



# GEDI AND TANDEM-X FUSION FOR 3D FOREST STRUCTURE PARAMETER RETRIEVAL

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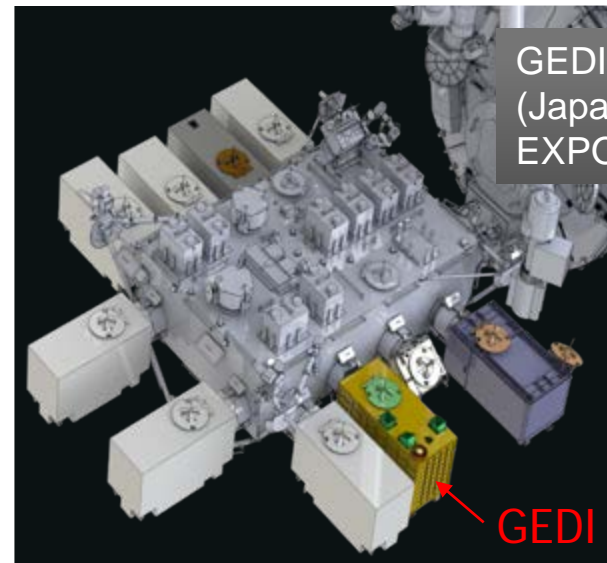
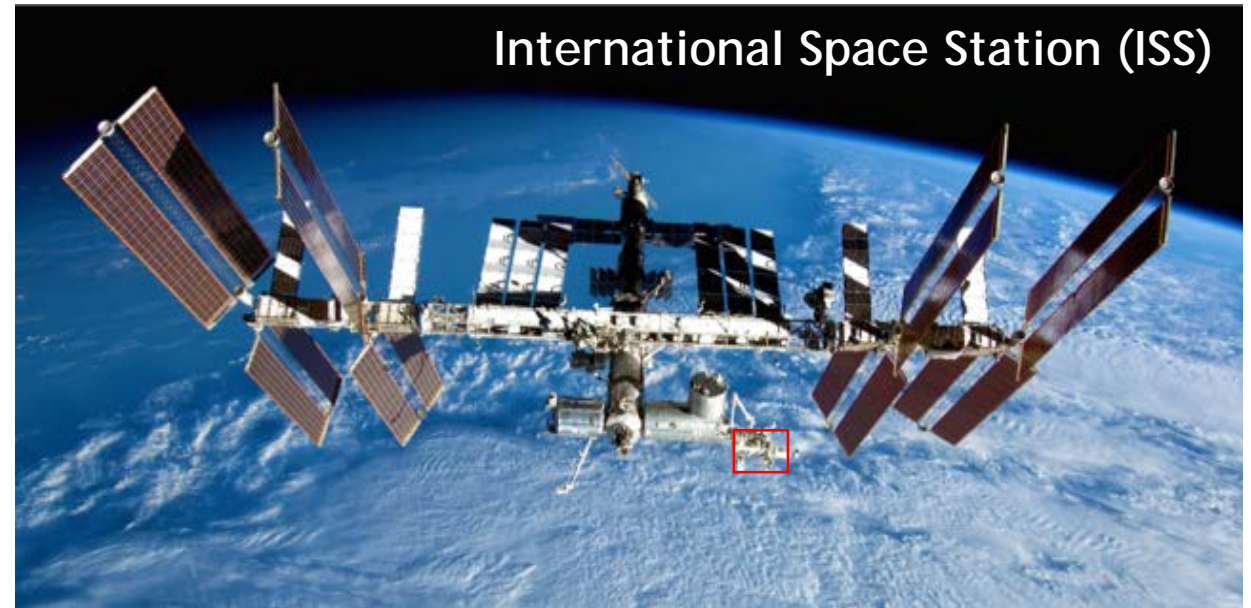
<sup>2</sup>University of Maryland, USA



# Earth Ventures Instrument (EVI)

## GEDI: Global Ecosystem Dynamics Investigation

- Selected in late 2014 for \$94 M (Class C mission)
- Multi-beam waveform lidar instrument
  - NASA Goddard Spaceflight Center (GSFC)
- Deployed on International Space Station
  - Launch on SpaceX-17: Nov 2018
  - Observations between +/- 50°N/S
- Nominal 2 year mission length

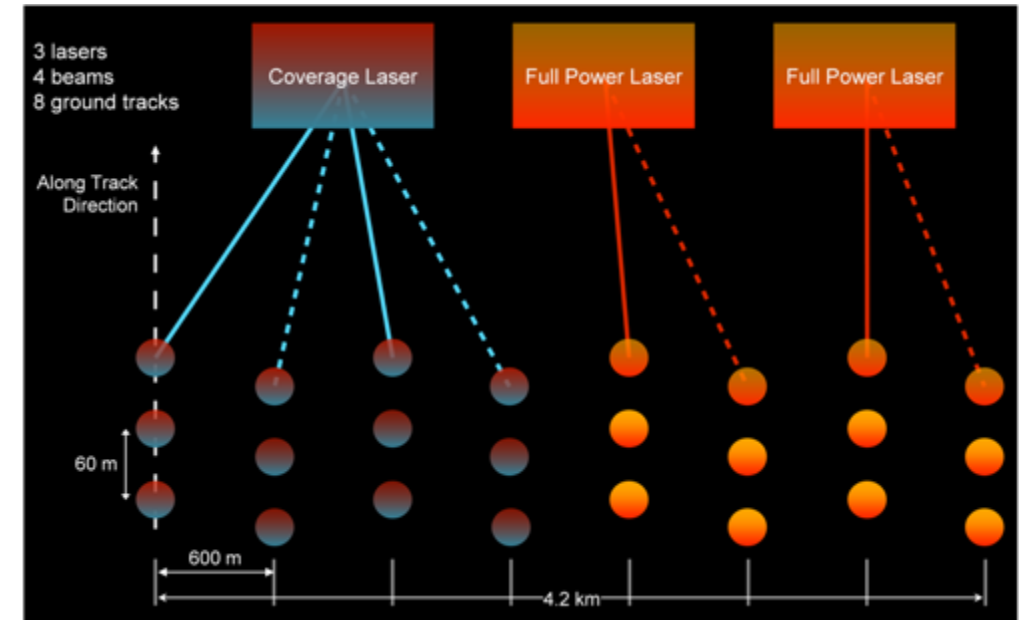


GEDI is deployed on the JEM-EF (Japanese EXPERIMENT MODULE – EXPOSED FACILITY).

# Mission Overview

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

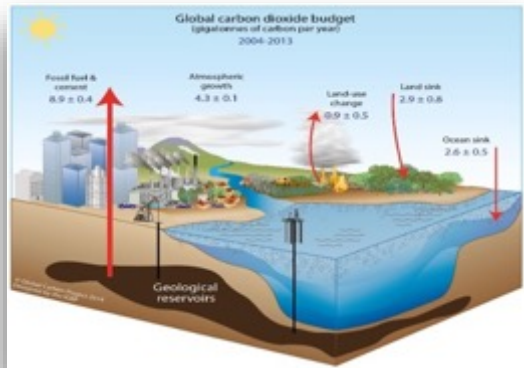
- GEDI produces high resolution laser ranging observations of the 3D structure of the Earth.
- GEDI makes precise measurements of forest canopy height, canopy vertical structure, and surface elevation.
- GEDI improves our ability to characterize important carbon and water cycling processes, biodiversity and habitat.



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

# Science Questions and Objectives

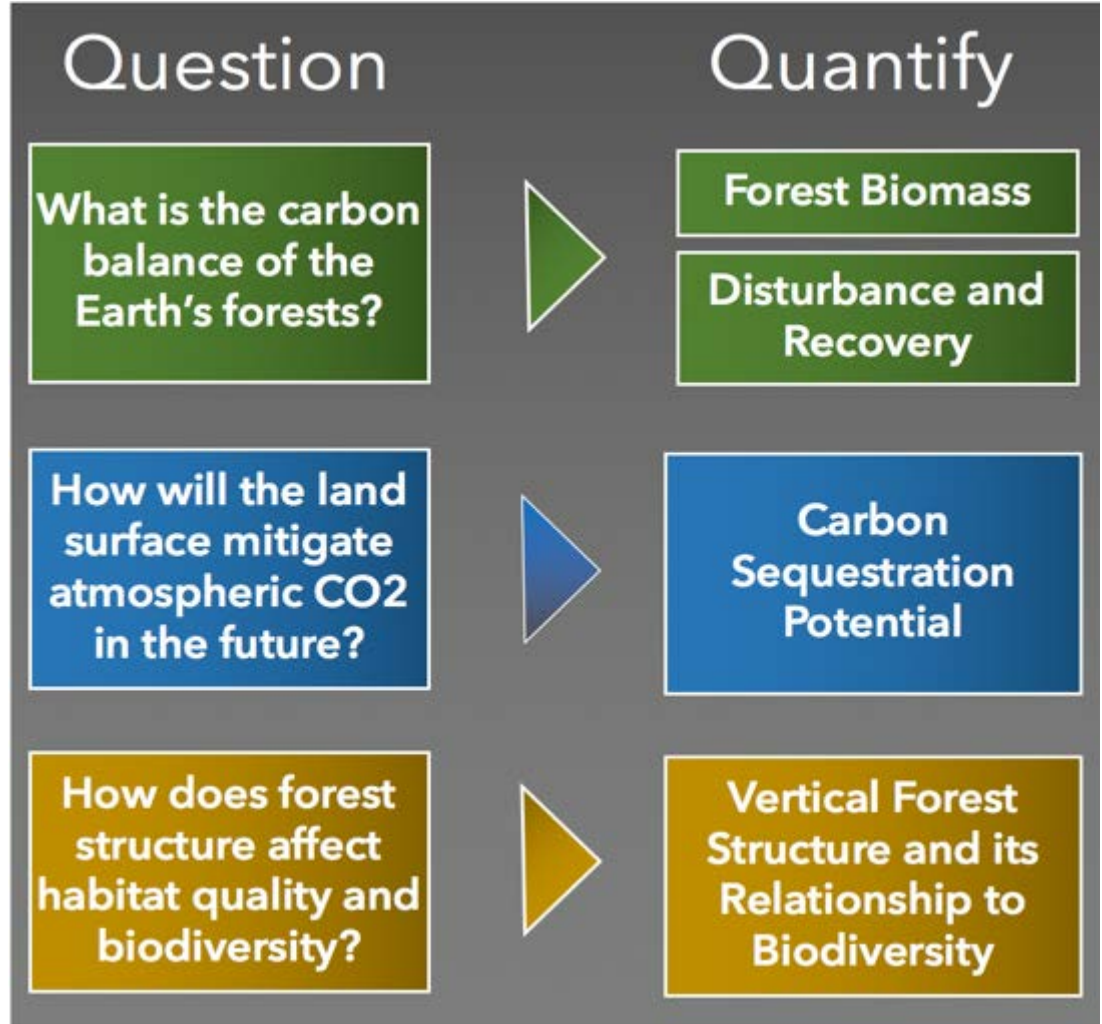
**GEDI Goal: Advance our ability to characterize the effects of changing climate and land use on ecosystem structure and dynamics**



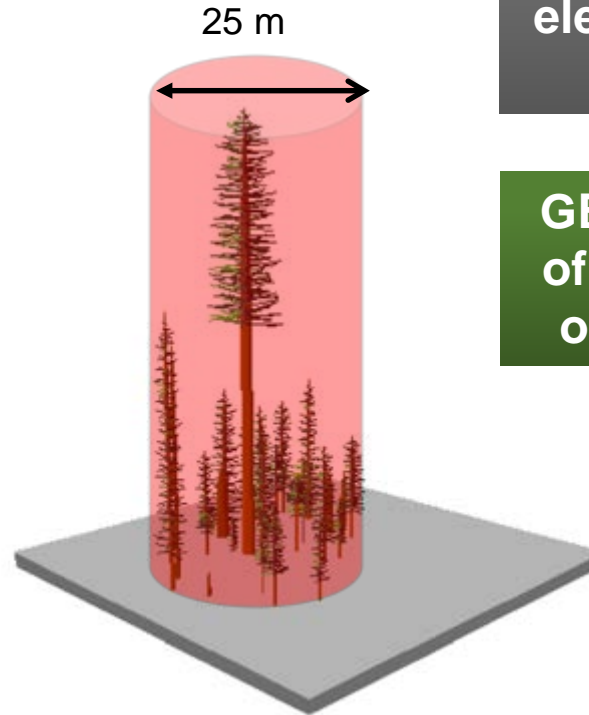
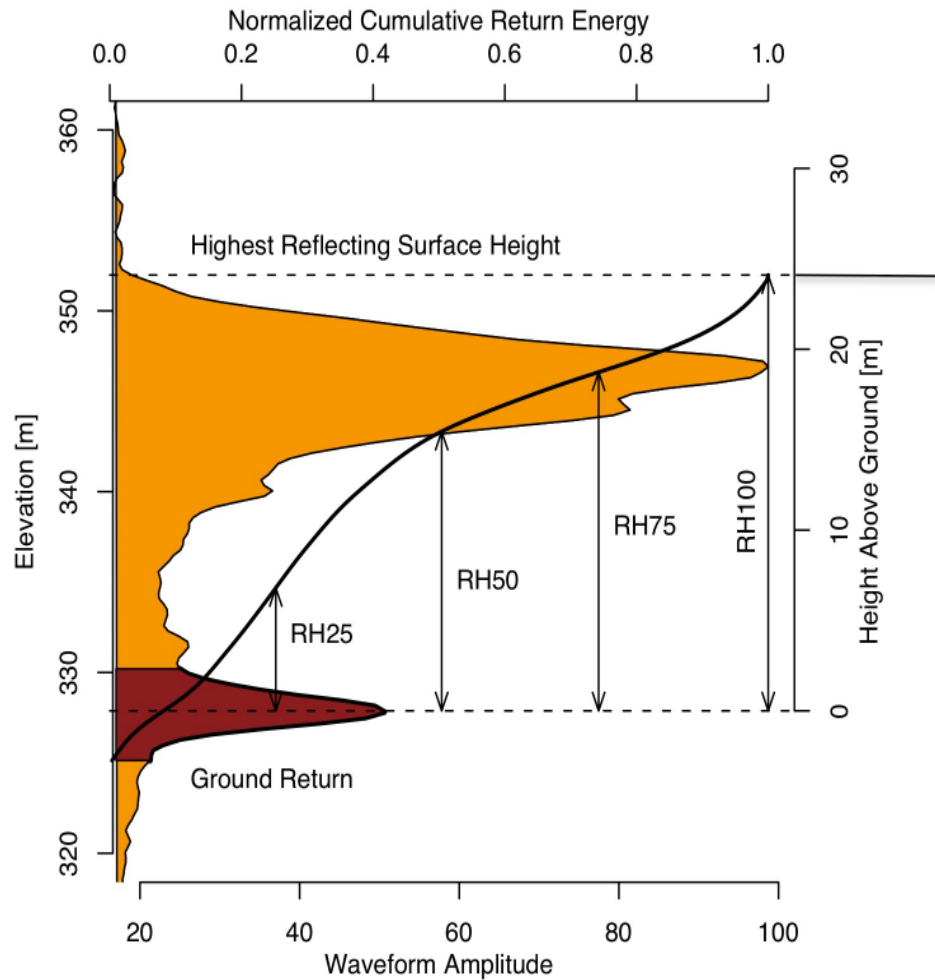
**Carbon Cycle**



**Biodiversity**



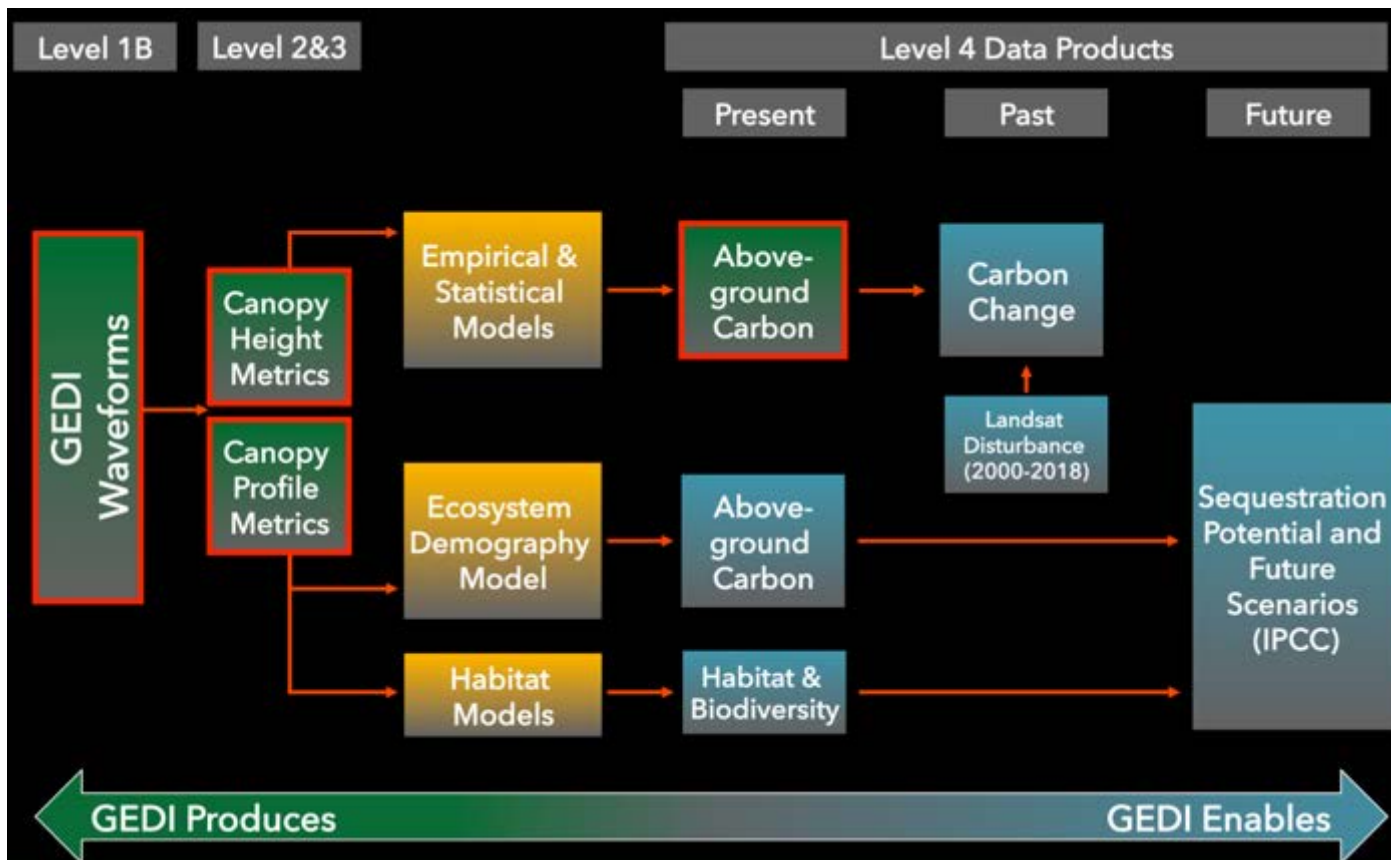
# GEDI Lidar Measurements



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

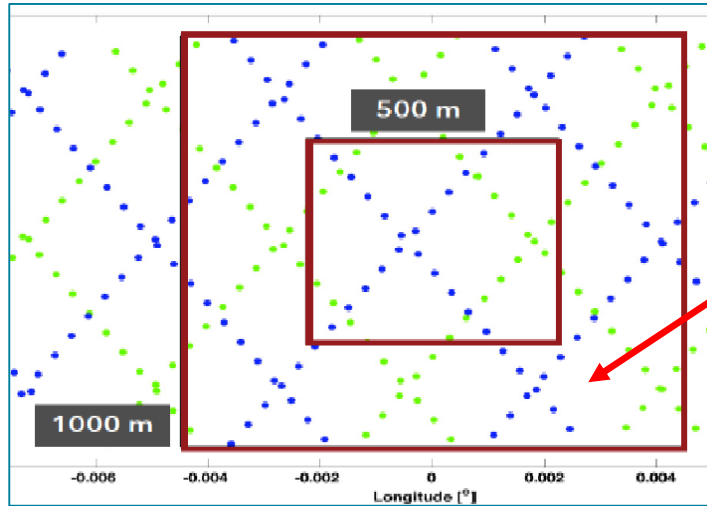
**GEDI makes 12 billion observations of forest and land surface structure over its nominal two-year mission**

# Science Approach and Data Products



ATBD #	Data products	Product leads	Resolution
L1A-2A	1A: Raw waveforms, 2A: Ground elevation, canopy top height, relative height (RH) metrics	Michelle Hofton Bryan Blair	25 m (~82 ft) diameter
L1B	Geolocated waveforms	Scott Luthcke Tim Rebold Taylor Thomas Teresa Pennington	25 m (~82 ft) diameter
L2B	Canopy Cover Fraction (CCF), CCF profile, Leaf Area Index (LAI), LAI profile	Hao Tang John Armston	25 m (~82 ft) diameter
L3	Gridded Level 2 metrics	Scott Luthcke Terence Sabaka Sandra Preaux	25 m (~82 ft) diameter
L4A	Footprint level above ground biomass	Jim Kellner Laura Duncanson John Armston	25 m (~82 ft) diameter
L4B	Gridded Above Ground Biomass Density (AGBD)	Sean Healey Paul Patterson	1 km (~0.6 mi) grid
Demonstrative products	Prognostic ecosystem model outputs	George Hurtt	Grid size: Variable
Demonstrative products	Enhanced height/biomass using fusion with TanDEM-X	Lola Fatoyinbo Seung-Kuk Lee	Grid size: Variable
Demonstrative products	Enhanced height/biomass and biomass change using fusion with Landsat	Matt Hansen Chenquan Huang	Grid size: Variable
Demonstrative products	Biodiversity/habitat model outputs	Scott Goetz Patrick Jantz Pat Burns	Grid size: Variable

# GEDI & TanDEM-X Fusion

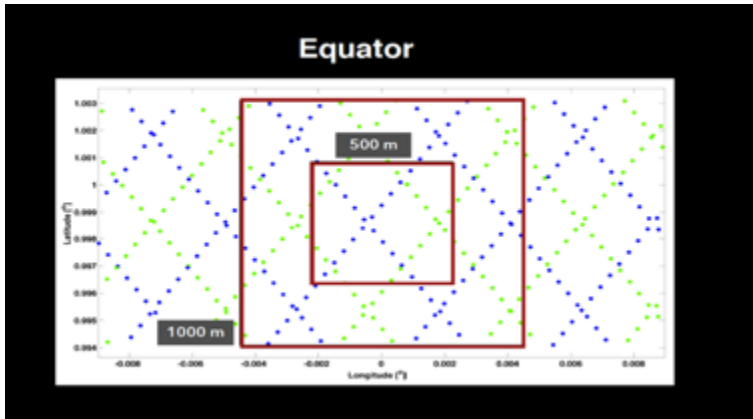


Can we fill in these gaps using fusion of TDX and GEDI?

- GEDI is sampling instrument
  - Gaps between ground tracks and adjacent swaths
- GEDI data combined with bistatic Interferometric SAR data from the TanDEM-X mission
  - Provide continuous mapping of forest structure and biomass while maintaining the fine resolution measurement of each footprint.
- We focus on using the TDX product available globally (not dual polarization product) in RVoG



# GEDI Data + Single pol. TanDEM-X



## Single-polarization (HH) Pol-InSAR Inversion (RVoG model)

Polarization	Independent Coherence	Assumption	Unknowns	Condition
Single-Pol.	$[\tilde{\gamma}(\vec{w}_1)]$	$m_1 = 0$	$h_v, \sigma, \phi_0$	Underdetermined problem

### Method1: Extinction $\sigma$ <Qi et al. Remote Sensing of Environment 2016>

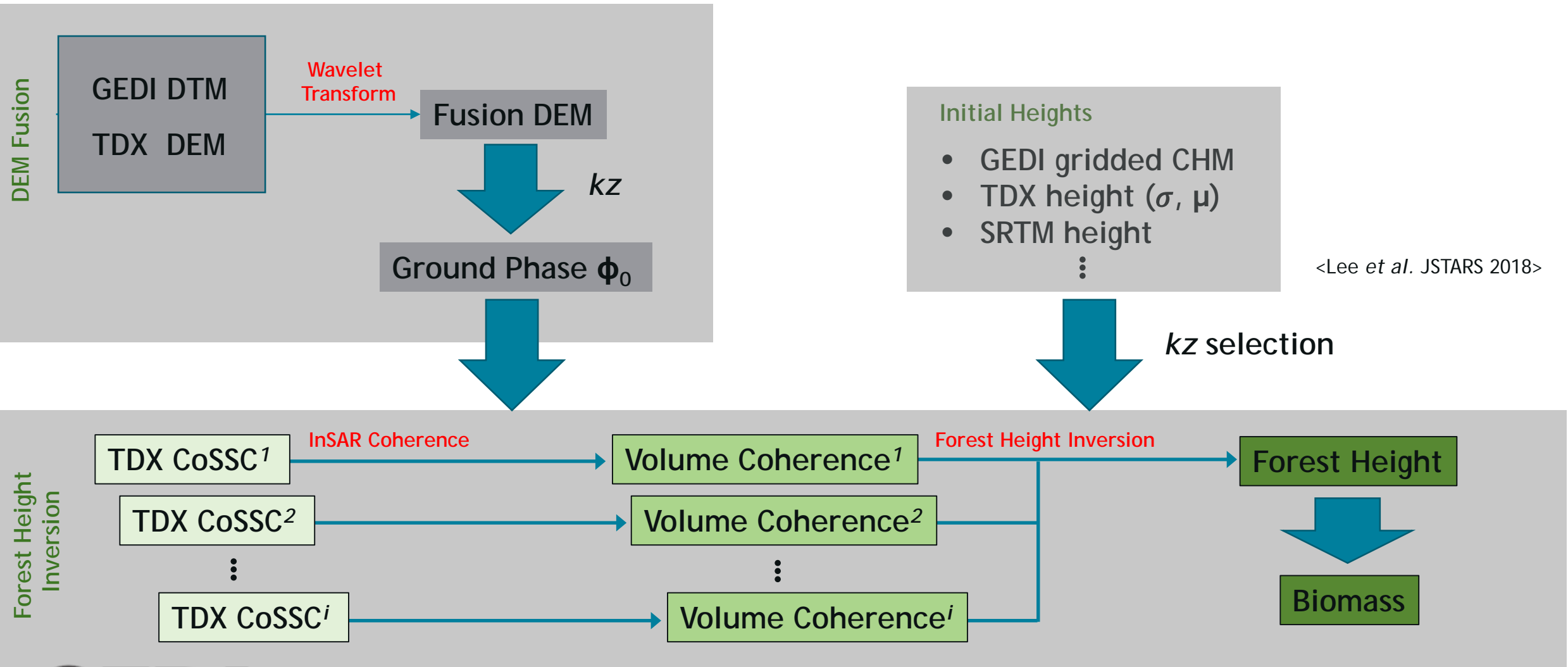
- Using GEDI RH metrics, volume coherence is simulated on each GEDI footprint.  
→ Optimization of the extinction
- Interpolation of  $\sigma$  in a grid

### Method2: Ground Phase $\phi_0$

- GEDI ground-level DEM on each GEDI footprint → Interpolation
- Merging → GEDI DTM and TanDEM-X DEM



# Multi-Baseline TDX Inversion; Fusion DTM



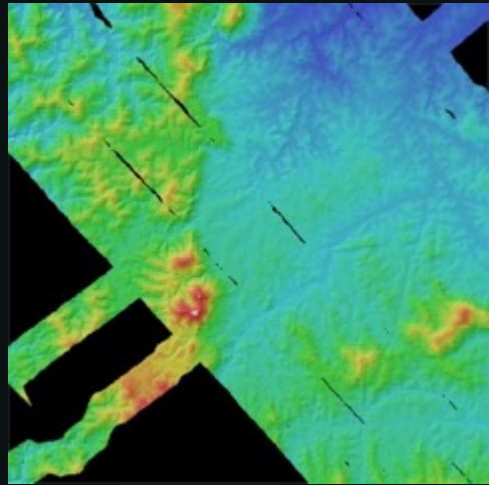
# GEDI and TDX DEMs Merging; Wavelet

Lope, Gabon

Lidar DTM

Interferometric SAR DEM

LVIS DTM (Airborne)

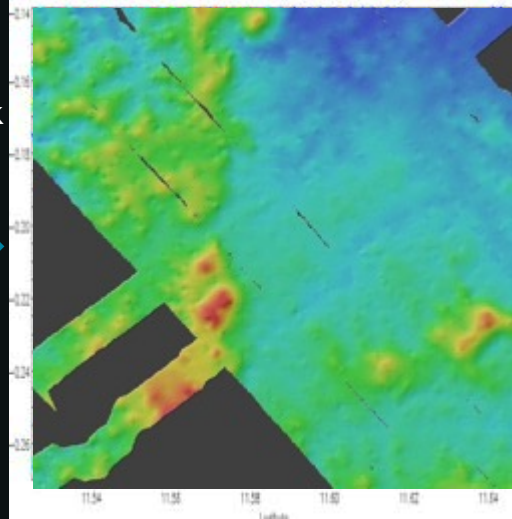


12.5 km

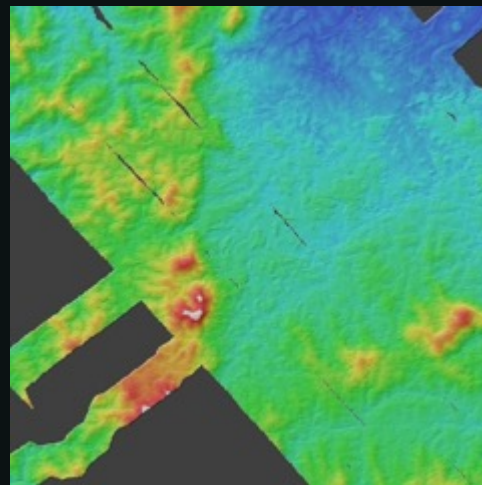
GEDI ground-track simulation



GEDI DTM (Spaceborne)



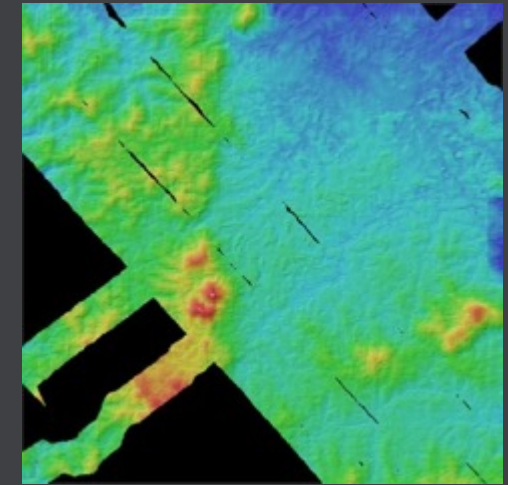
TanDEM-X DEM (Spaceborne)



Wavelet Transform



GEDI + TDX DTM (Fusion)



- ✓ Offsets are mitigated.
- ✓ Higher resolution

650 m



0 m

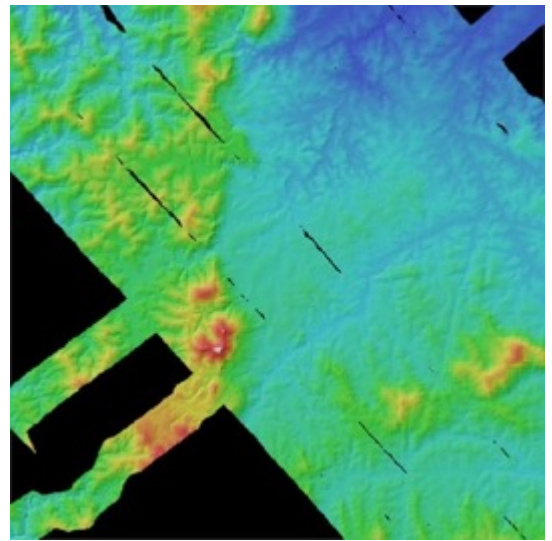
$\Delta H$	Fusion DTM	GEDI DTM	TDX DEM
Mean	0.4 m	0.2 m	23.1 m
Std.	8.8 m	11.7 m	12.4 m

# Forest Height Inversion Results

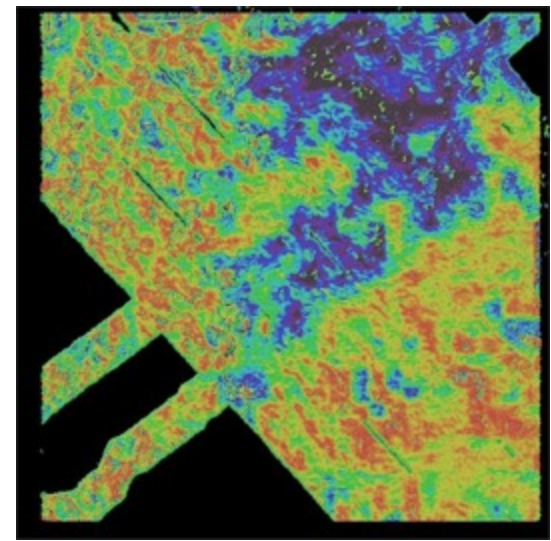
Lope, Gabon

LVIS

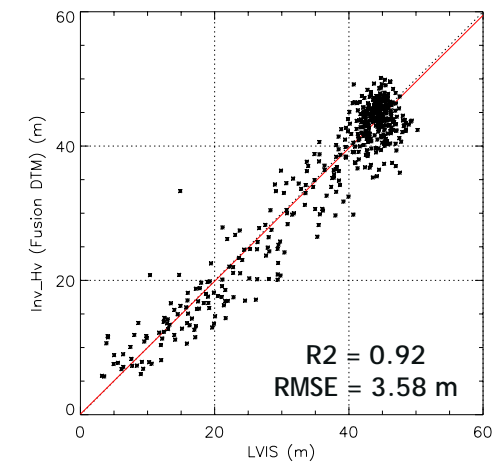
DTM



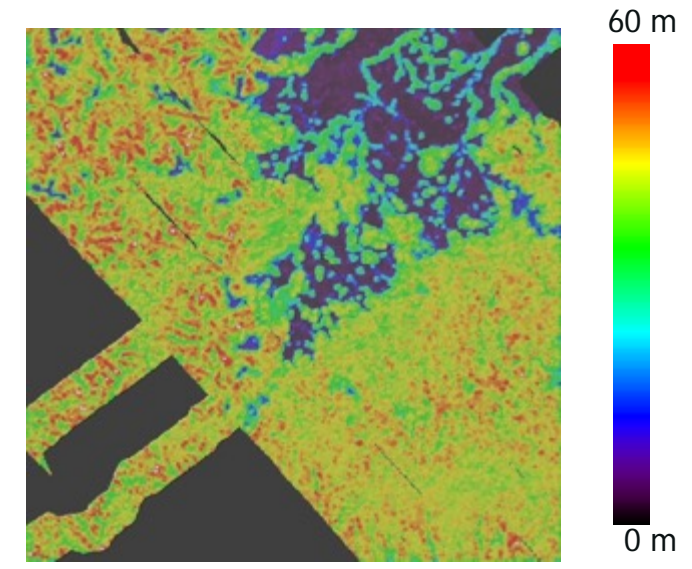
TDX Forest Height



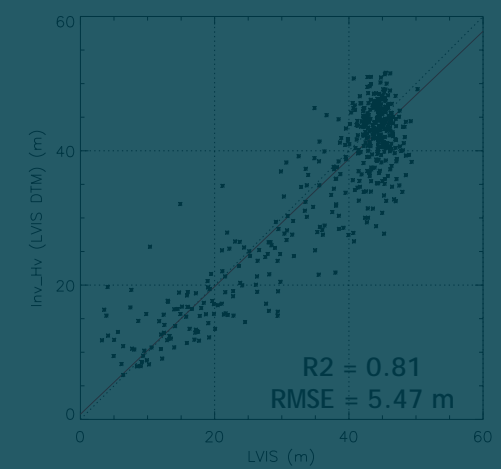
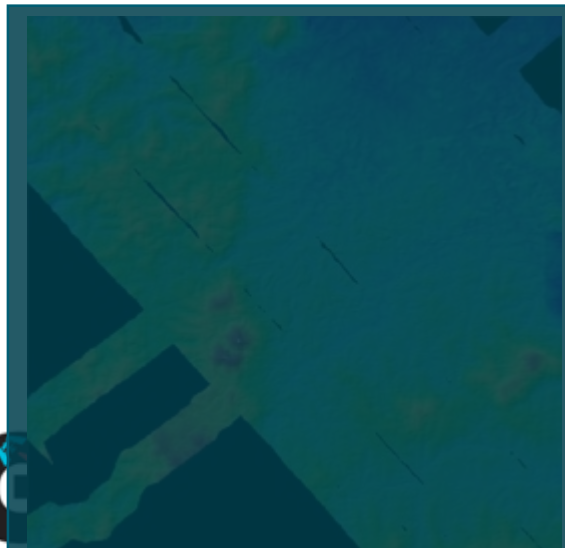
Validation



LVIS CHM



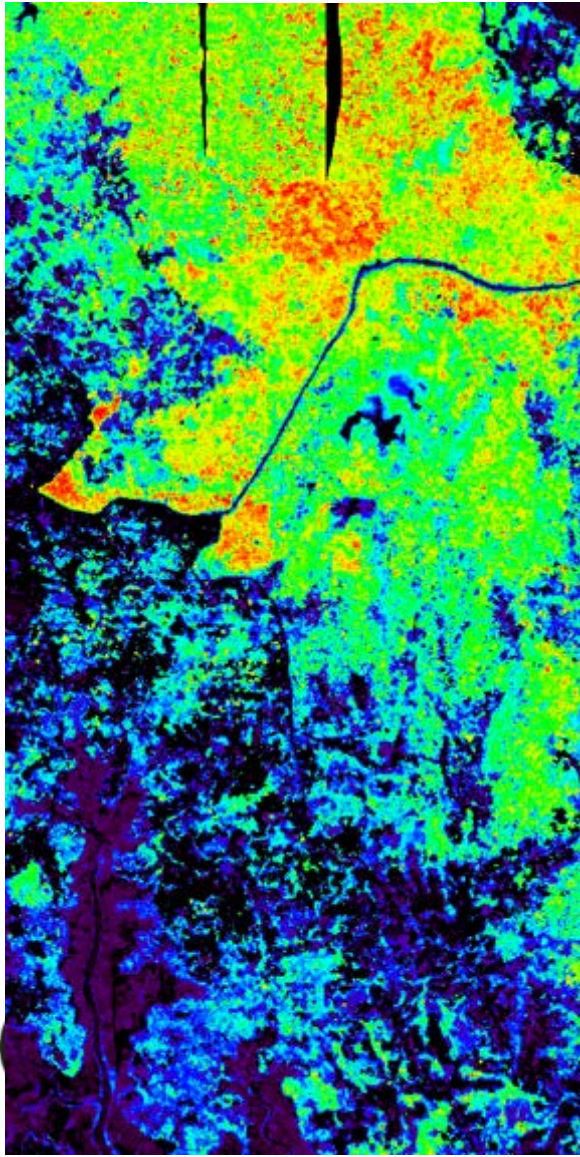
GEDI+TDX Fusion



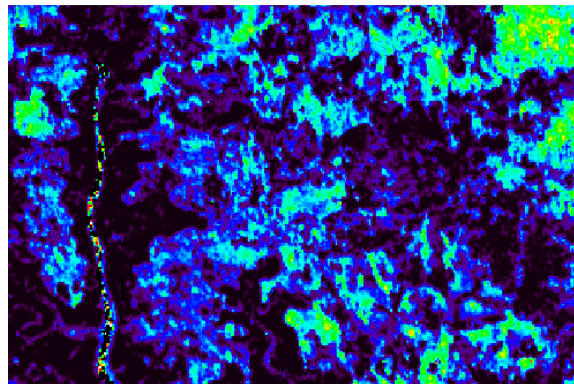
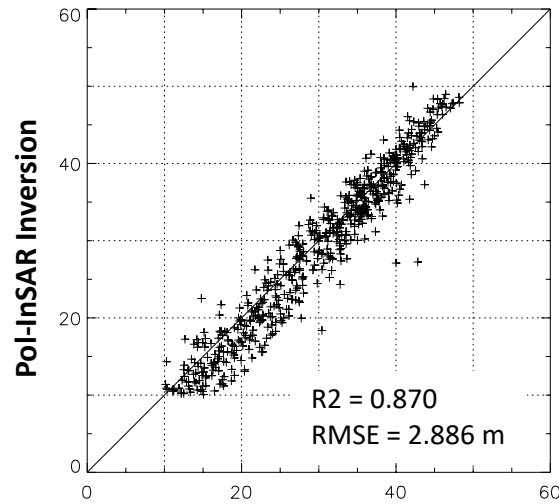
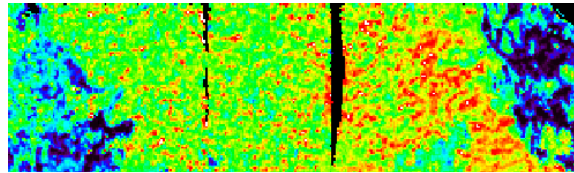
# Forest Height Inversion Results

Mondah, Gabon

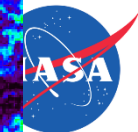
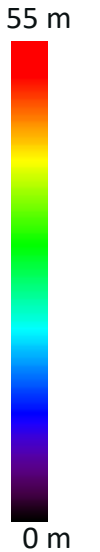
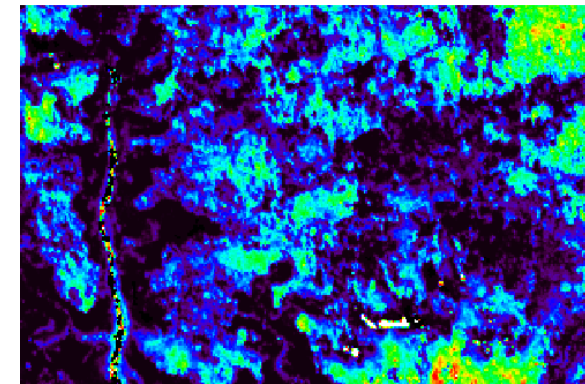
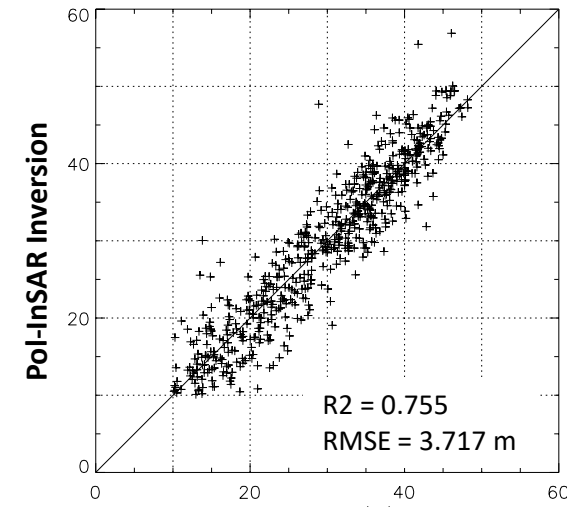
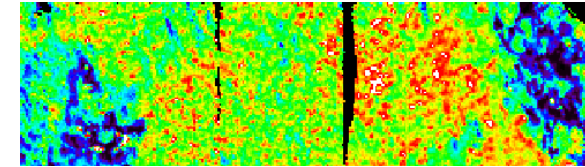
LVIS RH95



Inversion using LVIS DTM

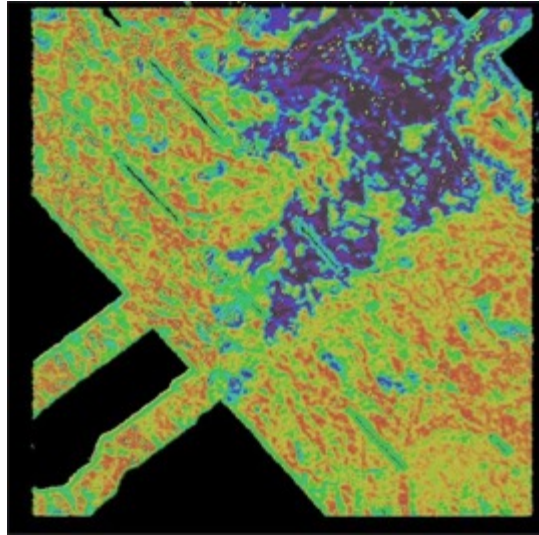


Inversion using Fusion DTM

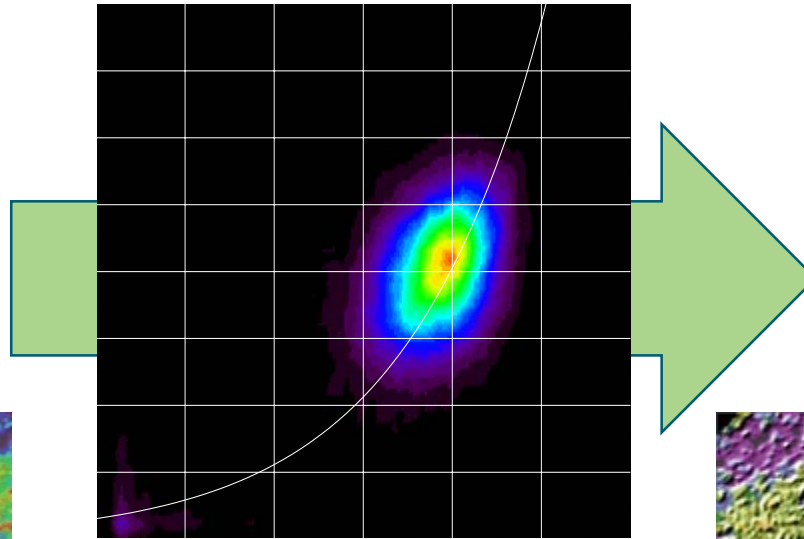


# Aboveground Biomass

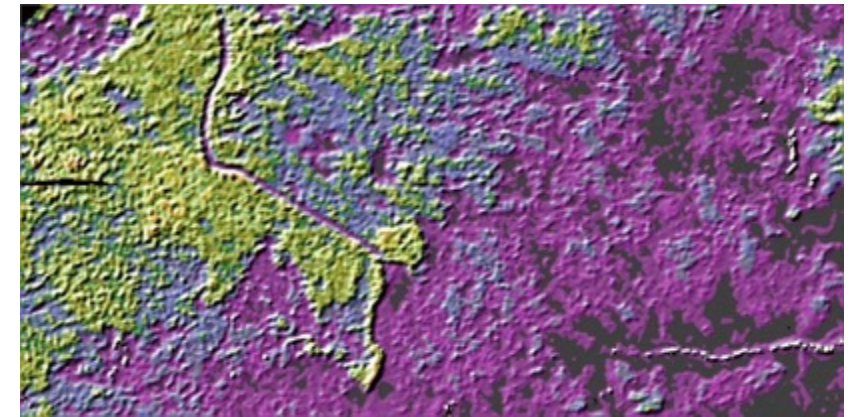
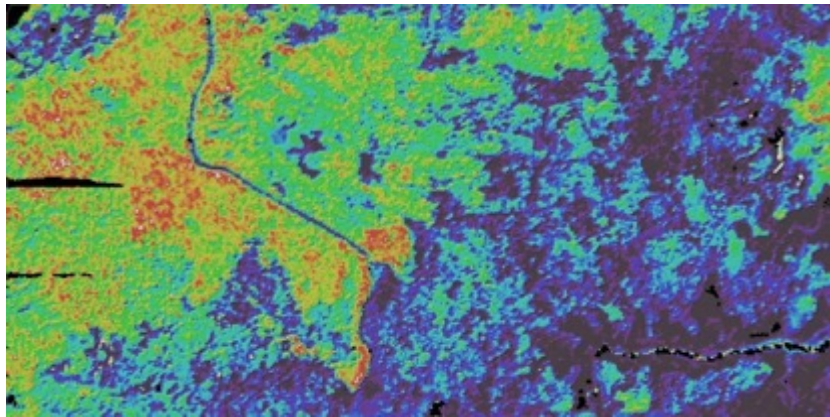
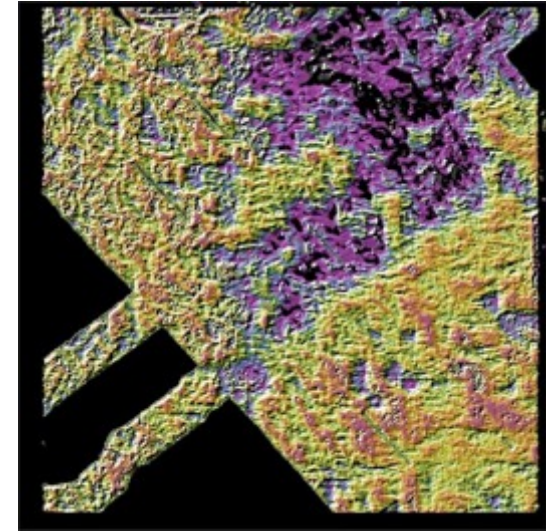
Forest Height Map



Height-biomass allometric Eq.  
from GEDI waveform lidar data



Aboveground Carbon Map



# GEDI Webpage: <https://gedi.umd.edu>

**GEDI**  
ECOSYSTEM LIDAR

MISSION INSTRUMENT SCIENCE APPLICATIONS DATA NEWS/EDUCATION

*Changes in land use and climate are fundamentally altering Earth's tropical and temperate forests ...*

**Global Ecosystem Dynamics Investigation (GEDI)**  
High resolution laser ranging of Earth's forests and topography from the International Space Station (ISS)

**THE MISSION SCIENCE**

GEDI will provide answers to how deforestation has contributed to atmospheric CO<sub>2</sub> concentrations, how much carbon forests will absorb in the future, and how habitat degradation will affect global biodiversity. >

Thank you!