GEDI
ECOSYSTEM LIDAR

# Global Ecosystem Dynamics Investigation

## Mission Status & Data Products


**GEDI Science Team**

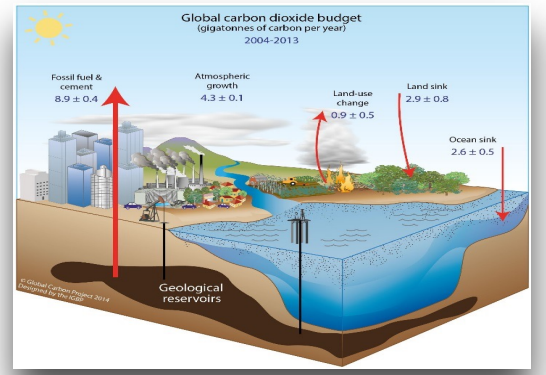
University of Maryland

# Presentation Outline

1. **GEDI overview**
   - Lidar measurements
   - Science approach
2. **GEDI mission status**
   - Schedule and extension
   - Impacts of ISS orbital pattern
3. **GEDI data products**
   - Level 1 & 2 product improvements
   - Level 3 gridded data products
   - New Level 4 data products
4. **GEDI-NISAR fusion**
5. **Summary**

# GEDI Science Questions and Objectives

**GEDI Goal: Advance our ability to characterize the effects of changing climate and land use on ecosystem structure and dynamics**



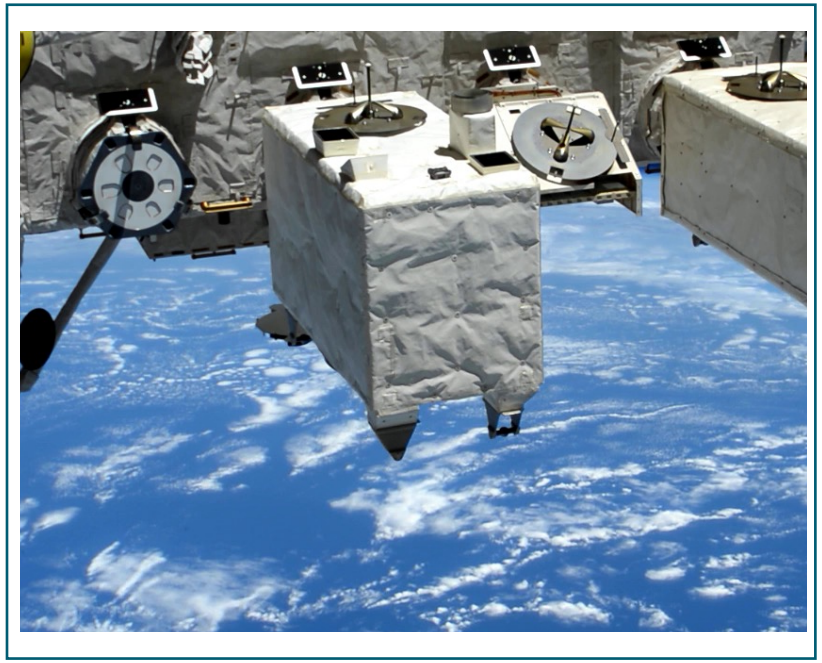

Carbon Cycle

Biodiversity

| Question | Applications |
|---|---|
| What is the carbon balance of the Earth's forests? | Forest Management & Carbon Cycling |
| How will the land surface mitigate atmospheric CO2 in the future? | Water Resources |
| | Weather Prediction |
| How does forest structure affect habitat quality and biodiversity? | Topography & Surface Deformation |

# Important Facts About GEDI

## High Resolution Laser Ranging of the Earth's Forests and Topography



- **Operational as of April 2019 on the ISS**
- **Nominal on-orbit mission length of two years (April 2021)**
  - Approved for mission extension through 2023
- **Uses a lidar instrument optimized for vegetation measurements**
  - 3 lasers with full waveform measurements in the NIR
  - 8 tracks of data with 25 m footprints, ~600 m between tracks
- **GEDI is a sampling mission but produces gridded data products as well**
  - 10 billion canopy structure measurements
  - Nominal 1 km grid resolution
- **>18 months of Release 2 data currently available at LPDAAC, and 1 year of Release 1 gridded data at ORNL DAAC**

GEDI ECOSYSTEM LIDAR

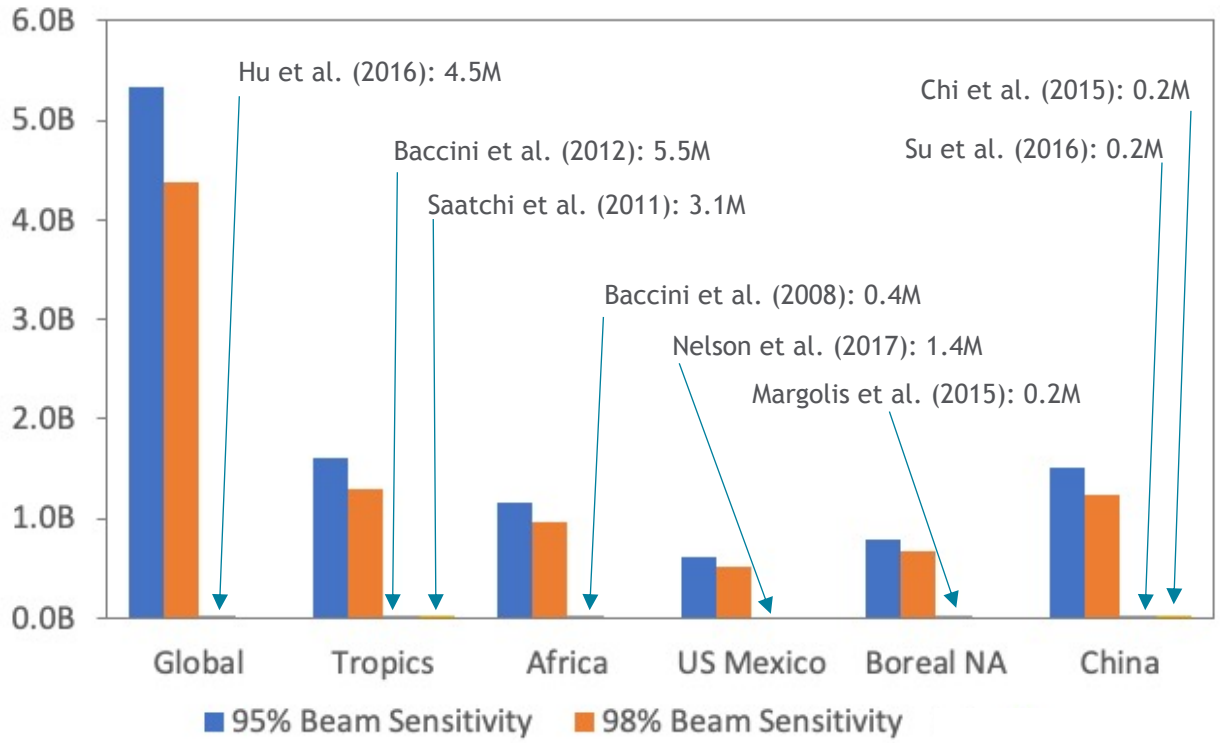


NASA

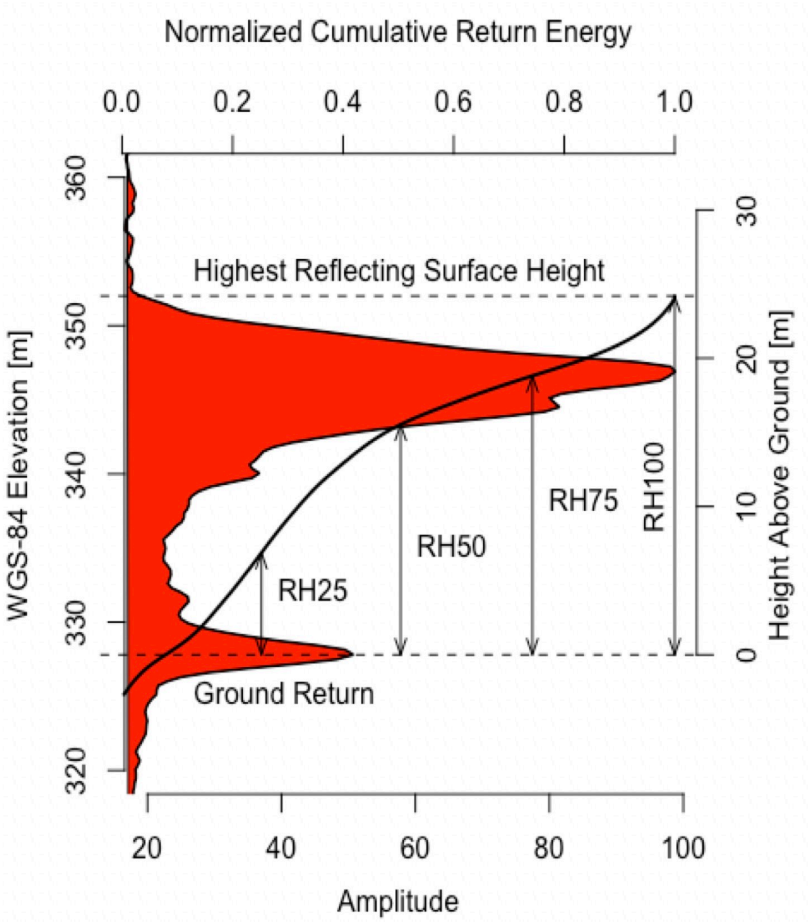
UNIVERSITY OF MARYLAND 1856

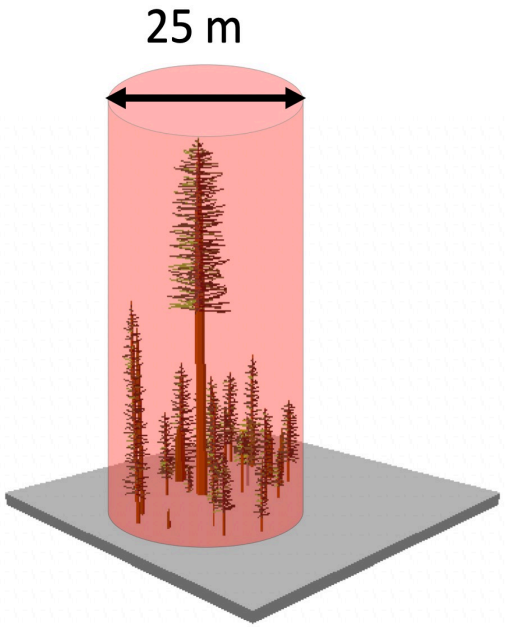
# Heritage

- **GEDI builds on a heritage of waveform lidar**
  - Land, Vegetation, and Ice Sensor (LVIS)
  - Ice, Cloud, and land Elevation Satellite (ICESat)
  - Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) concept
  - Mature algorithms and models
- **GEDI has vastly expanded the archive of space-based lidar**
  - 9.5 billion land surface measurements have been acquired (April 2019 – April 2021)
  - Compared to previous biomass studies, orders of magnitude more shots are publicly available (April 2019 – September 2020)

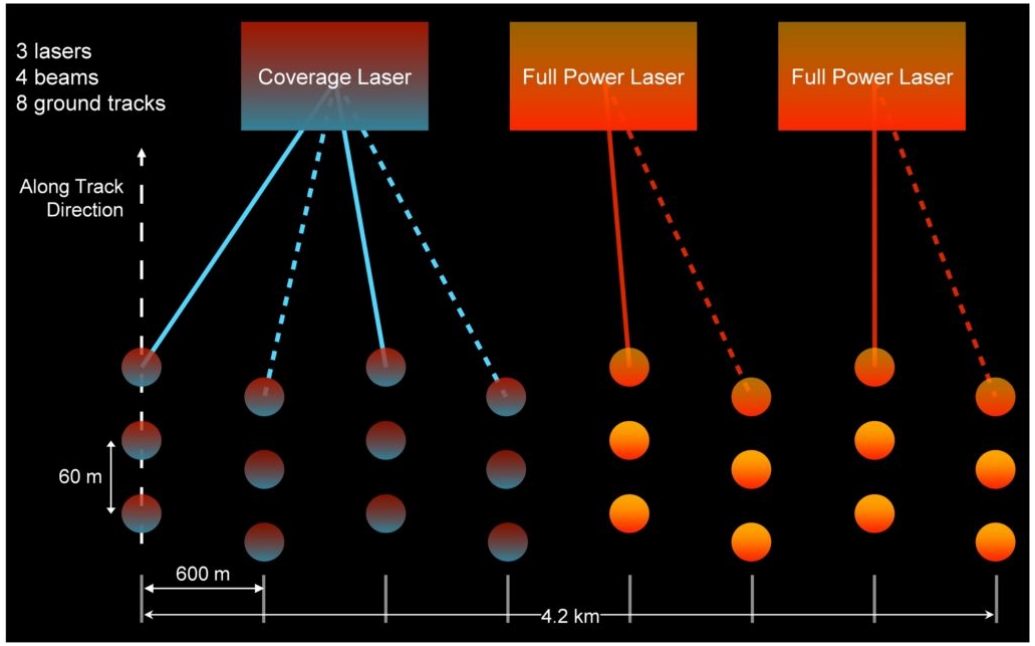


# GEDI Lidar Measurements

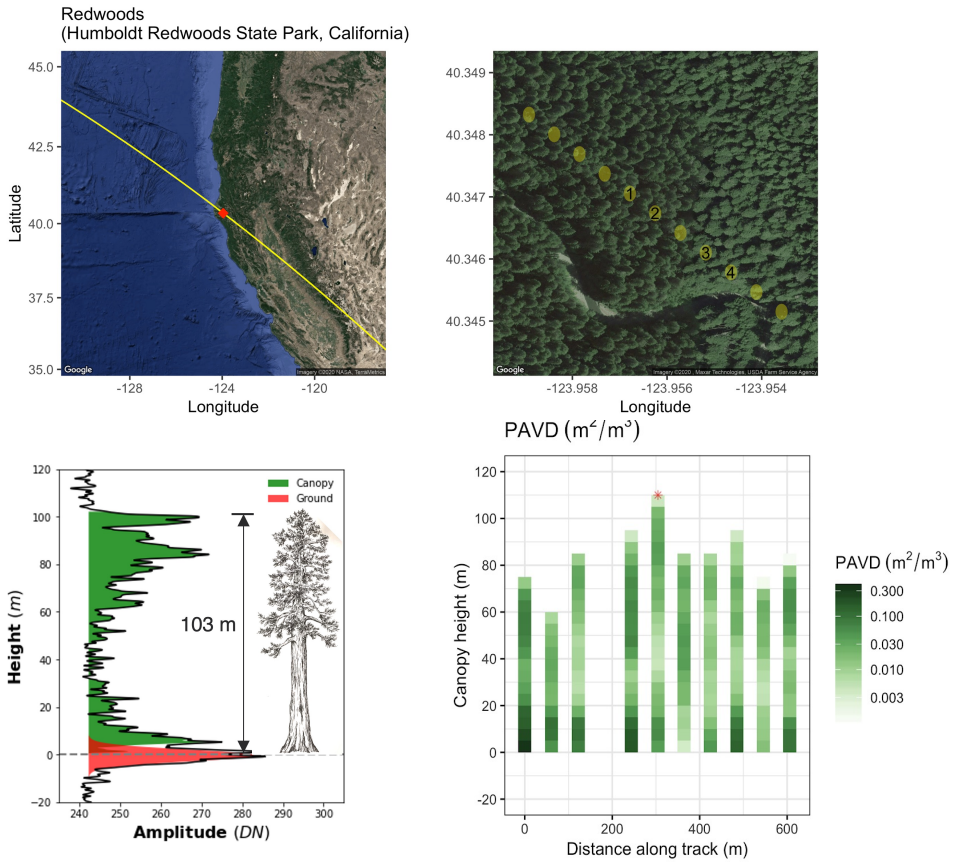


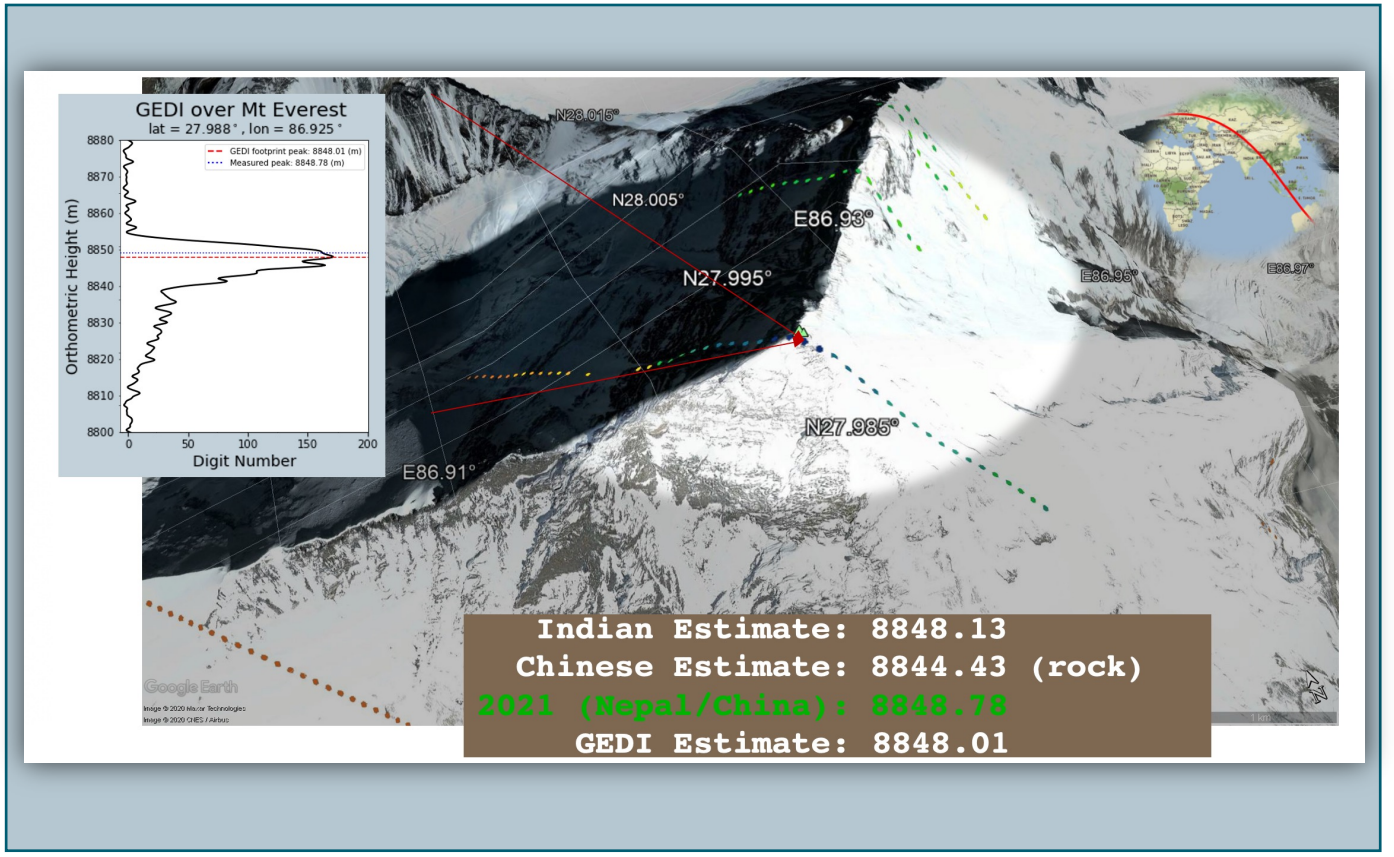




**GEDI's sole observable is the lidar waveform which provides ground elevation, canopy height, cover and various profiles and metrics**



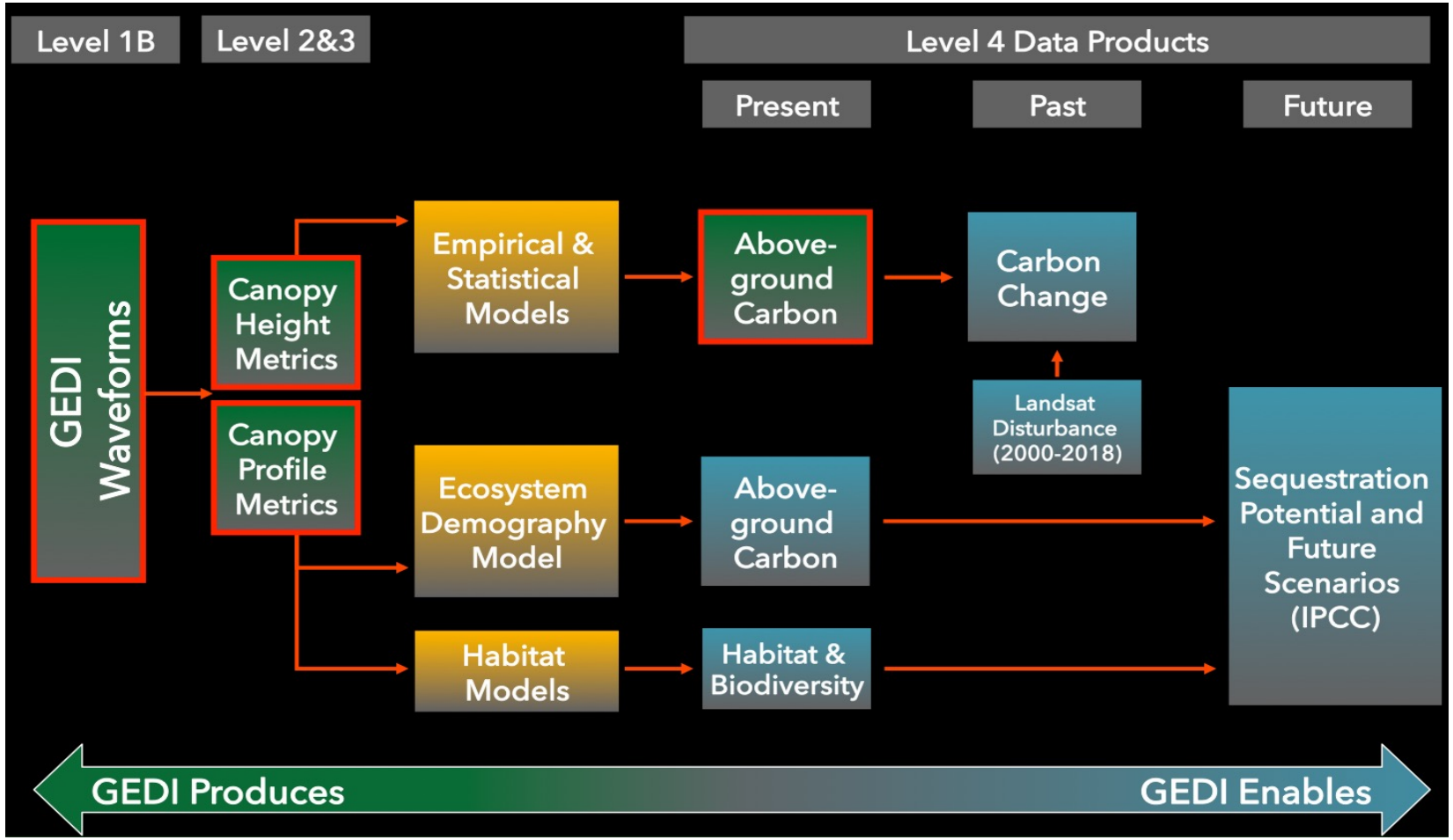
# GEDI Lidar Measurements



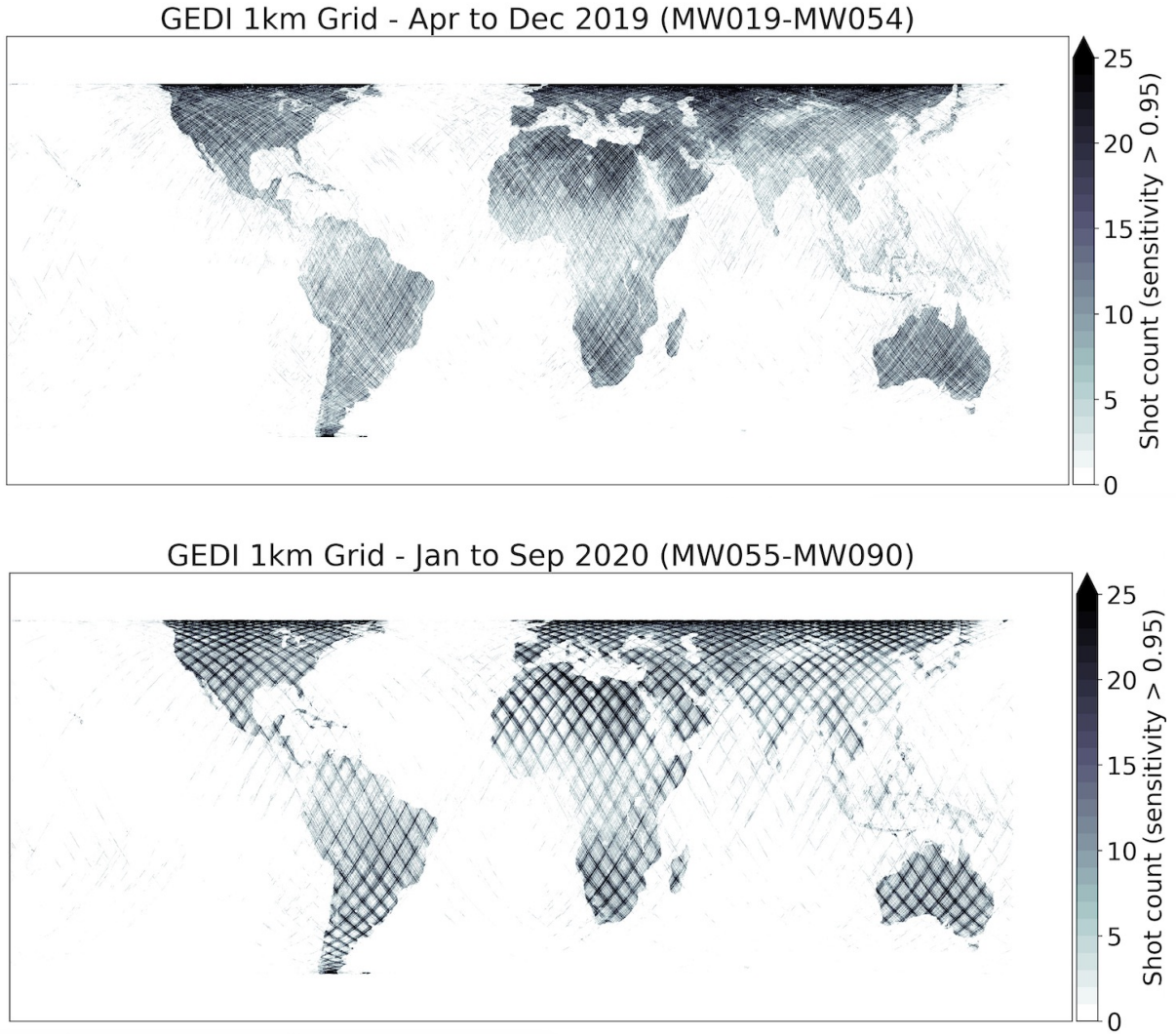

**GEDI is providing unprecedented mapping of ecosystem structure, biomass and topography**

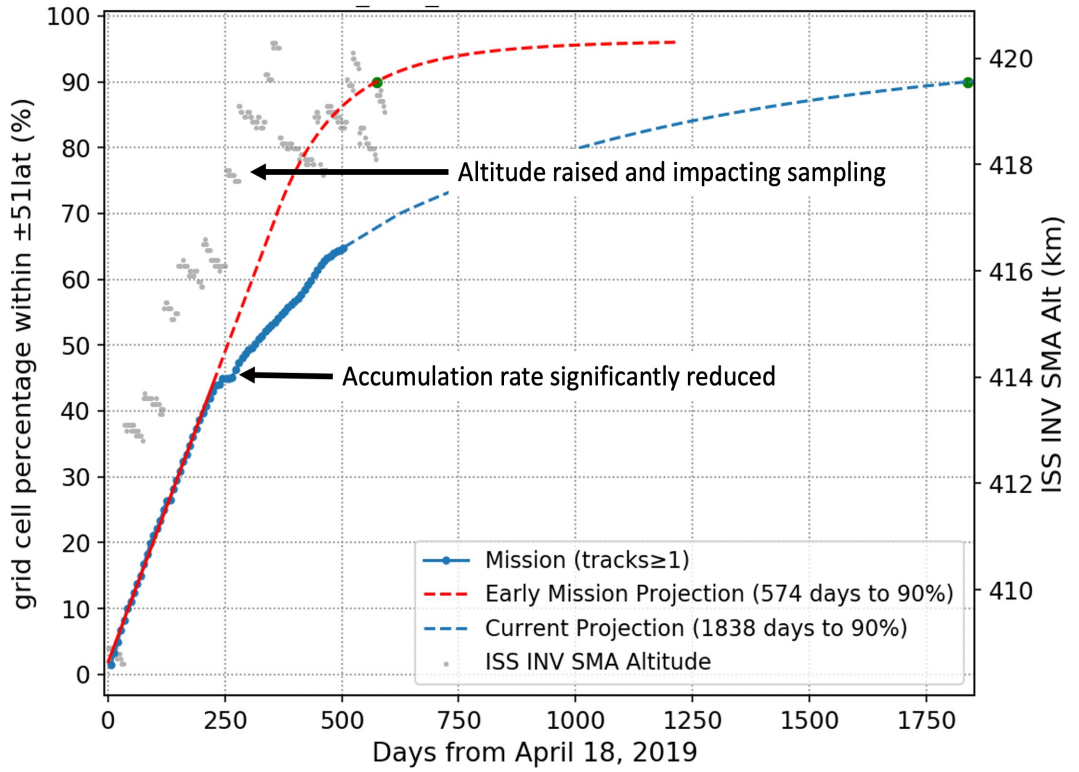
# Science Approach and Data Products




| Product | Description |
|---|---|
| Level 1 | Geolocated Waveforms |
| Level 2 | Canopy Height/Profile Metrics<br>• RH metrics<br>• Canopy top height<br>• Ground elevation<br>• Canopy cover and cover profile<br>• LAI and LAI profile |
| Level 3 | Gridded Footprint Metrics |
| Level 4 | Biomass |
| Level 4 | Demonstrative* Products<br>• Ecosystem model outputs<br>• Enhanced height/biomass using fusion with Tandem X & Landsat<br>• Habitat model outputs |

# Impacts of ISS Orbital Pattern

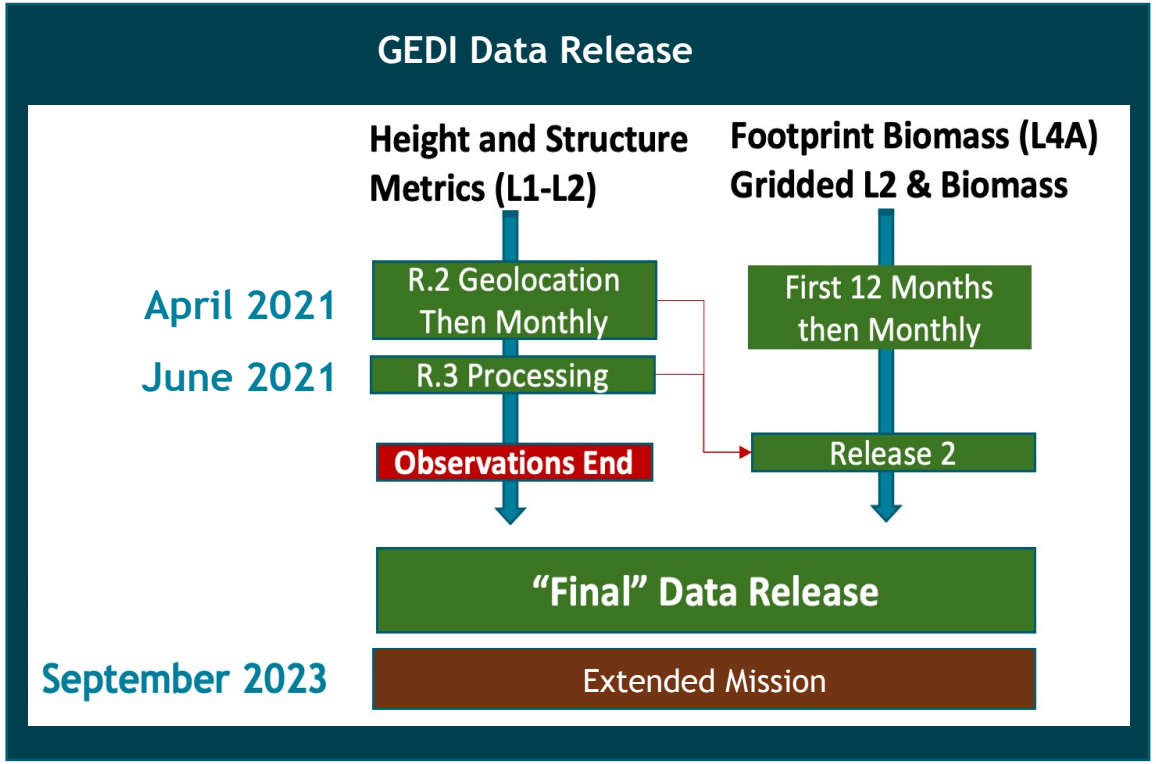


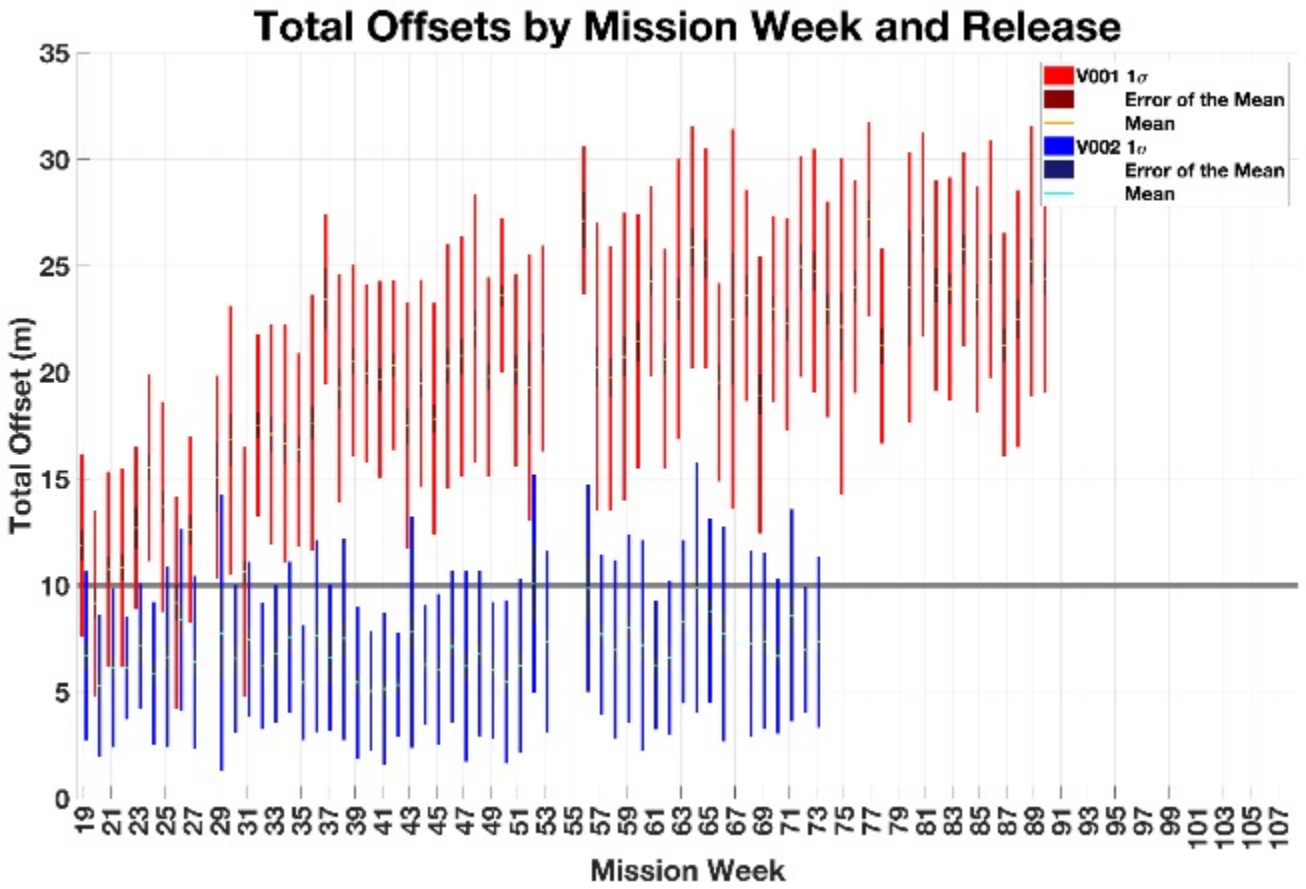

**Higher ISS altitudes lead to resonance and poor coverage**

# GEDI Mission Schedule and Extension

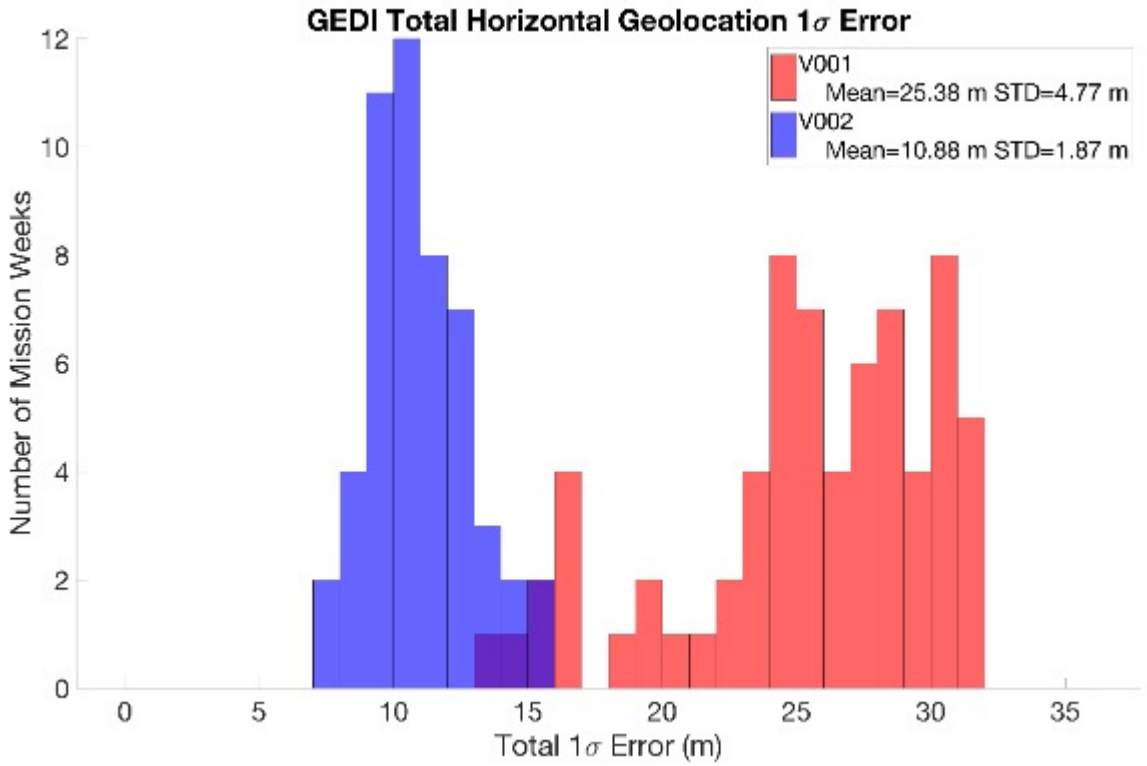
- **GEDI has past its two-year prime mission**
  - Has not yet met Level 1 requirements because of ISS orbital issues (coverage)
- **Extension proposal approved to take observations through 2023**
  - All systems are nominal
- **Presented to ISS and ROSCOSMOS to change ISS orbit**
  - Orbit will be lowered in 2022
- **Fusion efforts planning for NISAR and producing biomass at much finer resolutions with DLR using TanDEM-X, Landsat**
  - Using parametric error framework as possible with fusion efforts as well



# Level 1 & 2 Product Improvements

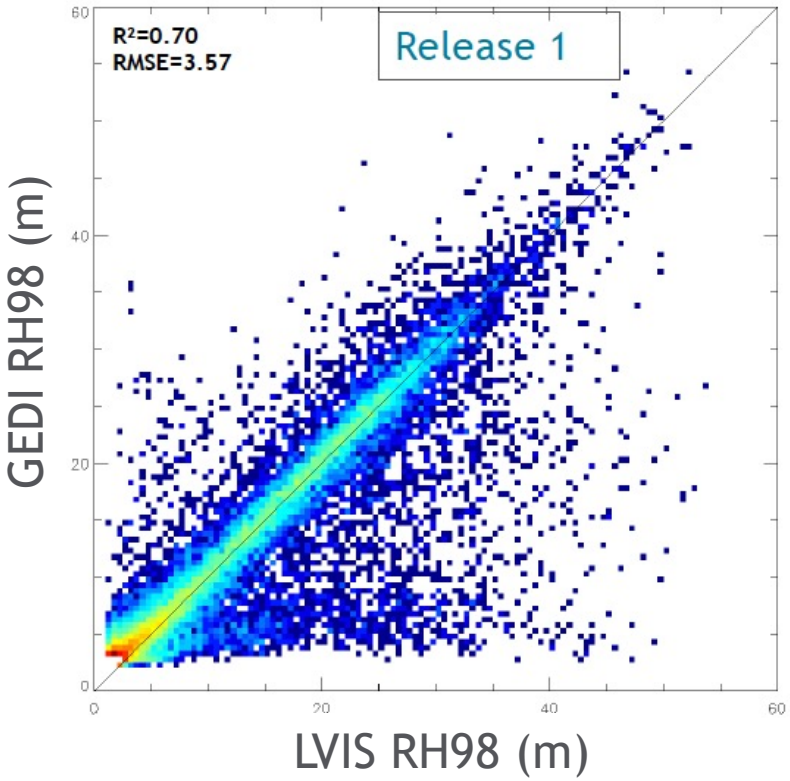


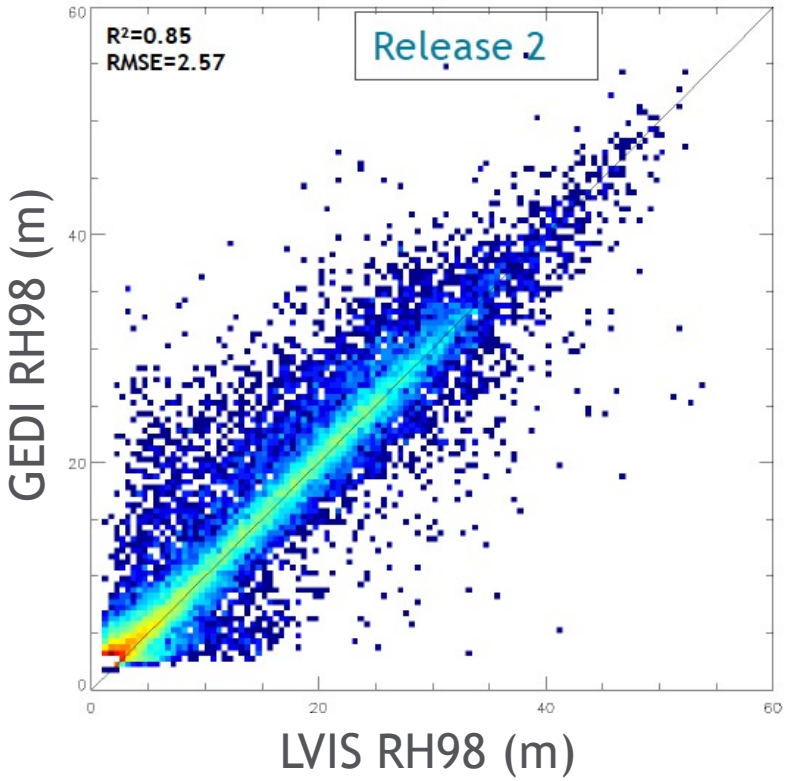

**Release 01**: 25.38 ± 4.77 m
**Release 02**: 10.88 ± 1.87 m

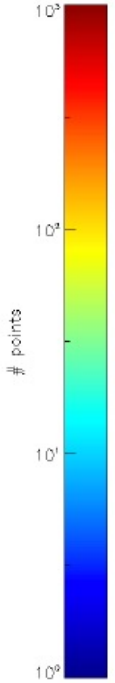


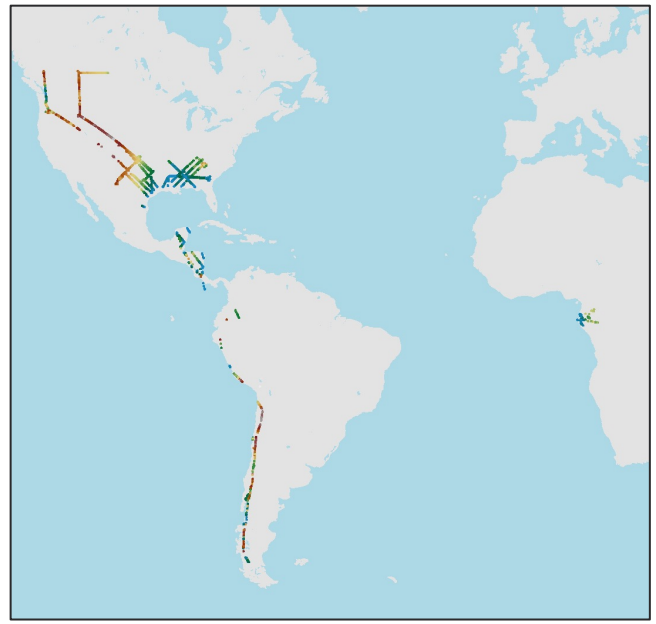

Horizontal geolocation validation comparing to 3DEP

# Level 1 & 2 Product Improvements



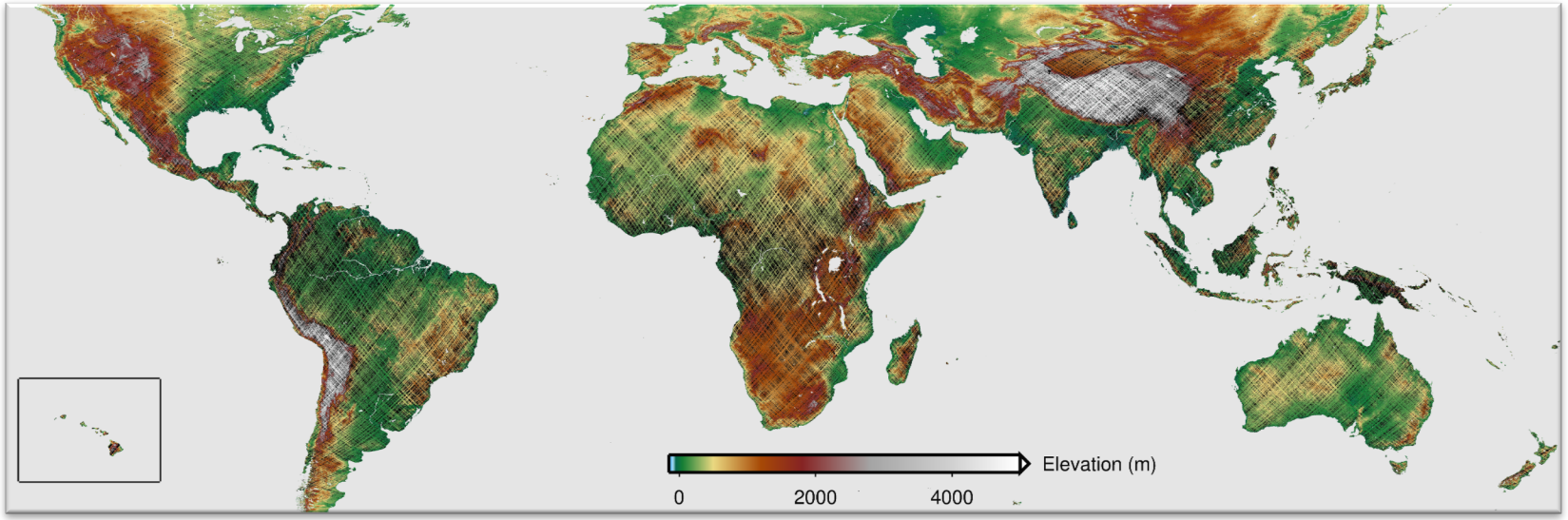



LVIS 2015 (transits to/from Chile/OIB)
LVIS 2016 (Gabon/AfriSAR)
LVIS 2019 (GEDI + transits / ABoVE)
Source: Michelle Hofton (NASA GSFC)

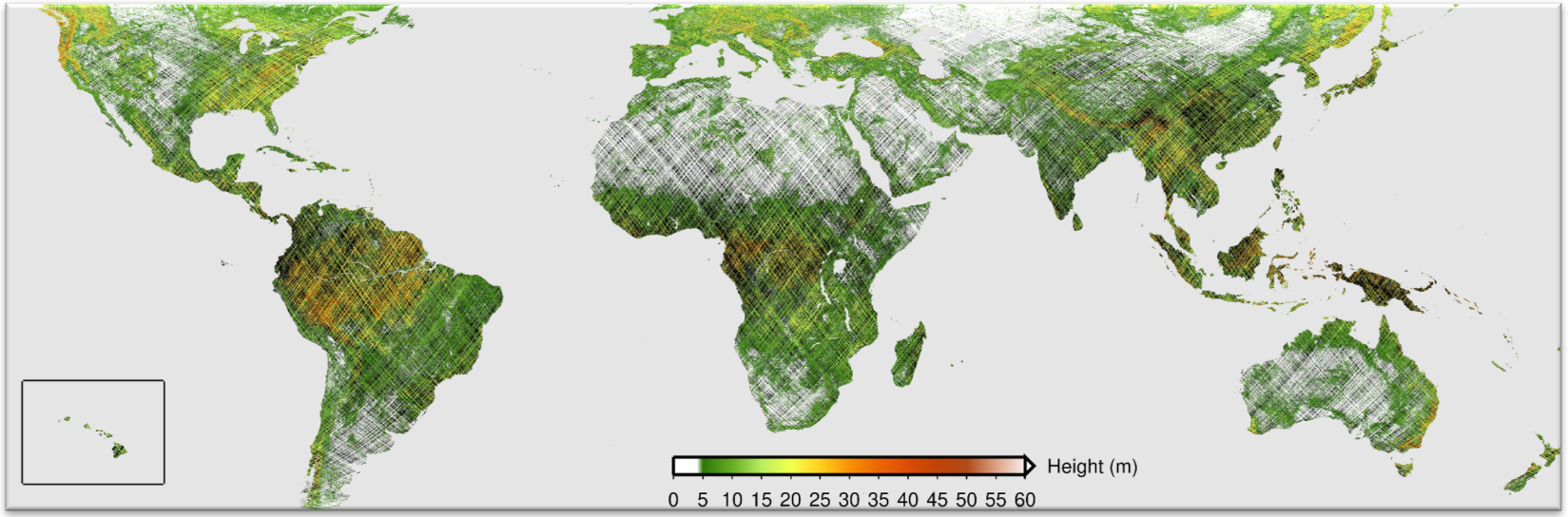
**GEDI Release 2 has improved waveform algorithm setting group selection**

# Level 3 Gridded Data Products

**Elevation**

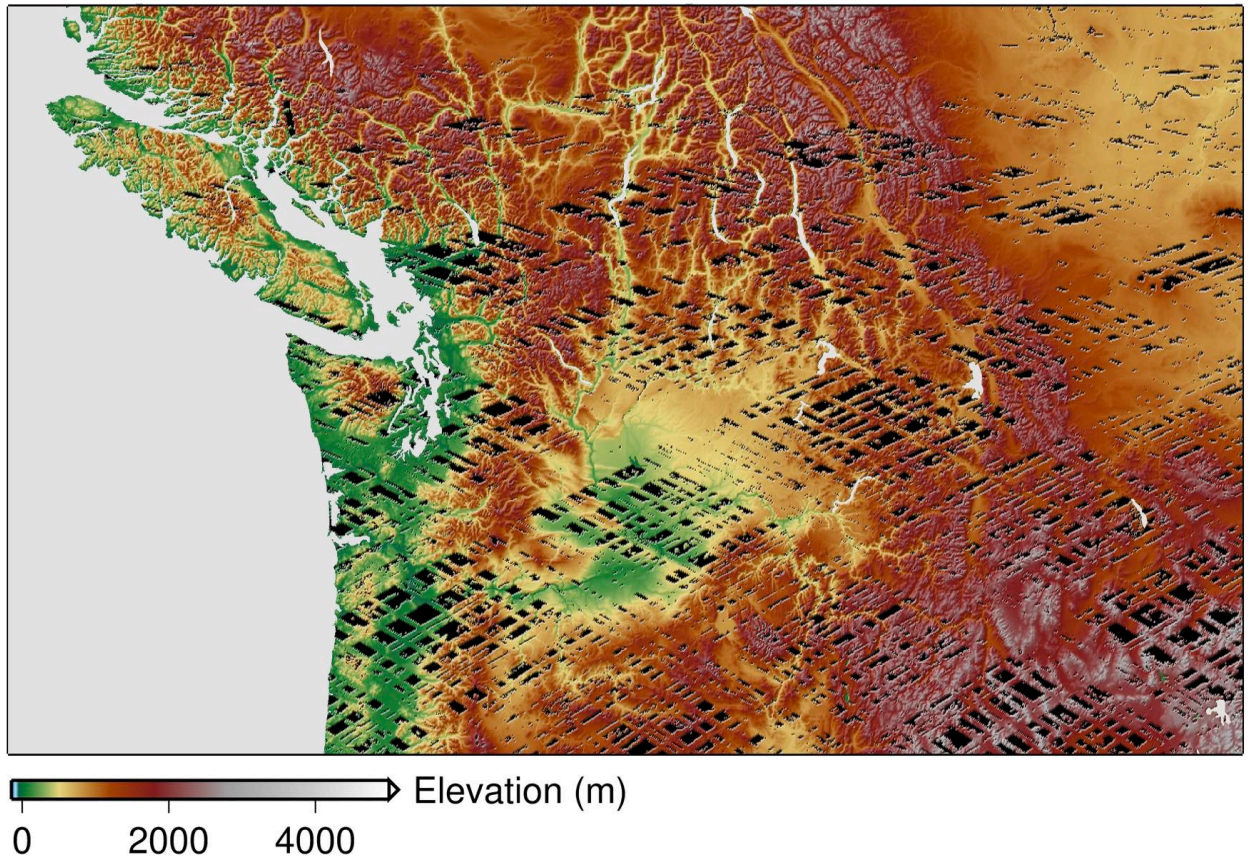



**Height**

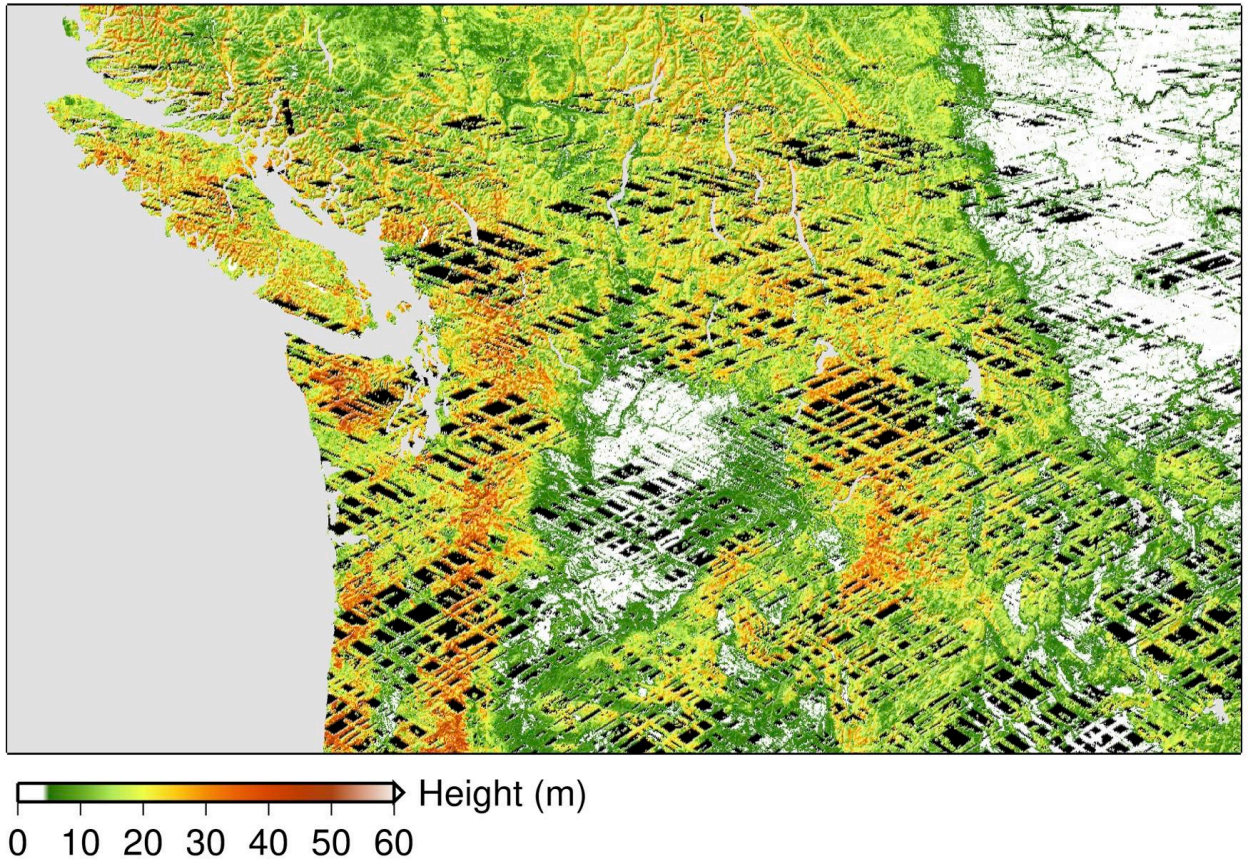


# Level 3 Gridded Data Products

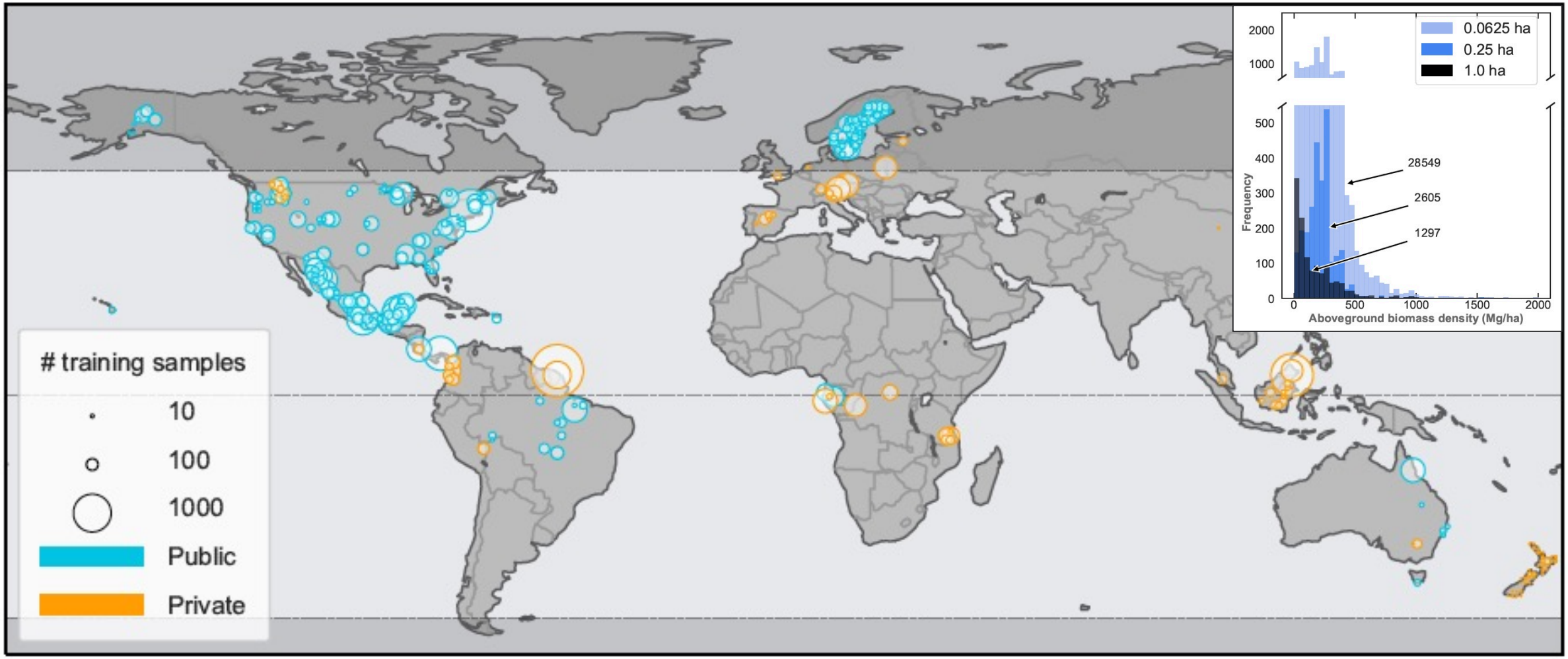
## Topography




## Canopy Height

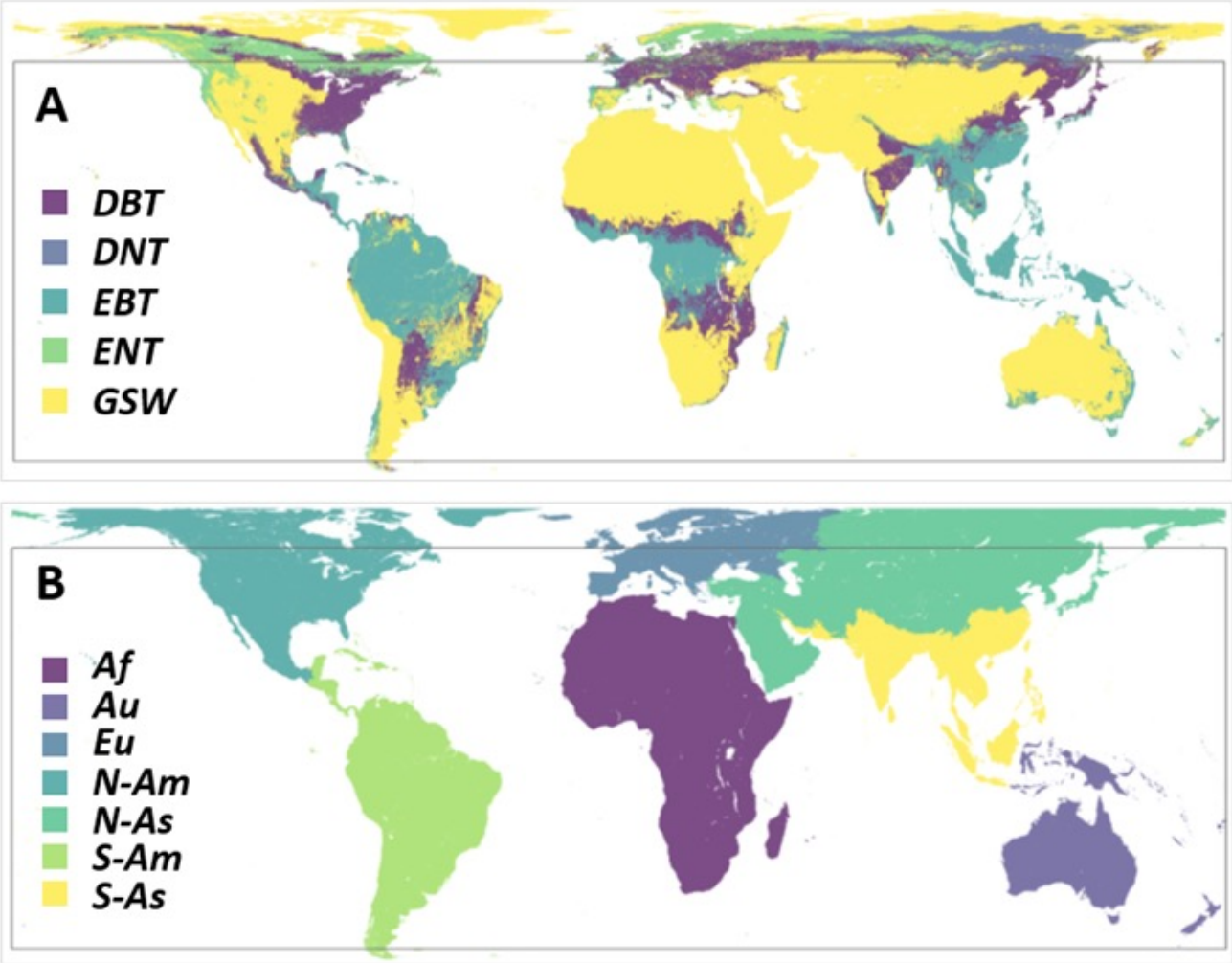


# GEDI Forest Structure & Biomass Database



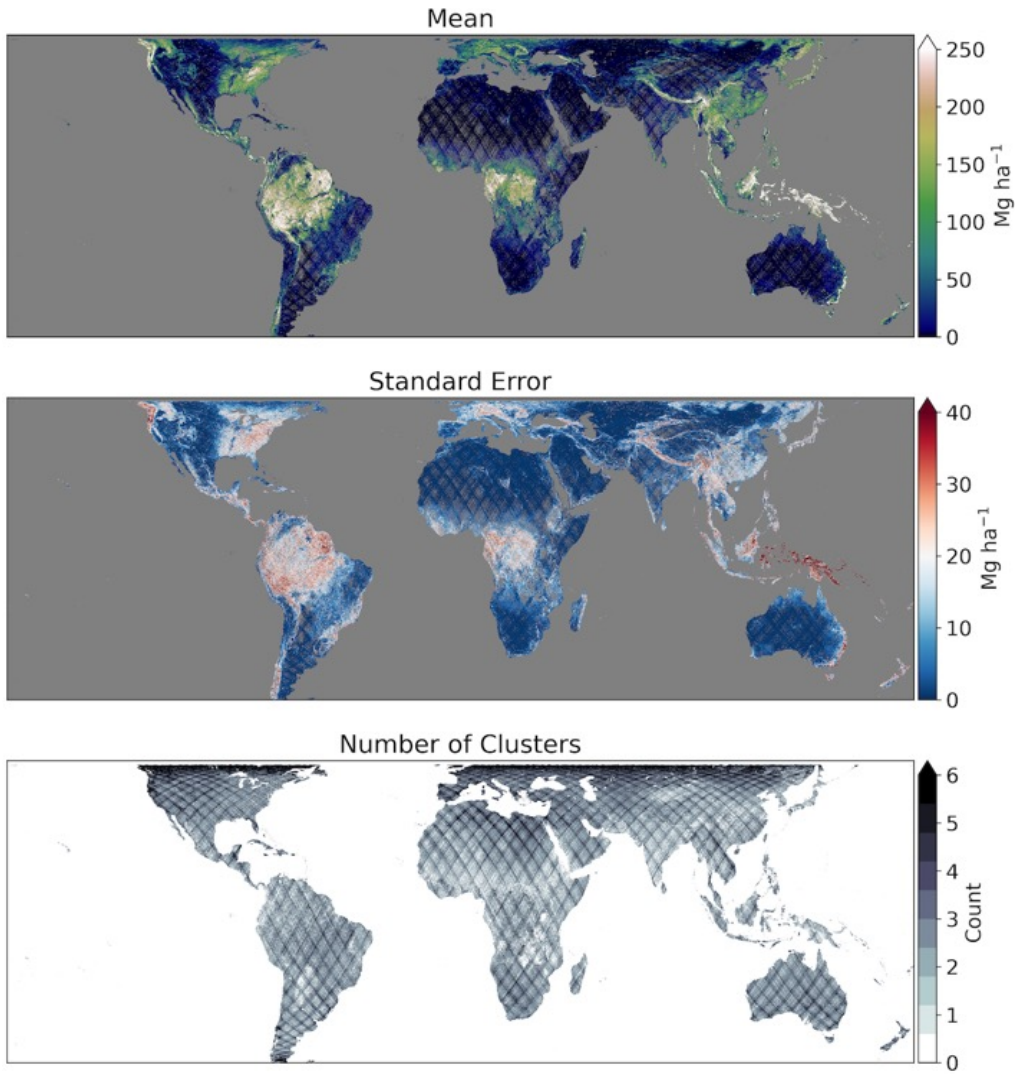

1.7 million trees | 12,510 plots | 22,709 subplots | 31,414 GEDI footprints

# New Level 4A Footprint Biomass Data Product




- **The GEDI04_A models are linear statistical models**
  - Variable model size (1 - 4 variables)
  - Transformation of the response and predictor variables
  - Model selection through geographic cross-validation
  - Prediction strata based on Plant Functional Type (A) and Region (B)
- **The GEDI04_A product has a 1:1 mapping with Release 1 Level 2A data**
  - Includes new algorithm setting group selection

# New GEDI Level 4B Gridded Biomass Product




1. **L4B Gridded Biomass Product**
   - 1 km map still under internal review and release to ORNL DAAC expected in August
   - ~10 km map being prepared for the NASA biomass harmonization activity
2. **Calibration and Validation**
   - Comparison of L4B estimates against FIA hexagon and FAO country estimates in progress
   - Modified estimation approach developed for large areas to account for covariances between cells and data gaps
3. **Documentation**
   - ATBD and Release 1 User Guide in revision
   - Hybrid/GHMB comparison in revision at RSE

GEDI ECOSYSTEM LIDAR



NASA

UNIVERSITY OF MARYLAND 1856

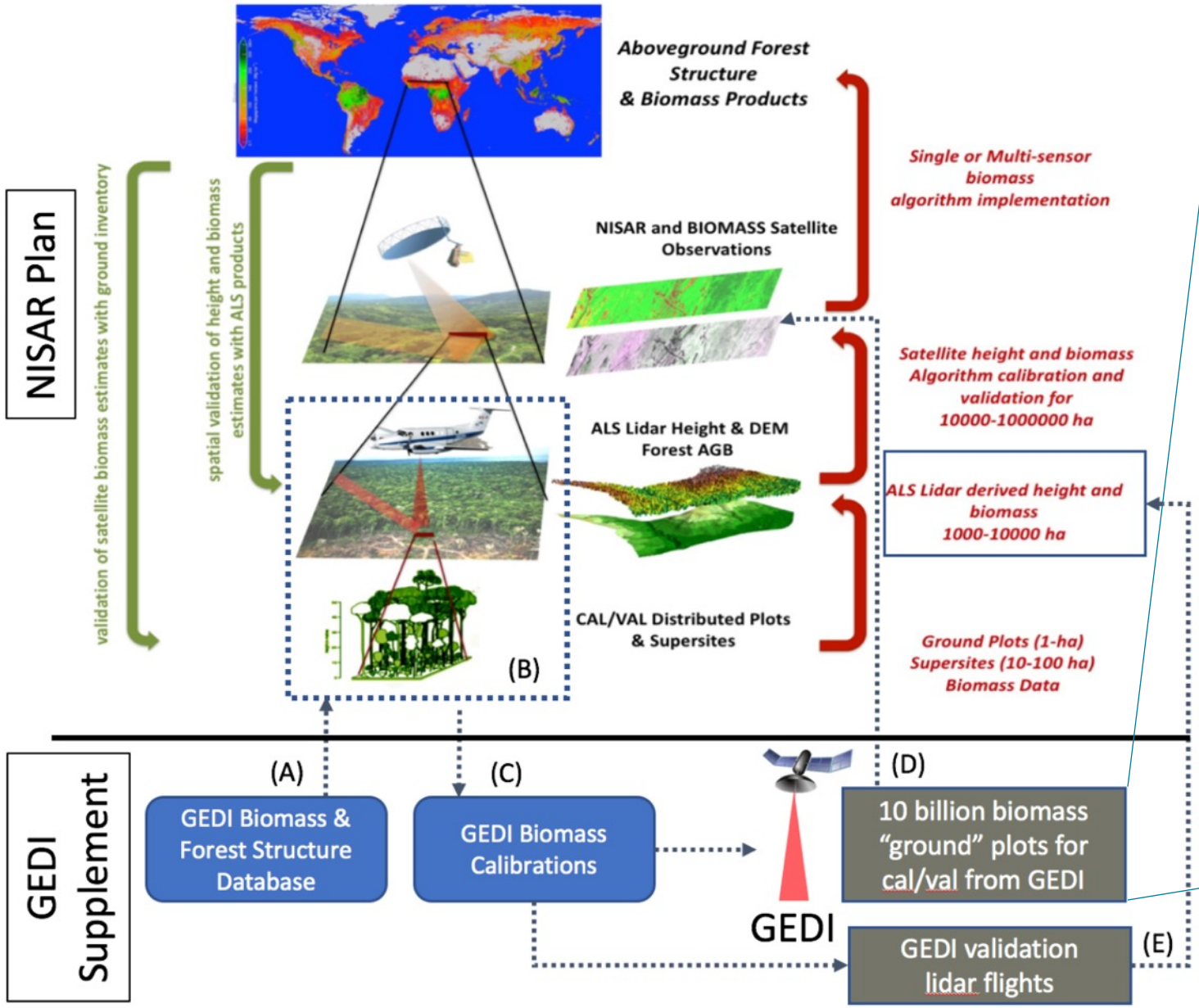
# New GEDI Level 4B Gridded Biomass Product

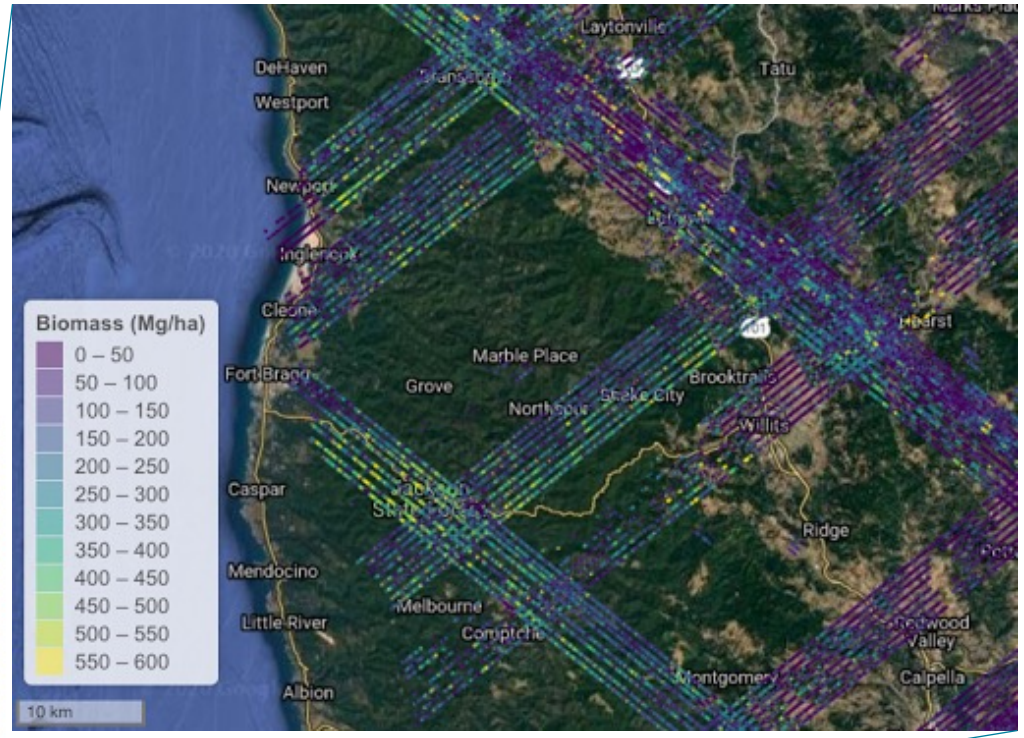
**L4B Gridded Biomass Product metrics:**

1. Mean (Mg $ha^{-1}$)
2. Model error variance
3. Sample error variance
4. Standard error (Mg $ha^{-1}$)
5. Percentage standard error
6. Number of clusters (tracks)
7. Number of samples (shots)
8. Quality flag
   0 = Outside GEDI domain
   1 = Land surface
   2 = Land surface and meets L1 requirements
9. L4A model ID

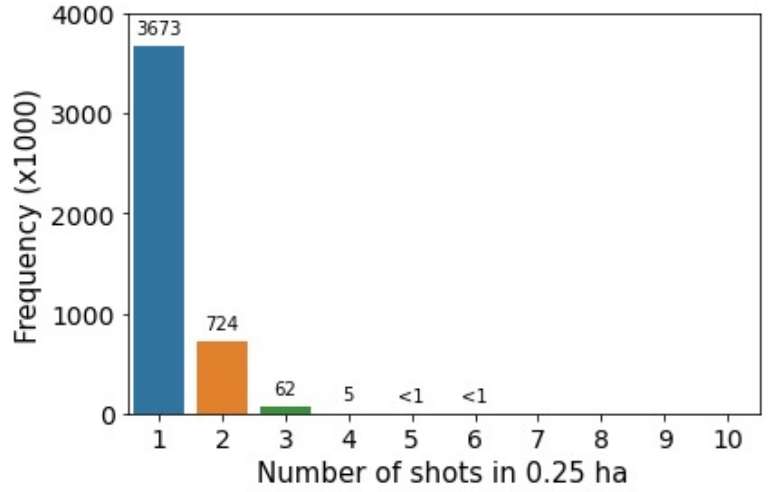
1. **L4B Gridded Biomass Product**
   - 1 km map still under internal review and release to ORNL DAAC expected in August
   - ~10 km map being prepared for the NASA biomass harmonization activity
2. **Calibration and Validation**
   - Comparison of L4B estimates against FIA hexagon and FAO country estimates in progress
   - Modified estimation approach developed for large areas to account for covariances between cells and data gaps
3. **Documentation**
   - ATBD and Release 1 User Guide in revision
   - Hybrid/GHMB comparison in revision at RSE

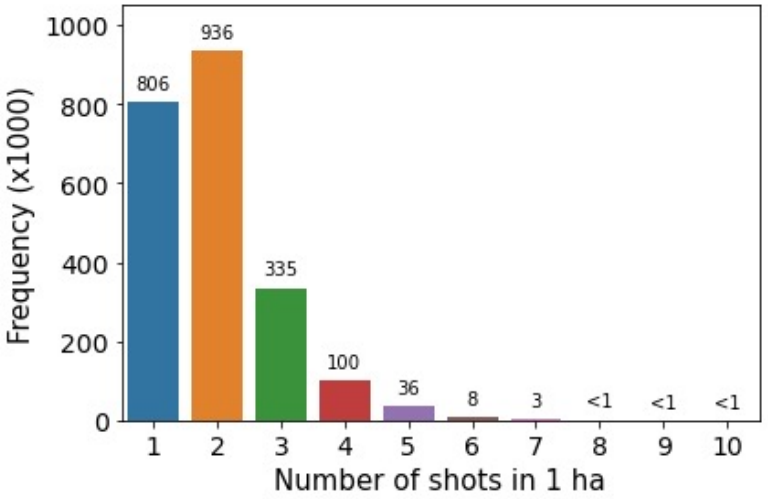
# Leveraging the GEDI mission for NISAR Cal/Val

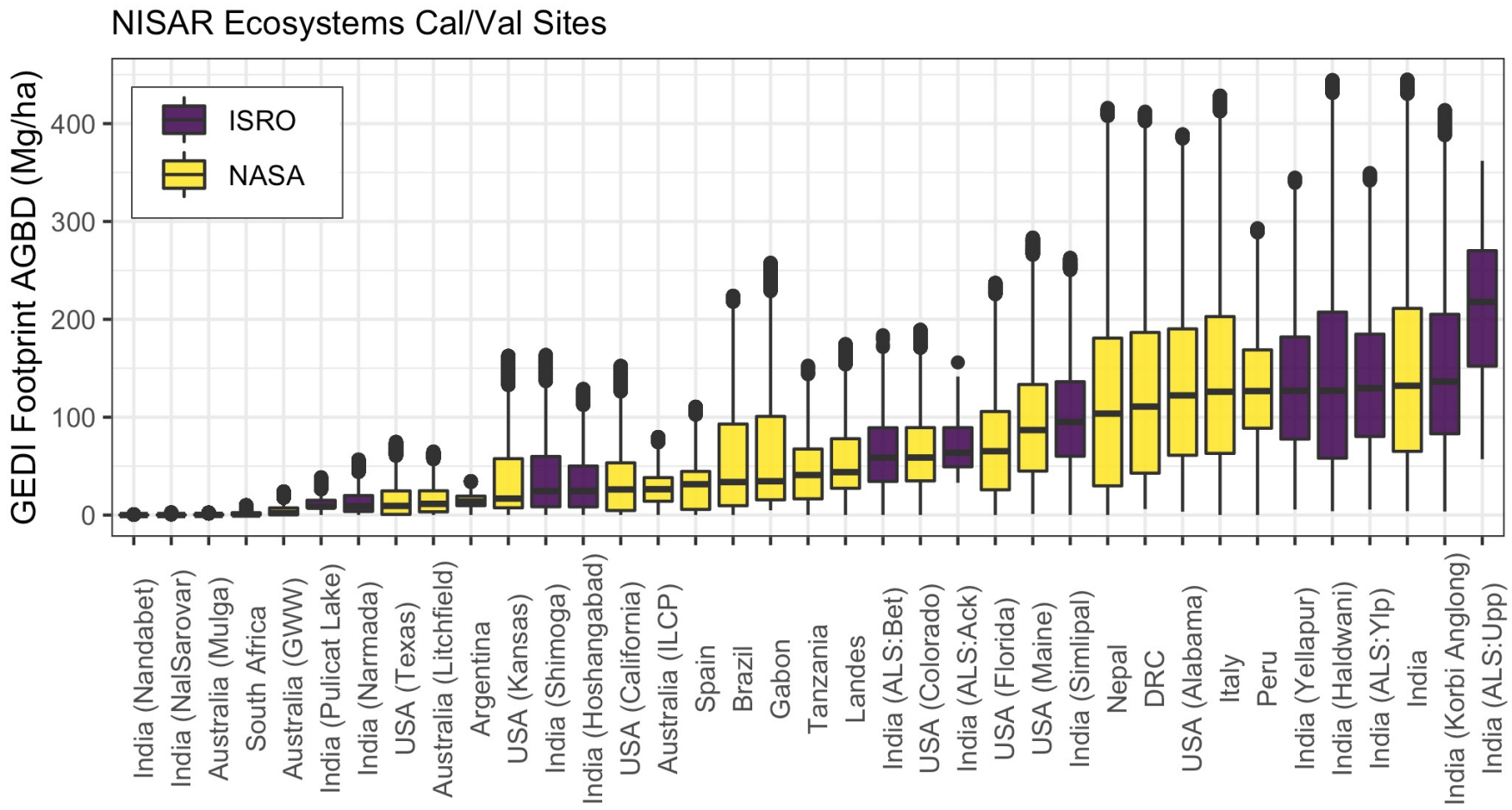


# A framework to improve NISAR Biomass using GEDI




NASA/ISRO sites being targeted in weekly GEDI Science Planning
>480,000 1 ha cells have at least 3 GEDI shots after 18 months on-orbit

GEDI ECOSYSTEM LIDAR

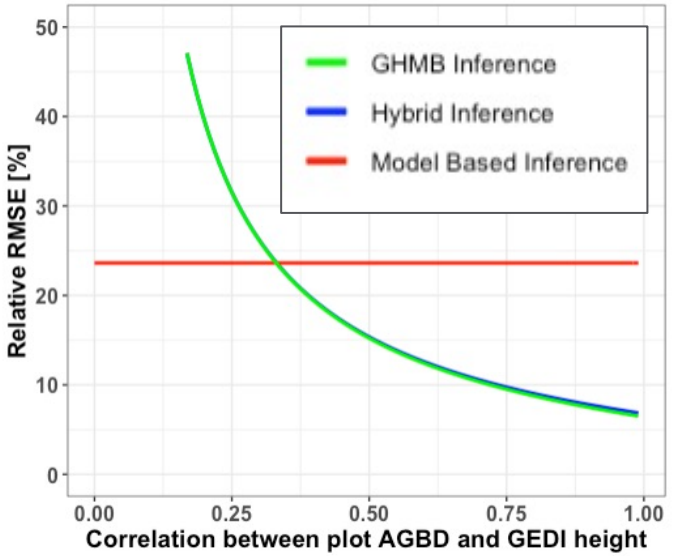


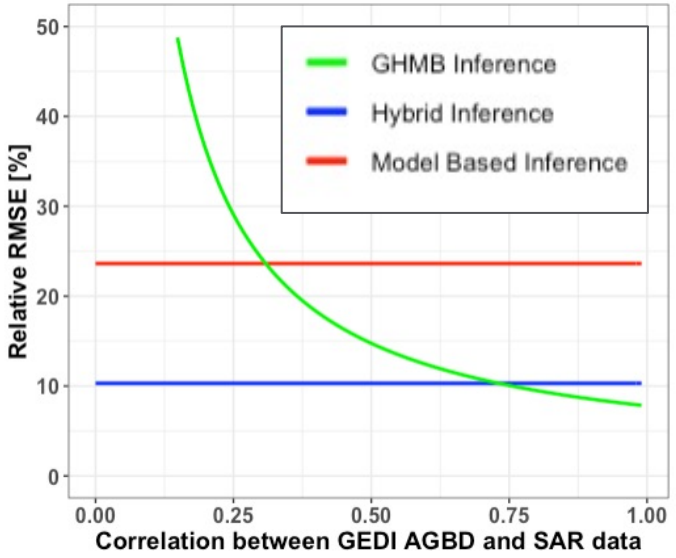
NASA

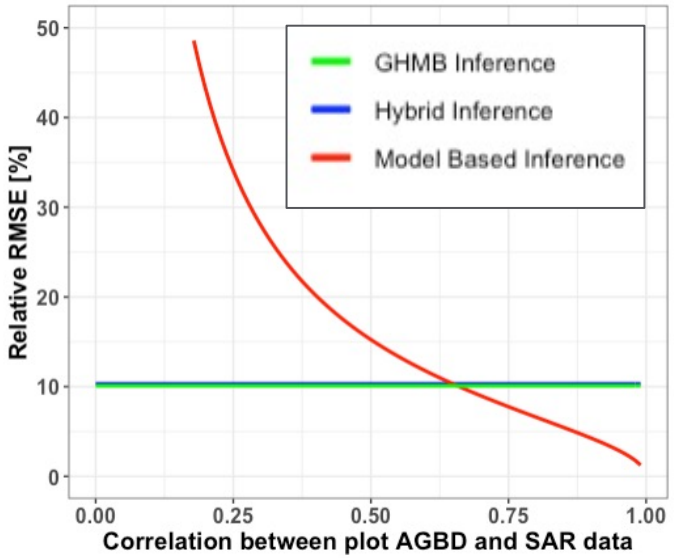
UNIVERSITY OF MARYLAND 18 56

# A framework to improve NISAR Biomass using GEDI

- **Uncertainty estimation methods: Hybrid (~GEDI), model based (~NISAR), GHMB (fusion)**
- **Local GEDI-based calibration of SAR models, GHMB outperforms model based inference (GEDI will help NISAR)**
- **GEDI sampling fractions smaller than about 2%, GHMB outperforms hybrid inference (NISAR will help GEDI)**
- **New experiments for NISAR**
  - Calibration of GEDI-SAR models at multiple resolutions (model/sampling error trade-off)
  - Sensitivity of GEDI measurements to short stature woody vegetation




Saarela *et al.* (2021) **Comparing methods for estimating forest biomass in connection with the GEDI mission** Submitted to "Remote Sensing of Environment"

# Summary

1. **GEDI prime mission ended in April 2021**
   - ISS orbital resonance is impacting ability to meet science requirements
   - Mission extension approved to 2023
   - ISS altitude to be lowered in 2022

2. **>18 months of GEDI L1 and L2 products are now publicly available (LP DAAC)**
   - Release 2 Level 1B → factor of two improvement in GEDI geolocation accuracy
   - Release 2 Level 2 → improved algorithms improve height estimation accuracy
   - Release 1 of Level 3 gridded products available at ORNL DAAC

3. **Release 1 of Level 4 products planned for Q3 2021 (ORNL DAAC)**
   - Release 2 will use the same algorithms, except will based on GEDI02_A R002 (improved geolocation)
   - GEDI04_A reprocessing will follow updates to GEDI02_A, improvements to calibration/validation data, and refinements of L4A model selection
   - These data underpin the development of GEDI-SAR (NISAR, TanDEM-X) fusion algorithms and products