2022 Pre-Season Hurricane Outlook

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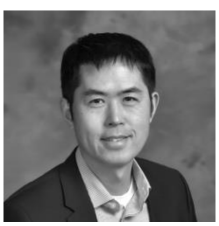

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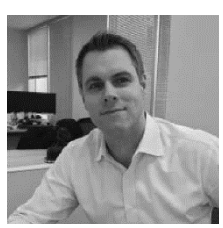

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1. Executive Summary

Once again, a consensus of forecasts is indicating an above average 2022 Atlantic hurricane season. The apparent silver lining this year is that forecasts indicate that the activity should be less than the record 2020 and highly active 2021 seasons. However, at this time last year the consensus was also for a slightly above average season. What we got was the third most active season ever, which certainly gives us reasons to question the usefulness of seasonal forecasts.

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

- Forecast Atlantic Multidecadal Oscillation (AMO) and Atlantic sea surface temperature (SST) are slightly lower than last year, which lends to a less active hurricane season than 2021.
- The El Nino Southern Oscillation (ENSO) is predicted to be a marginally weaker La Nina phase than last year, which will lead to weak vertical wind shear and enhanced hurricane activity.
- Negative ENSO conditions are associated with lower landfall rates for Gulf clusters in the Acrisure Re forecast model.
- Past analog years of 2006 and 2015 would indicate Quasi-Biennial Oscillation (QBO) is trending to a positive anomaly. 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.

The 2021 hurricane season was the third most active on record based on the total number of storms (21 named storms). It followed an extremely active 2020 season. This was the first time on record that two consecutive hurricane seasons exhausted the list of 21 storm names. In terms of US landfalling hurricanes and human impact, the season was fortunately less exceptional, and although Ida produced significant loss of life and property damage it could have been significantly worse if its track had been further east directly over New Orleans.

Scientists attribute the main driver of the heightened hurricane activity in recent years to the warm phase of the Atlantic Multidecadal Oscillation that began in 1995 and favors more, stronger and longer-lasting storms.

We are also continuing to see an increase in slow moving/stalling hurricanes. There is evidence from Kossin & Hall (2019) for a slowing of tropical cyclone forward speeds over the continental U.S. in recent decades, but these observed changes have not yet been confidently linked to climate change. The most recent examples include Harvey (2017), Florence (2018), Dorian (2019), Sally (2020) and Ida (2021). If a storm is slow moving or stationary, it means that the rainfall and destructive winds will last longer, prolonging the threat. Increased stalling and increased rain during stalls imply increased coastal rainfall from tropical cyclones, other factors equal. Over the 1944-2017 period, the annual mean coastal NA tropical cyclone speed has fallen from 18.6 to 15.5 km h−1, about 17%. The 0.05 quantile has decreased from 7.7 to 4.8 km h−1, about 38%. The stalling is driven not only by slower translation, but also the increasing tendency for abrupt changes in track direction. The computed residence-time distributions for tropical cyclones in confined coastal regions show that the tails of these distributions have increased by roughly 32%. Sally brought the highest observed water levels since Hurricane Katrina in 2005 to Pensacola, Florida. The Naval Air Station Pensacola reported more than 24 inches of rain as the storm's forward movement slowed to walking speed of around 2 mph along the coast. Hurricane Dorian remained stationary over the Grand Bahama Island for 14 hours during an abrupt change in direction. Hurricane Laura pushed a storm surge up to 18 feet above ground level into southwestern Louisiana. This was one of the highest readings on record in that state. On average, the forward speed of tropical cyclone translation has slowed since the mid-20th century which adds another threat as we look ahead to the 2022 hurricane season. (Kossin, Hall, 2019)

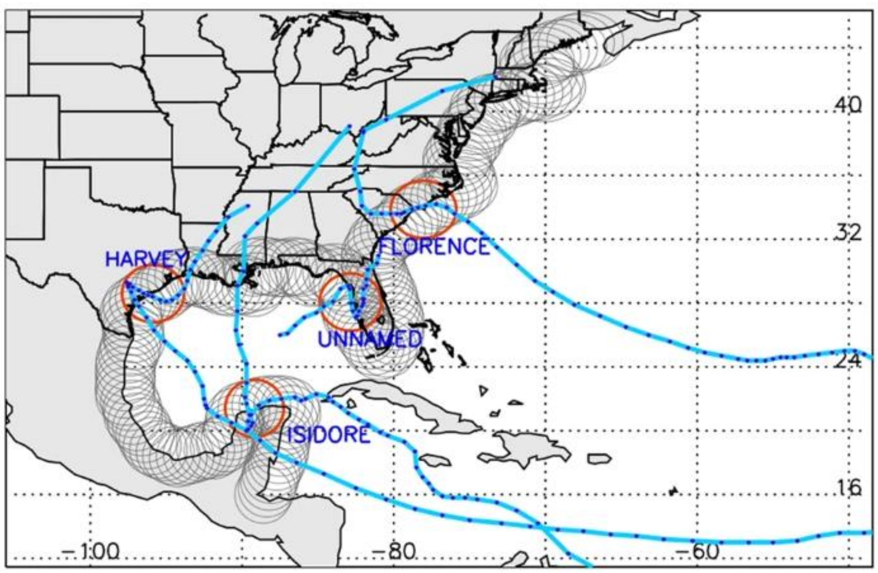


Fig 1: Examples of 4 TCs that stalled near the coast

2. Atlantic Sea Surface Temperature

Hurricanes require minimum 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 23rd, areas with sea surface temperatures over 26.5°C were slightly less extensive than May 23rd last year in some area of the Atlantic. However, the year over year SST difference map (Fig 3) shows some interesting details. The key difference this year is warmer SSTs in the Gulf of Mexico. Coastal waters along the northern and western parts of the Gulf of Mexico are clearly warmer than last year.

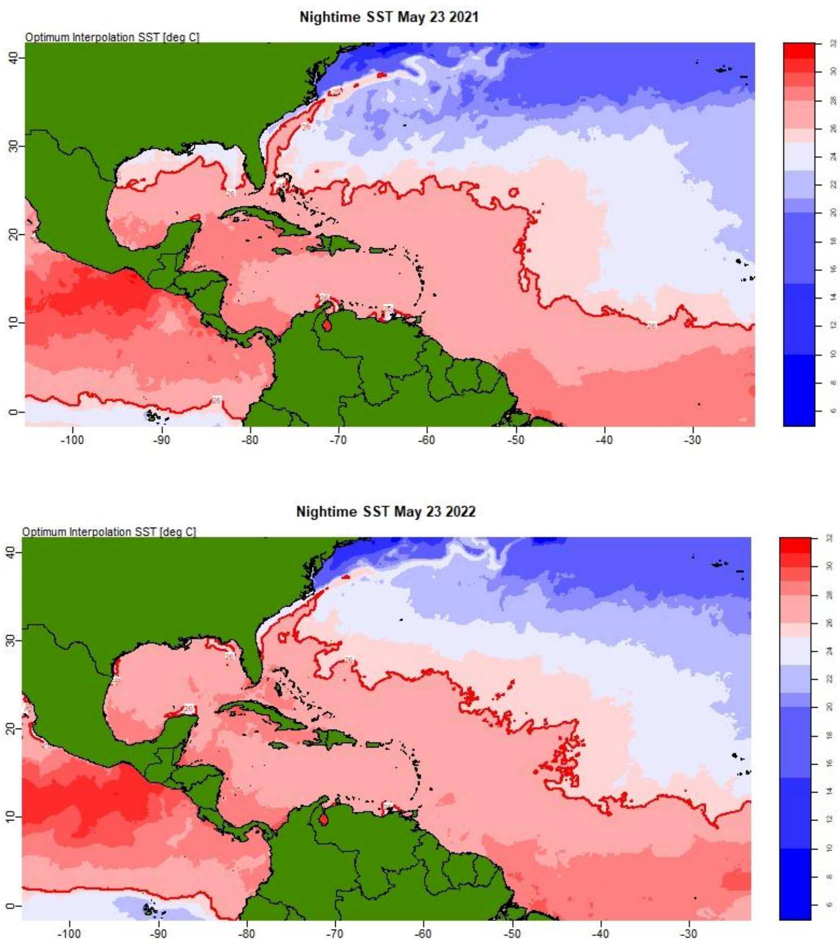


Fig 2: Nightime Sea surface temperatures for May 23, 2022 and May 23, 2021. The 26°C contour is shown as a red line.

Nighttime Sea Surface Temperature Difference (May 23, 2022-May 23, 2021)

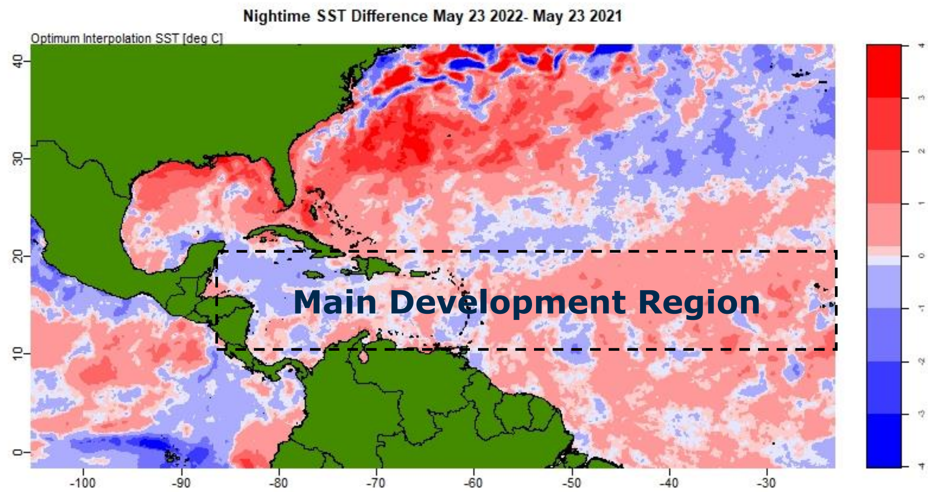


Fig. 3: Sea surface temperature difference in the North Atlantic from May 23, 2022 to May 23, 2021. Blue areas are colder than 2021.

These lower Atlantic SSTs were likely one of the reasons we had a slightly lower consensus forecast than last year. Unfortunately, the situation has now reversed and this year we clearly have higher sea surface temperatures across the whole of the Gulf, as well as more extensive areas of water over 26°C to the east of Florida and the Bahamas. However, we do see cooler SSTs in most of the Caribbean Sea compared to May 23rd, 2021.

In the context of this year's more rapid warming it is sobering to note that despite having relatively cool water surface water over a wide region of the Atlantic last year, we still ended up with a near record season, which also saw particularly high sea surface temperature anomalies developing in the later part of the season. Anomalies are defined as deviations from the mean temperature calculated for a specific reference period.

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 is the anomaly in degrees, whereas the ECMWF is a probability that it will exceed a given tercile in the overall distribution of SST.

Both show cooler conditions in the Caribbean Sea compared to the same forecasts last year and suggest that both the southeastern part of the Gulf and a substantial part of the Main Development Region (MDR) are likely to be cooler than last year. This should favor a less active season with less major hurricanes than last year. In fact, the ECMWF forecast predicts that the whole MDR will most likely be at or below average level, clearly cooler than last year.

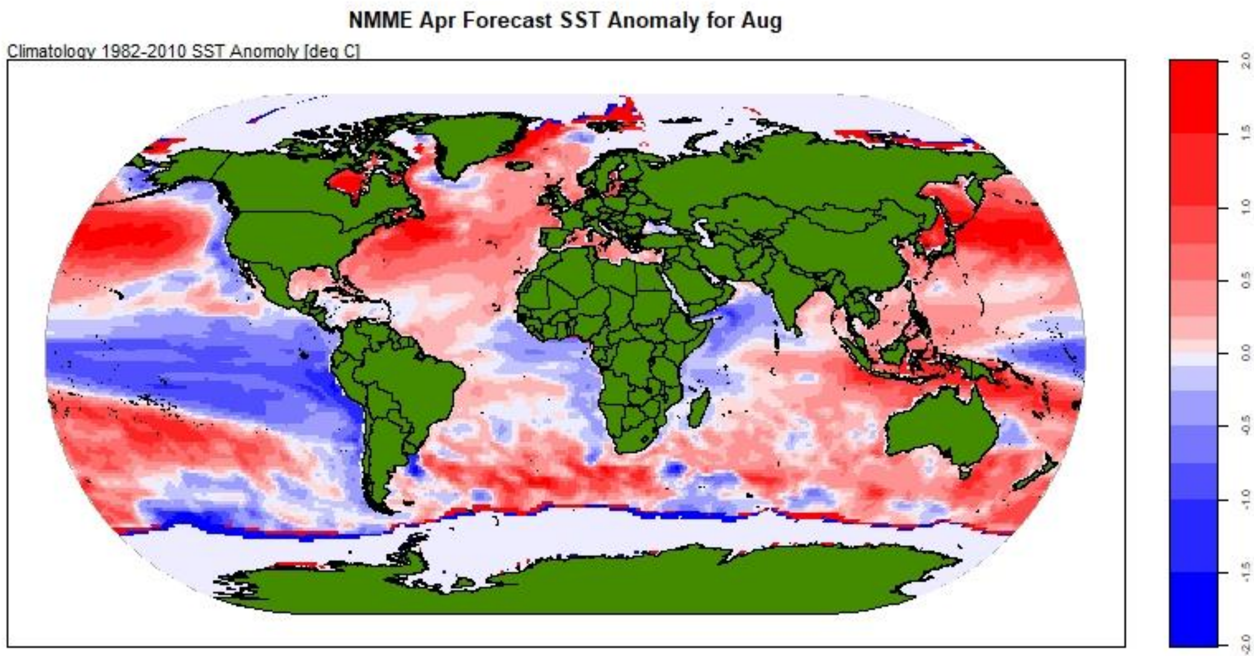


Fig 4: Sea surface temperature anomaly map created based on the April ensemble of the North American Multi Model Ensemble forecast. The baseline for the forecast anomalies is hindcast average SST from 1991 to 2020.

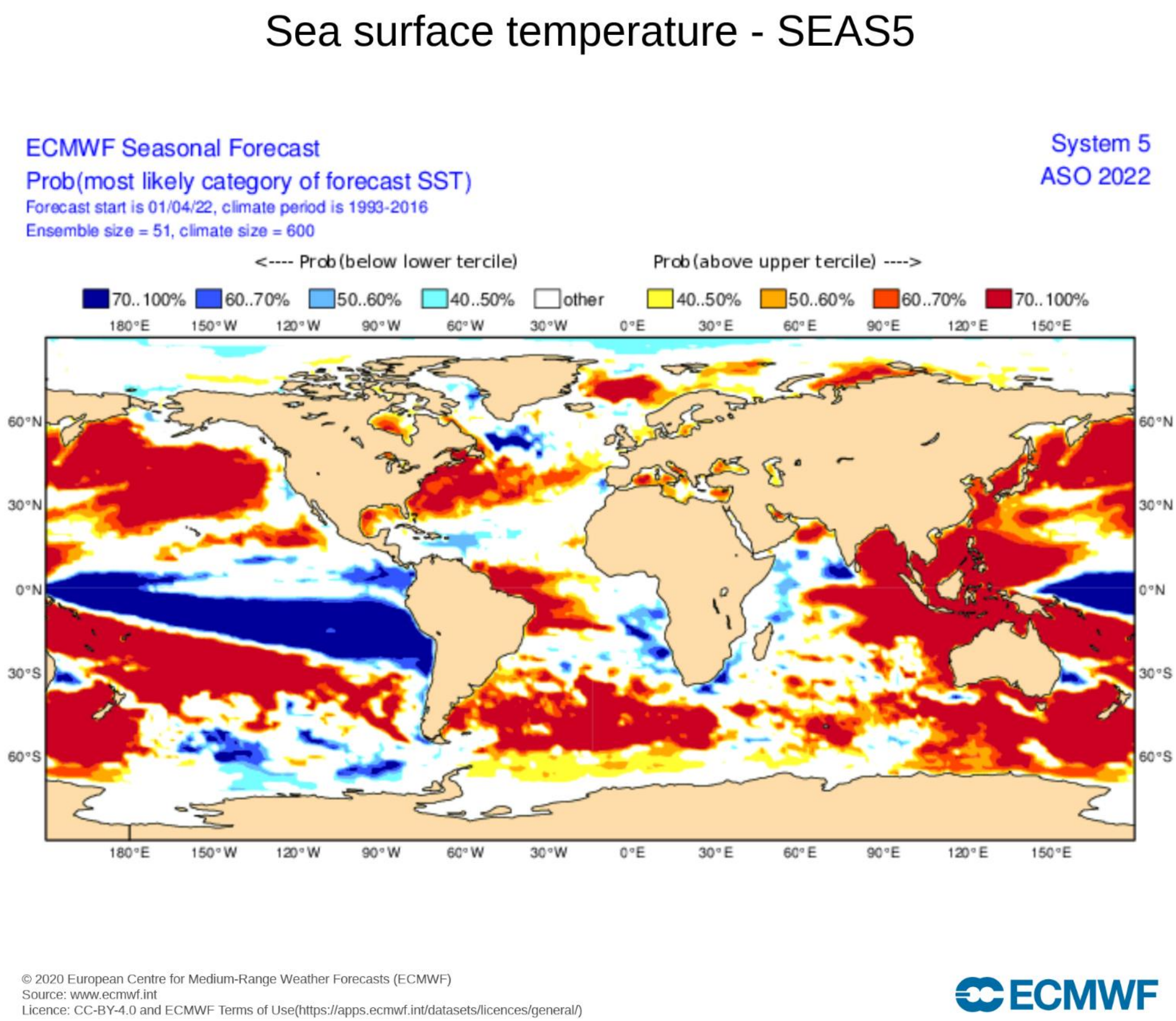


Fig 5: Sea surface temperature anomaly map created based on the April ensemble of the North American Multi Model Ensemble forecast. The baseline for the forecast anomalies is hindcast average SST from 1991 to 2020.

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.

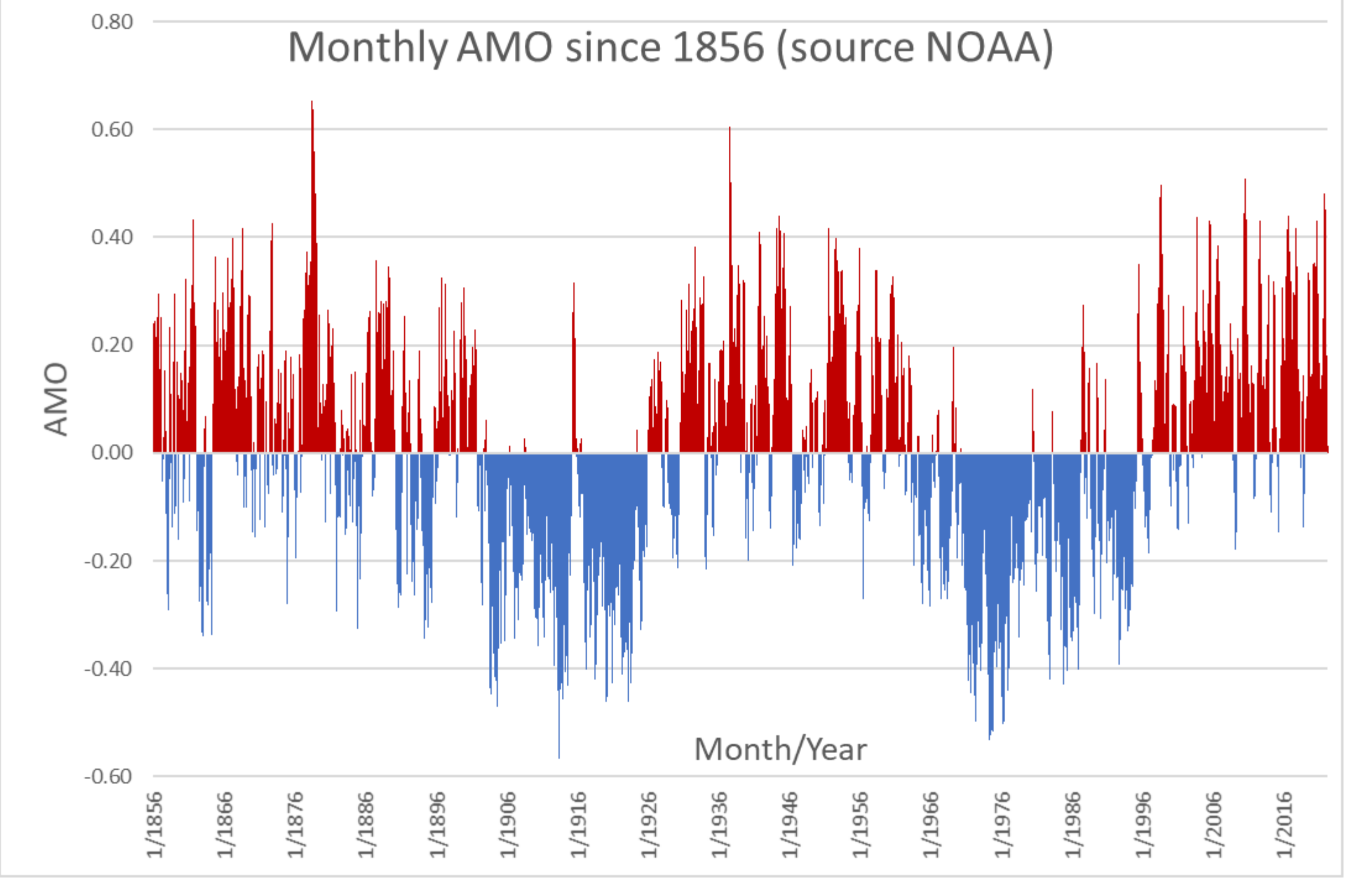


Fig. 6: Annual Atlantic Multidecadal Oscillation (AMO) index values since 1856. The multi decade periods of positive and negative AMO are clearly visible.

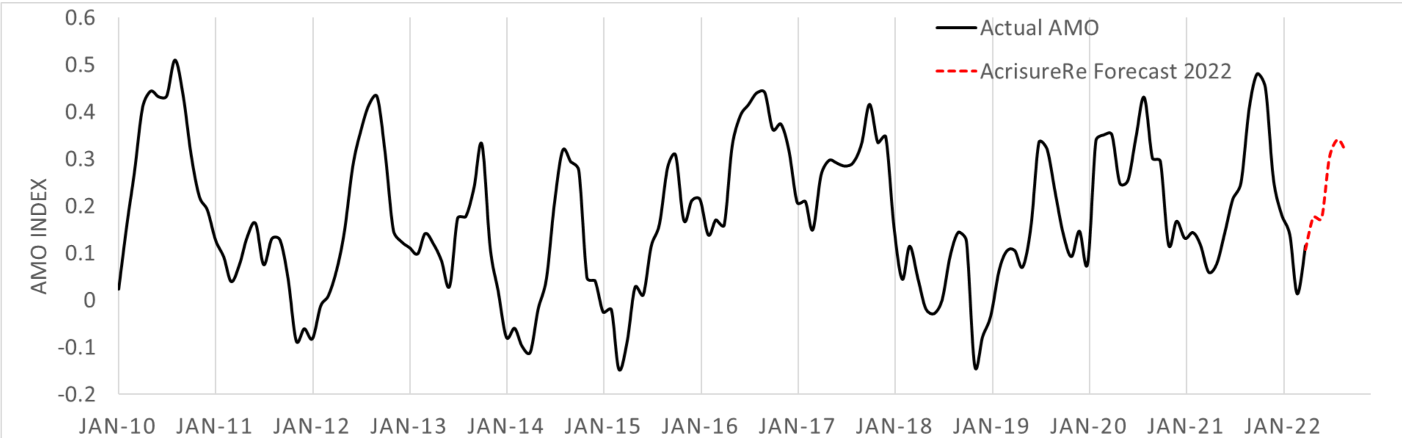


Fig 7: The unsmoothed AMO index since 2010 (black) and a Acrisure Re forecast for 2022 (red). The Acrisure Re forecast is based on a combination of North American Multi-Model Ensemble (NMME) six monthly sea surface temperature forecasts, and statistical techniques.

The AMO has been setting records over the last couple of years. In February and March 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 to become the highest since 1856. This was definitely warmer than forecasts had indicated and may well have been a significant driver of the long and active 2021 hurricane season.

This year the AMO is currently at its lowest March value since 2015, with forecasts currently indicating a weak positive AMO through the key months of the 2022 hurricane season. This would support forecasts for a slightly above average season unlike the record 2020 and extremely active 2021 seasons.

Looking at the SST forecasts for August (Figs 4 and 5) we can also see that the higher SSTs are forecast north of the main development region, which is again consistent with a less active season.

3. 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.

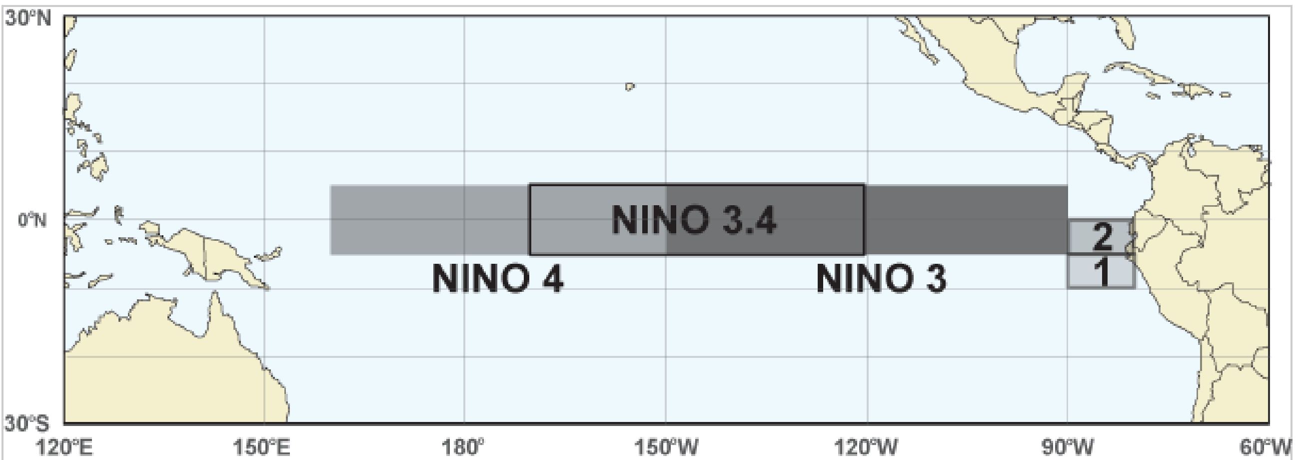


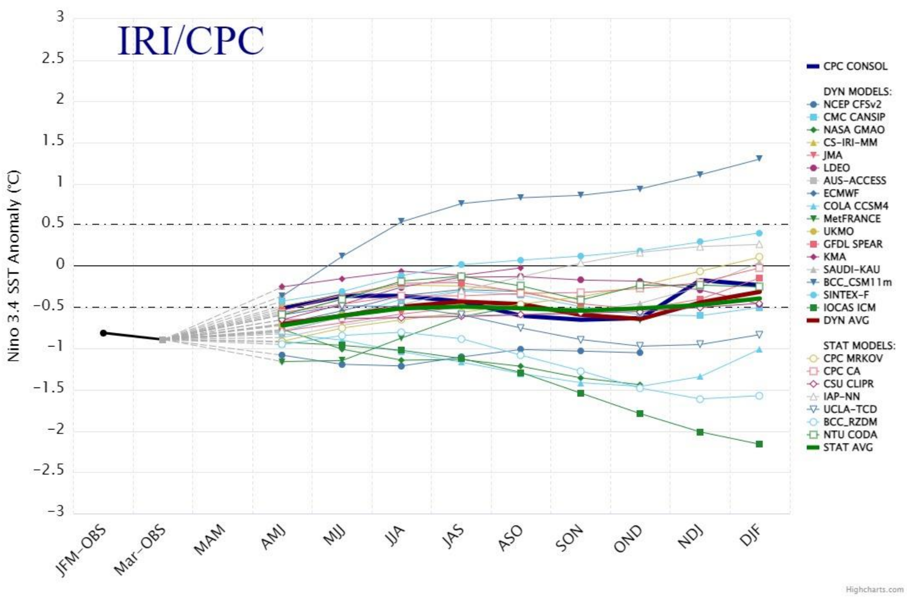
Fig 8: The regions used to calculate the various ENSO indices. One of the most commonly used indices is a three-month average of the NINO3.4 index. (source: BOM, Australia)

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.

Model Predictions of ENSO from Apr 2022



Model Predictions of ENSO from May 2022

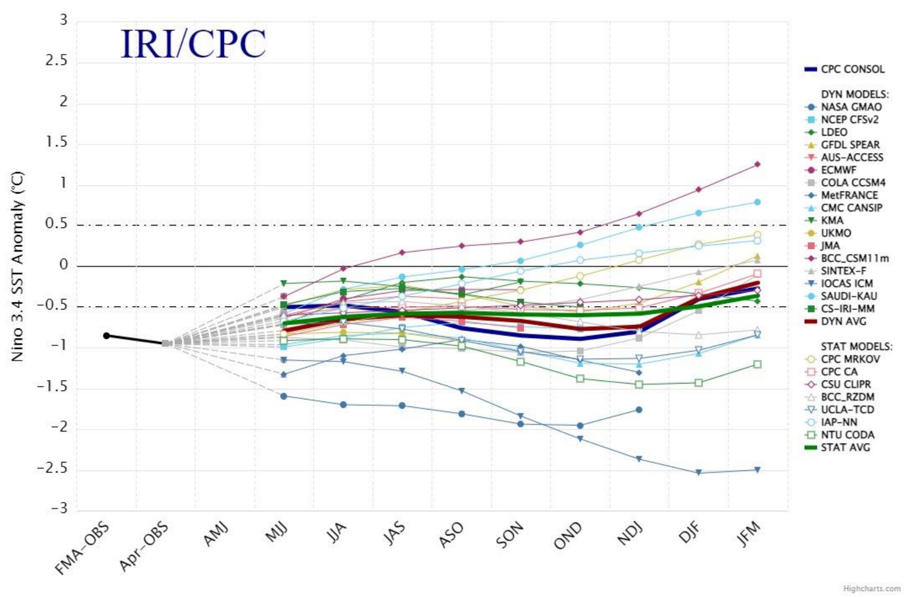


Fig. 9: April and May forecast plumes for ENSO defined as the NINO 3.4 Index averaged over 3 months. There are a range of dynamic and statistical models used to forecast ENSO, and generally the consensus forecasts shown in solid blue, green and red have more skill than most individual forecasts. The consensus is Neutral conditions for the key months of the hurricane season. Here we see a slight negative shift in the consensus towards a continuation of La Nina conditions.

This year in April we had slightly cooler than average surface waters across much of the tropical pacific (La Nina) particularly in the southern portion of the region (fig 10). These conditions have persisted into May and now far fewer models are predicting a shift from La Nina to Neutral conditions in June and July this year. The new consensus in the May predicts conditions remaining as weak La Nina, as shown in the forecast plume in fig 9. In April one model still predicted El Nino conditions, now in May no models predict El Nino for the key months of the hurricane season.

For the last two years, ENSO conditions at the peak of the hurricane season were more negative than predicted in April and May, by between 0.3 and 1°C, which was consistent with the high level of activity. This year we are already seeing a shift in the forecast towards more negative conditions, which could enhance peak season hurricane activity more than the initial forecasts anticipated.

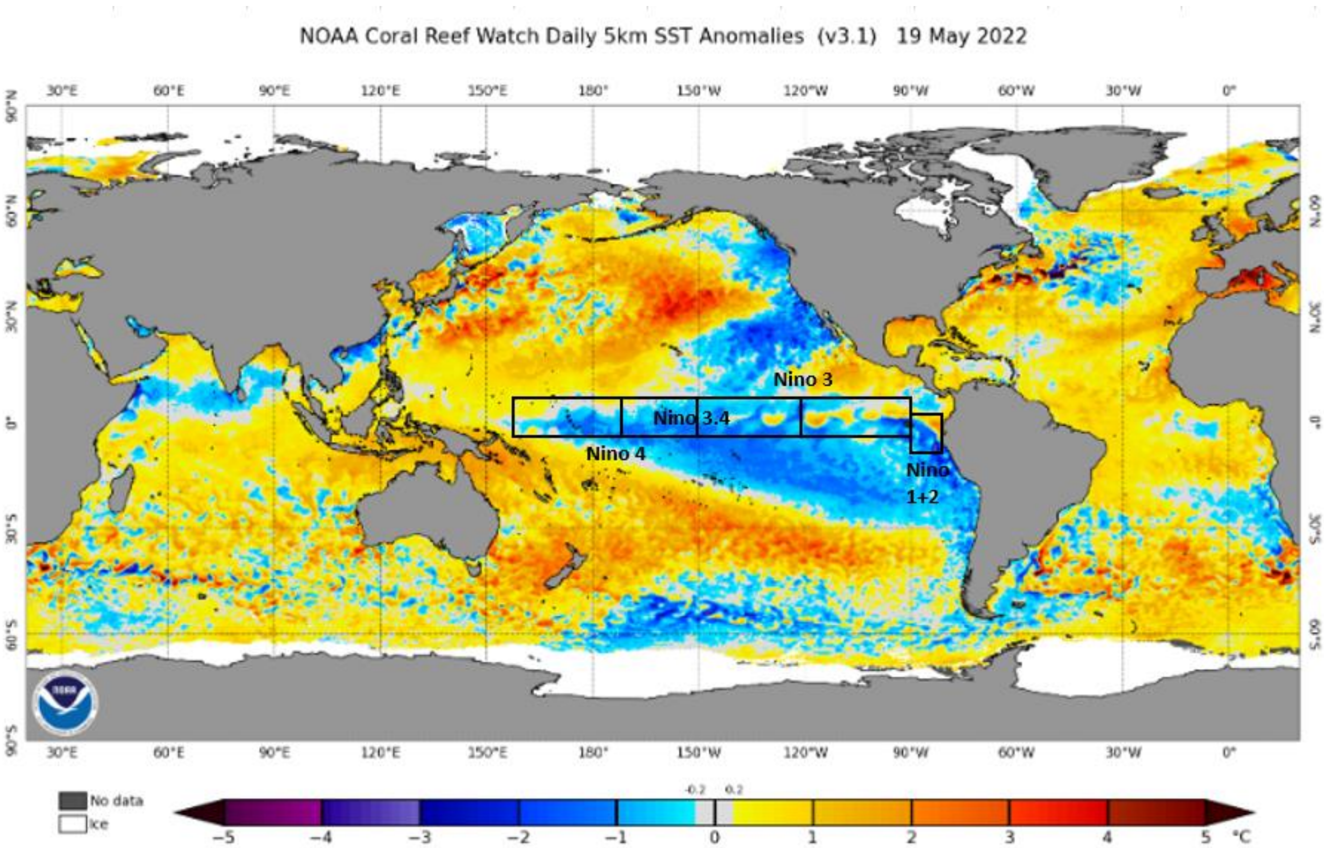


Fig 10: 5km Global SST Anomalies (source: NOAA)

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.

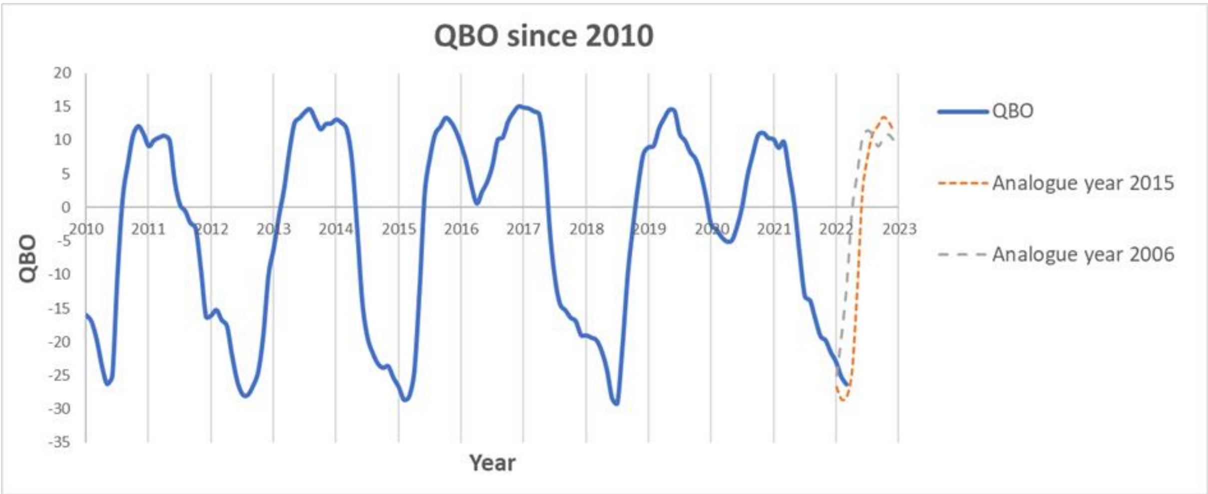


Fig. 11: QBO showing values since 2010. 2016 was a very unusual year with the QBO failing to oscillate to negative values for the first time since measurements began. 2018 marked a return to normal behavior, returning to positive values at the end of the year. Based on both analogue years, and statistical model analysis, QBO looks set to transition back to strongly positive later this 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.

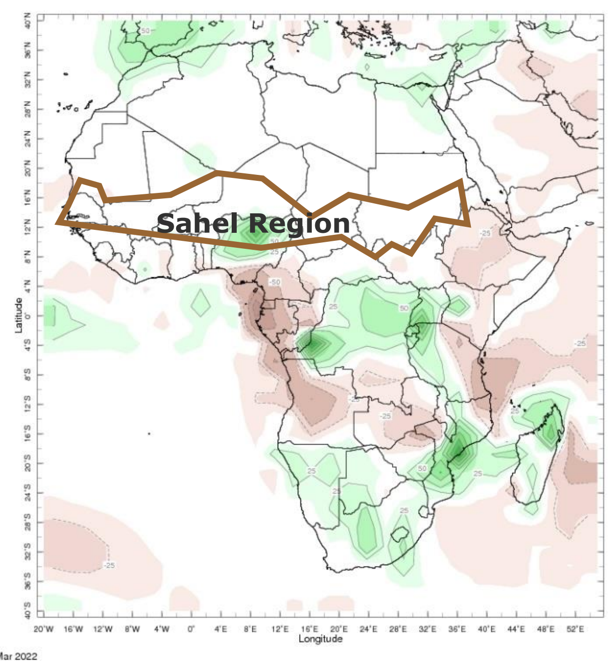
This year the QBO looks likely to be enter a positive phase at the start of the hurricane season and remain strongly positive throughout the season. Hence, although QBO only has a minor impact on hurricane activity, it may enhance activity this year.

4. 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 indicate no substantial anomaly as was the case last year.

Fig. 12: Precipitation anomaly map of Africa as of March 2022. (Green colors) represent areas of higher than average precipitation and the (brown colors) represent areas of lower than average precipitation.

5. 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.

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.

During the 2021 season, the MJO had a big impact throughout the season. In mid-June, the MJO was moving across the Western Hemisphere, creating a favourable environment in the Atlantic basin. This might have contributed to the formation of Bill, Claudette, Danny and Elsa in mid to late June. Then, throughout July and into the beginning of August, the MJO was moving across the Indian Ocean and Maritime continent, which is an unfavourable position for Atlantic storms. In that same period, not one named storm formed in the Atlantic.

In mid to late August there was a Kelvin wave crossing the Western Hemisphere. This added to the already favourable environment and might have influenced the increase in activity we saw at the end of August and beginning of September, especially as Ida was forming in late August.

These two types of tropical waves, as well as Saharan dust mentioned above, can have a large impact on when and where hurricanes form in the Atlantic basin throughout the season. Saharan dust is generally more active early in the season and supresses activity if there is a large concentration. The MJO and CCKWs can occur throughout the season and can facilitate or hinder the development of storms depending on the phase. These phenomena are hard to predict in the short-term, let alone the long-term, so they are of little use when forecasting for the entire season. But they are very important during the season, and they bear watching.

6. Pre-Season Storms

For the 7th straight season, 2021 featured a named storm in the Atlantic prior to the official start of the season on June 1st. The streak of pre-season storms even prompted the National Hurricane Center to move the first Tropical Weather Outlook from June 1st to May 15th to account for these early-forming storms. It is unclear what is causing this potential trend of storms forming before they generally have in the past, but climate change could be playing a role. The 2022 season, however, appears on track to break this streak. As of May 23rd, there were no named storms, although the NHC did classify the first invest of the season, Invest 90L on May 22nd, though that system failed to strengthen into a named storm.

Recent history might suggest that pre-season storms indicate a very active season is ahead. An analysis of Atlantic hurricanes seasons since 1966 does show that, on average, a season with a pre-season storm will have an above-average number of named storms and seasons without pre-season storms have a below-average number of named storms. However, there is minimal difference with regards to the number of hurricanes and major hurricanes whether there is a pre-season storm or not. If the pattern holds until the start of the season, it could foreshadow a season with slightly fewer named storms than otherwise expected. However, we should not expect this to impact the number of hurricanes and major hurricanes, and as we have seen over the last several years, we only need one major storm to define a 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 in order 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 slightly cooler Atlantic which is generally associated with less storm activity. In contrast the conditions in the Pacific as measured by ENSO are predicted to be mildly favorable. Overall, this is consistent with an above average season which is what the consensus of forecasts predicts.

Additional factors like QBO and Saharan dust don’t have a dramatic effect on the overall activity, but QBO is likely to be 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.

Hence overall at this early stage there is little to indicate that this year’s uniform set of predictions for an above average season is inconsistent with either current or forecast conditions a month or so after they were published.

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