NASA's Global Ecosystem Dynamics Investigation

Mission Update

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Presentation Overview

1. **Background**
   - Science objectives & mission status
   - Science approach & data products

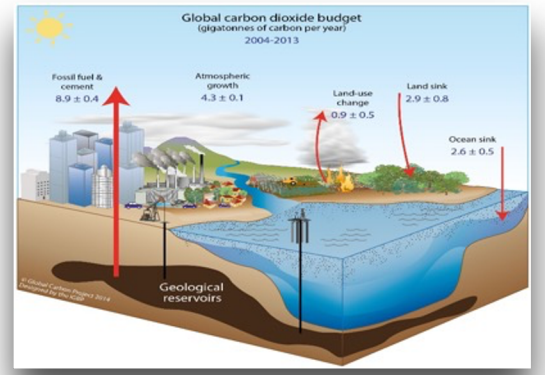
2. **Key Results**
   - Topography and canopy structure
   - Aboveground biomass
   - Biodiversity demonstration products

3. **Summary and Outlook**

GEDI ECOSYSTEM LIDAR

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	Quantify
What is the carbon balance of the Earth's forests?	Forest Biomass Disturbance and Recovery
How will the land surface mitigate atmospheric CO2 in the future?	Carbon Sequestration Potential
How does forest structure affect habitat quality and biodiversity?	Vertical Forest Structure and its Relationship to Biodiversity

GEDI ECOSYSTEM LIDAR

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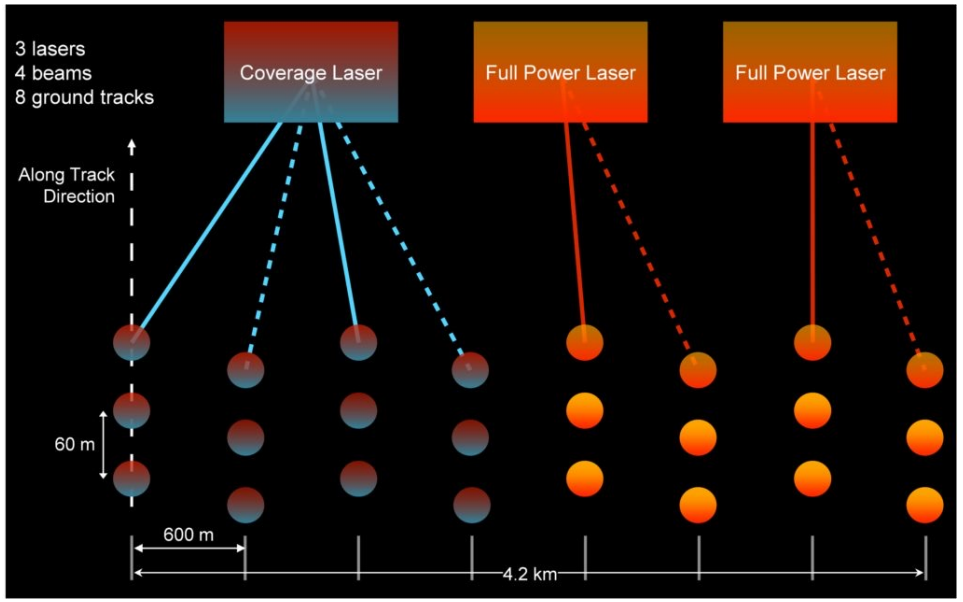
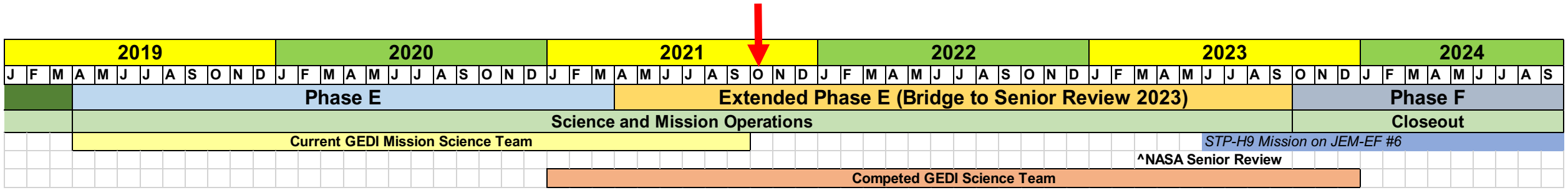
Important Facts About GEDI

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
  - Approved for mission extension through to January 2023
- **Uses a lidar instrument optimized for vegetation**
  - 3 lasers with full-waveform measurements at 1064 nm
  - Waveforms are processed to estimates of ground elevation, canopy height, cover and vertical profile metrics
  - 8 tracks of data with 25 m footprints, ~600 m between tracks
- **GEDI is a sampling mission but produces gridded data products**
  - >10 billion canopy structure measurements
  - 1 km grid resolution for standard products
- **Data products available today through NASA EarthData**
  - Version 2 of Level 1 and 2 footprint data (2+ years)
  - Version 1 of Level 3 gridded footprint metrics (1 year)
  - Version 1 of Level 4 footprint biomass (1.5 years)

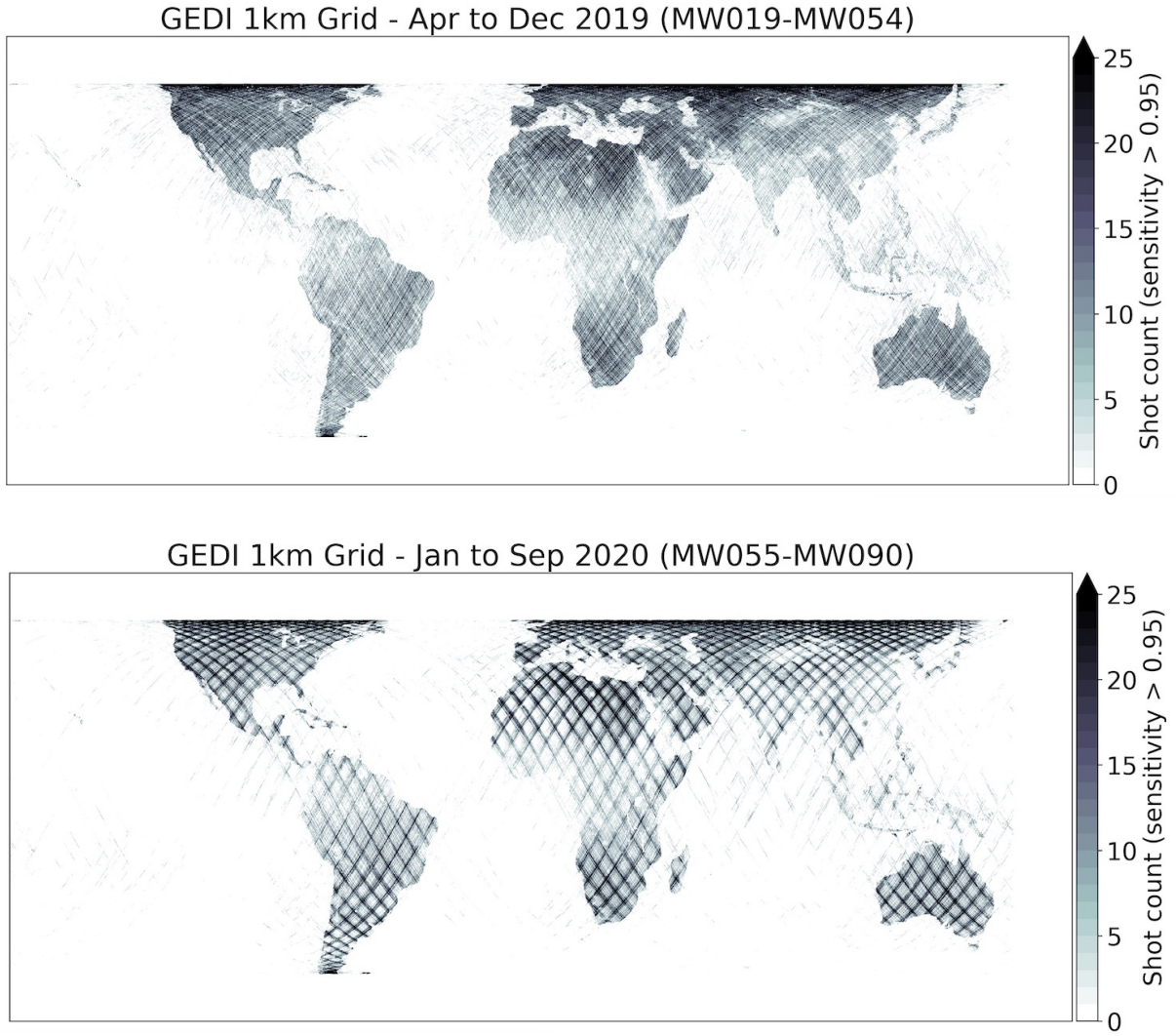
GEDI Mission Extension Timeline

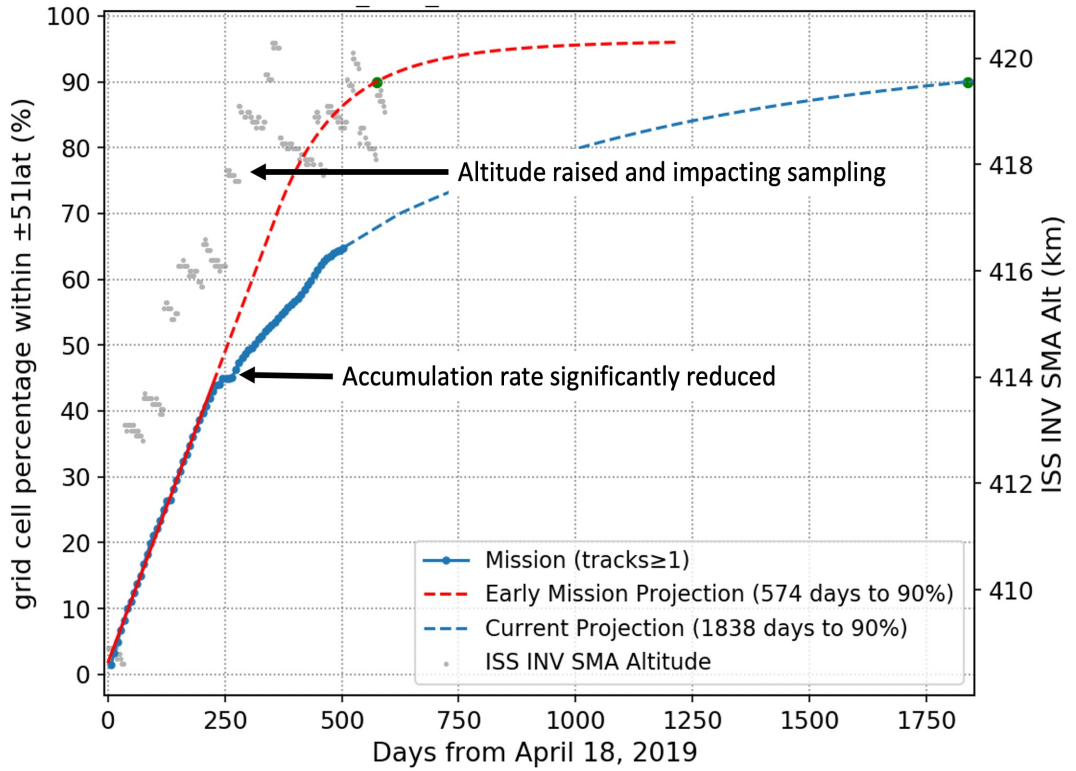


- GEDI will continue towards meeting its Level 1 Requirements given the extension period through to at least January 2023 with Phase F/Closeout beginning October 2023

- The STP-H9 Mission is currently slated to launch on SpX-28 in June 2023 and would utilize GEDI's location (JEM-EF #6), which would result in the removal of GEDI from that position

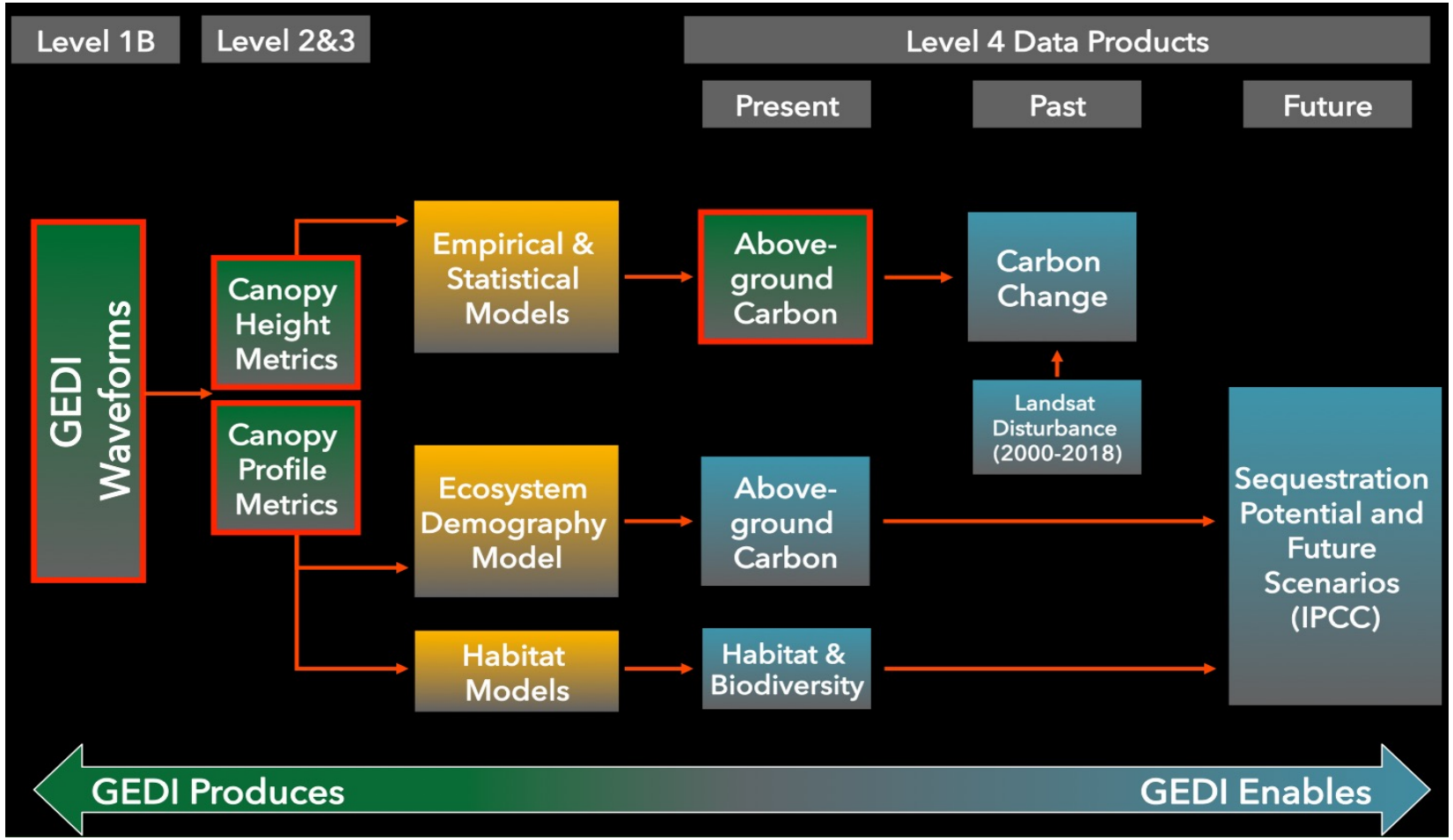
Impacts of ISS Orbital Pattern on GEDI Coverage





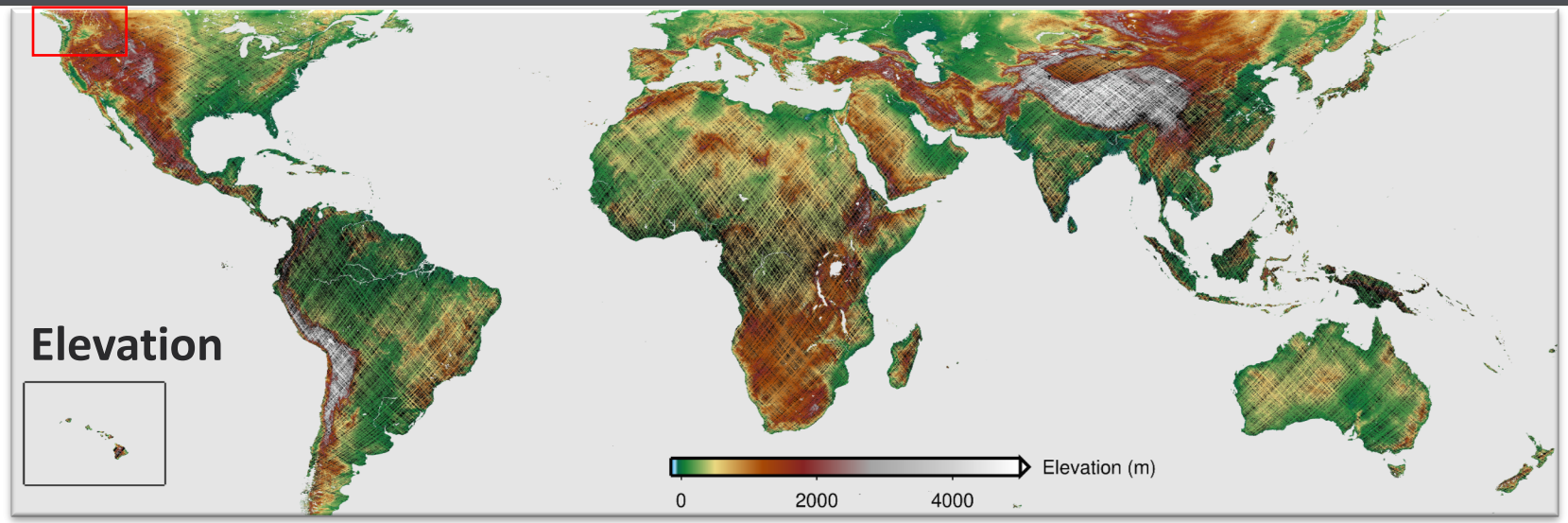
Higher ISS altitudes lead to orbital resonance and reduced coverage

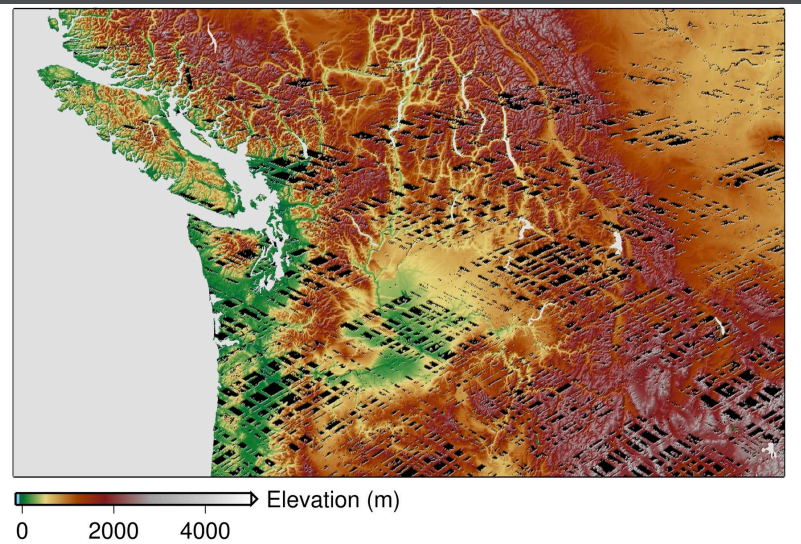
Science Approach and Data Products

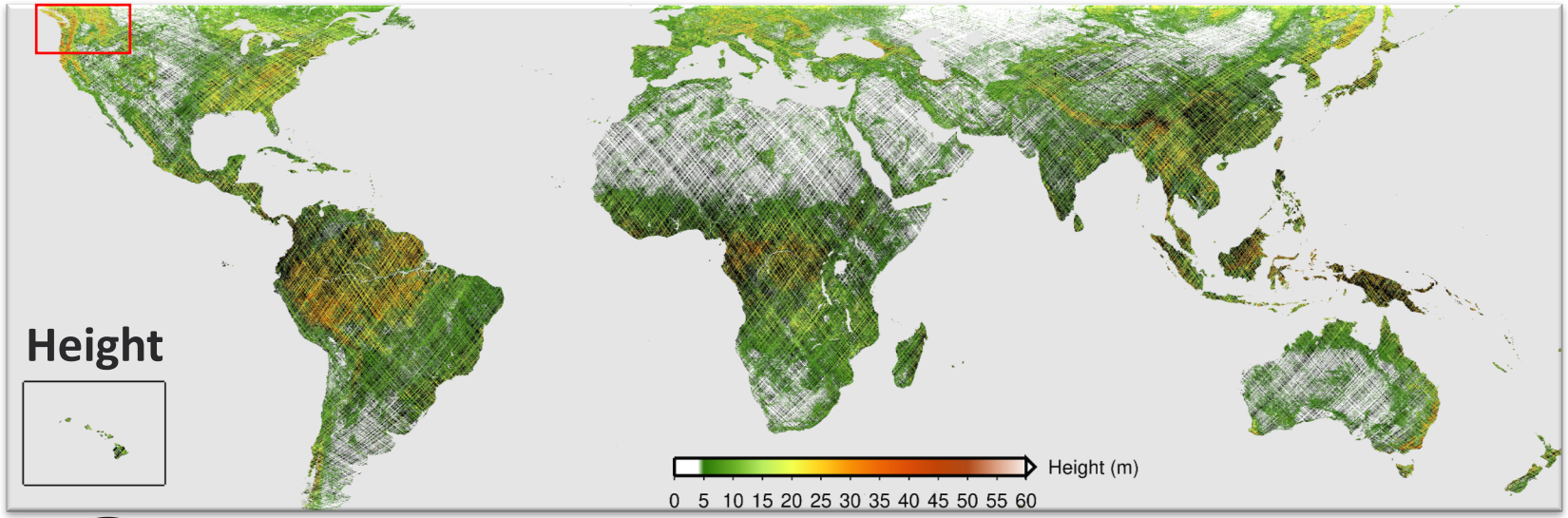


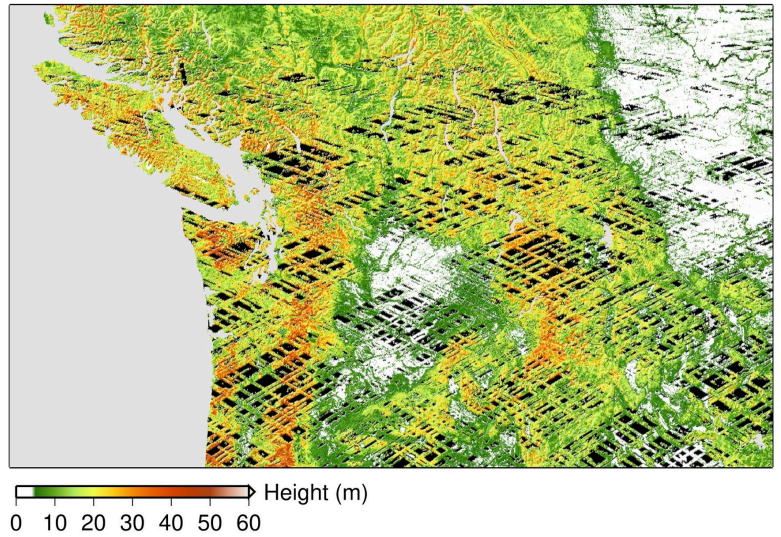
Product	Description
Level 1	Geolocated Waveforms
Level 2	Canopy Height/Profile Metrics • RH metrics • Canopy top height • Ground elevation • Canopy cover • PAI and PAVD
Level 3	Gridded Footprint Metrics
Level 4	Biomass
Level 4	Demonstrative Products • Ecosystem model outputs • Enhanced height/biomass using fusion with TanDEM-X & Landsat • Habitat model outputs

GEDI Gridded Topography and Height









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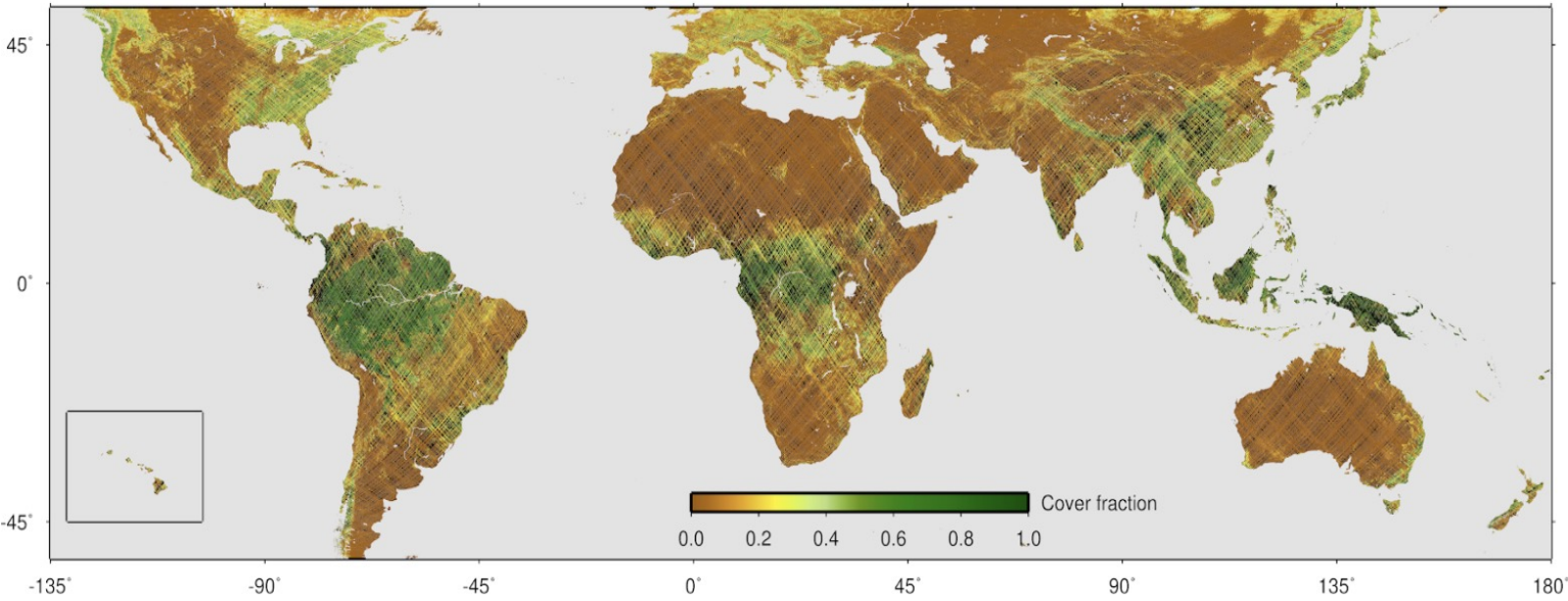
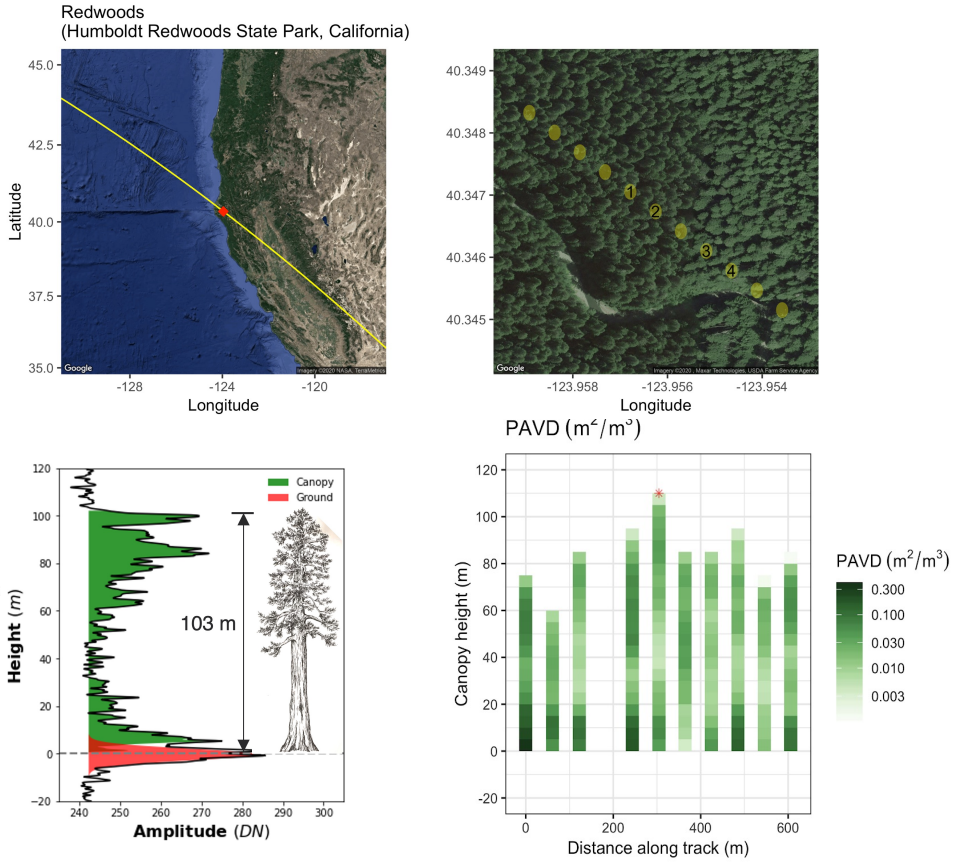
GEDI Canopy Cover and Vertical Profile Metrics

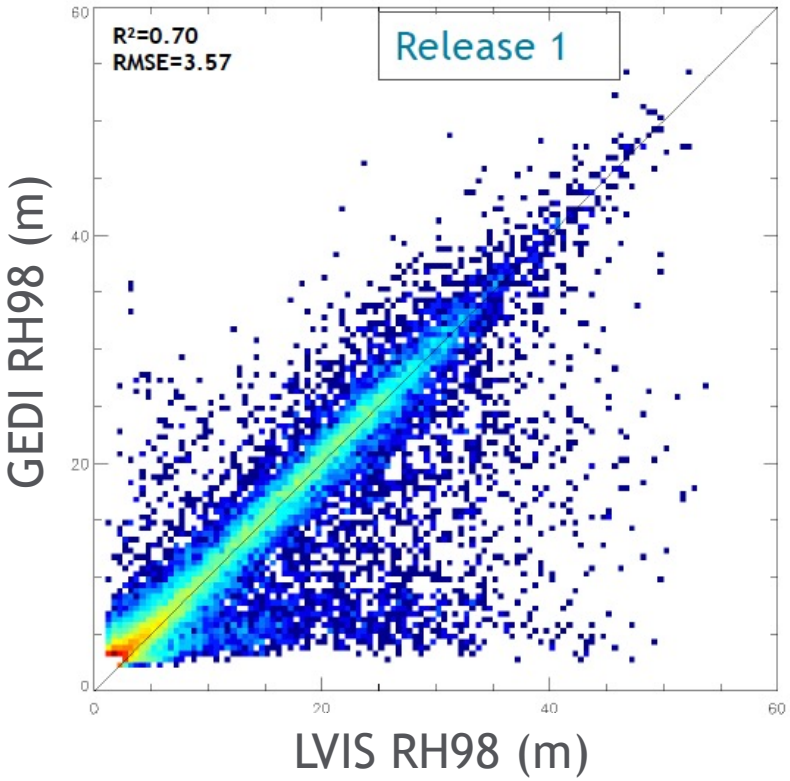
Canopy Cover (1 km mean)

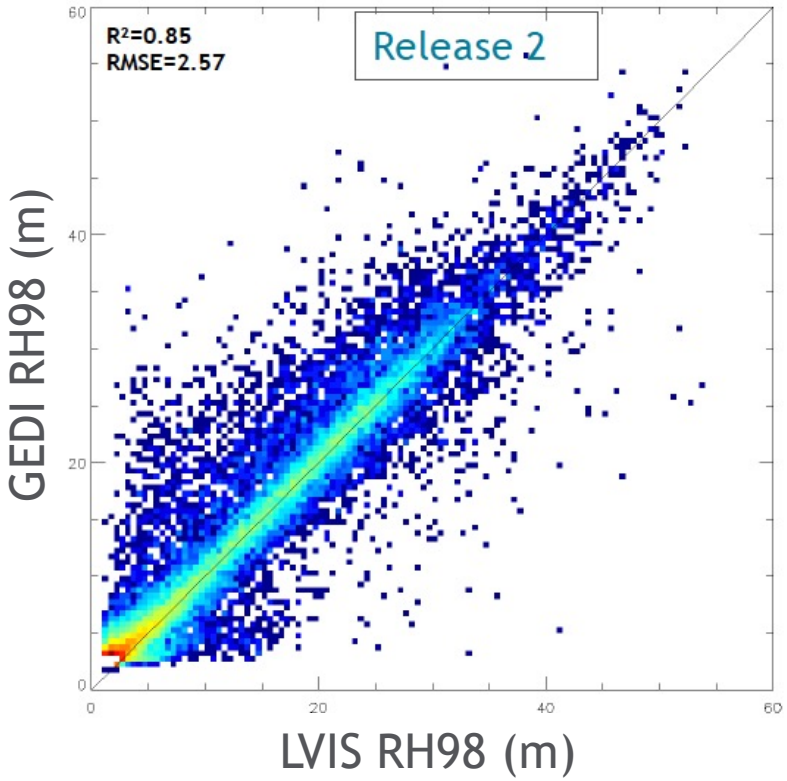


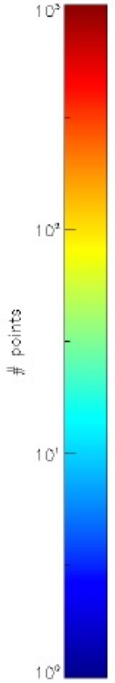


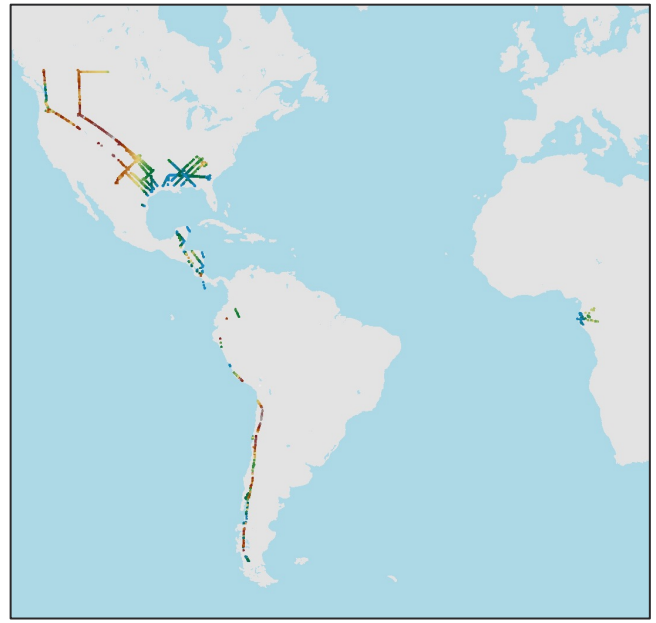
Gridded GEDI Level-2B metrics capture the spatial distribution of the high canopy cover areas

Comparison with NASA LVIS Observations





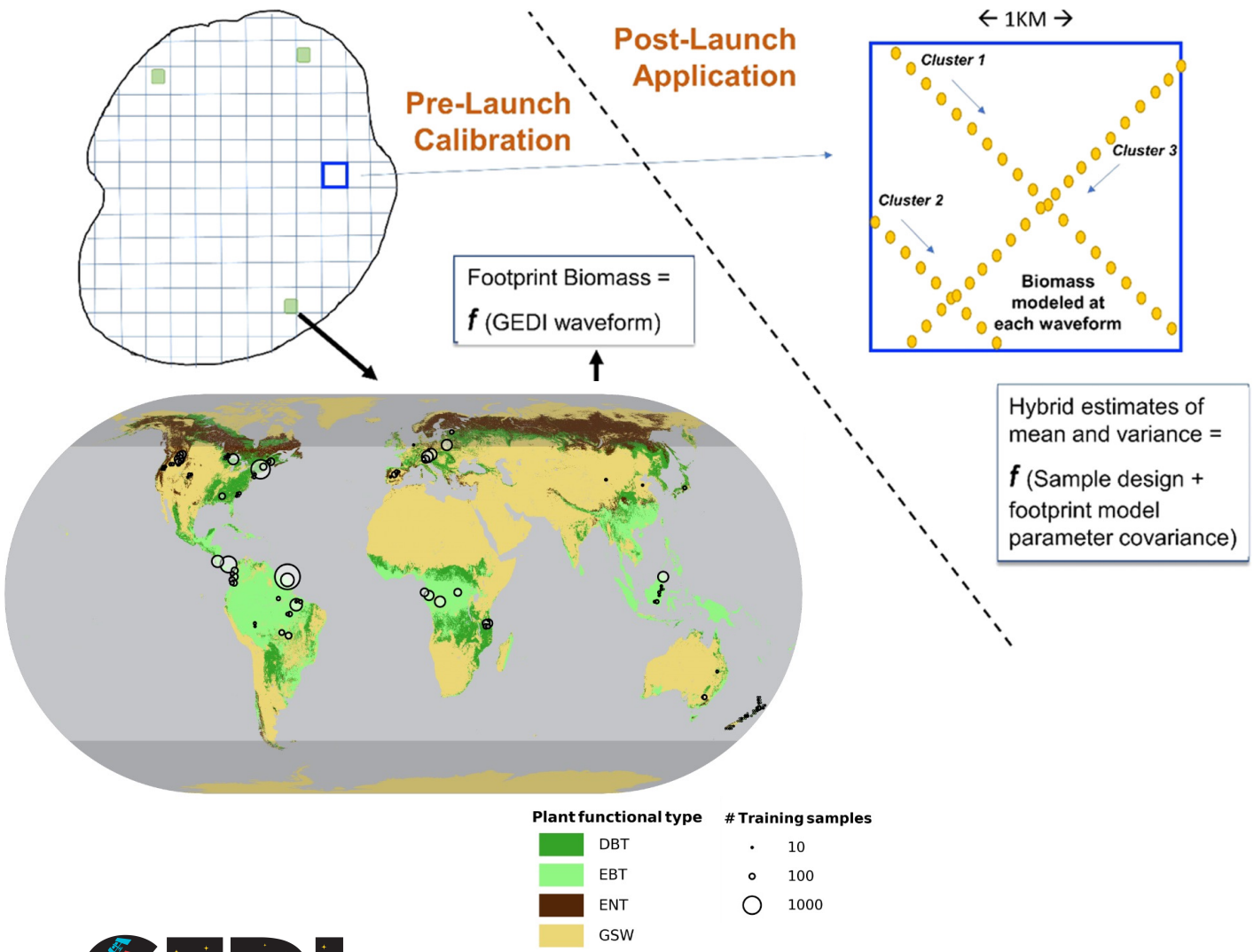




LVIS 2015 (transits to/from Chile/OIB)
LVIS 2016 (Gabon/AfriSAR)
LVIS 2019 (GEDI + transits / ABoVE)

GEDI Release 2 algorithm setting selection provides improved performance over dense canopy cover

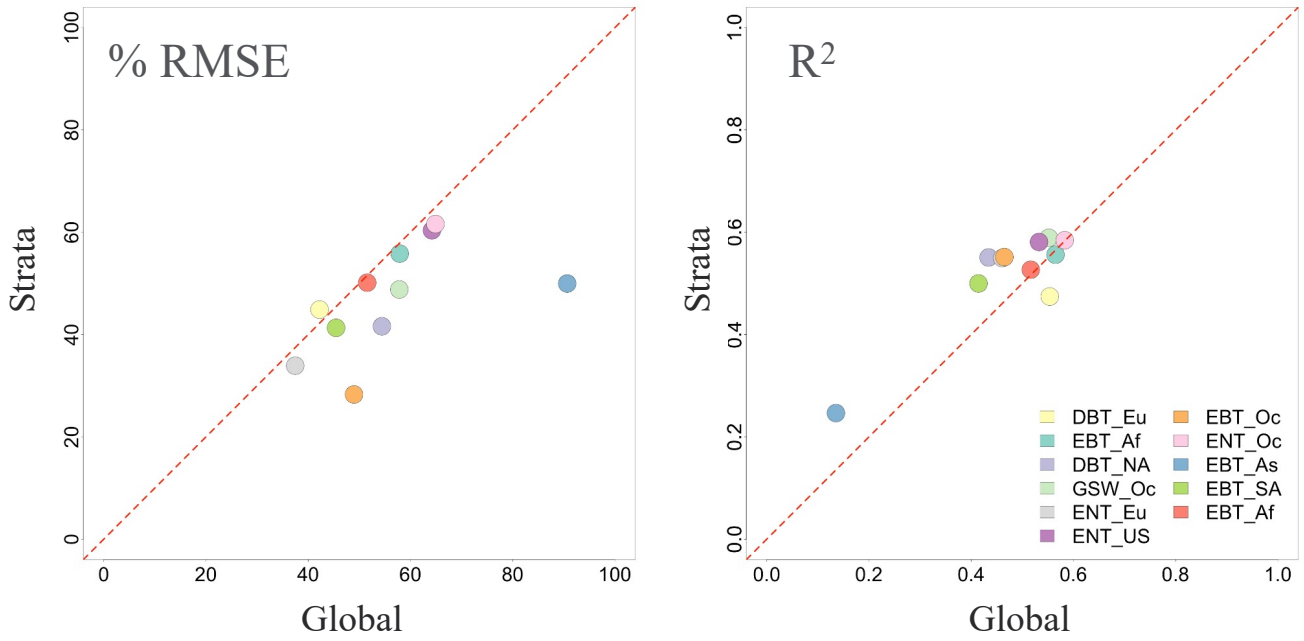
Development of GEDI Biomass Products



Key assumptions of the GEDI biomass estimation framework:

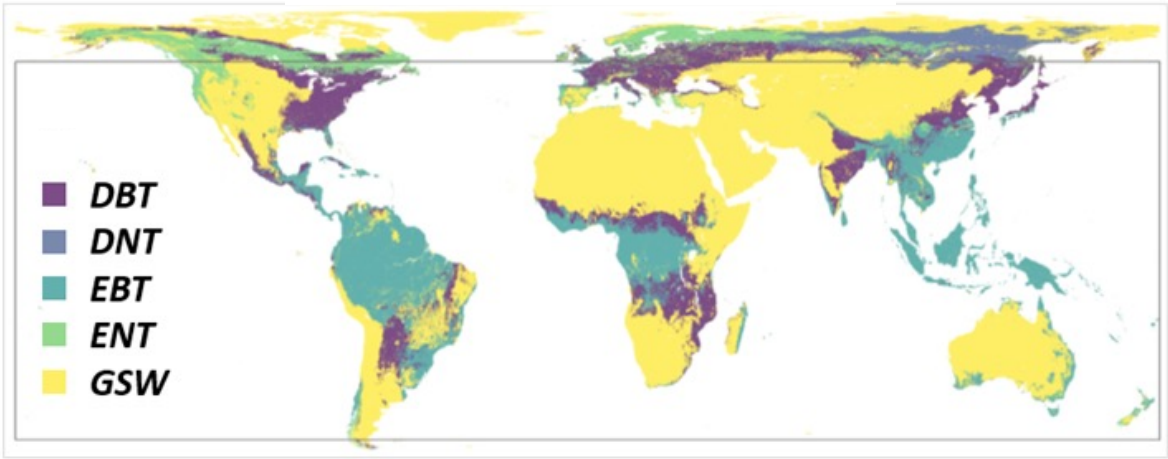
1. GEDI waveforms simulated from airborne data adequately represent measured waveforms
2. GEDI Level 4A footprint models are representative of the population to which they are applied
3. The footprint model parameter covariance matrix conveys the uncertainty of footprint-level AGBD predictions
4. The expected values of the GEDI hybrid estimators are unbiased

GEDI Footprint Biomass Models (Version 1)

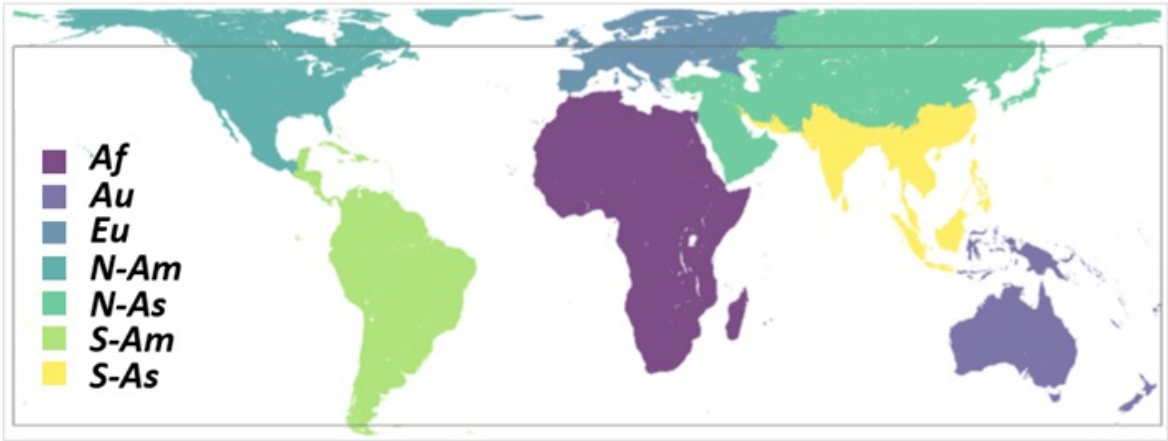


Geographic specificity led to improved model performance but was limited by the availability of high-quality field plot data

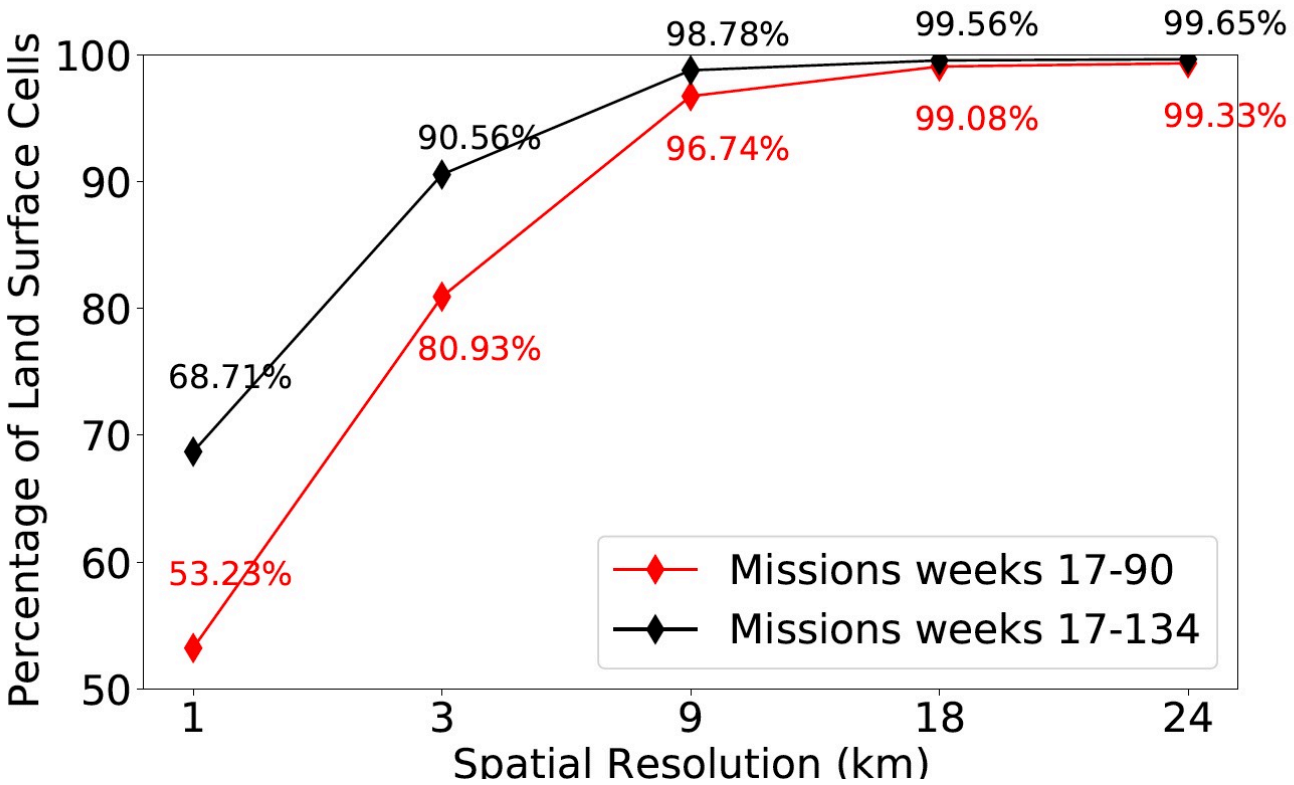
Plant Functional Type



Continental Region



GEDI Coverage for Biomass Estimation

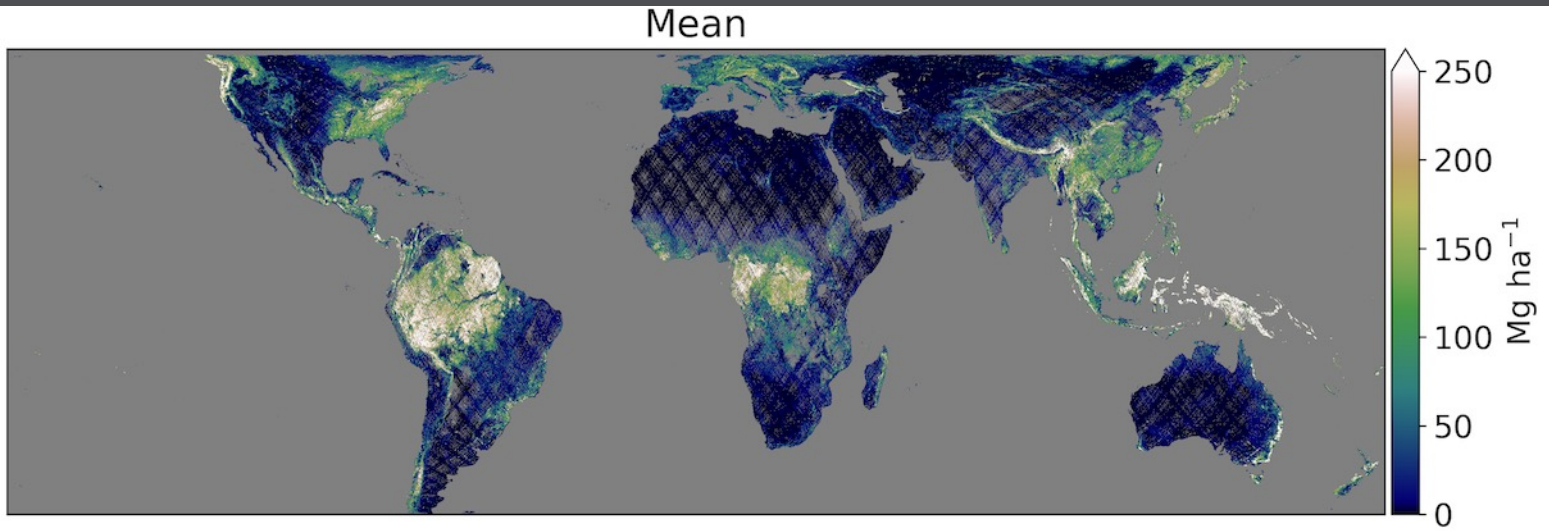


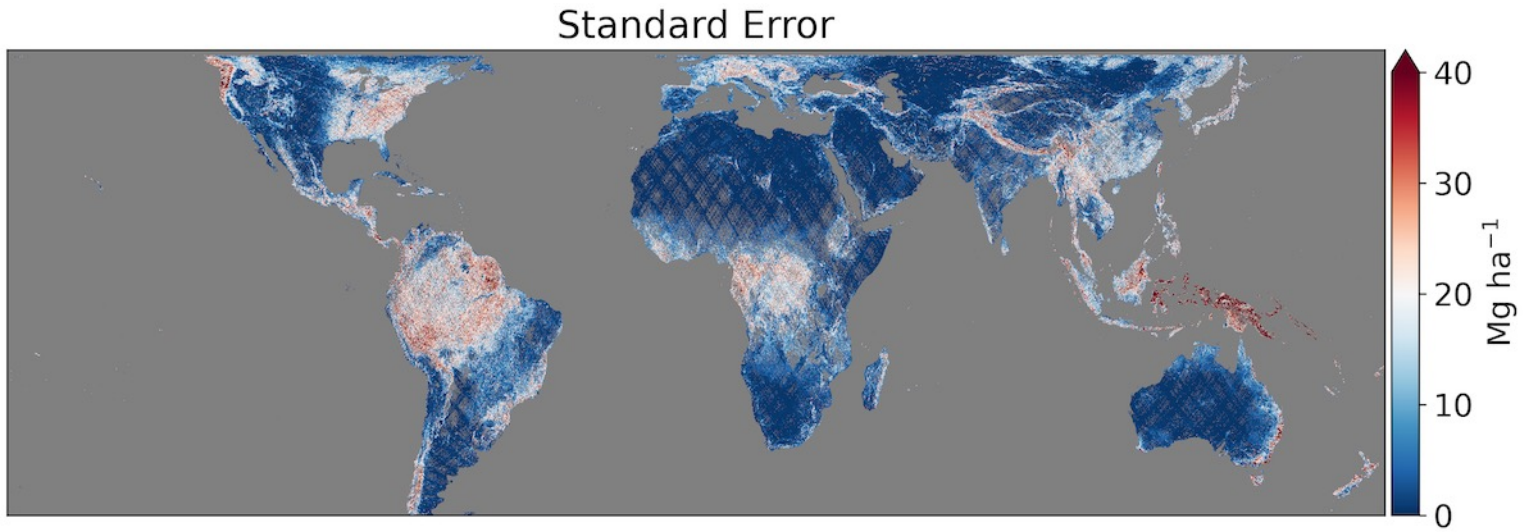
The GEDI hybrid inference framework requires:

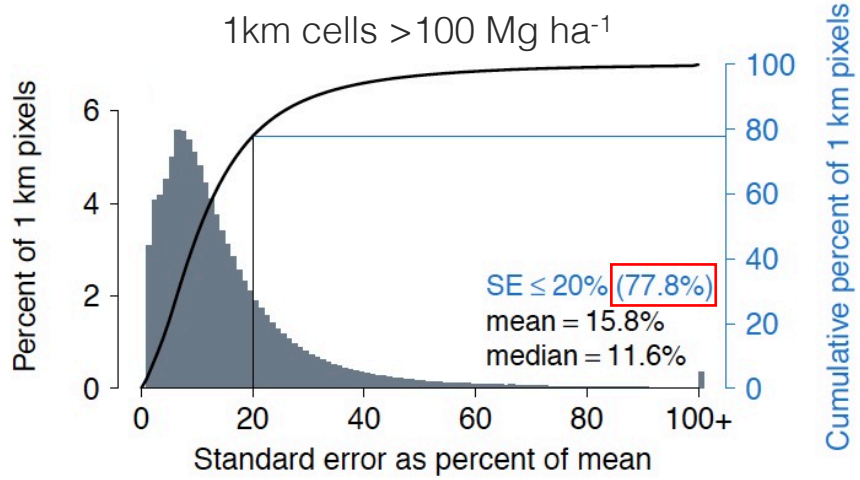
- Land surface waveforms
- Two or more tracks per cell
- Beam sensitivity >95%
- Leaf-on conditions in deciduous forests and woodlands

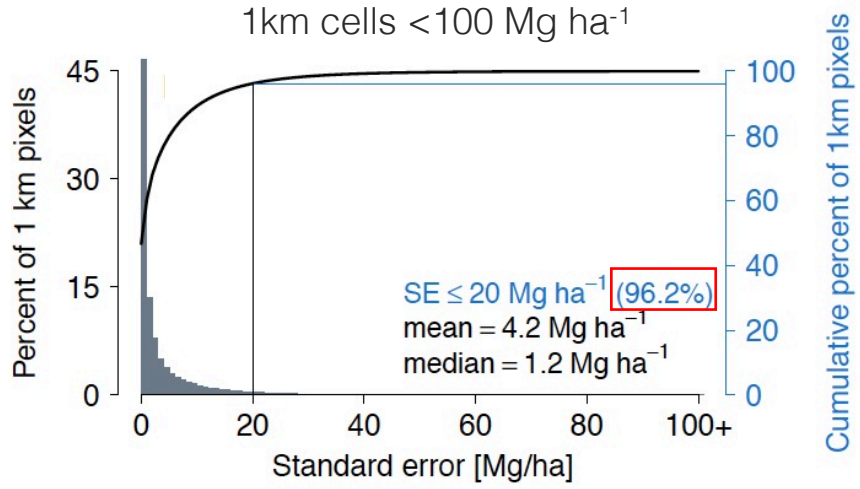
After two years on orbit, GEDI has sufficient high quality land surface measurements for wall-to-wall mapping of aboveground biomass at 10 km spatial resolution

GEDI Gridded Biomass (Version 1)





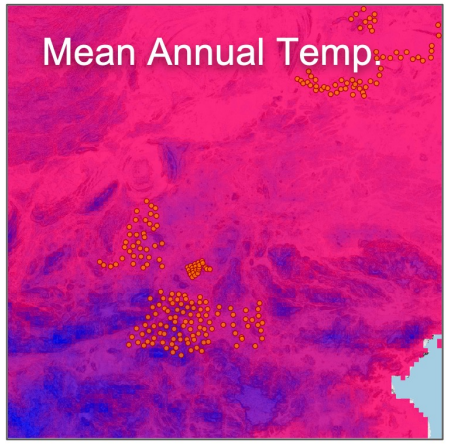


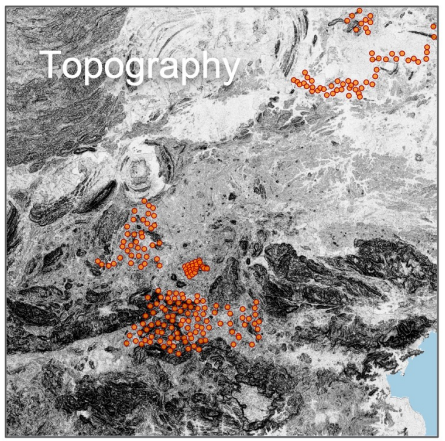


Demonstration Products: Biodiversity

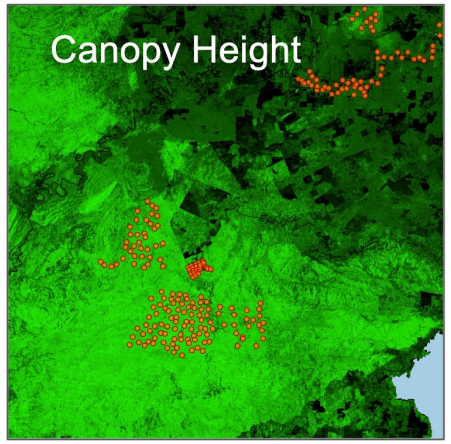
Species Habitat Variables

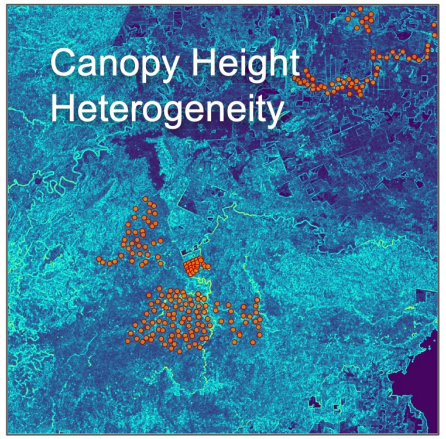
Widely-used





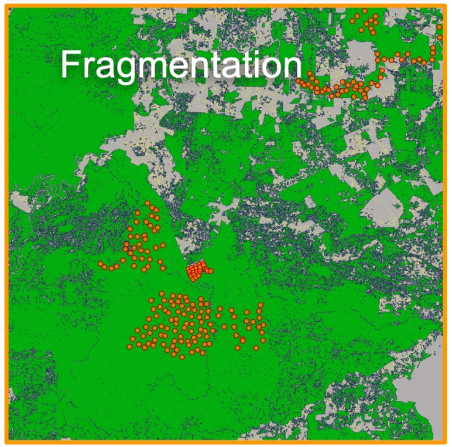
GEDI L2/3 and Demo.





GEDI Ext. Enabled

Waveform Structural Complexity Index (WSCI)



Modeling

Methodology

- Multi-scale variable optimization
- Ensemble machine learning (RandomForest, SVM, MARS, GLM, ANN, etc.)

Outcomes:

- Spatial prediction of multi-species habitat use
- Maps of potential habitat for threatened & endangered species
- Assessments of forest structure

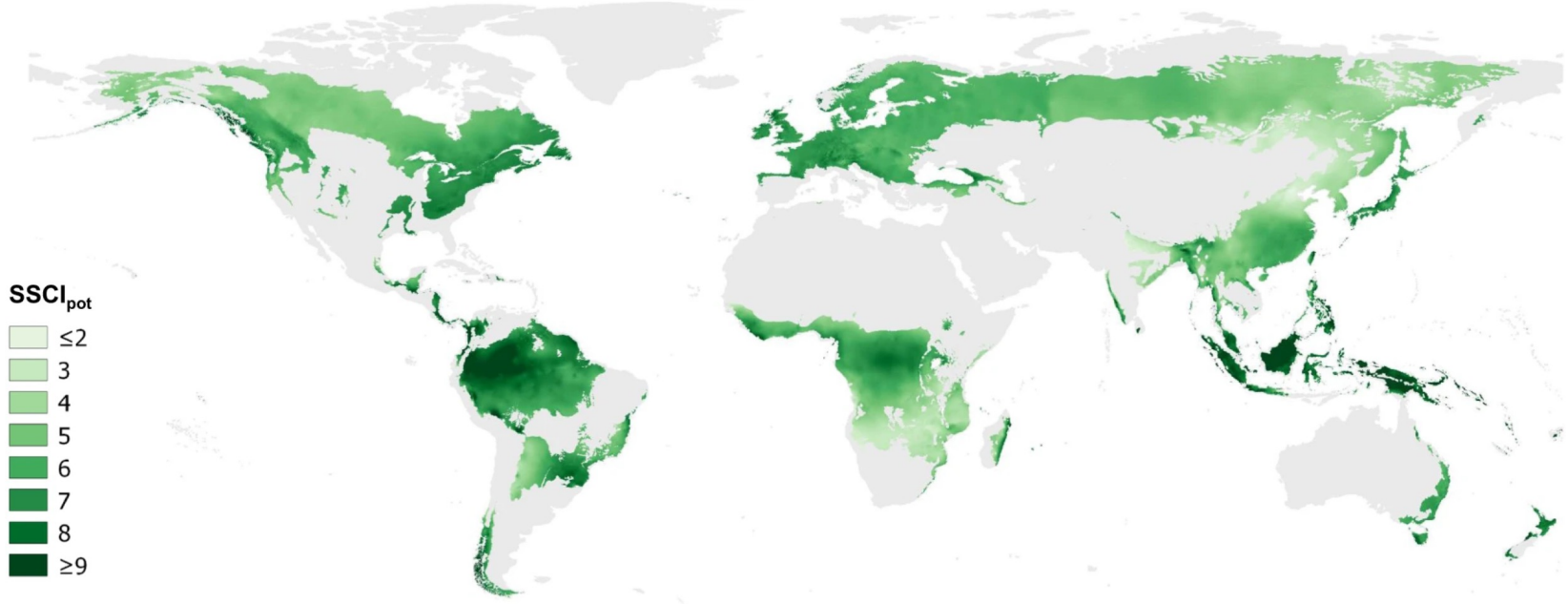
Proposed GEDI Extension Data Product: WSCI

Waveform Structural Complexity Index (WSCI)

- GEDI waveforms can be used to derive many structural metrics that reflect canopy complexity -> foliage height diversity, entropy, layering, etc.
- Stand Structural Complexity Index (SSCI) was recently demonstrated using TLS data Ehbrecht et al. (2021)

Analogous waveform metric can be created (WSCI)

Algorithm developed using simulated GEDI and Terrestrial Laser Scanning (TLS) data



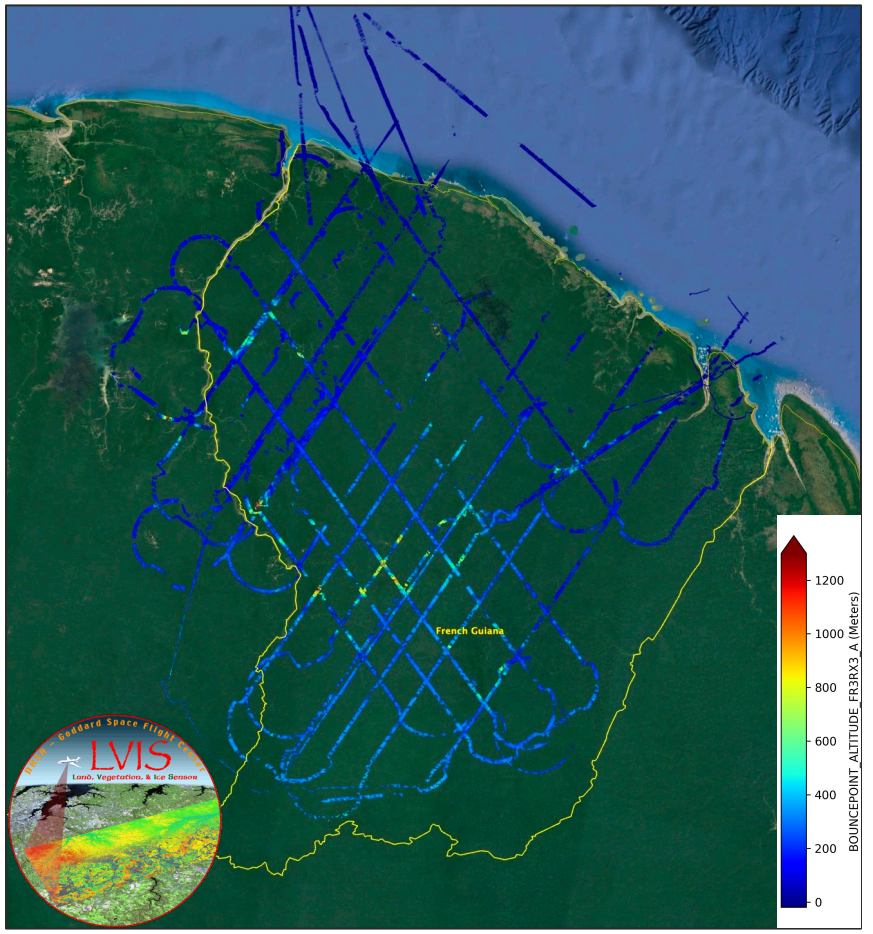
Potential structural complexity in forest ecoregions

Summary and Outlook

1. **GEDI is past its prime mission, which ended in April 2021**
   - Has not yet met Level 1 requirements because of ISS orbital issues (coverage)
   - Extension proposal approved to take observations through to January 2023
   - Request to ISS and ROSCOSMOS to lower ISS orbit approved for early 2022

2. **Version 2 gridded structure & biomass products available Q4 2021**
   - ~50% of land surface cells meets L1 requirements after 18 months on-orbit
   - Important insights gained through comparison of GEDI with NFI design-based biomass estimates
   - GEDI 2021 CAL/VAL airborne campaign targeted Level 2 product improvements for input to Release 3

3. **GEDI has opened a new era of canopy structure mapping and biomass inference from space**
   - GEDI is the first mission to design and implement a formal inference framework for the estimation of biomass
   - GEDI measurements underpin the development of Lidar-SAR fusion algorithms and products for current and upcoming satellites (e.g., DLR TanDEM-X, NASA/ISRO NISAR)



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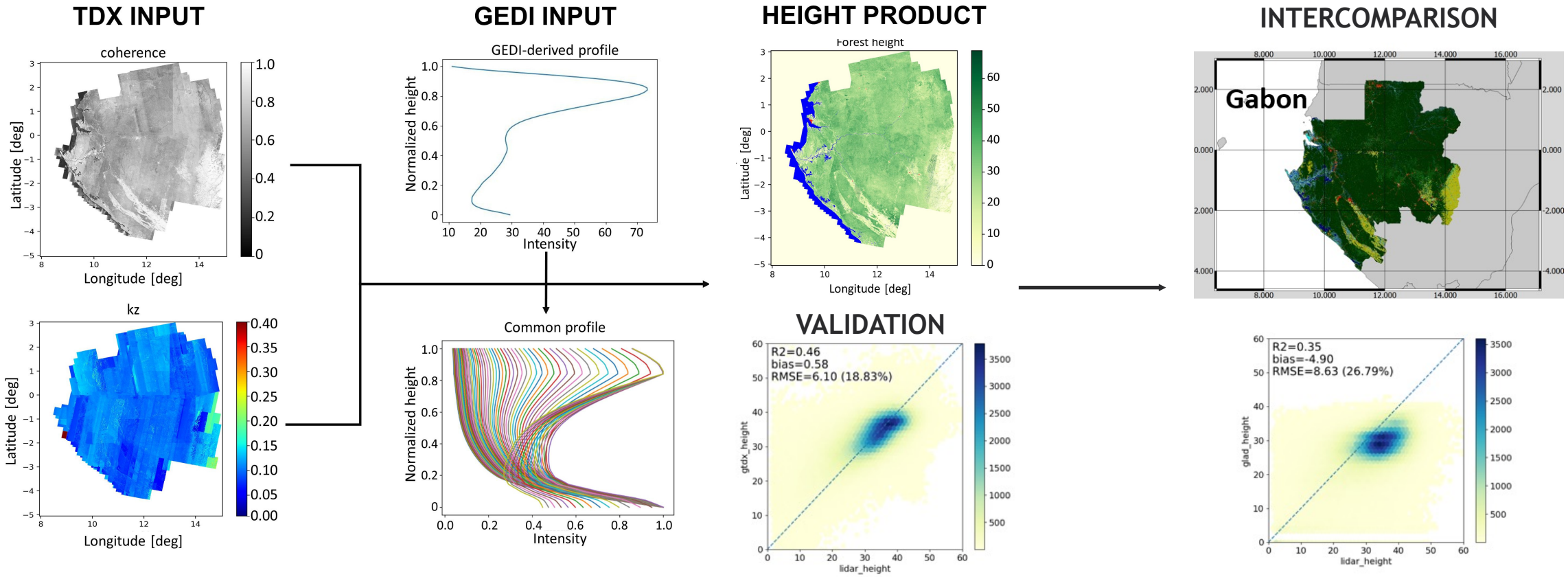
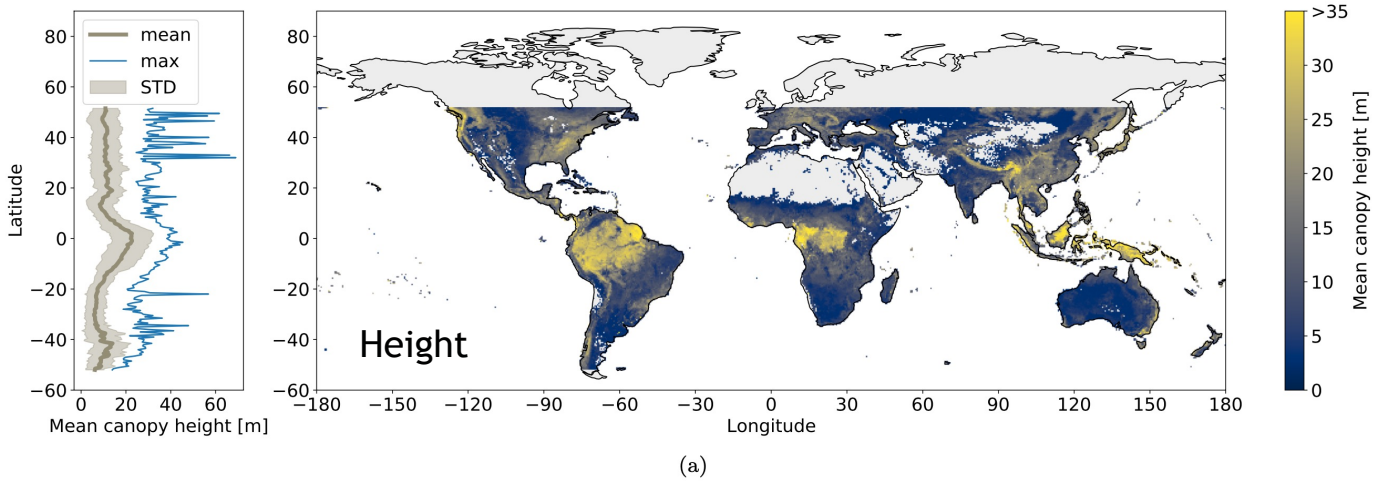
GEDI-SAR Fusion for High Resolution Mapping



GEDI & TanDEM-X fusion enables country scale 1 ha mapping of canopy height and biomass, capturing fine scale patterns where shot density is low

Characterizing Uncertainty with cNN



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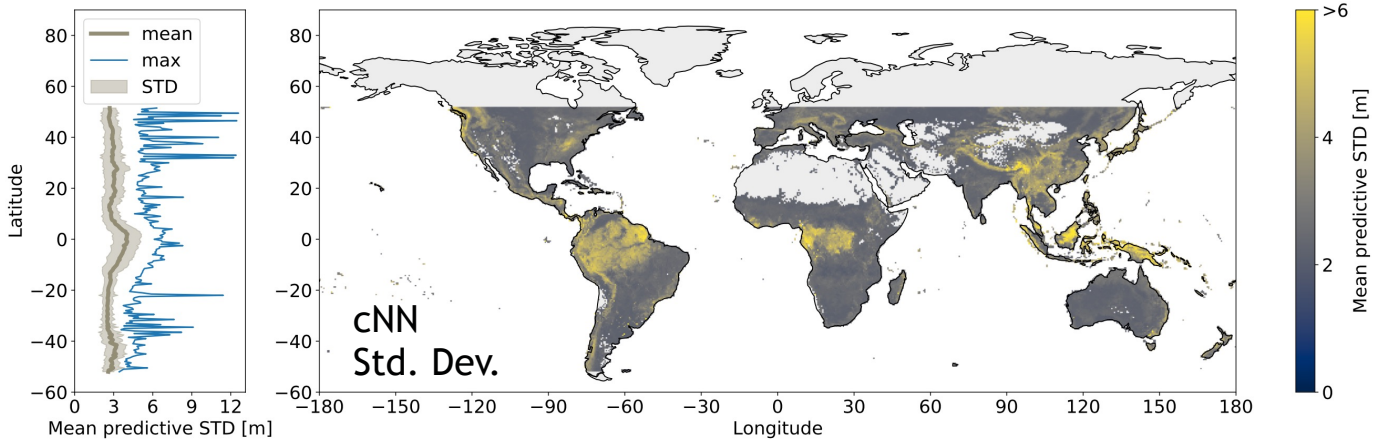

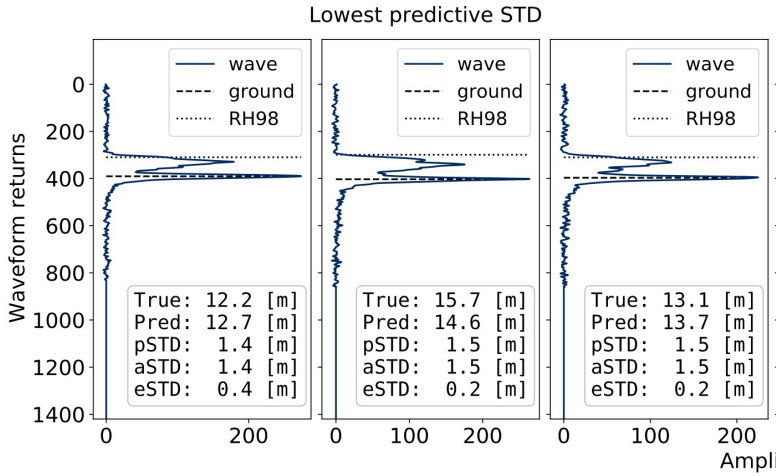

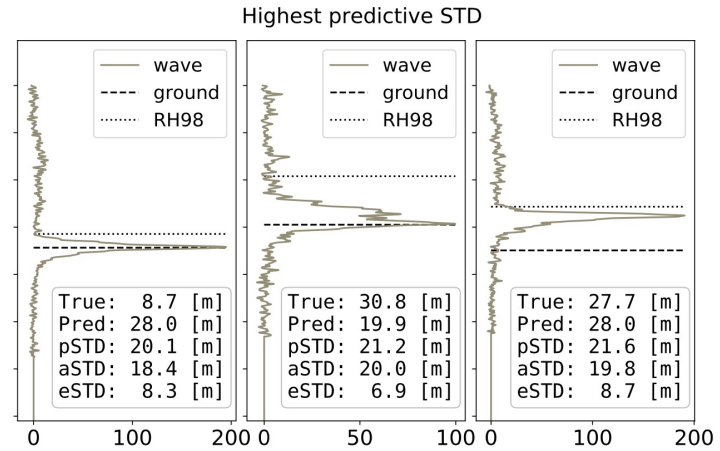

Lang et al. (2021)