THE Science BREAKER
SCIENCE MEETS SOCIETY

November 8, 2017

Earth & Space

The climate's barrier to coastal hurricanes

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This Break was edited by Max Caine, *Editor-in-chief* - TheScienceBreaker

Hurricanes are tremendously dangerous to lives and property, particularly when they approach land. In the Atlantic, hurricanes go through periods of higher- and lower-than-normal activity, and these periods can last 30 years or more. For example, we have been in an active period since around 1995, and before that we were in a quiet period since around the late 1960s.

Quite a lot of prior research has focused on this up-and-down behavior of Atlantic hurricane activity and has found that it is controlled by up-and-down changes in the tropical environment (between the equator and about 23°N latitude). For example, when tropical ocean temperatures are warmer than usual, there is greater hurricane activity because warmer water provides more energy for storms to form and strengthen. Similarly, when there is less vertical wind shear, hurricanes are more likely to form and intensify. Vertical wind shear describes the way wind changes with height. Hurricanes don't like shear because it "pushes them over", making them less efficient. They are most efficient when they stand vertically straight from the surface all the way to the bottom of the stratosphere (up to 60,000 feet or more).

So we know that when the oceans are warm and the shear is low in the tropics, there is usually greater hurricane activity. And vice versa. But this only tells us about *overall*, or *basin-wide*, Atlantic activity. Could there be regional differences in this behavior within the Atlantic as a whole? Our research was motivated by this question. We wanted to go beyond how the conditions in the tropics vary, and explore whether the up-and-down changes might have *patterns* of change associated with them, and whether hurricanes are affected by these patterns. Another way to phrase this question is: do warmer oceans and lower shear in the tropics affect hurricane risk in the same way for a person who lives on a Caribbean Island versus someone living, for instance, near the South Carolina coast.

We used an analysis technique that emphasizes "patterns of variability", known as principal component analysis, and we applied this technique to the historical records of ocean temperatures and shear in the Atlantic Ocean from 1948 to 2015. When we did this, two "centers of action" emerged. One was an elongated region confined to the tropics (from the equator to about 23°N latitude) and spanning from the west coast of Africa, through the Caribbean, to the east coast of Mexico. The other was a circular "bulls-eye" region just off the east coasts of Florida and the Carolinas.

The most interesting thing about these two regions is that they behave in perfect opposition to each other. That is, when one is high the other is low, and vice versa. So what does this mean? It means that when the ocean temperatures and vertical wind shear in the tropics are favorable for hurricanes to develop and strengthen, they are unfavorable near the U.S. east coast. And when the conditions are more hostile to hurricanes in the tropics, they are more friendly to hurricanes approaching the U.S. coast. So the climate system actually provides a barrier of sorts that protects the coast from hurricane threats during periods when the basin-wide activity is at its greatest. Another way to say this is that when Mother Nature encourages lots of hurricanes to form and strengthen in the tropics, she also tends to slam the door on them if they come near the U.S. coast. On the other hand, during the quiet

periods there are fewer hurricanes wandering the Atlantic, but the ones that do happen to approach the U.S. coast are much more likely to strengthen as they approach the U.S. coast. In this case, the overall threat is lower because the overall hurricane activity is lower, but it can still be particularly dangerous when a hurricane does manage to form and approach the U.S. coast.

The relationship described by this study is very fortuitous for people and infrastructure along the U.S. coast, and is a lucky by-product of the present climate system. But at this point, we have no way of knowing whether the relationship might be degraded or enhanced as the planet warms due to greenhouse gas emissions. If it's degraded, then we lose the natural barrier and U.S. coastal hazard exposure and risk could increase significantly. This would fall under the heading of a "climate surprise", and is an unsettling prospect given the present vulnerability of the coast.