State of the Science FACT SHEET

Atlantic Hurricanes, Climate Variability and Global Warming

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION • UNITED STATES DEPARTMENT OF COMMERCE

Researchers at the National Oceanic and Atmospheric Administration (NOAA) developed this summary and assessment on the relationship between Atlantic hurricanes and climate change.

What Makes a Hurricane Season Active or Quiet?

Atlantic hurricanes, also called Atlantic tropical cyclones, are intense storms that occur over the North Atlantic Ocean, Caribbean Sea and Gulf of Mexico. Whether an Atlantic hurricane season is active or relatively quiet depends mainly upon the large-scale atmospheric and oceanic environment within the Main Development Region (MDR, which spans the tropical North Atlantic Ocean and Caribbean Sea), during the peak months (August-October) of the hurricane season.

The conditions typically associated with active Atlantic hurricane seasons, and more intense hurricanes, include:

- warmer sea surface temperatures (SSTs) in the MDR
- increased thunderstorm activity
- reduced vertical wind shear (changes of wind direction and/or speed with height) within the MDR (Fig. 1)

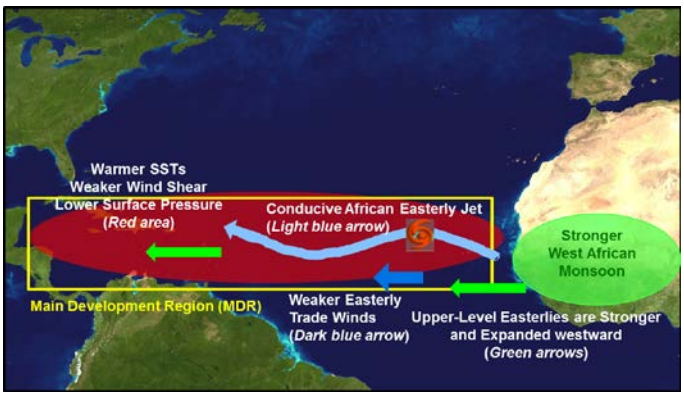

Figure 1: Factors conducive to increased Atlantic hurricane activity

Has Atlantic Hurricane Activity Increased?

Over the last century, there has been a warming trend in the global annual-mean surface temperatures, and in the August-October SSTs averaged across the Atlantic MDR (Fig. 2, top two green curves). The raw counts for Atlantic hurricanes shows a similar upward trend (Fig. 2, blue curve). However, when the hurricane record is adjusted with an estimate of storms that stayed at sea and were likely "missed" in the pre-satellite era, there is no significant increase in Atlantic hurricanes since the late 1800s (Fig. 2, red curve).

The number of hurricanes making U.S. landfall shows no trend over the past century (Fig. 2, orange curve).

A prominent feature of both the raw and adjusted (Fig. 2, red curve) hurricane records is their strong multi-decadal variability. High-activity eras occurred during 1880-1900, 1945-1970 and 1995-present. Low-activity eras occurred during 1901-1930 and 1971-1994. This variability is consistent with changing phases of the Atlantic Multi-decadal Oscillation (AMO) (Fig. 2, bottom green curve). The most recent active period for Atlantic hurricanes began in 1995 as the MDR warmed and atmospheric conditions became conducive for increased hurricane activity, similar to the mid-20th Century.

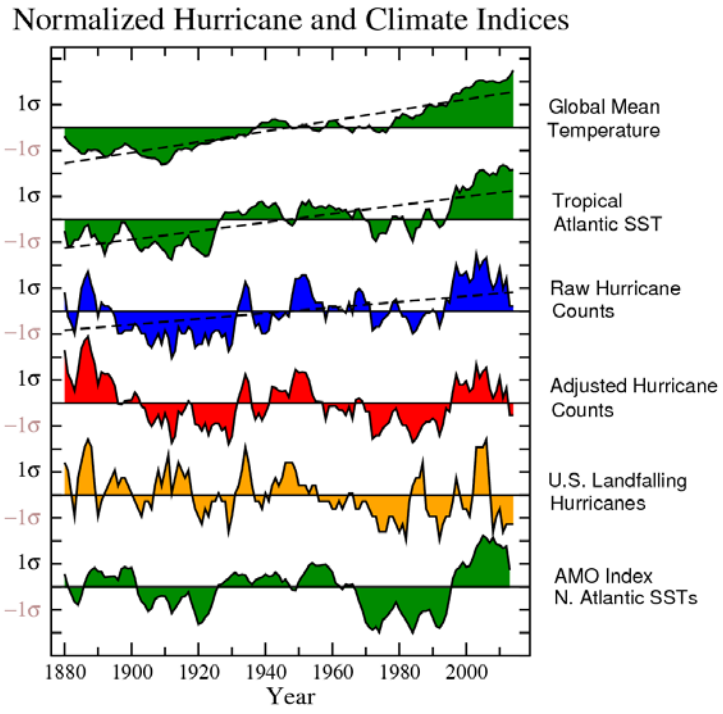

Figure. 2. Five-year running means of normalized Atlantic hurricane and related temperature indices (1878-2016). Top two green curves: global annual-mean surface temperature anomalies (top) and August-October Main Development Region (MDR) SST anomalies (second from top). Blue curve: unadjusted Atlantic hurricane counts. Red curve: adjusted Atlantic hurricane counts. Orange curve: U.S. landfalling hurricane counts. Bottom green curve: North Atlantic (50°-65°N) detrended SST anomalies, an index of the Atlantic Multi-decadal Oscillation (AMO). Vertical axis tic marks denote one standard deviation intervals (shown by the σ symbol). Dashed lines indicate statistically significant linear trends. Only the top three indices have statistically significant trends. Source: Updated from Journal of Climate, vol. 24, 1736-1746 (2011).

What Causes Changes in Atlantic Hurricanes?

The Atlantic Multi-decadal Oscillation is a variation in North Atlantic Ocean temperatures, with warm (positive) and cool (negative) phases historically lasting 25-40 years each. The

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AMO is a main climate pattern associated with changes in Atlantic hurricanes.[1] During the AMO warm phase, SSTs within the MDR are unusually warm compared to the tropical average, and atmospheric conditions are conducive for more Atlantic hurricane activity (Fig.1).

Variability in the frequency of major hurricanes is also linked to changing phases of the AMO.[1] The AMO warm phase was associated with above-average numbers of major hurricanes during the 1950s and 1960s and also beginning in 1995, while the AMO cool phase was associated with below-average major hurricane numbers during 1971-1994.

There is debate about what the AMO actually represents, and in particular whether it primarily reflects natural variability, or whether it has been or can be substantially affected by human influences such as aerosol effects.

Can We Detect Human Influence on Atlantic Hurricanes?

Human-caused increases in greenhouse gas concentrations have very likely contributed to the warming of the Atlantic MDR over the past century (Fig 2, second green curve from top). A reduction in aerosol/particle pollution since the 1970s has likely contributed to the warming over the past 40 years. However, the likely presence of natural multi-decadal Atlantic variability makes it difficult to reliably quantify human effects on trends, both long- and short-term, in Atlantic hurricane activity.

Sophisticated modeling studies are therefore used to address potential human impacts. Based on these studies, the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5)[2] concluded that there is medium confidence that reduced aerosol forcing over the North Atlantic basin contributed to the observed increase in Atlantic tropical cyclones since the 1970s.

Should We Expect Changes Because of Global Warming?

The IPCC AR5[2] assessed published projections of late 21st century tropical cyclone activity in response to human-caused climate warming for assumed future emission scenarios. The report concluded that globally, increases in near-storm precipitation and wind intensity were likely, along with a decrease or no change in tropical storm frequency. The projected increases are about 4% for global average hurricane wind speeds and 10-15% for near-storm precipitation rates, with slightly larger increases projected for the Atlantic basin, according to a recent NOAA study.[3] The increased modeled precipitation rates were largely driven by increased water vapor in the warmer simulated atmosphere.

Atlantic hurricane frequency projections vary widely across studies (from a 50% decrease to a 50% increase), probably due to differing sea surface warming patterns projected by climate models. Models project increased global frequency of very intense (Cat. 4-5) storms, which are the most damaging, but this signal is weaker for Atlantic storms.

Will Hurricane-related Storm Surges Change Due to Sea Level Rise?

The vulnerability of coastal regions to storm-surge flooding is expected to increase with projected sea-level rises and coastal development, although this vulnerability will also depend upon future storm characteristics. A U.S. Interagency Task Force on sea level rise and coastal flooding[3] concluded that global sea level rose by about 0.16 to 0.21 m (7 to 8 inches) between 1900 and 2015. The task force also established plausible global sea-level rise scenarios, which range from 0.3 to 2.5 m (1 to 8 feet) by 2100. Under high emissions, IPCC AR5[2] projects a likely rise of about 0.5-1.0 m (1.5-3 feet) by 2100. Regional sea level rises along the northeastern U.S. and western Gulf coasts are projected to be 30 to 50% higher than the global mean.[4]

Where Do We Need to Focus Our Research?

More research is needed to better understand the causes of trends and multi-decadal fluctuations in hurricane activity. That research should consider not only improved climate modeling and observational studies of the internal oceanic and atmospheric processes, but also other natural and human-caused influences including greenhouse gases, aerosols/dust, volcanoes, and solar variations. Future sea level rise projections need to be better constrained, as rising sea levels can have disastrous consequences for coastal communities regardless of future hurricane activity.

References

[1] *Journal of Climate*, vol. 19, 590-612 (2006).
[2] Climate Change 2013: The Physical Science Basis. Contribution of Working Group 1 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (2013).
[3] *Journal of Climate*, vol. 28, 7203-7224 (2015).
[4] Global and Regional Sea Level Rise Scenarios for the U.S. NOAA Tech. Rep. NOS CO-OPS 83 (2017).