storm max.) formed on May 27th. On the back end of the season, Hurricane *Otto* was the first hurricane known to make landfall on Thanksgiving Day and was the Atlantic's strongest hurricane on record so late in the calendar. In essence then the 2016 hurricane season ran from January 12th to November 25th and is only rivaled by the 1938 season (January 3rd to November 10th) from a duration standpoint.

- **Quiet Peak** - On the flip side of an unusually prolonged season, the climatological peak of the season was surprisingly quiet. The September ACE Index was only 25, while the October ACE Index was 69 – the highest value since 1963, which was also

69. This was also the first year since 1963 as well when October generated a higher ACE Index contribution than August and September combined.

- ***Matthew*** - And last but not least, there was *Matthew*. This hurricane bedeviled forecasters and every resident, property owner, and vacationer alike along the Eastern Seaboard. A week or so before hugging the coastline, *Matthew* was projected to take a more direct northward and very eerily similar track to that of *Hazel* (1954). Then *Matthew* underwent rapid intensification – specifically 80 mph of intensification in 24 hours, which was the 3rd strongest rapid intensification in the Atlantic on record and becoming the first Category 5 hurricane in the Atlantic basin since *Felix* (2007). Even more impressive, *Matthew* became the lowest latitude Atlantic Category 5 hurricane on record. The ACE Index contribution of *Matthew* alone was 49.

And then there was the track of *Matthew* itself – a U.S. landfall was predicted almost anywhere from Cape Canaveral, Fla. to Cape Lookout, N.C. after crossing land in Haiti and Cuba. The actual U.S. landfall was at Cape Romain National Wildlife Refuge, S.C. as a Category 1 hurricane. Because *Matthew* ran parallel to the Southeastern Atlantic Seaboard, slight shifts on order of 10s of miles that are almost impossible to really predict, made huge differences in actual storm surge, wave set up, and rainfall.

Case in point - the following image (Figure 2) is from NOAA and depicts the recurrence interval of the worst case 24-hour rainfall experienced for *Matthew*. The recurrence interval is the probability of a natural hazard event (rainfall in this case) occurring annually and is usually expressed as a percentage. For instance, 1 in 100 years is the 1% annual chance (= 1/100), while the 1 in 500 year event (=1/500) is the 0.2% annual chance, and so on. In the matter of just miles *Matthew* delivered anywhere from over "1,000 year storm" rainfall totals (>1/1000 or 0.1%) to less than "10 year storm rainfall (<1/10 or 10%). Fourteen inches of rain was predicted in Carteret County at one point – the actual was closer to 2 inches (mostly less) and again, a subtle shift of hurricane *Matthew's* track north or south would have had tremendous differences.

In terms of beach erosion, Bogue Banks sustained little damage from a "volumetric" or sand loss sense. The beaches are surveyed every year before hurricane season as a continual indicator of beach health. A post storm survey can be discretionarily conducted if warranted as was the case with *Matthew*. The survey was completed __ days after *Matthew* crossed south of Bogue Banks – we actually gained a little of sand across the 128,393 linear feet of Bogue Banks beach as measured from the dune top down underwater to the depth of -12 feet (NAVD 88). This is considered as our "shock absorbing sand box", and again we fared well.

It will be good to catch our breath after this hurricane season, and hopefully we don't have as an early of start as we did last year (2016).

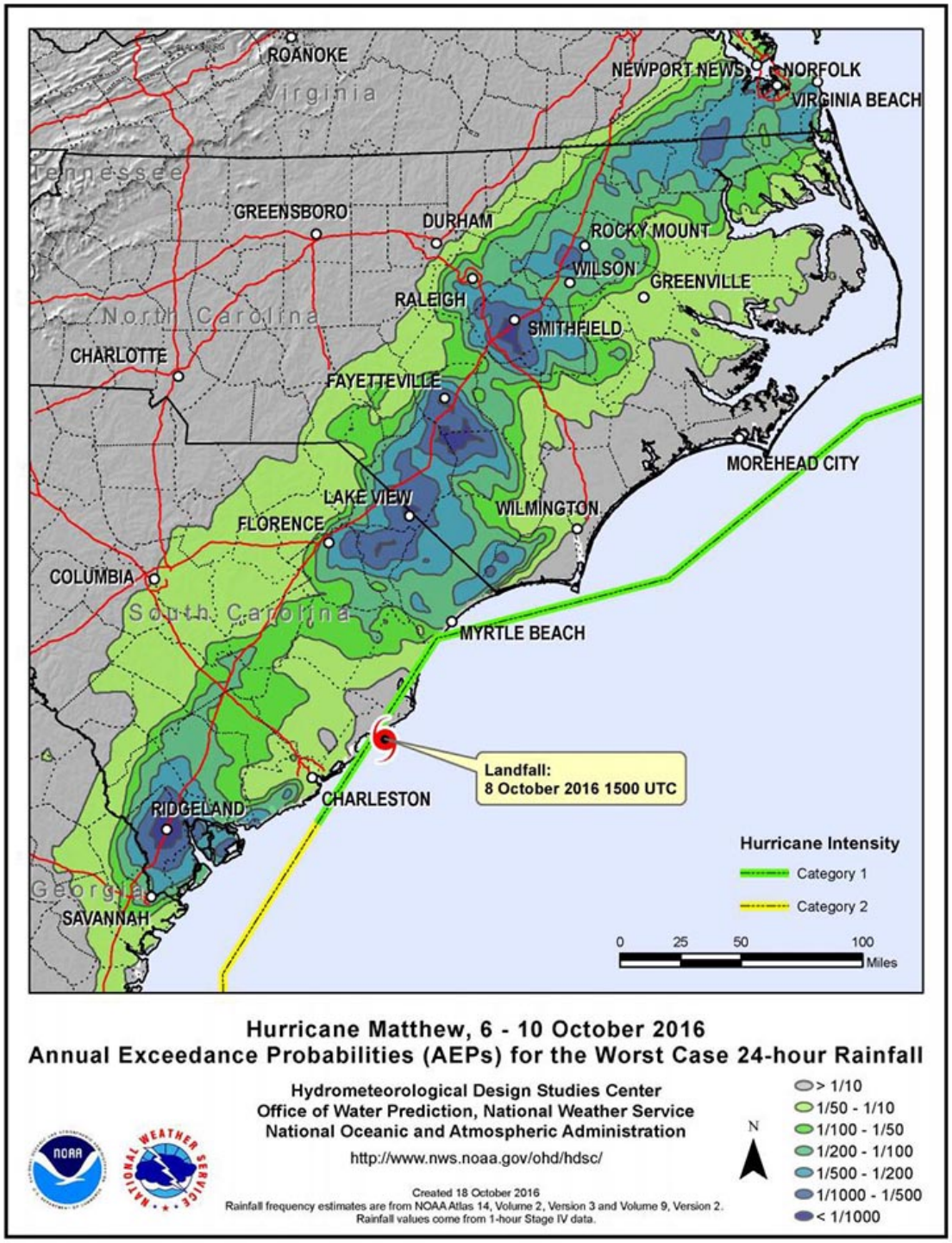

Figure 2 – Maximum 24-hour rainfall totals for Hurricane *Matthew* from October 6 – 10 along much of the Southeastern Atlantic Seaboard. Several localities experienced rainfall totals that are expected 1/1000 years, producing record flooding. Other locations along the North Carolina Coastal Plain received almost no rain.

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