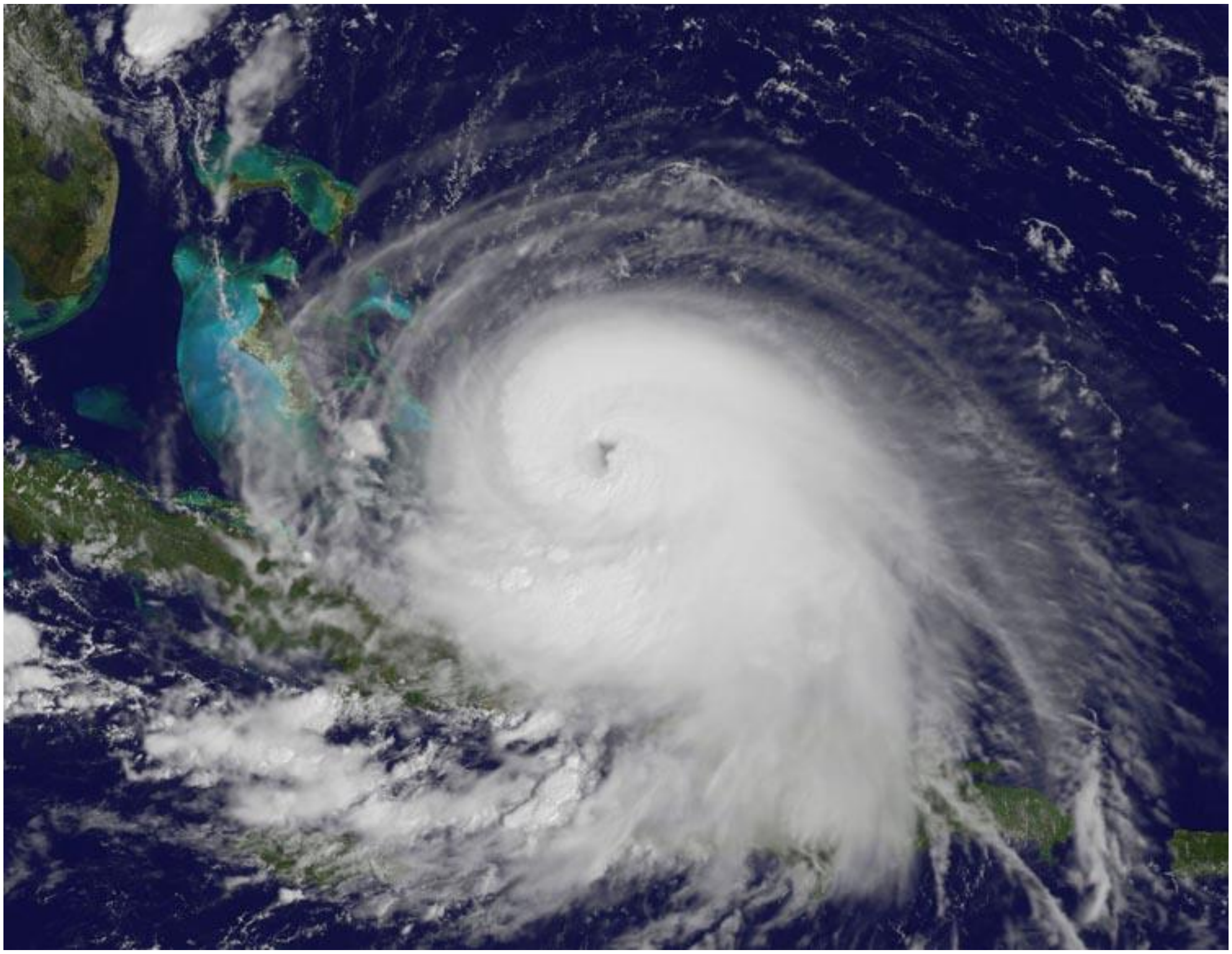
2016 Hurricane Outlook

Tyler Stanfield

April 3rd, 2016

June 1st - November 30th



GOES-13 Visible Satellite Imagery of Hurricane Joaquin as seen on October 1st, 2015 at 10:30AM EDT.

Hurricane Alex

On January 7, the National Hurricane Center noted an extratropical low that could develop tropical or subtropical characteristics over the subsequent days as it traversed the central Atlantic. On January 13, the low was able to develop deep convection close enough to the center to be classified as Subtropical Storm Alex. Alex was the first tropical or subtropical storm to form in January since 1978, and only the fourth known tropical or subtropical cyclone formation during the month on record. Alex then organized further and acquired enough tropical characteristics to become a hurricane at 15:00 UTC on January 14 making it only the second recorded hurricane to have formed in the month of January. The last advisory for Alex occurred on January 15 when the storm transitioned back into an extratropical cyclone as it passed through the Azores Islands.

Introduction

The 2016 Hurricane season will kick off on June 1st, 2016 and last through November 30th. The Atlantic hurricane season (1981-2010) averages 12.1 named storms, 6.4 hurricanes, and 2.7 major hurricanes. This outlook will help illustrate what my thoughts are on this upcoming season as well as hopefully help us better understand the variables that will shape the activity we may see across the Atlantic basin this season.

Analysis

I. Atlantic Multidecadal Oscillation

The 2015 hurricane season was met with great opposition as a very strong El Nino event climaxed over the fall and a very evident negative Atlantic Multidecadal Oscillation regime shift that made its presence felt across the Atlantic. These factors helped prohibit a large majority of storm development across the region leading to the hurricane season only producing 55% of the normal amount of accumulated cyclone energy usually seen. This was the third straight below average season seen in the Atlantic basin raising large speculation that the Atlantic Multidecadal Oscillation has weakened rapidly due in large part to the long period of inactivity in the ENSO between 2012 and 2015. The lack of an El Nino to revitalize the Atlantic basin during these seasons became the turning point that allowed for the rapid decay of the AMO from its positive state in 2012 to a negative state by the beginning of 2014. This apparent collapse of the current positive AMO regime, as observed as well by Colorado State University's Dr. Phil Klotzbach, has left many questioning as to whether or not we may see a more permanent negative regime of the Atlantic Multidecadal Oscillation take over in its place.

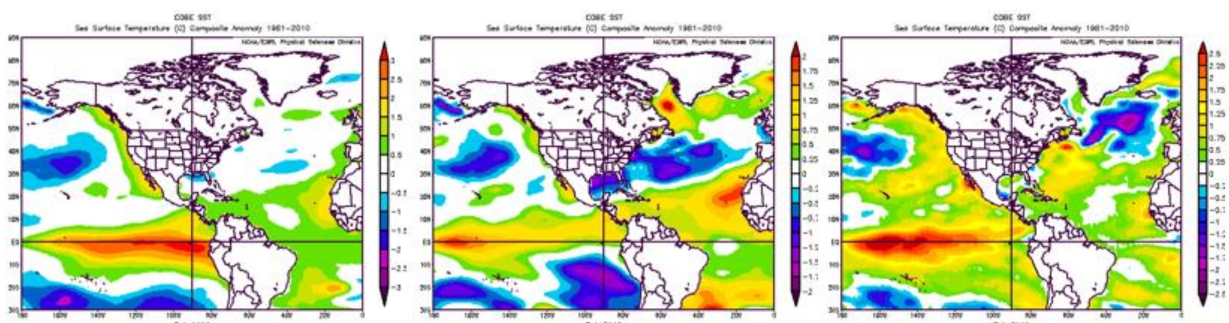


Figure 1. ESRL COBE SST February Sea Surface Temperature Composite Anomaly maps of 1998(left), 2010 (middle), and 2016 (right).

This subject is still being heavily studied as we continue to better understand the AMO. As of right now; however, it appears quite clear that a regime shift has occurred in the Atlantic basin allowing for a negative AMO phase to take hold. This regime shift is clearest when looking at Dr. Klotzbach and Gray's 2008 Atlantic Multidecadal Oscillation and Thermohaline Circulation index. This index clearly showed 2015 as the Atlantic's first full fledge negative AMO season with likely many more to come as this regime shift takes over. The strong skepticism still remains that such a short lived positive AMO phase could have occurred as the last positive AMO phase lasted for nearly 40 years and this phase was sustained for only half of that time. This observation will have to be greatly studied as we try to better understand what makes the Atlantic Multidecadal Oscillation shift, but it appears likely that the breakdown of the Atlantic Hadley Cell and long stretch of ENSO inactivity from 2012 to 2015 played a big role in the rapid deterioration of this phase which was not foreseen to fall during this decade. The negative AMO regime shift is reflected in my outlook that will be displayed toward the end of this entry. The weakening of the AMO noted clearly when comparing years following large El Nino events in this last positive regime help add evidence to what seems to have been a quick demise to a very strong positive AMO regime.

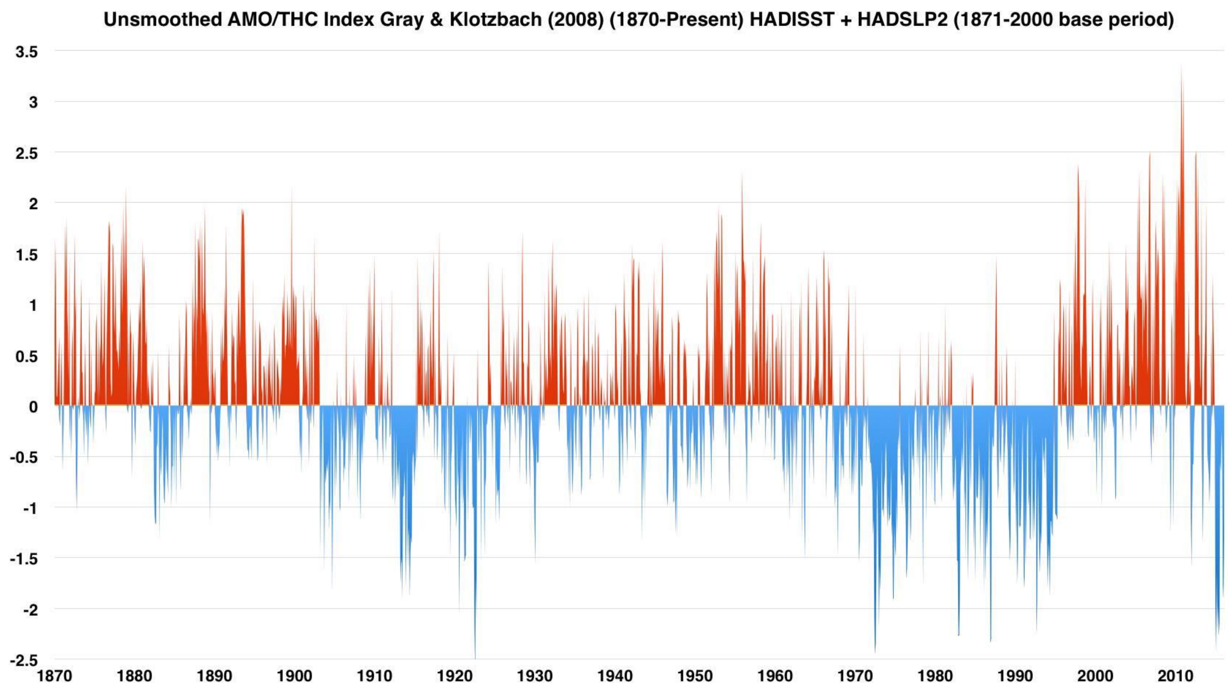


Figure 2. Unsmoothed Atlantic Multidecadal Oscillation and Thermohaline Circulation Index developed by Dr. Klotzbach and Dr. Gray of Colorado State University created by Eric Webb depicting the recent AMO regime shift from positive to negative.

II. El Nino Southern Oscillation

Despite the less favorable AMO, another topic at hand will be the evolving ENSO (or El Nino Southern Oscillation). The “super” El Nino of 2015 peaked over the late fall and early winter reaching a three-month average peak of 2.3C above normal in Nino region 3.4. Now that the event has peaked there is only one thing left for it to do which is for it to weaken. The temperature depth subsurface anomalies and thermocline animations clearly show that our once raging El Nino has now calmed down. Values in Nino region 3.4 are now closer to 1.5C above normal and continue their slow descent back to neutral conditions. The question raised now that El Nino has left its mark is how quickly will we see the ENSO cool? Most climate models that are a part of the Climate Prediction Center ENSO guidance have the ENSO cool rapidly through the remainder of spring and into summer. This cooling has become quite pronounced when viewing the evolution of the subsurface SST thermocline which is the measurement of subsurface ocean water temperatures of the equatorial Pacific.

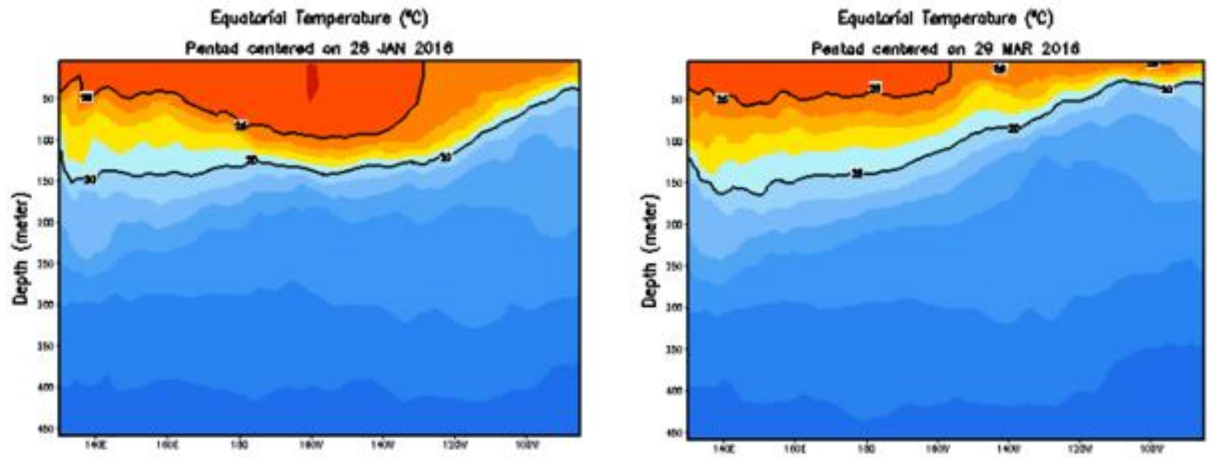


Figure 3. NOAA/PMEL Depth-longitude sections of anomalous equatorial ocean temperature measurements from January 26, 2016 (left) and March 29, 2016 (right).

In a neutral state the thermocline is asymmetrical with average easterly trade winds enhancing upwelling across the eastern equatorial Pacific generally making the western hold much more warmth under the surface. During an El Nino event, these easterly trade winds weaken or reverse which reduce upwelling across the eastern Pacific and this lessened force allows for the warmth that is stockpiled over the west to propagate eastward closer to the international dateline (as seen in the left image of Figure 2 above). The shift in distribution of warmth is what gives the ENSO its power. In reference to Figure 2, the image to the right shows you the most recent image of the equatorial Pacific thermocline which indicates the subsurface Pacific returning to its neutral state as easterly trade winds return and the remnant warm oceanic kelvin wave dissipates. What this tells you about the Pacific is that the ENSO is preparing for yet another change. This change is likely to come in the form of a La Nina event toward the end of 2016. A La Nina event occurs when the average easterly trade winds accelerate enhancing the subsurface upwelling that occurs in the eastern equatorial Pacific which causes much of the eastern and central Pacific to cool as the thermocline shifts further west. La Nina events typically follow El Nino events in most ENSO progressions due to the acceleration of easterly trade winds that occur naturally after the collapse of an El Nino event. The last such trade off occurred in 2010 when the El Nino of 2009 collapsed and gave way to a strong La Nina in fall of 2010 and lasted through 2011. However 2009's El Nino only ranked as a moderate event and to understand the dramatic shift between an El Nino event as strong as 2015 shifting to a La Nina you would have to look at none other than 1997-1998. The 1997 El Nino arguably shares the title still with 2015's El Nino event with 2016 poised to follow in similar footsteps of 1998 with a developing La Nina being incubated in the form of a cool subsurface oceanic kelvin wave that has developed over the central and western Pacific.

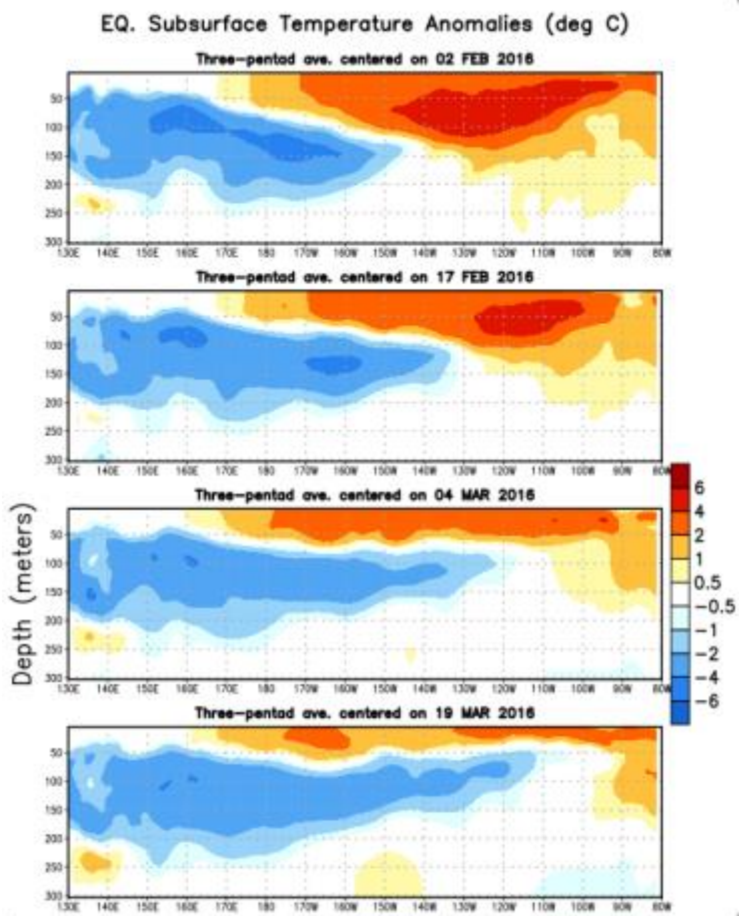


Figure 4. NOAA/PMEL Temperature Depth Sea Surface Temperature Anomalies for the equatorial Pacific from February 2, 2016 to March 19, 2016. The image depicts a large cold oceanic kelvin wave developing in the subsurface waters of central and western Pacific and propagating eastward.

With the likelihood of a La Nina event increasing as we approach the fall, it appears with near certainty that a La Nina event will have arrived by winter of 2016-2017. The newest update to the CFSv2 has helped to better clarify the overall timing of this ENSO transition, as well as it has fallen into a much better consensus with dynamic climate models, as it was trying to unrealistically redevelop an El Nino event prior to the update. With the addition of the CFSv2 to the consensus it seems increasingly likely that La Nina may arrive sooner which could have beneficial implications for tropical cyclone development across the tropical Atlantic. La Nina events cool the eastern equatorial Pacific to well below normal temperatures which serves to decrease convective convergence as a cool and dry environment serves to suppress the upper atmosphere creating sinking air. This atmospheric suppression not only leads to below normal convective activity (rainfall) across the eastern pacific and parts of South America, but also decreases vertical wind shear across the Caribbean Sea as there is less convective outflow to enhance this vertical wind shear. It is important as to whether or not vertical wind shear is increased due to its impact on tropical cyclones. Wind shear, also known as upper level winds, have to be light and calm over a tropical cyclone in order for the storm to build and intensify. Tropical cyclones are like atmospheric heat engines. They need to breathe and they need a fuel source in order to succeed in expending heat from the surface into the atmosphere. If vertical wind shear is high, it serves to limit the growth of convection around the storm which "chokes" the system and will either lead to a struggle to maintain strength or cause the storm to completely dissipate. La Nina events work opposite to that of El Nino events which is why you can clearly note the difference in Atlantic hurricane activity when these ENSO events are active. During an El Nino event, vertical wind shear is enhanced which limits hurricane activity in the Atlantic. While in a La Nina event, vertical wind shear is reduced further allowing the intensification and formation of hurricanes in the Atlantic basin.

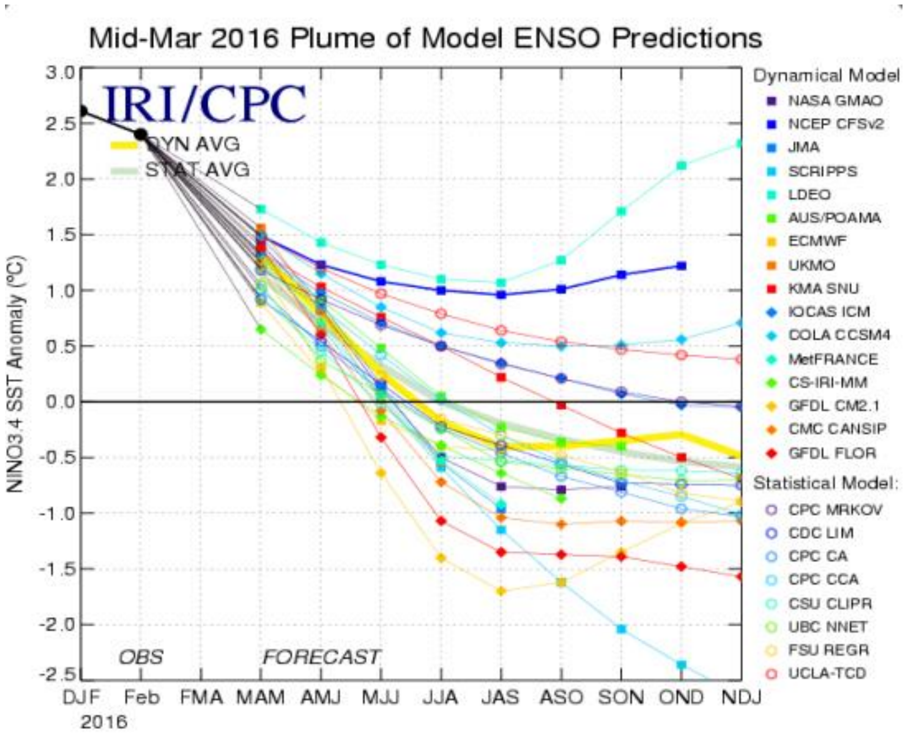


Figure 5. NOAA Climate Prediction Center Mid-March 2016 Plume of Model ENSO predictions using dynamical and statistical climate models that depict a consensus for a developing La Nina event by autumn.

III. African Easterly Jetstream & Sahel

Another variable not always publicized as much as the AMO and ENSO that factors heavily into the Atlantic hurricane outlook are the African Easterly Jetstream & Sahel conditions. African Easterly Waves, commonly tagged "Cape Verde hurricanes", make up a large portion of the tropical cyclones that develop across the Atlantic. These tropical waves either develop off the coast of Africa, hence where they get their name, or they remain an entity until they can find a better environment to develop as they head west, such as Hurricane Katrina of 2005. 2015 saw an increase in potency of these African Easterly Waves through the peak months of the hurricane season which allowed storms such as Fred, Grace, and Ida to develop despite the very hostile conditions that awaited them during the El Nino dominated season. These vigorous tropical waves were a symptom of a wetter than average Sahel regions and aided by slower trade winds and convectively coupled kelvin waves. Although CCKW are not predictable in a long range forecast like this, a wetter than average Sahel is exactly what is occurring once again this year which will reduce the amount of Saharan dust that will be capable of leaving the continent of Africa during the hurricane season. Even with a wetter Sahel, however, a stronger Azores

High over the northeast Atlantic could cause trouble for African Easterly Waves trying to develop. A stronger Azores High favors the acceleration of easterly trade winds across the central and eastern Atlantic which will make it hard for systems to converge and develop a strong and healthy circulation. This has been seen in other seasons such as 2013 when Tropical Storm Chantal raced across the central Atlantic at 30mph and quickly fell apart entering the Caribbean as the center of circulation was no longer able to hold together under the stress of the opposing trade winds on its southern side. If we were to see another strong Azores High like this it could cause similar issues and inhibit development in this region. However, the overall effects from the wetter Sahel and active African Easterly Jetstream will likely prove to be beneficial to the upcoming season and serve to generate storms as we head deeper into peak season.

Analogs

After discussing the AMO, ENSO, and AEJ, it seems to be clear the next step is to try to find years that resemble 2016 the best. With the demise of the “super” El Nino happening much like that of 1997-1998, it seemed reasonable to add 1998 in as a year that could closely resemble what 2016 will be like for hurricane activity in the Atlantic basin. The overall ENSO change, 500mb height pattern, and overall storm activity seems to match up very well with how I feel like the 2016 hurricane season will be although my one drawback is the strength of the AMO being much different now than it was then. 1998 is also my only analog I will be using from the recent positive AMO regime due to the sudden shift in the AMO. My other analogs for this season include 1886, 1906, 1973, and 1983. All of these seasons featured a negative Atlantic Multidecadal Oscillation with a transitioning ENSO from a strong El Nino to a La Nina (cool neutral in 1983). The average activity from these analogs is 10.8 named storms, 6.6 hurricanes, and 2.4 major hurricanes which is remarkably close to the climatological average for the Atlantic basin.

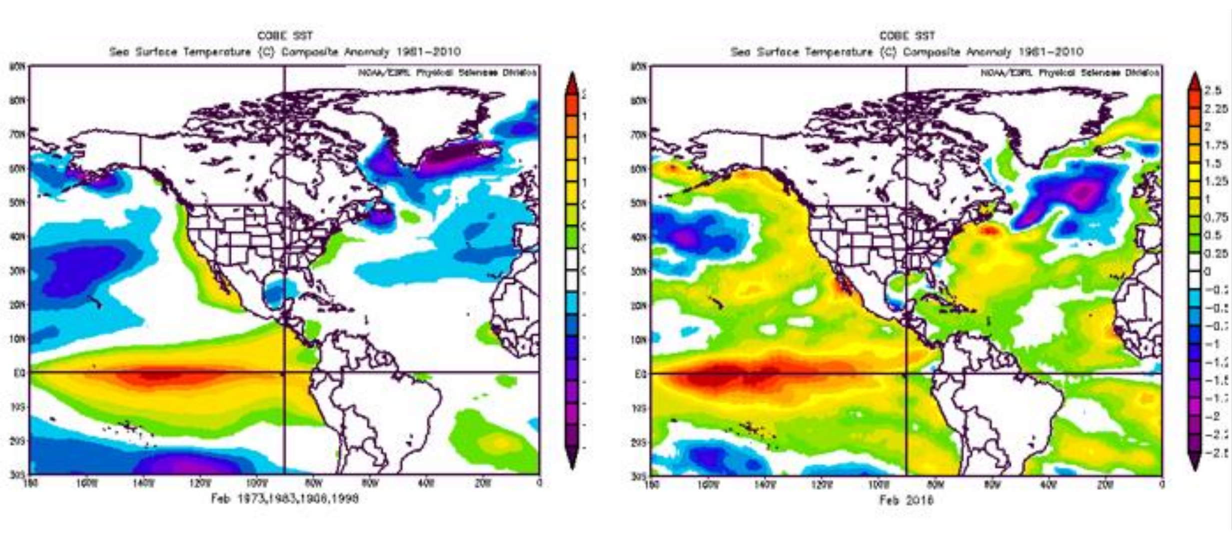


Figure 6. Sea Surface Temperature Composite Anomaly comparing the analog average (with exception to 1886) to 2016 for the month of February which depicts a very strong resemblance to one another.

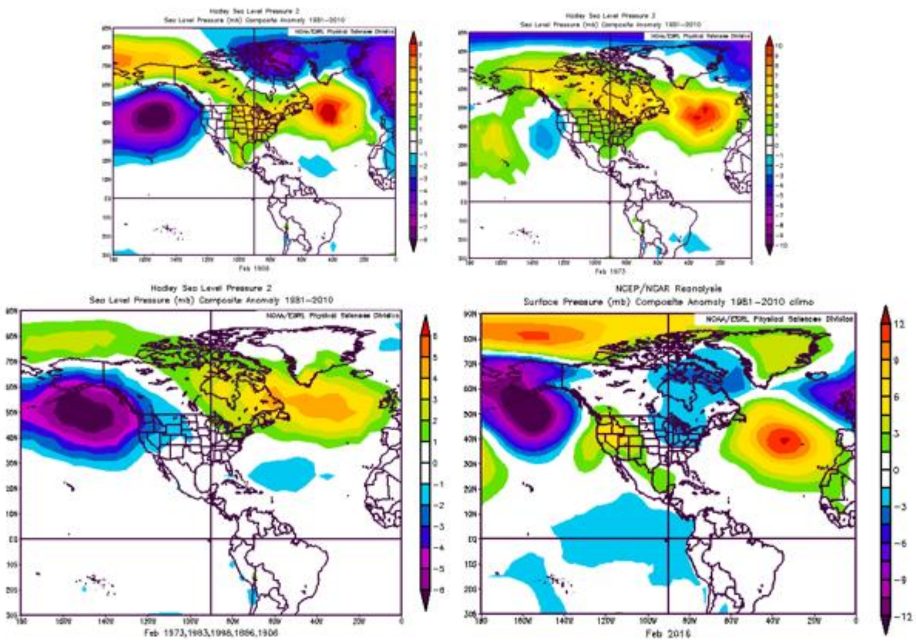


Figure 7. Sea Level Pressure Composite Anomalies for the month of February. Sample composites from individual years of 1906 (top right), 1973 (top left), and 2016 (bottom left). Averaged Sea Level pressures from the analog years (bottom right).

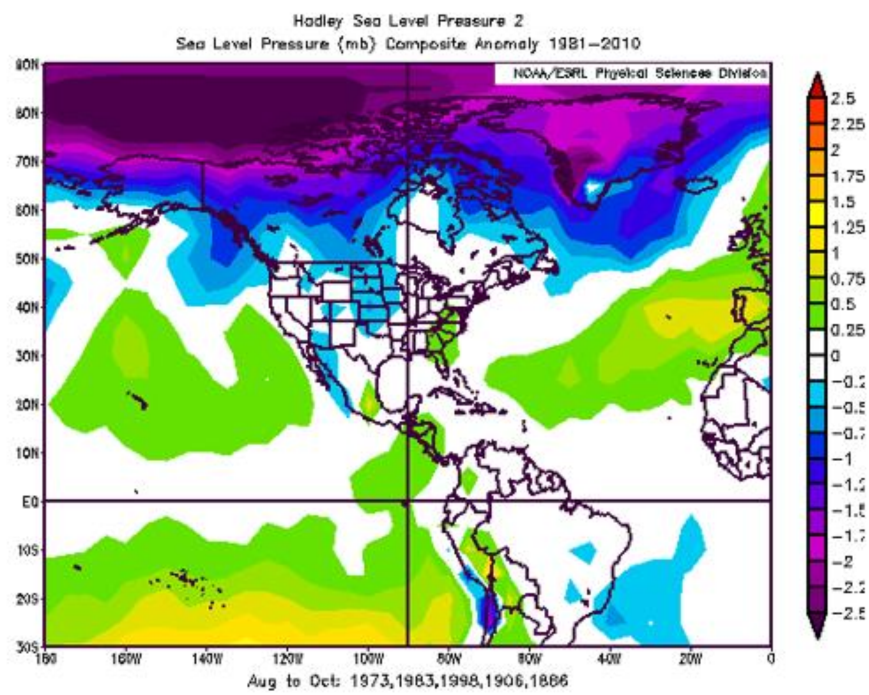


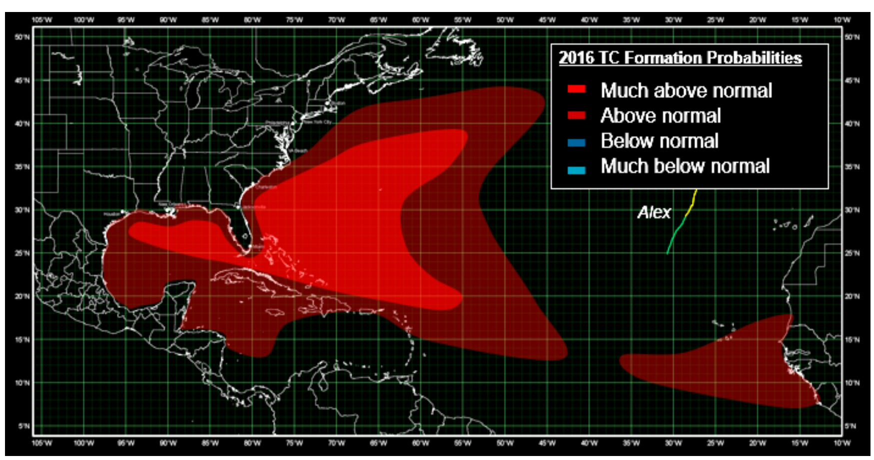
Figure 8. Analog Averaged Sea Level Pressure Composite Anomaly for August to October depicting above normal surface pressure across the subtropical central and eastern Atlantic during peak of hurricane season.

When compiling composites for these seasons I could not help but notice these years had above normal sea level pressures across Northeast Atlantic Ocean and a strong trough in the Gulf of Alaska during the month of February (Figure 6.) This pattern with strong ridging over the North Atlantic then gives way to a northerly displaced Azores high with a strong trough favored near the Canadian maritime during the peak of hurricane season. This kind of pattern would favor an overall favorable pattern for tropical cyclones to recurve well east of North America or miss the trough completely, due to timing matters, and be shoved west into the continent. Something to note from Figure 8. is the clear above normal surface pressures that are favored over the subtropical central and eastern Atlantic Ocean during peak hurricane season which could serve to amplify convergence and artificially lower pressures across the tropical Atlantic as well as aid in tropical cyclone formation across the region during the peak of the season. I will not dive deep into storm track as it would be foolish to speculate exactly the track of such storms that were to develop during the 2016 season, however this will be a developing topic that will be revisited as we near June.

Outlook Overview

The 2016 Hurricane Season is expected to experience near average activity with accumulated cyclone energy forecasted to be 70% to 110% of normal. It appears likely that the 2015 El Nino event will continue to weaken as we move closer to summer with most climate models now in consensus that the ENSO will reach neutral conditions by the beginning of summer. The Climate Prediction Center also agrees with my belief that there is an increasing likelihood that a La Nina event will emerge by fall of 2016. This likelihood is represented in my outlook. The overall favorability of the Atlantic remains the biggest question heading into the hurricane season. The biggest impact to the Atlantic's favorability in tropical cyclone formation comes from the Atlantic Multidecadal Oscillation and Thermohaline Circulation which appears to have experienced a clear regime shift over the last two years and now represents a negative phase. This will serve to put a cap on extreme amounts of activity that was previously witnessed during the Atlantic Active period from 1995-2013. This regime shift; however won't make or break the overall activity of tropical cyclones. Other countering benefits to tropical cyclone development in the Atlantic will include a wetter Sahel, increased AEJ, weaker vertical wind shear than what was previously seen during El Nino, and above normal sea surface temperatures in the Southwestern Atlantic Ocean and Caribbean Sea. Overall these benefits will serve to aid in tropical cyclone formation despite the overall unfavorable regime.

Figure 9. Tyler Stanfield's 2016 Tropical Cyclone formation probabilities for the Atlantic Basin.



I. April Outlook

Most Likely Scenarios

La Nina Event w/ Weak AMO (60%)
11 Named Storms
5 Hurricanes
2 Major Hurricanes
ACE 75% of Normal

ENSO Neutral w/ Weak AMO (25%)
10 Named Storms
6 Hurricanes
2 Major Hurricane
ACE 77% of Normal

ENSO Neutral w/ Strong AMO (10%)
14 Named Storms
7 Hurricanes
3 Major Hurricane
ACE 124% of Normal

La Nina Event w/ Strong AMO (5%)
16 Named Storms
9 Hurricanes
4 Major Hurricanes
ACE 141% of Normal

Forecast Mean
11.5 Named Storms
5.8 Hurricanes
2.4 Major Hurricanes
ACE 83.7% of Normal

My Forecast
13 Named Storms
6 Hurricanes
3 Major Hurricanes
ACE 85% of Normal

Range Forecast
10-14 Named Storms
4-8 Hurricanes
1-4 Major Hurricanes
ACE 70-110% of Normal

This outlook was derived through determining the most likely scenarios that could occur during this hurricane season, using an average of other seasons that fell into these categories from 1950-2015, and using percentile of probability that this scenario would play out to determine the overall forecast mean.

After discussing all of the variables that will be tied into the 2016 Atlantic hurricane season, it is my pleasure to share with you my forecast for the upcoming season. My April forecast calls for 13 named storms, 6 hurricanes, and 3 major hurricanes with accumulated cyclone energy 85% of normal. This outlook does not include Hurricane Alex as it was a system that developed outside of the normal hurricane season. This would mean that the overall forecasted numbers would be 14 named storms, 7 hurricanes, and 3 major hurricanes.

June Outlook

I will have a new hurricane outlook scheduled and prepared for June 1, the official first day of hurricane season. Thank you for reading!

***DISCLAIMER:** Tyler Stanfield is an amateur weather enthusiast pursuing a career in meteorology at the University of Oklahoma. This hurricane outlook is intended for educational and personal use only and should not be used in place of an official hurricane outlook made by NOAA or any other credible source.