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

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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 Topography

• 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
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 Armstrong | 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 Armstrong | 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
- Enhanced height/biomass using fusion with TanDEM-X:
  - Lola Fatoynbo
  - Seung-Kuk Lee
  - Grid size: Variable
- Enhanced height/biomass and biomass change using fusion with Landsat:
  - Matt Hansen
  - Chenquan Huang
  - Grid size: Variable
- Biodiversity/habitat model outputs:
  - Scott Goetz
  - Patrick Jantzi
  - Pat Burns
  - Grid size: Variable
GEDI & TanDEM-X Fusion

- 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)

<table>
<thead>
<tr>
<th>Polarization</th>
<th>Independent Coherence</th>
<th>Assumption</th>
<th>Unknowns</th>
<th>Condition</th>
</tr>
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<tbody>
<tr>
<td>Single-Pol.</td>
<td>$\widetilde{\gamma}(\tilde{w}_1)$</td>
<td>$m_1 = 0$</td>
<td>$h_v, \sigma, \phi_0$</td>
<td>Underdetermined problem</td>
</tr>
</tbody>
</table>

Method 1: Extinction $\sigma$

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

Method 2: 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

Initial Heights
- GEDI gridded CHM
- TDX height ($\sigma$, $\mu$)
- SRTM height

InSAR Coherence
- TDX CoSSC$^1$
- TDX CoSSC$^2$
- TDX CoSSC$^i$

Volume Coherence
- Volume Coherence$^1$
- Volume Coherence$^2$
- Volume Coherence$^i$

Forest Height Inversion

Forest Height

Biomass

<Lee et al. JSTARS 2018>
GEDI and TDX DEMs Merging; Wavelet

LVIS DTM (Airborne)

GEDI DTM (Spaceborne)

TanDEM-X DEM (Spaceborne)

GEDI + TDX DTM (Fusion)

- GEDI ground-track simulation
- Interpolation (krig2d)
- Lower spatial resolution (???) m
- Ground-level DEM
- Global scale X-band InSAR DEM
- Higher spatial resolution (12 m)
- Offsets on vegetated areas

- Offsets are mitigated.
- Higher resolution

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

Lope, Gabon
Forest Height Inversion Results

Lope, Gabon

DTM  TDX Forest Height  Validation

LVIS  GEDI+TDX Fusion

LVIS CHM

R2 = 0.92  RMSE = 3.58 m

R2 = 0.81  RMSE = 5.47 m
Forest Height Inversion Results

Mondah, Gabon

LVIS RH95

Inversion using LVIS DTM

R² = 0.870
RMSE = 2.886 m

Inversion using Fusion DTM

R² = 0.755
RMSE = 3.717 m

Pol-InSAR Inversion

0 m
55 m
Aboveground Biomass

Forest Height Map

Aboveground Carbon Map

Height-biomass allometric Eq. from GEDI waveform lidar data

0 700 Mg/ha
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!