


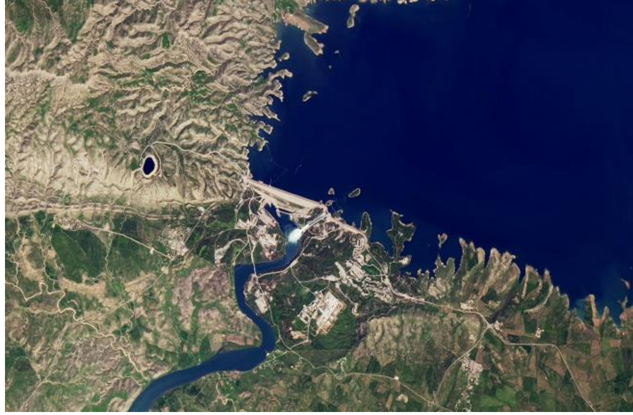

# The NISAR Mission’s Plans for Applications & Urgent Response


## Dr. Cathleen Jones

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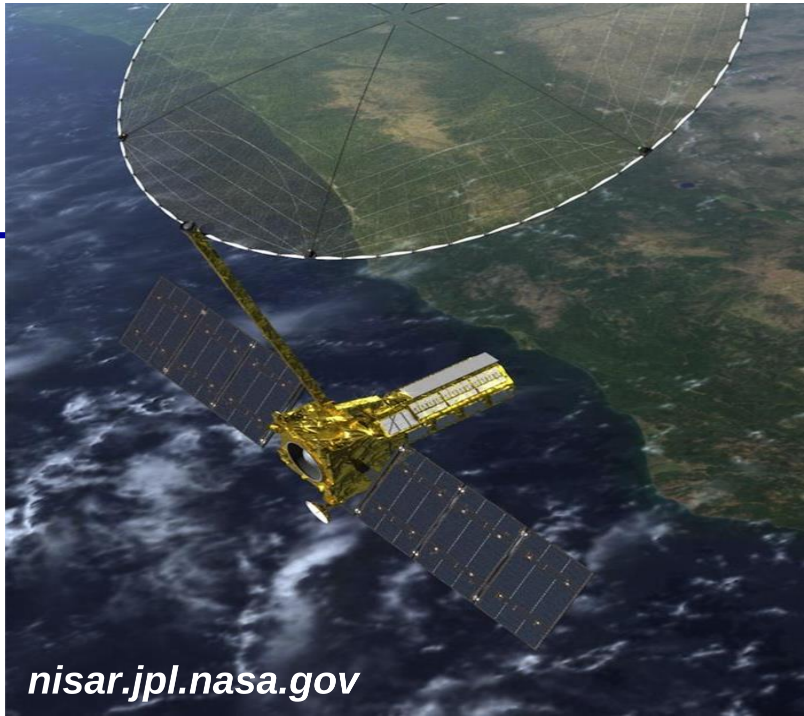
Jet Propulsion Laboratory
California Institute of Technology

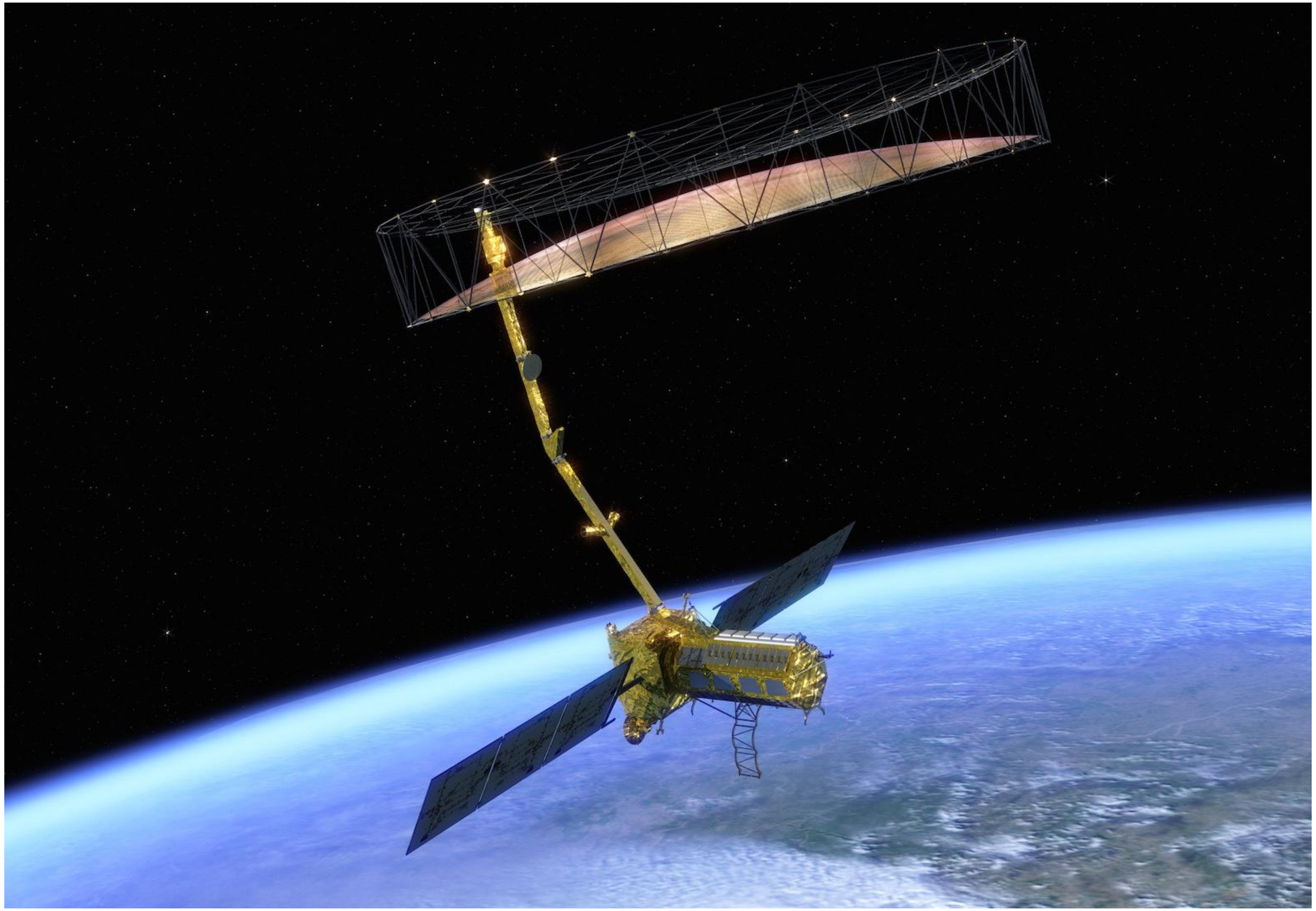
## Collaboration: NASA + Indian Space Research Organisation

**Instruments:**
ISRO S-band SAR
NASA L-band SAR

**Launch: India, Satish Dhawan SC**
Oct 2022 – Jan 2023

**Dr. Gerald Bawden**
Program Scientist for NISAR
NASA Headquarters

**Dr. Paul Rosen**
Project Scientist for NISAR
JPL/CalTech



# Mission Overview

# NASA - NISAR Science & Applications Objectives

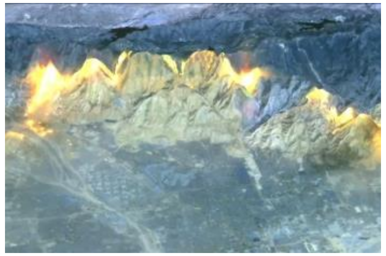
## Key Scientific Objectives

- Improve knowledge for forecasts of earthquakes, volcanic eruptions, and landslides
- Understand the response of ice sheets and glaciers 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

## Key Applications Objectives

- Apply NISAR's unique data sets to for urgent response and hazard mitigation
- Enhance agricultural monitoring capability in support of food security objective
- Understand societal impacts of dynamics of water, hydrocarbon, and sequestered $CO_2$ reservoirs



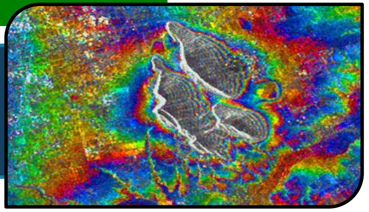



# NISAR: Indian Space Research Organisation Science/Applications

NASA-ISRO Synthetic Aperture Radar (NISAR) Mission

**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



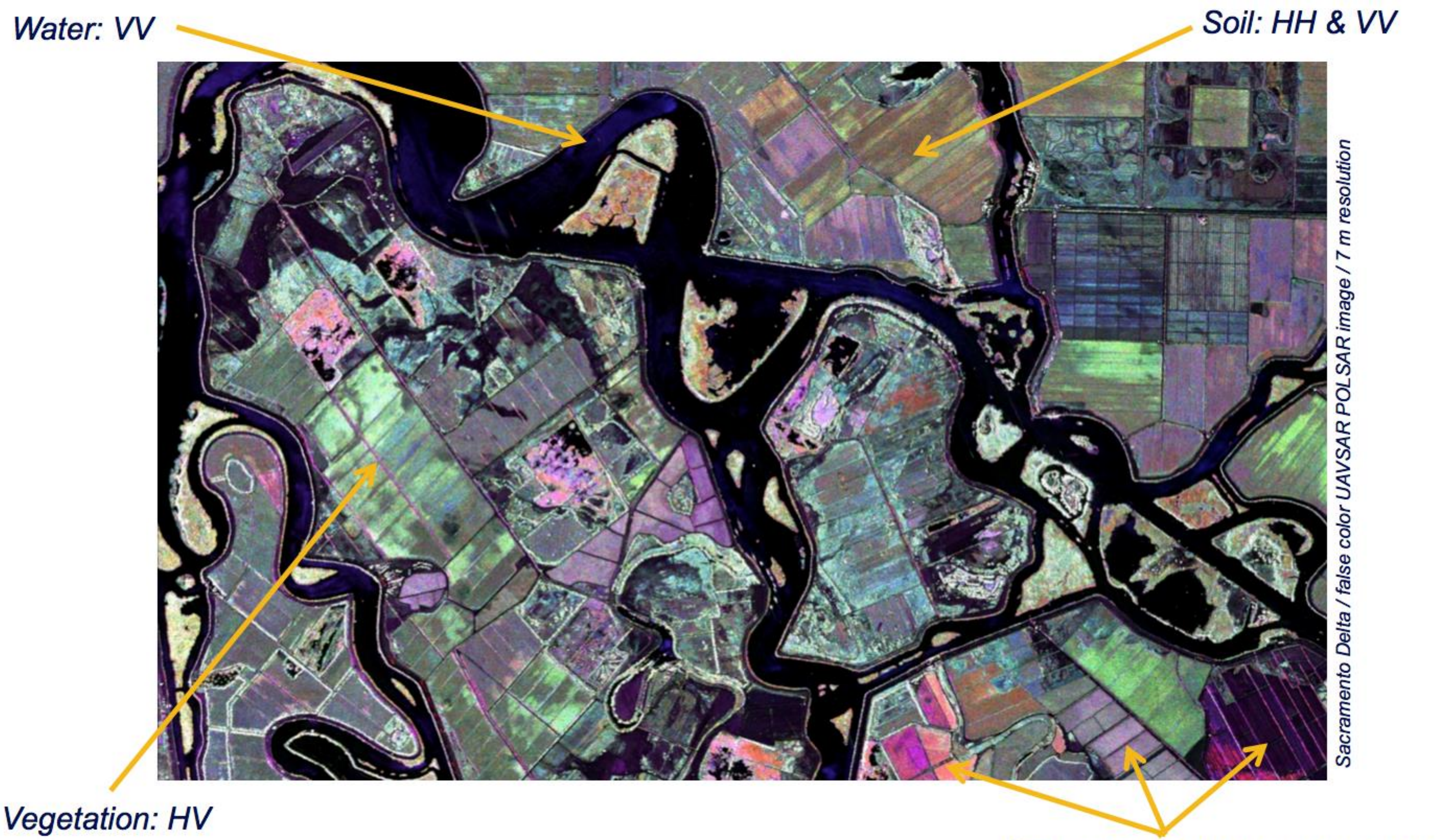
**Cryosphere:** 3.1 Polar Ice Shelf / Ice sheet; 3.2 Sea Ice Dynamics; 3.3 Mountain snow/ glacier 3.4 Glacier dynamics/ hazard (Himalayan Region); 3.5 Climate response to glaciers; 3.6 Sea–Ice advisory on safer marine navigation in Antarctica region

**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

# SAR Capability #1: PolSAR




Red = HH, Blue = VV, Green = HV
(HH => Horizontal Transmit, Horizontal Receive)

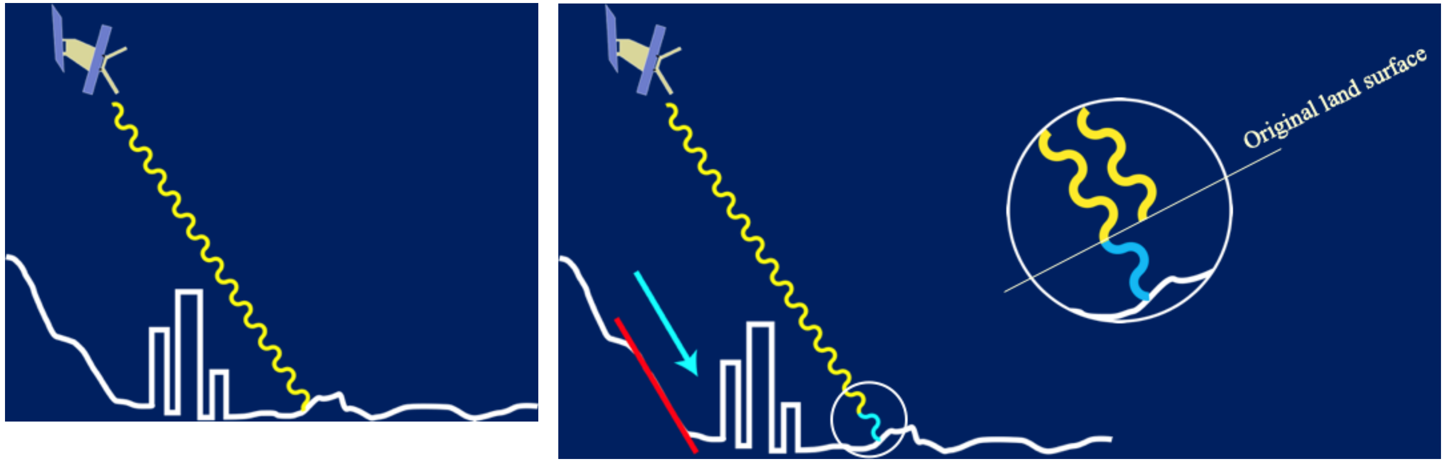
**Polarimetric SAR (PolSAR)**
**Determine surface properties**

Uses:

- Flood extent (w/ & w/o vegetation)
- Land loss/gain
- Coastal bathymetry
- Soil Moisture & Biomass
- Vegetation type, status
- Pollution & pollution impact (water, coastal land)
- Water flow in some deltaic islands

# SAR Capability #2: InSAR

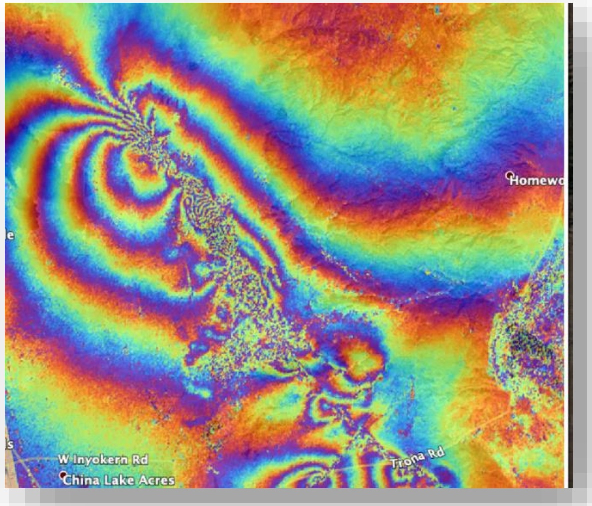
Interferometric Phase Change (360º = ½ radar wavelength) when land surface moves towards/away from the radar antenna




## Interferometric SAR
## Use of phase change to determine displacement

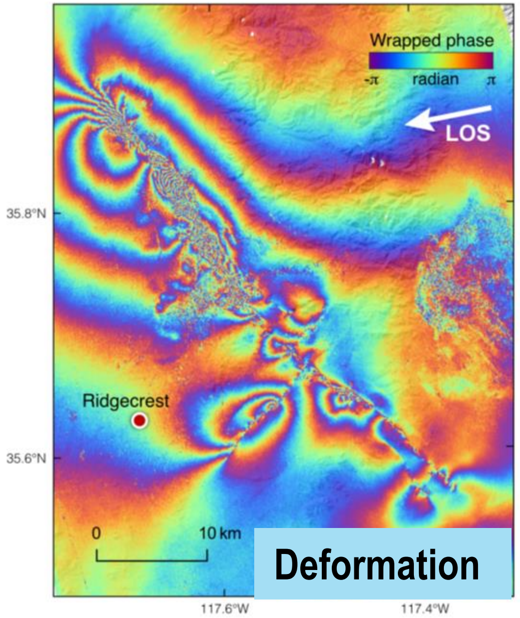
**Applications:**

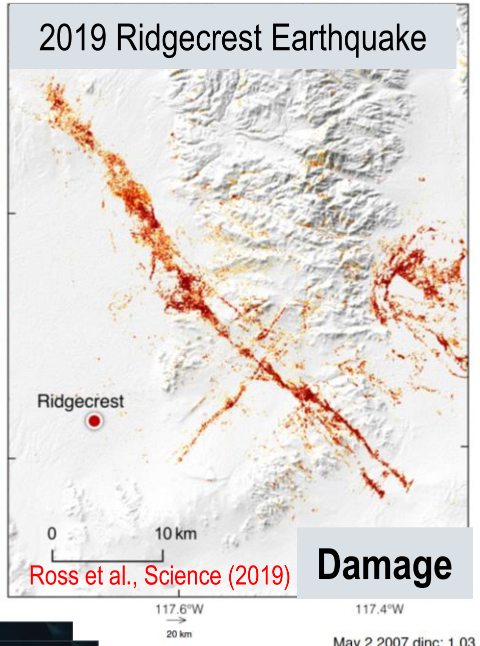
- **Geophysical monitoring / modeling**
- **Subsidence (e.g., due to fluid withdrawal)**
- **Inundation below vegetation**
- **Change in flood extent**
- **Damage (catastrophic change)**

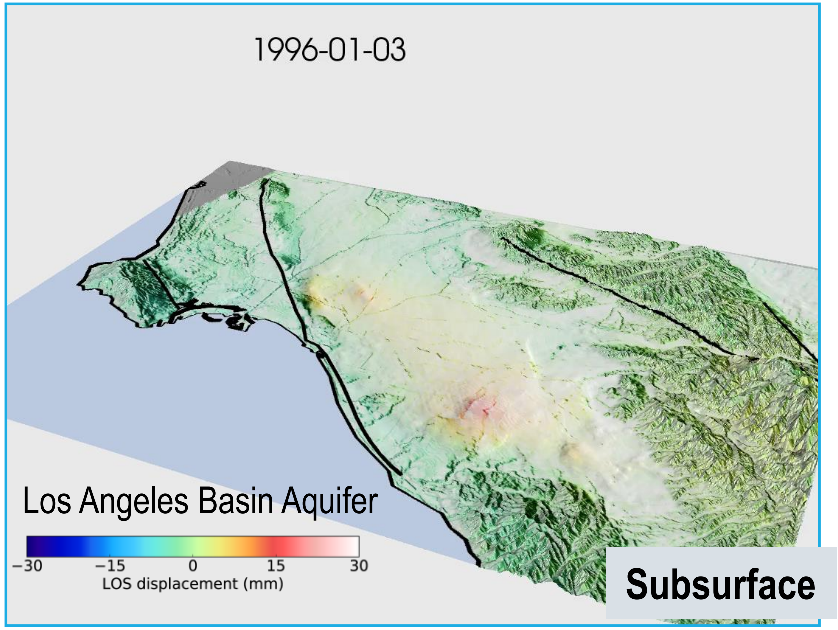


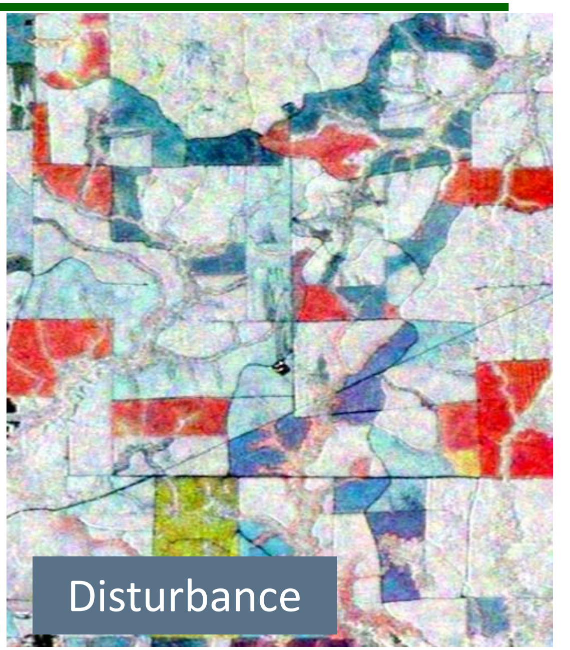

**Interferogram**
Each color cycle represents ½-wavelength change in line-of-sight distance to the ground

# Science: Geohazards, Ecosystems, Cryosphere

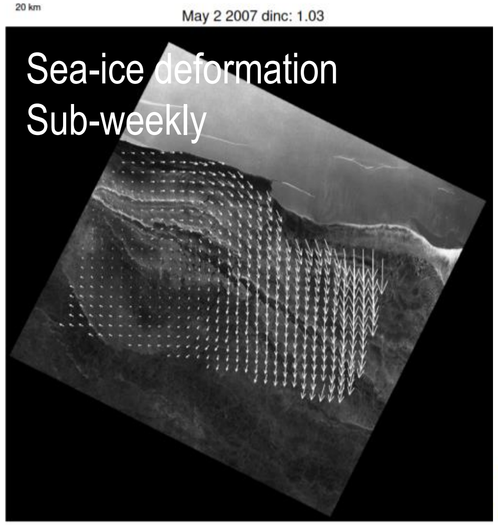


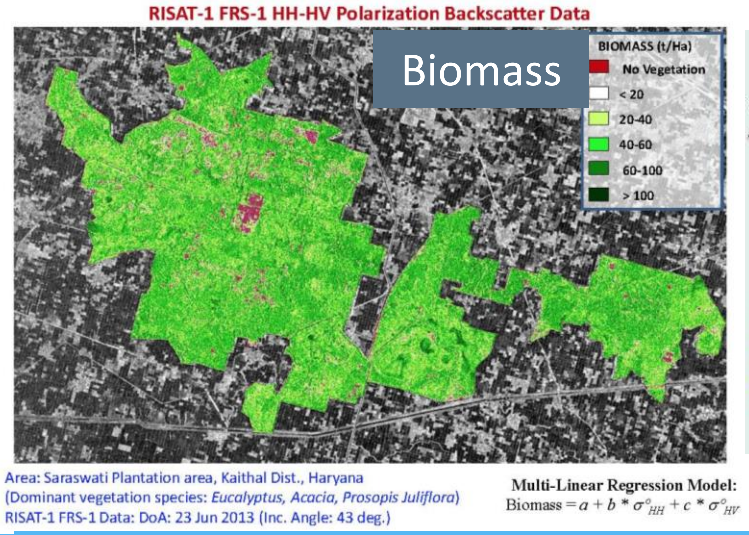



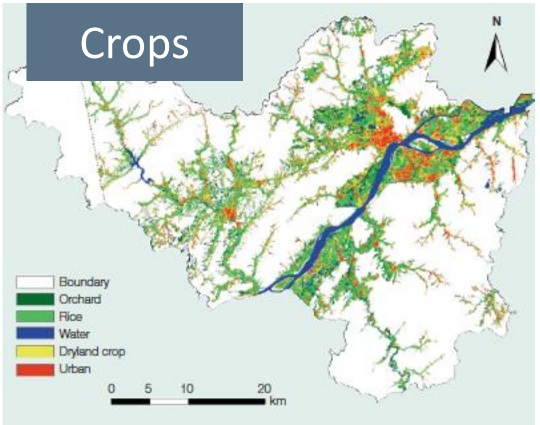





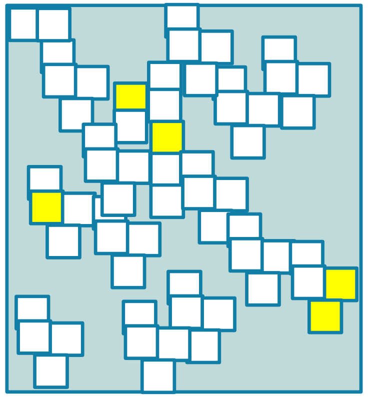


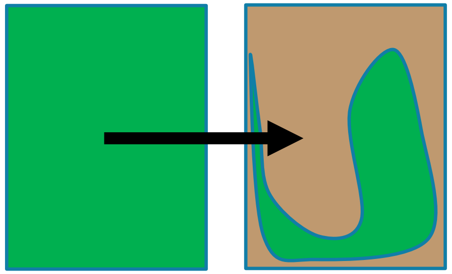
# Ecosystems Requirements

**Active agricultural crop area**



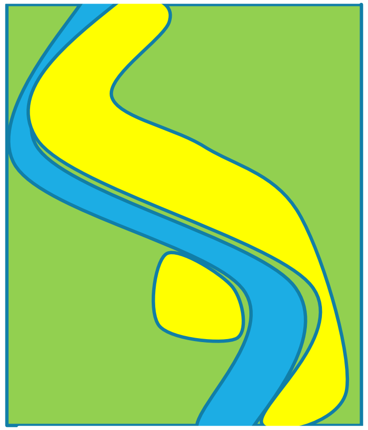
Accuracy: 80% at 1 ha resolution every 3 months

**Detection of Forest Disturbance**



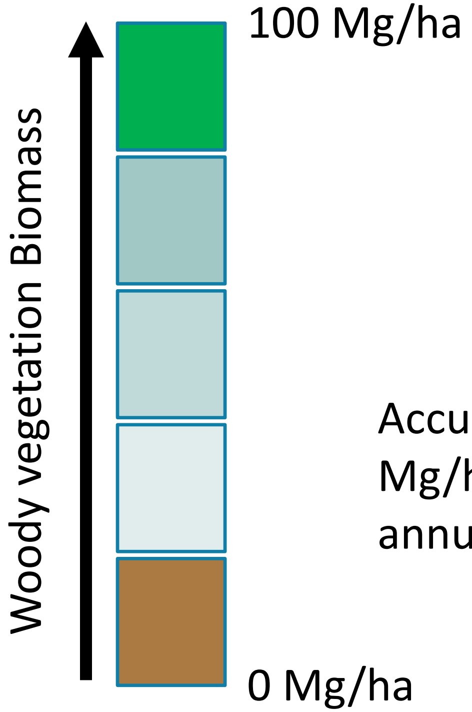
Accuracy: > 50% disturbance at ha scale annually

**Wetland inundation extent**



Accuracy: 80% at 1 ha resolution every 12 days

**Biomass**




Accuracy: 20 Mg/ha annually

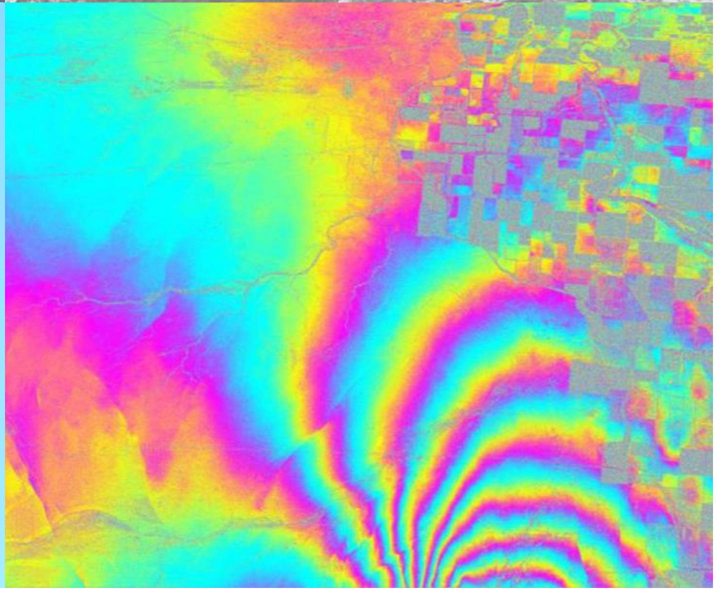
# Deformation Requirements



Ice Shelf Elevation
σ ≈ 100 mm/yr
@ 100 m

Permafrost
σ ≈ 4 mm/yr
(snow-free
over 90 days)

σ ≈ 2 mm/yr
(Annual
Deformation
Rate)



Co-Seismic
σ ≈ 4-25 mm/yr @
separations up to
100m
(Small-Large
deformation)

# NISAR Science Handbook

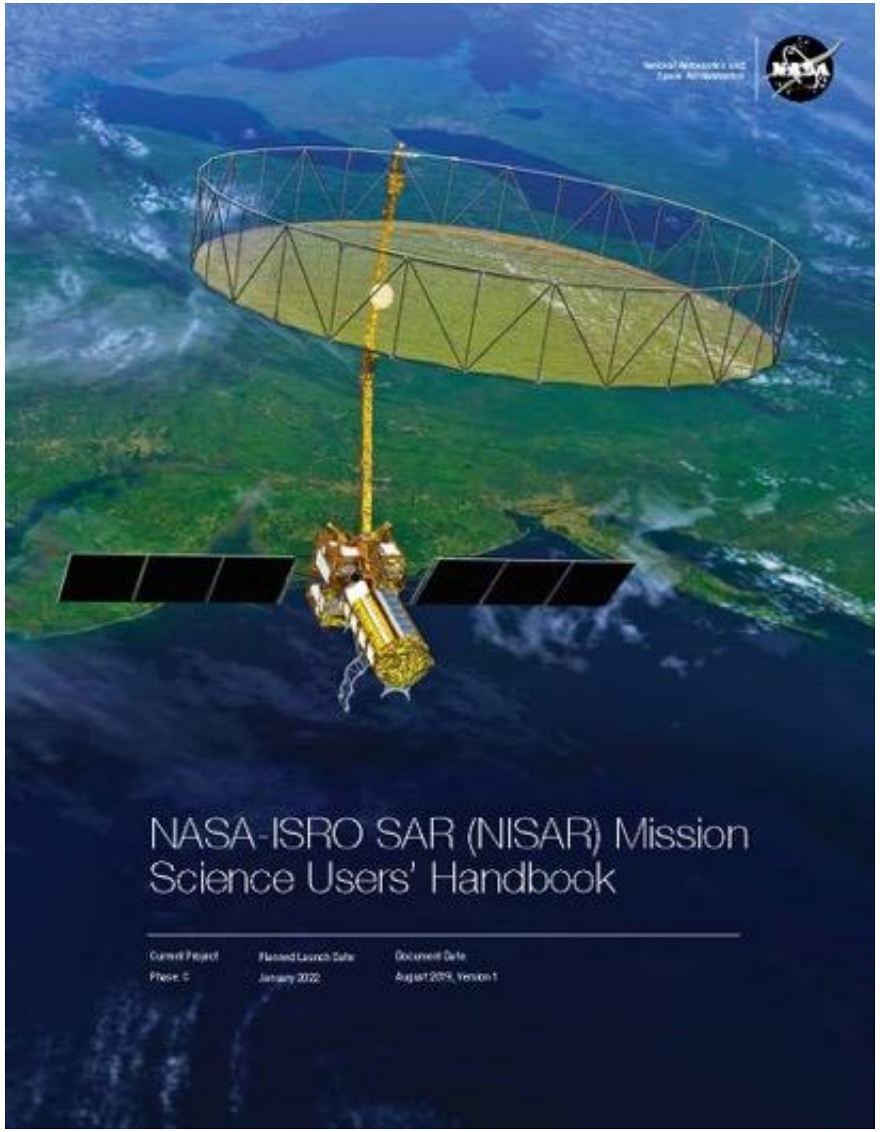




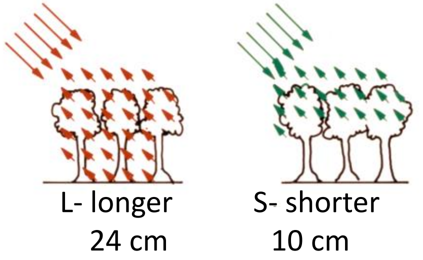

**Table of Contents**

# The Instruments

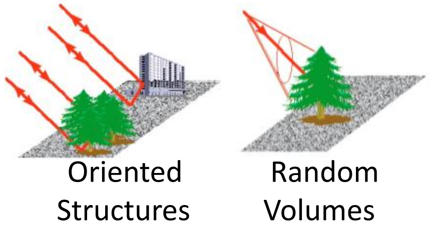
# NISAR instrument Characteristics

| 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* | *Polar coverage: Emphasize Antarctic* |

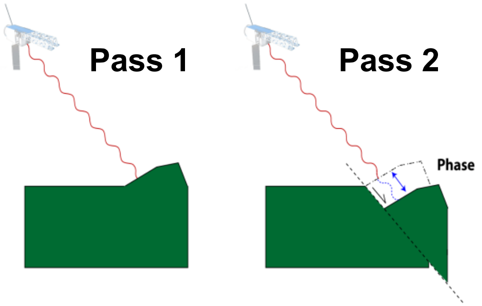
## L- and S-band Wavelength




## Polarimetry

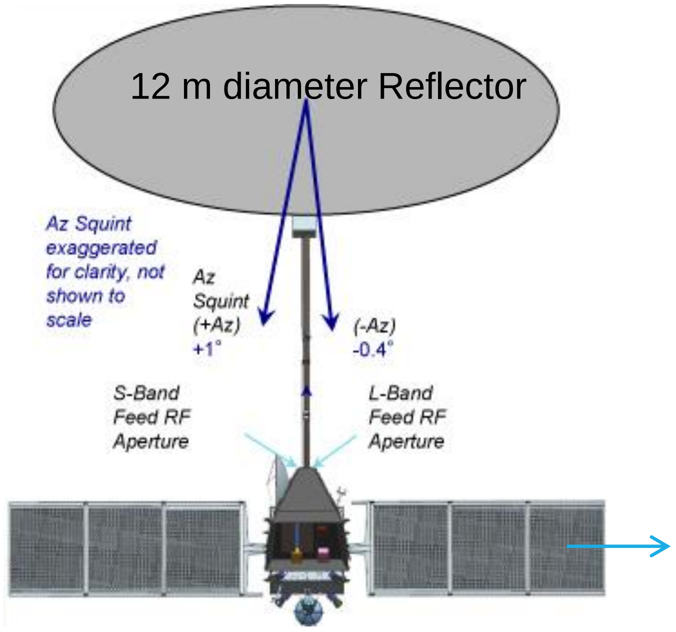



## Repeat Pass InSAR

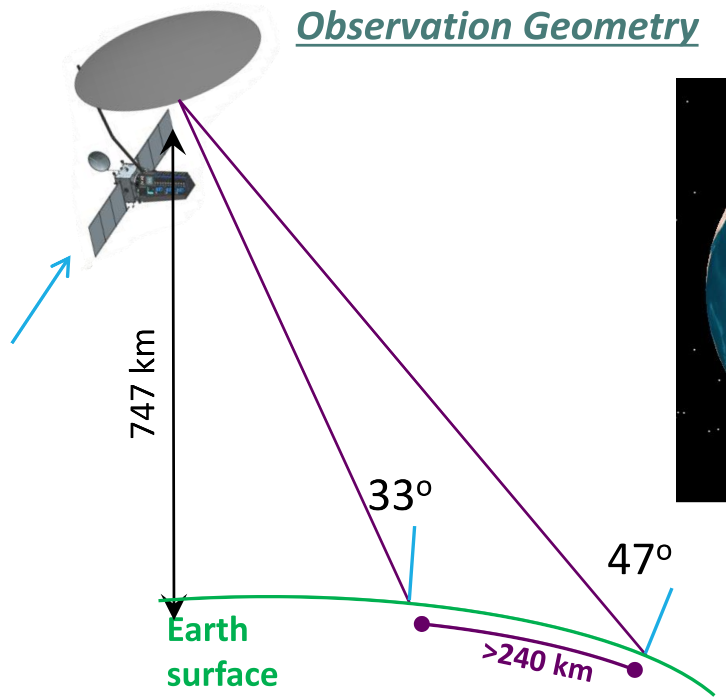


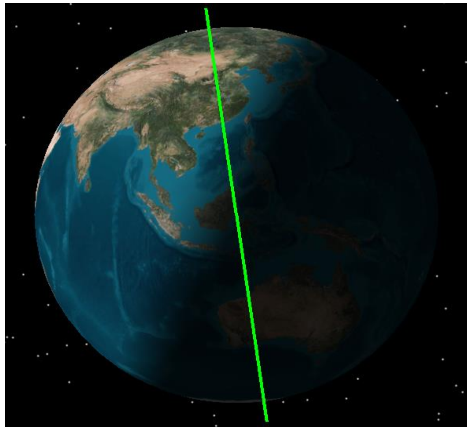
# NISAR Imaging and Orbit Geometry

- Wide swath (240 km) in all modes for global coverage at 12-day repeat
- 2-5 passes over a site depending upon latitude
- Data acquired ascending and descending
- Left-looking imaging geometry



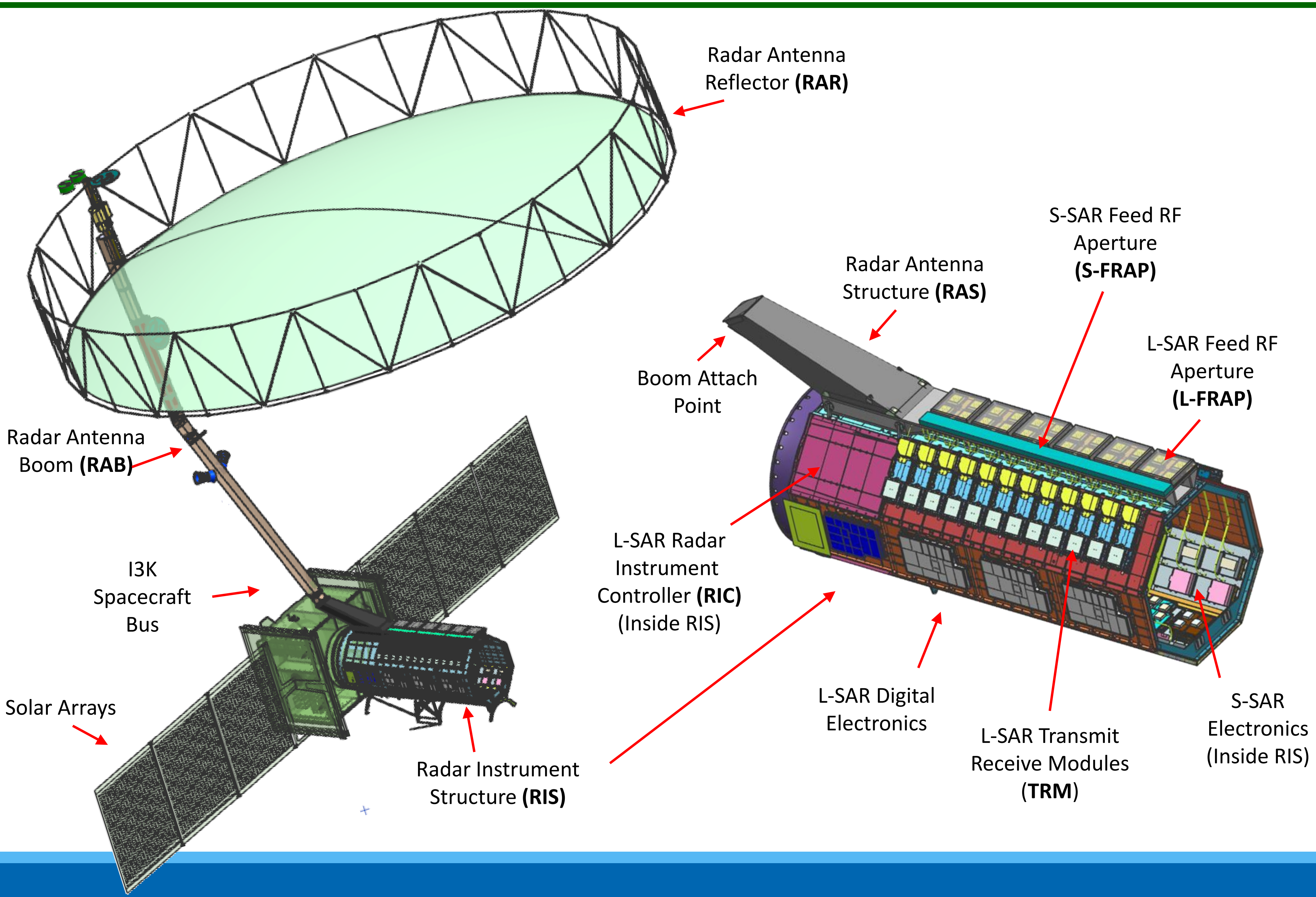

***Observation Geometry***



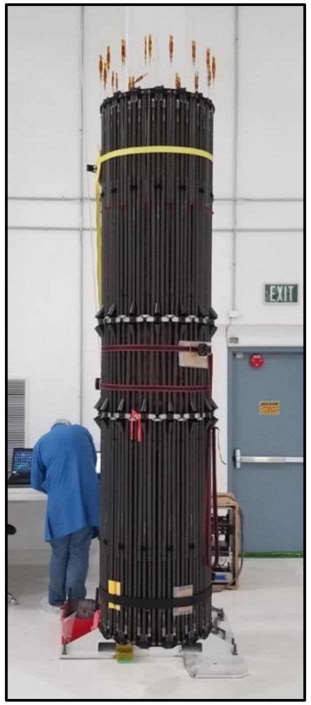



6 AM / 6 PM Orbit
98.5° inclination
Arctic Polar Hole: 77.5 Lat
Antarctic Polar Hole: 87.5 Lat

# Instrument Physical Layout

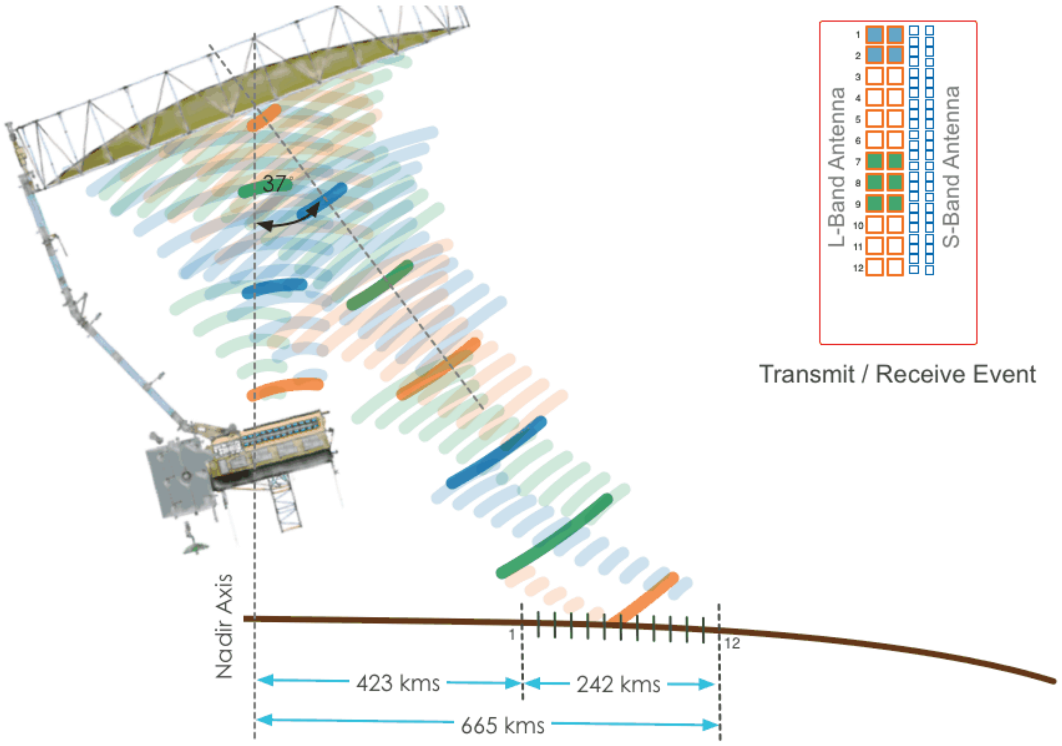


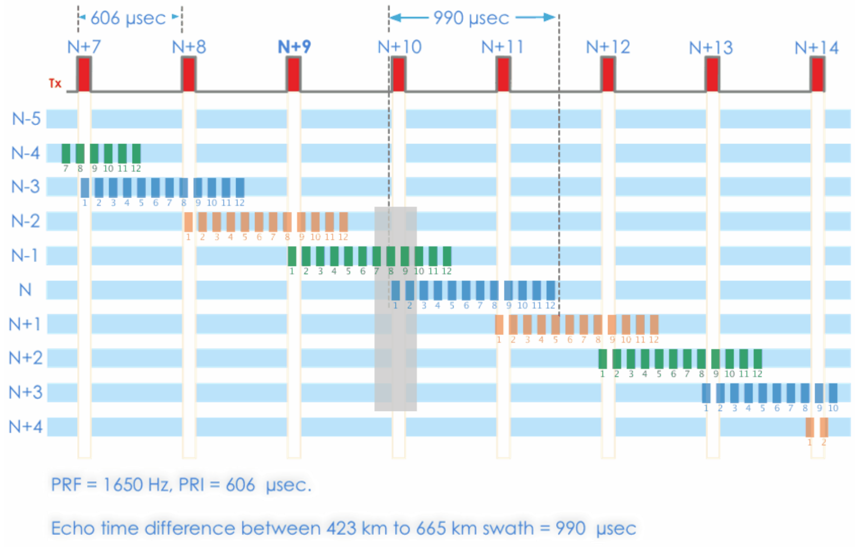
# 12-meter diameter Reflector




# Measurement Technique
## SweepSAR

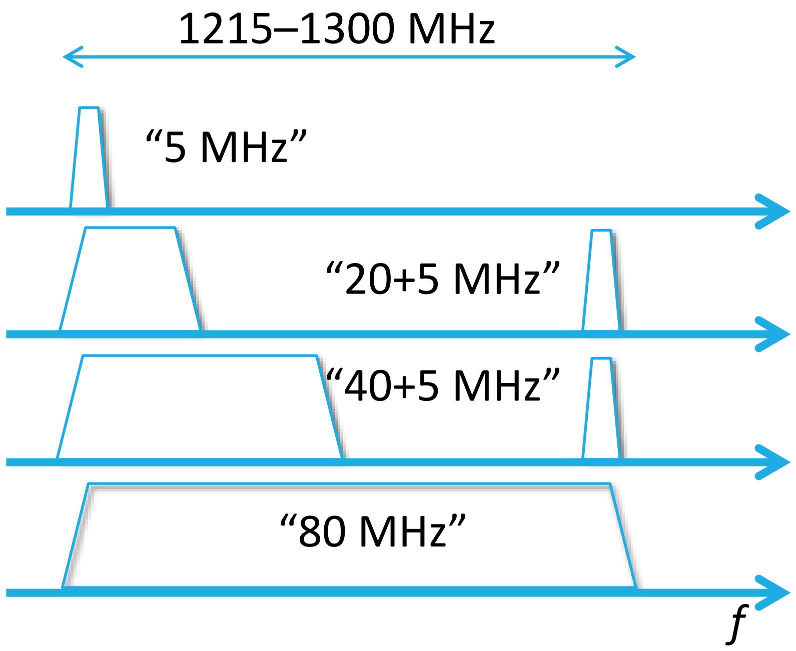
- **SweepSAR**
  - On Transmit, illuminate the entire swath of interest
  - On Receive, steer the beam in fast time to follow the angle of the echo coming back to maximize the SNR of the signal and reject range ambiguities
  - Allows echo to span more than 1 Inter-Pulse Period (IPP)
- **Consequences**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

- L-band modes used for land and land-ice imaging include 5 MHz sideband
  - Useful for ionospheric correction
  - Used for all L-band polarization modes
  - Ensures interferometric compatibility independent of bandwidth and polarization




- Dual-pol mode options
  - Lower band **HH / HV** – Upper band **HH / HV** (default mode for globe)
    - Known to work well for ionosphere correction
  - Lower band **HH / HV** – Upper band **VV / VH** (possible soil moisture mode)
    - Doubles transmit power
    - May not work well for ionosphere – ***needs study***
  - Lower band **RH / RV** – Upper band **RH / RV** (experimental mode)

# The Observation Plan

# Orbit Cycle Coverage – 12-Day Repeat

- Nearly all land within view is imaged every 12 days
- Not shown are ISRO Antarctic Mosaic portions (cycles 11,12,13)
- SP observations (even cycle)
- Urban areas, streaks of non-coverage from 2nd 3rd days of cycle culled
- 80 MHz SP half-swath mode for Ice Sheets illustrated here as full-swath

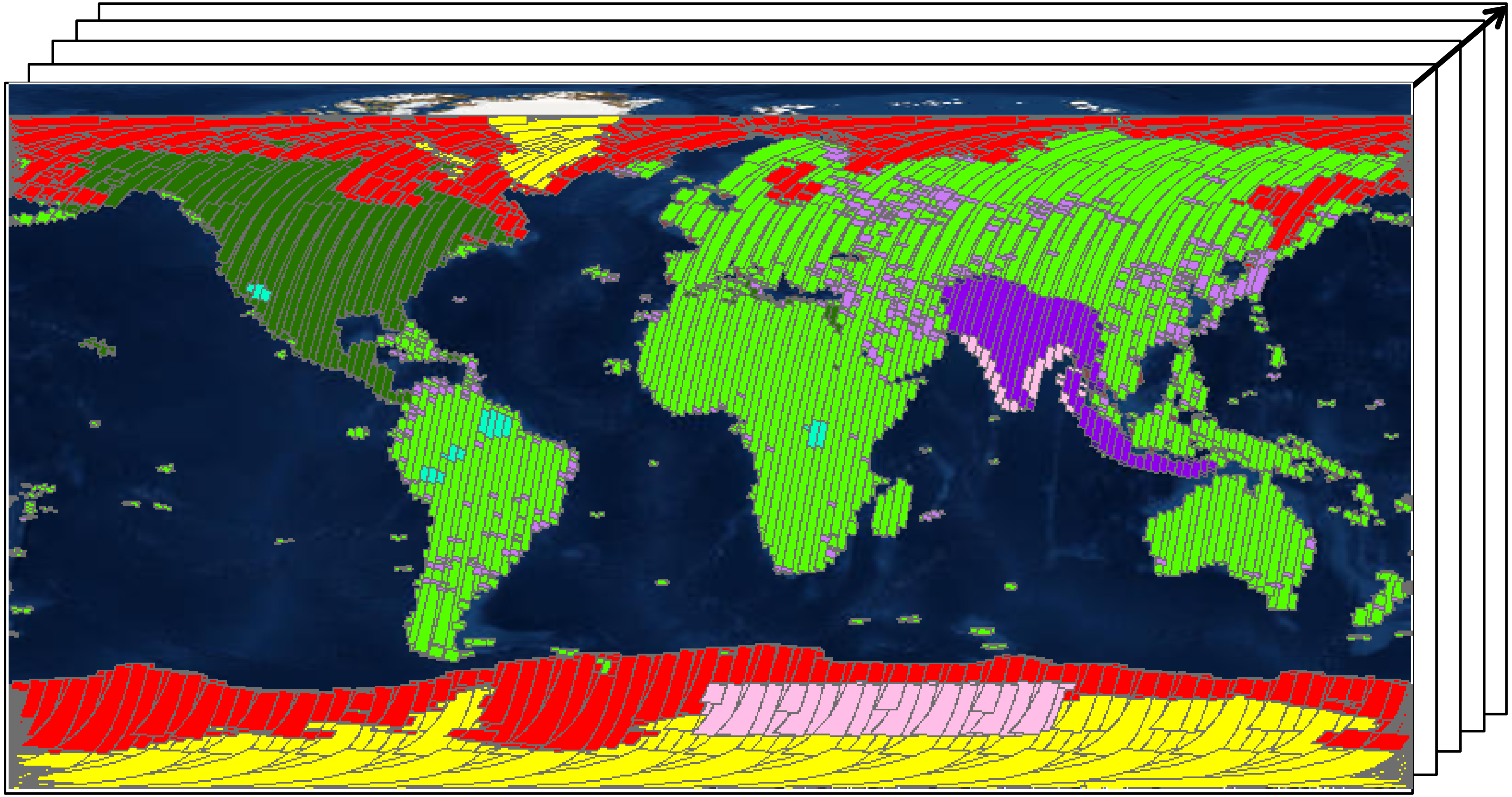
- Background land LSAR 20+5 MHz DP
- Land Ice LSAR 80 MHz SP half swath
- Sea Ice LSAR 5 MHz SP
- ISRO Sea Ice LSAR 20+5 MHz DP; SSAR 25 MHz CP only descending
- Urban areas LSAR 40+5 MHz DP
- Agriculture LSAR 40+5 MHz QP
- ISRO Agriculture LSAR 40+5 MHz QP; SSAR 25 MHZ QP only descending
- Low Data rate study mode single pol LSAR 20+5 MHz SP
- Agriculture/Sea Ice SSAR CP RH/RV 25
- Systematic coverage LSAR 20+5 MHz DP; SSAR 25 MHz RH/RV CP
- High resolution deformation (Disaster/urgent response) LSAR 40+5 MHz DP; SSAR SP HH (or SP VV)75 MH
- Systematic Coverage and Deformation LSAR DP 20+5 MHz; SSAR DP 37.5 MHz
- Ocean LSAR SP VV 5 MHz; SSAR DP VV/VH 10 MHz

tmapping, Aerogrid, IGN, IGP

# NISAR Systematic Observations

No target conflicts: overlapping targets uses union of all modes specified

Colors indicate different radar modes



Persistent updated measurements of Earth

J. Doubleday
P. Sharma, JPL

# Coverage differences at Poles

•NISAR is a **left-looking only** mission (was Left + Right originally)

-Arctic coverage is now limited to <77.5°N

-Antarctic coverage is now <87.5 °S, nominally imaging about the same area of sea ice

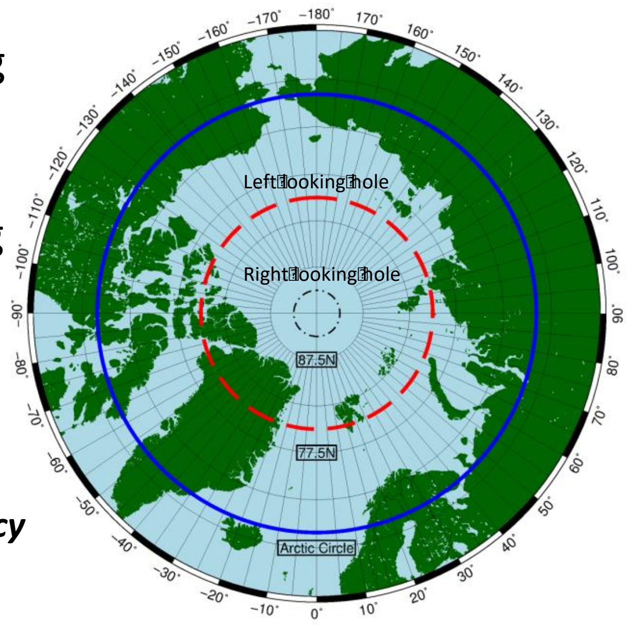
-Full coverage of imaged sea ice in both poles is retained in acquisition schedule (no culling of overlapping orbits)

•In order to meet NISAR sea ice motion requirement, Sentinel-1 is now included to meet requirement:

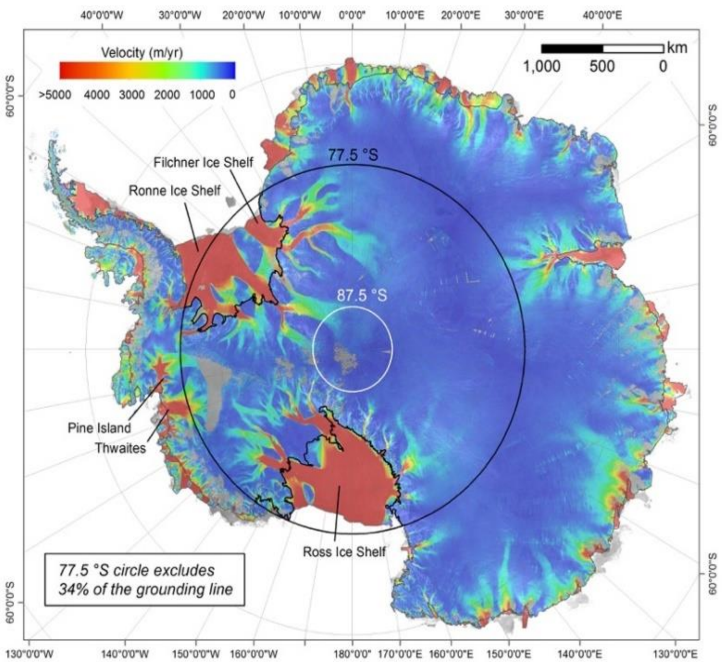
***The NISAR project shall measure sea ice velocity at 100 m/day accuracy on a 5 km grid every 3-days over at least 70% of the Arctic and Antarctic sea ice extent.***

•Positive aspects are that including Sentinel-1 increases coverage, improves product availability temporally and spatially, and will improve accuracy.

• Including RCM may lead to 1-day products, which becomes useful for modeling.




Arctic Sea Ice coverage is much reduced for left-looking mission

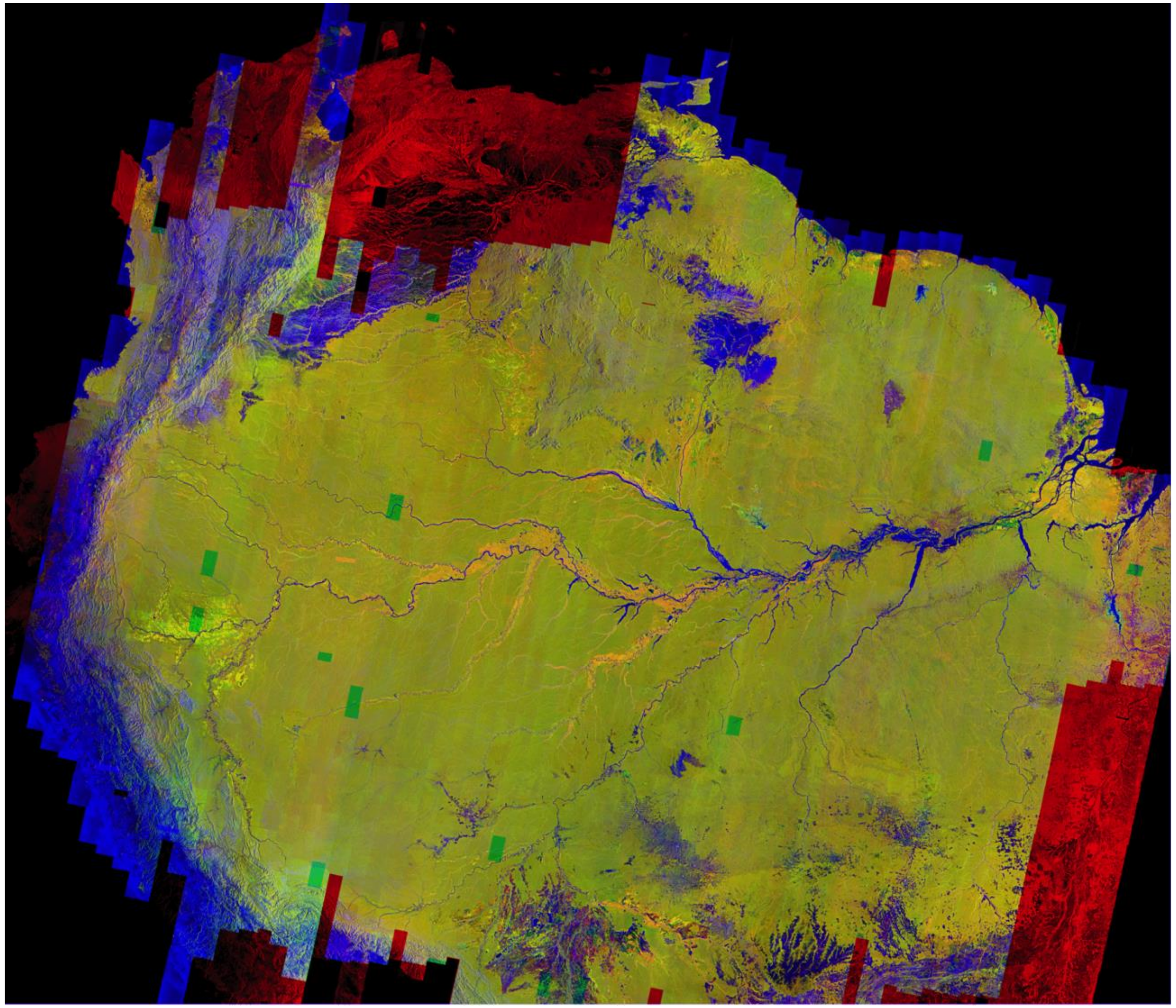



Antarctic Sea Ice coverage about the same for left-looking mission, but ice sheet coverage is much improved

# Science & Applications

## SELECTED EXAMPLES

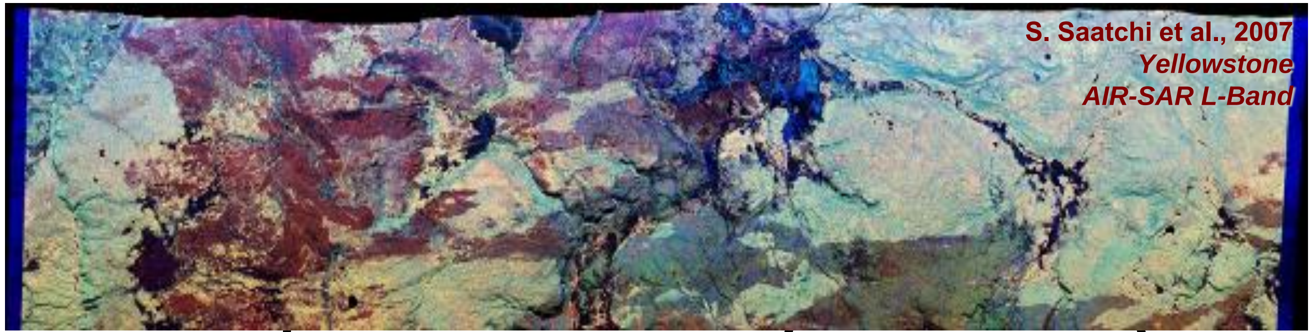
# Measuring the Global Terrestrial Carbon Cycle



NISAR will measure changes in forests and agricultural globally and seasonally

# Global Monitoring of Vegetation Disturbance and Recovery

NISAR will provide annual vegetation disturbance and deforestation maps globally at spatial scale of ~1 ha

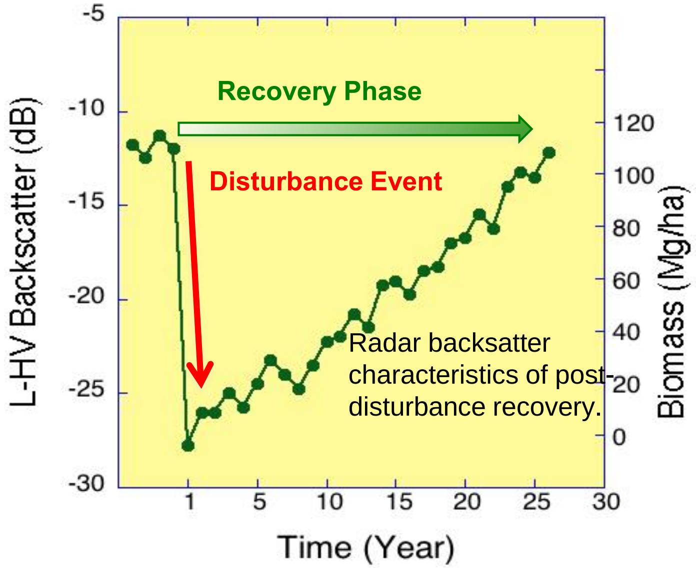



***Cross-pol measurement is key*** to detecting structural differences in vegetation, driving requirement for multi-pol baseline and cross-pol threshold radar capability.

2003 Burn

Recovery after 1988 Burn

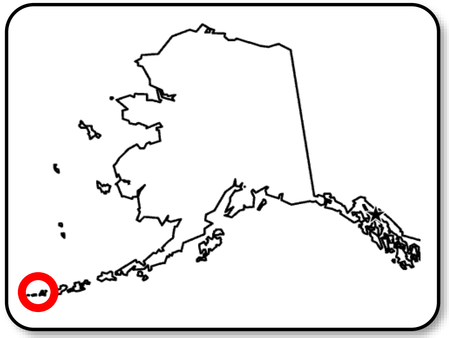
Pine Beetle Disease



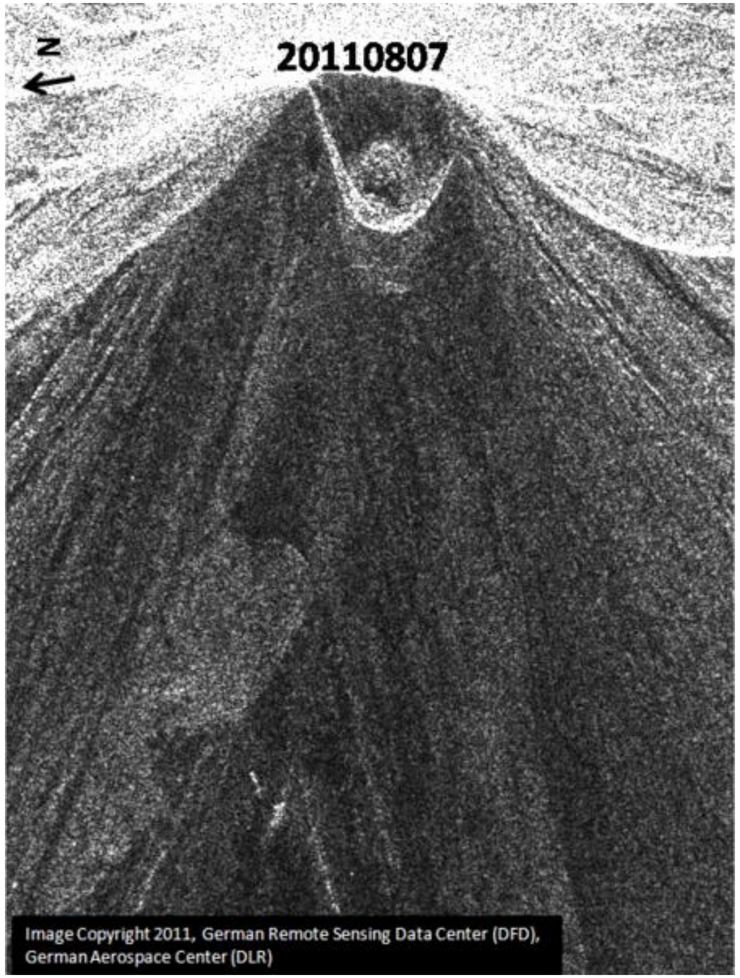

NISAR will quantify fluxes in terrestrial sources and sinks of carbon resulting from disturbance

## Radar observations of recent activity at Mount Cleveland

- Optical sensors yield little information due to cloud cover
- Radar data can see through clouds, ash, and smoke
- Active radars can operate day and night

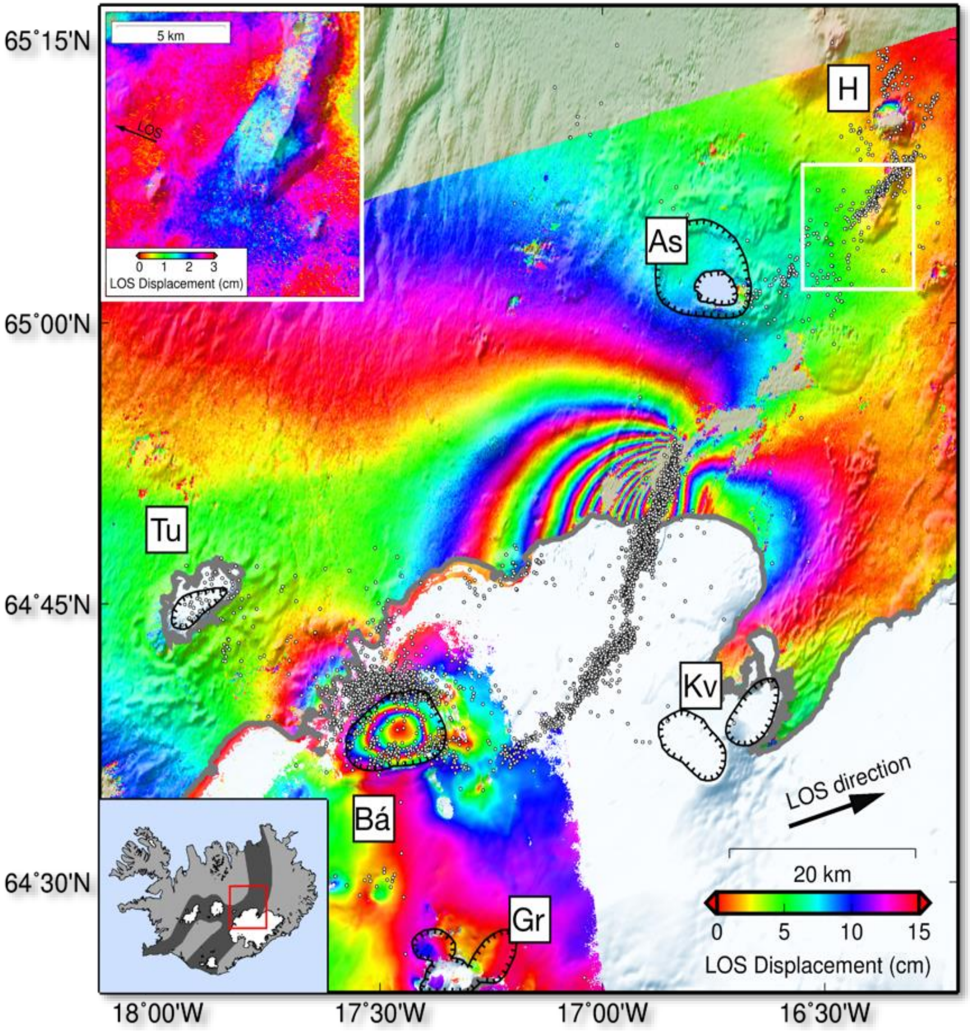


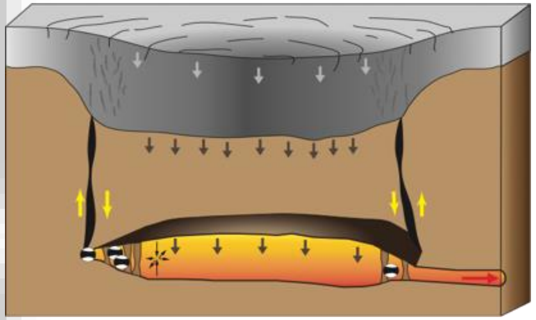
2011 Dome Growth of Mount Cleveland from SAR



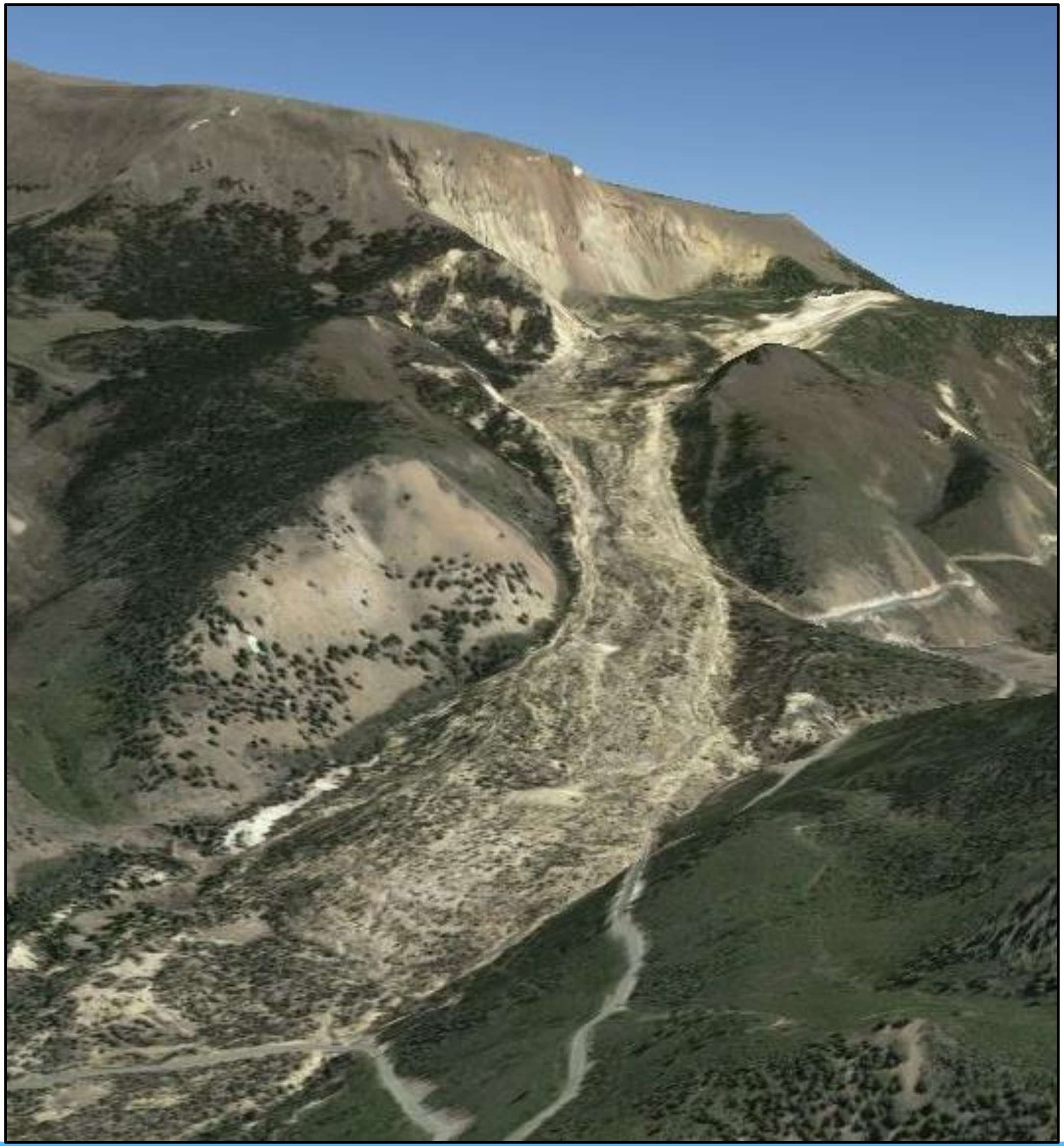
## Collapse of Bárdabunga Caldera (Iceland) & associated plate boundary rifting

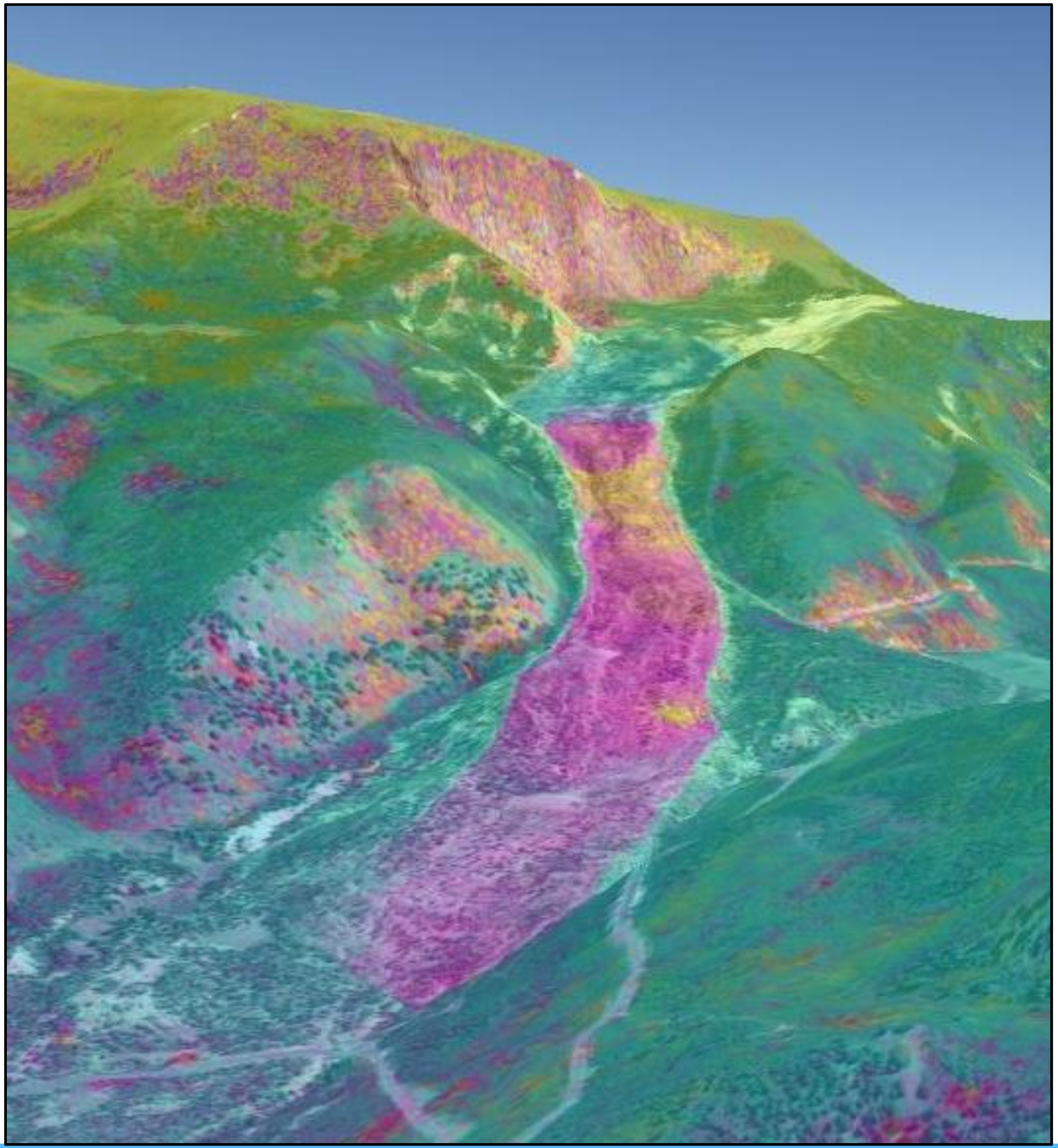
**Fast Sampling (COSMO-SkyMed 1-day) fills in Radarsat 2 24-day pairs**



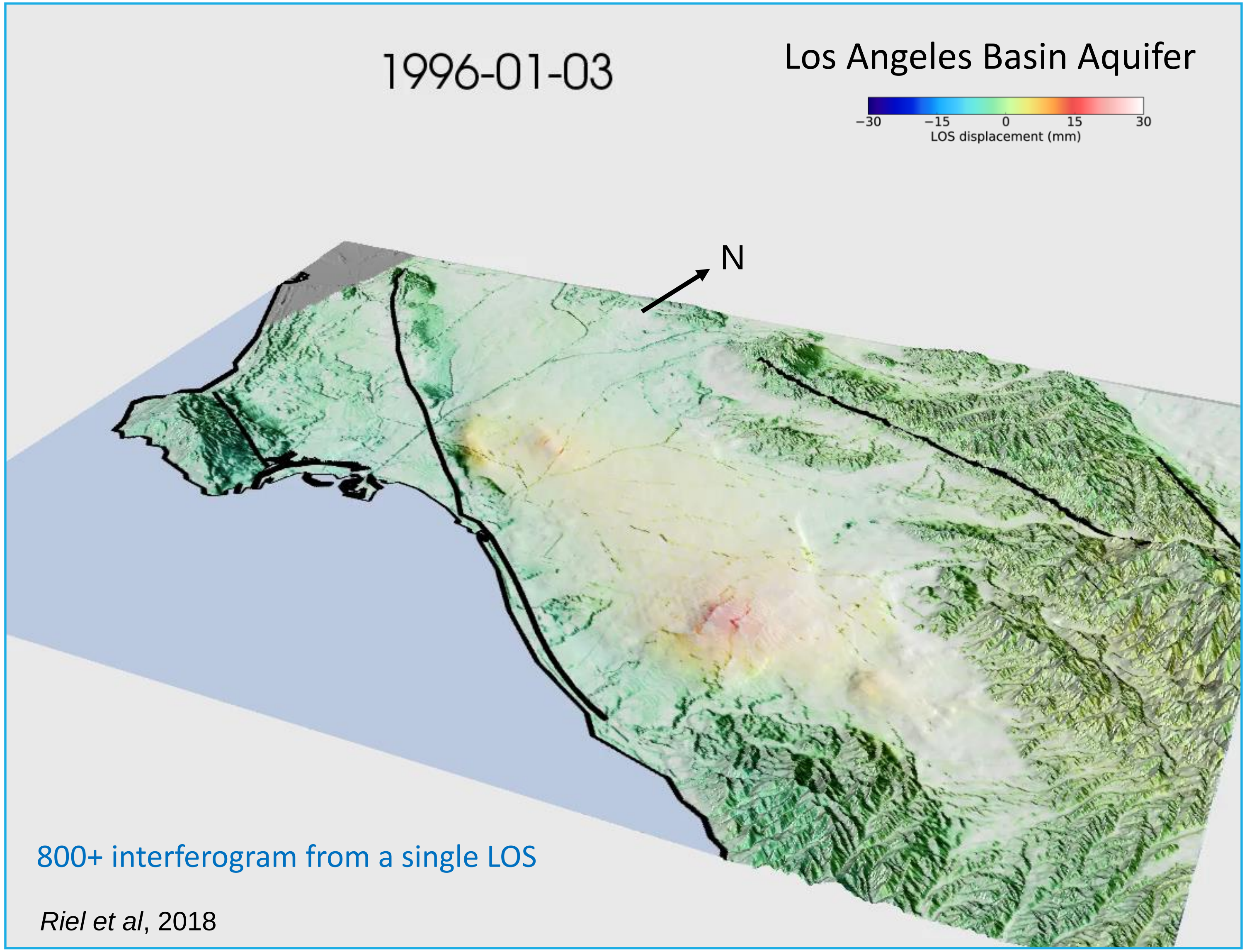



# UAVSAR – Slumgullion Landslide, Colorado





# Natural/Anthropogenic Subsurface Pumping and Recharge

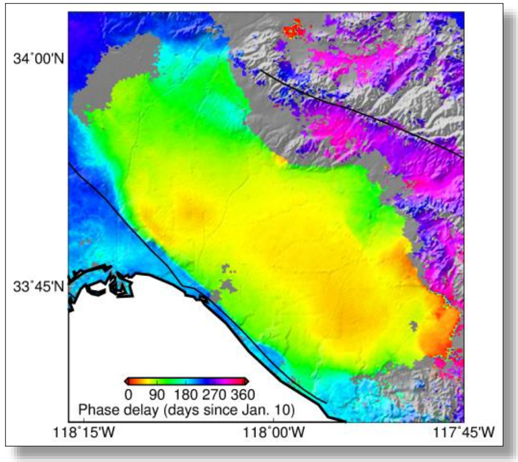



800+ interferogram from a single LOS

*Riel et al*, 2018

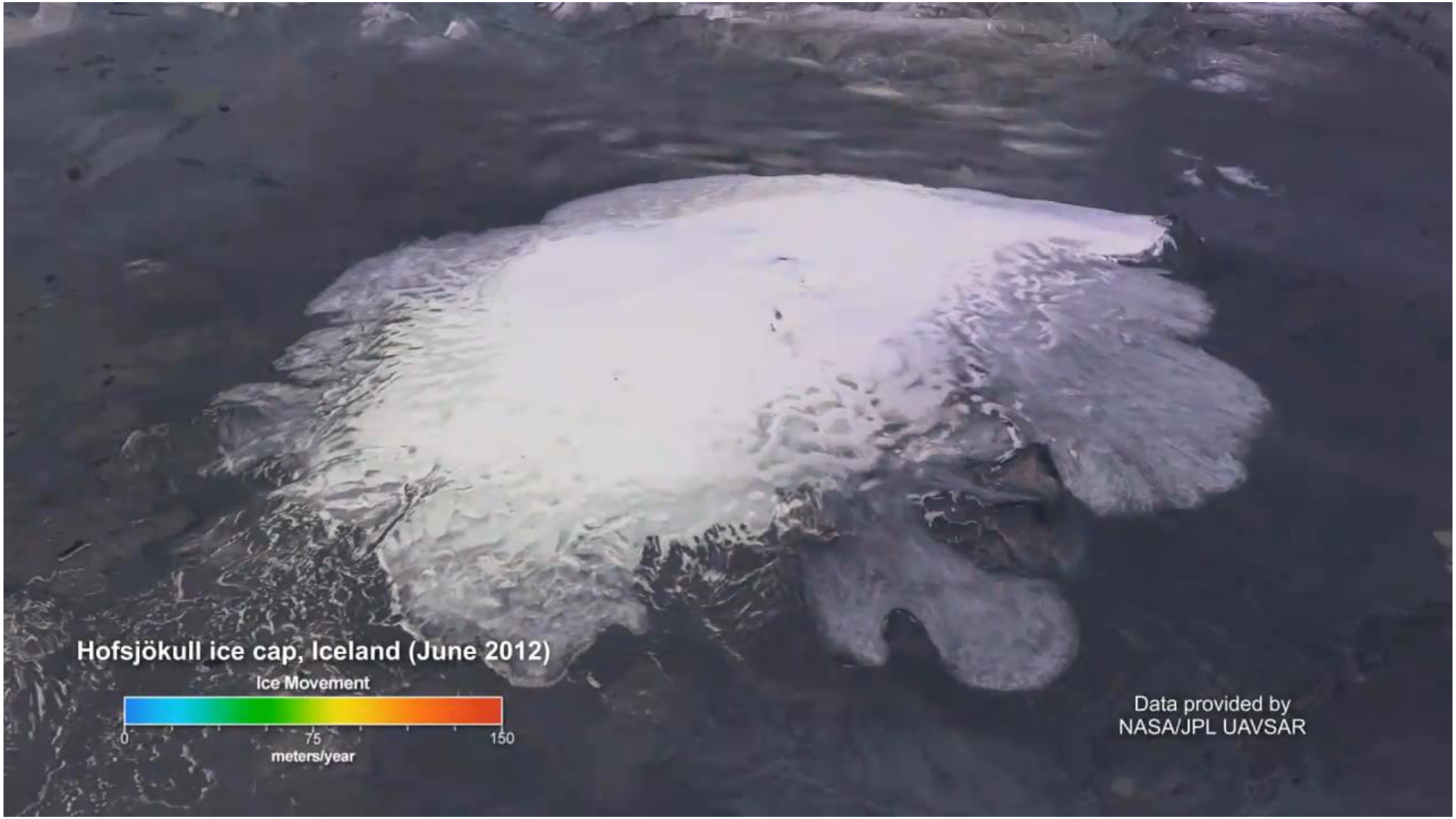
**We are in the era of InSAR time series**

Timing of peak seasonal uplift

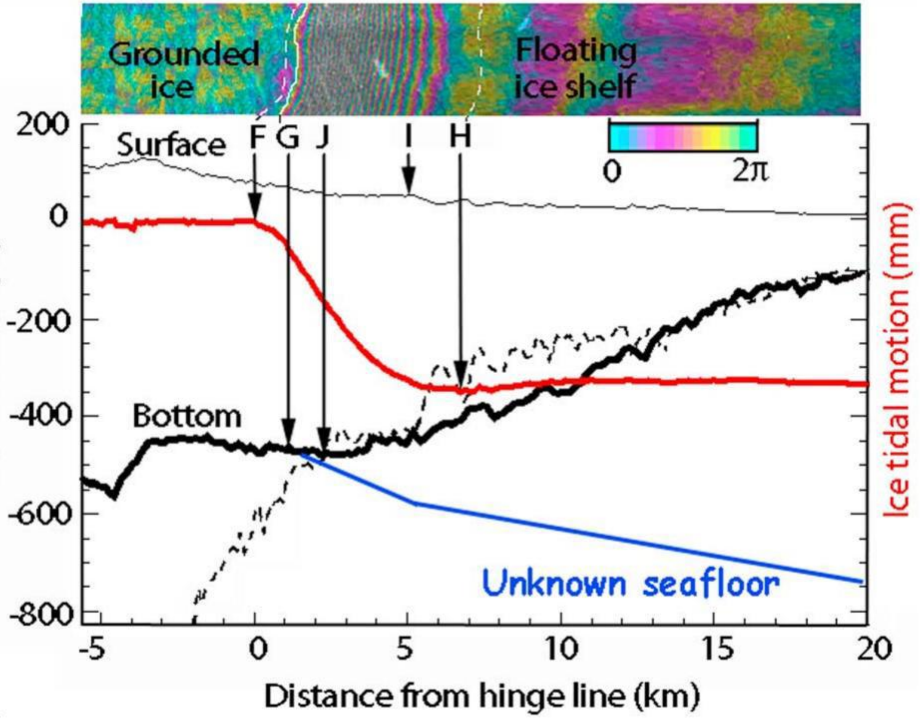


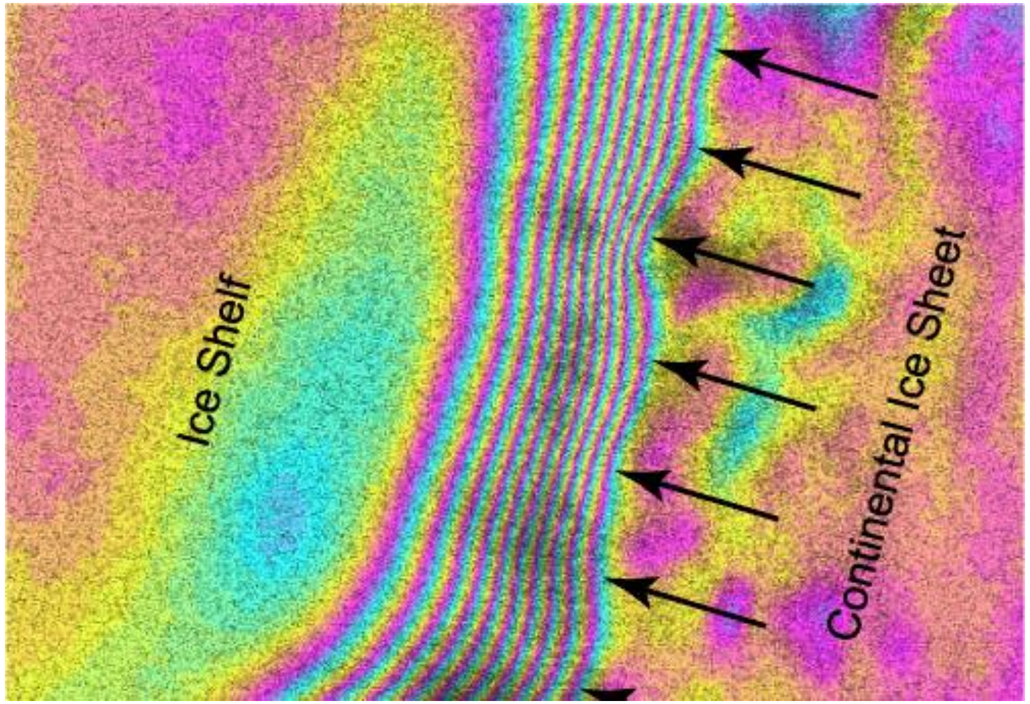

Also see:
*Bawden et al., 2001*
*Lanari et al*, 2004

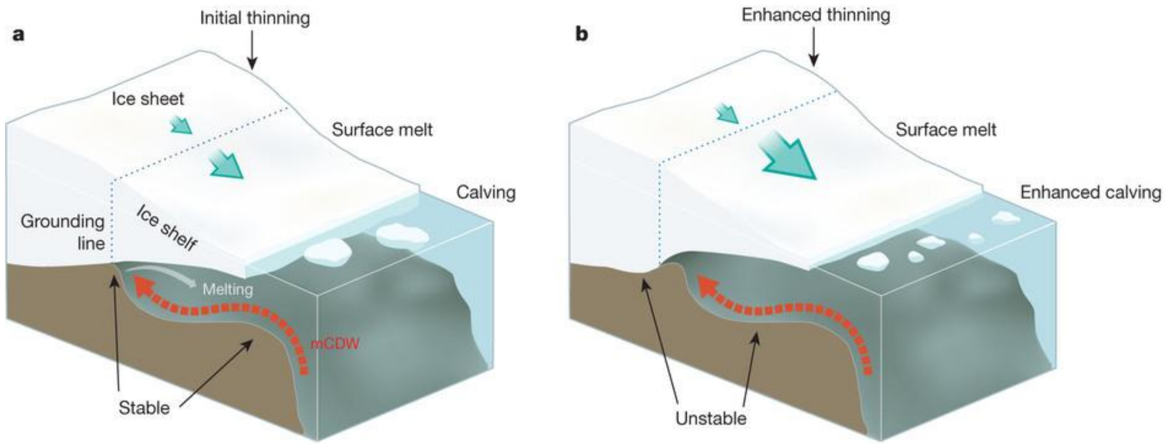
# Capturing Ice Dynamics of Earth to Constrain Climate Models



# NISAR will image grounding line positions: the hinge line of ongoing and future instabilities



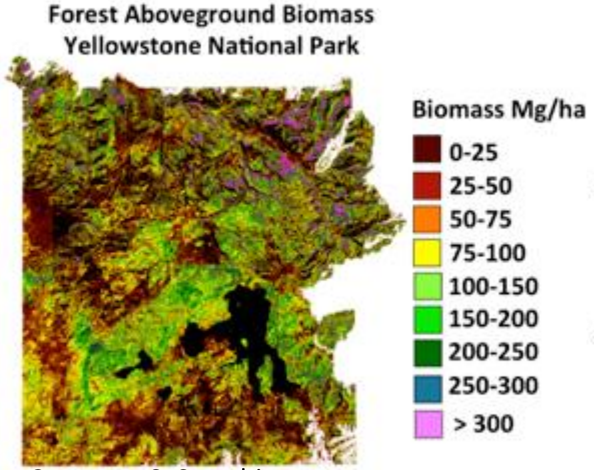

Grounding lines (G) are imaged by InSAR with 100 m horizontal precision (10 km with visible image; 1 km with laser altimetry).

Critical to know GL position for ice stream stability and modeling.

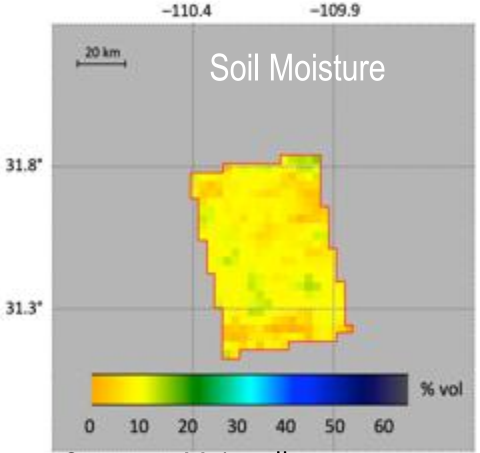
# Societal Challenges / Applied Science

| Challenge | Benefit Through Regular SAR Monitoring of: |
|---|---|
| Global Food Security | - Soil moisture and crop growth at agricultural scale<br>- Desertification at regional scales |
| Freshwater Availability | - Aquifer use/extent regionally<br>- Water-body extent changes<br>- Glaciers serving as water sources |
| Human Health | - Moisture and vegetation as proxy for disease and infestation vectors |
| Disaster Prediction & Hazard Response | - Regional building damage and change assessment after earthquakes<br>- Earthen dams and levees prone to weakening<br>- Volcanoes, floods, fires, landslides |
| Climate Risks and Adaptation | - Ice sheet/sea-ice dynamics; response to climate change<br>- Coastal erosion and shoreline migration |
| Urban Management and Planning | - Urban growth through coherent change detection<br>- Building deformation and urban subsidence |
| Human-activity Based Climate Change | - Deforestation’s influence on carbon flux<br>- Oil and gas reservoirs |

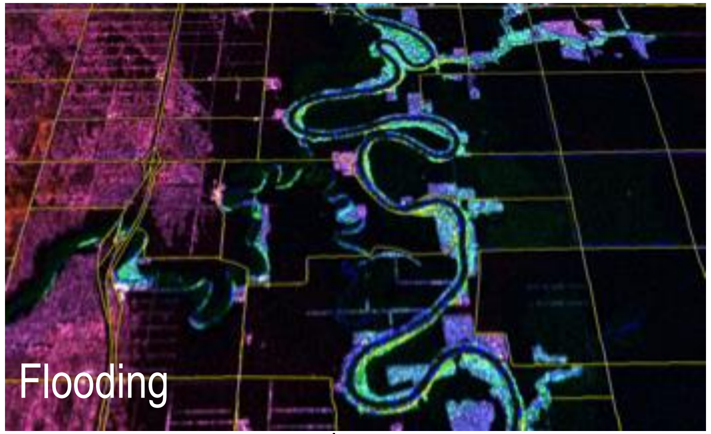
# Numerous NISAR Applications Products



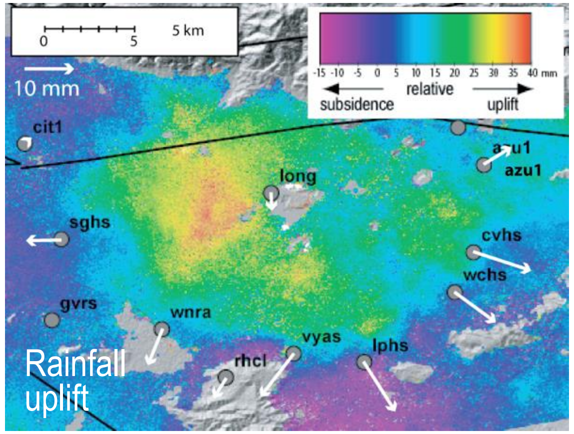

Courtesy: S. Saatchi




Courtesy: M. Lavalle

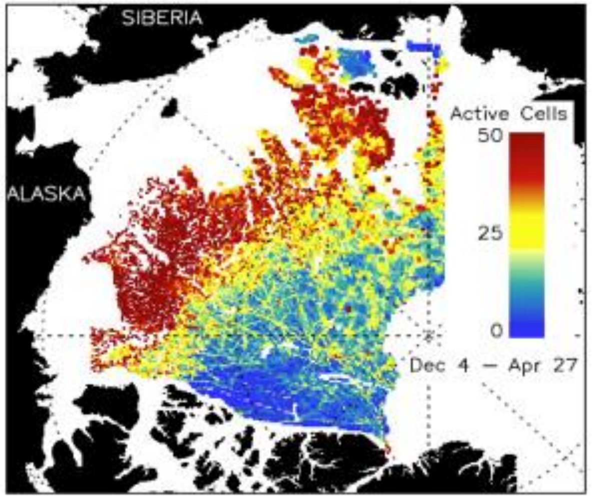



Courtesy: G. Breckenridge/S. Nghiem



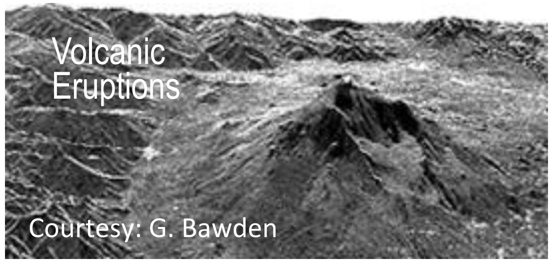

Courtesy: G. Bawden

Courtesy: S.-H. Yun

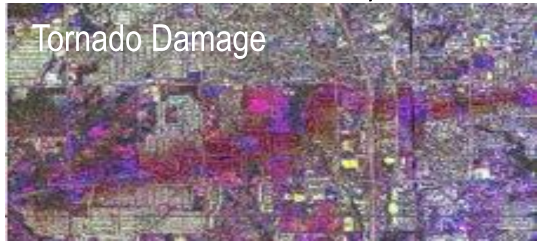


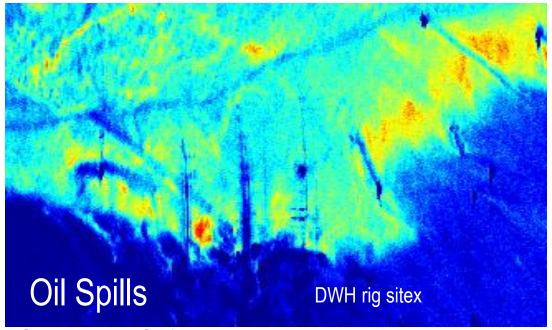

Courtesy: R. Kwok

Sea Ice Extent/ Ice and Ship Tracking

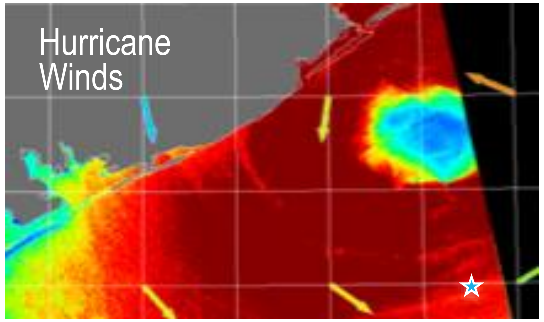



Courtesy: G. Bawden

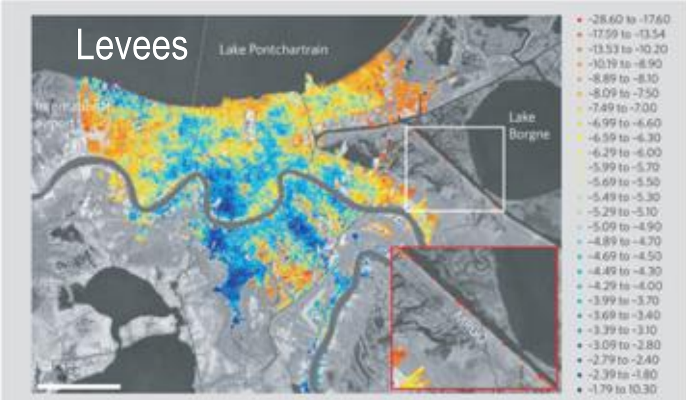



Courtesy: C. Jones



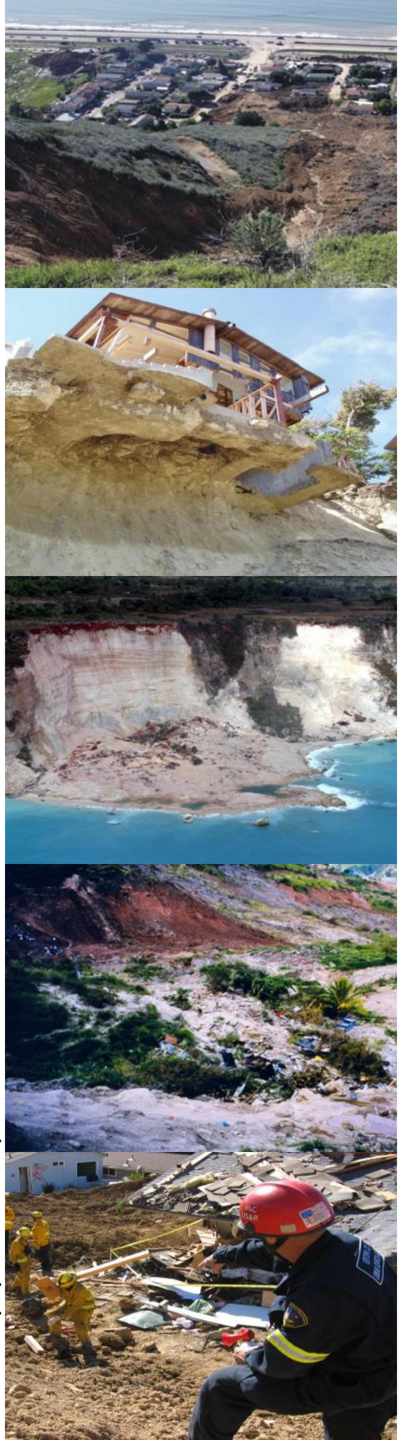

Courtesy: G. Bawden




Dixon et al, Nature 2006

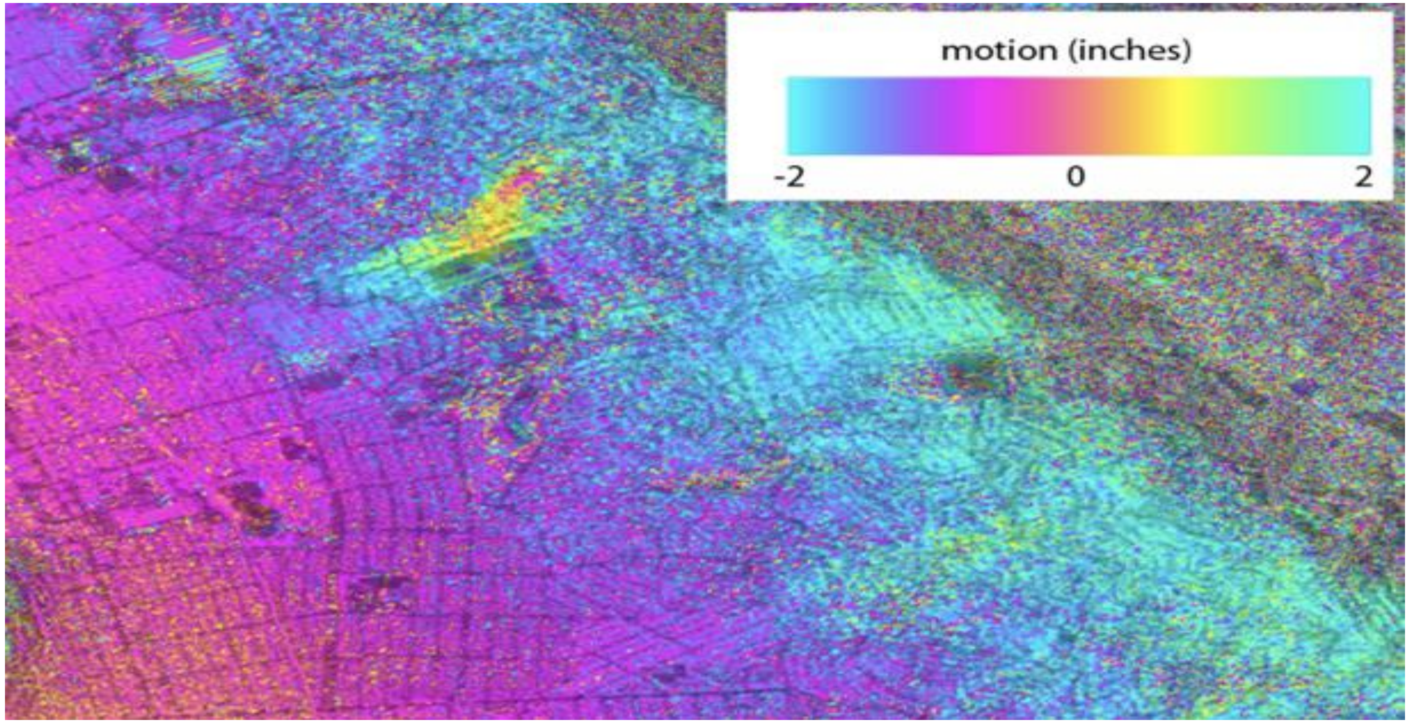
# Landslide Hazards to Infrastructure

**Landslides and other geologic hazards kill dozens of people and cause several billion dollars of damage every year in the United States. Landslides can also cause significant environmental damage and societal disruption. NISAR will enable detection of slow-moving landslides, so damage can be avoided, and potentially provide forewarning of rapid landslides prior to their catastrophic failure.**



Photos (top-to-bottom): USGS, USGS, USGS, NOAA, FEMA

***Ground movement of landslides in the Berkeley Hills of California between 2008 and 2010 was imaged using the NASA UAVSAR instrument, NISAR's airborne prototype.***




***nisar.jpl.nasa.gov***

NASA-ISRO Synthetic Aperture Radar (NISAR) Mission

# Application White Papers

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

**Application Area**

**Hazards**

- Sinkholes and Cavern Collapse (PDF, 2.01 MB)
- Volcanic Hazards (PDF, 1.62 MB)
- Landslides (PDF, 1.25 MB)
- Floods (PDF, 2.98 MB)
- Induced Seismicity (PDF, 1.76 MB)
- Hazards in Texas (PDF, 5.1 MB)

**Maritime Hazards and Coastal Waters**

- Coastal Land Loss (PDF, 2.56 MB)
- Oil Spills (PDF, 3.48 MB)
- Ice Sheets, Glaciers, and Oceans (PDF, 1.19 MB)
- Marine Hazards (PDF, 1.44 MB)
- Sea Ice (PDF, 2.21 MB)

**Ecosystem**

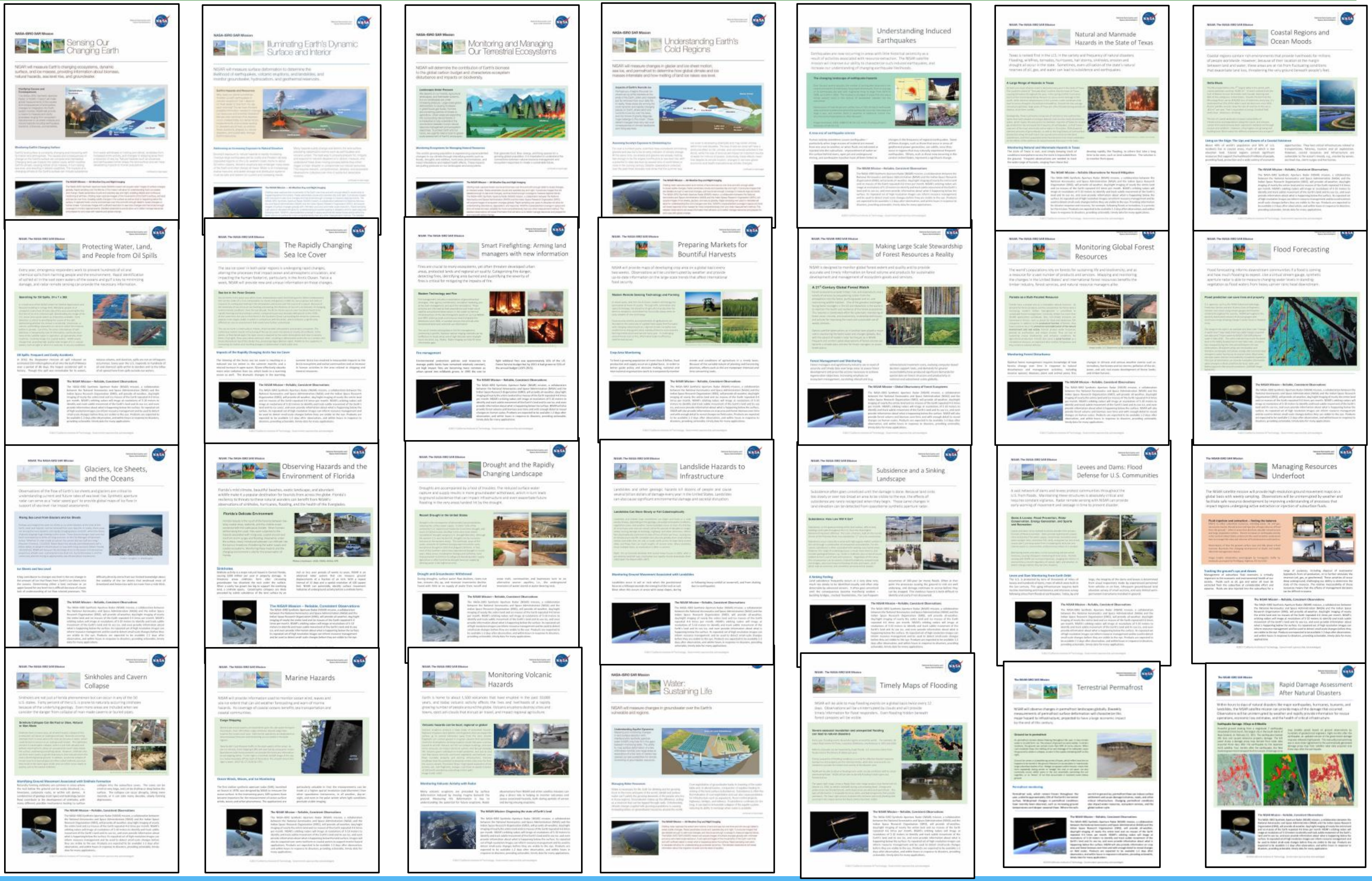
- Fire Management (PDF, 1.78 MB)
- Food Security (PDF, 1.01 MB)
- Soil Moisture and Water Resources (PDF, 1.31 MB)
- Forest Resources (PDF, 2.02 MB)
- Timber and Forest Disturbance (PDF, 2.7 MB)
- Flood Forecasting (PDF, 3.52 MB)
- Hazards in Florida (PDF, 3.53 MB)

**Underground Reservoirs**

- Drought and Groundwater Withdrawal (PDF, 3.06 MB)
- Oil, Gas, and Water Underground Reservoirs (PDF, 2.09 MB)

**Critical Infrastructure**

- Levees and Dams (PDF, 1.92 MB)
- Subsidence (PDF, 2.58 MB)
- Damage Mapping (PDF, 3.66 MB)
- Changes in Permafrost (PDF, 797 KB)



# Soil Moisture Application White Paper

National Aeronautics and Space Administration

NISAR: The NASA-ISRO SAR Mission

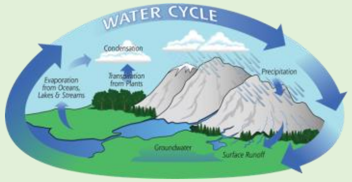
## Water: Vital for Life and Civilization

NISAR will provide maps of surface soil moisture globally every 6 to 12 days at the spatial scale of individual farm fields. This offers unprecedented detail and is vital for monitoring the habitats of plants, animals and humans.

### Surface soil moisture

Water is critical to life on Earth. The health and continued existence of all life on Earth depends on having access to water. The amount and timing of surface water can vary in ways that significantly affect quality of life. On the one hand, excess water can lead to flooding, landslides, crop failures and outbreak of vector-borne disease. On the other hand, water shortage causes drought, wildfires and stress on farming activity.

Adapting to surface water conditions requires information, from regional scales down to the scale of an individual field. Maps of soil moisture provide essential information, because they help link the major components of the Earth's water cycle among precipitation, evaporation, storage, and runoff. Field-scale maps are required to identify the fine spatial details needed for agriculture.




Photos : USDA (left), USGS (right)

### Surface Water and Soil Moisture

Soil wetness affects a large part of human life and civilization. The impact of either excess or inadequate surface water can be devastating, and even seemingly small variations can have a large impact on crop yield and insect populations. Soil moisture, measurable from space with synthetic aperture radar, is an excellent indicator of surface water availability and is widely used in agriculture and forest resource and fire management.

### 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. NISAR will also provide information on crop area and forest biomass over time and with enough detail to reveal changes on field scales. 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.



National Aeronautics and Space Administration

NISAR: The NASA-ISRO SAR Mission

**Floods:** Floods cause devastation in many parts of the world every year. Soil moisture information helps in predicting the flood potential. Although floods are triggered by heavy rainfall, saturated soil vastly increases the chances of flood because the soil can no longer absorb rainwater. Floods can occur within a watershed when rain that is not absorbed by the soil drains through a narrow outlet too slowly to accommodate the rate of rainfall. Because watersheds can be very small (10 ha, or 0.1 $km^2$), the currently available spaceborne soil moisture maps at ~25 km spatial resolution are not adequate for many watersheds. NISAR's field-scale mapping capability (200m resolution) will alleviate this problem.

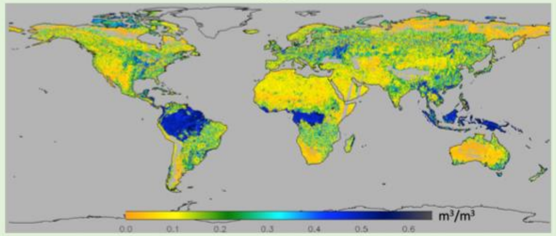
**Landslides:** Landslides often develop abruptly, leaving little time for residents to escape. Landslides are often preceded by wetting of the soil, which causes the soil to become loose (less cohesive). Considering that areas of landslide can be small and that they occur on sloped terrain, improving the spatial resolution of soil moisture maps is critical if they are to be used for landslide hazard identification.

**Wildfires:** In recent years, wildfires have caused numerous catastrophes, especially in the western U.S., and the problem is apparently becoming more severe. Not only can NISAR monitor the current condition of a major wildfire by characterizing the vegetation, but surface soil moisture plays an important role in predicting the probability of a fire outbreak, because a prolonged dry condition is often one of the prerequisites of fire outbreak.

**Vector-borne disease:** According to the World Health Organization, vector-borne diseases account for more than 17% of all infectious diseases, causing more than 700,000 deaths annually. Wet soil conditions are highly correlated with the extent of stagnant water that encourages insect disease vectors. These waterbodies are often too small to directly detect from space. Therefore, the high-resolution soil moisture can be an effective indicator of the likelihood of the vectors and the presence of disease.

**Agriculture:** Accurate information of soil moisture at the scale of a single agricultural field allows for efficient irrigation, water use, and fertilization. Efficient irrigation conserves water resources, which are increasingly depleted in the U.S. and world-wide due to drought and the growing demand for food. Optimized fertilization reduces cost and prevents excess nutrients from polluting a river system. Soil moisture conditions have been reported traditionally by field agents, and NISAR aims at providing for the first time the information at these field scales in an automated, uniform, and reliable way.

**Radar imaging of soil moisture**




Global map of surface soil moisture imaged by the radar onboard NASA's Soil Moisture Active Passive satellite (SMAP) at 3-km spacing over an 8-day period in May, 2015. NISAR radar will operate in a similar way of the SMAP radar but at enhanced spacing to allow soil moisture mapping at the field-scale. From Kim, S.B., et al., Surface soil moisture retrieval using the L-band synthetic aperture radar onboard the Soil Moisture Active Passive (SMAP) satellite and evaluation at core validation sites, *IEEE Trans. Geosci. Remote Sens.*, *55*, 1897 - 1914, 2017

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

# Damage Proxy Map Application White Paper

National Aeronautics and Space Administration

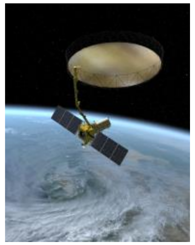
**The NISAR-ISRO SAR Mission**

## 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.



*Continued from front page*

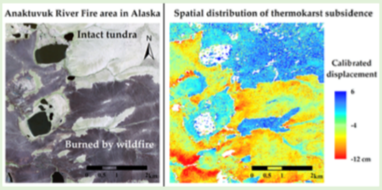
Permafrost degradation has major implications for the economy. As permafrost thaws and ground ice melts, the soils lose strength and the surface can subside and collapse. The costs to maintain and repair infrastructure affected by thaw-induced soil failure and subsidence are projected to continue to 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.

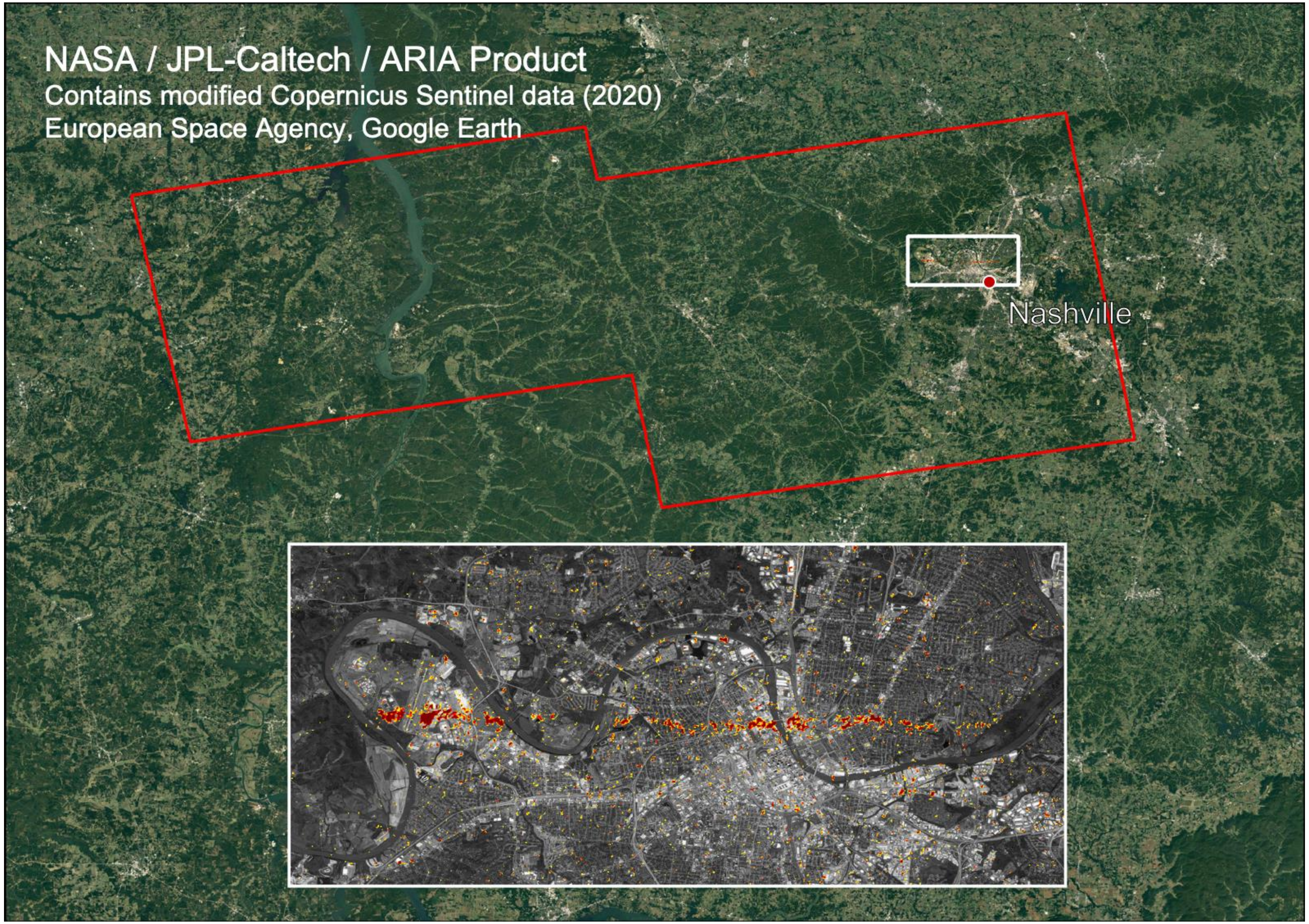



*SAR deformation analyses reveal that the areas of large post-fire subsidence (shown in yellow red in the right panel) coincide with the burn scar (dark patches in the left panel)*

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

# ARIA Damage Proxy Map
# Nashville Tornado March 3, 2020



# Applications & Urgent Response

# Utilization Plan

NASA - ISRO SAR Mission

## NISAR Utilization Plan

**4 September 2018**

**JPL D-102207**

Prepared by:

E. Natasha Stavros
Deputy Applications Lead

Cathleen E. Jones
Science Team Applications Co-Lead

Susan E. Owen
Deputy Applications Lead

Jet Propulsion Laboratory, California Institute of Technology

Approved by:

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Program Scientist

Paul A. Rosen (Date) 9/7/2018
Project Scientist

David S. Green (Date) Sept 11/18
Applied Science Program Manager

JPL
Jet Propulsion Laboratory
California Institute of Technology

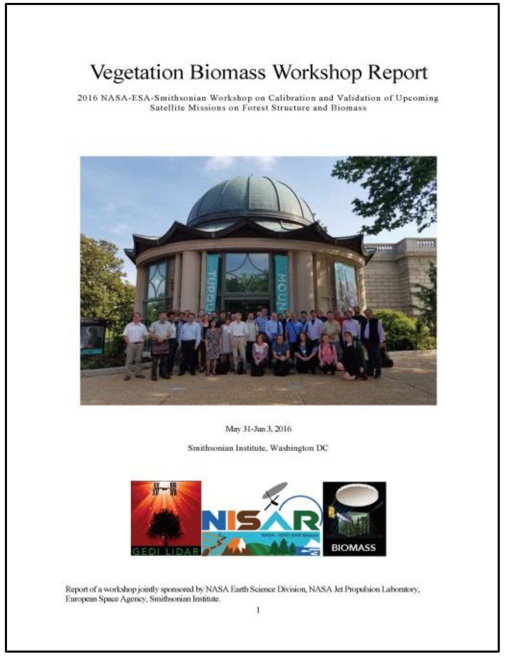
**Contents**





- Focused community workshops
- Training
- Envoys to user community
- Early Adopters Program

# Community Workshops


Vegetation Biomass Workshop Report

2016 NASA-ESA-Smithsonian Workshop on Calibration and Validation of Upcoming Satellite Missions on Forest Structure and Biomass

May 31-Jun 3, 2016

Smithsonian Institute, Washington DC

Report of a workshop jointly sponsored by NASA Earth Science Division, NASA Jet Propulsion Laboratory, European Space Agency, Smithsonian Institute.

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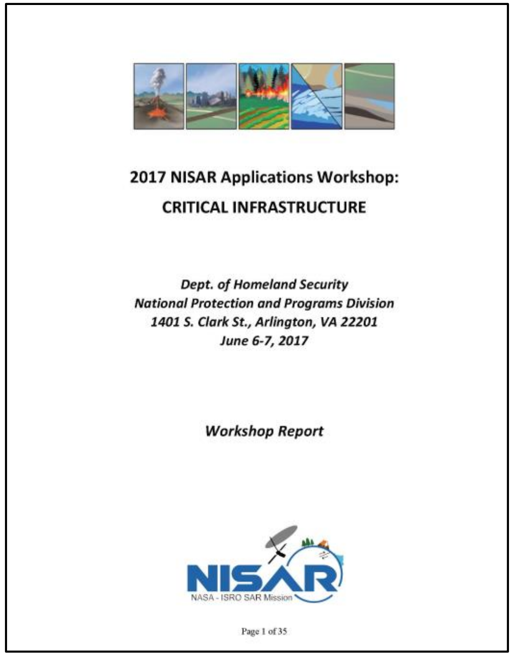
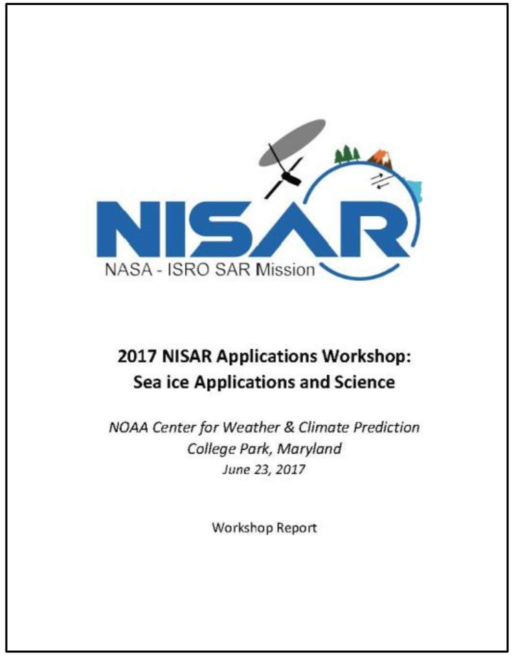

2017 NISAR Applications Workshop:

CRITICAL INFRASTRUCTURE

*Dept. of Homeland Security*
*National Protection and Programs Division*
*1401 S. Clark St., Arlington, VA 22201*
*June 6-7, 2017*

*Workshop Report*

Page 1 of 35


2017 NISAR Applications Workshop:
Sea ice Applications and Science

*NOAA Center for Weather & Climate Prediction*
*College Park, Maryland*
*June 23, 2017*

Workshop Report

FY17

- Critical Infrastructure (DHS)
- Oceans: Sea Ice (NOAA)

FY18

- Forest and Disturbance
- Agriculture and Ecosystems
- Wetlands
- SAR Literacy

FY19

- GeoHazards: Landslides
- GeoHazards: Volcanos

FY20/21

- GeoHazards: Earthquakes
- Subsidence and Resource Extraction (Planned Summer 2021)

FY21/22

- Weather-Related Hazards
- Disaster Response

# Urgent Response Plan

- Urgent Response Plan – Outline of tasks/info/decisions needed to effectively implement NISAR Urgent Response
- Science Team Activity: Provide input to Program through Working Groups
- Science Team Activity: Define and help develop an Urgent Response Tasking Request System

**Urgent Response Plan**

**Draft – 28 February 2018**

AUTHORS
Cathleen E. Jones

Jet Propulsion Laboratory, California Institute of Technology

ii

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**Contents**



iii

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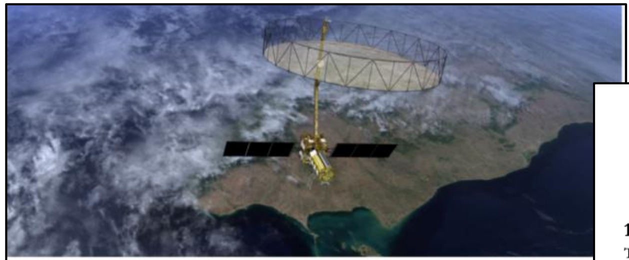


**FINAL REPORT**

**NISAR Urgent Response Working Group #1**

**17 December 2019**

**Working Group Members**

| Name | Affiliation | Representing |
|---|---|---|
| Cathleen Jones | Jet Propulsion Laboratory | Team Lead, Critical Infrastructure & Underground Reservoirs |
| Josef Kellndorfer | Earth Big Data, LLC | Ecosystems & Surface Hydrology/Floods |
| Zhong Lu | Southern Methodist Univ. | Geological Hazards |
| Frank Monaldo | NOAA | Maritime Hazards (including Tropical Storms) |
| Maher Hanna | Jet Propulsion Laboratory | NISAR Project |
| Priyanka Sharma | Jet Propulsion Laboratory | NISAR Project |
| Susan Owen | Jet Propulsion Laboratory | NASA HQ, NISAR Applied Science Program |

1

**1. Overview**

The NISAR Science Team (ST) is providing input to the NISAR Program and Project to help inform their decisions on implementing an urgent response plan that enables the mission to meet its L1 Urgent Response requirement and to serve the urgent response community in a substantive way. The ST plans to form a series of working groups (WGs) on urgent response (UR), rotating membership among interested ST members and selecting those with experience relevant to the charge of the particular WG. This is the report of the 1st Urgent Response Working Group (URWG #1).

**2. Charge to Working Group**

Provide recommendations to the NISAR Program and Project on urgent response events anticipated to be relevant to NISAR, specifically

1) The types of events to which NISAR should expect to respond
2) Criteria for response initiation
    a. Preplanned response thresholds
    b. geographic regions
    c. times of year, if relevant
3) Automatic triggering mechanism, if applicable
4) Expected criteria for response termination
5) Expected frequency of events, if known

# Urgent Response: Automatic Requesting

- Science Team's URWG#1 reviewed disaster event types to identify those likely to use NISAR data for response
- Identified events for which requesting could be automated
- Recommended event thresholds & automation mechanisms

| 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 |

*The assumption is that International Charter initiation will be automatable, although at present the announcements are made through email to agency points-of-contact. *Note: ISRO has expressed interest in providing automation of tasking requests for International Charter activations. They would initiate the request to the standard UR request interface used for all disasters.*

# ESTO Smart Tasking Project

Develop and demonstrate a prototype system that *automatically* requests *urgent response* tasking when it recognizes event criteria recommended by the NISAR Science Team for

1) *Earthquakes (global extent)*
2) *Major fires (U.S.)*

And in response to *manual requests* made through a web interface for

3) *International Disasters Charter activations*.

An automated detection and tasking capability would significantly reduce latency, increase utility of NASA's data for urgent response, support studies of dynamic processes, and support future mission architectures that include on-board acquisition/downlink automation.

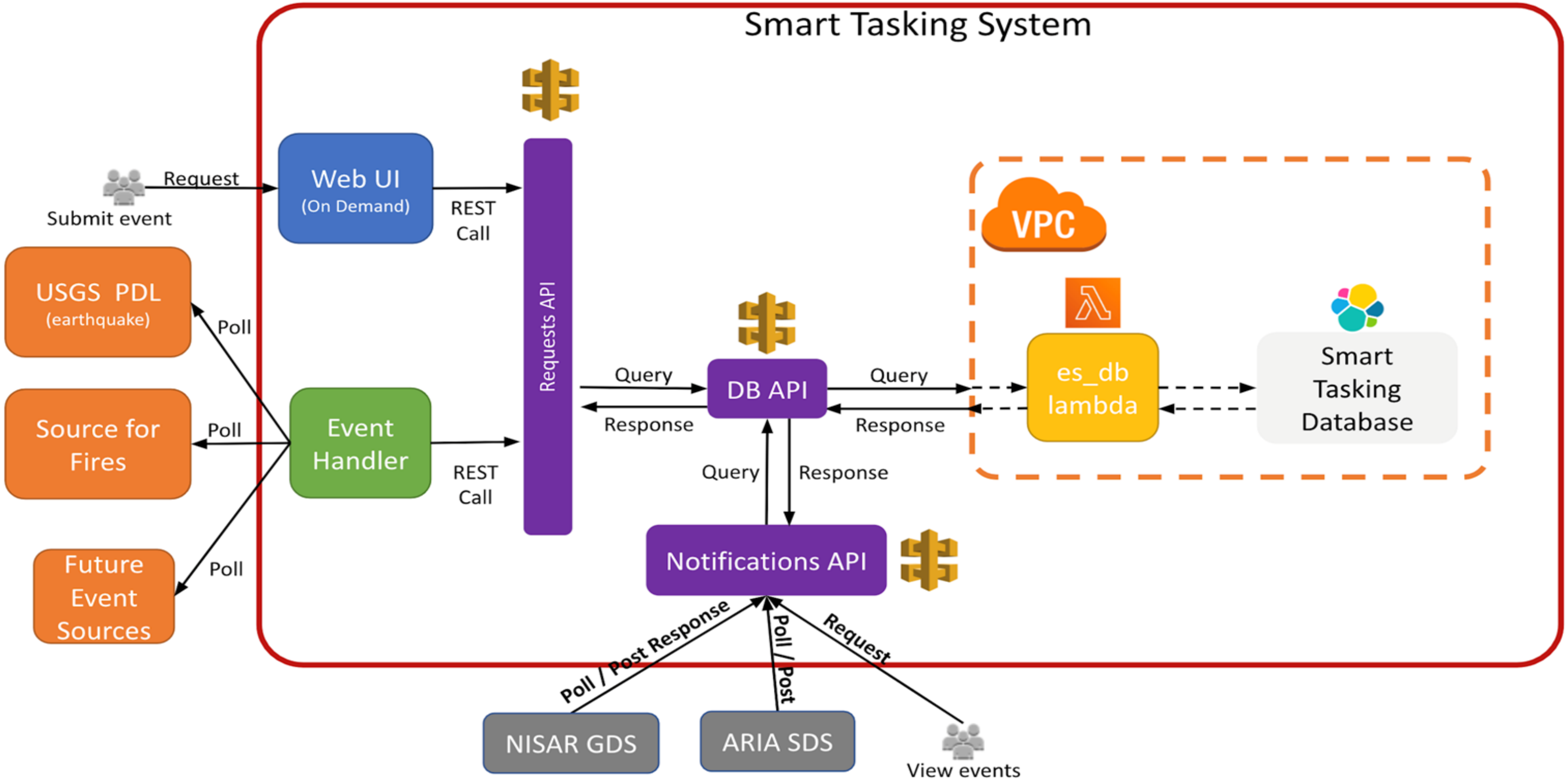
Recognize when earthquakes and fires are occurring, and prioritize NISAR observations of them

- Mission-compatible cybersecurity: Work with NISAR Mission Systems personnel to determine content, format, and interface for requests and event criteria. Develop interfaces to NISAR Ground Data System.
- Demonstrate system capability by tasking ARIA, a rapid imaging and analysis system for natural hazards, to process Sentinel-1 SAR images in response to recognized Quake and Fire events.

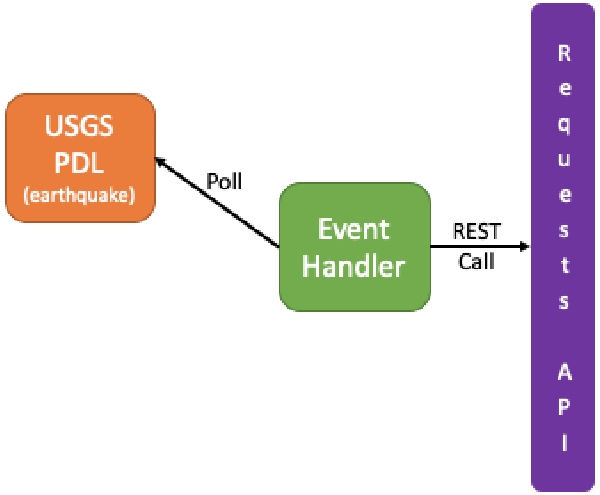
- **Demo Interfaces and APIs 11/19**
- **Demo automated earthquake response 02/20**
- **Demo manual request handling 04/20**
- **Demo automated fire response 07/20**
- **Develop ARIA & NISAR GDS interface 08/20**
- **System demo with ARIA 10/20**
- **Completion of initial prototype 10/31/2020**

**ARIA = Advanced Rapid Imaging & Analysis (H. Hua, D. Bekaert);**
**NISAR Science Team (D. Bekaert, C. Jones)**

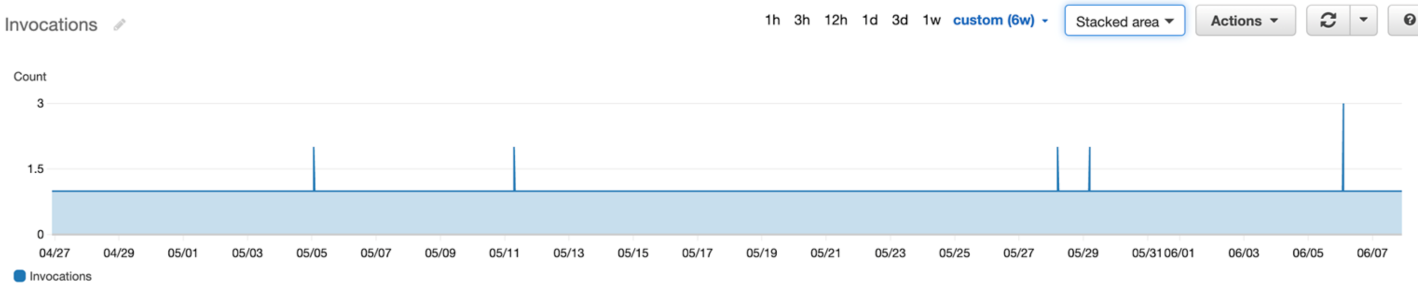
# Server-less light Architecture



# Automatic Ingestion of Events from Sources

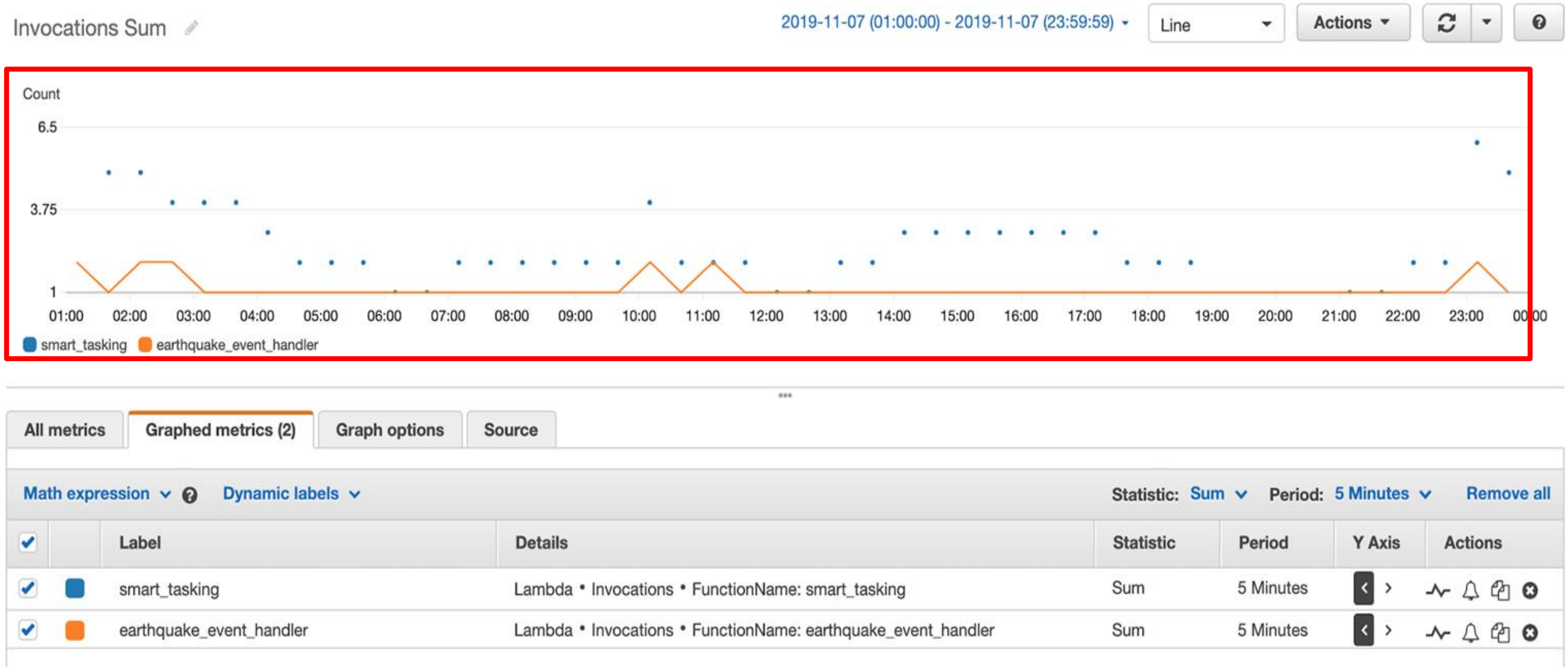



- Event Handler (AWS Lambda) is invoked every 10 minutes
- Polls for USGS NEIC PDL notifications
- Makes POST request to Requests API



# Earthquake Test, M2.0 Threshold

## CloudWatch Metrics

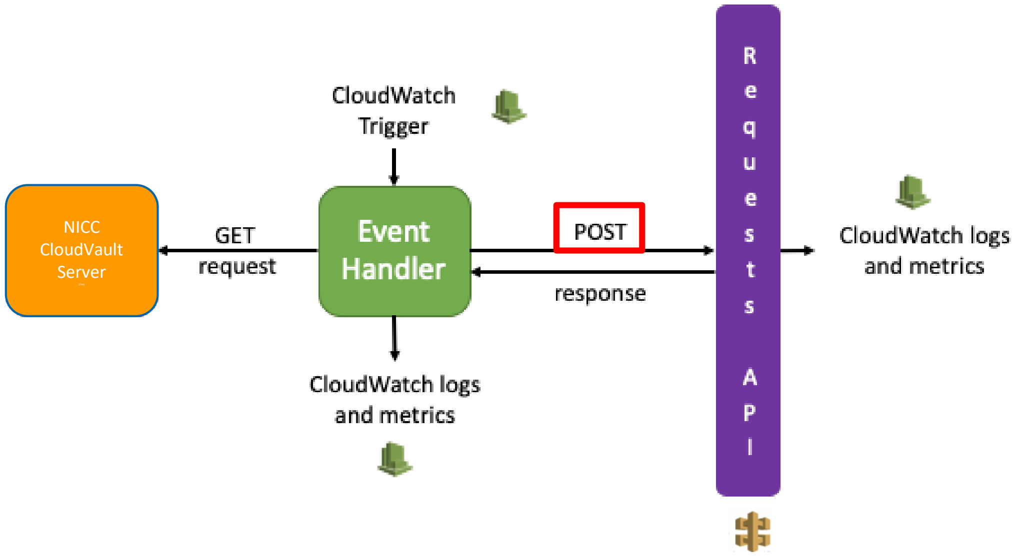



**Correlation between execution of the earthquake event handler and the API**

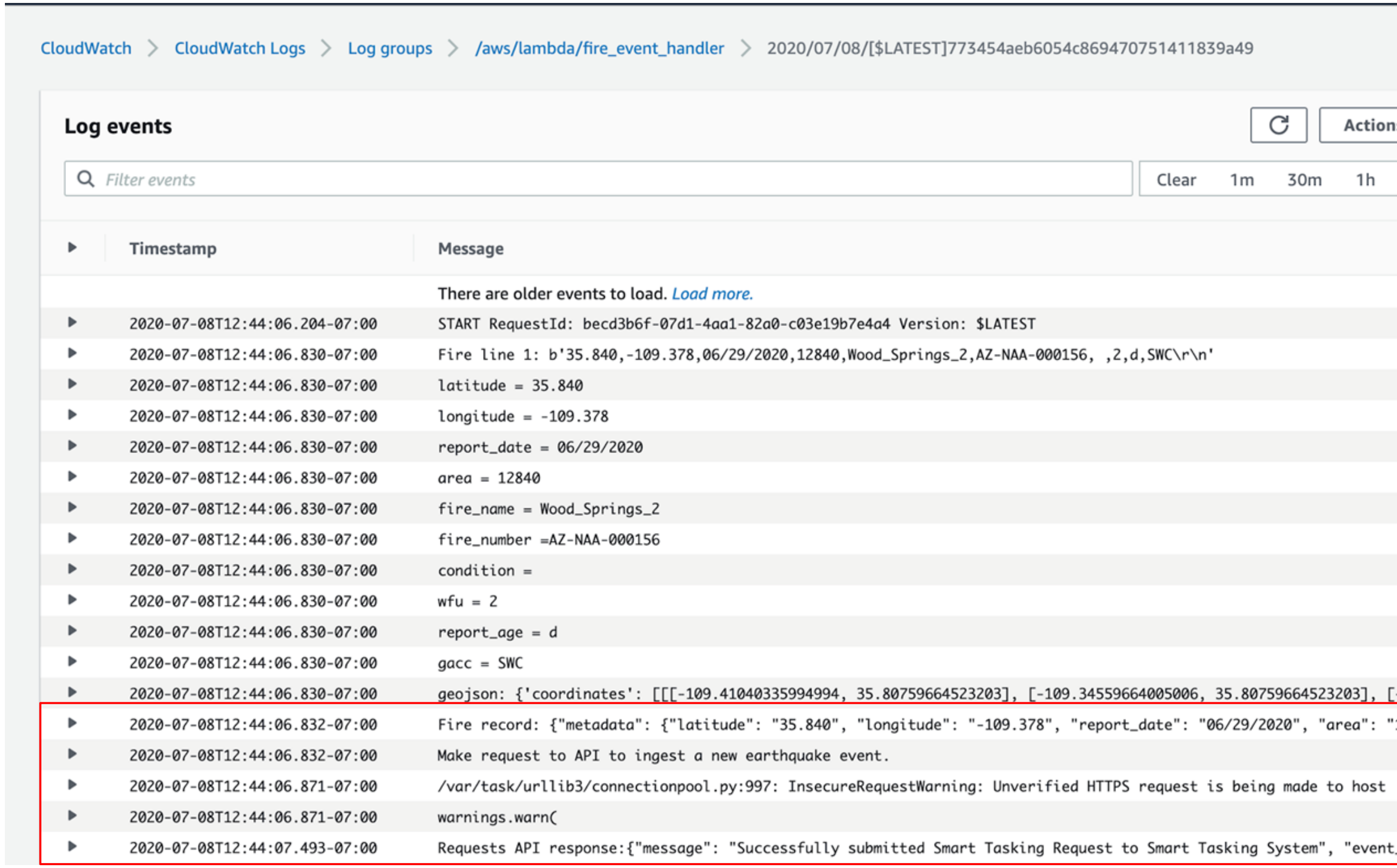
# Fire Event Handler

**Event Handler makes POST request to Requests API**

- Event type
- Event time (ISO [8601])
- Location (Geojson)
- Requestor ID (Registered user / source)
- Metadata blob from source
- [Interface of Event Handlers to API Gateway Documentation]()

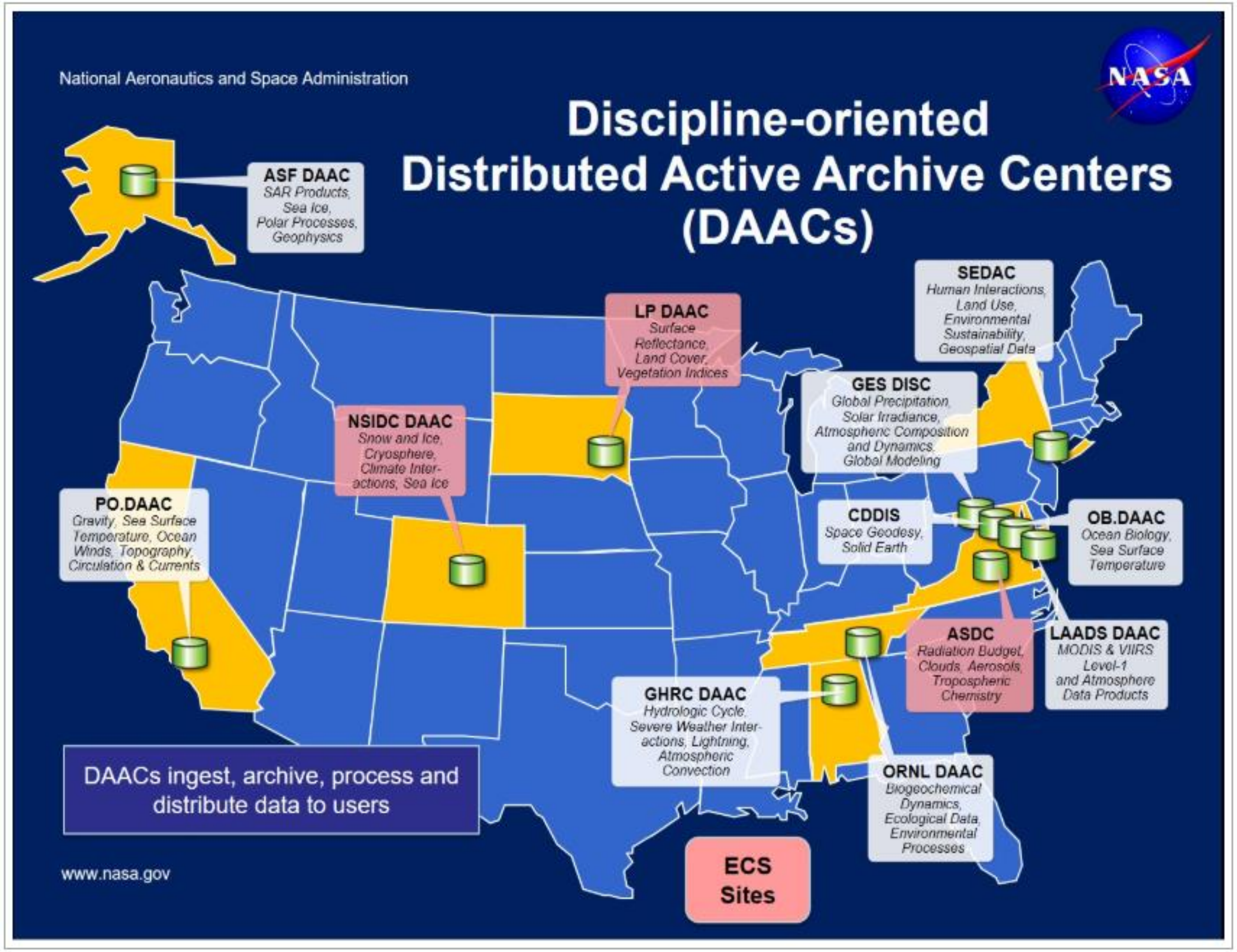



## Fire Event Handler Logs



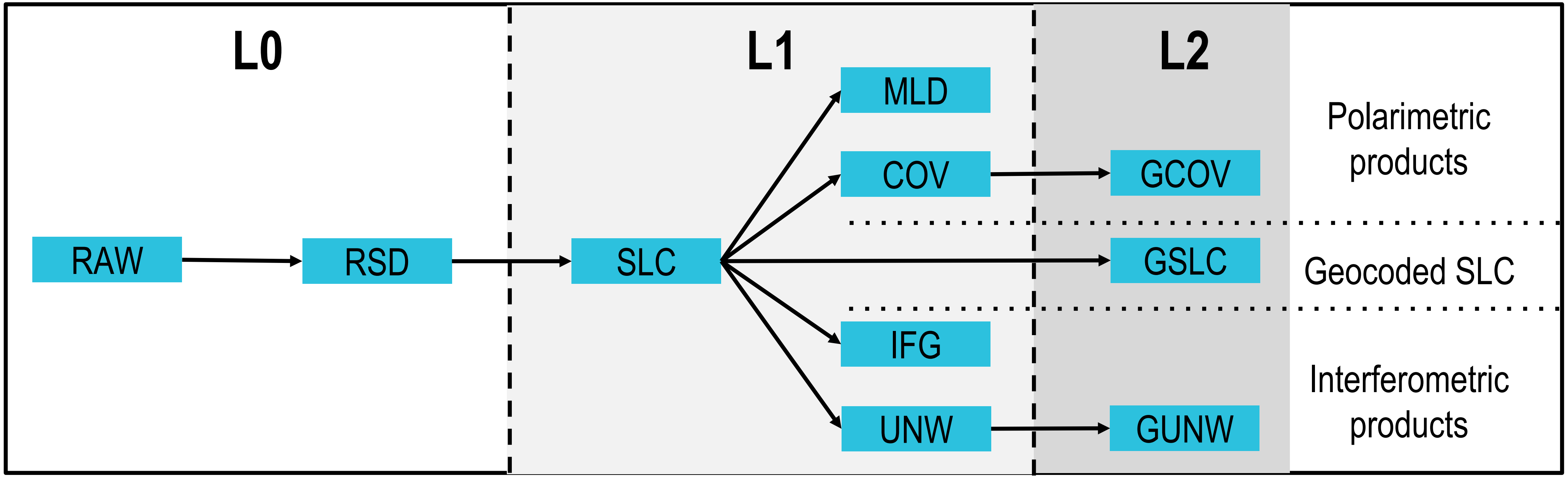
# The Data

## NASA DAACs


National Aeronautics and Space Administration
NASA
Discipline-oriented Distributed Active Archive Centers (DAACs)
ASF DAAC
SAR Products, Sea Ice, Polar Processes, Geophysics
SEDAC
Human Interactions, Land Use, Environmental Sustainability, Geospatial Data
LP DAAC
Surface Reflectance, Land Cover, Vegetation Indices
GES DISC
Global Precipitation, Solar Irradiance, Atmospheric Composition and Dynamics, Global Modeling
NSIDC DAAC
Snow and Ice, Cryosphere, Climate Interactions, Sea Ice
PO.DAAC
Gravity, Sea Surface Temperature, Ocean Winds, Topography, Circulation & Currents
CDDIS
Space Geodesy, Solid Earth
OB.DAAC
Ocean Biology, Sea Surface Temperature
ASDC
Radiation Budget, Clouds, Aerosols, Tropospheric Chemistry
LAADS DAAC
MODIS & VIIRS Level-1 and Atmosphere Data Products
GHRC DAAC
Hydrologic Cycle, Severe Weather Interactions, Lightning, Atmospheric Convection
ORNL DAAC
Biogeochemical Dynamics, Ecological Data, Environmental Processes
DAACs ingest, archive, process and distribute data to users
ECS Sites
www.nasa.gov

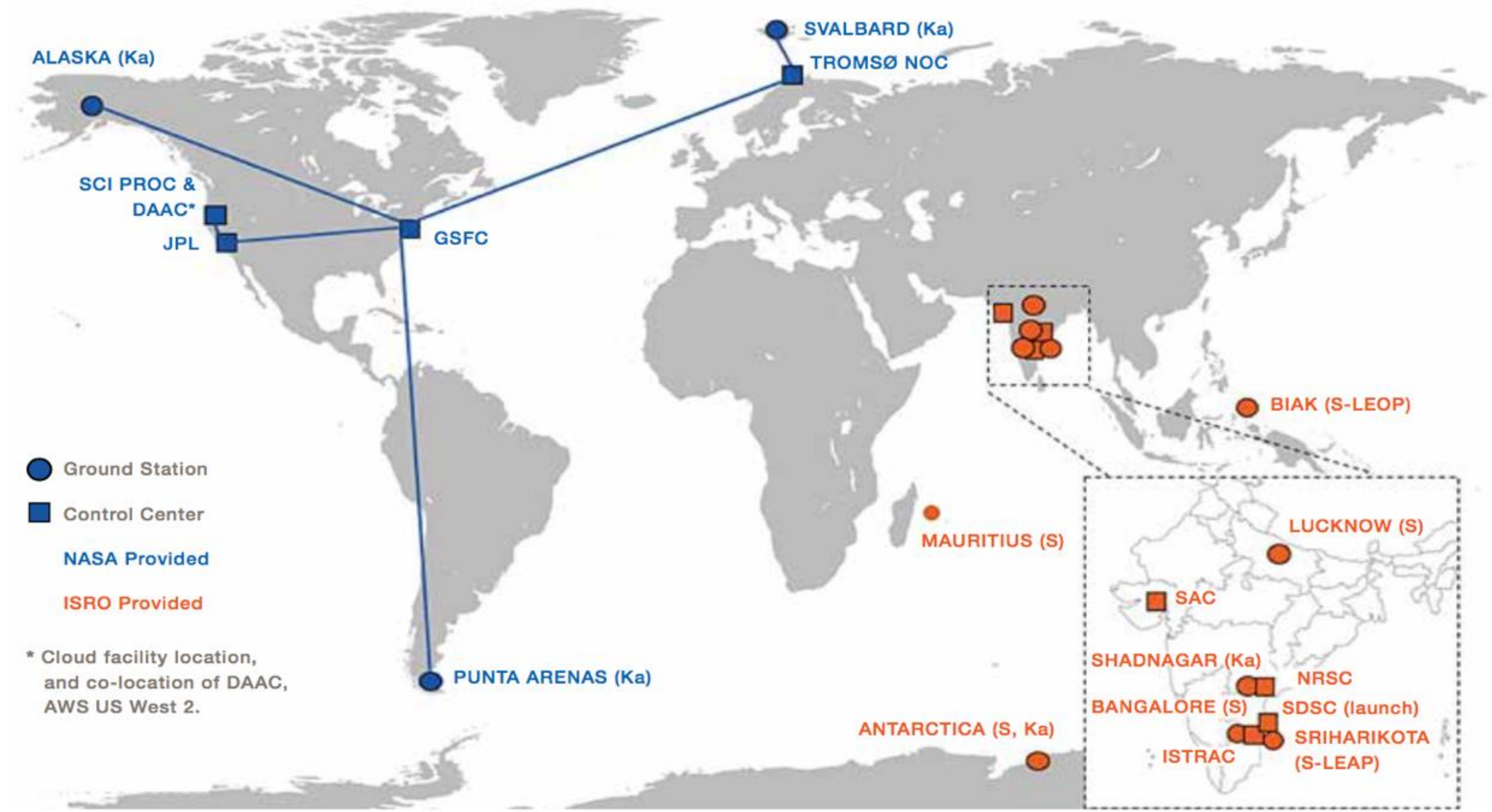
# NISAR Global Product Suite

- 35 Tbits of raw L-band data per day on average
- 6-8 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






# NISAR Ground Receiving Network



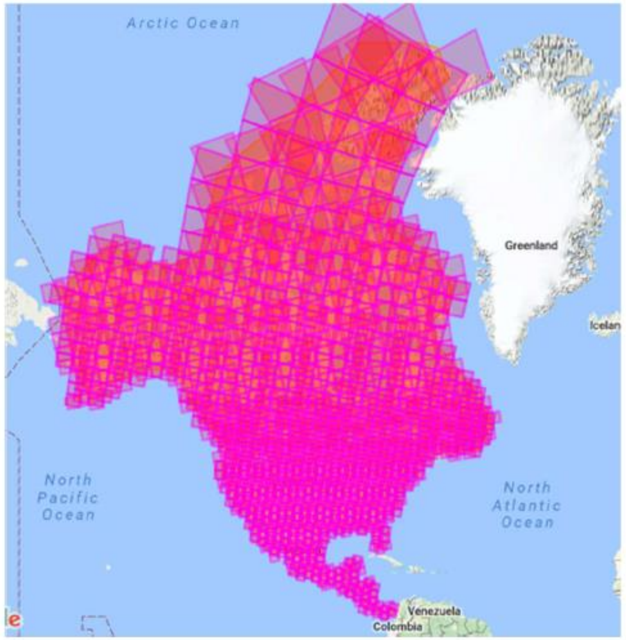

41 Tbits / day total L+S band science data downlink

*nisar.jpl.nasa.gov*

NASA-ISRO Synthetic Aperture Radar (NISAR) Mission

# NISAR Support of U.S. Federal Agencies' Satellite Needs Working Group

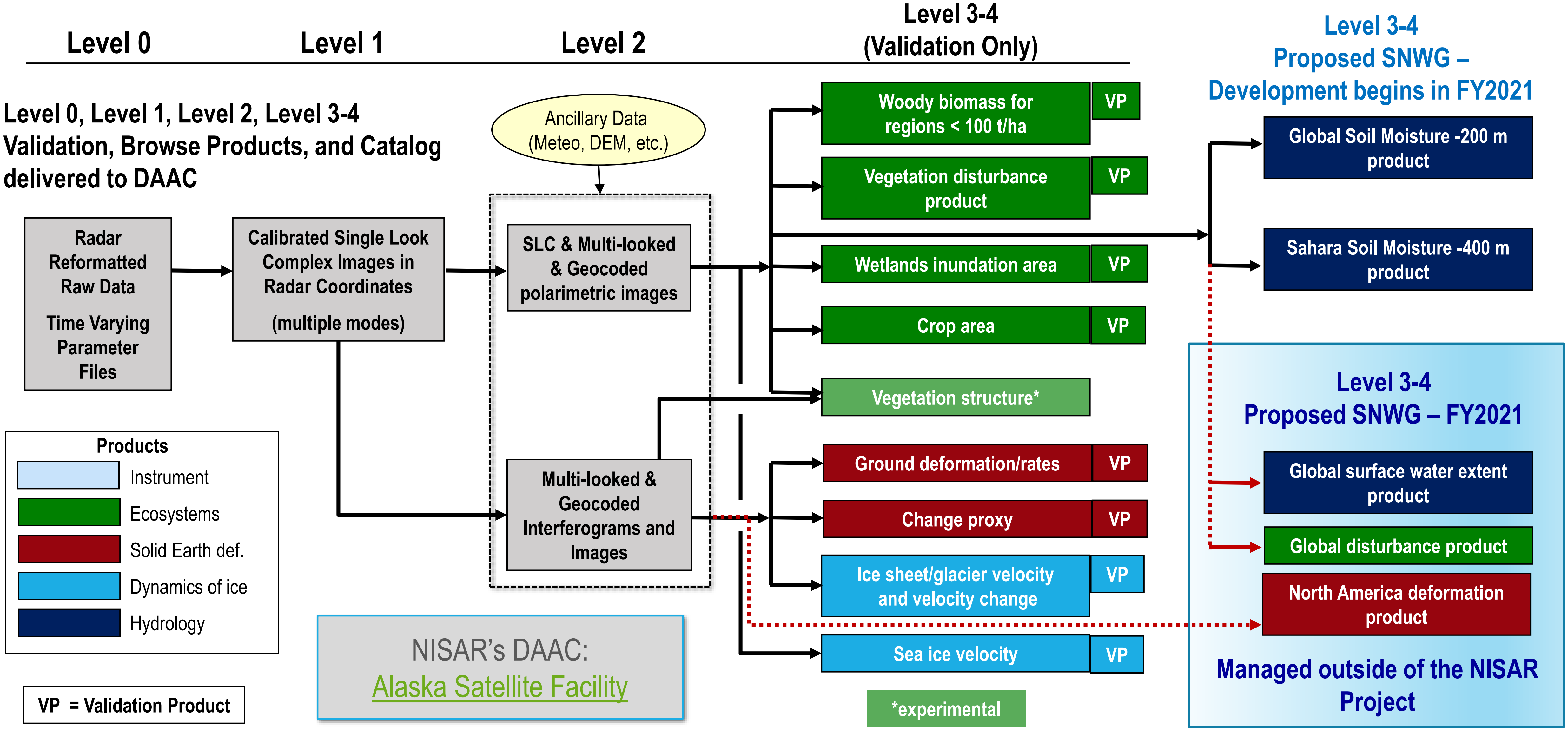
- As a result of the 2016 SNWG recommendations, the NISAR project was directed to augment the downlink system to accommodate higher bandwidth and more polarization diversity over North America
- Since augmentation start in 2018, the NISAR project at JPL and the NASA Near Earth Network teams have
  - **Increased the planned average downlink capacity from 26 Tb/day to 35 Tb/day**
  - Developed a mission plan to operate over North America (and Hawaii) with greater polarimetric diversity and wider bandwidth consistent with meeting the baseline NISAR science requirements
  - Studied the impact of these changes on overall observatory utilization and resource constraints




**NEN AS4 Antenna at ViaSat Facility**

**One of NEN Augmentations for SNWG**

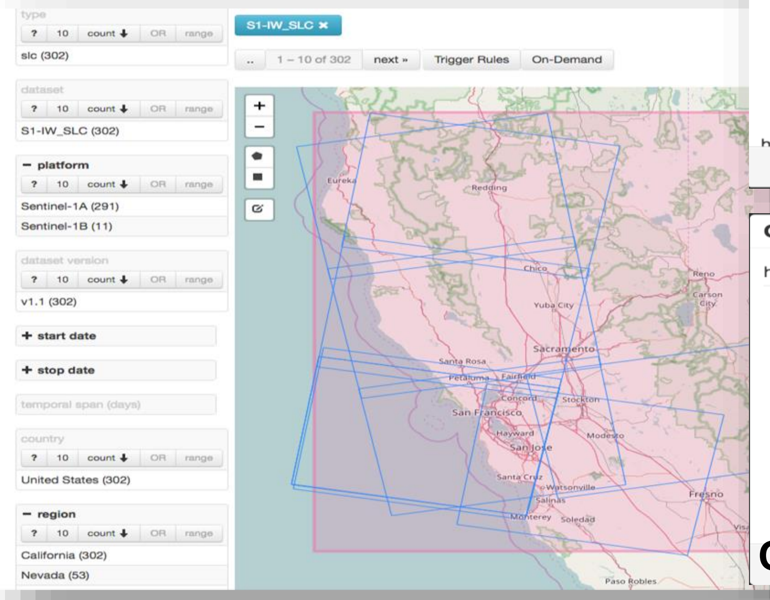
# NISAR Science Data Analysis and Archive Approach

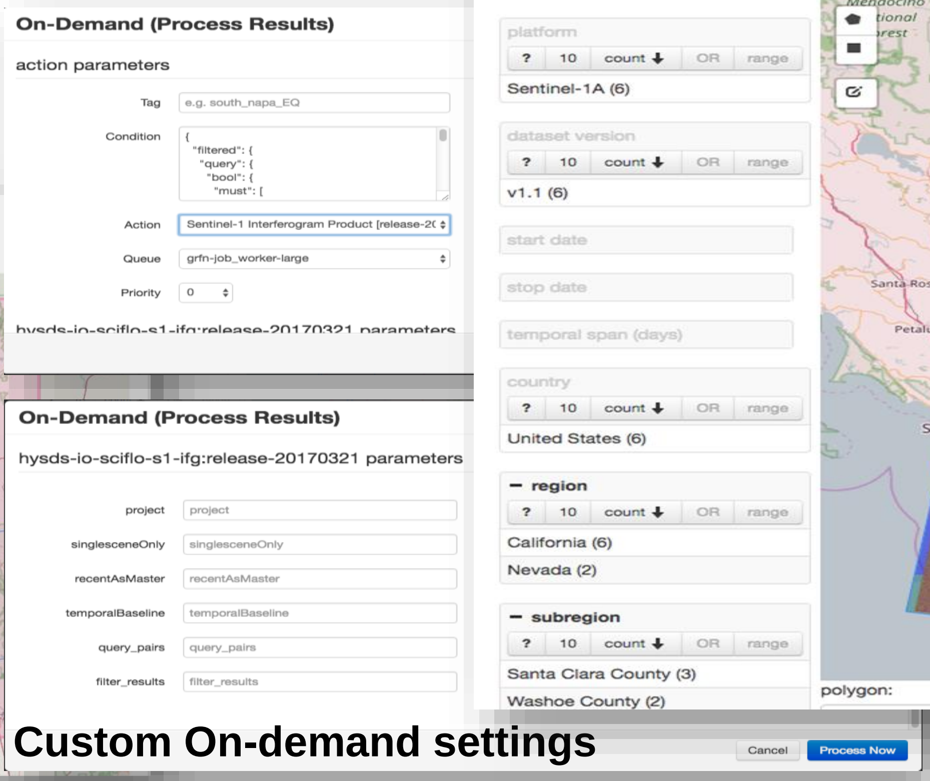


# NISAR Data Processing and Access Moving to the Cloud

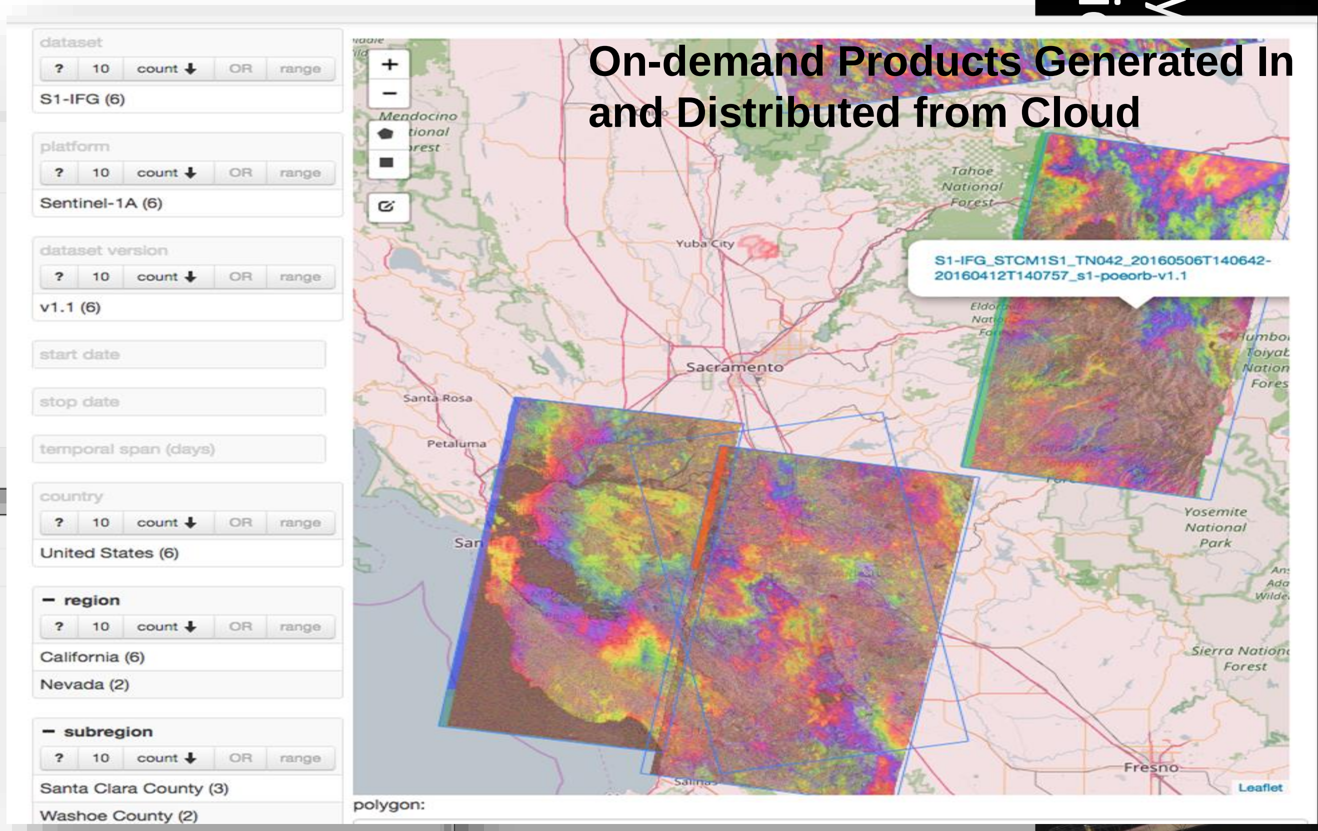
- Cloud Processing and distribution allows scalability and localization with users
- On-demand processing allows users to satisfy their needs without high-capability computing and networks.
- Prototyped with ARIA/GRFN Cloud Processing System

**Selection of Data**




**Custom On-demand settings**

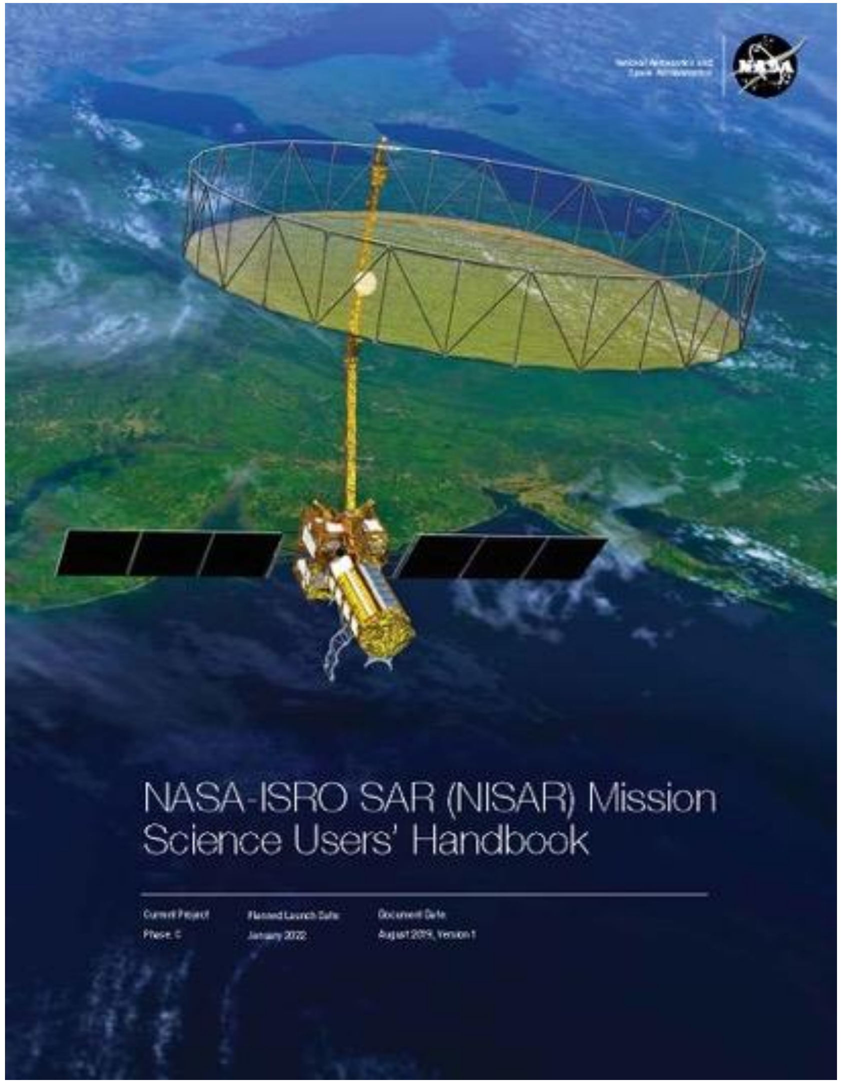



**On-demand Products Generated In and Distributed from Cloud**

NASA-ISRO Sy
(NISAR) Missi

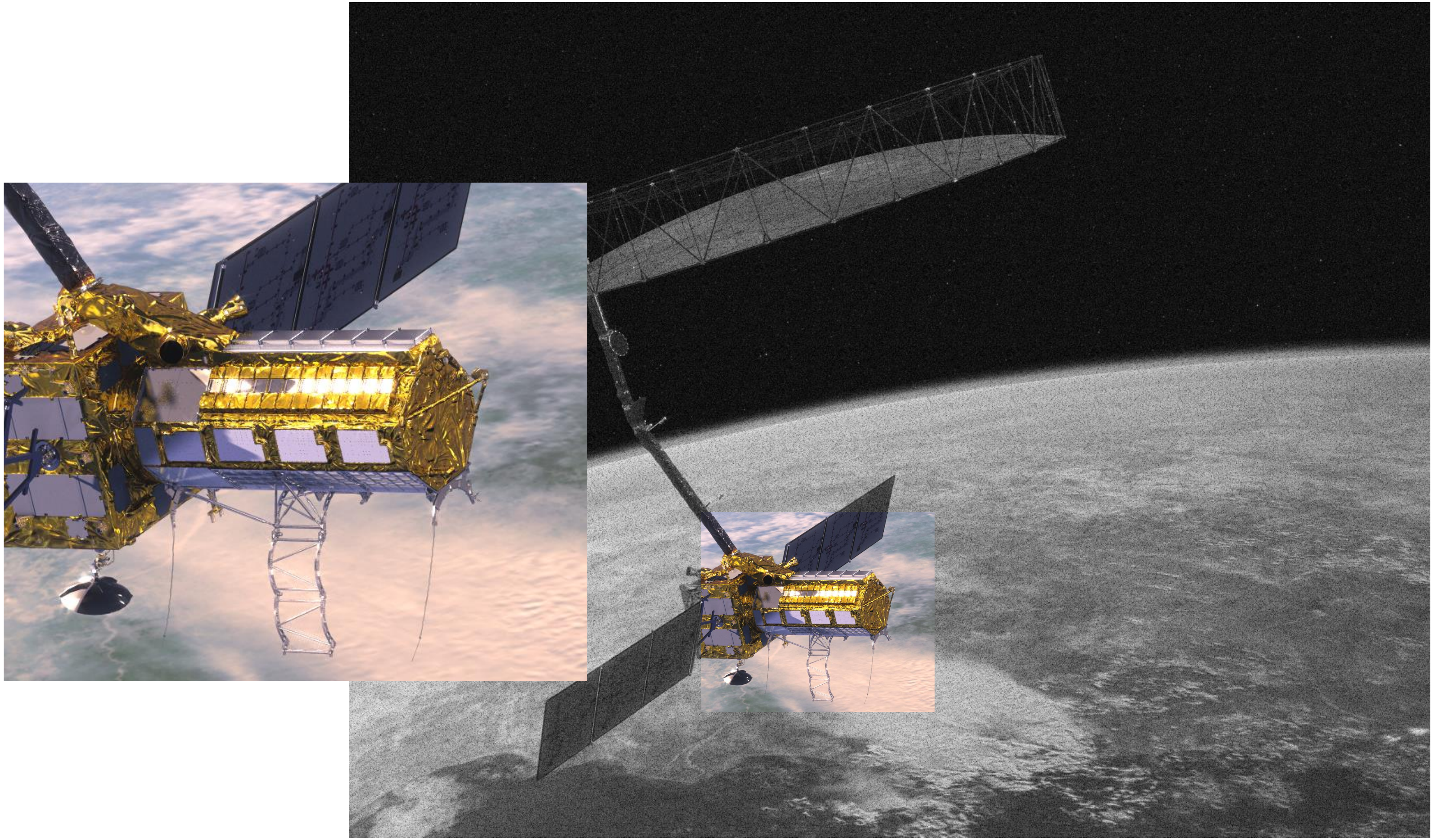
## Summary

- NISAR mission is science-driven to address key questions in solid Earth, ecosystems, cryospheric, hydrological sciences
- To address the requirements, NISAR exhibits
  - Consistent global imaging over the life of the mission
  - Polarimetric, interferometric modes
  - Ionospheric correction band
  - Dual frequency L and S-band primarily over India
- Global L0-L2 product suite of interferometric and polarimetric products, *free and open*
  - *NISAR-simulated products available from the airborne UAVSAR L-band SAR*
- In consideration: An integrated urgent response request system, with automated mission systems response mechanisms

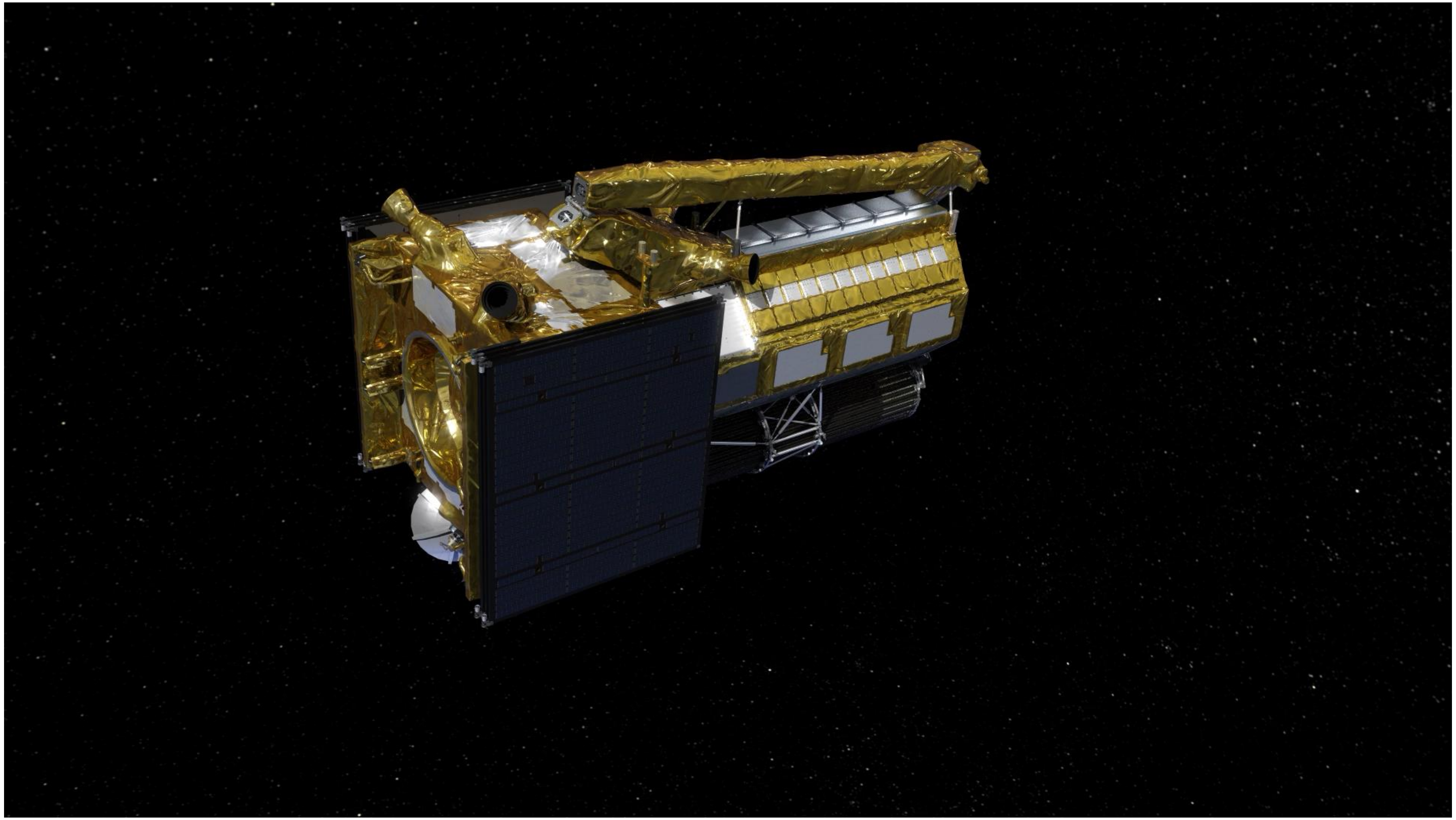



http://nisar.jpl.nasa.gov

# … AND A MYSTERY



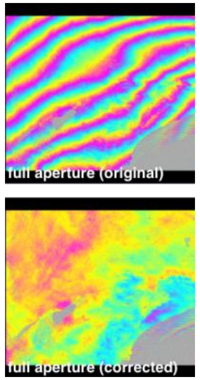
# THANK YOU!!! QUESTIONS?? (AND MYSTERY SOLVED)



# Backup Slides

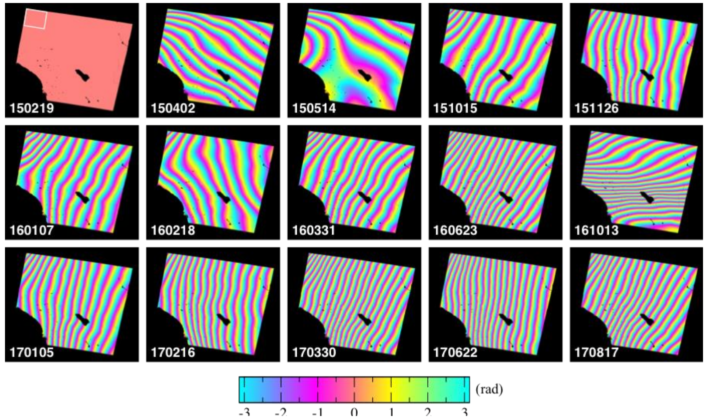
# Interseismic Deformation with ALOS-2 Wide-swath
# A Taste of NISAR

## Ridgecrest, Ca Earthquakes July 4 & 5, 2019

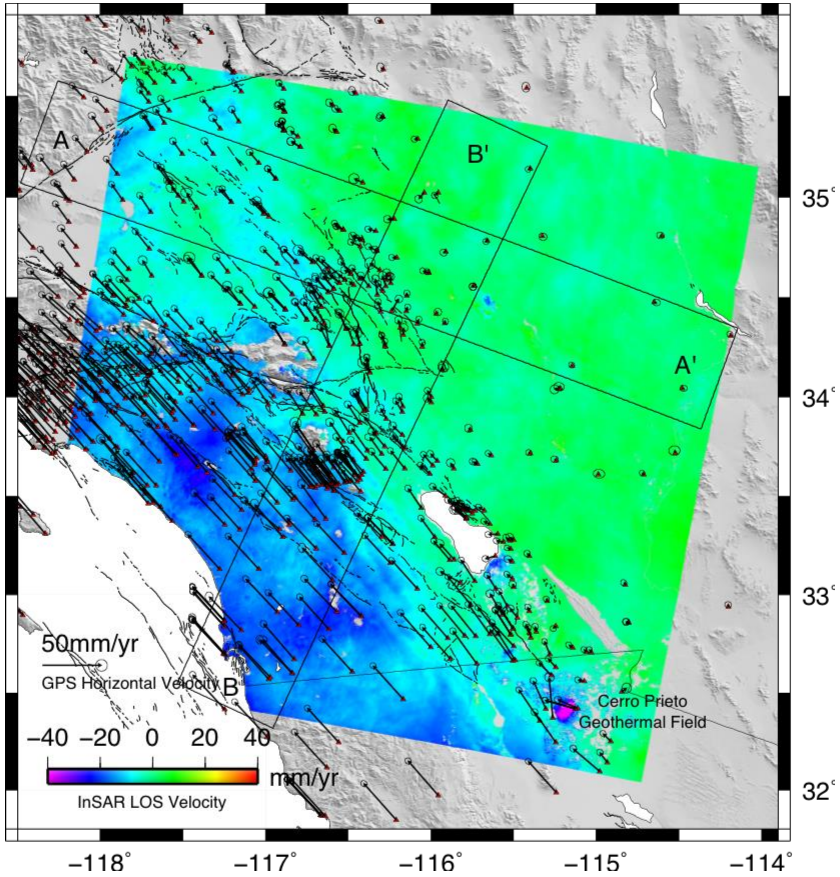



Ionospheric corrections with split-spectrum method on ALOS-2 wide-swath InSAR

Ionospheric corrections on each scene of time series




Liang, C., Z. Liu, E. J. Fielding, and R. Burgmann (2018), InSAR Time Series Analysis of L-Band Wide-Swath SAR Data Acquired by ALOS-2, *IEEE Transactions on Geoscience and Remote Sensing*, *56*(8), 4492-4506, doi:10.1109/tgrs.2018.2821150.




Mean interseismic velocity of Southern California between Feb. 2015 and July 2017

Ionospheric corrections enable measurement of large-scale ground deformation with L-band InSAR without using outside calibration

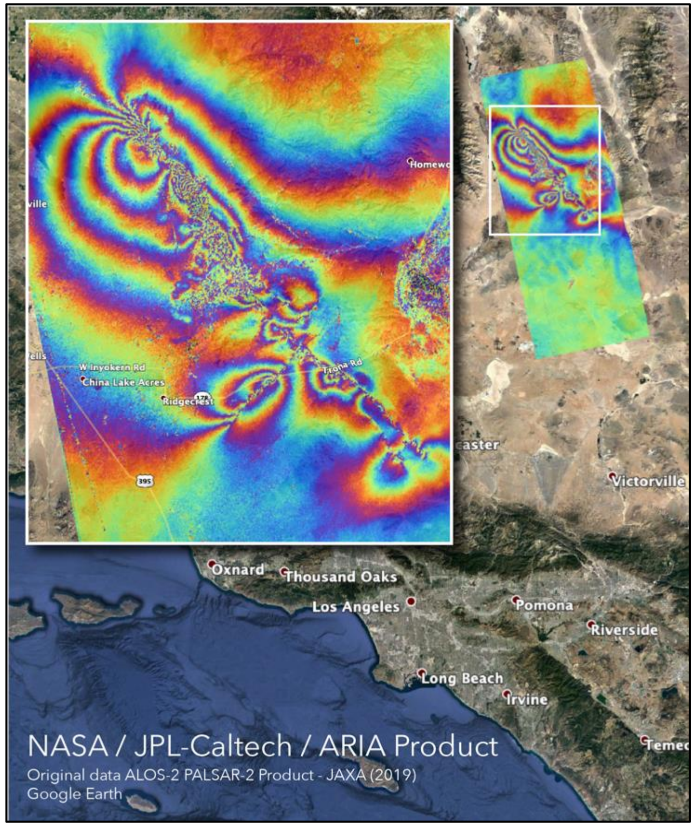
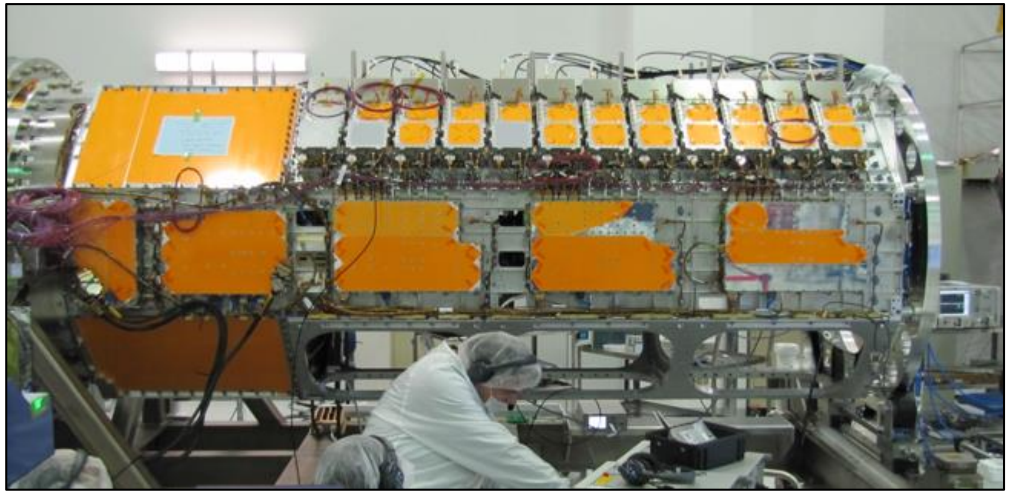


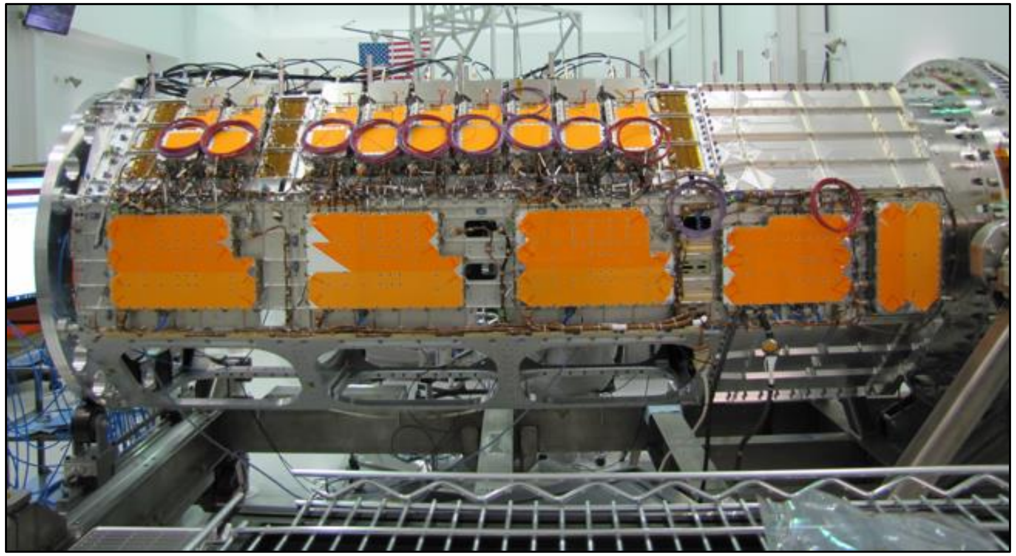

Image generated from ALOS-2 data acquired well before the events, and again after the earthquakes

# L-SAR Integration Nearly Complete



*V-Polarization L-Band Synthetic Aperture Radar*

*Astro reflector and cradle installed onto the DTM radar instrument structure and stowed boom at JPL. May 2020*



*H-Polarization L-Band Synthetic Aperture Radar*