

Mumbai may be vulnerable to future hurricanes

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Rain in Mumbai. Credit: Flickr user abhijit chendvankar

Historically, tropical cyclones (also known as hurricanes) have rarely hit Mumbai, India. But how will future storms impact this coastal city on the Arabian Sea? That's the focus of a leading-edge study underway by the Lamont-Doherty Earth Observatory's Initiative on Extreme Weather and Climate.

"While several cyclones did strike the city during the seventeenth, eighteenth, and nineteenth centuries, Mumbai's more recent history has not seen a significant [cyclone](#) landfall," said professor Adam Sobel, the lead researcher on the project. "But recent history is not an adequate guide to the future where extreme weather events are concerned. Just ask any resident of New York City."

The catastrophic flooding that accompanied the landfall of Superstorm Sandy in 2012 also had seemed a remote possibility, Sobel points out. Before Sandy, New York had experienced no severe impacts from a hurricane landfall since 1821. "Having Sandy still fresh in our minds helps to motivate this [Mumbai] project."

The decision to focus specifically on Mumbai grew out of a conversation with world-renowned novelist Amitav Ghosh, who reached out with a question after reading Sobel's critically acclaimed book, *Storm Surge: Hurricane Sandy, Our Changing Climate, and Extreme Weather of the Past and Future*. Ghosh asked about the possibility of a tropical cyclone hitting Mumbai, and the question became the impetus for the new research.

Unique Vulnerabilities

If a serious cyclone were to strike Mumbai, the results could be catastrophic, says Sobel, because the city is very low-lying, heavily developed right to the shore, and densely populated. "That's exactly the recipe for an awful disaster: high vulnerability and low awareness of the

risk. Emergency planning is crucial."

Sobel proposed the "Storm surge risk to Mumbai" project early last year and secured support from the Global Innovation Fund for a small project.

Mumbai's physical characteristics would expose the city and its residents to great harm should a cyclone make landfall. The city is largely built on artificial land and would be severely flooded by a storm surge of a few meters' height, such as even a moderately severe cyclone could produce. Kyle Mandli, a Columbia University assistant professor and a member of the research team, has performed preliminary simulations showing that the depth and shape of the ocean bottom off the coast of Mumbai appear conducive to such a surge. Recent development of the city has removed much of the natural capital, such as coastal mangroves and floodplains, which would historically have offered protection.

The project is also exploring the impacts of climate change and sea-level rise. Since the sea would start at a higher level if a storm strikes, the resulting storm surge would cause a deeper flood than it would have done in the past when the local sea level was lower.



The city of Mumbai is built right up to the water's edge. Credit: United Nations University in Bonn

Predicting the Unpredictable

The core of the research relies on novel models, developed at Lamont, to study both tropical cyclone probability and the physics of storm surge. These computer models project risks far into the future. Climate change is part of the calculation.

"Our preliminary assessment indicates that the city currently has all the ingredients in place for a truly awful disaster," said Sobel. "This prospect

motivates the need for a proper, quantitative, scientific assessment of this risk,"—which is precisely what his team is working on.

To measure the risk, Sobel and the research team—including Lamont's Suzana Camargo, Chia-Ying Lee, Kyle Mandli, as well as Michael Tippett from the Department of Applied Physics and Applied Mathematics and Zachary Burt from the Mailman School of Public Health—are working first to calculate the probability of an intense tropical cyclone making landfall in Mumbai. Second, they are gauging the storm surge and total flood level that would result from a tropical cyclone landfall. Both steps are carried out for a range of possible tracks, intensities, and sizes of the [tropical cyclones](#), to properly characterize the risk in a probabilistic way.

Because tropical cyclones are not simulated well in global climate models, the tropical cyclone calculation requires a specialized model for "downscaling"—that is, simulating smaller-scale tropical cyclones given information about the large-scale climate. Researchers generate a large set of synthetic tropical cyclones from which they can estimate the probability of landfalls that are too rare to be well represented in the historical record. Sobel and colleagues have developed a prototype tropical downscaling model, which is unique and also available to the public and other researchers. The team will compare their simulation to another, currently available, model so they can compare the two models for a better estimate.

"I anticipate by the end of two years we will have a risk assessment of the probability of a cyclone and estimates of the flooding threat," said Sobel. "However, we are now expanding the scope of the project to explore the potential economic and health impacts of flooding." He has begun seeking additional funding and exploring scientific collaborations in order to continue this direction of research.

Partners in Problem-Solving

The study is a collaboration with the Columbia Global Center in Mumbai. The Mumbai site is one of eight Columbia University Global Centers. At each Center, the university seeks to form collaborations with regional communities and scholars to explore solutions to the world's biggest problems. Mumbai Global Center director Ravina Aggarwal has embraced the Lamont project as an opportunity raise awareness about Mumbai's [extreme weather](#) risk.

"Even though cyclones may not be seen as the imminent threat in a city that is resource-crunched and does need to make choices, the study enables people who care about climate to come together. The potential to avoid disaster at various intervals becomes stronger," said Aggarwal.

The project also aligns with a newly launched university priority, Columbia World Projects, which is committed to harnessing the power of the University to have the greatest possible impact on global problems.

By advancing this work before Mumbai faces a real tropical cyclone, the city will hopefully have the information and insightful strategies to save property and lives.

Provided by Columbia University

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