NISAR and Applications of SAR Interferometry

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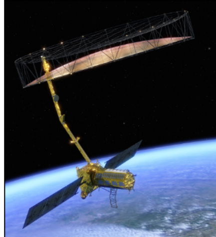
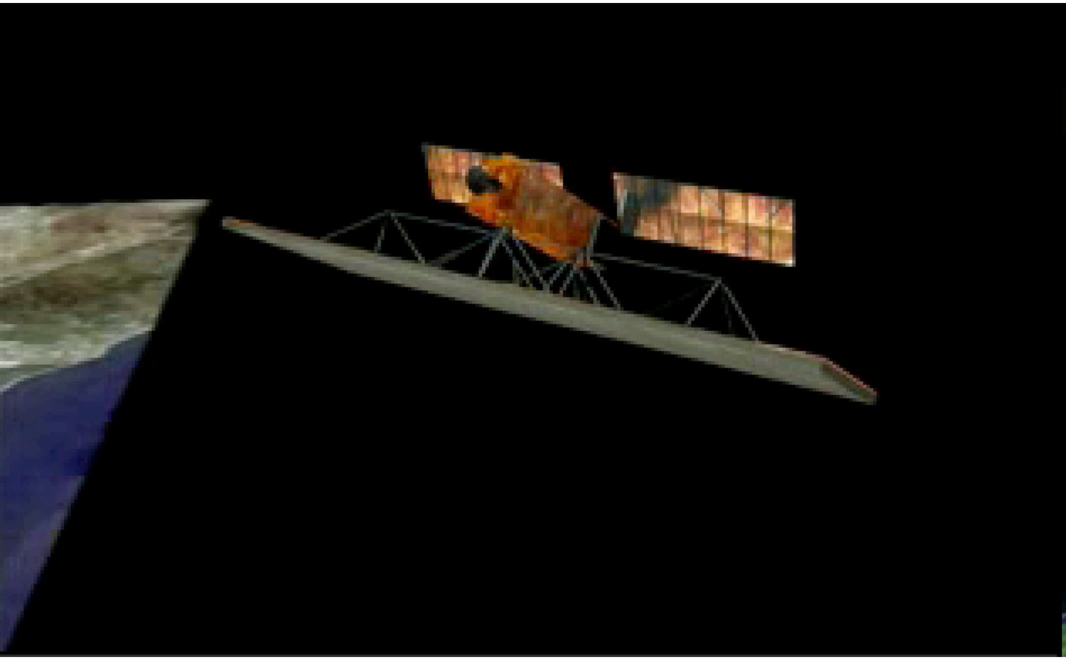
NASA-ISRO Synthetic Aperture Radar (NISAR) Mission



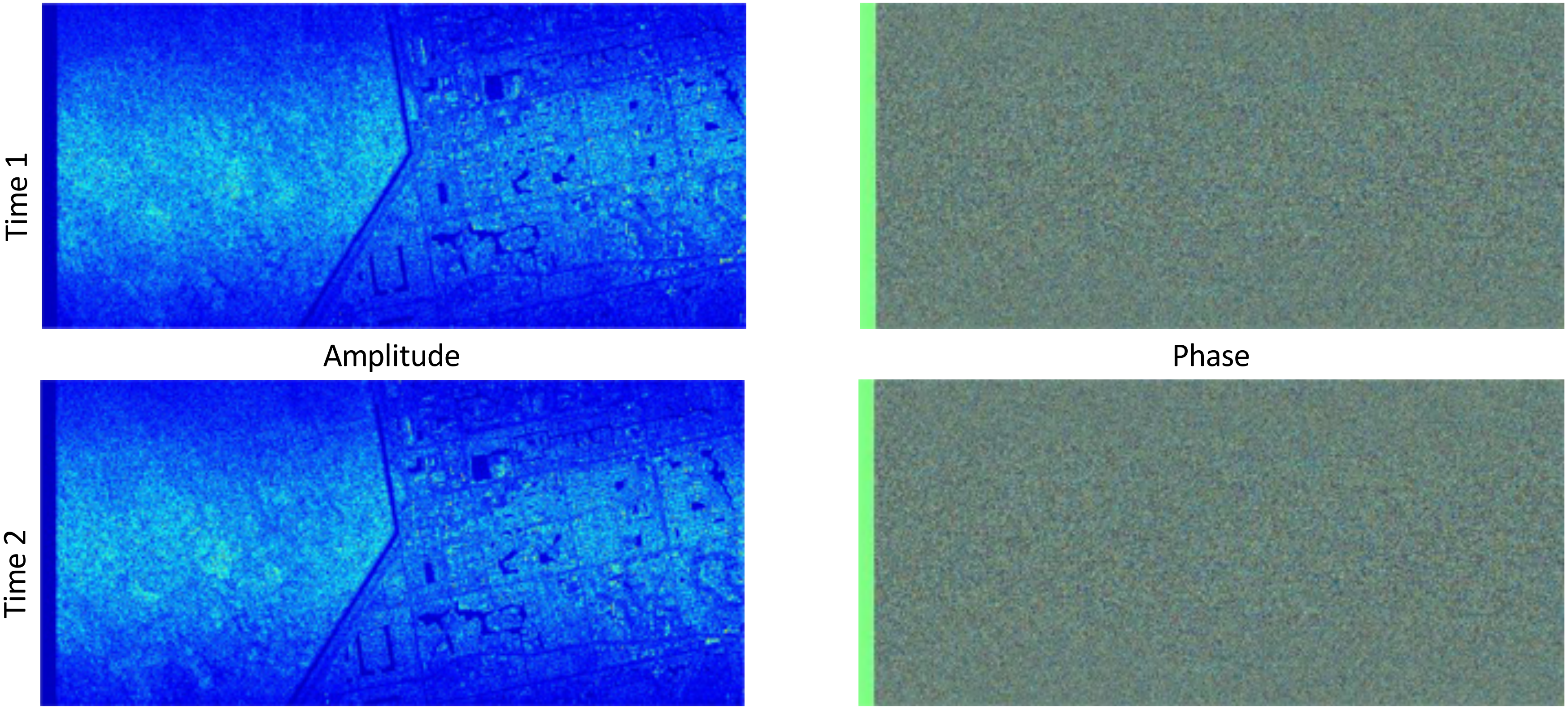
Active and Passive Remote Sensing

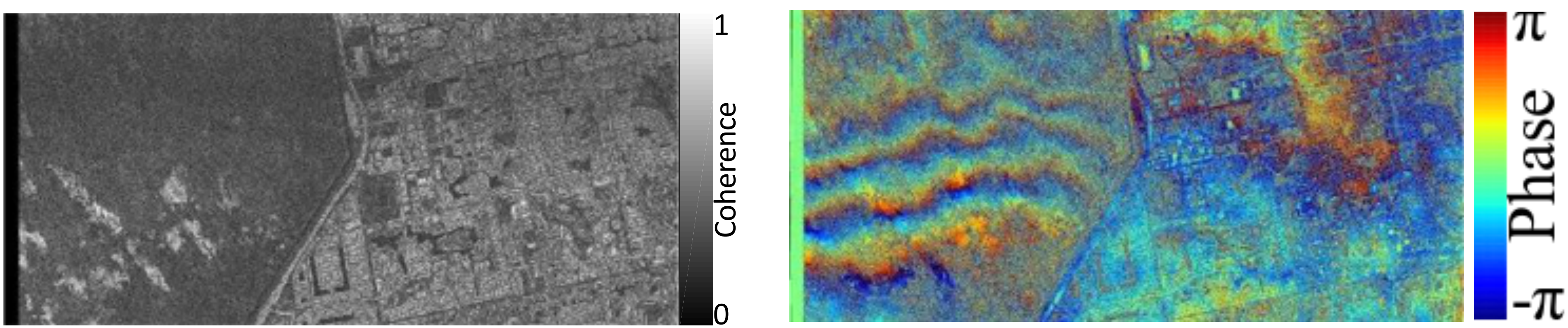
Active



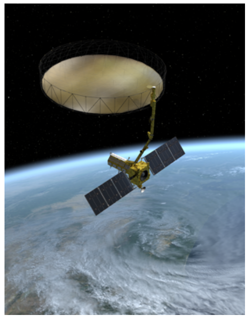
Passive

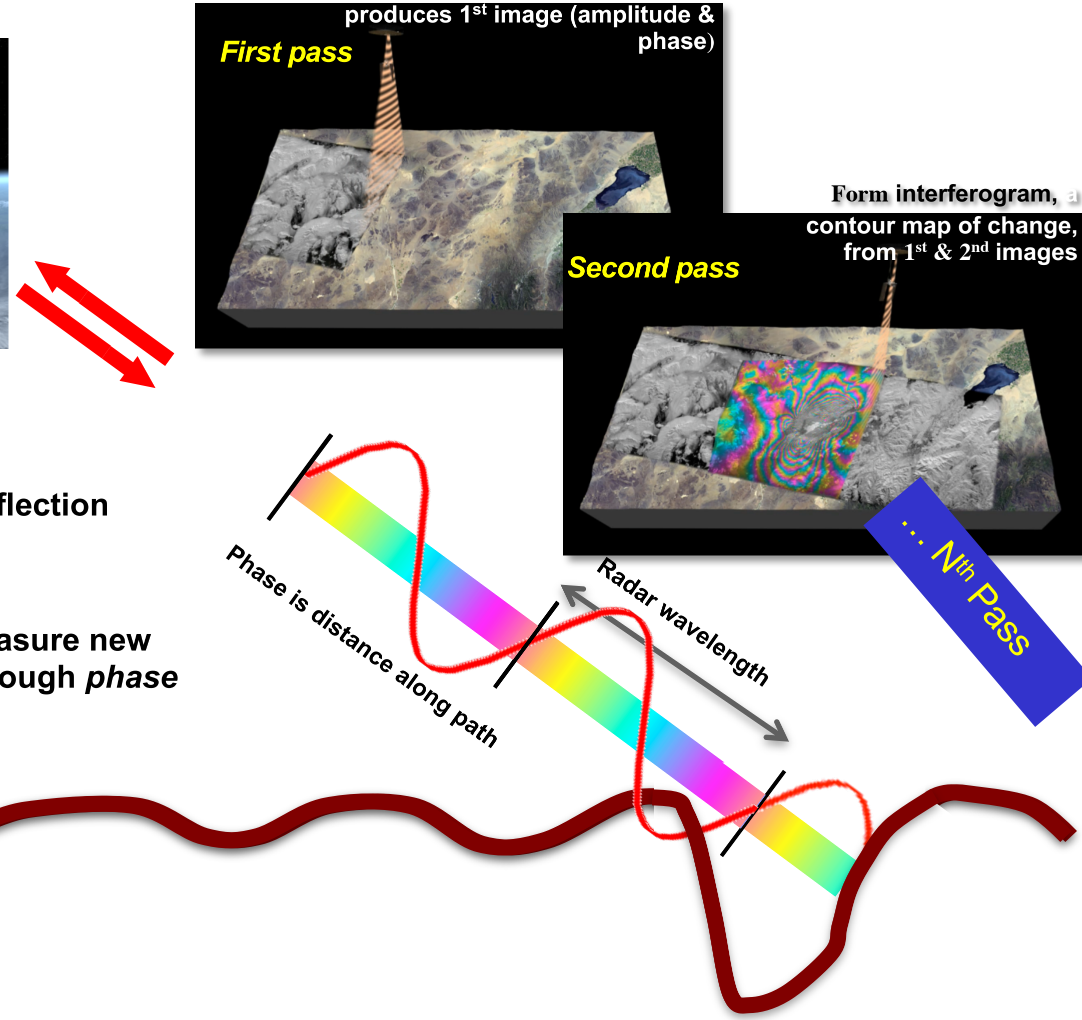
Interferometric Observables





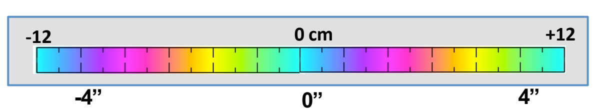
SAR Interferometry: Surface Deformation





Radar flies over an area to measure reflection

Radar flies again over the area to measure new reflection and change of distance through *phase change*



NASA-ISRO Synthetic Aperture Radar Mission

NISAR

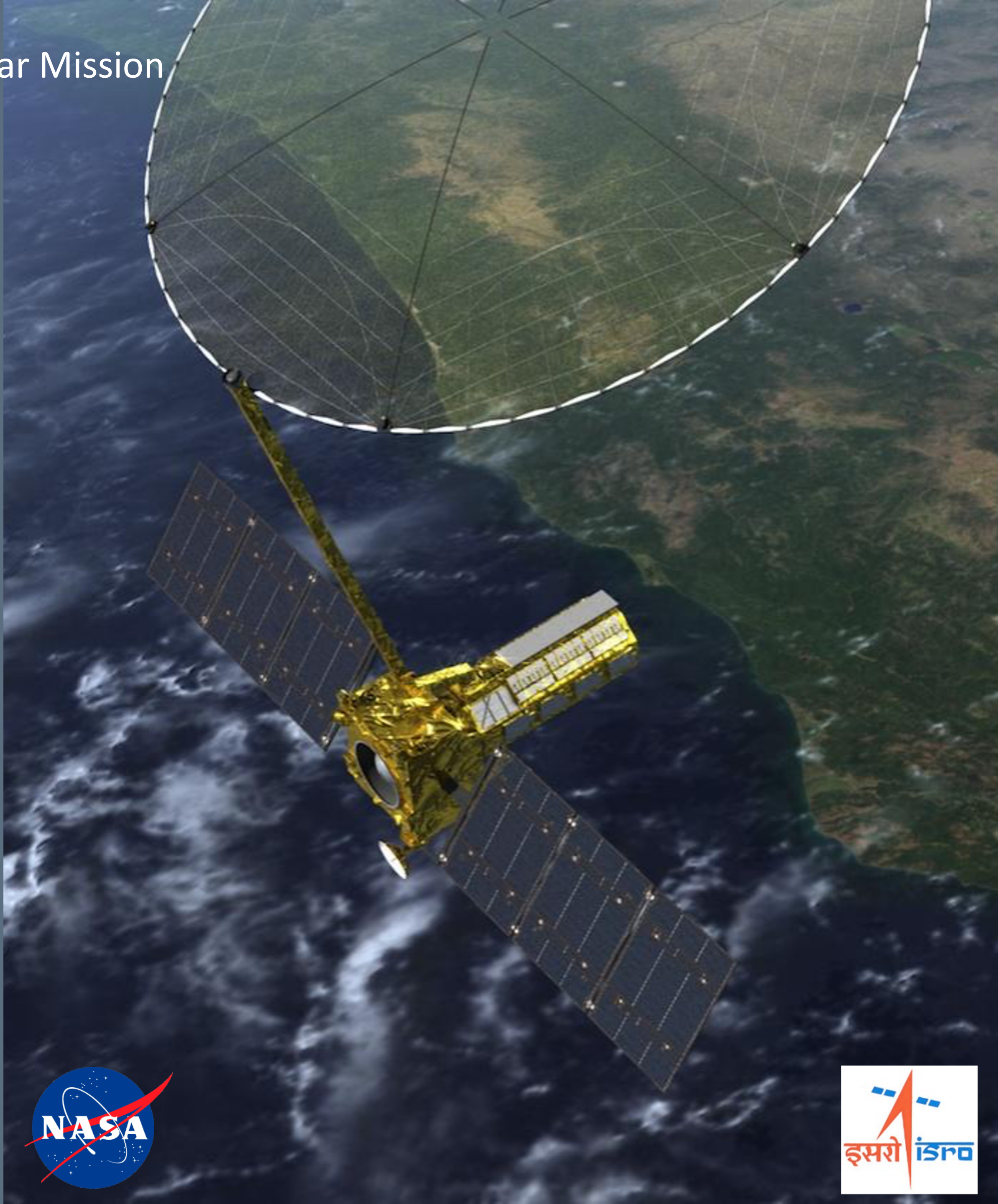
Near-global land coverage

Free & open data policy

Launch: 2022

Lifetime: 3+ years

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



NISAR Science Observation Overview

Key Research Objectives:

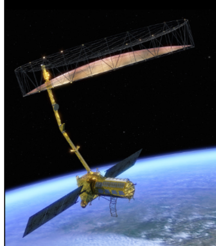
- Understand the response of ice sheets to climate change and the interaction of sea ice and climate
- Understand the dynamics of carbon storage and uptake in wooded, agricultural, wetland, and permafrost systems
- Determine the likelihood of earthquakes, volcanic eruptions, and landslides

Key Applications Objectives:

- Understand societal impacts of dynamics of groundwater, hydrocarbon, and sequestered CO_2 reservoirs
- Provide agricultural monitoring capability in support of food security objectives
- Apply NISAR's unique data set to explore the potentials for urgent response and hazard mitigation

- Partnership with the Indian Space Research Organisation (ISRO)
- Joint NASA-ISRO research objectives
- Joint development and operation of space-borne observatory
- Dual-frequency, polarimetric, repeat-pass interferometry SAR

NASA-ISRO Synthetic Aperture Radar (NISAR) Mission

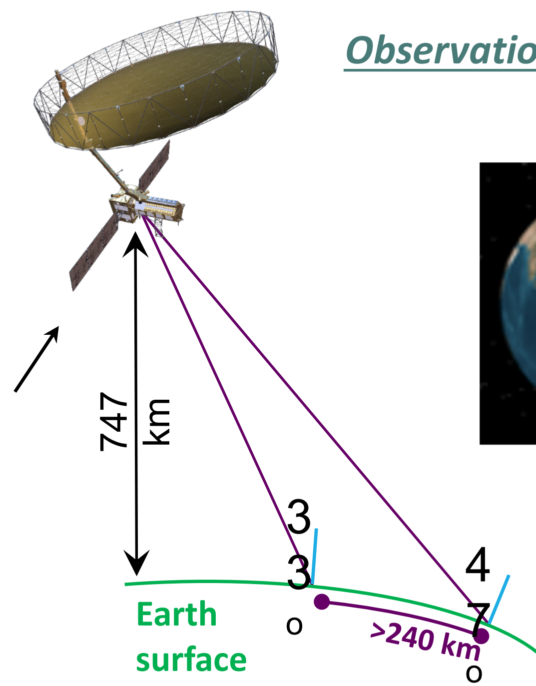


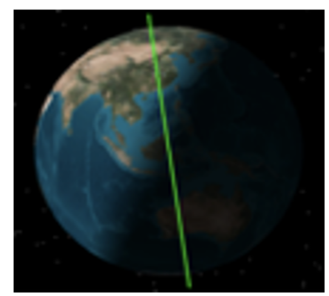
NISAR Science Observation Overview

NISAR Will Uniquely Capture the Earth in Motion

NISAR Characteristic:	Enables:
L-band (23 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (9 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath > 240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass estimation
12-day exact repeat	Rapid Sampling
3 – 10 meters mode-dependent SAR resolution	Small-scale observations
3 yrs (NASA) / 5 yrs (ISRO) science operations	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry
Orbit control < 500 meters	Deformation interferometry
> 10% (S) / 50% (L) observation duty cycle	Complete land/ice coverage
Left-only pointing (Left/Right capability)	Uninterrupted time-series Rely on Sentinel-1 for Arctic

Observation Geometry





6 AM / 6 PM

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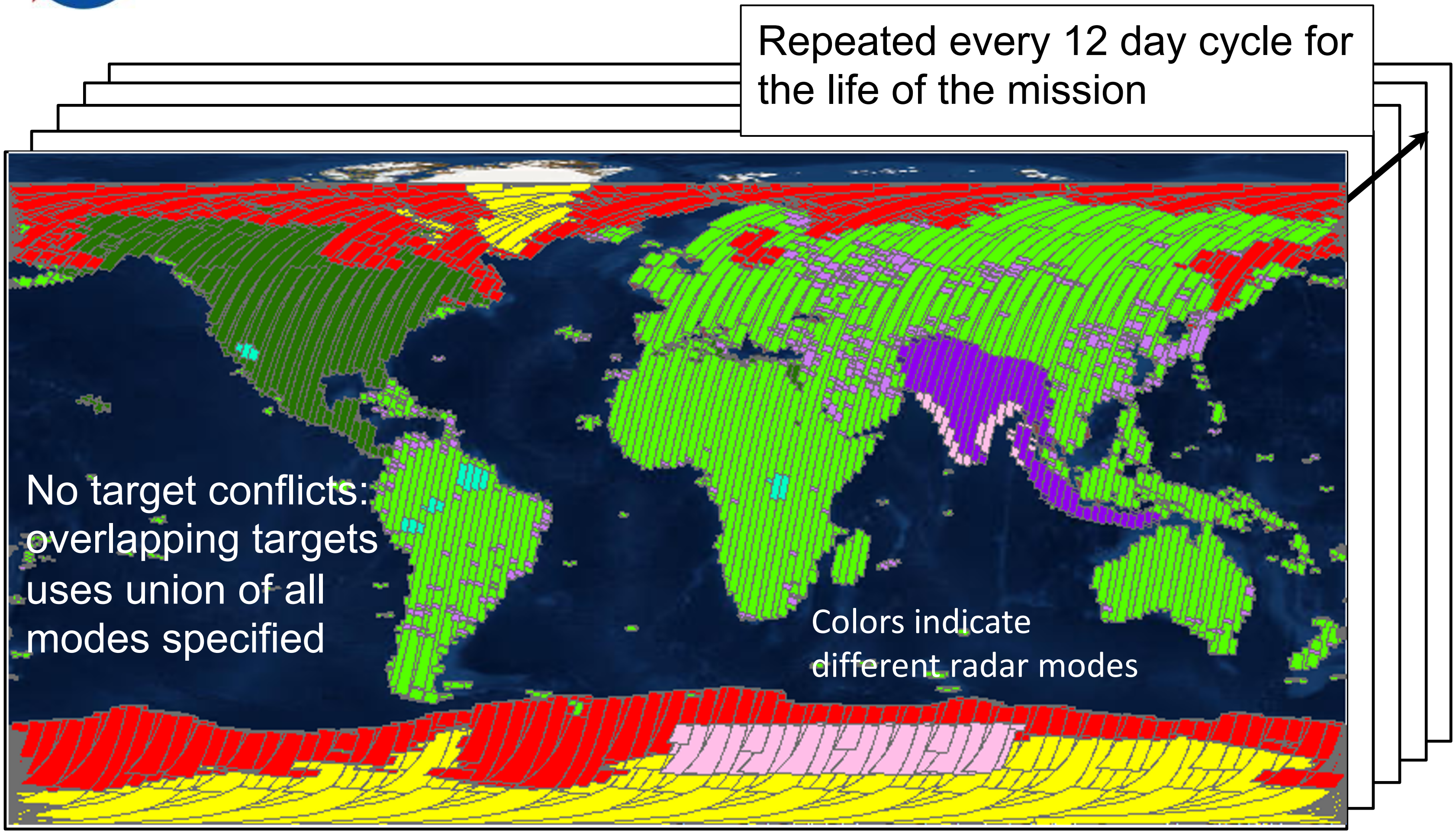
NISAR Systematic Observations



Persistent updated measurements of Earth
41 Tbits / day total L+S band science data downlink
120 Tbytes / day total L+S band L0-L2 data products

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J. Doubleday
P. Sharma,
JPL

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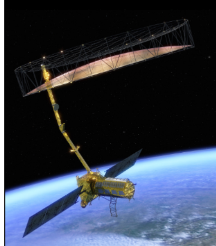
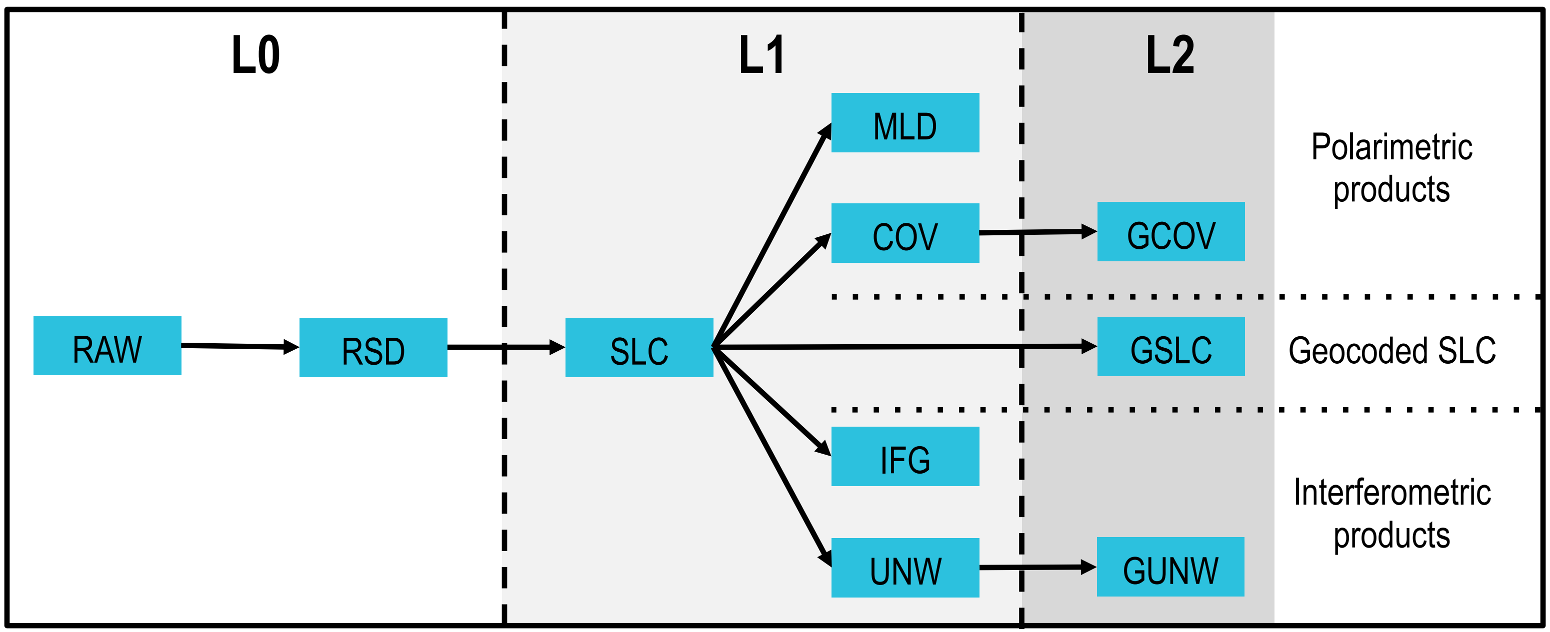


NISAR Global Product Suite

- 26-35 Tbits of raw L-band data per day on average
- 3-6 Tbits of raw S-band data per day on average
- L-SAR L0a, L0b, L1, and L2 science products
- S-SAR L0 science product of data downlinked through NASA Ka-band
- Free and open archive in Alaska Satellite Facility DAAC



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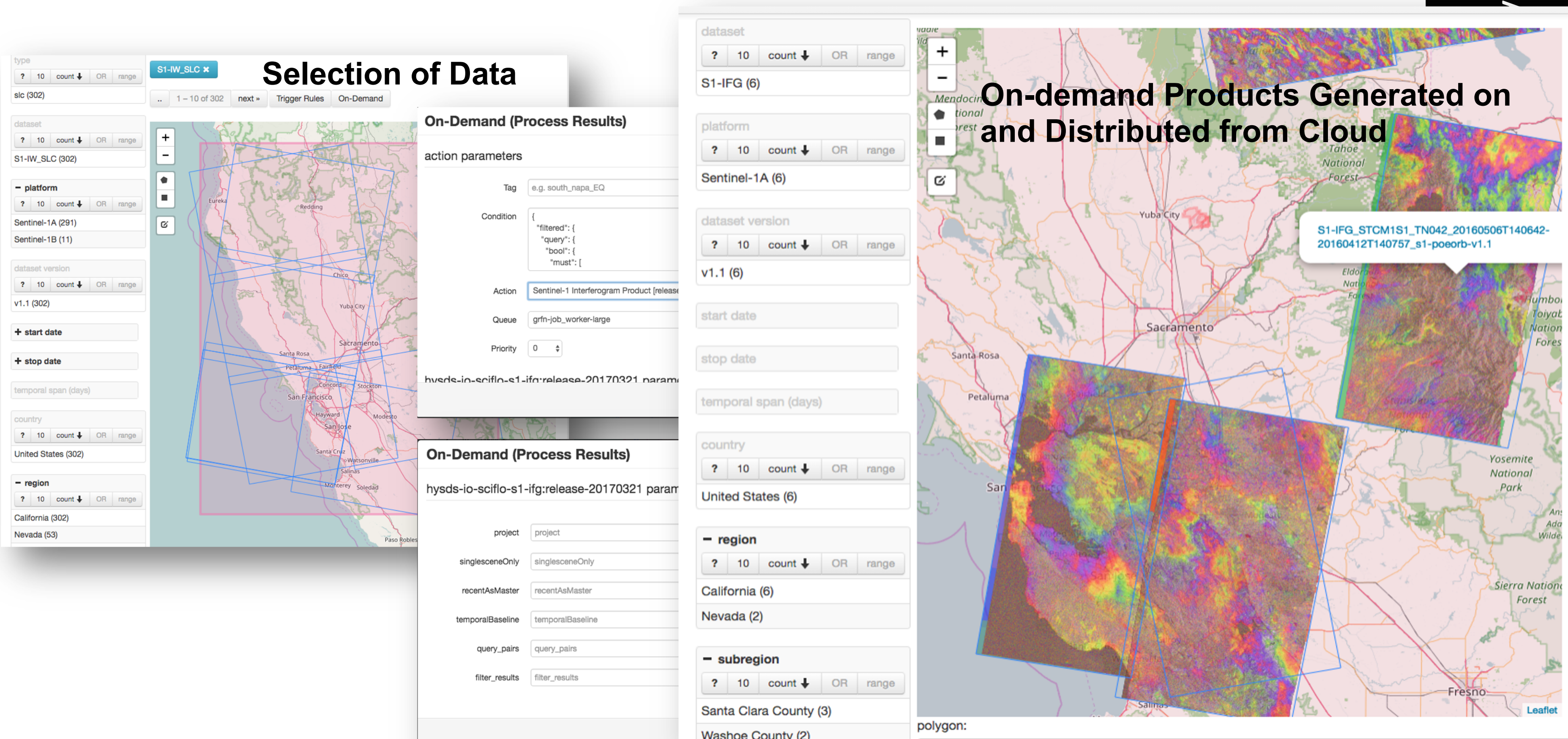
NISAR Data Processing and Access Moving to the Cloud

- Cloud Processing and distribution allows scalability and localization with users
- On-demand processing allows users to satisfy their needs without high-capability computing and networks.
- Prototyped with ARIA/GRFN Cloud Processing System



Custom On-demand settings

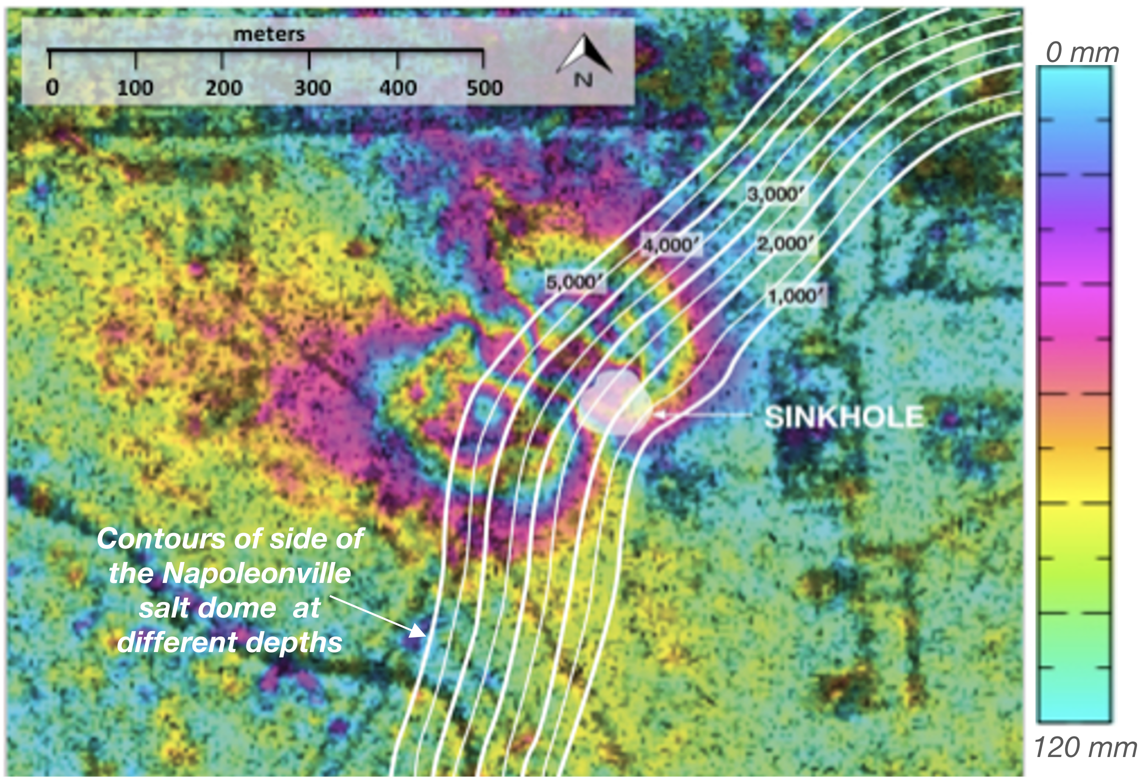
NASA-ISRO Synthetic

Photos (top-to-bottom): On Wings of Care, USGS, USGS, National Cave/Karst Research Institute, Scott Ehardt (public domain)

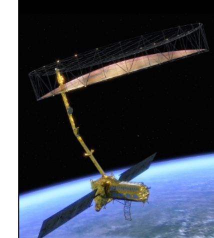
Sinkholes and Cavern Collapse

Sinkholes 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. With NISAR, experts will be able to measure surface movement directly through repeat imaging of an area.

Interferogram showing ground movement that preceded catastrophic collapse by at least 30 days. The sinkhole formed near Bayou Corne, Louisiana [Jones & Blom, Geology, 2014].



NASA-ISRO Synthetic Aperture Radar (NISAR) Mission

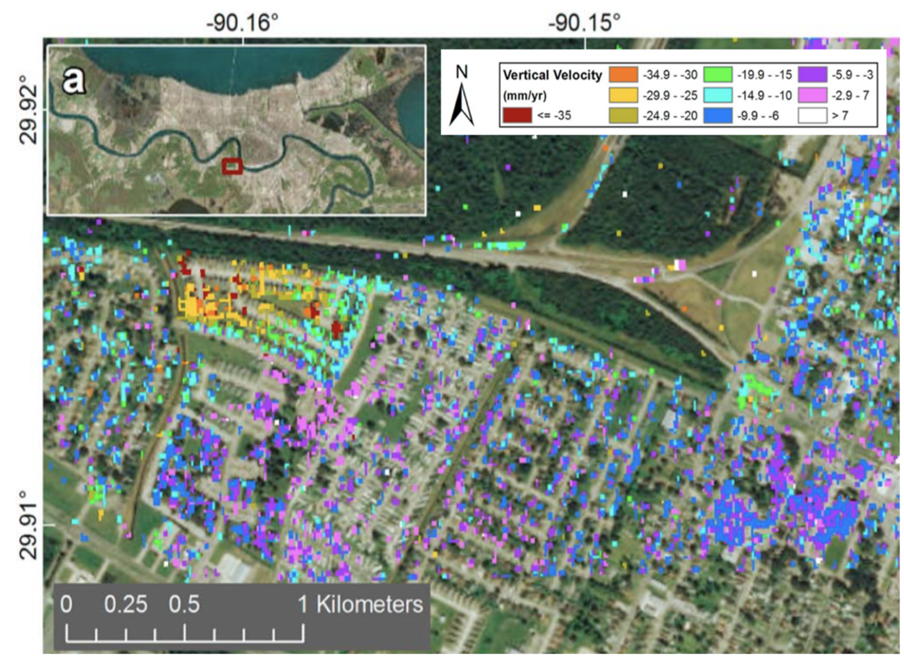


Subsidence and a Sinking Landscape

Photos (top-to-bottom): Carol M. Highsmith Archive/Library of Congress, Calif. DWR, USGS, NASA/JPL-Caltech, Batu Osmanoglu

Subsidence often goes unnoticed until the damage is done. Because land sinks too slowly or over too broad an area to be visible to the eye, the effects of subsidence are rarely recognized when they begin. Those same changes in land elevation can be detected from spaceborne synthetic aperture radar like NISAR.

Map showing subsidence in a suburb of New Orleans, Louisiana, produced using data from the NASA UAVSAR instrument [Jones et al., 2016].



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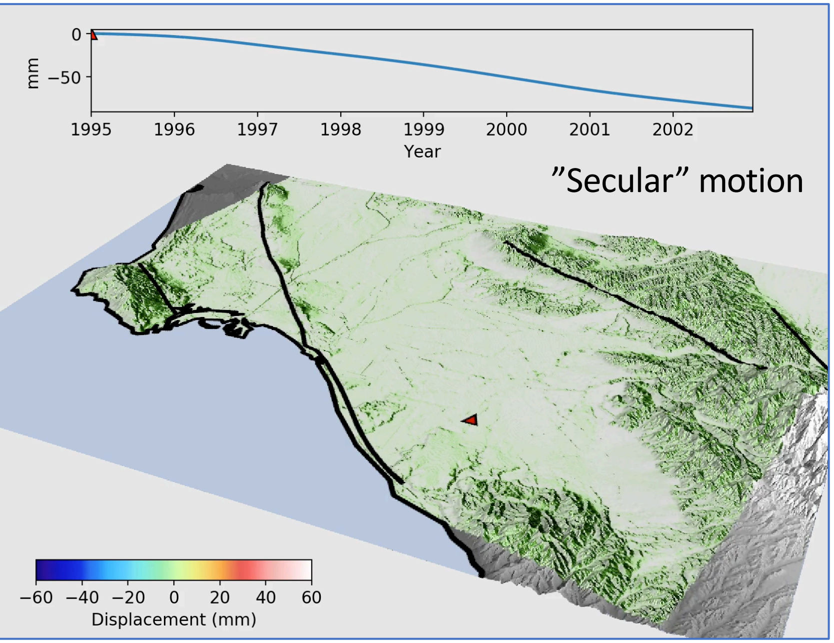
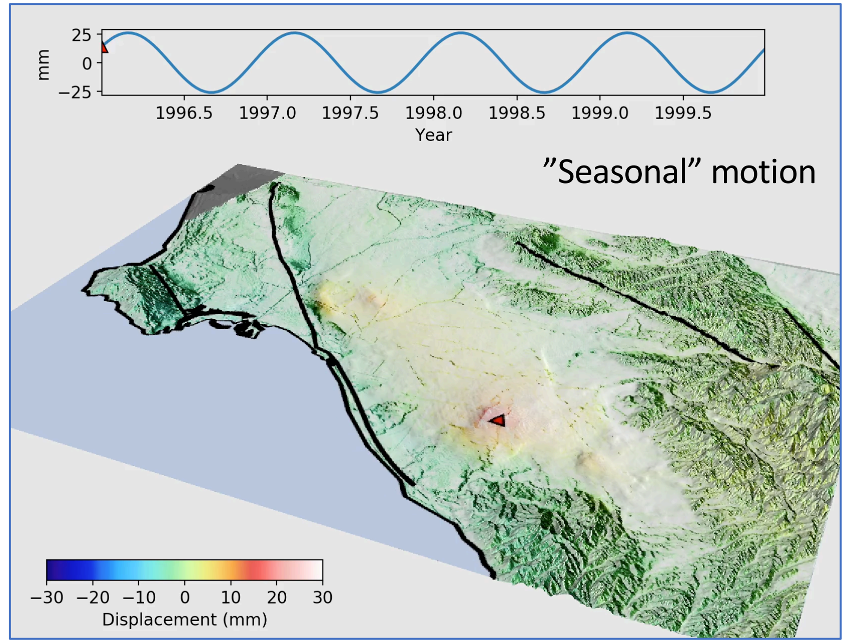
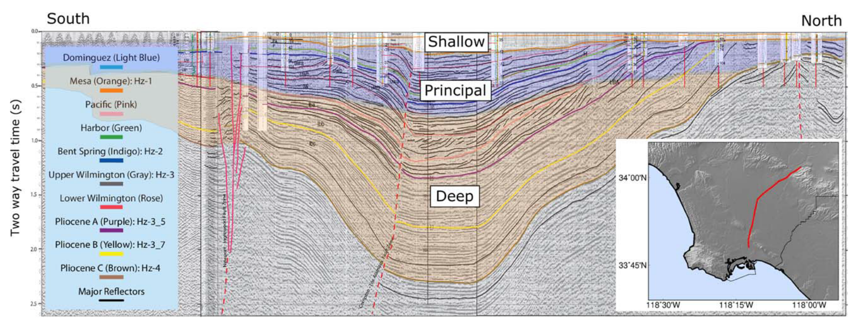
Earth's Dynamic Subsurface





- Data ➔18-year time series (881 igrams) + GPS + Hydraulic head from observation wells + geologic structure model
- Spatial pattern of seasonal ground deformation near the center of the basin corresponds to a diffusion process with peak deformation occurring at locations with highest groundwater production.
- Seasonal ground deformation associated with shallow aquifers used for the majority of groundwater production
- Long-term ground deformation over broader areas - correlated with delayed compaction of deeper aquifers and potential compressible clay layers.



Quantifying Ground Deformation in the Los Angeles and Santa Ana Coastal Basins Due to Groundwater Withdrawal, B. Riel et al., *Water Resources Res.*, **54**, doi:10.1029/2017WR021978, 2018.

Courtesy: M. Simons, B. Riel (Caltech)

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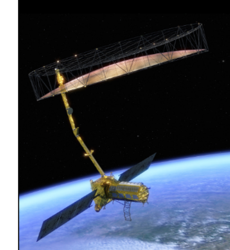
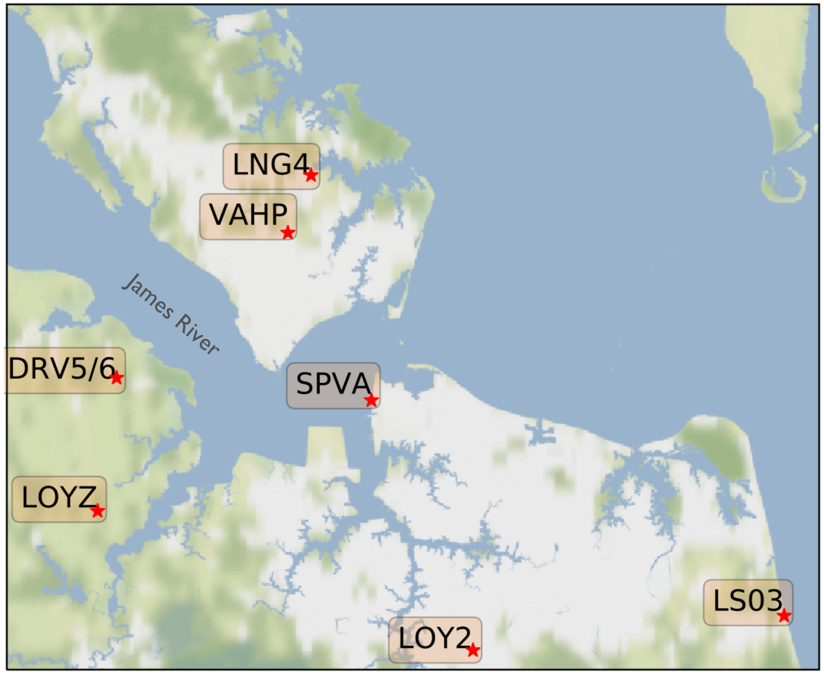


Towards Sustained Monitoring of Subsidence in Hampton Roads

Brett A. Buzzanga[1], Dr. David Bekaert[2], Dr. Ben Hamlington[2], Simran Sangha[2,3]

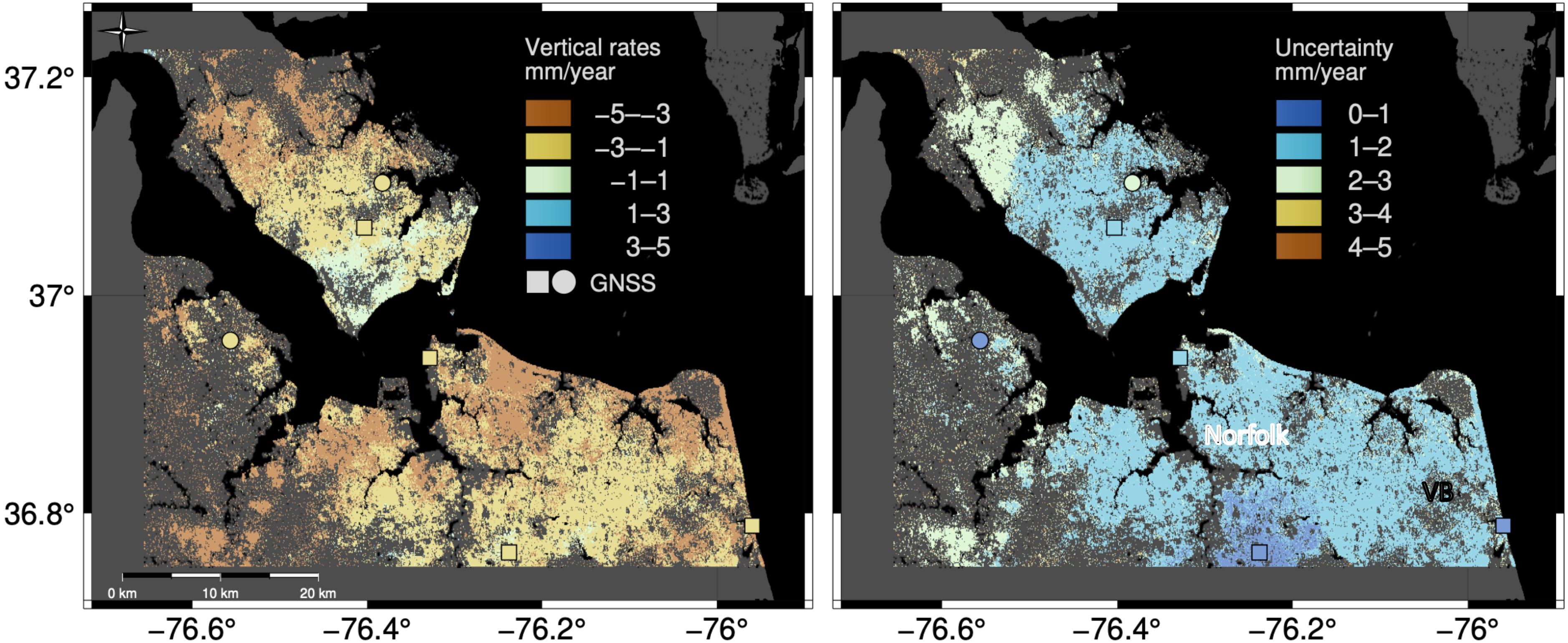
1. ODU 2. NASA JPL 3. UCLA

- The Sentinel-1 constellation has been acquiring SAR data globally every 6 - 12 days since 2014
  - Commitment by EU to sustain until 2030+
  - **Unprecedented resource for VLM generation**
- NASA JPL's ARIA system has been automatically processing Sentinel-1 InSAR products
  - Provided in a public archive
  - Suitable for mapping VLM
- GNSS observations are needed to convert InSAR VLM map into the geodetic reference frame
- Over Norfolk, Sentinel-1 acquired 75 images between March 2015 and June 2019



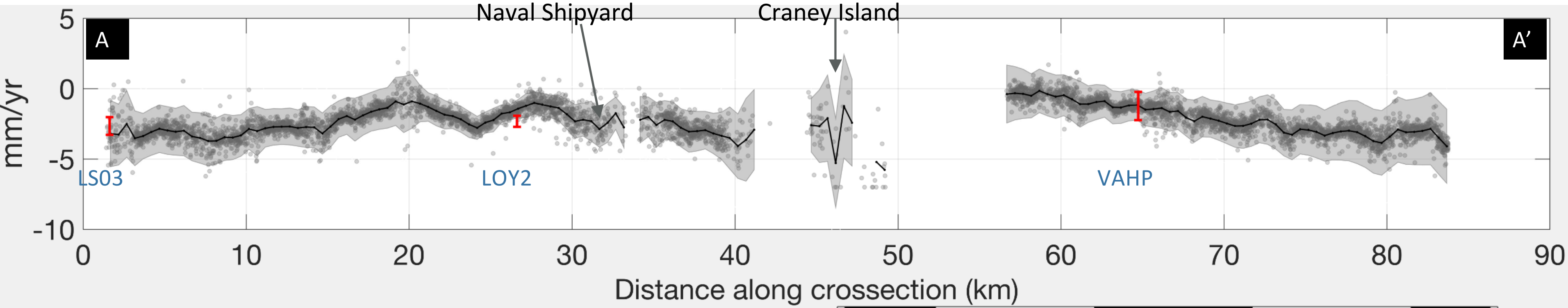
VLM Rate and Uncertainty

Buzzanga et. al, (*in review*)

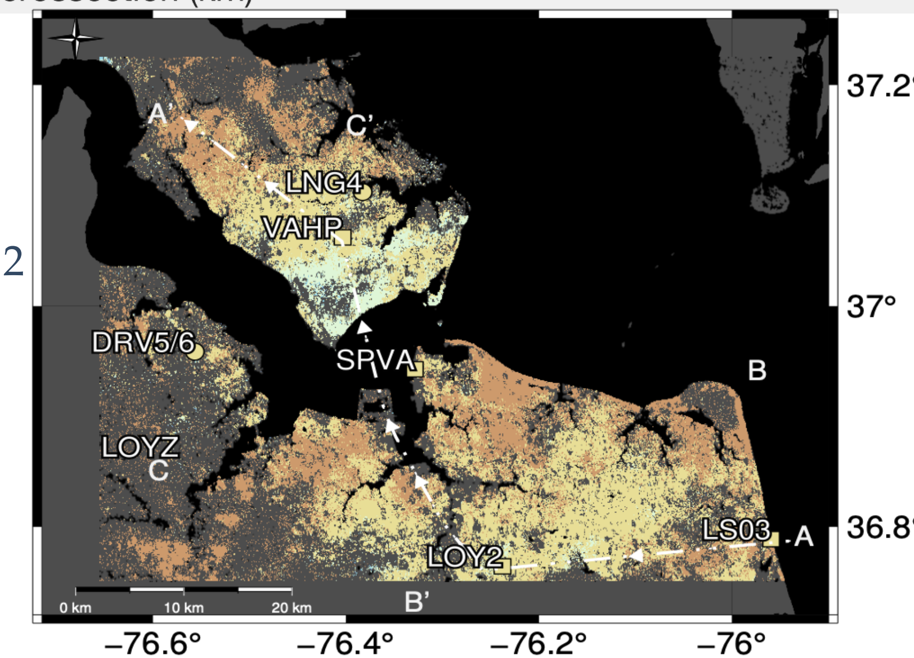


- There is **substantial spatial variability**, especially inland from the coast and in Hampton/Newport News
- **On average, study area is subsiding** at -2.80 ± 1.75 mm/yr
  - Norfolk: -3.32 ± 1.62 mm/yr
  - Virginia Beach: -2.72 ±1.57 mm/yr

Spatial Variability of VLM in HR



- ~2 - 3 mm/yr of subsidence in southern VB
- Norfolk Shipyard ~ 2 mm/yr
  - Stabilizing since construction ended in ~2012
- Hotspot of subsidence at Craney Island
- Southern Hampton/Newport News relatively stable



- Future work is focused on:
  - Implementing noise corrections to increase VLM accuracy
  - Expanding area of analysis to coastal Virginia and the eastern seaboard
  - Developing modeling strategies to disentangle causes of subsidence

Any Questions?

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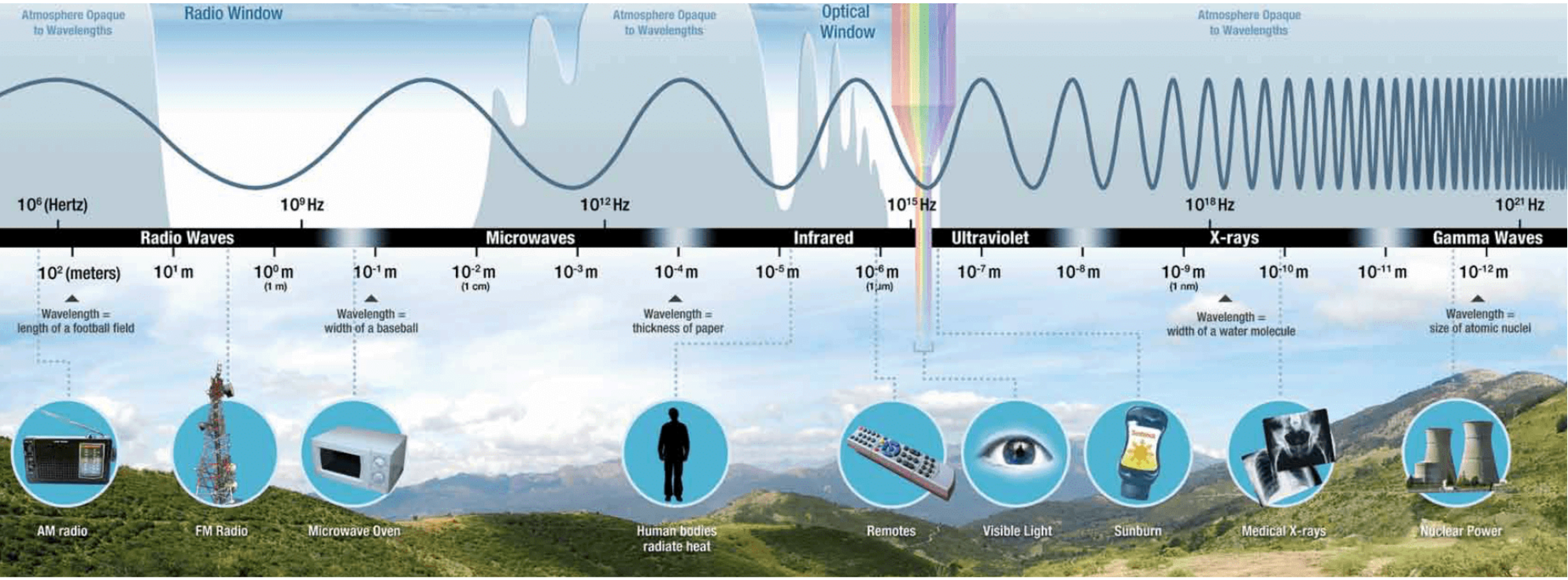
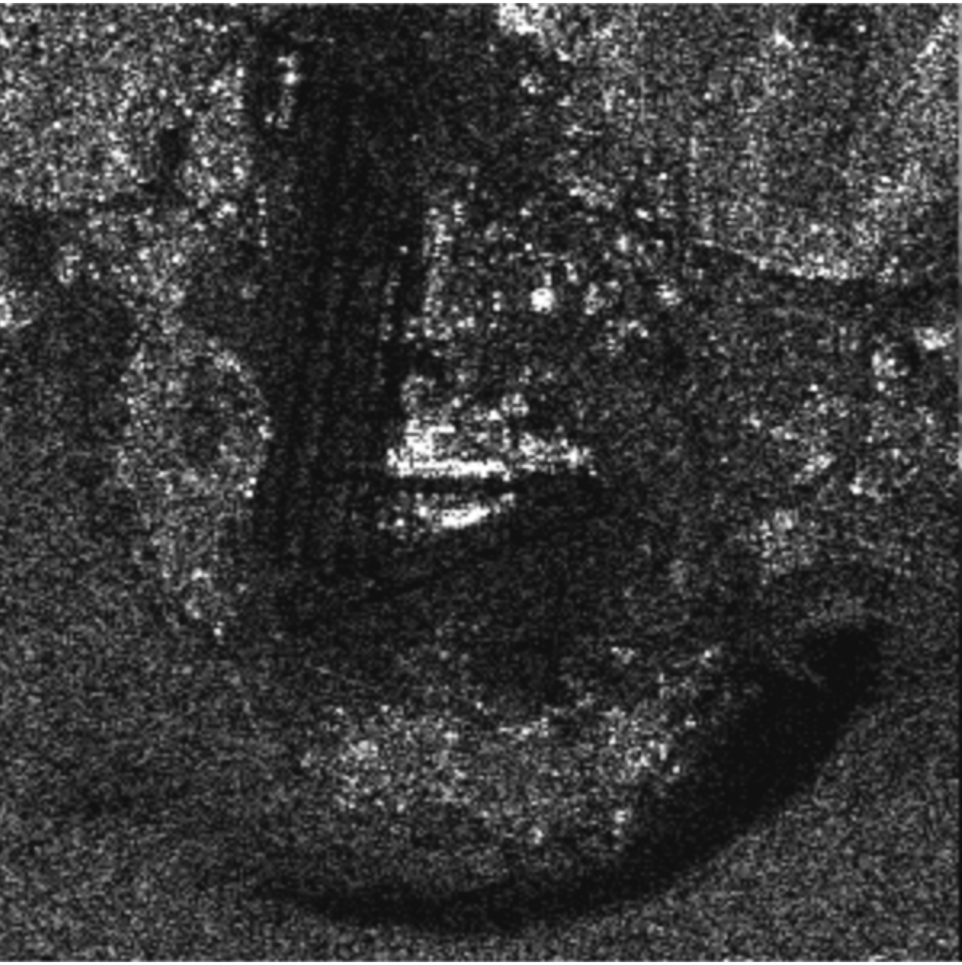
Electromagnetic Spectrum



Active and Passive Remote Sensing

Active / Envisat, 2009



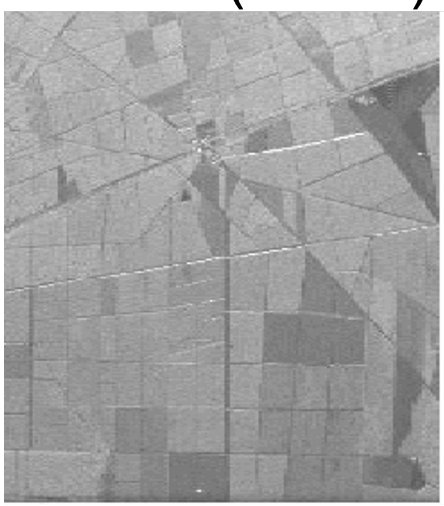
Passive / Landsat, 2004

Wavelength and polarization

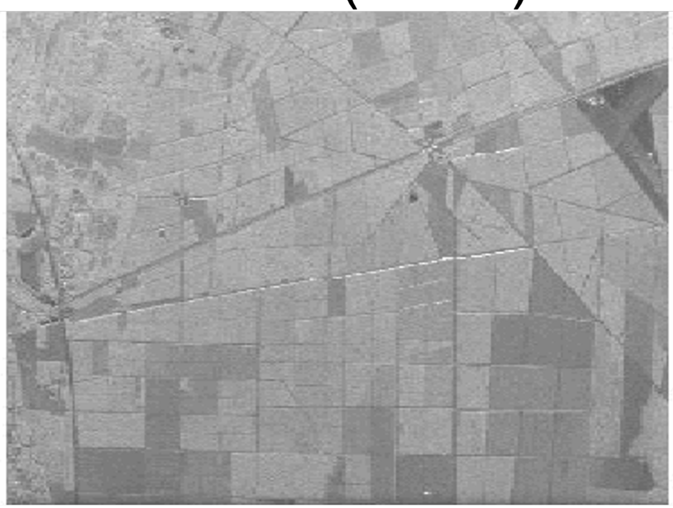
C-band (5.7 cm)

L-band (24 cm)

P-band (68 cm)



L-band HH

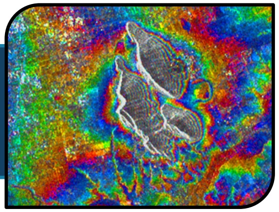


L-band VV

L-band HV

NISAR: Indian Space Research Organisation Proposed Applications

Ecosystem Structure: 1.1 Agriculture biomass & Crop monitoring; 1.2 Forest biomass; 1.3 Forest disturbance; 1.4 Mangroves / Wetlands; 1.5 Alpine vegetation; 1.6 Vegetation phenology; 1.7 Soil moisture; 1.8 Ecosystem stress assessment



Land Deformation: 2.1 Inter-seismic / Co-seismic deformations; 2.2 Landslides; 2.3 Land subsidence; 2.4 Volcanic deformations

Cryosphere: 3.1 Polar Ice Shelf / Ice sheet; 3.2 Sea Ice Dynamics; 3.3 Mountain snow/ glacier 3.4 Glacier dynamics/ hazard (Himalayan Region); 3.5 Climate response to glaciers; 3.6 Sea–Ice advisory on safer marine navigation in Antarctica region

Coasts & Ocean: 4.1 Coastal erosion / shoreline change; 4.2 Coastal subsidence and vulnerability to sea-level rise; 4.3 Coastal bathymetry; 4.4 Ocean surface wind; 4.5 Ocean wave spectra; 4.6 Ship detection; 4.7 Coastal watch services; 4.8 tropical cyclone

Disaster Response: 5.1 Floods; 5.2 Forest fire damage assessment; 5.3 Coastal oil spill; 5.4 Earthquakes / Others

Geological Applications: 6.1 Structural & Lithological mapping; 6.2 Lineament mapping; 6.3 Paleo-Channel study; 6.4 Geomorphology; 6.5 Land degradation mapping; 6.6 Geo-archaeology; 6.7 Mineral explorations

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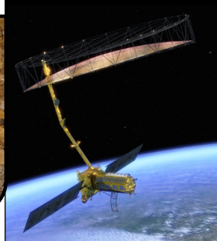
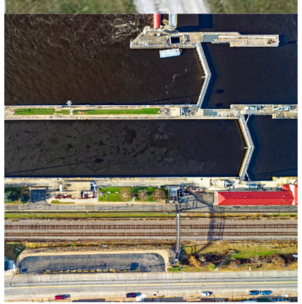






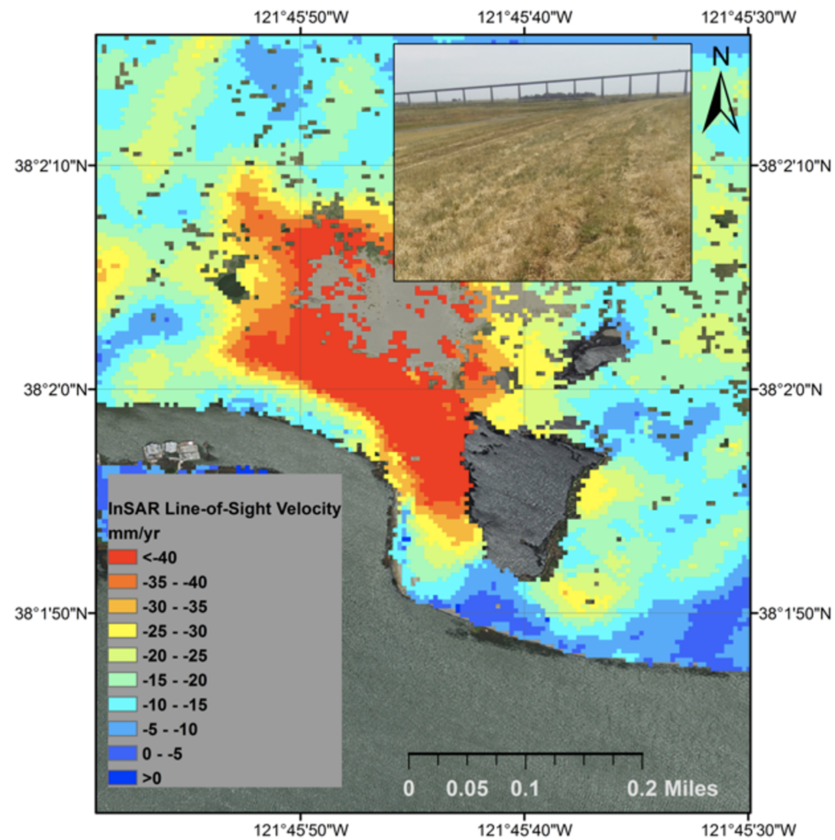


Photos (top-to-bottom): NOAA, Texas A&M Forest Service, NOAA, FEMA, Tom Fisk (Pexels)

Levees and Dams

A vast network of dams and levees protect communities throughout the U.S. from floods. Maintaining these structures is absolutely critical and requires constant vigilance. Radar remote sensing with NISAR can provide early warning of movement and seepage in time to prevent disaster.

Map showing rate of ground movement along one of the levees that prevents flooding of an island in the Sacramento-San Joaquin Delta [Deverel et al., 2016]. The inset photo shows a view looking east towards the area of most rapid movement.



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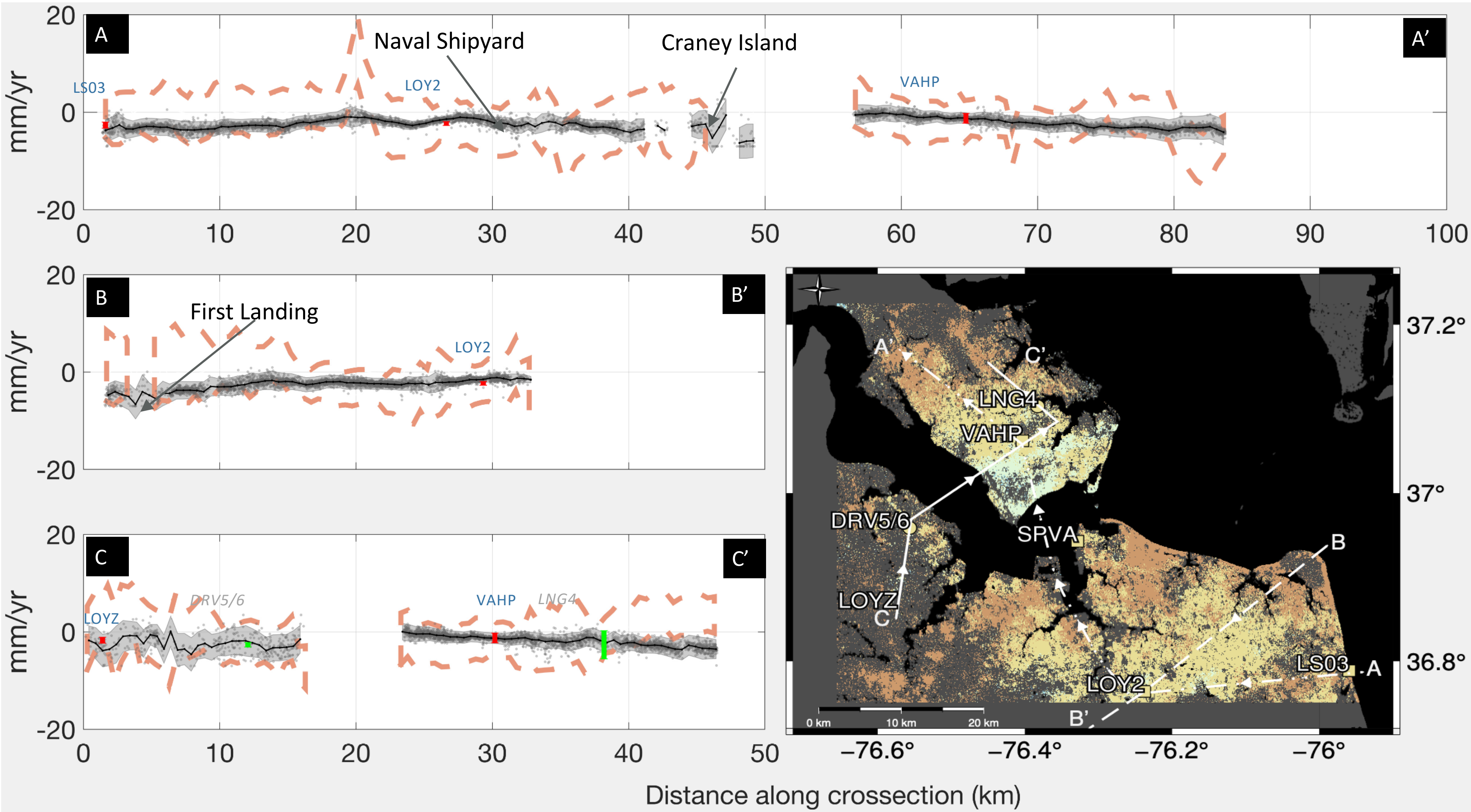
Historic ALOS-1 vs Sentinel-1 Comparison



- New satellite with consistent revisit times allow for improved VLM estimates
  - Current results consistent with previous work (orange dashed; Bekaert et. al, *2017*)
  - Uncertainties of the new Sentinel-1 VLM rates are 2-3 times better than historic ALOS

Presenter Notes for each slide (should also be in each slide)

Slide 1:

The 75 unique images 167 geocoded unwrapped interferogram standard products by the ARIA system at JPL (uses ISCE; full parameter information can be found here: https://aria.jpl.nasa.gov/node/97)

We split the northern and southern regions before performing the inversion (using GIANT)

We converted from LOS to up assuming negligible horizontal as indicated by the GPS solutions.

The upper region was referenced to VAHP; the lower region was referenced to a weighted (by variance) average of the LOY2, LS03 and LOYZ

We only included interferograms with average coherence > 0.525 and pixels that didn't maintain 0.215 coherence for the entire time series were masked.

Slide 2:

Results of SBAS processing (GIAnT) and tieing to GPS using a weighted (station variance) average reference (squar

Rates are estimated by simple least squares to displacements (no corrections; though GACOS were tested); Uncer

Hot colors indicate subsidence, and the square/circular markers show the locations of the GNSS stations for comp

Only the square markers were used for tieing the LOS rates to vertical; the lower circular stations was in a region