ESA's Earth Explorer BIOMASS Workshop
XVII (17) EEBIOMASS Special Session

NISAR for Ecosystems

14:05 – 14:35 CET

Paul Siqueira

Microwave Remote Sensing Laboratory

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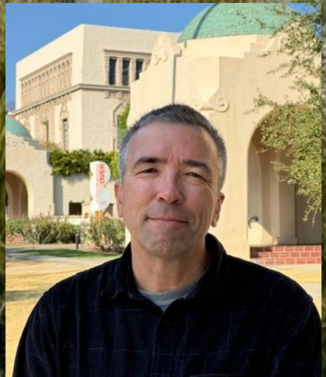
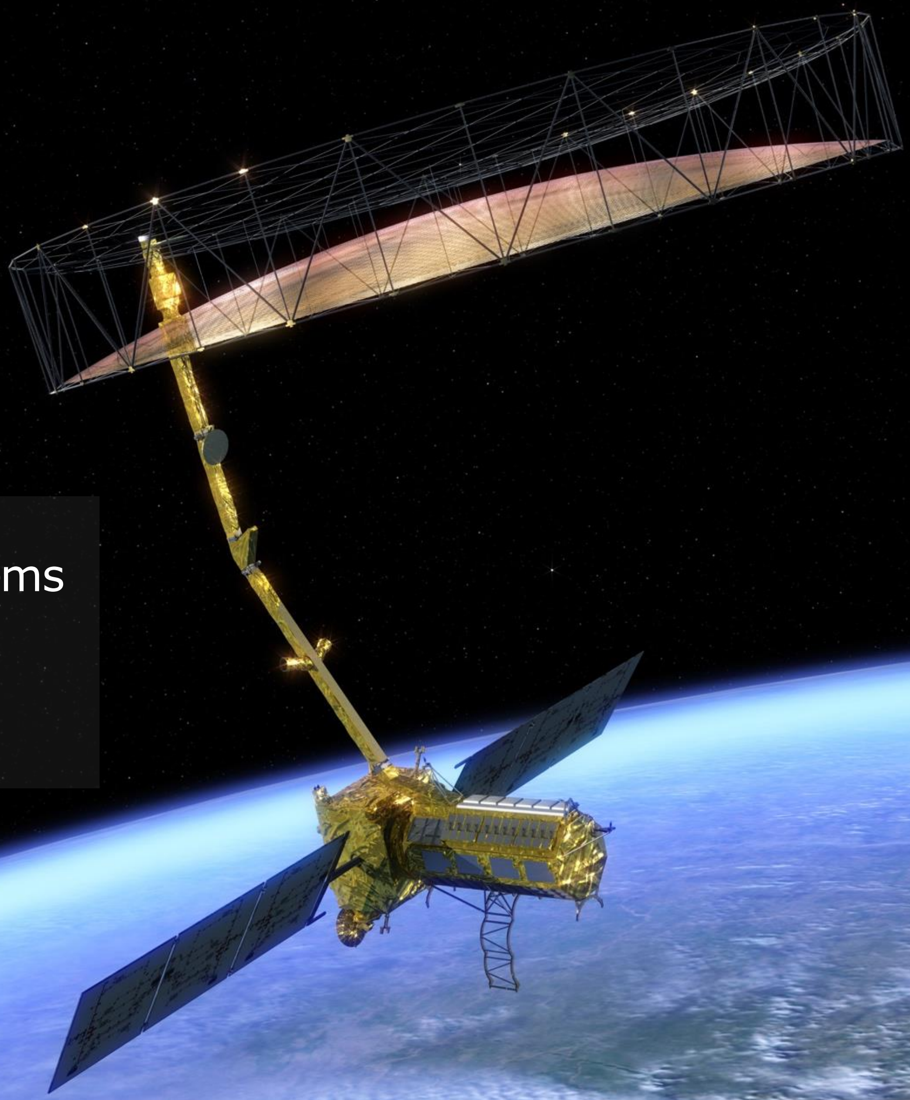
Caltech, Geological and Planetary Sciences (GPS)



Ecosystem Science with NISAR



Paul Siqueira
Lead NISAR Ecosystems Science Team

UMass /Amherst

Ralph Dubayah,
John Armston UMD

Bruce Chapman,
Sassan Saatchi,
Alex Christensen,
KC Cushman,
Erika Podest, JPL

Anup Das,
Chakrapani Patnaik,
ISRO

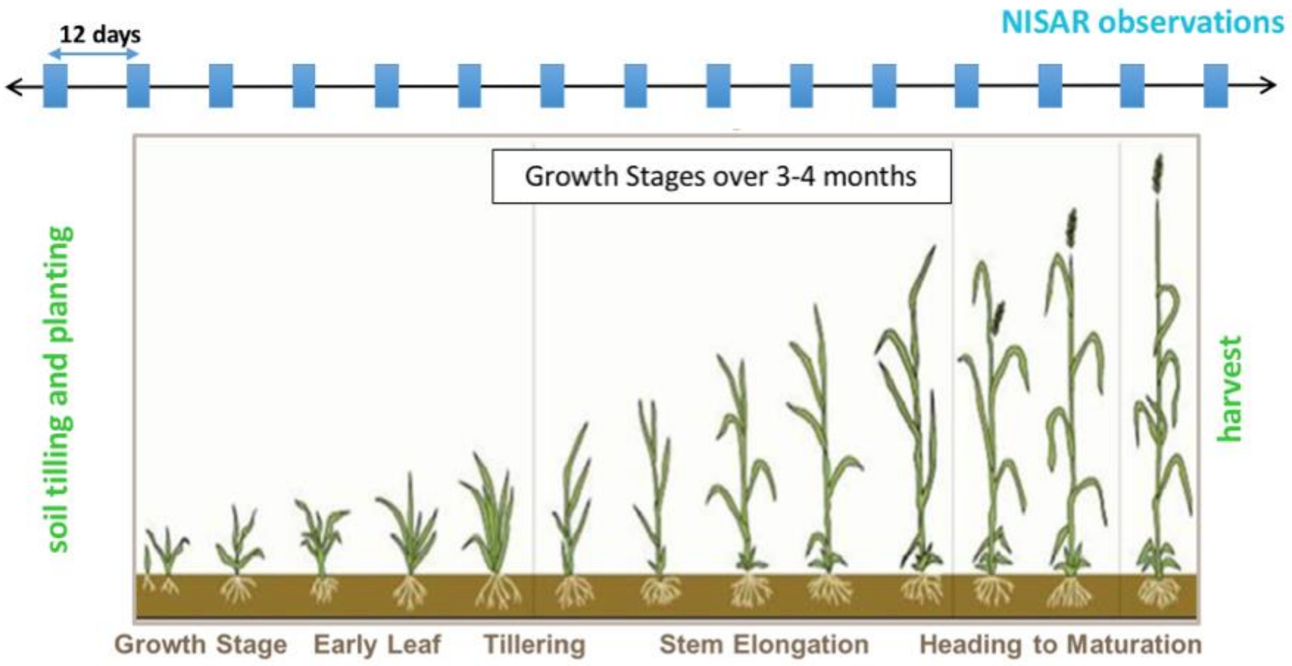
Josef Kellndorfer,
Earth Big Data

Kyle McDonald,
Nick Steiner CCNY

Narayanarao
Bhogapurapu,
UMass

- Biomass
- Disturbance
- Inundation
- Agriculture

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



NISAR is in its final stages of integration and test!

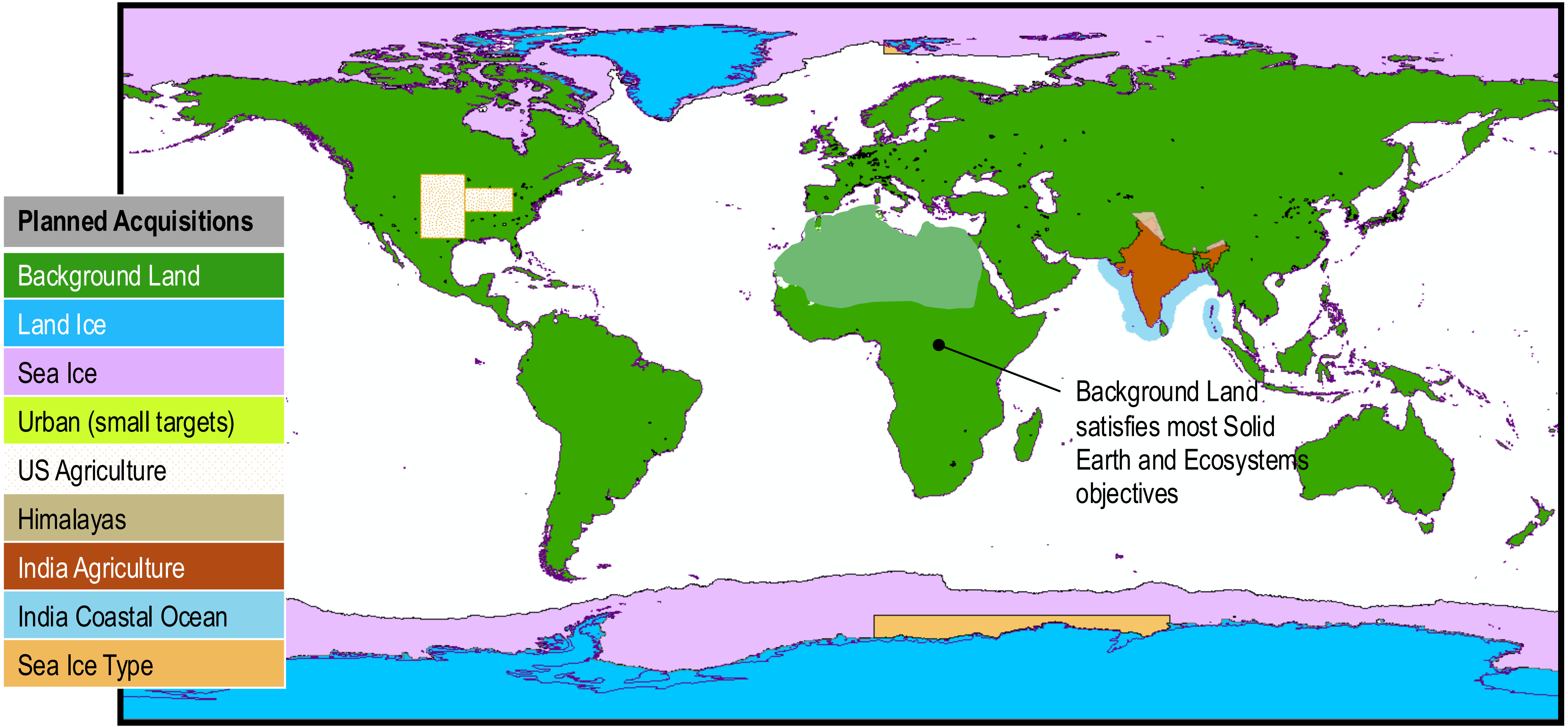
What defines ecosystems?

- Ecosystems
  - Vegetation: Forests, Agriculture, Woody encroachment & Desertification
  - Biodiversity: Forests as a biomarker for habitats
  - Ecosystems services: O2, water purification, fire control, resources
  - Marker of change in our environment

- Driven by the water cycle
- Structural components span the range of centimeters to meters
- Global in extent
- Vertical structure, horizontal distribution, complexity of living organizisms
  - Dual- and Quad-polarization are interesting tools to explore

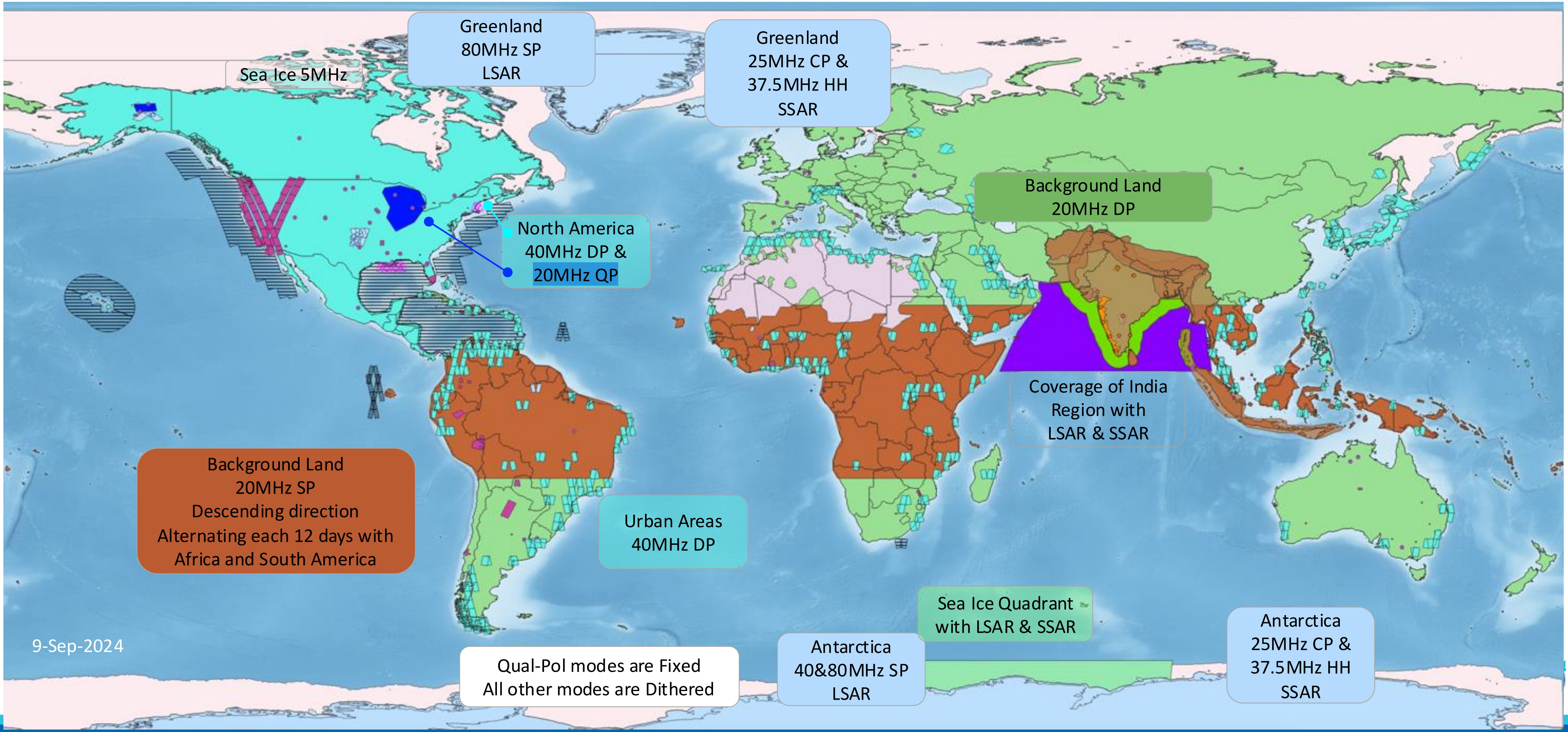
Mode-Specific Science Targets in Observation Plan

- 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



US-Quad-pol collection over the states of Illinois, Michigan, Ohio, and parts of Alaska.

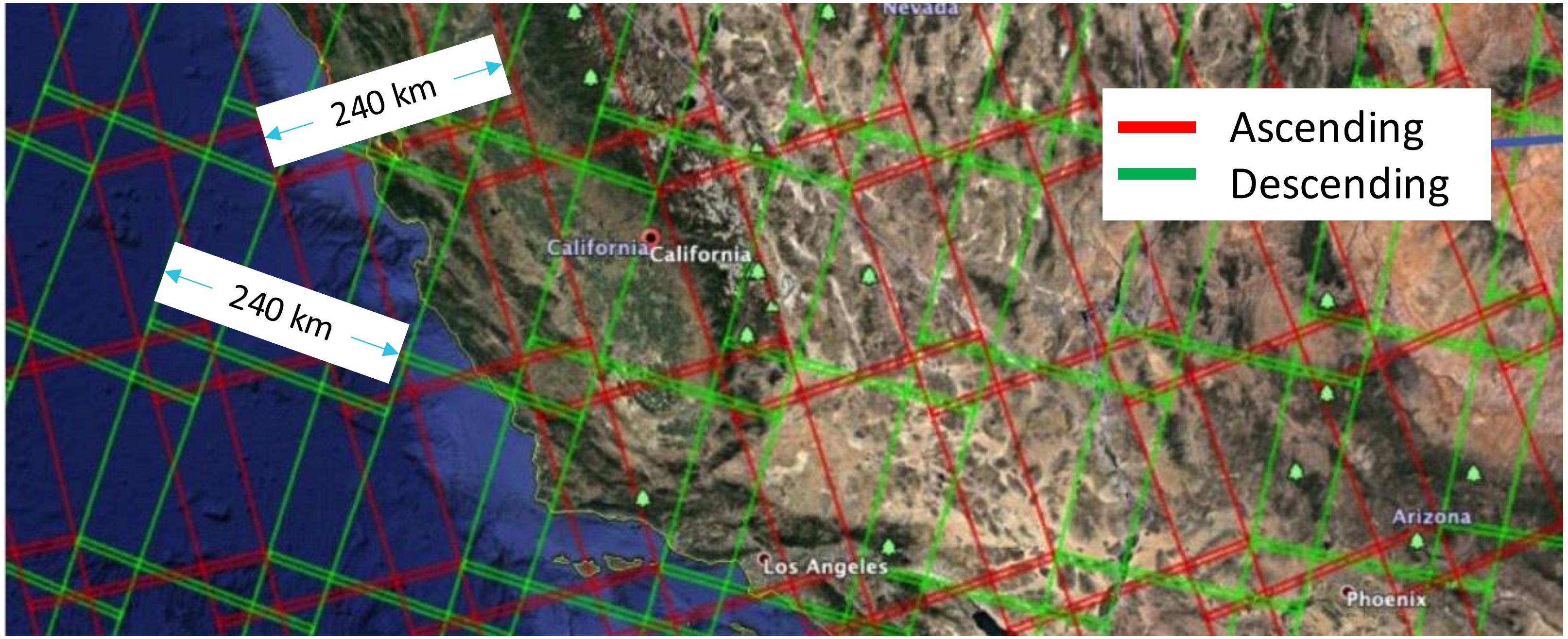
More detailed mode coverage



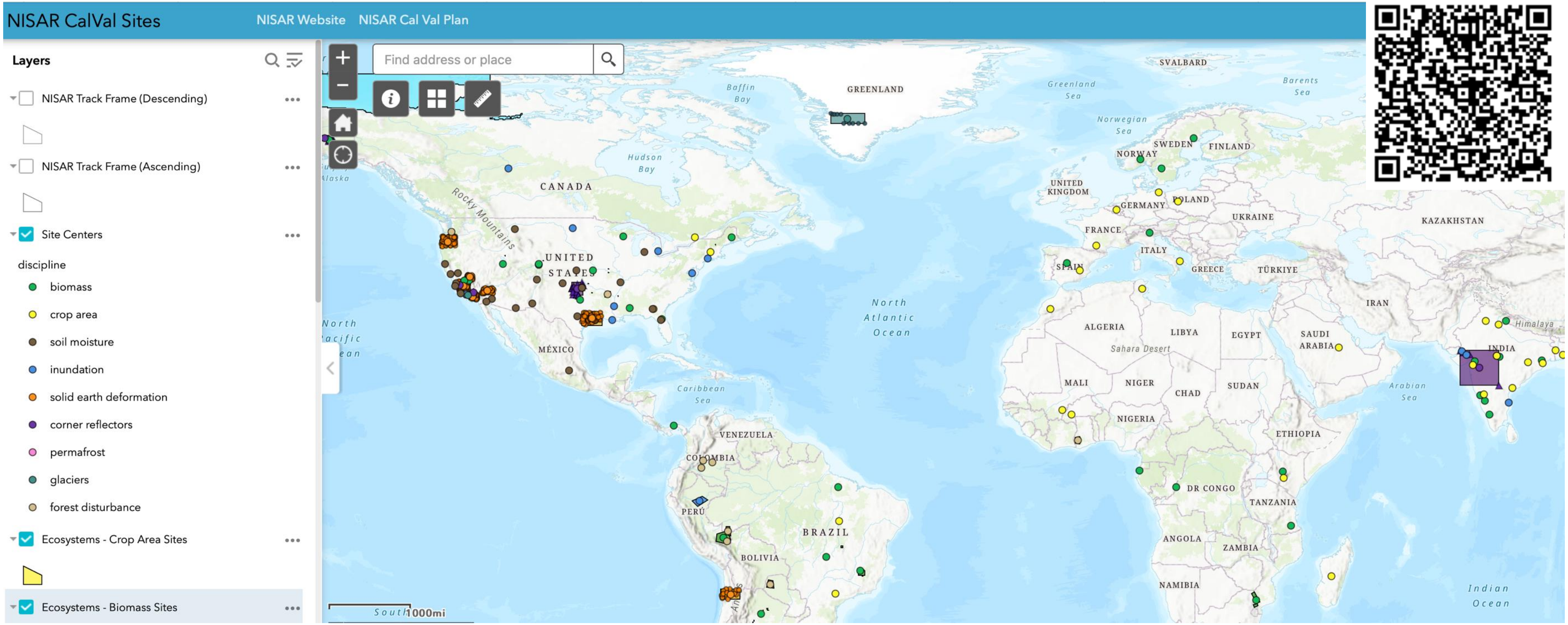
9-Sep-2024

Track/Frame Data Collection

- Data are planned to be collected in track/frame coordinate system
- 173 unique tracks that comprehensively span the equator
- Within a single track/frame, data collection mode will be uniform, at the lowest bandwidth
- Higher bandwidth segments delivered separately

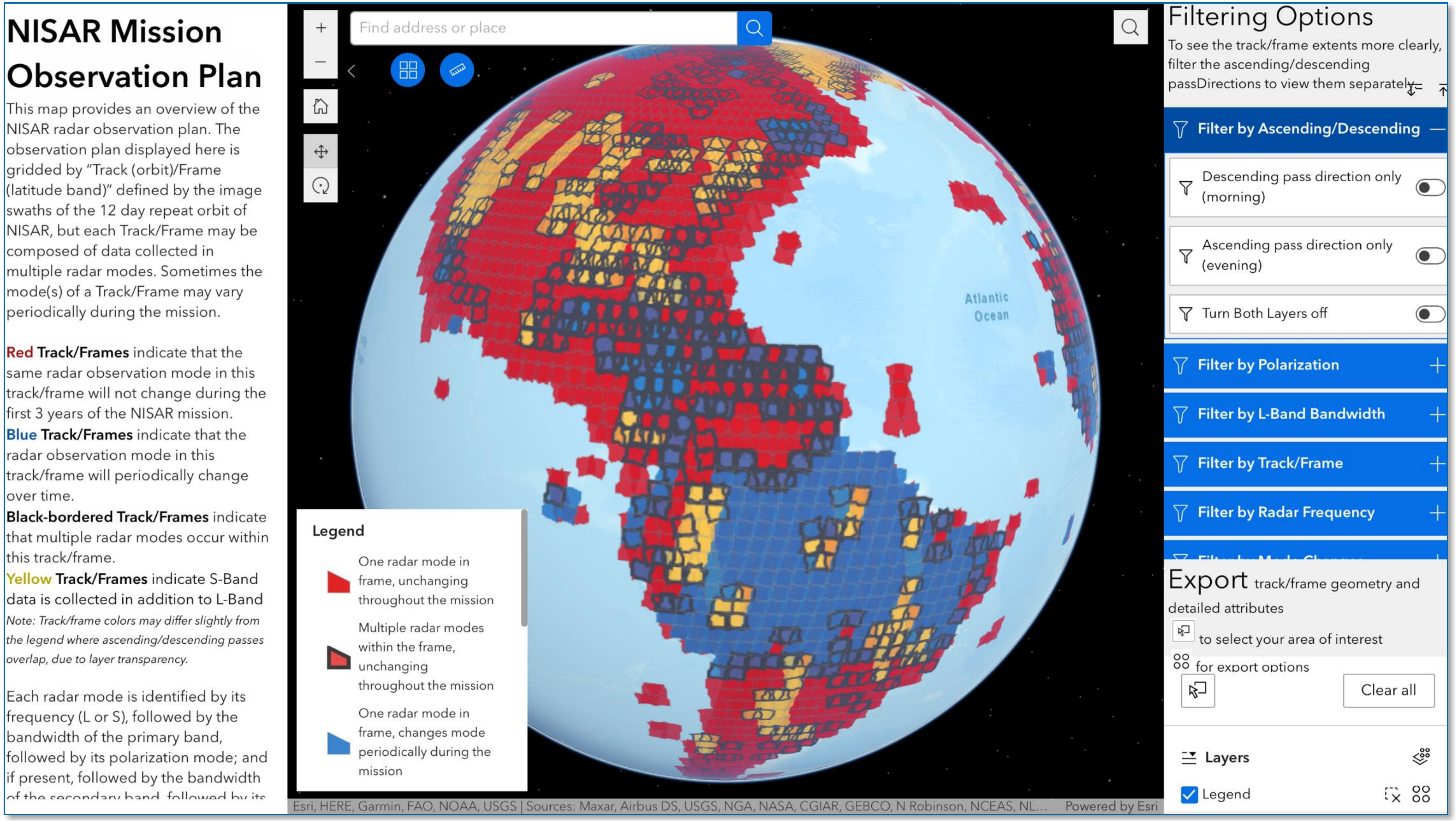


Cal/Val Sites & Track/Frame database



- Use the QR code above to go to the website that shows the track/frames and different cal/val sites

NISAR Mission Observing plan

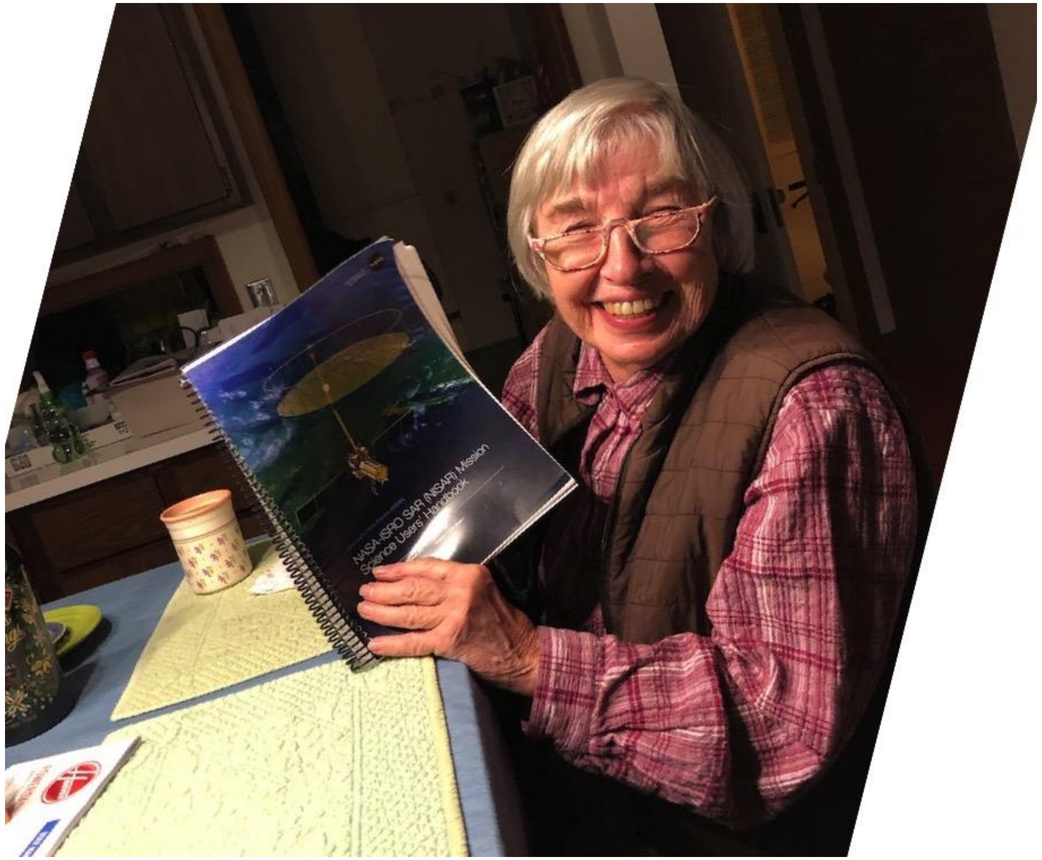


NISAR modes and track frame can also be explored via the observing plan website.

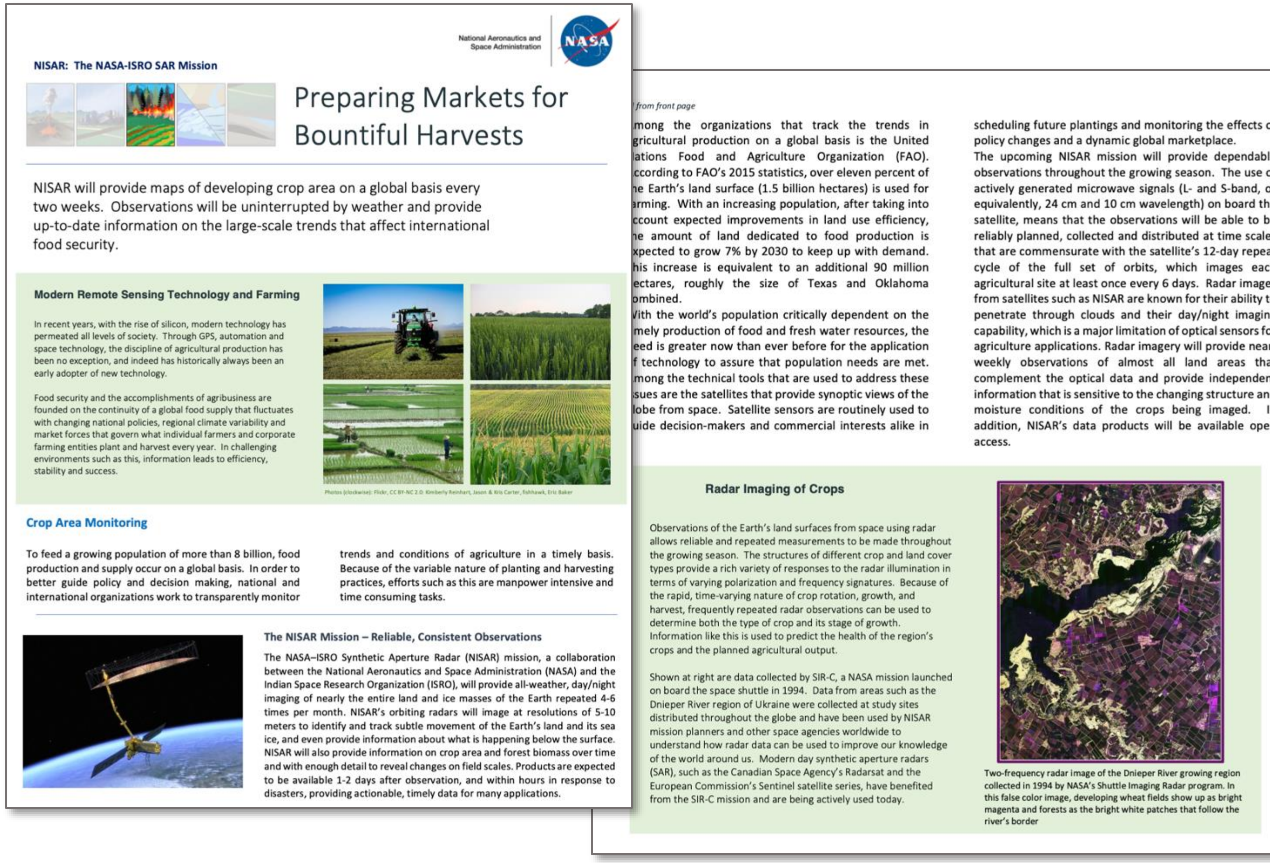
Data can be selected and explorted into different formats (JSON, etc.)

NISAR
Learn More

- NISAR science handbook
  - Available now as a pdf (nisar.jpl.nasa.gov/getengaged/resources/)
  - Being updated now



- NISAR applications white papers
  - 26 one-page double sided suitable for printing flyers



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.

from front page

mong the organizations that track the trends in gricultural production on a global basis is the United lations Food and Agriculture Organization (FAO). ccording to FAO's 2015 statistics, over eleven percent of he Earth's land surface (1.5 billion hectares) is used for arming. With an increasing population, after taking into ccount expected improvements in land use efficiency, he amount of land dedicated to food production is xpected to grow 7% by 2030 to keep up with demand. his increase is equivalent to an additional 90 million ectares, roughly the size of Texas and Oklahoma ombined.

Vith the world's population critically dependent on the mely production of food and fresh water resources, the eed is greater now than ever before for the application f technology to assure that population needs are met. mong the technical tools that are used to address these sues are the satellites that provide synoptic views of the lobe from space. Satellite sensors are routinely used to uide 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.

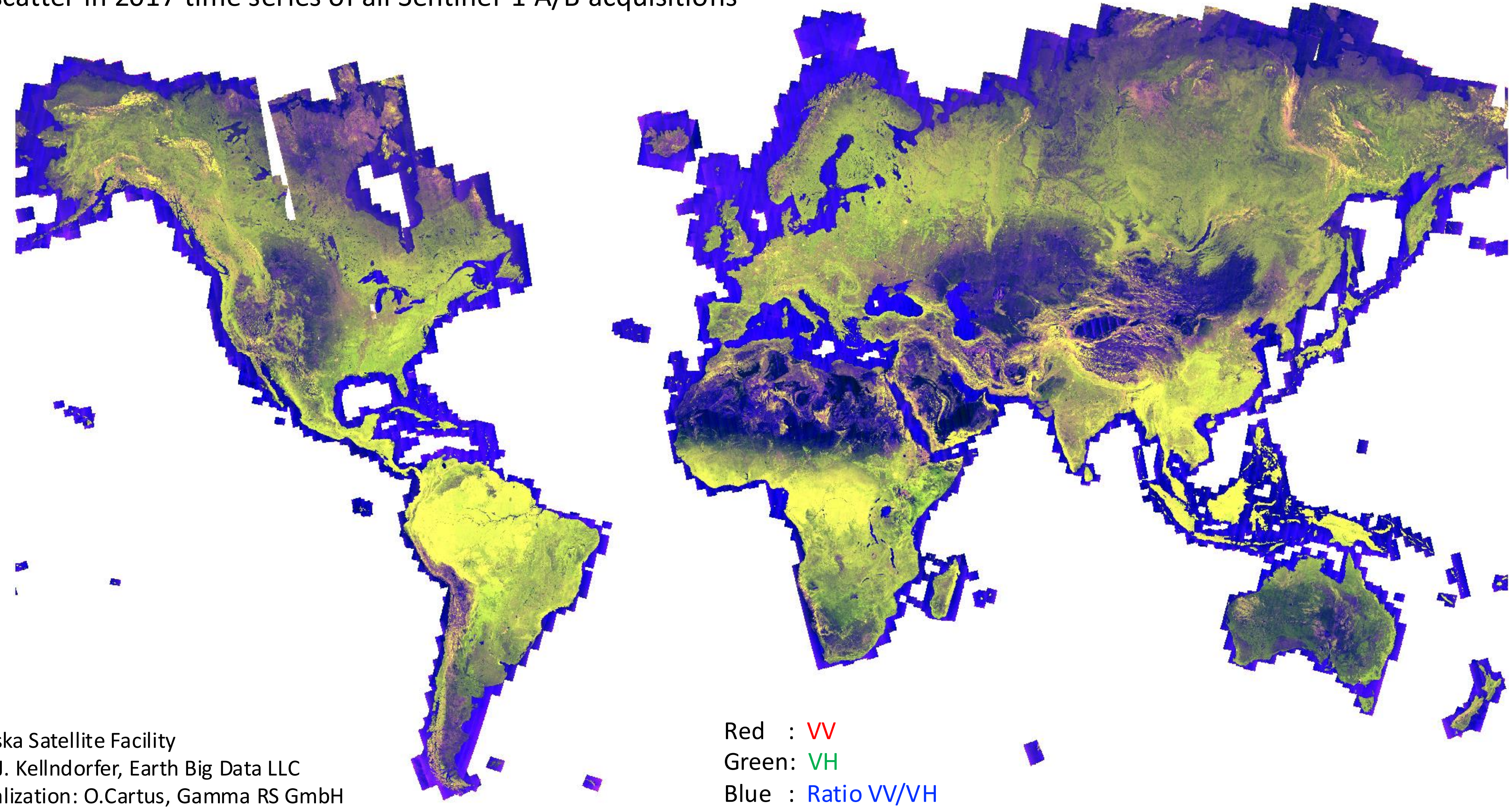
Shown at right are data collected by SIR-C, a NASA mission launched on board the space shuttle in 1994. Data from areas such as the Dnieper River region of Ukraine were collected at study sites distributed throughout the globe and have been used by NISAR mission planners and other space agencies worldwide 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

University of Massachusetts Amherst BE REVOLUTIONARY™

2017 Sentinel-1 C-band Backscatter of Earth

Median backscatter in 2017 time series of all Sentinel-1 A/B acquisitions



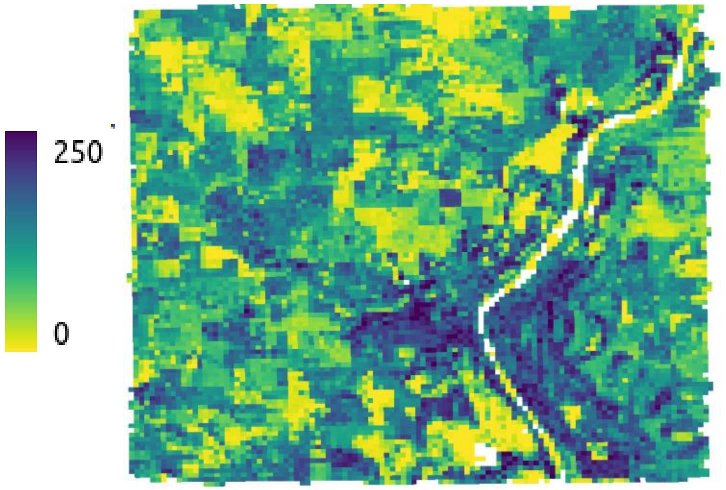
Data Source: ESA/Alaska Satellite Facility
RTC Data Processing: J. Kellndorfer, Earth Big Data LLC
Mosaicking and Visualization: O.Cartus, Gamma RS GmbH

Red : VV
Green: VH
Blue : Ratio VV/VH

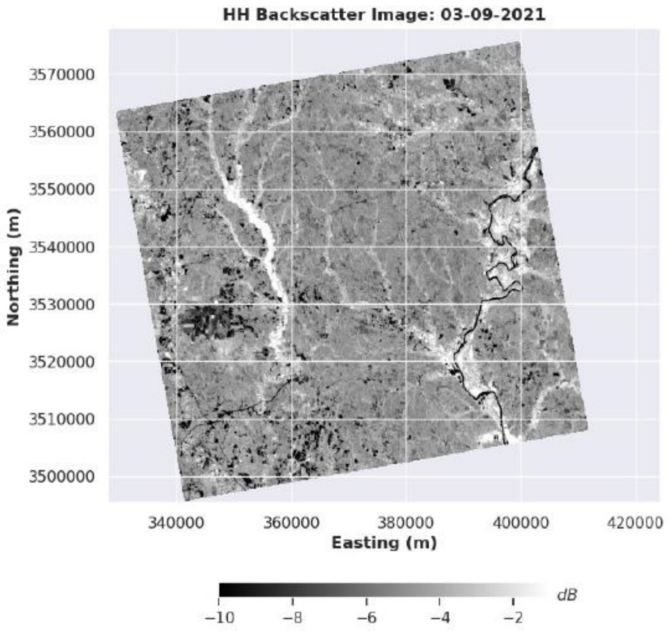
NISAR Mission at a glance

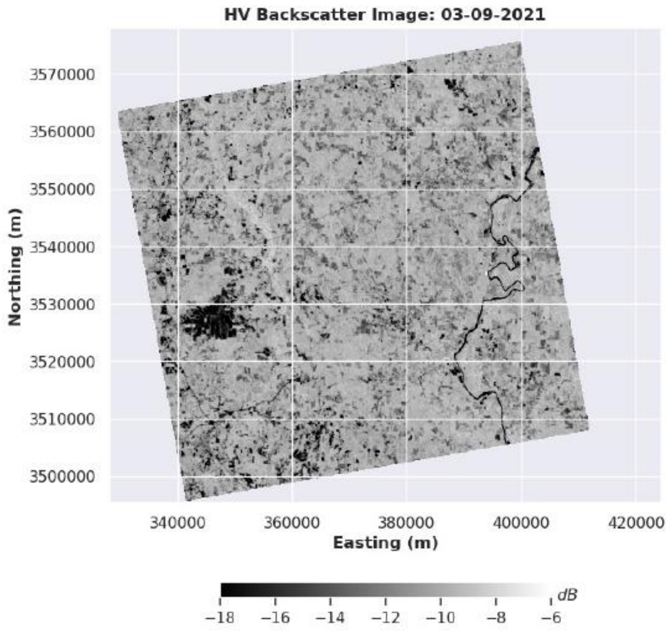
- Four Level-1 Disciplines
  - *• Ecosystems/Hydrology, • Ice Sheets, • Solid Earth Dynamics, • Applications*
- L- & S-band 12-day orbital repeat, left-looking only mission (observations are during ascending and descending passes, so effectively two observations every 12 days)
- 240 km swath using SweepSAR
- Dominant observing mode is L-band dual-pol, 20 m multi-looked resolution. S-band collected outside of India at Cal/Val sites.
- Launch coming soon!
- 4.5 TB/day data downlink
- NISAR is a requirements driven mission.
- Example of a NISAR requirement (biomass):
  - NISAR will estimate global above ground biomass up to 100 t/ha at a 1 ha resolution, with an accuracy of 20 t/ha.
- NISAR reliable time-series observations will provide an unprecedented tool for monitoring the terrestrial environment and ecological habitats
- Data downloadable via the Alaska Satellite Facility (ASF) DAAC. Amazon Web Services (AWS) primary mechanism of getting data

Biomass Highlights
ALOS-2 over NEON site, Lenoir Landing, NC

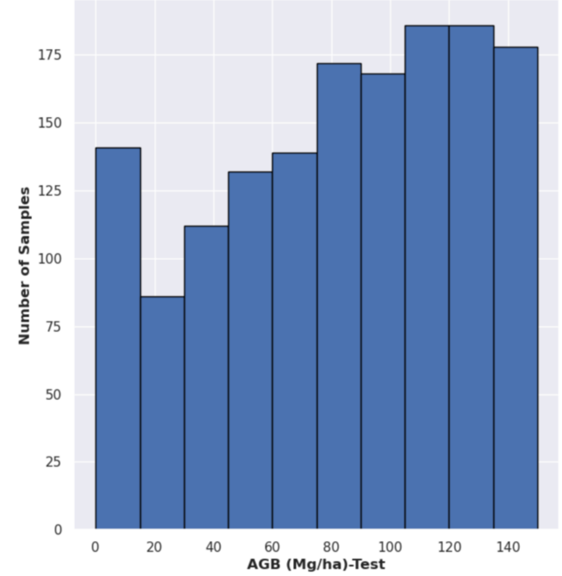


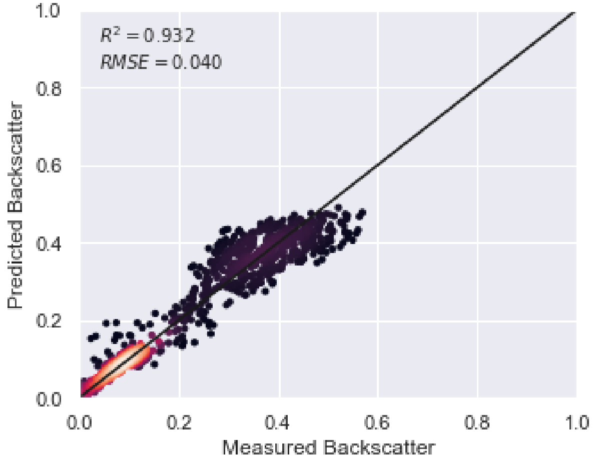
Lenoir Landing Aboveground biomass variations from ALS data

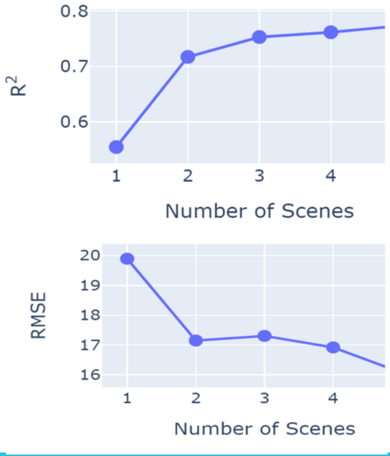


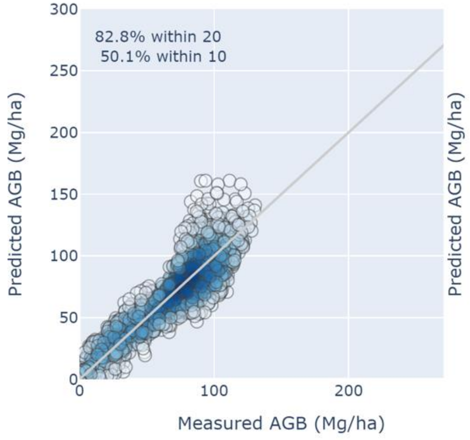


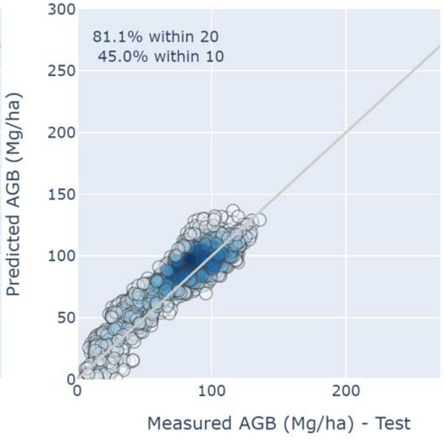
Testing Samples









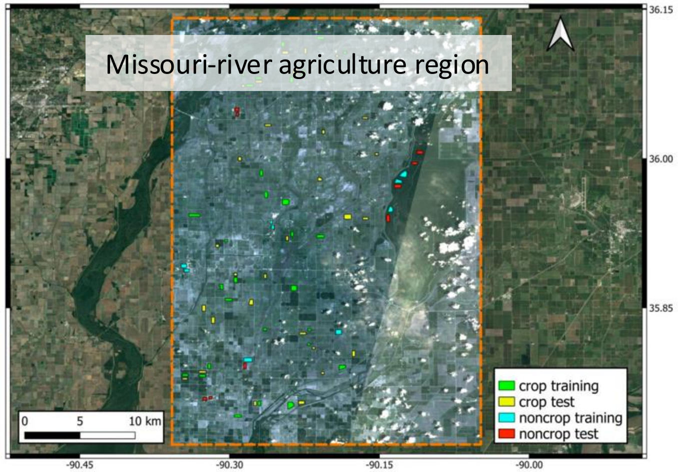


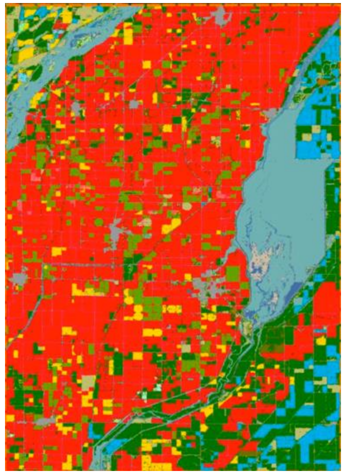
Crop Area Highlights

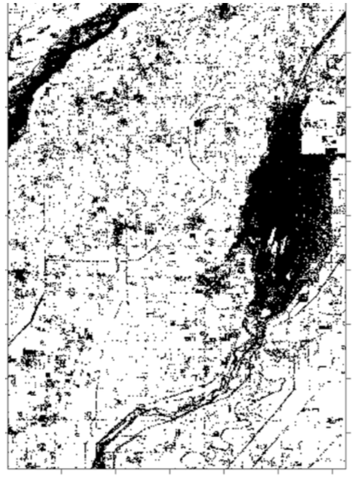
Classification of Crop Area using PALSAR, Sentinel-1, and Planet Data for the NISAR Mission

remote sensing

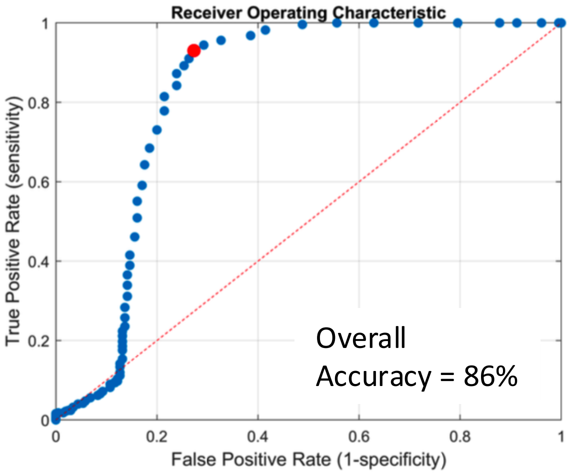
G. Anconitano, S. Kim, B. Chapman, J. Martinez, P. Siqueira and N. Pierdicca



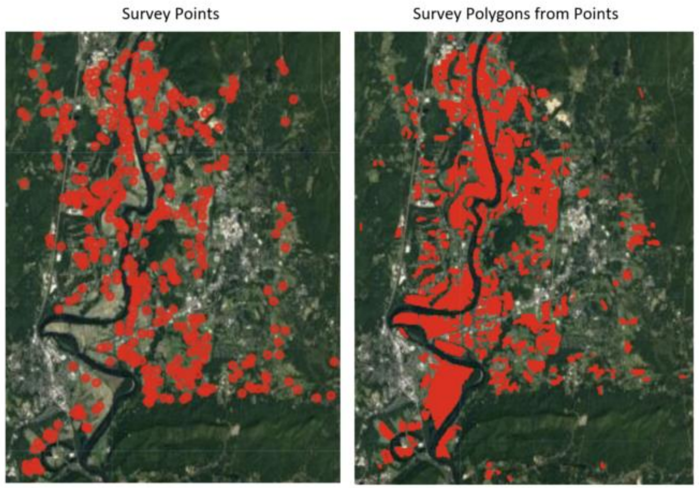


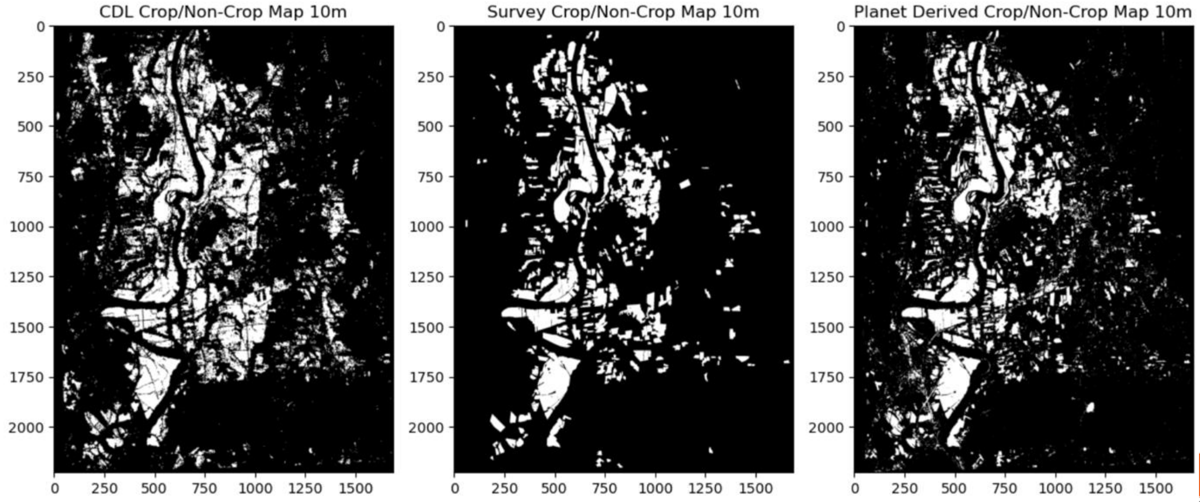


L-band ALOS HV

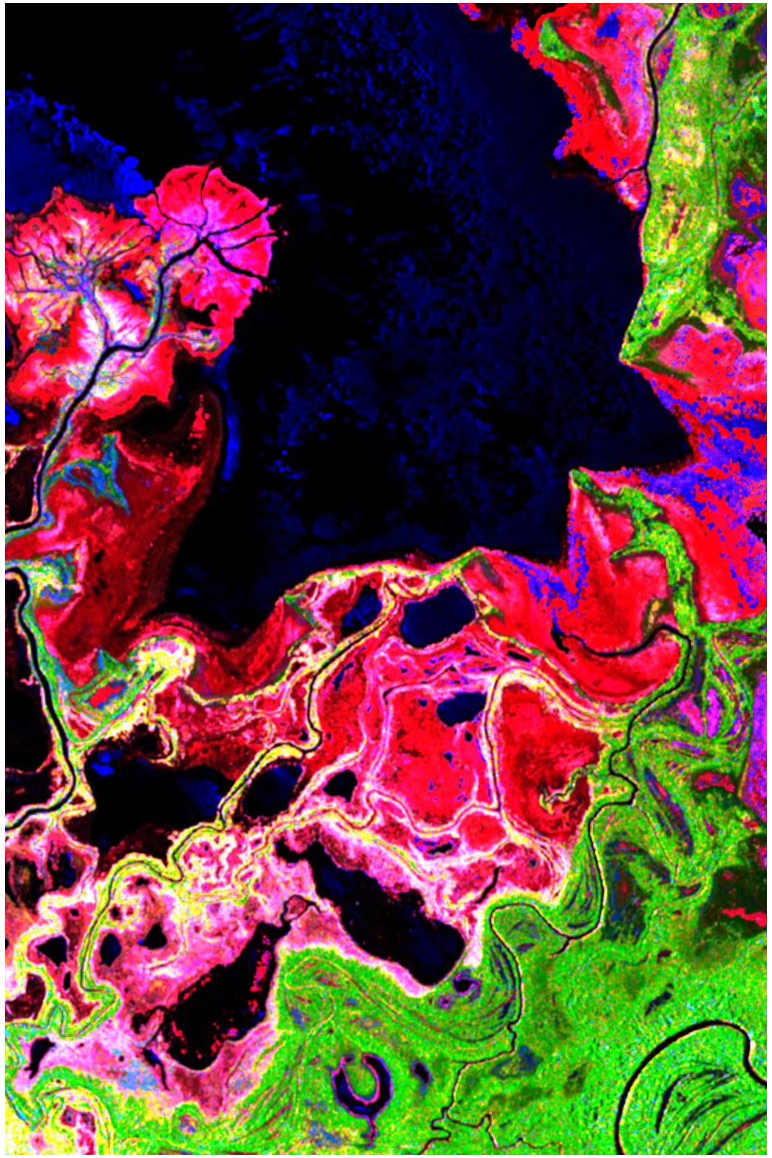


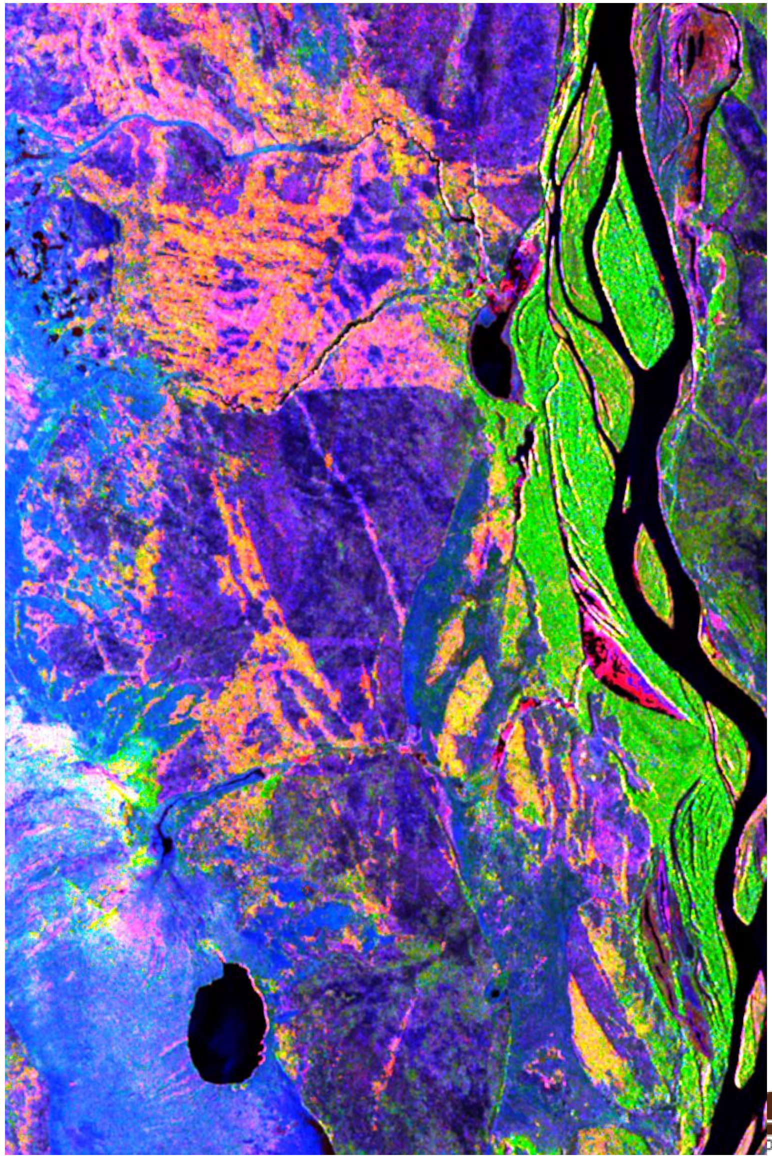
Protype testing CoV NDVI & windshield survey for crop/non-crop



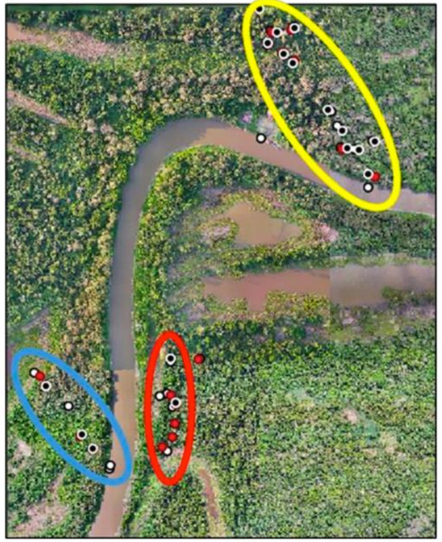


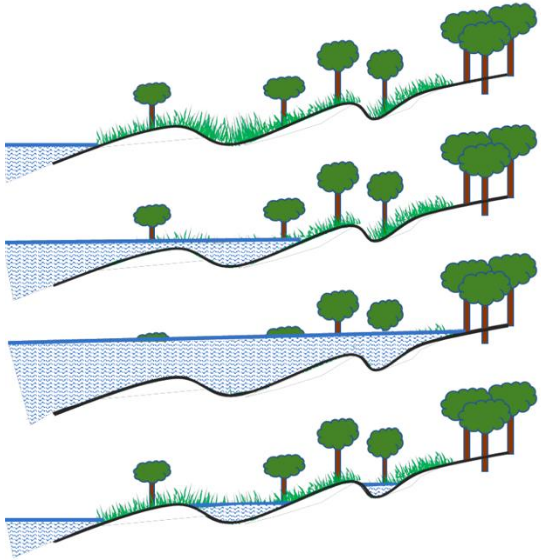
Wetlands: Peace-Athabasca Delta, Alberta
Scattering Mechanisms (double-bounce, volume, surface)

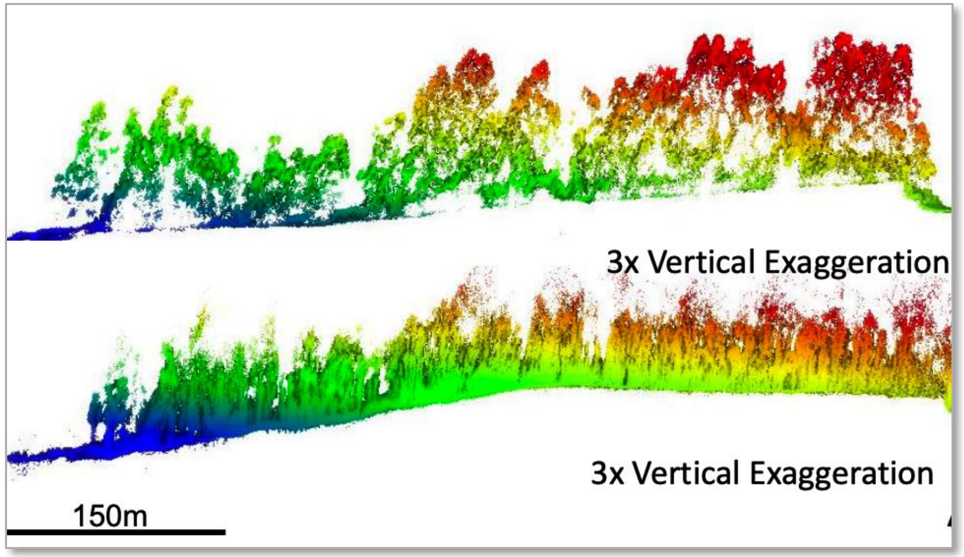


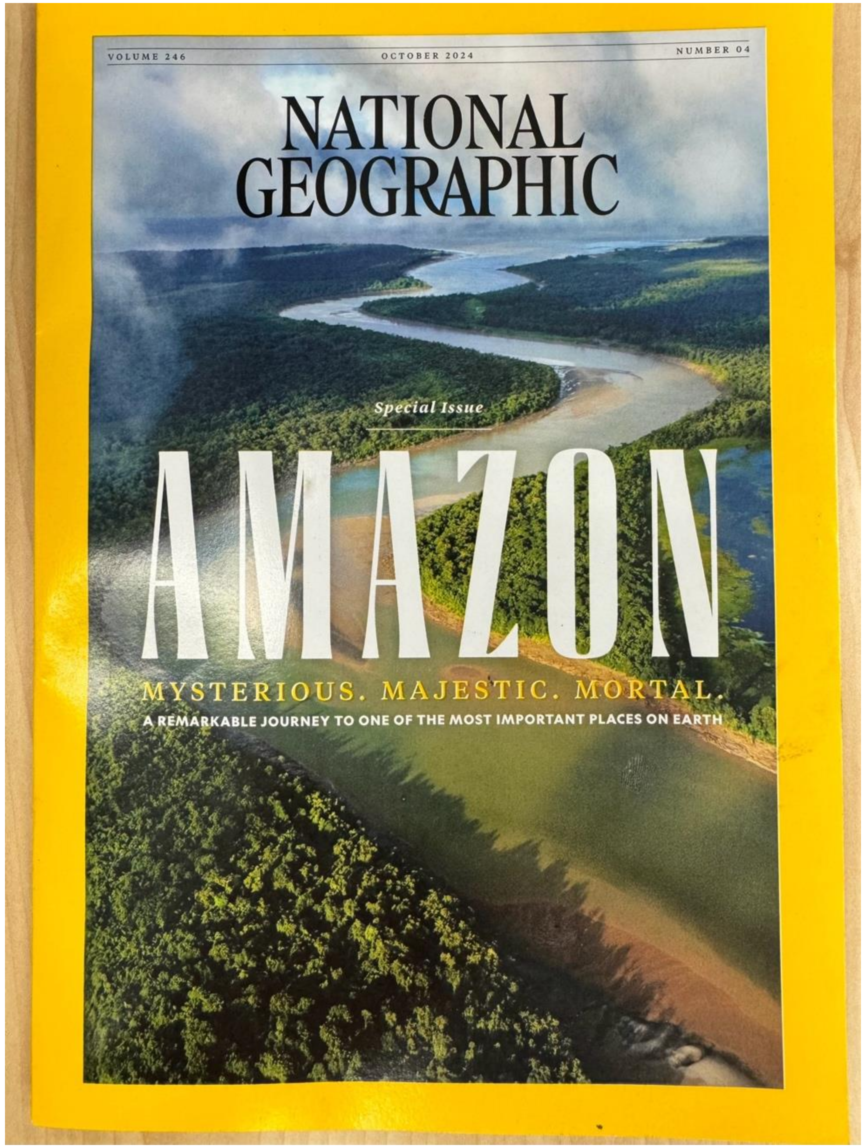


Weltands Highlights
Pacaya Samiria, Peru

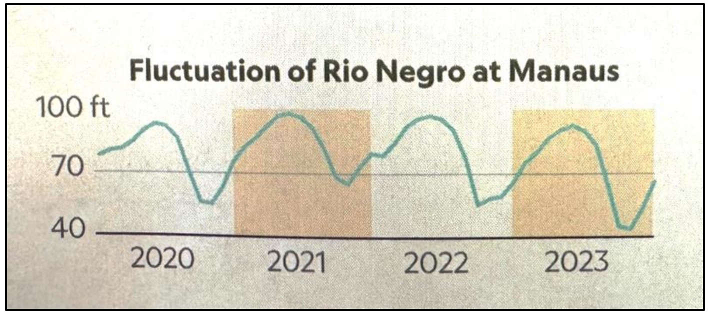




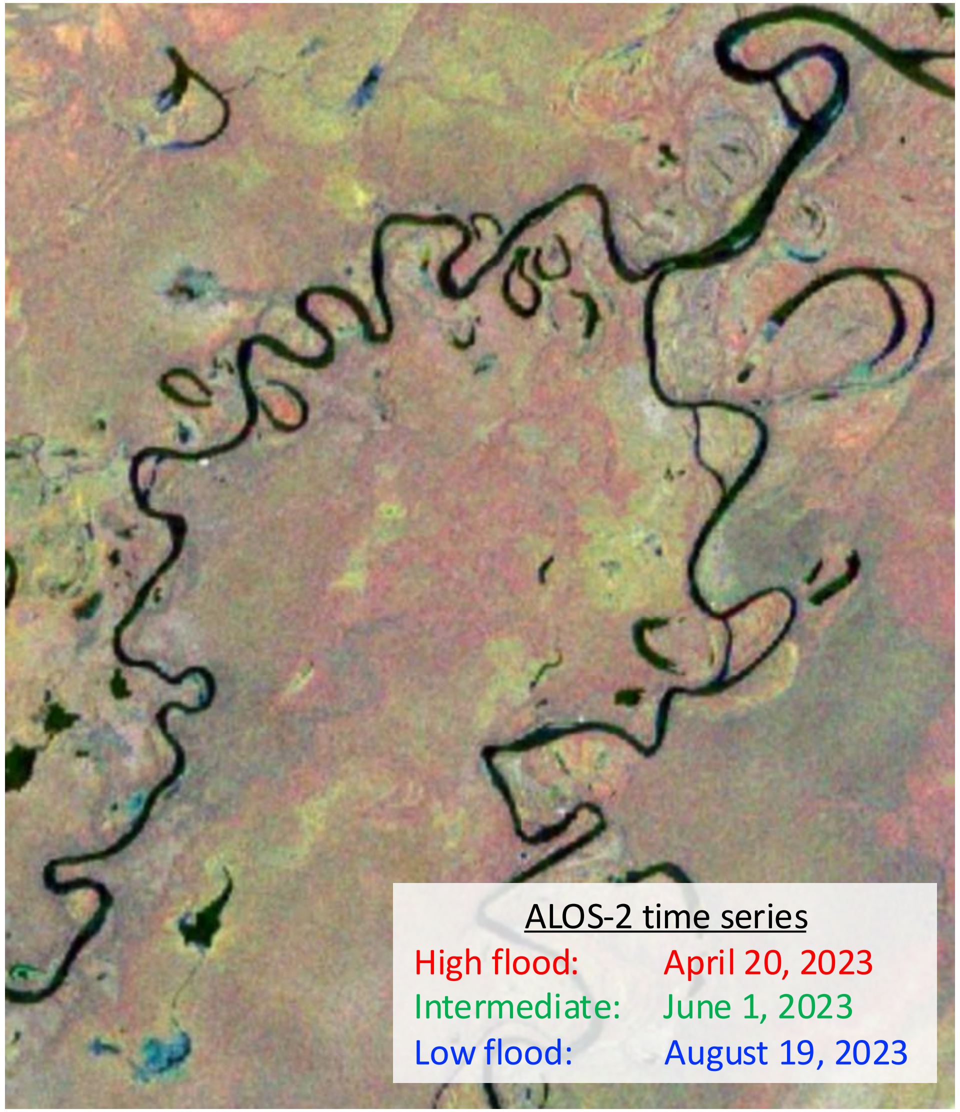




Thiago Sanna Freire Silva w/"terrestrial" lidar



Wetlands Highlights
Pacaya Samiria



Single Jupyter notebook

0 Getting Started

0.1 Overview of the Coefficient of Variation

Python code to implement coefficient of variation (CV) for crop/non-crop classification using a Receiver Operating Characteristic (ROC) curve for a time-series of SAR images. The notebook statistically calculates the CV for a stack of time-series imagery. The CV output is then used to generate a ROC curve by using the USDA Cropland Data Layer (CDL) as ground truth. Pixels classified by the CDL as "Water" are masked and not used in classification because, water has a high variation measurement not comparable to the CV values of other non-cropland land covers and is often missclassified because of this. The statistic Youden's Index is calculated to detemine the ideal threshold on the curve to use for best classification results. The accuracy of the classification compared to the CDL as ground truth are calculated for the CV crop/non-crop classification. The classified image is exported as a Geotiff. A CSV file is exported containing accuracy statistics for the classification.

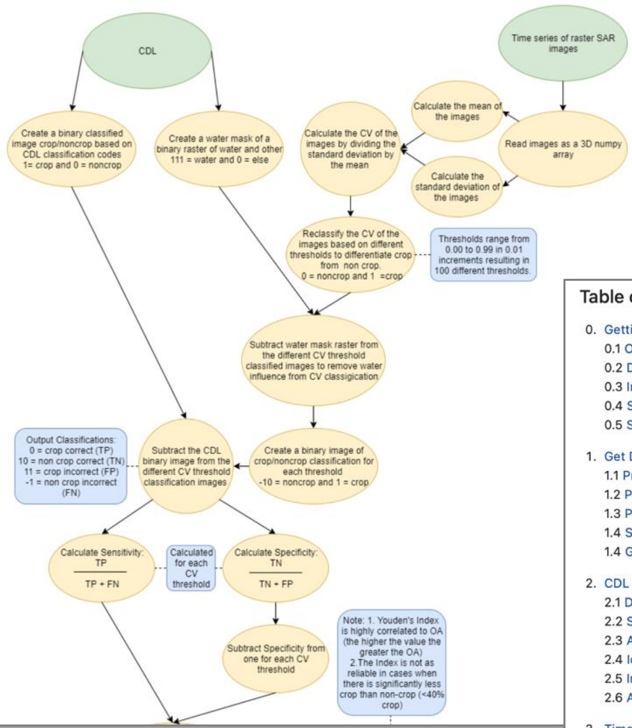
Coefficient of Variation is calculated by: Standard Deviation/Mean

Datasets needed:

```
Timeseries of SAR imagery

CDL available at https://nassgeodata.gmu.edu/CropScape/
```

0.2 Data Flow Diagram



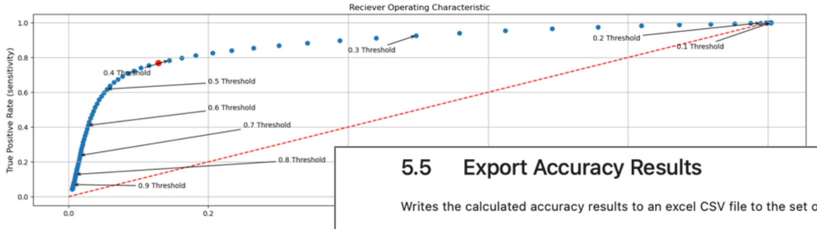
5.2 Display Youden's Index

```
x, y = data100.T
plt.scatter(x, y)
plt.plot([0.0, 1.0], [0.0,1.0], linestyle= "--", color = "red")
plt.plot([fpr_specificity_ideal], [tpr_sensitivity_ideal], marker='o', markersize=8, color="red")

#arrows highlighting where each threshold value is
plt.annotate('0.1 Threshold', xy=(sub_specificity_x[10], sensitivity_y[10]),arrowprops=dict(arrowstyle='->'), xytext=(0.87, 0.85))
plt.annotate('0.2 Threshold', xy=(sub_specificity_x[20], sensitivity_y[20]),arrowprops=dict(arrowstyle='->'), xytext=(0.75, 0.9))
plt.annotate('0.3 Threshold', xy=(sub_specificity_x[30], sensitivity_y[30]),arrowprops=dict(arrowstyle='->'), xytext=(0.4, 0.83))
plt.annotate('0.4 Threshold', xy=(sub_specificity_x[40], sensitivity_y[40]),arrowprops=dict(arrowstyle='->'), xytext=(0.05, 0.7))
plt.annotate('0.5 Threshold', xy=(sub_specificity_x[50], sensitivity_y[50]),arrowprops=dict(arrowstyle='->'), xytext=(0.2, 0.65))
plt.annotate('0.6 Threshold', xy=(sub_specificity_x[60], sensitivity_y[60]),arrowprops=dict(arrowstyle='->'), xytext=(0.2, 0.5))
plt.annotate('0.7 Threshold', xy=(sub_specificity_x[70], sensitivity_y[70]),arrowprops=dict(arrowstyle='->'), xytext=(0.25, 0.4))
plt.annotate('0.8 Threshold', xy=(sub_specificity_x[80], sensitivity_y[80]),arrowprops=dict(arrowstyle='->'), xytext=(0.3, 0.2))
plt.annotate('0.9 Threshold', xy=(sub_specificity_x[90], sensitivity_y[90]),arrowprops=dict(arrowstyle='->'), xytext=(0.1, 0.05))

#Setting plot layout
plt.grid()
plt.title('Reciever Operating Characteristic')
plt.ylabel('True Positive Rate (sensitivity)', fontsize=12)
plt.xlabel('False Positive Rate (1-specificity)', fontsize=12)
plt.rcParams['figure.figsize'] = (10,10)

plt.show()
```



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5.5 Export Accuracy Results

Writes the calculated accuracy results to an excel CSV file to the set output di

```
[118]: CV_classification_binary = "NISAR_L3_CropAreaClassification.tif" #
       CV_classification_filename_with_accuracy = "CV_classification_with_
       Accuracy_results = "NISAR_L3_CropAreaClassification_accuracy_statis

[119]: l0 = [best_thresh]
       l1 = [p_overall_correct]
       l2 = [p_crop_correct1]
       l3 = [p_non_correct1]
       l4 = [p_crop_incorrect1]
       l5 = [p_non_incorrect1]
       l6 = [crop_p_accuracy]
       l7 = [non_p_accuracy]
       l8 = [crop_u_accuracy]
       l9 = [non_u_accuracy]
       l10 = [Kappa_coefficient]
       l11 = [j_statistic]
       l12 = [AUC]

       df = pd.DataFrame({"Threshold": l0, "Overall Correct": l1, "% crop correct": l2, "% non-crop correct": l3, "% crop incorrect": l4, "%

       df.to_csv(str(aoi_dir / Accuracy_results))

       df
```

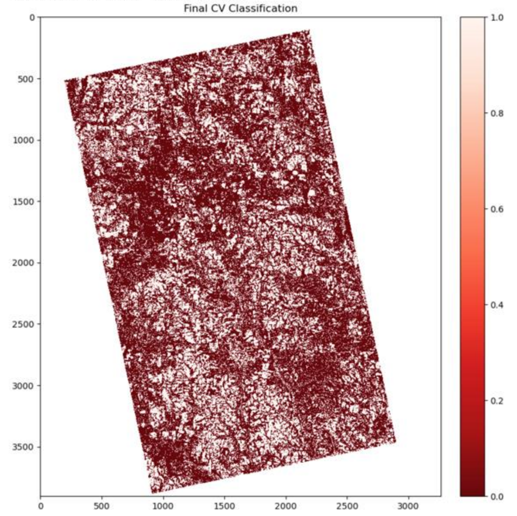
[119]:

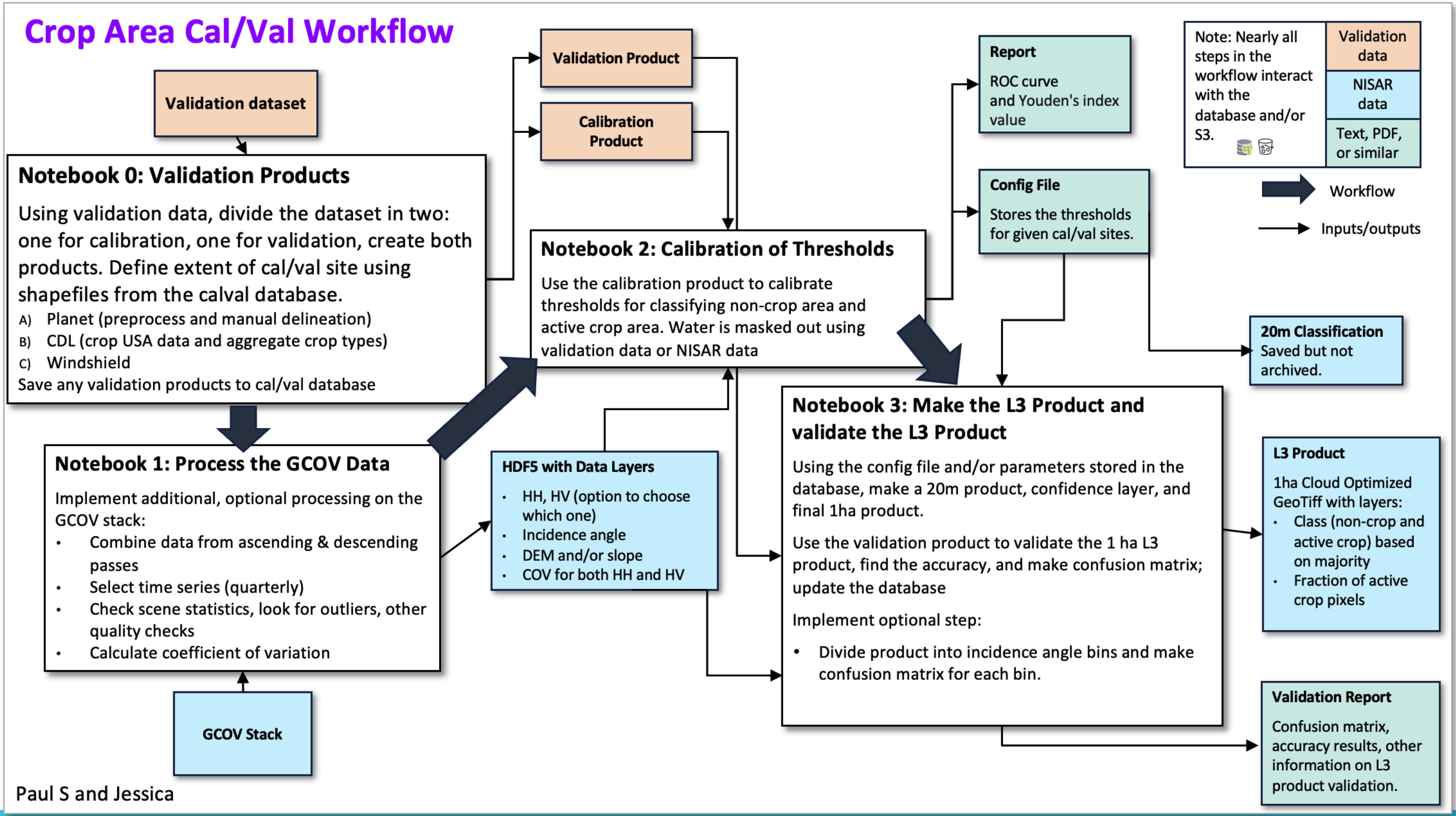
	Threshold	Overall Correct	% crop correct	% non-crop correct	% crop incorrect	% non-crop incorrect	% Crop Producers Accuracy	% Non-crop Producers Accuracy	% Crop Users Accuracy	% Non-crop Users Accuracy	Kappa Coefficient	J-statistic	AUC
0	0.38	78.91	25.07	53.84	8.39	11.34	74.91	82.61	68.86	86.51	0.55	0.58	0.85

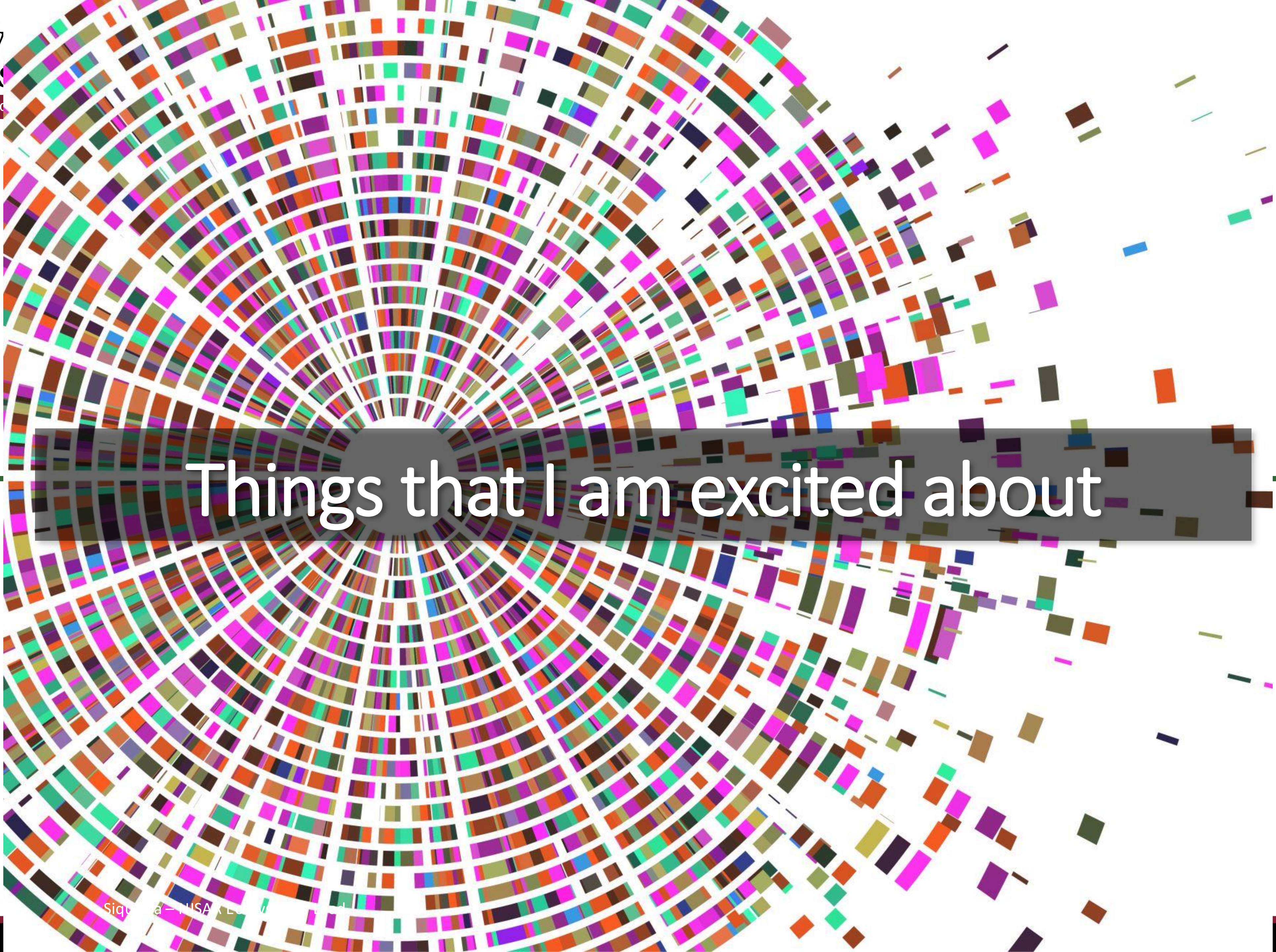
5.6 Export the Classified Image

Writes the array to a geotiff that is classified by the Youden's Index ideal threshold based on CV to the set output directory.

```
[123]: str(aoi_dir / CV_classification_binary)

[123]: '/scratch/alex_eco_test/Little_River_GA/NISAR_L3_CropAreaClassification.tif'

[120]: # Define write_geotiff function - writes an array to a geotiff
       def write_geotiff_export(image, geotrans, cols, rows, spatial_ref, nodata, outfilename):
           driver = gdal.GetDriverByName('GTiff')
           outRaster = driver.Create(outfilename, cols, rows, 1, gdal.GDT_Float32)
           outRaster.SetGeoTransform(geotrans)
           outband = outRaster.GetRasterBand(1)
           outband.WriteArray(image)
           outRasterSRS = osr.SpatialReference()
           outband.SetNoDataValue(np.nan)
           outRasterSRS.ImportFromWkt(spatial_ref)
           outRaster.SetProjection(outRasterSRS.ExportToWkt())
           outband.FlushCache()

       write_geotiff_export(CDL_CVideal, geotransform, cols, rows, spatialref, np.nan, str(aoi_dir / CV_classification_

       plt.imshow(CV_reclass_ideal,interpolation='nearest',cmap='Reds_r');
       plt.colorbar(fraction=0.046*CV_reclass_ideal.shape[0]/CV_reclass_ideal.shape[1],pad=0.04);
       plt.title('Final CV Classification');
       print('Crop pixels marked in white (Crop=1, Non-Crop=0)')

Crop pixels marked in white (Crop=1, Non-Crop=0)
```




Crop Area Cal/Val Workflow
Validation dataset
Validation Product
Calibration Product
Notebook 0: Validation Products
Using validation data, divide the dataset in two: one for calibration, one for validation, create both products. Define extent of cal/val site using shapefiles from the calval database.
A) Planet (preprocess and manual delineation)
B) CDL (crop USA data and aggregate crop types)
C) Windshield
Save any validation products to cal/val database
Report
ROC curve and Youden's index value
Config File
Stores the thresholds for given cal/val sites.
Note: Nearly all steps in the workflow interact with the database and/or S3.
Validation data
NISAR data
Text, PDF, or similar
Workflow
Inputs/outputs
Notebook 2: Calibration of Thresholds
Use the calibration product to calibrate thresholds for classifying non-crop area and active crop area. Water is masked out using validation data or NISAR data
20m Classification
Saved but not archived.
Notebook 3: Make the L3 Product and validate the L3 Product
Using the config file and/or parameters stored in the database, make a 20m product, confidence layer, and final 1ha product.
Use the validation product to validate the 1 ha L3 product, find the accuracy, and make confusion matrix; update the database
Implement optional step:
• Divide product into incidence angle bins and make confusion matrix for each bin.
Notebook 1: Process the GCOV Data
Implement additional, optional processing on the GCOV stack:
• Combine data from ascending & descending passes
• Select time series (quarterly)
• Check scene statistics, look for outliers, other quality checks
• Calculate coefficient of variation
HDF5 with Data Layers
• HH, HV (option to choose which one)
• Incidence angle
• DEM and/or slope
• COV for both HH and HV
L3 Product
1ha Cloud Optimized GeoTiff with layers:
• Class (non-crop and active crop) based on majority
• Fraction of active crop pixels
GCOV Stack
Validation Report
Confusion matrix, accuracy results, other information on L3 product validation.
Paul S and Jessica



Things that I am excited about

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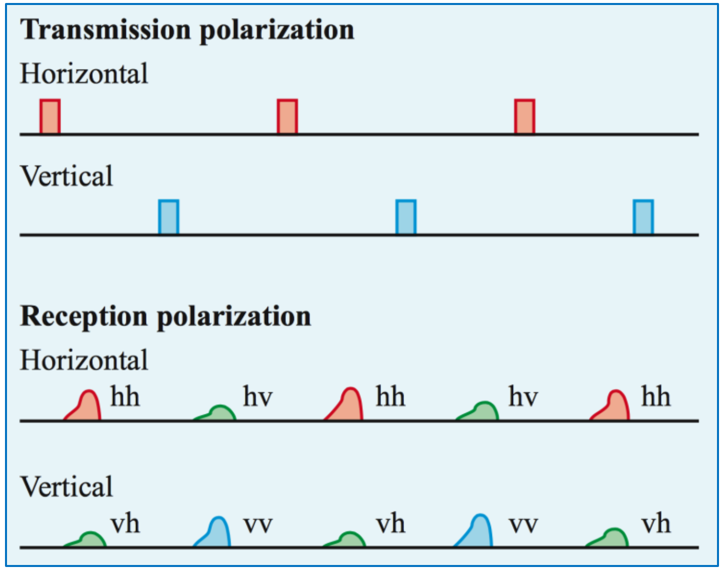
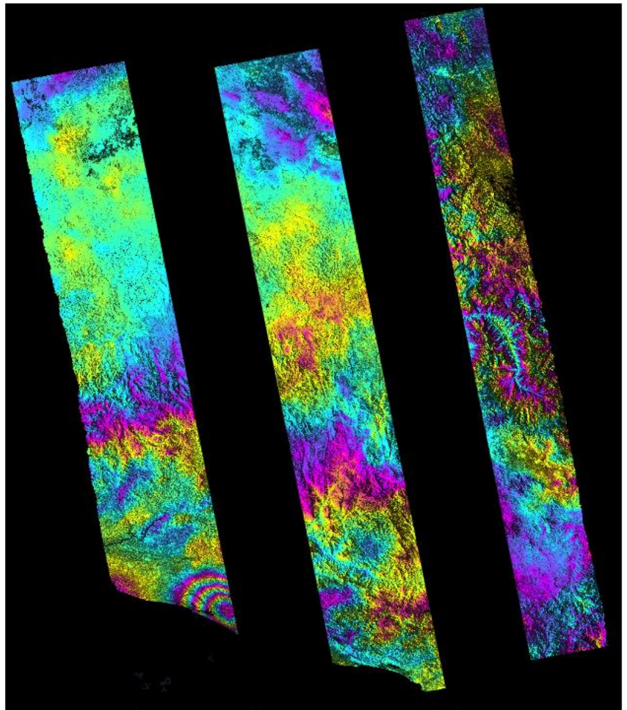
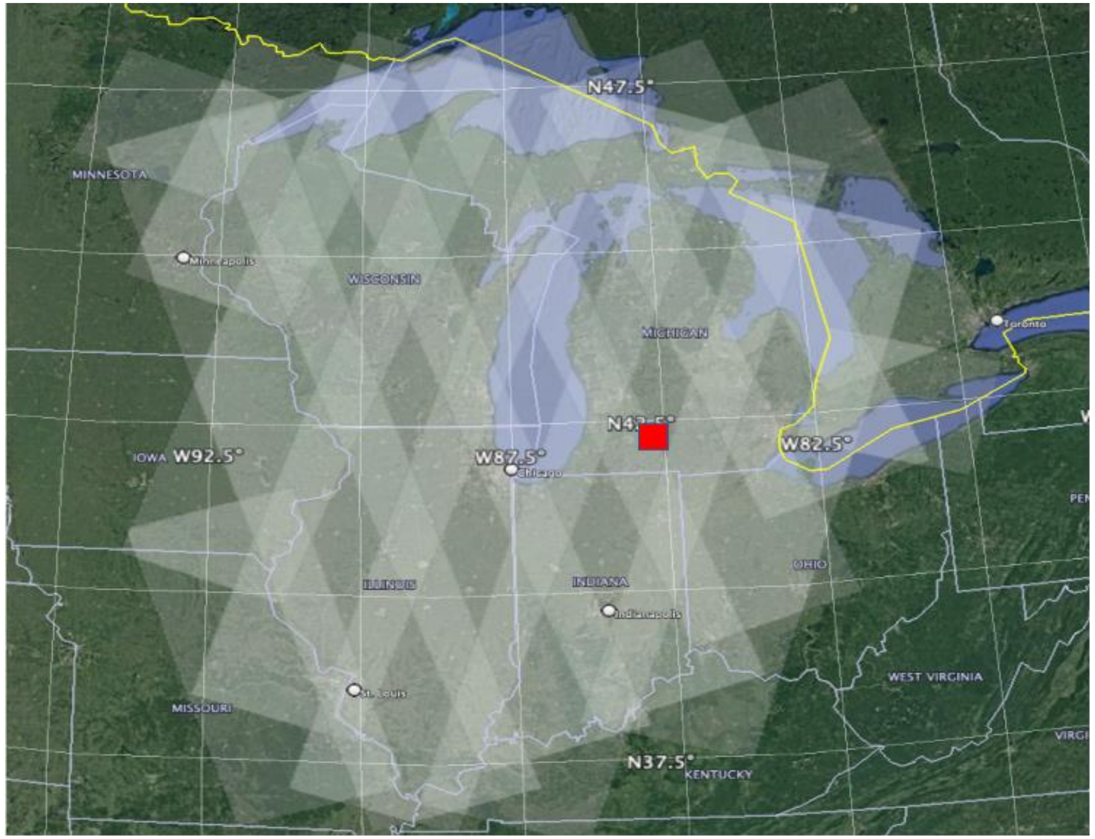
Quad-pol data collections!





Sentinel-1 Interferogram used as proxy

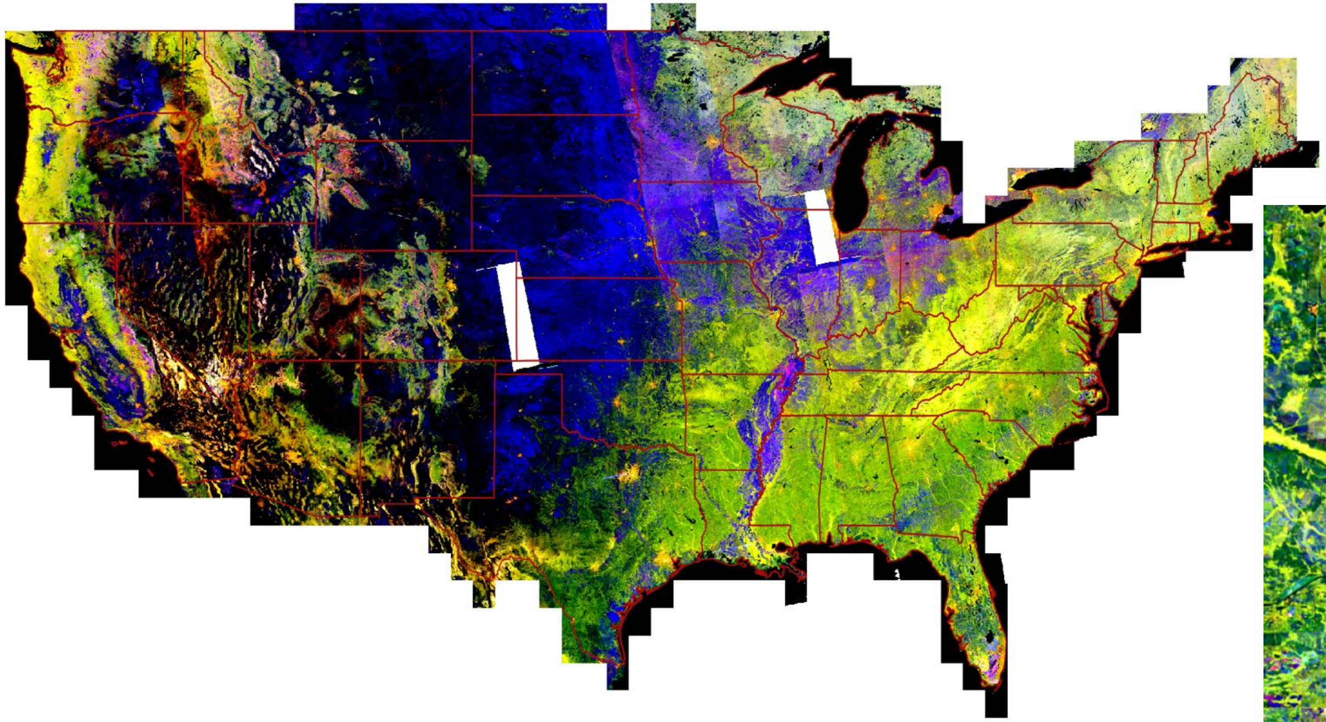


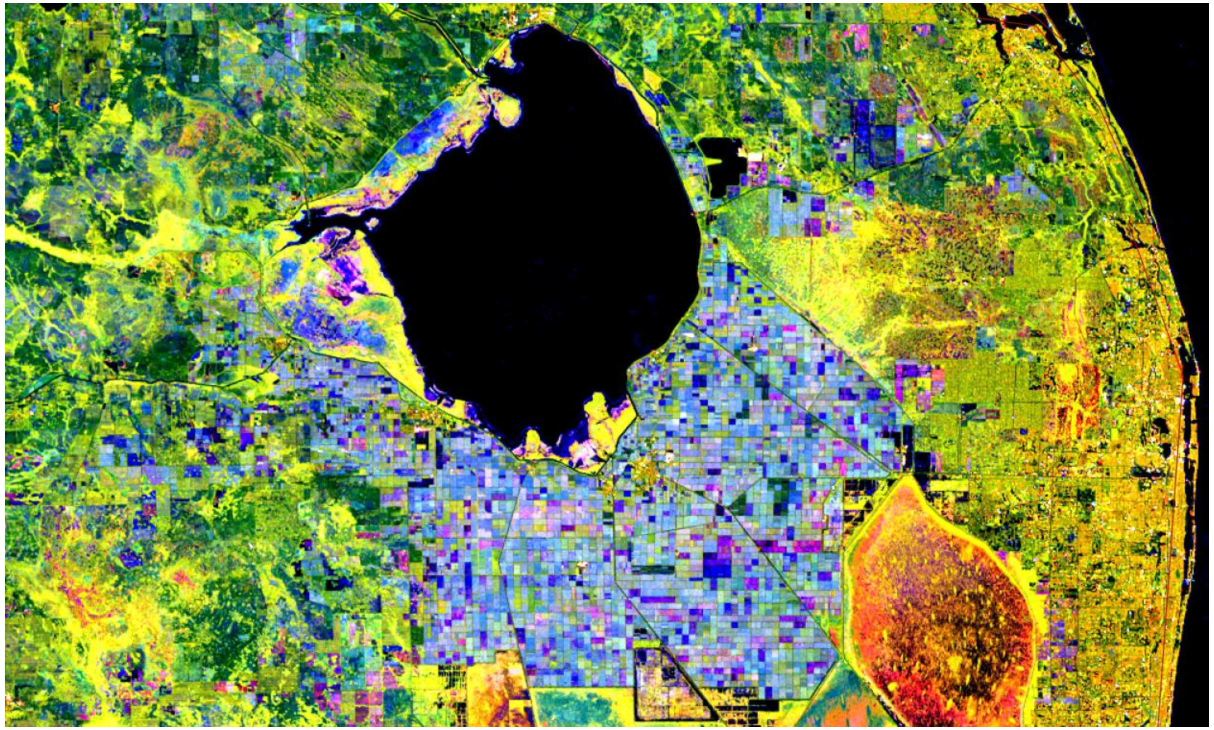
Michigan State Agriculture cal/val site indicated in Red

- Metrics of SAR backscatter over an observation time series (e.g., annual, season can be used to monitor agricultural activity.

C-VV Median / C-VH Median / C-VH p95-p5

Sentinel-1 2017, Ascending Near over Far Range





Data Source: ESA/Alaska Satellite Facility
RTC Data Processing: Earth Big Data LLC
Mosaicking and Visualization: Earth Big Data LLC

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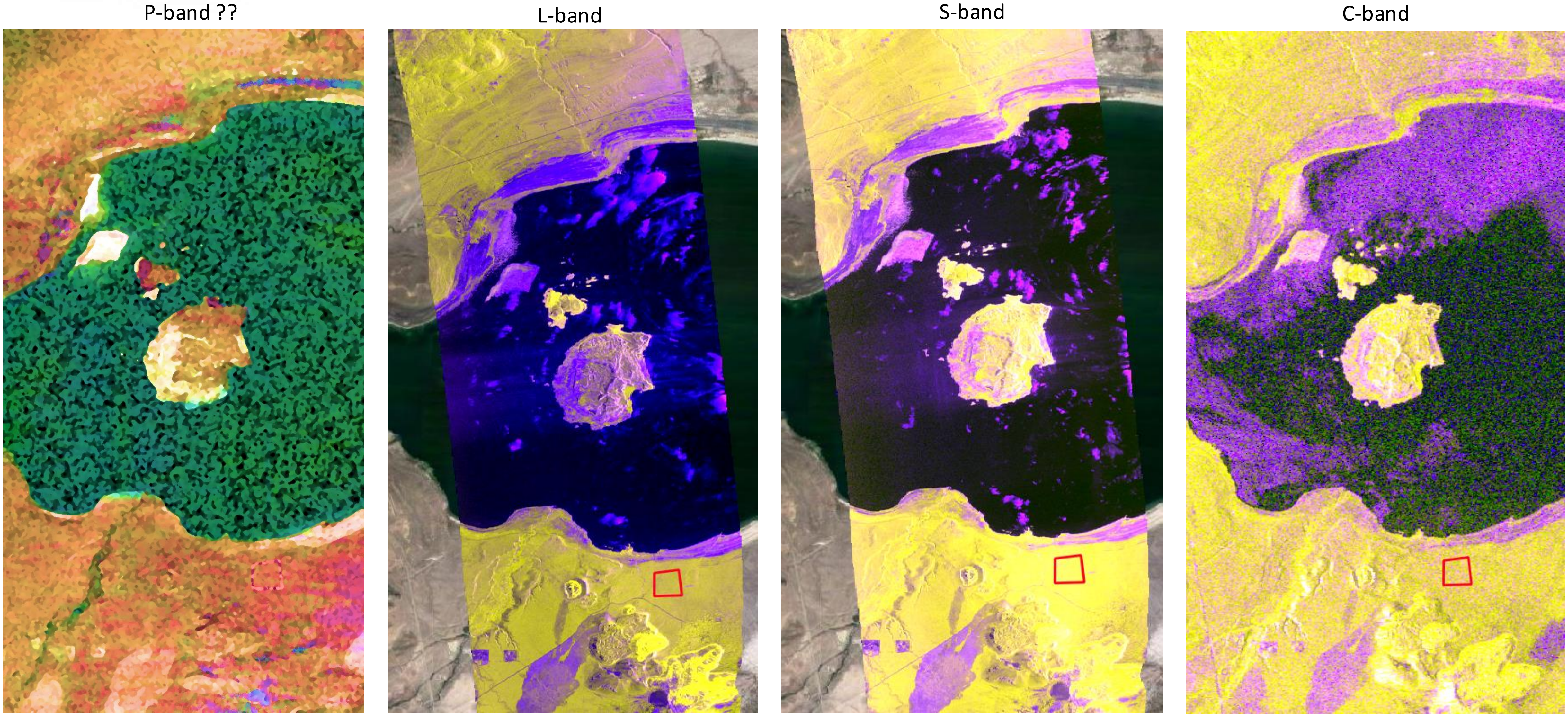
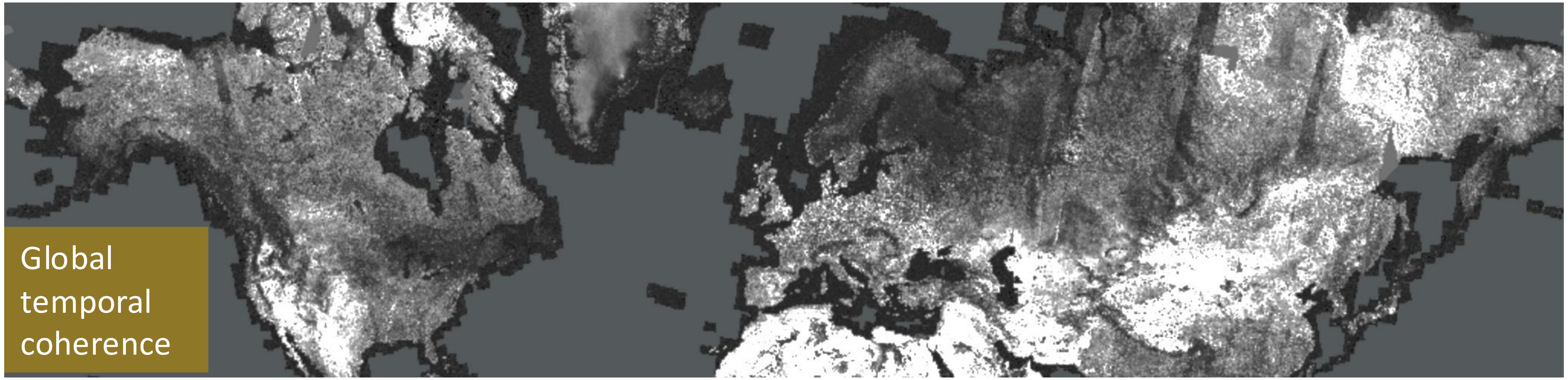
False color image: |VV|, |HV|, |VV/HV|

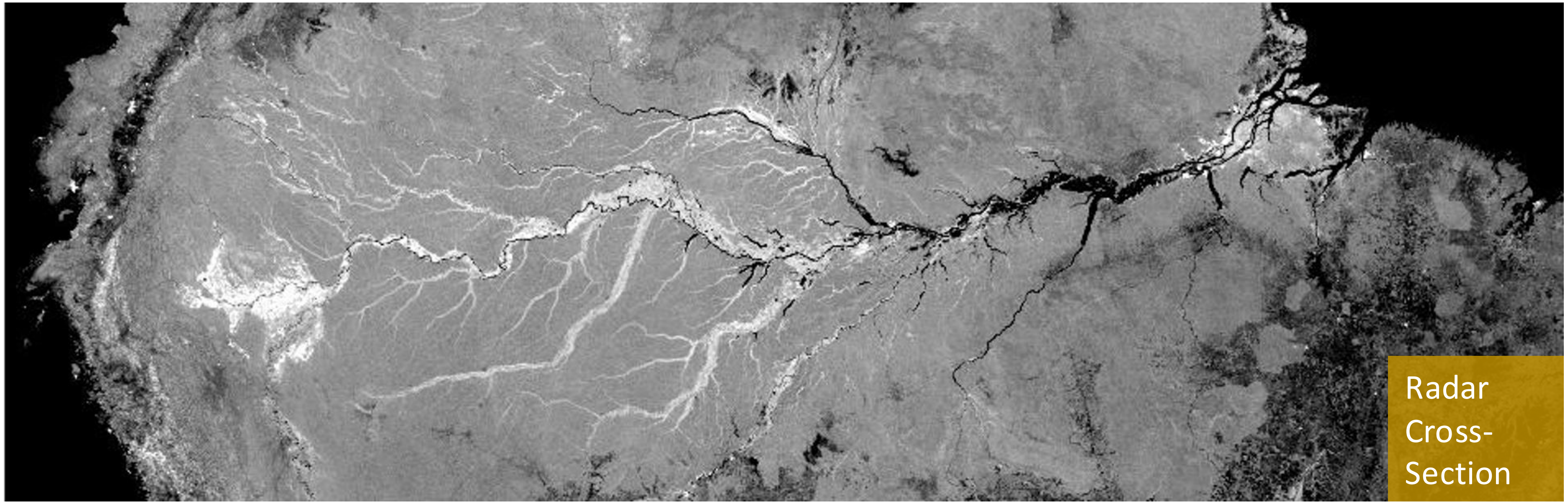
Scale [dB]: (-30 to -10, -35 to -15, **4 to 12**)

Multifrequency!



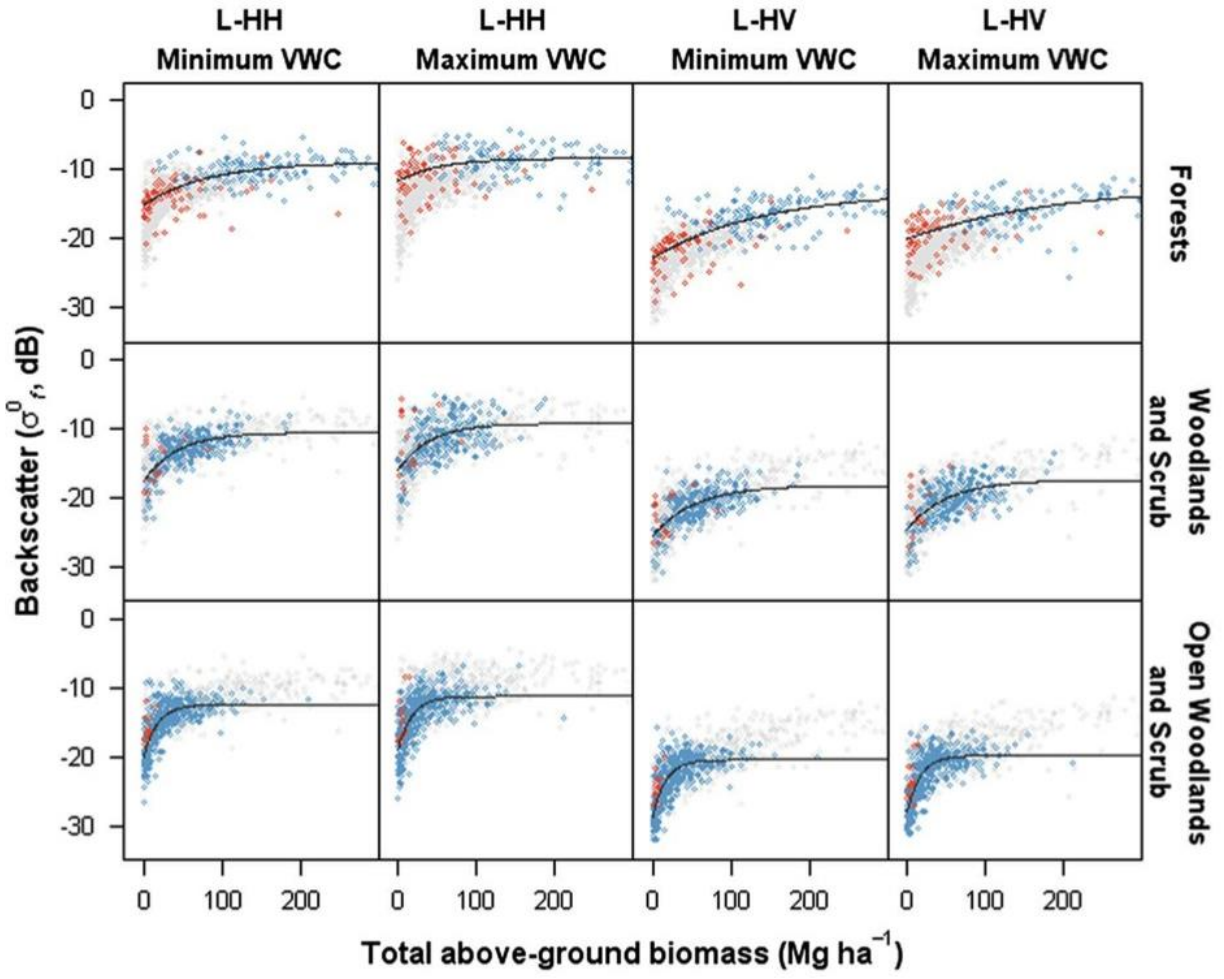
Time Series



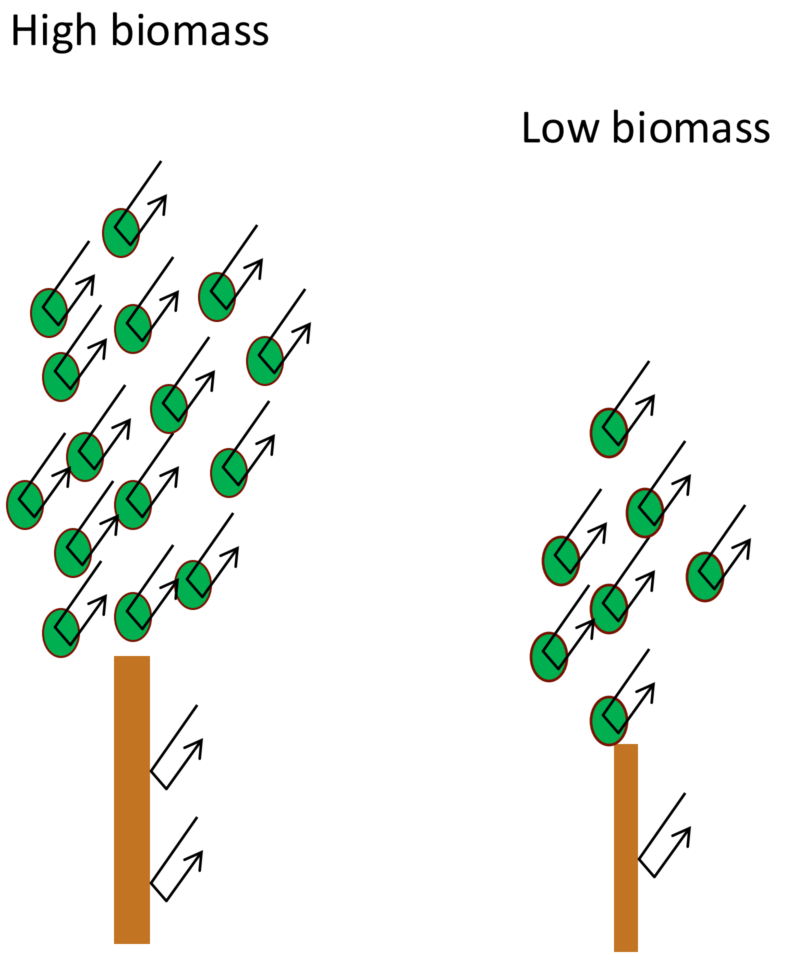


Biomass and Volume Scattering

increased biomass is associated with increased radar power return

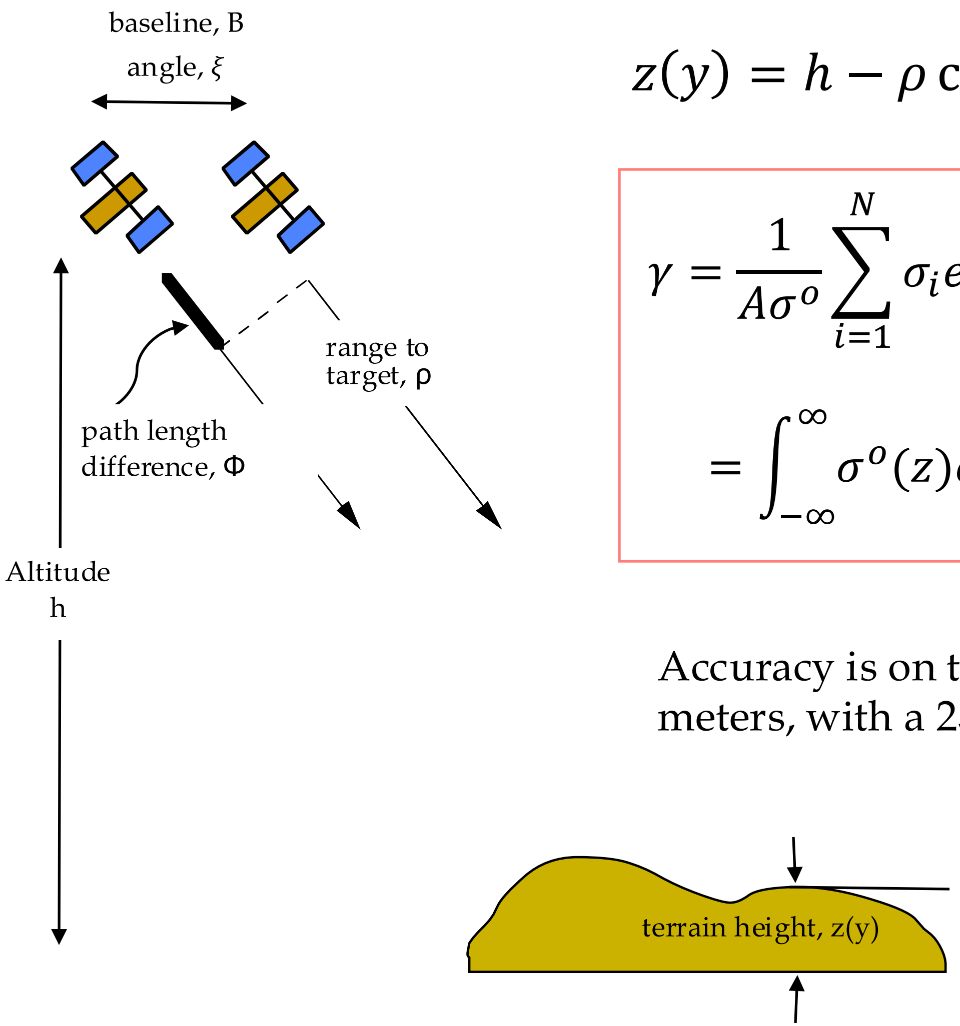


ALOS remnant (blue) and non-remnant (red) biomass relationships in the presence of vegetation water content (VWC) [Lucas et al., JSTARS, 2010]



Sensitivity to Volume Scattering

- Path length difference can be used to resolve positional ambiguity and determine the height of the terrain.



$$z(y) = h - \rho \cos\left(\xi - \sin^{-1}\left(\frac{\lambda\Delta\phi}{4\pi B}\right)\right)$$

$$\gamma = \frac{1}{A\sigma^o}\sum_{i=1}^{N}\sigma_i e^{-jk_z z_i}$$

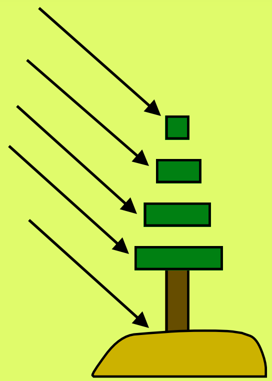
$$= \int_{-\infty}^{\infty}\sigma^o(z)e^{-jk_z z}dz$$

Accuracy is on the order of meters, with a 25m resolution.

Derivative of interferometric phase with respect to height

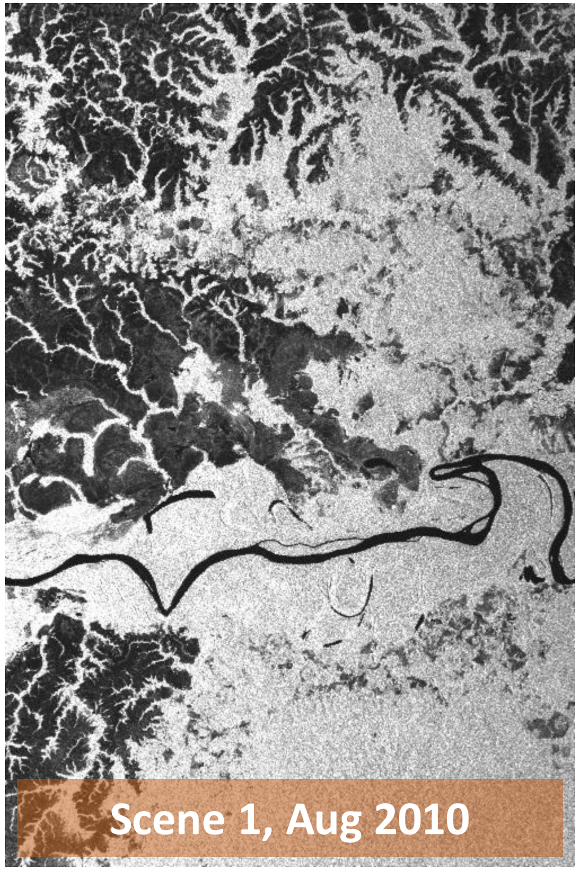
$$k_z = \frac{k_0 B\cos(\theta - \xi)}{\rho\sin\theta}$$

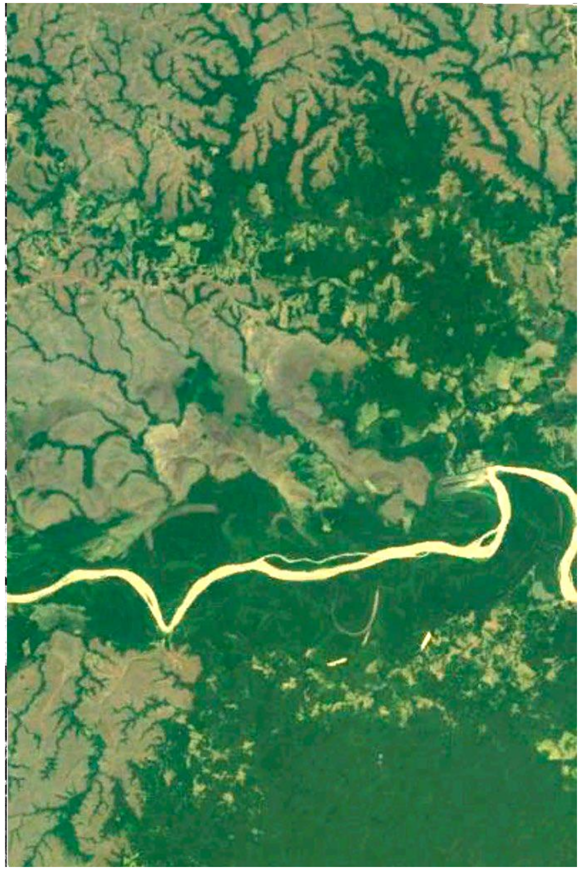
When the signal return comes from multiple heights, a unique signature is observed by the interferometer.

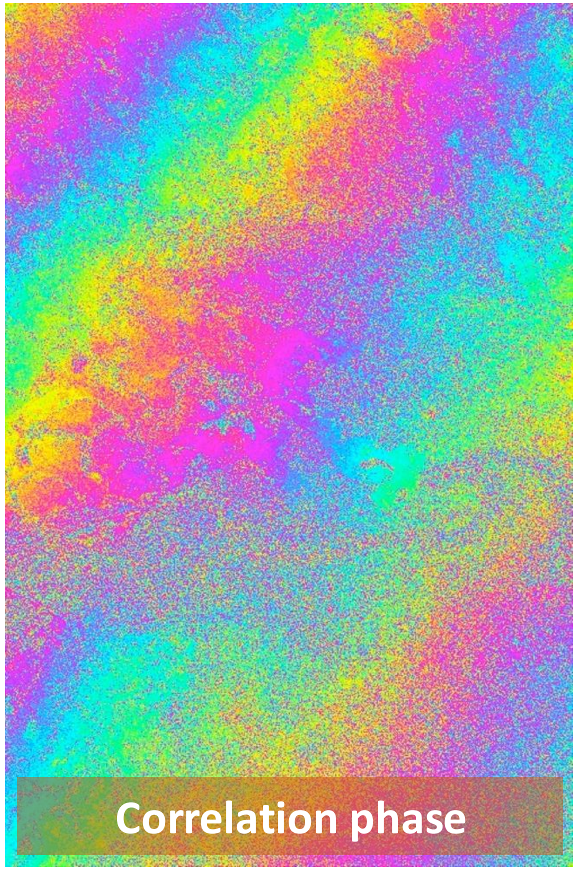


Interferometry

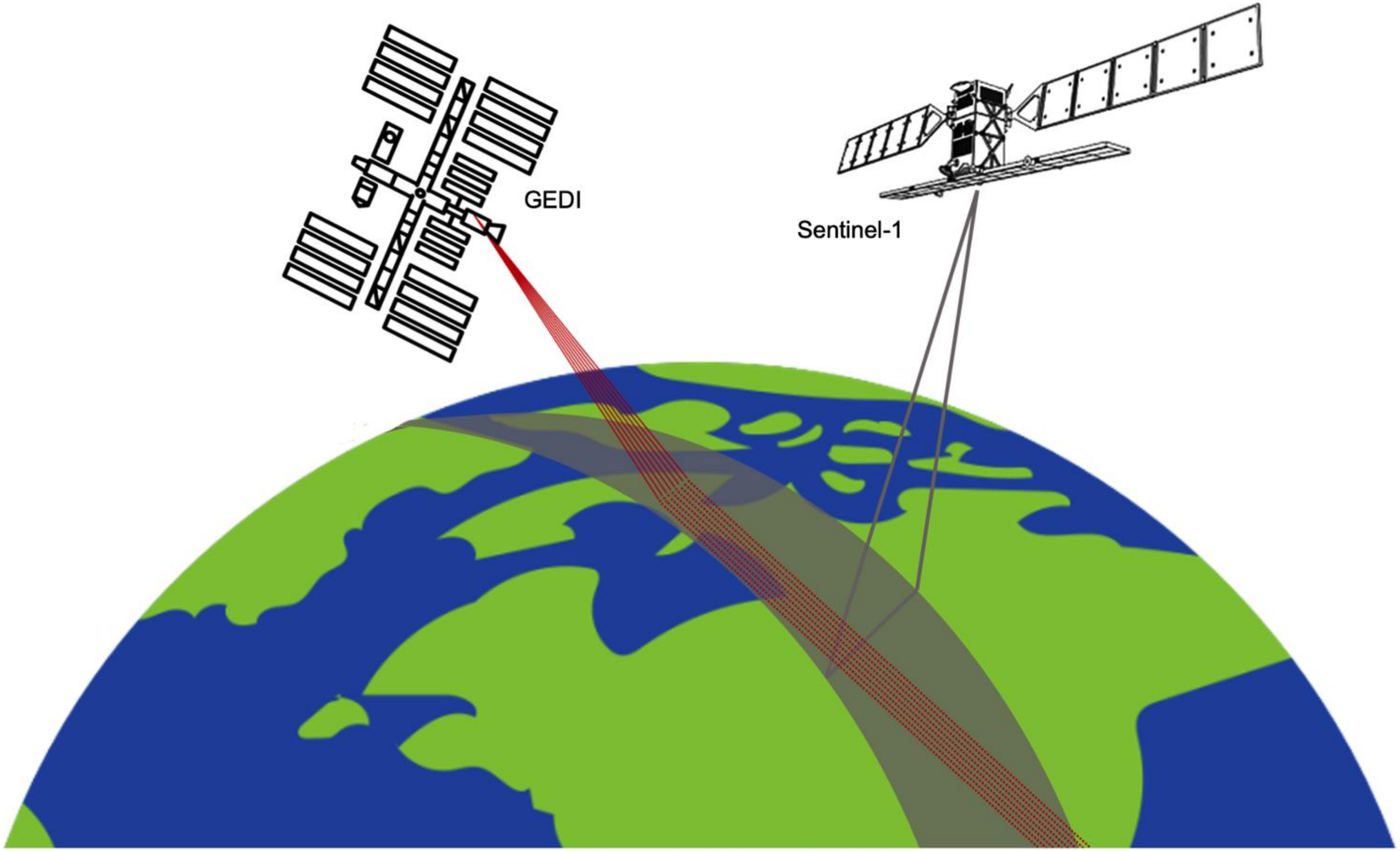
- Interferometry combines two radar scenes to create one, consisting of complex numbers (magnitude and phase)
- Interferometric magnitude is called the ”Coherence”.
- Interferometric phase is related to the topography







Lidar & SAR
A match made in "heaven"



Savanna-Bio: Biomass estimation with new spaceborne missions for MRV in Dry Forests and Savannas

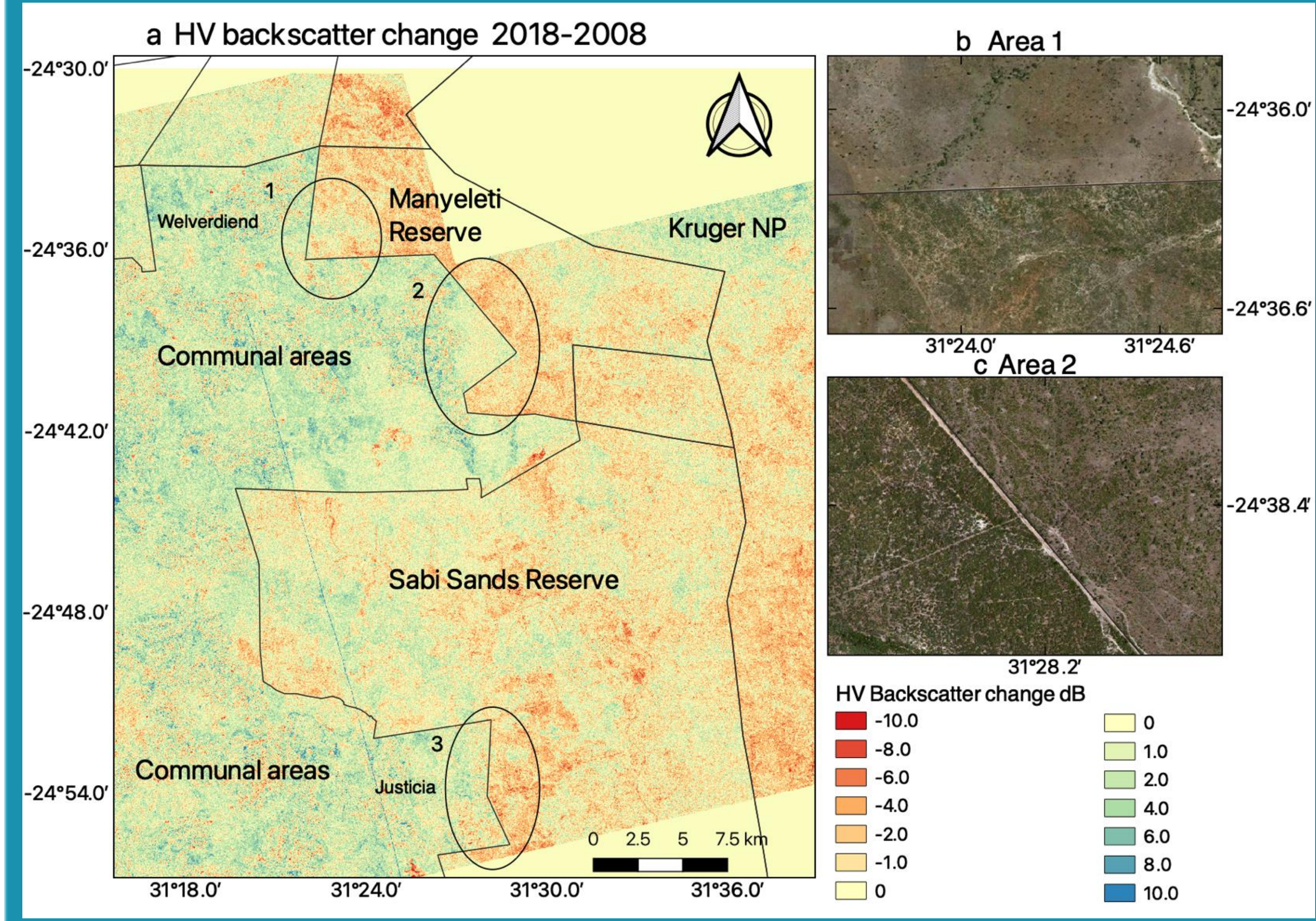
John Armston, Laura Duncanson
Mikhail Urbazaev
University of Maryland

Konrad Wessels
Xiaoxuan Li
George Mason University

Paul Siqueira
Narayanarao Bhogapurapu
University of Massachusetts

Rajashekar Gopalakrishnan ISRO, India
Sean Healey USFS, USA
Moses Cho CSIR, South Africa
Lungile Moyo & Sindisiwe Mashele DEFF, South Africa
Peter Scarth & Stuart Phinn UQ, Australia
Daniel Tindall Qld DESI, Australia

Disturbance Lowveld, South Africa



K. Wessels, X. Li, A. Bouvet, R. Mathieu, R. Main, L. Naidoo, B. Erasmus, G. Asner, "Quantifying the sensitivity of L-Band SAR to a decade of vegetation structure changes in savannas," RSE 2023

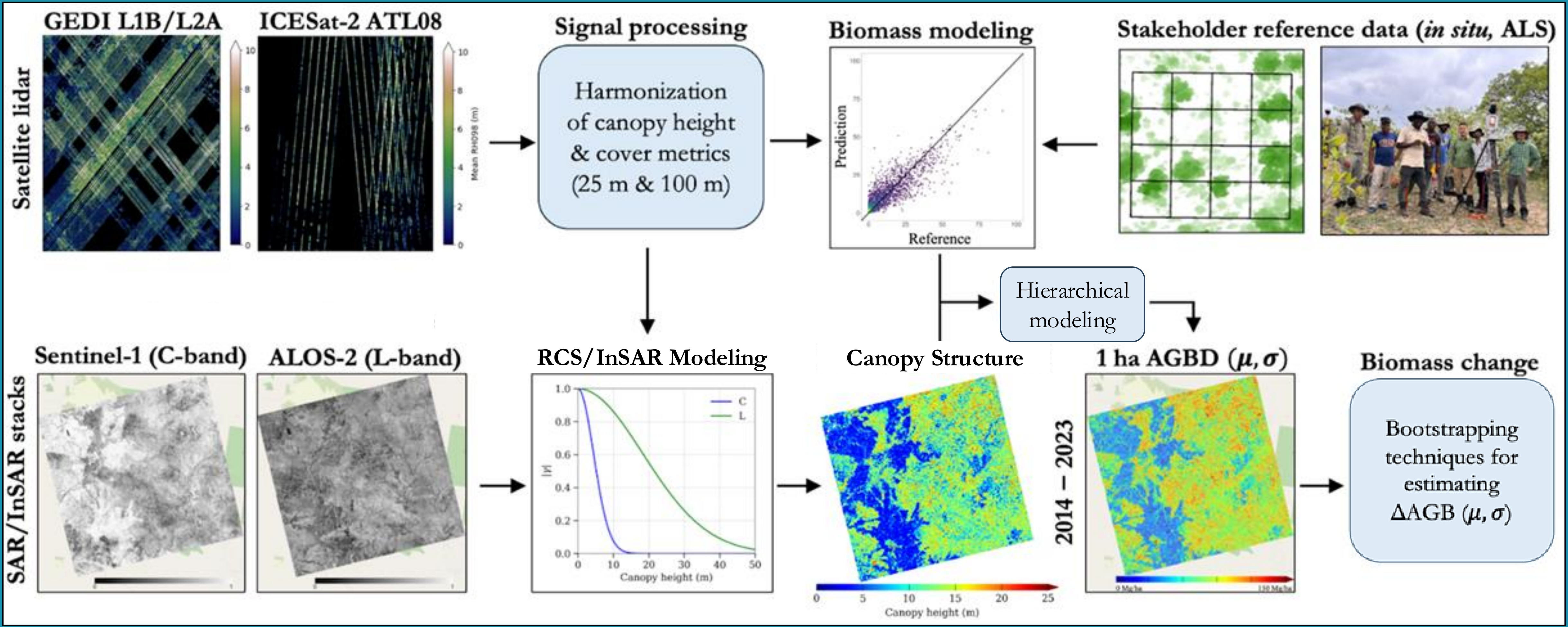
The effects of a fence line on disturbance regimes can clearly be seen in the image

Disturbance likely caused by impact of high elephant numbers and prescribed burns in the conservation areas of the indicated Reserves

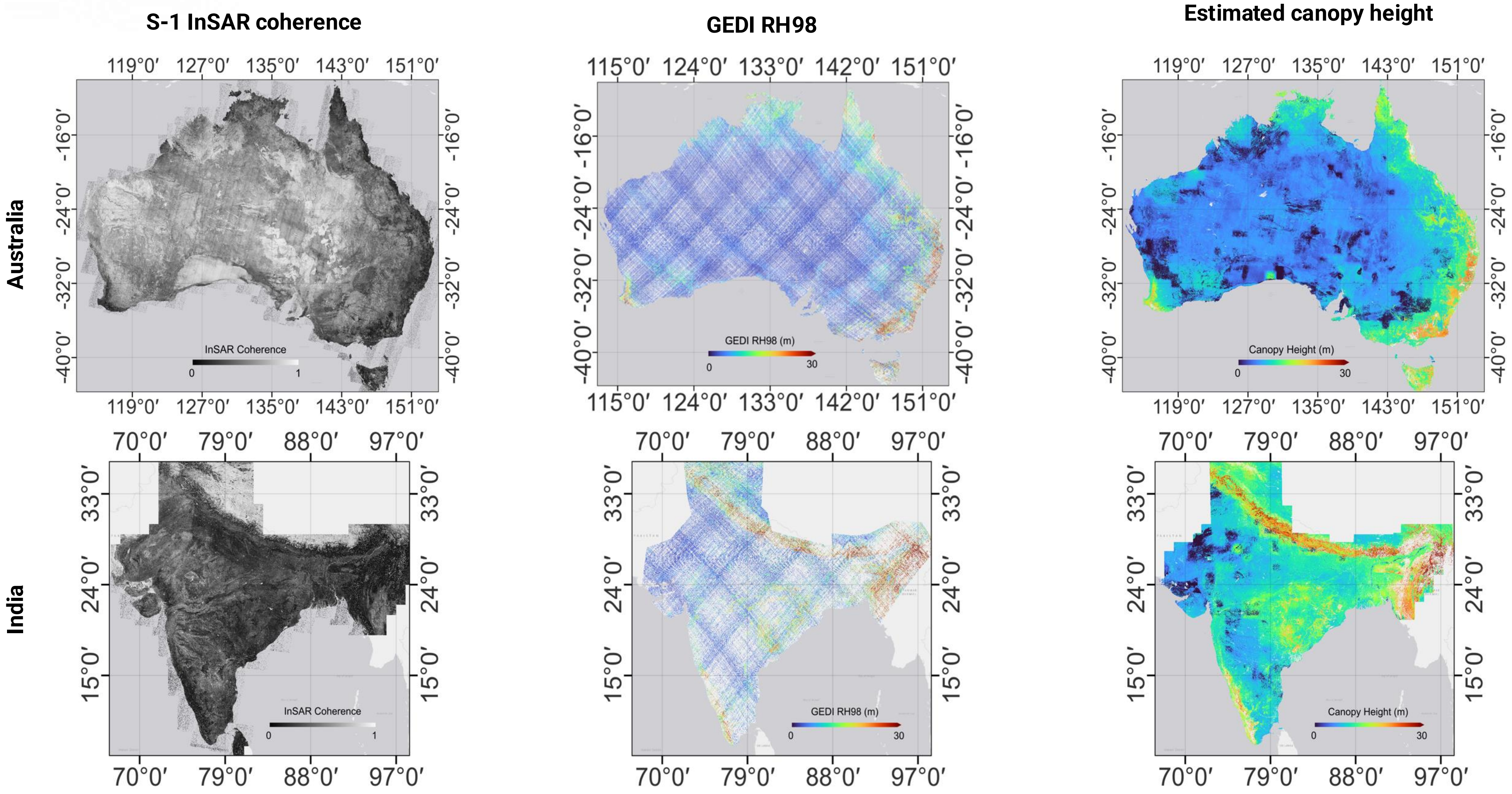
National Aeronautics and Space Administration

CMS CARBON MONITORING SYSTEM

OUR APPROACH TO MAPPING SAVANNA ABOVEGROUND BIOMASS AND CHANGE



Continental-scale results



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Workingn with colleagues

Fieldwork in India (Hoshanagabad & Pripiya, MP)

Take-home messages

- Dependable L-band time-series (2 observations every 12 days)
  - S-band data over agriculture cal/val sites
- High resolution (~20m),
- Dual-polarized (HH, HV); Quad-pol over India and parts of the US
- Ground-projected data will be co-registered to a fixed grid making time series analysis will be very simple
- Available over all land surfaces, globally

will change the way that we use data for Ecosystems

- Downlink data rate is 4.5 TB/day
- Learning how to work with data in the cloud is an important skill to have