



Hazard Assessment with SAR: What to Expect from the NISAR Mission

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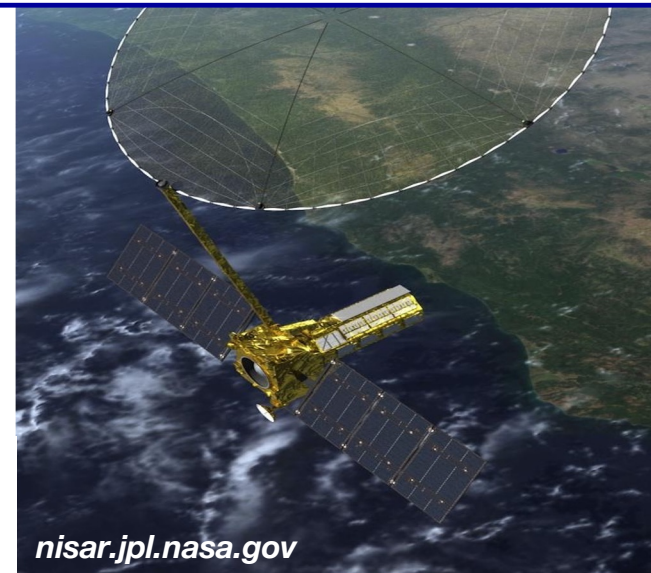
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Jet Propulsion Laboratory
California Institute of Technology



NISAR – NASA ISRO SAR Mission

- **Collaboration of NASA and the Indian Space Research Organization (ISRO)**
- **Launch in Jan. 2024**
- **Two radars**
 - L-band (24 cm) global land + sea ice – higher coherence than C-band
 - S-band (10 cm) India's AOIs
- **12 day orbit repeat interval**
- **Product delivered in ~24 hours**
 - 5 hours for disaster response
- **Data is free and open to all**
 - Hosted at the Alaska Satellite Facility

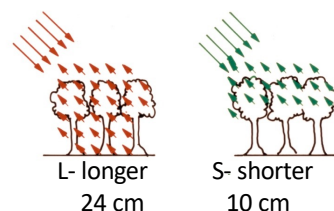
Flight Configuration of NISAR



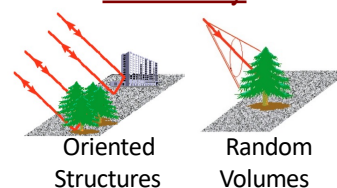
NISAR instrument Characteristics

NISAR Characteristic:	Enables:
L-band (24 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (9 cm wavelength)	Sensitivity to lighter 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/time series
3 – 10 meters mode-dependent SAR resolution	Small-scale observations
Pointing control < 273 arcseconds	Deformation interferometry
Orbit control < 500 meters	Deformation interferometry
L/S-band > 50/10% observation duty cycle	Complete land/ice coverage
Left-Looking	Uninterrupted time series; More Antarctic coverage

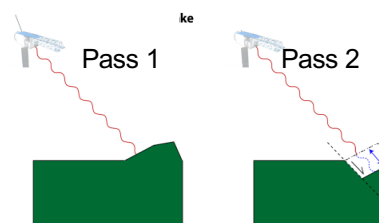
L- and S-band Wavelength



Polarimetry

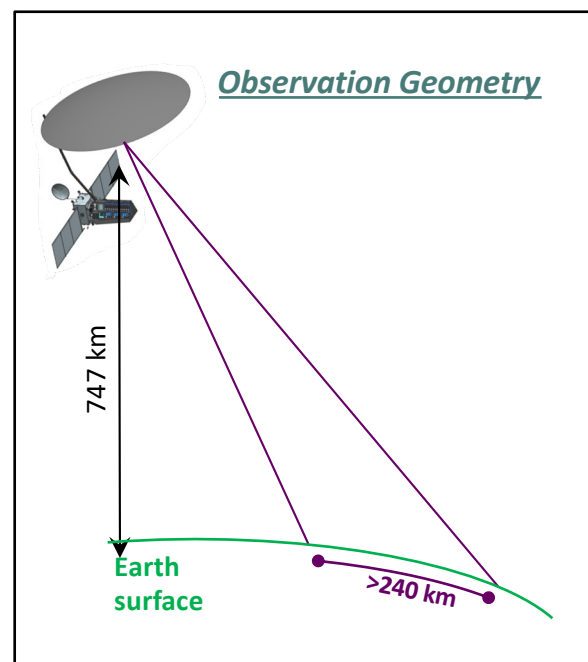


Repeat Pass InSAR



6 AM / 6 PM Orbit
98.5° inclination
Arctic Polar Hole: 77.5 Lat
Antarctic Polar Hole: -87.5 Lat

Observation Geometry



Measurement Technique

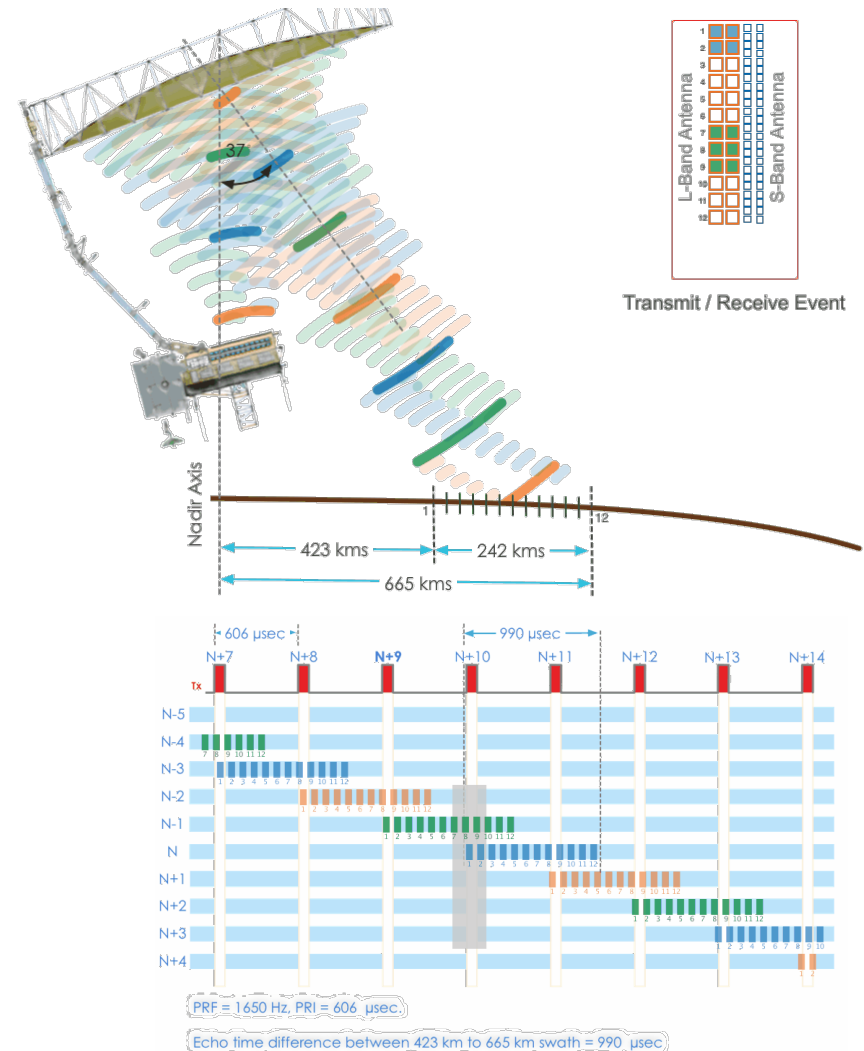
SweepSAR

- SweepSAR**

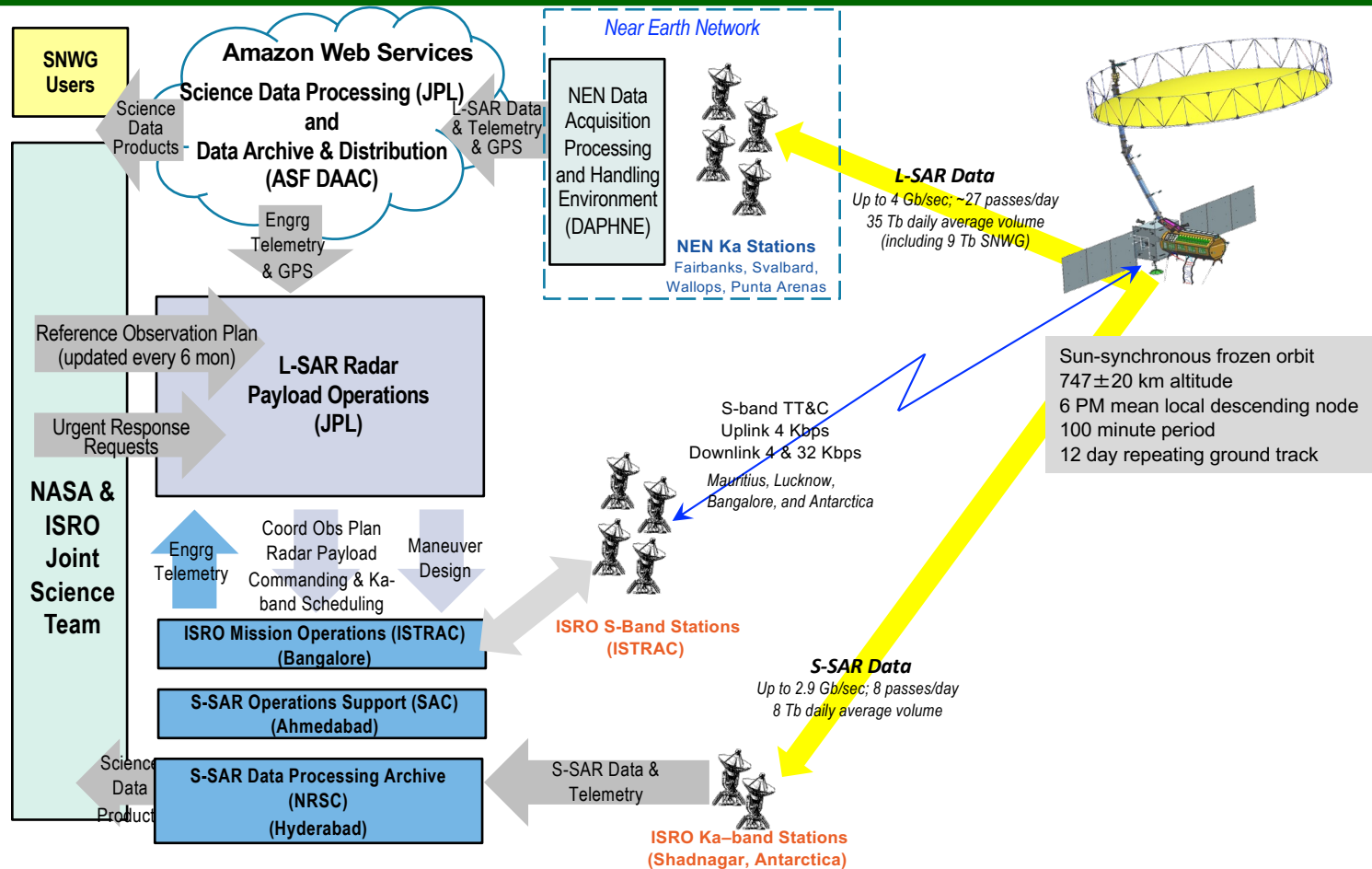
- On Transmit, illuminate the entire swath of interest
- On Receive, steer the beam in fast time to follow the angle of the echo coming back to maximize the SNR of the signal and reject range ambiguities
- Allows echo to span more than 1 Inter-Pulse Period (IPP)

- Consequences**

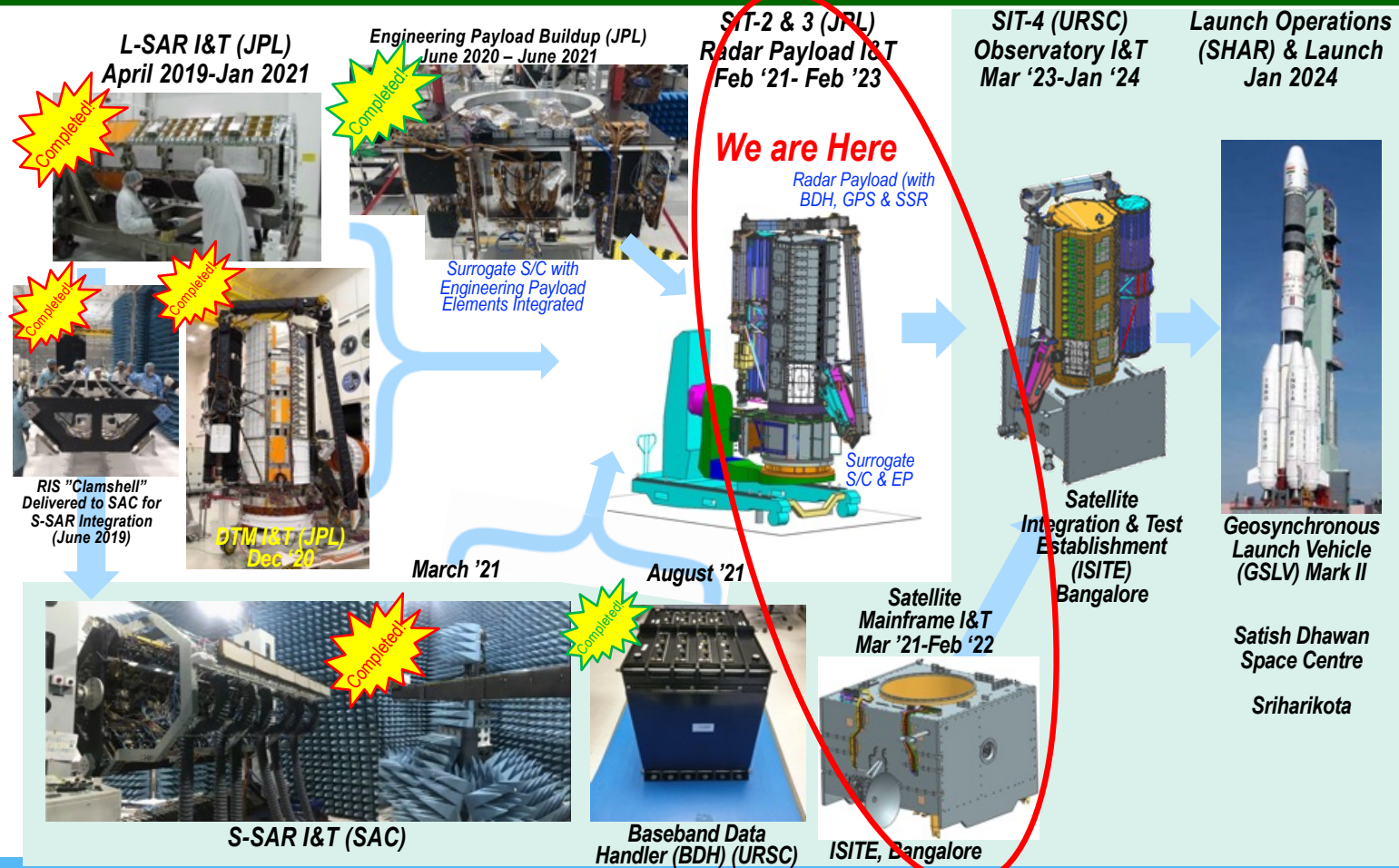
- 4 echoes can be simultaneously returning to the radar from 4 different angles in 4 different groups of antenna beams
- Each echo needs to be sampled, filtered, beam-formed, further filtered, and compressed
- On-board processing is not reversible – Requires on-board calibration before data is combined to achieve optimum performance



NISAR Operations Overview



NISAR Development Status



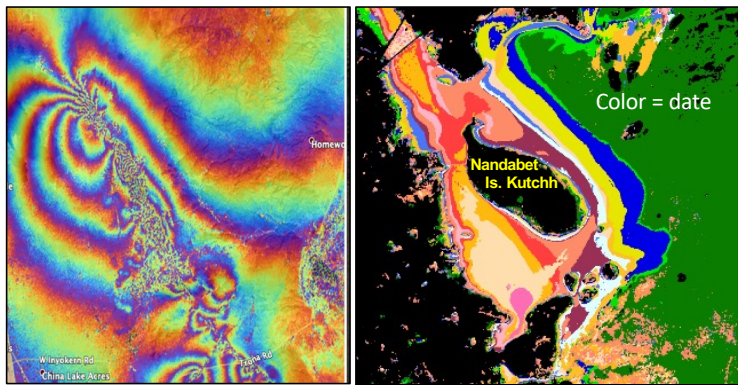
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Solid Earth, Ecosystems, Cryosphere
Science and Applications Mission

Mission Status

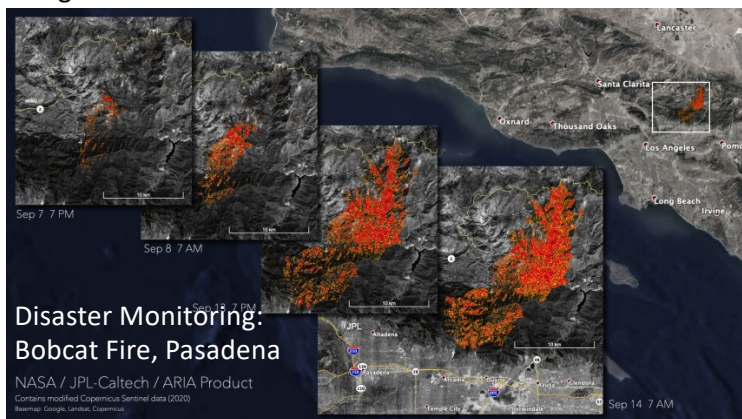


*Flight Boom currently being integrated
with flight model radar structure; Flight
Reflector integration late May 2022*



Earthquake Dynamics,
Ridgecrest

Wetland Inundation, India



Disaster Monitoring:
Bobcat Fire, Pasadena

• Dynamics of Ice: Ice sheets, Glaciers, and Sea Level

- ❑ Will there be catastrophic collapse of the major ice sheets, including Greenland and West Antarctic and, if so, how rapidly will this occur?
- ❑ What will be the resulting time patterns of sea-level rise?
- ❑ How are alpine glaciers changing in relation to climate?

• Ecosystems and Biomass Change

- ❑ How do changing climate and land use in forests, wetlands, and agricultural regions affect the carbon cycle and species habitats?
- ❑ What are the effects of disturbance on ecosystem functions and services?

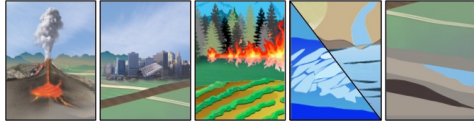
• Solid Earth Deformation

- ❑ Which major fault systems are nearing release of stress via strong earthquakes?
- ❑ Can we detect future eruptions of volcanoes?
- ❑ What are optimal remote sensing strategies to mitigate disasters and monitor/manage water and hydrocarbon extraction and use?
- ❑ Where is subsidence occurring, by how much, and due to what processes?

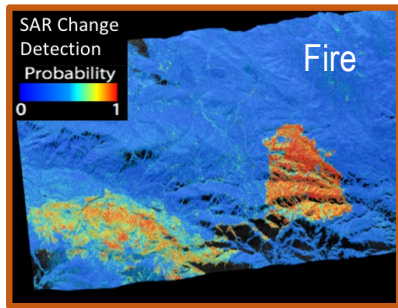
• Coastal Processes

- ❑ What is the state of important mangroves?
- ❑ How are Indian coastlines changing?
- ❑ What is the shallow bathymetry around India?
- ❑ What is the variation of winds in India's coastal waters?

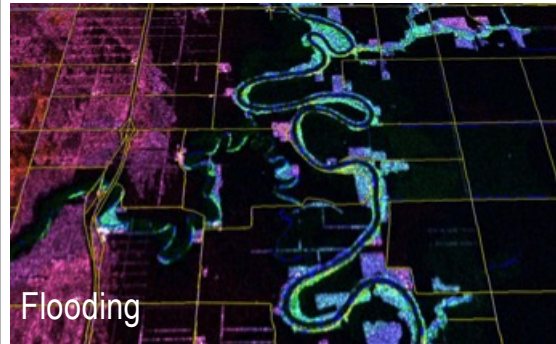
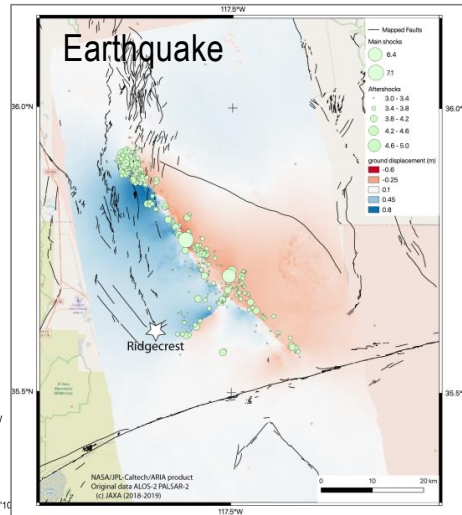
Hazard Response



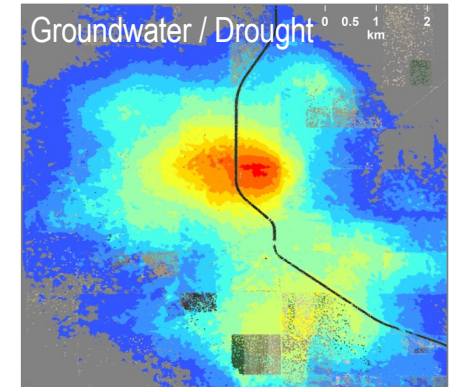
NISAR Hazard Applications



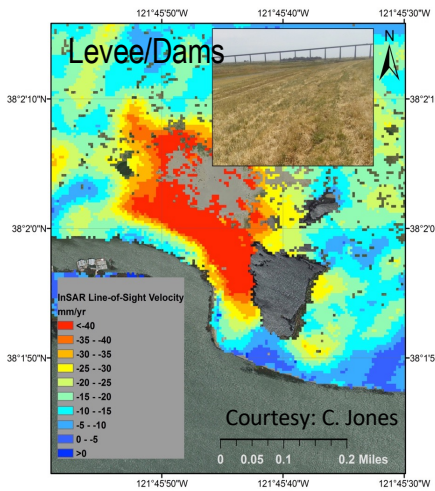
Courtesy: UAVSAR Project



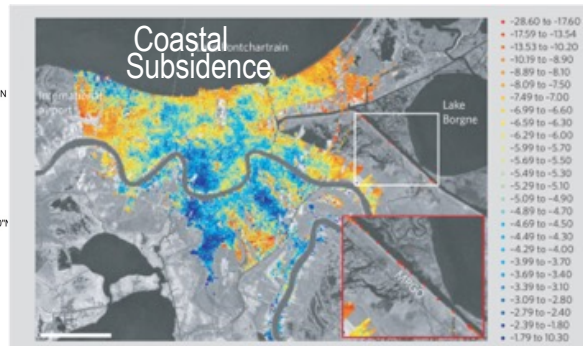
Courtesy: G. Breckenridge/S. Nghiem



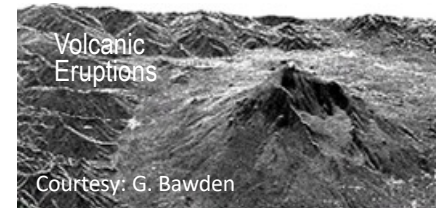
Courtesy: C. Jones



Courtesy: C. Jones



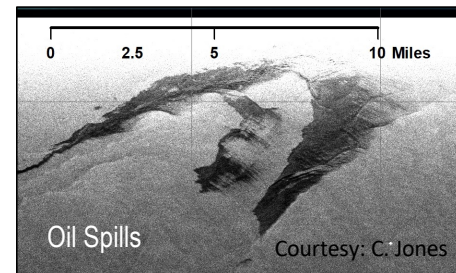
Dixon et al, Nature 2006



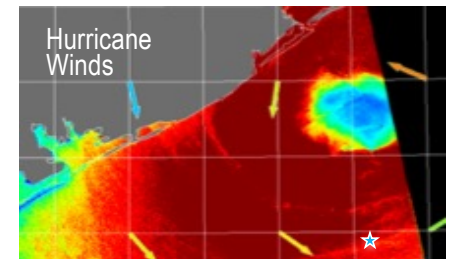
Courtesy: G. Bawden



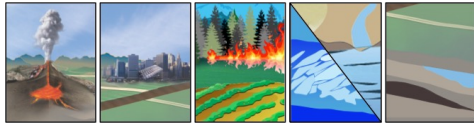
Courtesy: S.-H. Yun



Courtesy: C. Jones

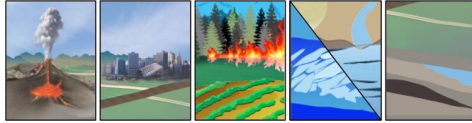


Courtesy: G. Bawden



Societal Challenges / Applied Science

Challenge	Benefit Through Regular SAR Monitoring of:
Climate Risks and Adaptation	<ul style="list-style-type: none"> - Ice sheet/sea-ice dynamics; response to climate change - Coastal erosion and shoreline migration
Global Food Security	<ul style="list-style-type: none"> - Soil moisture and crop growth at agricultural scale - Desertification at regional scales
Freshwater Availability	<ul style="list-style-type: none"> - Aquifer use/extent regionally - Water-body extent changes - Glaciers serving as water sources
Human Health	<ul style="list-style-type: none"> - Moisture and vegetation as proxy for disease and infestation vectors
Disaster Management & Hazard Response	<ul style="list-style-type: none"> - Regional building damage and change assessment after earthquakes - Earthen dams and levees prone to weakening - Volcanoes, floods, fires, landslides
Urban Management and Planning	<ul style="list-style-type: none"> - Urban growth through coherent change detection - Building deformation and urban subsidence
Human-activity Based Climate Change	<ul style="list-style-type: none"> - Deforestation's influence on carbon flux - Oil and gas reservoirs



Urgent Response Capability

NISAR tasking & processing systems provide low latency downlink & processing for disaster response, including retasking to obtain new scenes in extreme cases (e.g., ocean scenes for major hurricanes)

Latency goal: 5 hours from acquisition to product delivery

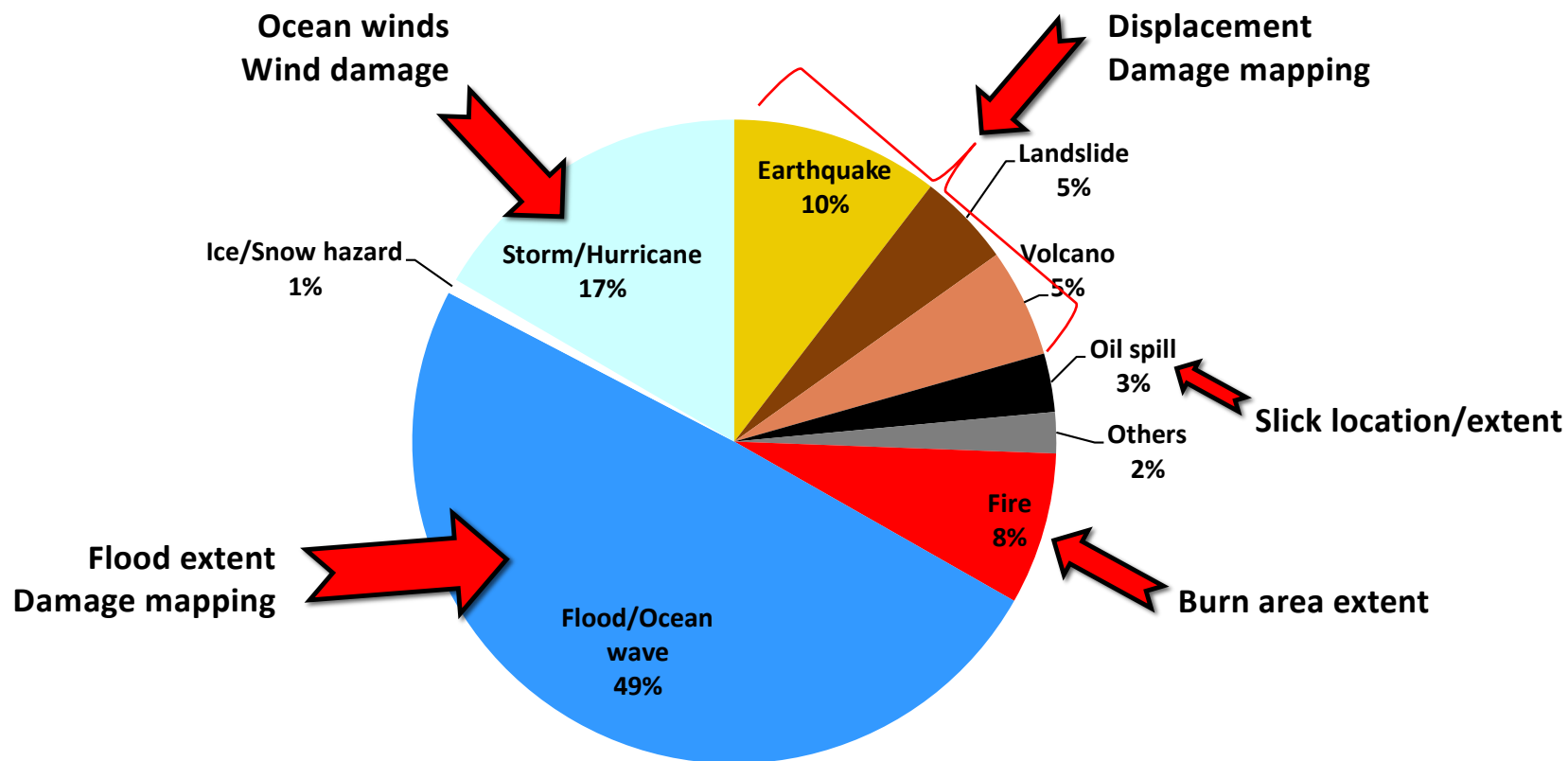
Major earthquakes (7+ & USGS PAGER red/orange) will automatically trigger requests, others by request

- Most land scenes will already be in acquisition plan, so they will be tagged for immediate expedited processing upon downlink.
- New scenes (e.g., ocean) require retasking
 - Forewarned events can be requested in advance
 - Gulf of Mexico & Caribbean Sea are in standard plan
 - Best case, requests received by Weds. can be acquired on Saturday

Topic	Event	Classification
Geological Hazards	Volcano Eruption	Catastrophic Event, Automatable
	Earthquake	Catastrophic Event, Automatable
	Landslide	Catastrophic Event, Manual
	Other Geological Hazards	Catastrophic Event, Manual
Critical Infrastructure	Levee, Dam, Bridge Failure	Catastrophic Event, Manual
	Industrial Accident	Catastrophic Event, Manual
	Secondary impact of other events	Catastrophic Event, Automatable
Underground Reservoirs	Mine, Cavity Collapse	Catastrophic Event, Manual
	Induced Seismicity	Catastrophic Event, Automatable
Surface Hydrology	Storm Surge Flooding	Forewarned Disaster
	Riverine Floods	Forewarned Disaster
	Ice Jams	Forewarned Disaster
Ecosystems	Forest Fires	Catastrophic Event, Automatable
	Agriculture, Secondary Impact	Forewarned Disaster
Maritime Hazards	Oil Spills	Catastrophic Event, Automatable
	Oceanic Storm (Hurricane, Typhoon, Other)	Forewarned Disaster
	Icebergs	Forewarned Disaster
	Tsunami	Catastrophic Event, Manual
	Ship or Aircraft Distress – Lost at Sea - Maritime Accident	Catastrophic Event, Manual

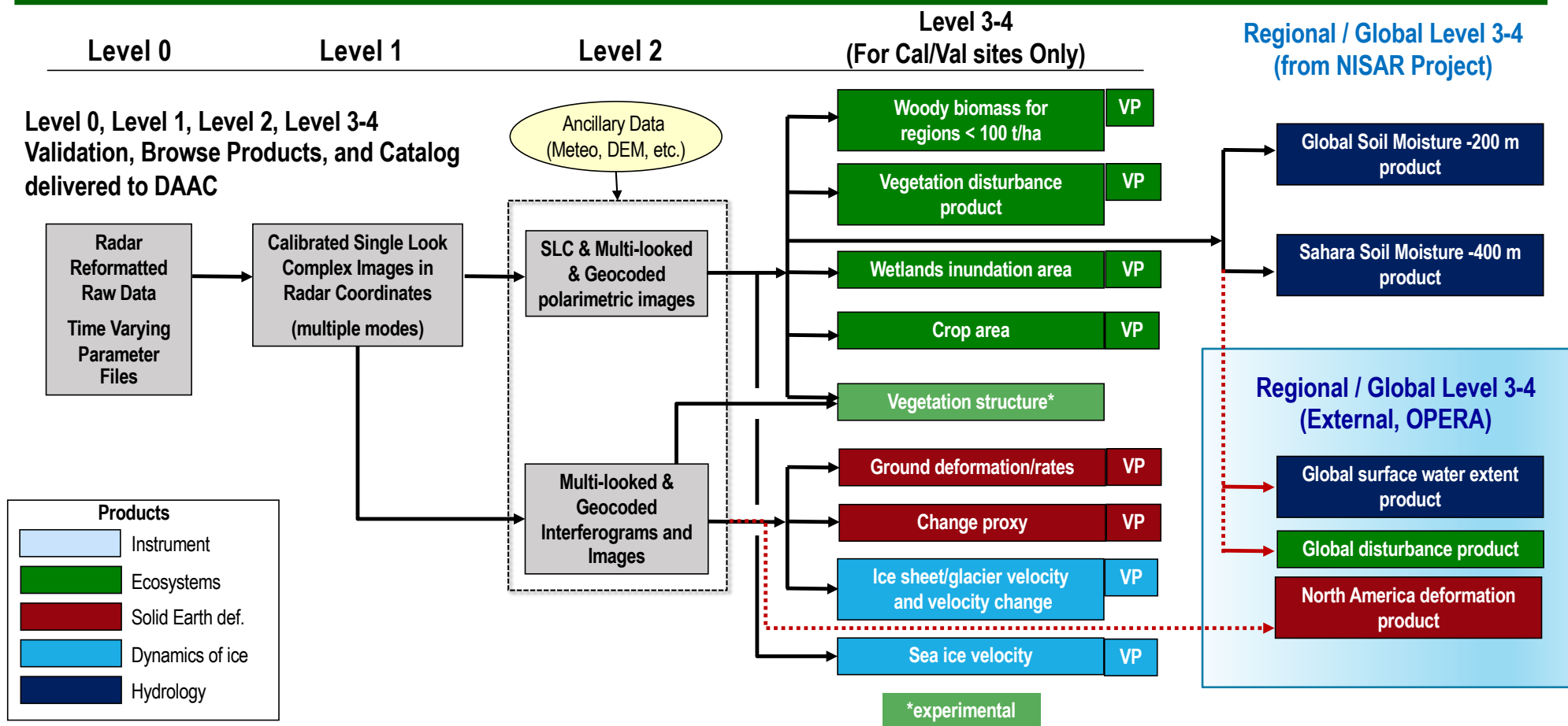
EXPECT NISAR RESPONSE FOR THESE EVENTS

Hazard-relevant Information from SAR



October 15, 2020 – Statistics of 680 International Disasters Charter Activations to date

NISAR Science & Information Products



NISAR-Like Data from L-band UAVSAR Instrument

<https://uavsar.jpl.nasa.gov/cgi-bin/data.pl>

UAVSAR Data Search
A GeoJSON file with all flown lines is available here.

Date range: Tue, 1 Jan 2008 to Tue, 17 May 2022

Processing modes: ☒ PolSAR, ☐ InSAR Pair, ☐ InSAR Browse, ☐ SLC Stack, ☐ TomoSAR, ☐ TopSAR (Ka-band)

Band: ☒ L-band, ☐ P-band, ☐ Ka-band

Specialized Products: ☒ Simulated NISAR

Search

Lat: Lng: [Show] 440 products from 73 flight lines found [Hide]

Zoom in to click on a flight line

Map

- beafo_01104 (1) - Beaufort Sea, AK
- beafo_19103 (1) - Beaufort Sea, AK
- Bigisl_32905 (1) - Big Island, HI
- bonanW_03603 (6) - Bonanza Creek LTER
- brazos_14938 (3) - Brazos River, TX
- dhorse_18519 (4) - Deadhorse Legacy Line
- eighty_13055 (1) - Rabi Forest, Gabon
- eighty_14047 (1) - Lope National Park, Gabon
- evergl_15704 (1) - Everglades, FL
- FLcoas_00103 (1) - Central West Coast, FL
- fortym_14045 (1) - Lope National Park, Gabon
- grmesa_09305 (1) - Grand Mesa, CO
- Grmind_00004 (2) - Glaciers, Greenland
- Grmind_00005 (3) - Glaciers, Greenland
- gulfco_14013 (2) - Gulf Coast, LA
- gulfco_27086 (1) - Gulf Coast, LA
- gulfco_27802 (9) - Mike Island
- gulfco_27803 (8) - white lake
- Haywrd_14501 (19) - Hayward Fault, CA
- height_13059 (1) - Rabi Forest, Gabon
- hslxt_13058 (1) - Rabi Forest, Gabon
- htwent_13057 (1) - Rabi Forest, Gabon
- htwent_14049 (1) - Lope National Park, Gabon
- hundre_13056 (1) - Rabi Forest, Gabon
- hundre_14048 (1) - Lope National Park, Gabon
- kakisa_11703 (4) - Kakisa Lake, Canada
- lopemp_14043 (2) - Lope National Park, Gabon
- NISARA_00914 (8) - Arkansas 1
- NISARA_02602 (12) - Yucatan Lake, LA
- NISARA_06800 (7) - Forest management and Arkansas agriculture
- NISARA_13904 (5) - ORNL, TN
- NISARA_13905 (6) - Coweeta, NC
- NISARA_22802 (12) - Tifton, GA

Google Earth

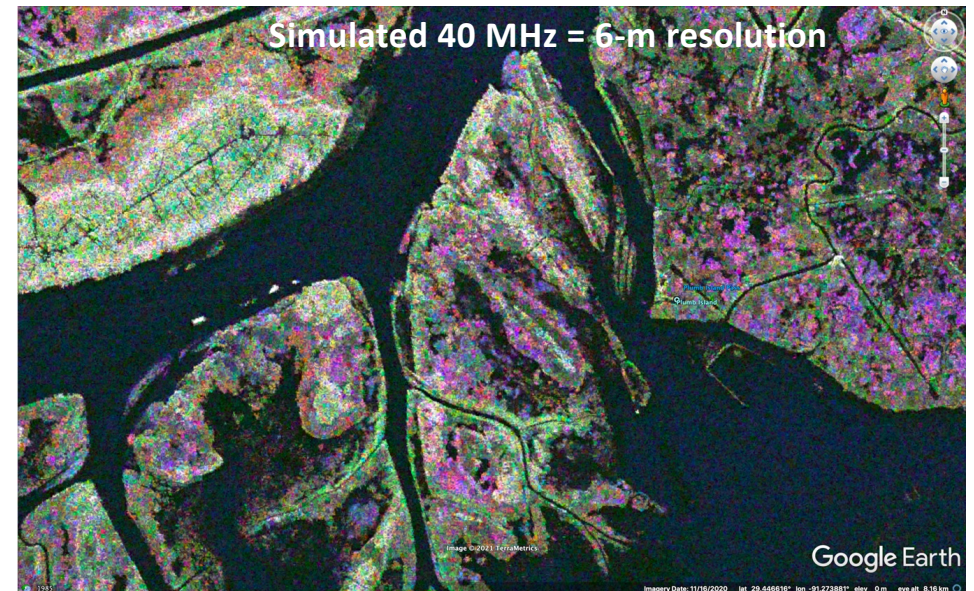
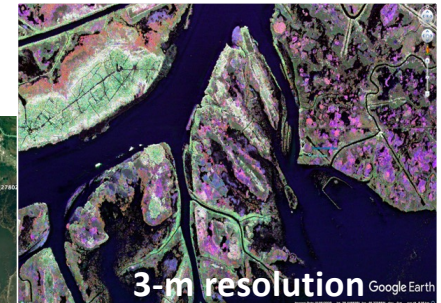
Last updated: October 26, 2021

Keyboard shortcuts Map data ©2022 Google, INEGI 1000 km Terms of Use

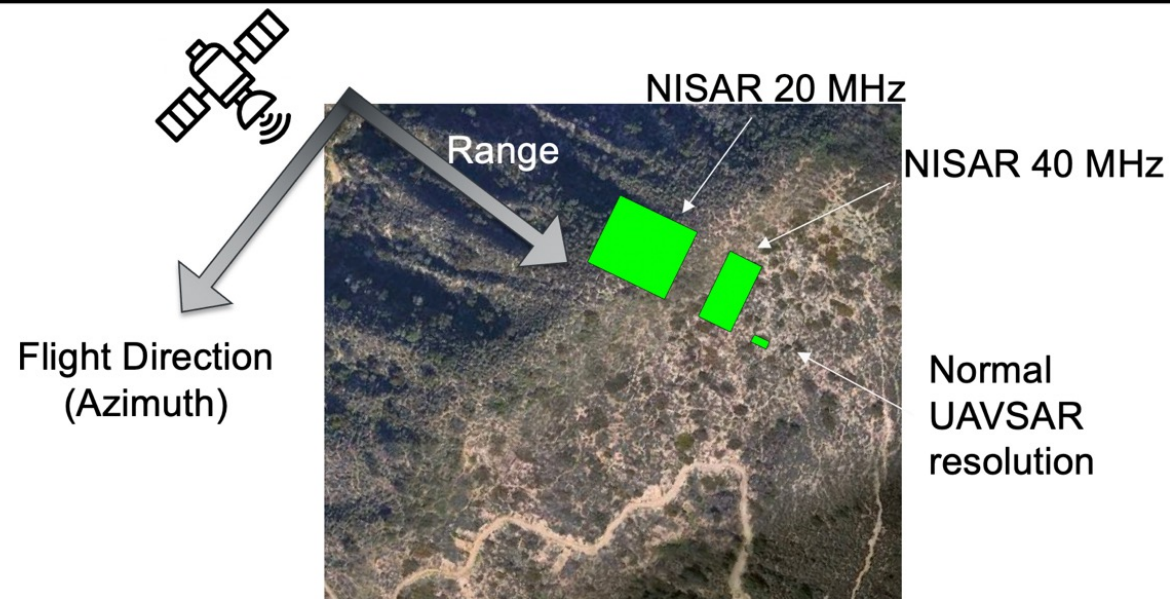
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(CL 07-1343)

Full Resolution
UAVSAR



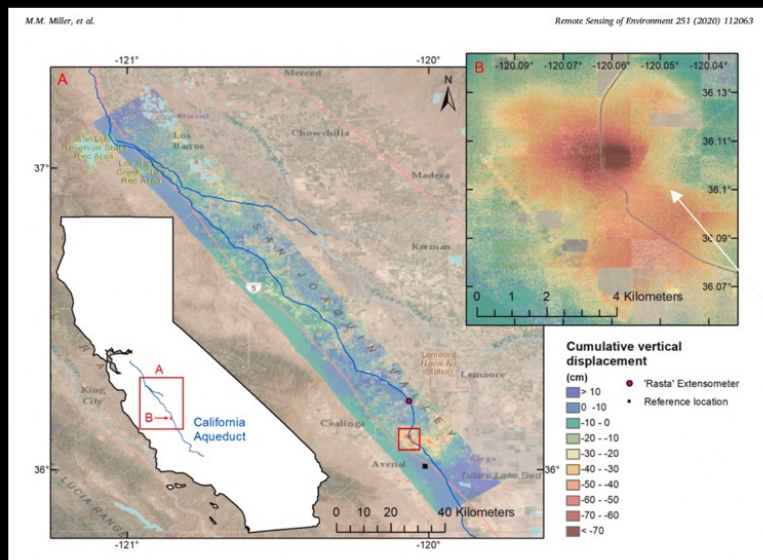
Visualizing Pixel Size Differences



California Central Valley

Groundwater extraction, subsidence impact to the California Aqueduct

Aqueduct Subsidence



Miller, 2020

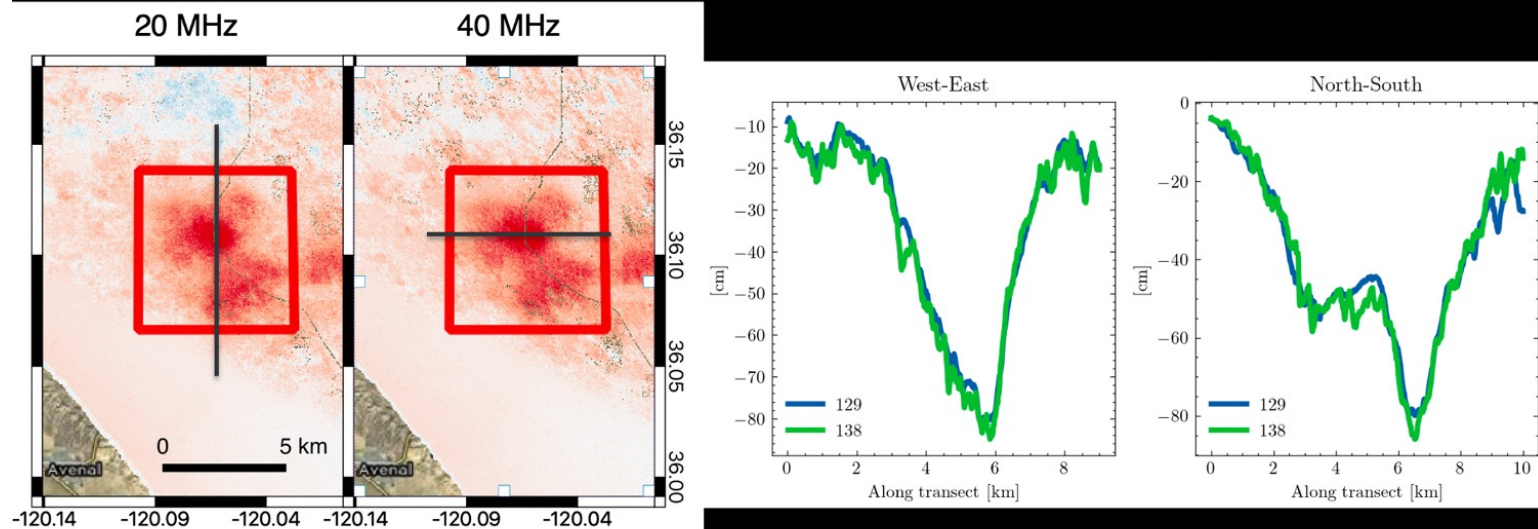
Questions:

1. Will coarser NISAR underestimate subsidence?

-104 cm subsidence

At L-band, there is little difference between 20 MHz and 40 MHz for this deep subsidence bowl.

Aqueduct Subsidence Feature

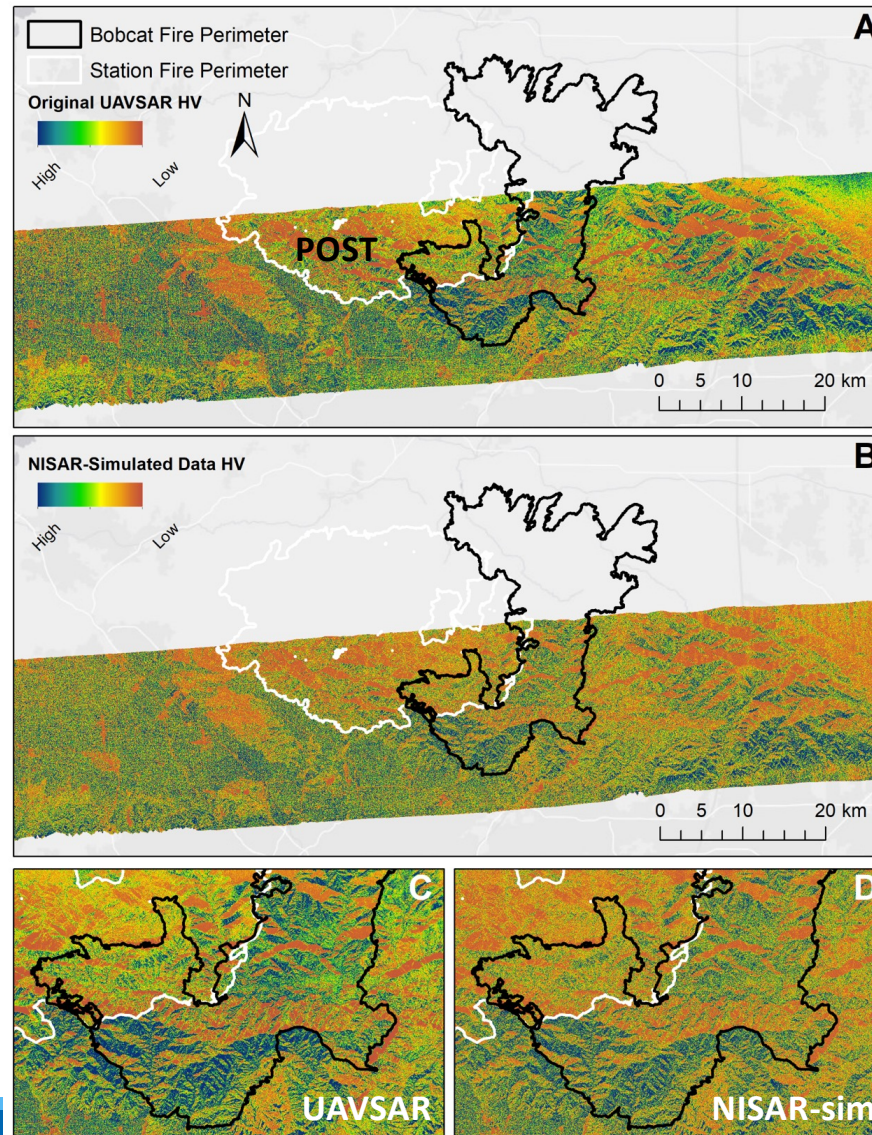


Used 4 connections in the interferogram network (temporal baseline varied)

PRE-VS-POST FIRE FUEL LOAD

Bobcat Fire (pre)
vs.
Station Fire (post)

Southern California



A. Original UAVSAR HV Image

Green/Blue areas show more volume scattering from vegetation – relates to fuel load

Orange/red (low HV) follow earlier fire's burn area outline

B. NISAR-Like HV Image

Qualitatively the same

Paper in prep: An, K., Jones, C. E., & Lou, Y (2022). Developing a detection and monitoring framework for wildfire regimes with L-Band Polarimetric SAR.



NISAR Applications White Papers



2/26/2019

Soil Moisture and Water Resources

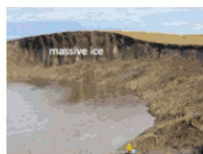
PDF, (1.31 MB)



2/26/2019

Damage Mapping

PDF, (3.66 MB)



2/26/2019

Changes in Permafrost

PDF, (797 KB)



2/26/2017

Sinkholes and Cavern Collapse

PDF, (2.01 MB)



2/26/2017

Volcanic Hazards

PDF, (1.62 MB)

The NISAR-ISRO SAR Mission



National Aeronautics and Space Administration



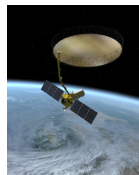
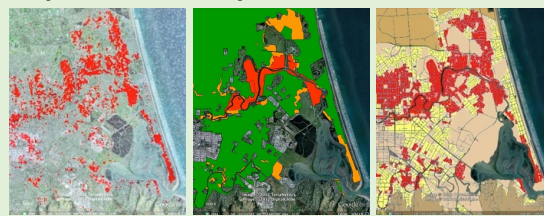
Rapid Damage Assessment After Natural Disasters

Within hours to days of natural disasters like major earthquakes, hurricanes, tsunamis, and landslides, the NISAR satellite mission can provide maps of the damage that occurred. Observations will be uninterrupted by weather and rapidly provide information for rescue operations, economic loss estimates, and the health of critical infrastructure.

Earthquake Damage: 3 Days vs 8 Months

Powerful ground shaking from a magnitude 7 earthquake devastated Christchurch, the largest city in the South Island of New Zealand, on February 22, 2011. The earthquake claimed 185 lives and caused extensive property damage. The left panel shows a damage proxy map derived from radar data acquired three days after the earthquake by the Japanese ALOS satellite. Four months after the earthquake, the New Zealand government released the first version of damage zone

map (middle panel) based on ground observations by hundreds of geotechnical engineers. Eight months after the earthquake, an updated version of the government damage map was released (right panel). This manually produced map was in even closer agreement to the automatically generated damage proxy map from satellite radar data acquired only three days after the earthquake.



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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Continued from front page

Permafrost degradation has major implications for the economy. As permafrost thaws and ground ice melts, the soils lose strength and the surface can subside and collapse. The costs to maintain and repair infrastructure affected by thaw-induced soil failure and subsidence are projected to continue to increase rapidly in Alaska and across the Arctic. Transportation is particularly affected, as roads and airstrips may require increased maintenance or relocation. Permafrost thaw also contributes to increasing rates of coastal and fluvial erosion, which threaten numerous Arctic communities. Permafrost degradation and thaw-induced subsidence further change local drainage and wetness. Consequently, changes in permafrost conditions in a warming world will have complex, multi-faceted impacts on transportation conditions, water resources, and ecosystem services, such as the provision of fish, game, and timber.

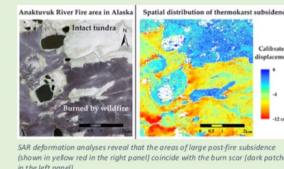
Monitoring ongoing and predicting future changes in permafrost landscapes is critical for the economy, local residents, and the scientific community. However, such assessments are complicated by the sparsity of observations and by the complex interactions between permafrost soils, wildfire, ecosystems, and hydrology. To address the paucity of ground observations in these vast, sparsely populated regions, satellite observations such as those from NISAR are critical. They are also crucial for documenting and understanding the complex

interactions that determine the vulnerability and resilience of permafrost. For instance, wildfires constitute a major disturbance that can induce permafrost degradation and, ultimately, disappearance. However, depending on the local conditions, permafrost may recover aided by the rapid regrowth of reflective vegetation and insulating organic soils.

NISAR will enable unprecedented insights into changing permafrost landscapes. It will provide precise measurements of subsidence induced by the melting of subsurface ice as permafrost thaws, and of annual frost heave and settlement, which occurs as water expands upon freezing and contracts upon thawing. Using a technique called synthetic aperture radar interferometry, the radar observations can be turned into maps of surface elevation changes. Infrastructure planners, businesses, and residents alike will be able to access critical information on subsidence and associated hazards related to frozen ground dynamics, thanks to NISAR's open data policy. NISAR's frequent radar observations will further provide a detailed record of changes in surface vegetation, soil moisture, lake and river ice, and inundation, all of which are vital to transportation conditions, water resources, and provision of food and raw materials. In summary, NISAR will enable unprecedented insight into the hazards, as well as the resources, of these rapidly changing regions.

Fire-induced permafrost degradation

At more than 200,000 acres, the Anaktuvuk River Wildfire on Alaska's North Slope triggered widespread degradation of the underlying ice-rich permafrost. InSAR analyses revealed pronounced subsidence within the fire perimeter in 2008-2009. The comparison between a high-resolution optical image (left) and the SAR deformation map (right) clearly shows that the distribution of intense subsidence was restricted to the burned area. Fieldwork and high-resolution imagery corroborate the interferometric findings of pronounced and spatially variable subsidence. InSAR techniques have great potential for quantifying subsidence induced by permafrost degradation with a high spatial and temporal resolution.



National Aeronautics and Space Administration

For more information, visit <http://nisar.jpl.nasa.gov/applications>

Jet Propulsion Laboratory / California Institute of Technology / Pasadena, California / www.jpl.nasa.gov

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<http://nisar.jpl.nasa.gov/applications>

- NISAR will have
 - Consistent global L-band imaging
 - Polarimetric, interferometric modes
 - Dual frequency L and S-band primarily over India
 - Global L0-L2 product suite of interferometric and polarimetric products, *free and open*
- NISAR mission addresses key questions in solid Earth, ecosystems, cryospheric, and hydrological sciences
- Same data is used for many applications (resource management, risk reduction, situational awareness)
- Disaster response and support for applications are a priority
- NISAR-like data are available to evaluate NISAR's capabilities for different applications.

<http://nisar.jpl.nasa.gov>

