GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

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University of Maryland
Principal Investigator
<table>
<thead>
<tr>
<th>GEDI SCIENCE TEAM</th>
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<tbody>
<tr>
<td>Ralph Dubayah</td>
<td>University of Maryland</td>
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<tr>
<td>J. Bryan Blair</td>
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<td>German Aerospace Center</td>
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<td>Anu Swatantran</td>
<td>University of Maryland</td>
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"New space-based observations using lidar should have high priority and are recommended to provide complementary information on forest height and structure."

Committee on Earth Observations (2014)
"New space-based observations using lidar should have high priority and are recommended to provide complementary information on forest height and structure."

Committee on Earth Observations (2014)
We Are Not Alone

Global Ecosystem Dynamics Investigation

New space-based observations using lidar should have high priority and are recommended to provide complementary information on forest height and structure.

Committee on Earth Observations (2014)

GEDI LIDAR
Earth Ventures Instrument (EVI)
Earth Ventures Instrument (EVI)

- Selected in August 2014 for $94 M (Class C)
- PI-mode Mission
- Multi-beam waveform lidar instrument build by NASA Goddard Spaceflight Center
- Deployed on International Space Station in 2018
GEDI Science Objectives

**Question**

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

**Quantify**
What is the carbon balance of the Earth’s forests?

Quantify:
- Forest Biomass
- Disturbance and Recovery
GEDI Science Objectives

Global carbon dioxide budget
(gigatonnes of CO_2 per year)
2004-2013

Fossil fuel & cement
32.6 ± 1.5

Atmospheric growth
15.8 ± 0.4

Land-use change
3.3 ± 1.8

Land sink
10.6 ± 2.9

Ocean sink
9.5 ± 1.8

Produced by the International Geosphere-Biosphere Programme for the Global Carbon Project.
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GEDI Science Objectives

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

Land-use change
3.3 ± 1.8

Land sink
10.6 ± 2.9
GEDI Science Objectives

**Question**

- What is the carbon balance of the Earth’s forests?
- How will the land surface mitigate atmospheric CO₂ in the future?

**Quantify**

- Forest Biomass
- Disturbance and Recovery
GEDI Science Objectives

Question

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

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

Quantify

Forest Biomass

Disturbance and Recovery

Carbon Sequestration Potential
GEDI Science Objectives

Sequestration Potential (95% of maximum AGB)

Total Potential = 0.5 GtC (1.8 Gt CO$_2$)

Ecosystem Demography (ED) model initialized with 1 ha canopy height distributions from lidar
**GEDI Science Objectives**

**Question**

- What is the carbon balance of the Earth’s forests?
- How will the land surface mitigate atmospheric CO₂ in the future?
- How does forest structure affect habitat quality and biodiversity?

**Quantify**

- Forest Biomass
- Disturbance and Recovery
- Carbon Sequestration Potential
- Vertical Forest Structure and its Relationship to Biodiversity
GEDI Science Objectives

What is the carbon balance of the Earth's forests?
How will the land surface mitigate atmospheric CO₂ in the future?
How does forest structure affect habitat quality and biodiversity?

Quantify

Forest Biomass
Disturbance and Recovery
Carbon Sequestration
Vertical Forest Structure and its Relationship to Biodiversity

Derived from GEDI-like lidar

Fig. 1. The densities of foliage (measured in square feet of leaf silhouette per cubic foot of space) are plotted along the abscissa. The height in feet above the ground is the ordinate. F.H.D. is foliage height diversity. B.S.D. is bird species diversity, and P.S.D. is plant species diversity.
GEDI Science Objectives

Question

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

How will the land surface mitigate atmospheric CO$_2$ in the future?

How does forest structure affect habitat quality and biodiversity?

Quantify

Forest Biomass

Disturbance and Recovery

Carbon Sequestration Potential

Vertical Forest Structure and its Relationship to Biodiversity
GEDI Lidar Instrument

Self-contained Laser Altimeter
Lidar Measurement
Lidar Measurement

25 m
Lidar Measurement
GEDI Laser Track Coverage

15,000,000,000
GEDI Laser Track Coverage

15,000,000,000,000

LAND SURFACE LASER OBSERVATIONS IN ONE YEAR
3 lasers
7 beams
14 ground tracks

GEDI Laser Track Coverage

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION
GEDI Laser Track Coverage

- 3 lasers
- 7 beams
- 14 ground tracks

Coverage Laser

Full Power Laser

Coverage Laser

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION
GEDI Laser Track Coverage

- 3 lasers
- 7 beams
- 14 ground tracks

- Coverage Laser
- Full Power Laser
- Coverage Laser

Distance:
- 500 m
- 6.5 km
Global Ecosystem Dynamics Investigation

- GEDI Laser Track Coverage
- 3 lasers
- 7 beams
- 14 ground tracks

Along Track Direction

60 m

500 m

6.5 km

1 2 3 4 5 6 7 8 9 10 11 12 13 14
GEDI Laser Track Coverage

- 3 lasers
- 7 beams
- 14 ground tracks

Along Track Direction

60 m

500 m

6.5 km

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION
GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

GEDI Laser Track Coverage

3 lasers
7 beams
14 ground tracks

Along Track Direction

60 m

500 m

6.5 km

1 2 3 4 5 6 7 8 9 10 11 12 13 14

COVERAGE LASER

FULL POWER LASER

COVERAGE LASER
International Space Station

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION
Japanese Experiment Module
Japanese Experiment Module
Science Approach

Level 1B

GEDI Waveforms
Science Approach

GEDI Waveforms

- Canopy Height Metrics
- Canopy Profile Metrics
- Habitat Metrics
- Objective 4

Level 1B  Level 2&3
Science Approach

Level 1B

- GEDI Waveforms
  - Canopy Height Metrics
  - Canopy Profile Metrics

Level 2&3

- Empirical & Statistical Models
- Ecosystem Demography Model
- Habitat Metrics
- Objective 4
Science Approach

Level 1B: GEDI Waveforms
- Canopy Height Metrics
- Canopy Profile Metrics
- Habitat Metrics

Level 2&3:
- Empirical & Statistical Models
- Ecosystem Demography Model

Level 4 Data Products:
- Above-ground Carbon

Objective 1: Canopy Height Metrics, Canopy Profile Metrics
Objective 4: Habitat Metrics
Science Approach

Level 1B
GEDI Waveforms
- Canopy Height Metrics
- Canopy Profile Metrics
- Habitat Metrics

Objective 4

Empirical & Statistical Models
- Ecosystem Demography Model

Objective 1

Above-ground Carbon

Objective 2

Above-ground Carbon

Past
Carbon Change
Landsat Disturbance (2000-2018)

Present

Level 2&3
Science Approach

Objective 1: Carbon Change
- Landsat Disturbance (2000-2018)

Objective 2: Sequestration Potential and Future Scenarios (IPCC)

Objective 3: Canopy Height Metrics
- Canopy Profile Metrics
- Ecosystem Demography Model

Objective 4: Habitat Metrics

Level 1B: GEDI Waveforms

Level 2&3: Empirical & Statistical Models

Level 4 Data Products:
- Present
- Past
- Future

Global Ecosystem Dynamics Investigation
GEDI Data Products

Level 2 Footprint Products
- Canopy Height Metrics
- Canopy Profile Metrics
GEDI Data Products

Level 2 Footprint Products
- Canopy Height Metrics
- Canopy Profile Metrics

Level 3 Gridded Products
# Model Investigative Products

<table>
<thead>
<tr>
<th>LEVEL 4 PRODUCT</th>
<th>RESOLUTION</th>
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<tr>
<td><strong>EMPIRICAL MODEL OUTPUTS</strong></td>
<td></td>
</tr>
<tr>
<td>Aboveground Carbon</td>
<td>25 m / 500 m</td>
</tr>
<tr>
<td>Aboveground Carbon Change (2000-2018)</td>
<td>500 m grid</td>
</tr>
<tr>
<td><strong>ECOSYSTEM MODEL OUTPUTS</strong></td>
<td></td>
</tr>
<tr>
<td>Aboveground Carbon and Carbon Flux</td>
<td>500 m grid</td>
</tr>
<tr>
<td>Carbon Sequestration Potential</td>
<td>500 m grid</td>
</tr>
<tr>
<td><strong>ENHANCED RESOLUTION FROM FUSION</strong></td>
<td></td>
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<tr>
<td>High Resolution Height and Carbon from Landsat</td>
<td>30 m</td>
</tr>
<tr>
<td>Height, Structure and Carbon from Tandem-X</td>
<td>Variable</td>
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</tbody>
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Approach to Errors

1. Lidar Footprint
   - Lidar Model EAGC
   - Field Plot

2. Field EAGC
   - Scatter plot showing discrepancies

3. EAGC ± ε
   - Grid indicating 500 m cells

Level 1 Requirements:
- 80% of 500 m cells meet carbon accuracy of 20%
Approach to Errors

Assume we can get this to within 35%-40% RMSE.
Assume we can get this to within 35%-40% RMSE.

Biomass estimate for each 25 m footprint.
Approach to Errors

1. Lidar-to-field RMSE
2. Number of Passes
3. Number of Footprints
4. Biomass variance within cell (from footprints)

Assume we can get this to within 35%-40% RMSE.
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Biomass estimate for each 25 m footprint.

500 m Biomass +/- error (after one year of operation).

1. Lidar-to-field RMSE
2. Number of Passes
3. Number of Footprints
4. Biomass variance within cell (from footprints)
80% of 500 m cells have standard error < 20% after one year of operations
Collaboration with German Aerospace Center (DLR)

- Provides high-resolution topographic data
- Interferometric methods retrieve some canopy structure
- Possibility of enhanced resolution and retrievals using fusion
Fusion with Tandem-X Data

Collaboration with German Aerospace Center

Traunstein Forest, Germany

- Provides high-resolution topographic data
- Interferometric methods retrieve some canopy structure
- Possibility of enhanced resolution and retrievals using fusion

Height Derived from Airborne Lidar

Height Derived from Tandem-X
Fusion with Tandem-X Data

Simulated GEDI Tracks

GEDI/Tandem-X Height

Hubbard Brook, US

RMSE = 2.5 m

$r^2 = 0.80$
GEDI potentially provides unprecedented calibration/validation data sets enabling enhanced mapping with BIOMASS, NISAR and other radar missions.
GEDI potentially provides unprecedented calibration/validation data sets enabling enhanced mapping with BIOMASS and other radar missions.

Considerations for BIOMASS

Saatchi et al.
Considerations for BIOMASS

GEDI potentially provides unprecedented calibration/validation data sets enabling enhanced mapping with BIOMASS, NISAR, and other radar missions.

3 ORDERS OF MAGNITUDE

Increase in number of pan-tropical observations available for fusion with radar
Potential Synergies
• Provide accurate **canopy structure** and **height** for calibration and validation
Potential Synergies

• Provide accurate *canopy structure* and *height* for calibration and validation

• Provide up to 15 billion estimates per year of *footprint level biomass* for calibration and validation
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- Provide 500 m **gridded biomass estimates**, including high biomass areas after one year.
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  • Approach 4 ha resolution after 2+ years on orbit
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- Provide dense network of **below canopy ground topography** for pol-InSAR models.
Potential Synergies

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- Provide 500 m **gridded biomass estimates**, including high biomass areas after one year:
  - Approach 4 ha resolution after 2+ years on orbit.
- Provide dense network of **below canopy ground topography** for pol-InSAR models.
- Potential for **explicit fusion-based modeling** for structure for pol-InSAR and tomographic methods.
Considerations for BIOMASS
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- GEDI nominal launch date 2018 and nominal mission length is one year
  - GEDI lasers demonstrated 6+ years of lifetime
  - Programmatic priorities will be main determinant of GEDI operational lifetime
Considerations for BIOMASS

• GEDI nominal launch date 2018 and nominal mission length is one year
  • GEDI lasers demonstrated 6+ years of lifetime
  • Programmatic priorities will be main determinant of GEDI operational lifetime

• Scale issues: GEDI footprints are 0.05 ha
  • But there are lots of them. How to optimally use for validation and calibration?
  • Can we leverage orbital cross-over points?
GEDI Ground Tracks

After 1 year

Number of Tracks inside 500 m Box

% of Grids
GEDI Ground Tracks

40° Latitude
GEDI Ground Tracks

40° Latitude

After 1 year

Number of Tracks inside 500 m Box

% of Grids
Considerations for BIOMASS
Considerations for BIOMASS

- Can we complement approaches to calibration?
  - Each mission needs field-based biomass but maybe at different scales
  - Explore leveraging field data acquisition
  - 1 ha plots are not optimal for GEDI unless stem-mapped
    - Expected GEDI geolocation accuracy is 8 m
Considerations for BIOMASS

• Can we complement approaches to calibration?
  • Each mission needs field-based biomass but maybe at different scales
  • Explore leveraging field data acquisition
  • 1 ha plots are not optimal for GEDI unless stem-mapped
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• Approaches to physically-based carbon estimation
  • GEDI uses individual-based ecosystem model based on height distributions (the ED model)
  • What will BIOMASS do and should we consider complementing differing model approaches?
  • Can we leverage common ancillary data such as soils, climate, and land use?
Considerations for BIOMASS

BIOMASS/GEDI/NISAR Science Team collaboration should address common cal/val and science issues
The stage is set.

GEDI LIDAR

BIOMASS
The stage is set.

GEDI LIDAR

BIOMASS

ICESAT-2

ALOS-2