State of the Science FACT SHEET

Atlantic Hurricanes, Climate Variability and Global Warming

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION • UNITED STATES DEPARTMENT OF COMMERCE

This summary and assessment on the relationship between Atlantic hurricanes and climate change was developed by numerous researchers within the National Oceanic and Atmospheric Administration (NOAA).

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 quiet generally depends upon the large-scale atmospheric and oceanic environment within the main development region, which spans the tropical North Atlantic Ocean and Caribbean Sea.

The conditions typically associated with active Atlantic hurricane seasons include:

- warmer tropical North Atlantic sea surface temperatures (SSTs)
- increased thunderstorm activity
- reduced vertical wind shear (changes of wind direction and/or speed with height) within the main development region, among other features (Fig. 1)

These conditions also produce more intense hurricanes.

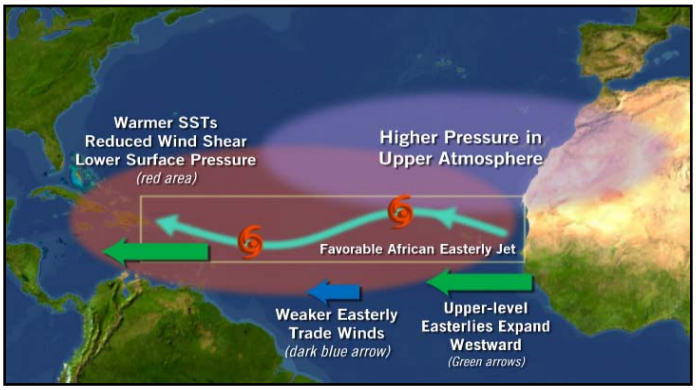

Figure 1: Factors conducive to increased Atlantic hurricane activity.

Has Atlantic Hurricane Activity Increased?

The unadjusted record shows an increase in Atlantic hurricanes since the early 1900s (Fig. 2, blue curve). When 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).

Data limitations preclude a confident assessment of trends in major hurricanes (categories 3-5; not shown) over the past century. The number of hurricanes that make U.S. landfall has not significantly increased or decreased (Fig. 2, orange curve).

Since the early 1970s, however, the numbers of Atlantic hurricanes (Fig. 2) and major hurricanes have increased. Much of this recent increase in Atlantic hurricane activity began in 1995 as the tropical North Atlantic warmed and atmospheric conditions became conducive for increased hurricane activity, similar to the mid-20th Century.

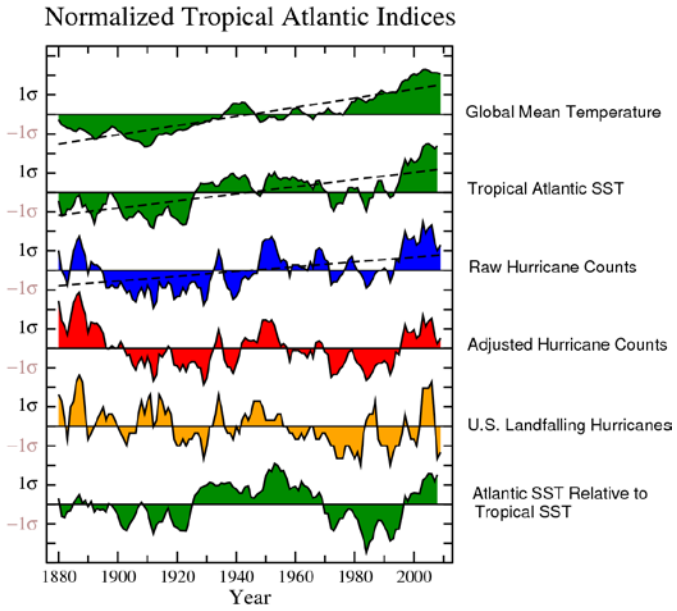

Figure. 2. Five-year running means of tropical Atlantic indices. Green curves depict global annual-mean temperature anomalies (top) and August-October Main Development Region (MDR) SST anomalies (second from top). Blue curve shows unadjusted Atlantic hurricane counts. Red curve shows adjusted Atlantic hurricane counts that include an estimate of "missed" hurricanes in the pre-satellite era. Orange curve depicts annual U.S. landfalling hurricane counts. Bottom green curve depicts August-October anomaly of MDR SST minus tropical mean SST. Vertical axis tic marks denote one standard deviation intervals (shown by the σ symbol). Dashed lines show linear trends. Only the top three curves have statistically significant trends. Source: Journal of Climate*, vol. 24, 1736-1746 (2011).*

What Causes Changes in Atlantic Hurricanes?

One influence is the Atlantic Multi-decadal Oscillation (AMO). The AMO is a variation in North Atlantic Ocean temperatures, with cool and warm phases historically lasting 25-40 years each. During the AMO warm phase, North Atlantic sea-surface temperatures are unusually warm compared to the tropical average and the atmospheric conditions over the Atlantic are conducive for more Atlantic

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hurricane activity (Fig.1). There is uncertainty about what triggers the change in the phases of the AMO, whether the AMO is a true oscillation, and whether it incorporates any human influences such as aerosol effects.

Variability in the frequency of major hurricanes (categories 3-5) is also linked to the AMO. Changes in the AMO were associated with an above-average number of major hurricanes from the 1940s to the late 1960s, followed by a period of below-average major hurricane numbers (1971-1994) and now an above-average number of major hurricanes since 1995.

Can We Detect Human Influence on Atlantic Hurricanes?

Human-caused increases in greenhouse gas concentrations have very likely contributed to the warming of the tropical North Atlantic sea-surface temperatures observed over the past century (Fig 2.)

Hurricane activity changes over decades. These changes, combined with evolving methods to observe and record storm frequency and intensity, complicate identifying long-term trends as well as the attribution to human influences.

Projected trends in hurricane activity for the 21st Century must be interpreted with an understanding of these large historical fluctuations.

In 2006, the World Meteorological Organization (WMO) convened an expert team of hurricane-climate researchers to assess the causes of past changes in hurricane activity. The team also reviewed climate model projections of potential 21st Century changes in global hurricane activity. In a 2010 assessment[1], the team concluded that it remains uncertain if past changes in any tropical cyclone activity (frequency, intensity, rainfall, etc.) exceed the natural variability.

Should We Expect Changes Because of Global Warming?

The World Meteorological Organization team concluded[1] that globally, by the late 21st Century, greenhouse warming would likely cause:

- the number of tropical cyclones to remain at current levels or to decrease by up to one-third
- the average intensity of tropical cyclones to increase by up to 10%
- near-storm rainfall rates to increase by about 20%

The 21st Century climate model projections of Atlantic tropical storm frequency do not currently provide a consensus on future changes. Some models project increases of up to 60% in Atlantic tropical storm numbers, while others project decreases of up to 60%.

Studies available for the Atlantic Basin suggest increased hurricane intensity, hurricane rainfall rates and the numbers of the most intense hurricanes over the 21st Century. However, the projections for intensity and intense hurricane numbers in particular have relatively large uncertainty and further research is needed to increase understanding.

Will Hurricane-related Storm Surges Change Due to Global Warming?

The vulnerability of coastal regions to storm-surge flooding is expected to increase with future sea-level rise and coastal development, although this vulnerability will also depend upon future storm characteristics.

There are large ranges in the 21st Century projections for Atlantic hurricane characteristics and for the magnitude of regional sea level rise along the U.S. coastlines. However, according to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change[2], the average rate of global sea level rise over the 21st Century will very likely exceed that observed during 1961-2003 for a range of future emission scenarios.

Where Do We Need to Focus Our Research?

Researchers will need to look more closely at what causes changes to hurricane frequency and intensity. Internal climate variability on multi-decadal timescales may be a very important influence. However, studies should consider other natural and human-caused influences, such as aerosols/dust, volcanoes, solar variations, and greenhouse gases. There is much research still to be done to understand and predict these complex phenomena.

[1] "Tropical Cyclones and Climate", *Nature Geoscience*, vol. 3, 157-163 (2010).

[2] "Global Climate Projections", In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (2007).