Global Ecosystem Dynamics Investigation

Current Status and Performance

Scott Goetz

Deputy Principal Investigator

Northern Arizona University

Ralph Dubayah

Principal Investigator

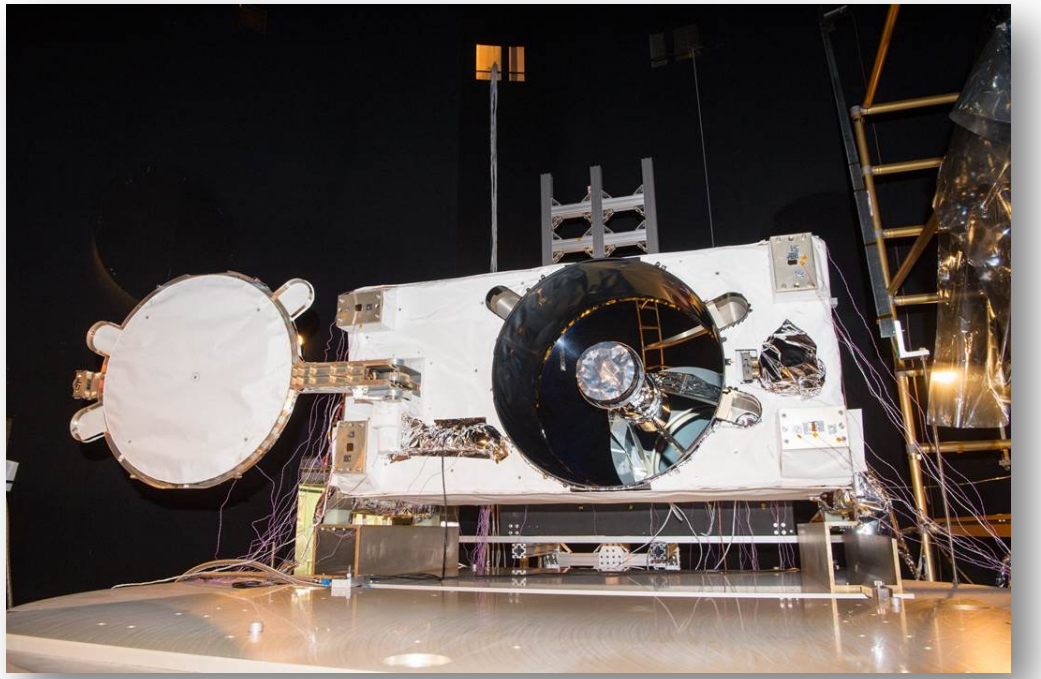
University of Maryland

GEDI

ECOSYSTEM LIDAR

GEDI: NASA Earth Ventures Instrument (EVI)

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



Key Facts

- Joint project of University of Maryland and NASA GSFC
- Operational on ISS (JEM-EF) from April 2019 to March 2023
- Currently in hibernation until Fall, 2024

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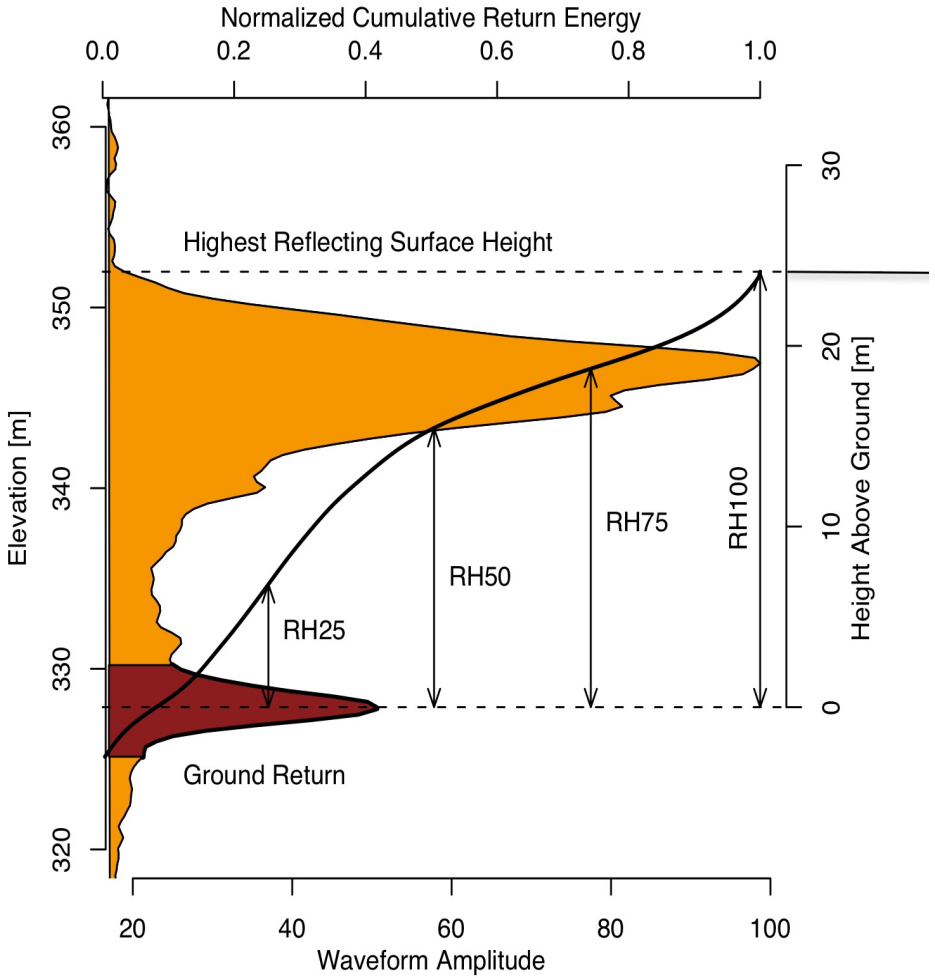
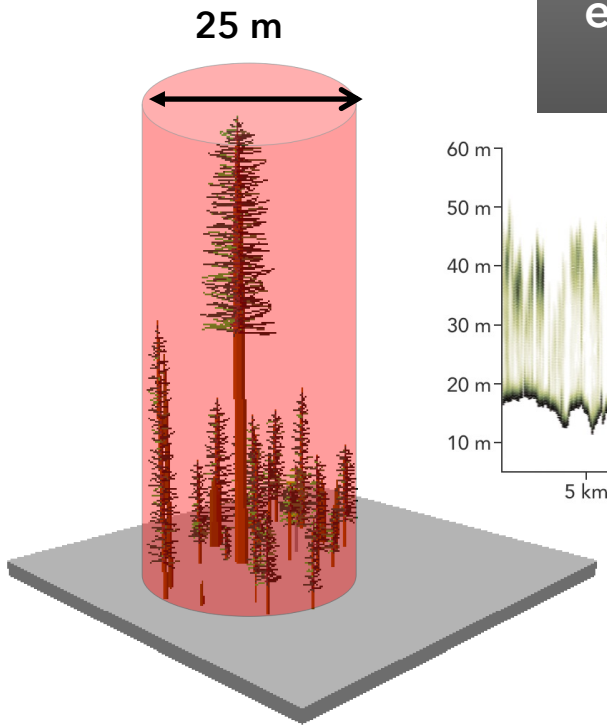
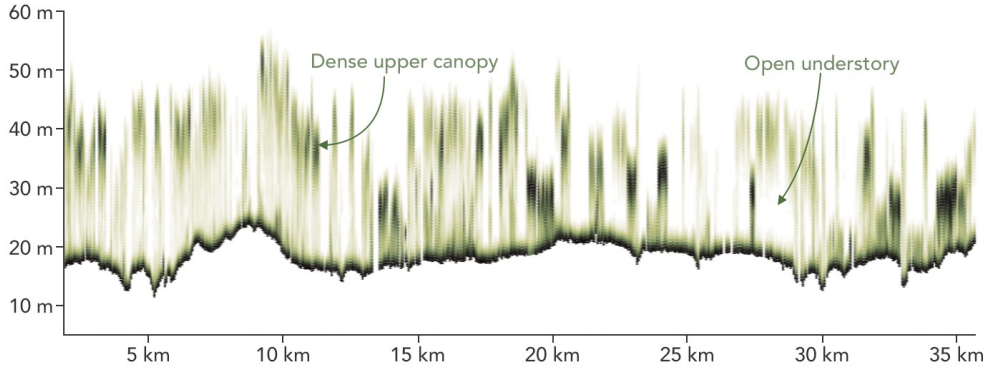
GEDI Lidar Measurements





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



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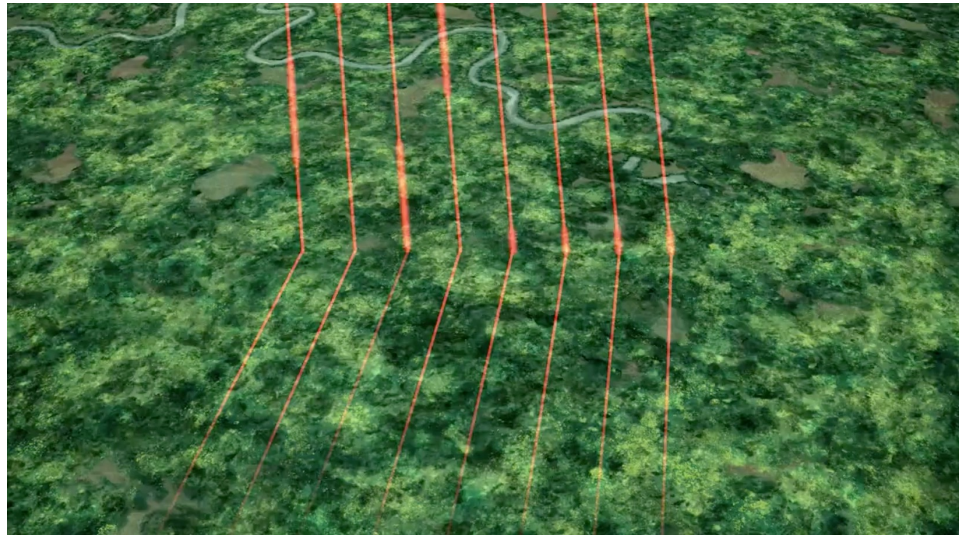
GEDI Observations

GEDI uses 3 lasers to produce 8 transects of lidar waveforms.

Each footprint provides the complete vertical structure of the canopy.



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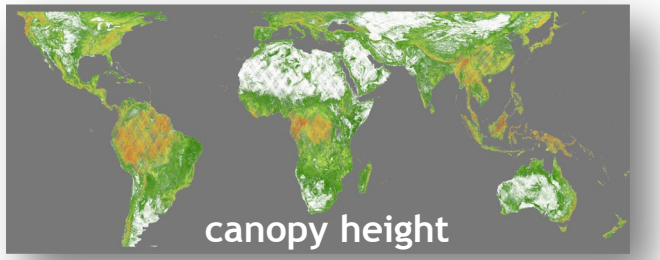
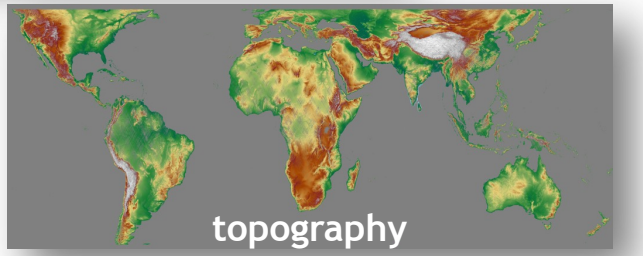
GEDI Specifications

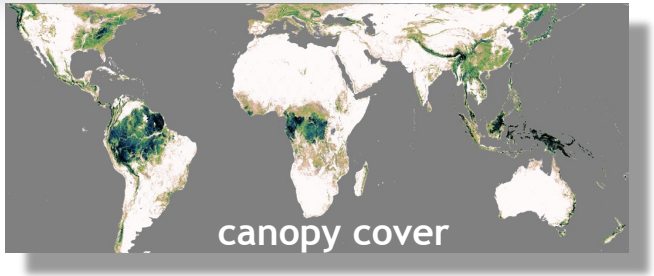
Specification	
Length of Record	April 2019 to March 2023 (Epoch I)
Spatial Resolution	25 m footprint, 1 km grid (finer grids forthcoming)
Coverage	Variable between 51.6° N & S
Sampling	60m along track, 600 m across track
Temporal Frequency	Non-specific and variable by ISS altitude
Latency	All Version 2 data sets at DAAC by July 2023
Geolocation Accuracy	11 m (1σ) → 8 m (by 2024)
Product Accuracies	Within L1 requirements

GEDI Major Products

- Canopy height metrics
  - RH height metrics
- Canopy vertical structure and cover
  - Total cover, cover by height
  - Plant area index (PAI), plant area volume density (PAVD)
  - Foliage height diversity, structural complexity
- Bare earth topography
- Biomass
  - Density and total, including uncertainty
- Resolutions
  - 25 m (samples)
  - 1 km grids
  - Other resolution grids







Total land returns:	20 billion
Weekly collection:	90 million

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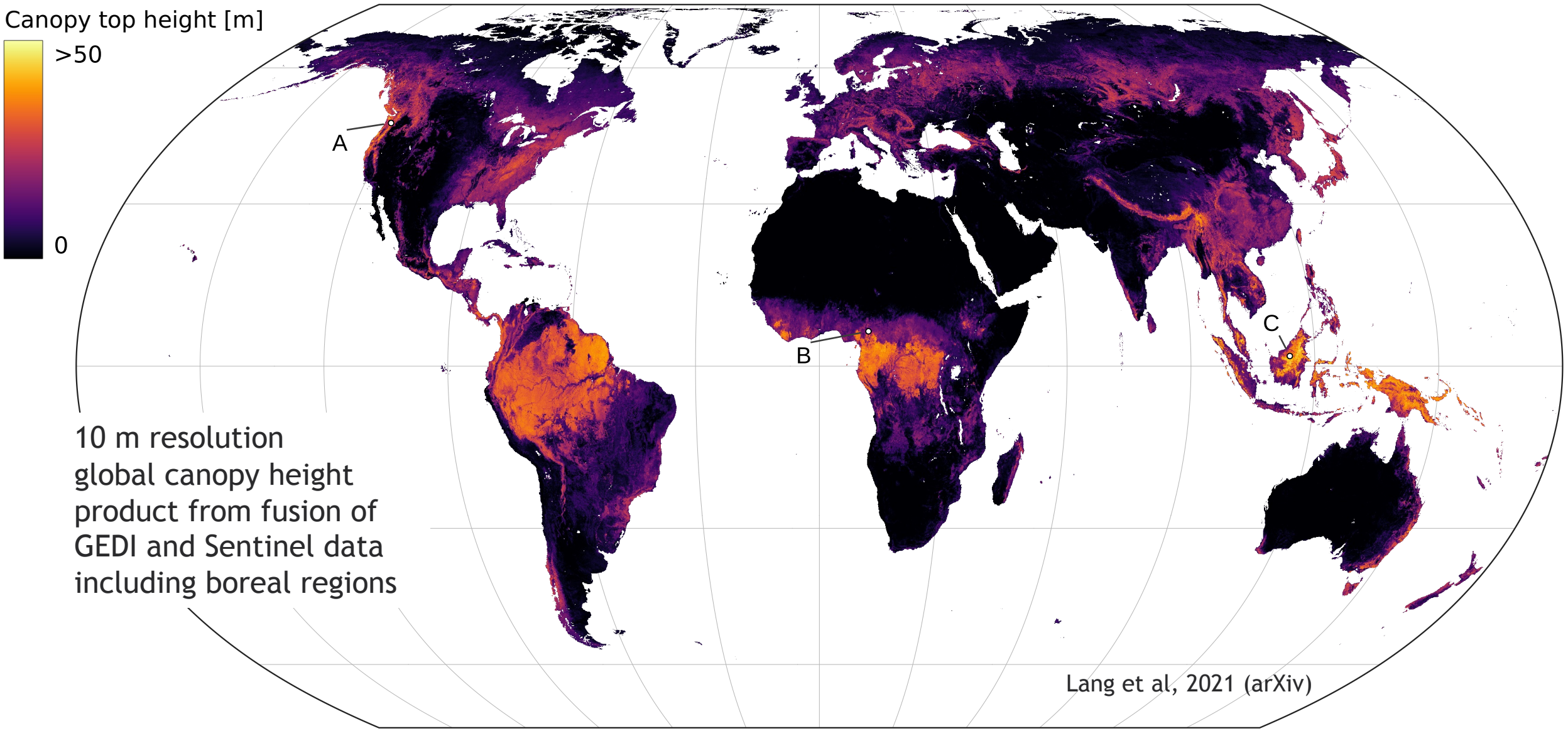
Canopy Height

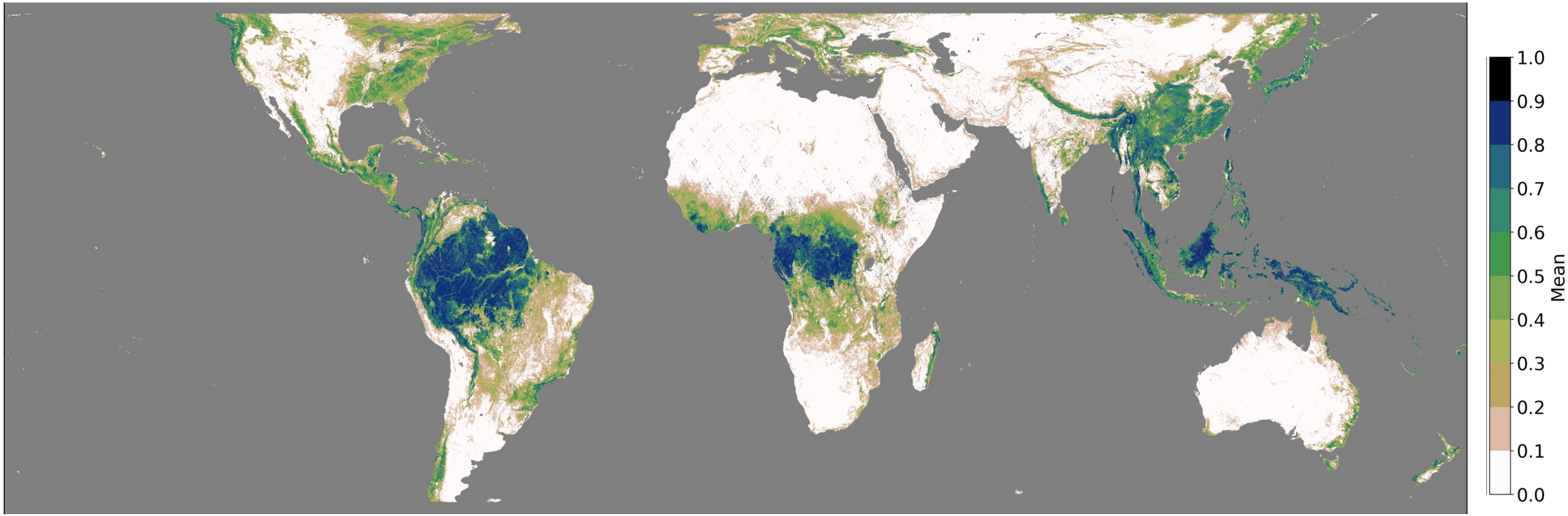


10 m resolution global canopy height product from fusion of GEDI and Sentinel data including boreal regions

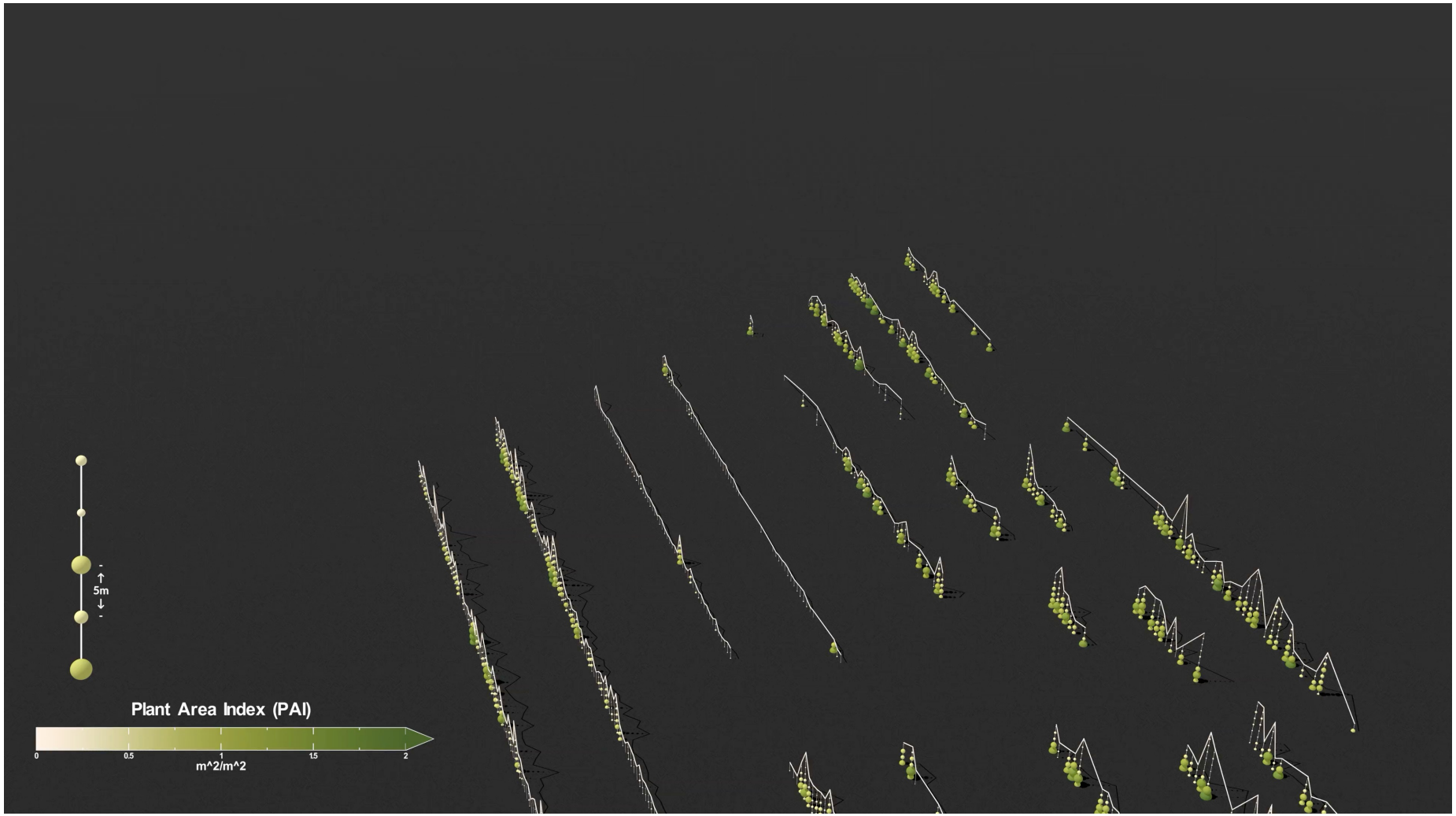
Lang et al, 2021 (arXiv)

Canopy Cover Fraction: A Uniquely GEDI Product

GEDI's map of cover is accurate even in dense forests

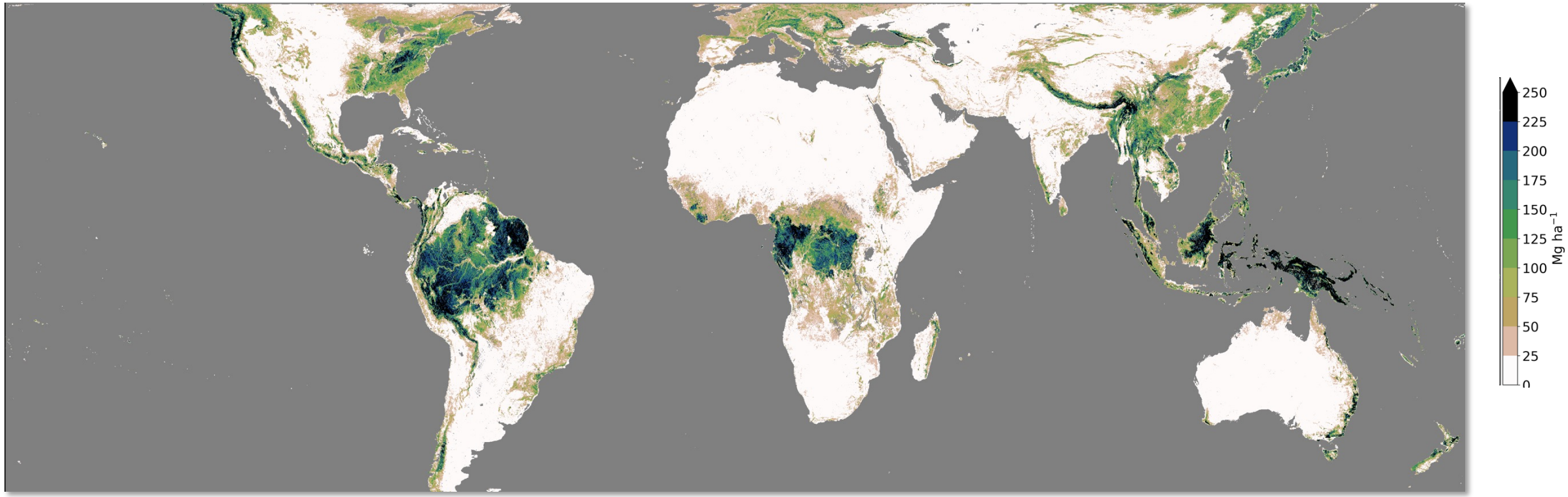


GEDI Plant Area Index (PAI)



Biomass Density (2019-2021)

GEDI's map of biomass density uses observations from a single instrument within a consistent statistical framework to estimate stocks and their uncertainties



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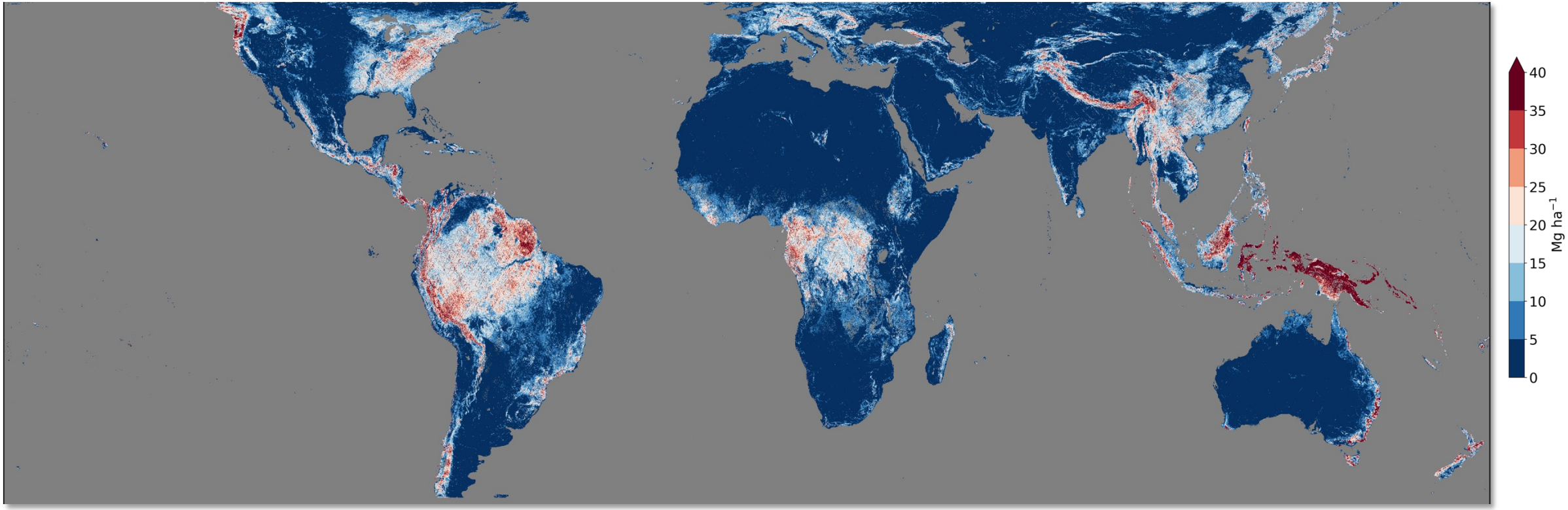
Biomass Uncertainty

GEDI is the first mission to provide statistically rigorous estimates of biomass uncertainty across the globe for various areas, from plots to entire countries



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GEDI Data Product Release

GEDI Standard Data Product Version 02 History, Trend, Quality Summary			
Product Name	**Description**	**Version 02 Data Processed**	**Performance Summary**
GEDI01_A	Footprint level waveform data	2019-01-03 through 2023-03-22	Nominal performance with no degradation or deleterious trends. Geolocation performance is 11m 1σ (3DEP comparisons)
GEDI01_B	Geolocated footprint level waveform data	2019-01-03 through 2023-03-22	
GEDI02_A	Geolocated footprint level elevation and canopy height metrics	2019-01-03 through 2023-03-22	Nominal performance with no degradation or deleterious trends.
GEDI02_B	Geolocated footprint level canopy cover and vertical profile metrics	2019-01-03 through 2023-03-22	
GEDI04_A	Geolocated footprint level empirical biomass	2019-01-03 through 2023-03-22	
GEDI03	Geolocated footprint level empirical biomass	2019-01-03 through 2022-01-19	Spatial sampling impact from resonant 4-day repeat orbit. Impact mitigated with ISS altitude lowering.
GEDI04_B	Gridded Empirical Biomass and Variance	2019-01-03 through 2021-08-04	

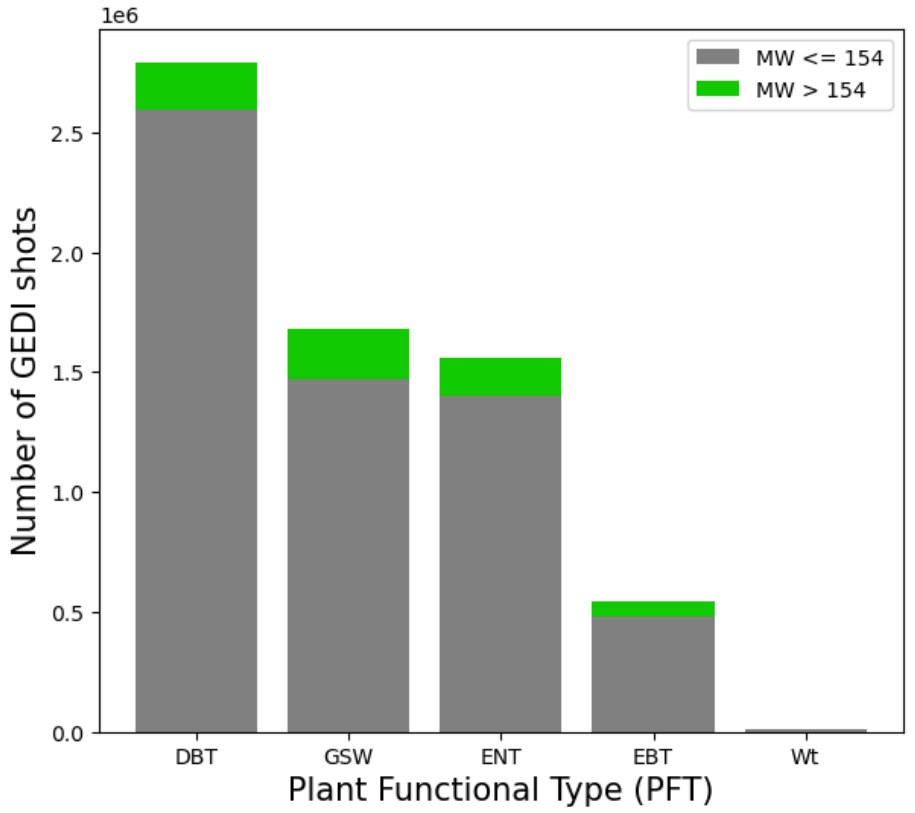
- **Complete V2 data set for first observing epoch (2019-2023) released by July 2023**

Validation of GEDI Products

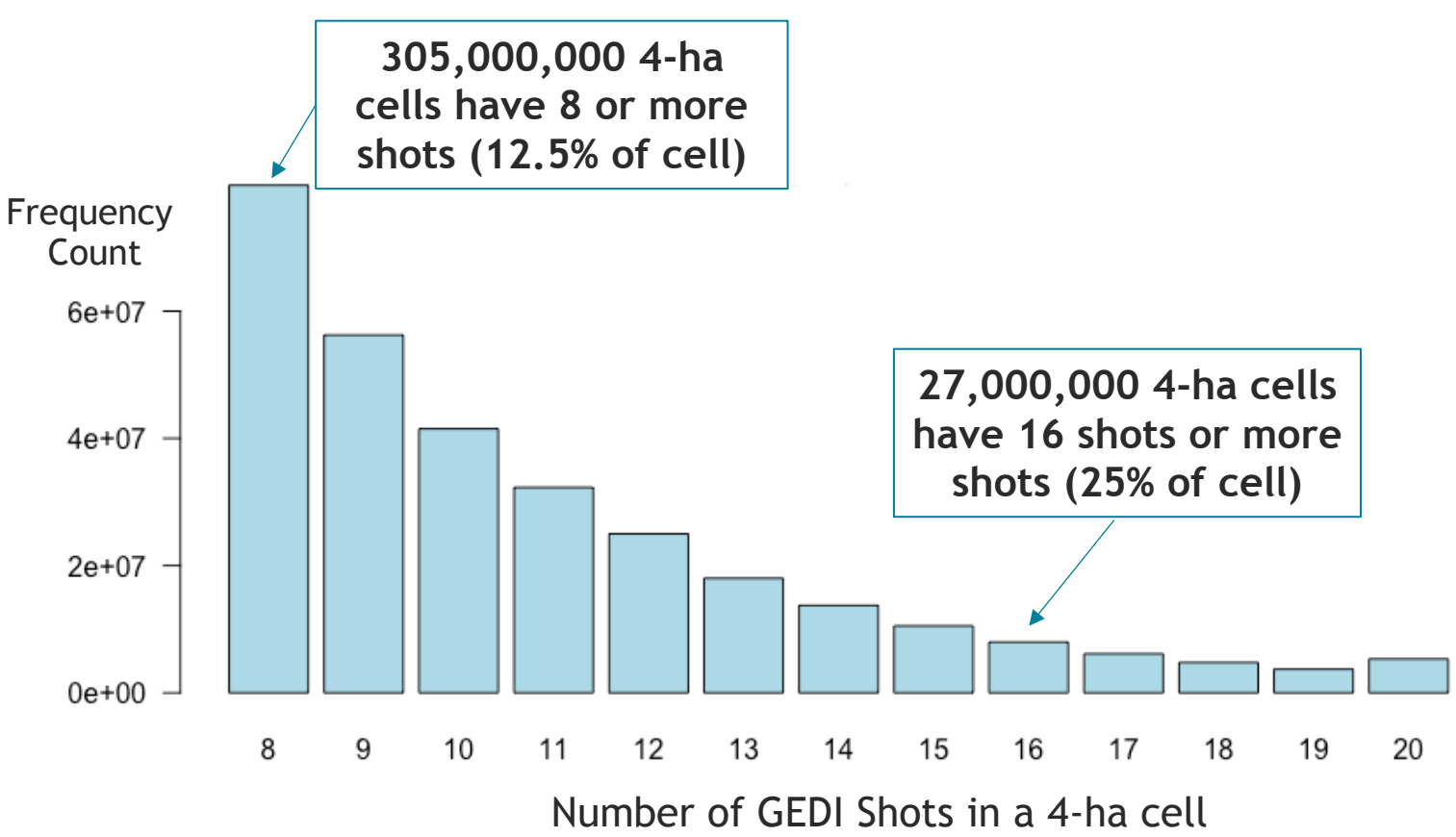
- Many new studies are attempting validation of GEDI products against ALS, ICESat and ICESat-2, and internally (trends in GEDI data)

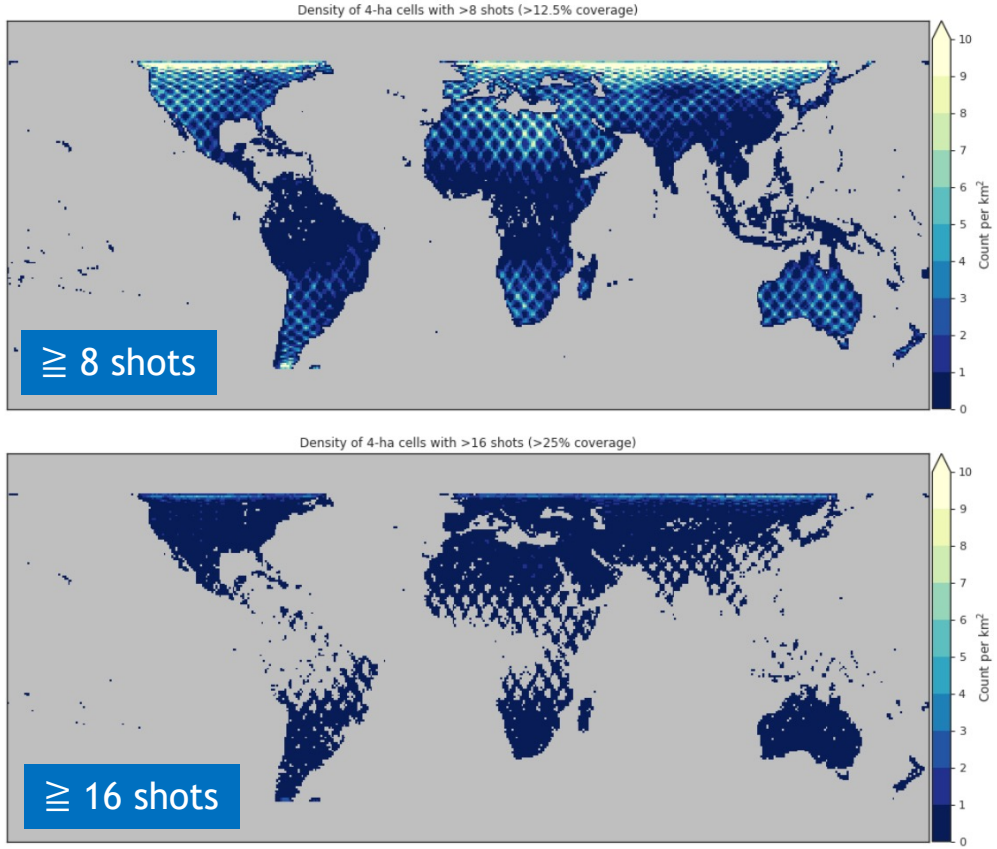
1. Correcting for geolocation error is required to assess measurement performance at the footprint level
2. Correct filtering for sub-orbit granules affected by low clouds and fog must be identified and removed from sample
3. Level 2 and Level 4 algorithm setting group and quality filtering have differences
4. Mismatches in scale (e.g. between ICESat and GEDI) lead to spurious conclusions of bias
5. Trend analyses must account for uneven sampling resulting from orbital resonance

GEDI uses a vast dataset of shots accurately co-located over ALS data



GEDI Provides Millions of Cal/Val Cells for BIOMASS





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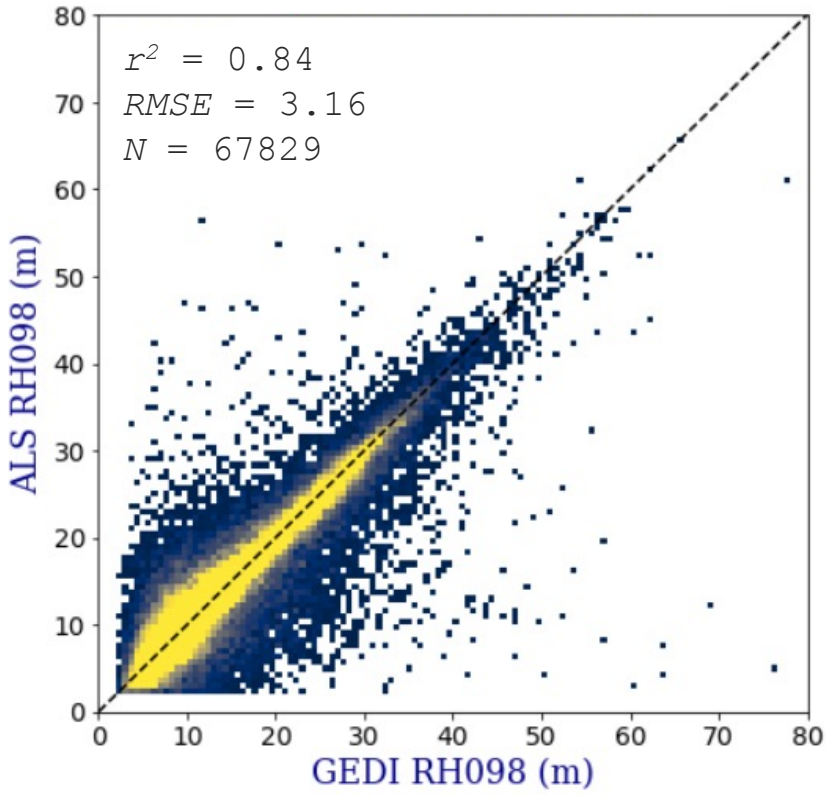
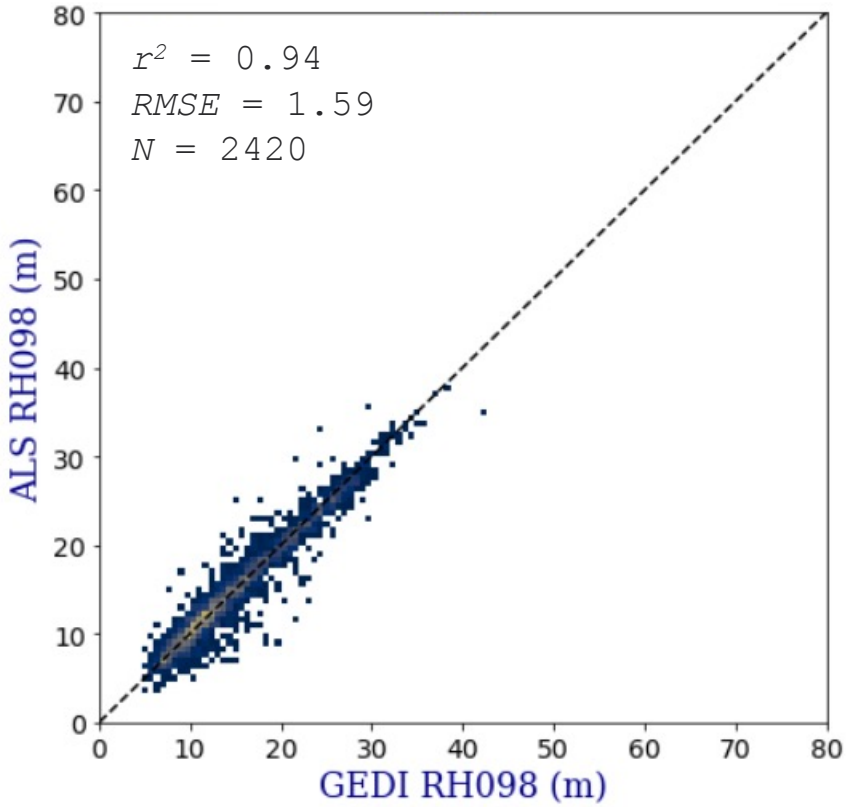
Validation of Canopy Height

Global comparisons against GEDI's Forest Structure and Biomass Database (FSBD)

Footprint Scale [25 m]



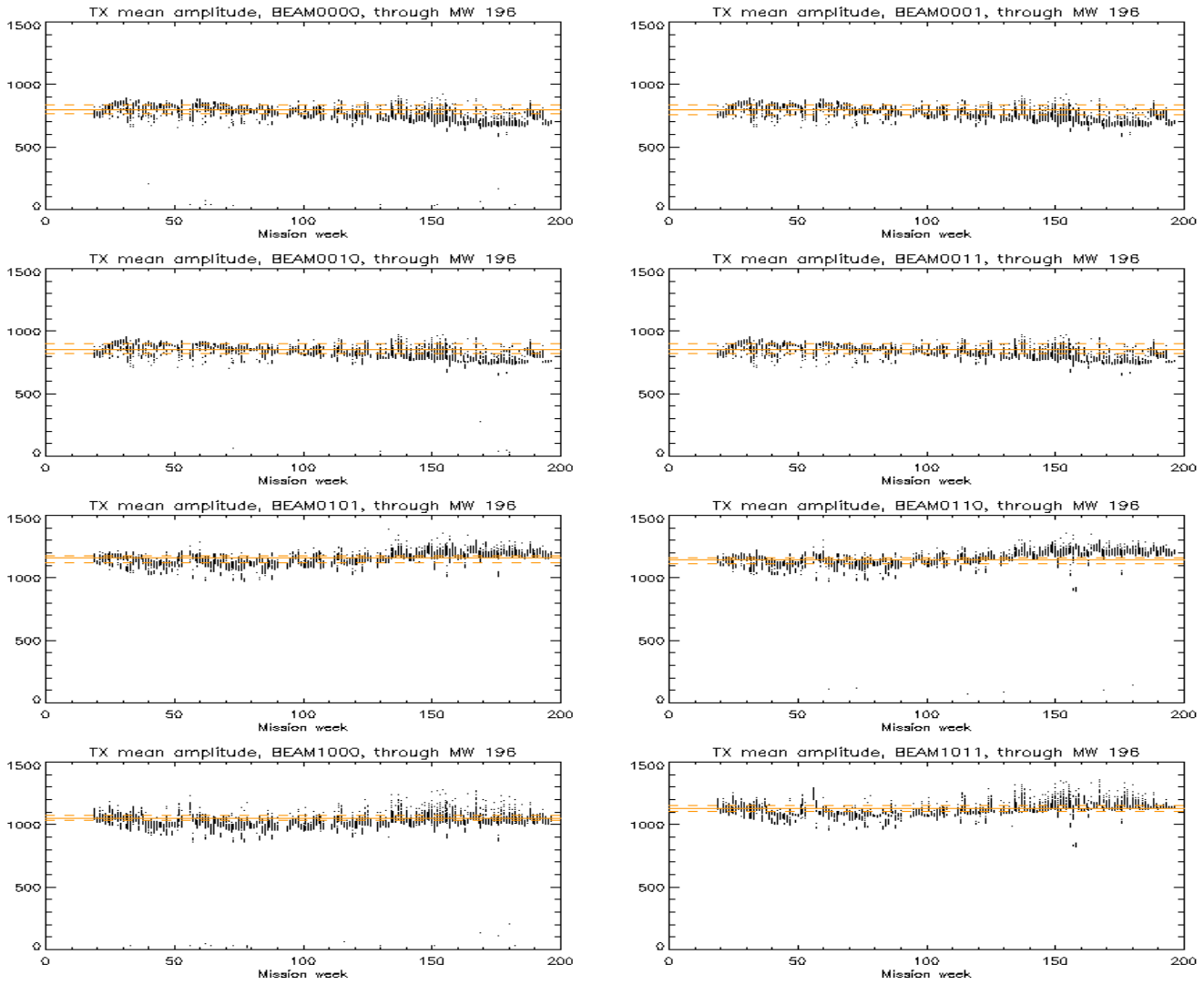
BIOMASS Scale [4-ha]



- **Version 3 processing improves quality filtering, geolocation and algorithms**

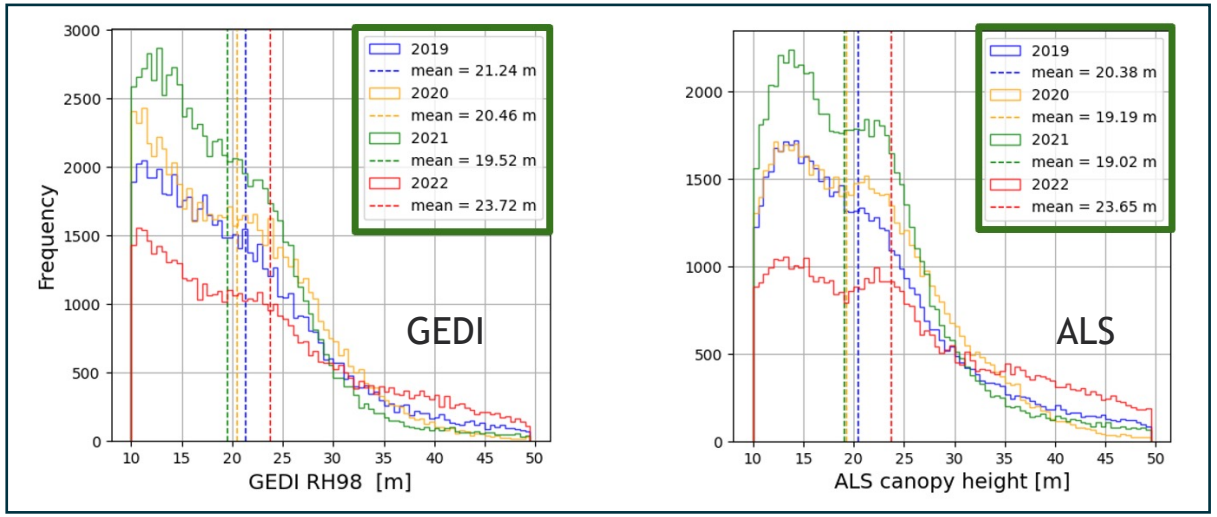
Laser performance has been excellent

- Laser performance has shown little trend in power
  - Laser output power steady (~5% drop on Laser 1)
  - Mission will increase output power as required once GEDI is re-installed
  - Laser pulse width only slowly changing or steady with time

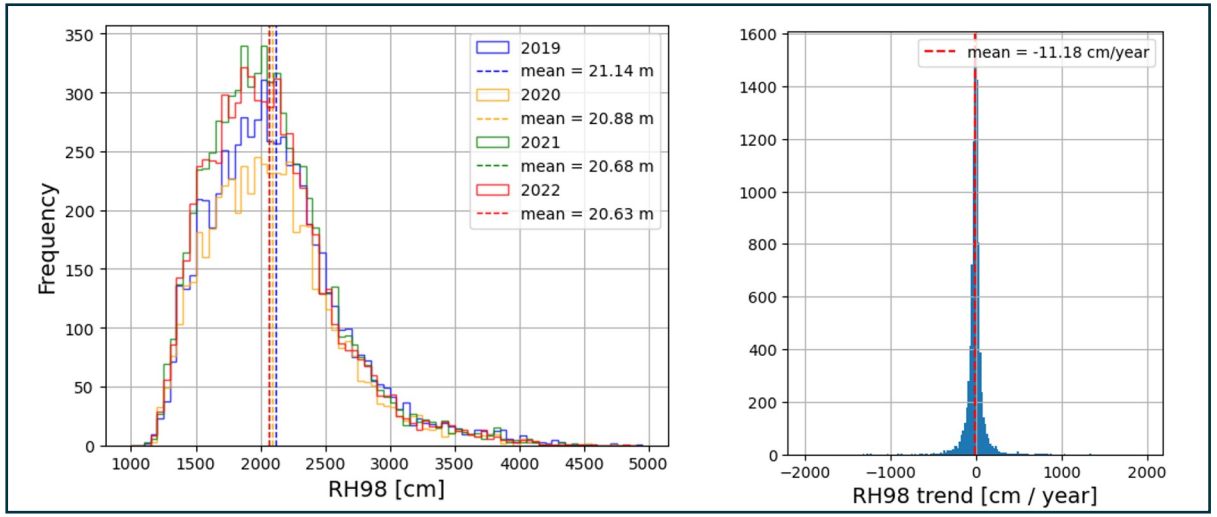


GEDI measurements are stable across years

NEON



Global



- 10 km hexagon areas
- No trends relative to multiyear ALS data acquisitions (NEON sites in the US)
  - Mean difference: +10 cm/yr
  - Median difference: 0 cm/yr
- Small global mean trend (-11 cm/yr) across all data
  - Likely caused by differential sampling, changes in cloudiness, inadequate disturbance and other filtering
  - Note GEDI waveform height bin accuracy is only 15 cm

Year to year variations in average measurements are small and unlikely to caused by any change in instrument capability

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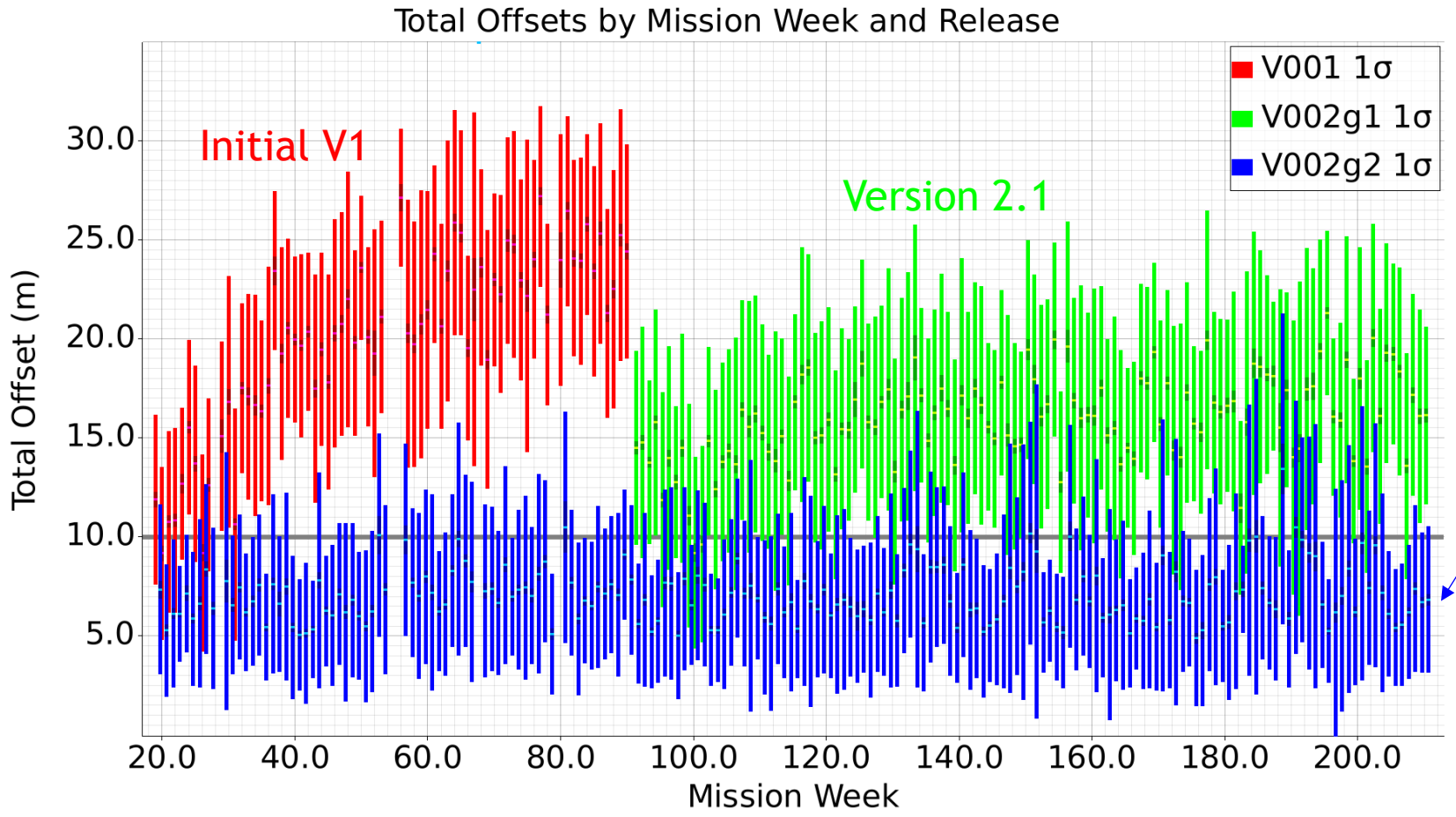
GEDI geolocation is improving



Version 2.2
Current geolocation
11m (1σ)
[~50% of data < 11m]

GEDI req. is 10 m (1σ)

V3 will reduce error to about 8 m (1σ)

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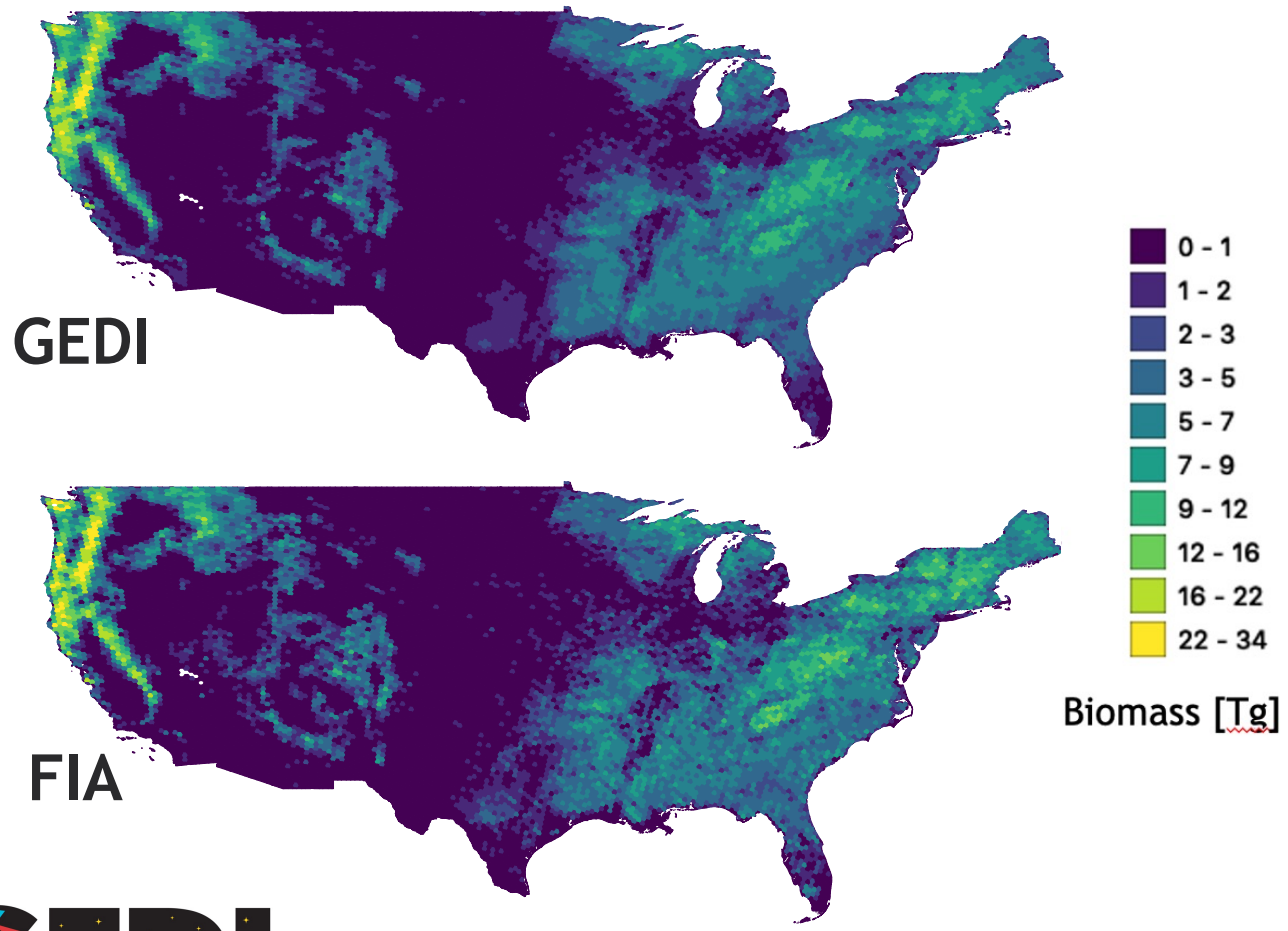
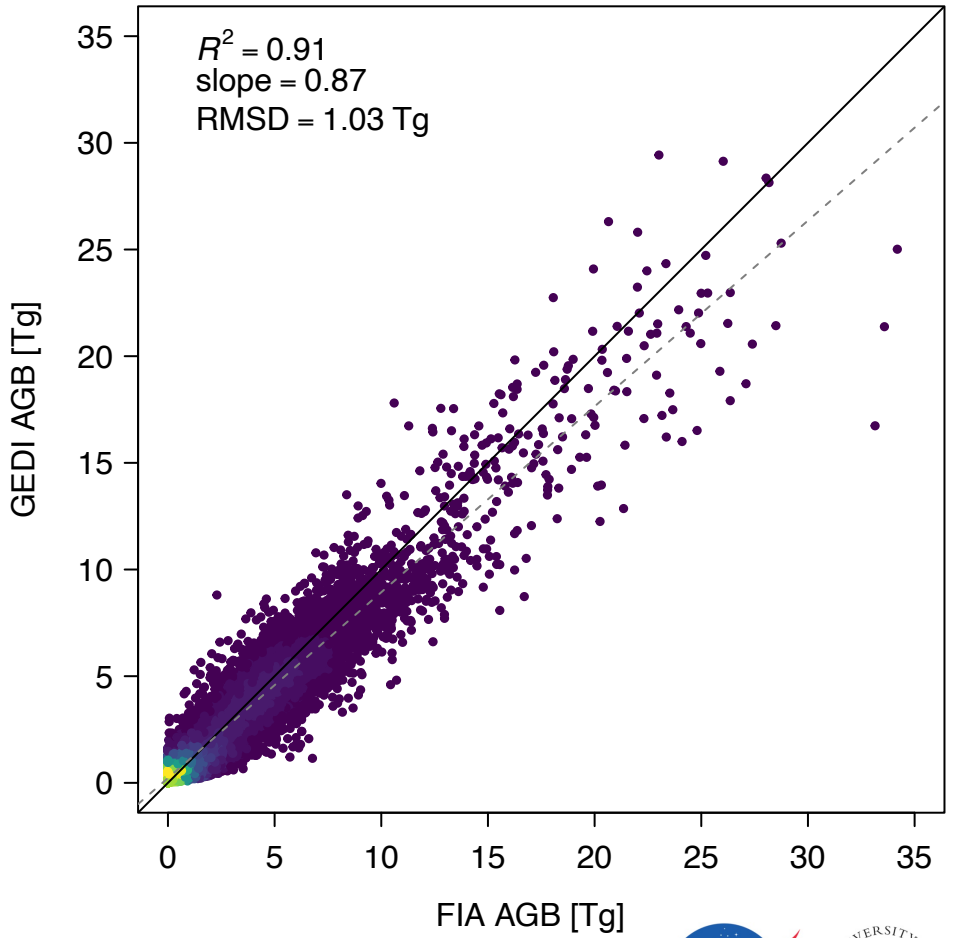
Validation of GEDI again US NFI

Improved sub-orbit and other quality filtering significantly removed bias from Version 1 estimates





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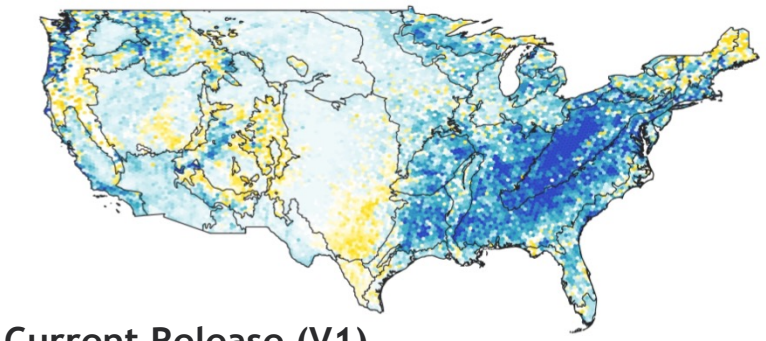
Improved Processing Removes Biases

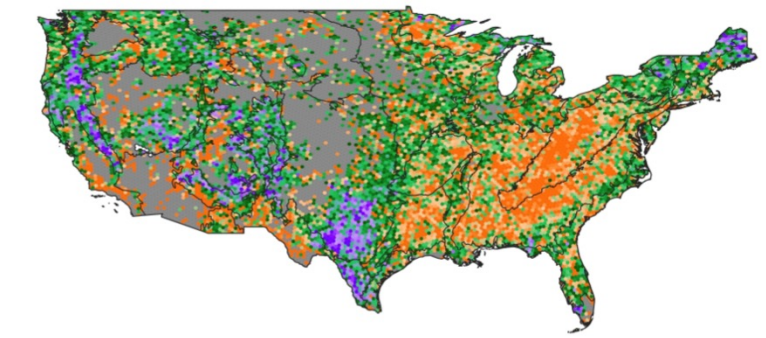
FIA (NFI) - GEDI

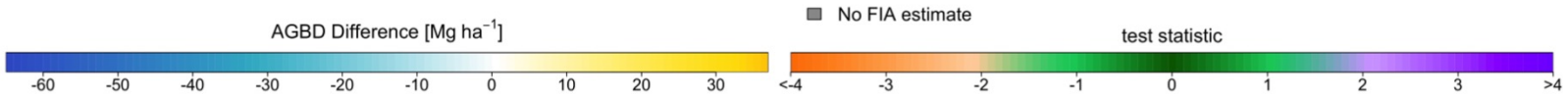
AGBD Difference

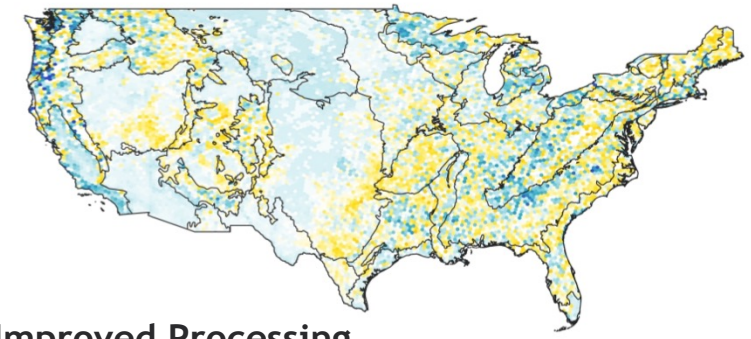
Difference Test Statistic

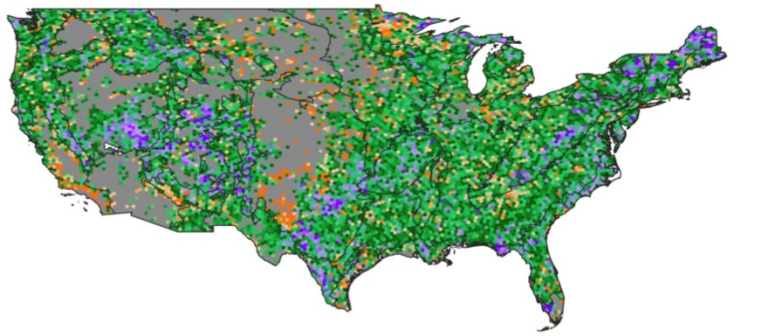
Current Release (V1)



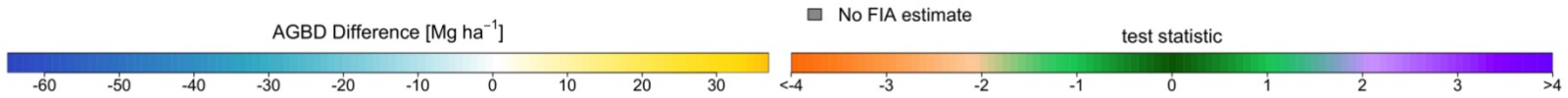


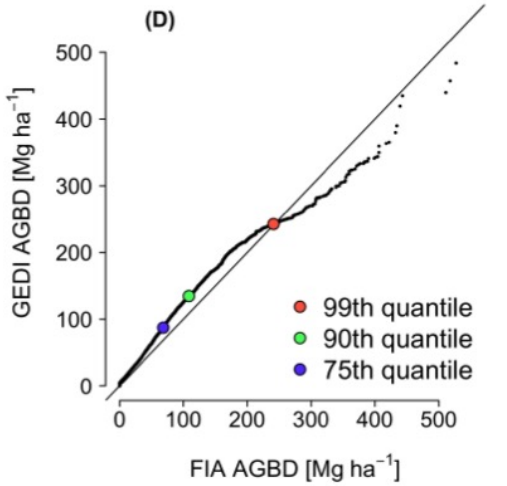


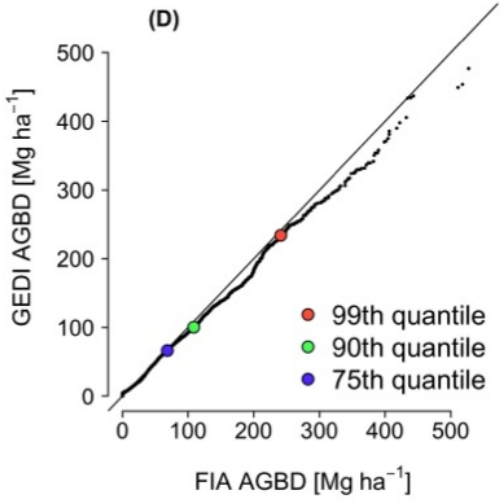




Improved Processing

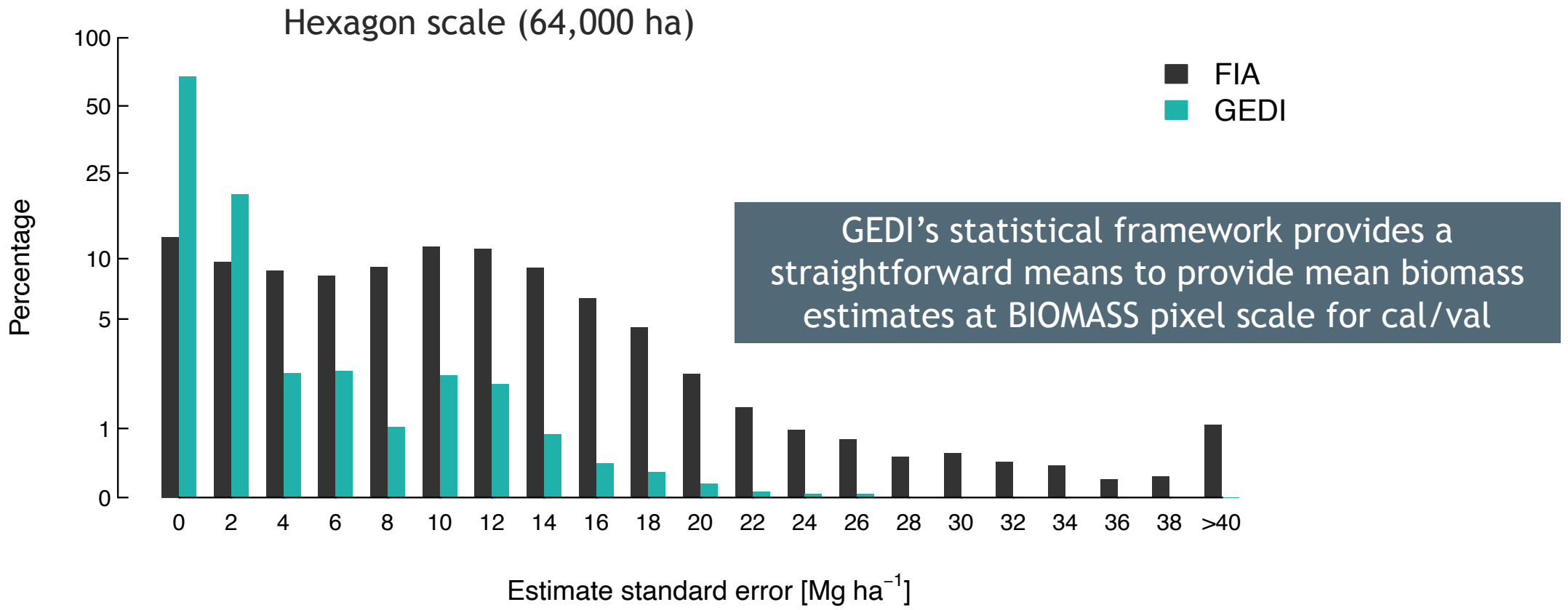






Improved Precision and Increased Resolution

GEDI has provided increased precision and vastly finer resolution for national inventories



GEDI's statistical framework provides a straightforward means to provide mean biomass estimates at BIOMASS pixel scale for cal/val

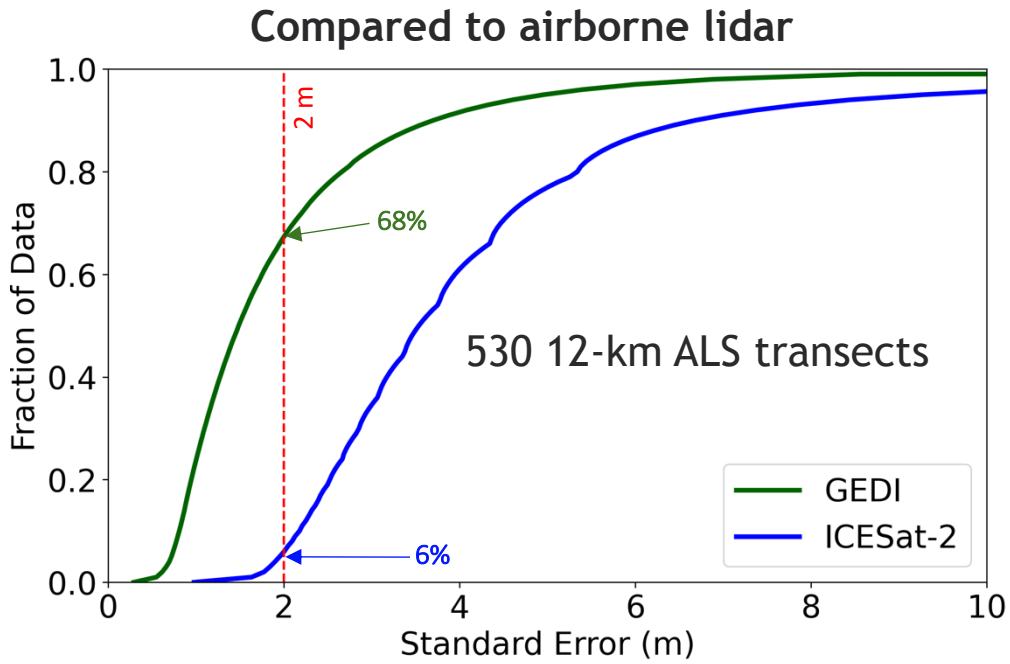
GEDI provides superior coverage to ICESat-2

GEDI and ICESat-2 gridded canopy height (1-km) products (Amazon)

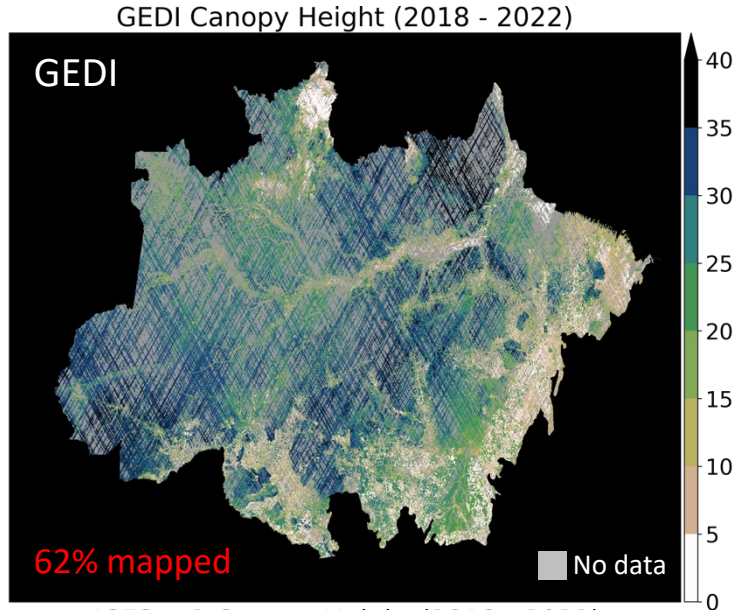
- 62% has been mapped by GEDI in 3 years but only 11% by ICESat-2 in 4 years

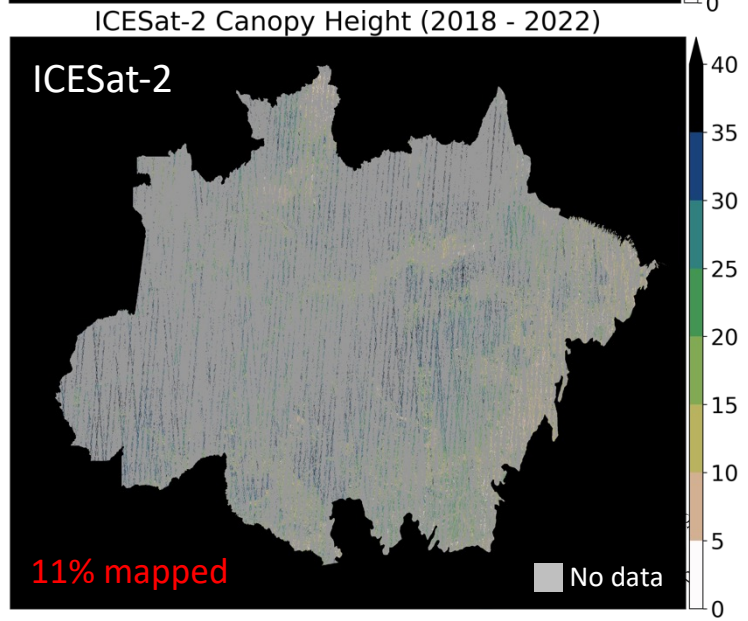
- 68% of GEDI 1 km cells meet a 2 m accuracy vs. 6% for ICESat-2

- ICESat-2 does not appear to meet GCOS ECV height accuracy requirements



GEDI provides far better coverage and much lower standard errors





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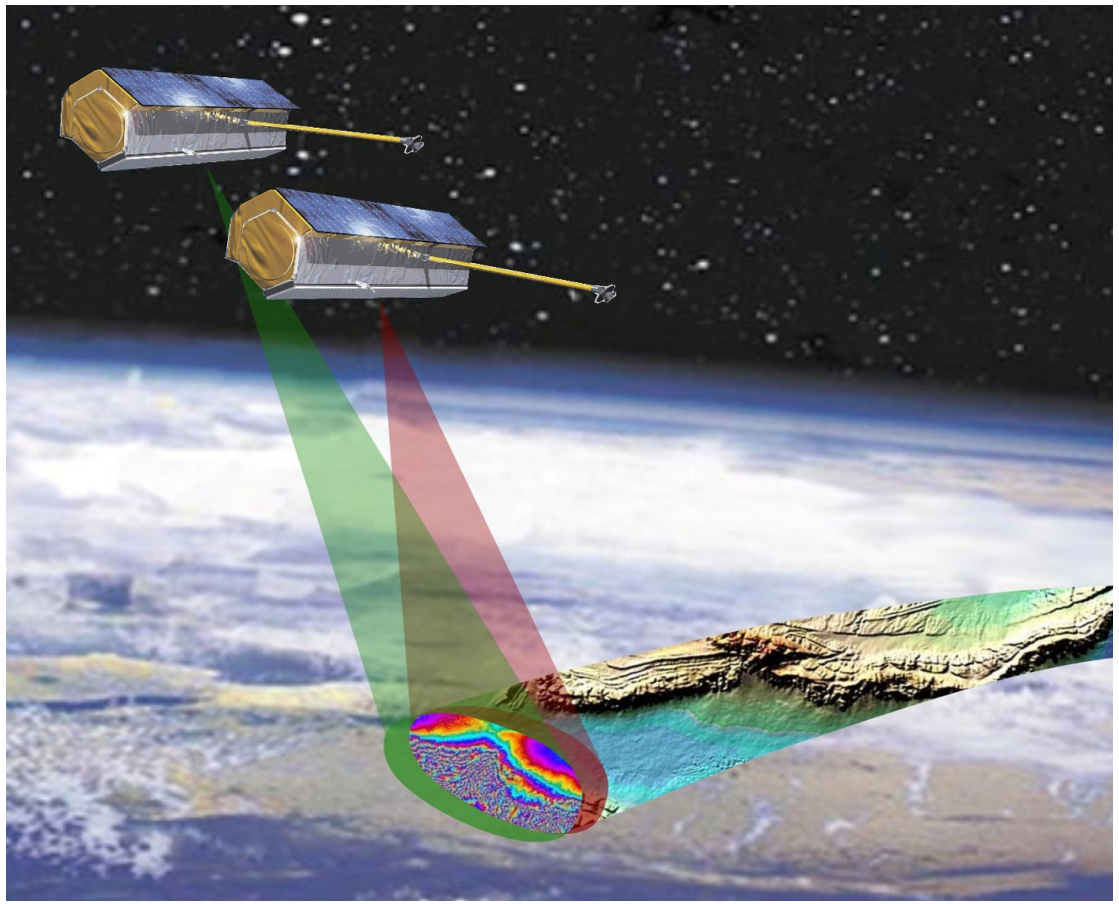
Fusion of TanDEM-X and GEDI



Combine wall-to-wall SAR with GEDI for high-res mapping

- **TanDEM-X (TDX) provides high-resolution interferometric coherence observations**
- **Responsive to ecosystem structure**
- **Physically-based modeling provides exemplar for potential BIOMASS fusion**

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DLR AIRBUS DEFENCE & SPACE

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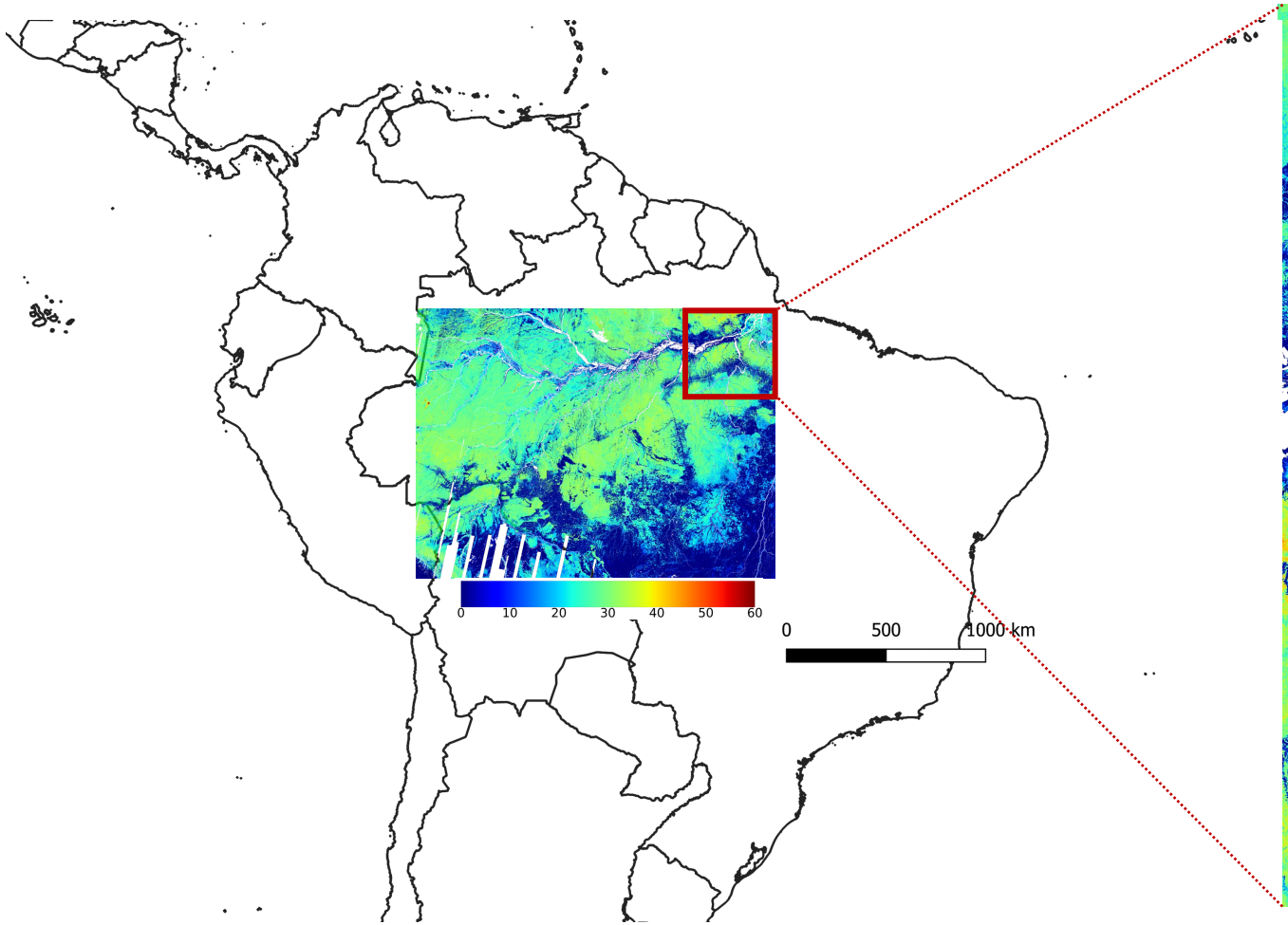
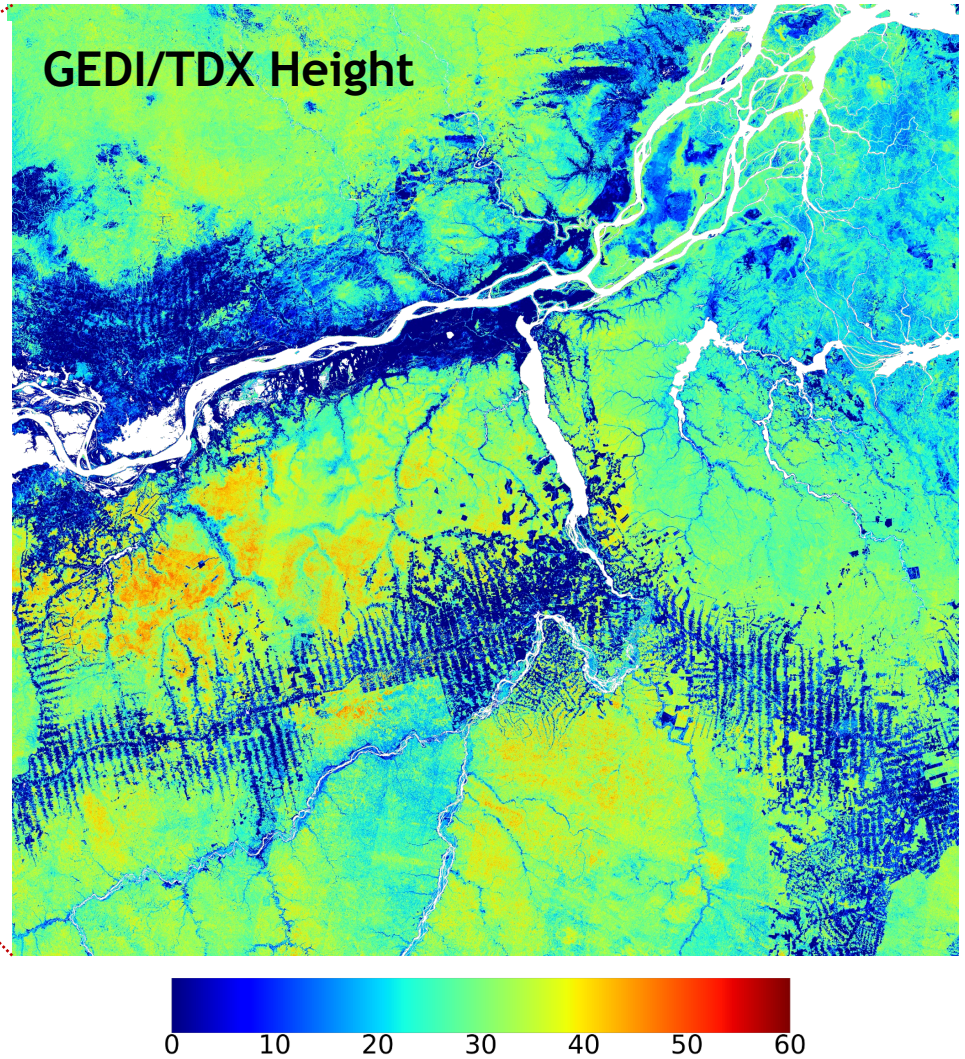
Canopy Height Detail: Amazon Basin





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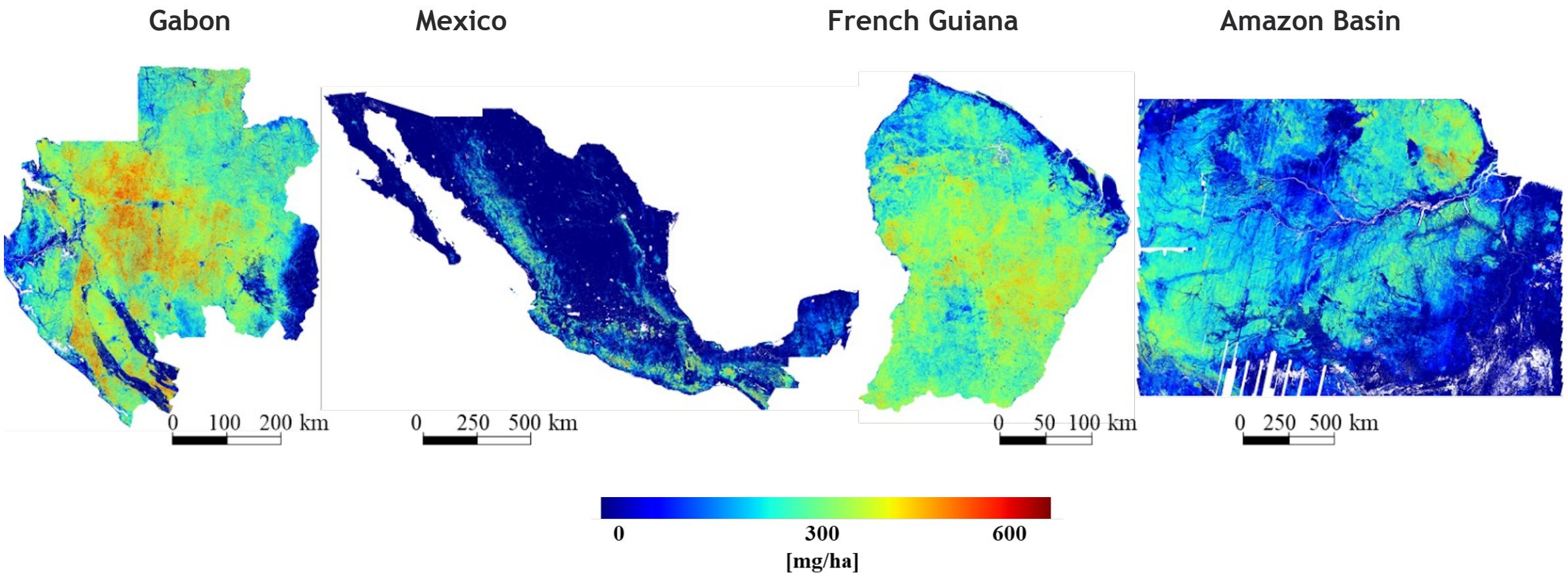
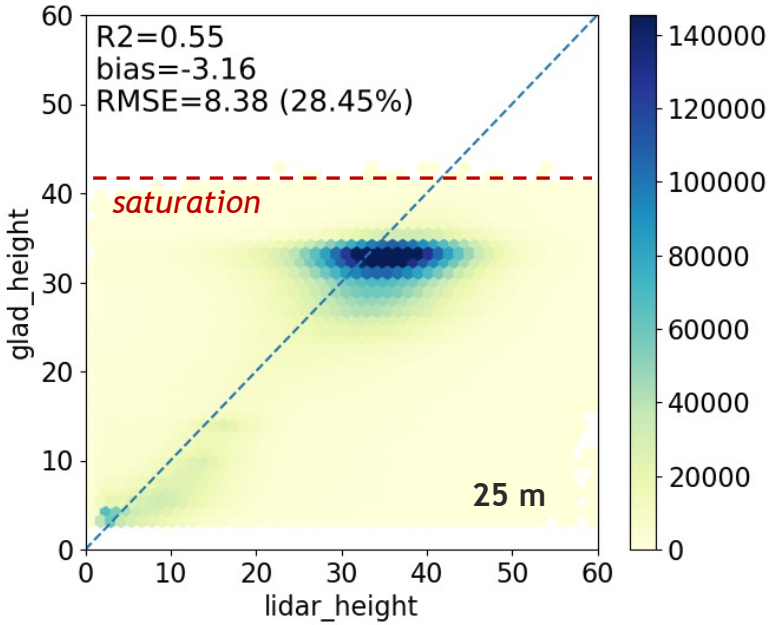
Biomass (25 m)

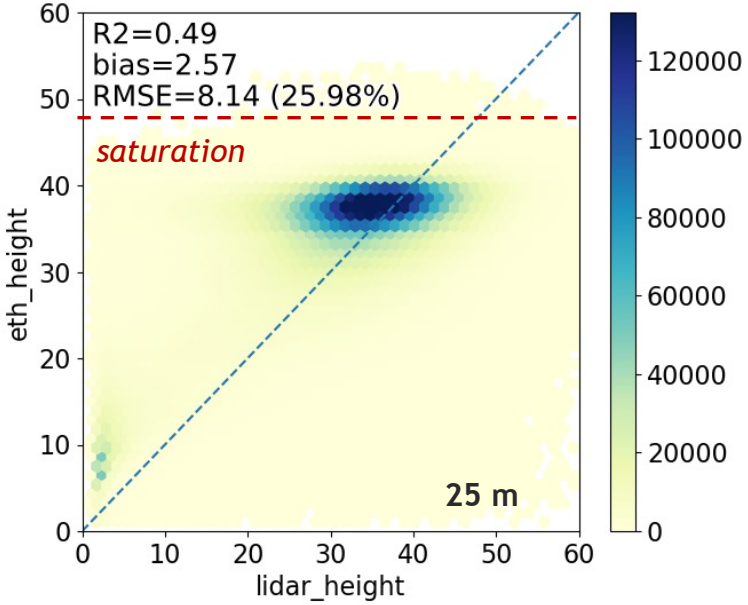

Gabon
Mexico
French Guiana
Amazon Basin
0 100 200 km
0 250 500 km
0 50 100 km
0 250 500 km
0
300
600
[mg/ha]

Is GEDI-TDX Fusion Better than Other Types?

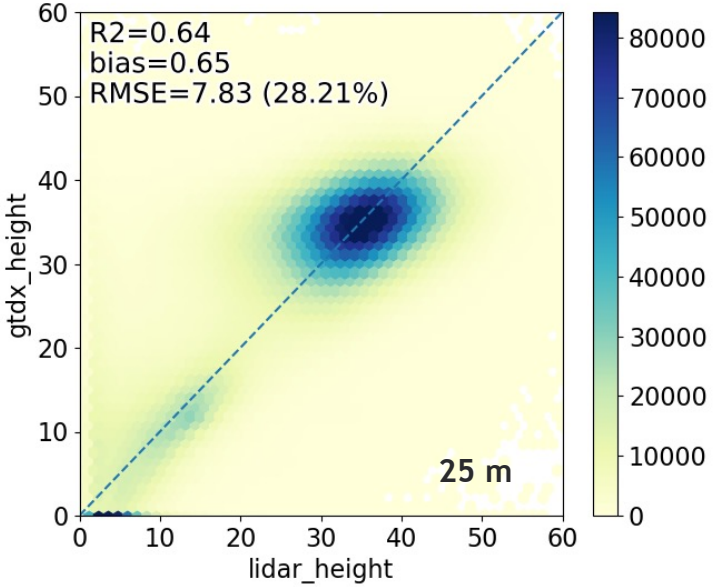
GEDI-Landsat (GLAD)

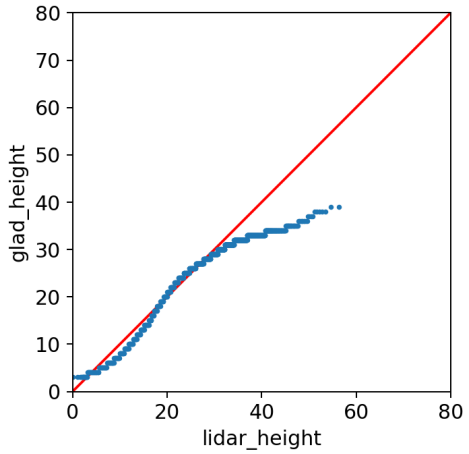


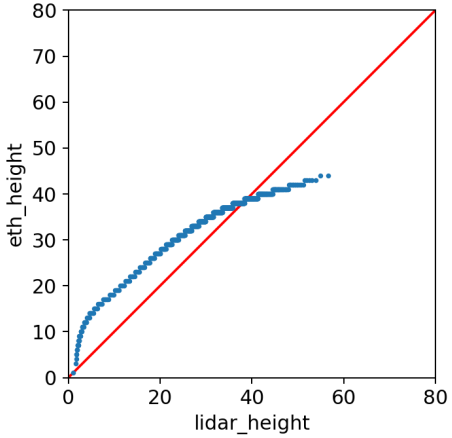
GEDI-Sentinel (ETH)

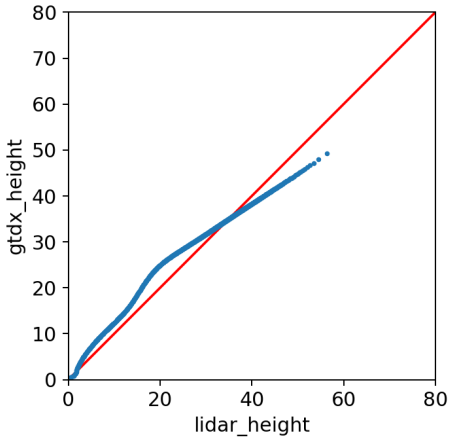


GEDI-TDX (CMS)









GEDI ECOSYSTEM LIDAR

NASA

UNIVERSITY OF MARYLAND

Current & Future Status

- GEDI paused in March 2023
  - Currently hibernating with survival heaters
- Planned redeployment in Fall 2024
  - Could remain on ISS through 2030
- Activities during observational pause:
  - Complete Version 2 & 3 data releases
    - Includes updates to geolocation, filtering, algorithms
  - New products
    - Complexity, GEDI-ICESat2 fused products, higher resolution grids

DATE	2019				2020				2021				2022				2023				2024				2025				2026				2027				2028				2029				2030			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
PHASE		PHASE E							Mission Extension I								Mission Extension II												Mission Extension III (upon review)																			
ACTIVITY		On-Orbit Operations															STORAGE				On-Orbit Operations								Mission Operations (upon review)																			

Conclusions

- GEDI is successfully completing its first epoch (2019-2023) of observations
  - All V2 data sets will be available in July 2023
  - Improved V3 data (and potentially v4) data sets available by September 2024
- GEDI is meeting expected accuracies for biomass at the footprint and 1 km scale
  - GEDI mission sees no significant degradation or trends over four years of operation
  - Validation of GEDI data must be done carefully
  - Proper processing and quality filtering are required and are updated in Version 3 release
- GEDI is a remarkable resource for the BIOMASS mission
  - GEDI has by far the most observations of ecosystem structure and biomass for the current epoch
  - Its redeployment in Fall of 2024 provides contemporaneous data for BIOMASS and a second epoch of biomass observations
  - GEDI's statistical framework allow for the estimation of uncertainty in height and biomass at appropriate scales for BIOMASS

The GEDI mission strongly welcomes and encourages increased collaboration with BIOMASS