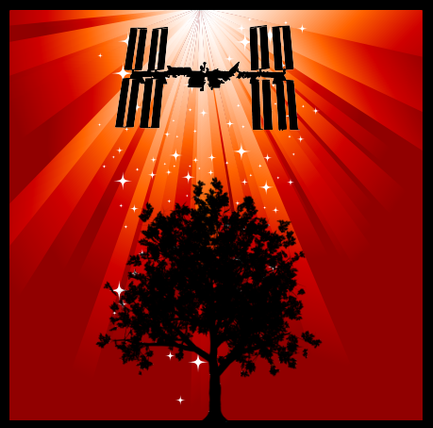


GEDI LIDAR

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

Ralph Dubayah
University of Maryland
Principal Investigator

GEDI SCIENCE TEAM

Ralph Dubayah	University of Maryland
J. Bryan Blair	NASA Goddard
Scott Goetz	Woods Hole Research Center
Temilola Fatoyinbo	NASA Goddard
Matt Hansen	University of Maryland
Sean Healey	US Forest Service
Michelle Hofton	University of Maryland
George Hurtt	University of Maryland
James Kellner	University of Maryland
Scott Luthcke	NASA Goddard
Kostas Papathanasiou	German Aerospace Center
Anu Swatantran	University of Maryland

NASA

UNIVERSITY OF MARYLAND 18 56

THE WOODS HOLE RESEARCH CENTER

FOREST SERVICE US DEPARTMENT OF AGRICULTURE

Pantone Solid Coated 123C
Pantone Solid Coated 322C

BROWN

DLR

We Are Not Alone

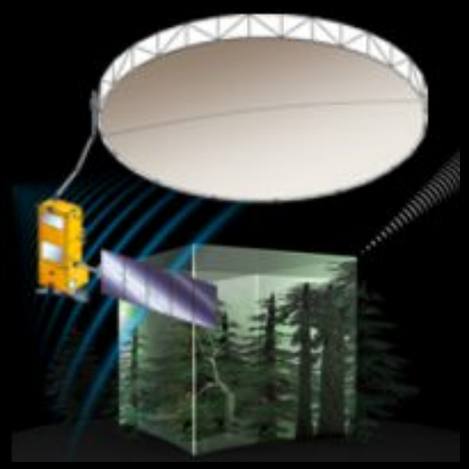
"New space-based observations using lidar should have high priority and are recommended to provide complementary information on forest height and structure.

Committee on Earth Observations (2014)

We Are Not Alone

"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)



BIOMASS

NISAR
NASA - ISRO SAR Mission

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

We Are Not Alone

GEDI LIDAR

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

Earth Ventures Instrument (EVI)

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

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

GEDI Science Objectives

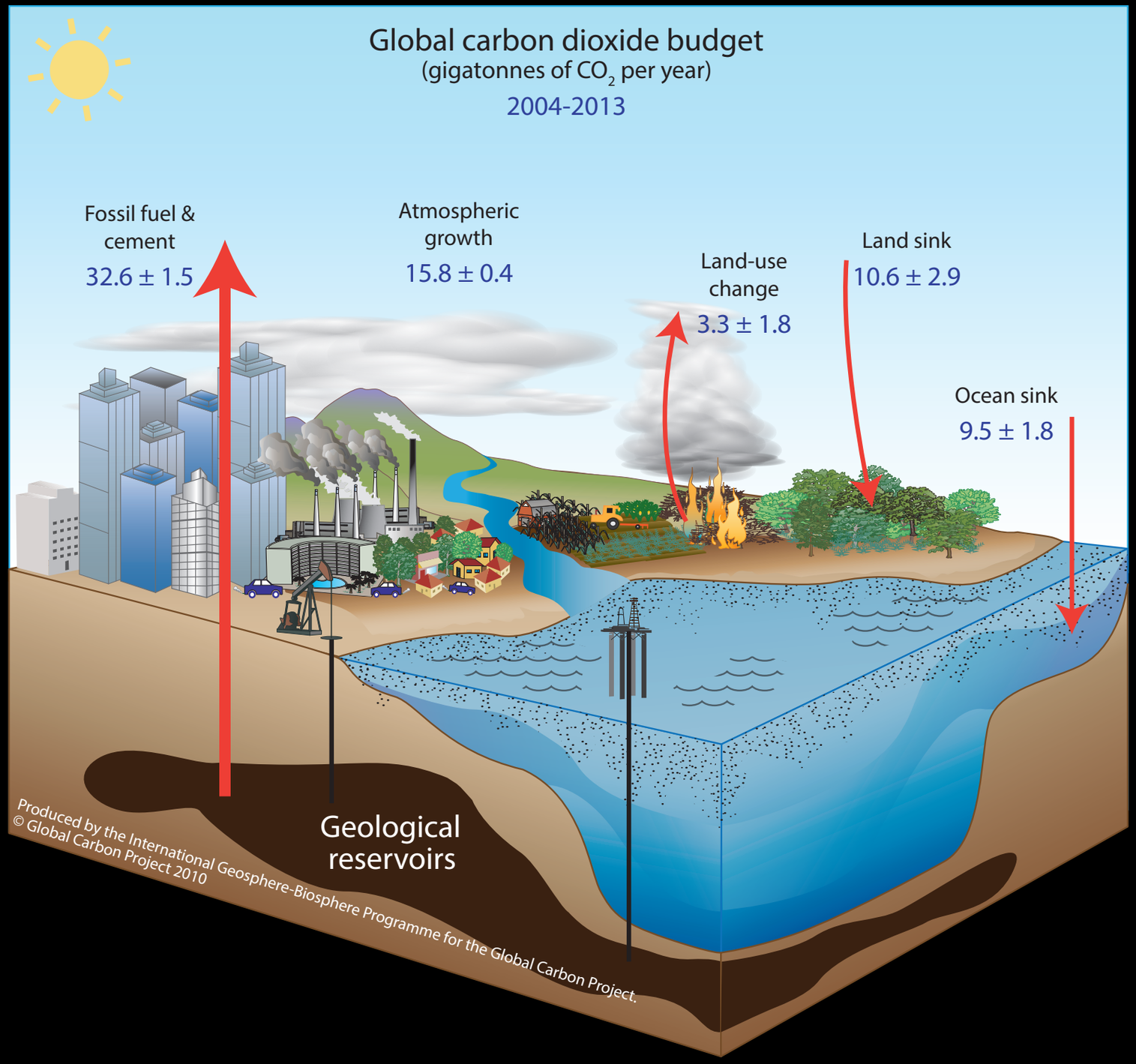
Question

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

Quantify

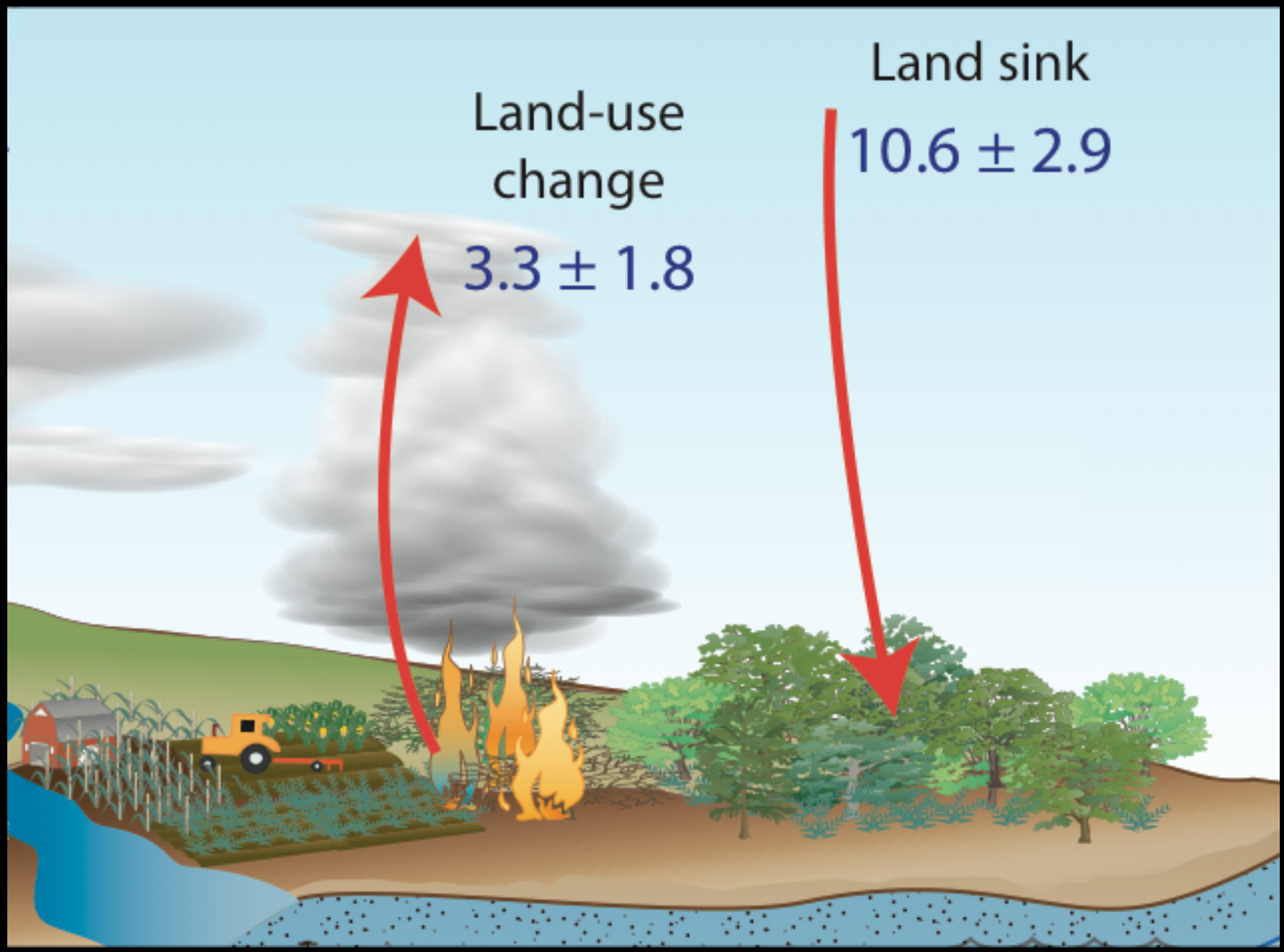
- Forest Biomass
- Disturbance and Recovery

GEDI Science Objectives



GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

GEDI Science Objectives



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?

Quantify

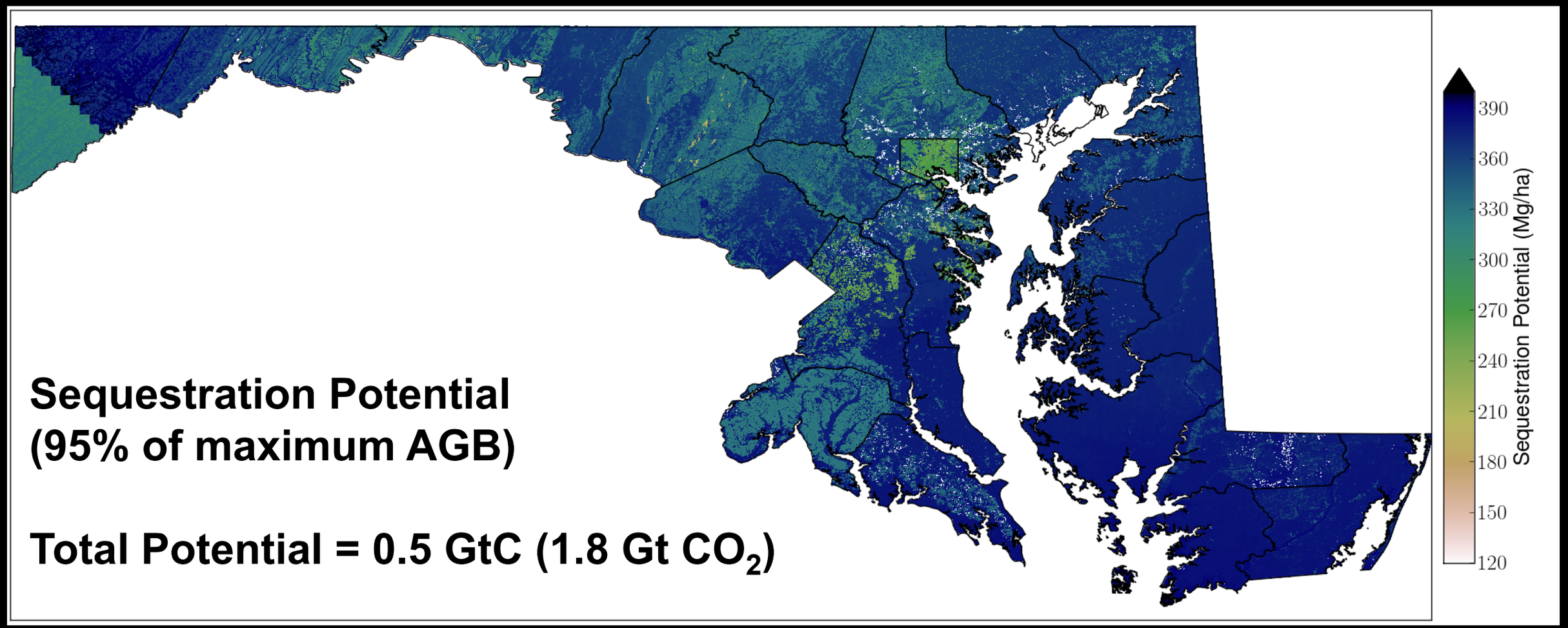
Forest Biomass

Disturbance and Recovery

GEDI 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

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	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

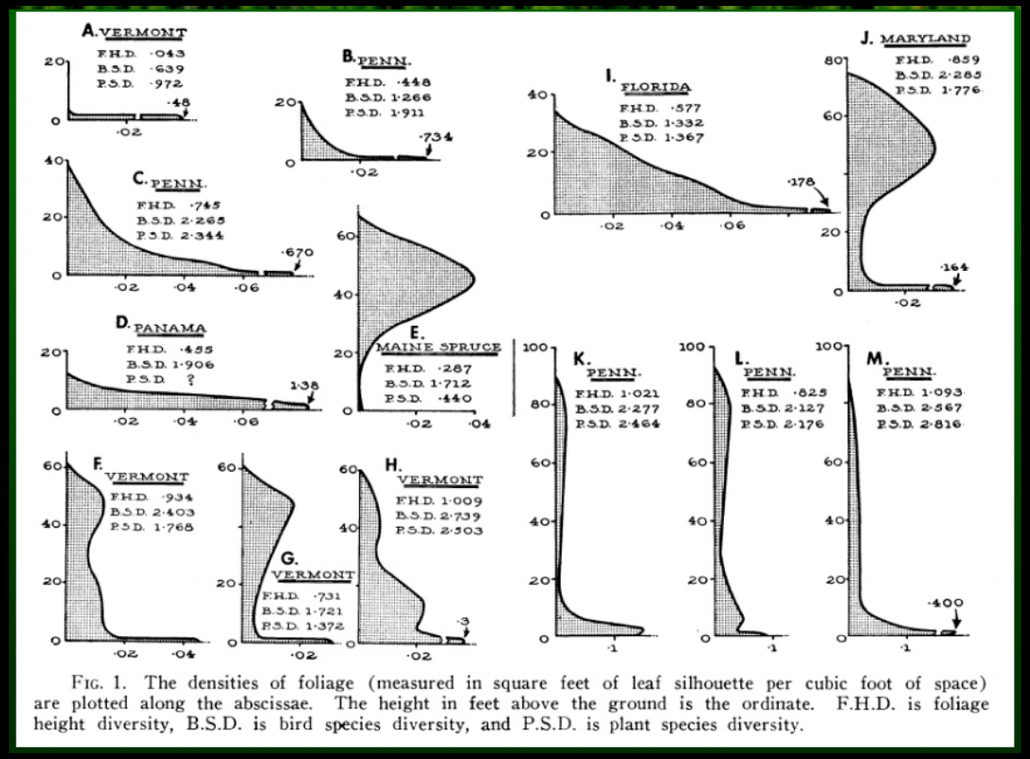
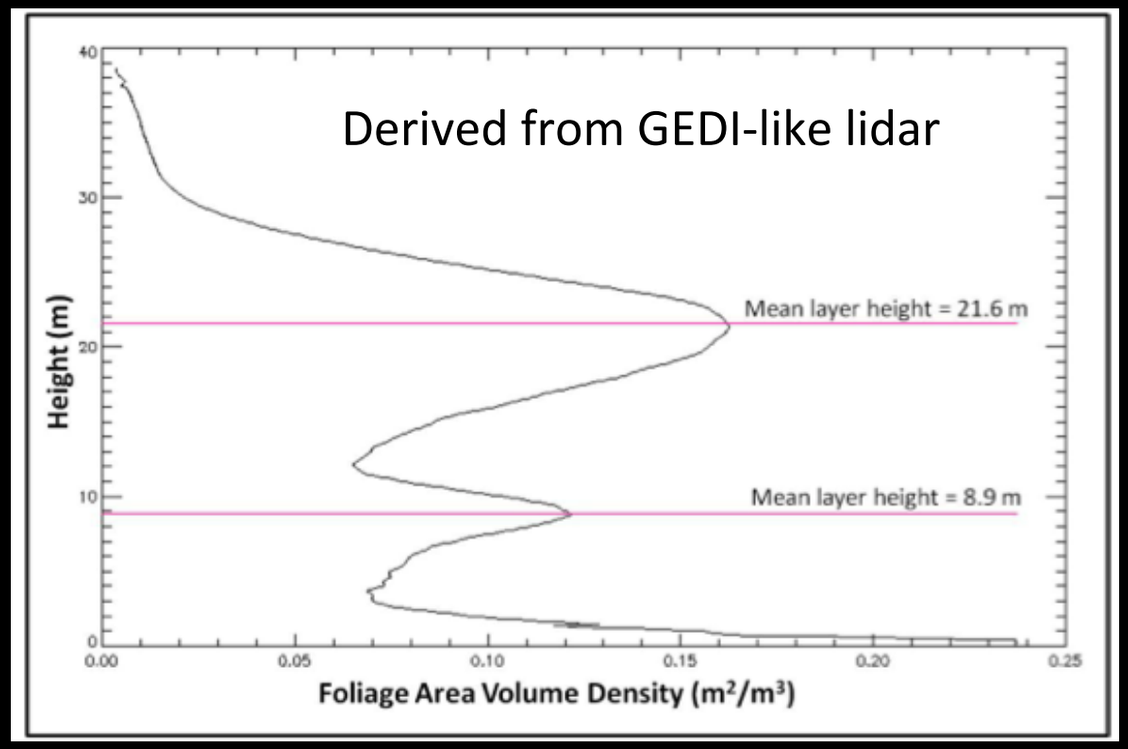
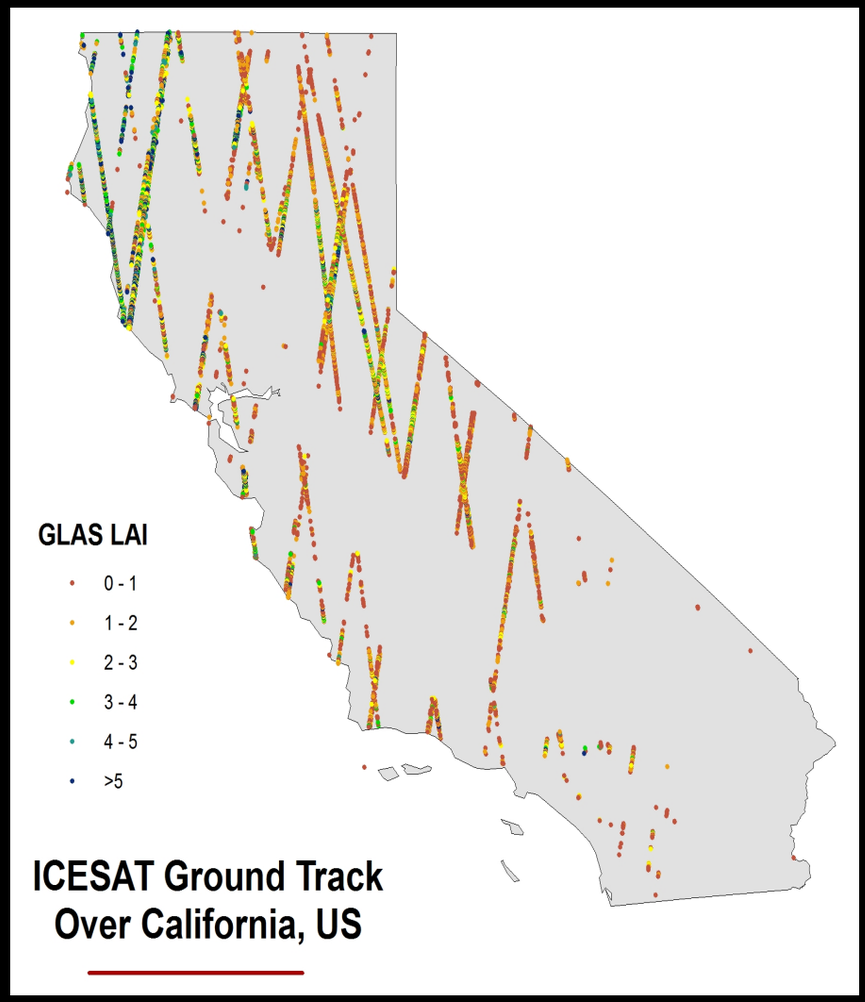
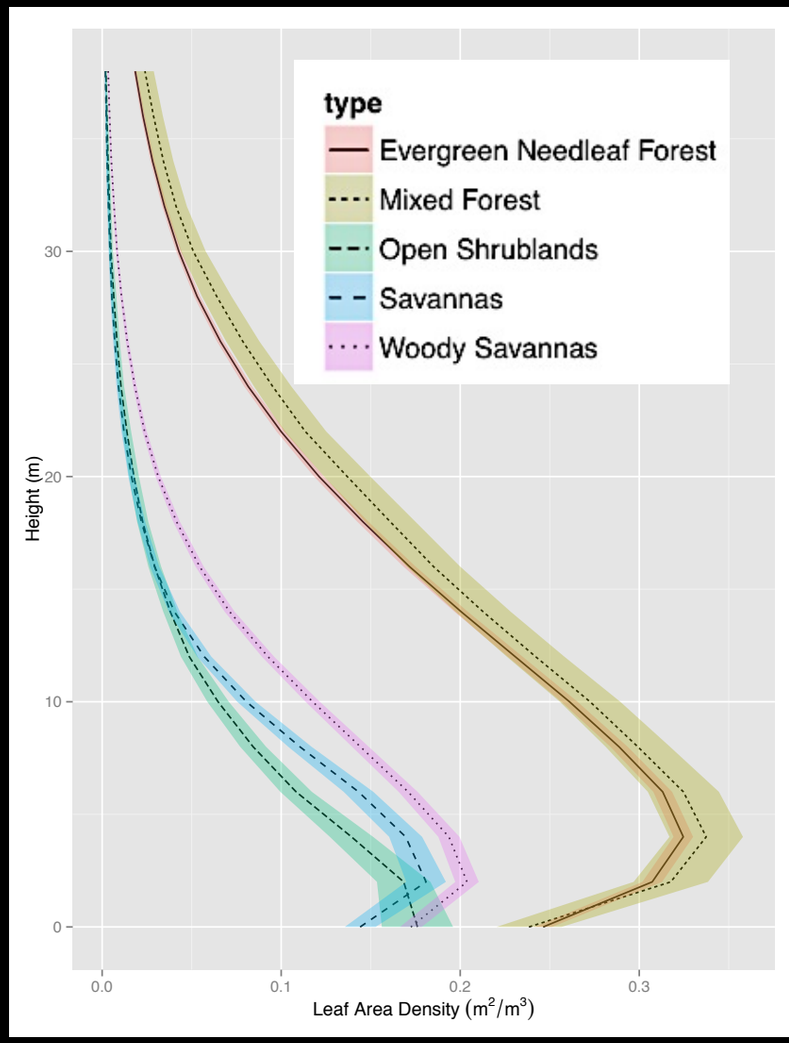


FIG. 1. The densities of foliage (measured in square feet of leaf silhouette per cubic foot of space) are plotted along the abscissae. The height in feet above the ground is the ordinate. F.H.D. is foliage height diversity, B.S.D. is bird species diversity, and P.S.D. is plant species diversity.







GEDI 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
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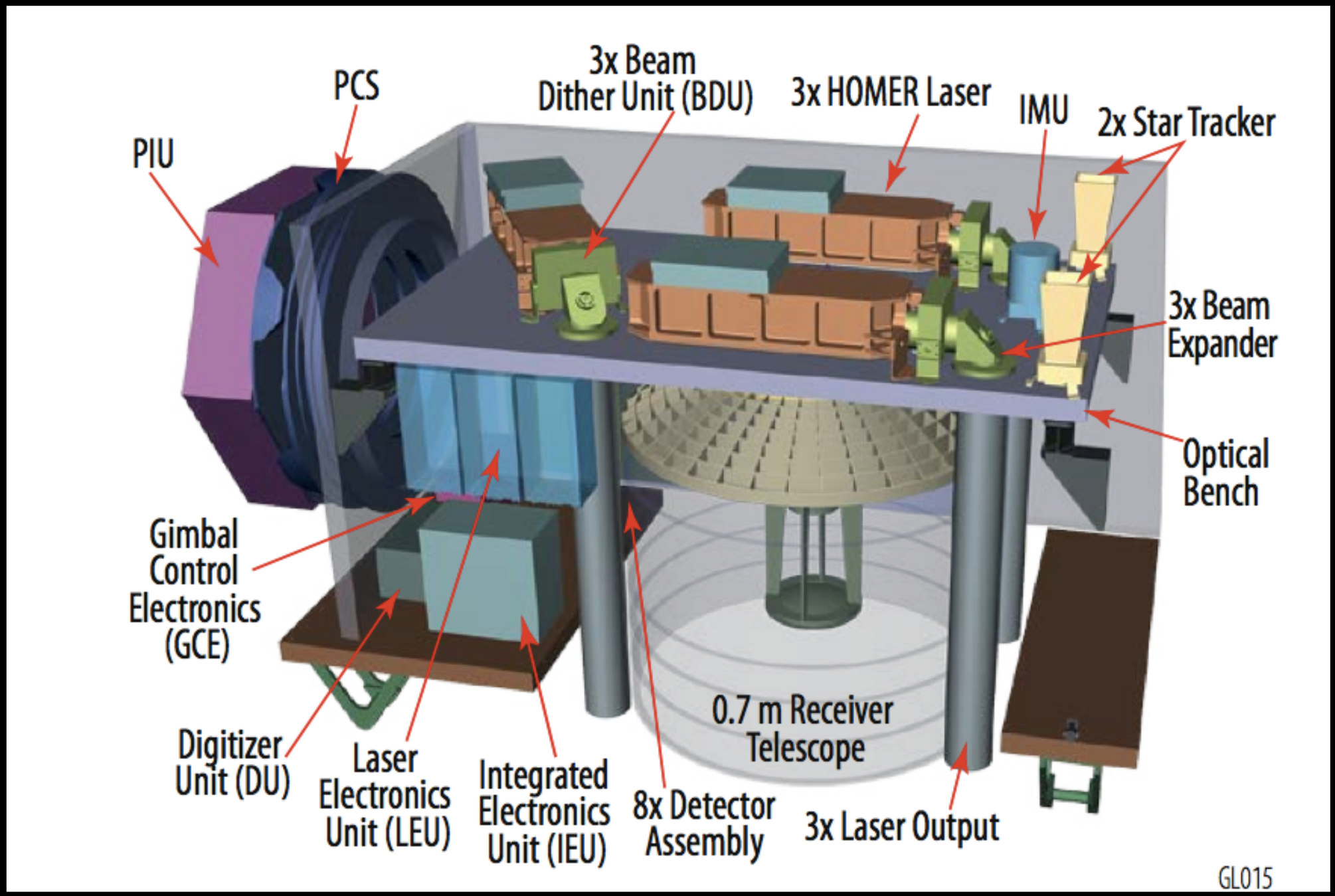
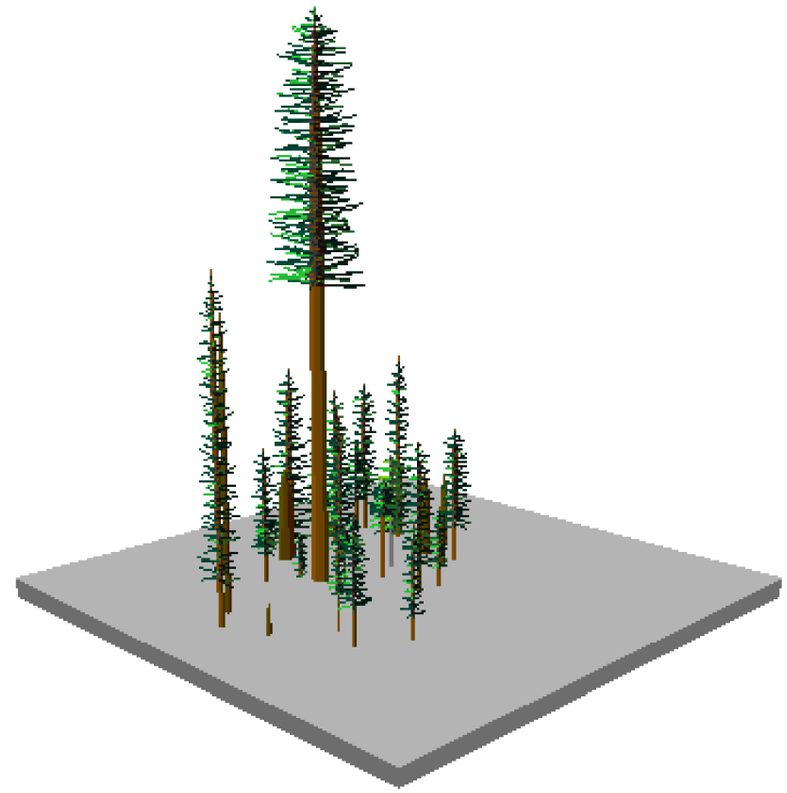
GEDI Lidar Instrument

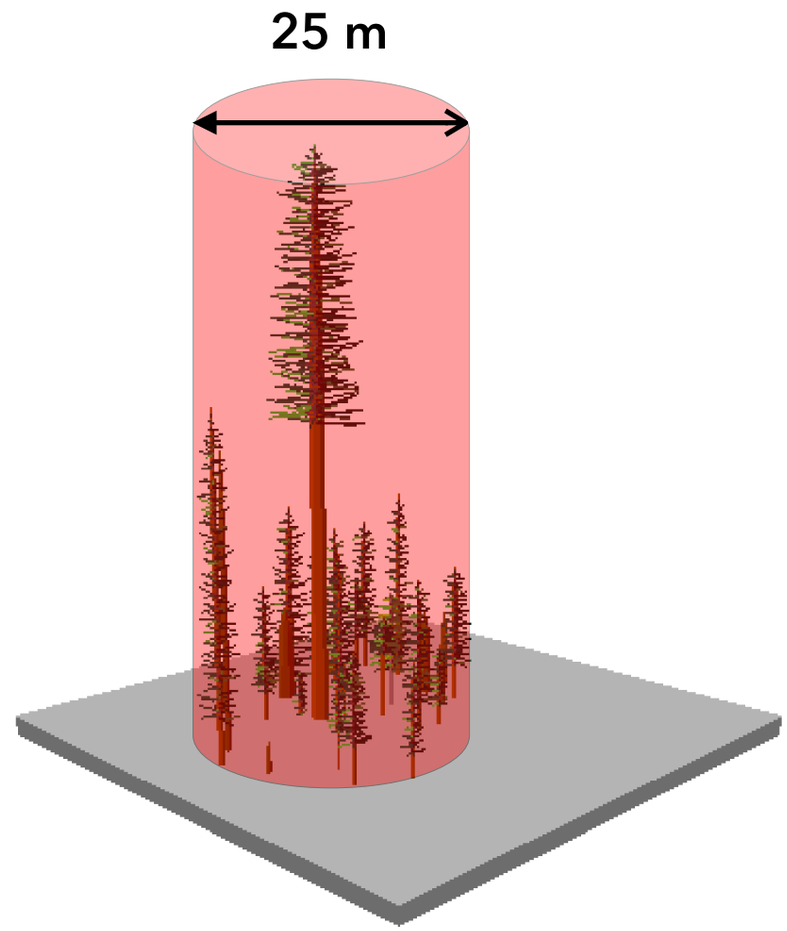
Self-contained Laser Altimeter



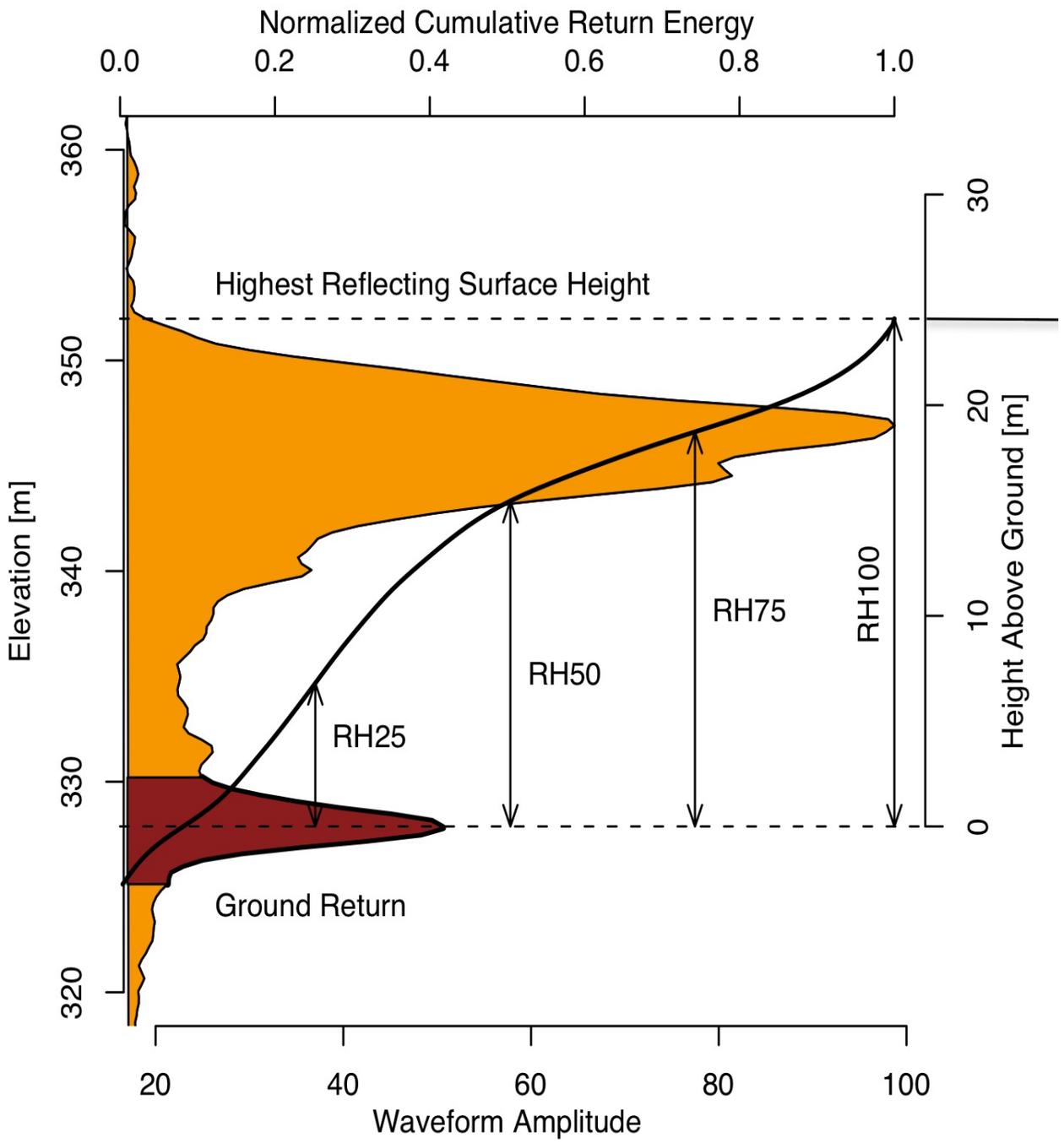
Lidar Measurement

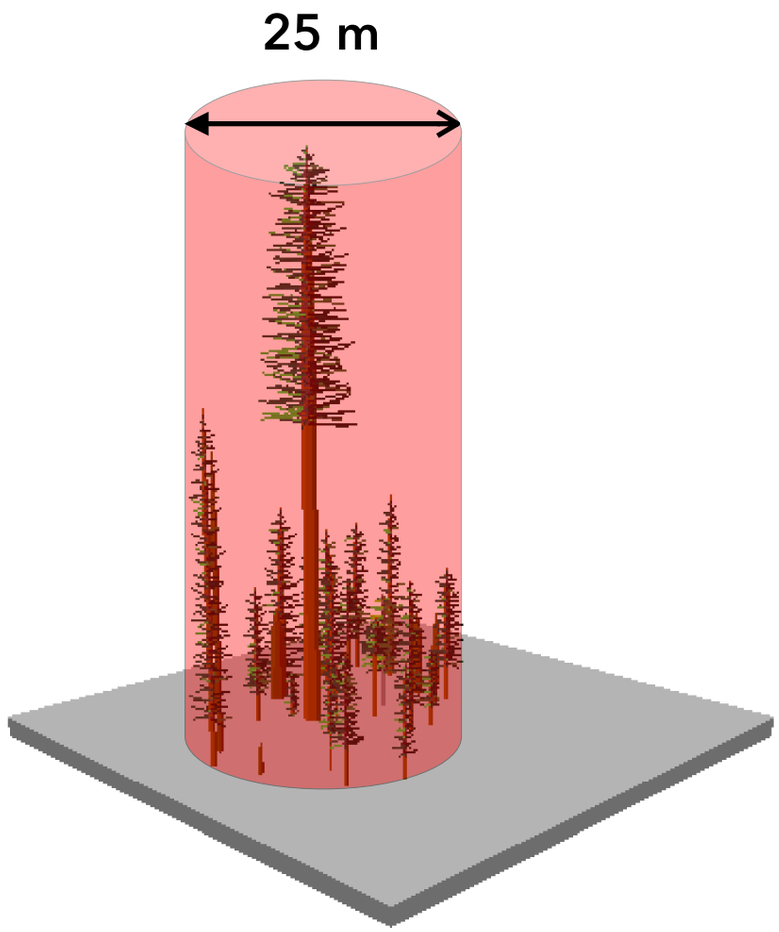


Lidar Measurement



Lidar Measurement





GEDI Laser Track Coverage

15,000,000,000

GEDI Laser Track Coverage

15,000,000,000

LAND SURFACE LASER
OBSERVATIONS IN ONE YEAR

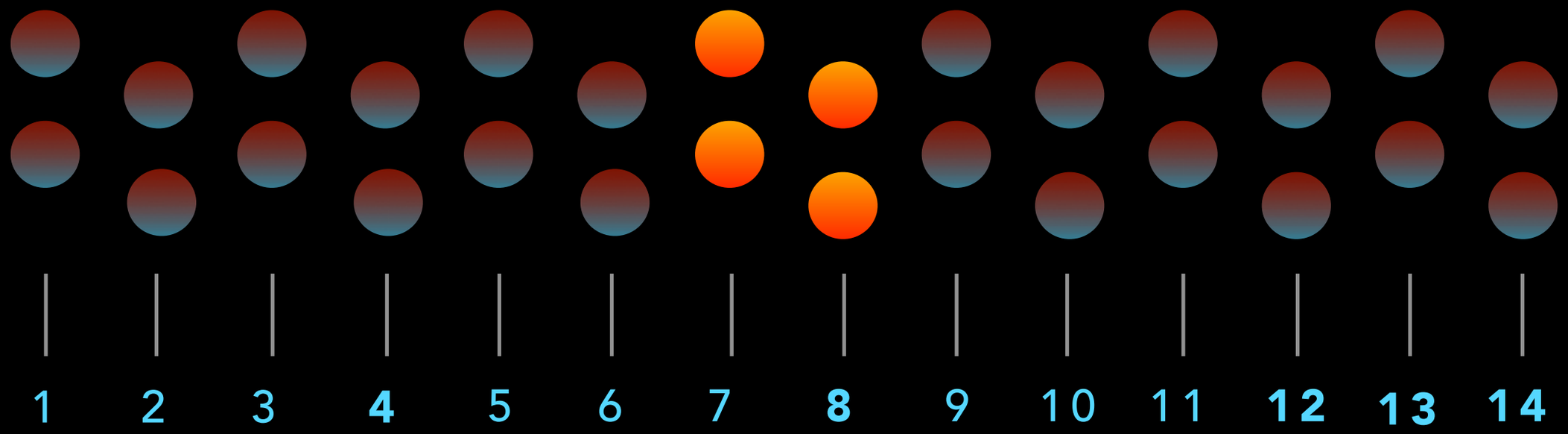
GEDI Laser Track Coverage

3 lasers
7 beams
14 ground tracks

COVERAGE LASER

FULL POWER LASER

COVERAGE LASER



GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

GEDI Laser Track Coverage

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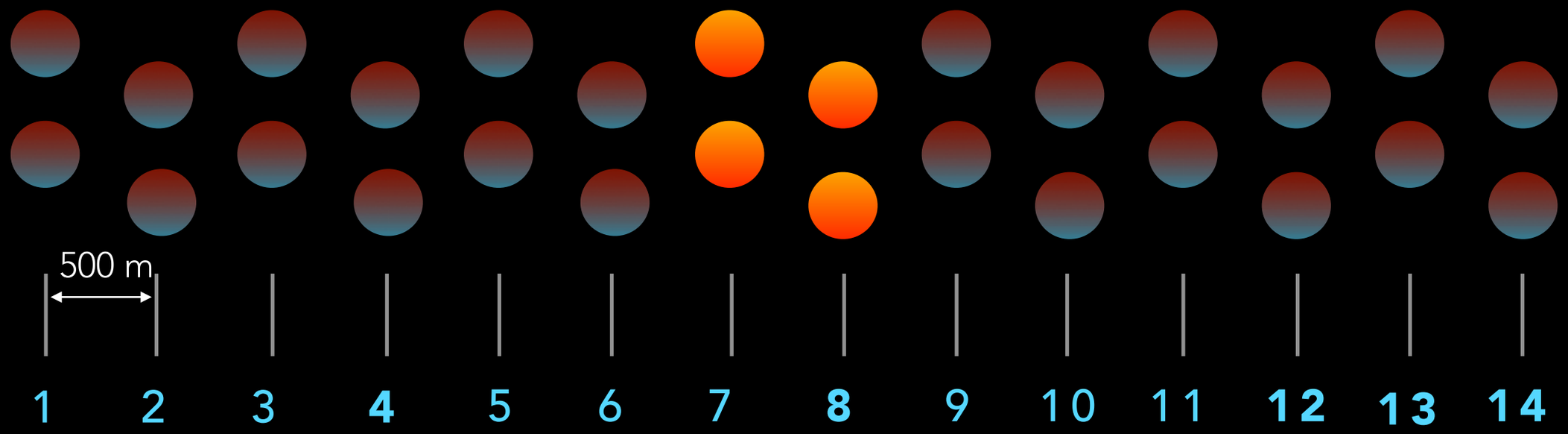
7 beams
14 ground tracks

COVERAGE LASER

FULL POWER LASER

COVERAGE LASER



GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

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GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

GEDI Laser Track Coverage

3 lasers
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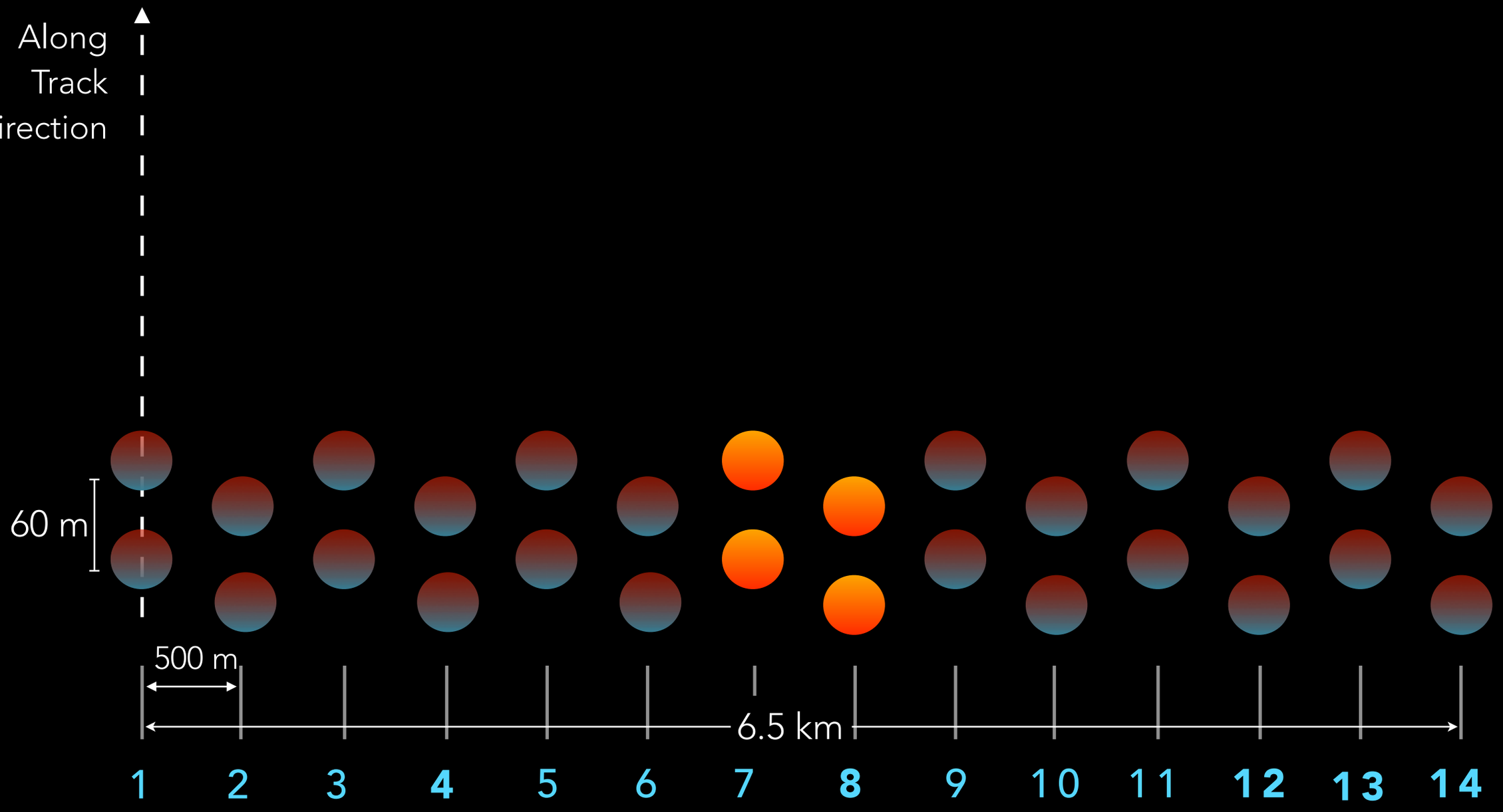
14 ground tracks

COVERAGE LASER

FULL POWER LASER

COVERAGE LASER

Along Track Direction



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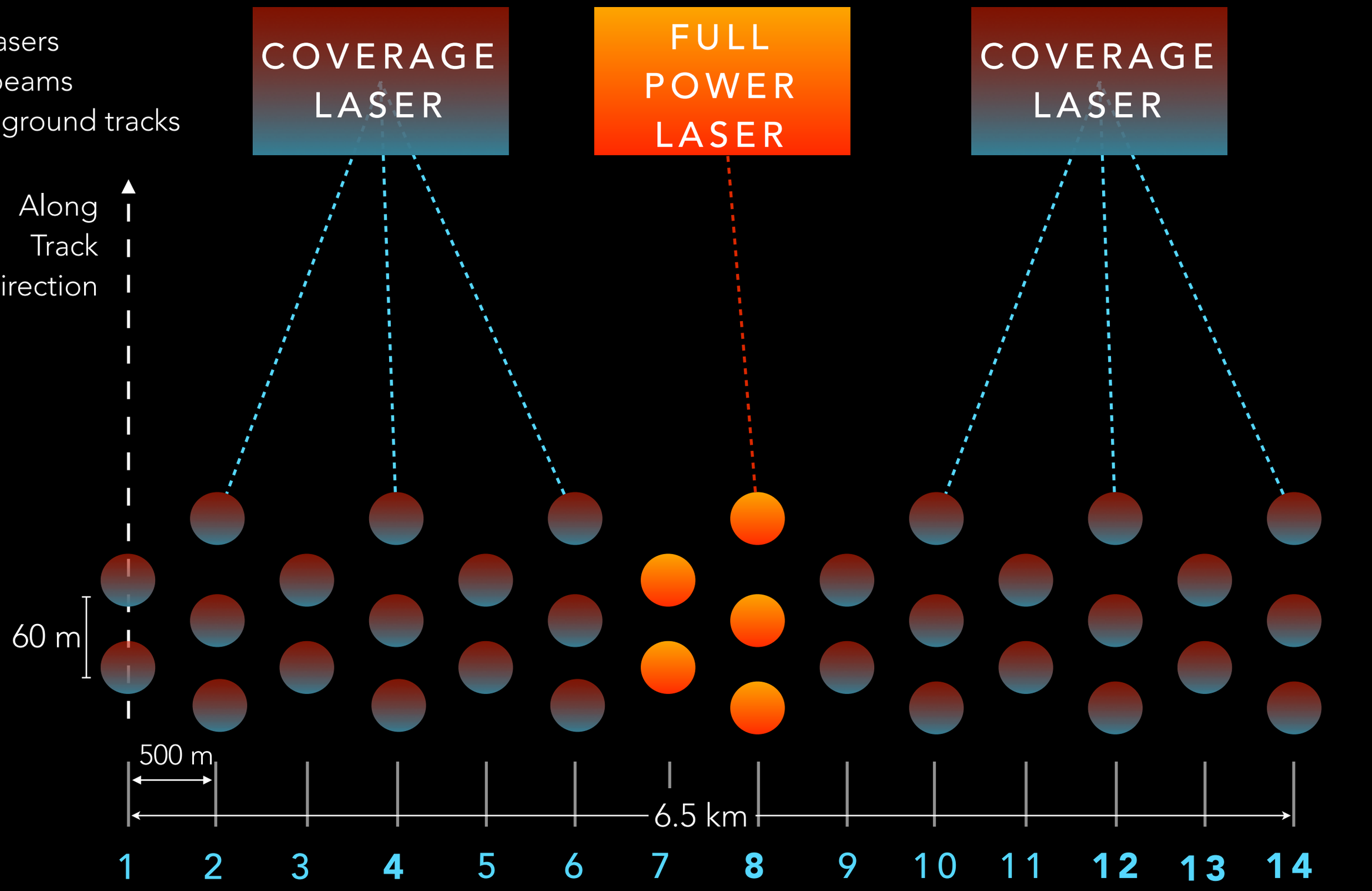

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

GEDI Laser Track Coverage

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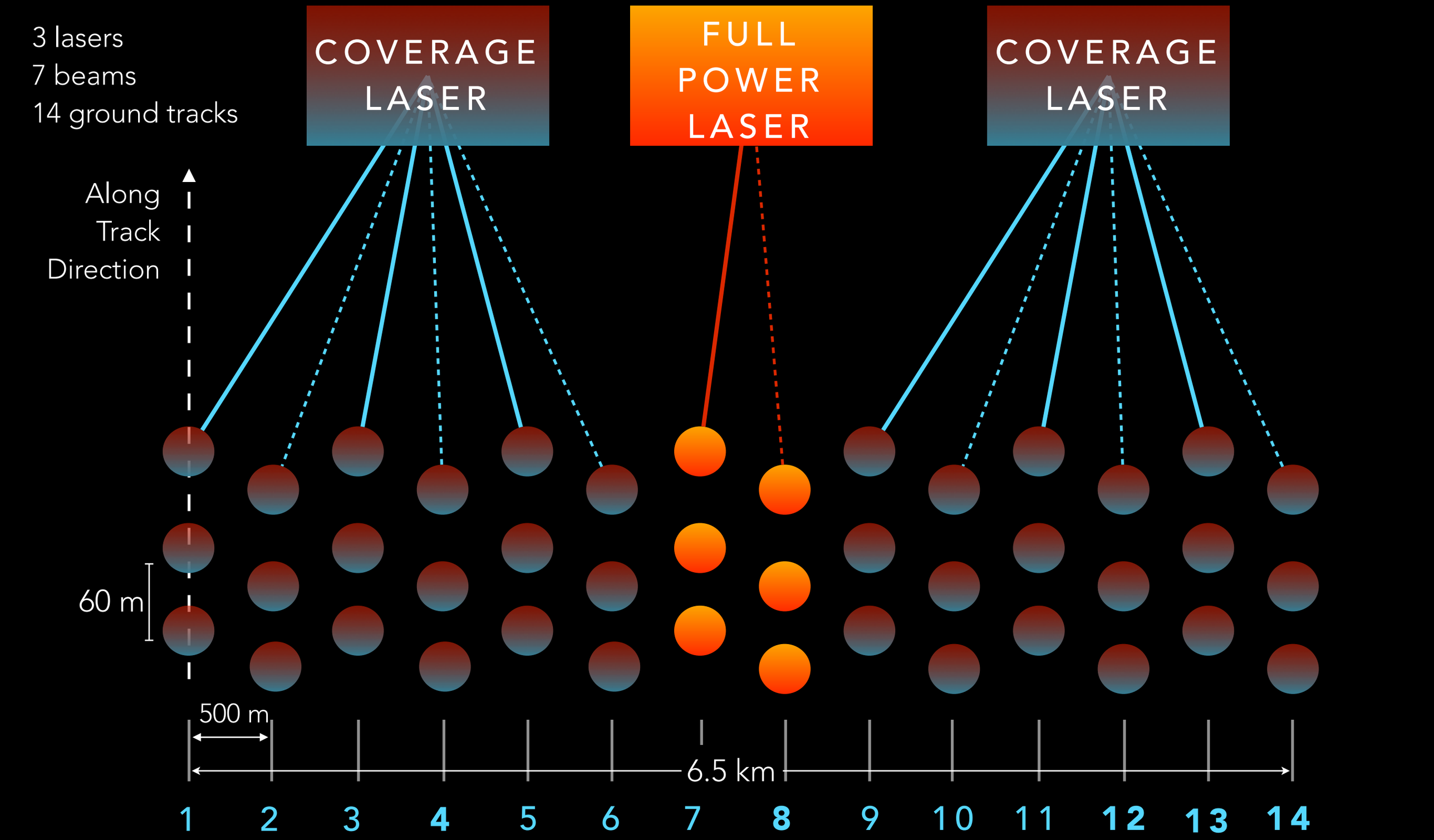


International Space Station

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

International Space Station

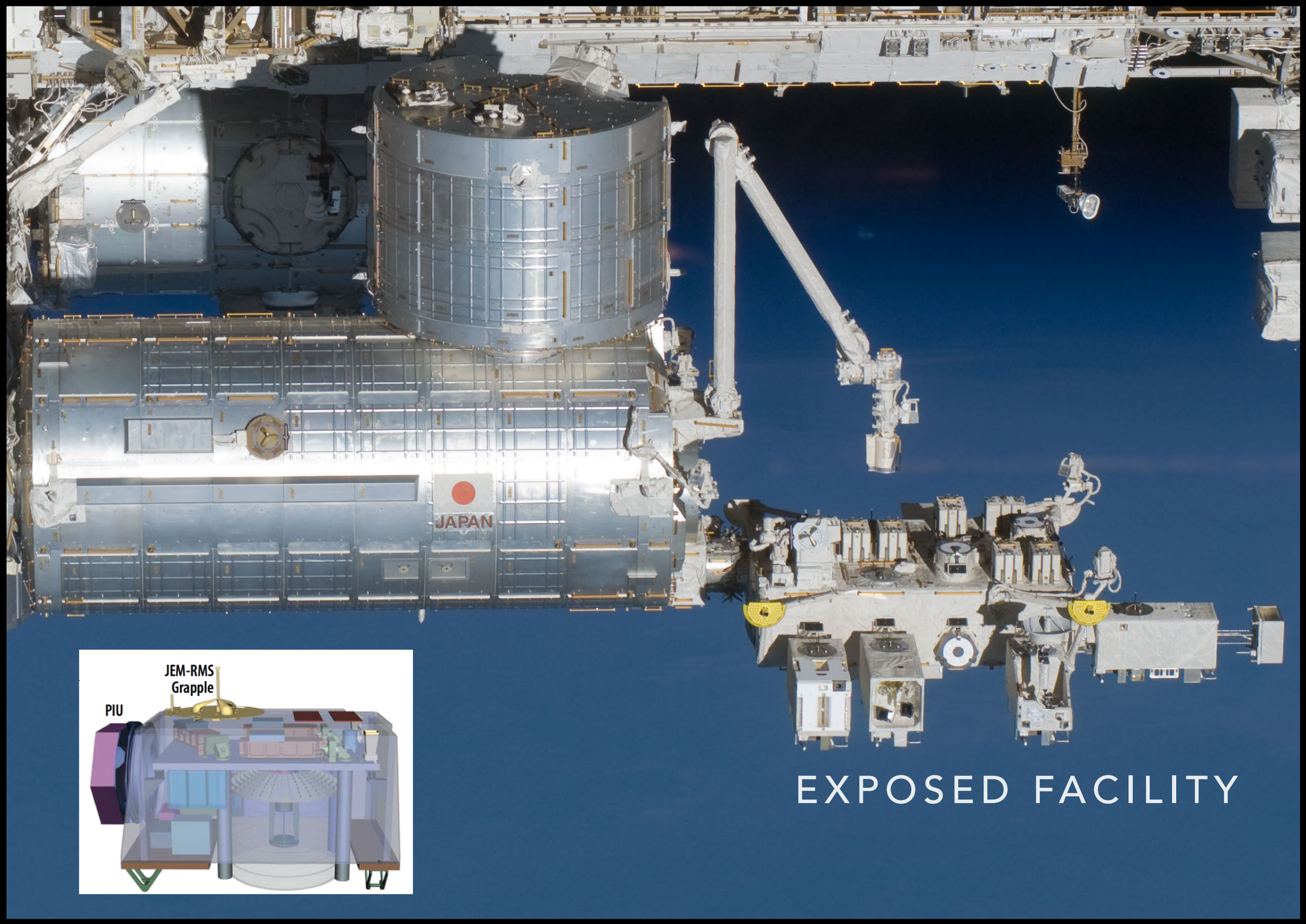
SPACE-X
DRAGON
CAPSULE

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

Japanese Experiment Module

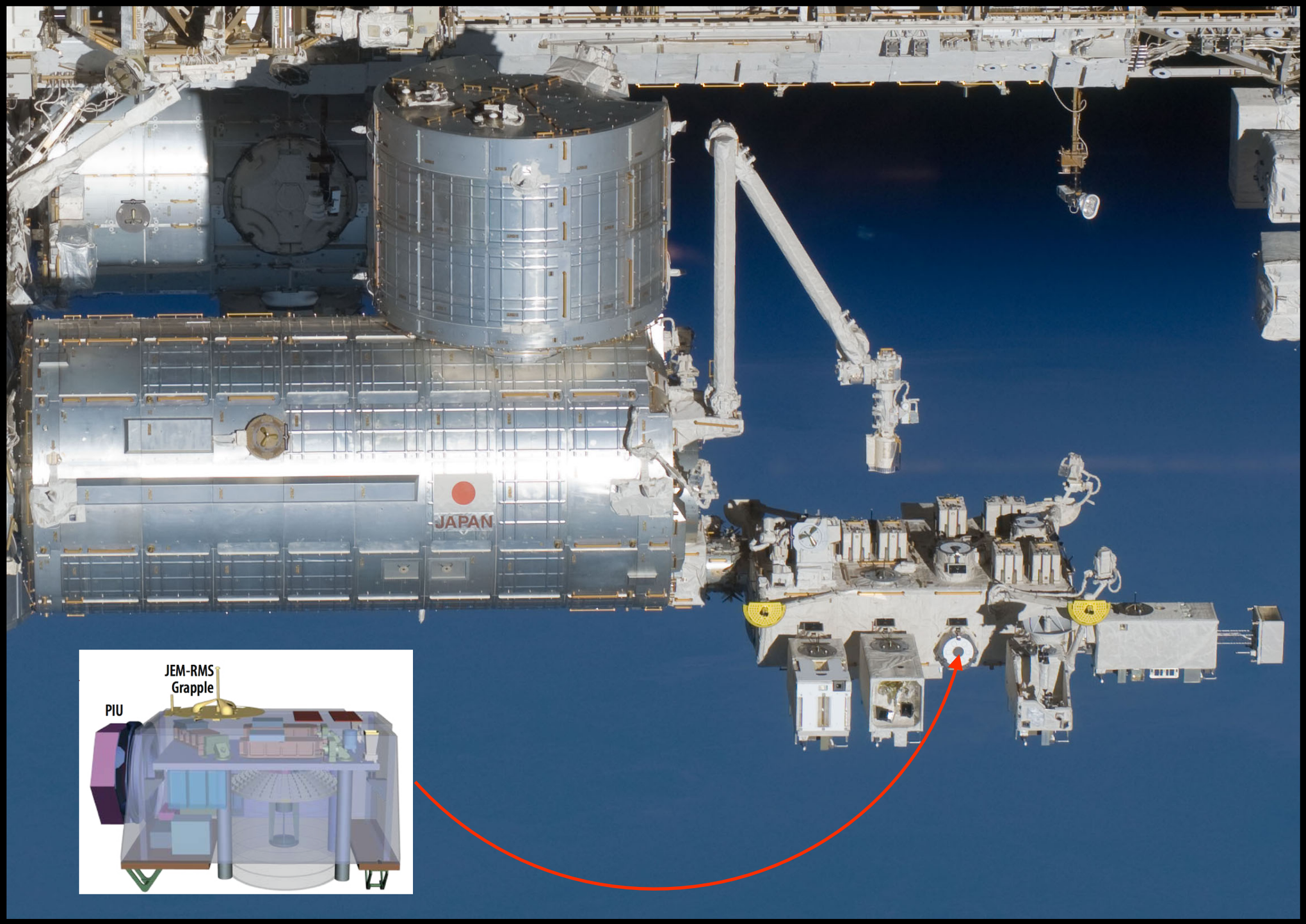
GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

Japanese Experiment Module



GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

Japanese Experiment Module



GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

Science Approach

Level 1B

GEDI Waveforms

Science Approach

Level 1B

Level 2&3

GEDI Waveforms

Canopy Height Metrics

Canopy Profile Metrics

Habitat Metrics

Objective 4

Science Approach

Level 1B

Level 2&3

GEDI Waveforms

Canopy Height Metrics

Canopy Profile Metrics

Habitat Metrics

Objective 4

Empirical & Statistical Models

Ecosystem Demography Model

Science Approach

Level 1B

Level 2&3

Level 4 Data Products

Present

GEDI Waveforms

Canopy Height Metrics

Canopy Profile Metrics

Habitat Metrics

Objective 4

Empirical & Statistical Models

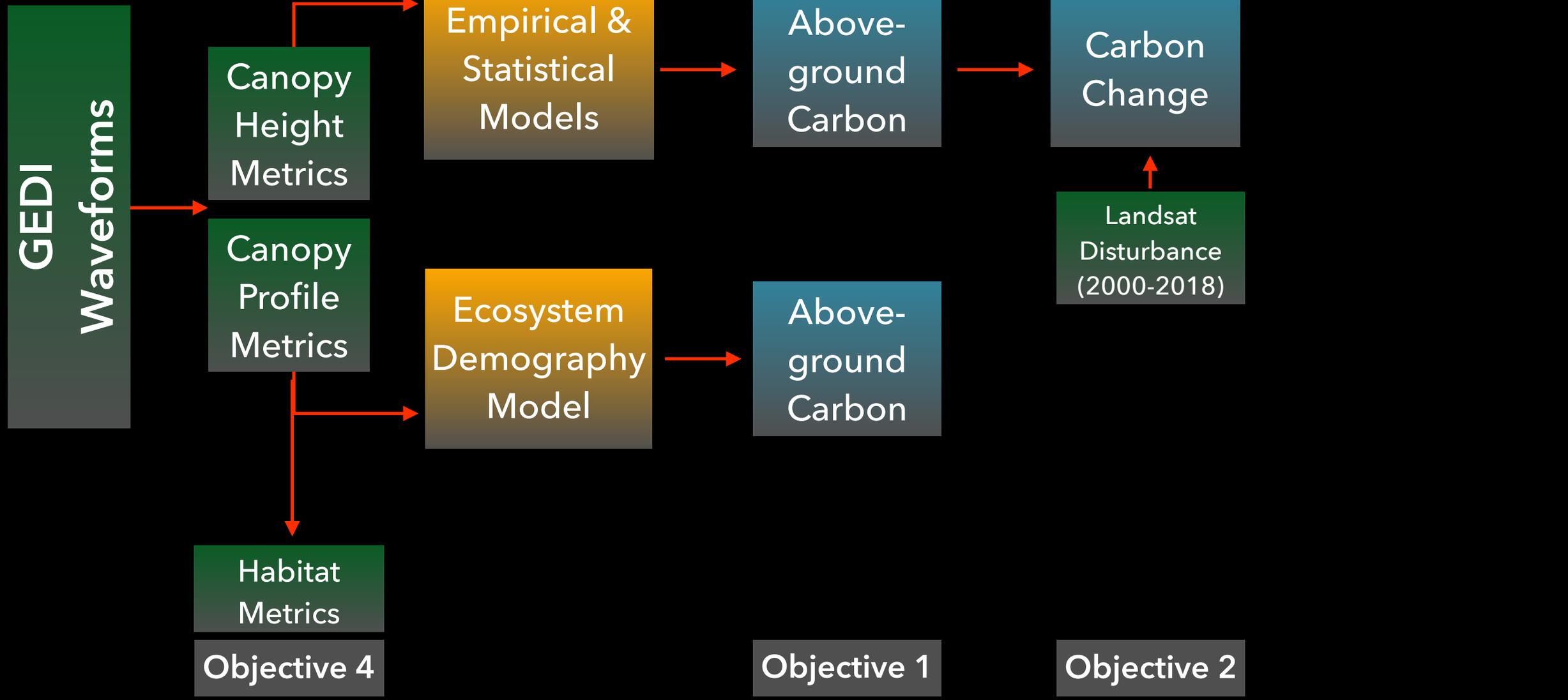
Ecosystem Demography Model

Above-ground Carbon

Above-ground Carbon

Objective 1

Science Approach



Science Approach

Level 1B

Level 2&3

Level 4 Data Products

Present

Past

Future

GEDI Waveforms

Canopy Height Metrics

Canopy Profile Metrics

Habitat Metrics

Objective 4

Empirical & Statistical Models

Ecosystem Demography Model

Above-ground Carbon

Objective 1

Carbon Change

Landsat Disturbance (2000-2018)

Objective 2

Sequestration Potential and Future Scenarios (IPCC)

Objective 3

GEDI Data Products

Level 2 Footprint Products

Canopy Height Metrics

Canopy Profile Metrics

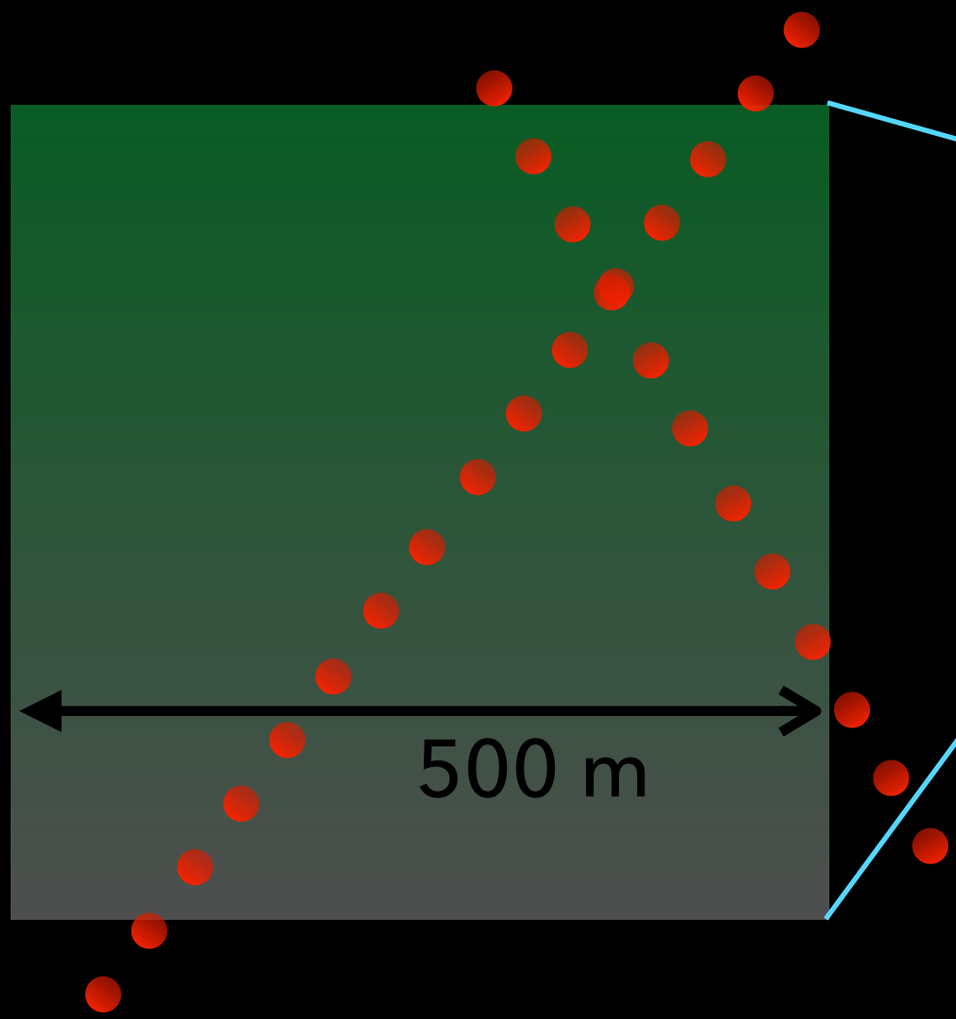
GEDI Data Products

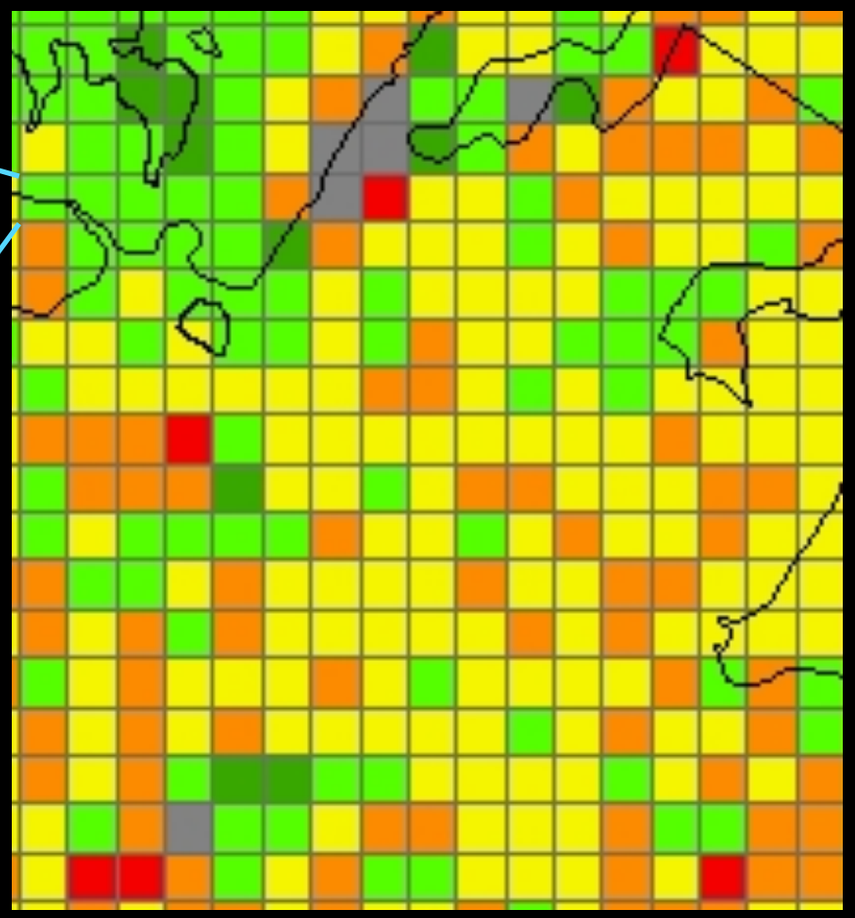
Level 2 Footprint Products

Canopy Height Metrics

Canopy Profile Metrics

Level 3 Gridded Products

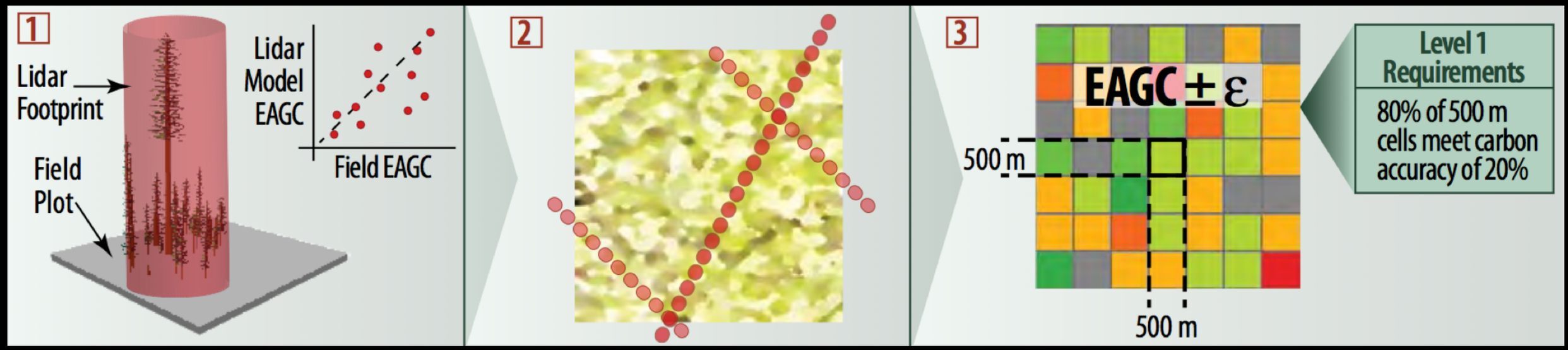




Model Investigative Products

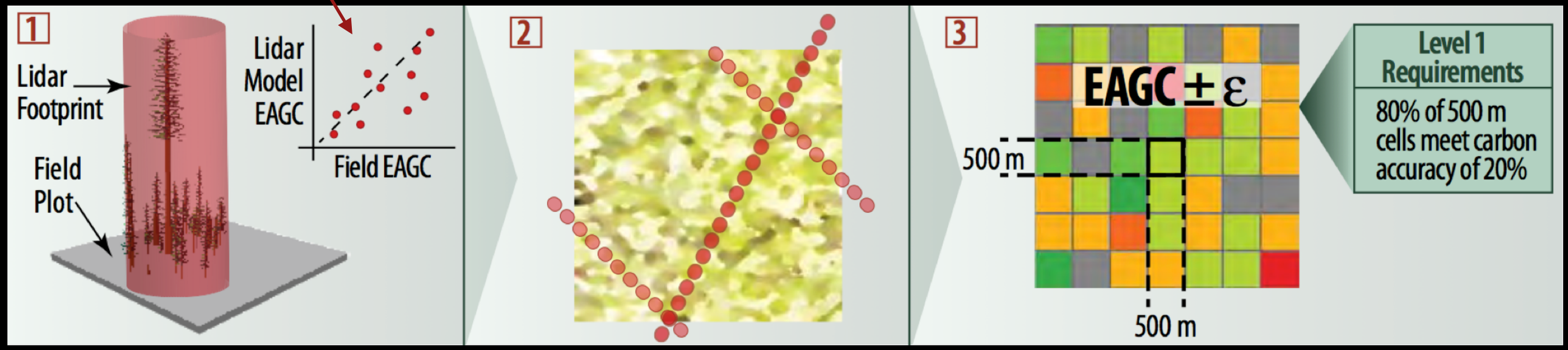
LEVEL 4 PRODUCT	RESOLUTION
EMPIRICAL MODEL OUTPUTS	
Aboveground Carbon	25 m / 500 m
Aboveground Carbon Change (2000-2018)	500 m grid
ECOSYSTEM MODEL OUTPUTS	
Aboveground Carbon and Carbon Flux	500 m grid
Carbon Sequestration Potential	500 m grid
ENHANCED RESOLUTION FROM FUSION	
High Resolution Height and Carbon from Landsat	30 m
Height, Structure and Carbon from Tandem-X	Variable

Approach to Errors



Approach to Errors

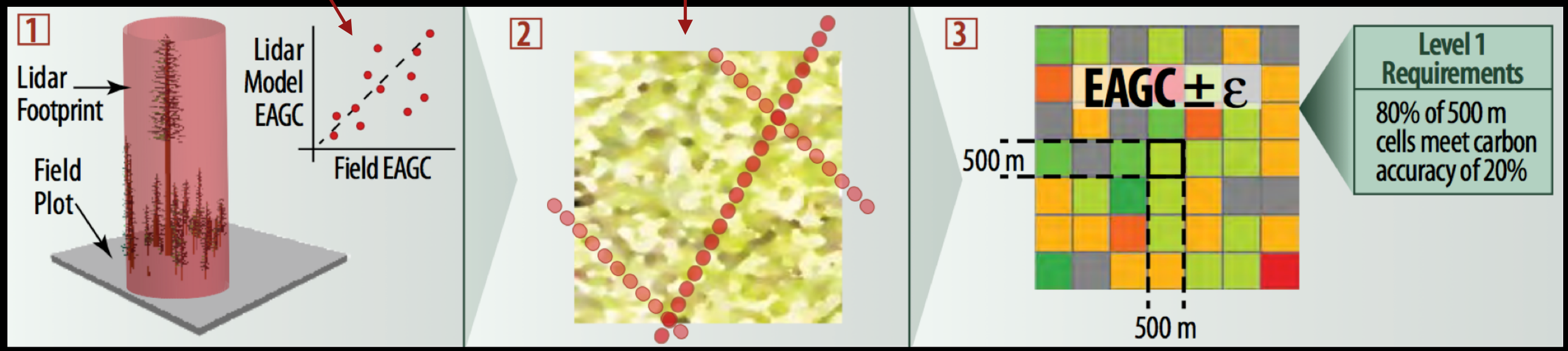
Assume we can get this to within 35%-40% RMSE



Approach to Errors

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

Biomass estimate for each 25 m footprint



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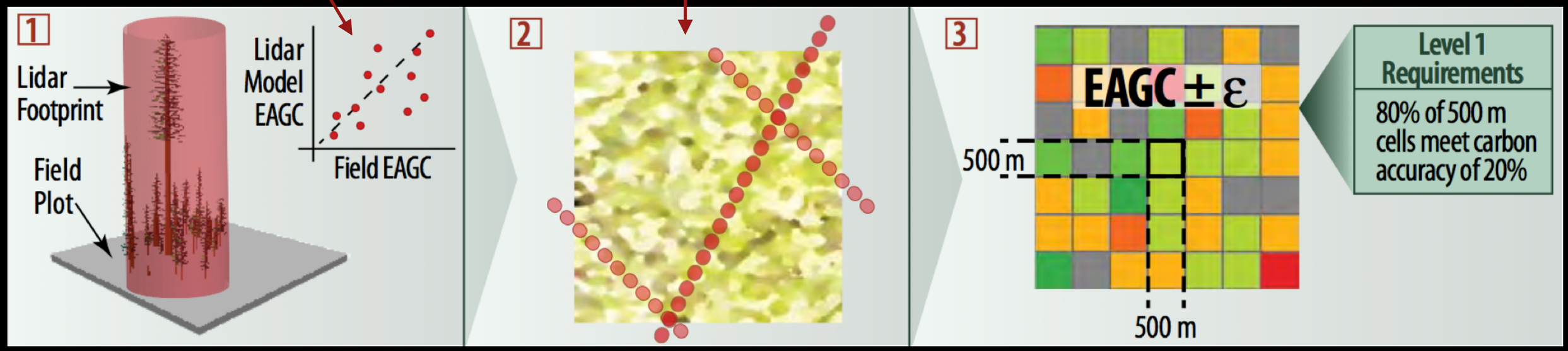


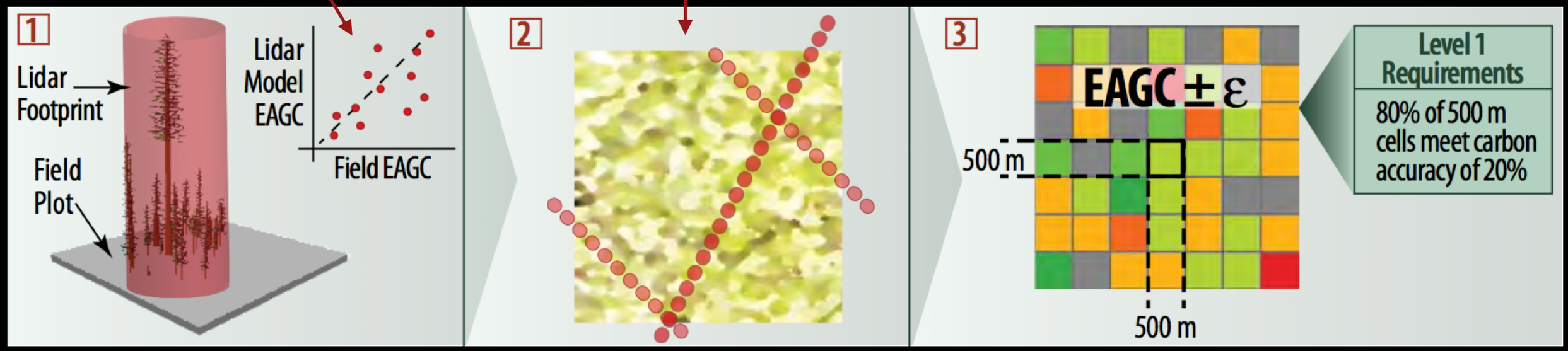
1. Lidar-to-field RMSE
2. Number of *Passes*
3. Number of *Footprints*
4. Biomass variance within cell (from footprints)

Approach to Errors

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

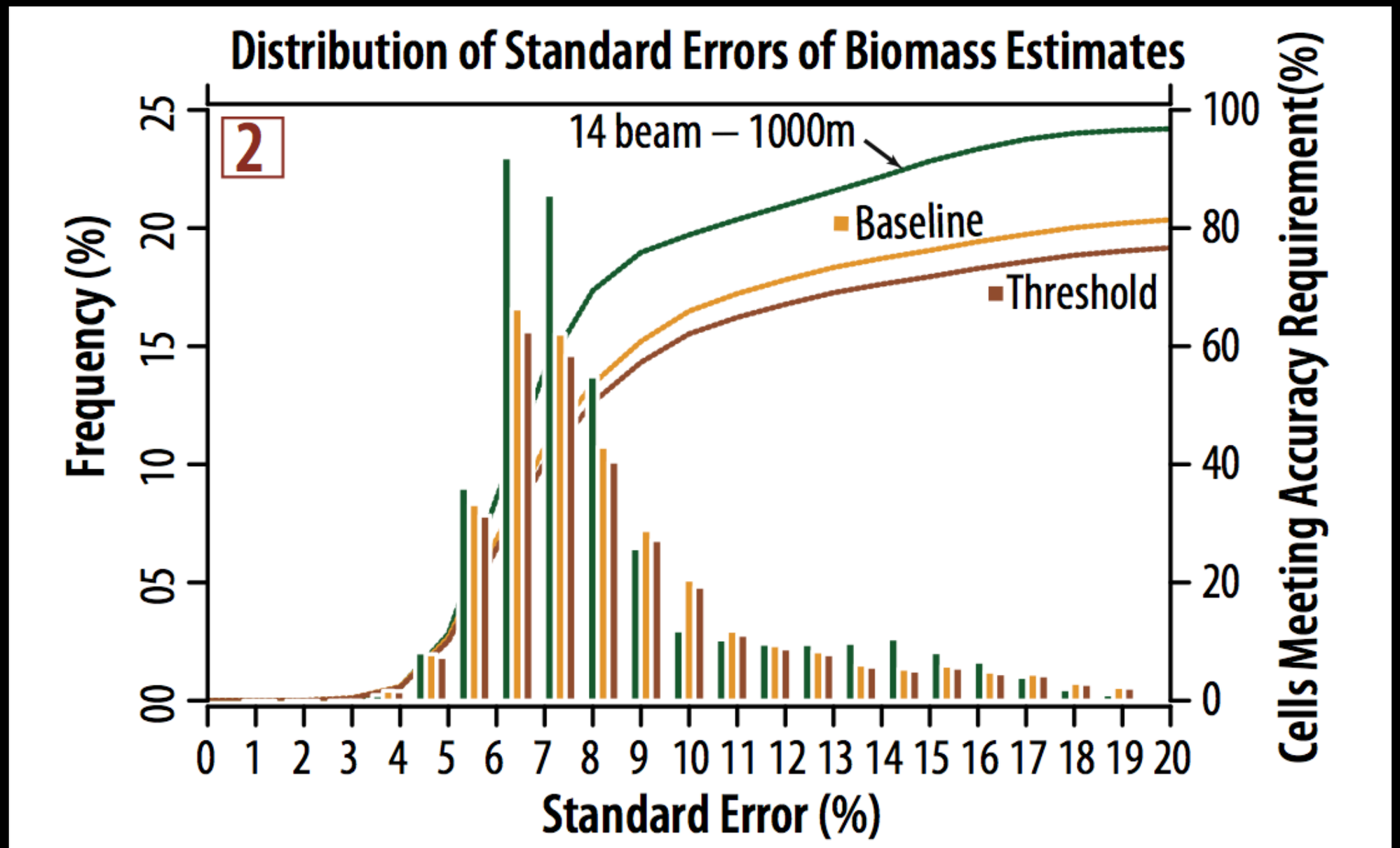
Biomass estimate for each 25 m footprint

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)

Expected Biomass Errors

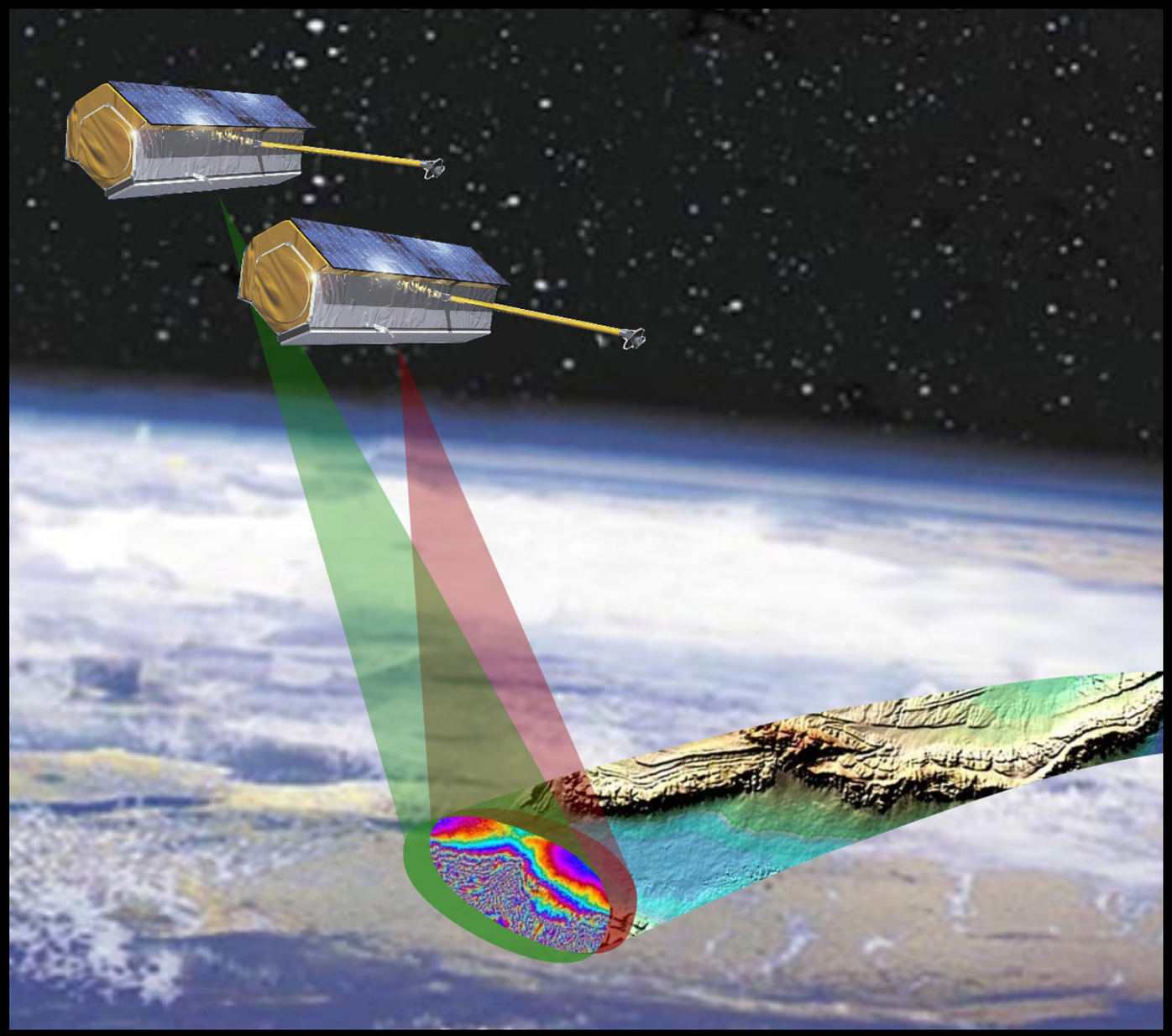


80% of 500 m cells have standard error < 20%
after one year of operations

Fusion with Tandem-X Data

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

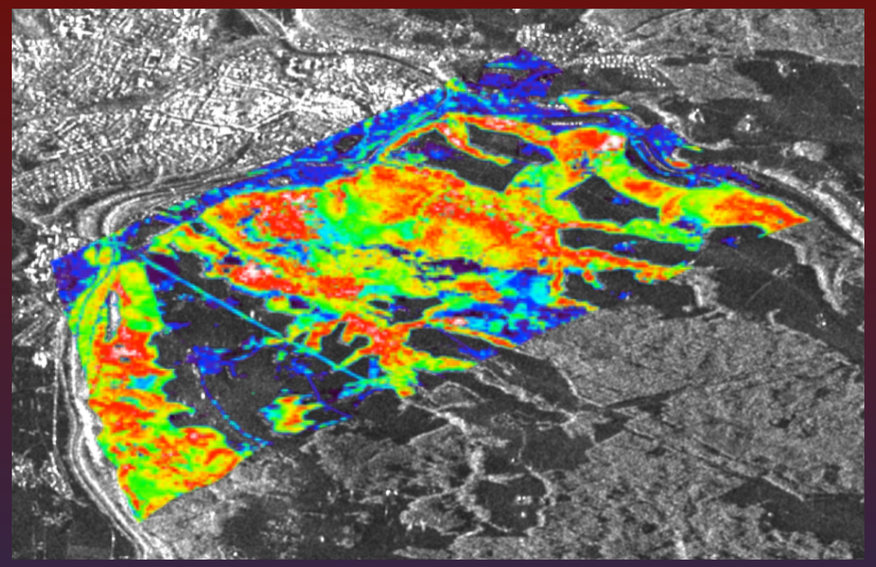
Fusion with Tandem-X Data

Collaboration with German Aerospace Center

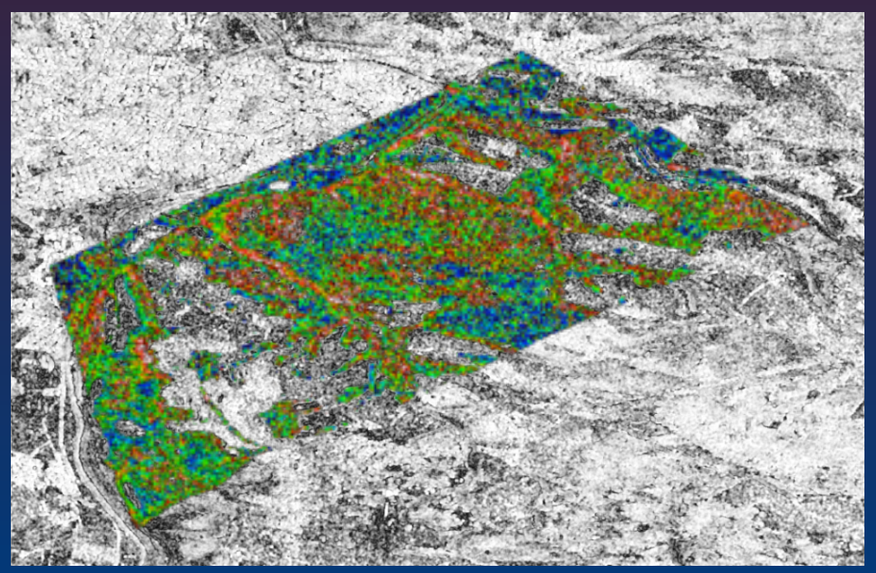
DLR

Traunstein Forest, Germany

Height Derived from Airborne Lidar



Height Derived from Tandem-X



- Provides high-resolution topographic data
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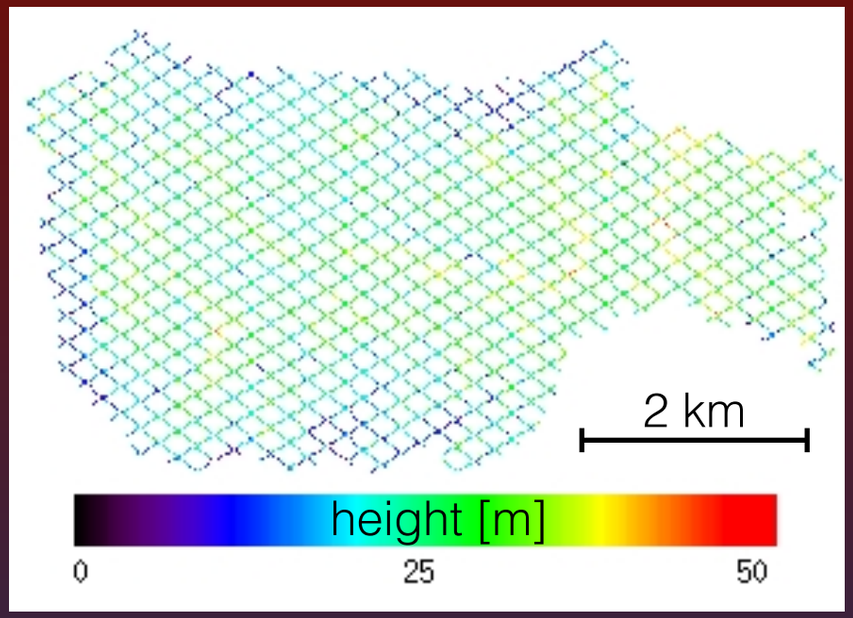
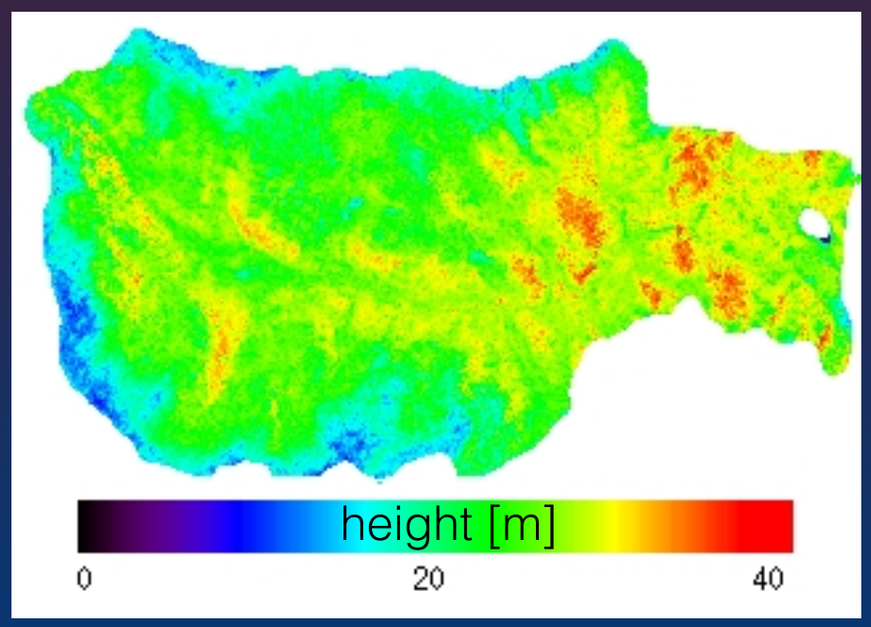
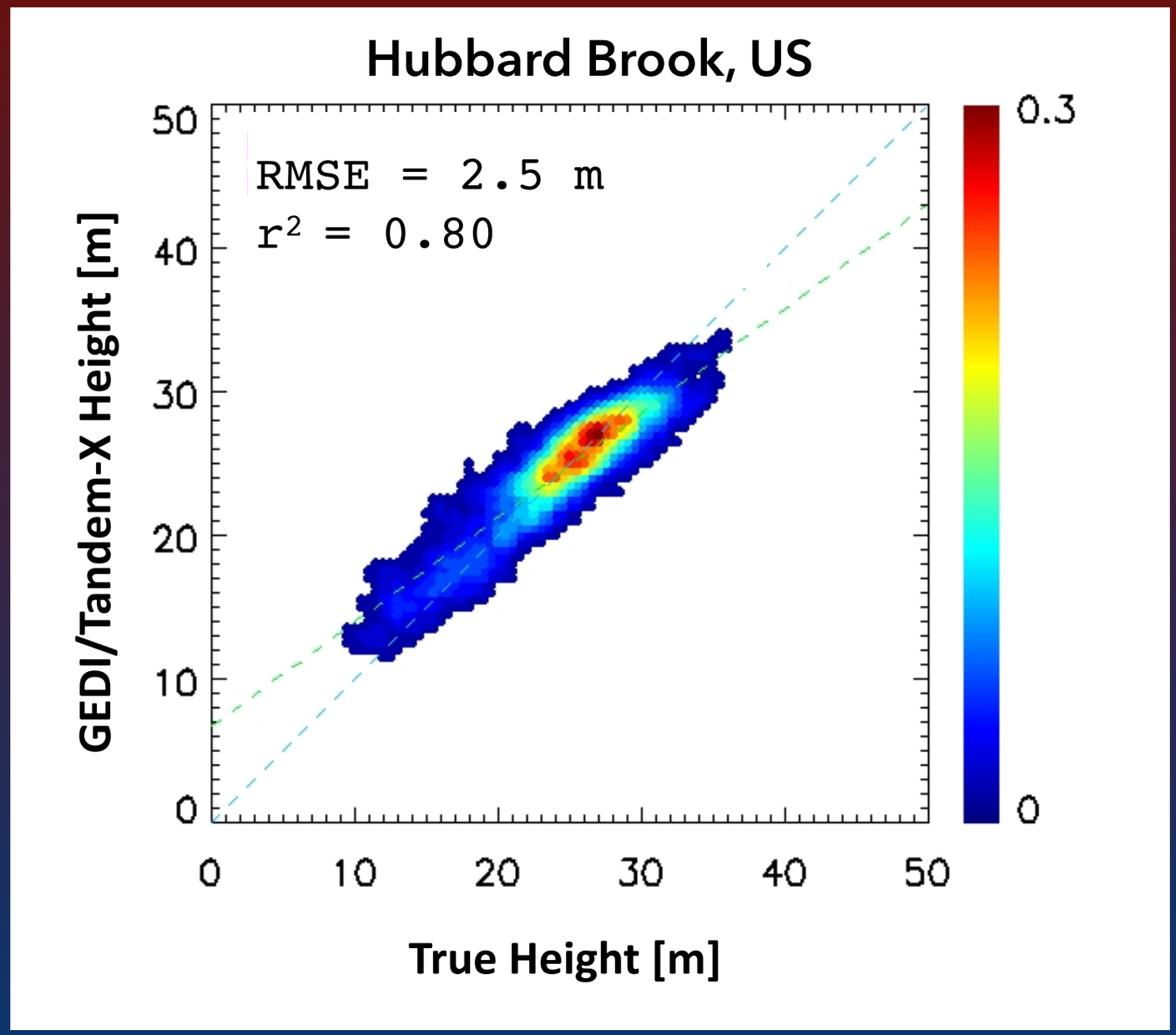
Fusion with Tandem-X Data

Simulated GEDI Tracks





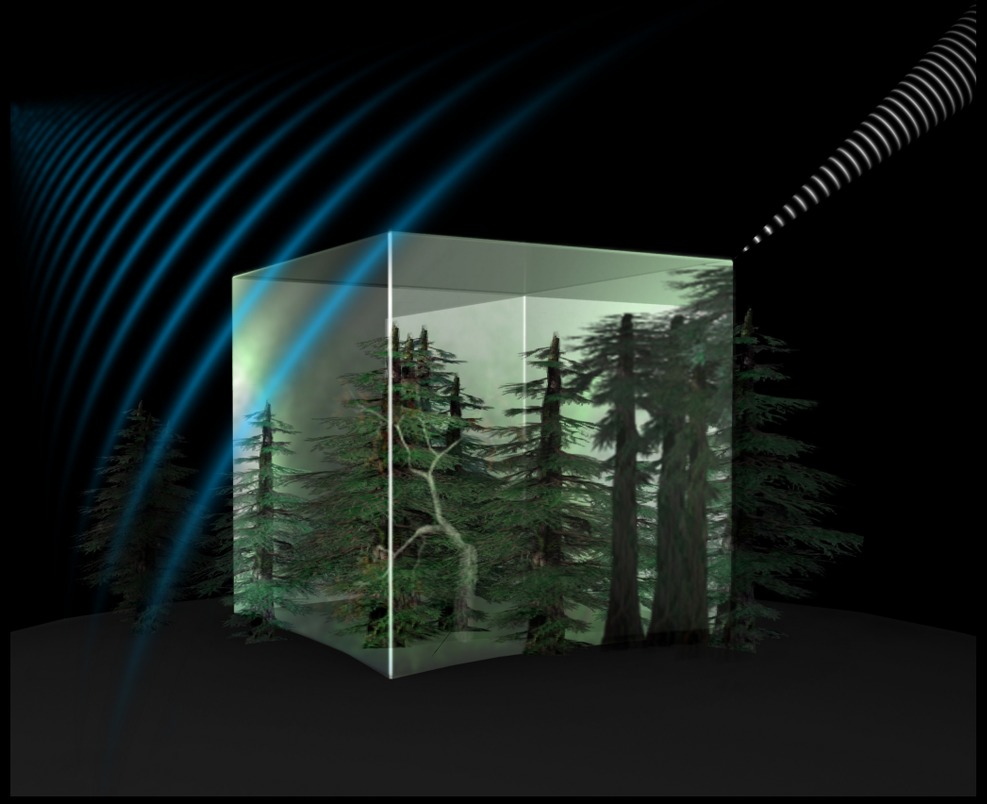
GEDI/Tandem-X Height



Considerations for BIOMASS

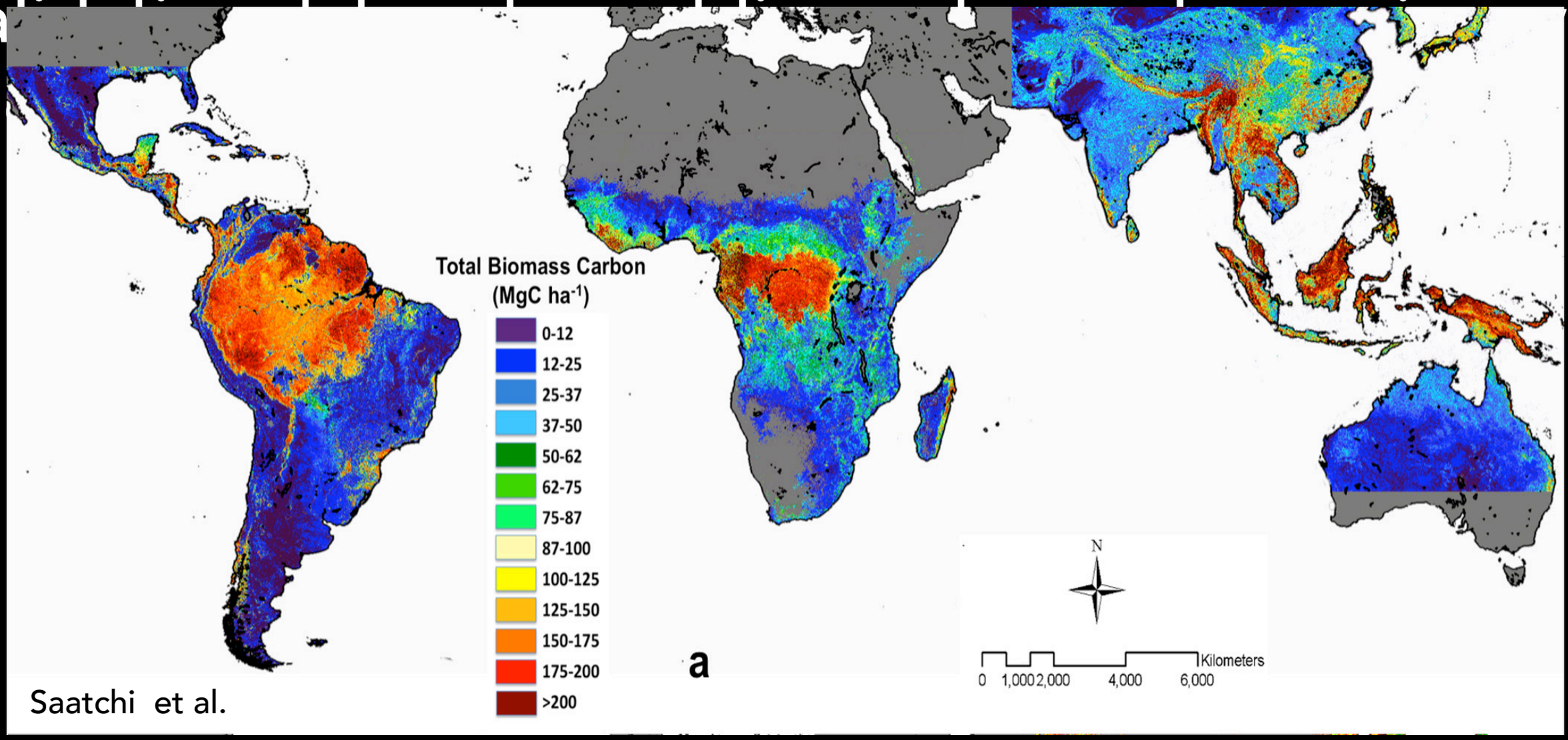
GEDI potentially provides unprecedented calibration/ validation data sets enabling enhanced mapping with BIOMASS, NISAR and other radar missions

BIOMASS



Considerations for BIOMASS

GEDI potentially provides unprecedented calibration/ va[illegible]ith BI[illegible]



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

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

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- 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

Potential Synergies

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  - Approach 4 ha resolution after 2+ years on orbit

Potential Synergies

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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

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

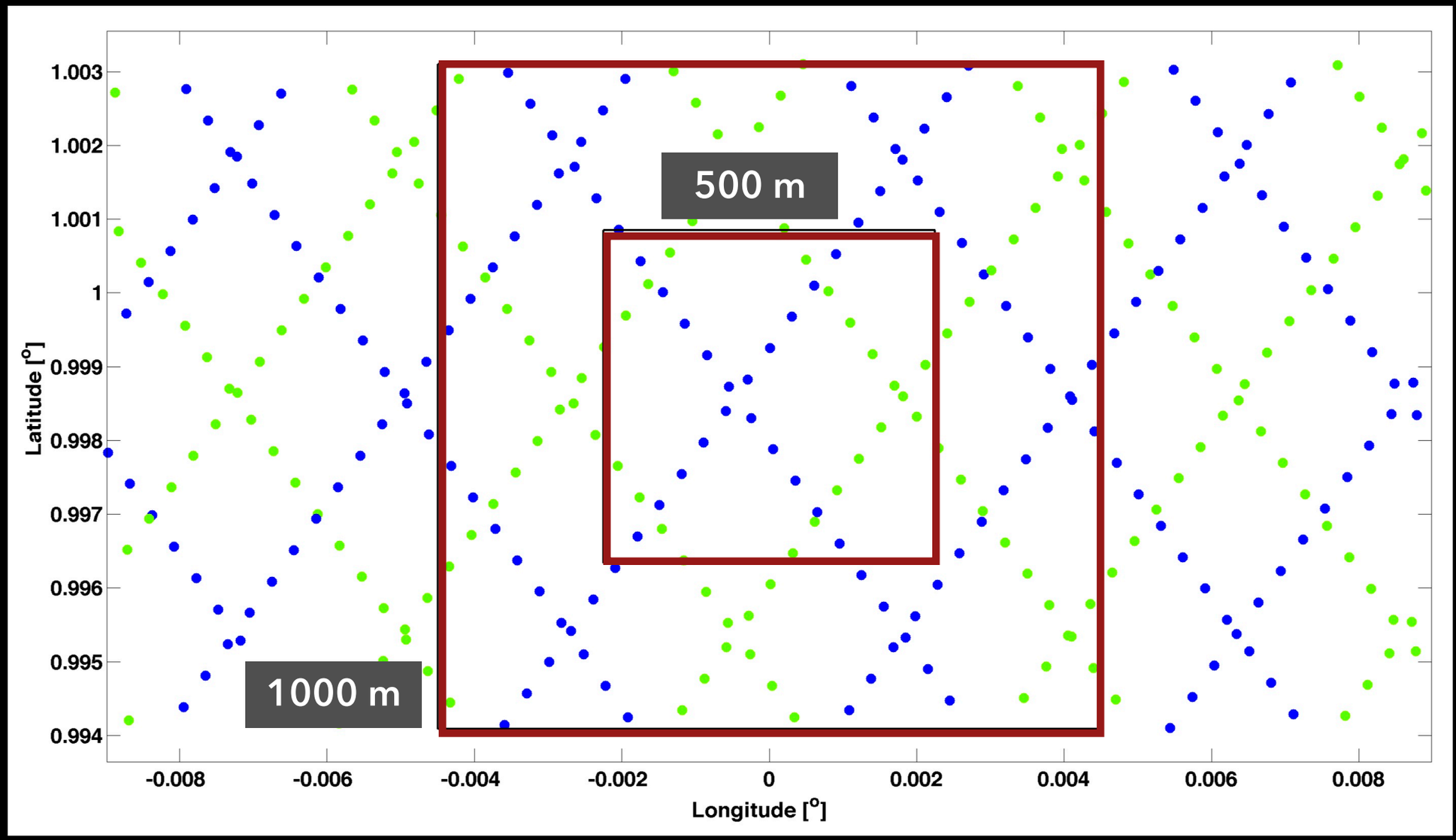
Considerations for BIOMASS

- 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

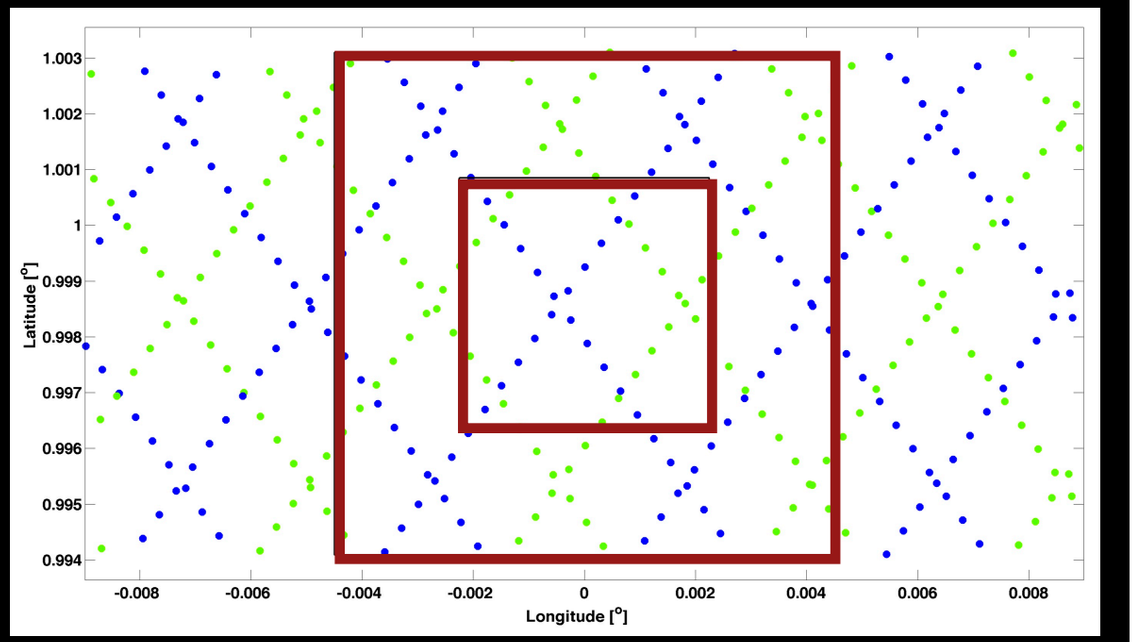
- Scale issues: GEDI footprints are 0.05 ha
  - But there are *lots* of them. How to optimally use for validation and calibration?
  - Can we leverage orbital cross-over points?

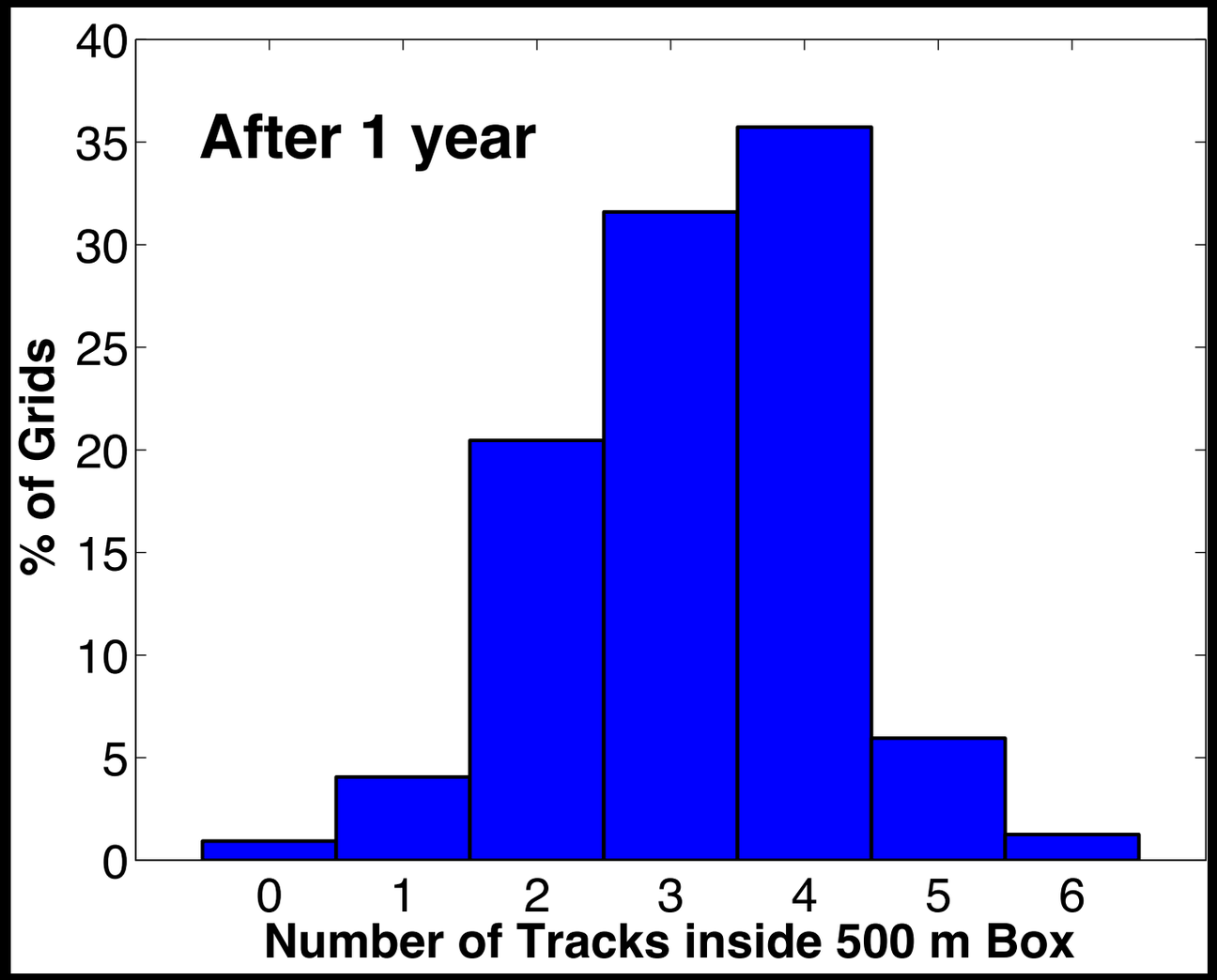
GEDI Ground Tracks

Equator



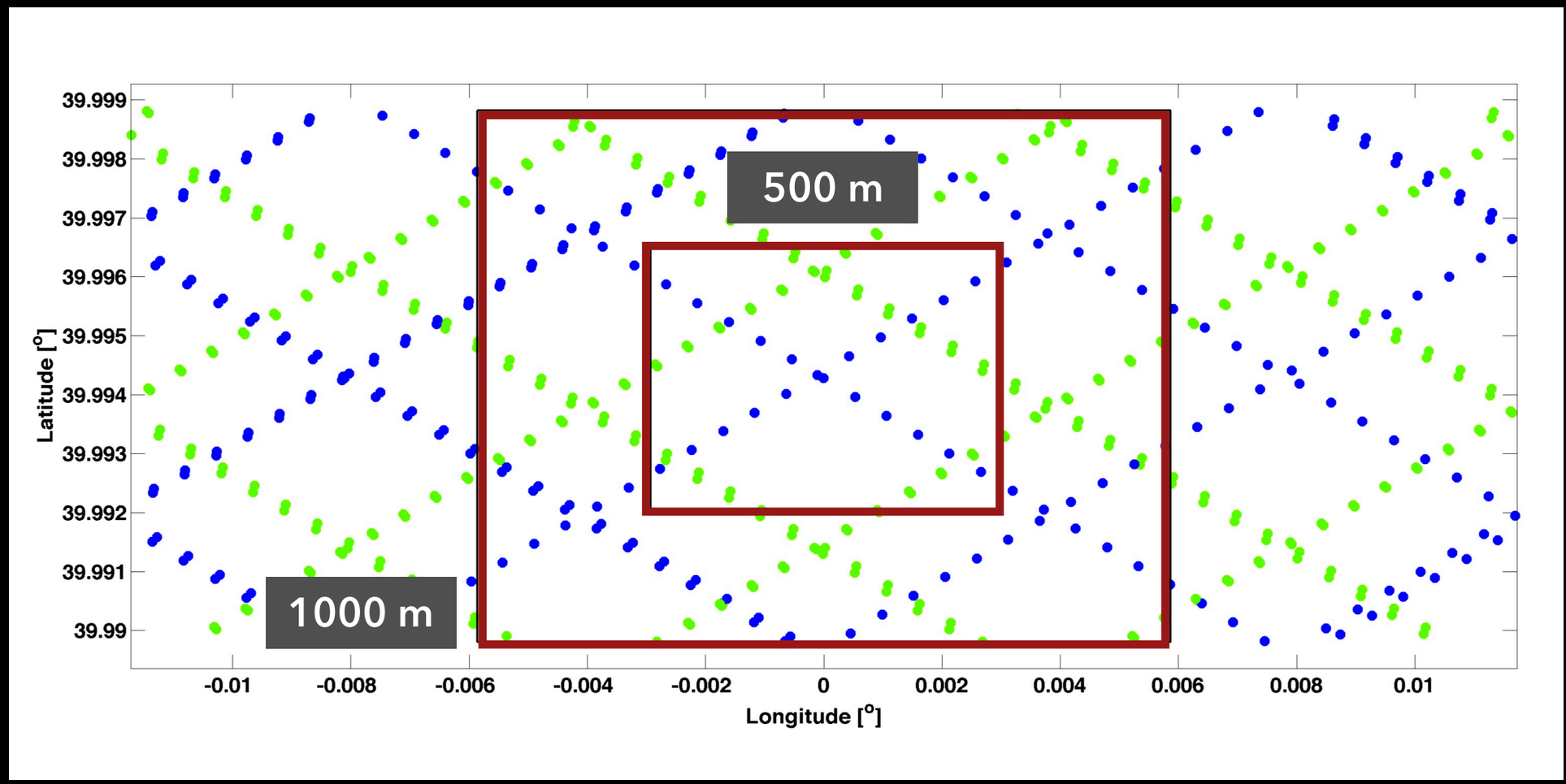
GEDI Ground Tracks





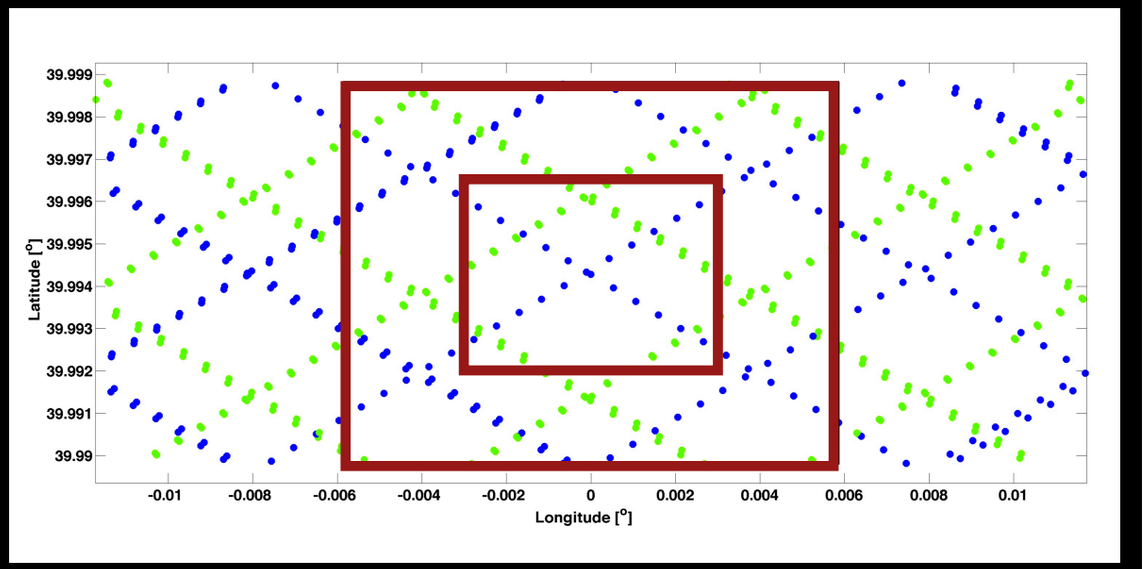
GEDI Ground Tracks

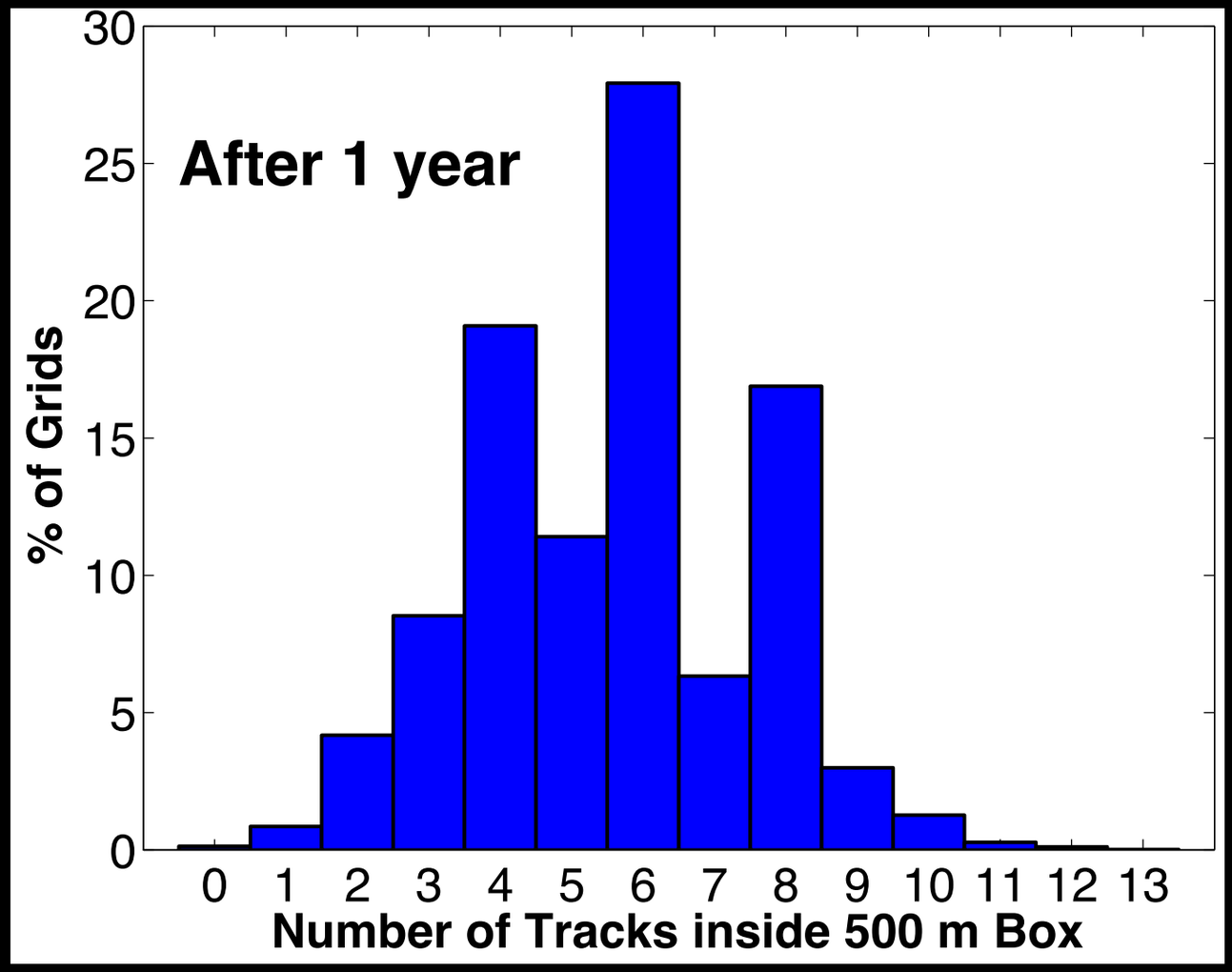
40° Latitude



GEDI Ground Tracks

40° Latitude





Considerations for BIOMASS

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- 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

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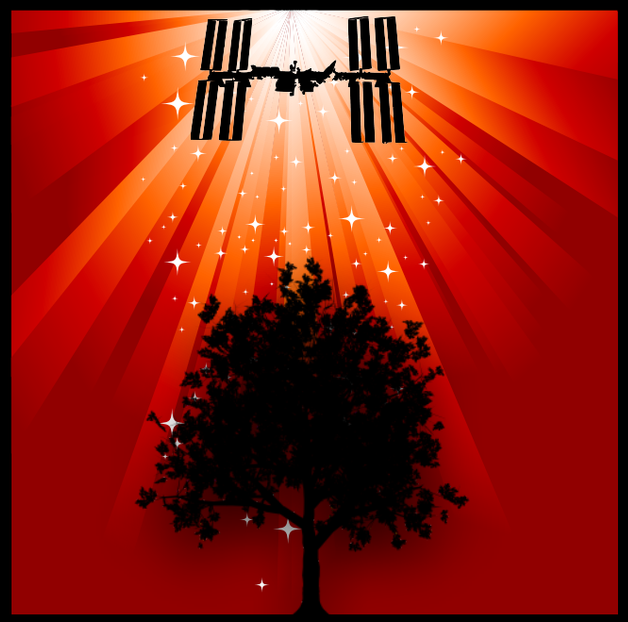
- Approaches to physically-based carbon estimation
  - GEDI uses individual-based ecosystem model based on height distributions (the ED model)
  - What will BIOMASS do and should we consider complementing differing model approaches?
  - Can we leverage common ancillary data such as soils, climate, and land use?

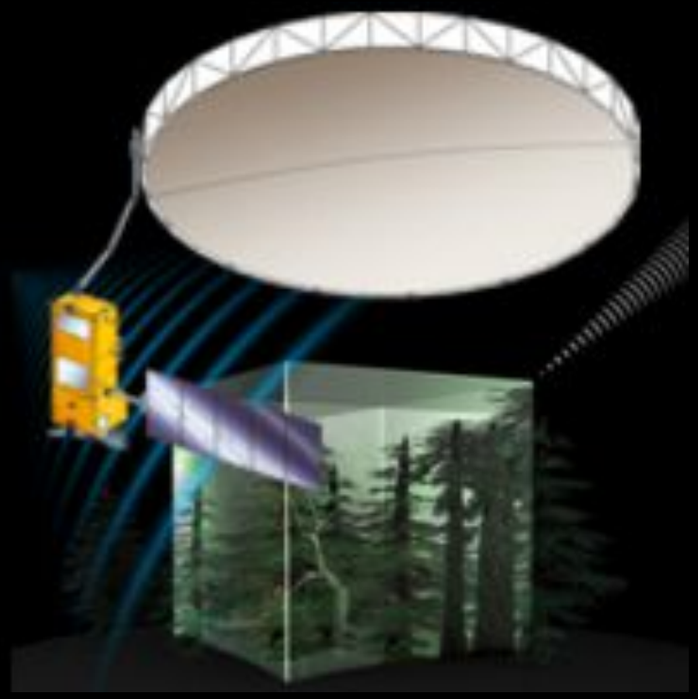
Considerations for BIOMASS

BIOMASS/GEDI/NISAR Science Team collaboration should address common cal/val and science issues

The stage is set.



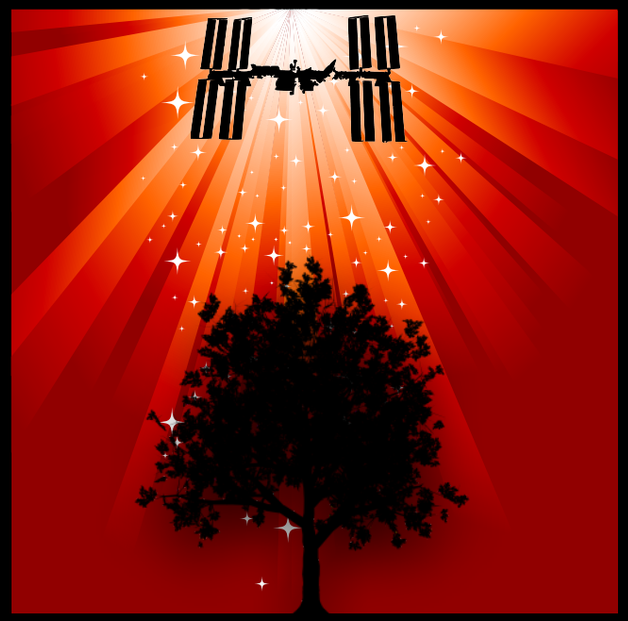
GEDI LIDAR



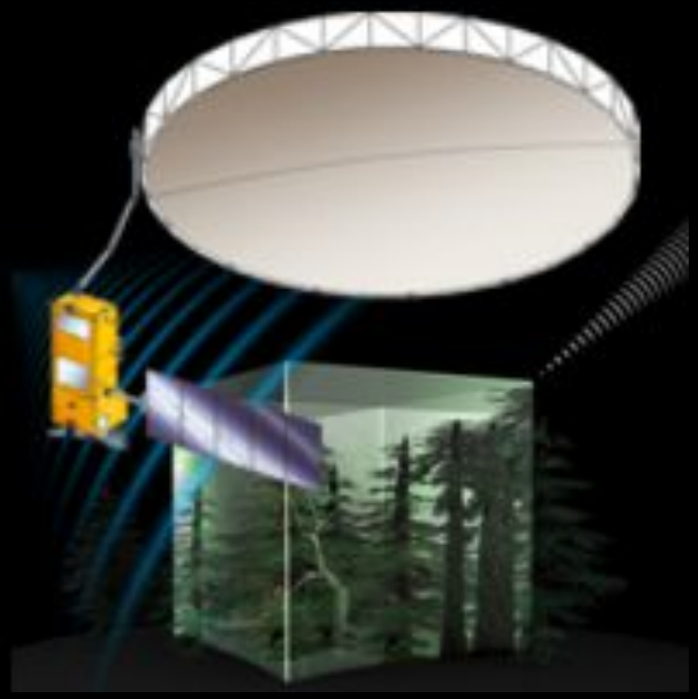
BIOMASS

The stage is set.

NISAR
NASA - ISRO SAR Mission



GEDI LIDAR



BIOMASS

TanDEM

ICESAT-2

ALOS-2