NOAA's 2016 Atlantic Hurricane Season Outlook

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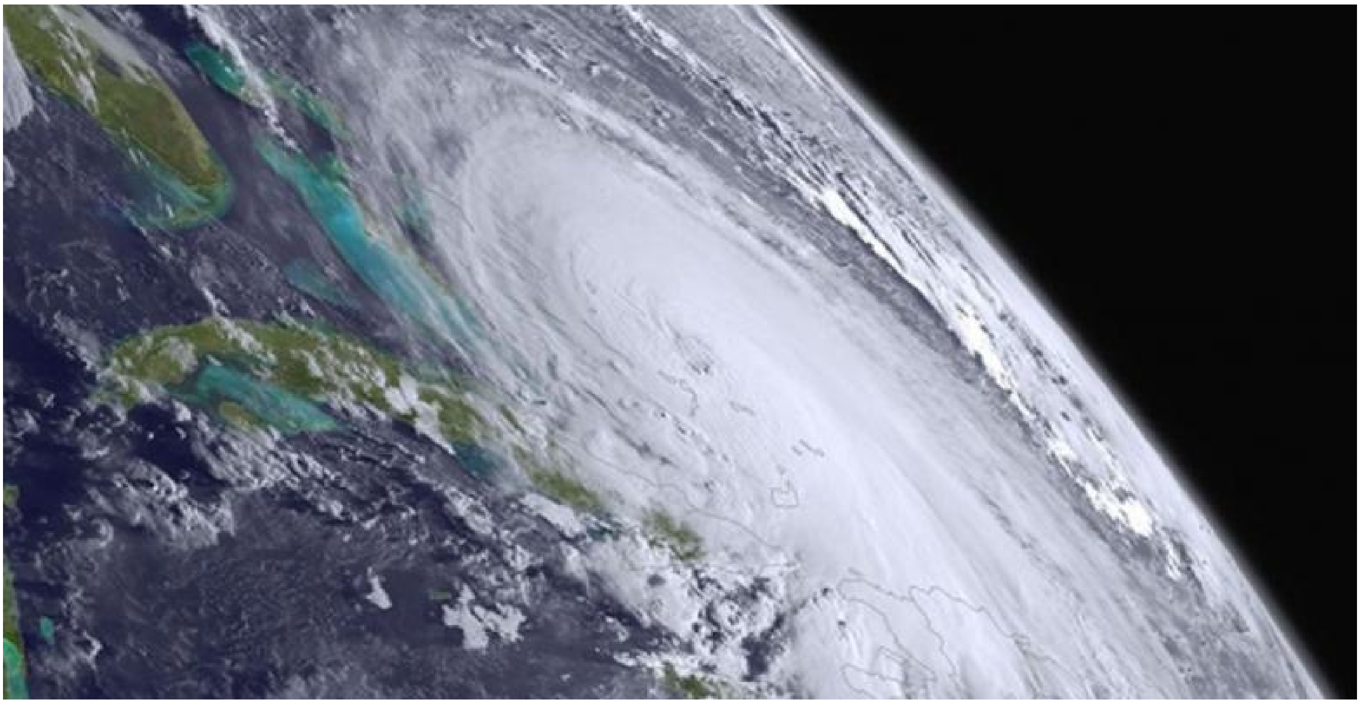

2016 Atlantic Hurricane Season Outlook: Summary

NOAA's 2016 Atlantic Hurricane Season Outlook indicates that a near-normal hurricane season is most likely. The outlook calls for a 45% chance of a near-normal season, a 30% chance of an above-normal season, and a 25% chance of a below-normal season. See NOAA definitions of above-, near-, and below-normal seasons. The Atlantic hurricane region includes the North Atlantic Ocean, Caribbean Sea, and Gulf of Mexico.

a. Predicted Activity

This is a more challenging hurricane season outlook than most because it is difficult to determine whether there will be reinforcing or competing climate influences on tropical storm development. The outlook calls for a 70% probability for each of the following ranges of activity during the 2016 hurricane season:
• 10-16 Named Storms, which includes Alex in January
• 4-8 Hurricanes, which includes Alex in January
• 1-4 Major Hurricanes
• Accumulated Cyclone Energy (ACE) range of 65%-140% of the median, which includes Alex in January

The seasonal activity is expected to fall within these ranges in 70% of seasons with similar climate conditions and uncertainties to those expected this year. These ranges do not represent the total possible ranges of activity seen in past similar years. These expected ranges are centered near the 1981-2010 seasonal averages of 12 named storms, 6 hurricanes, and 3 major hurricanes.

b. Reasoning behind the outlook

NOAA's Atlantic hurricane season outlook is based on predictions of the main climate factors known to influence seasonal Atlantic hurricane activity, along with model predictions of regional and global atmospheric and oceanic conditions.

A main climate factor that influences the Atlantic hurricane season, called the Atlantic Multi-decadal Oscillation (AMO), sets the backdrop upon which other climate phenomena such as El Niño and La Niña overlay. The AMO results in Atlantic hurricane seasons exhibiting 25-40 year periods of generally above-normal activity (called a high-activity era) followed by 25-40 years of generally below-normal activity (called a low-activity era). At present, there is uncertainty as to whether or not the warm AMO and high-activity era for Atlantic hurricanes which began in 1995 has ended, and whether a cool AMO and low-activity era similar to that observed during 1971-1994 has begun.

Two other sources of uncertainty for this outlook are the rate at which the current El Niño impacts dissipate and the rate at which La Niña subsequently develops and intensifies. La Niña favors a more active hurricane season, and the Climate Prediction Center currently predicts about a 70% chance of La Niña during the peak months (August-October) of the hurricane season.

Therefore, it is difficult to predict whether there will be reinforcing or competing climate factors during the hurricane season. The current outlook reflects three general scenarios, each of which has historically produced different hurricane season strengths.
• Scenario 1: Above-normal season most likely if both La Niña and the conditions associated with the high-activity era and warm AMO develop
• Scenario 2: Near-normal season most likely if La Niña develops and the conditions associated with a low-activity era and cool AMO also develop.
• Scenario 3: Below-normal season likelihood increases if La Niña does not develop and conditions typically associated with a low-activity era and cool AMO do develop.

Because of these differing scenarios, there is reduced confidence in predicting whether the season will be above normal or below normal.

This Atlantic hurricane season outlook will be updated in early August, which coincides with the onset of the peak months of the hurricane season.

Preparedness for Tropical Storm and Hurricane Landfalls:

It only takes one storm hitting an area to cause a disaster, regardless of the overall activity. Therefore, residents, businesses, and government agencies of coastal and near-coastal regions are urged to prepare every hurricane season regardless of this, or any other, seasonal outlook.

Predicting where and when hurricanes will strike is related to daily weather patterns, which are not reliably predictable weeks or months in advance. Therefore, it is currently not possible to accurately predict the number or intensity of landfalling hurricanes at these extended ranges, or whether a particular locality will be impacted by a hurricane this season.

DISCUSSION

1. Expected 2016 activity

NOAA's 2016 Atlantic Hurricane Season Outlook indicates that a near-normal hurricane season is the most likely (45% chance), with a 30% chance of an above-normal season and a 25% chance of a below-normal season. See NOAA definitions of above-, near-, and below-normal seasons.

An important measure of the total seasonal activity is NOAA's AccumulatedCyclone Energy (ACE) index , which accounts for the combined intensity and duration of named storms and hurricanes during the season. This outlook indicates a 70% chance that the 2016 seasonal ACE range will be 65%-140% of the median. According to NOAA's hurricane season classifications, an ACE value between 71.4% and 120% of the 1981-2010 median reflects a near-normal season. Values above this range reflect an above-normal season and values below this range reflect a below-normal season.

The 2016 Atlantic hurricane season is predicted to produce (with 70% probability for each range) 10-16 named storms (which includes Hurricane Alex in January), of which 4-8 are expected to become hurricanes, and 1-4 of those are expected to become major hurricanes. These ranges are centered near the 1981-2010 period averages of 12 named storms, 6 hurricanes and 3 major hurricanes.

Predicting the location, number, timing, and strength of hurricanes landfalls is ultimately related to the daily weather patterns including genesis locations and steering patterns, which are not predictable weeks or months in advance. As a result, it is currently not possible to reliably predict the number or intensity of landfalling hurricanes at these extended ranges, or whether a given locality will be impacted by a hurricane this season. Therefore, NOAA does not make an official seasonal hurricane landfall outlook.

2. Science behind the 2016 Outlook

NOAA's Atlantic hurricane season outlooks are based on predictions of the main climate factors known to influence seasonal Atlantic hurricane activity. They also takes into account dynamical model predictions from the NOAA Climate Forecast System (CFS), NOAA Geophysical Fluid Dynamics Lab (GFDL) models FLOR-FA and HI-FLOR, the European Centre for Medium Range Weather Forecasting (ECMWF), the United Kingdom Meteorology (UKMET) office, the EUROpean Seasonal to Inter-annual Prediction (EUROSIP) ensemble, along with ENSO (El Niño/ Southern Oscillation) forecasts from statistical and other dynamical models contained in the suite of Niño 3.4 SST forecasts compiled by the IRI (International Research Institute for Climate and Society) and the NOAA Climate Prediction Center.

a) The Atlantic Multi-Decadal Oscillation (AMO)/ Atlantic sea surface temperatures

Three climate factors which are known to strongly influence the hurricane season include the Atlantic Multi-Decadal Oscillation (AMO), the El Niño / Southern Oscillation (ENSO) cycle, and year-to-year fluctuations in Atlantic SSTs. The AMO produces strong multi-decadal fluctuations in Atlantic hurricane activity, while ENSO and year-to-year fluctuations in Atlantic SSTs contribute to inter-annual variations in hurricane activity.

This year, there is uncertainty surrounding not only the phase of the AMO, but also the phase and strength of ENSO. This combination of uncertainties is problematic from a forecast perspective, because some combinations of ENSO and the AMO are known to reinforce each other, while others are known to offset each other.

Examples of reinforcing climate factors include (1) the combination of La Niña during a high-activity era and warm AMO, which typically produces an above-normal season, and (2) the combination of El Niño during a low-activity era and cold AMO, which typically produces a below-normal season. Conversely, near-normal seasons are often seen when there are competing factors such as the combination of La Niña during a low-activity era and cold AMO or the combination of El Niño during a high-activity era and warm AMO.

Uncertainty in the phase of the AMO translates into uncertainty as to whether or not the current high-activity era for Atlantic hurricanes has ended and whether a low-activity era for Atlantic hurricanes has begun.

Some observations-- pro- and con-- of whether we might be transitioning (or may already have transitioned) to an Atlantic low-activity era and cool AMO phase are:

Pro: The Atlantic hurricane season has featured reduced activity for the last three years . All other periods in which three consecutive seasons were not above normal occurred during a low-activity era.

Con: Studies (Bell and co-authors, 2014, 2015) suggest that the reduced Atlantic hurricane activity during 2013-2015 largely reflects strong inter-annual variability linked to (a) a similar record-strength and rare circulation pattern during both 2013 and 2014 and (b) a strong El Niño during 2015 (Bell and co-authors, 2016).

Pro: The reduced Atlantic hurricane activity during 2013-2015 occurred in combination with significantly enhanced activity in the central eastern Pacific hurricane basins during 2014-2015. This dipole pattern is opposite to that observed during most of the Atlantic high-activity years of 1995-2012.

Pro: These multi-basin changes in hurricane activity have been associated with changes in global SST patterns. Since 2013, the SST anomaly pattern, especially during the cool seasons, has resembled the cool phase of the AMO, whereas during 1995-2012 it reflected the warm AMO phase. The recent cooling has been especially prominent at high latitudes , and might reflect a weakening of the Atlantic Thermohaline Circulation- an underlying driving mechanism of the AMO cool phase.

Con: It is unclear if the observed SST changes over the past three years are truly part of a multi-decadal signal or if they reflect shorter term variability.

Pro: The difference during ASO in area-averaged SST anomalies between the MDR and the remainder of the global Tropics has a stronger relationship to seasonal Atlantic hurricane activity than do SST anomalies in the MDR alone. Since 2010, the relative strength of the positive SST anomalies in the MDR has decreased sharply compared to the remainder of the global Tropics. In fact, during the last two years, SST anomalies in the MDR were comparable to or cooler than the remainder of the global Tropics. These conditions are typical of the cool AMO phase, and with the previous low-activity era for Atlantic hurricanes.

Con: During 2014 and 2015, the decrease in MDR SST anomalies compared to the remainder of the global Tropics was partly the result of warmer SSTs in the equatorial Pacific, which were associated with the eventual development of a very strong El Niño. A similar relative cooling of the MDR was observed during the strong 1997 El Niño.

Con: Just last year, SST anomalies in the MDR were 5th warmest on record during the peak months of the hurricane season. Also, SST anomalies in the MDR warmed considerably as the summer progressed. One could argue that such a significant warming is not consistent with a cool AMO phase. Alternatively, one could argue that the cool AMO phase has not yet developed sufficiently to affect the SST anomaly patterns in the MDR during ASO. Either scenario lead to an uncertain prediction of the SST anomalies in the MDR during ASO 2016.

Pro: NOAA's high-Resolution CFS model is predicting below-average SSTs in the MDR during ASO 2016, along with a strong La Niña. Yet, the model is predicting a near-normal hurricane seasons for both the Atlantic and eastern Pacific. Such a prediction is consistent with the combination of La Niña and the cool AMO phase, and it is not consistent with the combination of La Niña and the warm AMO phase.

b. Possible La Niña

El Niño is now dissipating. The recent sub-surface temperature anomaliesshow that the El Niño-related warming is now confined to the upper 30m of the central and east-central equatorial Pacific. They also show an extensive area of below-average SSTs at depth extending across most of the equatorial Pacific, with those cool anomalies reaching the surface in the eastern Pacific. If the trade winds strengthen in the next few months, the resulting upwelling will bring enough colder water to the surface to produce La Niña. A similar scenario was observed during May-August 1998 in association with the rapid demise of the 1997-98 El Niño. That El Niño was followed by a strengthening La Niña during the 1998 Atlantic hurricane season.

The Climate Prediction Center currently predicts about a 70% chance of La Niña during ASO 2016. Based on the suite of ENSO forecasts issued by the IRI, the average of the dynamical models predicts La Niña to develop during June-August, and to approach moderate strength during ASO.

La Niña favors a stronger hurricane season by producing more conducive atmospheric conditions within the MDR, including 1) weaker vertical wind shear resulting primarily from weaker upper-level westerly winds, 2) decreased sinking motion, and 3) decreased stability. However, the overall hurricane season strength depends not only on La Niña, but also on the phase of the AMO. If La Niña develops, an above-normal season would be much more likely if the warm AMO signal also appears. A near-normal season would be most likely if La Niña develops but the warm AMO signal does not appear.