State of the Science FACT SHEET

Atlantic Hurricanes and Climate Change

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION • UNITED STATES DEPARTMENT OF COMMERCE

Summary

Here, we address three important and societally relevant questions about Atlantic hurricane activity and climate: 1) Has there been a change in the number of Atlantic hurricanes? 2) Has human-caused climate change had any detectable influence on hurricanes and their impacts? 3) What changes do we expect going forward with continued global warming?

Several Atlantic hurricane activity metrics show pronounced increases since 1980. However, evidence for any significant trends is much weaker considering trends beginning from the early 20th century, partly due to observed data limitations. Decreases in aerosol forcing since the 1970s and multidecadal ocean circulation changes are thought to be contributing to the increased Atlantic hurricane activity since 1980, though their relative contributions are still uncertain and with no scientific consensus. While greenhouse gas-induced warming may have also affected Atlantic hurricane activity, a detectable greenhouse gas influence on hurricane activity has not been identified with high confidence. This is partly due to the masking of any century-scale trends by pronounced multidecadal variability due to aerosols and/or internal variability. Determining the relative contributions of aerosols, internal variability, and other factors to the recent multidecadal variations in Atlantic hurricane activity has important implications for predictions for the coming decades.

Future projections include increased risk of coastal inundation during storms due to sea level rise, likely increased hurricane rain rates and wind intensities, and possible increased numbers of Category 4-5 hurricanes, along with decreased numbers of tropical storms and hurricanes (all categories combined).

Observed Atlantic Hurricane Changes

Several measures of historical Atlantic hurricane activity, including annual numbers of tropical storms, hurricanes, and major hurricanes, as well as hurricane intensities, power dissipation index (PDI), and rapid intensification occurrence, all show pronounced increases since around 1980. Since the 1940s and 50s, major hurricane annual counts and related measures have shown pronounced multidecadal variations, including a major hurricane "drought" lasting from the 1970s through the mid-1990s. An increase in stalling near-coastal U.S. tropical cyclones and increases in accumulated rainfall during such stalls has been observed since about 1950. On the century time scale (e.g., since 1900) there has been no significant trend in annual numbers of U.S. landfalling tropical storms, hurricanes, or major hurricanes (Fig. 1). A decreasing trend since 1900 in the propagation speed of tropical storms and hurricanes over the continental U.S. has been reported. Basin-wide annual counts of tropical storms, hurricanes, and major hurricanes since the late 1800s show strong rising trends, but after taking into account changes in observing capabilities, studies suggest no strong evidence for a significant upward trend in any of these basin-wide storm count metrics (Fig. 1).

In terms of important environmental factors related to hurricanes, observed tropical Atlantic and Gulf of Mexico sea surface temperatures show pronounced warming since 1900 as well as multidecadal variability. Since 1950, tropical Atlantic vertical wind shear, sea surface temperatures, and inferred Atlantic Ocean Meridional Overturning Circulation all show pronounced multi-decadal variations that are well-correlated to Atlantic major hurricane counts. Economic damage in the U.S. from hurricanes has increased remarkably over the past century, as has the population and value of built infrastructure in hurricane-prone regions. Prehistoric geologic proxy records of hurricane activity covering thousands of years in some locations offer a complementary source of information on the potential for centennial-scale Atlantic hurricane variability originating from natural causes.

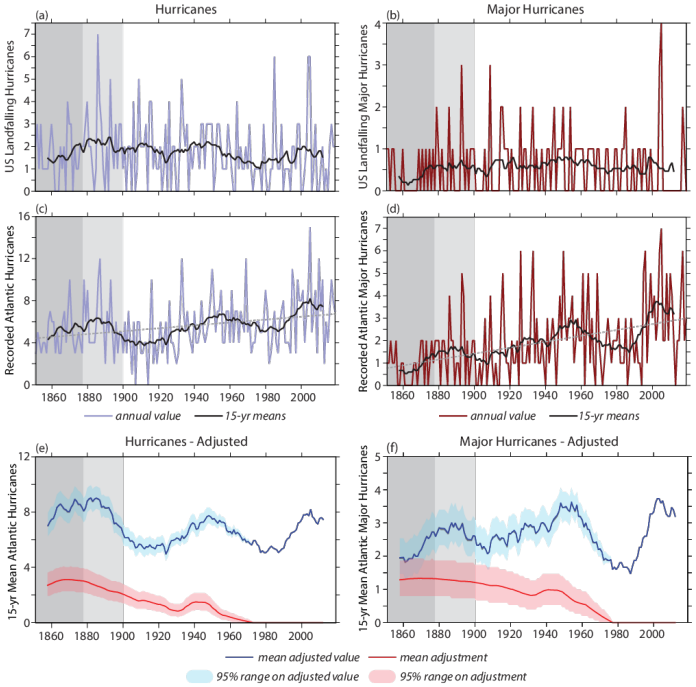

Fig. 1. Atlantic hurricane (Cat. 1-5; left column) and major hurricane (Cat. 3-5; right column) count time series since 1851. Darker gray shading in earlier decades denotes lower confidence due to more limited observing capabilities. Top row: U.S. landfalling counts; middle row: raw Atlantic basin-wide counts; bottom row: Atlantic adjusted basin-wide counts (blue line) including estimated adjustments (red line) for likely missing storms. Red and blue shading: 95% confidence ranges on adjusted values. Source: Vecchi et al., Nat. Comm*. 2021.*

Attribution of Observed Atlantic Hurricane Changes

For global mean temperature, the Intergovernmental Panel on Climate Change Sixth Assessment Report made highly confident attribution statements linking global warming to anthropogenic increases in greenhouse gases. The observed global warming trend since the late 1800s stands out from multidecadal variations in the record. This warming trend is consistent with climate model simulations that include anthropogenic increases in greenhouse gases, changes in anthropogenic aerosol forcing and natural volcanic emissions. In contrast, for Atlantic hurricane activity, the attribution of

observed changes to increasing greenhouse gases is not yet assessed as highly confident, apart from impacts related to sea level rise.

Observed hurricane data generally either do not show clear centennial-scale trends or do not cover enough years to assess century-scale trends. Pronounced multidecadal variations typically dominate over long-term (centennial-scale) trends over decadal timescales for Atlantic hurricanes. One statistical study concluded that the probability of extreme tropical cyclone rainfall events like that during Hurricane Maria has increased over parts of Puerto Rico since 1956 due to long-term climate change. However, recent observed increases (e.g., since 1980) in Atlantic hurricane activity are generally not representative of longer-term (70-year to centennial-scale) trends, in cases where such longer-term records are available. Rather, trends since 1980 appear to represent the latest upswing in a series of multi-decadal variations, leaving open the question of what caused the multi-decadal swings.

Two leading candidates for causing the pronounced multidecadal variability in Atlantic basin-wide hurricane activity and related metrics since about 1950 are temporal changes in anthropogenic aerosols and internal climate variability associated with Atlantic Ocean circulation changes. A recent NOAA modeling study demonstrated how the observed increase in Atlantic tropical storm frequency since 1980 can be partly reproduced by the simulated response to reduced anthropogenic aerosol forcing during that time, resulting from more stringent air pollution measures over North America and Europe. Recent NOAA studies have shown that multidecadal variations of tropical North Atlantic vertical wind shear and associated major hurricane counts are well-correlated to a subsurface ocean "fingerprint" of multidecadal variations in the Atlantic Ocean Meridional Overturning Circulation, and that these inferred multidecadal ocean circulation variations are more likely due to internal variability than changes in aerosol forcing. A further linkage has been proposed between multidecadal swings in major hurricane counts and variations in atmospheric dust loading--from natural or anthropogenic sources. Greenhouse gas-induced climate warming may also have contributed to the post-1980 Atlantic hurricane changes, including the observed increase in rapid intensification, which one modeling study links in part to greenhouse gas-dominated anthropogenic forcing. However, confident quantitative attribution of observed multi-decadal Atlantic hurricane variability to the above mechanisms remains an unsettled topic of research. Particularly active areas of research include the uncertain modeled response of the Atlantic basin to anthropogenic aerosol forcing and the uncertain magnitude of internal multidecadal variability of the Atlantic Ocean Meridional Overturning Circulation, which is apparently underestimated in many climate models.

Despite difficulties in attributing past multidecadal Atlantic hurricane variations to aerosols, internal natural variability, or other factors, the implications of such attributions are substantial. For example, in Fig. 1(f) if the multidecadal Atlantic major hurricane drought in the 1970s and 80s were primarily aerosol-induced, then one might expect continued elevated Atlantic major hurricane counts in coming decades (in combination with any greenhouse gas-induced trend) since we don't anticipate a resumption of high levels of anthropogenic aerosol emissions from North America or Europe. However, if the Atlantic major hurricane drought were primarily a natural fluctuation due to ocean circulation changes, then another such period of reduced activity might be expected to recur in the coming few decades.

Concerning event attribution, model simulations of current and preindustrial conditions and observed records of extreme rainfall in general have been used to attribute extreme rainfall amounts in several recent tropical cyclone events partly to anthropogenic forcing such as increased greenhouse gases.

There is disagreement among the few published analyses on whether U.S. hurricane damage, when normalized by temporal changes in exposed wealth, has increased since 1900. However, these studies agree that increases in population and wealth, including the value of built infrastructure in hurricane-prone regions, are dominant over hurricane changes in explaining the increase over the past century in annual economic damage from U.S. landfalling hurricanes.

Future Atlantic Hurricanes and Global Warming

A detectable greenhouse gas-induced change in historical observed Atlantic hurricane behavior would raise confidence in projected 21st century changes under various greenhouse gas-dominated global warming scenarios. However, since a highly confident attribution has not yet been established for Atlantic hurricanes, future projections rely mostly on climate models alone. This contrasts with the case for global and regional temperatures and sea-level rise-related impacts, where projections are relatively much more confident.

Based on a survey of existing studies, with regards to future North Atlantic, Caribbean Sea, and Gulf of Mexico tropical storm and hurricane activity, a 2 ˚C (4 ˚F) global warming scenario would be expected to lead to the following:

- Storm inundation levels during hurricane surge events will increase due to sea level rise, anticipated to rise by about 2 to 3 ft (0.4 to 0.8 meters) by 2100. This sea level rise will contribute toward significantly more coastal destruction and increased economic damages.
- Rainfall rates within tropical storms and hurricanes are projected to increase by about 15%.
- Numbers of Atlantic hurricanes reaching Category 4 or 5 intensity are projected to increase about 10% but with large uncertainty and with some studies projecting a decrease.
- Total numbers of Atlantic tropical storms and hurricanes combined are projected to decrease by 15%, but with large uncertainty; a minority of studies project an increase.
- Strongest winds of tropical storms and hurricanes are projected to increase about 3%.
- Other aspects of Atlantic hurricanes – such as named storm formation location, tracks, and size – may also change, but there is little consensus in available projections.

Additional Information and Links to Sources:

https://www.gfdl.noaa.gov/global-warming-and-hurricanes/