



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

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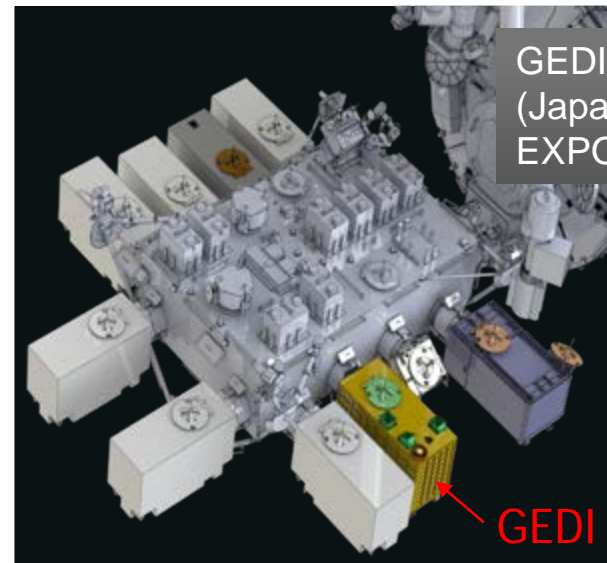
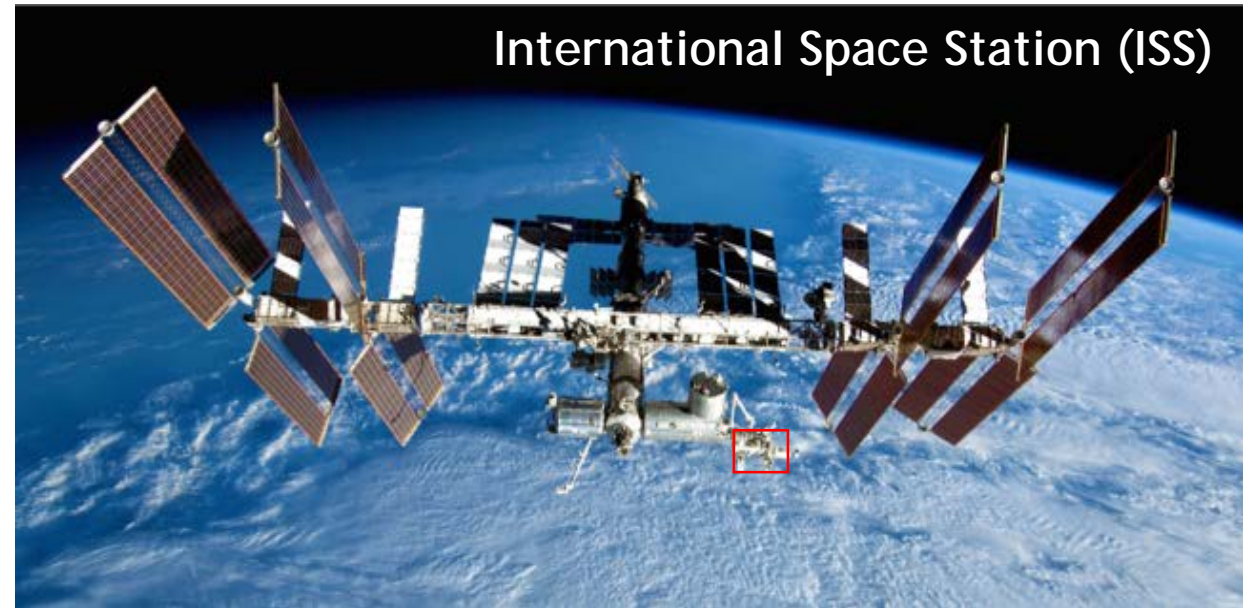
²University of Maryland, USA



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

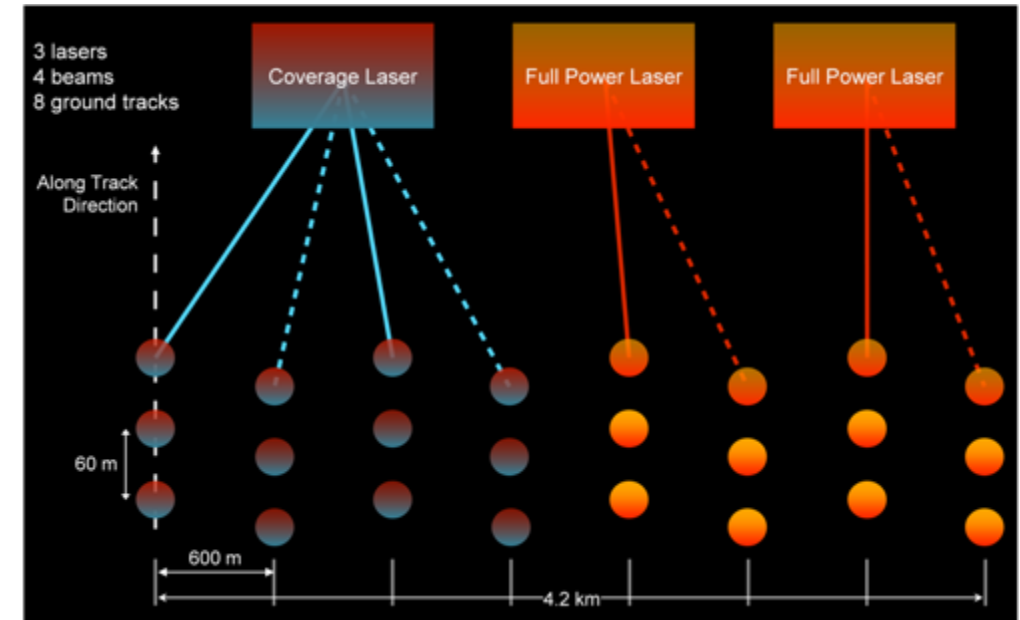


GEDI is deployed on the JEM-EF (Japanese EXPERIMENT MODULE – EXPOSED FACILITY).

Mission Overview

High Resolution Laser Ranging of the Earth's Forests and

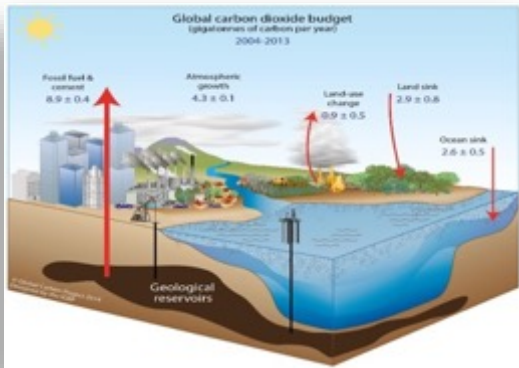
- GEDI produces high resolution laser ranging observations of the 3D structure of the Earth.
- GEDI makes precise measurements of forest canopy height, canopy vertical structure, and surface elevation.
- GEDI improves our ability to characterize important carbon and water cycling processes, biodiversity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

Question

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

Quantify

Forest Biomass

Disturbance and Recovery

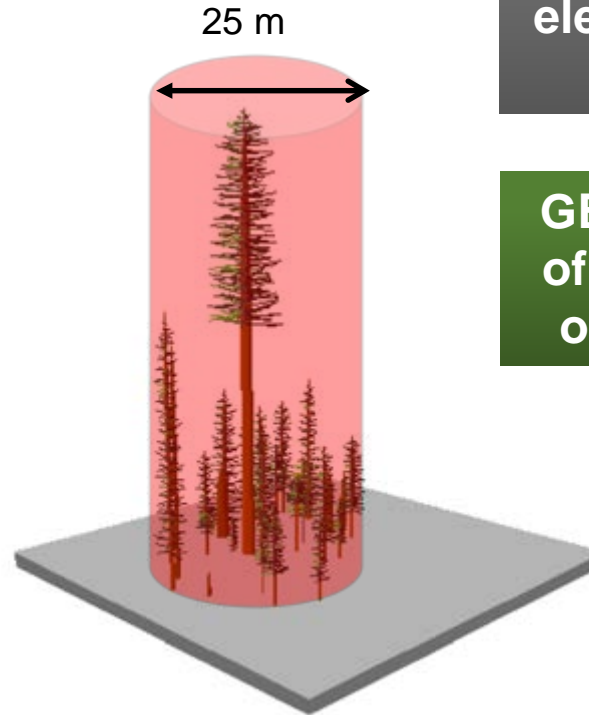
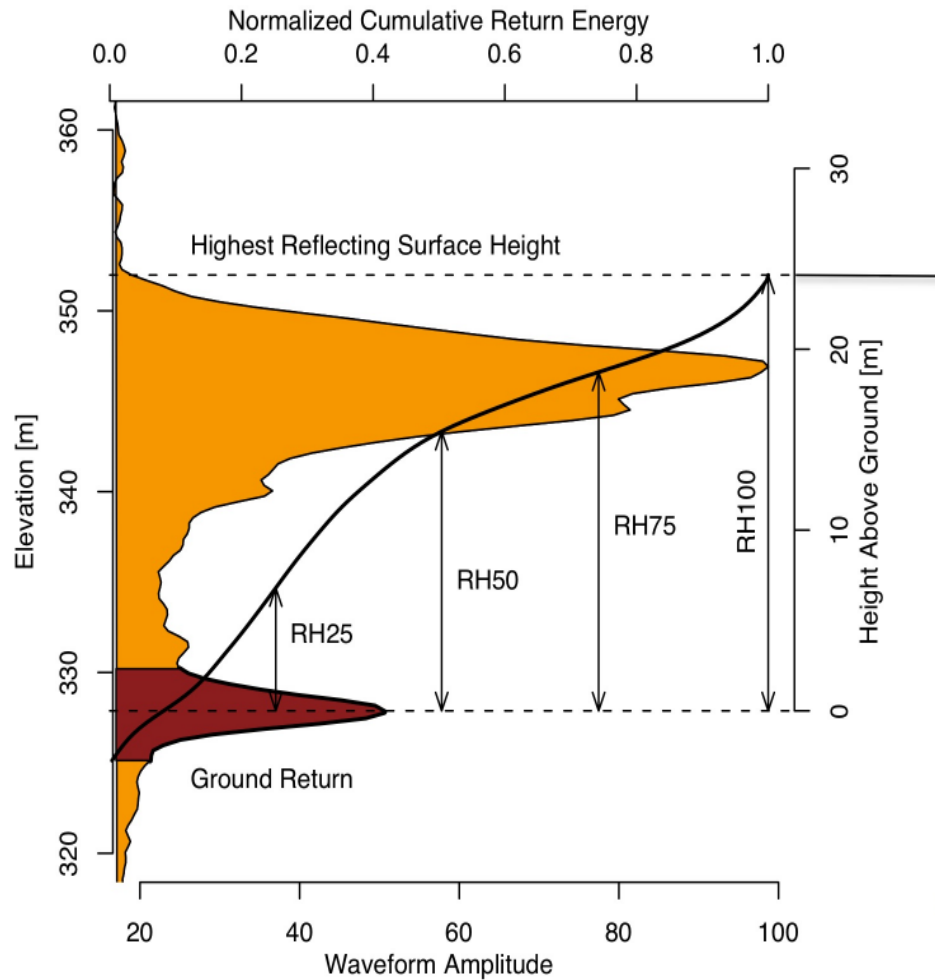
How will the land surface mitigate atmospheric CO₂ in the future?

Carbon Sequestration Potential

How does forest structure affect habitat quality and biodiversity?

Vertical Forest Structure and its Relationship to Biodiversity

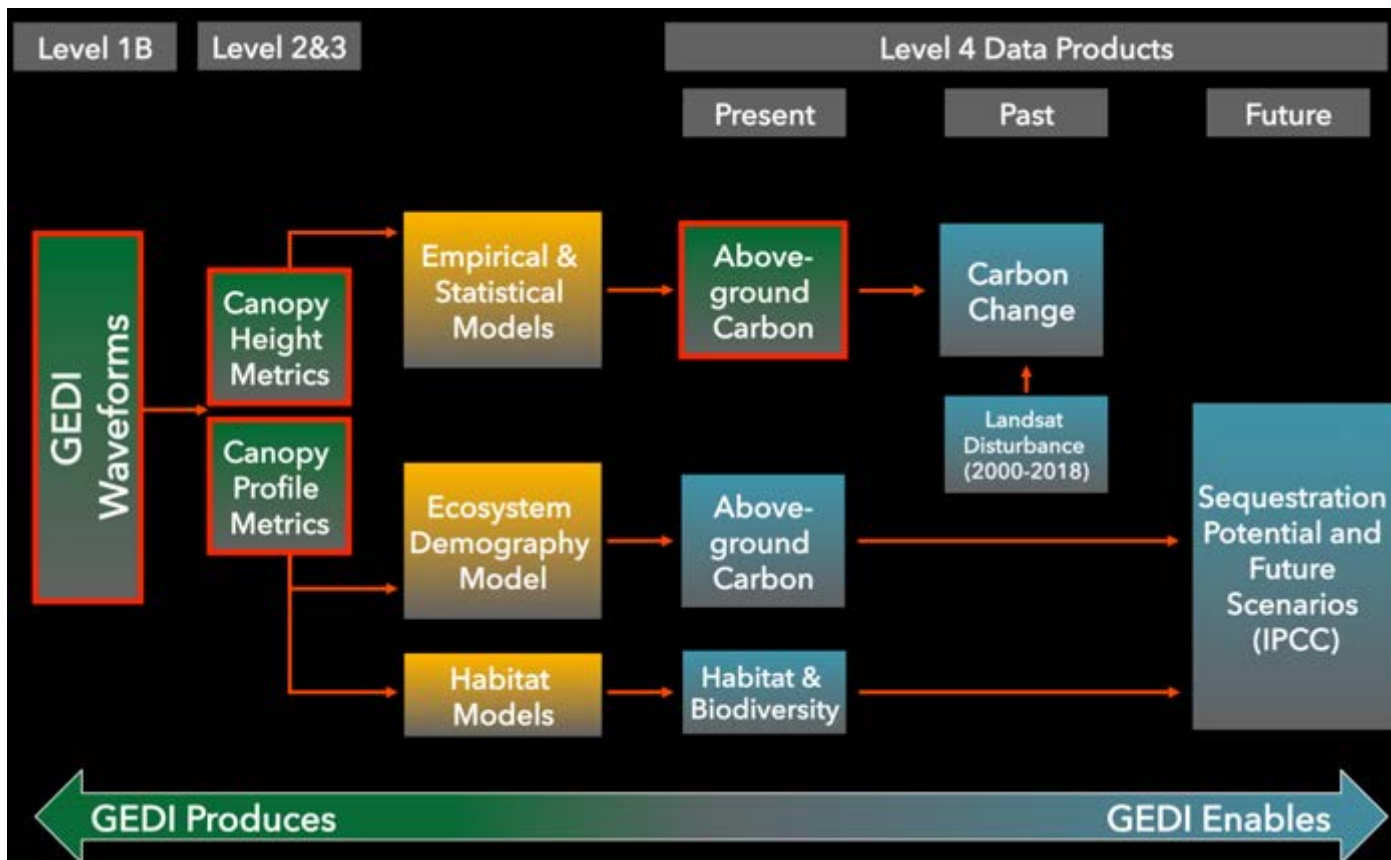
GEDI Lidar Measurements



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

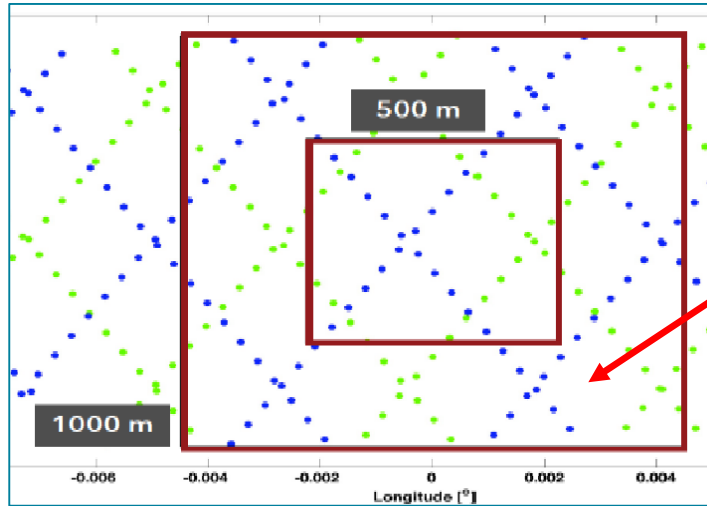
GEDI makes 12 billion observations of forest and land surface structure over its nominal two-year mission

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

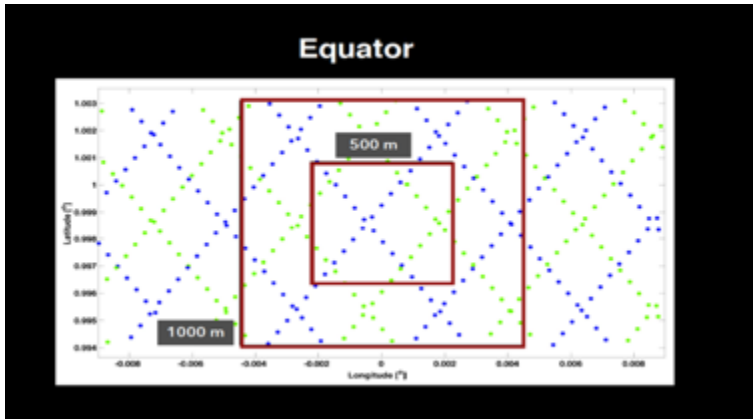


Can we fill in these gaps using fusion of TDX and GEDI?

- 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, σ, ϕ_0 | Underdetermined problem |

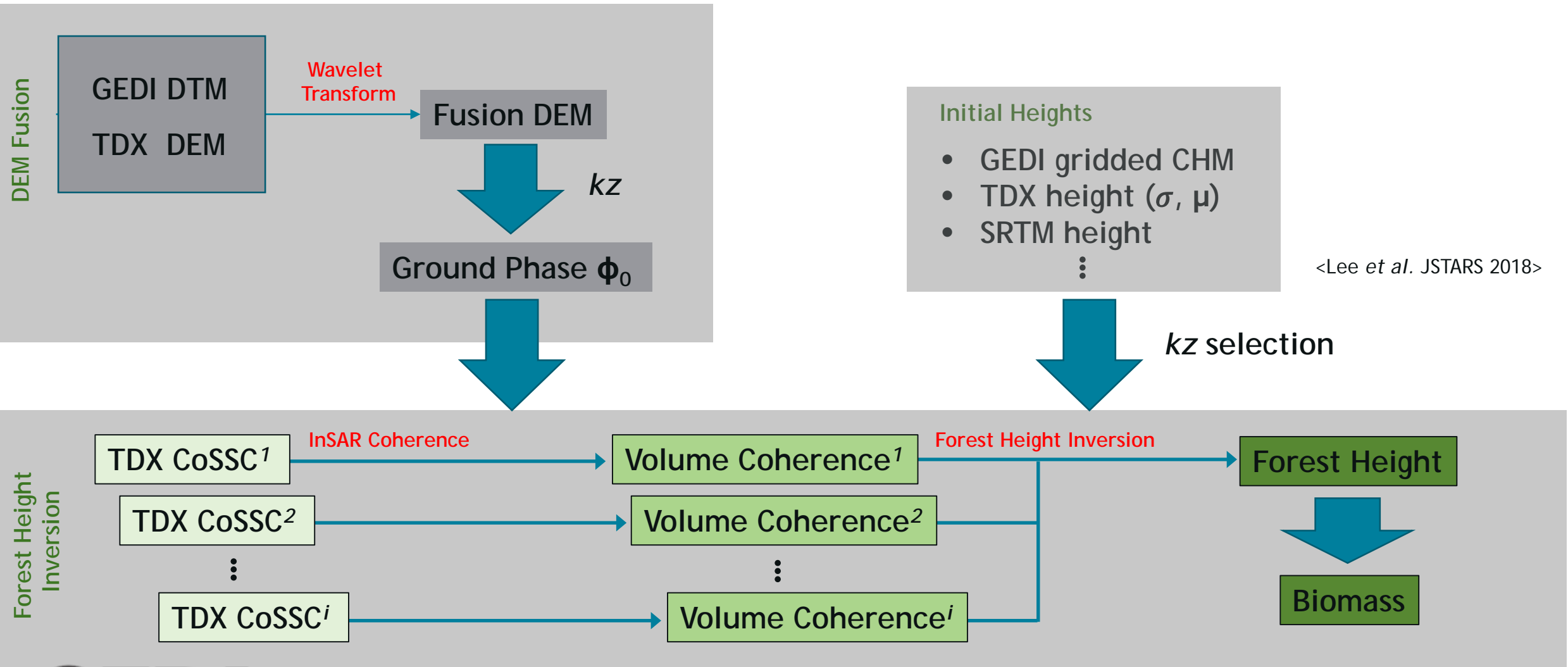
Method1: Extinction σ <Qi et al. Remote Sensing of Environment 2016>

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

Method2: Ground Phase ϕ_0

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

Multi-Baseline TDX Inversion; Fusion DTM



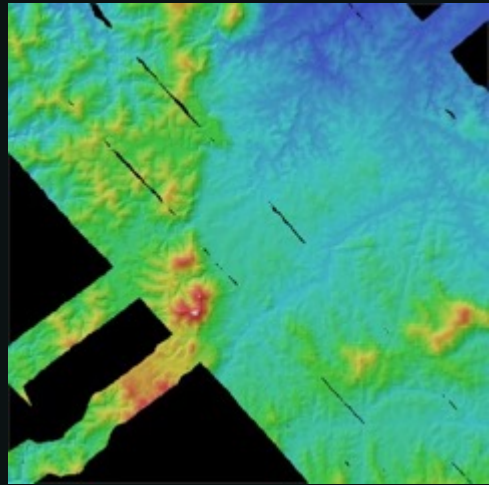
<Lee et al. JSTARS 2018>

GEDI and TDX DEMs Merging; Wavelet

Lope, Gabon

Lidar DTM

LVIS DTM (Airborne)

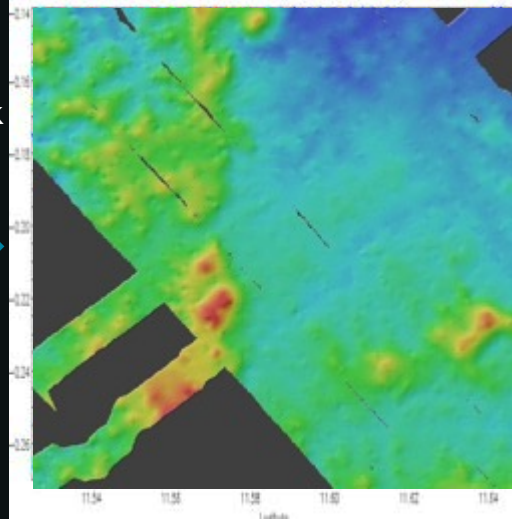


12.5 km

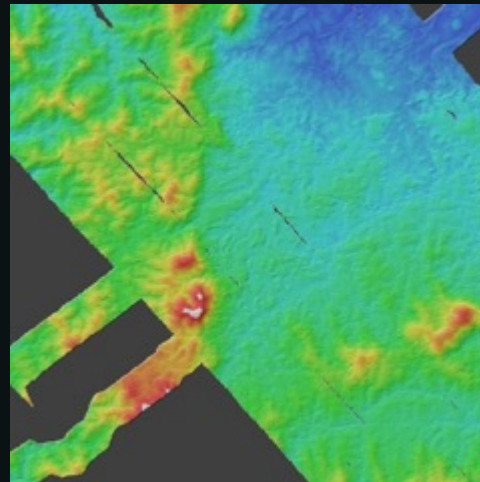
GEDI ground-track simulation



GEDI DTM (Spaceborne)



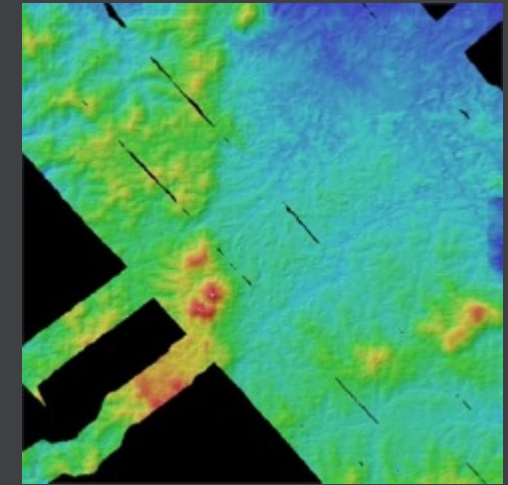
TanDEM-X DEM (Spaceborne)



Wavelet Transform



GEDI + TDX DTM (Fusion)



650 m

0 m

- ✓ Offsets are mitigated.
- ✓ Higher resolution

Interferometric SAR DEM

| ΔH | 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

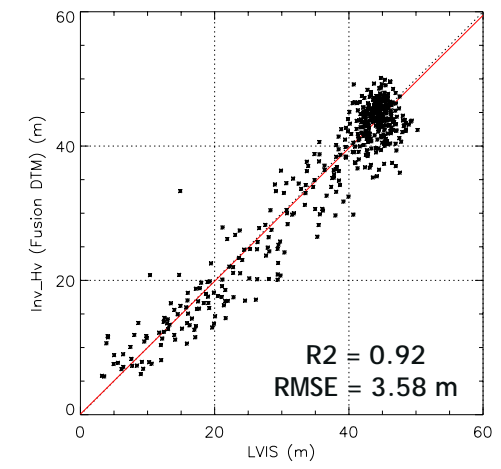
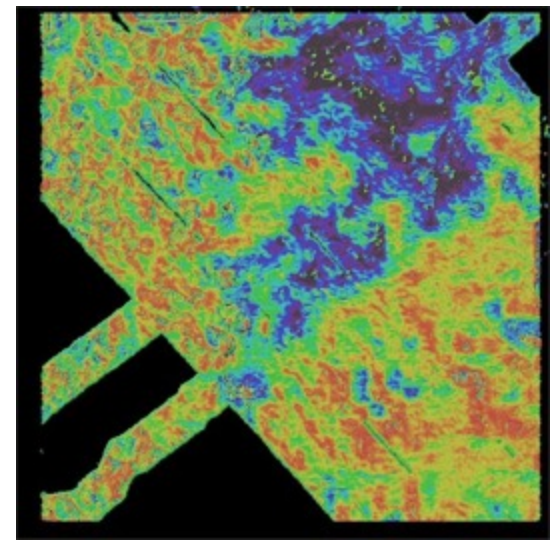
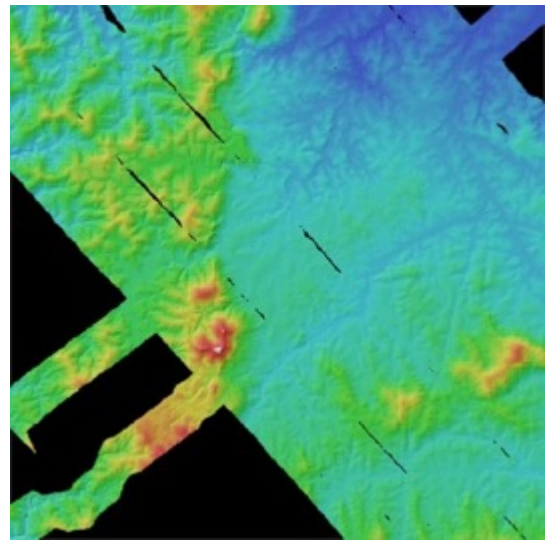
Lope, Gabon

DTM

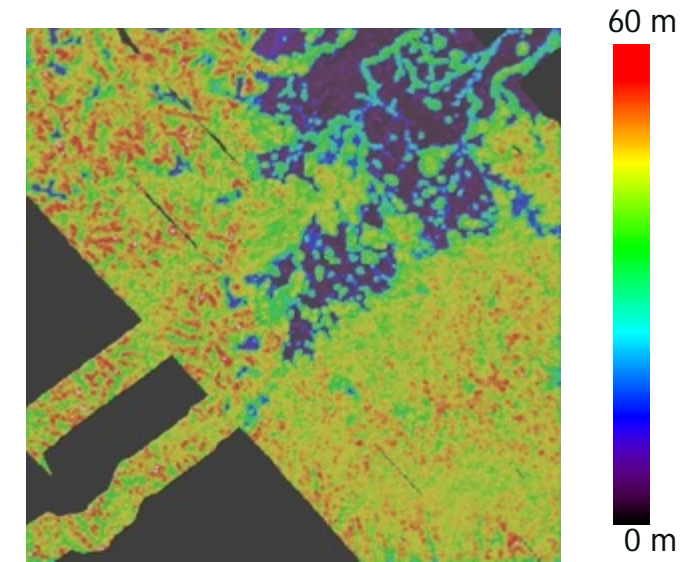
TDX Forest Height

Validation

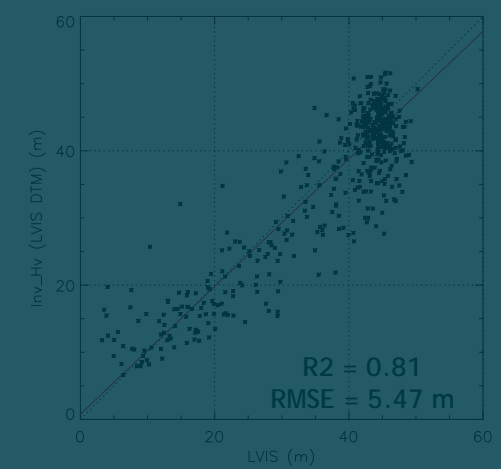
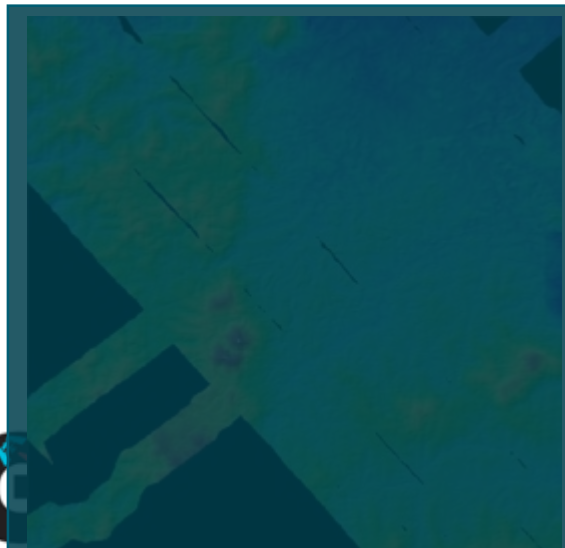
LVIS



LVIS CHM



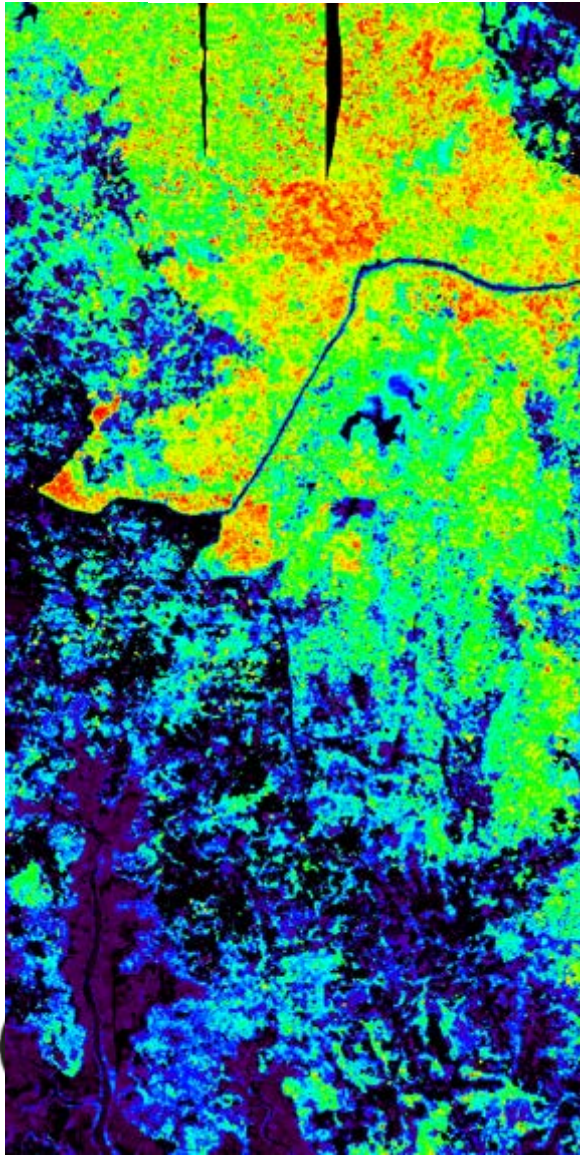
GEDI+TDX Fusion



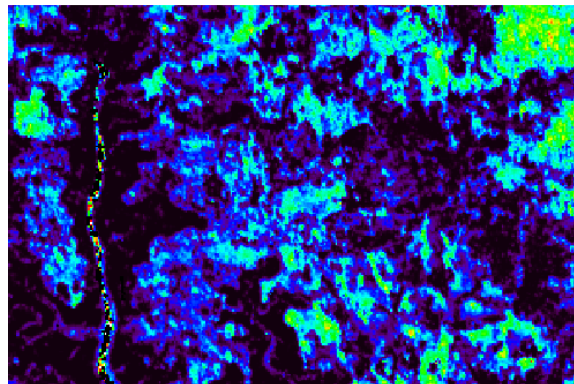
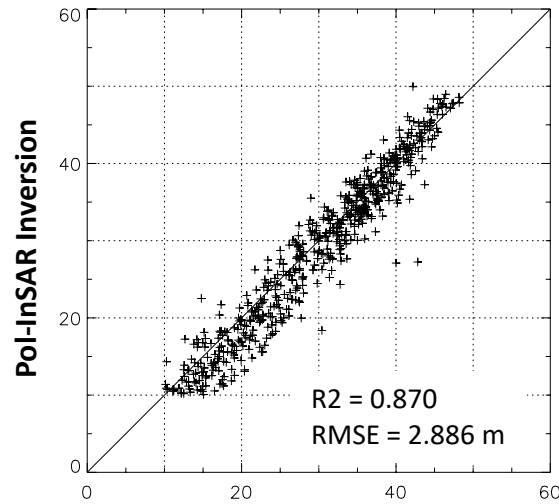
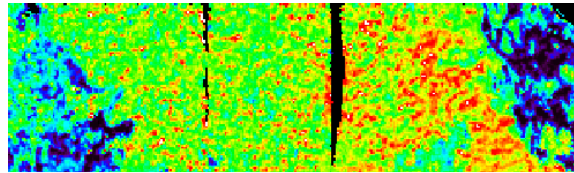
Forest Height Inversion Results

Mondah, Gabon

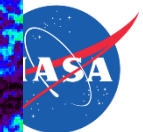
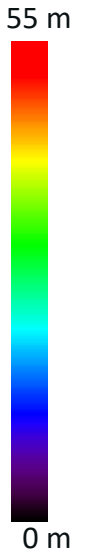
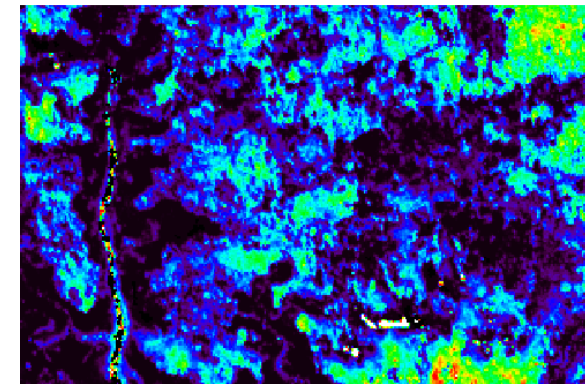
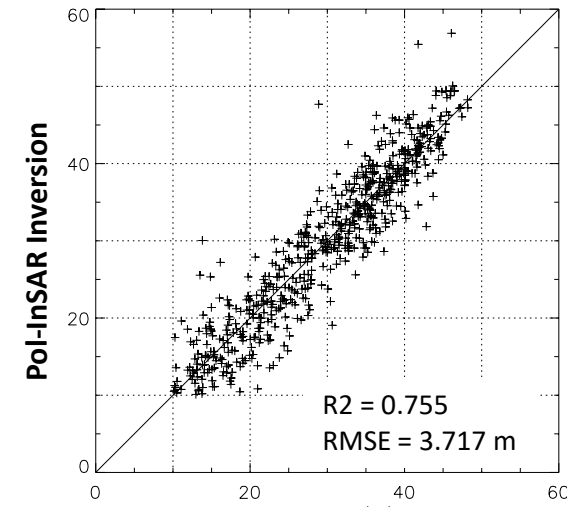
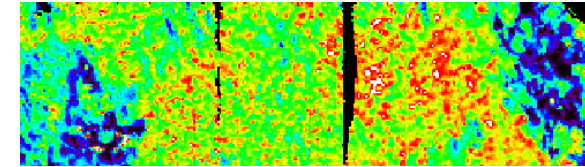
LVIS RH95



Inversion using LVIS DTM

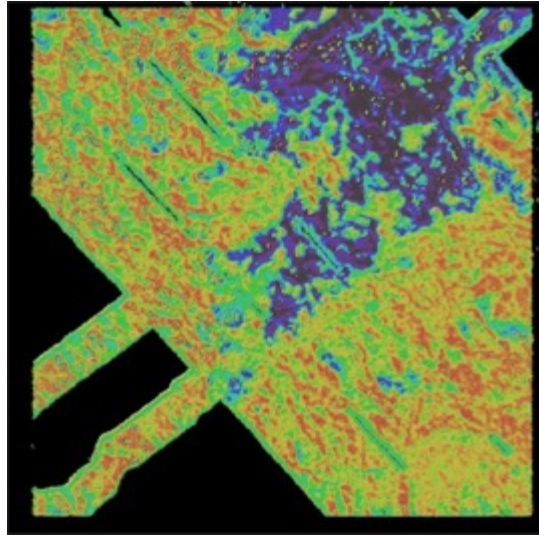


Inversion using Fusion DTM

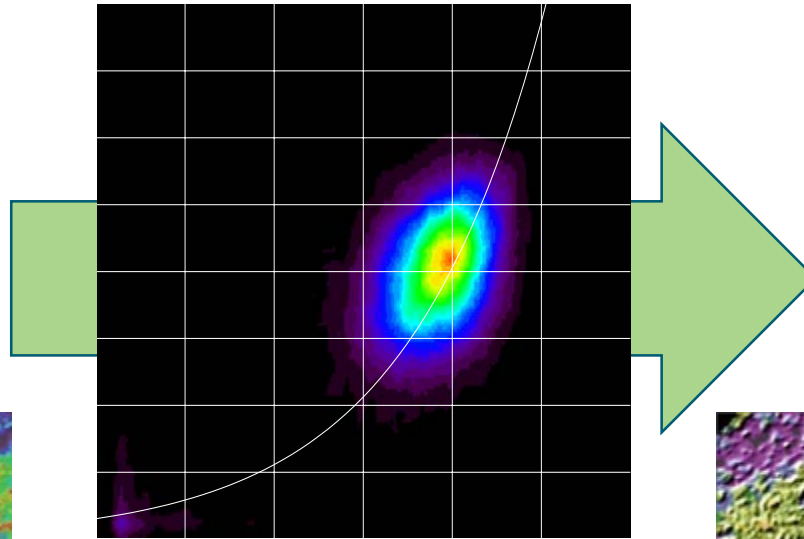


Aboveground Biomass

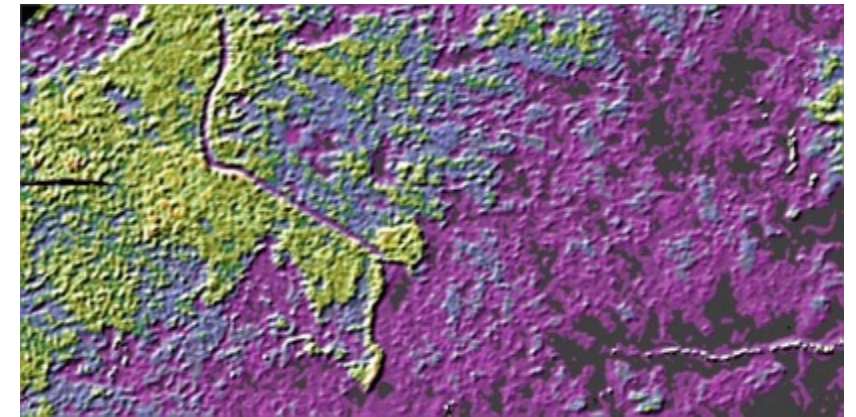
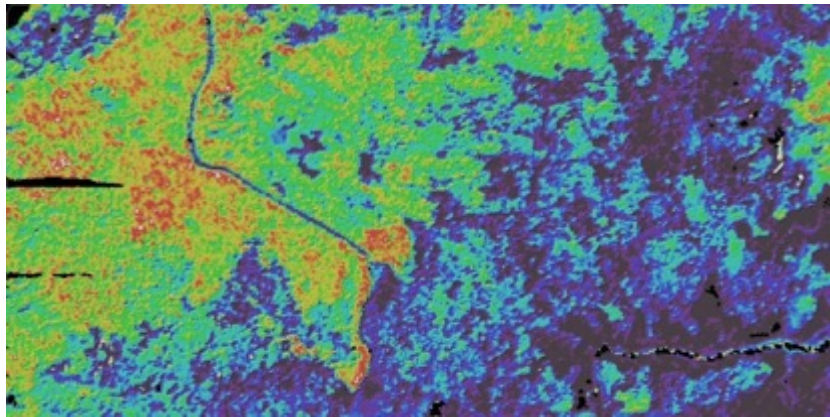
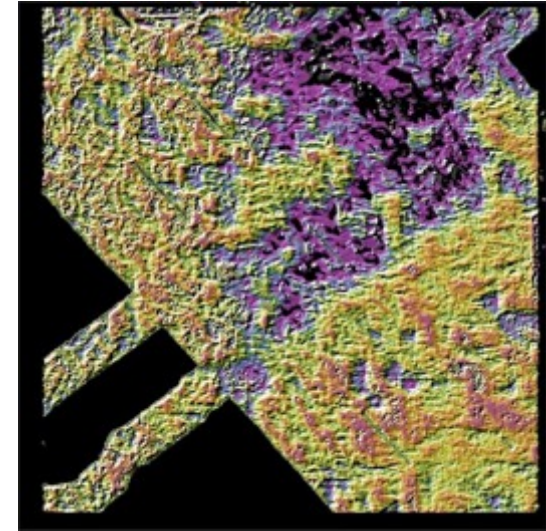
Forest Height Map



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 CO₂ concentrations, how much carbon forests will absorb in the future, and how habitat degradation will affect global biodiversity. >

Thank you!