Satellite radar system used to help preserve Angkor Wat temple

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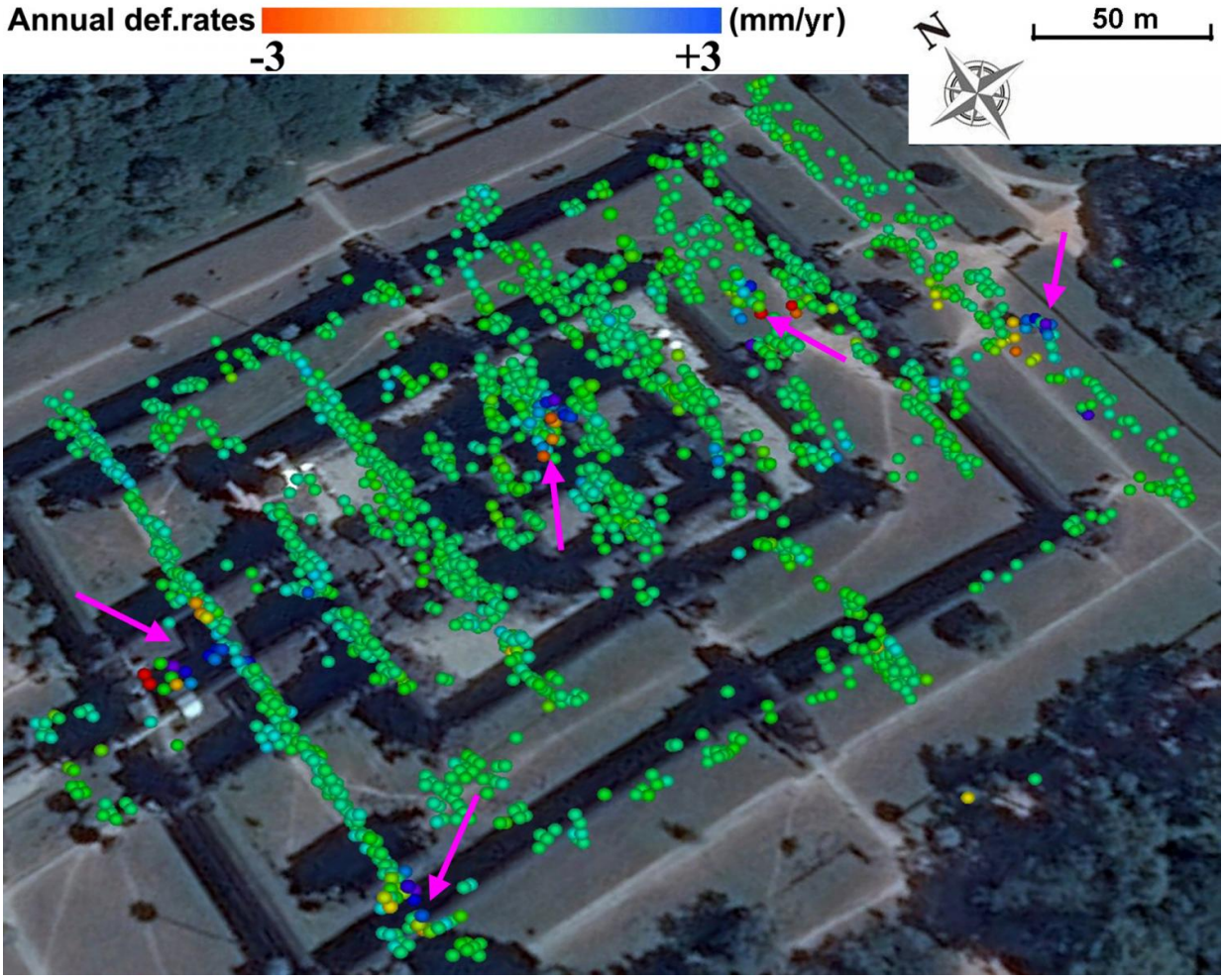
Monument collapsing in Angkor due to decay. Credit: F.Chen from the Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences

(Tech Xplore)—A team of researchers from several institutions in China and one in Cambodia has used a new type of satellite radar system to assess the likelihood of damage to the iconic Angkor Wat temple from higher amounts of water being extracted from the ground in the area. In their paper published in the journal *Science Advances*, the team describes the new technology, how it was used and offers opinions on how best to protect the ancient stone structure and those around it.

The Angkor Wat temple in Cambodia (built during the Khmer Empire between the 9th and 15th centuries) and other ancient stone buildings around it have been designated as a World Heritage site by Unesco—unfortunately, the buildings are all suffering from varying amounts of decay causing officials to worry that some are close to collapsing. Adding to the fears are worries that increased water extraction from the ground from nearby areas in recent years might be causing the ground beneath the buildings to shift more, causing even more problems. To find out if this is the case, the researchers turned to a new type of satellite radar system called synthetic aperture radar interferometry (InSAR).

With InSAR, two satellites are used to make very precise measurements of the same ground location over time using advanced radar techniques. The spacing of the satellites allows for tracking ground movement—in this new effort, measurements were made over the period 2011 through 2013. The researchers calculated that the ground around the Angkor monuments shifted less than 3 millimeters—which they suggest indicates that it is unlikely that increased water extraction has sped up the decay of the stone buildings. Instead, they note, the steady decline of the structures is due almost entirely to erosion, temperature fluctuations and seasonal changes to the water table due to cyclical dry and wet seasons. They suggest officials instead focus their efforts on mitigating damage due to climate change as some models have suggested the area might experience longer dry periods as the planet heats up.



Annual deformation rates (millimeters per year) on the Angkor Wat Temple. The pink arrows mark vulnerable monuments. Credit: Chen et al. Sci. Adv. 2017;3:e1601284

The researchers note that InSAR could be used to help understand conditions around other important ancient structures, offering those charged with protecting them a new tool as well.

Cracks and countermeasures on the second gallery of the Angkor Wat Temple. Credit: F.Chen from the Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences

More information: Fulong Chen et al. Radar interferometry offers new insights into threats to the Angkor site, *Science Advances* (2017). DOI: 10.1126/sciadv.1601284

Abstract

The conservation of World Heritage is critical to the cultural and social sustainability of regions and nations. Risk monitoring and preventive

diagnosis of threats to heritage sites in any given ecosystem are a complex and challenging task. Taking advantage of the performance of Earth Observation technologies, we measured the impacts of hitherto imperceptible and poorly understood factors of groundwater and temperature variations on the monuments in the Angkor World Heritage site (400 km2). We developed a two-scale synthetic aperture radar interferometry (InSAR) approach. We describe spatial-temporal displacements (at millimeter-level accuracy), as measured by high-resolution TerraSAR/TanDEM-X satellite images, to provide a new solution to resolve the current controversy surrounding the potential structural collapse of monuments in Angkor. Multidisciplinary analysis in conjunction with a deterioration kinetics model offers new insights into the causes that trigger the potential decline of Angkor monuments. Our results show that pumping groundwater for residential and touristic establishments did not threaten the sustainability of monuments during 2011 to 2013; however, seasonal variations of the groundwater table and the thermodynamics of stone materials are factors that could trigger and/or aggravate the deterioration of monuments. These factors amplify known impacts of chemical weathering and biological alteration of temple materials. The InSAR solution reported in this study could have implications for monitoring and sustainable conservation of monuments in World Heritage sites elsewhere.