NASA-ISRO SAR (NISAR) Ecosystem & Carbon Cycle Science

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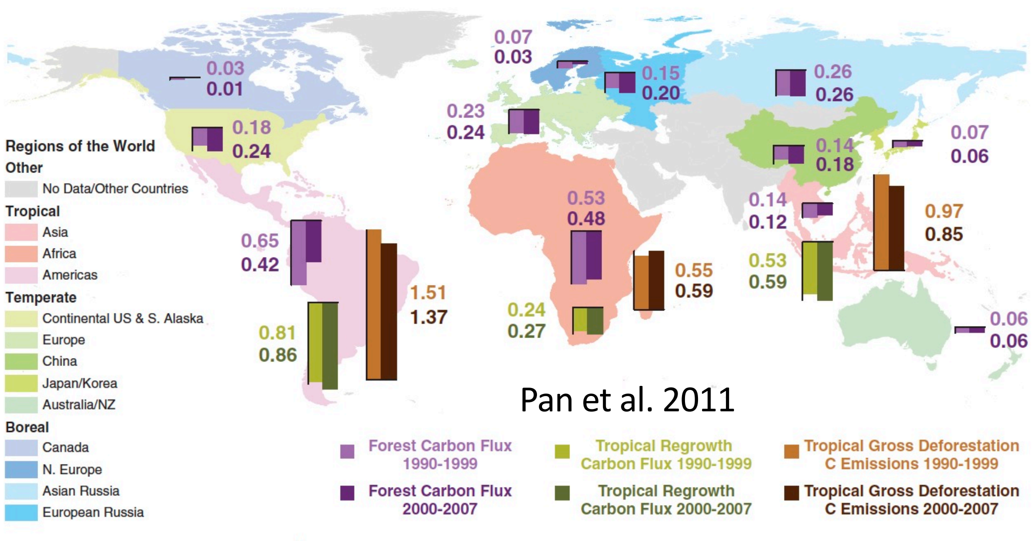
Artist's Concept

NASA - ISRO SAR Mission

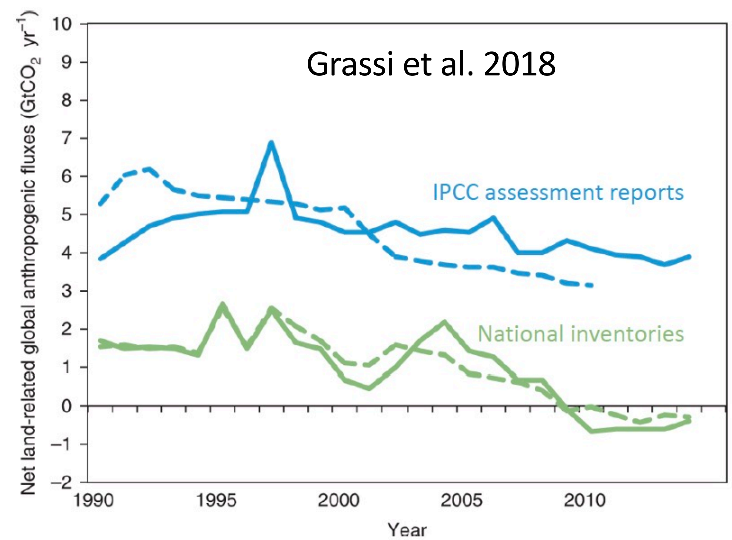
Overview

- Forestry in a Global Perspective
- Developing Dedicated Missions & Synergistic Approaches
- Combining Science and Applications
- NISAR and Ecosystem Science
- Global Biomass Mapping and Monitoring
- Validation/Verification and the Role of Forestry Community

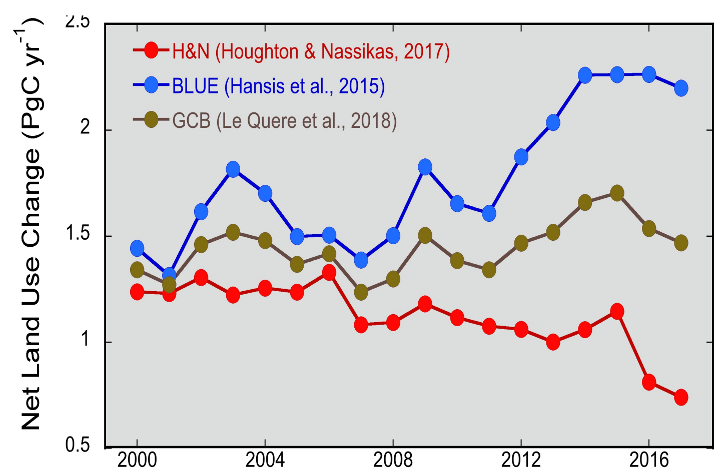
aboveground live biomass carbon stocks & changes



Comparison of the global net anthropogenic land-related CO2 fluxes estimated by AR5 and countries' GHGIs.



- Forest Inventory data are not systematic and synchronous globally
- Forest definition and carbon reporting varies at national scales (trees outside forest definition are ignored)
- Emissions are not calculated systematically everywhere
- Removals do not include dynamics of land use change (secondary forests in tropics)



Applications of Remote Sensing in Forest Ecosystems
Biomass Inventory, Disturbance and Recovery Measurements

Carbon Emissions and Removals from Deforestation, Degradation, Regeneration

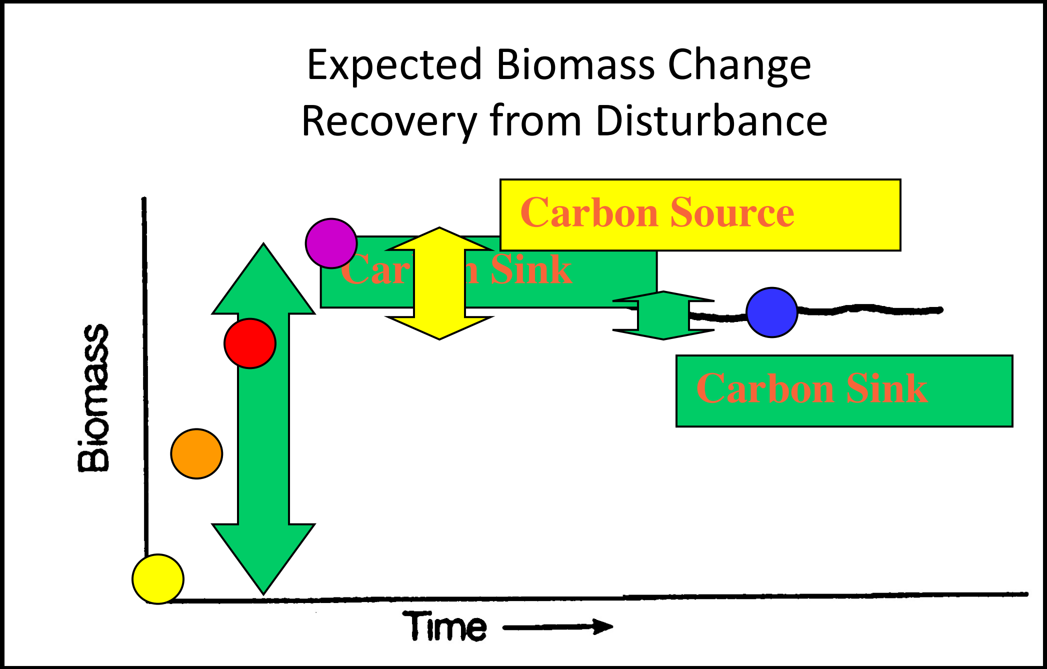
deforestation

degradation

Regeneration

$$\Delta C = \sum \Delta A \cdot \boxed{B} \cdot E_{def} + \sum A \cdot \boxed{\Delta B} \cdot E_{\deg} + \sum A \cdot \boxed{\Delta B} \cdot R_{reg}$$

where A is the area of forest type, with biomass B, emission efficiency factor E, and removal efficiency R

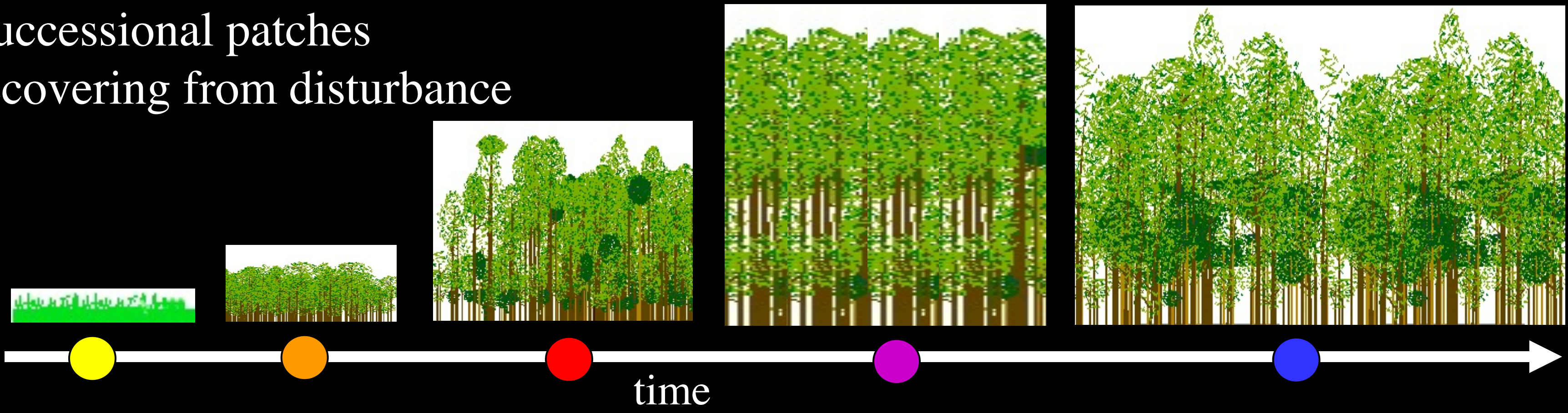


Carbon disturbance recovery dynamics are non-linear as the all-aged successional patches become desynchronized to produce the mixed-aged mature-forest mosaic.

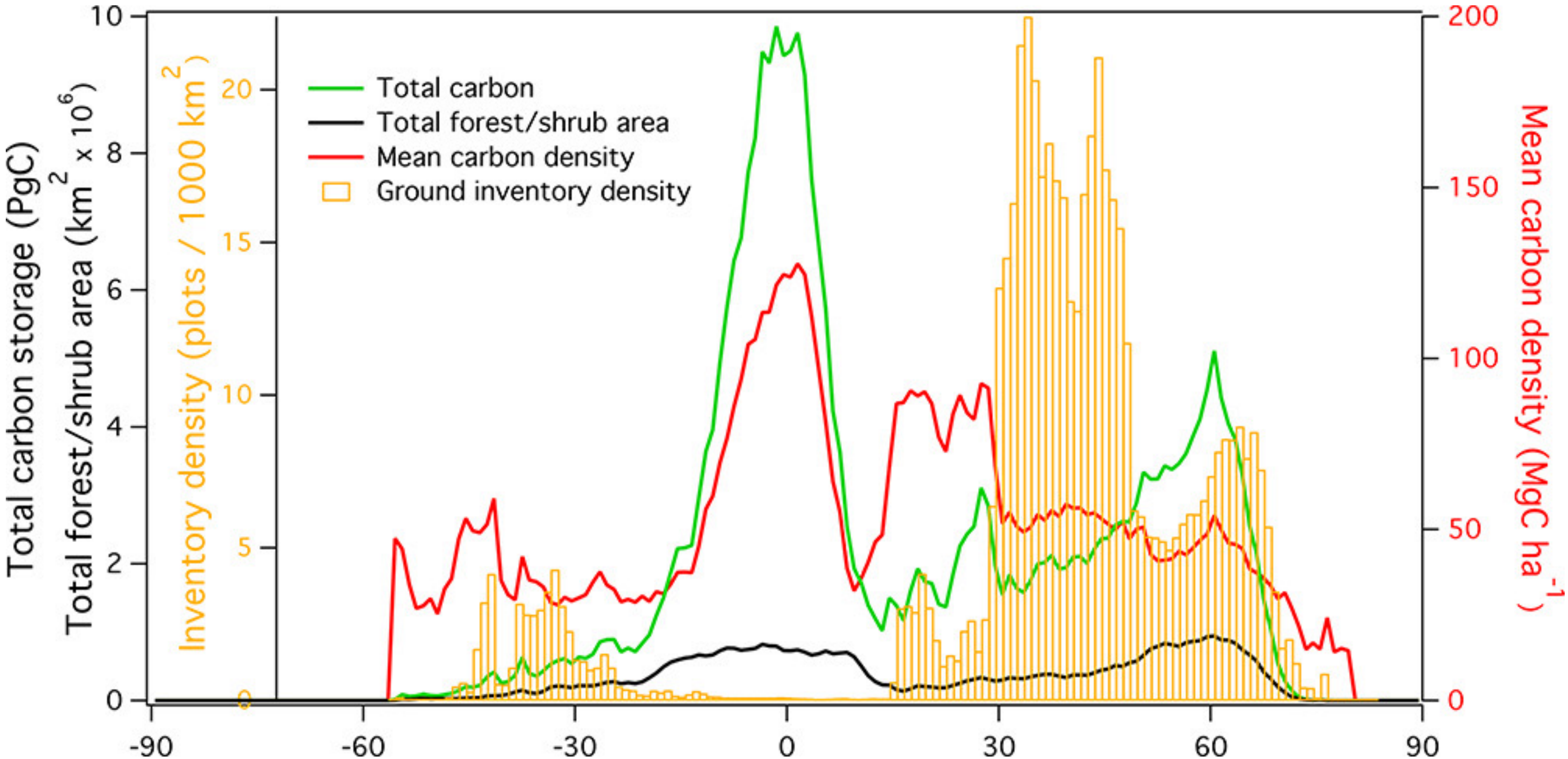
Shugart, 2011

Mature forest is a mosaic

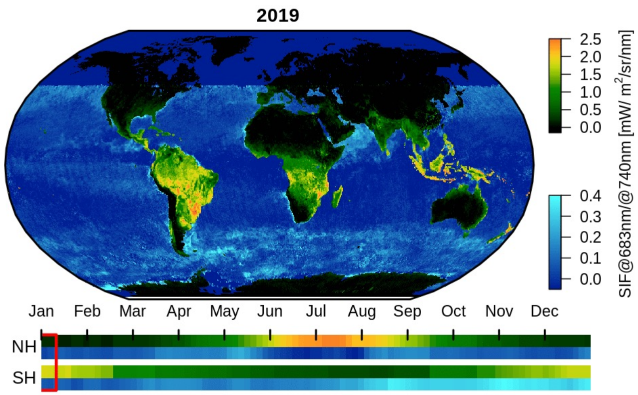
Successional patches recovering from disturbance



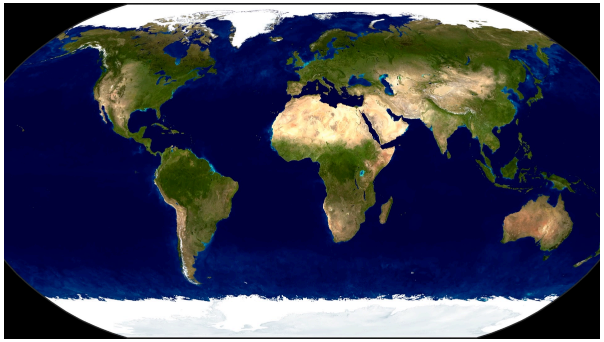
State of Carbon and Inventory of Global Forests



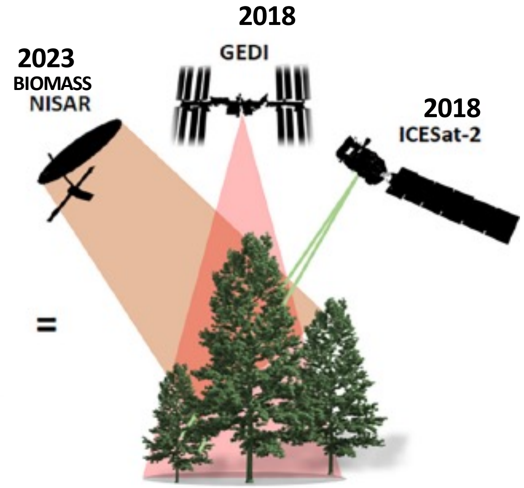
New Observations of Carbon Stocks and Dynamics

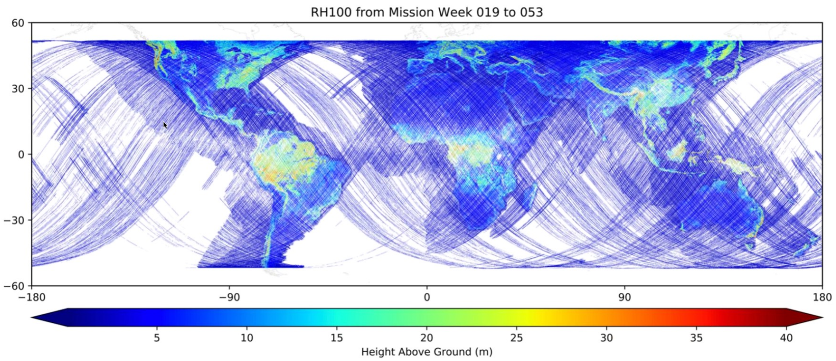


History or Evolution of SIF Measurement
Koehler et al (TROPOMI)

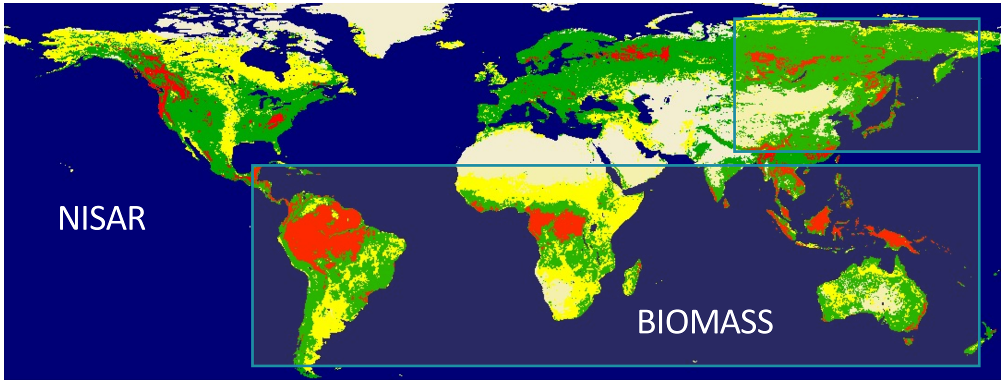


"Bowman et al. 2017: CMS-Flux, courtesy Eastham (MIT)"





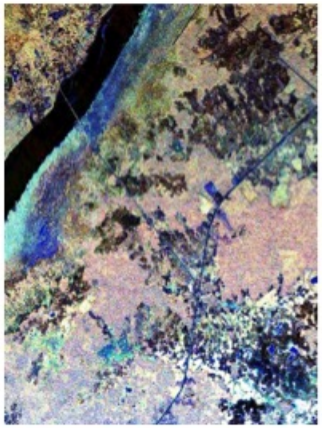
GEDI Data 2019-2020



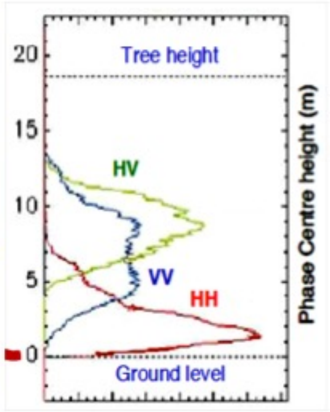
Post-2020 Space & Ground Observations of Forest Biomass

BIOMASS & NISAR Measurements

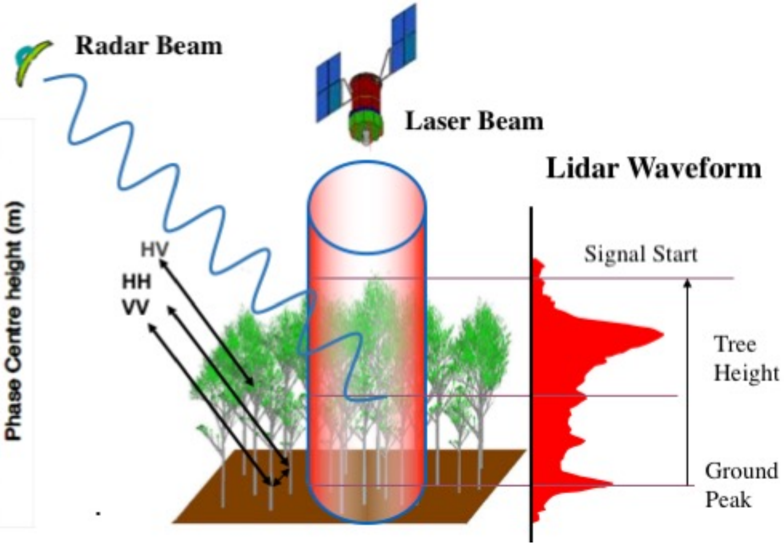
Polarimertic SAR Image



PolinSAR Measurements



GEDI Measurements

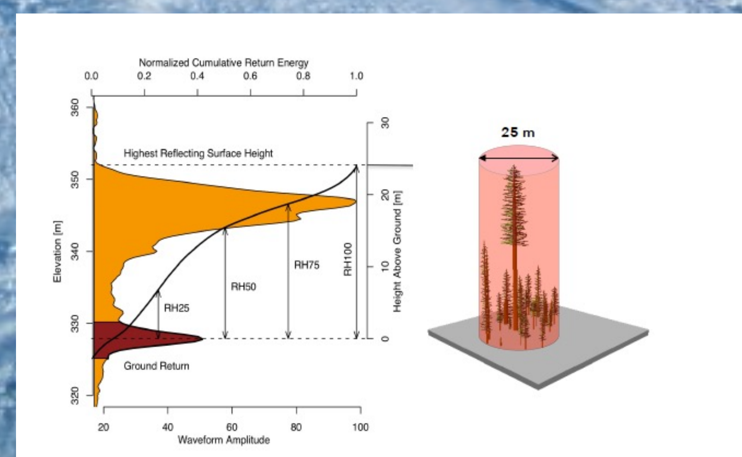


Ground Measurements

International Space Station

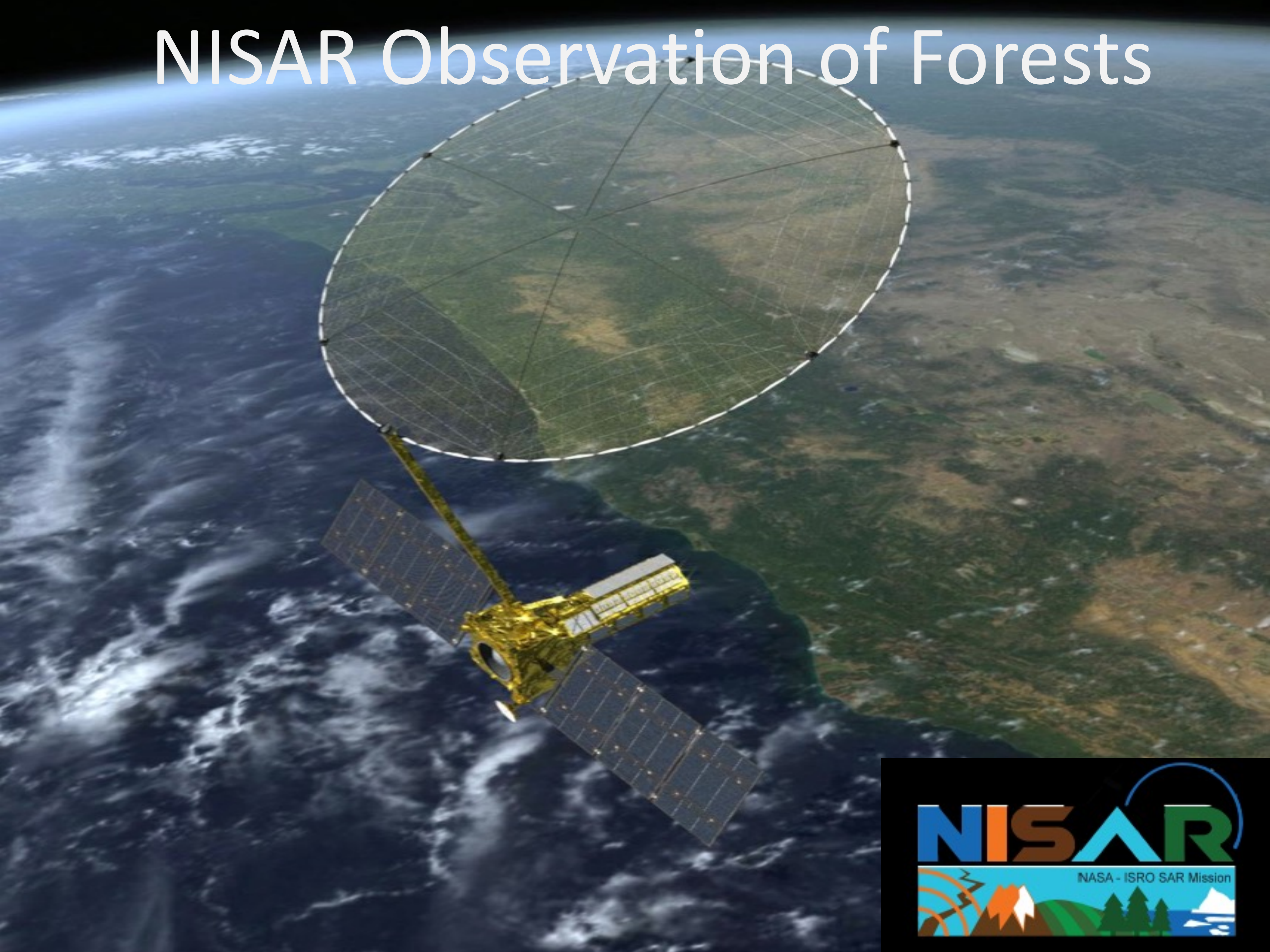
GEDI Lidar Observations
+/- 50 degrees Latitudes

SPACE-X
DRAGON
CAPSULE



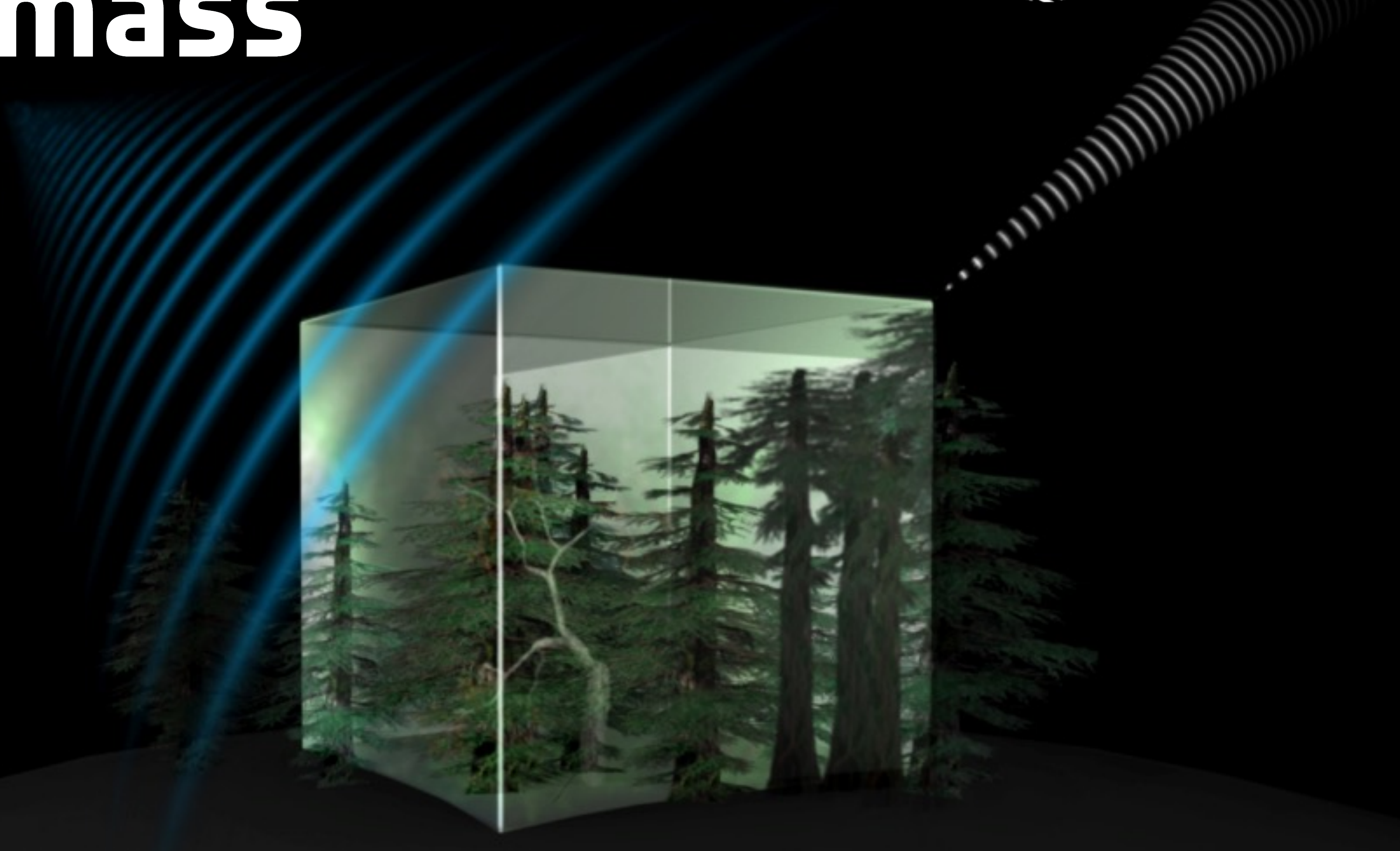
GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

NISAR Observation of Forests



esa

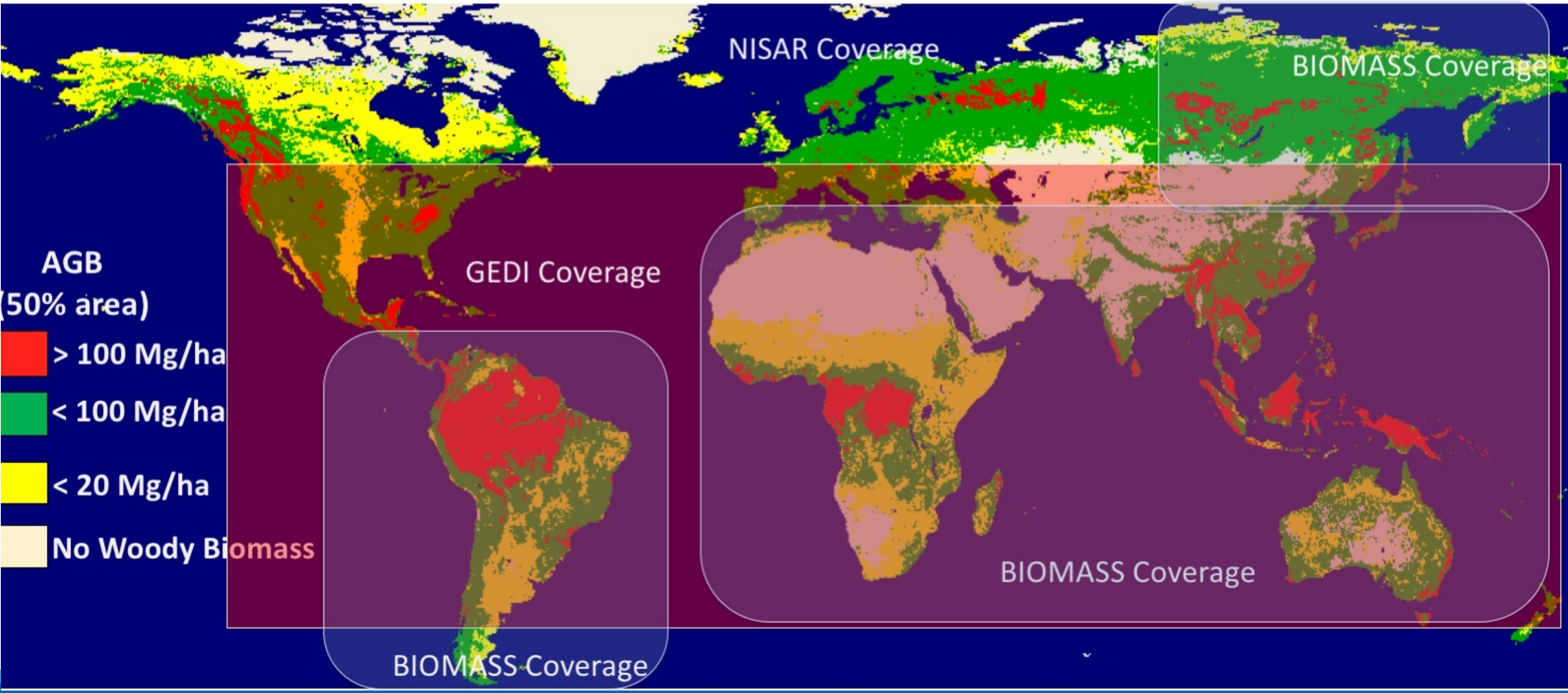
biomass



An Earth Explorer to observe forest biomass

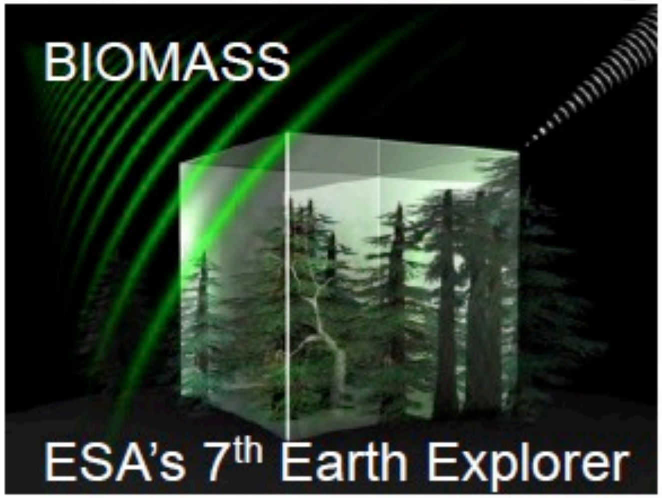
Synergistic Forest Observations

- NISAR: Global Coverage, sensitivity to AGB < 100 Mg/ha
- BIOMASS: Tropical and East Eurasia Coverage, Sensitivity to AGB > 50 Mg/ha
- GEDI:Sampling between 50 deg North and South, Sensitivity to AGB > 20 Mg/ha

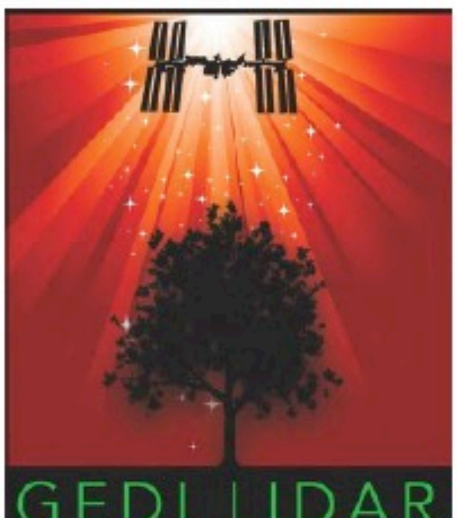


Where we'll be in 5 year's time

Forest biomass & height



Forest structure & lower level biomass

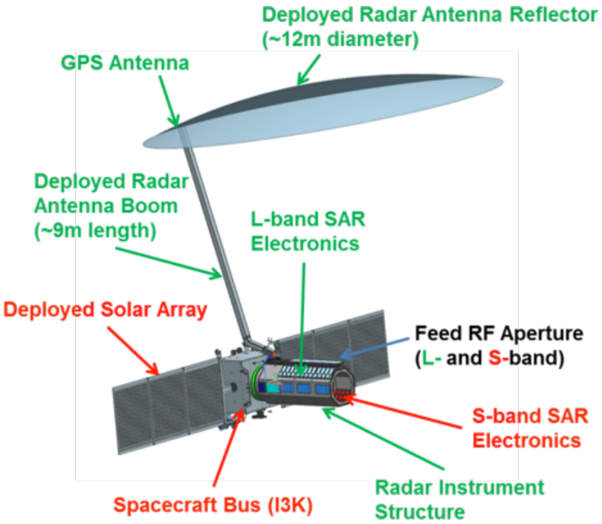


Forest structure & biomass

The "4th mission"; in situ networks

NISAR Concept Observatory & Work Share

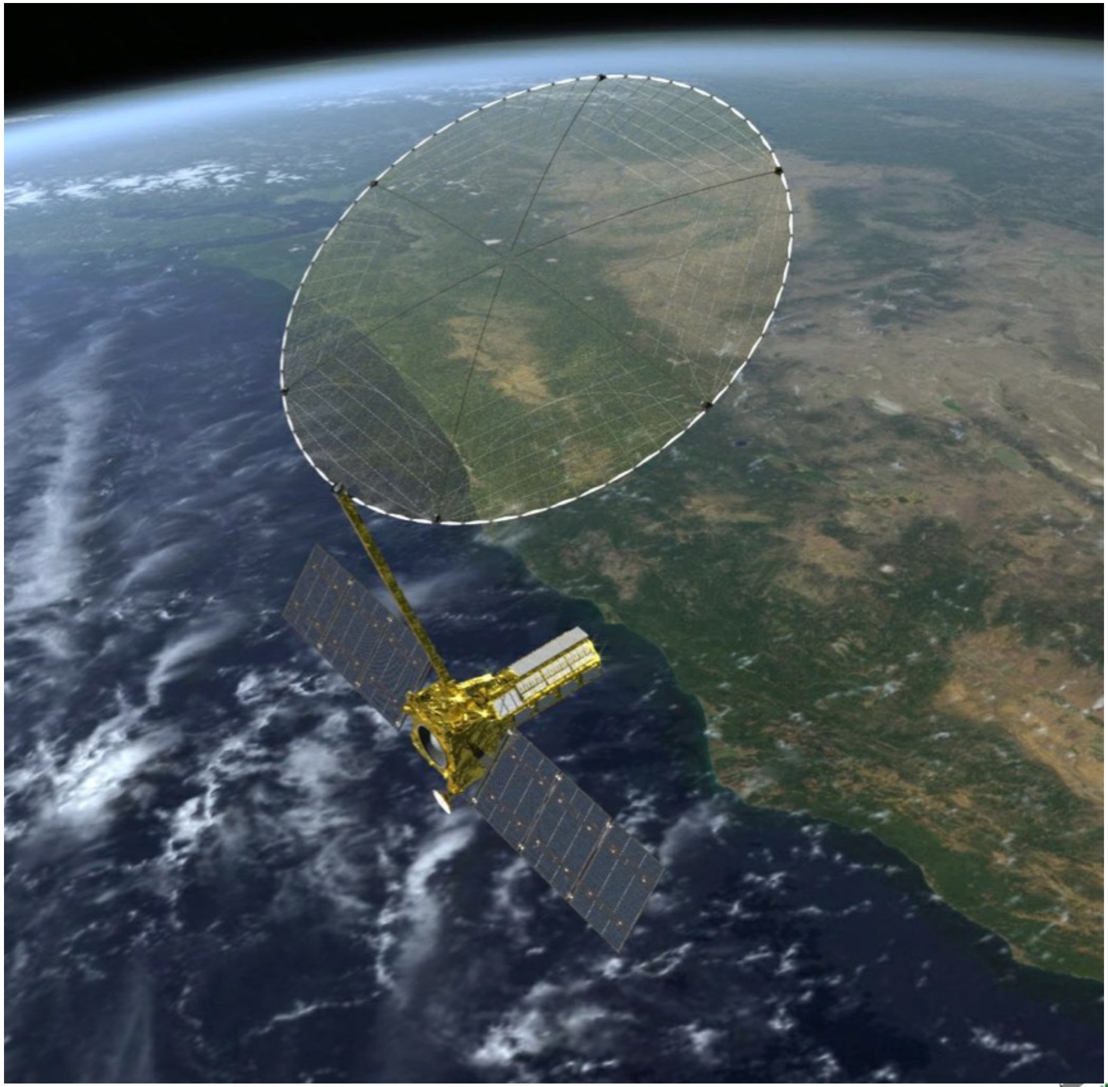
On-Orbit Configuration



GSLV Mark-II

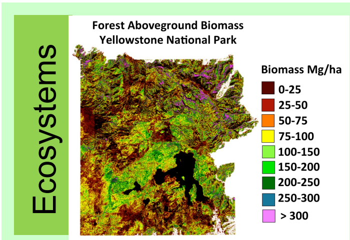
ISRO

NASA

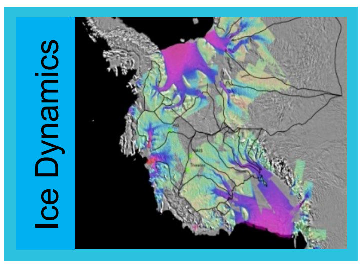


NISAR Science:
Measuring the Earth in Motion

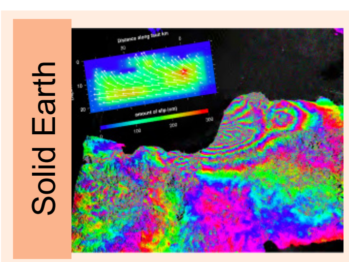
- Biomass, disturbance, agriculture
- Response to climate change & CO_2



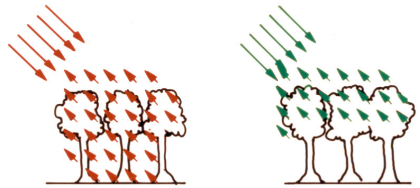
- Ice velocity
- Response to climate change & sea level rise



- Surface deformation, disruption
- Hazards response, water resources



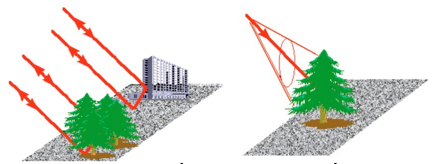
L- and S-band Wavelength



L- longer
24 cm

S- shorter
10 cm

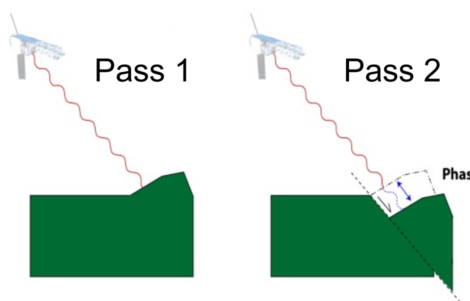
Polarimetry



Oriented Structures

Random Volumes

Repeat Pass InSAR



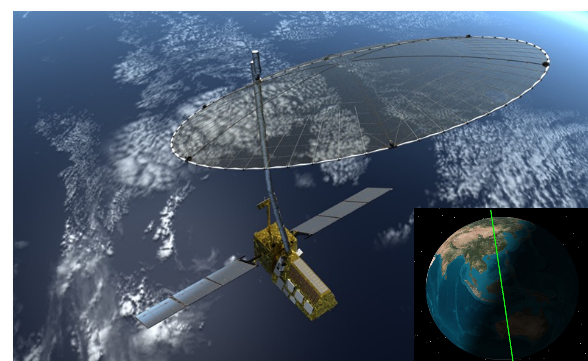
- Measurement accuracy
- Time-series-enabled science

↓

- 12-day exact repeat orbit
- 5-10 m resolution
- Global coverage
- 3 years of observations

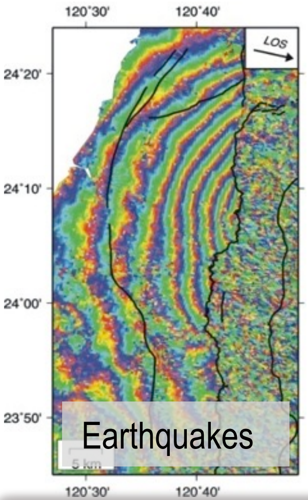
↓

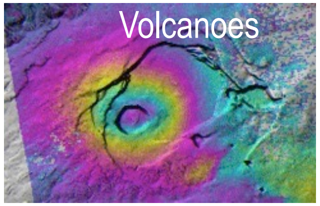
- Swath > 240 km
- 747 km altitude, circular, 98 deg. inclination, sun-sync (6AM-6PM)
- Pointing control < 273 arcsec
- Orbit control < 500 m
- > 30% observation duty cycle
- Left/Right pointing capability

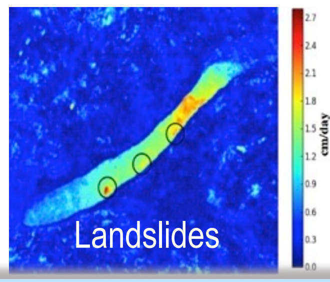


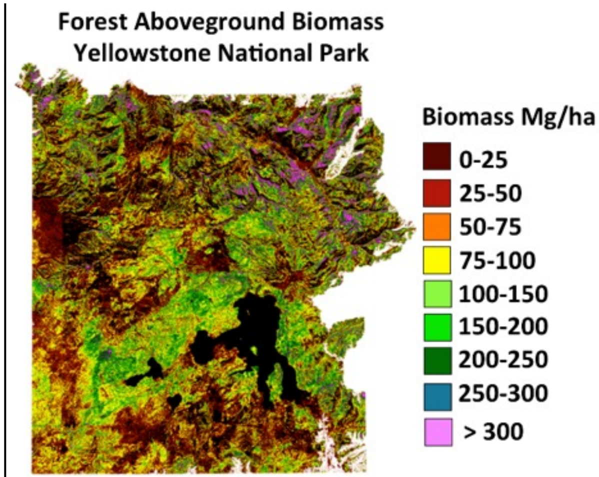
NASA - ISRO SAR Mission

Examples
Proposed NISAR Science and Applications Products

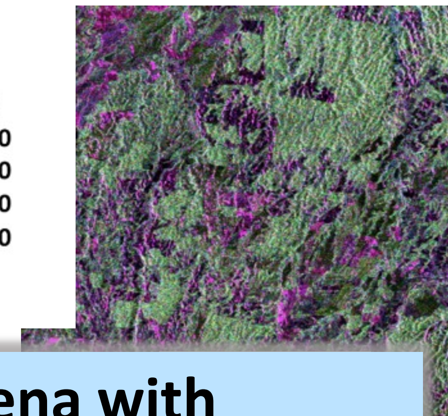




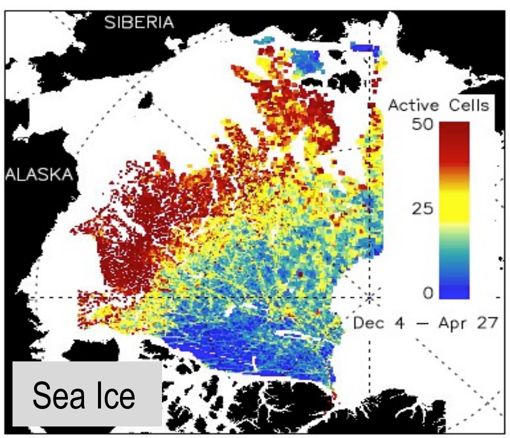


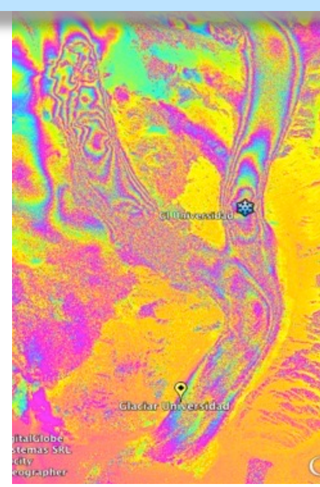


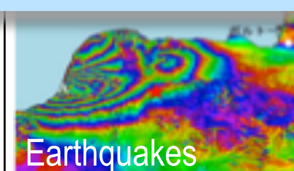
Ecosystems

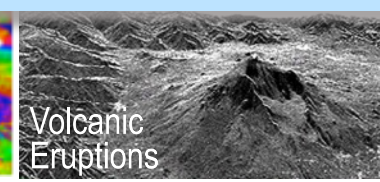


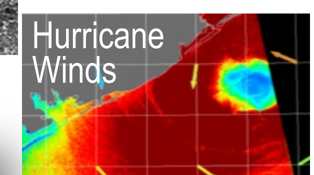
NISAR would capture these and other phenomena with unprecedented coverage and accuracy

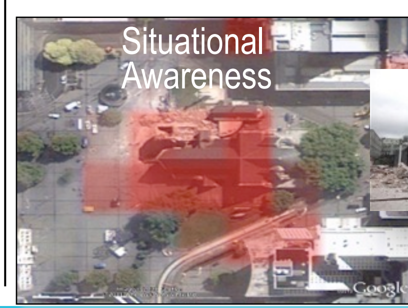






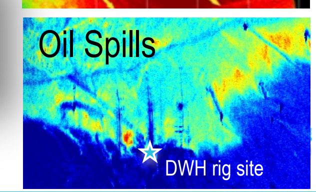






Earthquake
Damage

Christchurch
Cathedral



Proposed NISAR Level-1 Science Requirements in Plain English

For a minimum of 3 years:

a) *Measure ground movements in areas of expected solid earth deformation every 12 days from two directions to understand the processes causing earthquakes, volcanic eruptions, landslides, aquifer and reservoir variations , etc.*

b) *Measure flow of Earth's ice sheets and glaciers every 12 days from two directions to understand their interaction with global climate*

c) *Measure sea ice movements in both the Arctic and Antarctic to understand their interaction with global climate*

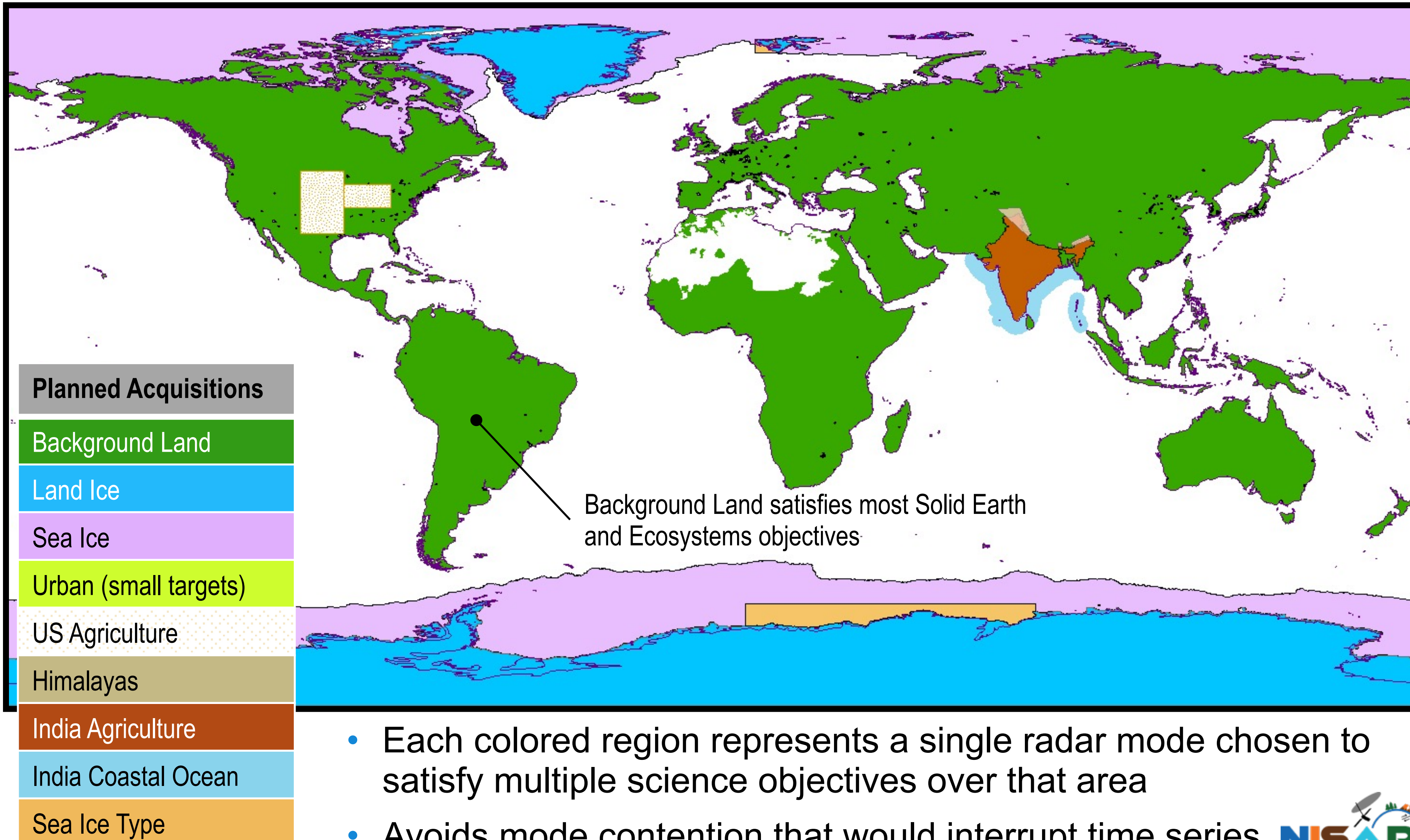
d) *Measure the dynamics of global woody aboveground biomass*

e) *Measure the dynamics of major wetlands and agricultural systems*

f) *In the event of a major natural or anthropogenic disaster anywhere in the world, task observations and downlinks rapidly on a best efforts basis*

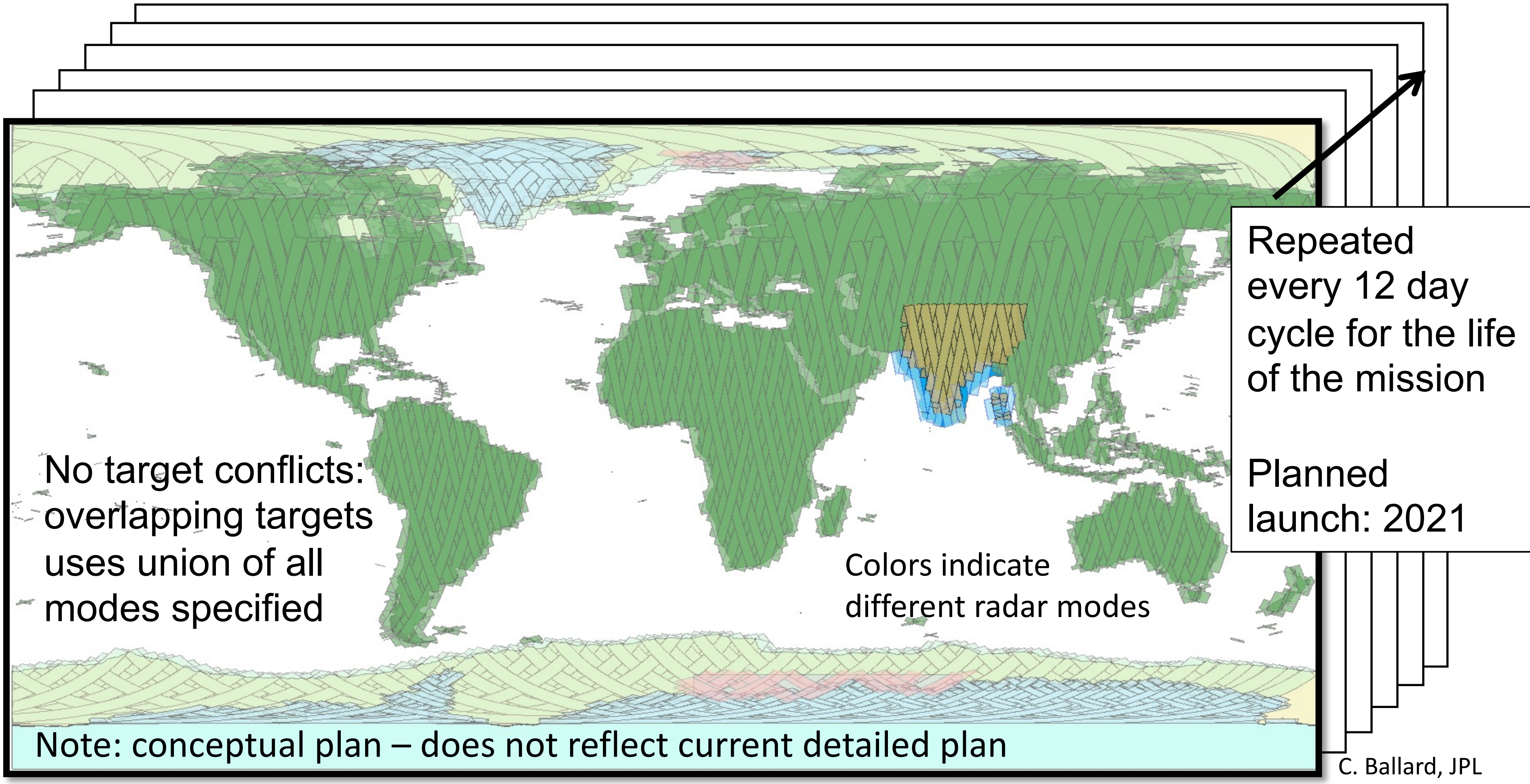
NISAR
NASA - ISRO SAR Mission

Mode-Specific Science Targets in Observation Plan (Pre-2016)



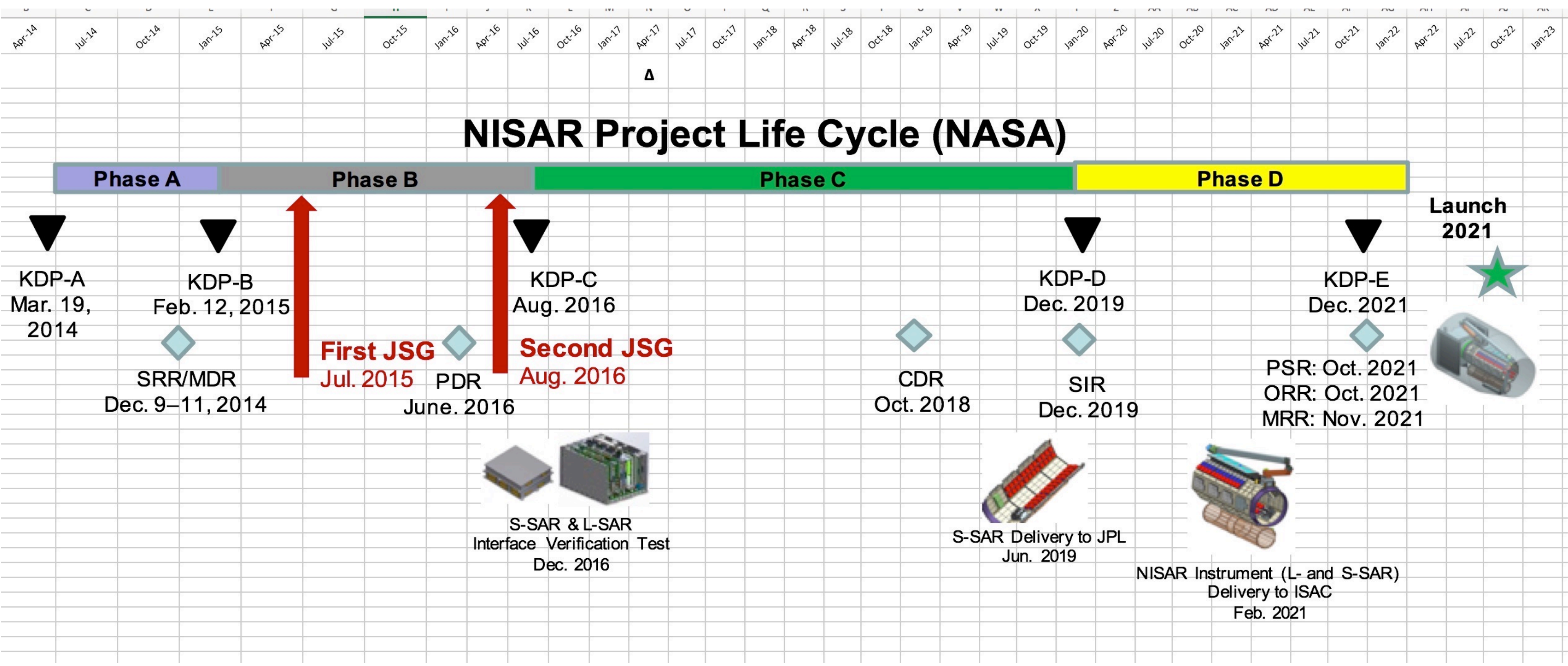
- Each colored region represents a single radar mode chosen to satisfy multiple science objectives over that area
- Avoids mode contention that would interrupt time series

NISAR Systematic Observations



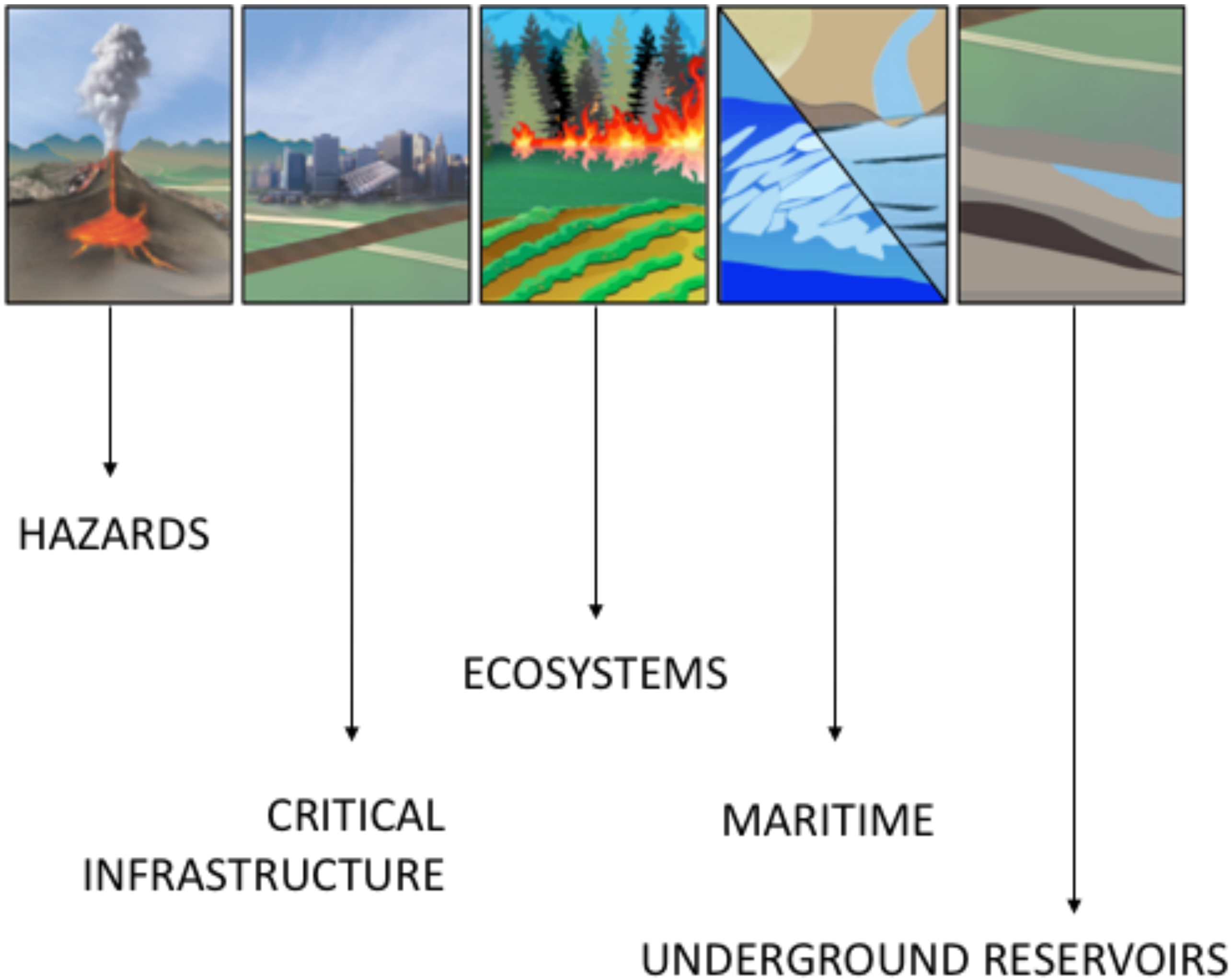
Persistent updated measurements of Earth

Individual Activity & Timeline



Action Taken: Socialize NISAR's Capabilities & Value

NISAR APPLICATIONS WHITE PAPERS



ECOSYSTEMS: Food Security

National Aeronautics and Space Administration

NISAR: The NASA-ISRO SAR Mission

Preparing Markets for Bountiful Harvests

NISAR will provide maps of developing crop area on a global basis every two weeks. Observations will be uninterrupted by weather and provide up-to-date information on the large-scale trends that affect international food security.

Modern Remote Sensing Technology and Farming

In recent years, with the rise of silicon, modern technology has permeated all levels of society. Through GPS, automation and space technology, the discipline of agricultural production has been no exception, and indeed has historically always been an early adopter of new technology.

Food security and the accomplishments of agribusiness are founded on the continuity of a global food supply that fluctuates with changing national policies, regional climate variability and market forces that govern what individual farmers and corporate farming entities plant and harvest every year. In challenging environments such as this, information leads to efficiency, stability and success.

Photos (clockwise): Flickr, CC BY-NC 2.0: Kimberly Reinhart, Jason & Kris Carter, fishhawk, Eric Baker

Crop Area Monitoring

To feed a growing population of more than 8 billion, food production and supply occur on a global basis. In order to better guide policy and decision making, national and international organizations work to transparently monitor trends and conditions of agriculture in a timely basis. Because of the variable nature of planting and harvesting practices, efforts such as this are manpower intensive and time consuming tasks.

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.

Continued from front page

Among the organizations that track the trends in agricultural production on a global basis is the United Nations Food and Agriculture Organization (FAO). According to FAO's 2015 statistics, over eleven percent of the Earth's land surface (1.5 billion hectares) is used for farming. With an increasing population, after taking into account expected improvements in land use efficiency, the amount of land dedicated to food production is expected to grow 7% by 2030 to keep up with demand. This increase is equivalent to an additional 90 million hectares, roughly the size of Texas and Oklahoma combined.

With the world's population critically dependent on the timely production of food and fresh water resources, the need is greater now than ever before for the application of technology to assure that population needs are met. Among the technical tools that are used to address these issues are the satellites that provide synoptic views of the globe from space. Satellite sensors are routinely used to guide decision-makers and commercial interests alike in scheduling future plantings and monitoring the effects of policy changes and a dynamic global marketplace.

The upcoming NISAR mission will provide dependable observations throughout the growing season. The use of actively generated microwave signals (L- and S-band, or equivalently, 24 cm and 10 cm wavelength) on board the satellite, means that the observations will be able to be reliably planned, collected and distributed at time scales that are commensurate with the satellite's 12-day repeat cycle of the full set of orbits, which images each agricultural site at least once every 6 days. Radar images from satellites such as NISAR are known for their ability to penetrate through clouds and their day/night imaging capability, which is a major limitation of optical sensors for agriculture applications. Radar imagery will provide near-weekly observations of almost all land areas that complement the optical data and provide independent information that is sensitive to the changing structure and moisture conditions of the crops being imaged. In addition, NISAR's data products will be available open access.

Radar Imaging of Crops

Observations of the Earth's land surfaces from space using radar allows reliable and repeated measurements to be made throughout the growing season. The structures of different crop and land cover types provide a rich variety of responses to the radar illumination in terms of varying polarization and frequency signatures. Because of the rapid, time-varying nature of crop rotation, growth, and harvest, frequently repeated radar observations can be used to determine both the type of crop and its stage of growth. Information like this is used to predict the health of the region's crops and the planned agricultural output.

Shown at right are data collected by SIR-C, a NASA mission launched on board the space shuttle in 1994. Data from areas such as the Dnieper River region of Ukraine were collected at study sites distributed throughout the globe and have been used by NISAR mission planners and other space agencies worldwide to understand how radar data can be used to improve our knowledge of the world around us. Modern day synthetic aperture radars (SAR), such as the Canadian Space Agency's Radarsat and the European Commission's Sentinel satellite series, have benefited from the SIR-C mission and are being actively used today.

Two-frequency radar image of the Dnieper River growing region collected in 1994 by NASA's Shuttle Imaging Radar program. In this false color image, developing wheat fields show up as bright magenta and forests as the bright white patches that follow the river's border

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**

Applications Webpage

Application Area | **Events/Workshops**

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)

Placeholder Workshop (Mmmm dd-dd, yyyy):
- Link to Agenda
- Link to Final Report

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)

Sea ice Applications and Science Workshop (June 23, 2017):
- Link to Agenda
- Link to Final Report (PDF, 5.01 MB)

Ecosystem
- Fire Management (PDF, 1.78 MB)
- Food Security (PDF, 1.01 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)

Vegetation Biomass Workshop (May 31-Jun 3, 2016):
- Link to Agenda
- Link to Final Report (PDF, 6.95 MB)

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

Placeholder Workshop (Mmmm dd-dd, yyyy):
- Link to Agenda
- Link to Final Report

Critical Infrastructure
- Levees and Dams (PDF, 1.92 MB)
- Subsidence (PDF, 2.58 MB)

Critical Infrastructure Workshop (June 6-7, 2017):
- Link to Agenda
- Linkto Final Report (PDF, 1.78 MB)

- 21 white papers
- Available online
- Distributed in hardcopy to
  - Policy makers
  - Fed & state agencies
  - …

Level 2 Urgent Response Requirements

	L2-PRS-578	**3.5 Urgent Response Operations**
L2-PRS-510	**Urgent Response Latency**	For major natural or anthropogenic disasters response, the NISAR project shall have the capability to reschedule the Observatory's planned observations within 24 (TBR) hours of event notification to mission team. Note: The 24 hours (TBR) refers to the scheduling process for file uplink + radiation of new observation instructions to the spacecraft and not to the data acquisition window.

L2-PRS-511	**Urgent Response Data Delivery Latency**	For major natural or anthropogenic disasters response, the NISAR project shall have the capability to deliver the L0B data products of the "rescheduled" disaster observation to users within 5 (TBR) hours of data acquisition.

L0B data: Raw data with some ancillary information

Sub-optimal for the vast majority of end users

Project is considering developing an automated processing stream through L2 for urgent response

Science Team: Urgent Response Plan

Status: DRAFT 1 Complete & Reviewed by DPAs, Project; HQ

Urgent Response Plan

Draft – 28 June 2017

*Jet Propulsion Laboratory, California Institute of Technology

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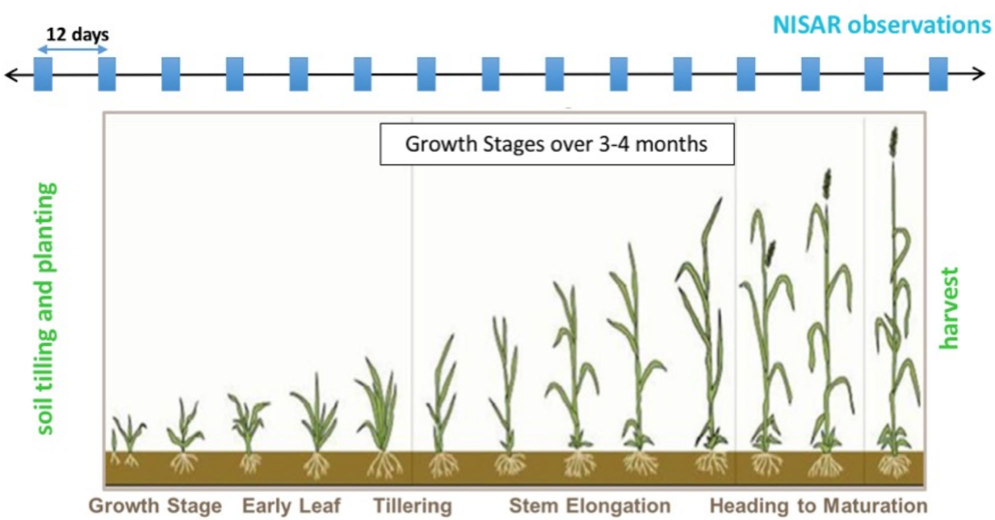
Contents

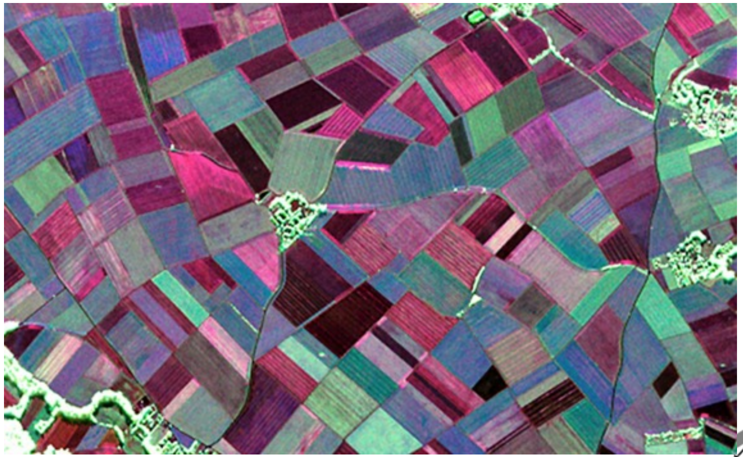
NISAR Ecosystem Science

- Biomass
- Disturbance
- Inundation
- Agriculture

Dense-time series of L-band data (dual-pol)



L-band Observation of Croplands

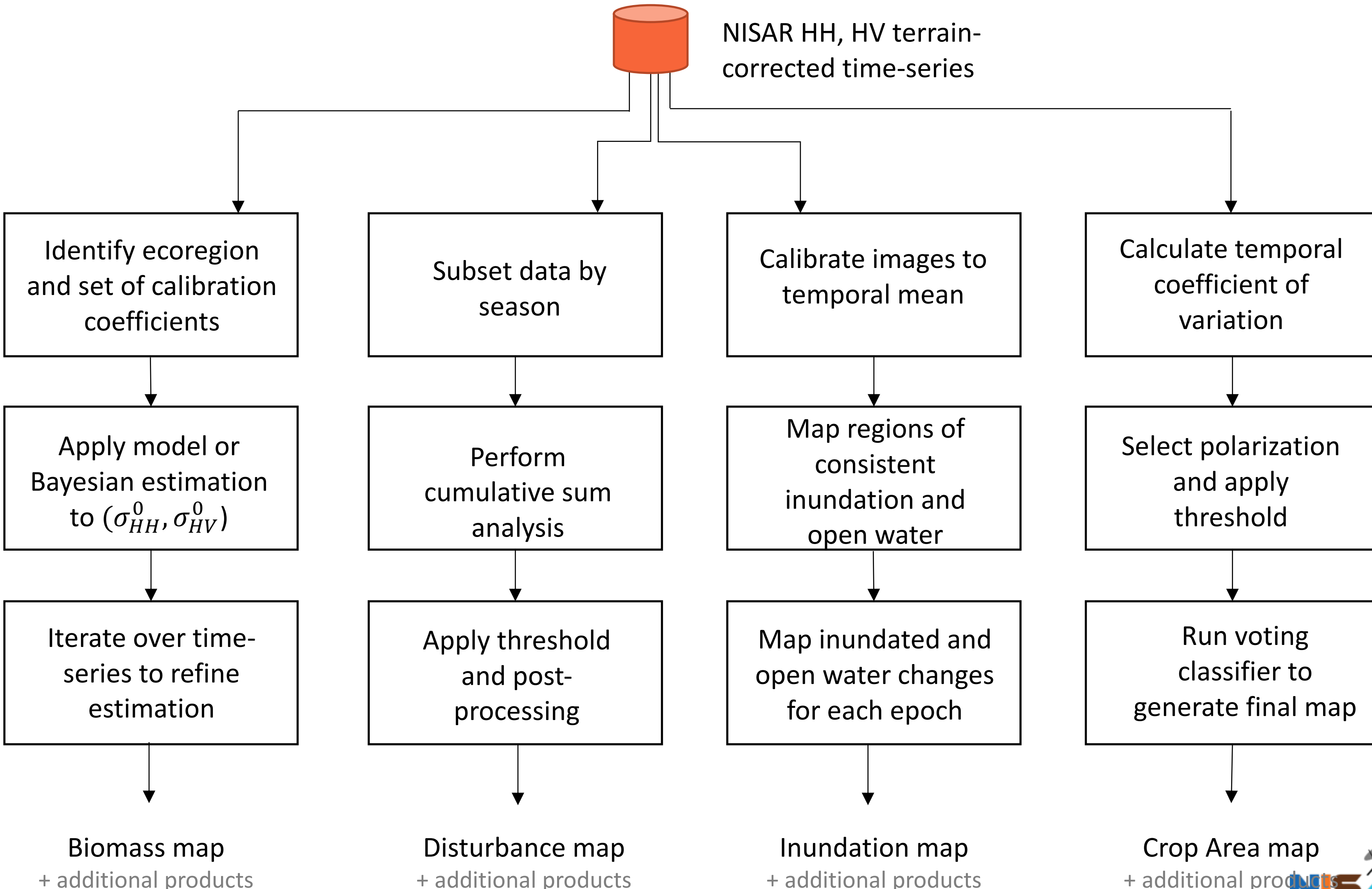


NISAR Ecosystem Requirements

NISAR ecosystems has four Level 2 science requirements

- **Biomass**
  - Annually map aboveground woody vegetation biomass at the hectare scale. Accuracy shall be within 20 Mg/ha for 80% of areas of biomass less than 100 Mg/ha.
- **Disturbance**
  - Map global areas of vegetation disturbance at 1 ha resolution annually for areas losing at least 50% canopy cover with a classification accuracy of 80%
- **Agriculture**
  - Map crop area at 1 ha resolution every 3 months with a classification accuracy of 80%.
- **Inundation**
  - Map inundation extent within inland and coastal wetlands areas at a resolution of 1 hectare every 12 days with a classification accuracy of 80%.
- **Soil Moisture/Freeze-thaw**
  - Map surface soil moisture every 12 days and monitor the soil/vegetation freeze/thaw cycles

NISAR Ecosystems Algorithm Overview

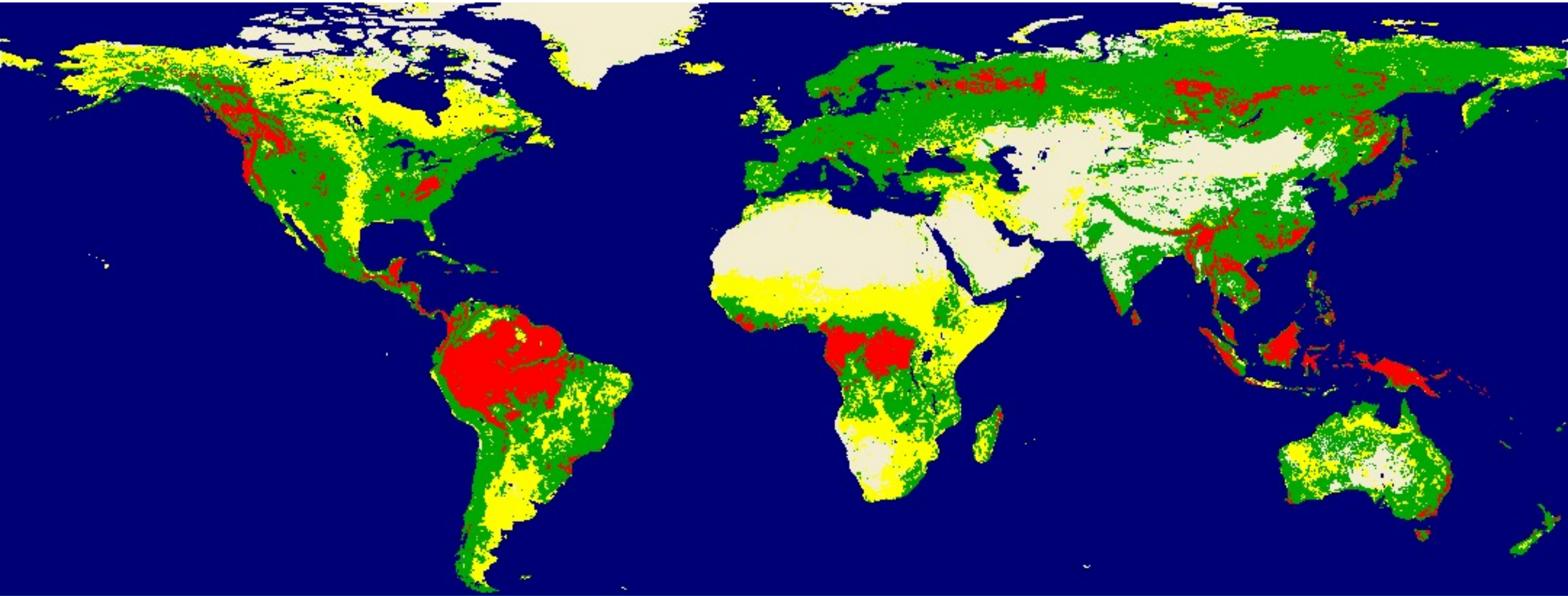


NISAR Biomass L2 Requirement

NISAR will measure aboveground woody vegetation biomass annually at the hectare scale (1 ha) to an RMS accuracy of 20 Mg/ha for 80% of areas of biomass less than 100 Mg/ha.

Regions with AGB < 100 Mg/ha 50% of area	Regions with AGB > 100 Mg/ha 50% of area	Regions with AGB < 20 Mg/ha 50% of area	Regions with No woody vegetation	Open Water

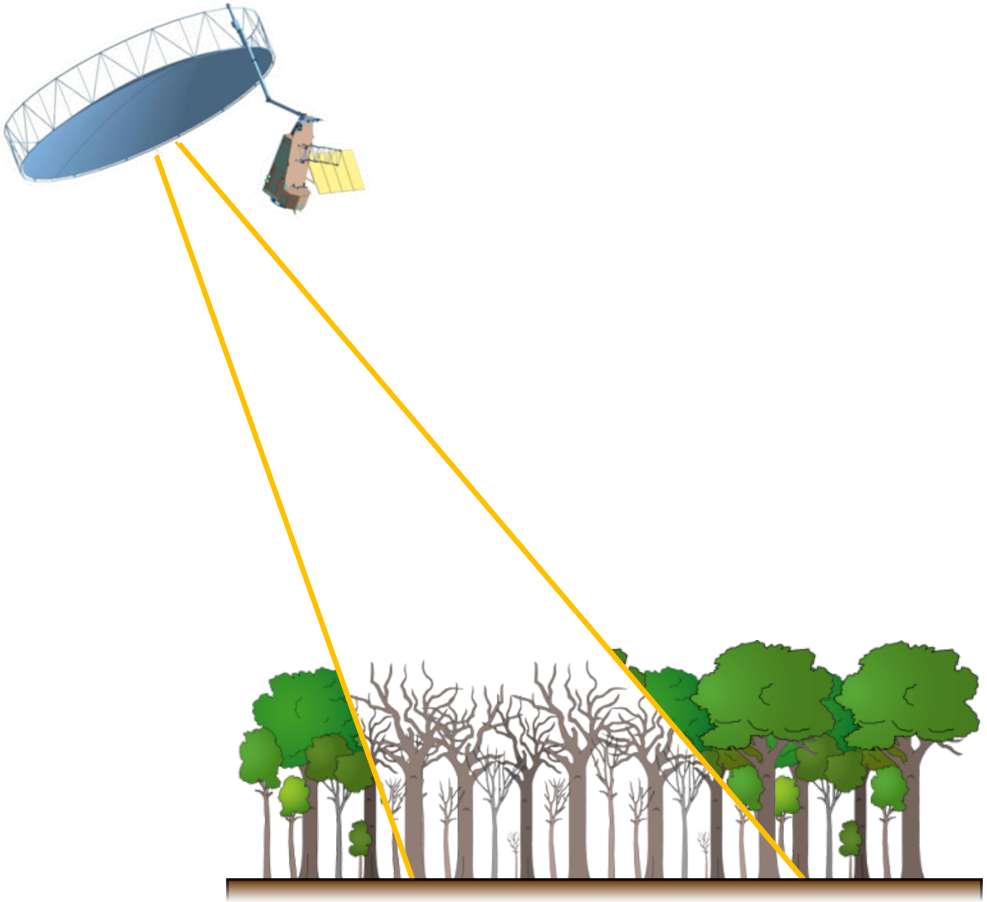
The global distribution of regions dominated by with woody biomass < 100 Mg/ha



Measuring biomass from space with radar needs the longest possible wavelength

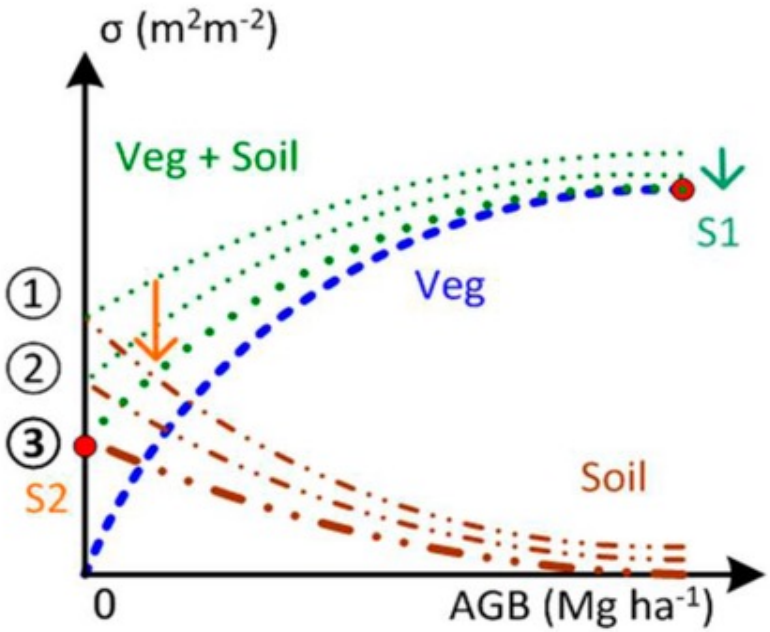
Mapping forest biomass needs a radar sensor that

1. penetrates the canopy in all forest biomes
2. interacts with woody vegetation elements
3. allows forest height to be estimated with a single satellite (affordability)



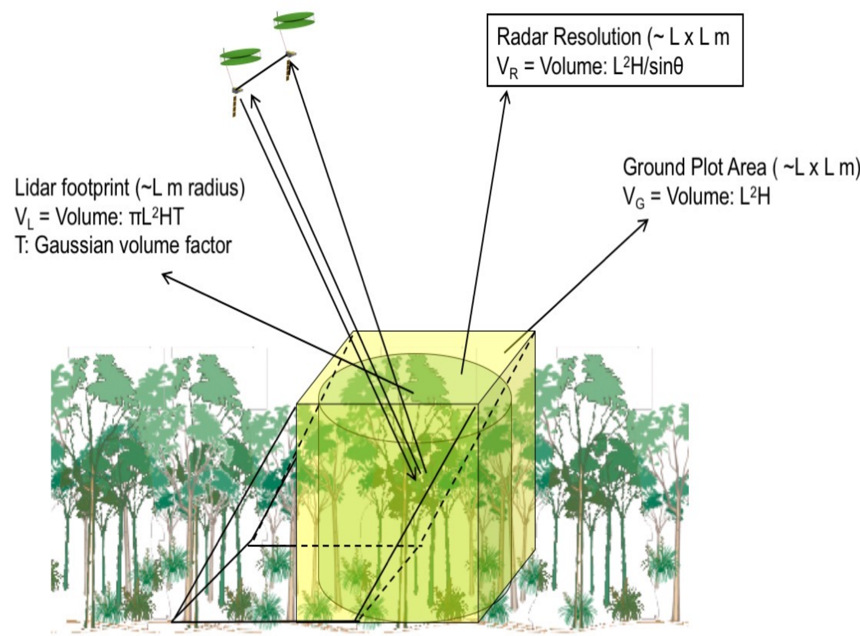
Phenomenology of SAR Measurements of Vegetation

Impact of vegetation and soil



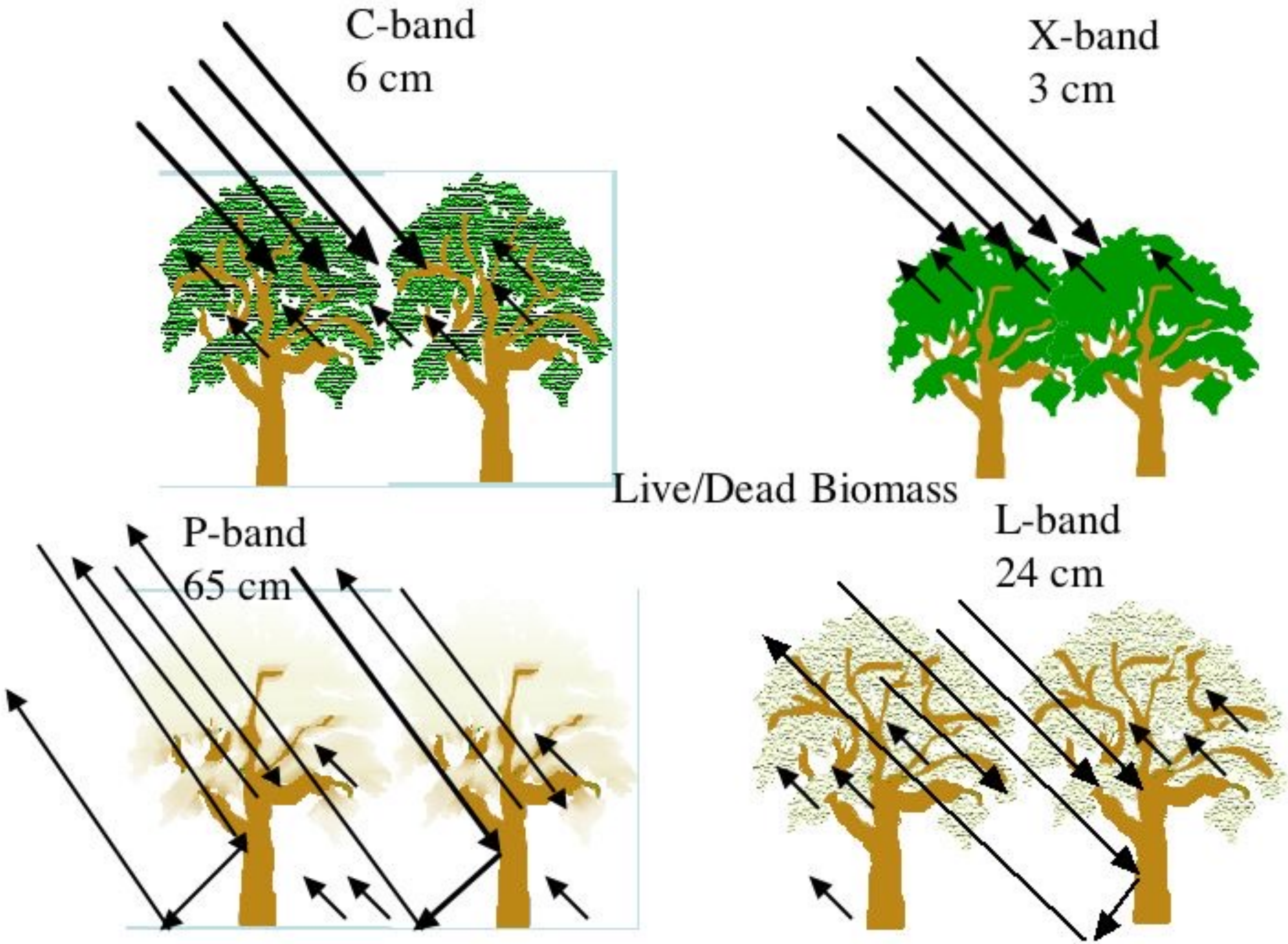
(Values are not to scale)

Radar & Lidar Resolution Cells



At footprint scale: $V_G \neq V_L \neq V_R$

Scattering Phenomenology



Dielectric Constant of Vegetation

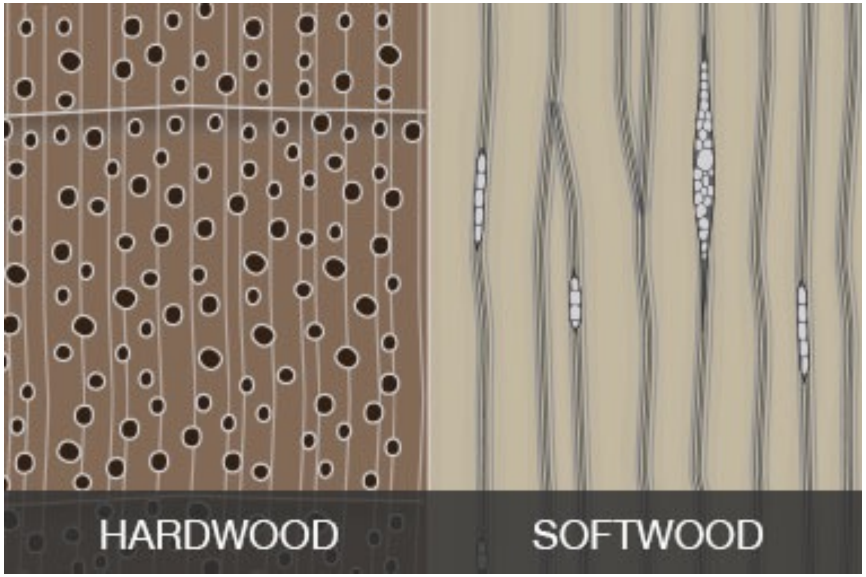
Complex Dielectric Constants of Wood Perpendicular E-Field										
WOOD TYPES	SEASON	Frequency (MHz)								
		50	100	200	400	600	800	1300	2400	3200
SOFT	WINTER	55	53	51	50	48	46	44	42	40
	SUMMER	50	48	47	46	45	44	41	40	38
HARD	WINTER	25	24	23	22	21	20	18	17	16
	SUMMER	23	21	21	20	20	19	17	16	15

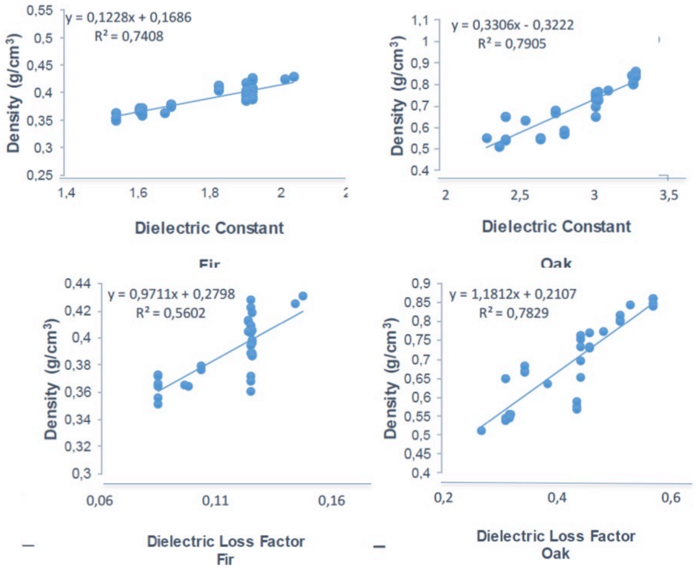
Wood Grain Perpendicular to E-Field (Summer)									
Wood Type	Frequency (MHz)								
	50	100	200	400	600	800	1300	2400	3200
Softwood	15.2	8.01	4.50	3.01	2.78	2.85	3.40	5.00	6.10
Hardwood	15.2	7.98	4.41	2.91	2.63	2.65	3.11	4.48	5.47

$$\varepsilon_r = \epsilon_r' + i\epsilon_r''$$

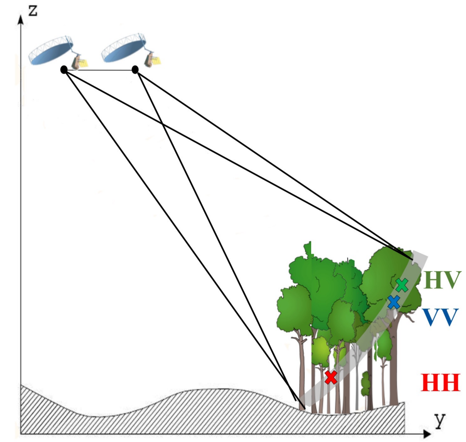
Stored Energy/dispersion

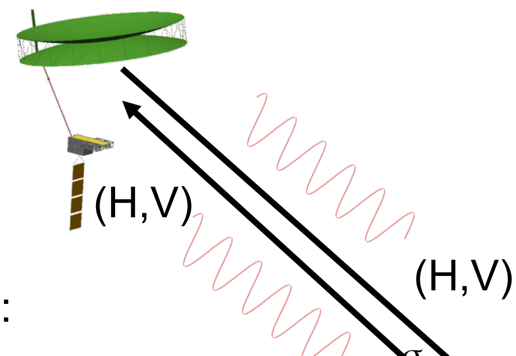
Loss factor





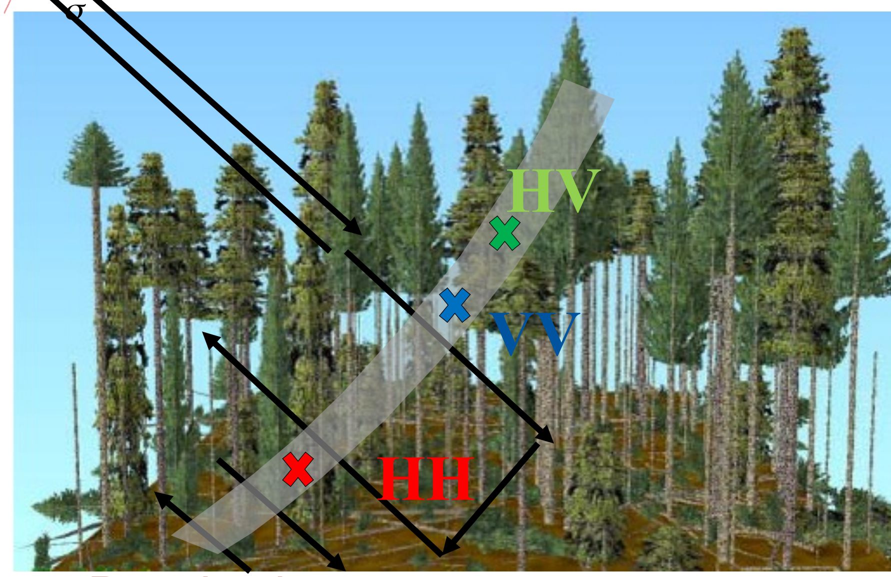
SAR Interaction with Structure of Vegetation





Backscatter Measurements:

$$\sigma_{(H,V)} = \sigma_{crown} + \sigma_{stem} + \sigma_{ground}$$



$$\sigma_{(H,V)} = f(vol, W_d, \Omega)$$

vol : forest volume (size)

W_d : wood density (dielectric constant)

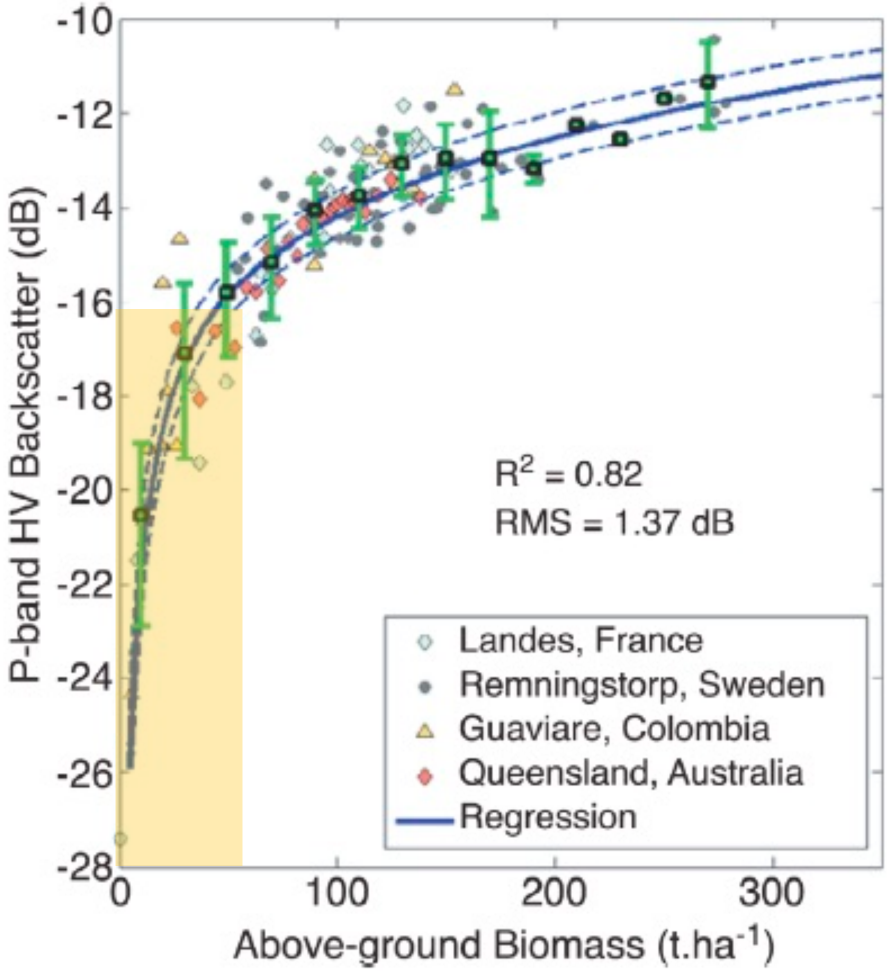
Ω : shape and orientation of components

Measurement Variables: Frequency, Angle, Polarization

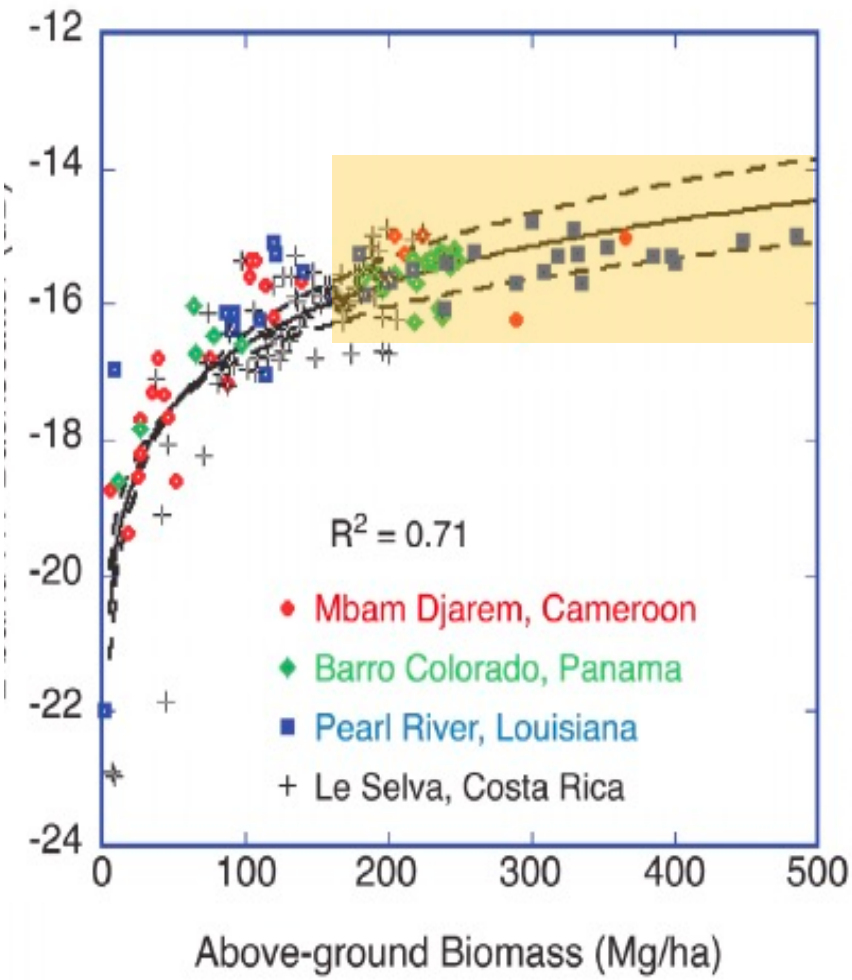
high spatial resolution, seasonal to annual revisit time, all time capability

SAR Sensitivity to Aboveground Biomass (AGB)

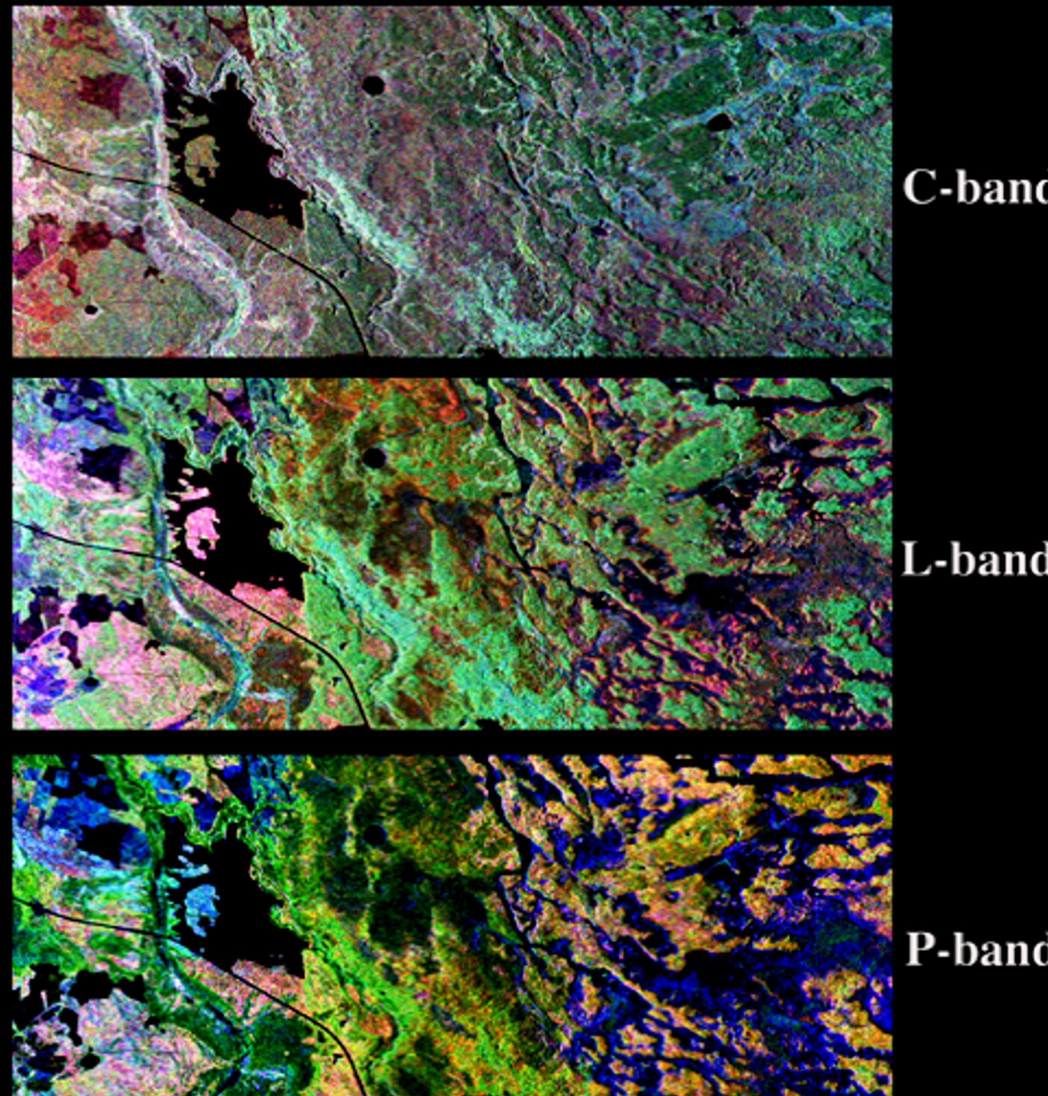
P-band (~ 70 cm)



L-band (~ 25 cm)

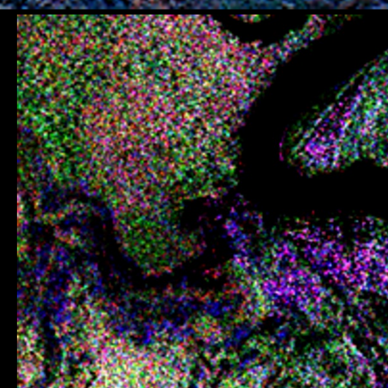


Radar Backscatter Images at HH, HV, and VV polarizations over boreal forests



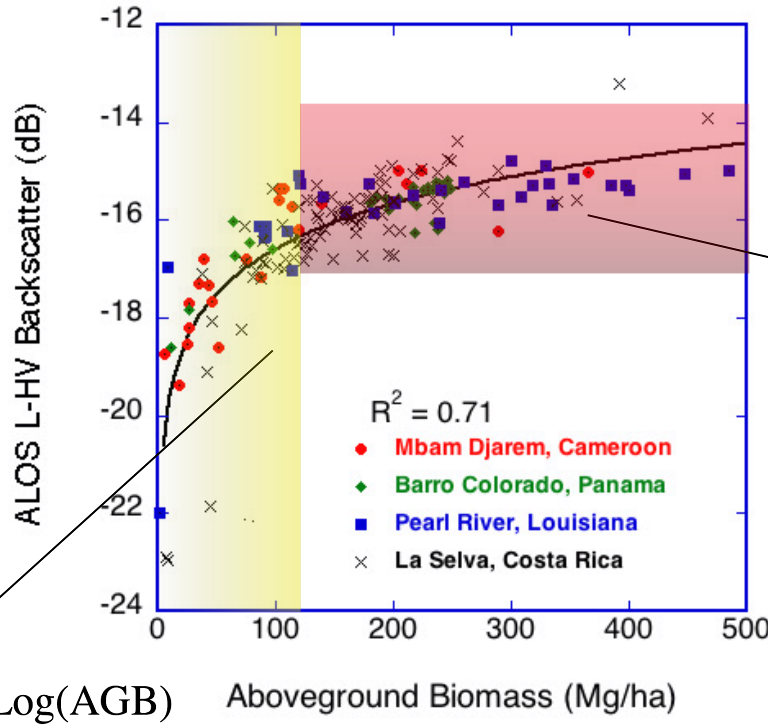
C-band

L-band



P-band

L-band Radar Sensitivity to Biomass



High Priority Fusion Region
Lower to no sensitivity of radar
Domain of data fusion and synergism with GEDI and BIOMASS

$$LHV\ (dB) = -22.5 + 3.0 Log(AGB)$$

Biomass < 100 Mg/ha
Low Priority Fusion Region
Higher sensitivity of radar
Domain of NISAR Performance

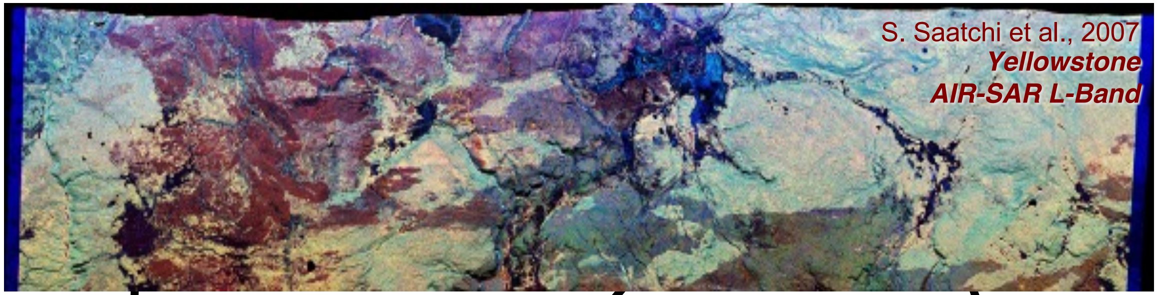
Global Biomass Product must be derived from Fusion Approach

For low biomass density (100 Mg/ha) radar sensitivity is high but impacted by structure & environment

For high biomass density (>100 Mg/ha) data fusion with GEDI and/or BIOMASS required

Global Monitoring of Vegetation Disturbance and Recovery

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

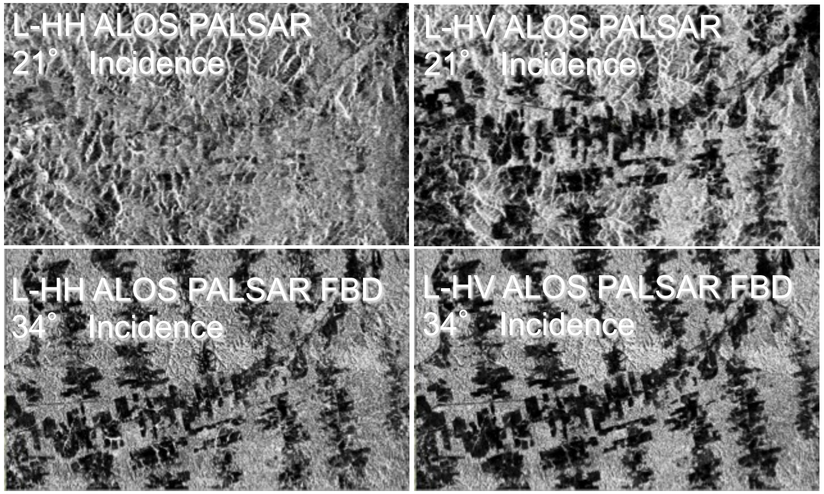


Cross-pol measurement is key to detecting structural differences in vegetation, driving requirement for multi-pol baseline and cross-pol threshold radar capability.

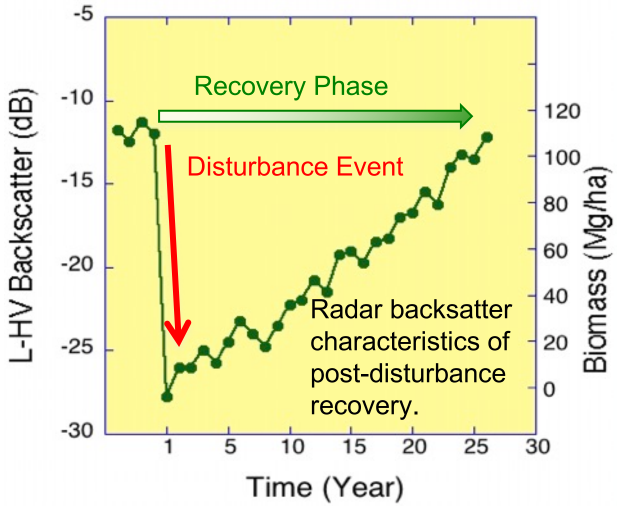
2003 Burn

Recovery after 1988 Burn

Pine Beetle Disease



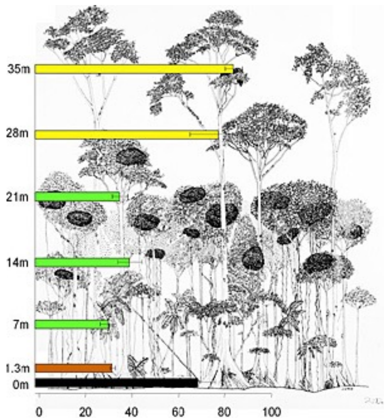
NISAR would provide acquisitions with both polarization and incident angle variations; both critical for effective disturbance monitoring.

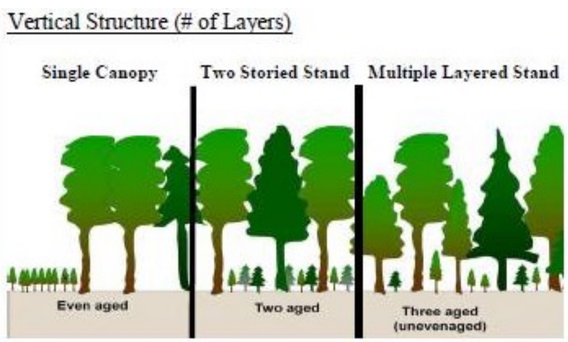


NISAR would quantify fluxes in terrestrial sources and sinks of carbon resulting from disturbance

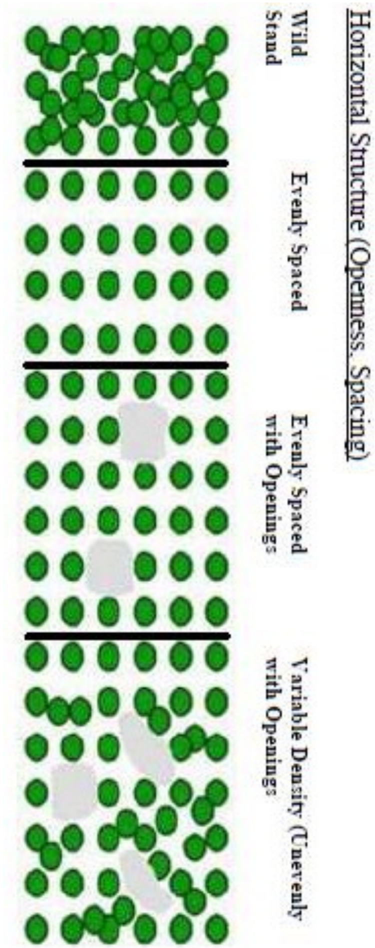
What Impacts Radar Observation of Forests

Vertical Structure

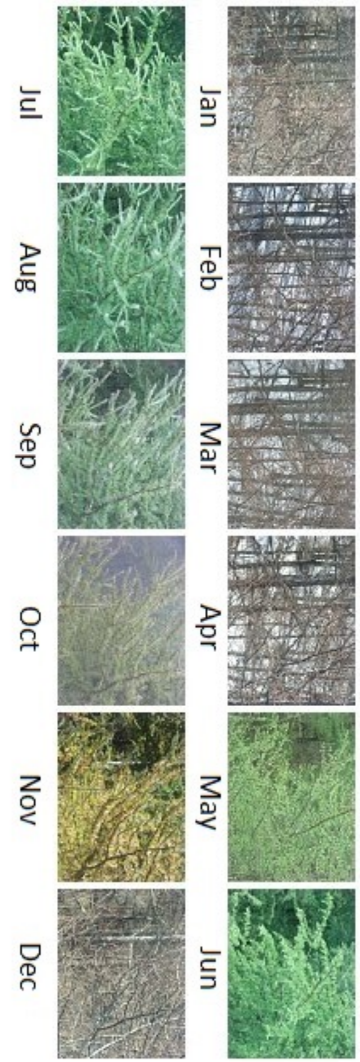




Horizonthal Structure



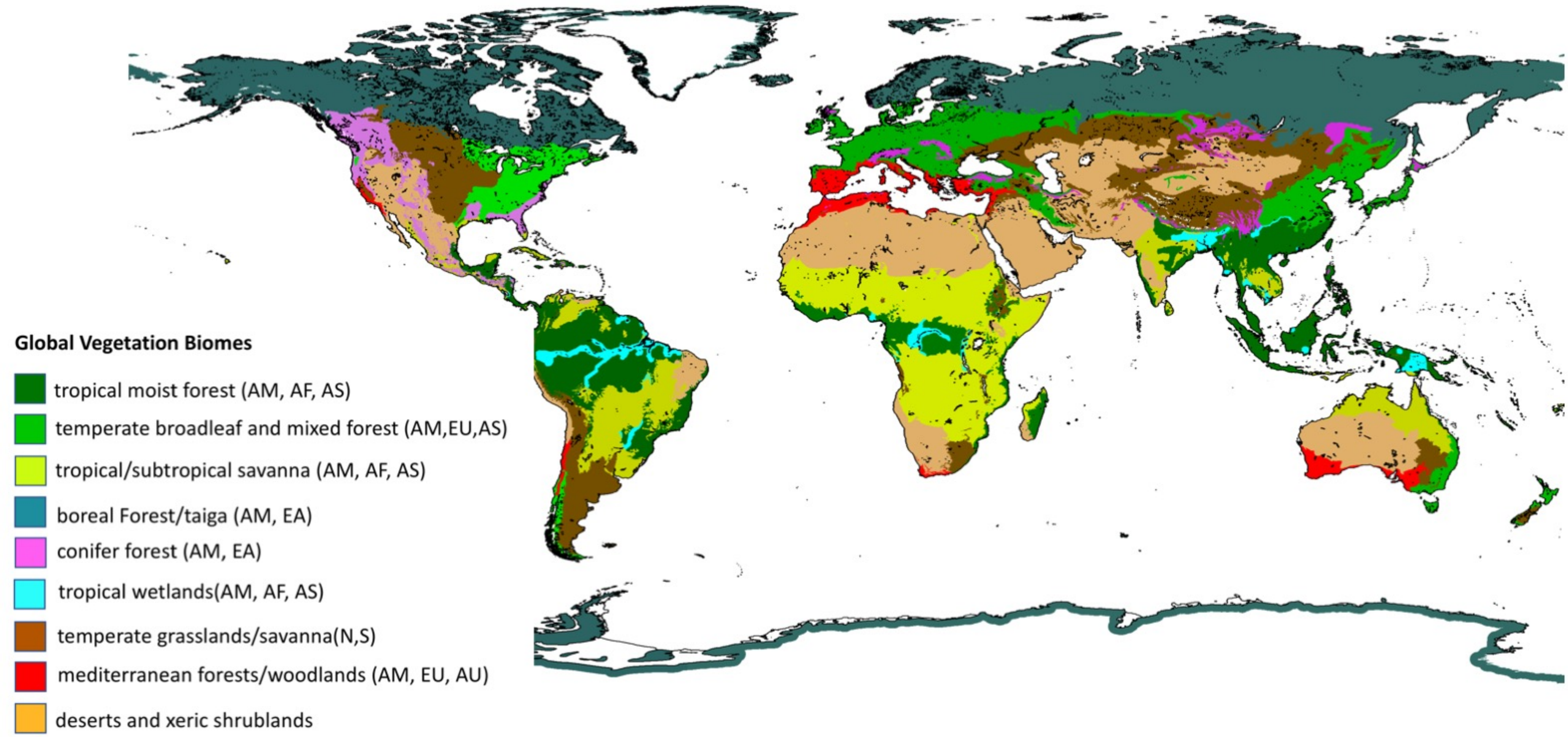
Canopy/Soil Moisture



Landscape

Global Distribution of Biomes

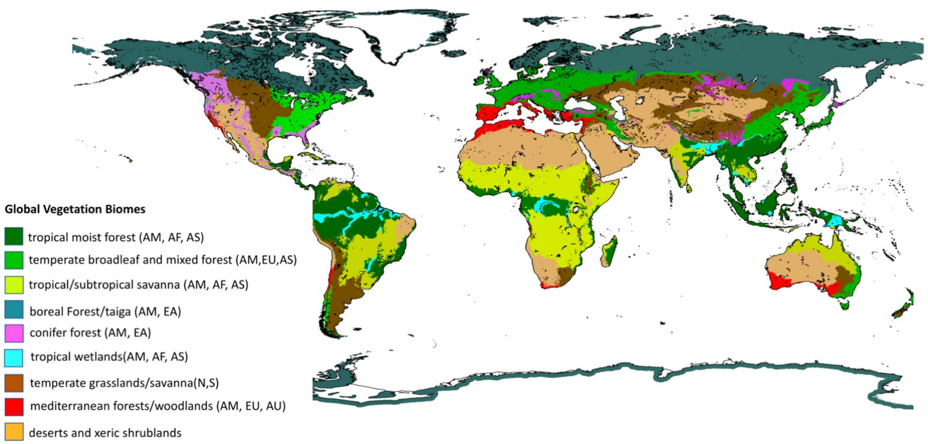
Global Vegetation Biomes



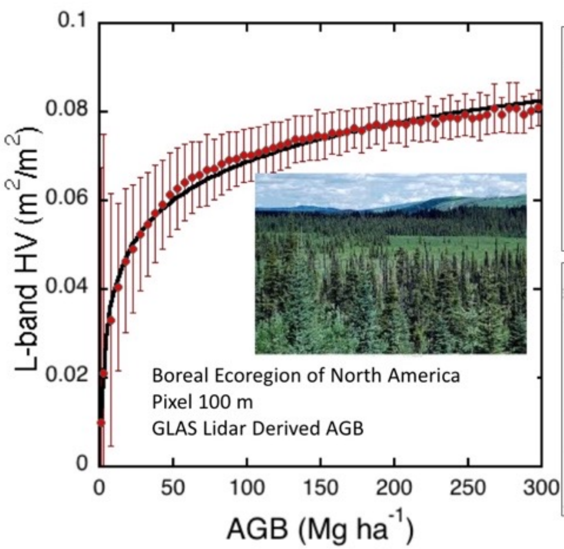
This document contains export-restricted data.

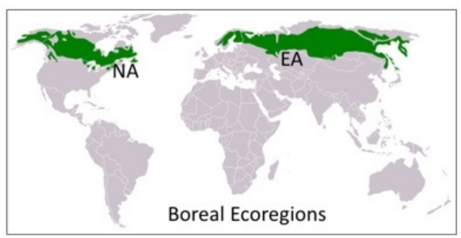
NISAR Biomass Number of Global Models

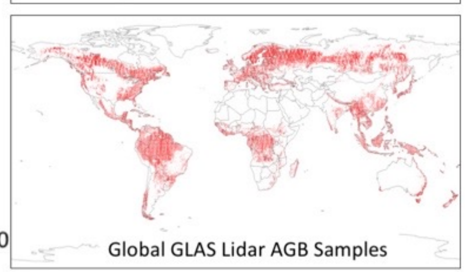
Global Vegetation Biomes



Yu and Saatchi, 2016

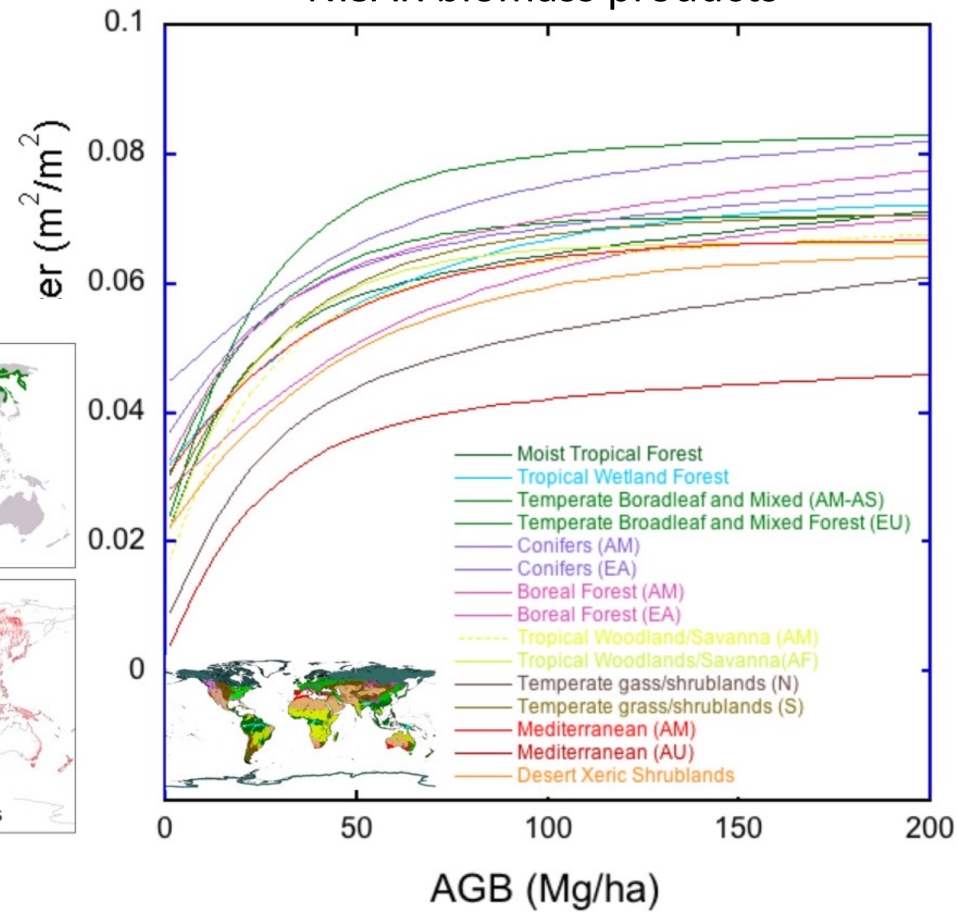






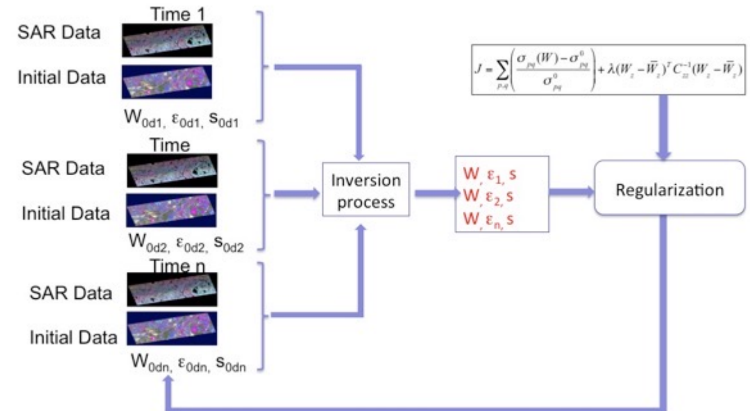
Observing System Simulation Experiment (OSSE) Results:

A total of 15 ecoregion specific backscatter models are required for NISAR biomass products

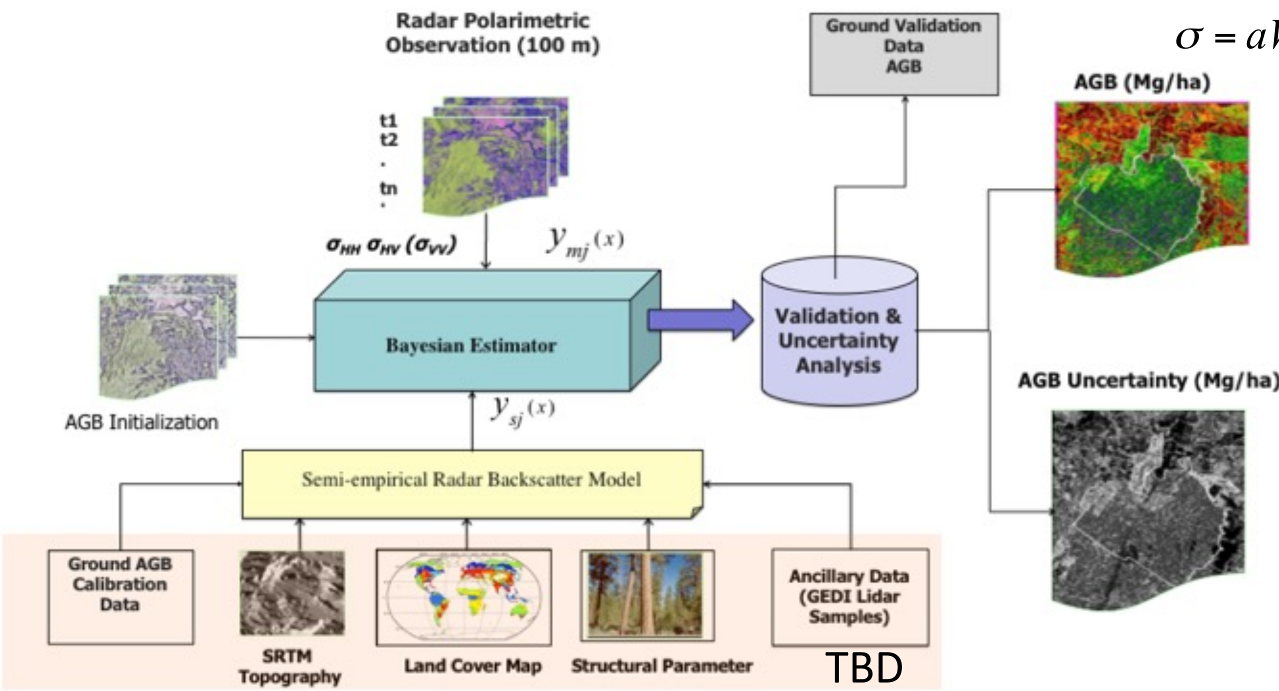


Ecosystems
Level 3 Biomass Algorithm

- Level 3 validated algorithm starts with Level 2 NISAR data products, georeferenced, ground-range, terrain-corrected NISAR imagery of HH, and HV polarizations
- Initialization will be based on existing biomass maps & typical range of soil moisture & roughness
- Global Land cover map will be used in setting the algorithm parameters



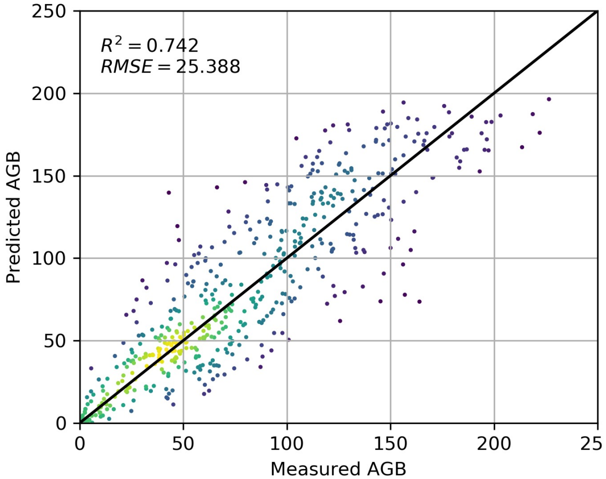
$$\sigma = aW^{\alpha}(1-e^{-\beta W}) + c\Gamma W^{\gamma} e^{-\beta W} + Se^{-\beta W}$$



Calibration & Validation data will allow adjusting the algorithm parameters during the post-launch commissioning phase of mission before official data acquisition

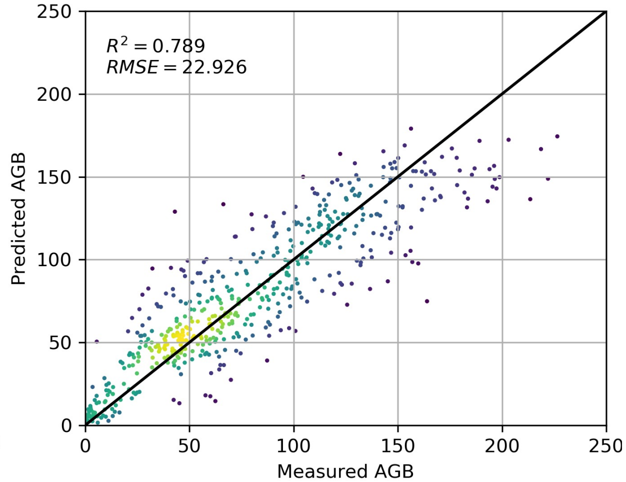
NISAR Biomass Algorithm Implementation

5 scenes summer



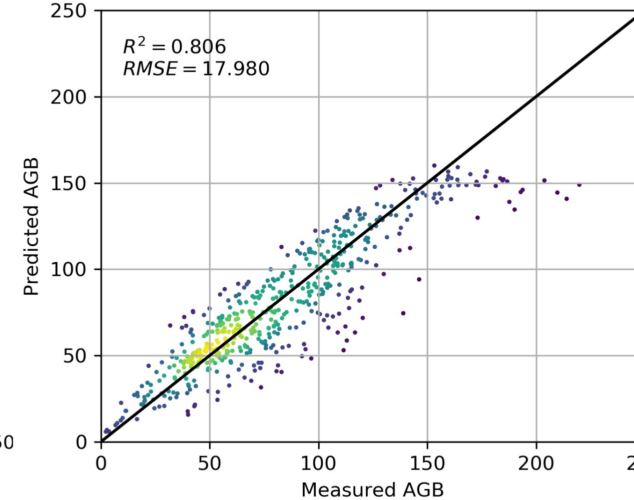
67.0% within 20 Mg/ha.
45.4% within 10 Mg/ha.

10 scenes spring & summer

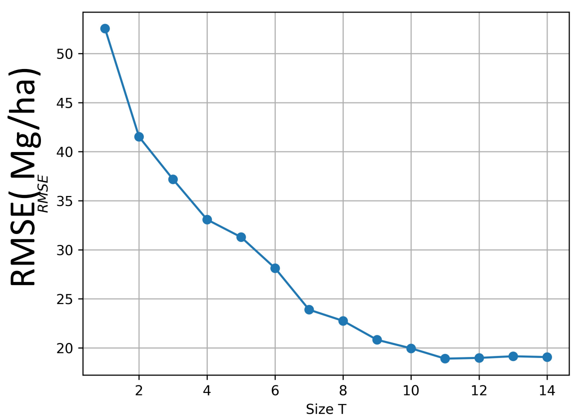


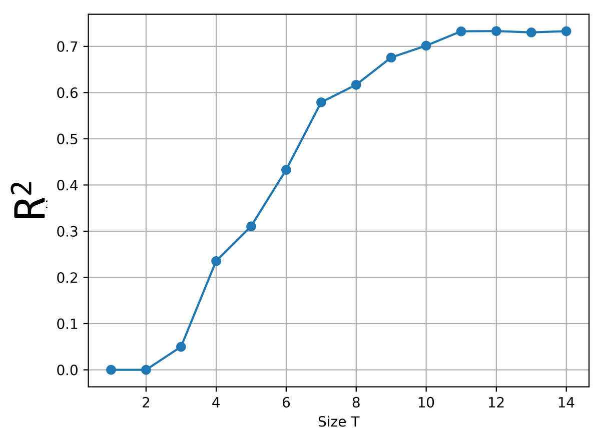
74% within ±20 Mg/ha.
46% within ±10 Mg/ha.

14 scenes spring, summer & fall



82% within ±20 Mg/ha.
51% within ±10 Mg/ha.

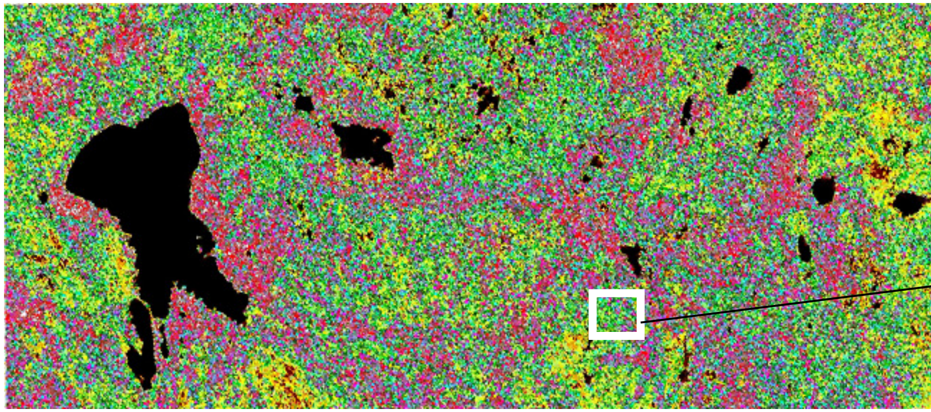


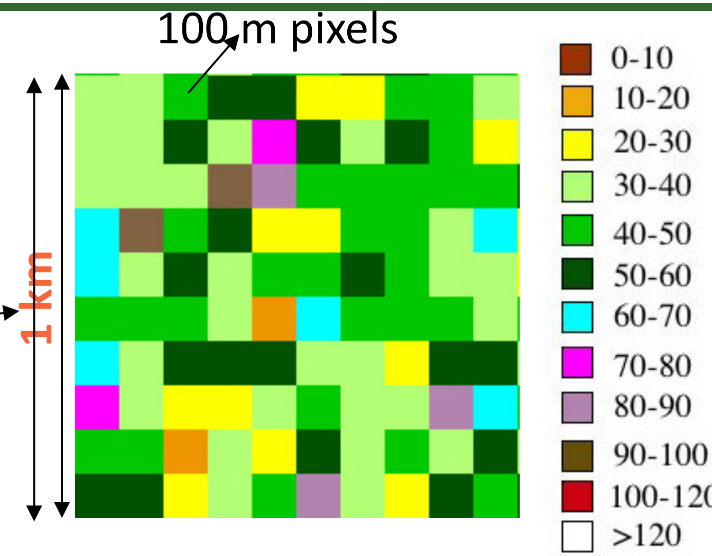


530 lidar derived biomass used in model validation

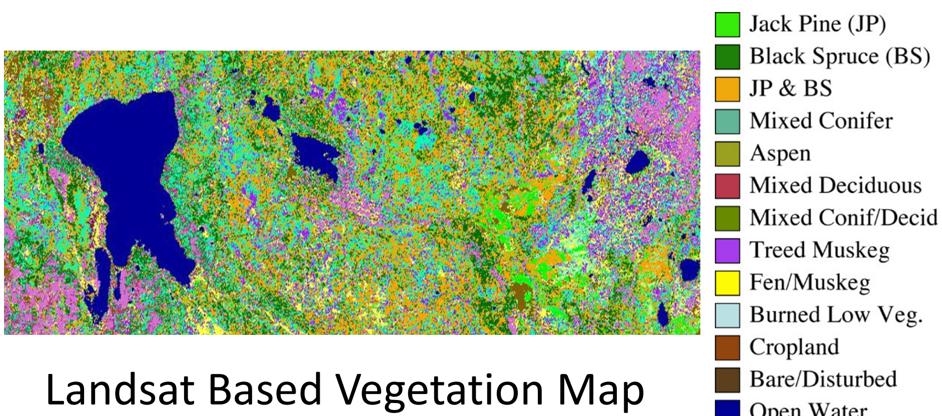
Winter scenes with snow cover require model improvement

Biomass Estimation from SAR Polarimetry

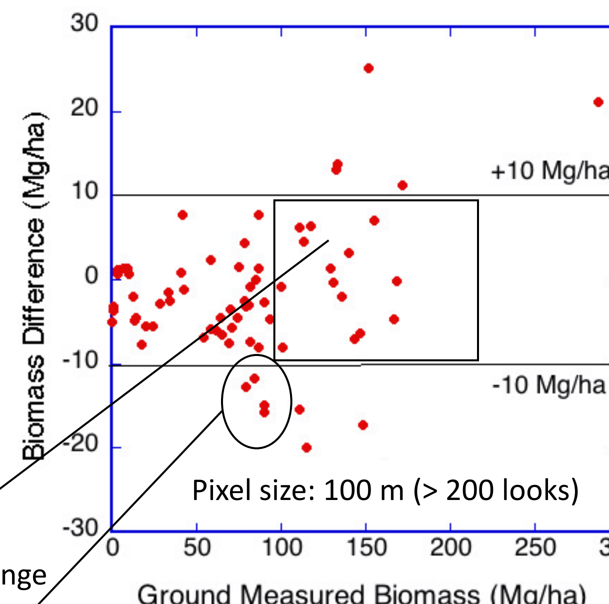




L-band Radar predicted Biomass Map
BOREAS Study Area
(Ranson et al. 1995)
(Saatchi & Moghaddam, 2000)



Landsat Based Vegetation Map

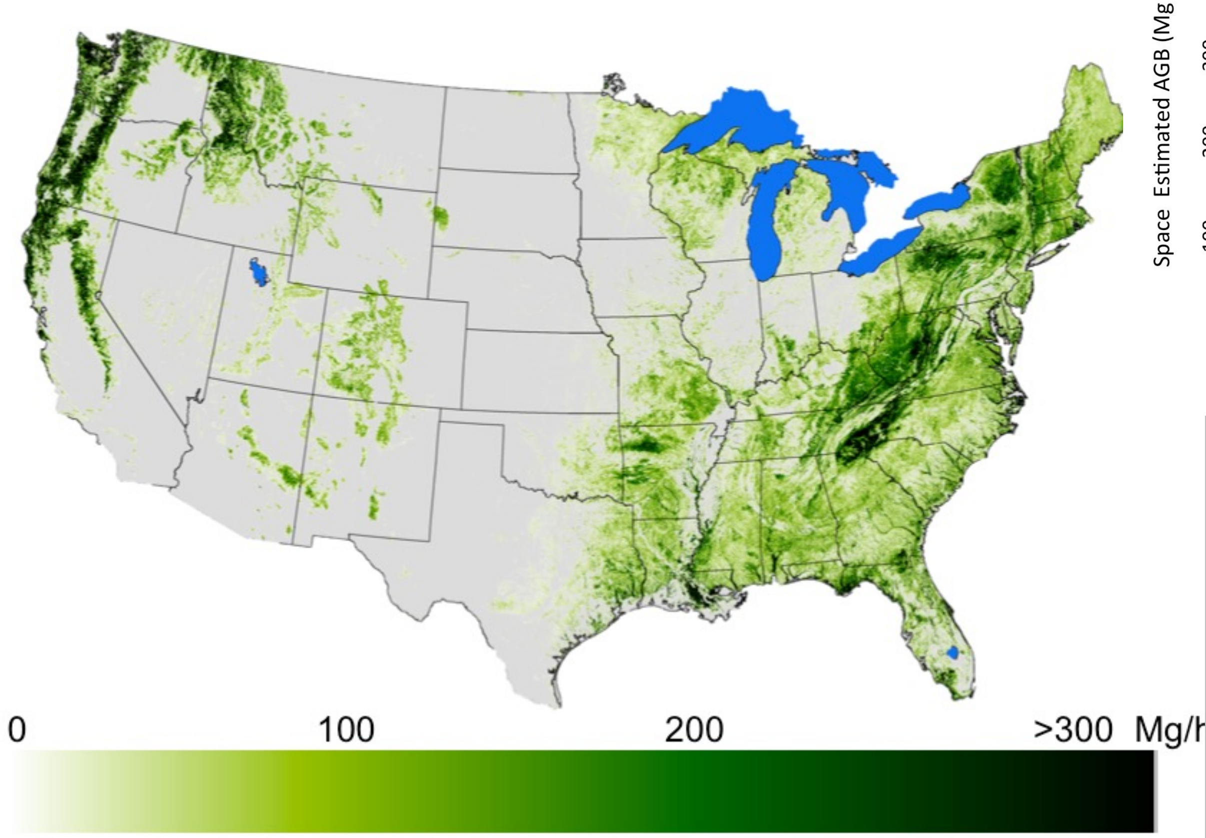


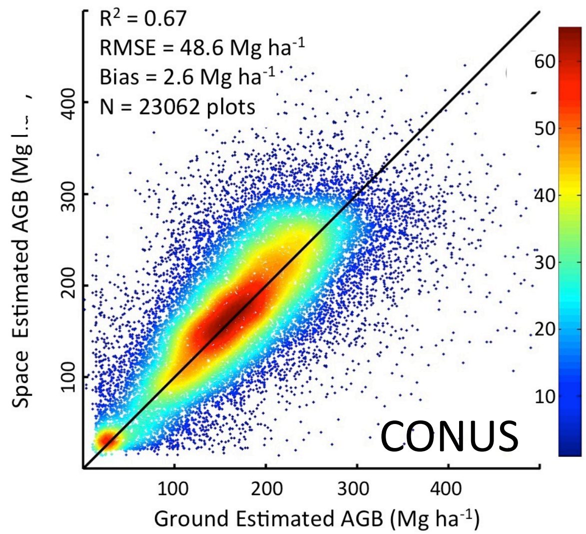
Possible areas of extended range

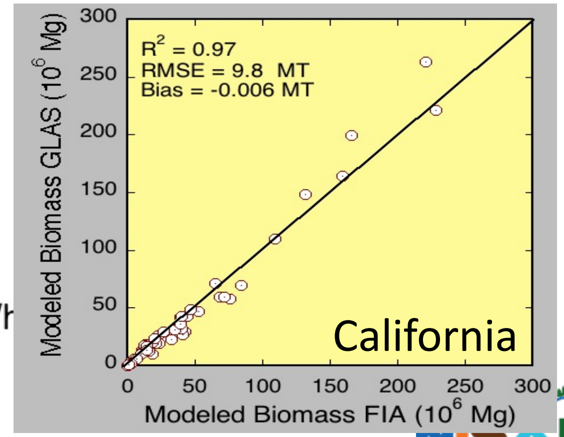
Possible areas of larger errors

CONUS Carbon Stock and Uncertainty

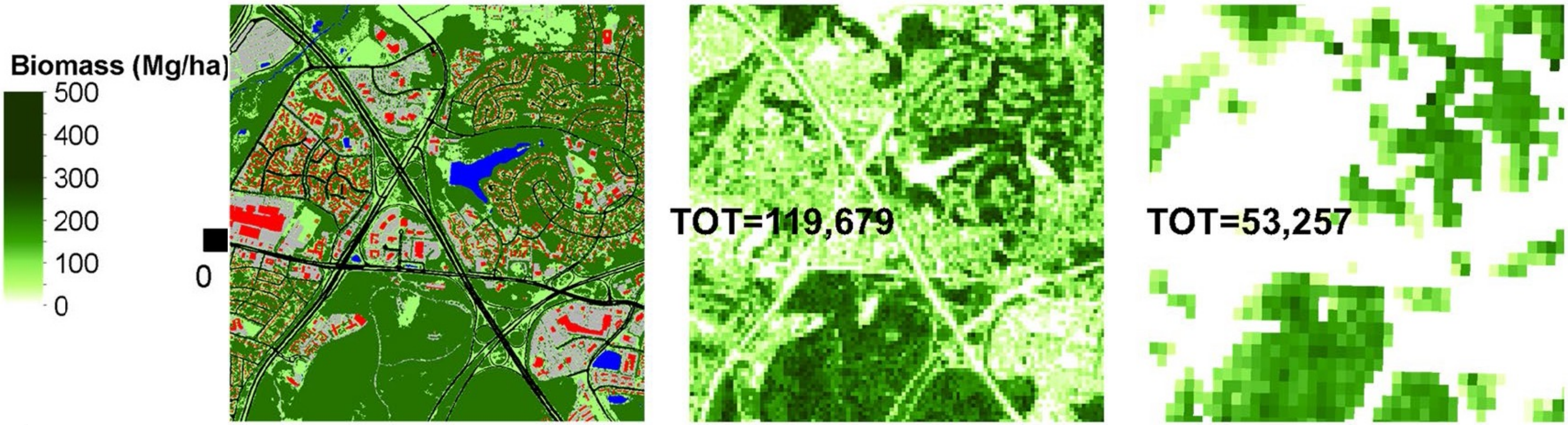
Large Scale Annual Forest Biomass Mapping

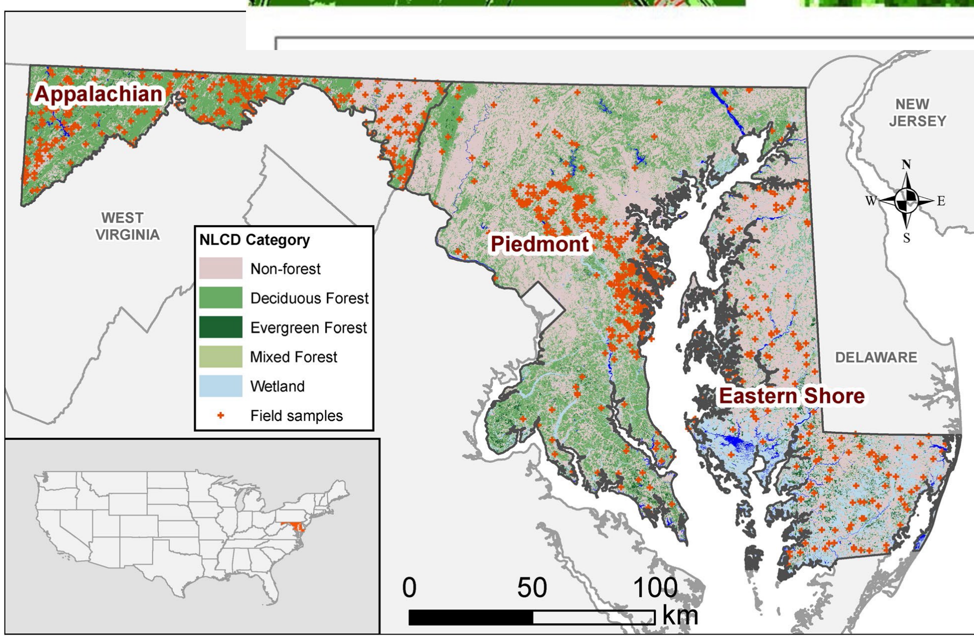


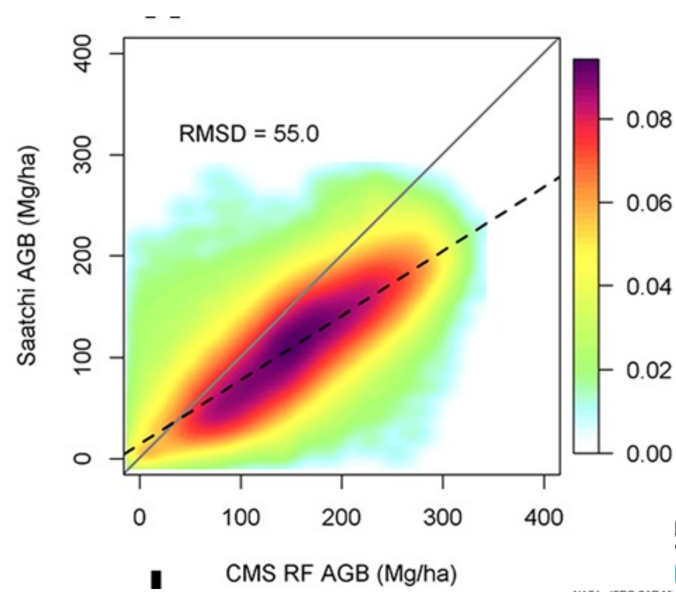




Validation of biomass product with ground and lidar



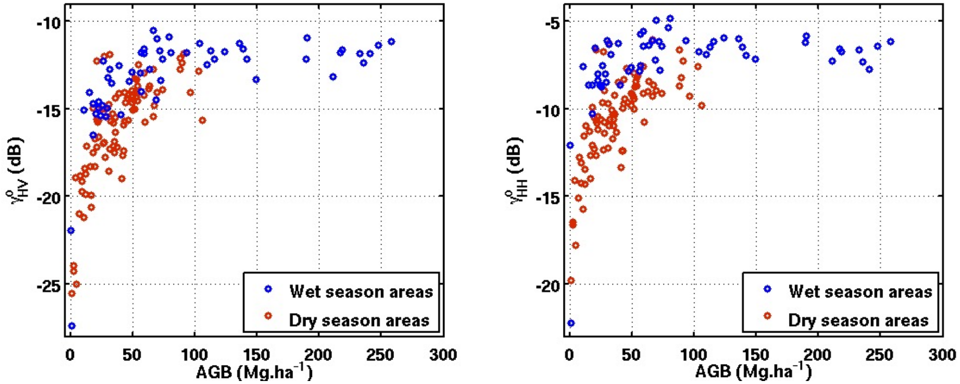


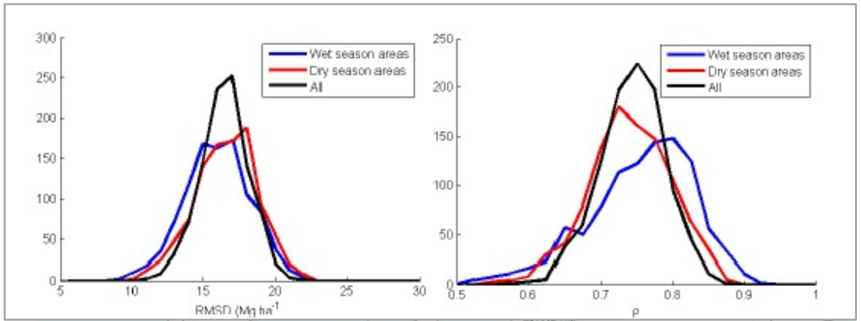


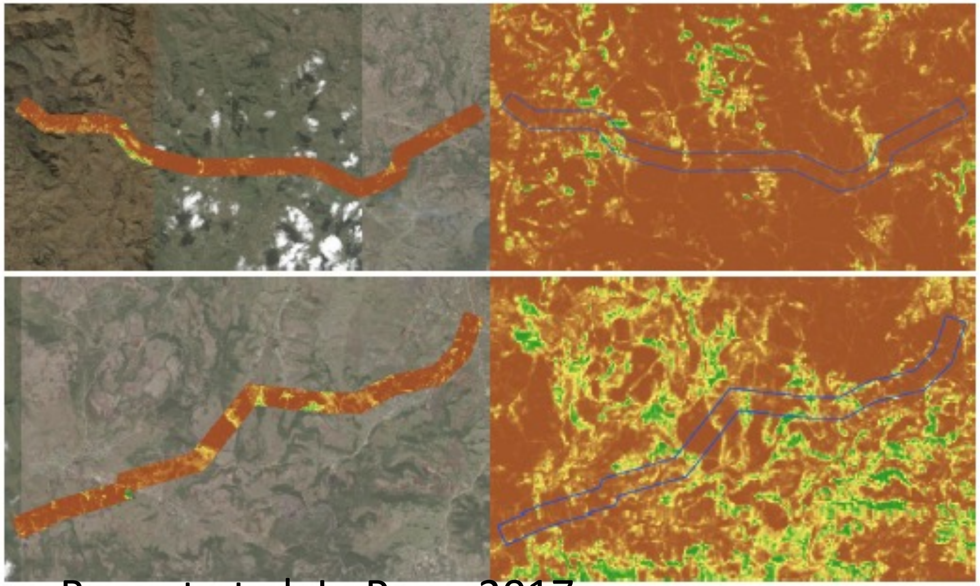
NASA - ISRO SAR Mission

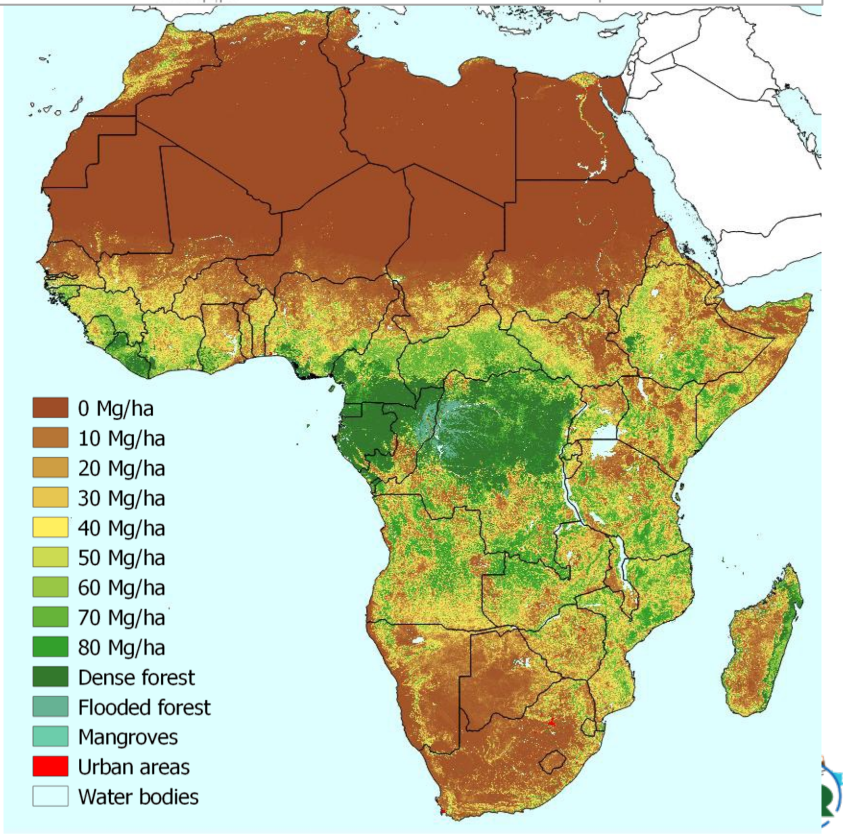
Large Scale Biomass Mapping

$$\sigma^0 = Ax^{\alpha}(1 - e^{-Bx}) + Cx^{\beta}e^{-Bx} + D$$



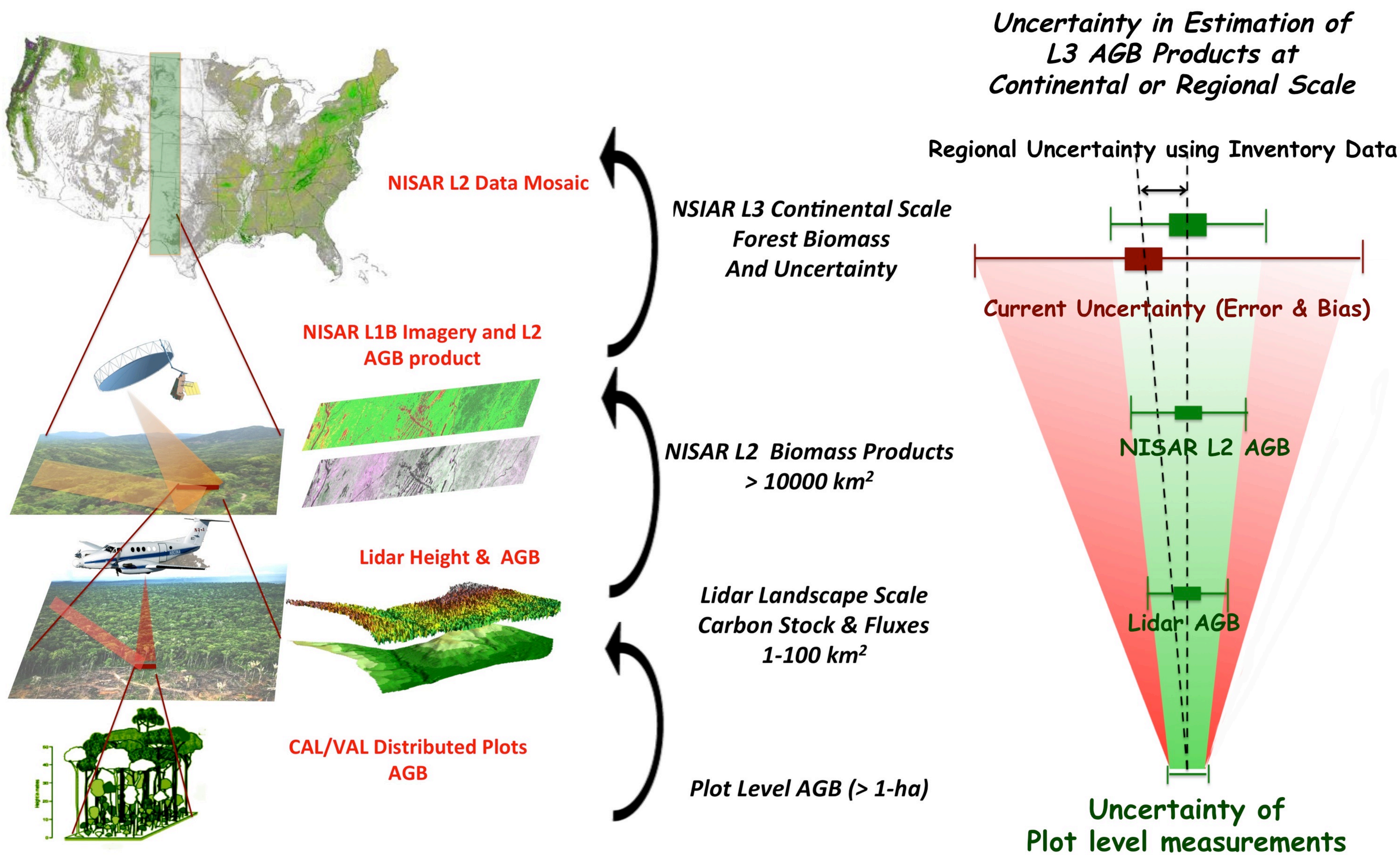






Bouvet et al. In Press 2017

NISAR Biomass CAL/VAL Approach



Validation Methods, Resources, Data Availability

Validation**: The process of assessing the relationship or the quality of data products derived from a measuring instrument by independent means and reporting the uncertainty: **Uncertainty Assessment of Products

- Validation process must provide unambiguous achievement of science requirements for L2 products
- Uncertainty assessment must follow accepted approaches, based on direct comparison with independent correlative measurements, and presented in normally used metrics in order to facilitate acceptance and implementation.
- NISAR will use range of methodologies for Validation :
  - In situ networks of large biomass plots
  - Airborne based biomass products using Lidar
  - National Forest Inventory plots (NFI) for regional uncertainty assessments
  - Comparison with other satellite products for regional comparisons (GEDI, BIOMASS)

Post-launch CAL/VAL Activities

- **Calibration of algorithm using NISAR data**
  - Perform algorithm adjustments using selected sites within first 180 days of the mission
- **Validation of algorithm and data products**
  - Perform validation of algorithm over the sites with high quality plots and lidar data
  - Support acquisition of airborne lidar (including ground plots if required) for validation sites (
  - Perform statistical regional comparison using updated NFI data from different countries
  - Perform regional comparisons with other satellite products for consistency of patterns and products (GEDI and BIOMASS)

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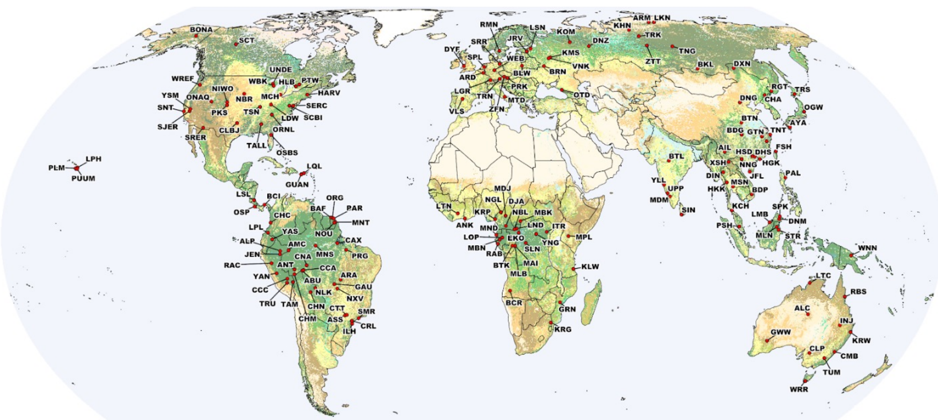
Ecosystem Cal/Val sites → S-band coverage

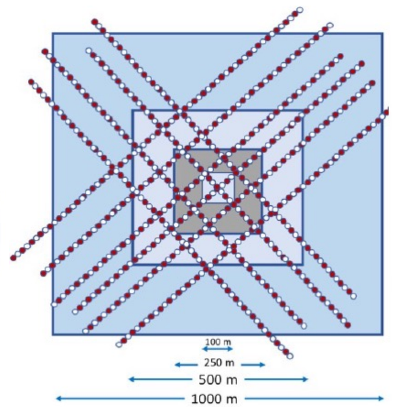
- Location of Cal/Val sites (biomass, wetlands, agriculture)

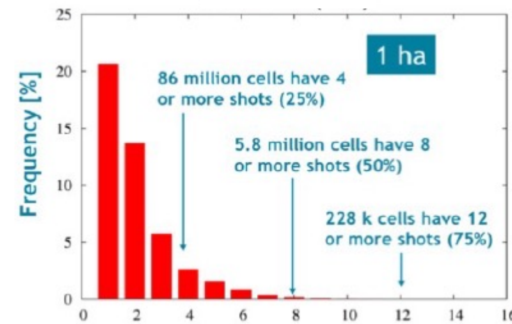
NASA - ISRO SAR Mission

NISAR-GEDI Data Fusion

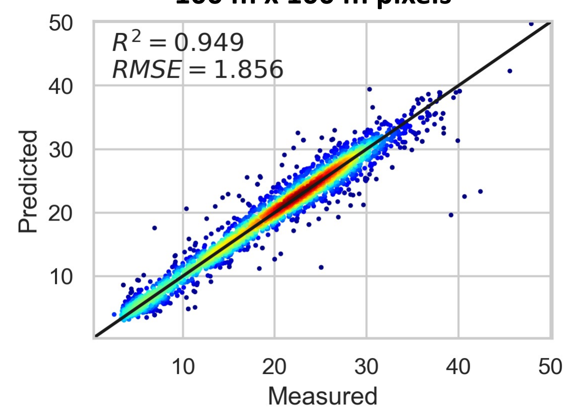


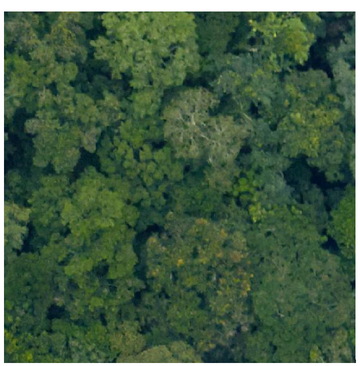
Supersites for Biomass Map Validation

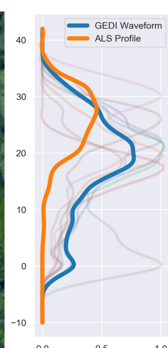


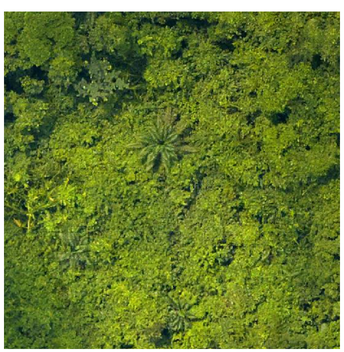


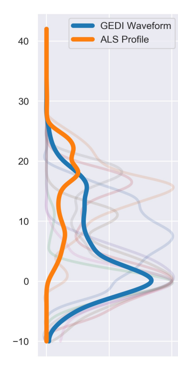
100 m x 100 m pixels





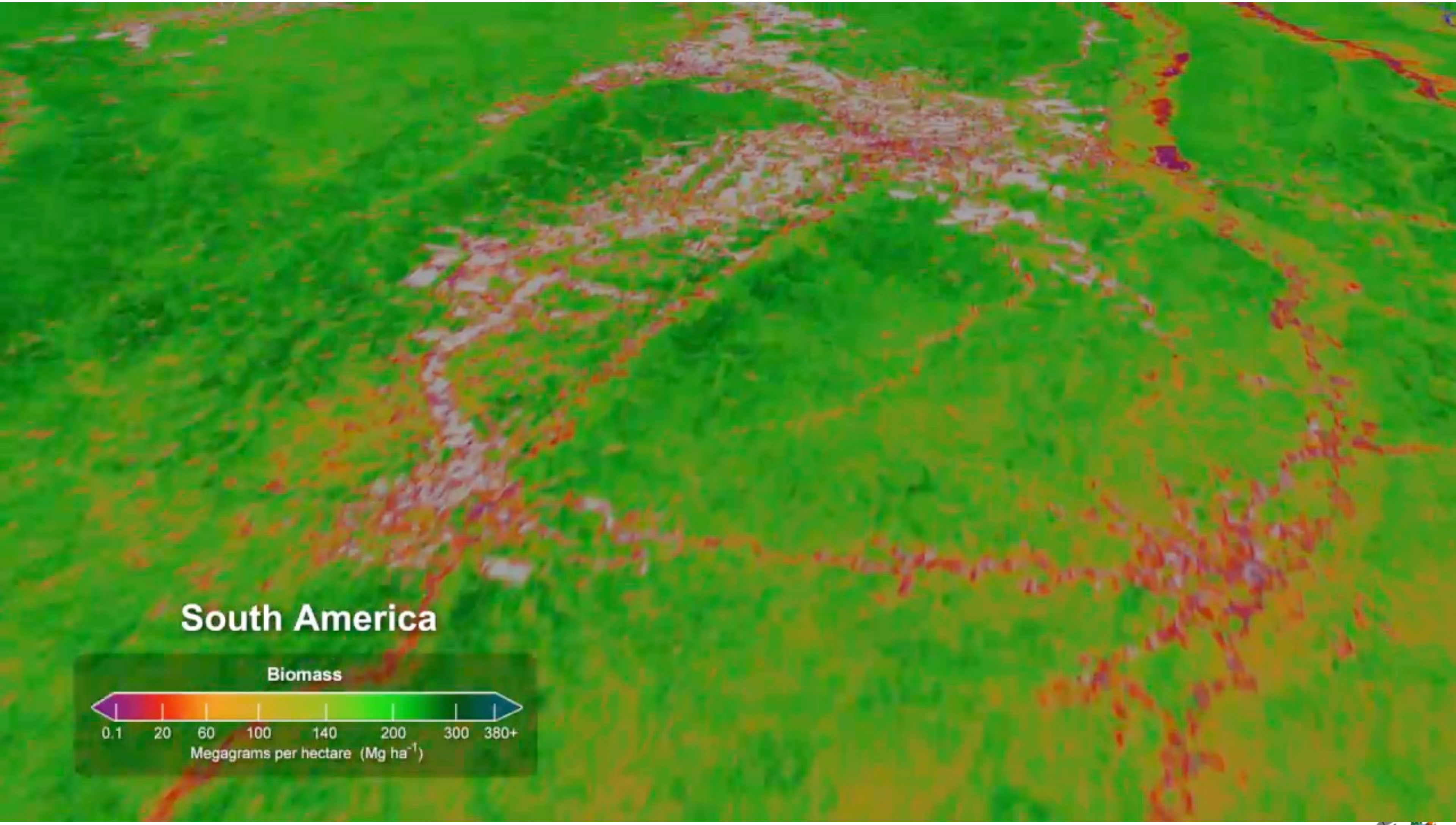






NISAR/GEDI Data Fusion

Simulations from GLAS Lidar and ALOS/PALSAR



NASA - ISRO SAR Mission

Summary

NISAR will provide the first forestry dedicated global observations for:

- Monitoring forest carbon stocks and changes
- Monitoring changes of forest cover from disturbance (fire, hurricane, insects, droughts)
- Monitoring recovery of forest after disturbance or timber logging
- Monitoring forest health and productivity by providing habitat structure