# Global Warming and East Coast Hurricanes

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This Communication is also our Monthly Temperature Update for August 2018. Monthly temperature updates are available from either web page (Hansen or Sato) or directly here.

Maps below show the temperature anomaly for the past three months and the seasonal mean (Northern Hemisphere Summer). We draw attention to the cool region southeast of Greenland and warmth in the middle of the North Atlantic.

Wally Broecker suggested decades ago that freshwater injection onto the North Atlantic could cause shutdown of the overturning ocean circulation (AMOC, Atlantic Meridional Overturning Circulation). Rahmstorf et al. (2015)[1] present evidence that a 20th century trend toward the cooling southeast of Greenland was due to a slowdown of AMOC, linking the trend to observed freshening of the North Atlantic surface water that may have been due to some combination of anomalous sea ice export from the Arctic, Greenland melt, and increased precipitation and river runoff.

In our paper on ice melt, sea level rise and superstorms[2] we conclude from multiple lines of evidence that a 21st century slowdown of AMOC is underway. Ocean surface temperature response to AMOC slowdown, in addition to cooling southeast of Greenland, includes warming off the U.S. East Coast, a temperature pattern emerging from high ocean resolution simulations (Saba et al., 2015)[3].

So, does global warming have a hand in the magnitude of the Hurricane Florence disaster on the U.S. East Coast? Yes, we can say with confidence, it contributes in several ways.

First, there is the fact that sea level rise due to global warming is already well over a foot along the U.S. East Coast. Ice melt due to global warming accounts for about 20 cm (8 inches) global average sea level rise (Fig. 29 in our Ice Melt paper[2]). Slowdown of the Gulf Stream, which is a part of the AMOC slowdown, adds to East Coast sea level. The slowdown reduces the west-to-east upward slope of the ocean surface across the Gulf Stream[4], causing piling up of water on the East Coast. The combined sea level rise from these effects, which is also responsible for "sunny day flooding" on the Eastern Seaboard, makes hurricane storm surges greater.

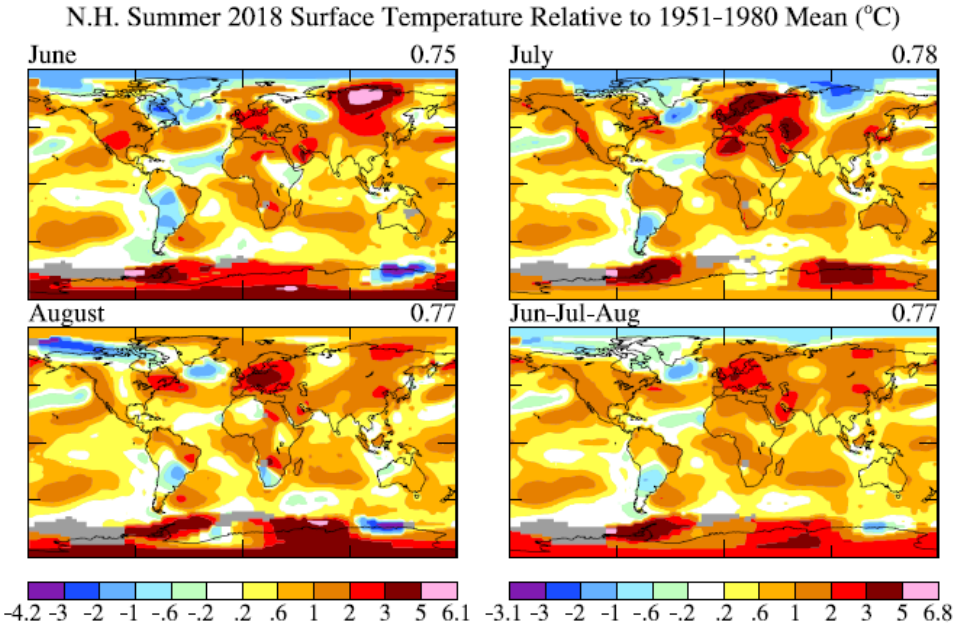


**Figure 1. Surface temperature anomalies for the past three months.**

Second, the warmer ocean surface and atmosphere result in greater rainfall amounts. Of course the primary reason for extraordinary rainfall amounts from Florence was the storm's slow movement.

Third, warmer ocean surface provides more fuel for tropical storms and expands the ocean area able to generate and maintain these storms. Part of a given hurricane's strength can be attributed to such extra warming of the ocean surface. That effect was pronounced in the case of Hurricane Sandy, which maintained hurricane wind speeds all the way to New York City because of the unusually warm sea surface off the United States East Coast.

What about the track of Florence and the fact that it stalled, resulting in huge local rainfall totals? The track and speed of a given hurricane depend on large scale mid-latitude weather patterns that are largely a matter of chance. As the area in which "tropical" storms can form expands poleward, the opportunity for a mid-latitude high pressure system to push a storm westward may increase, but we are unaware of specific studies. What we can say is that historical hurricane tracks may not be an accurate picture of future tracks.

The number of hurricanes striking the continental U.S. does not show a notable trend (Fig. 2). Indeed, the current decade has only the rest of this year and next year to add to its total to avoid being the decade with the smallest number of hurricanes hitting the continental United States. This small reduction in landfalls seems to be a matter of chance.[5] Damage per hurricane is more important. Global warming already has a large impact on damage for reasons given above. Those impacts, especially those arising from increasing sea level, may accelerate exponentially, if high fossil fuel emissions continue.[2]

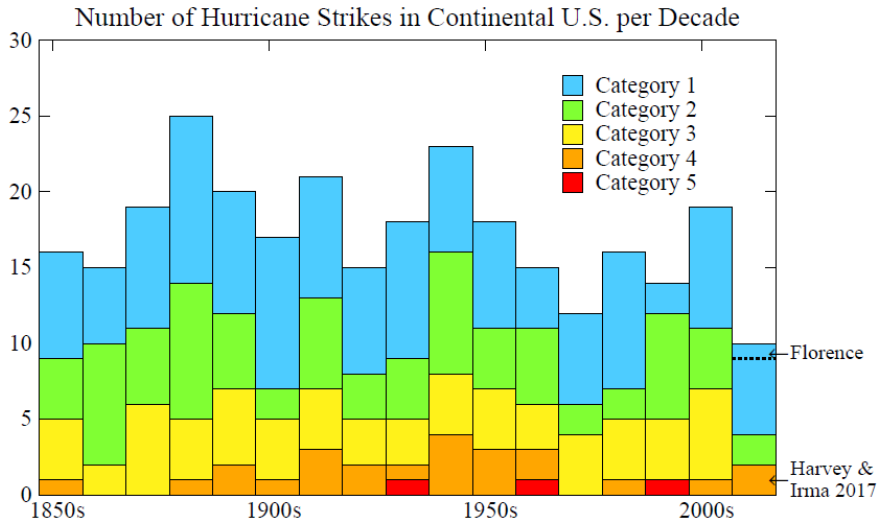


**Fig. 2. The three category 5 hurricanes to strike the U.S. were: Labor Day (Sept. 1935, SW FL, 892 hPa, 184 mph), Camille (Aug 1969, LA & MS, 909 hPa), Andrew (Aug 1992, SE FL, 922 hPa, 167 mph); source: http://www.aoml.noaa.gov/hrd/hurdat/All_U.S._Hurricanes.html.**

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[2] Hansen, J., M. Sato, P. Hearty, R. Ruedy, M. Kelley, V. Masson-Delmotte, G. Russell, G. Tselioudis, J. Cao, E. Rignot, I. Velicogna, B. Tormey, B. Donovan, E. Kandiano, K. von Schuckemann, P. Kharecha, A.N. Legrande, M. Bauer, and K.-W. Lo: Ice melt, sea level rise and superstorms:/ evidence from paleoclimate data, climate modeling, and modern observations that 2 C global warming could be dangerous *Atmos. Chem. Phys.*, **16**, 3761-3812. doi:10.5194/acp-16-3761-2016.

[3] Saba, V.S., Griffies, S.M., Anderson, W.G., Winton, M., Alexander, M.A., Delworth, T.L., Hare, J.A., Harrison, M.J., Rosati, A., Vecchi, G.A., and Zhang, R.: Enhanced warming of the Northwest Atlantic Ocean under climate change, J. Geophys. Res., 120, doi:10.1002/2015JC011346, 2015.

[4] Ezeer, T. and L. P. Atkinson: Accelerated flooding along the U.S. East Coast: On the impact of sea-level rise, tides, storms, the Gulf Stream, and the North Atlantic Oscillations, Earth's Future, 2, 362-382, 2014.

[5] Hall, T. and E. Yonekura: North American tropical cyclone landfall and SST: a statistical model study, J. Climate, 26, 8422-8439, 2013.