

Global Ecosystem Dynamics Investigation (GEDI) Mission Update

GEDI Science Definition Team



ALOS Kyoto & Carbon Initiative – 24th Science Team Meeting
RESTEC HQ, Tokyo – January 29–31 2018



Presentation Outline

- **The GEDI Mission**
 - Science questions and objectives
 - Engineering and mission status
 - Science approach and data products
- **The GEDI Approach**
 - Biomass from footprints to the grid scale
 - A statistical framework for fusion
 - Biomass calibration for other SAR missions

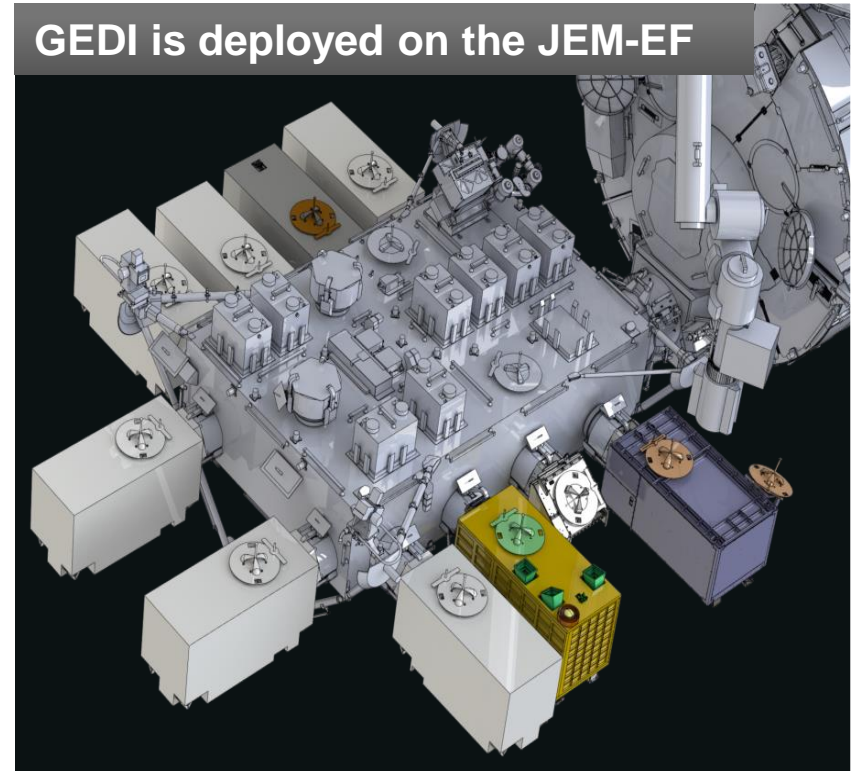
Earth Ventures Instrument (EVI)



- Deployed on International Space Station
 - Launch on SpaceX-18: May 2019
 - Observations between +/- 51.5° N &
- Nominal 2 year mission length

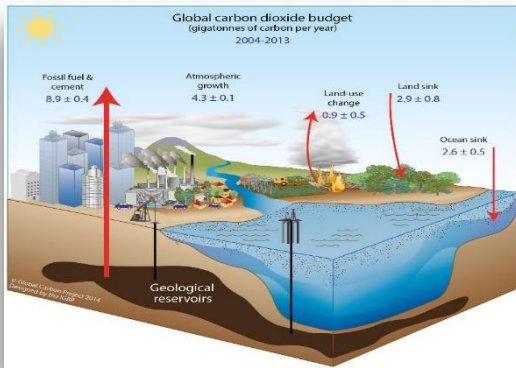
- Multi-beam waveform lidar instrument
 - NASA Goddard Spaceflight Center (GSFC)
- \$94 M (Class C mission)

GEDI is deployed on the JEM-EF



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

What is the carbon balance of the Earth's forests?

Quantify

Forest Biomass

Disturbance and Recovery

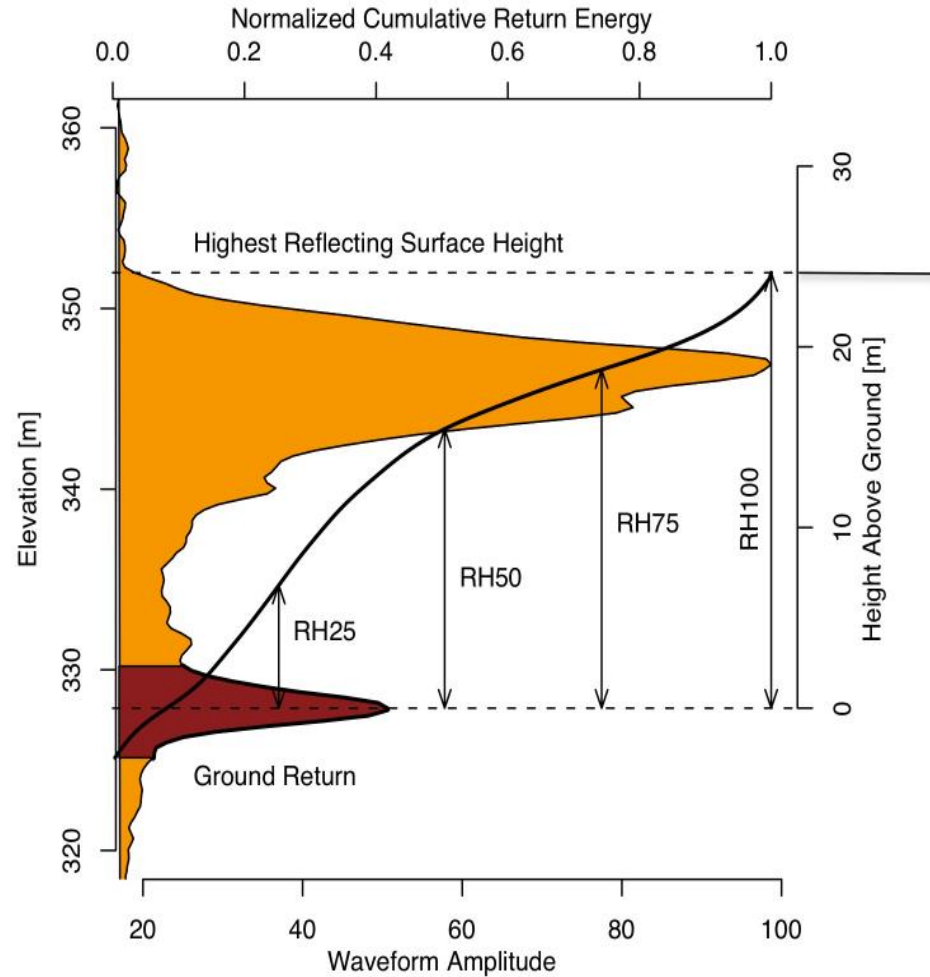
How will the land surface mitigate atmospheric CO₂ in the future?

Carbon Sequestration Potential

How does forest structure affect habitat quality and biodiversity?

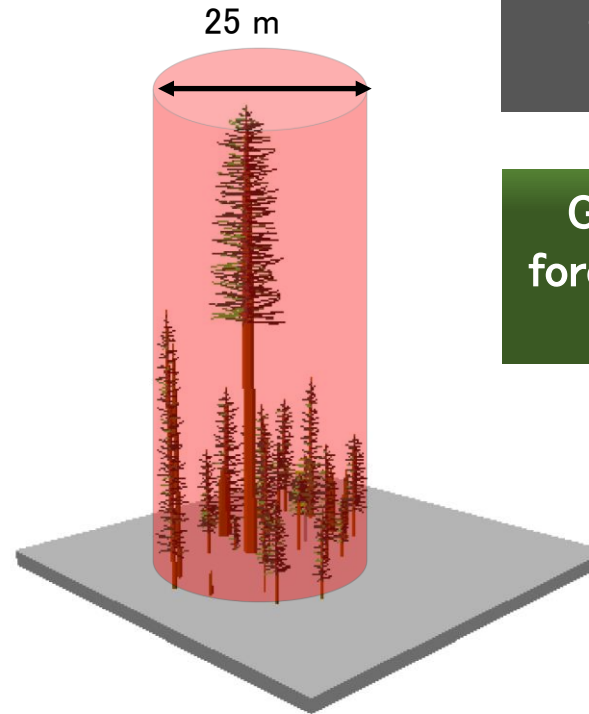
Vertical Forest Structure and its Relationship to Biodiversity

GEDl Lidar Measurements

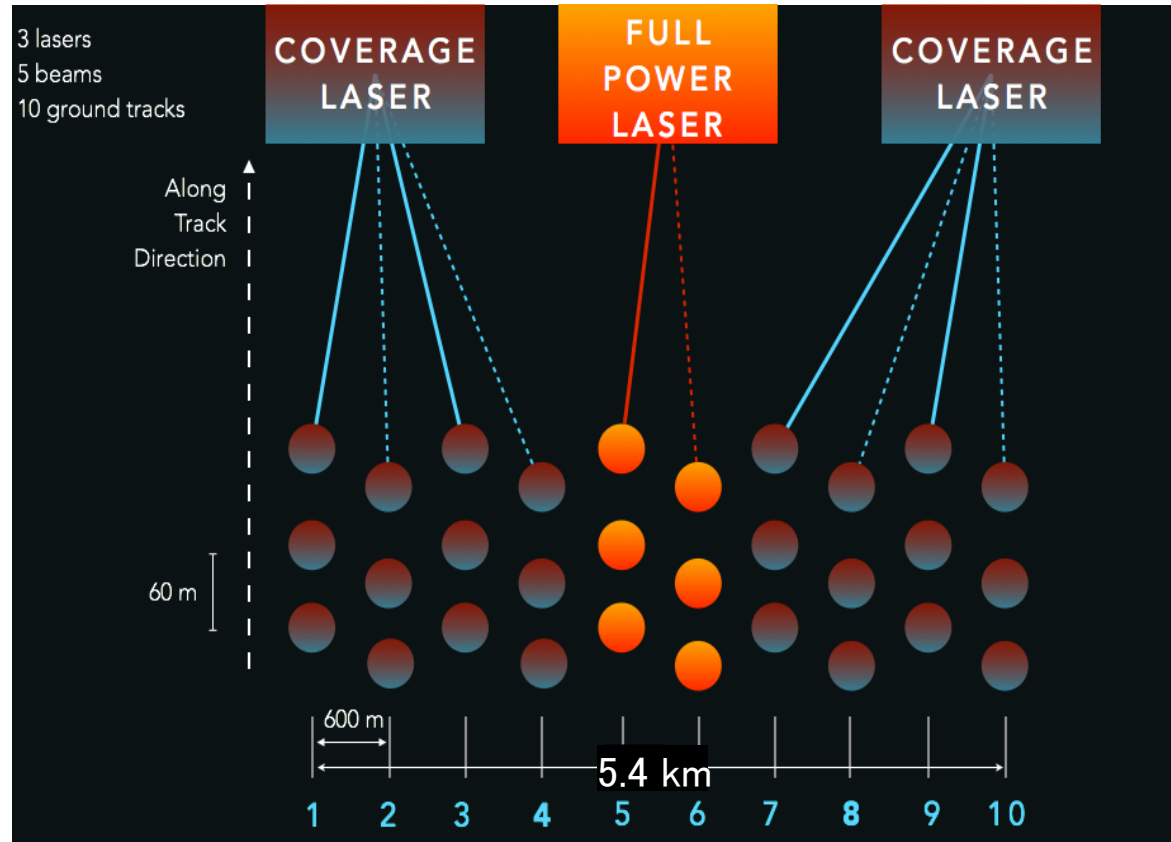


GEDl's sole observable is the lidar waveform which provides ground elevation, canopy height, cover and various profiles and metrics.

GEDl makes 12 billion observations of forest and land surface structure over its nominal two-year mission



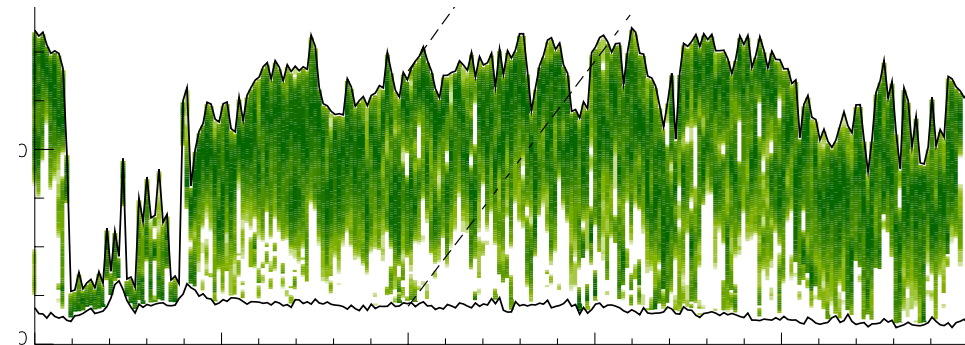
GEDI Observations



GEDI uses 3 lasers to produce 10 transects of lidar waveforms.

Each footprint provides the complete vertical structure of the canopy.

Dithering can be turned off for contiguous, along-track coverage.



Baseline Requirements

Gridded Biomass

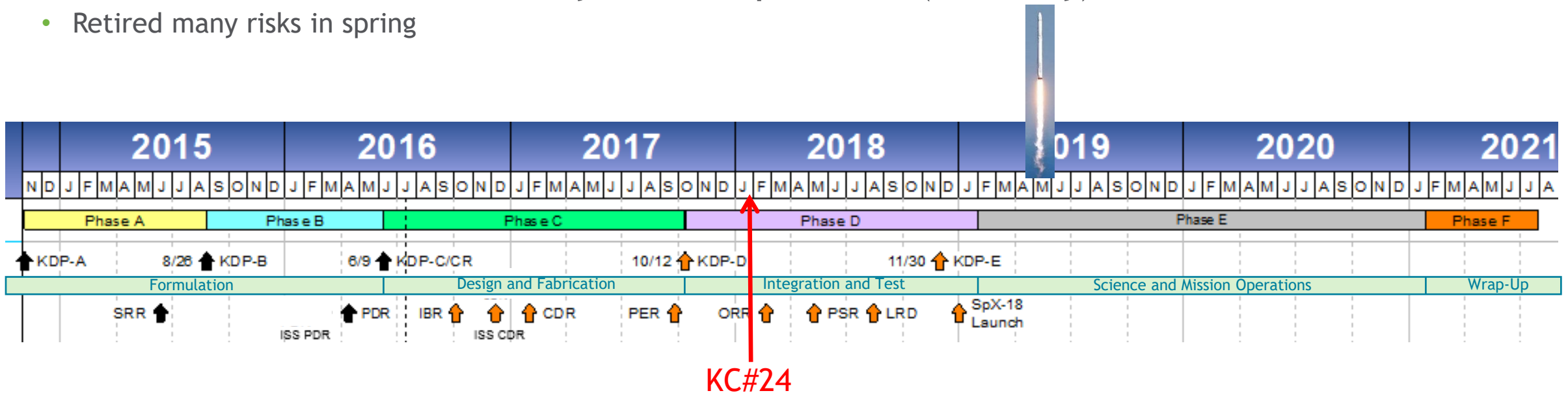
- Acquire lidar canopy vertical profile data required to estimate aboveground woody carbon density for the Earth's global tropical and temperate forests within the ISS orbital coverage at ≤ 1 km resolution. At the end of **two years** after on-orbit checkout, **at least 80% of the 1 km cells will meet an accuracy within 20% standard error, or 20 Mg/ha** whichever is greater, subject to instrument availability.

Transects of Vertical Profiles

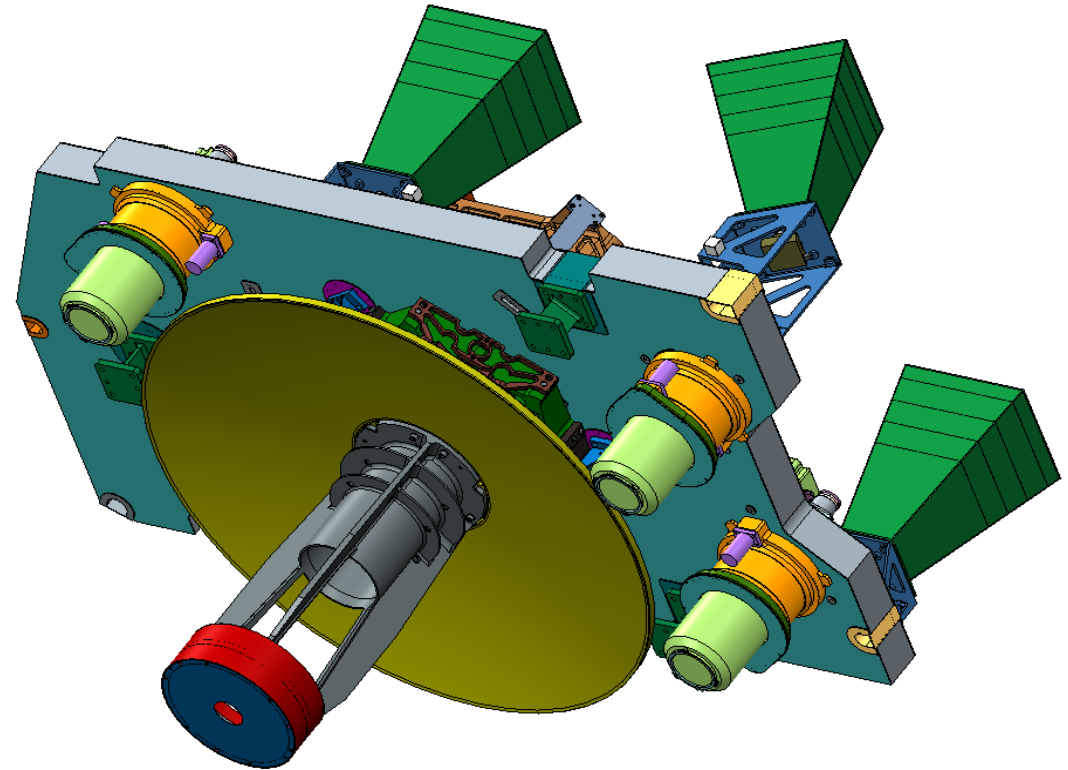
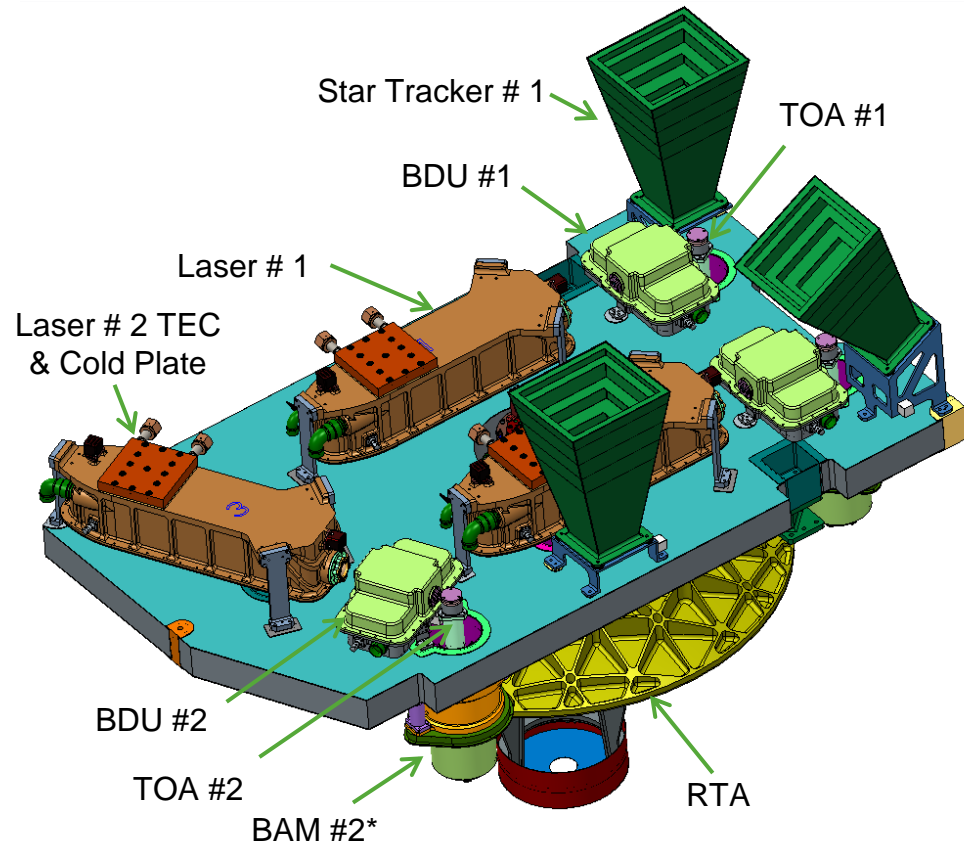
- Acquire transects (that is, near contiguous, along-track laser footprint observations) of tropical & temperate forest canopy vertical profiles from the top of canopy to the ground. Instrument performance must be sufficient to acquire profiles in conditions of up to about **95% canopy cover for all beams**. Additionally, at least one laser beam must have sufficient power to acquire profiles in conditions of up to about 98% canopy cover.
- Record, validate, publish, and deliver science data records (L0-L1B) and validated data products and model outputs (L2-L4) to the DAAC designated by NASA for use by the scientific community.

Current Mission and Engineering Status

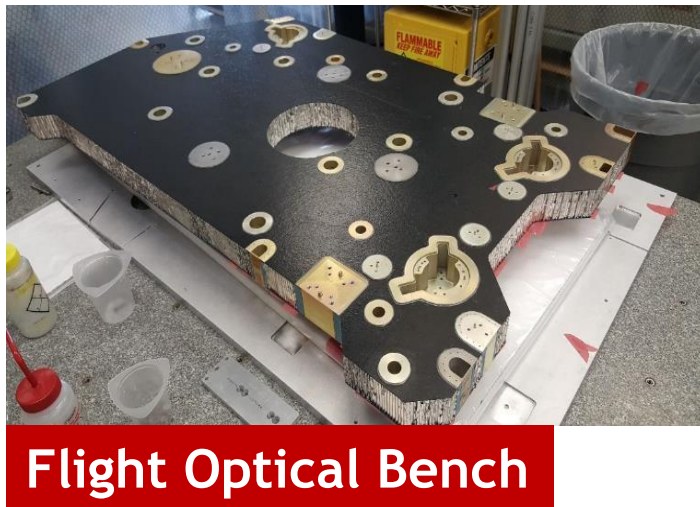
- GEDI successfully passed key milestones:
 - Confirmation Review and Critical Design Review (CDR)
- Currently in Phase C
- All Algorithm Theoretical Basis Documents (ATBDs) have been created and externally reviewed
- Integration & Test has begun
- On schedule towards launch on May 2019 on Space-X 18 (SPX delay)
 - Retired many risks in spring



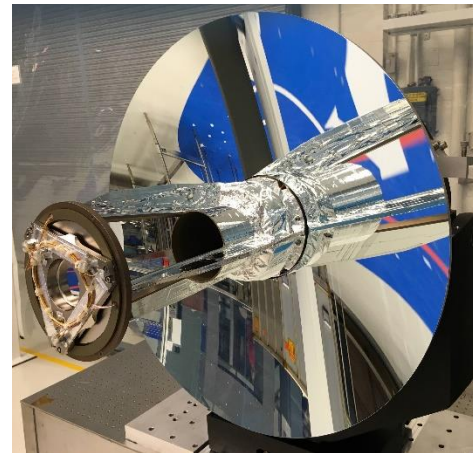
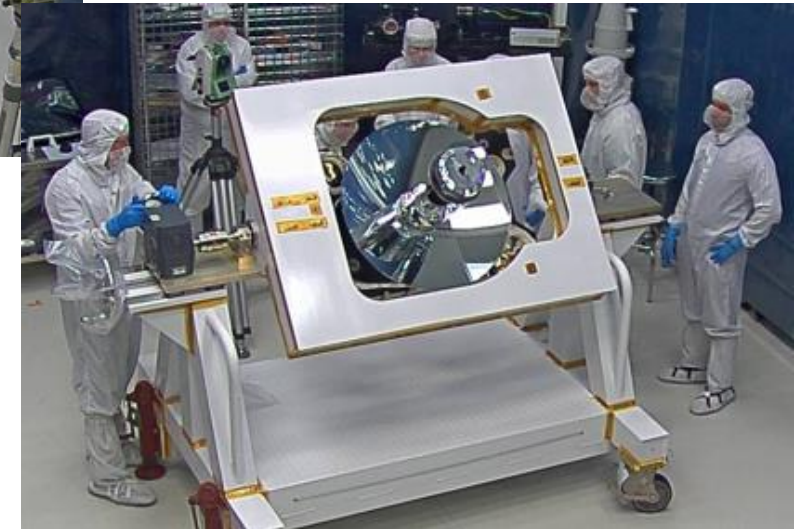
GEDI Lidar Instrument



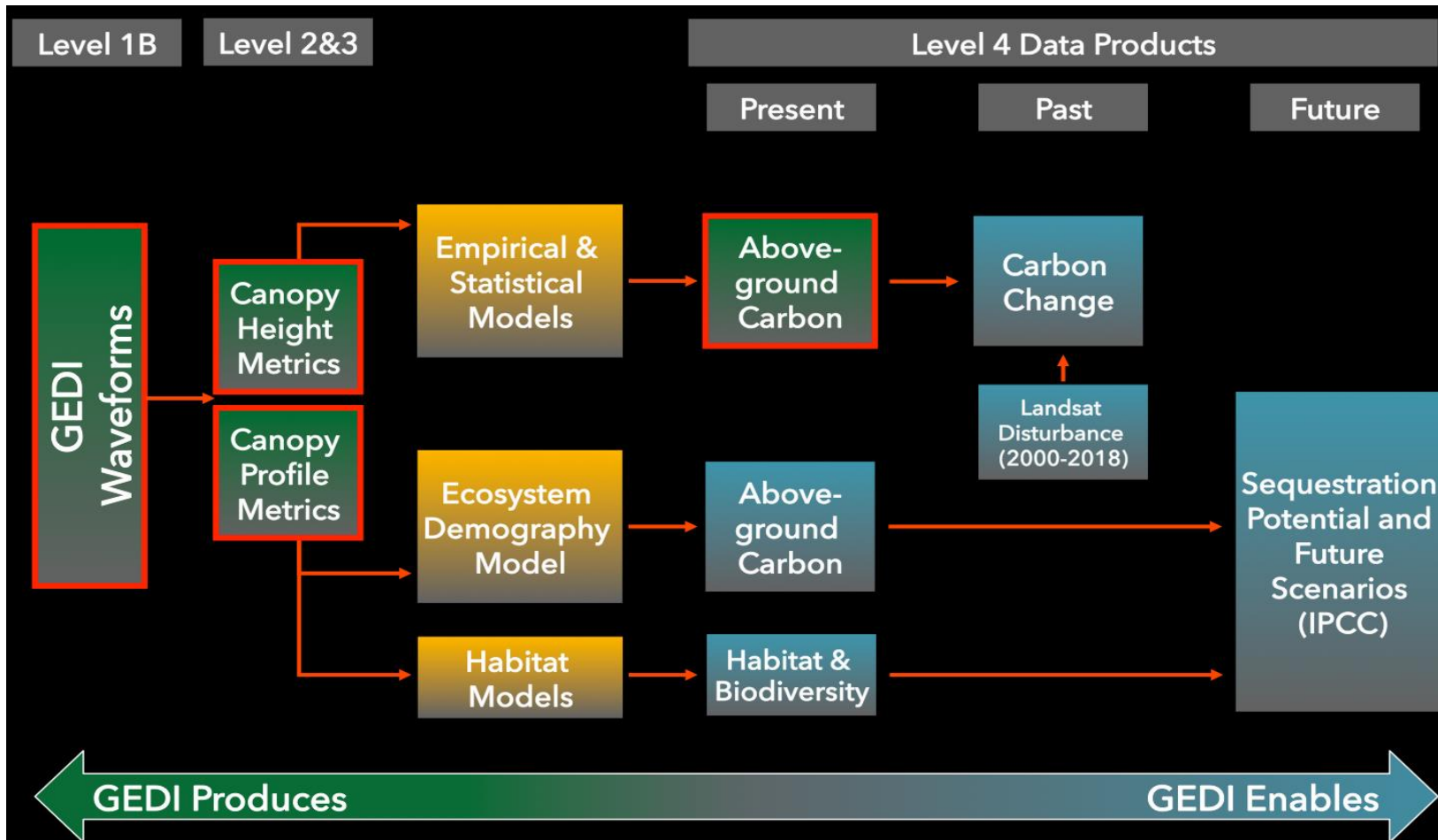
GEDI Hardware



Integration of Optical Bench
with Mirror Assembly



Science Approach and Data Products



Product	Description
Level 1	TX/RX Waveform Parameters Geolocated Waveforms
Level 2	Footprint Cover & Height Metrics <ul style="list-style-type: none"> Relative Height (RH) metrics Ground and canopy top elevation Canopy cover vertical profile LAI vertical profile
Level 3	Gridded Footprint Metrics
Level 4	Above Ground Biomass
Level 4	Demonstrative Products <ul style="list-style-type: none"> Ecosystem model outputs Enhanced height/biomass using fusion with TanDEM-X & Landsat Habitat model outputs

GEDI Data Products

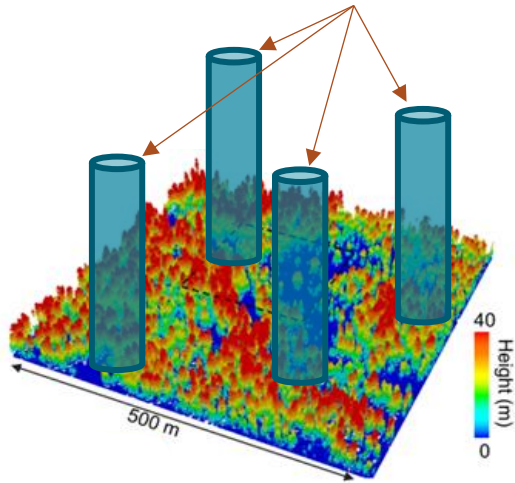
Product/ Data File	Description	Source	First Data Delivery After IOC	Data Latency	Archive Site
GEDI00_B	Level 0B Instrument Products	MOC	Within 24 hours of receipt at GSFC	Within 24 hours of receipt at GSFC	LPDAAC
GEDI01_A-TX	Level 1A-TX Transmitted Waveform Fitted Parameters	SOC	First 2 months of L1 released at 6 months	4 months in monthly intervals	LPDAAC
GEDI01_A-RX	Level 1A-RX Received Waveform Fitted Parameters	SOC	First 2 months of L1 released at 6 months	4 months in monthly intervals	LPDAAC
GEDI01_B	Level 1B Calibrated and Geolocated Waveforms	SOC	First 2 months of L1 released at 6 months	4 months in monthly intervals	LPDAAC
GEDI02_A	Level 2A Elevation and Height Metrics	SOC	First 2 months of L2 released at 6 months	4 months in monthly intervals	LPDAAC
GEDI02_B	Level 2B Canopy Cover and Vertical Profile Metrics	SOC	First 2 months of L2 released at 6 months	4 months in monthly intervals	LPDAAC
GEDI03	Level 3A Gridded Land Surface Metrics	SOC	Populated with first 2 months of L2 data at 6 months	4 months in monthly intervals	ORNLDAAAC
GEDI04_A	Level 4A Footprint Above Ground Biomass	SOC	First 12 months of L3 data at 17 months	6 months after global sampling required to meet L1 requirement	ORNLDAAAC
GEDI04_B	Level 4B Gridded Above Ground Biomass	SOC	First 12 months of L3 data at 17 months	6 months after global sampling required to meet L1 requirement	ORNLDAAAC

GEDI Algorithm Theoretical Basis Documents (ATBDs)

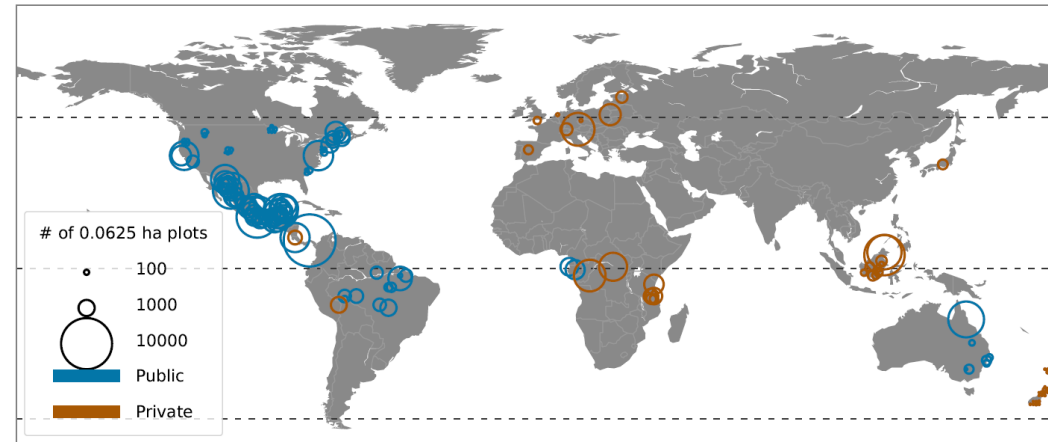
Product / Data File	ATBD Title	Authors
GEDI01_A-TX GEDI01_A-RX GEDI02_A	Transmit and Receive Waveform Interpretation And Generation of L1A and L2A Products	Michelle Hofton (UMD) and J. Bryan Blair (NASA/GSFC)
GEDI01_B	Geolocated Waveforms	Scott Luthcke (NASA/GSFC), Tim Rebold (EST/GSFC), Taylor Thomas (EST/GSFC) and Teresa Pennington (SGT/GSFC)
GEDI02_B	Footprint Cover and Profile Metrics	Hao Tang (UMD) and John Armston (UMD)
GEDI03_A	Gridded Land Surface Metrics	Scott Luthcke (NASA/GSFC), Terence Sabaka (NASA/GSFC) and Sandra Preaux (SGT/GSFC)
GEDI04_A	Footprint Above Ground Biomass	James Kellner (Brown University), Laura Duncanson (UMD) and John Armston (UMD)
GEDI04_B	Gridded Above Ground Biomass	Sean Healey (USFS) and Paul Patterson (USFS)

GEDI Biomass: From Footprints to Grid Cells

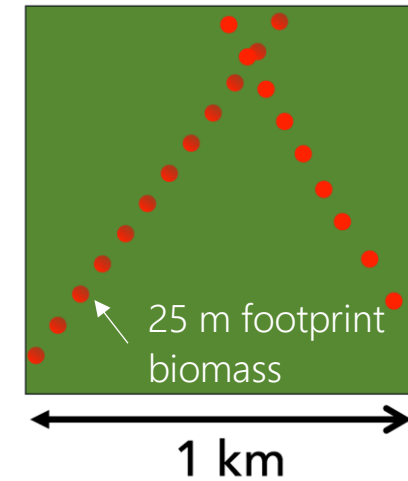
1. Create simulated waveforms



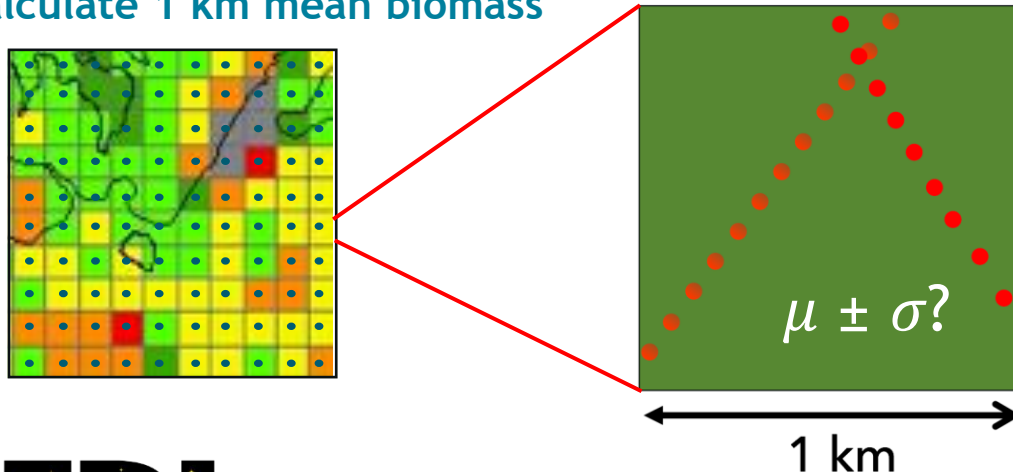
2. Develop relationships among GEDI metrics and biomass



3. Apply calibration equations to GEDI data on-orbit for footprints



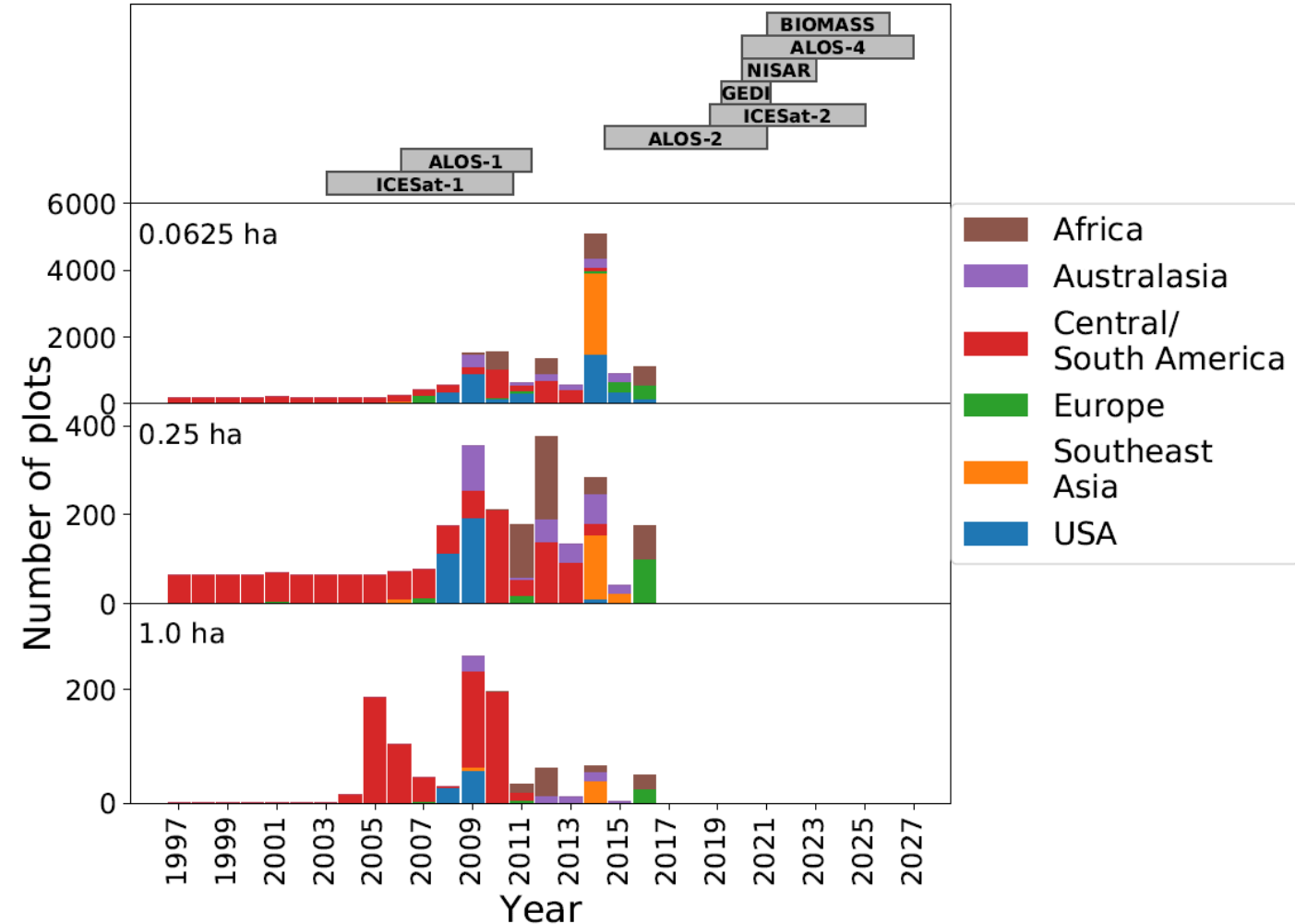
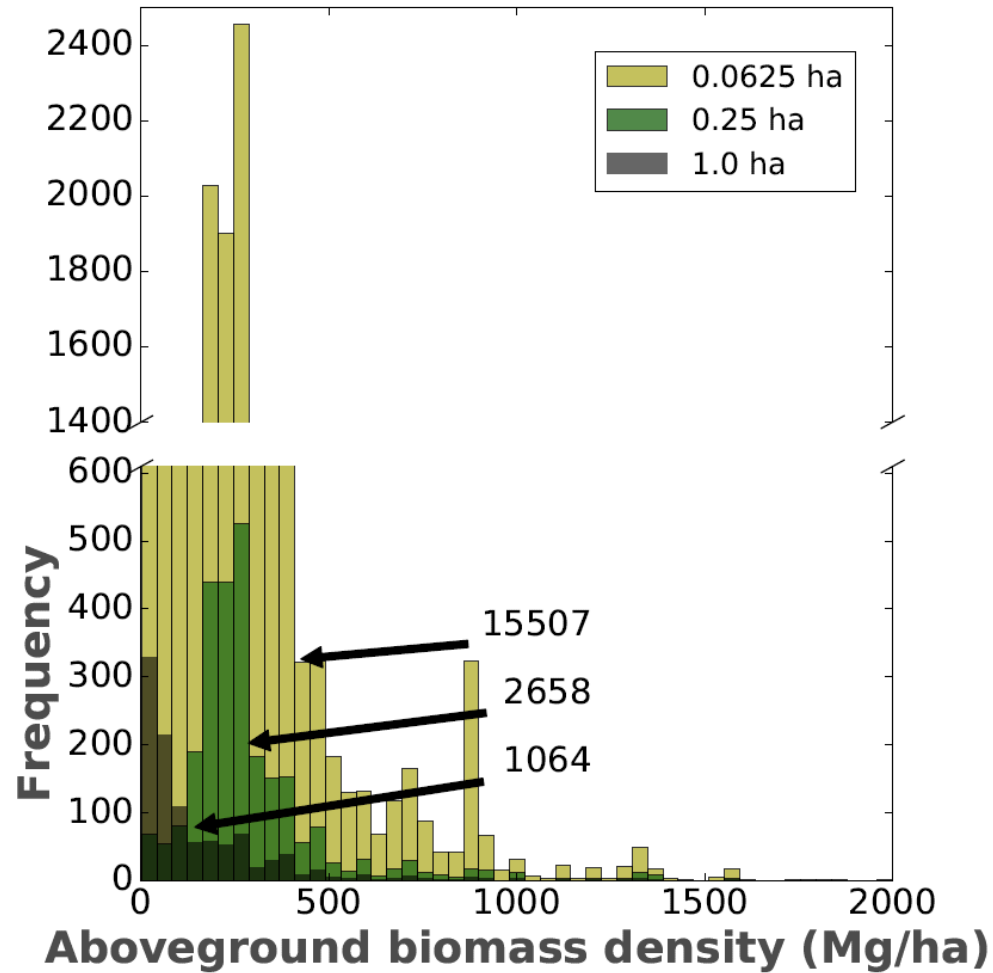
4. Calculate 1 km mean biomass



Correct estimation of $\mu \pm \sigma$ for a 1 km cell is not straightforward

Two-stage (model + sampling error) hybrid estimation theory based on cluster sampling correctly propagates errors

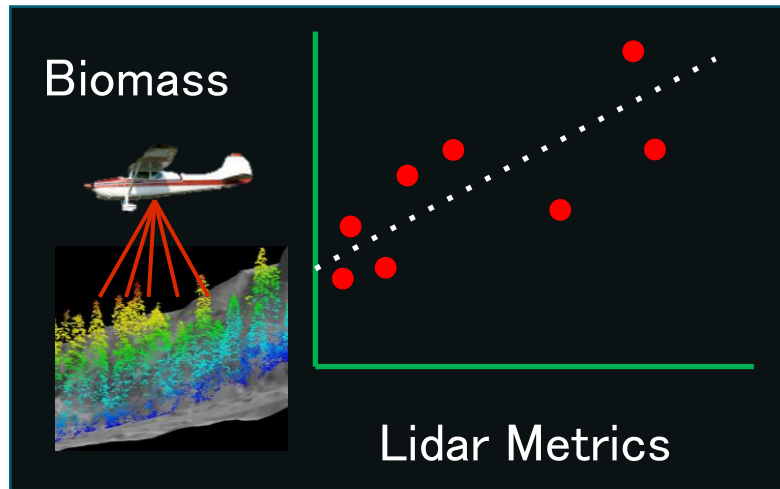
GEDI Forest Structure and Biomass Database



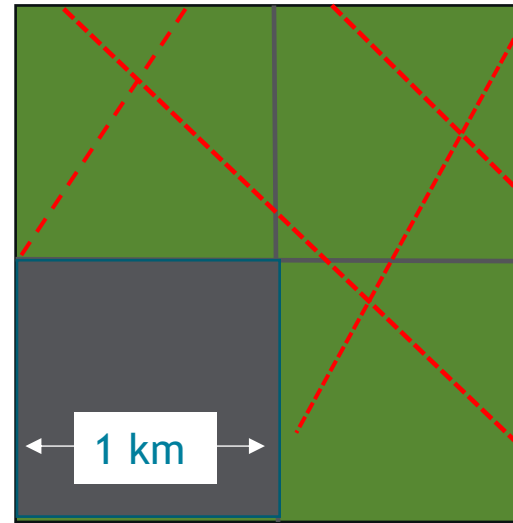
GEDI/SAR Fusion in Statistical Framework

- Unlike heights, biomass is not *measured*, but *modeled* -> requires proper error propagation
- Use hierarchical model-based inference to estimate biomass using ancillary imagery
 - Two regression equation errors plus sampling errors

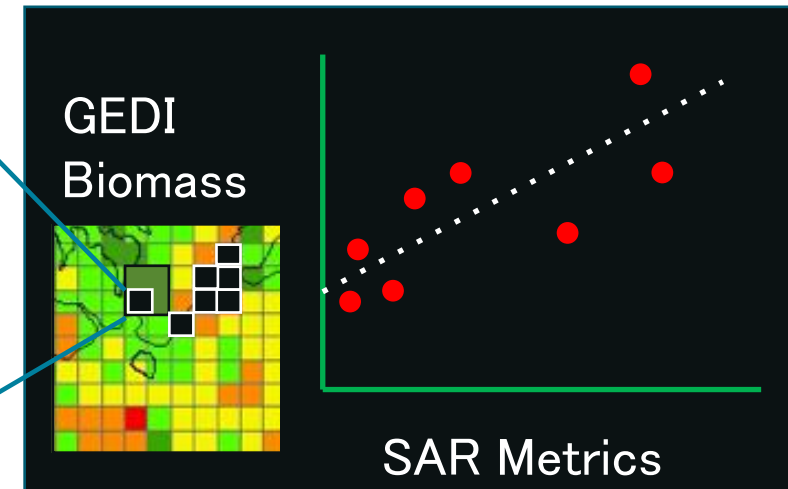
STAGE 1: Develop calibration between GEDI-like lidar and field plots



STAGE 2: Apply calibration equation to GEDI data on-orbit



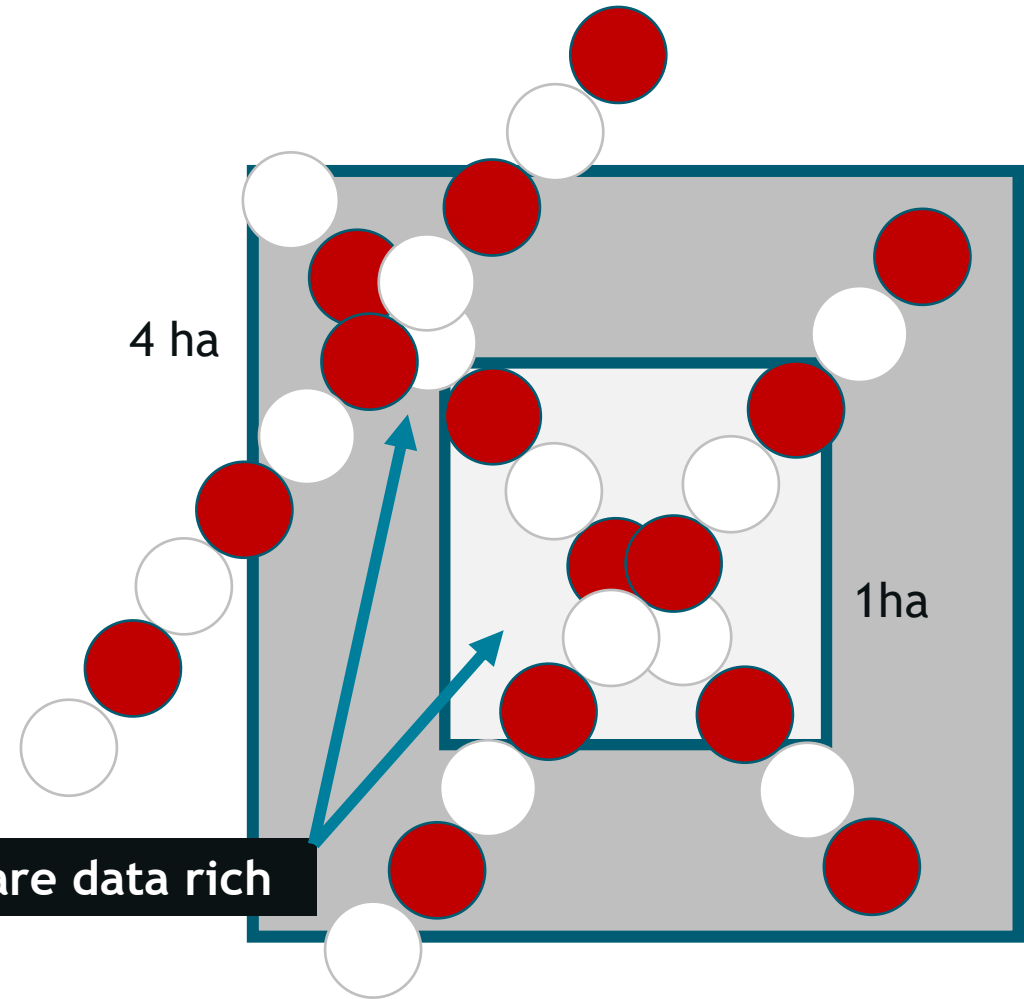
STAGE 3: Develop relationship between GEDI biomass and SAR and map across landscape $[\mu, \sigma]$



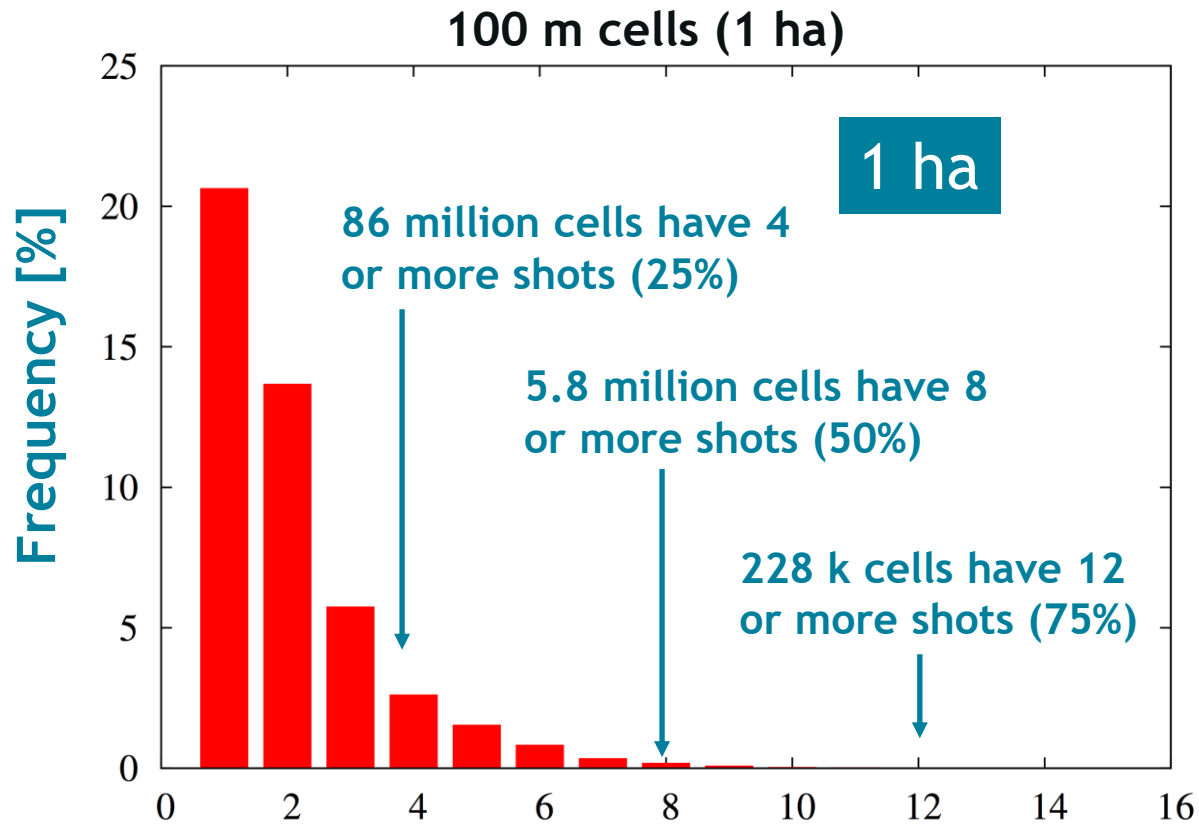
Enable predictions
 $[\mu, \sigma]$ for cells with or without GEDI data

Biomass Calibration for Other SAR Missions

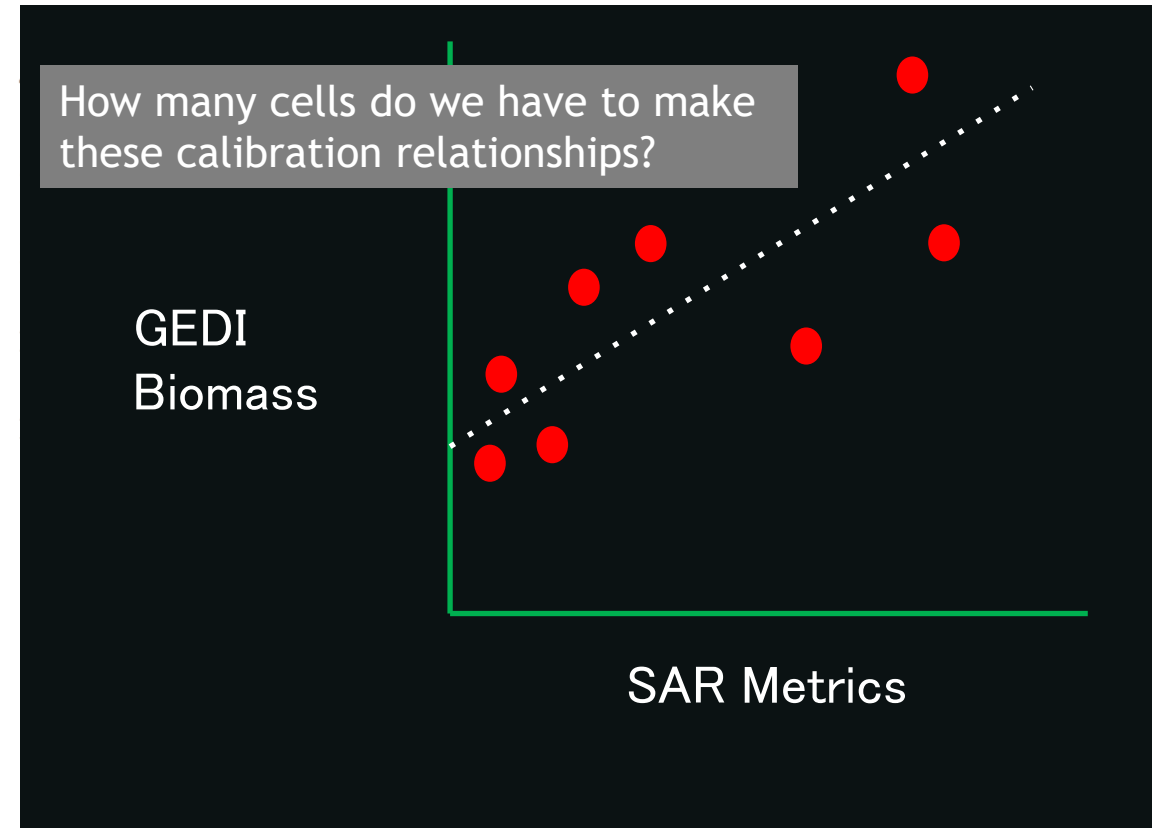
- GEDI biomass estimates are at the footprint level
- Other SAR missions plan to produce coarser biomass estimates, e.g.
 - 1 ha (NISAR)
 - 4 ha (BIOMASS)
- GEDI provides sufficient sampling to calibrate at these resolutions near orbital crossovers and adjacent tracks



Biomass Calibration for Other SAR Missions



Number of Cloud-free GEDI Footprints [cumulative =>]



Summary

- GEDI mission on track and instrument scheduled for launch in May 2019
- We are entering an era of accelerated observations needed to model the Earth's carbon cycle
- GEDI is paying careful attention to developing and implementing sound statistical frameworks for error propagation and fusion with SAR
- A coordinated cal/val strategy is required for the upcoming confluence of SAR and Lidar missions
 - CEOS Land Product Validation Subgroup Biomass Focus Area
https://lpvs.gsfc.nasa.gov/Biomass/AGB_home.html

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