How an unusually warm Indian Ocean caused flooding on Yangtze River

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The Leshan Giant Buddha on a tributary of theYangtze River is the tallest stone Buddha statue in the world. On Aug. 18, 2020, flood waters reached the toes of the statue for the first time since 1949. Credit: Sheng Kong

A devastating Yangtze River flood in China in 2020 wasn't supposed to happen, according to the norms of climate experienced in Asia.

Summer flooding in the region often follows El Niño events, the climate phenomenon that is associated with warm water in the eastern equatorial Pacific Ocean. The year 2020, though, was preceded only by a weak El Niño and thus the flood during the summer monsoon season in Asia was unexpected. The flood killed 141 people, caused an estimated $11.8 billion in damage, and displaced millions of people at the peak of COVID-19, exacerbating the public health crisis.

In search of an explanation, climate modelers at Scripps Institution of Oceanography at UC San Diego and colleagues investigating the event identified a new culprit: an especially thick layer of warm water just below the surface of the Indian Ocean that set into motion climate effects that stretched to Africa and Australia.

"The results of our study surprised us," said Shang-Ping Xie, a professor of climate science at Scripps Oceanography whose portion of the research was funded by the National Science Foundation. "They show that the Indian Ocean, which is much smaller than the Pacific, can generate variability largely on its own and help predict devastating climate events over the rim countries that border the Indian Ocean."

The study might provide a new way to predict the weather that affects the billions of people who live on Indian Ocean coastlines and farther inland. The research shows the importance of how all ocean basins interact with each other, meaning forecasters should not rely on data from just one region, said the authors.

The paper appears in the journal *Proceedings of the National Academy of Sciences* March 8.

The events described in the paper took place in 2020 but began in fall 2019 with a particular set of circumstances in the Indian Ocean. The western side of the basin, toward the east African coast, was unusually warm. The topmost layer of warm surface water was 70 meters (250 feet) thicker than normal. The eastern side, generally around Indonesia, was unusually cold. Two extremes like that set up what is called a dipole in ocean temperature. The weather difference between the two poles stokes winds in the way winds kick up anywhere where high- and low-pressure weather systems interact.

The Indian Ocean dipole contributed to disasters in surrounding continents including bushfires that burned 18 million acres in Australia in September 2019 and conditions that gave rise to a December 2019 plague of crop-eating locusts in East Africa. The quirk also set in motion a series of storms and rain bands in East Asia from China to Japan. Collectively the storm winds generated waves below the ocean surface called Rossby waves. Such waves can run across the entirety of ocean basins from west to east. They generally move at such a slow pace that once they are affected by the winds, the odd temperature difference in the Indian Ocean creates an imprint on the ocean basin's deep memory that can last for several seasons.

So it was in the Indian Ocean that the effects of the dipole lingered into 2020. Over the past decade and a half, Xie's research team had identified the existence of a certain recurring regional pattern that includes Indian Ocean warming and distinct atmospheric circulation patterns that intensify monsoon rains over East Asia. Their work established that this regional pattern could be excited by El Niño via Rossby waves in the Indian Ocean.

Mainstream forecasting has traditionally focused on what is happening in the Pacific Ocean when deciding if winter seasons will be El Niños, La Niñas, or somewhere in between. The most commonly used predictor of

El Niño or La Niña years is the location of a pool of warm water along the equatorial Pacific, which tends to move in a pendulum fashion between the western and eastern boundaries of the basin.

Xie and his co-authors chose to look beyond the Pacific to see what happened if they used sea-surface temperature trends in multiple ocean basins for forecasts. They found this technique would have predicted the flooding. The model also managed to pick up on the fact that the regional pattern could be triggered even without a strong El Niño.

"This marks an important occasion in that climate models outperformed the observation-based predictions that operational agencies still rely on," said Xie. "These are the same computer models scientists use to project future climate change in the face of increasing greenhouse gases in the atmosphere."

More information: Zhen-Qiang Zhou et al. Historic Yangtze flooding of 2020 tied to extreme Indian Ocean conditions, *Proceedings of the National Academy of Sciences* (2021). DOI: 10.1073/pnas.2022255118