Science 20 SEP 2022 3:11 PM AEST Share

International team of scientists find many coastal cities worldwide vulnerable to sea level rise due to rapid land sinking

A team of international scientists has found that many densely populated coastal cities worldwide are at a high risk of extreme relative sea level rise as land sinks due to groundwater extraction and other industrial processes.

The team of scientists, led by Nanyang Technological University, Singapore (NTU Singapore), The University of New Mexico, ETH Zürich, and NASA's Jet Propulsion Lab, managed by the California Institute of Technology, processed satellite images of 48 of the largest coastal cities worldwide from 2014 to 2020 to measure land subsidence rates using a cloud-based processing system. The study found that cities like Tianjin (China), Ho Chi Minh City (Vietnam), Chittagong (Bangladesh), Yangon (Myanmar), and Jakarta (Indonesia) are experiencing rapid land subsidence.

As Earth's ice sheets melt and warming sea water expands, sea levels are rising globally. However, land subsidence can occur much more quickly than sea level rise, greatly aggravating the problem of coastal flooding, according to the scientists.

The results of the study, titled Land subsidence intensifies sea-level rise: an InSAR analysis of 48 major coastal cities, were published in the journal Nature Sustainability in September

"By estimating how much and how fast these densely populated coastal cities are subsiding, our study helps constrain projections of coastal flooding in the coming decades as we expect more land to be flooded due to rising sea levels and land subsidence," said lead author Cheryl Tay, a Ph.D. student at NTU's Asian School of the Environment.

UNM Department of Earth and Planetary Sciences Assistant Professor Eric Lindsey specializes in satellite data analysis and monitoring rates of land subsidence. He is one of the co-authors of the study which began when he was a research fellow at NTU's Earth Observatory of Singapore. Lindsey spent several years in Southeast Asia studying the movement of the Earth's surface to monitor subsurface hazards that can lead to disasters such as the flooding in Jakarta, Indonesia.

"This study highlights the value of high-resolution satellite observations for better understanding this issue – subsidence rates can vary quickly across small areas, meaning that land-based measurements often do not capture the true scale of the problem," said Lindsey.

To acquire accurate land subsidence measurements, Lindsey and coauthors compiled data collected by the Sentinel-1 satellites operated by the European Space Agency (ESA). Since the launch of the first Sentinel-1 satellite in 2014, they have been orbiting Earth using radar to measure subtle changes in the altitude of the surface. This technique is known as Interferometric Synthetic Aperture Radar or InSAR. Each Sentinel-1 satellite takes 90 minutes to complete one orbit.

However, due to the Earth's rotation, it can take up to 12 days for a satellite to pass over the same location twice. This results in twice-monthly observations of the Earth's surface for every point on

the planet. ESA collects, stores, and provides free global access to the raw data that is transmitted back to Earth.

To further his research on land subsidence, Lindsey has teamed up with UNM's Center for Advanced Research Computing (CARC) to host and process data that will help researchers determine the actual condition of aquifers around the world with a focus on the state of New Mexico.

To create land subsidence maps, Lindsey first compiles all the satellite images collected over an area. This means he routinely downloads hundreds or thousands of high-resolution images covering approximately 24,000 square miles each. These data are combined and processed together to form a record of the ground's slow motion toward or away from the satellite, with a precision of centimeters or better. However, the large number of images required in this process takes up tens of terabytes of data. This enormous amount of data can be problematic and requires massive storage capacities.

"For this study, we used a cloud processing system that gave us access to plenty of processing power and nearly unlimited storage," said Lindsey. "However, we found that this flexibility comes with a cost, which was much higher than if we could host the data locally."

To help solve these storage problems, Lindsey was recently awarded a National Science Foundation (NSF) grant to establish new data storage nodes at UNM CARC. This increased storage capacity combined with CARC's high-speed parallel computing abilities will enable him to process the hundreds of terabytes of data needed to update these coastal land subsidence maps as well as to examine land subsidence caused by groundwater extraction across the Southwestern US.

The 48 cities surveyed as part of the NTU study were selected based on a minimum population of five million in 2020 and located a maximum of 50 kilometers from the coast. A comparison of coastal cities worldwide shows the fastest velocities of relative local land subsidence are concentrated in Asia, especially Southeast Asia.

Land subsidence varies at a neighborhood and even block level but across the 48 cities surveyed, the team found a median sinking speed of 16.2 millimeters (mm) per year, while some of them have land that is sinking at 43 mm a year. The current global mean sea-level rise is 3.7 mm/year. Coastal cities experiencing notable land sinking with a velocity faster than 20 mm per year include Tianjin (China), Ho Chi Minh City (Vietnam), Chittagong (Bangladesh), Yangon (Myanmar), Jakarta (Indonesia), and Ahmedabad (India).

The findings are an example of groundbreaking research which seeks to address humanity's grand challenges on sustainability and accelerate the translation of research discoveries into innovations that mitigate human impact on the environment.

"Rapid sinking of the land is frequently caused by groundwater extraction," said Tay. "This is concerning in Asia where many coastal cities are now centers of growth, and their high demand for groundwater extraction to meet the water needs of growing populations."

"Our study highlights the fact that while this is a global issue, the response in many cases must be local," said Lindsey. "Slowing the rate of groundwater extraction to a sustainable level should be a top priority for all municipalities in coastal areas."

This research will contribute to the Singapore National Sea Level Program supported by the National Research Foundation, Singapore, and Singapore's National Environment Agency.