NISAR Cal/Val

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L-band Calibration

These L-band modes will be calibrated during the 90 day NISAR commissioning phase

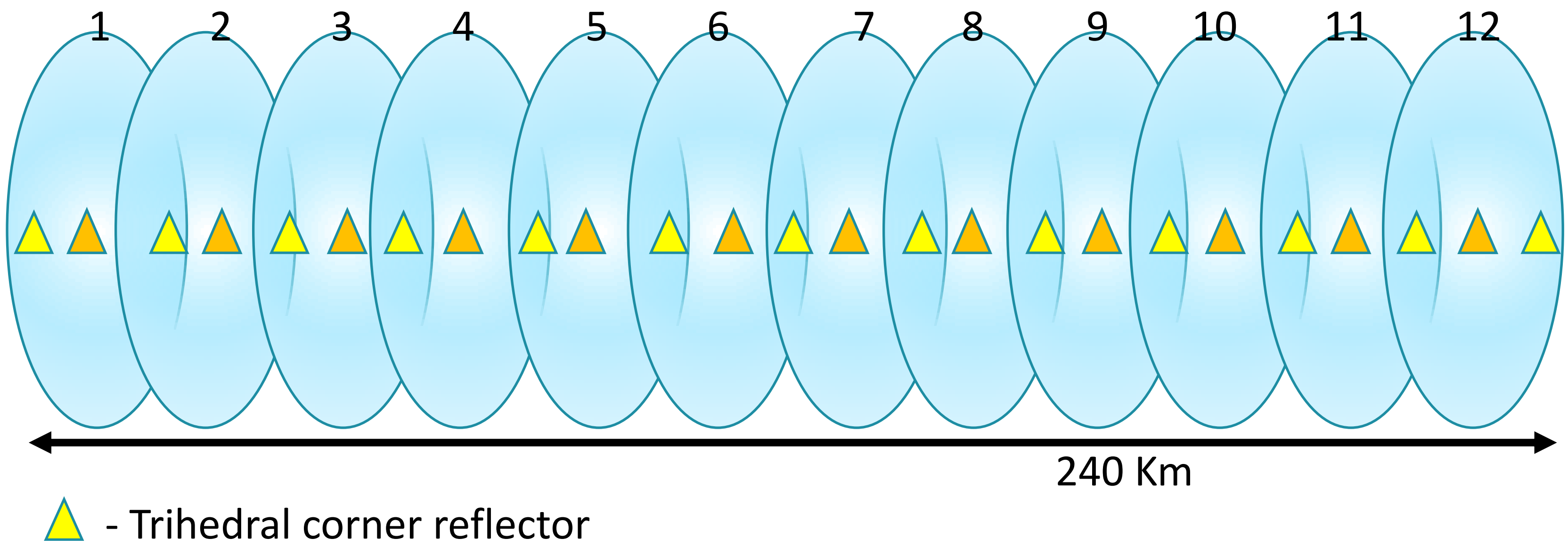
Mode	Pol.	Pulsewidth	Bandwidth	Science Target
L1	HH/HV	25	20+5	Background Land
	QQ	25	20+5	Background Land Soil Moisture
	QQ	20	20+5	Background Land Soil Moisture
L2	HH	40	77	Land Ice
	HH	45	40+5	Land Ice Low Res
	HH	25	20+5	Low Data Rate Study Mode
L3	VV	25	5	Sea Ice Dynamics
	HH/VV	20	5+5	Open Ocean
L4	VV/VH	25	20+5	India Land Characterization
L5	HH/HV	45	40+5	Urban Areas, Himalayas
	QQ	45	40+5	Urban Areas, Himalayas SM
	QQ	40	40+5	Urban Areas, Himalayas SM Hi Pwr
L6	HH/HV/VH/VV	45	40+5	US Agriculture, India Agriculture

Image calibration

Image Calibration Requirements	
Azimuth Resolution	< 7 m
Range Resolution	From 1.9 m to 30 m
Swath Width	242 km
Ambiguities	< -20 db (quad pol < -15 dB)
ISLR	< -22 dB
Co-pol radiometric calibration	< 0.9 db
Cross-pol radiometric calibration	< 1.2 dB
Noise equivalent σ^o	< -23 dB
Systematic phase error	< 3 degrees
Coherence	> 0.85

L-band Calibration

- NISAR will have 12 sub-beams
- An onboard digital beamforming algorithm will be used to form the NISAR 240 km range swath



13 reflectors will be deployed at the edge of each sub-beam in beam overlap areas
12 reflectors will be deployed at the middle of each sub-beam
Bright distributed targets will be also used to evaluate the calibration across the sub-beam overlap areas

Homogeneous Scene Calibration

Parts of the Amazon rainforest have fairly uniform L-band backscatter for a wide range of incidence angles, and have been used by other SARs to assess calibration.

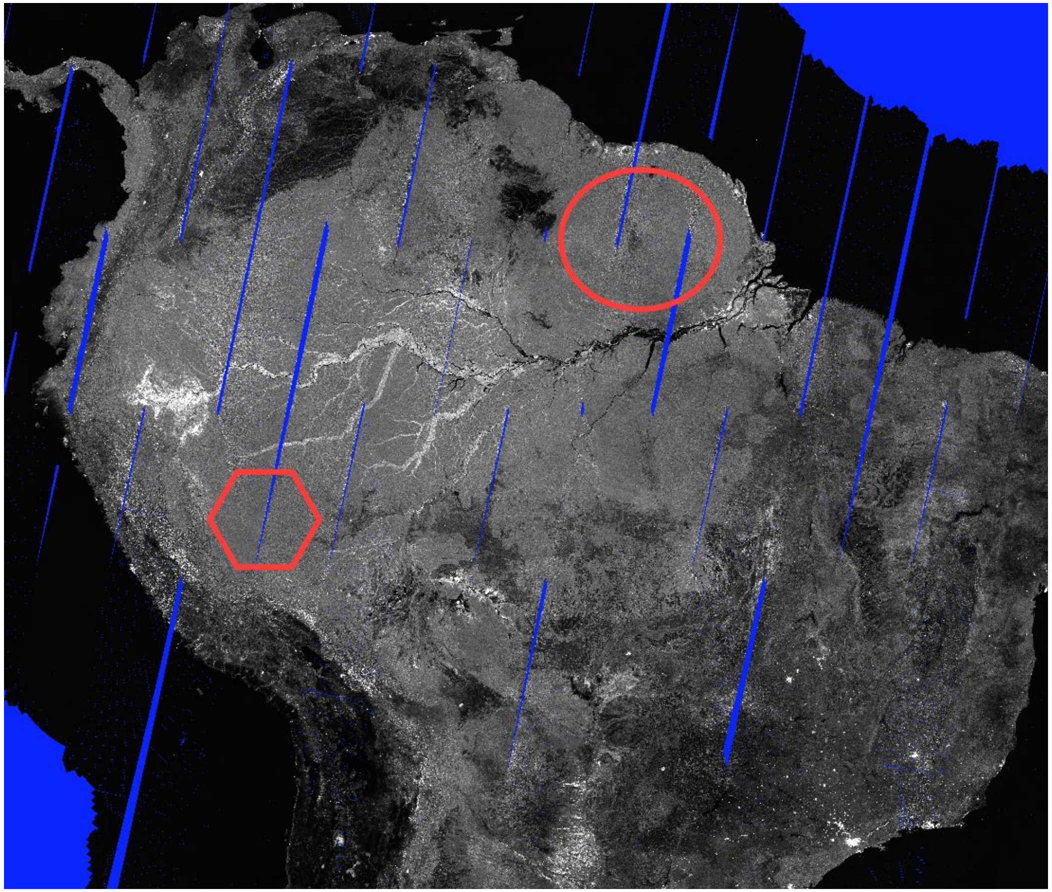
Backup locations in Africa and other areas will be identified if there are acquisition mode conflicts.

Must avoid areas subject to inundation and deforestation (or mask out these areas).

Distributed target sites must have uniform backscatter that span the 240 km cross-track swath.

These areas are useful for:

- Verifying antenna pattern calibration and digital beam-forming
- Cross-talk calibration and polarimetric calibration



SMAP Radar image composite shows that the Amazon Rainforest is impacted by inundation and deforestation

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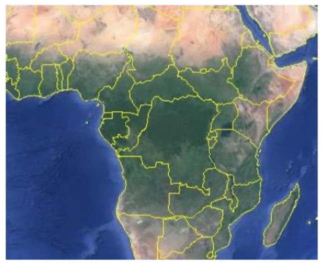
S-band Calibration

- ISRO is proposing a Cal/Val network for the S-band SAR calibration that includes sites in India and international locations.

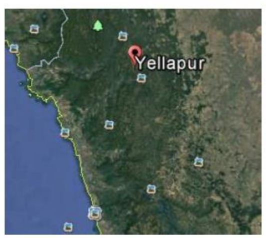
CAL-VAL SITES (Distributed Target Sites)

Amazon rainforest



Congo

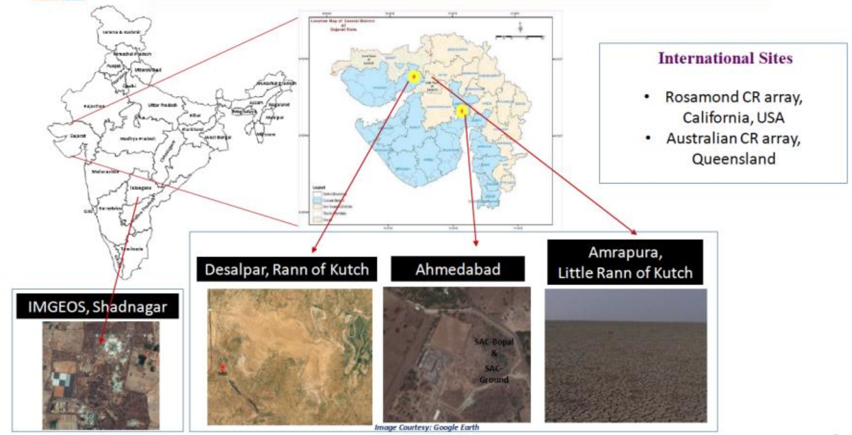
International Sites



Yellapur

Indian Site

CALIBRATION SITES (Point target Sites)



40 cm Square Trihedral

75 cm Square Trihedral

100 cms Dihedral

From S. Sharma, ISRO

Planned Field Activities

- Image Cal/Val
  - Deployment and maintenance of CRs
  - Collaboration with Geosciences Australia being discussed
- Ice velocity and displacement
  - Deployment and maintenance of GPS on Ice in Greenland and Antarctica
  - In collaboration with UNAVCO for Antarctic deployment of GPS
- Permafrost
  - Ground survey of seasonal deformation at two sites in Alaska
  - In collaboration with CRREL, NASA ABoVE
- Biomass
  - Airborne Lidar acquisitions over 15 field sites
  - Collaboration with NEON and others

Planned Field Activities

- Crop area
  - Field validation of VHR optical classifications
- Inundation extent
  - Field validation/modeling of inundation extent
  - Collaboration with SWOT and NASA ABoVE
- Sea Ice Velocity
  - GPS equipped buoys, an international collaboration
- Secular, co-seismic, and transient deformation
  - Utilize GPS data from networks of GPS stations

Secular, Co-seismic , and Transient Deformation

- Direct comparison of InSAR derived surface displacements with point observations of surface motion from collocated continuous GPS/GNSS stations
  - 11 locations selected, spanning different climate zones.
- Examination of the autocorrelation of noise in NISAR interferograms without comparison to GPS/GNSS, under the assumption that the surface deformation is essentially zero at all relevant spatial scales.
- Methodology is described in detail in the NISAR Solid Earth Science Algorithm Theoretical Basis Document (ATBD)
  - Online at the NISAR webpage

Cryosphere Science

- Networks of GPS stations deployed onto ice in Greenland and Antarctica
  - New: planning on a GPS station at the Antarctic South Pole, if NISAR can schedule repeat observations of that location.
- Directly compare estimated velocities and displacements

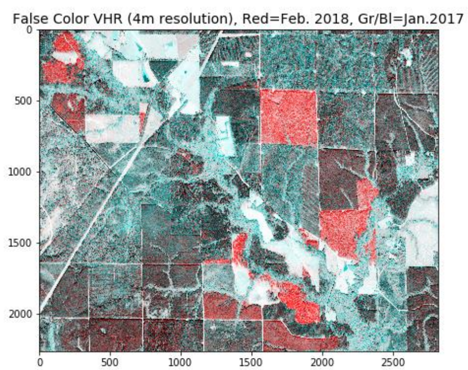
- Challenges for validation of permafrost deformation:
  - Difficult to measure on the ground without disturbing the soil and vegetation
  - Extreme seasonality
  - Soil moisture and inundation variability
  - Fine resolution spatial variability
- Validation approach:
  - Passive sites
    - Sites without expected deformation, such as gravely floodplain sites and bedrock
  - Active deformation sites
    - Measure thaw depth at beginning and end of summer season (model depth to deformation)
    - Measure Soil moisture using ABoVE protocols (to quantify impact)
    - **Measure Deformation through surveys using differential GPS**
    - Ground penetrating radar measurements at beginning and end of summer thaw
    - In collaboration with Cold Regions Research and Engineering Laboratory (CRREL)

Biomass

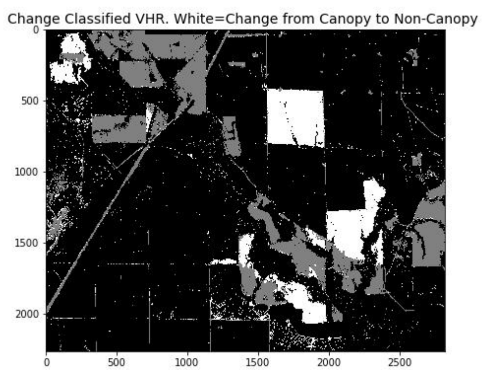
- Pre-launch
  - Using existing L-band SAR/Lidar/Field plot data from the ALOS-1/2 era
    - >30 sites spanning **15 distinct SAR/biomass ecoregions**
      - A study demonstrated the distinct SAR ⟺ biomass relationship for each of the 15 ecoregions (See ATBD)
      - Sites were selected from existing collaborations with established research study areas
      - Multiple sites and backup sites will be used to capture the variability of each ecoregion and verify performance of SAR-biomass relationship within each ecoregion.
    - Biomass and its uncertainty are estimated from ground plots using species or regional forest allometry
    - Airborne lidar data are used to extend our knowledge of biomass ranges for each site
      - Biomass and its uncertainty from Lidar data are estimated using models based on height metrics
    - Relate canopy height metrics to biomass for each ecoregion
    - GEDI is looking into these same issues, presenting opportunities for both projects to benefit through collaboration
- Post-launch
  - Update biomass for each site by collecting airborne Lidar data within one year of NISAR launch
    - Collect Lidar data over 15 Cal/Val sites representing the 15 ecoregions
    - Some Cal/Val sites may require additional field plot data to validate the Lidar biomass estimate
  - Compare NISAR algorithm results against Lidar biomass estimates

Forest Disturbance

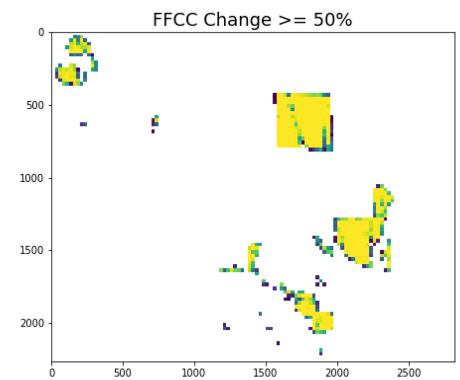
- Validation product:
  - Bi-temporal observations from Very High Resolution (VHR) optical data sets of resolutions of 5 meters or better
  - Supervised Classification approach
    - Uses machine learning approach like randomForest or SVM



Composite image



randomForest



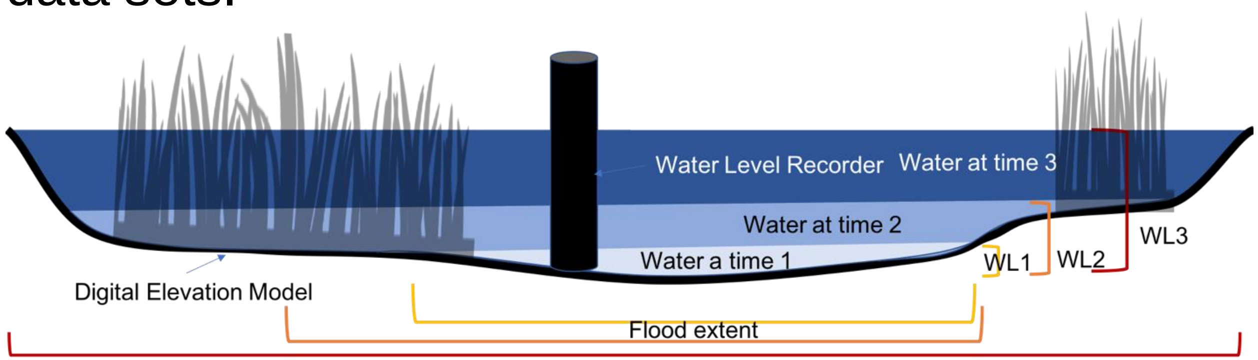
50% or more forest disturbance

Agricultural Crop Area

- Validation product:
  - Multitemporal observations (sampled throughout growing season) from Very High Resolution (VHR) optical data sets of resolutions of 5 meters or better
  - Supervised Classification approach
    - Uses machine learning approach like randomForest or SVM
    - Approach similar to forest disturbance validation product
  - Validated at JECAM/LTAR sites
    - JECAM is a subgroup of Group on Earth Observations (GEO)

Wetland Inundation

- Validation data sets for inundation
  - Ground transects
  - Models based on water level gauges and accurate DTM
  - High resolution multispectral/Thermal IR
  - Validated quad pol classifications for extended coverage
    - UAVSAR post-launch deployment to wetland Cal/Val sites coinciding with three consecutive NISAR acquisitions
- Validation data be obtained at the time of the NISAR overpass
- Classification accuracy of this product will be evaluated against the validation data sets.



Planned ecosystem campaign by UAVSAR In support of NISAR Cal/Val

- The use of C-band observations as a proxy for NISAR's L-band, as is often done for other disciplines, is likely not adequate for much of the development and testing of the NISAR ecosystem algorithms.
  - Response to soil moisture (AM to PM, and seasonal)
  - Response to vegetation structure
  - Temporal decorrelation
- 12 day repeats for both AM and PM takeoff times over a growing season
  - Current spaceborne L-band SAR do not acquire repeated observations at anywhere close to what is needed for algorithm development and testing.

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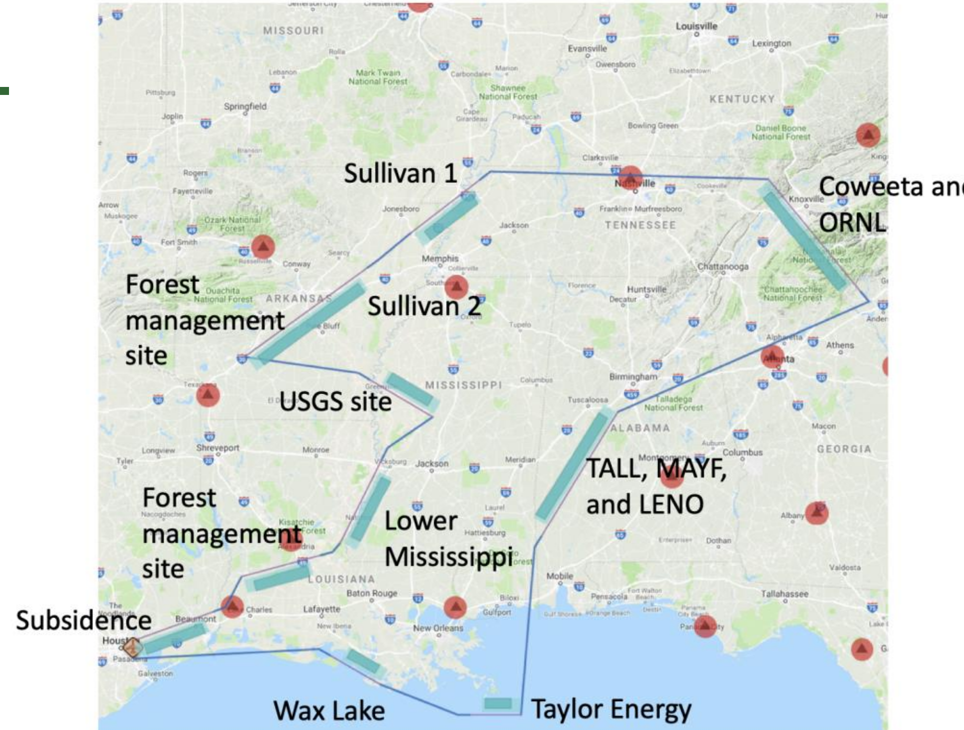
Planning Considerations

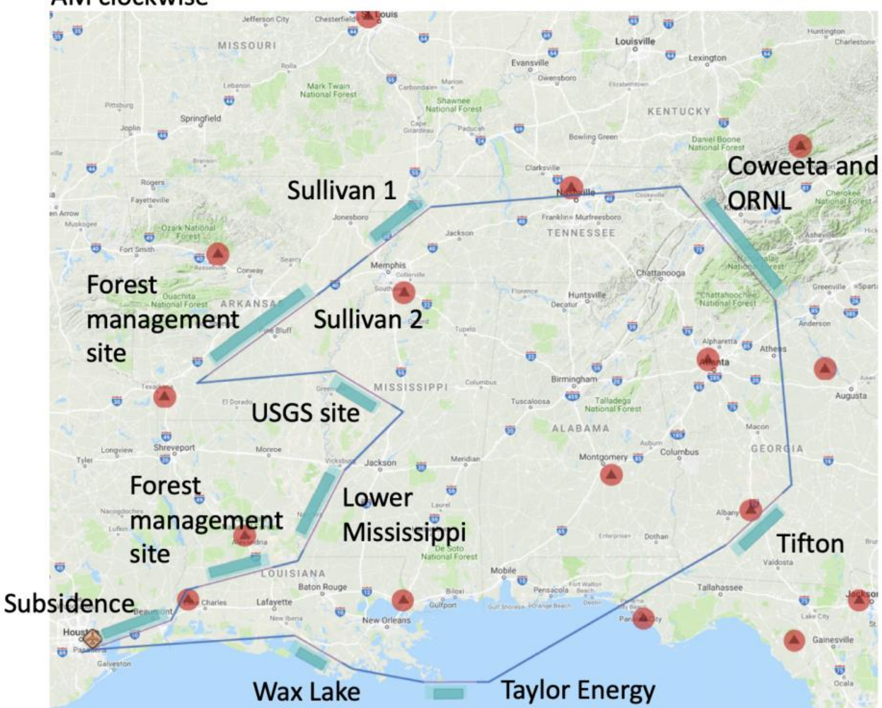
- Approximate dates: April -October 2019
- ~12 day repeats over 6 months
  - Capture growing season variability at NISAR repeat interval
- AM and PM flights offset by 0-12 days
  - Capture diurnal variations in soil moisture to be observed by NISAR ascending and descending data takes
- Observe sites where long term measurements already being acquired
- Collect data for all NISAR ecosystem requirements
  - Biomass, forest disturbance, wetland inundation, agriculture
- Validation data should be collected at every primary site

AM-PM
Basic observation plan

PM counter-clockwise



AM clockwise



Nominal swaths are indicated.

NISAR simulated products

The UAVSAR data will be used to produce NISAR-like products

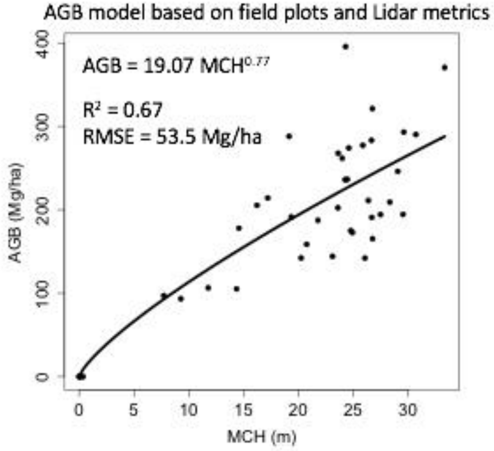
- Add noise, reduce incidence angle range, reduce resolution
- Process products representing all NISAR modes
  - Such as the background land split-spectrum quasi-quad-pol data sets
    - 20/40 MHz HH+HV and 5 MHz VV+VH
- Can compare standard quad-pol results against those from the simulated NISAR products

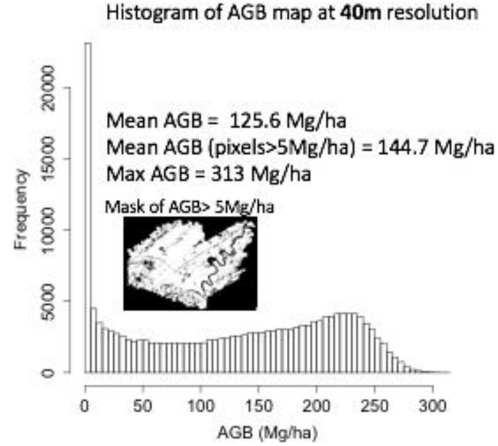
Validation data at primary sites

- **NEON sites (NSF funded sites), LTER**
  - Terrestrial sites (biomass) – LIDAR data, soil moisture, tree inventory data
  - Aquatic sites (wetlands) LIDAR data, soil moisture
  - Coweeta LTER - LIDAR data, soil moisture, tree inventory data
- **JECAM site in Georgia**
  - Crop type, planting/harvest dates, crop yield, soil moisture VHR optical
- **Sullivan Ag research site, LTAR site**
  - Crop type, planting/harvest dates, crop yield, soil moisture, VHR optical
- **SWOT Cal/Val sites in Mississippi**
  - Need to coordinate field campaign including deployment of pressure transducers
  - VHR optical data, and field measurements of inundation
- **Forest management sites**
  - Need to coordinate with forest management companies and timber industry
  - VHR optical data
- **SMAPVEX19**
  - Soil moisture measurements at Millbrook and Harvard forest
  - PALS airborne L-band radiometer

NEON biomass site

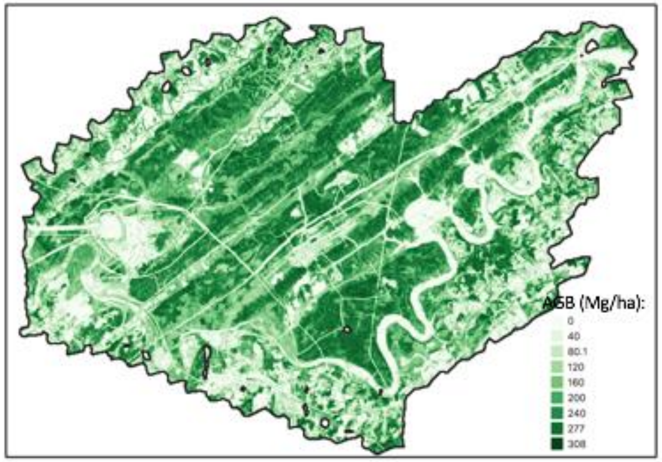
Example: Oak Ridge NEON Site





AGB: aboveground biomass

MCH: Lidar mean top canopy height



40m resolution biomass map

V. Meyers, 2018