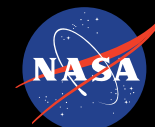




Credit: Florida Dept. of Environmental Protection

Sinkhole Detection from the Ground, Air, and Space

Cathleen E. Jones, Ph.D.



Jet Propulsion Laboratory
California Institute of Technology

Challenges

Sinkholes can:



Be Large or Small



Be Shallow or Deep

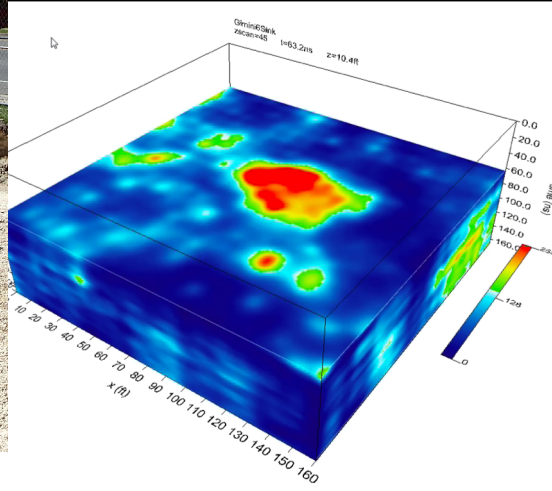


Occur Rapidly or Slowly



Ground-Based Detection

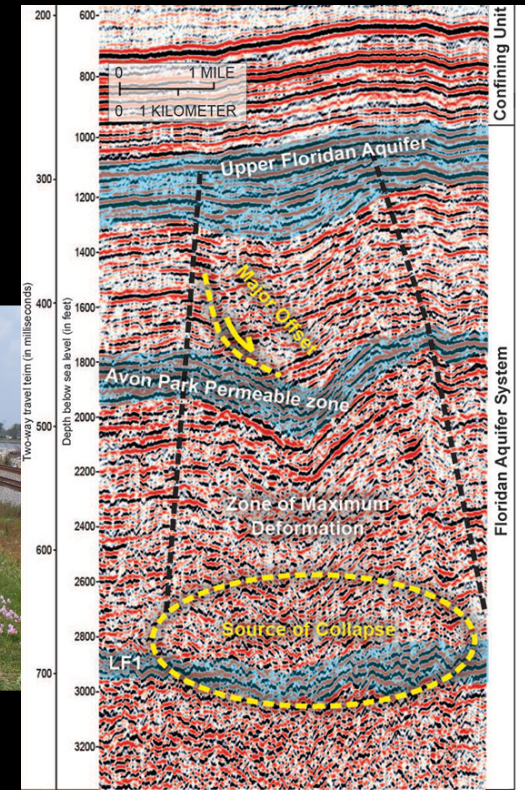
Ground Penetrating Radar



Reflection Seismology



Credit: USGS

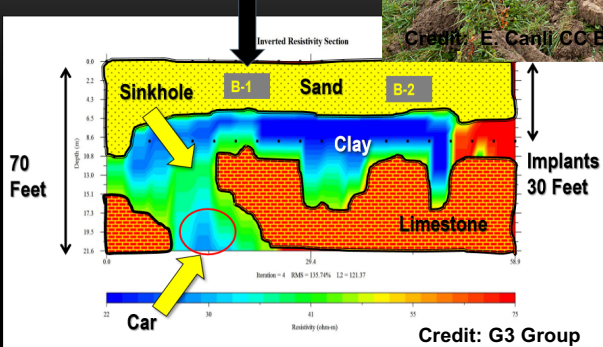


Electrical Resistivity Tomography



Credit: E. Canji CC By-SA 3.0

Case Study: Bordeaux Village Sinkhole



Credit: G3 Group

Microgravimetry



Credit: S. Vats CC By-SA 3.0

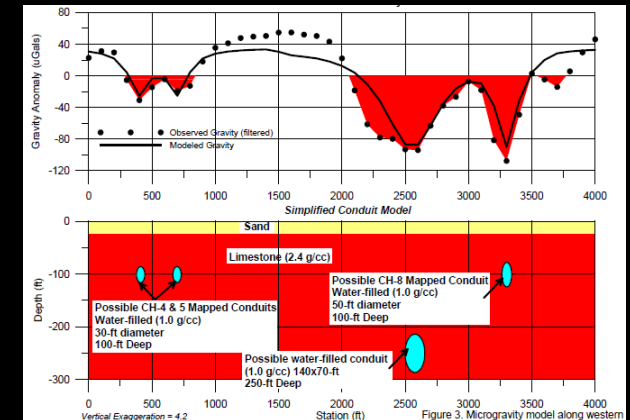
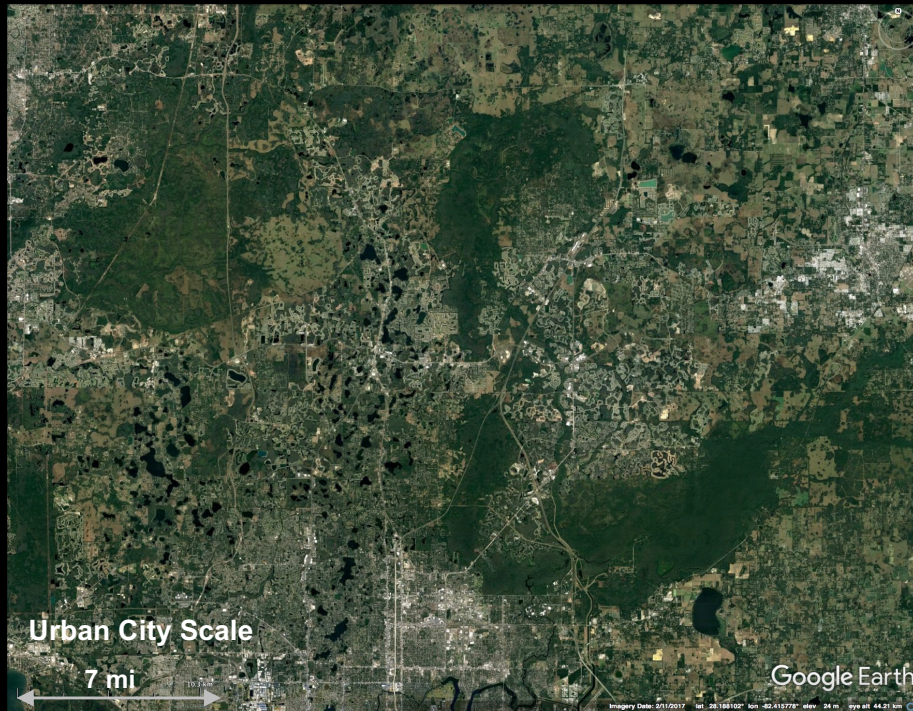


Figure 3. Microgravity model along western

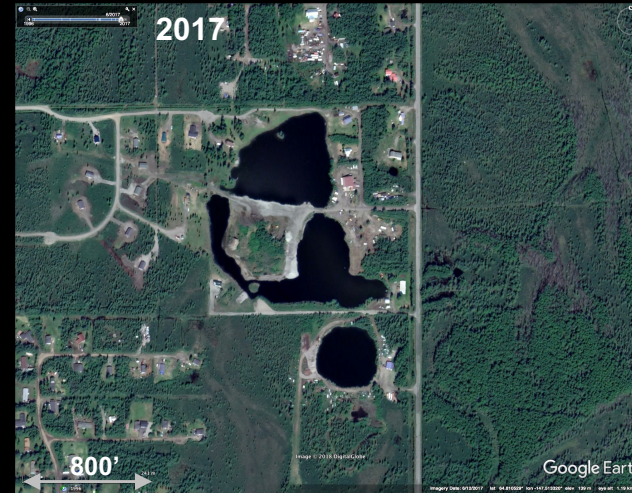
Problem of Scaling - Florida



Airborne or Spaceborne Remote Sensing

Spaceborne Remote Sensing

Problem of Scaling - Alaska



Airborne or Spaceborne Remote Sensing

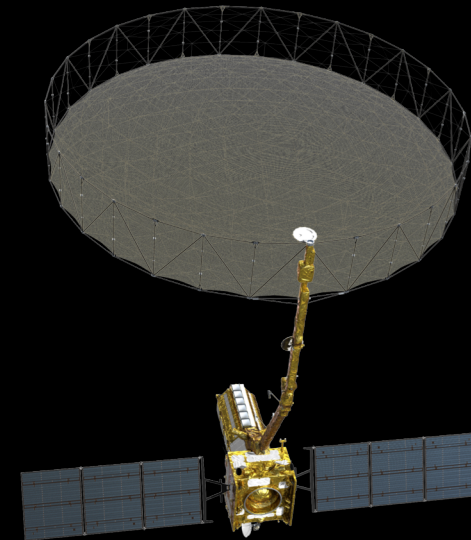
Spaceborne Remote Sensing & Free Access

Airborne & Spaceborne Radar

Synthetic Aperture Radar

Radar can...

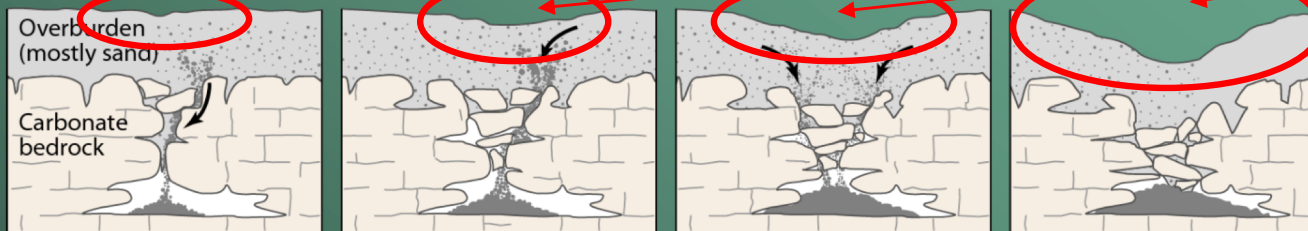
- 1) See through clouds, smoke, haze
- 2) Image day or night, in any light conditions
- 3) Rapidly image large areas (>1000 mi²) at relatively high resolution (~ 3 -40 ft)
- 4) Detect very small scale deformation or displacement of the ground



Detecting Sinkholes with Radar Interferometry (InSAR)

The airborne & space synthetic aperture radars image surface change only:

Gradual formation (*suffosional sinkholes*)



Can detect
Sensitivity: $\sim \frac{1}{4}'' - \frac{1}{2}''$

Sudden formation (*cover-collapse sinkholes*)



No surface
movement >>
Can't detect



Modified from Tihansky, USGS Circular 1182, 1999

Resolution: Depends upon instrument, but most can image at scale of a house or better.

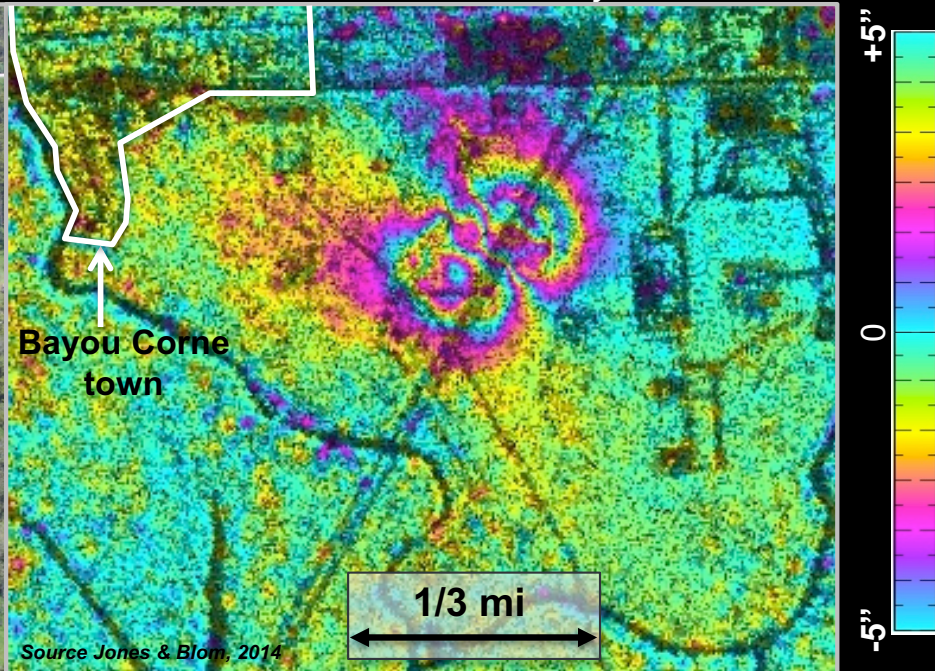
Bayou Corne, Louisiana, Sinkhole

Sinkhole formed on Aug. 3, 2012:



Credit: On Wings of Care, New Orleans, LA

Deformation occurred before July 2, 2012:



Source Jones & Blom, 2014



12/24/12



9/26/13

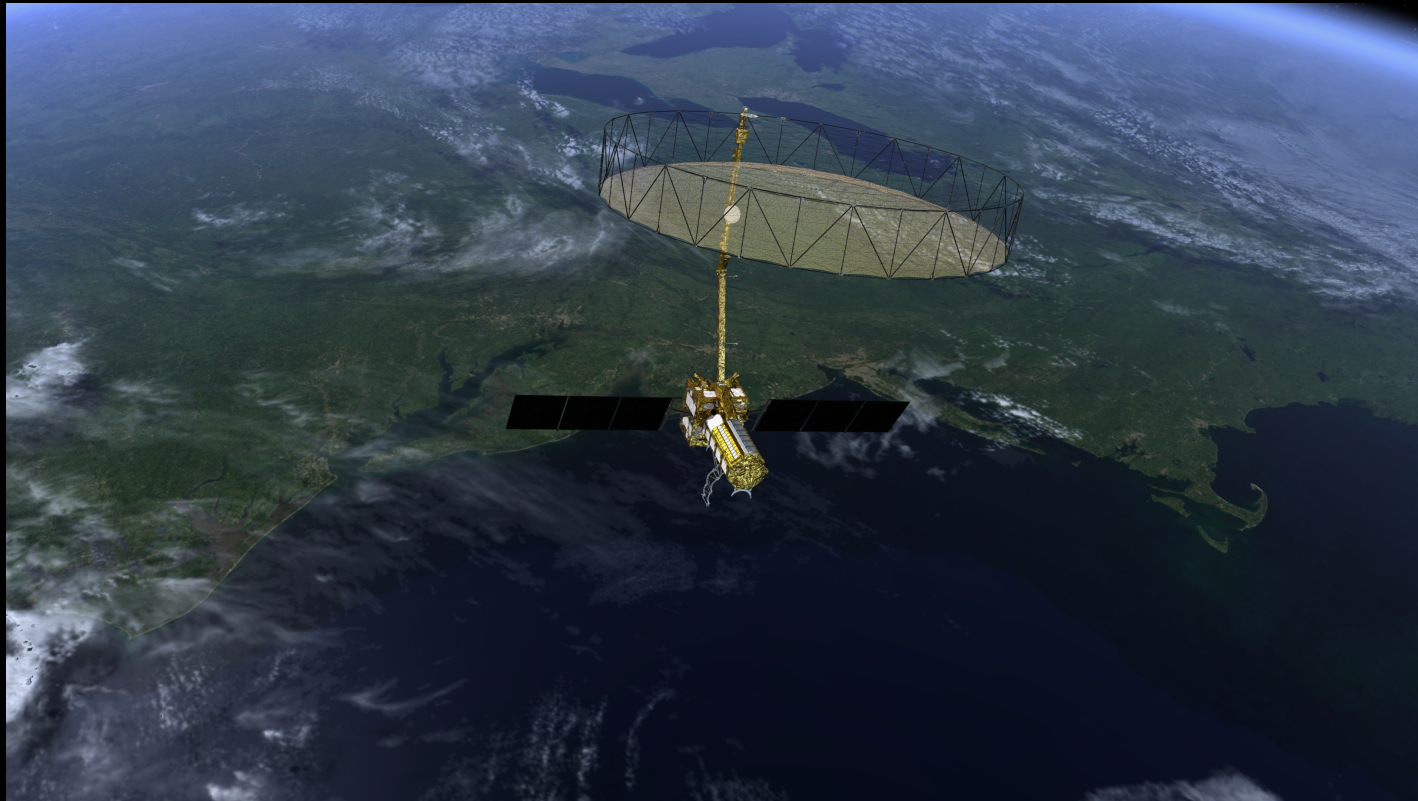


Video credit: Assumption Parish Office of Homeland Security and Emergency Preparedness

NISAR: NASA's Earth Mission to Provide Spaceborne InSAR

NASA-ISRO* Synthetic Aperture Radar Mission

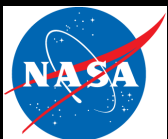
A NASA Earth Science Mission



*High resolution, cloud-free
imagery twice every 12-days*

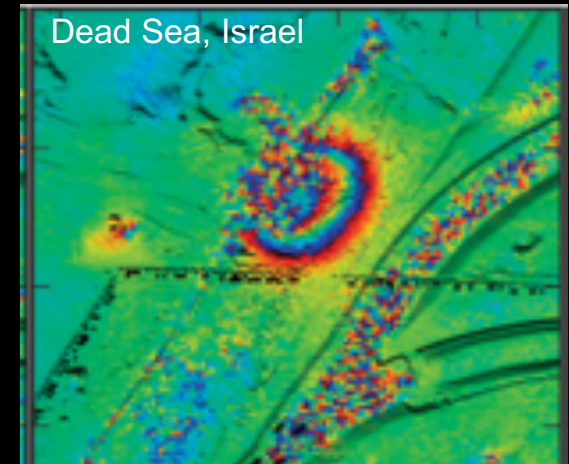
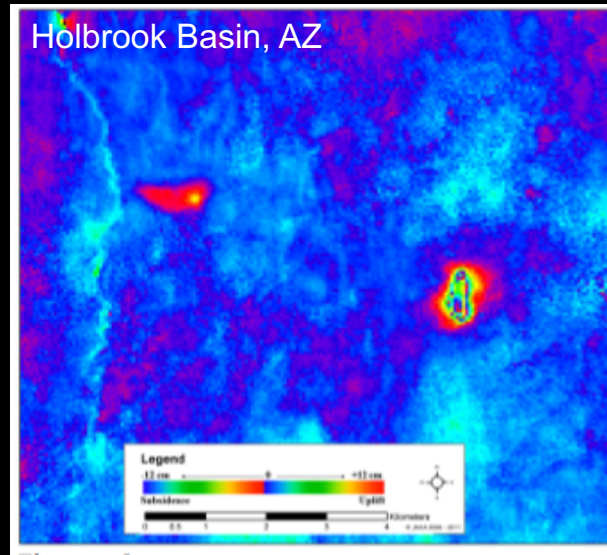
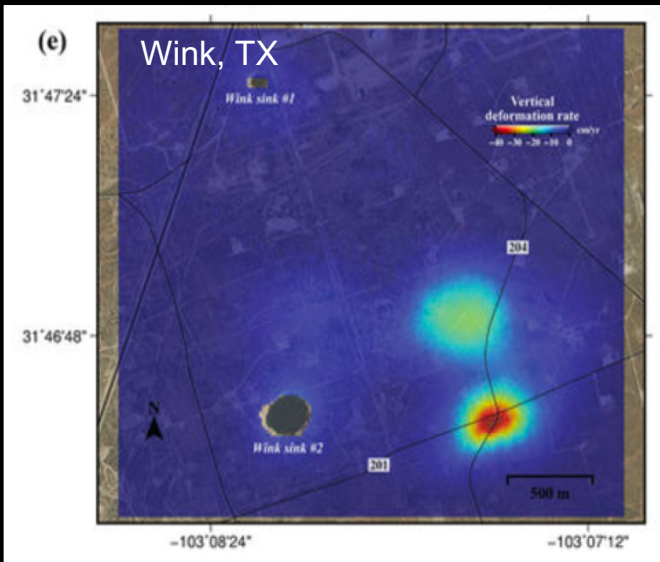
- Near-global land coverage
- Free & open data policy
- Launch: 2021
- Lifetime: 3+ years

*Indian Space
Research
Organization



Sinkhole Detection with Spaceborne Radars

Instances of Sinkhole Precursor Detection



Kim & Lu, 2018

Conway & Cook, 2013

Nof et al., 2013

Detecting Sinkholes with Radar Interferometry -- Limitations



Corvette Museum

Credit: Jason Polk

- Cannot:
- See below structures (e.g., Corvette Museum sinkhole)
- Image very small sinkholes
- Detect sinkholes that form without precursory surface movement

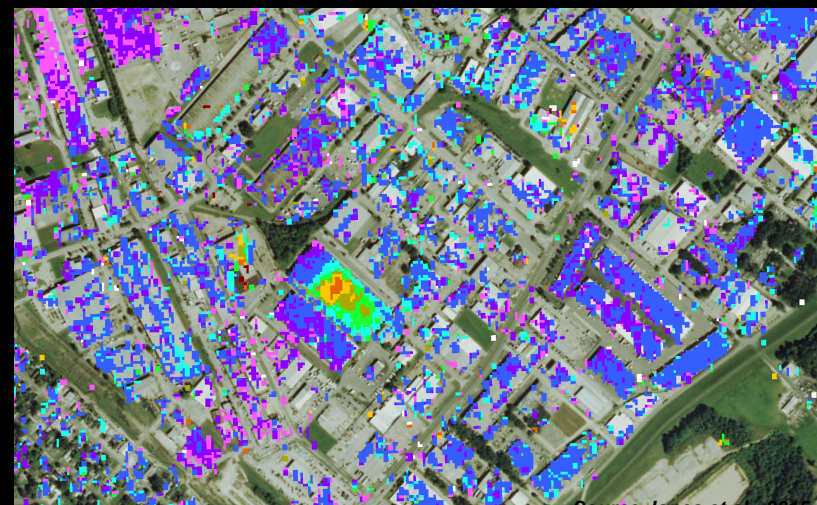
The Value of Remote Sensing

Combine Boots on the Ground & Eye in the Sky

Remote sensing will ...

- 1) Not replace people, who determine whether what is detected is a real hazard
- 2) Not detect all sinkholes before they happen
- 3) Inform targeted ground observations anomalies
- 4) Provide continual monitoring of 'hot spots' to see if they are expanding / changing
- 5) Be a game-changer for hazard monitoring

Example of False Positive: Bad Roof (New Orleans)



NASA-NISAR
Earth Observing Mission

Movie Credit: Franz Meyer,
Univ. of Alaska / Fairbanks

