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A Weaker Gulf Stream Means Trouble for Coastal New England

Bob Henson (/cat6/author/bob.henson) · March 5, 2018, 4:44 PM EST



Above: A row of homes in Scituate, Massachusetts, is surrounded by high-tide water at midday on Saturday, March 4, 2018. Image credit: Ralph Karl Swenson, Amateur Radio SKYWARN Spotter (N1YHS), via NWS Taunton Skywarn.

The rugged coast of New England has never recorded a one-two high-water punch like it's gotten this winter with the nor'easters dubbed Grayson (January 4) and Riley (March 2-3). These storms produced two of the three highest water levels ever measured in Boston Harbor, and both of them produced widespread damage along the Massachusetts coast, with many water rescues carried out. Nearly a million people along the East Coast remained without power on Monday, [reported weather.com \(https://weather.com/news/news/2018-03-03-winter-storm-riley-impacts-new-england-mid-atlantic-washington-dc-bomb-cyclone\)](https://weather.com/news/news/2018-03-03-winter-storm-riley-impacts-new-england-mid-atlantic-washington-dc-bomb-cyclone).

At least two more nor'easters are in the pipeline for New England, one later this week and another early next week. Neither of these should be on par with Grayson and Riley in their coastal effects, but they will prolong the misery and delay recovery efforts for thousands of residents along and near the shore.

In the longer range, there's a more ominous outlook. Sea level is expected to rise even faster along the Northeast U.S. coast than in most places around the world, thanks in large part to effects related to a weakening Gulf Stream. The renowned ferocity of nor'easters will thus play out atop a progressively rising sea surface, making coastal impacts progressively worse unless adaptation efforts can keep pace.



Julie Loncich

@JulieLoncich

“The 10 years I've lived here, I'd say probably the worst. It's changed. The water just comes so fast now. It comes so fast and so much that you just don't have as much time as you used to to get prepared and get out.” Residents return to [#Scituate](#).

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Two blockbuster events in the space of two months

In records going back to 1921, here's how the two big nor'easters of 2018 rank in terms of water levels in Boston Harbor:

—Grayson: 4.88' above MHHW

(http://www.bostonherald.com/news/local_coverage/2018/01/its_officially_a_record_storm_tops_blizzard_of_7 (mean higher high water), **highest on record**; previous record 4.82' on 2/7/1978 during the infamous

Blizzard of '78

—Riley: 4.4' above MHHW (<https://www.wunderground.com/cat6/winter-storm-riley-kills-7-knocks-out-power-2-million>), **third highest on record**, behind only the Blizzard of '78 and ahead of the 3.92' observed on 1/2/1987.

As shown in Figure 1 below, water levels on par with Grayson would be expected only about once every 100 years in Boston Harbor in today's climate. The odds of getting two storms of the magnitude of Riley and Grayson in the same year are in the ballpark of several thousand to one—if we assume that the climate is not changing. Climate change makes such events more likely, though, through rising sea levels. Whether or not climate change makes intense nor'easters like Riley and Grayson more common is uncertain, as we discuss below.

The record set by Grayson would not have been reached without the help of long-term sea level rise.

Water levels along the Massachusetts coast increased by roughly an inch per decade over the 20th century, almost twice the global average rate (<https://www.bostonglobe.com/metro/2016/02/25/sea-level-rise-here-was-quicker-century-than-elsewhere-and-that-bodes-ill-for-future/t7XOCWqGsnW1kPKH84W5BJ/story.html>) of about 0.54 inches per decade. Subsidence is exacerbating global sea level rise (<https://www.scientificamerican.com/article/sinking-atlantic-coastline-meets-rapidly-rising-seas/>), along many parts of the U.S. Atlantic coast. Since the 1990s, global sea level rise has been accelerating (<https://www.wunderground.com/cat6/sea-level-rise-accelerating-says-unnerving-new-research>); it's now running at around 1.2 inches per decade.

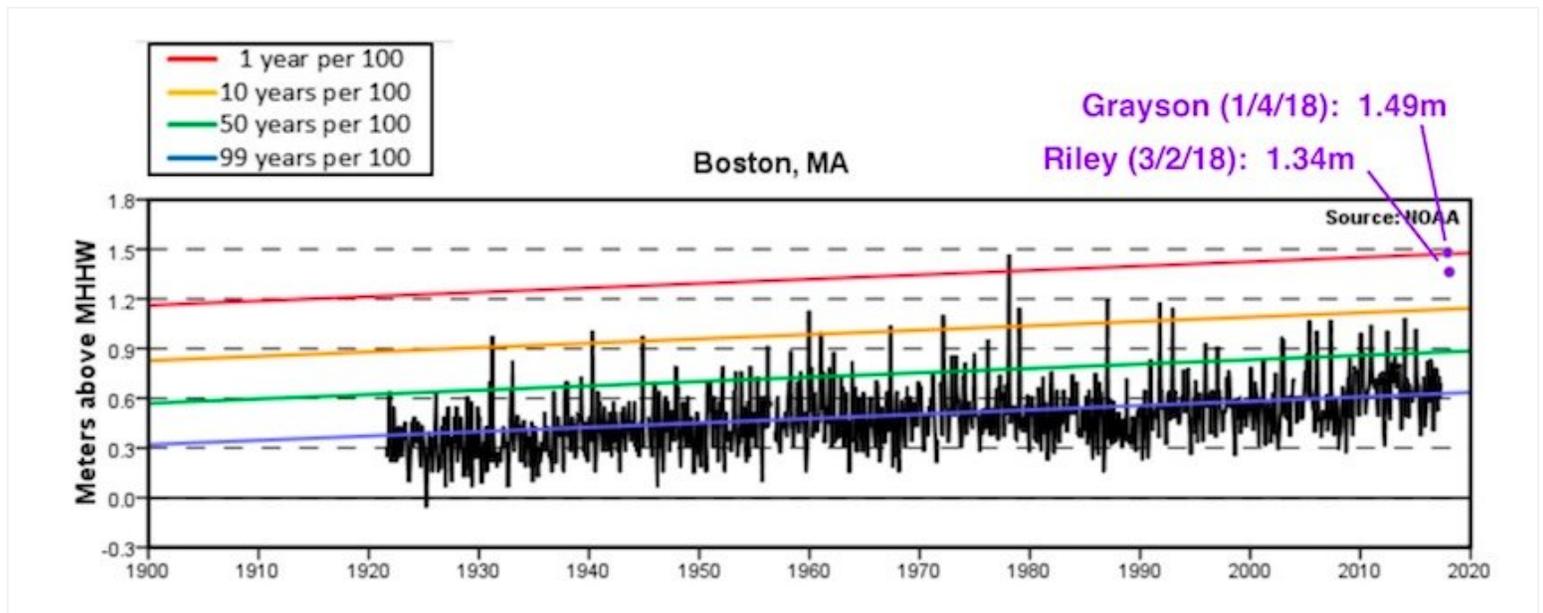


Figure 1. Extreme water levels in Boston Harbor since 1921. Added on the right-hand side are the water levels achieved by Winter Storm Grayson in January (1.49 meters) and Winter Storm Riley in March (1.34 meters). The plots show the monthly highest and lowest water levels with the 1%, 10%, 50%, and 99% annual exceedance probability levels in red, orange, green, and blue. The plotted values are in meters relative to the Mean Higher High Water (MHHW) or Mean Lower Low Water (MLLW) datums (https://tidesandcurrents.noaa.gov/datum_options.html) established by CO-OPS (1 foot = 0.3 meters). On average, the 1% level (red) will be exceeded in only one year per century, the 10% level (orange) will be exceeded in ten years per century, and the 50% level (green) will be exceeded in fifty years per century. The 99% level (blue) will be exceeded in all but one year per century, although it could be exceeded more than once in other years. Image credit: [NOAA Tides & Currents \(https://tidesandcurrents.noaa.gov/est/est_station.shtml?stnid=8443970\)](https://tidesandcurrents.noaa.gov/est/est_station.shtml?stnid=8443970).



Figure 2. Daniel Cunningham 22, dodges waves in his kayak on a flooded East Squantum Street in Quincy, Massachusetts, during a fierce nor'easter on March 2, 2018. Image credit: Stan Grossfeld/The Boston Globe via Getty Images.

The 2017 report, "[Global and Regional Sea Level Rise Scenarios for the United States](https://tidesandcurrents.noaa.gov/publications/techrpt83)" (<https://tidesandcurrents.noaa.gov/publications/techrpt83> Global and Regional SLR Scenarios for the US) had this to say about the future of sea level rise along the Northeast U.S. coast: "From Virginia through Maine and along the western Gulf of Mexico, sea-level rise is projected to be greater than the global average in nearly all global average sea level rise scenarios. For example, the sea in these regions would rise 1 to 1.6 feet higher than the global average rise of 3.3 feet under the intermediate scenario by 2100."

Change in Sea Surface Height, 1993–2015

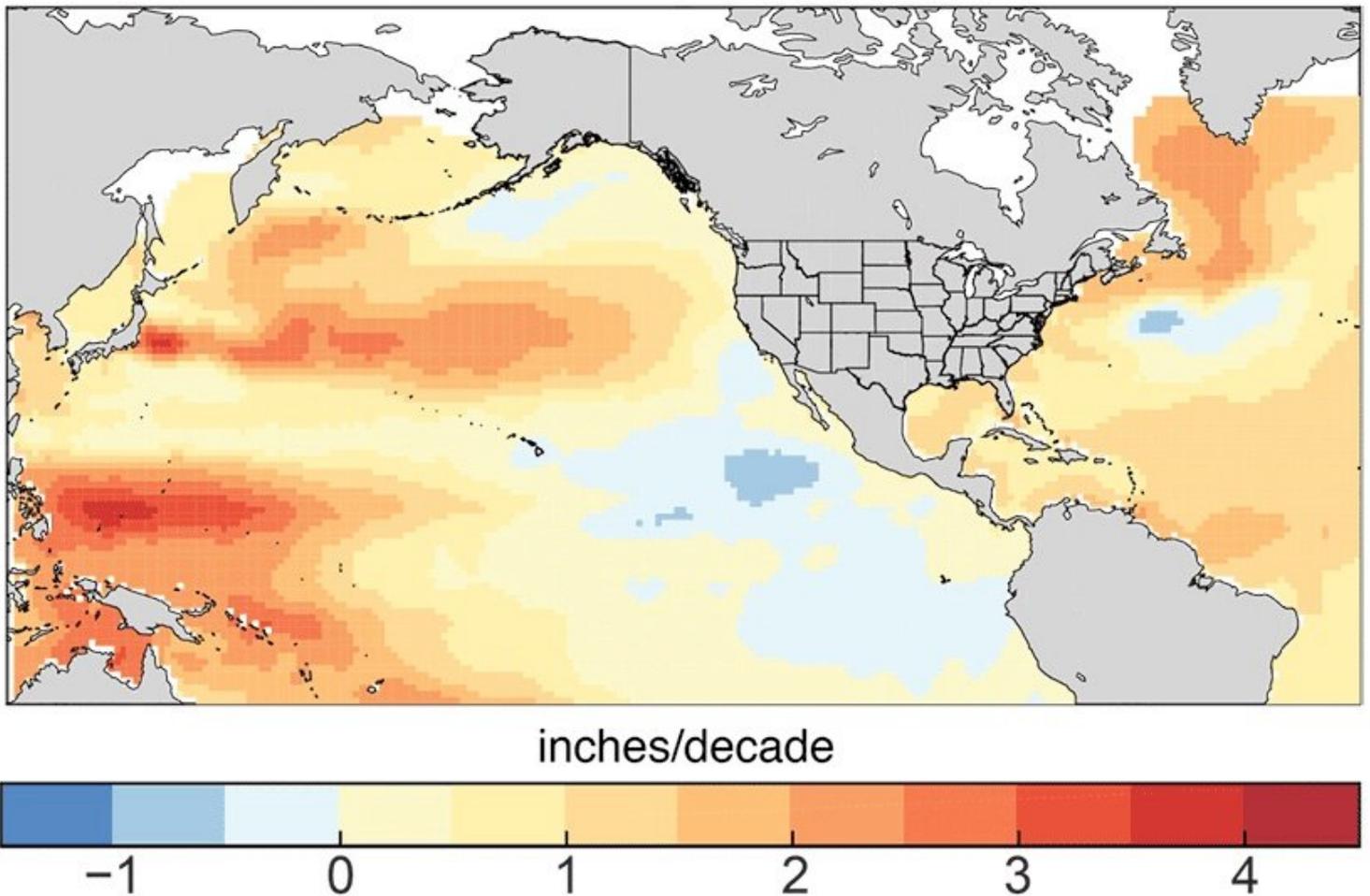


Figure 3. Rates of change from 1993 to 2015 in sea surface height from satellite altimetry data. Sea level rise along the Northeast U.S. coast was 1 – 2 inches per decade during this period. Image credit: [U.S. National Climate Assessment](https://science2017.globalchange.gov/chapter/12/). (<https://science2017.globalchange.gov/chapter/12/>).

Why the Gulf Stream matters to Massachusetts

The Gulf Stream plays a surprisingly large role in modulating sea level. As it wends its way northward, arcing away from the U.S. coast well before it reaches Massachusetts, the Gulf Stream separates colder waters along the Northeast U.S. coast from warmer water further offshore. It's not unlike a strong atmospheric jet stream separating colder air near the poles and warmer air near the tropics.

Because colder water is more dense, sea level tends to be lower in between the Northeast U.S. coast and the Gulf Stream, and higher on the opposite, warmer side of the current.

Sea surface temperature for the Northwest Atlantic, 4 March 2018

(NOAA/NESDIS geo-polar blended, 5-km analysis)

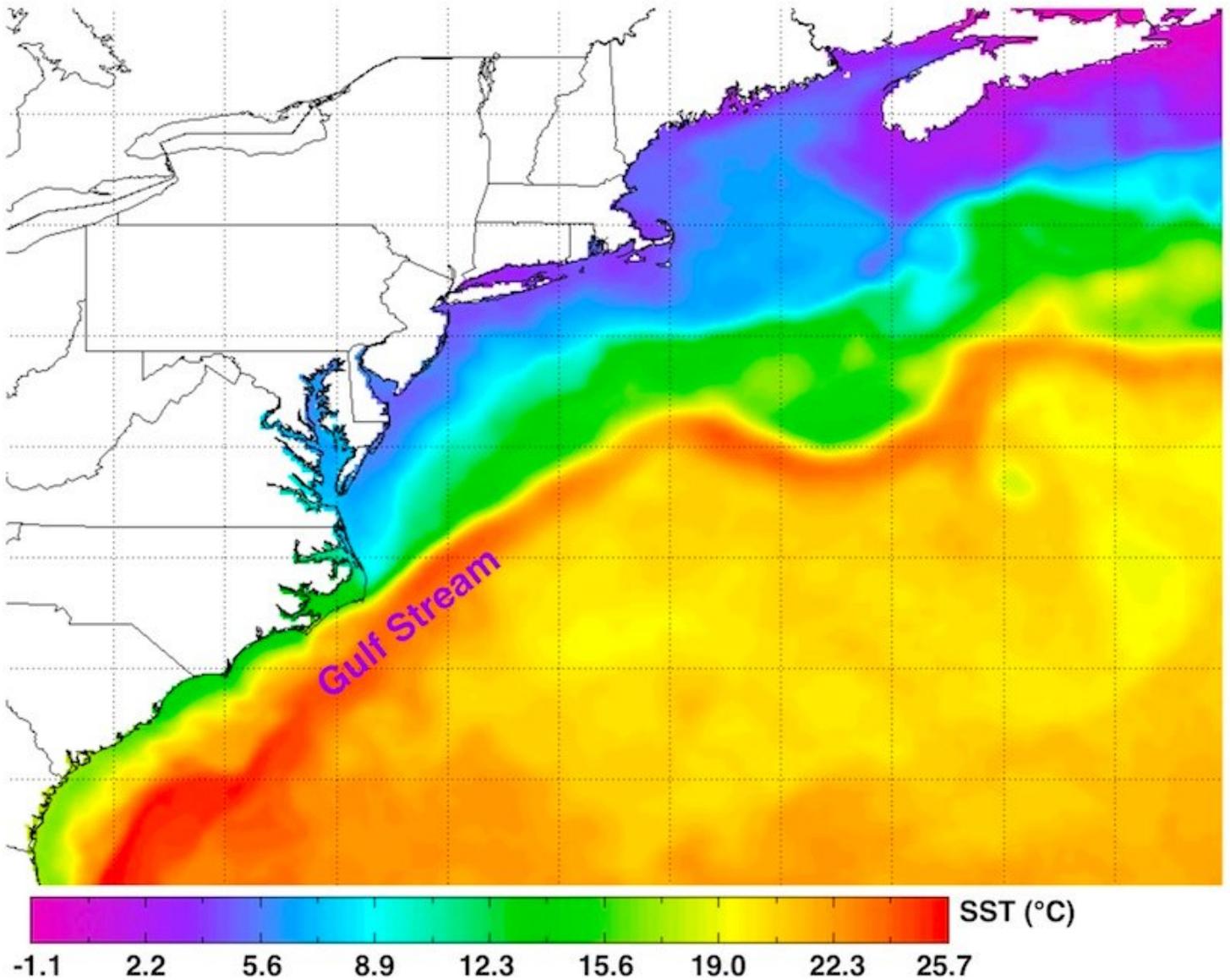


Figure 4. The Gulf Stream is easy to spot in this satellite-based analysis of sea surface temperatures across the Northwest Atlantic on Sunday, March 4, 2018. SSTs jump from less than 8°C (46°F) to more than 20°C (68°F) across a span of less than 100 miles off the North Carolina coast. Image credit: [NOAA/OSPO](http://www.ospo.noaa.gov/Products/ocean/sst/contour/) (<http://www.ospo.noaa.gov/Products/ocean/sst/contour/>).

What's concerning is that any major slowdown in the Gulf Stream would also tend to lessen the contrast in sea level from one side to the other—and this would act to push up sea levels along the Northeast U.S. coast, on top of the global rise produced by warmer seas and melting ice. The most likely mechanism for slowing the Gulf Stream and the broader Atlantic meridional overturning circulation (AMOC) would be an intrusion of fresh water into the North Atlantic from melting of the [Greenland Ice Sheet](http://people.oregonstate.edu/~schmita2/Projects/AMOC/) (<http://people.oregonstate.edu/~schmita2/Projects/AMOC/>), and/or [Arctic sea ice](https://news.yale.edu/2017/07/31/loss-arctic-sea-ice-impacting-atlantic-ocean-water-circulation-system) (<https://news.yale.edu/2017/07/31/loss-arctic-sea-ice-impacting-atlantic-ocean-water-circulation-system>).

Most research has found that such an AMOC slowdown is likely but would unfold gradually, with some decade-to-decade variability. The 2013 IPCC assessment showed a model consensus for the slowdown of between 11% and 34% this century, depending on how quickly we cut back on greenhouse gas emissions. However, recent studies from Yale University in 2017 suggest (<https://www.hakaimagazine.com/news/greenland-ice-melt-could-push-atlantic-circulation-collapse/>) that an all-out collapse of the AMOC within 300 years might be more plausible than earlier thought. (Here's a detailed explainer (<http://blogs.ei.columbia.edu/2017/06/06/could-climate-change-shut-down-the-gulf-stream/>) on recent research involving the long-term fate of the Gulf Stream/AMOC, courtesy of the State of the Planet website from the Earth Institute of Columbia University.)

It's also become apparent that the Gulf Stream and AMOC can slow down more dramatically for periods as brief as a few months, leading to shorter-term spikes in sea level. This happened in 2009-10, according to work led by Paul Goddard (University of Arizona) and published in 2015 (https://www.nature.com/articles/ncomms7346?message-global=remove&hc_location=ufi). Goddard and colleagues found that a strongly negative North Atlantic Oscillation favored strong northeast winds across the far northwest Atlantic, which not only played into a 30% slowdown of the AMOC but also pushed seawater directly toward the Northeast U.S. coast. Coastal sea levels from New York City northward jumped by a startling 5 inches in 2009-10, according to the study. The spike was short-lived: by 2011, sea levels had mostly returned to their previous levels. **Update:** Research published in 2016 (<https://sealevel.nasa.gov/news/52/neglected-effects-might-influence-sea-level>) by Christopher Piecuch (Woods Hole Oceanographic Institution) and colleagues suggests that at least half of the Northeast's sea level rise in 2009-10 can be explained by the "inverted barometer" effect—i.e., lower-than-average surface pressures predominating near the coast, allowing the sea surface to rise in response. In their Journal of Climate paper (<https://journals.ametsoc.org/doi/10.1175/JCLI-D-16-0048.1>), the authors assert that the connections between AMOC and Northeast U.S. sea level rise may be more than simple cause and effect: "...the extent to which overturning circulation and coastal sea level changes share common forcing, result from distinct (but still simultaneous) mechanisms, or are intimately coupled through complex ocean–atmosphere interactions should be explored in more detail in future investigations."

Even the hurricanes of 2017—specifically Jose and Maria—produced a temporary slowdown of 25-40% (<https://eos.org/articles/gulf-stream-slowed-as-hurricanes-struck>) in the Gulf Stream, according to data collected from undersea robotic gliders by Robert Todd and colleagues (WHOI). Jose and Maria both produced strong northerly winds running counter to the Gulf Stream as they headed out to sea.



Figure 5. A man walks slowly through a flooded sidewalk off Congress Street in Boston, where water was flowing over from Fort Point Channel in the Seaport district, during Winter Storm Riley on Friday, March 2, 2018. Image credit: John Tlumacki/The Boston Globe via Getty Images.

What about the nor'easters themselves?

“The storms we’re seeing now, people thought this was decades in the future,” Emily Norton, who directs the Sierra Club’s Massachusetts Chapter, told the Boston Globe (<https://www.bostonglobe.com/metro/2018/03/04/some-worry-boston-officials-aren-doing-enough-prepare-for-more-giant-storms/Y4Ezalh6Bl6AcdbbaJJ0xl/story.html>) after Riley struck. Grayson developed at an almost freakishly rapid pace (<https://www.wunderground.com/cat6/january-thaw-sight-after-two-week-wintery-onslaught-and-bomb-cyclone>), which boosted the power of its winds, waves, and surge. And as we outlined on Saturday (<https://www.wunderground.com/cat6/winter-storm-riley-kills-7-knocks-out-power-2-million>), Riley’s huge storm surge was a combined result of the storm’s intensity, its slow movement, and its juxtaposition with the full moon and the resulting high tides. Very warm waters across the Northwest Atlantic this winter may have teamed up with a strong, La Niña-influenced polar jet stream to fuel the growth of both Grayson and Riley.

While there’s no reason to expect that we’ll see Grayson- or Riley-caliber storms on a routine basis, climate change could make the strongest nor’easters a bit stronger, even apart from sea level rise. At least two model-based studies looking out through this century, one led by Brian Colle

(<https://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-12-00498.1>) (Stony Brook University) and the other by Christopher Marciano (<https://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-14-00418.1>) (North Carolina State University), found that the release of latent heat in winter storms near the U.S. East Coast could lead to lower surface pressures within the storms, which would tend to boost the coastal wind, wave, and surge threat.

The 2017 U.S. National Climate Assessment (<https://nca2014.globalchange.gov/>) notes that winter storms in the Northern Hemisphere have tended to become more frequent and intense since 1950, with the storm tracks shifting slightly poleward. However, the report cautions that there are major differences across regions and across models in the simulations of future winter storms. The assessment concludes: “Projections of winter storm frequency and intensity over the United States vary from increasing to decreasing depending on region, but model agreement is poor and confidence is low.”

In the end, the threat to coastal New England will continue to grow regardless of any change in nor’easters. All it takes is the wrong storm at the wrong time to push destructive waters into the coast, and the sea level supporting those surges and waves will only get higher with time. As we reported back in 2013 (<https://maps.wunderground.com/blog/JeffMasters/comment.html?entrynum=2347>), five feet of water into Boston Harbor—just an inch and a half more than Grayson—would flood more than 6% of the city. That extra inch and a half of water could be on Boston’s doorstep in little more than a decade, just waiting for the next nor’easter.

Jeff Masters contributed to this post.

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