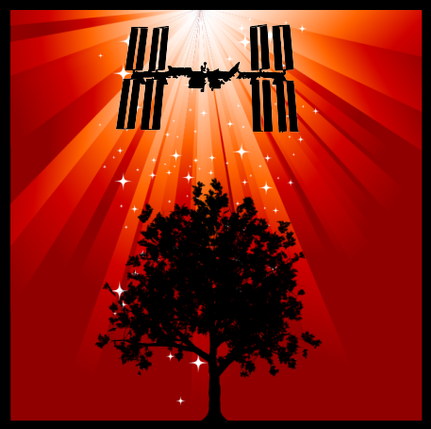
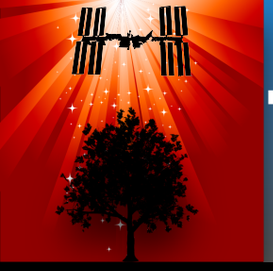
Remote Sensing of Ecosystem Structure and Dynamics



GEDI LIDAR
GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

Ralph Dubayah
University of Maryland
Principal Investigator



The Importance of Ecosystem Structure

- Ecosystem structure key element of Earth System
  - Carbon and nutrient cycling
  - Habitat quality and biodiversity
  - Forest health and productivity
  - Fire modeling
  - Hydrological cycling
  - Policy needs (REDD++, and others)

Ecosystem Structure is *Dynamic*

- Results from multiple process
- Organization and reorganization
- Disturbance key process -> both natural and anthropogenic
- Development across many temporal and spatial scales

One of the three important unifying concepts:
structure, composition and function
but difficult to quantify

The Role of Remote Sensing

- 40 years of remote sensing have not provided the needed 3D structure of forests

- Dominated by passive optical sensors
  - Landsat, AVHRR, MODIS, SPOT, VIIRS
  - Land cover, biological condition and phenology, disturbance

- Heroic efforts fall short -> *basic limitations of passive optical remote sensing for vertical structure*

- Entering new era of active remote sensing
  - Dominated by radar and lidar approaches
  - GEDI, ICESAT2, Tandem-X, NISAR, BIOMASS

Outline

- Brief overview of ecosystem structure
- Global Ecosystem Dynamics Investigation
  - Science goals
  - Instrument and measurement approach
  - Science data products
  - Potential of fusion

What is Ecosystem Structure?

- Many ecological definitions
  - “A set of functional elements of ecosystems that contain the spatial location of each component (biotic and abiotic) and the relationships between them”

- Our focus:

Spatial and vertical structure of forest canopy elements and variables derived from these elements

The Role of Canopy Structure

Vertical and Spatial Structure

Ecosystem Function

Composition and Floristics

Habitat and Biogeochemical Status

HUMAN IMPACTS

Habitat Heterogeneity

CLIMATE IMPACTS

Habitat Quality and Biodiversity

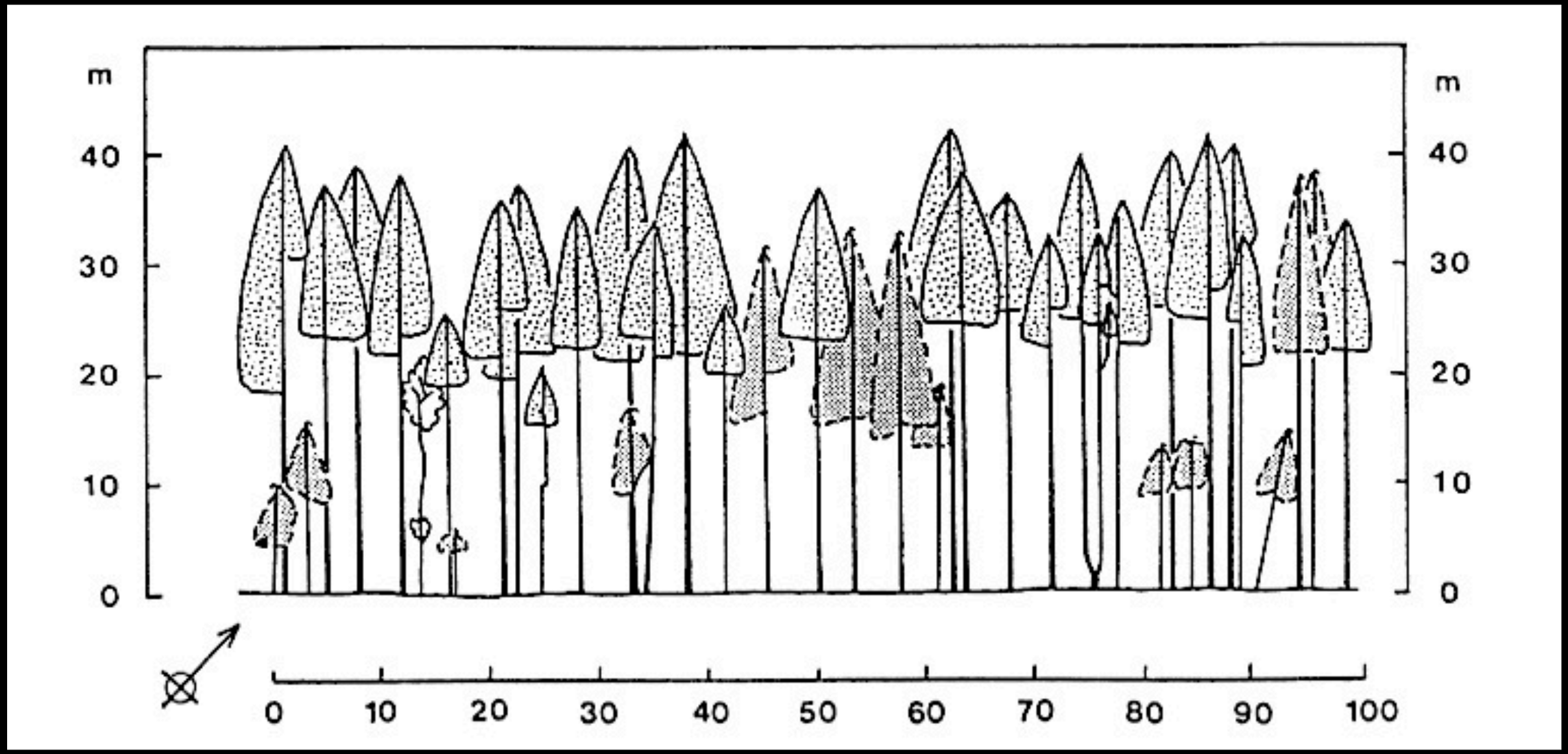
Biogeochemical Fluxes

Other Ecosystem Services

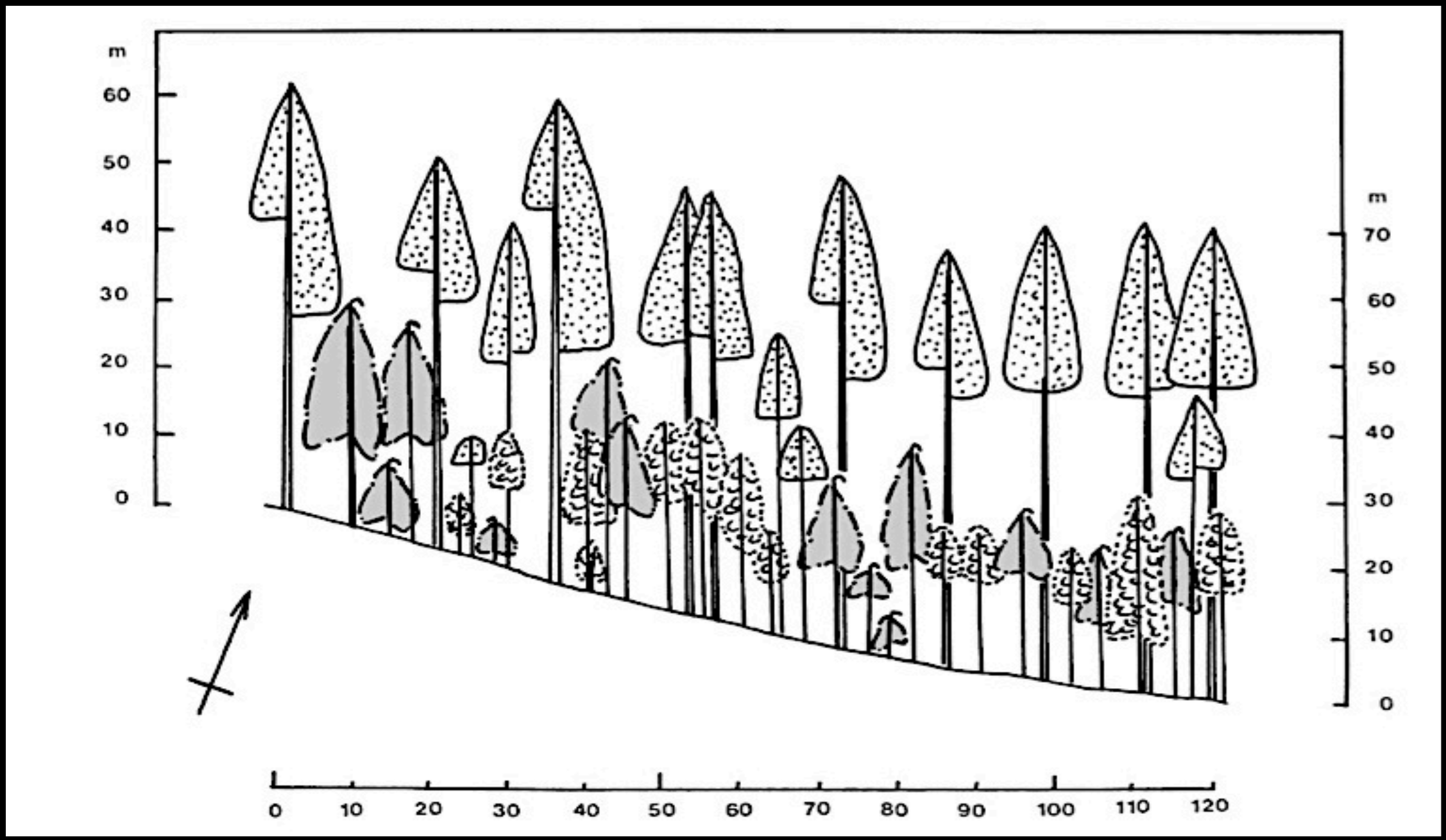
Some Desired Structures

Variable
Gap structure/connectivity
Canopy cover (vertical profile)
Maximum/mean canopy height
Canopy height profile
Canopy texture
Height size distribution
Landscape pattern/patch/edge
Topography
Dry biomass
Basal area
Stem density
LAI
Foliar Profile
Seral Stage
Canopy Layering

Accumulation/Exclusion



Maturation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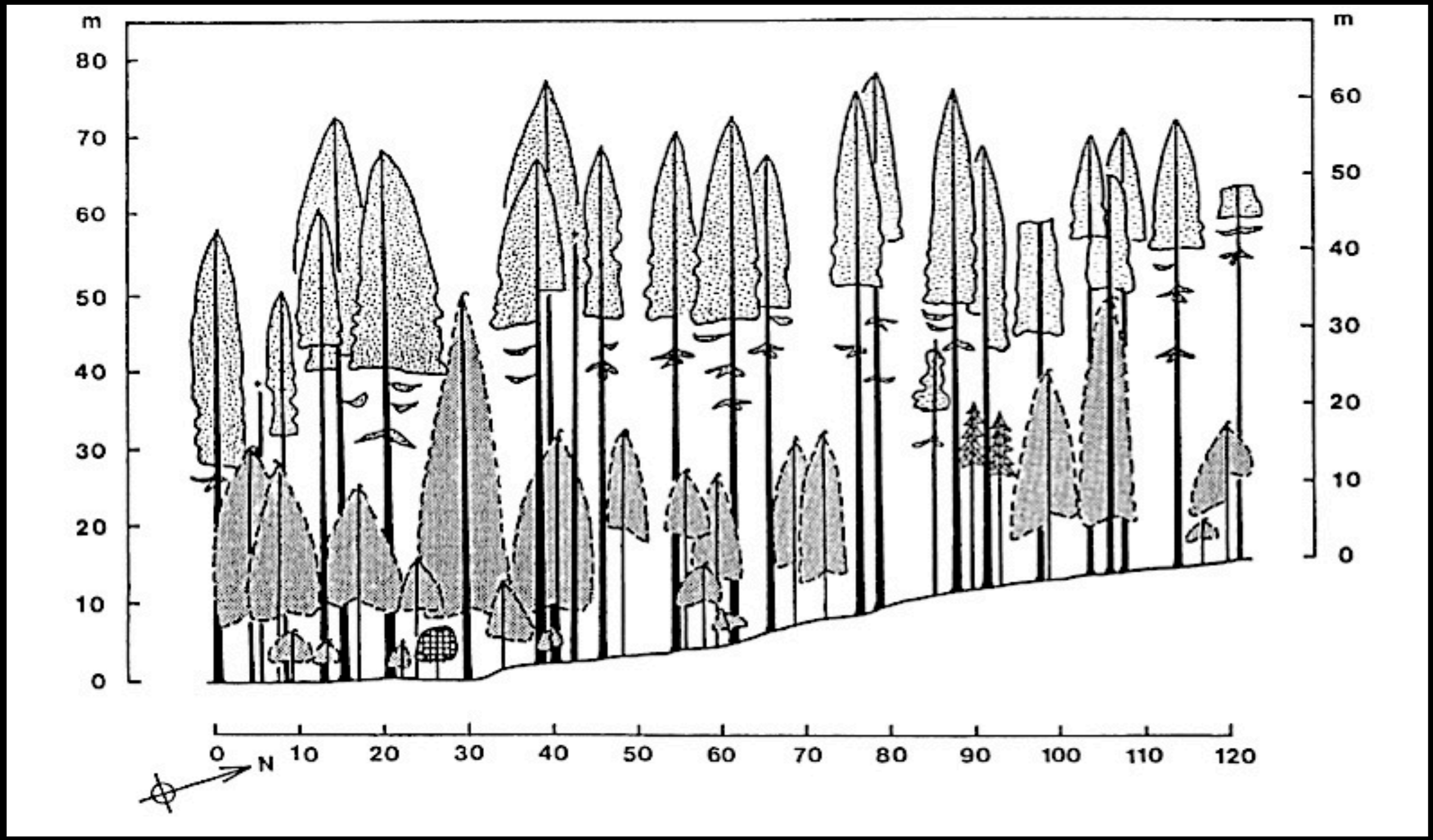
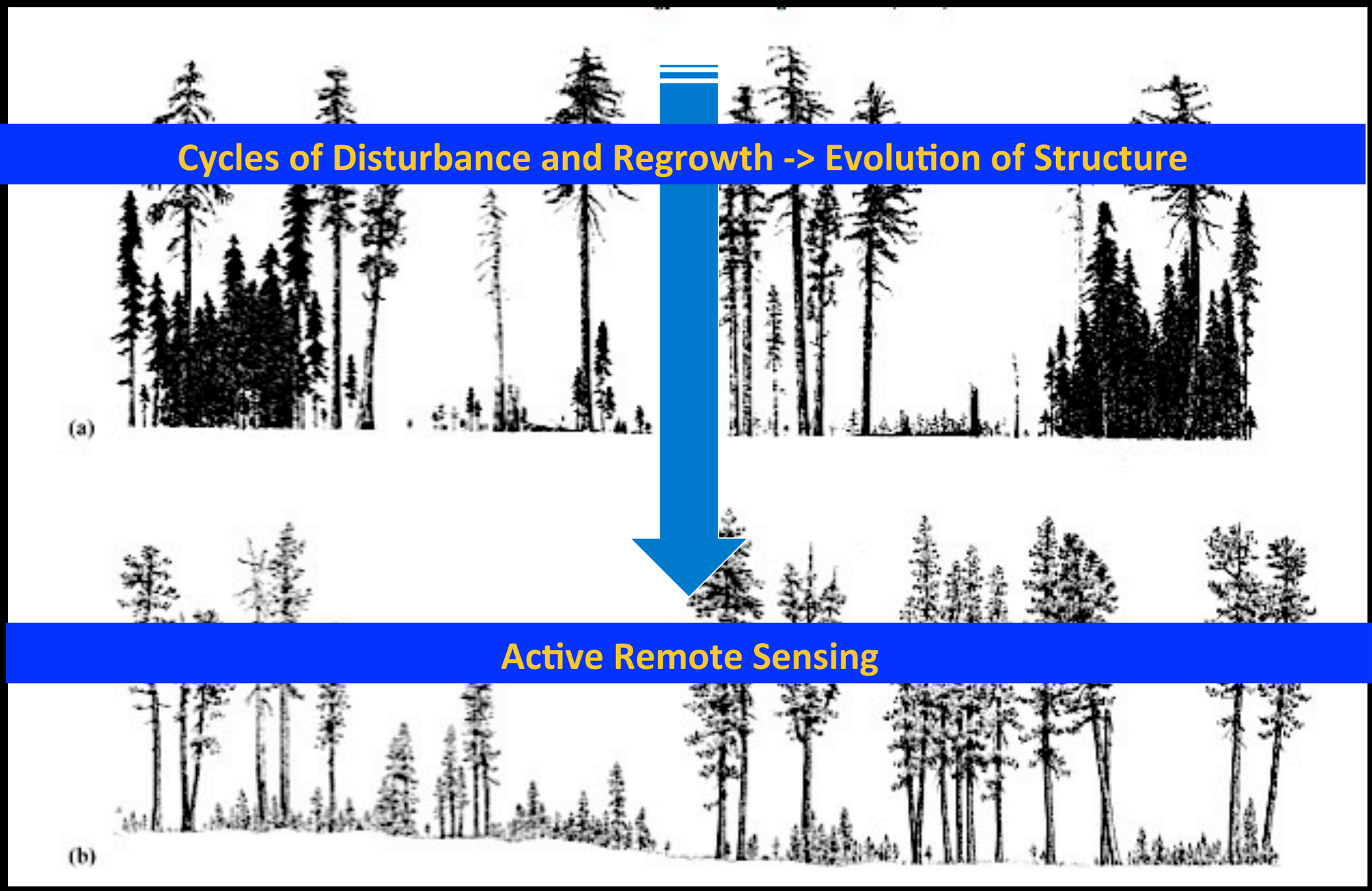
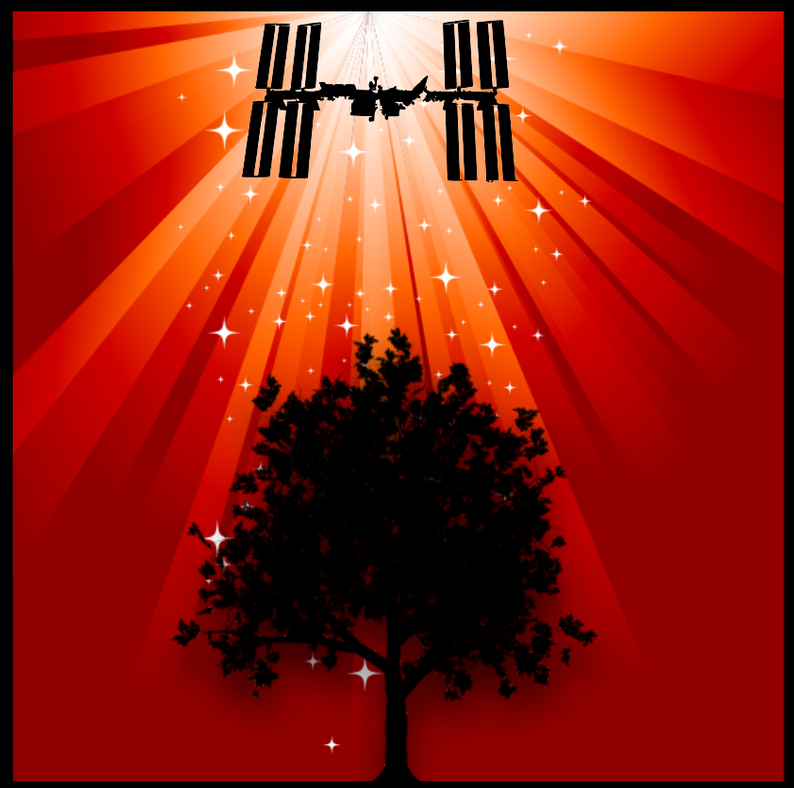
Vertical Diversity



Old Growth


Cycles of Disturbance and Regrowth -> Evolution of Structure
(a)
Active Remote Sensing
(b)

Global Ecosystem Dynamics Investigation



GEDI LIDAR

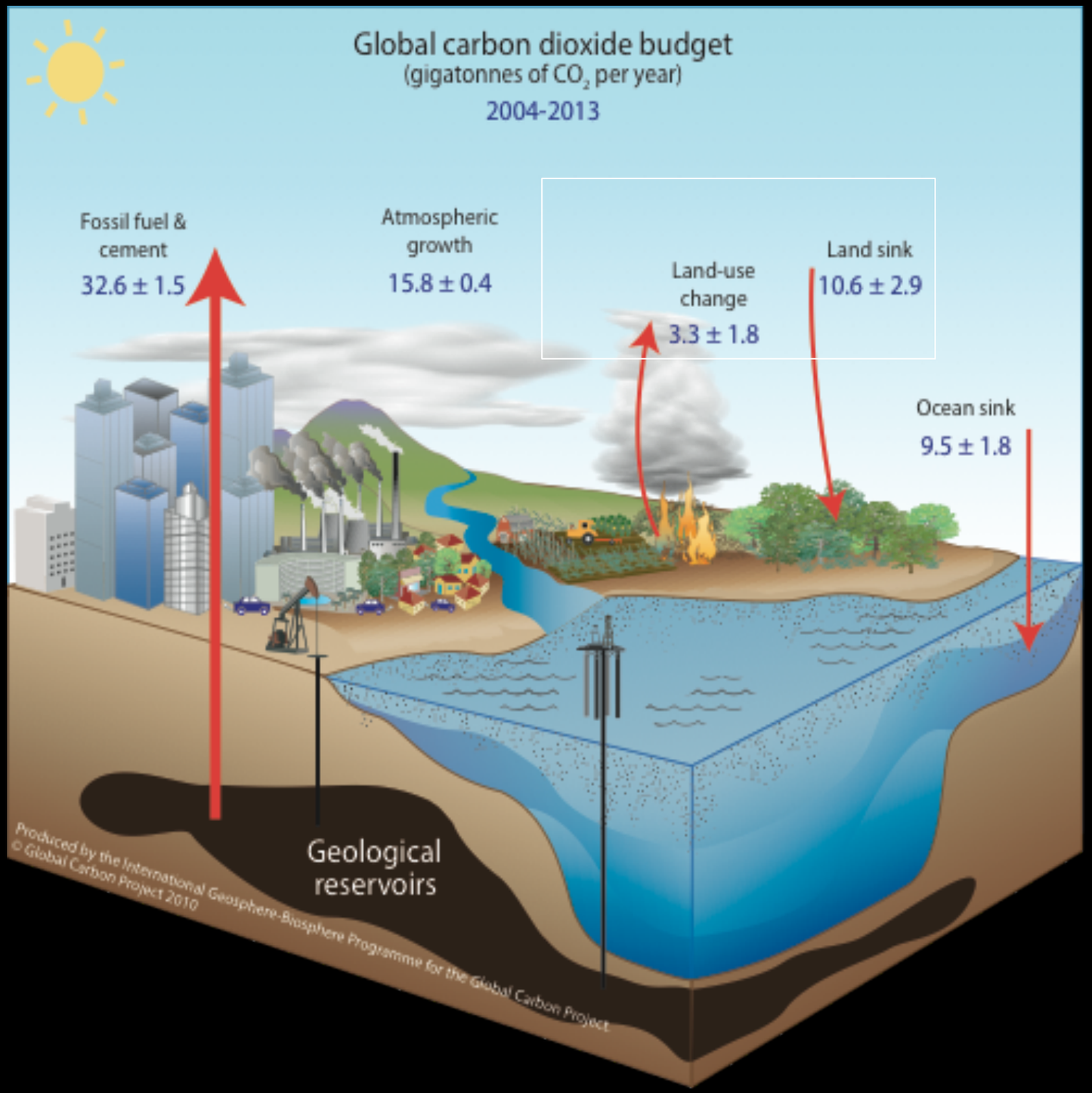
Earth Ventures Instrument (EVI)

- Selec t 2014 for $94 M
- P
- M lidar inst
  NA eflight Cen
- Deployed o International Space Station in 2018

Science Objectives

Question	Quantify
What is the carbon balance of the Earth's forests?	Forest Biomass
	Disturbance and Recovery
How will the land surface mitigate atmospheric CO_2 in the future?	Carbon Sequestration Potential
How does forest structure affect habitat quality and biodiversity?	Vertical Forest Structure and its Relationship to Biodiversity

The Carbon Cycle



- **What are the true magnitudes of terrestrial sequestration and emission?**
- **How will sequestration change with time?**
- **Where are the terrestrial carbon sinks located?**

Resolving key uncertainties requires greatly improved information on land surface carbon stocks and the net impact of forest loss and regrowth

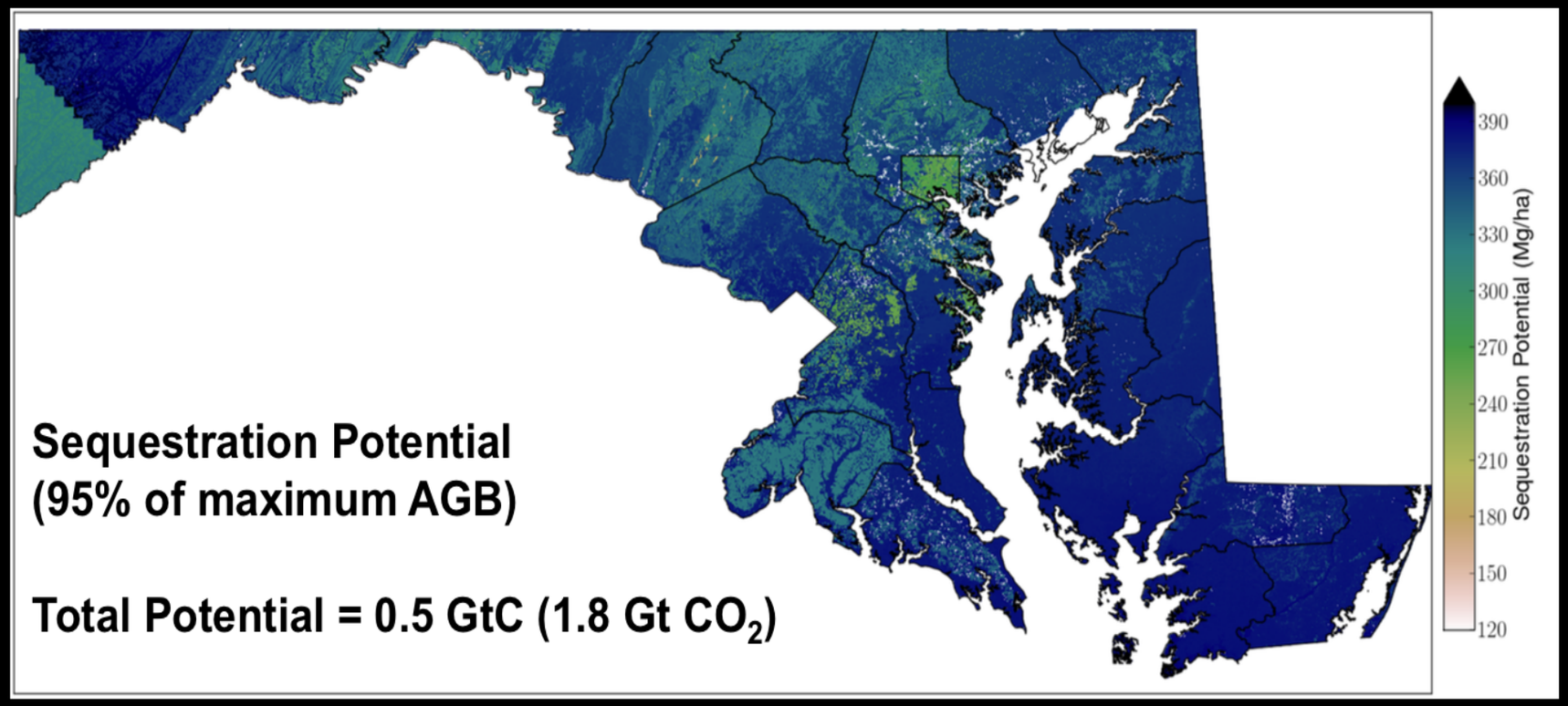
Objectives 1 & 2

Forest Biomass

Disturbance and Recovery

Modeling the Future: Carbon Sequestration Potential

- Ecosystem models provide a means for understanding how policy actions may impact the ability of the land surface to sequester carbon in the future.



Objective 3

Carbon Sequestration Potential

Ecosystem Demography (ED) model initialized with canopy height distributions from lidar. GEDI will provide data to do this globally.

Habitat Structure and Biodiversity

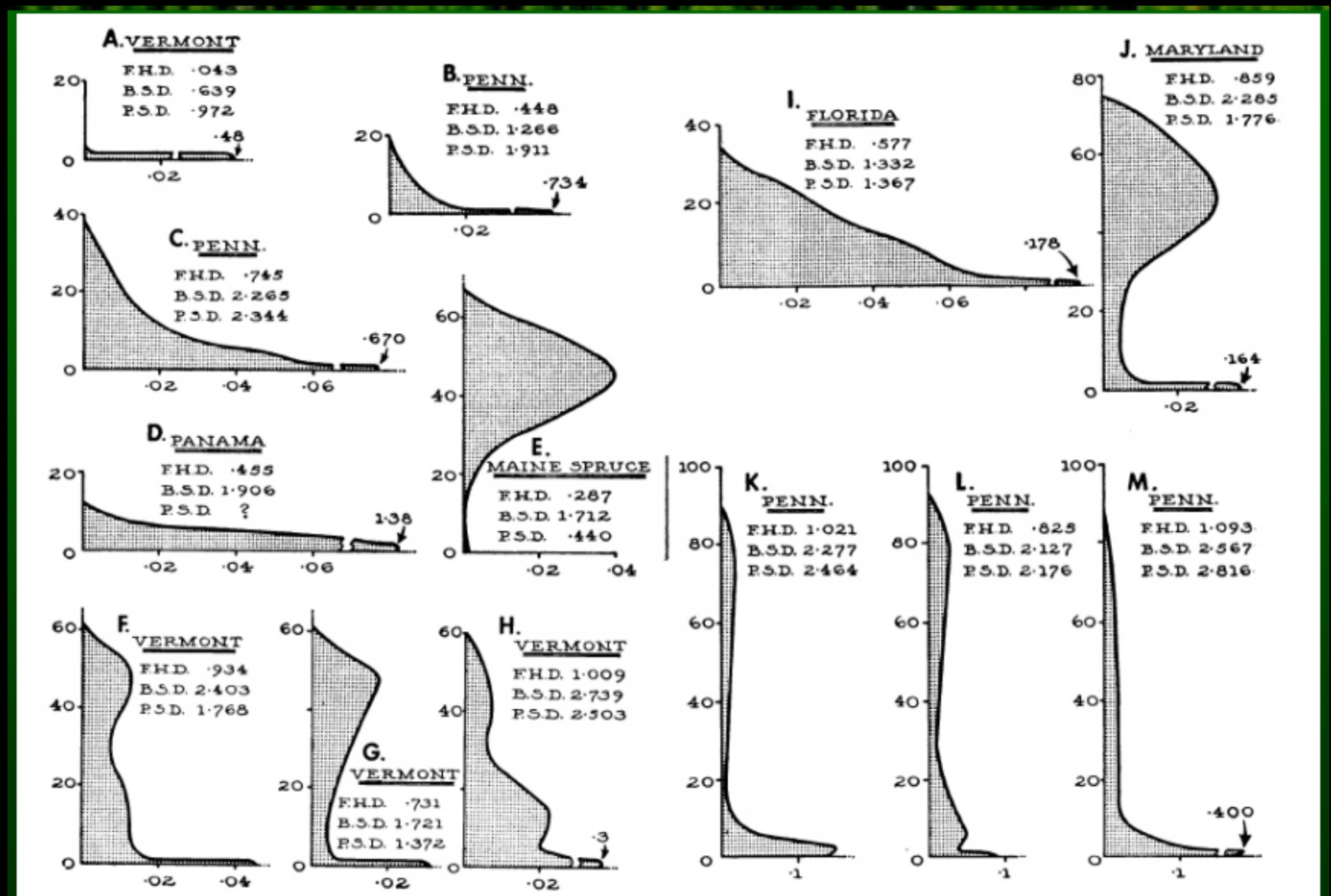
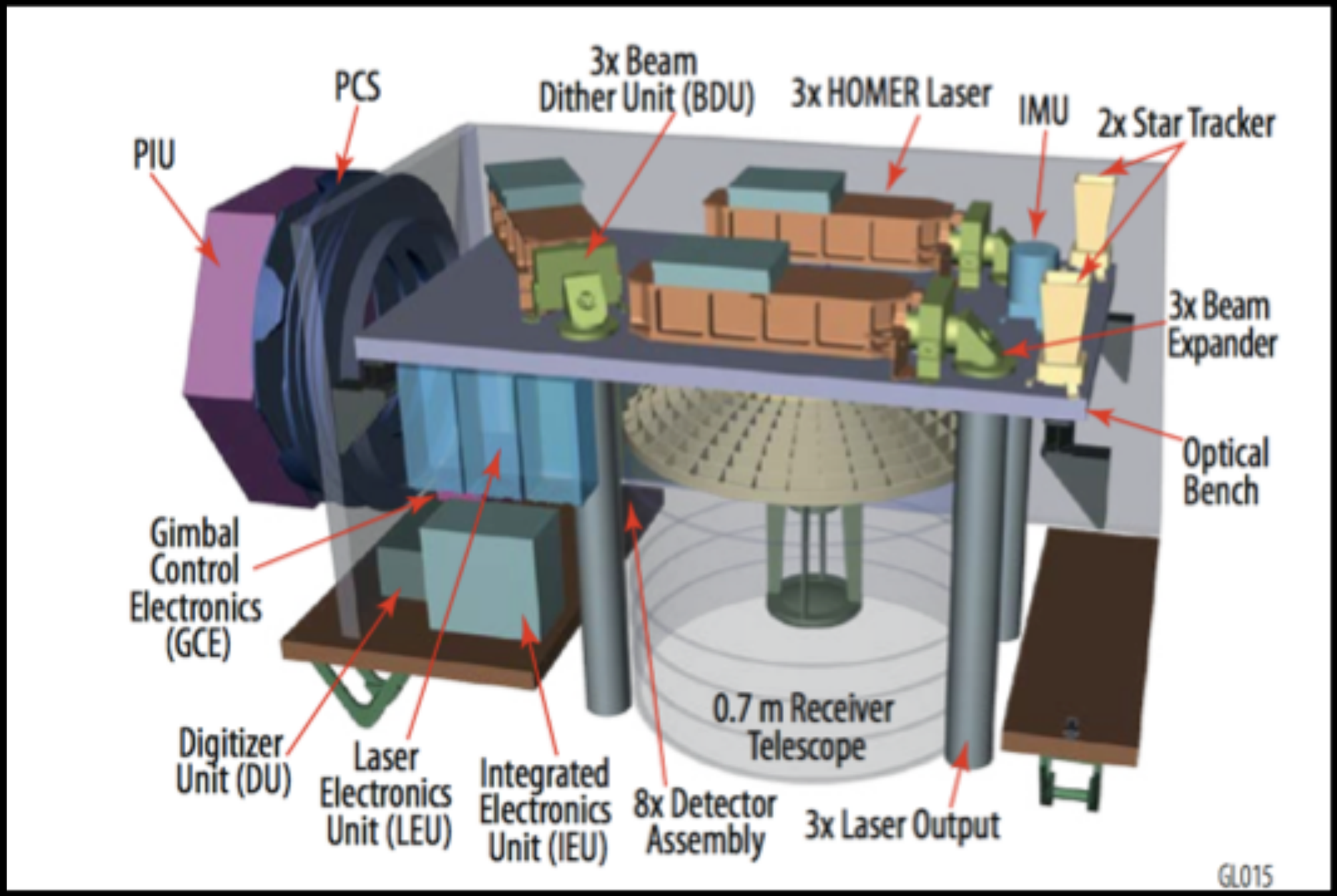


FIG. 1. The densities of foliage (measured in square feet of leaf silhouette per cubic foot of space) are plotted along the abscissae. The height in feet above the ground is the ordinate. F.H.D. is foliage height diversity, B.S.D. is bird species diversity, and P.S.D. is plant species diversity.

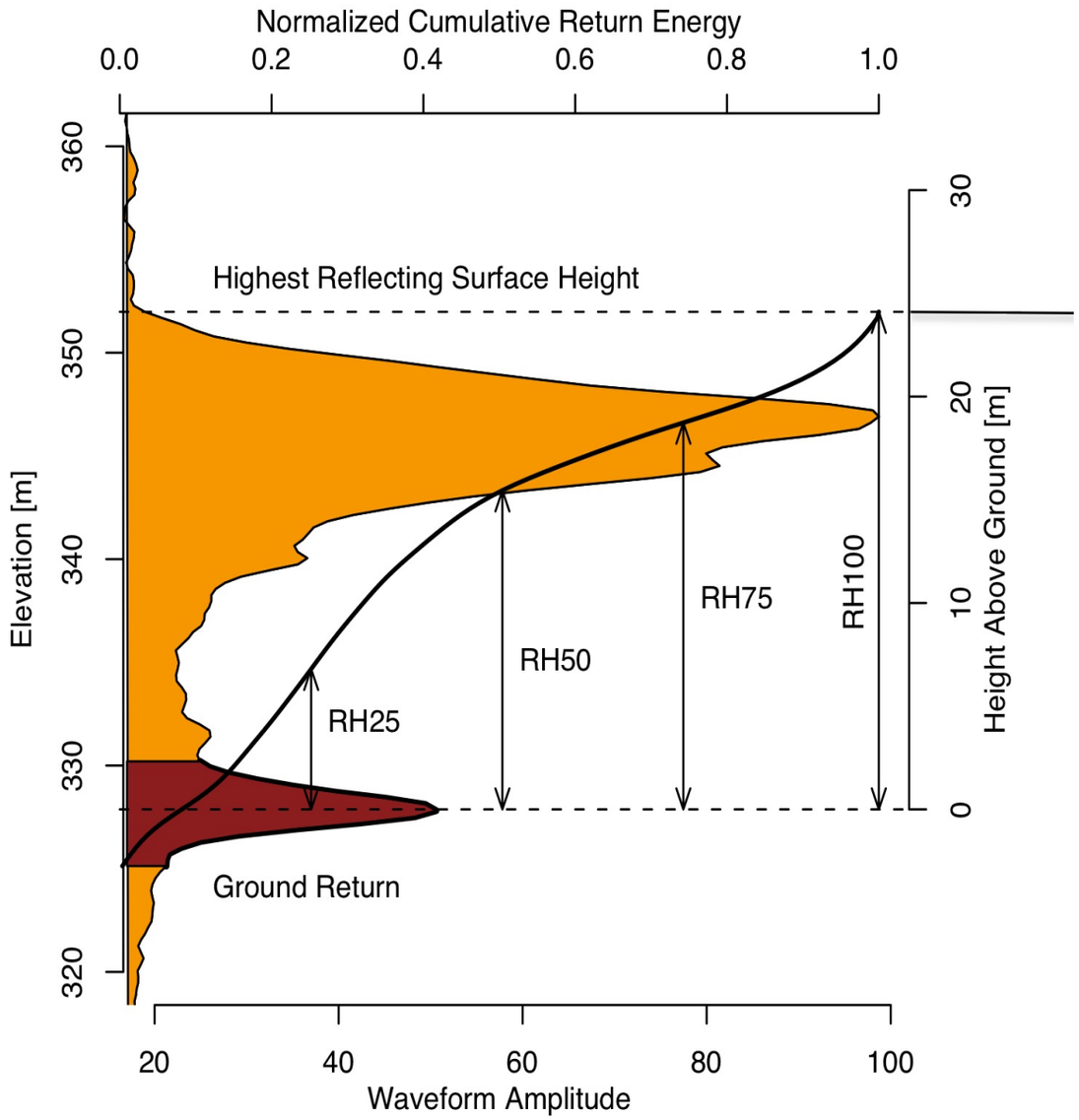
GEDI Lidar Instrument

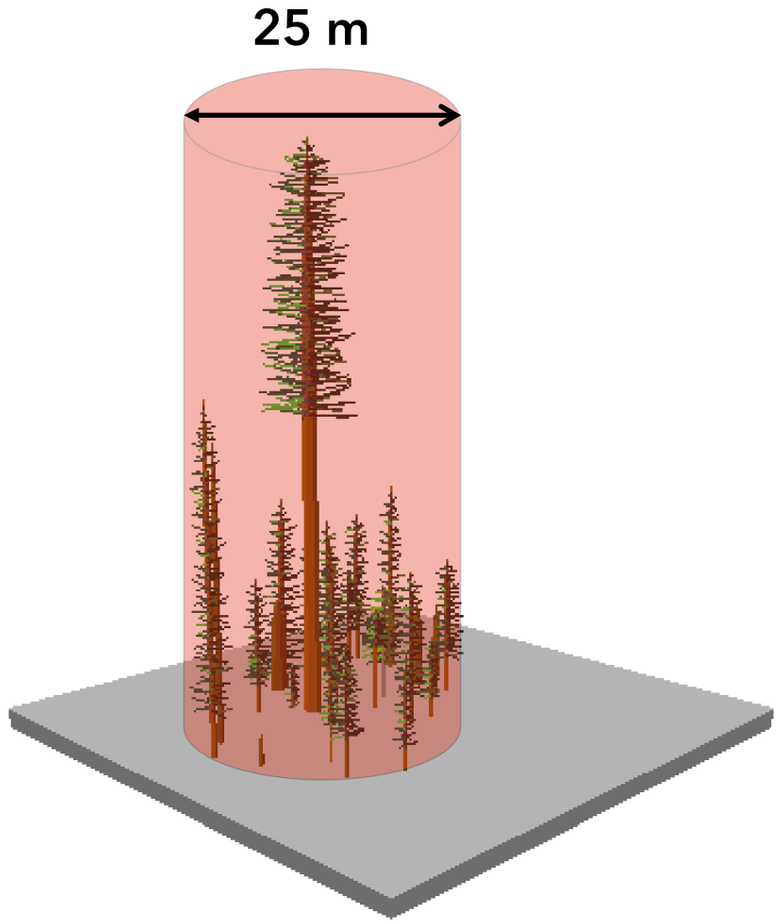
Self-contained Laser Altimeter



Lidar Measurement

- Sole GEDI observable is the lidar waveform



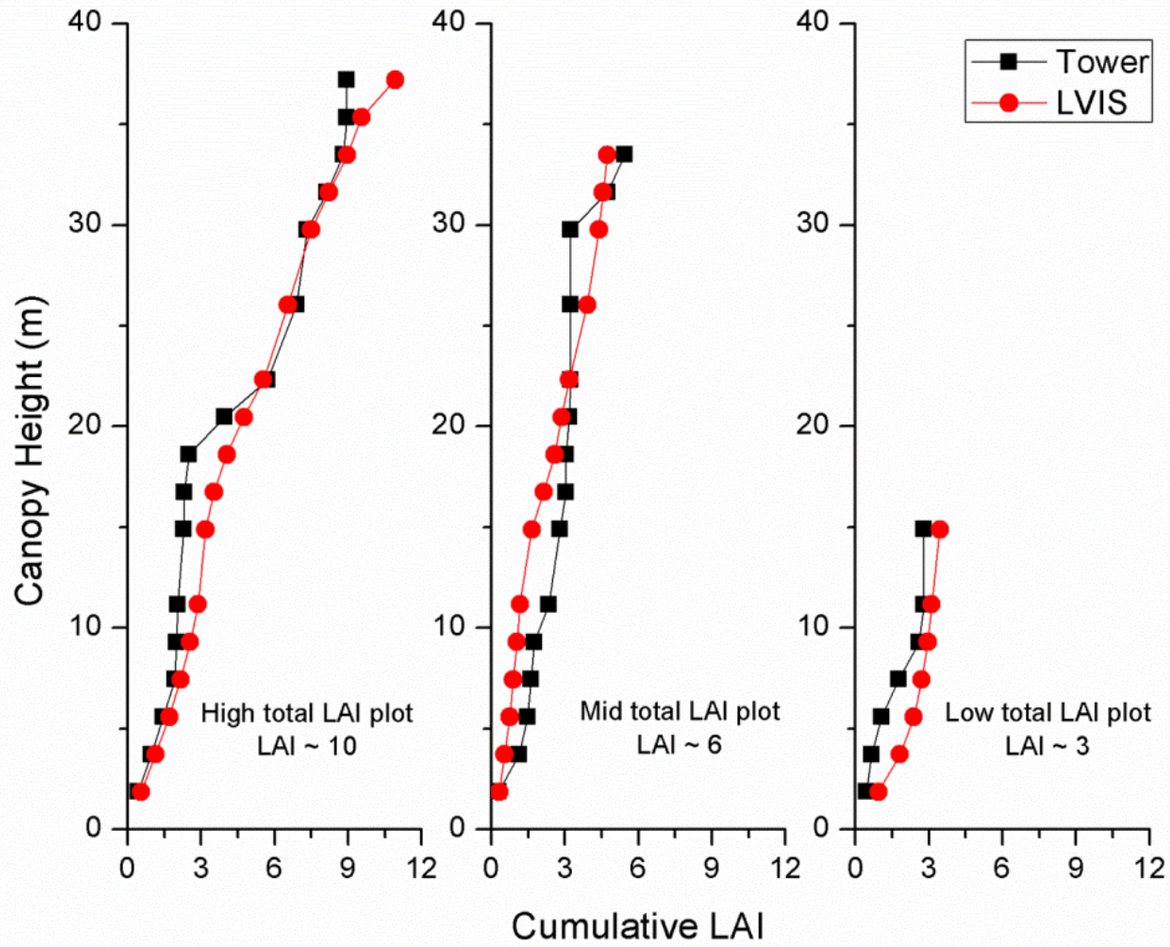


Canopy Structure From Lidar

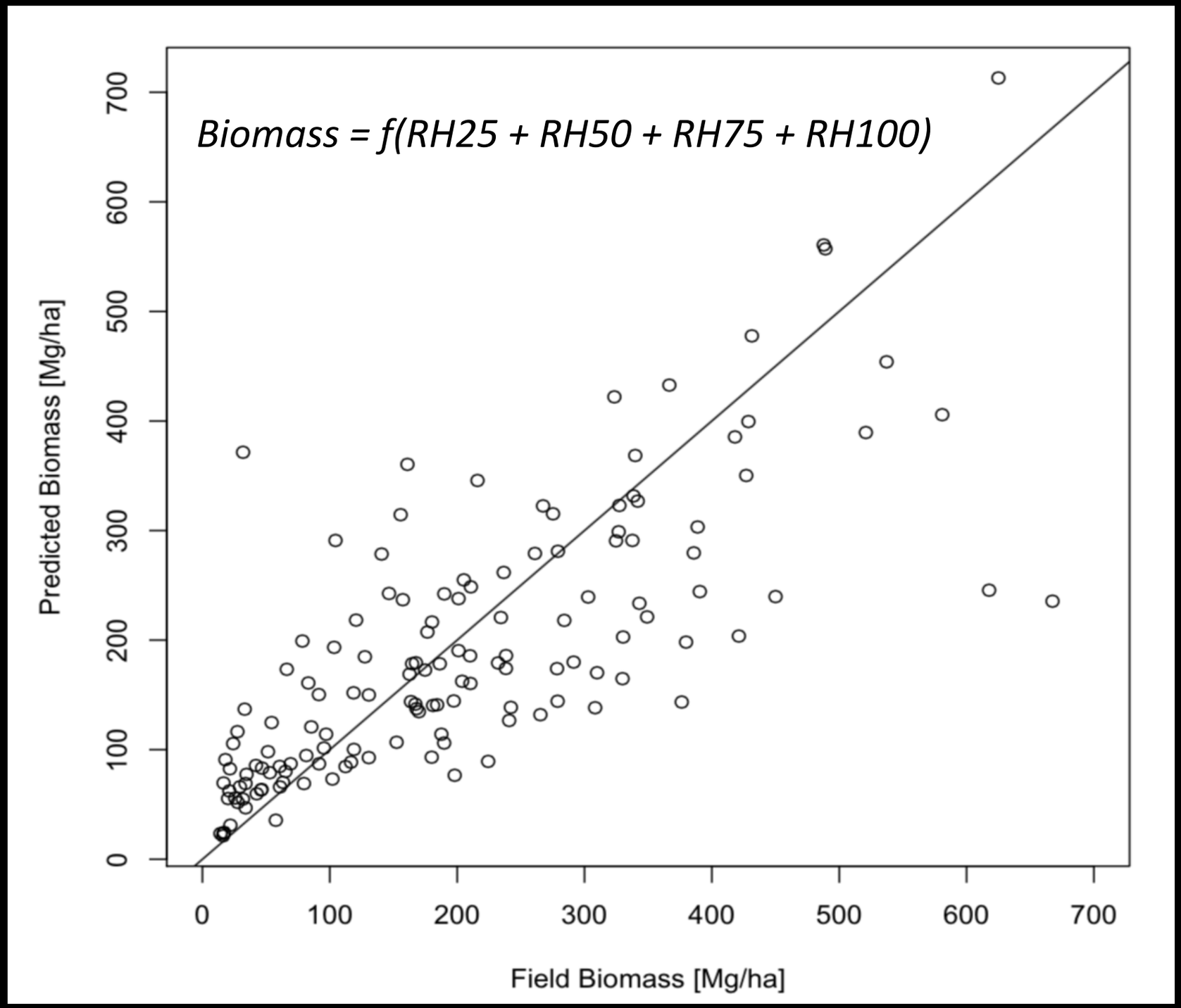
Variable	Derivation
Gap structure/connectivity	Direct
Canopy cover (vertical profile)	Direct
Maximum/mean canopy height	Direct
Canopy height profile	Direct
Canopy texture	Direct
Height size distribution	Direct
Landscape pattern/patch/edge	Direct
Topography	Direct
LAI	Direct
Basal area	Modeled
Stem density	Modeled
Biomass	Modeled
Foliar Profile	Modeled
Seral Stage	Modeled
Canopy Layering	Modeled

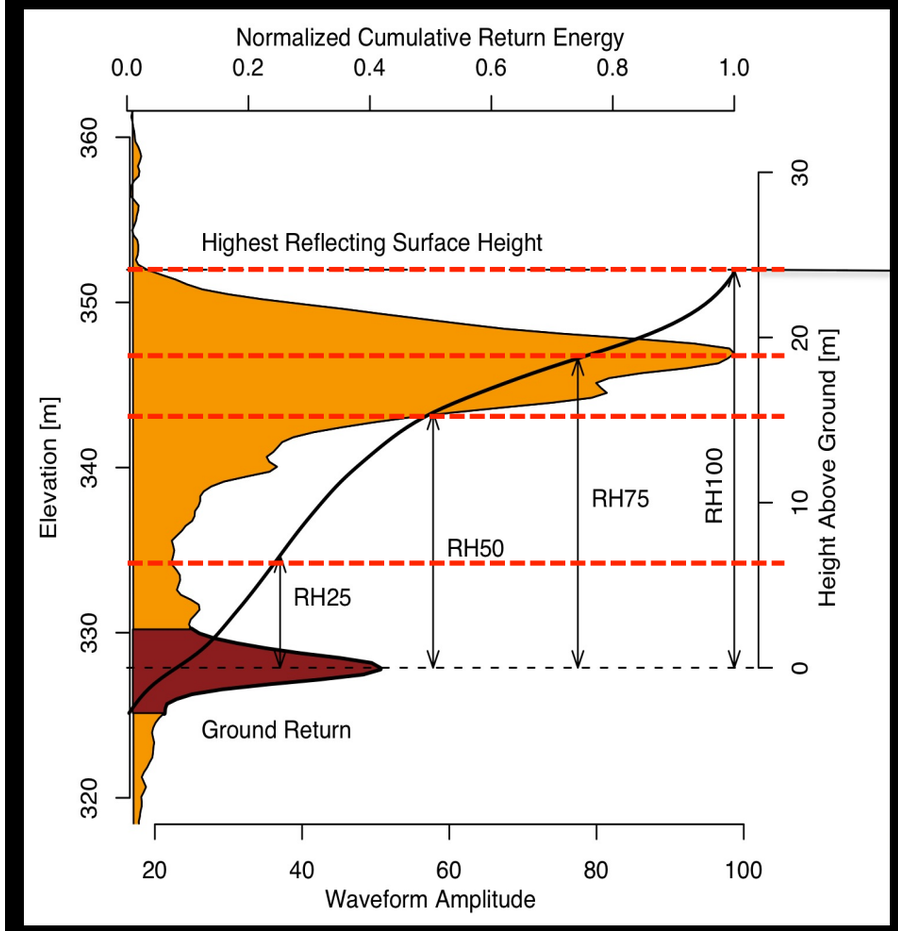
Direct LAI Profile Retrieval

Destructively sampled LAI from portable towers



Modeled Biomass





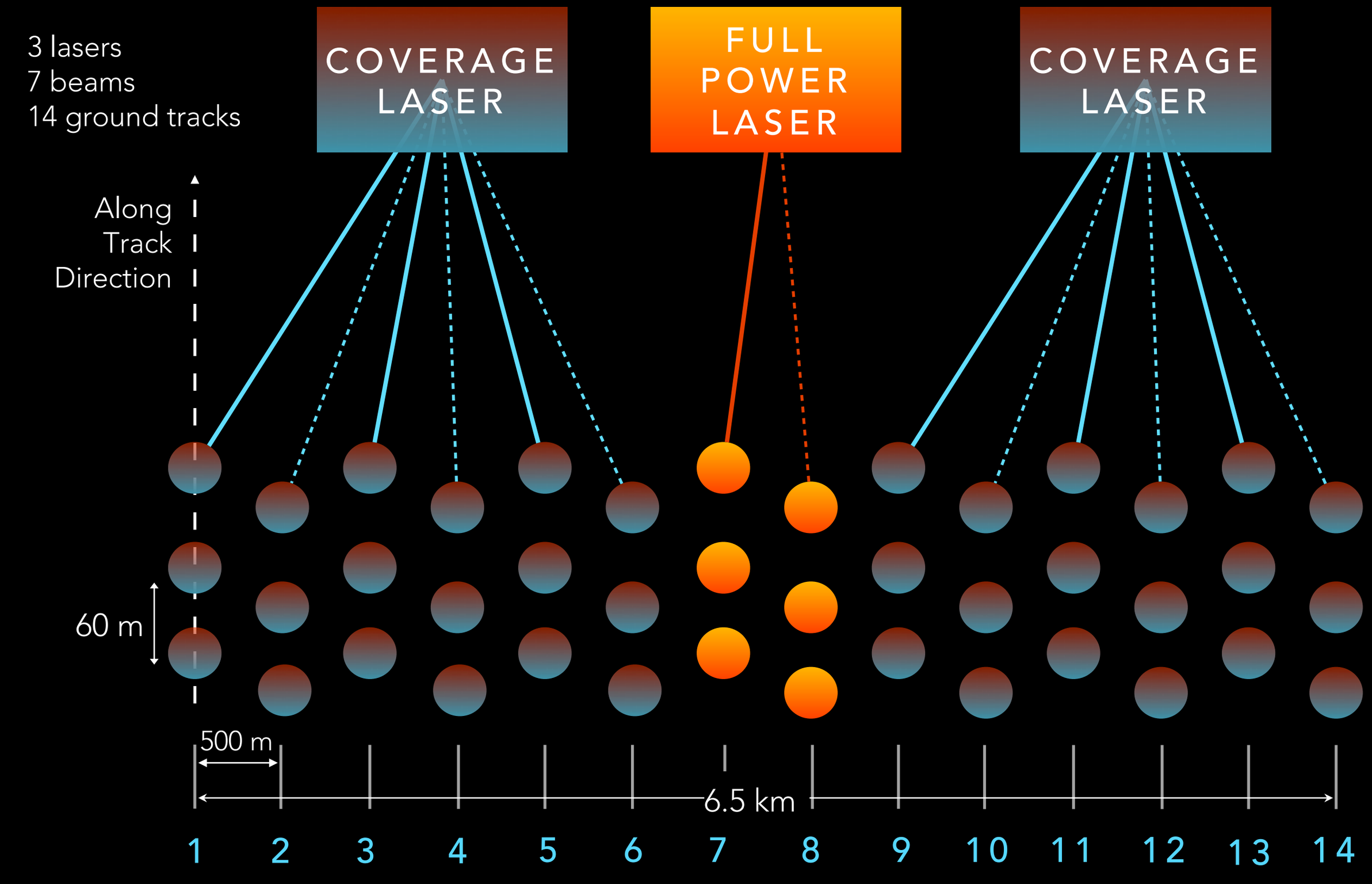
GEDI Laser Track Coverage

15,000,000,000

LAND SURFACE LASER
OBSERVATIONS IN ONE YEAR

GEDI Laser Track Coverage

3 lasers
7 beams
14 ground tracks



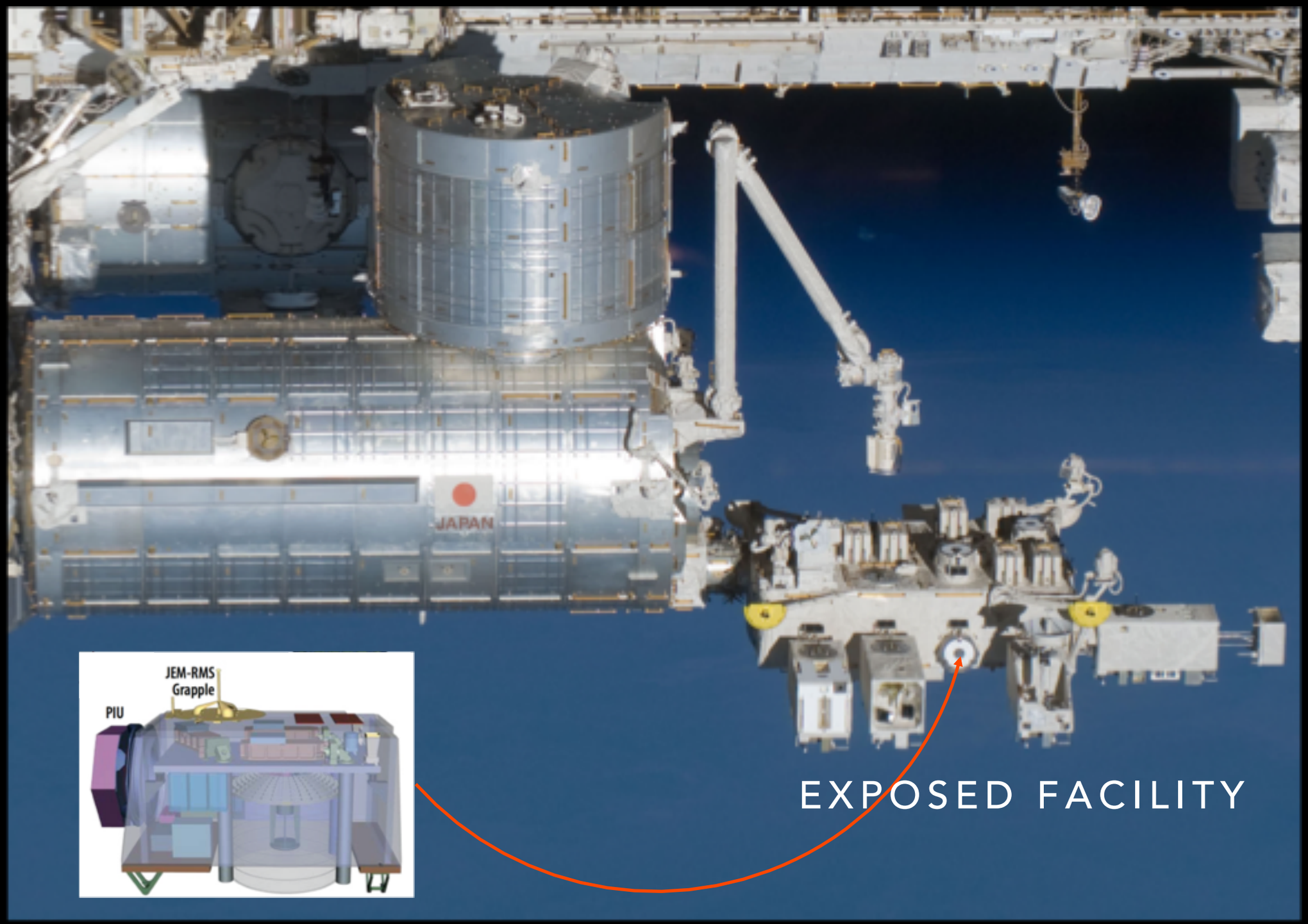
GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

International Space Station

SPACE-X
DRAGON
CAPSULE

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

Japanese Experiment Module



GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

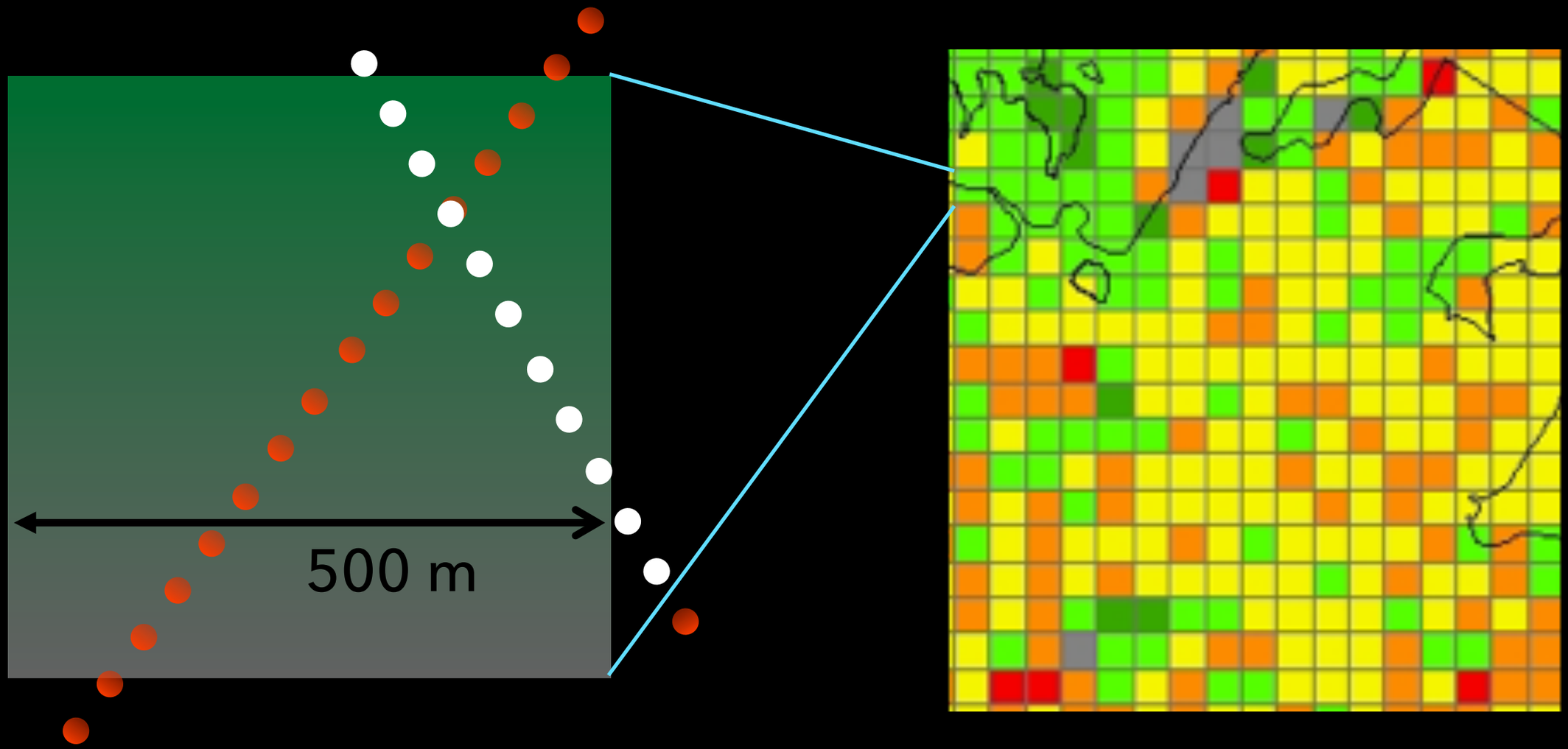
Science Approach and Data Products

Level 2 Footprint Products

Canopy Height Metrics

Canopy Profile Metrics

Level 3 Gridded Products



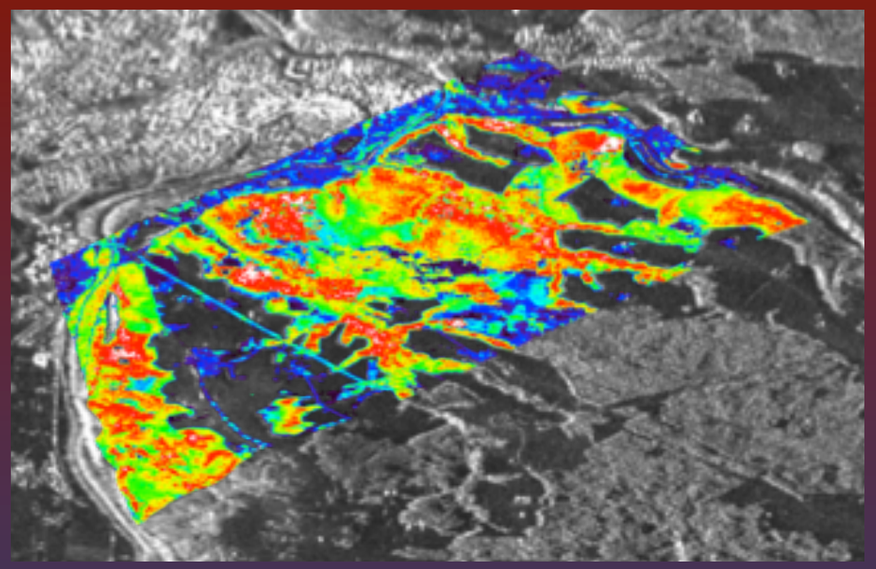
Fusion with Tandem-X Data

Collaboration with German Aerospace Center

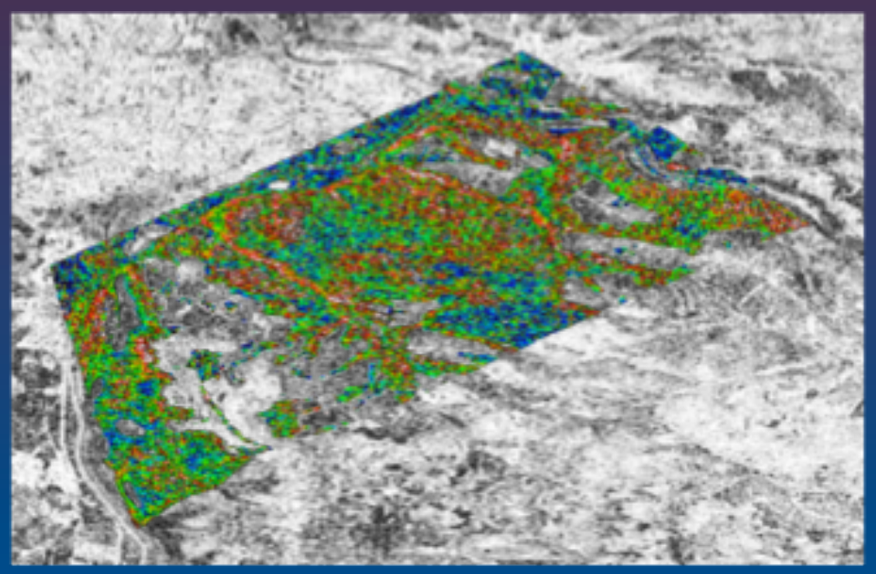
DLR

Traunstein Forest, Germany

Height Derived from Airborne Lidar



Height Derived from Tandem-X



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

Summary

- GEDI will provide unprecedented measurements of the forest height and structure at high spatial resolution
- Entering exciting era of ecosystem structure observation from lidar and radar
  - GEDI, ICESAT2, and SAR missions such as Tandem-X, NISAR, BIOMASS, Sentinel, ALOS-2 and others
- Fusion is the future
  - GEDI, ECOSTRESS and OCO-3 will enable a much more complete picture of ecosystem form, function and composition, and impacts on the carbon cycle and habitat

Advance our understanding of ecosystems and their response to complex and changing forces

The stage is set.