Spaceborne Lidar for Monitoring Vegetation Structure and Biomass Using GEDI

Part 2: Introduction to the GEDI Mission and Its Derived Products

Training Outline

Session 1

Introduction to Full Waveform Lidar

October 23, 2025

11 AM - 1 PM EDT

Session 2

Introduction to the GEDI Mission and its Derived Products

October 30, 2025

11 AM - 1 PM EDT

Session 3

Due to the lapse in federal government funding, ARSET is unable to conduct Part 3 of this training series.

We sincerely regret this inconvenience.

November 6, 2025

Opens November 6 – Due November 20 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend the 2 live sessions and complete the homework assignment before the given due date.

National Aeronautics and Space Administration

Spaceborne Lidar for Monitoring Vegetation Structure and Biomass Using GEDI

Part 2: Introduction to the GEDI Mission and Its Derived Products

Stephanie Jiménez, University of Alabama in Huntsville & NASA Marshall Space Flight Center

October 30, 2025

Session 1 – Trainers

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Part 2 Learning Objectives

By the end of this session, participants will be able to:

- Identify the general characteristics, strengths, and limitations of the GEDI mission and its data.
- Identify GEDI data products and their characteristics for elevation, canopy height, vegetation structure, and biomass estimation.
- Access and visualize GEDI elevation, height, vegetation structure, and biomass datasets for an area of interest using openly available tools.

How to Ask Questions

- Please write your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to answer all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.

Section 1

The Global Ecosystem Dynamics Investigation (GEDI) Mission Objectives and its Global Relevance

Earth Ventures Instrument on the International Space Station

Novel High-Resolution Laser Ranging of the Earth's Forests and Topography

Key Facts:

- Jointly led by the University of Maryland and NASA Goddard Space Flight Center.
- Each **waveform** collected over a ~25m diameter "footprint" location provides the **complete vertical structure**.
- Data collection began **April 2019 to March 2023** followed by a brief **hibernation until returning** to operation in **April 2024.**

Source: The GEDI Mission.

Partial Slide Credit: Dubayah, R. (2023). GEDI: NASA Panel on Earth Science Missions for Land Monitoring. [PowerPoint Slides]. USFS NASA Workshop.

Science Questions and Mission Objectives

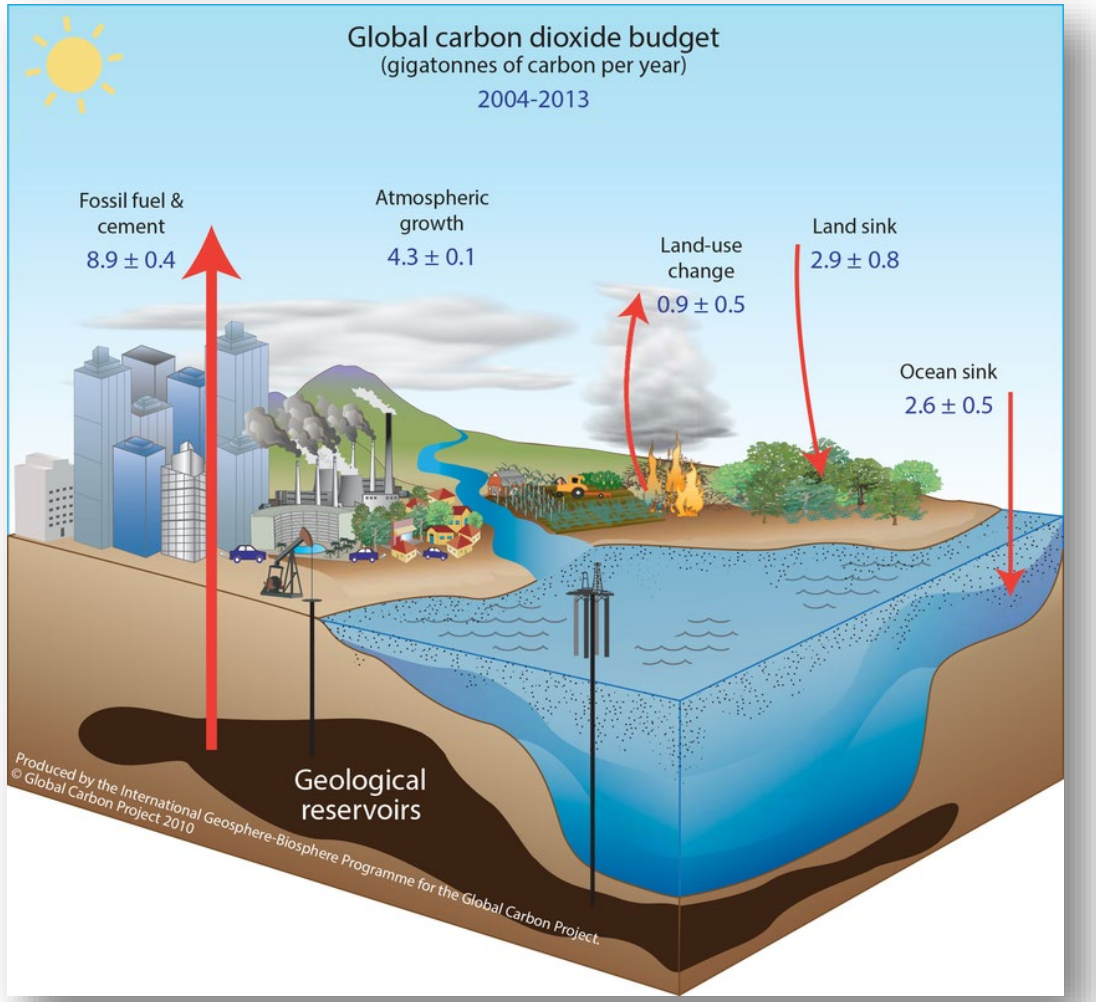
GEDI quantifies ecosystem structure to assess changes in biomass, land cover, and impacts to carbon, climate, and biodiversity.

Science Questions
What is the current state of Earth's forest structure?
What will forest dynamics look like in the future?
How does forest structure affect habitat quality and biodiversity?

Applications
Topography and Surface Deformation
Water Resources
Weather Prediction
Ecosystem & Fire Modelling and Management
Carbon Cycle Science

Applications – Ecosystem & Carbon Cycle Science

GEDI quantifies global biomass through time – a key component to quantifying fluctuations in the carbon cycle.

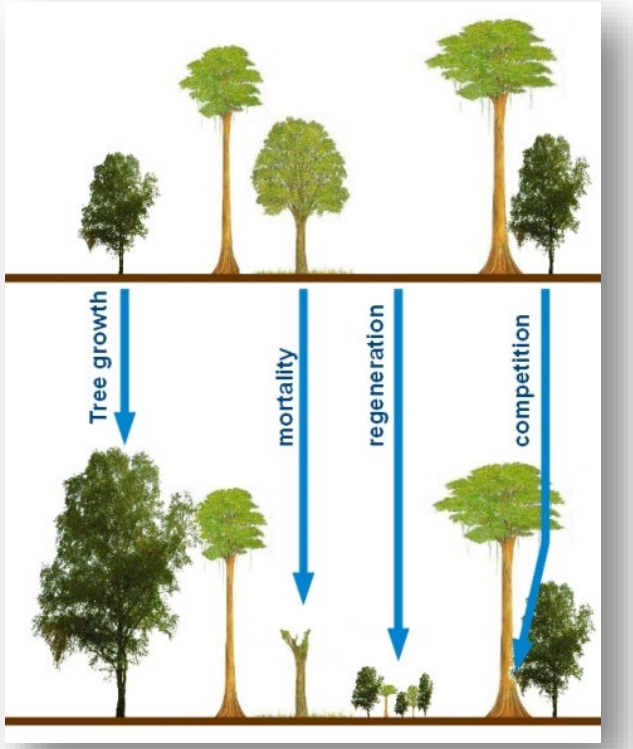


Partial Slide Credit: Dubayah, R. (2023). GEDI: NASA Panel on Earth Science Missions for Land Monitoring. [PowerPoint Slides]. USFS NASA Workshop.

Applications – Ecosystem & Fire Management & Modeling

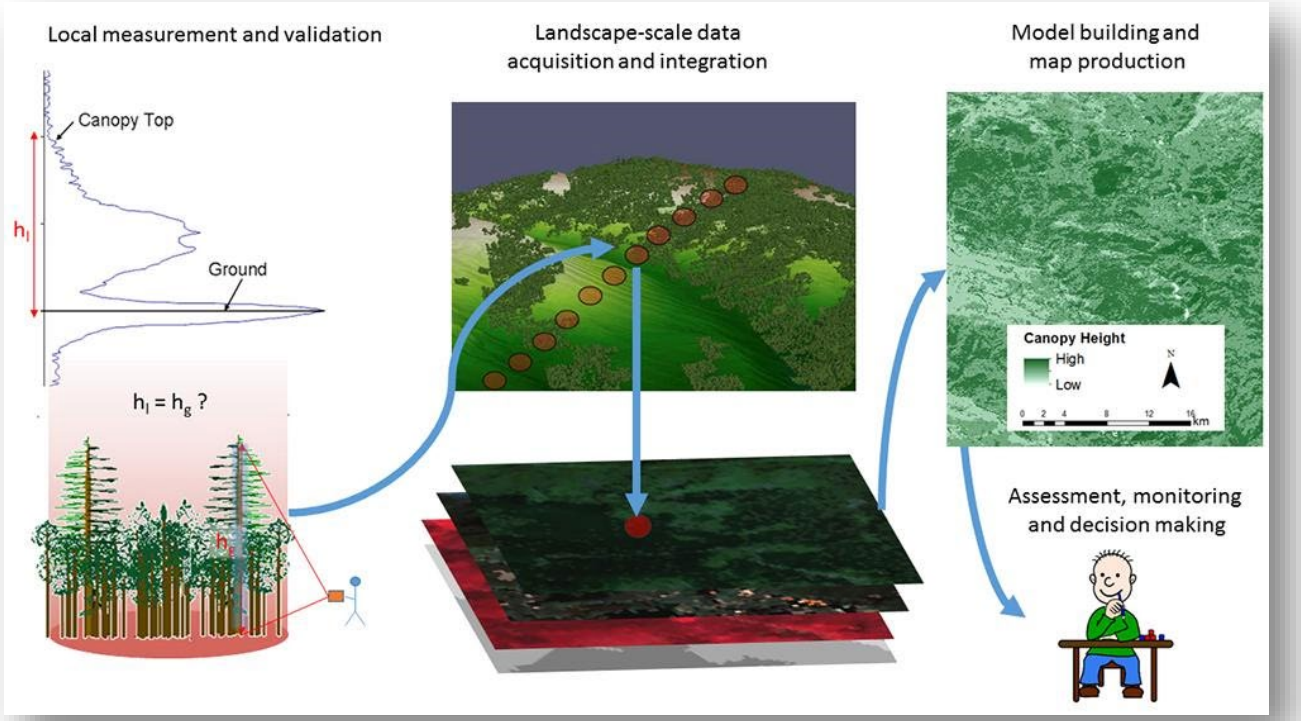
GEDI is sensitive to vegetation structure within a forest stand, and across a variable or disturbed landscape.

Forest Demographic Processes



Source: Forest processes based on "individual based dynamic vegetation model" (www.formind.org).

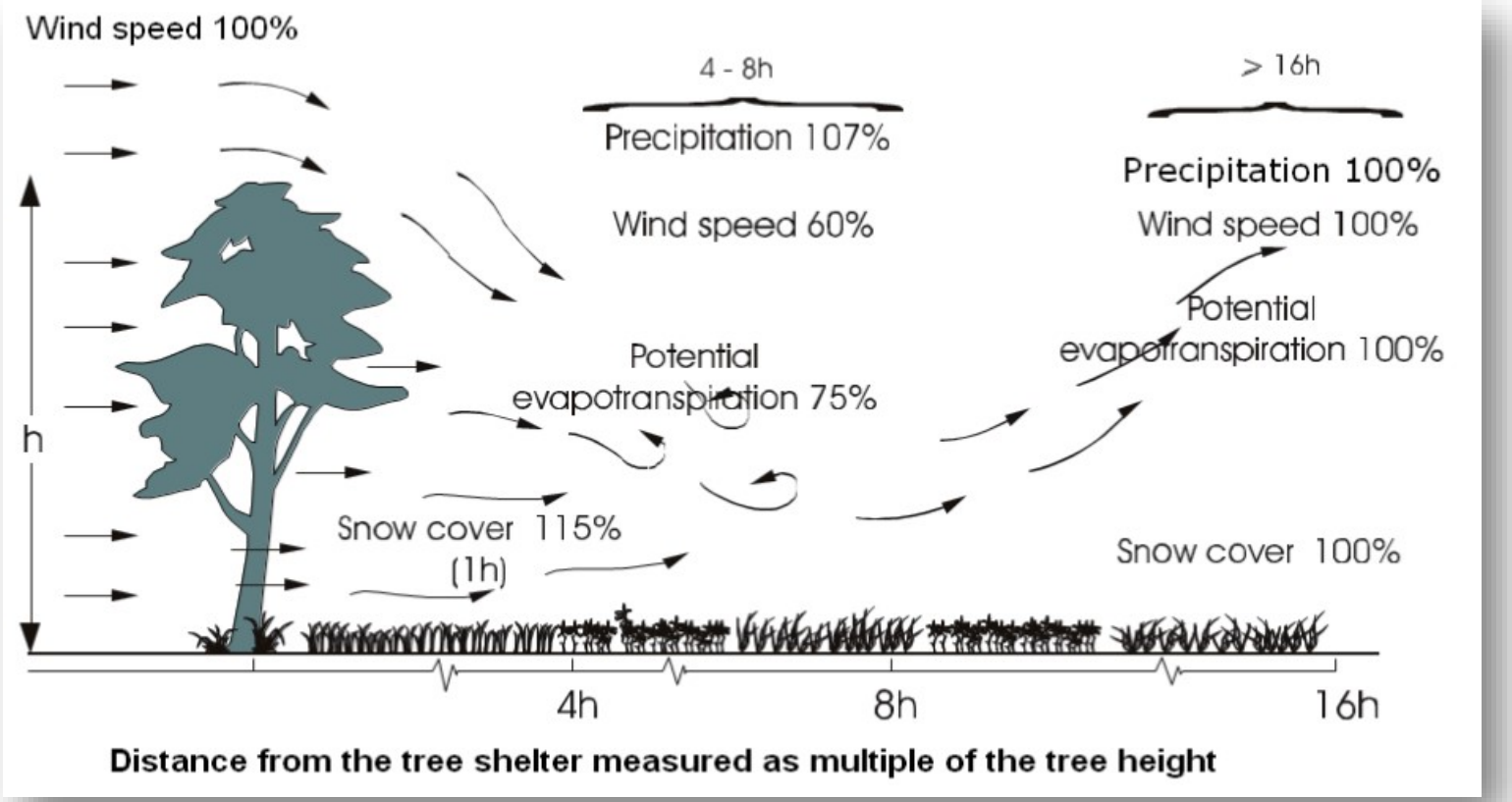
Data Flow for Generating GEDI Products for Wildland Fires



Source: Data flow for generation of GEDI-derived information products to aid managers and policy makers in assessments, monitoring and decision making related to wildland fire. Credit: Birgit Peterson. (The GEDI Mission).

Applications – Weather Prediction

GEDI's ability to capture ecosystem structure can provide insights into the meteorological effects of ecosystems.



Source: "Meteorological effects of tree canopies." Credit: 2015 Franciszek Woch et al."

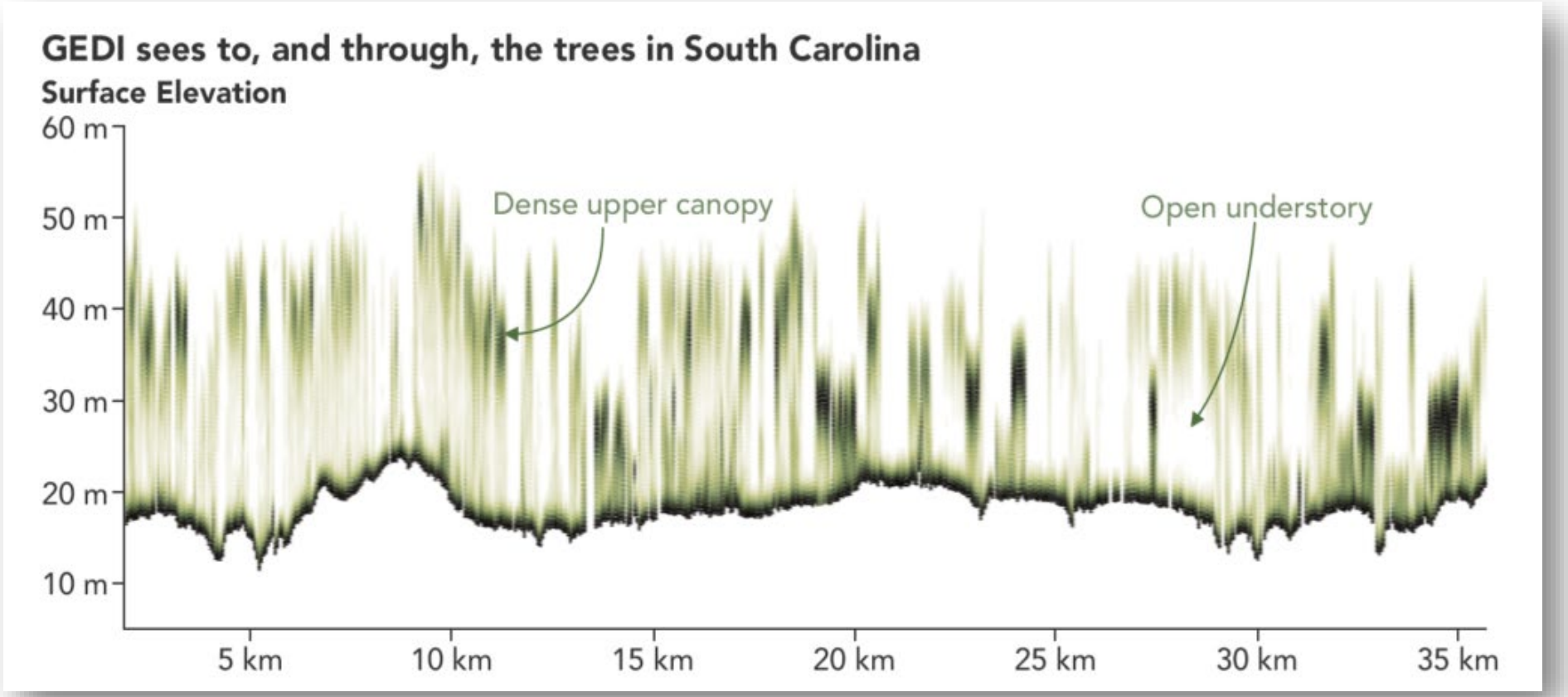
Applications – Water Resources

GEDI can detect water surface levels, even under forest canopies.

Source: Mangrove forest in Pongara National Park in Gabon, Africa, photographed during NASA's 2016 AfriSAR mission (The GEDI Mission).

Applications – Topography & Surface Deformation

GEDI helps map topography and surface deformation over diverse landscapes to monitor geophysical processes with accuracy.

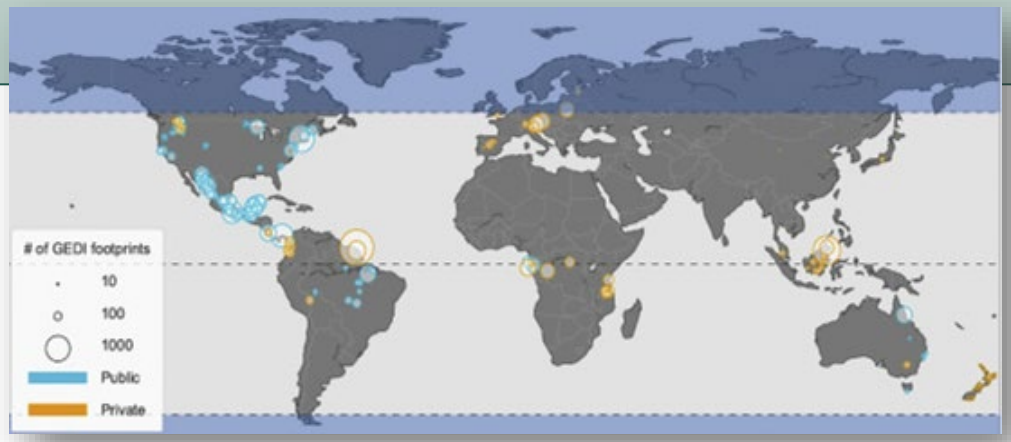


Source: "Data Collection Started" (The GEDI Mission).

Mission Specifications

Length of Record	**April 2019 to March 2023**. Hibernation until **return of GEDI in April 2024**.
Spatial Resolution	**25m** footprint or **1km** grid (mission) or other products from **10m to 12km**
Coverage	Variable between **51.6° N & S**
Sampling	**60m along** track, **600 m across** track, variable by lat & lon
Temporal Frequency	Non-specific and **variable by ISS** altitude
Latency	All Datasets: **LP & ORNL DAACs** including continuous version updates.
Geolocation Accuracy	Currently ~**10m** (1 sigma) to 8m or less (2024)
Accuracies	Varies

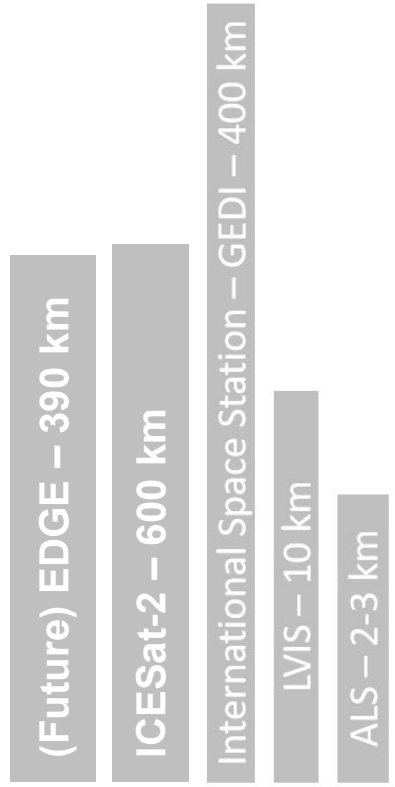
Slide Credit: Dubayah, R. (2023). GEDI: NASA Panel on Earth Science Missions for Land Monitoring. [PowerPoint Slides]. USFS NASA Workshop. Image Source: Dubayah et al., 2020.



GEDI and Other Lidar Systems

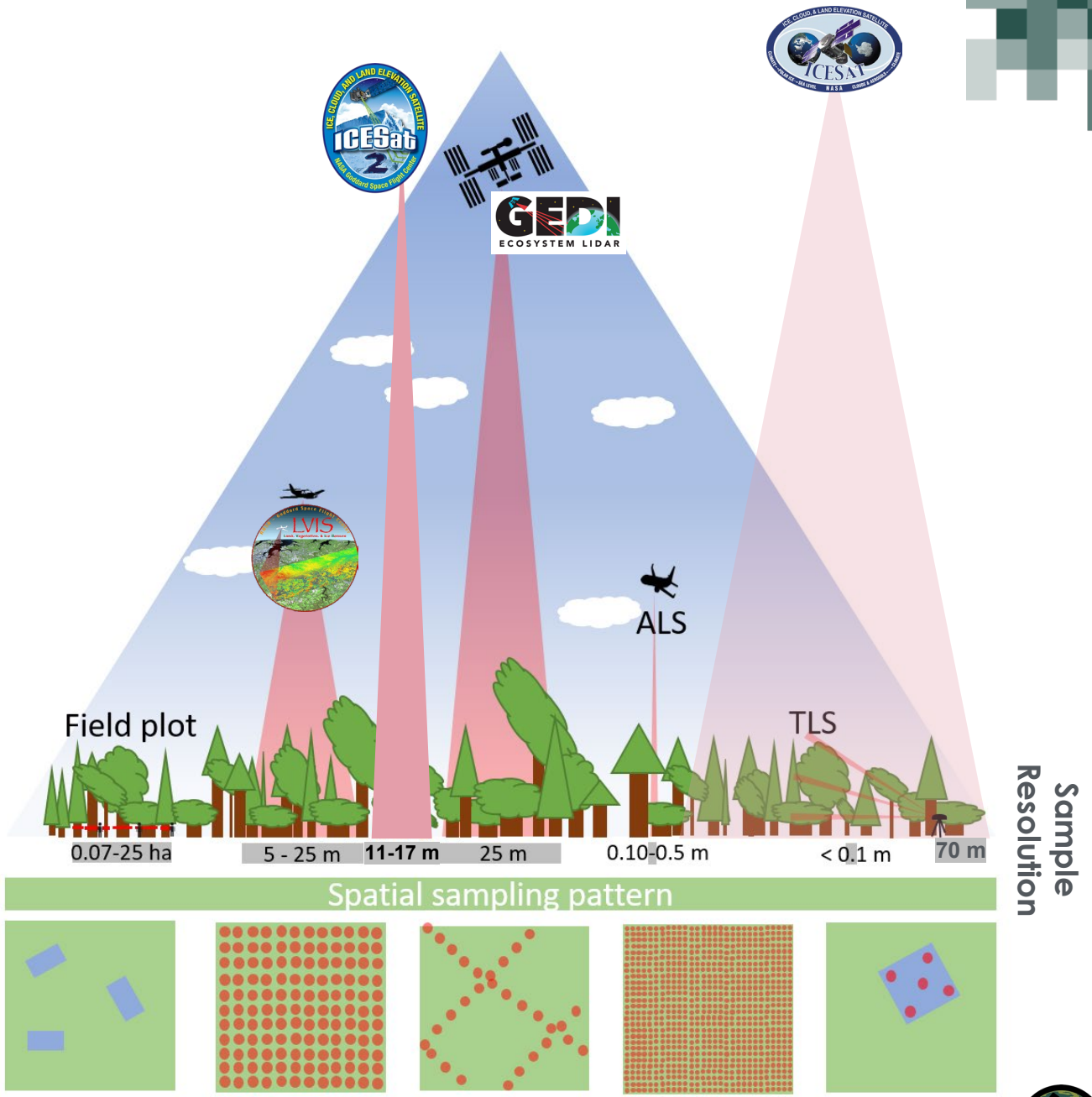
Differences and/or Trade-Offs:

- Spatial Coverage Areas
- Density of Observations
- Footprint Size
- Frequency of Observations
- Accuracy/Detail
- Cost $
- Computational Requirements
- Data Storage Requirements
- Staff and Skills

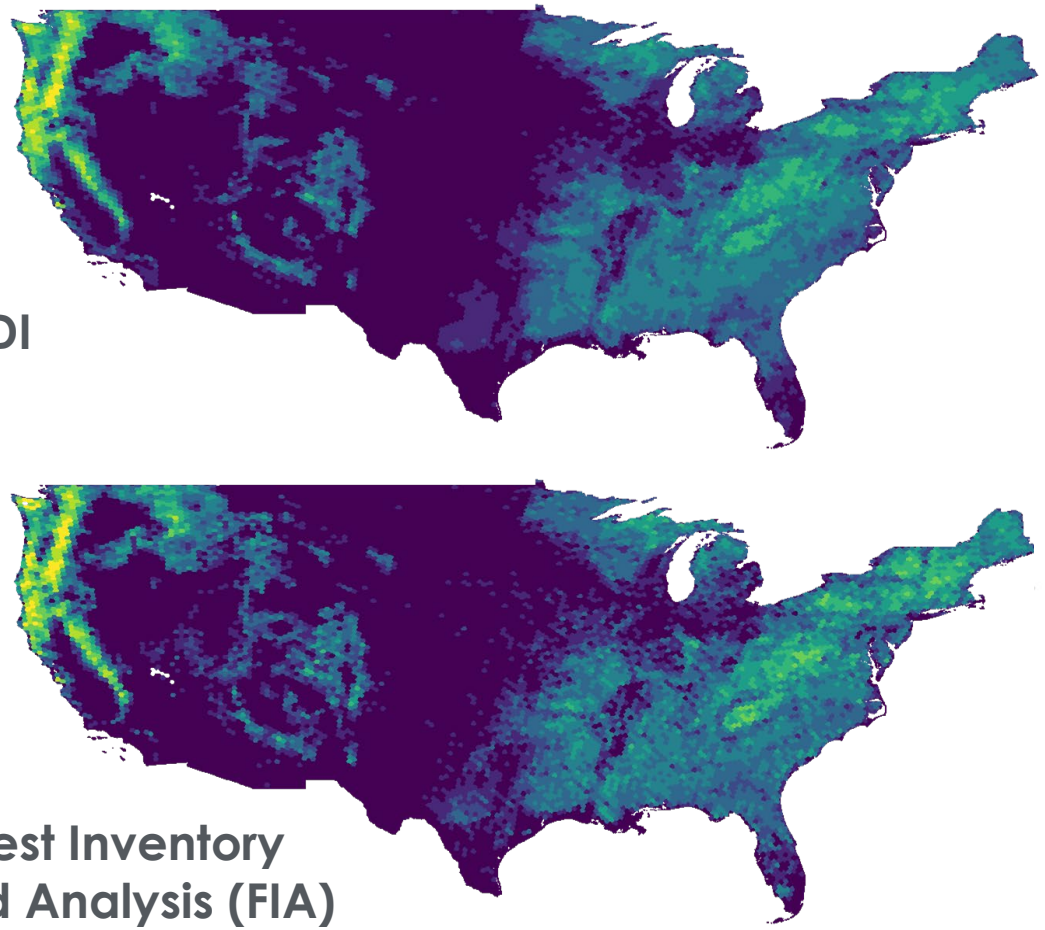


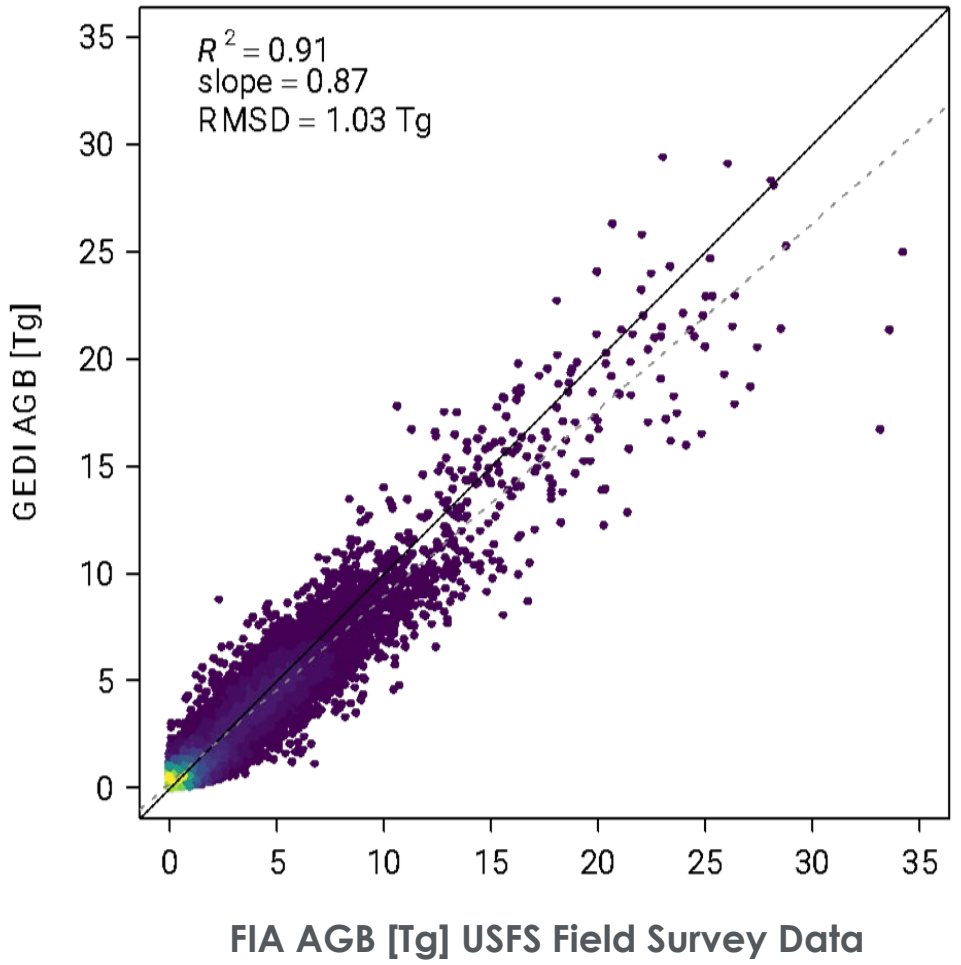
Altitude of Sensor

Source: (Adapted) The GEDI Mission calibration and validation.



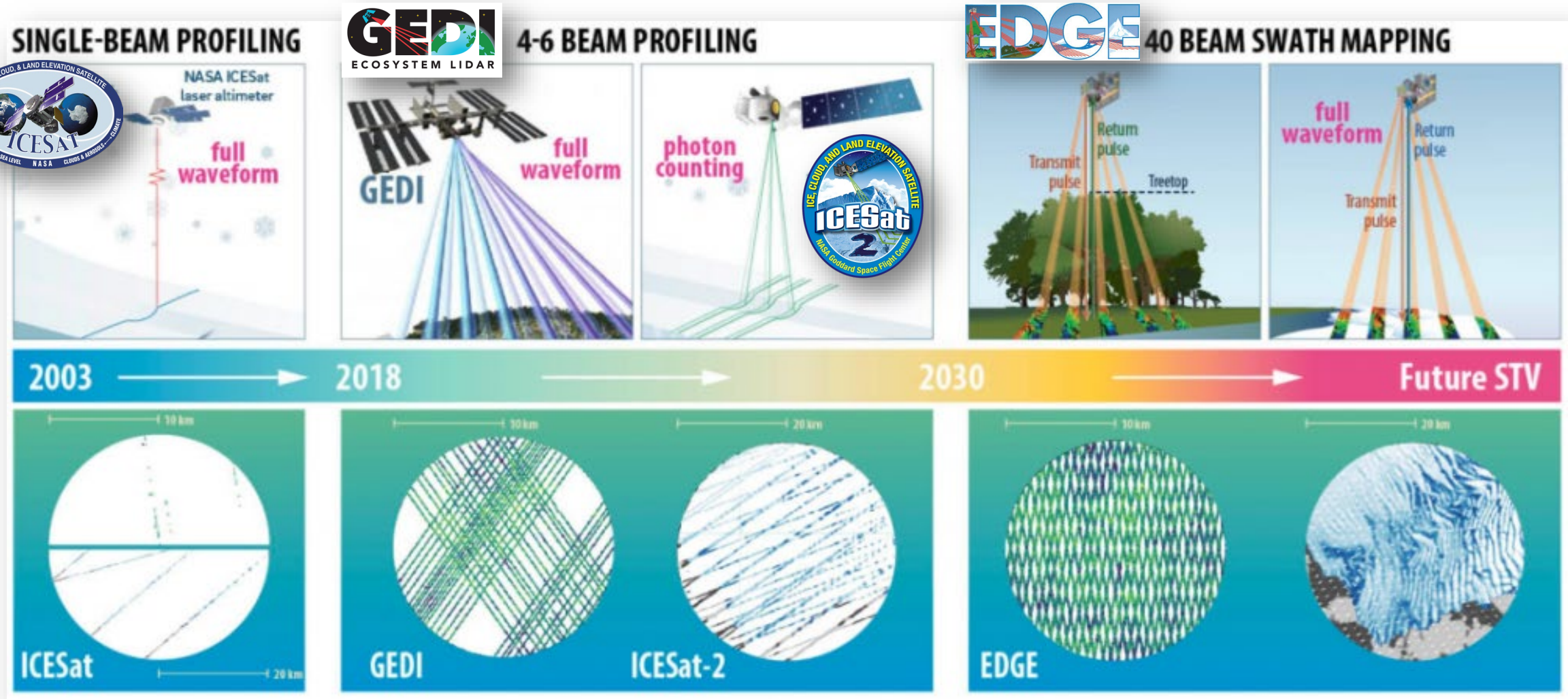
GEDI National Inventory: Example Calibration, Validation, and Derivation





Partial Slide Credit: Dubayah, R. (2023). GEDI: NASA Panel on Earth Science Missions for Land Monitoring. [PowerPoint Slides]. USFS NASA Workshop.

Continuous and Future Spaceborne Lidar Sampling



Source: [The Earth Dynamics Geodetic Explorer (EDGE).]

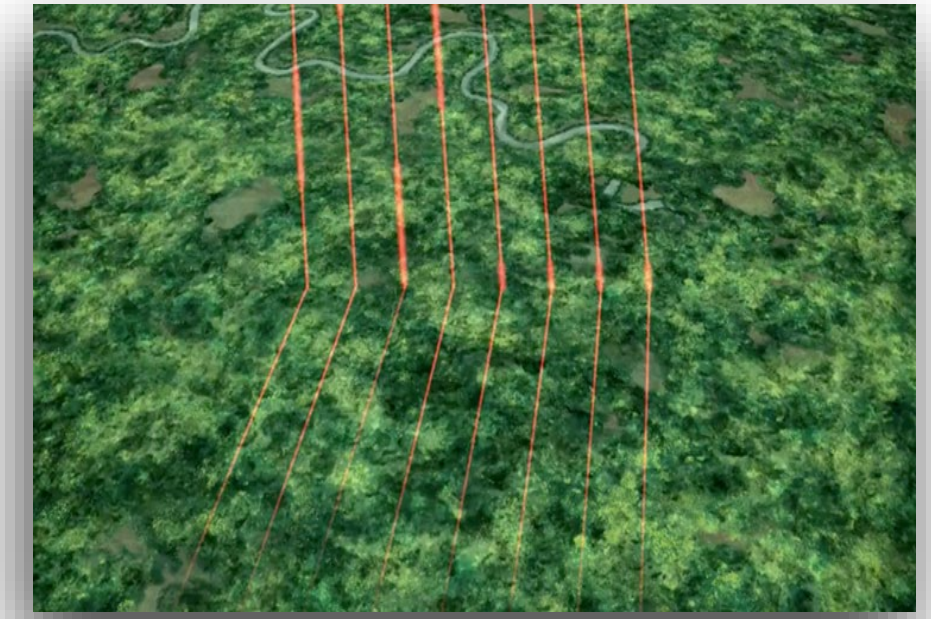
Section 2

Navigating the GEDI Ecosystem: Products and Tools

Data Products for Land Management & Monitoring

Datasets Across Levels 1-4 & Other Derived Products

- **Geolocated Waveform – L1B**
- **Height Metrics – L2A, L3, & Derived**
  - Canopy Height
  - Relative Height Metrics
  - Bare Earth Topography (Ground Elevation)
- **Vertical Structure – L2B, L4C, & Derived**
  - Total Canopy Cover & Canopy Cover by Vertical Height
  - Total Plant Area Index (PAI) & PAI by Vertical Height
  - Plant Area Volume Density (PAVD) by Vertical Height
  - Foliage Height Diversity
  - Waveform Structural Complexity Index (**WSCI**) and by Vertical Height – **L4C**
- **Biomass – L4A, L4B, & Derived**
  - Total Biomass
  - Biomass Density
  - Uncertainty Metrics



Total Land Returns: 20 billion
Weekly Collection: 90 million

Partial Slide Credit: Dubayah, R. (2023). GEDI: NASA Panel on Earth Science Missions for Land Monitoring. [PowerPoint Slides]. USFS NASA Workshop.

GEDI Uses HDF5 for Footprint-Level Datasets

What is an HDF5?

- Hierarchical Data Format version 5 (short file extension name as '**.h5**')
- HDF5 files are **organized like a file system** with a hierarchical structure.
- Arrays of different **types, shapes, and sizes** are stored with descriptive **metadata**.
    - **Groups:** Like directories/**folders**, hierarchical categories used to organize the data
    - **Datasets:** The actual data arrays (like **files**)
    - **Attributes: Metadata** attached to groups or datasets
    - **Root Group:** The top-level group (like the **root directory**)

Example Structure

Root Group/
- **Group 1/**
  - 'Dataset'
  - 'Dataset'
- **Group 2/**
  - 'Dataset'
  - **Subgroup 1/**
    - 'Dataset'
  - **Subgroup 2/**
    - 'Dataset'
- **Metadata/**
  - **Subgroup/**
    - 'Dataset'

L1B, L2A, L2B, L4A, L4C are ~25m footprint datasets.

Example GEDI HDF5 Format – L2A

Example HDF5 Structure	GEDI Footprint HDF5 Example Structure
Root Group/ • **Group 1/** – 'Dataset' – 'Dataset' • **Group 2/** – 'Dataset' – **Subgroup 1/** ▪ 'Dataset' – **Subgroup 2/** ▪ 'Dataset' • **Metadata/** – **Subgroup/** ▪ 'Dataset'	**Root Group =** GEDI L2A/ • **Group 1 =** METADATA/ – DatasetIdentification/ ▪ 'shortName' etc. • **Group 2** = BEAMXXXX/ – 'beam', etc. → each group contains datasets • **Group 3** = BEAMXXXX/ancillary • **Group 4** = BEAMXXXX/geolocation • **Group 5** = BEAMXXXX/land_cover_data • **Group 6** = BEAMXXXX/rx_1gaussfit • **Group 7** = BEAMXXXX/rx_1gaussfit/ancillary • **Group 8** = BEAMXXXX/rx_assess • **Group 9** = BEAMXXXX/rx_assess/ancillary • **Group 10** = BEAMXXXX/rx_processing_aN • **Group 11** = BEAMXXXX/rx_processing_aN/ancillary

Gridded, Aggregated, Derived, or Fused Data Products at Various Lower Resolutions and Temporal Aggregation Periods are GeoTIFFs

Example GEDI GeoTIFF Format – gedi_rh50_100m.tif

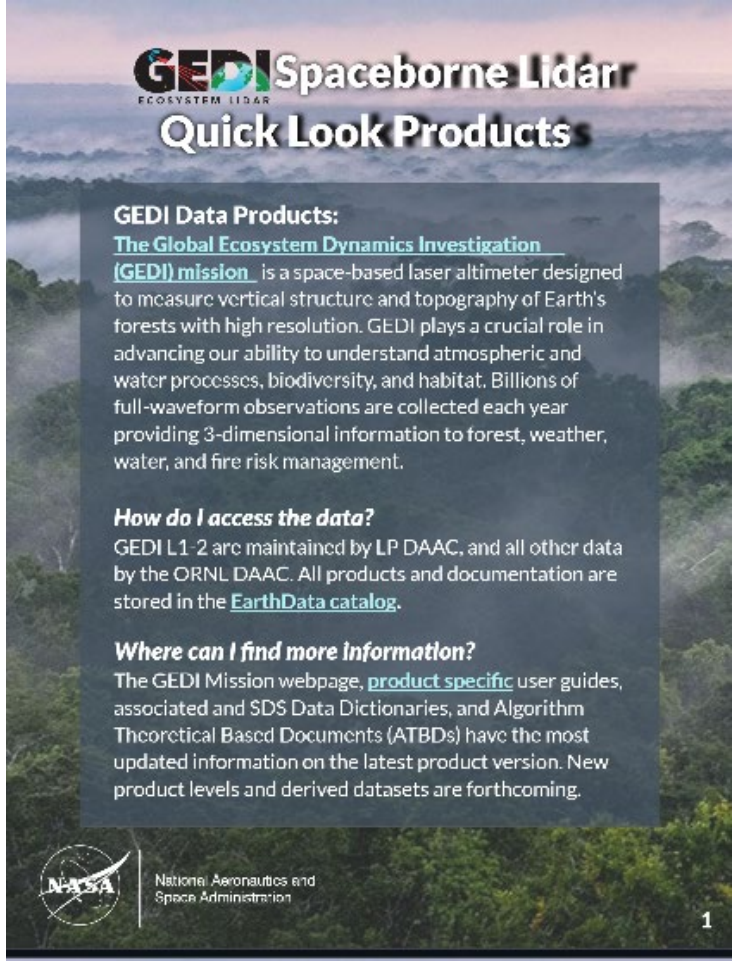
- Naming convention is specific to the data product and may include identifiers for:
  - Time Period
  - Version Number
  - Spatial Resolution
  - The Variable or Metric Itself
  - GEDI Product Level Short Name
  - Location

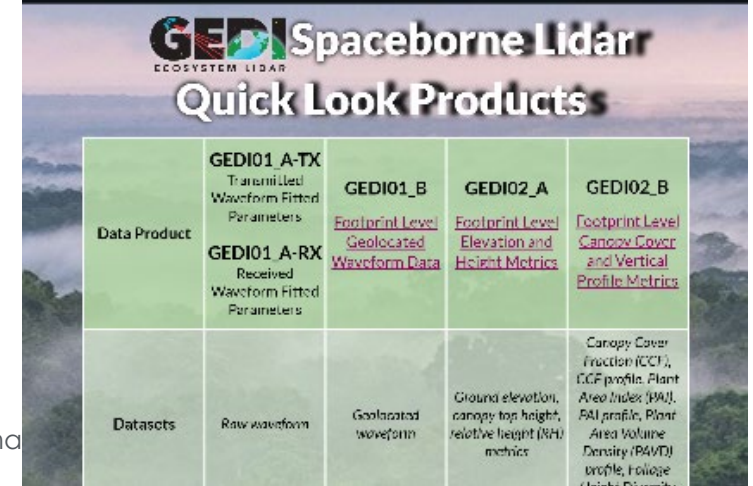
Example Structure	GEDI GeoTIFF Example Structure
Product datasets hold x number of files: • File may represent: <GEDI product>_<time_period>_<version>_<spat_res>_<metric>_<location>.tif	**The Global Vegetation Height Metrics from GEDI and ICESat-2 dataset holds 36 .tif files.** • Naming Convention: <instrument>_<metric>_<resolution>.tif – Each file has a different combination of results ▪ **<instrument>:** "gedi" or "icesat" ▪ **<metric>:** 'rh50", 'rh75", "rh90", "rh98", or "count" ▪ **<resolution>:** "100m", "200m", "1000m"

L3, L4B, gridded, or other derived products

GEDI Data Products

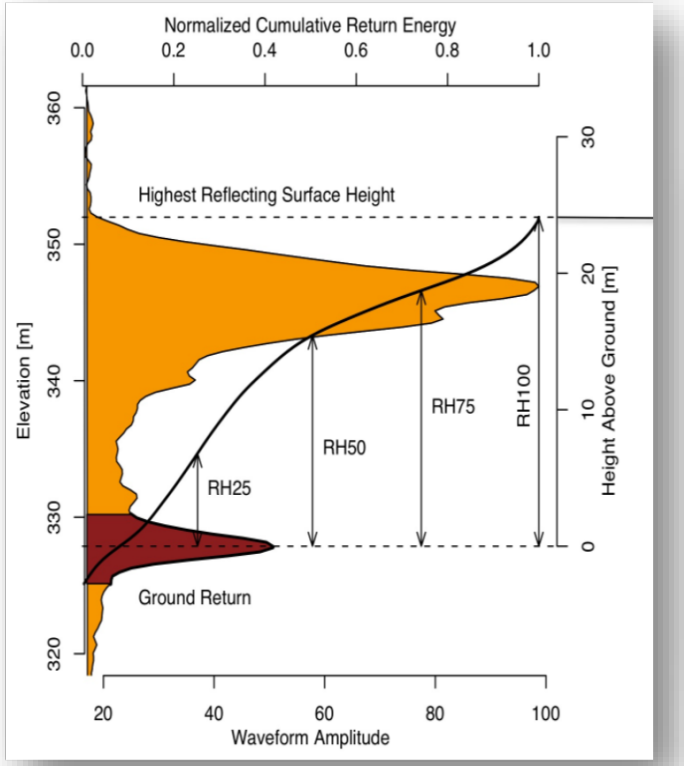
View or download the linked reference sheet for more detailed "quick looks" information.

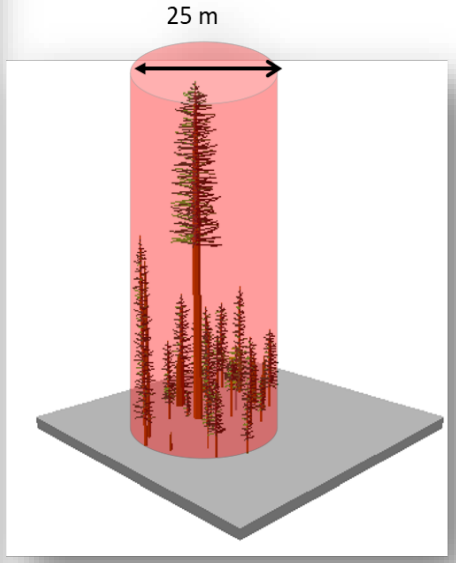




GEDI Data Products – Waveforms

Data Product	Resolution	Temporal Extent	Archive/ Format
GEDI01_A-TX Transmitted Waveform Fitted Parameters **GEDI01_A-RX** Received Waveform Fitted Parameters	25 m (~82 ft) diameter	2019-04-04 to 2023-03-16 & 2024-04-26 to Present	Not publicly available Not publicly available
GEDI01_B Footprint Level Geolocated Waveform Data			LP DAAC HDF5



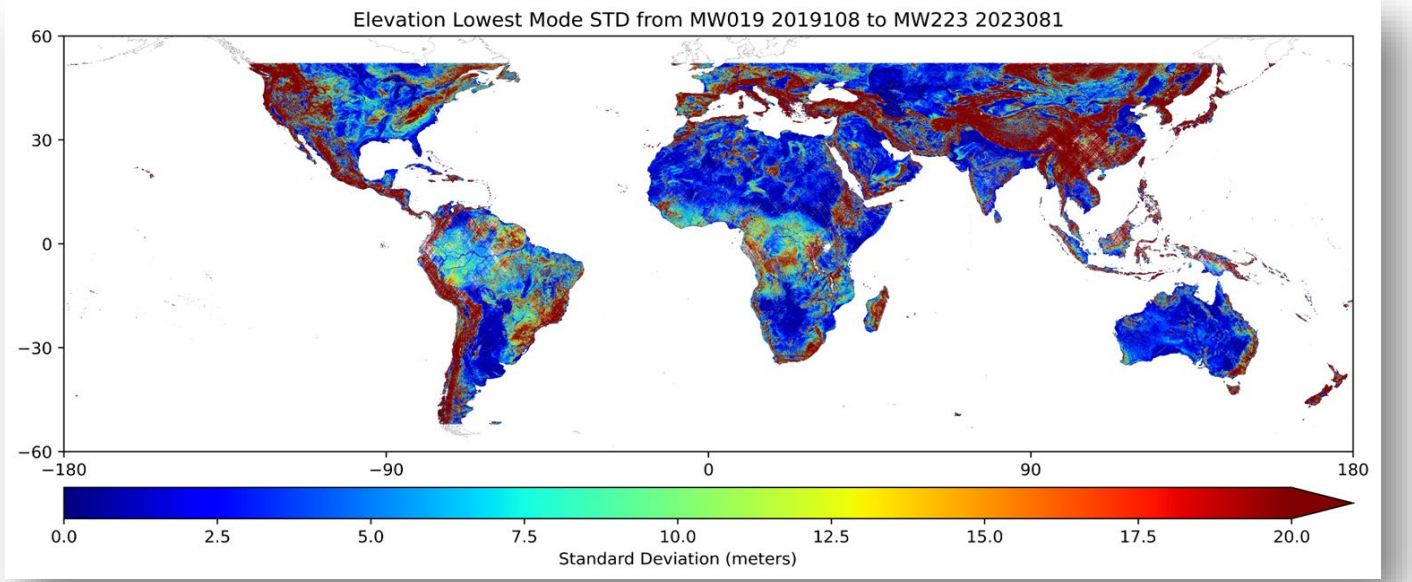


Source: The GEDI Mission

GEDI Data Products – Elevation and Height Metrics

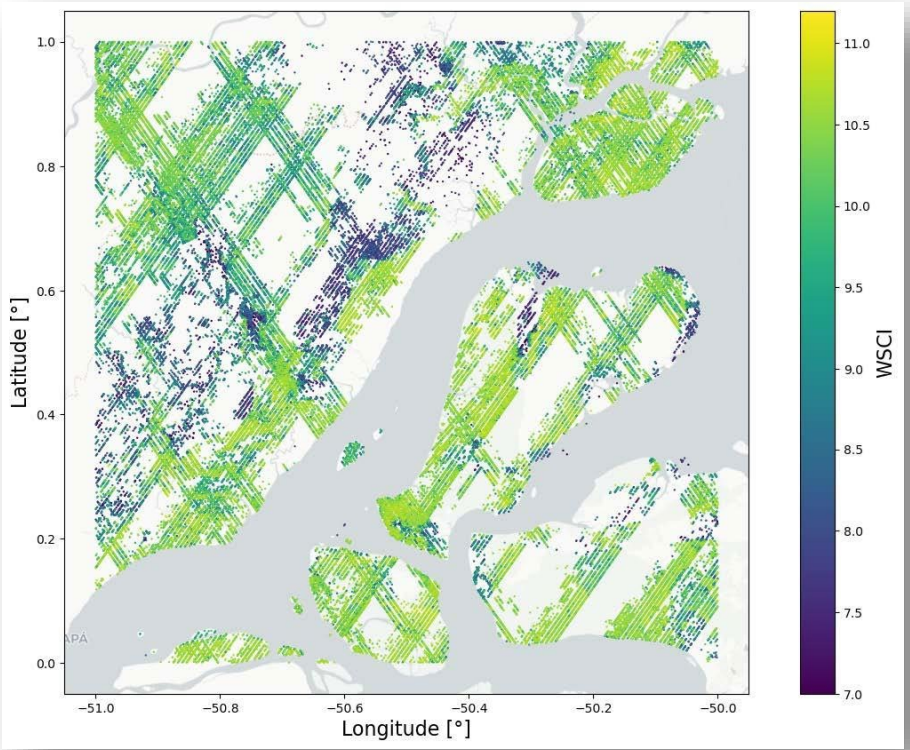
Data Product	Resolution	Temporal Extent	Archive/ Format
GEDI02_A Footprint Level Elevation and Height Metrics *Ground elevation, canopy top height, relative height (RH) metrics.*	25 m (~82 ft) diameter	2019-04-04 to 2023-03-16 & 2024-04-26 to Present	LP DAAC HDF5
GEDI03 Gridded Level 2 Land Surface Metrics *Mean canopy height, standard deviation of canopy height, mean ground elevation, standard deviation of ground elevation*	1 km (~0.6 mi) grids	2019-04-18 to 2023-03-22	ORNL DAAC GeoTIFF

Source: GEDI L3 in the ORNL DAAC.



GEDI Data Products – Vegetation Structure Metrics

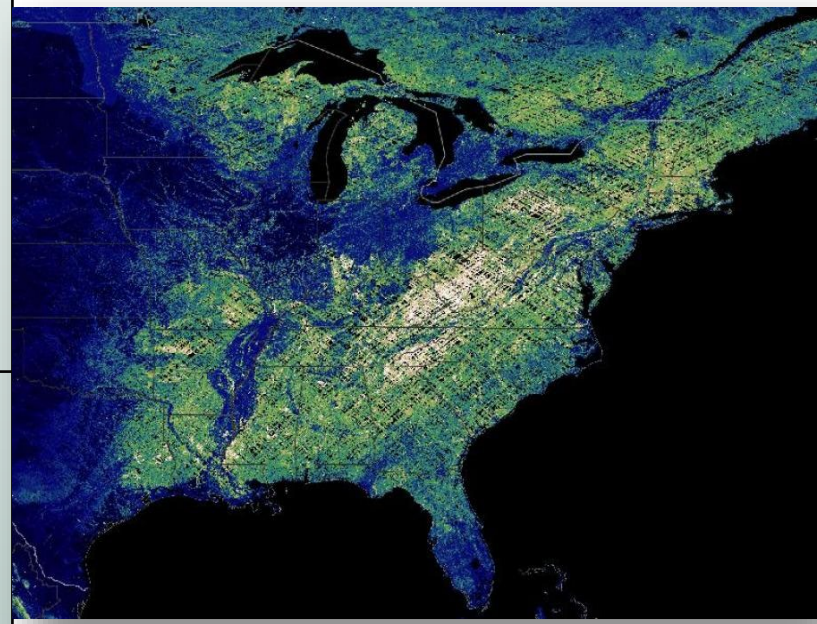
Data Product	Resolution	Temporal Extent	Archive/ Format
GEDI02_B Footprint Level Canopy Cover and Vertical Profile Metrics *Canopy Cover Fraction (CCF), CCF profile, Plant Area Index (PAI), PAI profile, Plant Area Volume Density (PAVD) profile, Foliage Height Diversity (FHD).*	25 m (~82 ft) diameter	2019-04-04 to 2023-03-16 & 2024-04-26 to Present	LP DAAC HDF5
GEDI04_C Footprint Level Waveform Structural Complexity Index *WSCI, WSCI lower and upper prediction intervals, vertical profile predictions and at lower and upper intervals.*		2019-04-17 to 2025-03-19	ORNL DAAC HDF5



Source: WSCI predictions over the Eastern Amazon L4C ORNL DAAC.

GEDI Data Products – Biomass Estimations

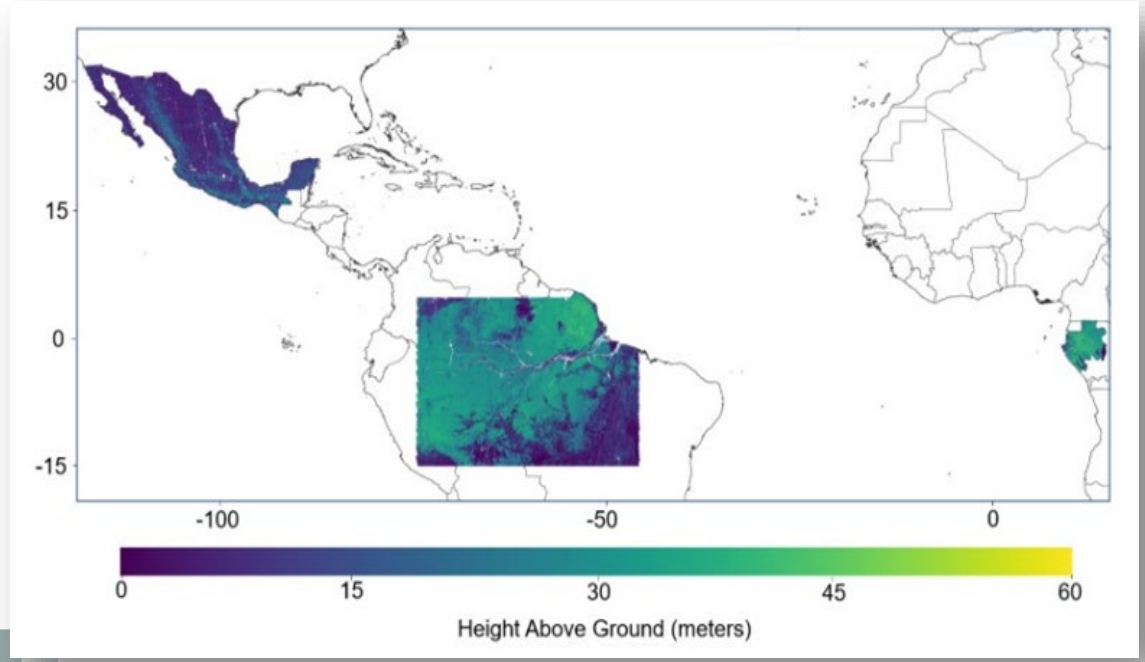
Data Product	Resolution	Temporal Extent	Archive/ Format
GEDI04_A Footprint Level Aboveground Biomass Density (AGBD) *AGBD, AGBD lower and upper prediction intervals, SE of AGBD, AGBD model prediction, and AGBD model prediction error*	25 m (~82 ft) diameter	2019-04-17 to 2025-03-19	ORNL DAAC HDF5
GEDI04_B Gridded Above Ground Biomass Density (AGBD) *Mean AGBD, uncertainty of mean AGBD, SE of mean AGBD, SE as fraction of mean AGBD, uncertainty by sampling or model method.*	1 km (~0.6 mi) grids	2019-04-18 to 2023-03-16	ORNL DAAC GeoTIFF



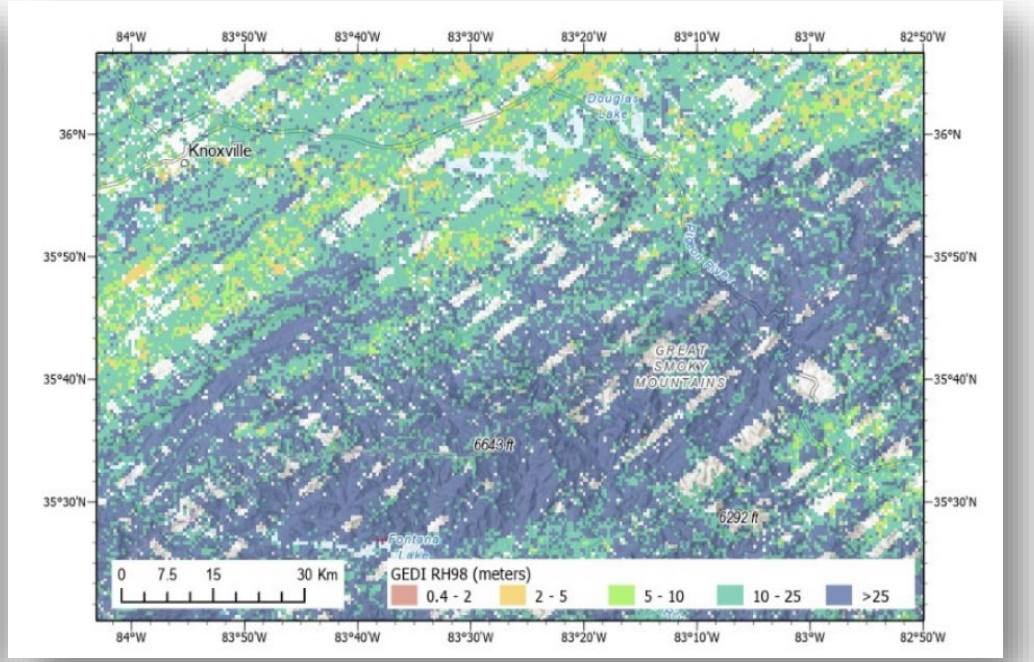
Source: NASA EarthData.

GEDI Data Products – Data Fusion Products (To-Date)

Data Product	Resolution	Temporal Extent	Archive/Format
Derived Product TanDEM-X Pantropical Forest Height and Biomass from GEDI and TanDEM-X Data Fusion	25 m, 100 m	2011-01-06 to 2021-08-18	ORNL DAAC GeoTIFF
Derived Product Global Vegetation Height Metrics from GEDI and ICESat-2	100 m, 200 m, 500 m, 1000 m	2019-01-01 to 2022-12-31	ORNL DAAC GeoTIFF



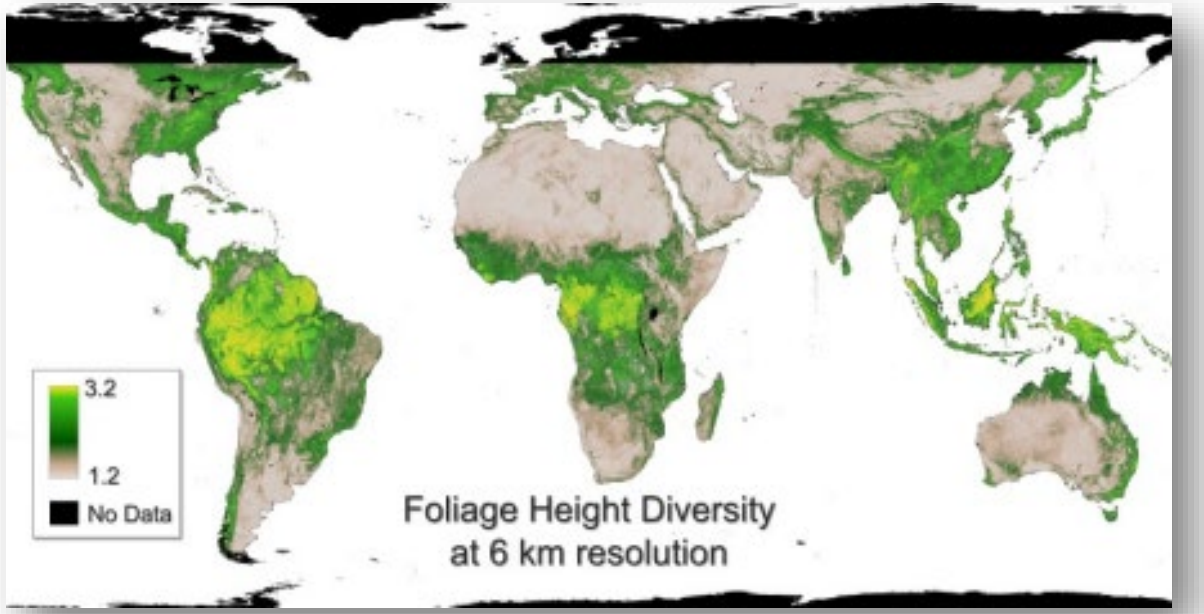
Source: Figure from ORNL



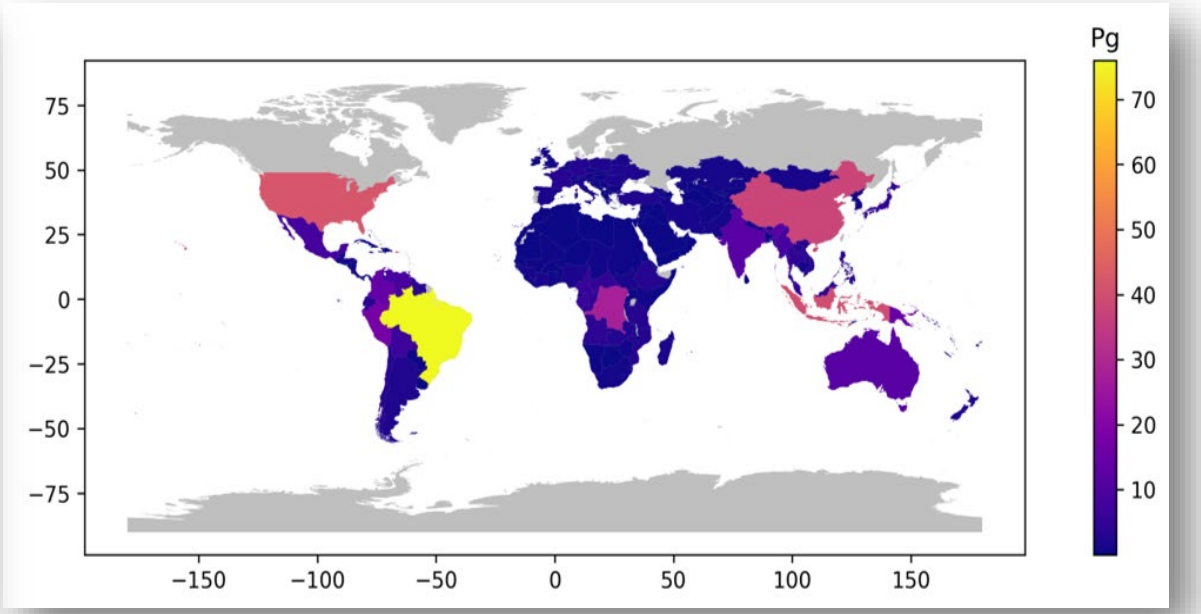
Source: ORNL DAAC

GEDI Data Products - Other Gridded and Derived Products

Data Product	Resolution	Temporal Extent	Archive/ Format
Derived Product Gridded GEDI Vegetation Structure Metrics and Biomass Density at Multiple Resolutions	1 km, 6 km, and 12 km grids	2019-04-17 to 2023-03-16	ORNL DAAC GeoTIFF
Derived Product Level 4B Country-level Summaries of Aboveground Biomass	Country level	2019-04-18 to 2023-03-16	ORNL DAAC GeoTIFF



Source: NASA ORNL DAAC.



Source: NASA ORNL DAAC.

Section 3

Accessing GEDI Data Products

Choosing a GEDI Data Product to Work With

	Data Metrics/Estimations	Temporal Period	Spatial Resolution	Advantages	Considerations
Footprint-Level **HDF5**	• **L1B** waveform • **L2A** elevation & heights • **L2B** vegetation structure • **L4A** biomass estimates • **L4C** waveform structural complexity	Footprints are **individually selectable** for **timestamp** across the mission lifetime.	Original **25m** diameter across the footprint	• Smaller scale for **local** applications • Can be used as **training** data samples, **cal/val**, **model inputs** themselves.	• **Not analysis ready**– recommend locally specific quality filtering. • **Require** coding/ **iterative processing** to subset the HDF5. • Cannot be opened in ArcGIS or QGIS.
Gridded, Aggregated, Data-Fused Products **GeoTIFF**	• **L3** height and biomass • **L4B** biomass • All **derived** products	**Aggregated** temporal **periods**, some for periods across several timestamps, others annually.	Gridded or **scaled** to 100m, 200m, 500m, 1km, 6km, 12km.	• **Readily usable** formats, **multiple resolutions**, and **time period** aggregates available. • Good for **regional**, **landscape**, or **global** studies. • Improved or extended results of footprint metrics and estimations.	• GeoTIFFs are **flexible** • **Quality** processing included but is **globally applied**.

Several Access, Processing, and Visualization Options

In Part 3

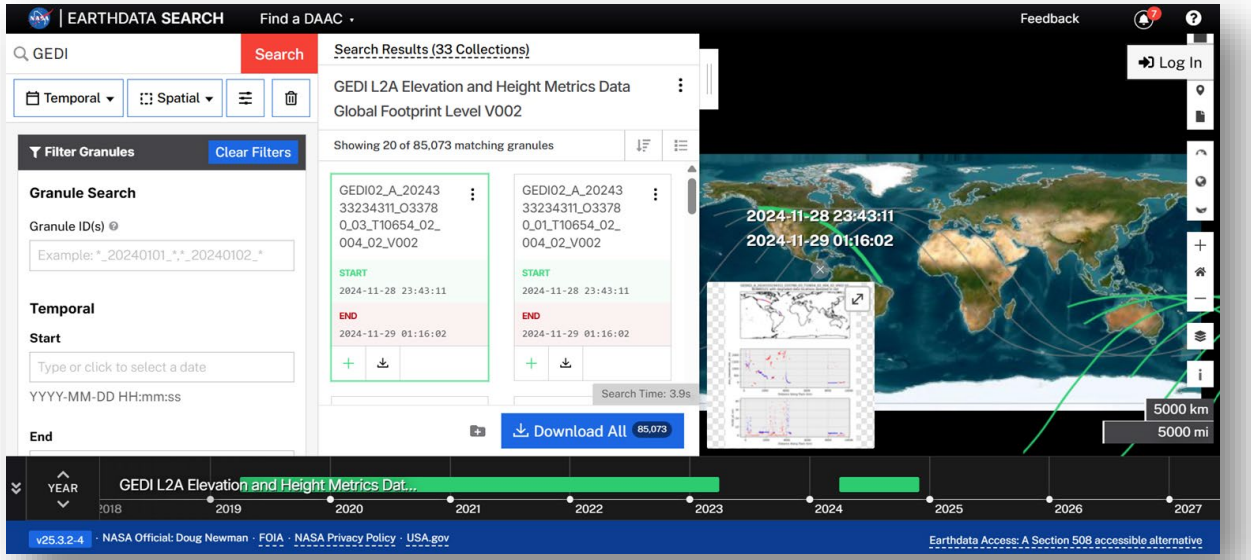
	NASA EarthData Search GUI	earthaccess Python library	TESViS	Harmony API	SlideRule Earth	rGEDI	Google Earth Engine	gediDB
* = HDF5, ** = GeoTIFF	All	All	L3**, L4A*, L4B**	L1B*, L2A*, L2B*, L4A*, L4C*	L1B*, L2A*, L4A*	L1B*, L2A*, L2B*,	L2A, L2B, L4A as vector & monthly rasters. L4B**, Gridded Veg Structure**	L1B*, L2A*, L2B*, L4A*, L4C*
Map Visualization Tool	✓		✓ (after processing)	Depends on the tool	✓	✓ (code)	✓	
3D Visualization Tool					✓	✓ (3D ALS point clouds)		
GUI	✓		✓		✓		✓	
API		✓	✓	✓	✓		✓	✓ (merge multiple products & formats)
Cloud Data Access	✓ (AWS)	✓ (AWS)		✓ (AWS)	✓ (AWS)		✓ (Google)	✓ (AWS)
Spatial Filtering	✓ (overlap, no clip)	✓	✓ (point only)	✓ (clip and subset)	✓ (clip and subset)	✓ (clip and subset)	✓ (clip and subset)	✓
Temporal Filtering	✓	✓	✓	✓	✓	✓	✓	✓
Python		✓	✓	✓	✓	NA	✓	✓
R		NA	✓			Documentation		
Command Line				✓	✓			
Tools	ORNL DAAC Tools		✓	✓	✓	✓ (customization)	✓	✓ (customization)

Tools for Accessing GEDI Data – NASA Earthdata Search and DAAC Tutorials

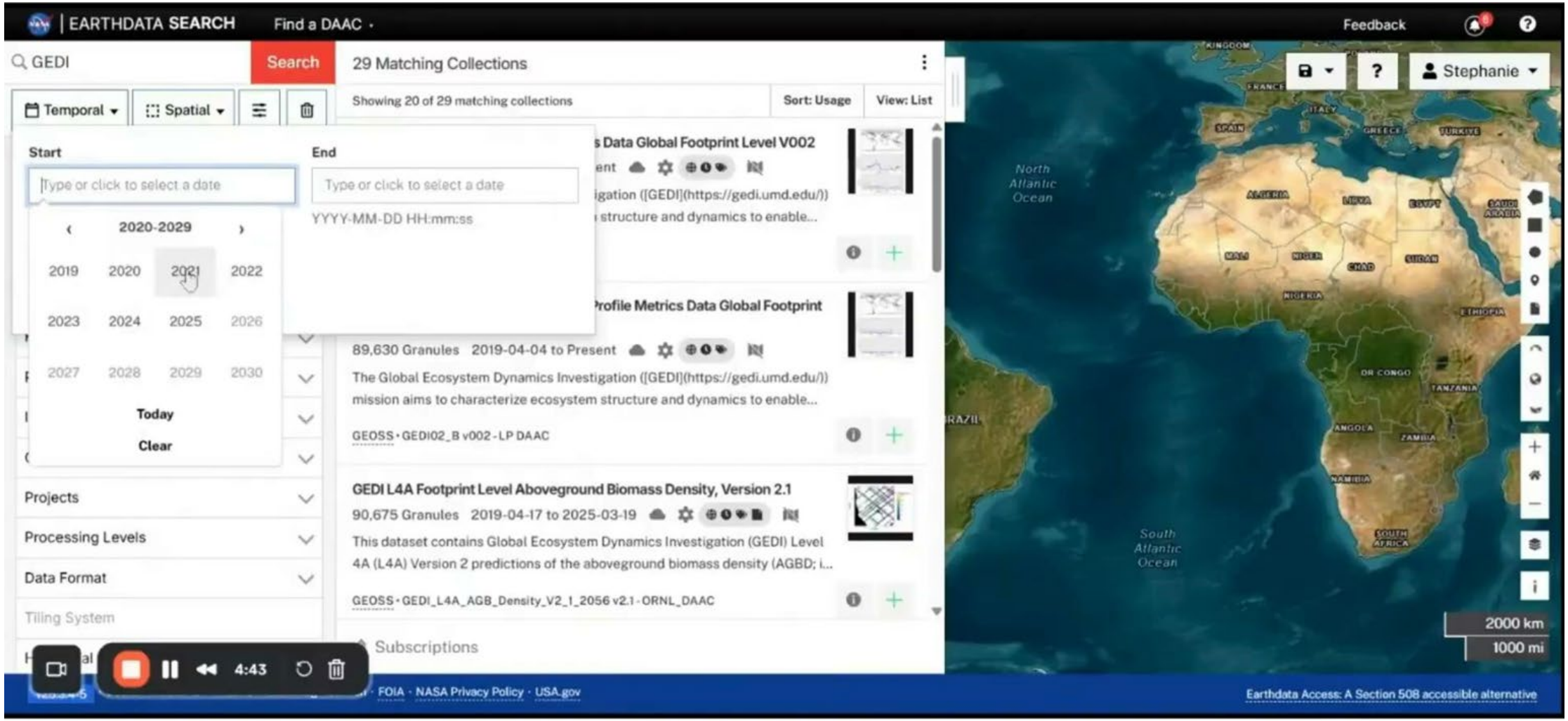
Any GEDI data product is available on Earthdata Search for download.

- EarthData is great for retrieving the gridded, aggregated, derived, and fused datasets.
  - Can be used to download HDF5 files, **but further processing tools or programming alternatives will be needed.**

  Existing tutorials and webinars for accessing GEDI data:
  - NASA LP DAAC Find and Use GEDI Webinar
  - LP DAAC GEDI-Data-Resources Github
  - NASA ARSET: Accessing and Analyzing Lidar Data for Vegetation Studies Part 2/4
  - Jupyter notebook tutorials in Python and R via NASA ORNL DAAC tutorials



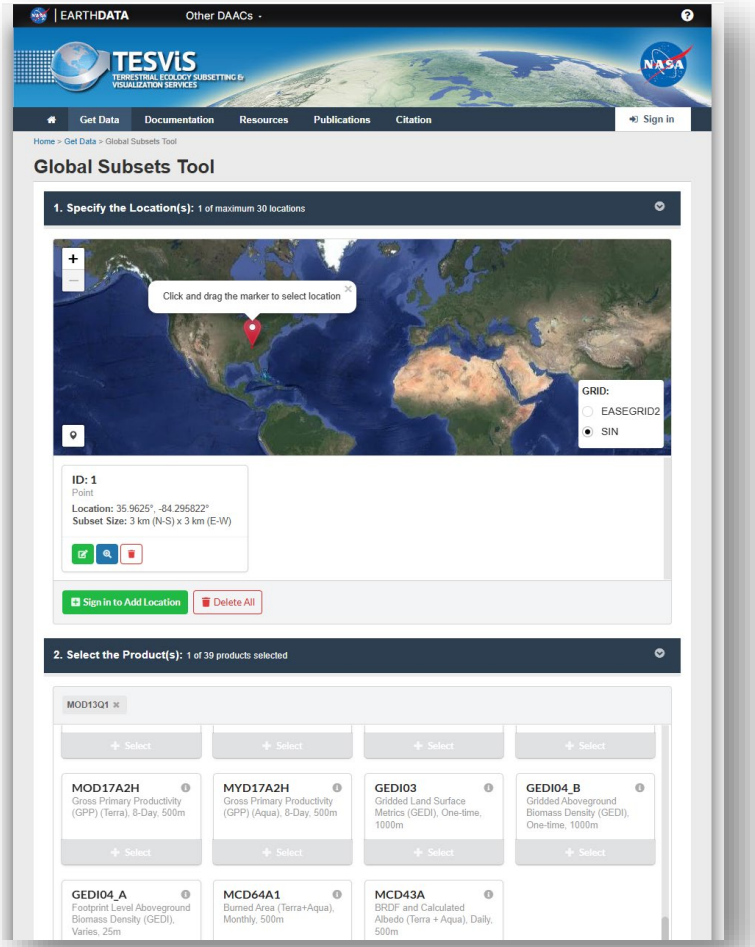
Tools for Accessing GEDI Data – NASA Earthdata Search



Tools for Accessing GEDI Data – TESViS

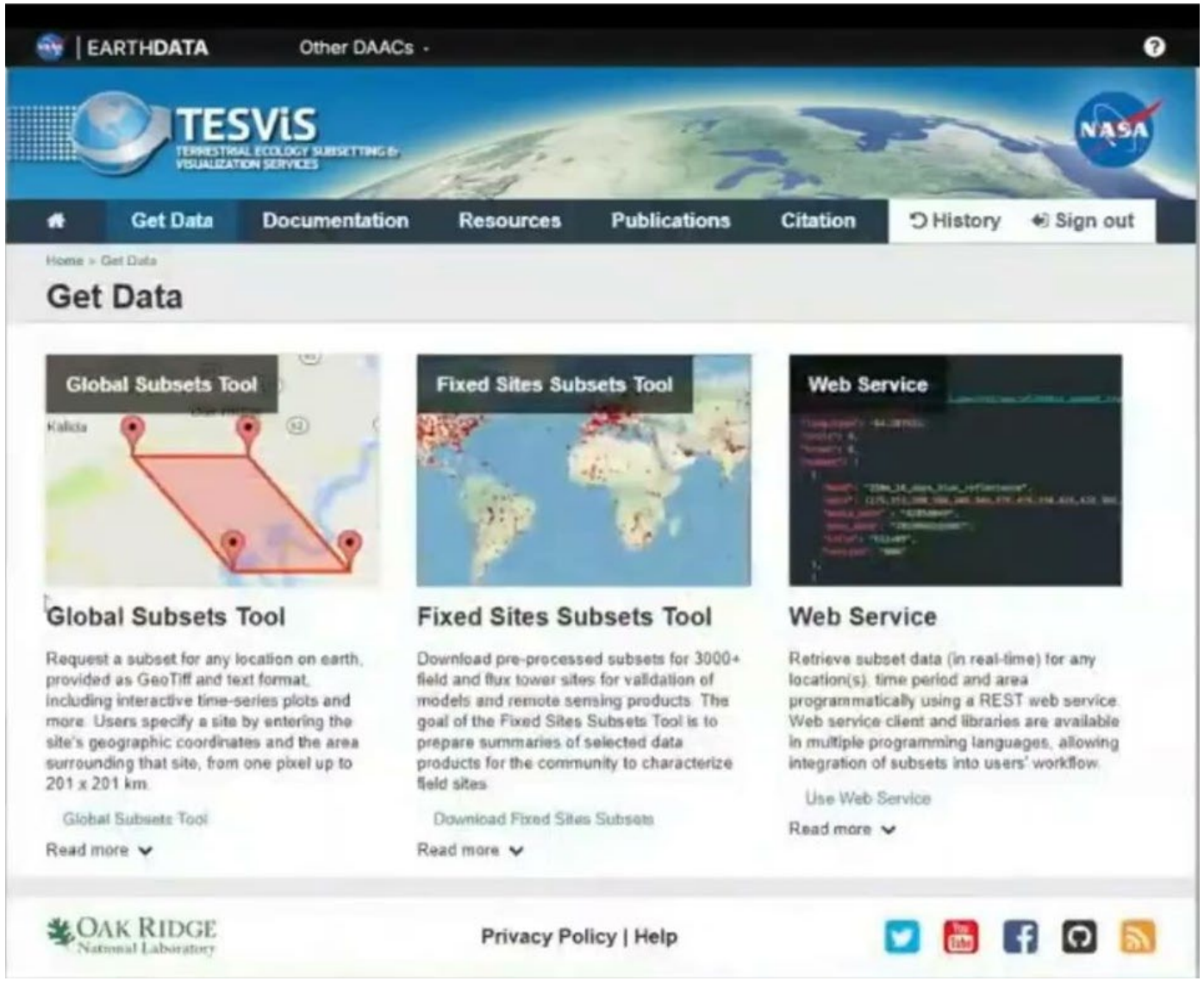
Terrestrial Ecology Subsetting and Visualization Services (TESViS)

- Global Subsets by location, Fixed Sites Tool for pre-processed subsets, REST API web service, or find related tutorials and webinars.

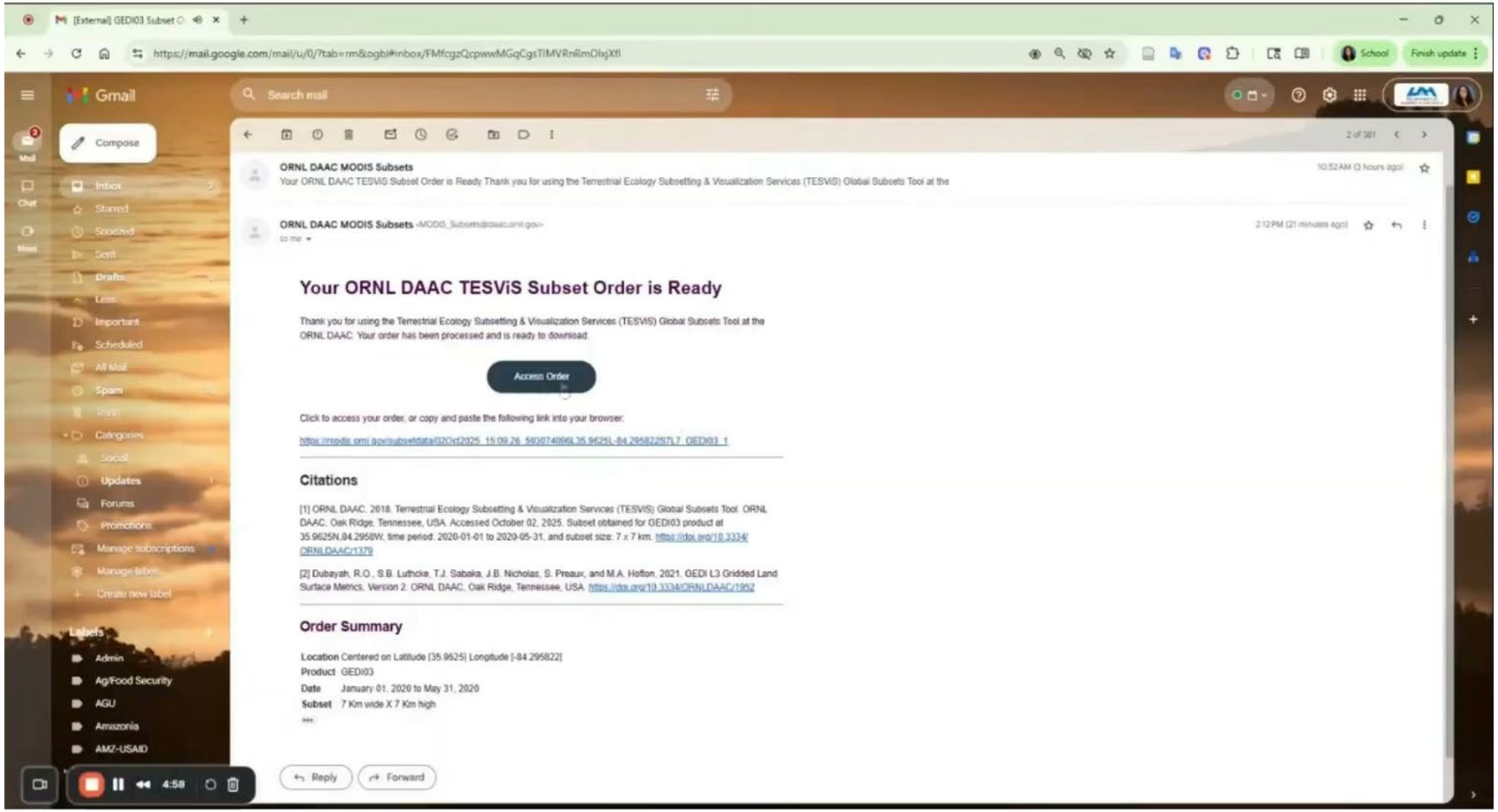


Easy selection of **L3** heights or **L4B** biomass at **1km** grids or footprint **L4A** biomass data only.

TESViS Example With L3 Gridded Height and Biomass Product



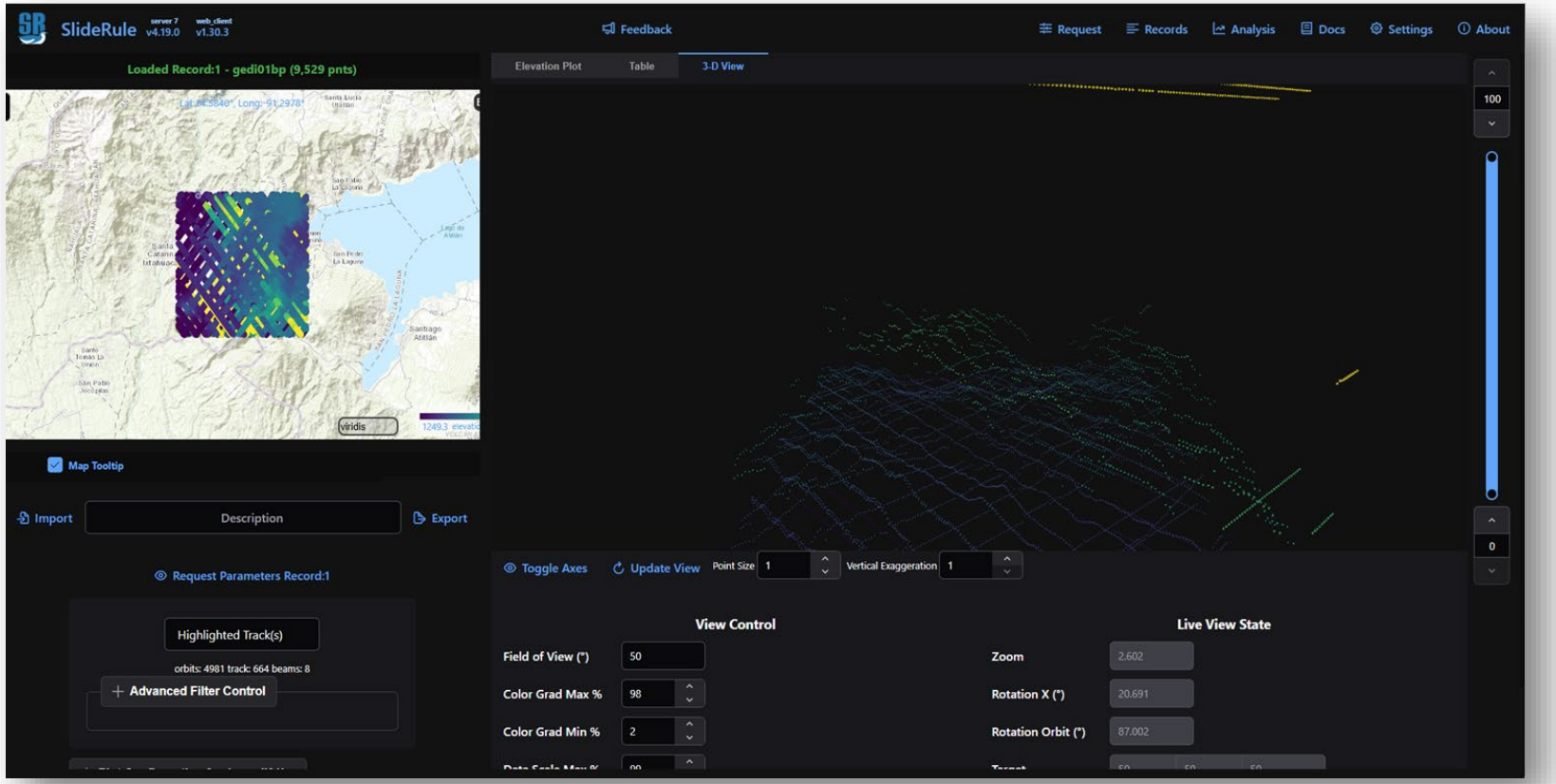
Email Notification when TESViS Download is Ready



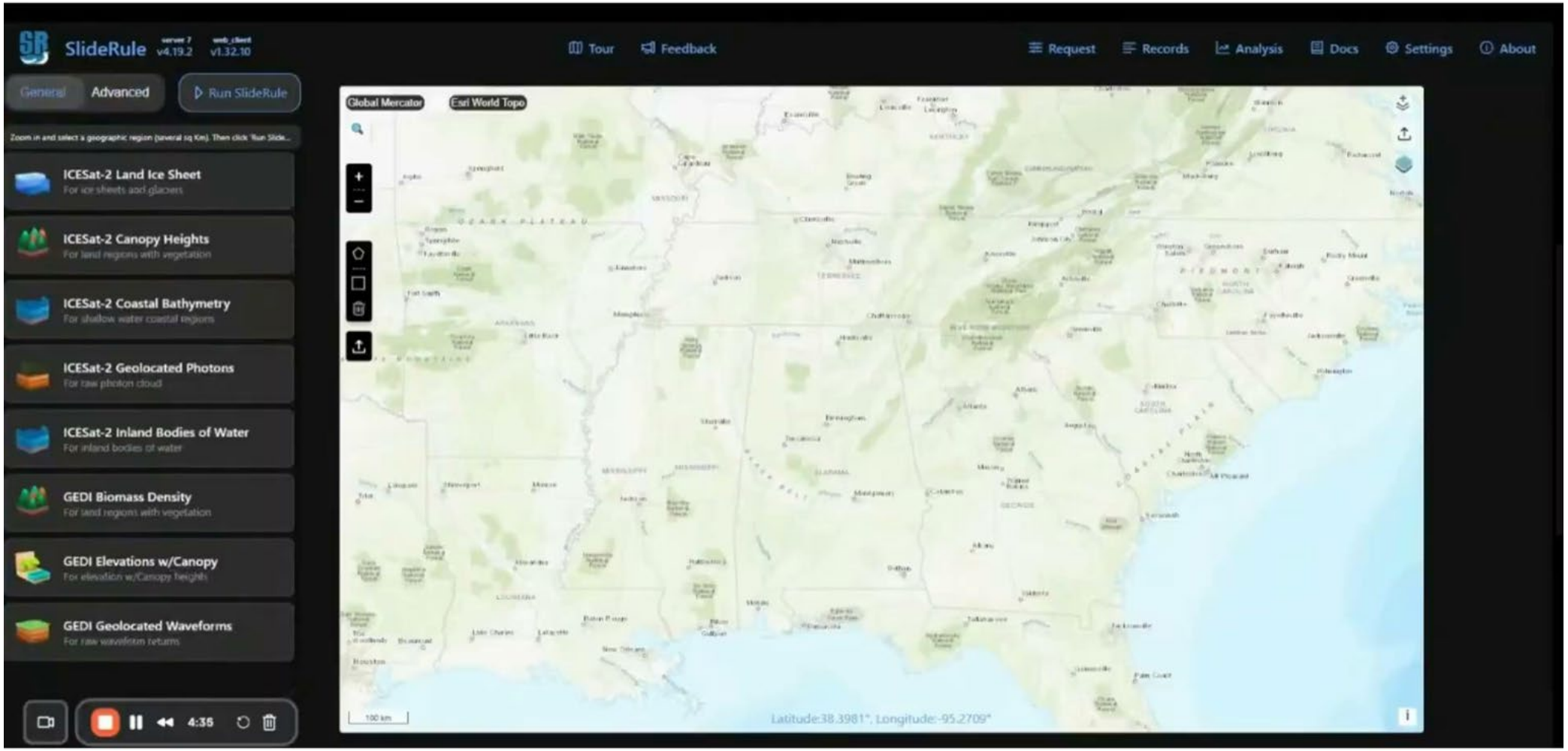
Tools for Accessing GEDI Data – SlideRule Client

L1B waveforms, L2A heights, & L4A biomass

- SlideRule API Documentation
- SlideRule Earth: Science data processing as a service
- SlideRule Client Web Application



SlideRule Client



Tools for Accessing GEDI Data – Harmony API

What do you do once you have the spatial and temporally relevant HDF5 files?

- Are the files clipped to the spatial extent?
- Do the files include ALL variables? How do you down select to a handful relevant to your analysis?
- Transform the data to a preferred and format compatible across multiple geospatial platforms.
- Harmony API works for L1B waveforms, L2A heights, L2B structure, L4A biomass, and L4C structural complexity – all footprints only with additional capabilities to subset the data.

Tutorial Requirements

- NASA Earthdata Access Account
- Google Drive Account
- Google Colab

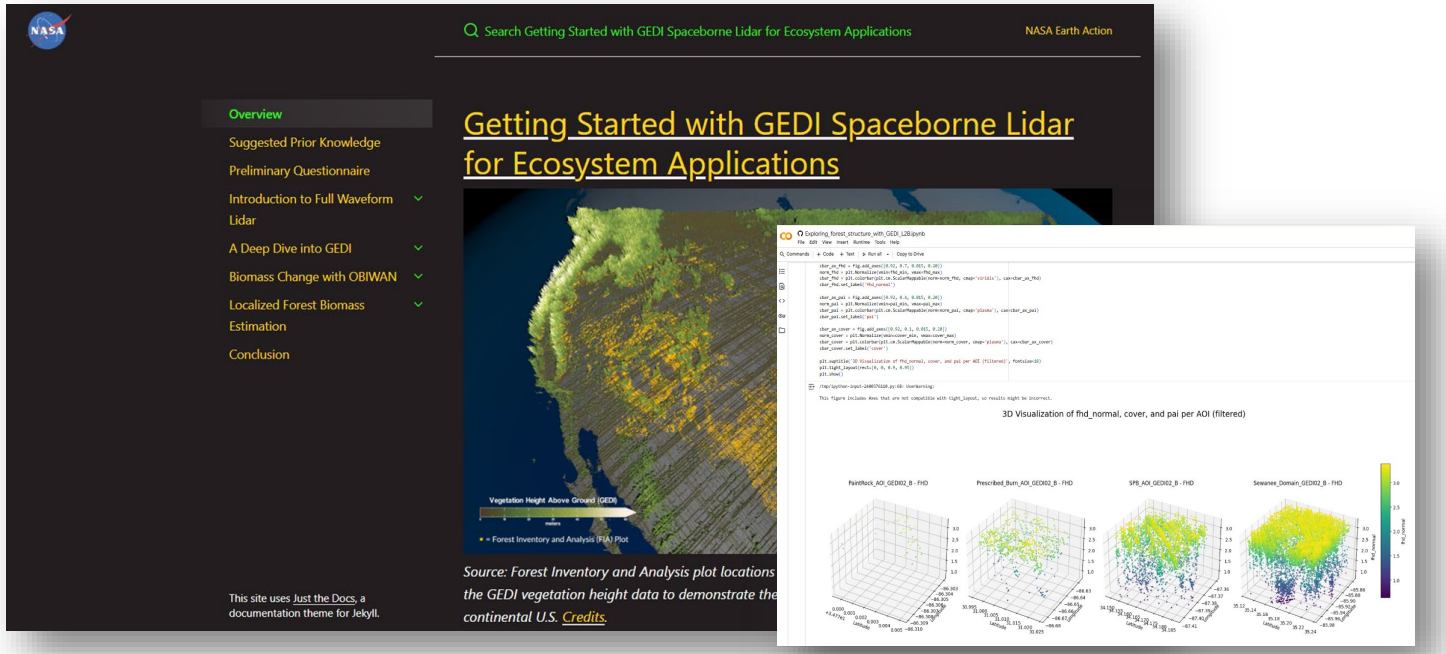
The Google Colab python notebook

- A GEDI data download, subset, analysis and visualization over a study area of Pinyon Pine forage sites in New Mexico, and Paint Rock Research Forest in North Alabama (part of GEO-TREES field data network).
- The Google Colab notebook indicates areas with "?" where the participants could change the code lines if plugin in a different GEDI data product or their own defined study area.

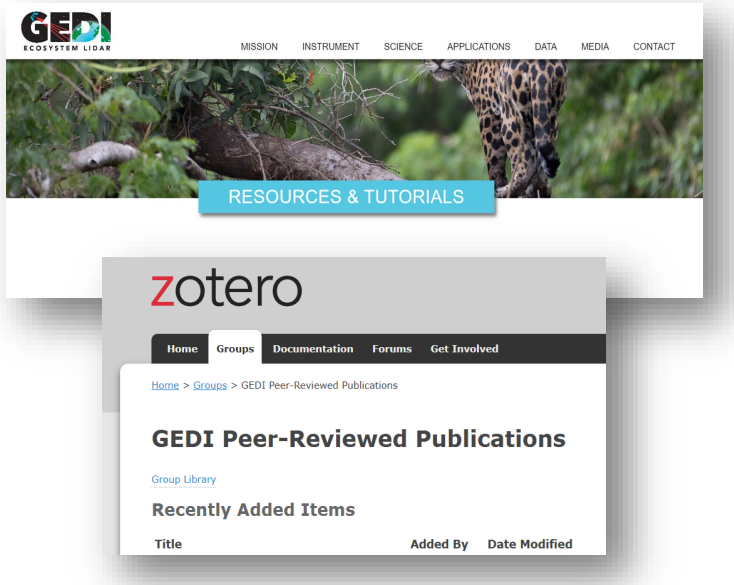
Select_GEDI_L2B_footprints.ipynb

Additional Resources & How to Stay Updated

- Reference the Algorithm Theoretical Based Documents and User Guides for a deeper understanding in data characteristics.
- ORNL & LP DAAC sites for acquiring and processing data.
- Google Earth Engine, rGEDI, gediDB, and the tools we mentioned are advancing functionalities.



Take the NASA EarthRISE GEDI applications focused training with hands-on tutorials for data preparation and analysis.



The research is active! Reference the collection of GEDI-related literature, Zotero group, and resources.

Part 2: Introduction to the GEDI Mission and Its Derived Products

Summary

Summary

- **Mission Objectives & Applications**: ISS-based GEDI (2019-2023, resumed 2024) quantifies ecosystem structure for carbon cycle science, fire management, weather prediction, water resources, and topography mapping beneath vegetation
- **Data Product Levels**: L1B (geolocated waveforms), L2A (elevation & height), L2B (canopy cover, PAI, PAVD, foliage height diversity), L4A (footprint biomass), L4C (structural complexity index)—each revealing different vegetation characteristics
- **File Formats & Resolutions**: Footprint datasets (~25m) use HDF5 hierarchical format requiring specialized processing; gridded products (L3, L4B at 1km+) use GeoTIFF format with quality filters pre-applied
- **Data Fusion Products**: GEDI combined with ICESat-2 (increased sampling), TanDEM-X InSAR (wall-to-wall tropical maps), and Landsat (canopy height) to overcome discrete sampling limitations
- **Calibration & Future Missions**: Field plots (USFS FIA) establish allometric relationships validating GEDI observations; future missions (EDGE, STV) will enhance sampling density and change detection
- **Access Tools**: Earthdata Search (download), TESViS (L3/L4B subsetting), SlideRule Client (cloud processing), Harmony API (HDF5 transformation), plus coding platforms (rGEDI, Google Earth Engine)

Session 3

Due to the lapse in federal government funding, ARSET is unable to conduct Session 3 of this training series.

We sincerely regret this inconvenience.

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 11/06/2025
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 11/20/2025**

- **Certificate of Completion:**
  - Attend the 2 live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Contact Information

Trainers:

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  - savannah.cooley@nasa.gov

- ARSET Website
- ARSET YouTube

Resources

- Dubayah, R.O., S.B. Luthcke, T.J. Sabaka, J.B. Nicholas, S. Preaux, and M.A. Hofton. 2021. GEDI L3 Gridded Land Surface Metrics, Version 1. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1865
- Dubayah, R., Blair, J. B., Goetz, S., Fatoyinbo, L., Hansen, M., Healey, S., Hofton, M., Hurtt, G., Kellner, J., Luthcke, S., Armston, J., Tang, H., Duncanson, L., Hancock, S., Jantz, P., Marselis, S., Patterson, P. L., Qi, W., & Silva, C. (2020). The global ecosystem dynamics investigation: High-resolution laser ranging of the Earth's forests and topography. Science of Remote Sensing, 1, 100002.
- Kellner, J. R., Armston, J., & Duncanson, L. (2023). Algorithm theoretical basis document for GEDI footprint aboveground biomass density (AGBD) [Article]. Earth and Space Science, 10, e2022EA002516. https://doi.org/10.1029/2022EA002516.
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- Potapov, P., Li, X., Hernandez-Serna, A., Tyukavina, A., Hansen, M. C., Kommareddy, A., Pickens, A., Turubanova, S., Tang, H., Silva, C. E., Armston, J., Dubayah, R., Blair, J. B., & Hofton, M. (2021). Mapping global forest canopy height through integration of GEDI and Landsat data. Remote Sensing of Environment, 253, 112165.

Tang, H. Armston, J. (2019, December 6). Algorithm Theoretical Basis Document for GEDI L2B: Footprint canopy cover and vertical profile metrics (Version 1.0). USGS/LP DAAC. LP DAAC


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!