2023 Pre-Season Hurricane Outlook

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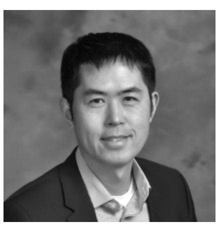

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1. Executive Summary

While most forecasts expected an above-average hurricane season in 2022 due to highly favorable conditions in the Atlantic and Pacific oceans, the season ended close to normal, despite some very powerful storms making landfall in the US and Canada. This year, the consensus of forecasts falls close to normal, but there is more uncertainty than usual due to both favorable and unfavorable conditions.

In this report we have looked at some of the key variables behind the forecasts to provide context.

- Forecasted Atlantic sea surface temperature (SST) are warmer than last year, especially in the Main Development Region (MDR). Nearly the entire Atlantic and Gulf of Mexico are forecasted to be above normal, suggesting more hurricane activity.
- The El Nino Southern Oscillation (ENSO) is predicted to be in a moderate to strong El Nino phase, which could lead to strong vertical wind shear and suppressed hurricane activity.
- Positive ENSO conditions are associated with a higher proportion of storms making landfall for Gulf clusters in the Acrisure Re forecast model, despite lower frequency of storms.
- Past analog years of 1978 and 1993 would indicate Quasi-Biennial Oscillation (QBO) is trending toward a negative anomaly, but should remain positive for most of the season. It has been claimed that positive QBO values are associated with more Cape Verde storms forming in the deep tropics.
- Conditions in the Sahel region of Africa appear to be very close to average. This means dust is unlikely to play a major role suppressing hurricane activity.

Overall, we will have competing forces in the Atlantic basin this year, with above average SSTs in the Atlantic forecasted and the predicted development of El Nino conditions. There have been very few instances of hurricane seasons with these conditions, so there are not many analogous seasons to look at for guidance. It is possible one of these forces dominates the other and we could have an above or below average season. However, the most likely outcome is for a near-normal season.

2. 2022 Hurricane Season in Review

The 2022 Atlantic hurricane season concluded with a tally of 14 named storms, eight of which graduated to hurricane status, exhibiting winds of 74 mph or higher. Two of these hurricanes further escalated to major hurricane status, reaching wind speeds in excess of 111 mph. Relative to the average hurricane season, which typically includes 14 named storms, seven hurricanes, and three major hurricanes, the 2022 season activity was close to the norm. In terms of Accumulated Cyclonic Energy (ACE), a measure of total storm energy, 2022 was slightly below the normal 123 ACE with 95 ACE. All-in-all, the 2022 Atlantic hurricane season was a near-normal season considering all metrics.

The US mainland bore the brunt of three hurricane landfalls during the season. Hurricane Ian was the first, making landfall as a Category 4 hurricane in Cayo Costa, Florida, and subsequently as a Category 1 in Georgetown, South Carolina. Ian brought tremendous wind and storm surge damage to the southwest Florida coast as well as flooding to parts of the state. With maximum sustained winds of 150 mph, Ian tied for the fifth-strongest US landfalling hurricane. Hurricane Nicole, a Category 1 storm, hit north Hutchinson Island, Florida. Outside the US mainland, Hurricane Fiona, also a Category 1 storm, struck near Punta Tocon, Puerto Rico before strengthening into a major category 4 hurricane. Fiona ultimately made a second landfall in Nova Scotia, becoming one of the most powerful storms to strike Canada, exhibiting the lowest atmospheric pressure of any storm to make landfall in Canada.

One distinctive aspect of the 2022 season was an unusual mid-season lull in storms, with no storms forming between July 3rd and August 31st, the first time since 1941 no storms formed between those dates. Due to anomalous cooling of sea surface temperatures in the subtropical Atlantic, August experienced a lot of mid-latitude anticyclonic wave breaking, which generally brings drier air to the tropics and increases wind shear over the main development region. These conditions most likely contributed to the complete shutdown of the Atlantic hurricane season during August. This quiet spell in August was followed by a surge in activity in September, resulting in seven named storms, including the two major hurricanes. However, October was well below average in terms of activity with only two short-lived storms forming during the month. A notable event in the 2022 season was the late-season Hurricane Nicole, which made landfall on November 10 along Florida's east coast.

3. Atlantic Sea Surface Temperature

Hurricanes require sea surface temperatures (SSTs) in excess of 26.5°C (79.7°F) before they can form, as hurricanes are effectively heat engines powered by warm ocean water. High sea surface temperatures alone do not ensure we will have an active season, but there is strong association between positive Atlantic sea surface temperature anomalies and active seasons.

As of May 22nd, areas with sea surface temperatures over 26.5°C were more extensive than May 23rd last year in some parts of the Atlantic, especially in the Main Development Region (MDR). However, the year over year SST difference map (Fig 3) shows some interesting details. Nearly the entire MDR is warmer than last year, as well as most of the Caribbean.

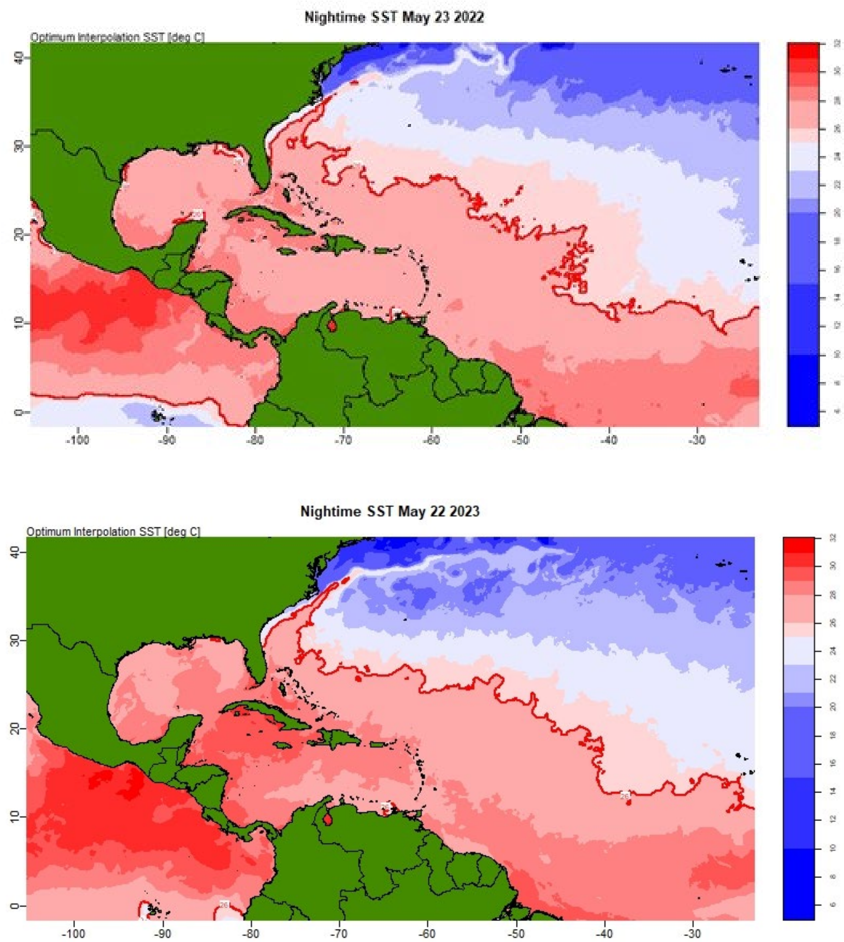


Fig 1: Nightime Sea surface temperatures for May 23, 2022 and May 22, 2023. The 26°C contour is shown as a red line.

Nighttime Sea Surface Temperature Difference (May 22, 2023-May 22, 2022)

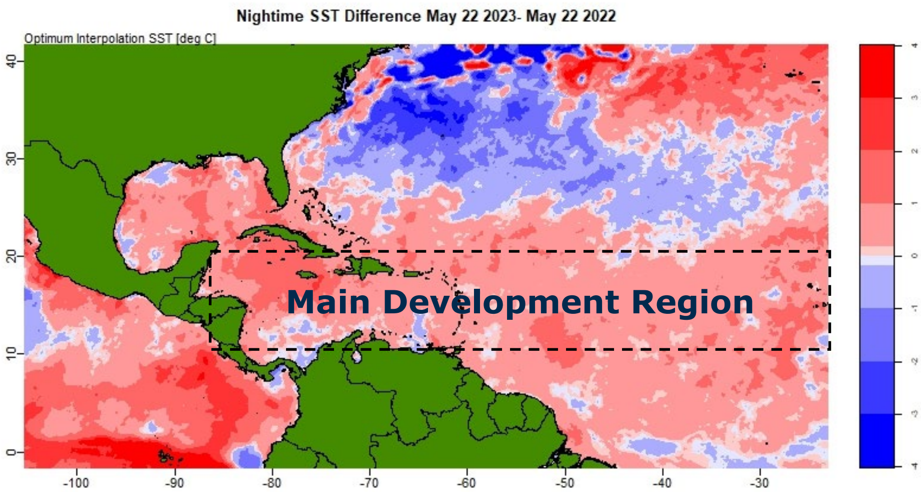


Fig. 2: Sea surface temperature difference in the North Atlantic from May 22, 2022 to May 22, 2023. Red areas are warmer than 2022.

This could lead to more storm activity in the eastern and central Atlantic. These storms, sometimes called Cape Verde storms, tend to recurve out to sea and not interact with land. Some models are predicting heightened activity in the central Atlantic and for the storms to recurve before reaching the Caribbean Islands and the U.S. mainland. However, that doesn't mean some of these storms won't reach land or that no storms will form in the Caribbean or Gulf of Mexico.

On the other hand, the North Atlantic is currently much cooler than last year. Last year we saw multiple storms form in the North Atlantic, potentially due to above average SSTs. This year, we might not see as many storms form in that region and any storms that do move over that area might struggle due to the relatively cooler waters.

Although current SST patterns are strongly correlated with what we are likely to see in the peak hurricane months of August and September, it is very useful to look at predictions as well. We include two examples below where the predicted SST data is presented as temperature anomalies. Positive anomalies, where the water is warmer than average, are shown in red, and blue is used to denote areas where it is cooler. The examples we show are from the NMME (North American Multi Model Ensemble) and the ECMWF (European Centre for Medium Range Weather Forecasting). Direct comparison is difficult as the plots are based on different reference periods for mean temperature and represent the forecast data in different ways. The NMME plot (Fig. 3) is the anomaly in degrees, whereas the ECMWF (Fig. 4) is a probability that it will exceed a given tercile in the overall distribution of SST.

Both show warmer than average conditions across nearly the entire Atlantic Basin, especially in the MDR and the Caribbean. Although SST forecasts for the Atlantic have been hit or miss in recent years, consensus from multiple model simulation gives more confidence to the possibility of these conditions verifying. If this forecast does play out, it would favor more activity in the Atlantic Basin.

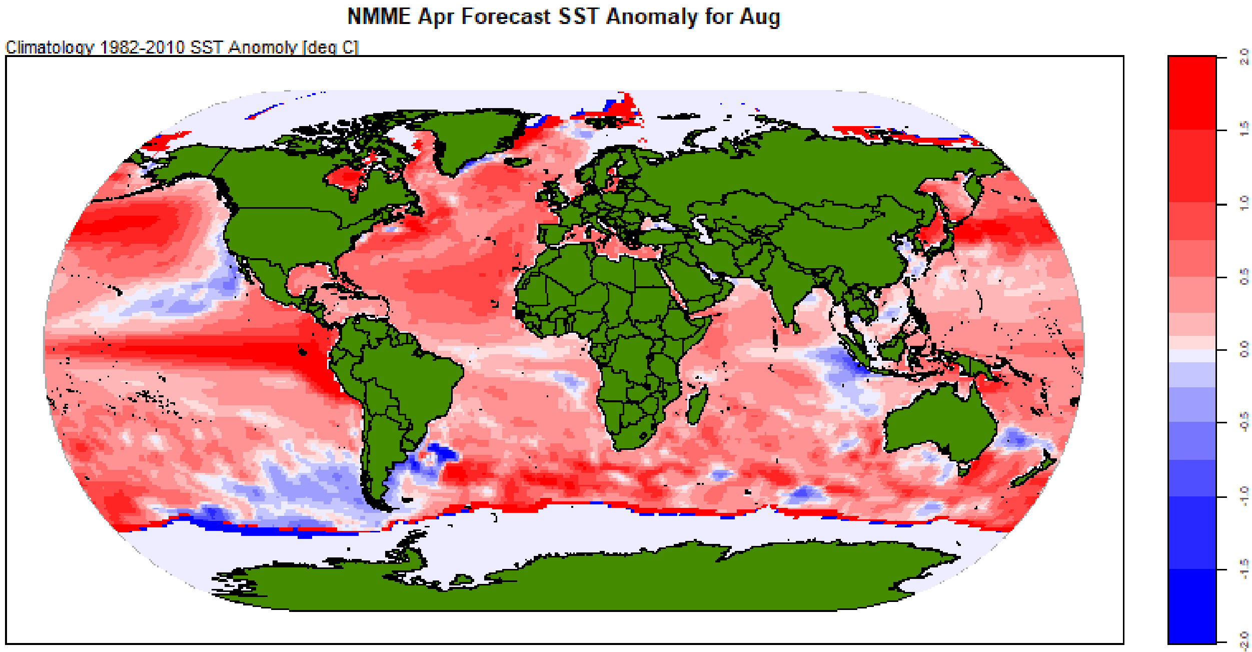


Fig 3: Sea surface temperature anomaly map created based on the April ensemble of the North American Multi Model Ensemble forecast. The baseline for the forecast anomalies is hindcast average SST from 1991 to 2020.

Sea Surface Temperature – SEAS5

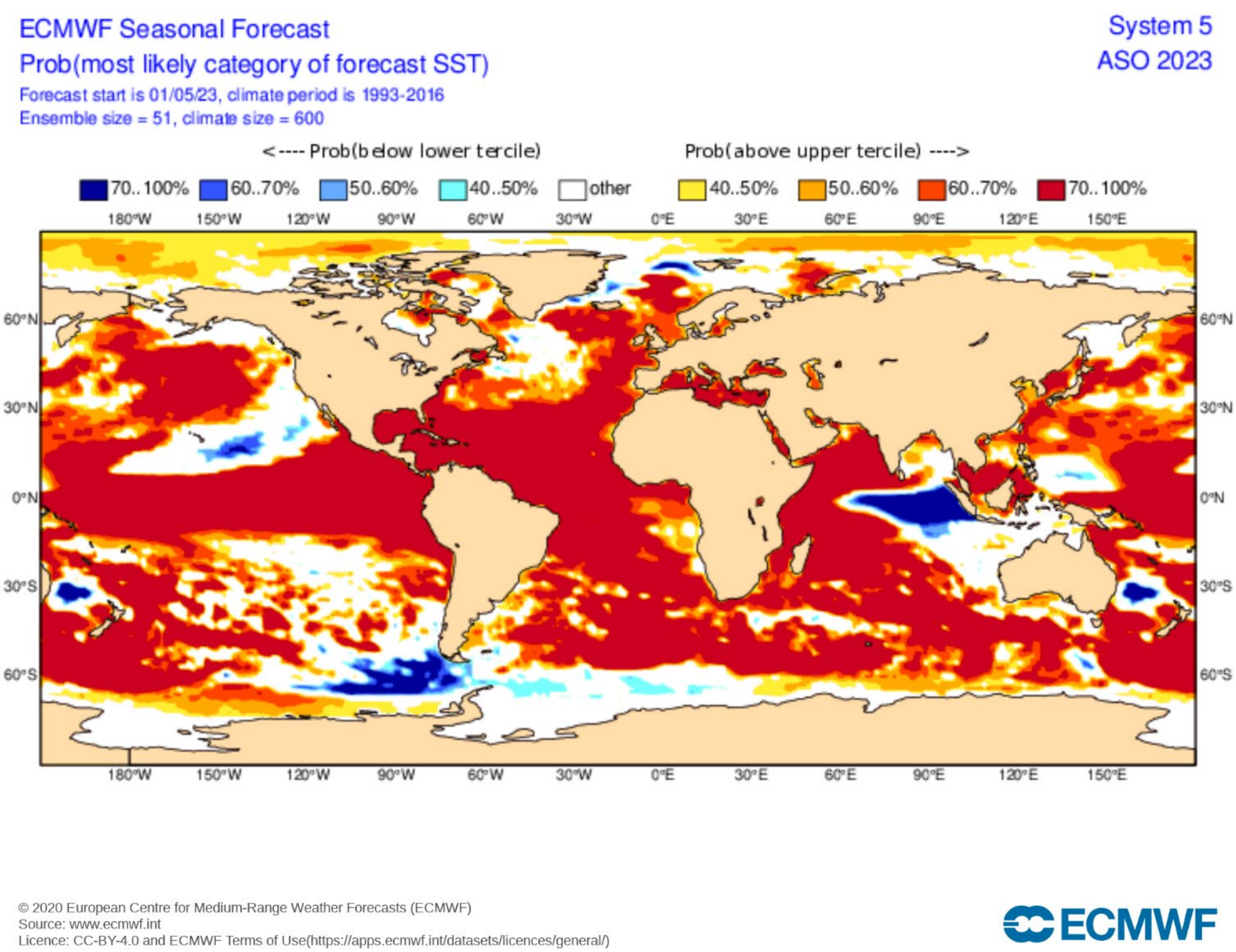


Fig 4: Sea surface temperature anomaly map created based on the May ensemble of the North American Multi Model Ensemble forecast. The baseline for the forecast anomalies is hindcast average SST from 1991 to 2020.

Atlantic Multi-Decadal Oscillation ("AMO")

Atlantic SST appears to oscillate with a period of multiple decades and has been linked by numerous studies with changes in numbers of hurricanes. This sea surface temperature variation is often quantified using the AMO index, calculated by averaging the SST across the whole Atlantic and is frequently used for statistical hurricane prediction. Though AMO indices can be defined using a couple of different approaches, there is general agreement that we have been in a positive phase since 1995, and that this positive phase has been associated with an above average numbers of hurricanes.

The AMO can be forecasted using SST forecast models, and Acrisure Re uses the North American Multi Model ensemble's six-month predictions alongside a statistical model to create a six-month AMO forecast.

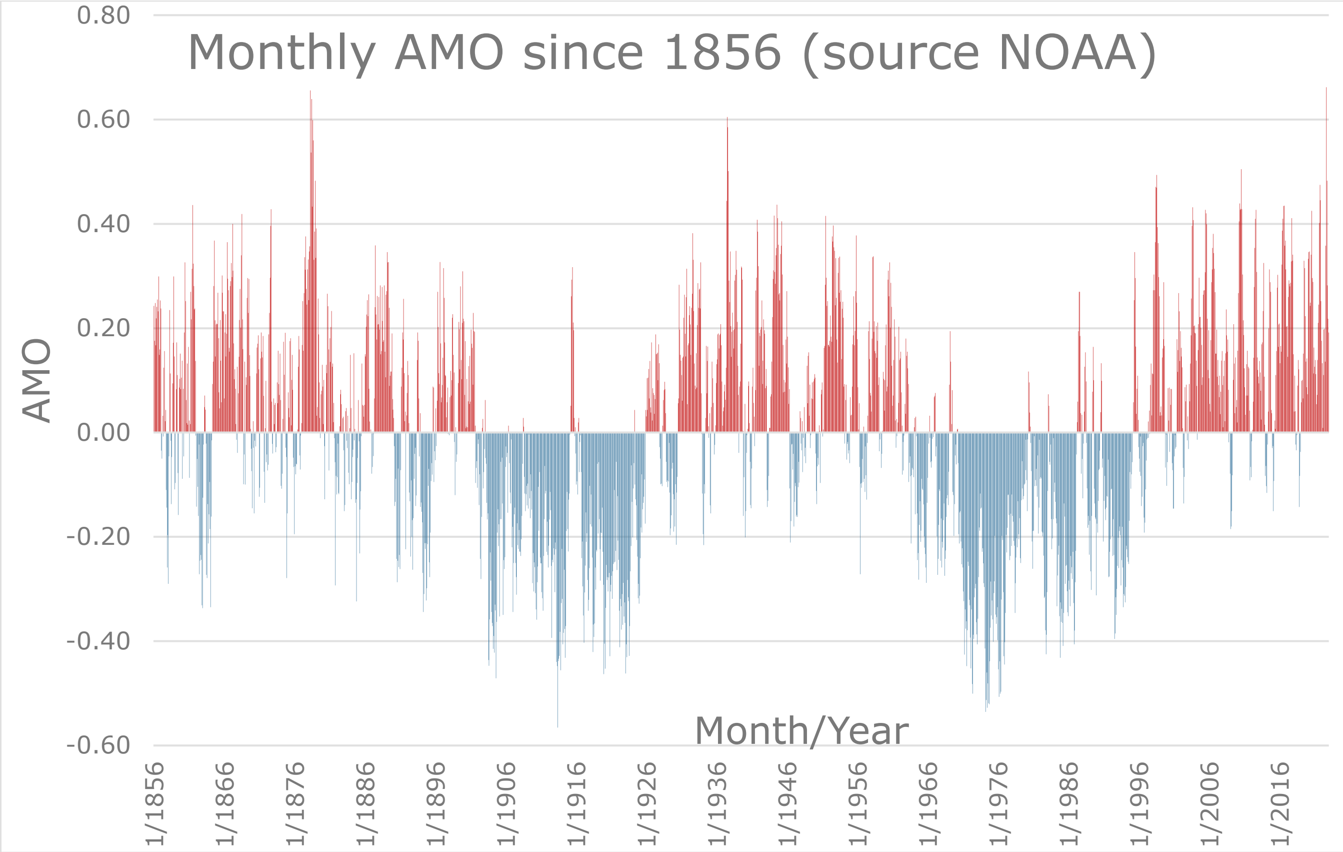


Fig. 5: Annual Atlantic Multidecadal Oscillation (AMO) index values since 1856. The multi decade periods of positive and negative AMO are clearly visible. The record high AMO index last September can be seen as the large red spike towards the end of the time series.

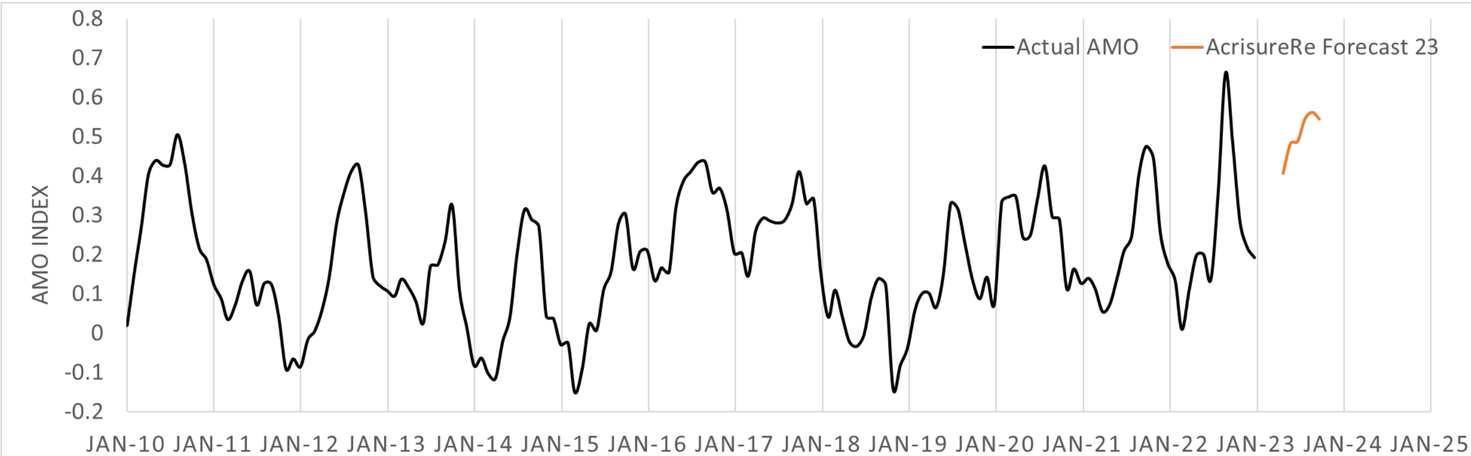


Fig 6: The unsmoothed AMO index since 2010 (black) and a Acrisure Re forecast for 2023 (red). The Acrisure Re forecast is based on a combination of North American Multi-Model Ensemble (NMME) six monthly sea surface temperature forecasts, and statistical techniques.

The AMO has been consistently setting records over the last couple of years. In February and March of 2020 we had the highest values of the AMO since 1950, and it remained very high throughout the highly active 2020 season. In 2021, the AMO values at this time of year were typical and remained barely positive for April and May, however they subsequently ramped up to record levels in October and November. This was warmer than forecasts had indicated and may well have been a significant driver of the long and active 2021 hurricane season. Last summer, we had the highest ever September AMO value, which was also the highest ever value of the index since 1856.

This year, NOAA has unusually not published values beyond January, but SST forecasts currently indicate solidly positive AMO through the key months of the 2023 hurricane season. Typically, positive ENSO conditions combined with positive AMO tend to be associated with average seasons.

4. Tropical Pacific Sea Surface Temperature (ENSO)

There is a strongly established link between the sea surface temperatures in the Tropical Pacific and hurricane activity. There are a range of indices used to quantify SST in the Pacific, and they all oscillate with a period of 3-7 years, defining what is known as the El Nino Southern Oscillation (ENSO). The NINO 3.4 Index is the most widely used in forecasts.

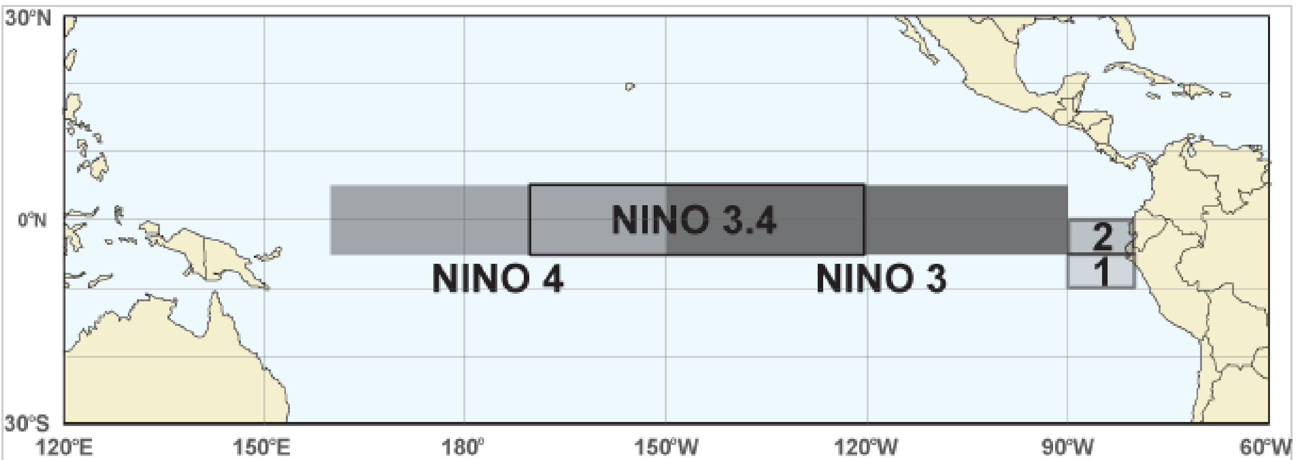
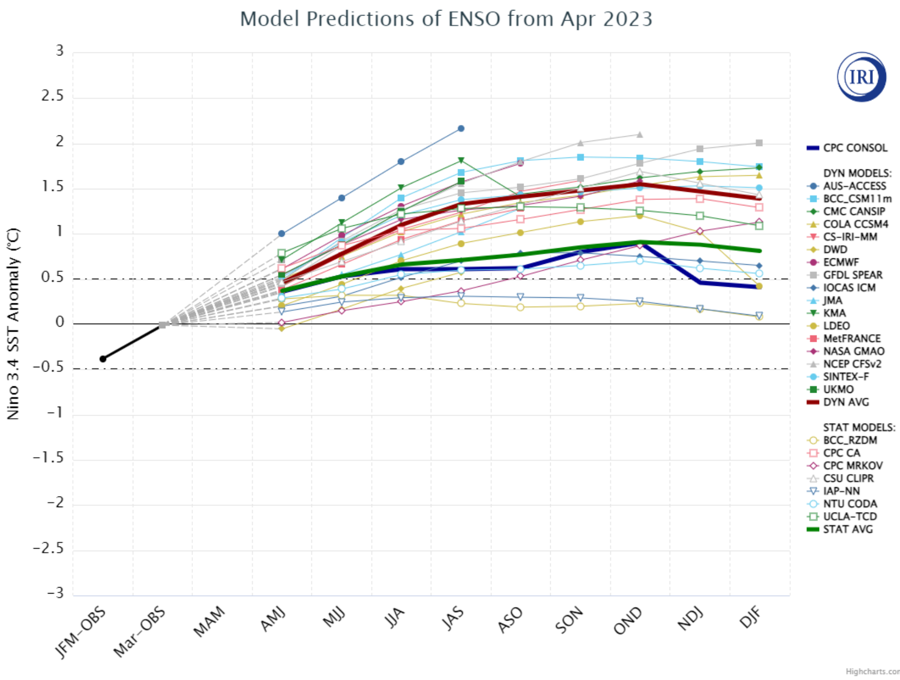


Fig 7: The regions used to calculate the various ENSO indices. One of the most commonly used indices is a three-month average of the NINO 3.4 index. (source: BOM, Australia)

For Neutral conditions the anomaly value is between 0.5 and -0.5. Above 0.5 we have El Nino, and less than -0.5 corresponds to La Nina conditions.

ENSO has been linked to a wide range of additional climate variations including Pacific typhoon activity, rain in California and tornado activity in parts of the US.

Warm (positive) phases of ENSO, El Nino events, are associated with above average wind shear in the Atlantic at latitudes where stronger hurricanes normally form leading to below average activity. La Nina (negative ENSO) events are conversely associated with more favorable conditions for Atlantic hurricane formation, and more active seasons. There is some evidence that US landfall probability is also dependent on ENSO conditions, though this is only true for hurricanes that form in the Western Atlantic and Gulf of Mexico. Interestingly, US landfall probabilities (per storm) may increase in Neutral and El Nino months, which partly counteracts the reduction of overall hurricane numbers in positive ENSO months.



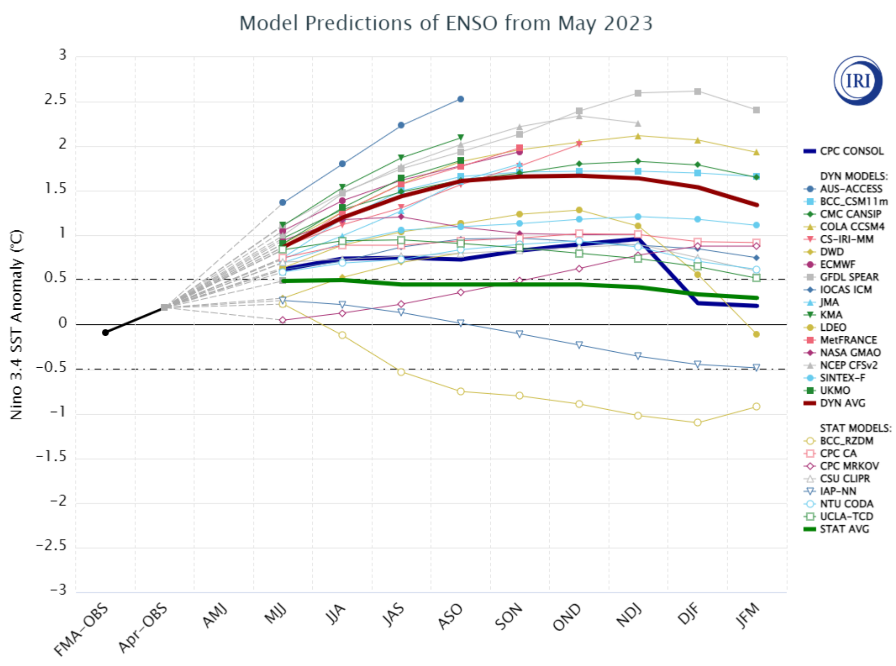


Fig. 8: April and May forecast plumes for ENSO defined as the NINO 3.4 Index averaged over 3 months. There are a range of dynamic and statistical models used to forecast ENSO, and generally the consensus forecasts shown in solid blue, green and red have more skill than most individual forecasts. The consensus is medium to strong El Nino conditions for the key months of the hurricane season.

As of April 2023, we now have a positive anomaly in the Nino 3.4 region, indicating warmer than normal SSTs in the central tropical Pacific. Most models have remained consistent in their predictions of moderate to strong El Nino conditions being present during the peak of hurricane season. However, the May forecasts are showing a larger spread of possible outcomes in the development of El Nino. Despite this, the Climate Prediction Center (CPC) is giving a greater than 90% chance of El Nino conditions being present during the hurricane season, and around 40-45% chance of a very strong El Nino (> 1.5 °C).

After three straight years of La Nina conditions (triple-dip La Nina), it appears we are headed back to El Nino conditions. Generally, this suppresses hurricane activity in Atlantic. This is due to increased wind shear over the MDR and Caribbean, which inhibits storms to form and strengthen. However, this is dependent on the ocean and atmosphere coupling together by peak hurricane season, which is uncertain. Another uncertainty is how strong the El Nino conditions will be during the peak season. Possibilities range from weak to very strong or something in between. It will be interesting to see how fast and strong El Nino develops and if this will be enough to counteract the expected warm waters in the Atlantic.

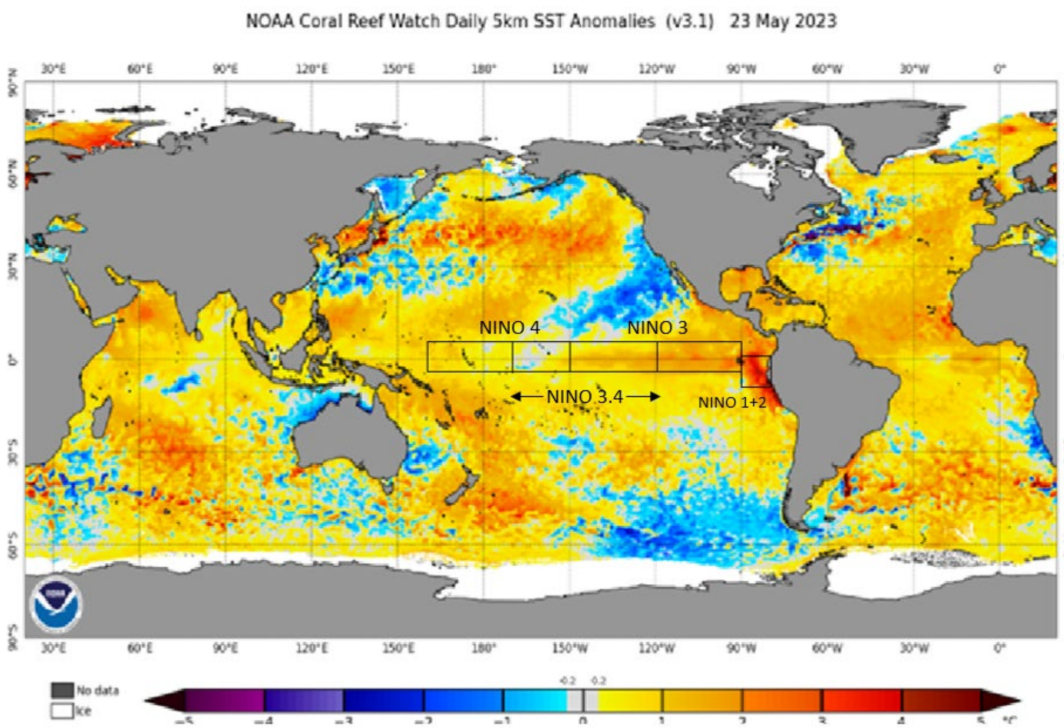


Fig 9: 5km Global SST Anomalies (source: NOAA)

The Quasi-Biennial Oscillation

The Quasi-Biennial Oscillation (QBO) is a regular 'see-sawing' of winds in the tropical stratosphere. A westerly QBO (a positive anomaly relative to average winds) enhances hurricane formation near the Equator by reducing wind shear over the Tropics. Conversely, an easterly QBO (negative anomaly) reduces hurricane formation near the Equator by increasing wind shear over the Tropics.

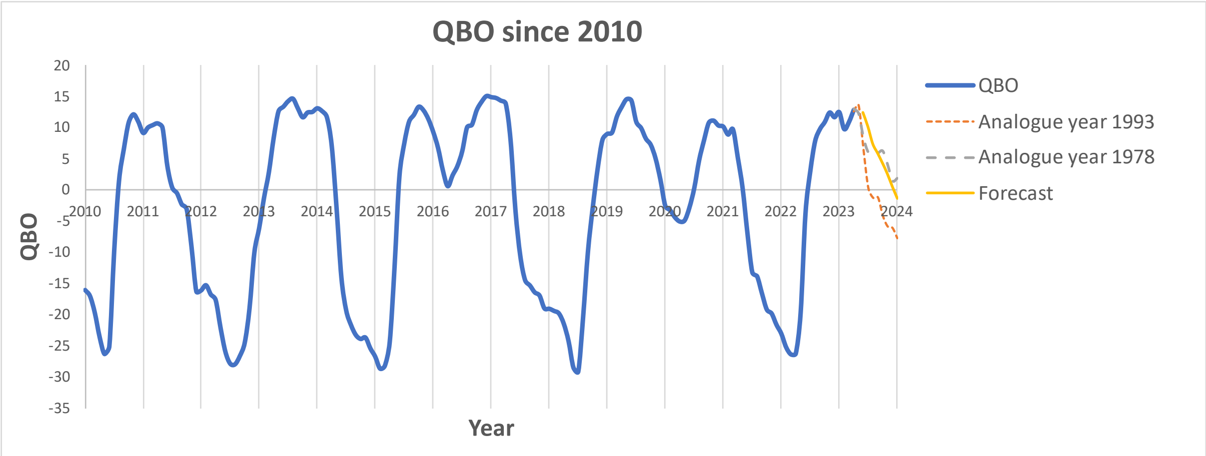


Fig. 10: QBO showing values since 2010. 2016 was a very unusual year with the QBO failing to oscillate to negative values for the first time since measurements began. 2018 marked a return to normal behavior, returning to positive values at the end of the year. Based on both analogue years, and statistical model analysis, the QBO looks set to transition to the negative phase either later this year or the beginning of next year .

Recent publications and some proprietary analysis by Acrisure Re have been unable to show significant impact of the QBO on overall hurricane activity, but it has been claimed that positive QBO values are associated with more Cape Verde storms forming in the deep tropics. The Acrisure Re proprietary analysis indicates that the QBO potentially increases the number of Cape Verde storms in September. Last year the QBO behaved as predicted and switched back to a negative phase for the key months of the hurricane season, potentially moderating the active season.

This year, the QBO starts off in the positive phase, but is expected to transition to the negative phase either later this year or early 2024. Given that the QBO will be weakening to the negative phase during the hurricane season and will potentially be close to neutral, the already small impact the QBO normally has will be muted this year.

5. Saharan Dust

During the hurricane season, Saharan dust can have a significant effect on hurricane activity, as dust inhibits activity in two key ways:

1. Dust absorbs relatively more infrared radiation than a dust free atmosphere, and thus heats up the atmospheric layers where it is present. In summer, the dust is generally transported out over the Atlantic at heights of a few kilometres, hence well within the lower atmosphere. The creation of a warm layer at relatively low to mid-level within the troposphere (lowest layer of the atmosphere where all of Earth's weather occurs) inhibits the rising of warm moist air from near the ocean surface, and thus suppresses the convection required to generate the thunderstorms that develop into tropical storms and hurricanes.
2. Capture of the incoming heat in the atmosphere stops that warmth reaching the ocean and further heating it.

The Saharan dust is produced by erosion of soil in Saharan Africa, and this erosion is more pronounced when the dust producing regions are dry. Hence the rainfall in the Western Sahel (near Saharan Africa), has a direct link with the amount of dust available to transport, and hence the rate of hurricane formation in the Atlantic.

The current precipitation data, and that for the last three months, are similar to last year, with some regions seeing above average rainfall, but no substantial anomalies. Therefore, we expect a near average Saharan Air Layer (SAL).

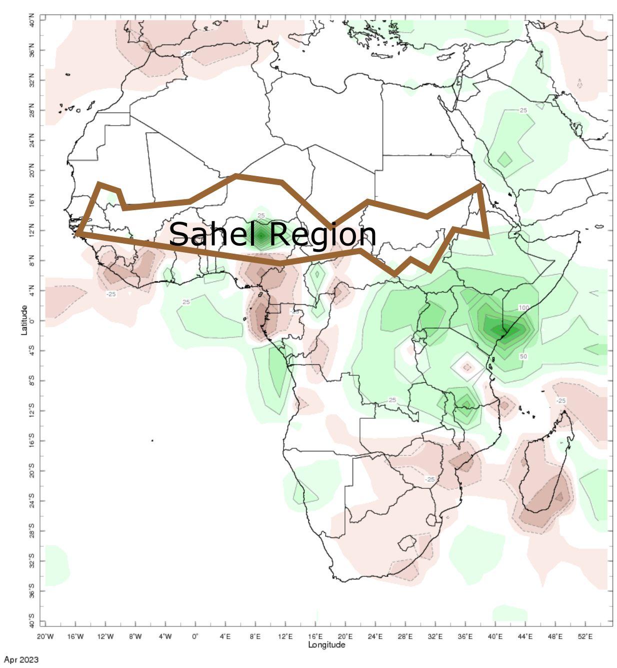


Fig. 11: Precipitation anomaly map of Africa as of April 2023. (Green colors) represent areas of higher than average precipitation and the (brown colors) represent areas of lower than average precipitation.

6. Intraseasonal Variability

While the above factors may impact the big picture for the season, there are some variables that influence the month-to-month variations in tropical cyclone formation. For example, the Madden-Julian Oscillation (MJO) has been shown to effect when hurricanes form. The MJO is an eastwardly migrating tropical wave that traverses the equator every 30 to 60 days. It is characterized by an area of enhanced rainfall and an area of supressed rainfall. Tropical storms and hurricanes are more likely to form when the area of enhanced precipitation is moving over the ocean, especially the Gulf of Mexico and Caribbean. In regions of below average convection, hurricane activity is diminished. During the 2022 Atlantic hurricane season, we saw some interesting interactions with the MJO. During August, the MJO was in a favorable phase for tropical cyclone development. However, due to other factors (see below), there was no tropical cyclone activity. On the other hand, October saw the MJO in a phase that generally does not favor hurricane development and was well below average in terms of storm development.

Another feature that impacts when storms may form are convectively coupled Kelvin waves (CCKW). These are also eastward-propagating tropical waves but move much faster than the MJO. CCKWs can influence tropical cyclone formation by enhancing convection (rainfall) and triggering African easterly waves (AEWs) which are known to be a main precursor for hurricanes to form over the Atlantic in the Main Development Region.

Last year, we saw another component of the atmosphere that contributes to intraseasonal variability. During August of 2022, there was anomalous cooling of the subtropical Atlantic sea surface temperatures between 25° N and 40° N latitude. These below average temperatures along with above average temperatures in the main development region led to a strong temperature gradient in the Atlantic. These conditions favor the development of mid-latitude anticyclonic wavebreaking, an event where the mid-latitude jet stream becomes highly amplified. Wavebreaking events can lead to dry air intrusions in the tropics and higher wind shear in the main development region. Both conditions suppress tropical cyclone activity and we saw this first hand in the extremely long dry spell last August. Monitoring the subtropical Atlantic SSTs will be another key indicator for potential active or inactive periods during the hurricane season.

7. Conclusions

There are many groups making pre-season hurricane forecasts and this report is designed to help put those forecasts into context. We have examined several key variables that have been associated with hurricane activity in numerous published scientific studies to create a qualitative overview of the likely conditions this summer.

The strongest predictors of hurricane activity are Atlantic and Pacific sea surface temperatures often expressed in terms of SST anomalies. This season we have predictions of a warm Atlantic which is generally associated with more storm activity. In contrast the conditions in the Pacific as measured by ENSO are predicted to be unfavorable. Overall, this is consistent with a near average season which is what the consensus of forecasts predicts. However, there is more uncertainty this year given the competing nature of the predicted Atlantic and Pacific SST conditions, the rate of development of El Nino and the recent lack of forecast verification for Atlantic SSTs.

Additional factors like QBO and Saharan dust don’t have a dramatic effect on the overall activity, but QBO is likely to be slightly favorable to hurricane activity at the peak of the season, and there is no reason to expect especially large amounts of dust to suppress activity either.

Overall, statistical and dynamical models, as well as a review of the key variables, are in agreement for a near average hurricane season for 2023. However, uncertainty is higher than normal with a below or above average season still a possibility. As always, despite the forecast, the hurricane season can be defined by one storm.

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