Jet Propulsion Laboratory
California Institute of Technology

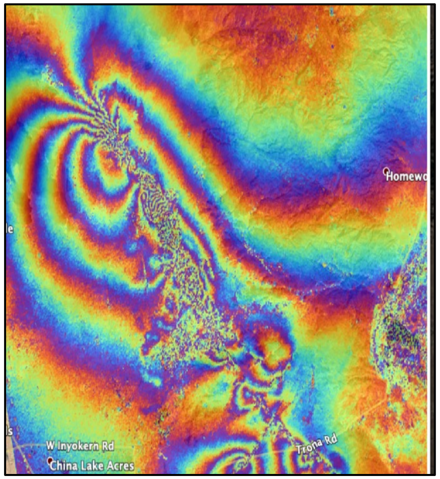
NASA-ISRO SAR (NISAR) Mission Overview

Paul A. Rosen
Jet Propulsion Laboratory
California Institute of Technology

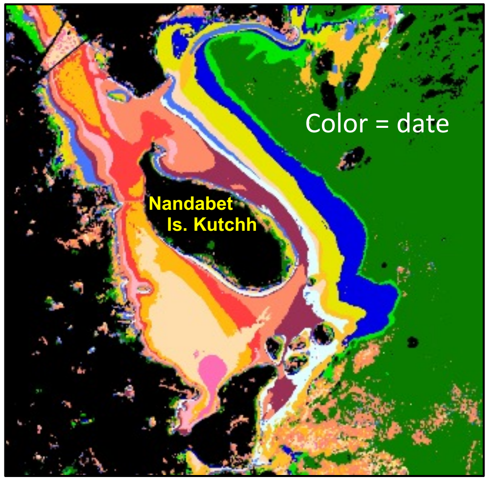
NISAR Project Team

2022 UNAVCO ISCE+ Course
August 26 2022

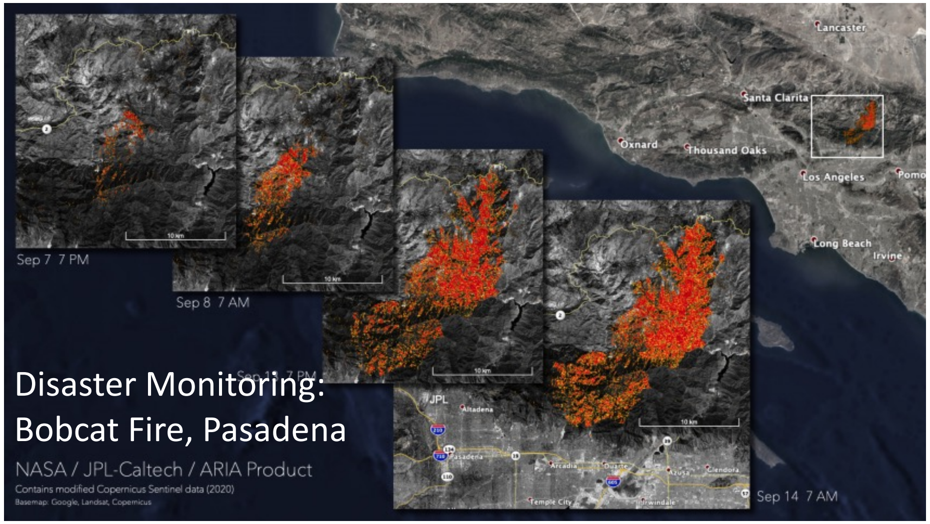
NISAR Science
Capturing a Dynamic Earth



Earthquake Dynamics, Ridgecrest



Wetland Inundation, India



Disaster Monitoring: Bobcat Fire, Pasadena

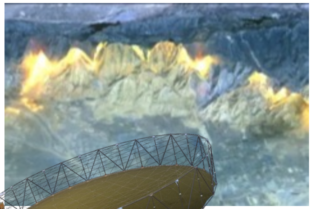
- **Dynamics of Ice: Ice sheets, Glaciers, and Sea Level**
  - *Will there be catastrophic collapse of the major ice sheets, including Greenland and West Antarctic and, if so, how rapidly will this occur?*
  - *What will be the resulting time patterns of sea-level rise?*
  - *How are alpine glaciers 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: Hazard Response**
  - *Which major fault systems are nearing release of stress via strong earthquakes?*
  - *Can we predict future eruptions of volcanoes?*
  - *What are optimal remote sensing strategies to mitigate disasters and monitor/manage water and hydrocarbon extraction and use*
- **Coastal Processes: India**
  - *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?*

NISAR Science Observation Overview

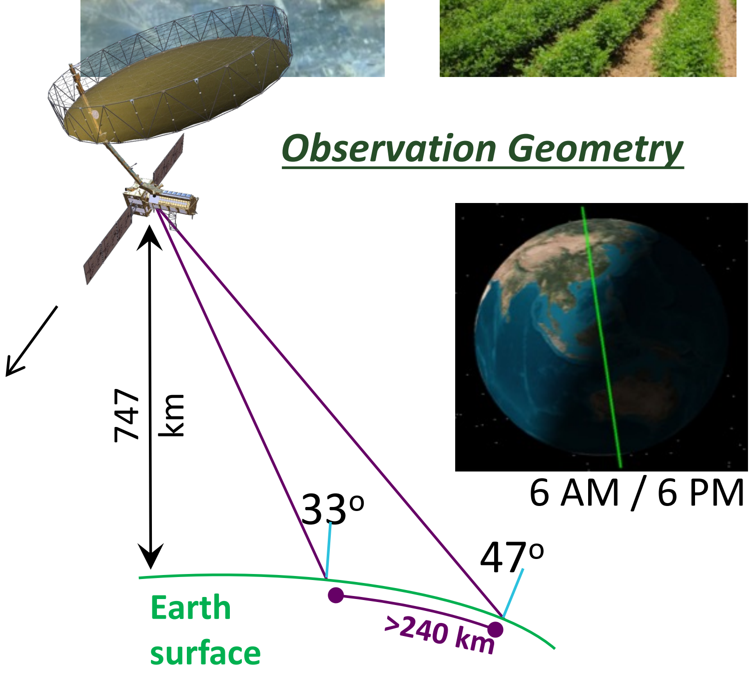
NISAR Characteristic:	Would Enable:
L-band (24 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (9.4 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath > 240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and 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

NISAR Will Uniquely Capture the Earth in Motion



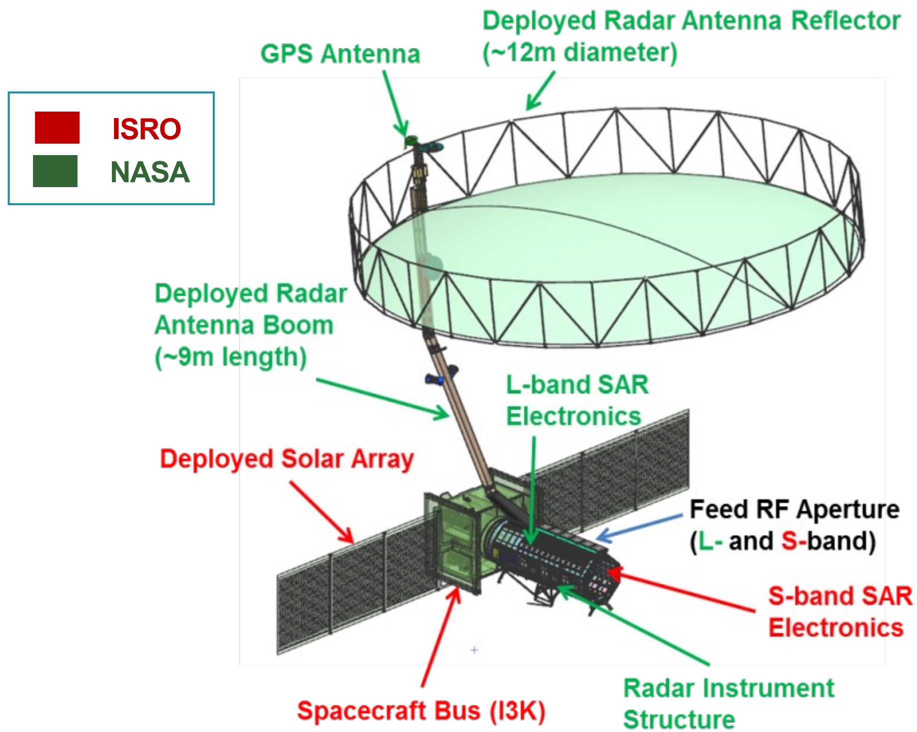



Observation Geometry



NASA-ISRO SAR Mission

Close integration with international partner

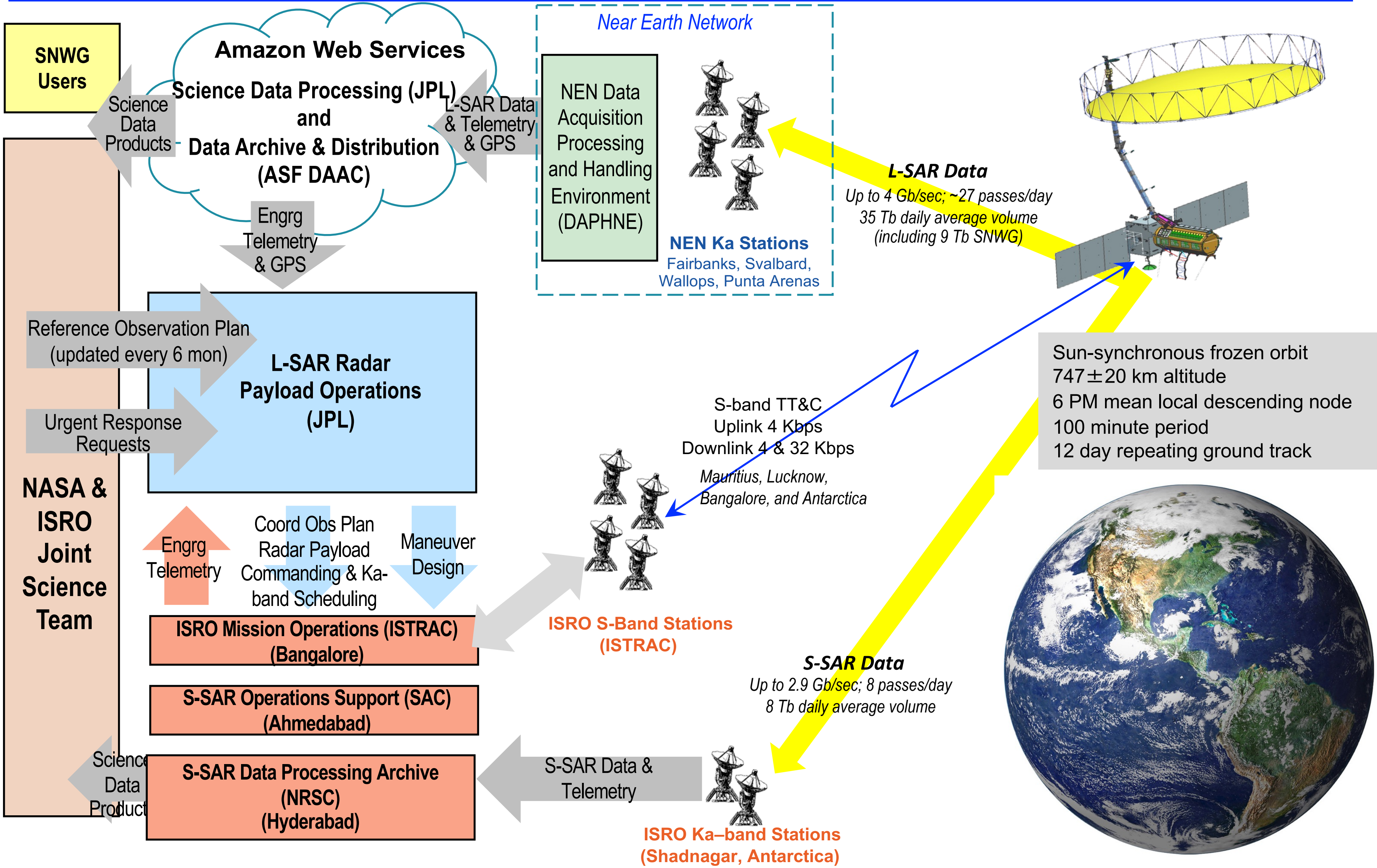


	Mass (kg)	Power (W)
Spacecraft Mainframe	920	1312
Engineering Payload	134	640
L-SAR	283	1515
S-SAR	314	2757
Common Instrument Structure	466	
Reflector and Boom	292	
Propellant	269	
Total	**2678**	**6224**

NASA Provides	ISRO Provides
• L-band SAR • Shared P/L structure & 12m reflector and boom	• S-band SAR • S-SAR baseband data handling (BDH)
• Engineering payload - GPS, Power & Pyro - Payload Data System with 12 Tb recorder - NEN-compatible high rate Ka-band system	• Spacecraft Bus (I3K) • ISRO-compatible high rate Ka-band system • Observatory I&T • GSLV Launch Vehicle
Integrated radar observation planning and operations	Spacecraft operations (command uplink, telemetry and tracking)
L-SAR data downlink to NEN Ka-band stations	S-SAR, select L-SAR data downlink to ISRO stations
L-band science data processing and distribution	S-band science data processing and distribution
NASA Science Team	ISRO Science Team

Simplify?

NISAR Operations Overview



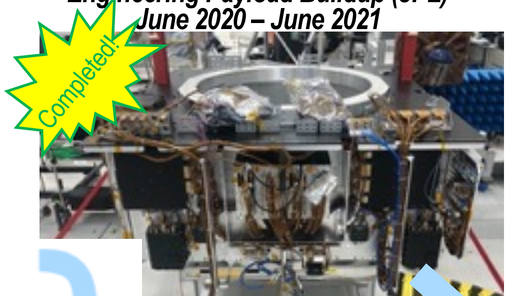
Simplify?

NISAR Development Status

NASA - ISRO SAR Mission

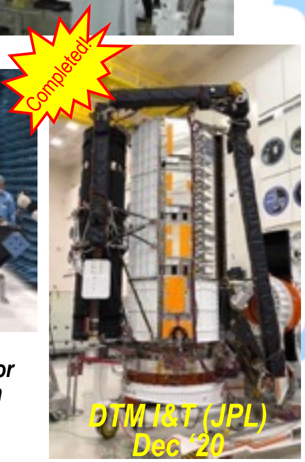
L-SAR I&T (JPL)
April 2019-Jan 2021

Engineering Payload Buildup (JPL)
June 2020 – June 2021



Surrogate S/C with Engineering Payload Elements Integrated

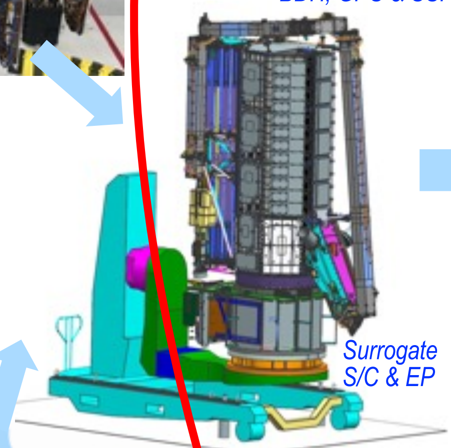
RIS "Clamshell" Delivered to SAC for S-SAR Integration (June 2019)



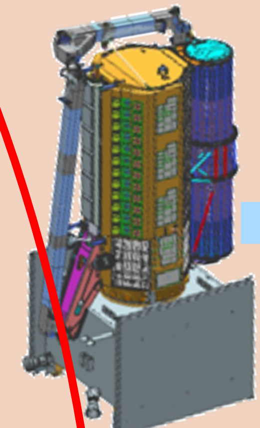
SIT-2 & 3 (JPL)
Radar Payload I&T
Feb '21- Feb '23

We are Here

Radar Payload (with BDH, GPS & SSR



SIT-4 (URSC)
Observatory I&T
Mar '23-Jan '24



Satellite Integration & Test Establishment (ISITE) Bangalore

Launch Operations (SHAR) & Launch
Jan 2024

Geosynchronous Launch Vehicle (GSLV) Mark II

Satish Dhawan Space Centre

Sriharikota

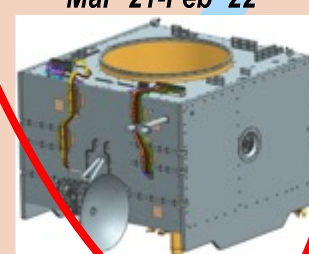
March '21

S-SAR I&T (SAC)

August '21

Baseband Data Handler (BDH) (URSC)

Satellite Mainframe I&T
Mar '21-Feb '22



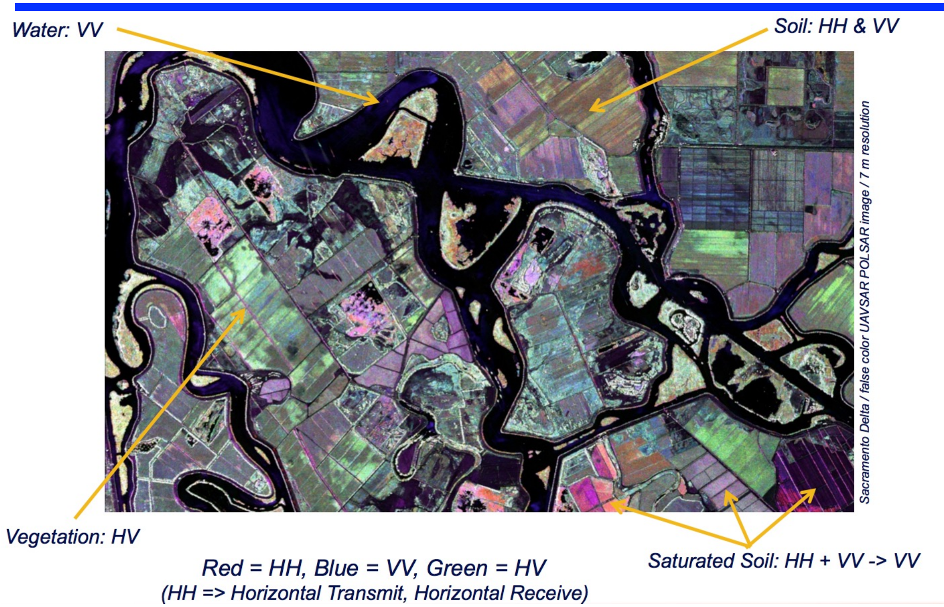
ISITE, Bangalore

Boom/Reflector Integration

Flight Boom & Reflector were previously integrated & environmentally tested on <u>flight spare</u> structure in 2020

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

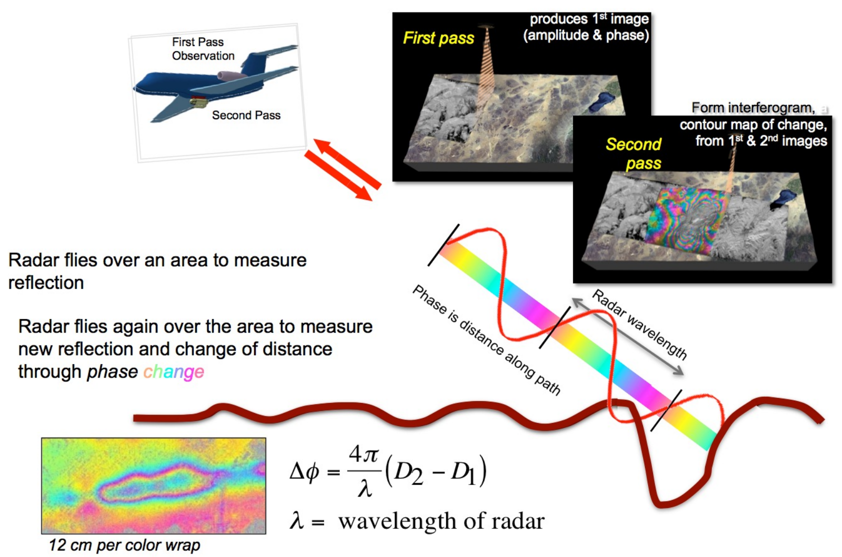
Versatility of SAR: Many Applications



Polarimetric SAR
Use of polarization to determine surface properties

Applications:

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



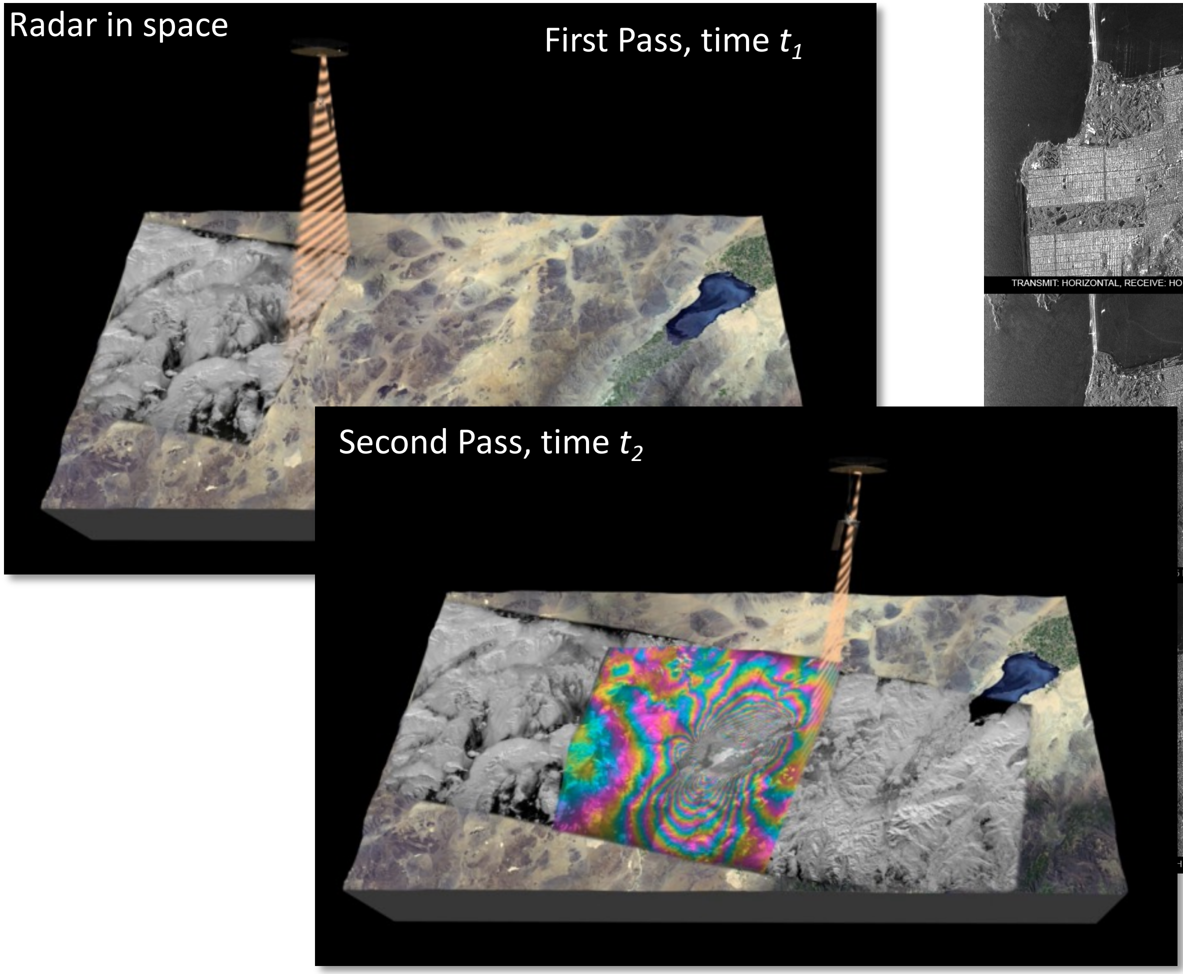
Interferometric SAR
Use of phase change to determine surface displacement

Applications:

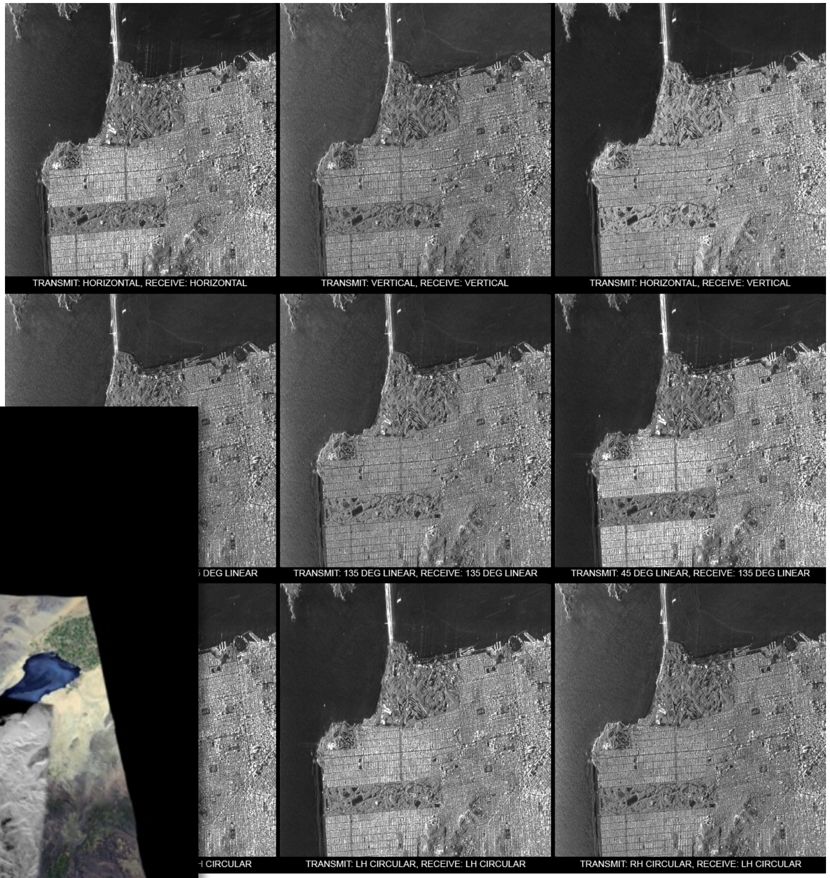
- **Geophysical modeling**
- **Subsidence due to fluid withdrawal**
- **Inundation (w/vegetation)**
- **Change in flood extent**
- **Water flow through wetlands**

NISAR Measurements to Achieve Science Objectives

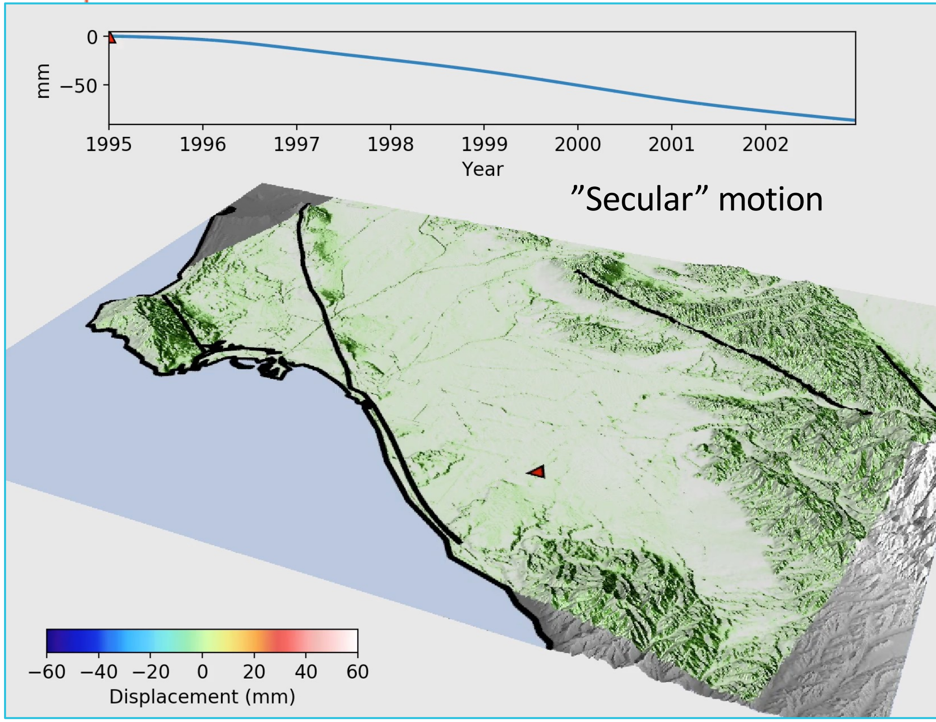
Repeat Pass Interferometry

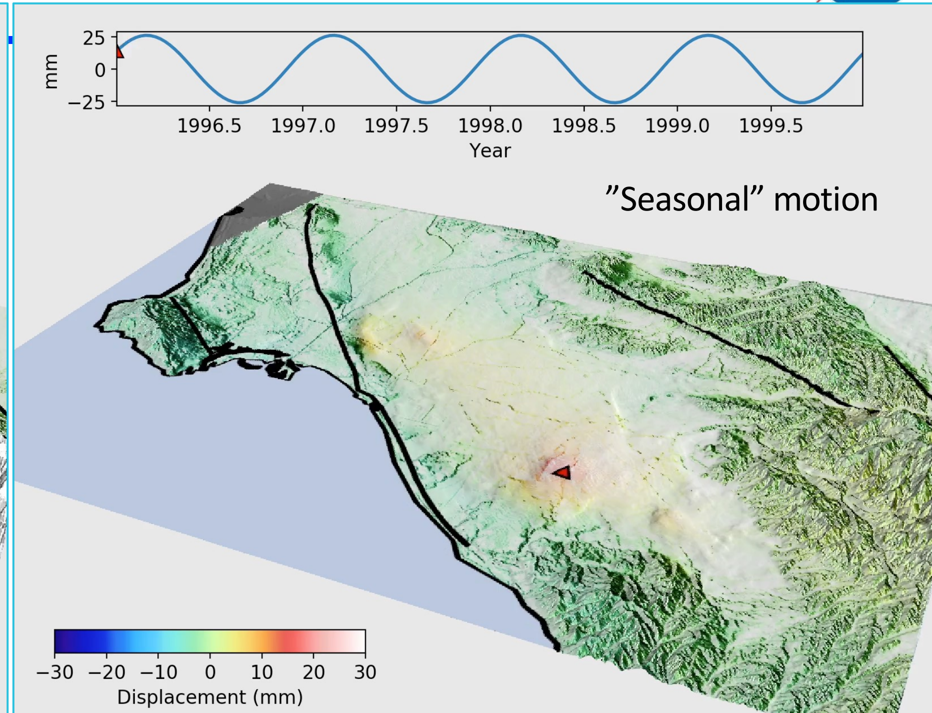


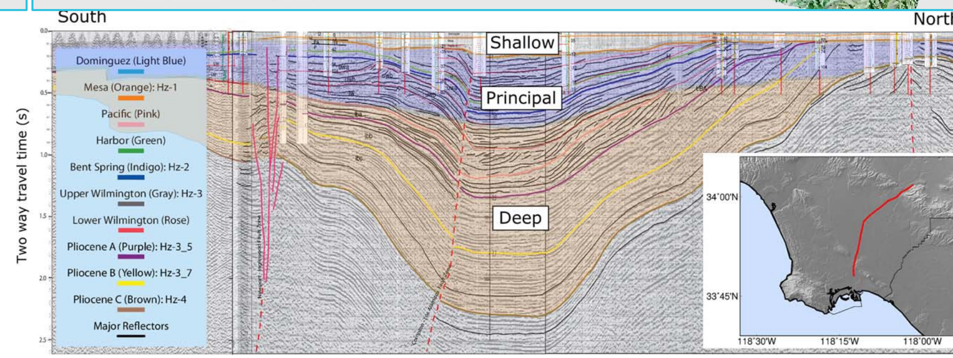
Polarimetric Diversity



Earth’s Dynamic Subsurface





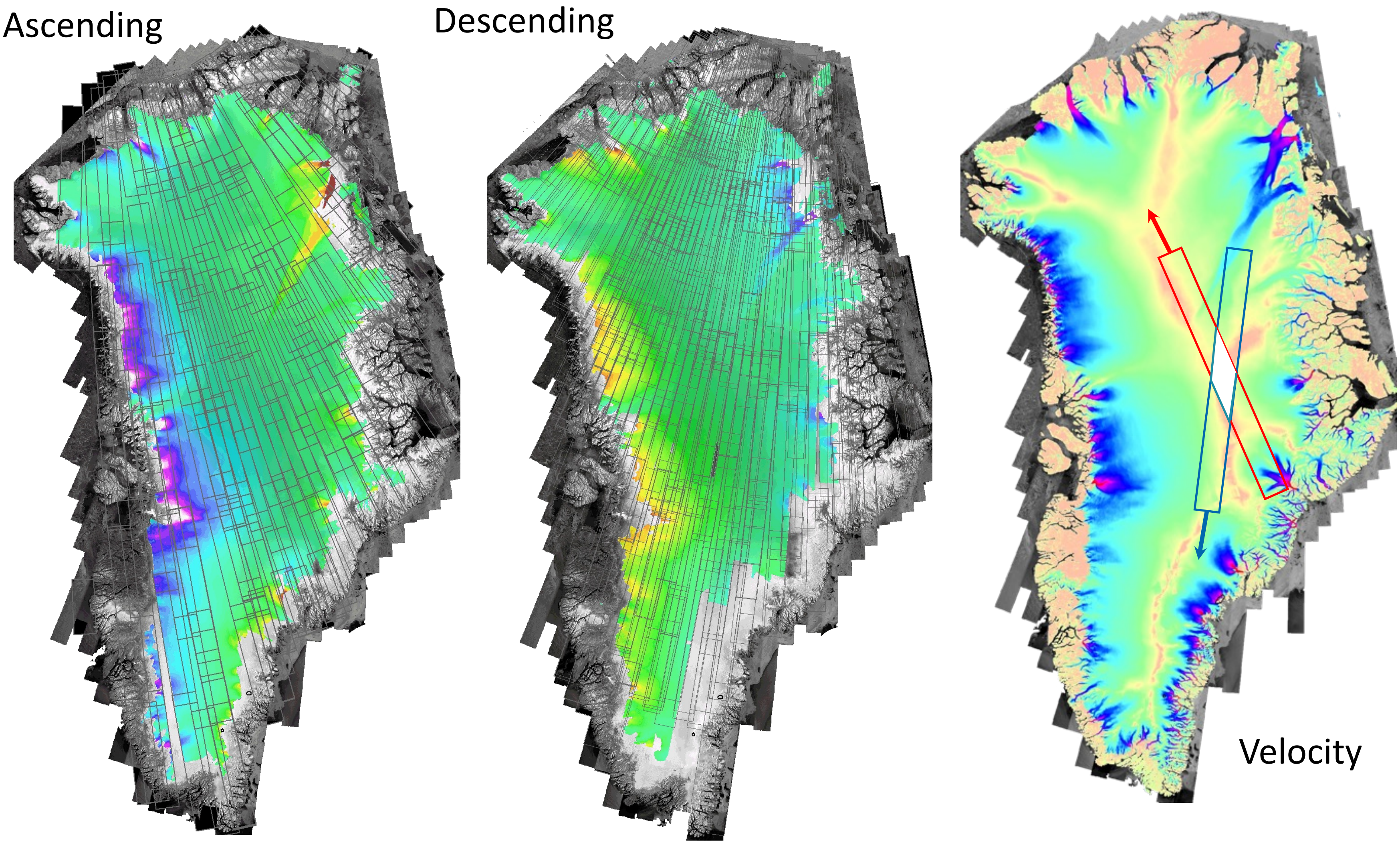


- Data ➔18-year time series (881 igrams) + GPS + Hydraulic head from observation wells + geologic structure model
- Spatial pattern of seasonal ground deformation near the center of the basin corresponds to a diffusion process with peak deformation occurring at locations with highest groundwater production.
- 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.

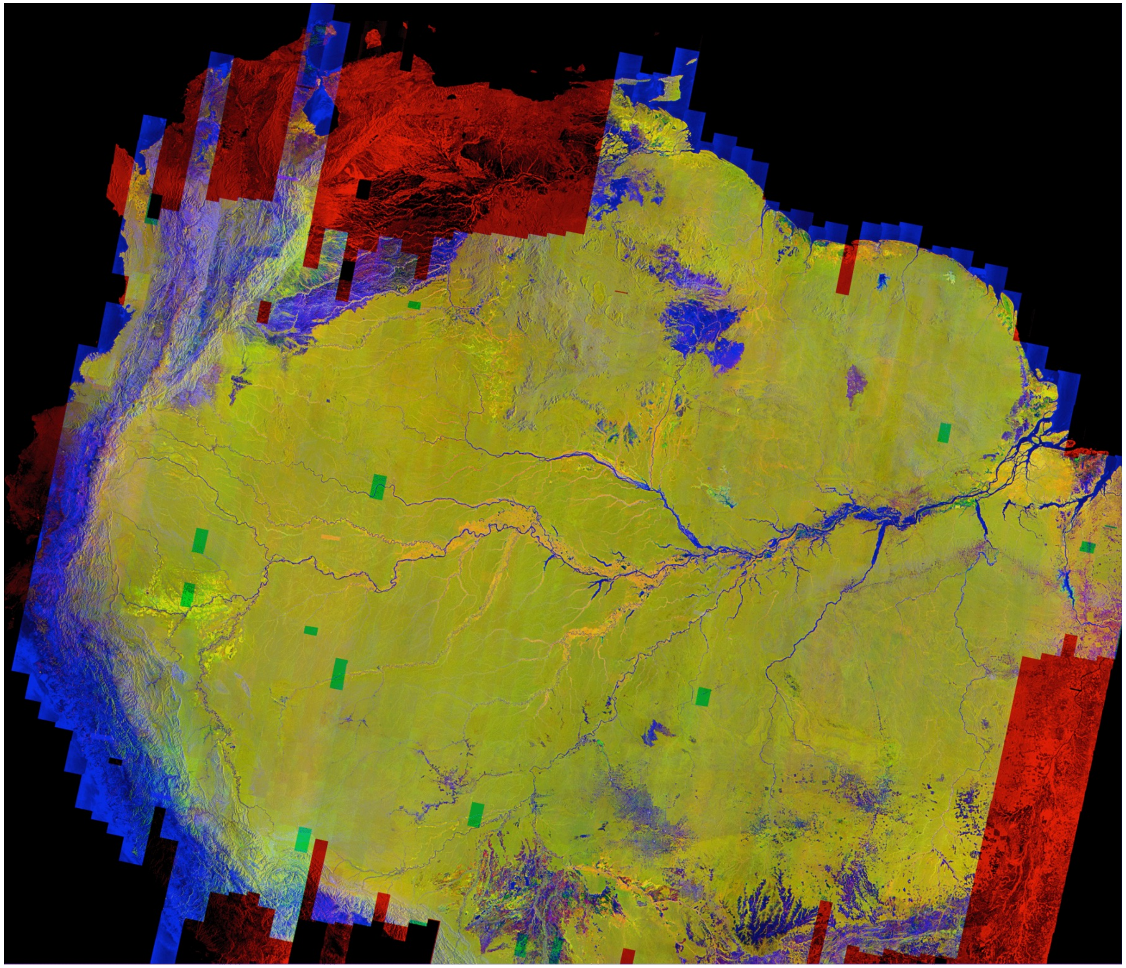
Courtesy: M. Simons, B. Riel (Caltech)

Ice Sheet Velocities and Variability



Courtesy: I. Joughin (U. Wash/APL)

Carbon Cycle Monitoring – Time Series for Biomass and Disturbance

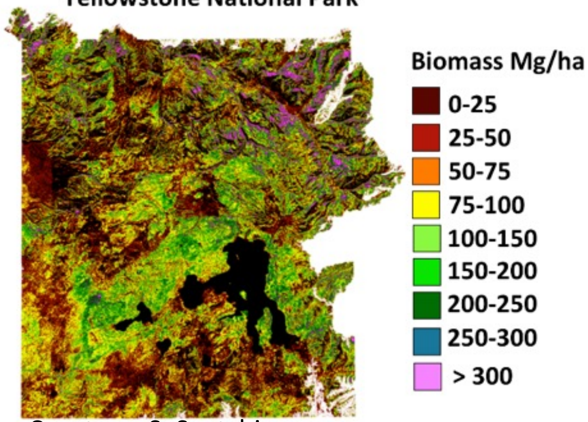


ALOS-1 Radar Image Mosaic of Amazon

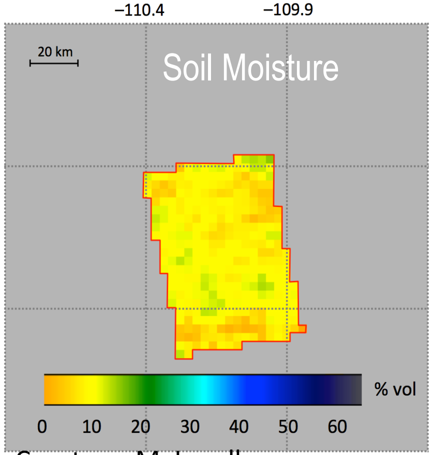
Courtesy: P. Siqueira (U. Mass Amherst)

Selected NISAR Applications Products

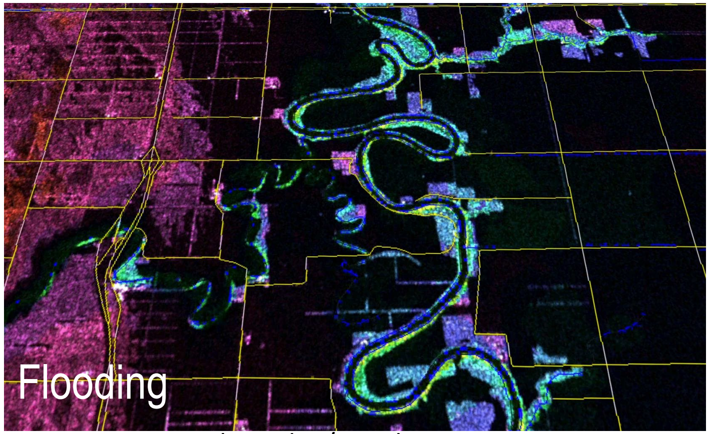
Forest Aboveground Biomass
Yellowstone National Park



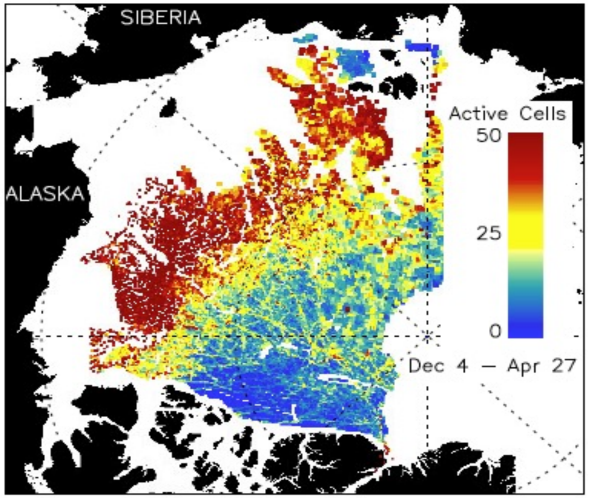
Courtesy: S. Saatchi



Courtesy: M. Lavalle

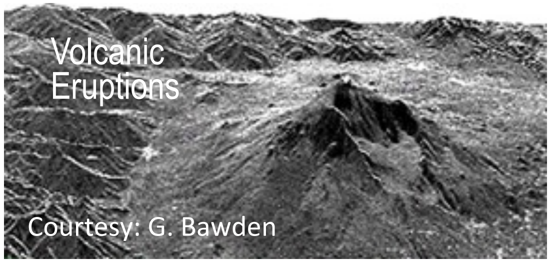


Courtesy: G. Breckenridge/S. Nghiem



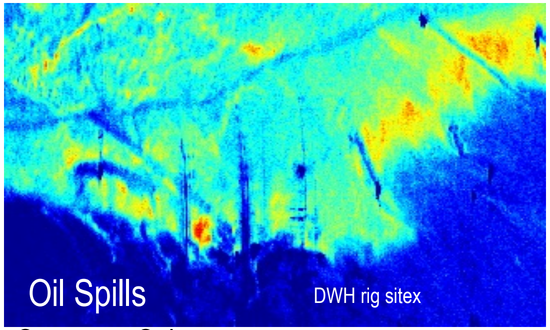
Courtesy: R. Kwok

Sea Ice Extent/ Ice and Ship Tracking

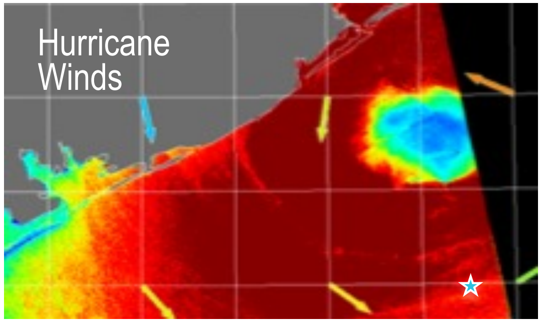


Courtesy: G. Bawden

Courtesy: S.-H. Yun



Courtesy: C. Jones



Courtesy: G. Bawden

Benefits of both US-contributed L-band SAR and India-contributed S-band SAR

- *Global* L-band and *globally-distributed but targeted* S-band data with unprecedented spatial and temporal sampling will drive new directions in science and applications, including high-resolution soil-moisture and crop assessments

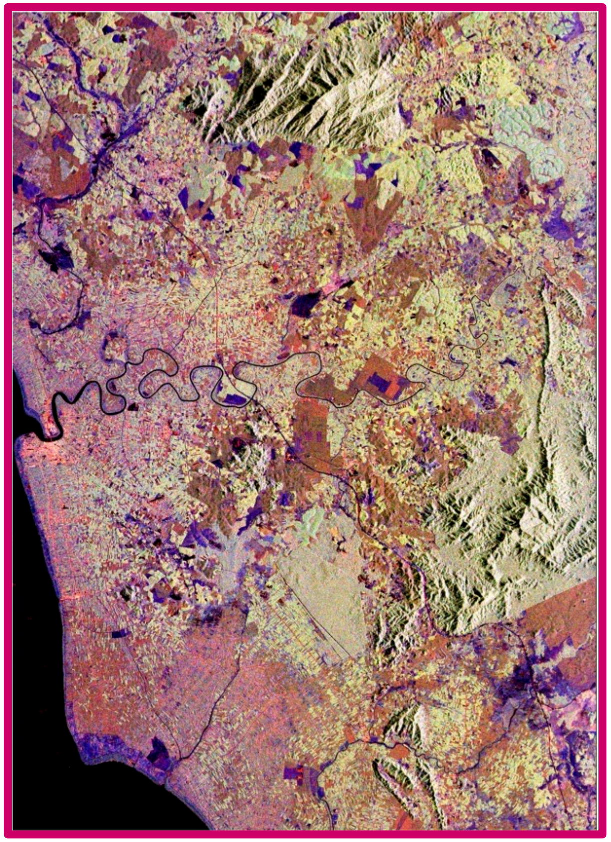
Wheat Fields,

Dnieper River, Ukraine

Red: LHH
Green: LHV
Blue: CHV

Rubber, banana, and oil palm trees,

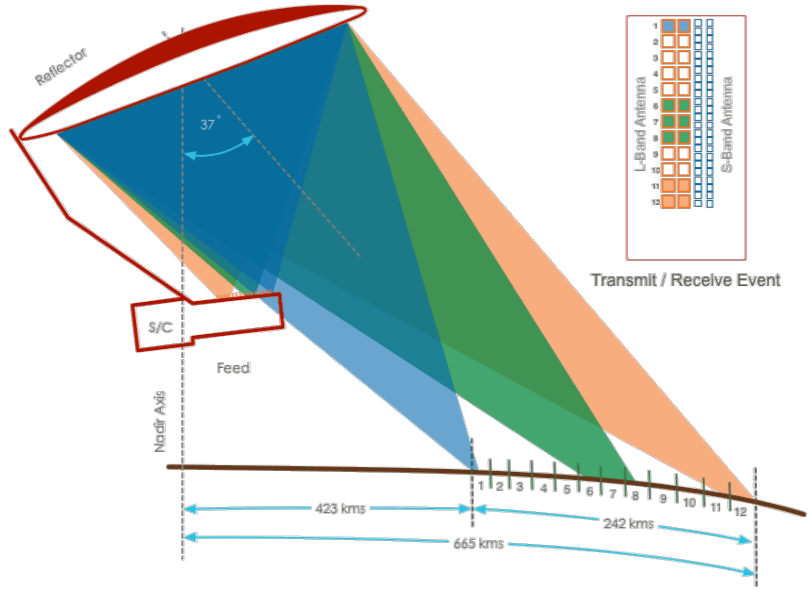
Muar, Malaysia

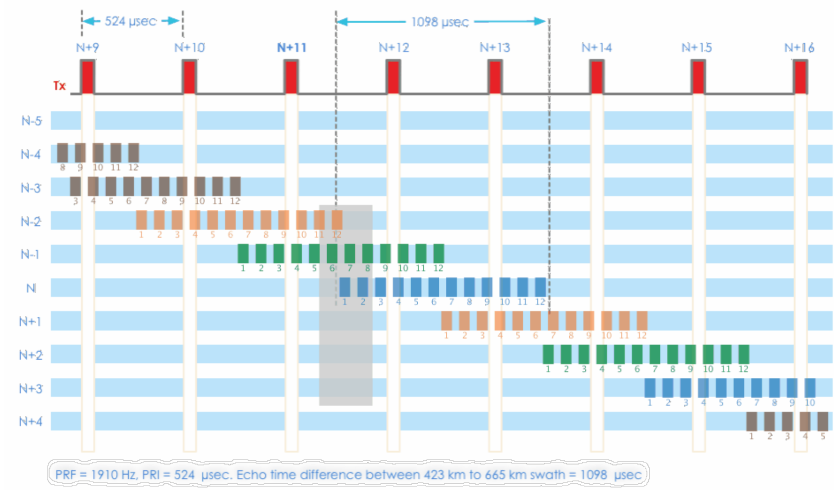


Examples of dual-frequency measurements from SIR-C/X-SAR

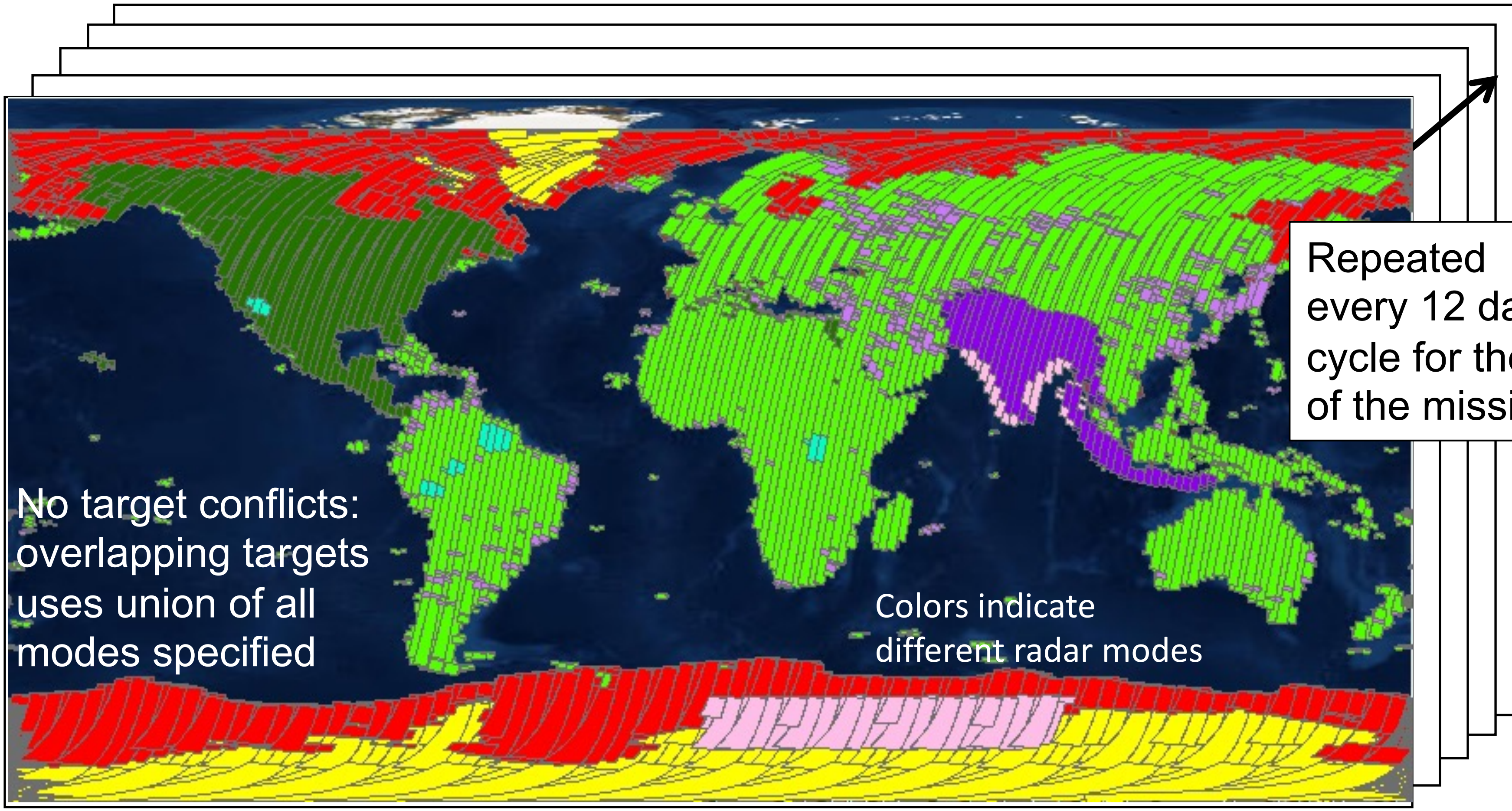
SweepSAR Measurement Technique

- **SweepSAR Basics**
  - On Transmit, illuminate the entire swath of interest (red beam)
  - 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 Systematic Observations



Repeated every 12 day cycle for the life of the mission

J. Doubleday
P. Sharma, JPL

Persistent updated measurements of Earth 1.6 PB raw data per year
Level-2 global products

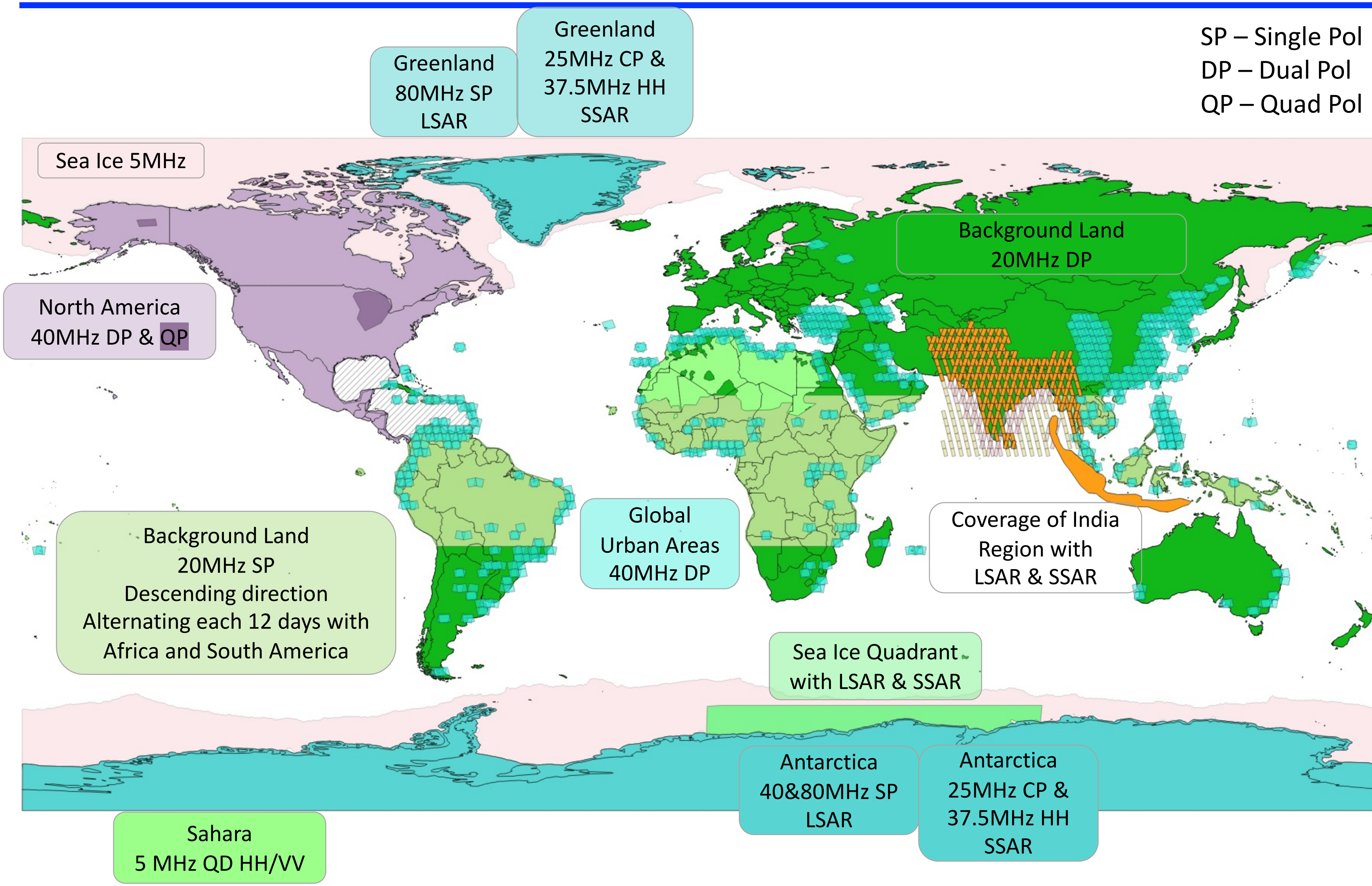
NISAR Science Observing/Operations Modes
Blanket Land and Ice Coverage Every 12 Days

- Observation strategy employs a small subset of possible modes

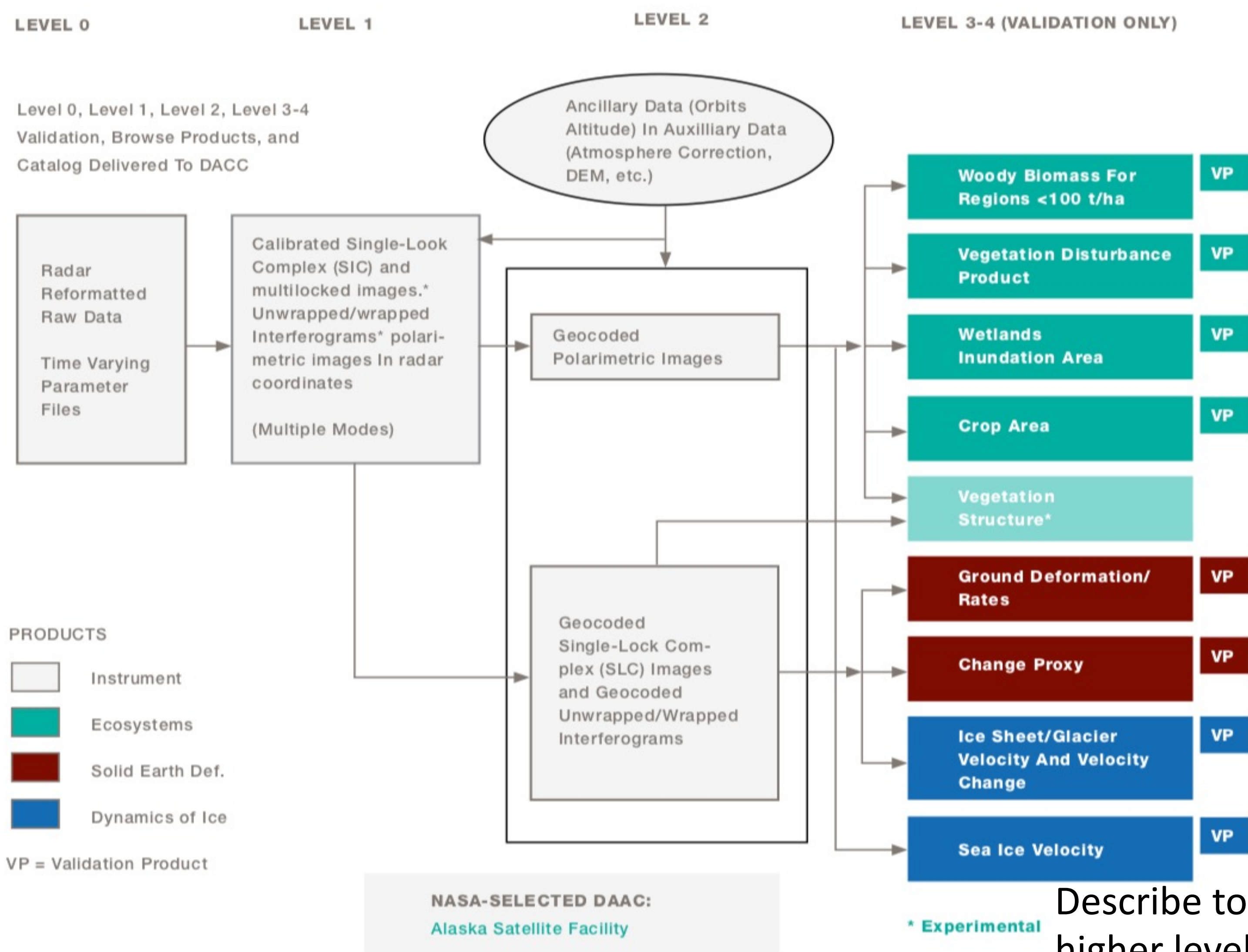
Observation Strategy	L-band		S-band		Culling Approach	
Science Target	**Mode+**	**Resolution**	**Mode**	**Resol.**	Sampling	Desc Asc
Background Land	DP HH/HV	12 m x 8 m			cull by lat	
Land Ice	SP HH	3 m x 8 m			cull by lat	
Sea Ice Dynamics	SP VV	48 m x 8 m			s = 1 p	
Urban Areas		6 m x 8 m			s = 1 p	
US Hi-Res					s = 1 p	
Himalayas			CP RH/RV		s = 1 p	
India Agriculture					s = 1 p	
India Coastal Ocean			DP HH/HV or VV/VH		s = 1 p	
Sea Ice Types	DP VV/VH				s = 3 p	

Current Observation Plan Observation Revised every 6 months

SP – Single Pol
DP – Dual Pol
QP – Quad Pol



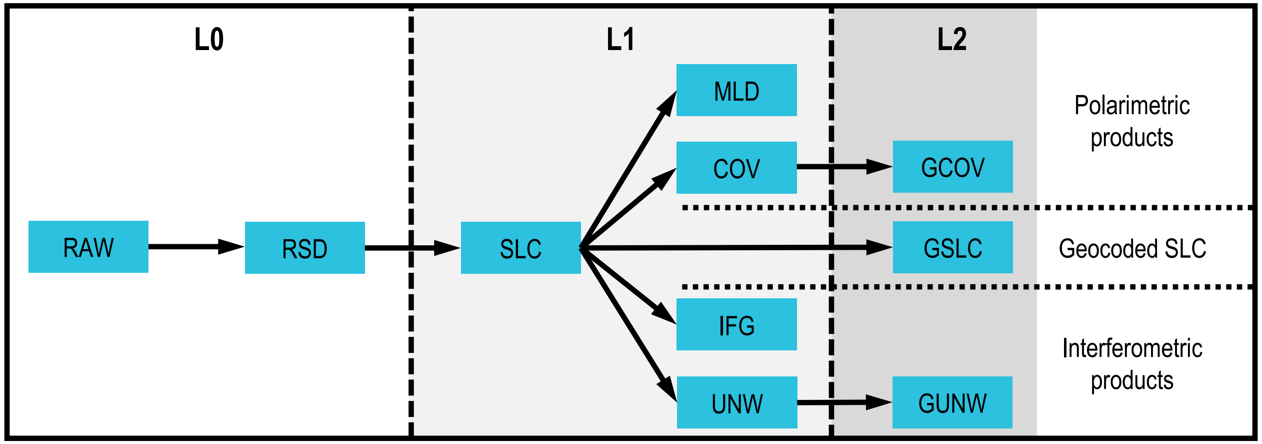
NISAR – Mission Data Products



Describe tools for higher level products

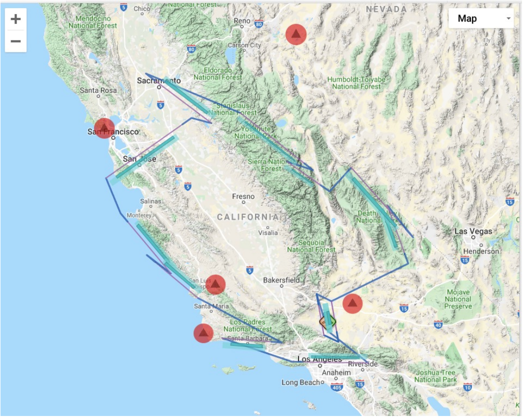
Science Data System Summary

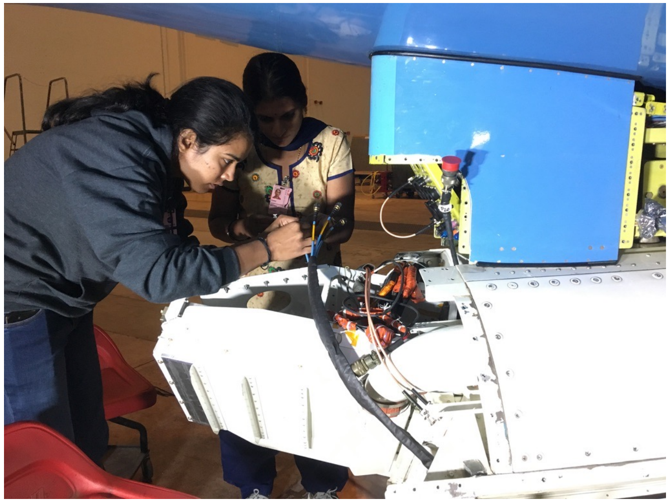
- Ingest 35 Tbits (4.4 TB) of raw data per day on average
- Automatically generate L-SAR L0a, L0b, L1, and L2 science products (> 70TB/day)
  - Generate S-SAR L0 science product for data downlinked through NASA Ka-band
- Perform bulk reprocessing twice during mission
  - 8 months of data after L2 product validation at 4x rate
  - 12 months of data at end of mission at 3x rate
  - Anticipate assessing additional processing / reprocessing options before launch
- Sample products derived from UAVSAR data, processed like NISAR, are available
  - https://uavsar.jpl.nasa.gov/science/documents/nisar-sample-products.html
- Open source (github) ISCE3 software already available, support these workflows and products

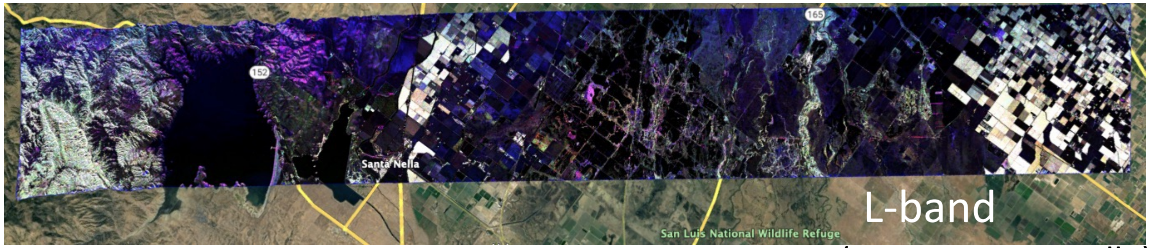


ISRO ASAR L+S Band Airborne Testbed on UAVSAR Platform

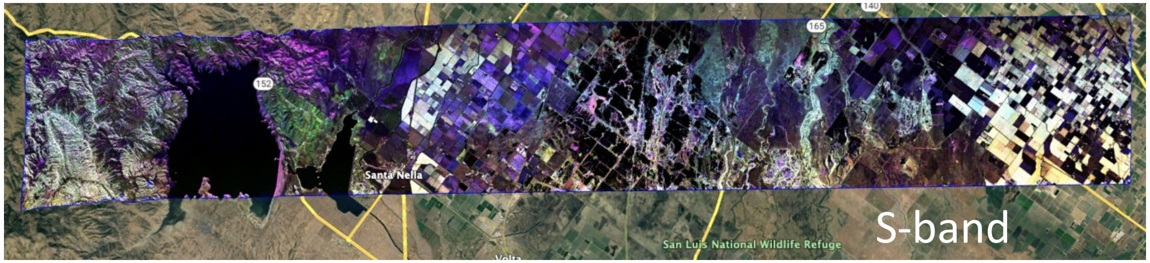
- 150+ L+S band polarimetric data sets from US ASAR Airborne campaigns over a range of NISAR science-related targets: Agriculture, Soil Moisture, Forests, Glaciers, Sea-ice, landslides
- 2019 Western Campaign
- 2021 East Coast Campaign
- Data Sets available at ASF DAAC







(courtesy M. Lavalle)



ASAR geocoded products generated through NISAR L2 processor

Science Data System Products Latency

Products	Requirement	Current Best Estimate	Urgent Response
L0	24 Hours	12 Hours	2 Hours
L1	9 Days	1 Day	4 Hours
L2	9 Days	2 Days	6 Hours

Note: SDS is sized to produce this data within 1 day latency, so the real bottleneck is receiving all the ancillary files, specifically the Medium accuracy Orbit Ephemeris from GPS.

Summary

- NISAR Instrument and Engineering Payload Integration and Test rapidly proceeding
- Integration with spacecraft planned to begin early 2023
- Global products to Level 2 fully and openly available to the global community
- Cloud-based data, tools and services to facilitate access and use
- Anticipated launch of NISAR in 2023/2024

For more information: ***https://nisar.jpl.nasa.gov***

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov