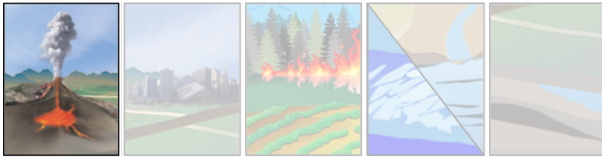




NISAR: The NASA-ISRO SAR Mission



Sinkholes and Cavern Collapse

Sinkholes are not just a Florida phenomenon but can occur in any of the 50 U.S. states. Forty percent of the U.S. is prone to naturally occurring sinkholes because of the underlying geology. Even more areas are included when we consider the danger from collapse of man-made caverns or buried pipes.

Sinkhole Collapse Can Be Fast or Slow, Natural or Man-Made

Sinkholes form in many ways, all of which lead to collapse of the overburden soil above an underground void. Naturally occurring sinkholes form in areas where the rock can dissolve in water, which could be due to erosion or an underground stream. The nightmare scenario is catastrophic collapse, where a vast hole abruptly and without warning forms above an unsuspected cavern deep below the surface, swallowing everything above. However, sinkholes also can form more slowly as gentle depressions that indicate where the rock is dissolving below ground. In addition, accidental collapse of mined caverns or buried pipes are often called sinkholes, because they result in the same types of pits and can either occur slowly or quickly, just as the natural sinkholes.

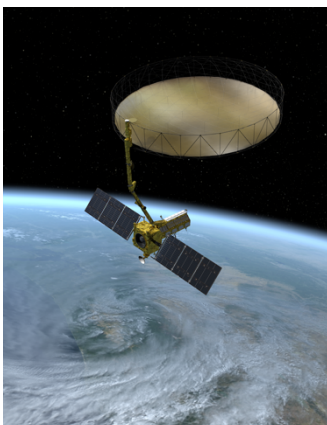


Photos (clockwise): On Wings of Care, USGS, USGS, National Cave/Karst Research Institute

Identifying Ground Movement Associated with Sinkhole Formation

Naturally forming sinkholes are common in areas where the rock below the ground can be easily dissolved, i.e., limestone, carbonate rocks, or within salt domes. A combination of geology (rock type) and hydrology (water flow) contribute to the development of sinkholes, with many different possible mechanisms leading to surface

collapse into the subsurface caves. The caves can be small or very large, and can be shallow or deep below the surface. The collapse can occur abruptly, taking mere seconds, or it can take many decades, slowly forming depressions.



The NISAR Mission – Reliable, Consistent Observations

The NASA–ISRO Synthetic Aperture Radar (NISAR) mission, a collaboration between the National Aeronautics and Space Administration (NASA) and the Indian Space Research Organization (ISRO), will provide all-weather, day/night imaging of nearly the entire land and ice masses of the Earth repeated 4-6 times per month. NISAR's orbiting radars will image at resolutions of 5-10 meters to identify and track subtle movement of the Earth's land and its sea ice, and even provide information about what is happening below the surface. Its repeated set of high resolution images can inform resource management and be used to detect small-scale changes before they are visible to the eye. Products are expected to be available 1-2 days after observation, and within hours in response to disasters, providing actionable, timely data for many applications..



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Reports of sinkholes in Florida and Kentucky have surfaced recently in the news. In one case, a sinkhole swallowed a house with a man inside; in another, antique cars at the National Corvette Museum fell into a sinkhole that appeared overnight. But those states are not alone in experiencing the phenomenon. Many areas in the U.S. and around the globe regularly experience sinkholes, and larger sinkholes can be visible from space. In the United States, sinkholes are common in areas with limestone and other easily dissolved rock. In addition to the continental U.S., Alaska and Hawaii are also at risk. Sinkholes in Hawaii result from collapsing lava tubes, whereas in Alaska a common cause of sinkholes is erosion associated with thawing of the permafrost.

With NISAR, experts will be able to measure surface movement directly through repeat imaging of an area and processing the sequence of images using a technique called synthetic aperture radar interferometry (InSAR) that can measure changes in

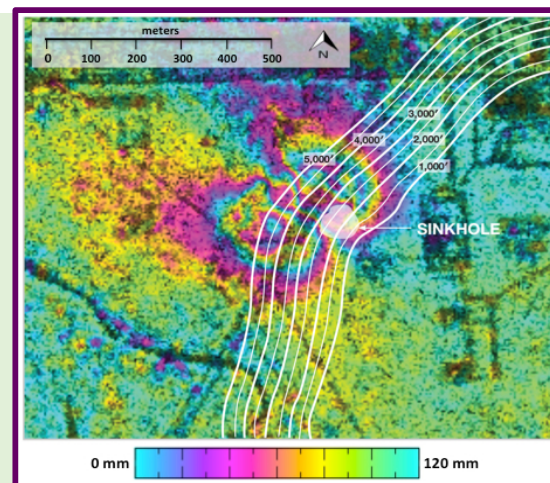
the distance between the radar antenna and the ground at the scale of a fraction of the radar wavelength (24 cm for NISAR). InSAR is a remote sensing method that can be used to measure surface deformation across large areas at one time. NISAR has sufficient resolution to identify localized movement of the sort associated with sinkholes at scales as small as 50 m on the surface. Radar has additional advantages, the most significant being the ability to see through clouds, smoke, and haze and to image the surface day or night without relying on solar illumination.

All NISAR data products, including the InSAR interferograms, will be available with open access through a web portal. In this way, the nation's investment in radar data remotely acquired from space can be most widely used in disaster response and to help prevent natural and accidental hazards from becoming disasters.

Ground Movement Preceding Sinkhole Formation

Some, but not all, sinkholes will experience relatively small scale ground movement at the surface prior to the abrupt collapse of catastrophic formation. One example is shown at the right, where ground movement prior to formation of the Bayou Corne sinkhole was captured using UAVSAR, NASA's airborne prototype for the NISAR space mission. The colors of the interferogram show contours of ground movement.

A regular schedule of radar imaging with NISAR, which will image all the land in the United States and nearly all land globally, would enable detection of some cases where the movement started days prior to the collapse. This imaging program will also be able to help identify the slow-collapse sinkholes that can cause damage to structures through slow but inexorable settling. In this way, remote monitoring from space can help to identify this relatively common and highly destructive hazard more quickly, efficiently, and economically, protecting lives and property.



InSAR interferogram showing ground movement that preceded catastrophic collapse by at least 30 days. The sinkhole formed near Bayou Corne, Louisiana. The area of the ground that moved was much larger than the initial sinkhole that formed (grey circle, shown above contours of the Napoleonville salt dome) [Jones & Blom, 2014].