Birth of a storm in the Arabian Sea validates climate model

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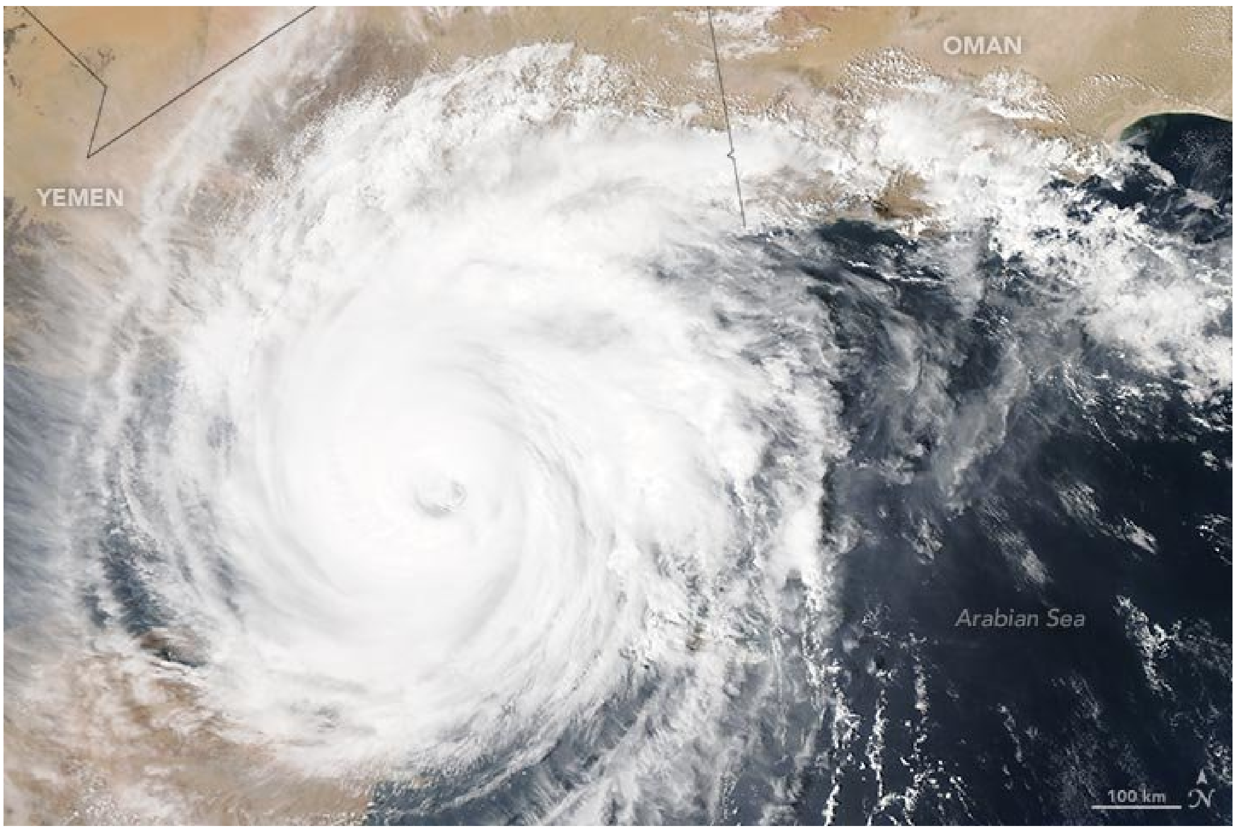

Cyclone Chapala over the Gulf of Aden Nov. 2, 2015. Credit: NASA image by Jeff Schmaltz, LANCE/EOSDIS Rapid Response

Researchers from Princeton University and the National Oceanic and Atmospheric Administration (NOAA) report in the journal *Nature*

Climate Change that extreme cyclones that formed in the Arabian Sea for the first time in 2014 are the result of global warming and will likely increase in frequency. Their model showed that the burning of fossil fuels since 1860 would lead to an increase in the destructive storms in the Arabian Sea by 2015, marking one of the first times that modeled projections have synchronized with real observations of storm activity, the researchers said.

In October 2014, Cyclone Nilofar formed off the western coast of India. The unusual system was the first extremely severe cyclonic storm (ESCS)—defined by wind speeds greater than 102 miles per hour—on record to appear in the Arabian Sea after South Asia's monsoon season. Cyclones commonly develop in the Arabian Sea after the monsoon season, but none as ferocious as Nilofar, which produced winds of up 130 miles per hour and led to the evacuation of 30,000 people in India.

Then, in 2015, two even stronger extreme cyclones rolled in off the Arabian Sea—in one week. From Oct. 28 to Nov. 4, Cyclone Chapala—the second strongest cyclone ever recorded on the Arabian Sea—brought winds of up to 150 miles per hour and dumped the equivalent of several years' worth of rain on the arid nations of Yemen, Oman and Somalia. Cyclone Megh unleased a second wave of destruction only a few days later. The storms killed 27 people and devastated the already fragile economies and infrastructures of the affected nations. The Yemeni island of Socotra was destroyed by flooding and wind damage.

The researchers analyzed simulations of global and regional cyclone cycles shortly after the 2015 storms to help determine their cause.

Especially notable is that their model projected an increase in post-monsoon extreme cyclones in the Arabian Sea by 2015 that was similar to what actually happened, said first author Hiro Murakami, an associate research scholar in Princeton's Program in Atmospheric and Oceanic Sciences. It is difficult for a climate model to accurately project for a defined location at a certain time.

"This may be the first time that we see synchronicity between a modeled projection and real observations of storm activity in a specific region during a specific season," Murakami said. He worked with Gabriel Vecchi, Princeton professor of geosciences and the Princeton Environmental Institute, and Seth Underwood at NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) located on Princeton's Forrestal Campus.

"It is still challenging to predict the year in which an ESCS will occur in the future," Murakami said. "What we emphasize is that the probability of occurrence is increasing relative to that in preindustrial conditions. It would not be surprising if we see a new ESCS generated in late season in the next few years."

This year, Cyclone Ockhi, which formed Nov. 29 and dissipated Dec. 6, left at least 39 dead in Sri Lanka and India. Belonging to the lower classification of a very severe cyclonic storm, Ockhi was nonetheless the most intense Arabian Sea cyclone since Megh with wind speeds peaking at 115 miles per hour.

These powerful new storms strike areas of the world made vulnerable by poverty, conflict and a lack of experience with a cyclone's heavy wind and rain, Murakami said.

"Large economic losses would be expected in Africa, the Middle East and South Asia along the Arabian Sea," he said. "These countries are highly sensitive to storm hazards and impacts due to a lack of adaption strategies. These regions experience comparatively low climatological storm exposure."

The driving force behind the appearance of the ESCSs was higher-than-normal temperatures. Murakami, Vecchi and Underwood used a high-resolution model at GFDL known as HiFLOR to simulate cyclone activity in the Arabian Sea under two scenarios. The first was natural variability such as some years being hotter than others. HiFLOR is able to reproduce observed variations in the frequency of category 4 and 5 hurricanes in the North Indian Ocean, then project that fluctuation onto other regions and storm systems. This results in a realistic simulation of natural variability.

The second simulation factored in increased atmospheric concentrations of sulfate, organic carbon, black carbon and other compounds that result from human activities. Black carbon and sulfates especially result from burning fossil fuels and biomass such as wood, a popular fuel in South Asia. The researchers ran their simulations with the levels of these substances as they were in the years 1860, 1940, 1990 and 2015.

They found significant increases in the occurrence of post-monsoon ESCSs in the Arabian Sea in 1990 and 2015—the latter of which matched the recent storms. (Real observations of extreme cyclone activity in the Arabian Sea are limited because there was no full weather-satellite coverage in this area before 1998.) New models are being developed to more accurately account for the influence of human-made aerosols on the creation of extreme cyclones over the Arabian Sea, Murakami said.

The paper, "Increasing frequency of extremely severe cyclonic storms over the Arabian Sea," was published in the December 2017 print edition by *Nature Climate Change*.

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