National Aeronautics and Space Administration

The International Space Station as a Key Platform to Synergize Observations of Fundamental Ecosystem Properties

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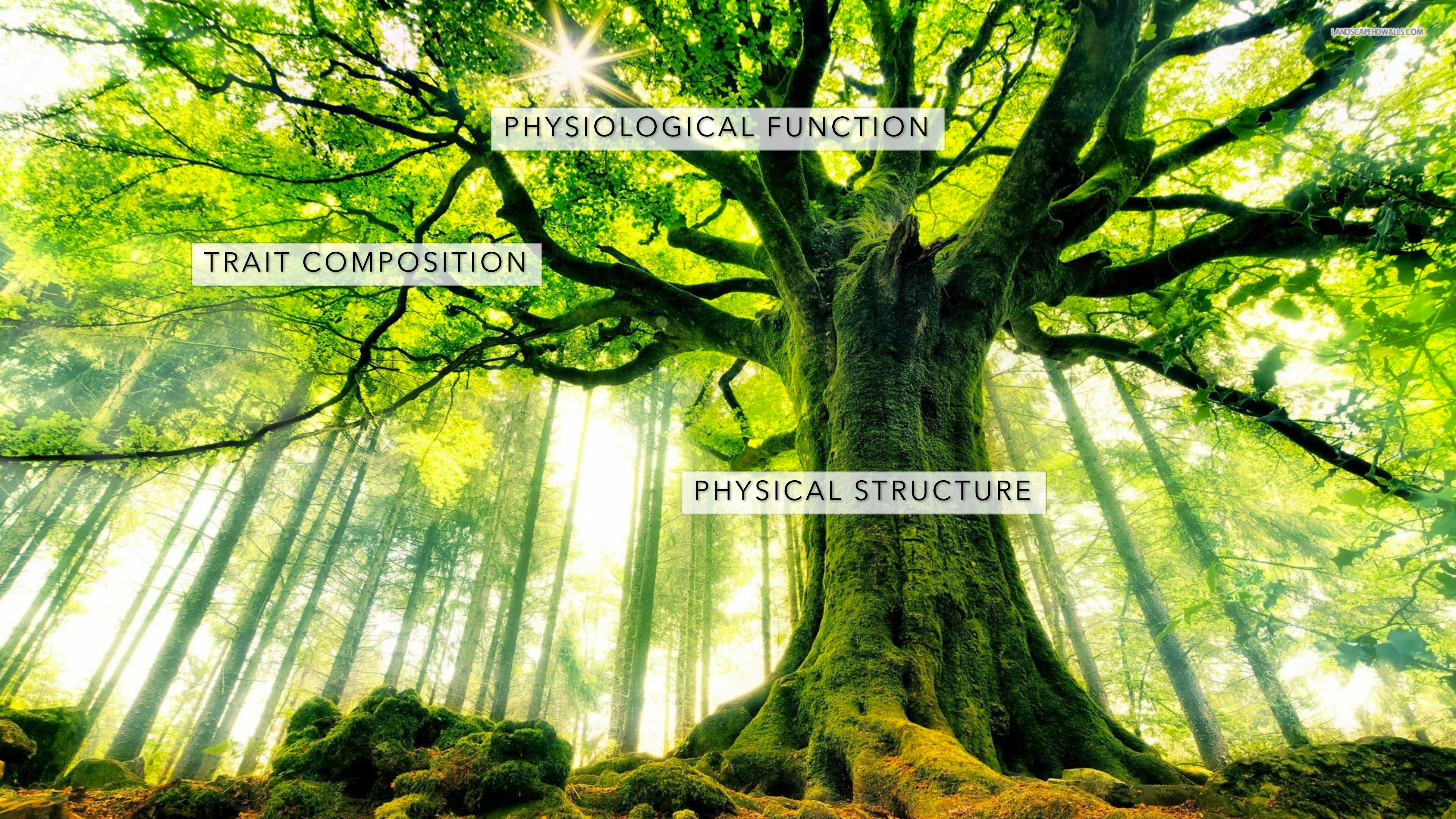
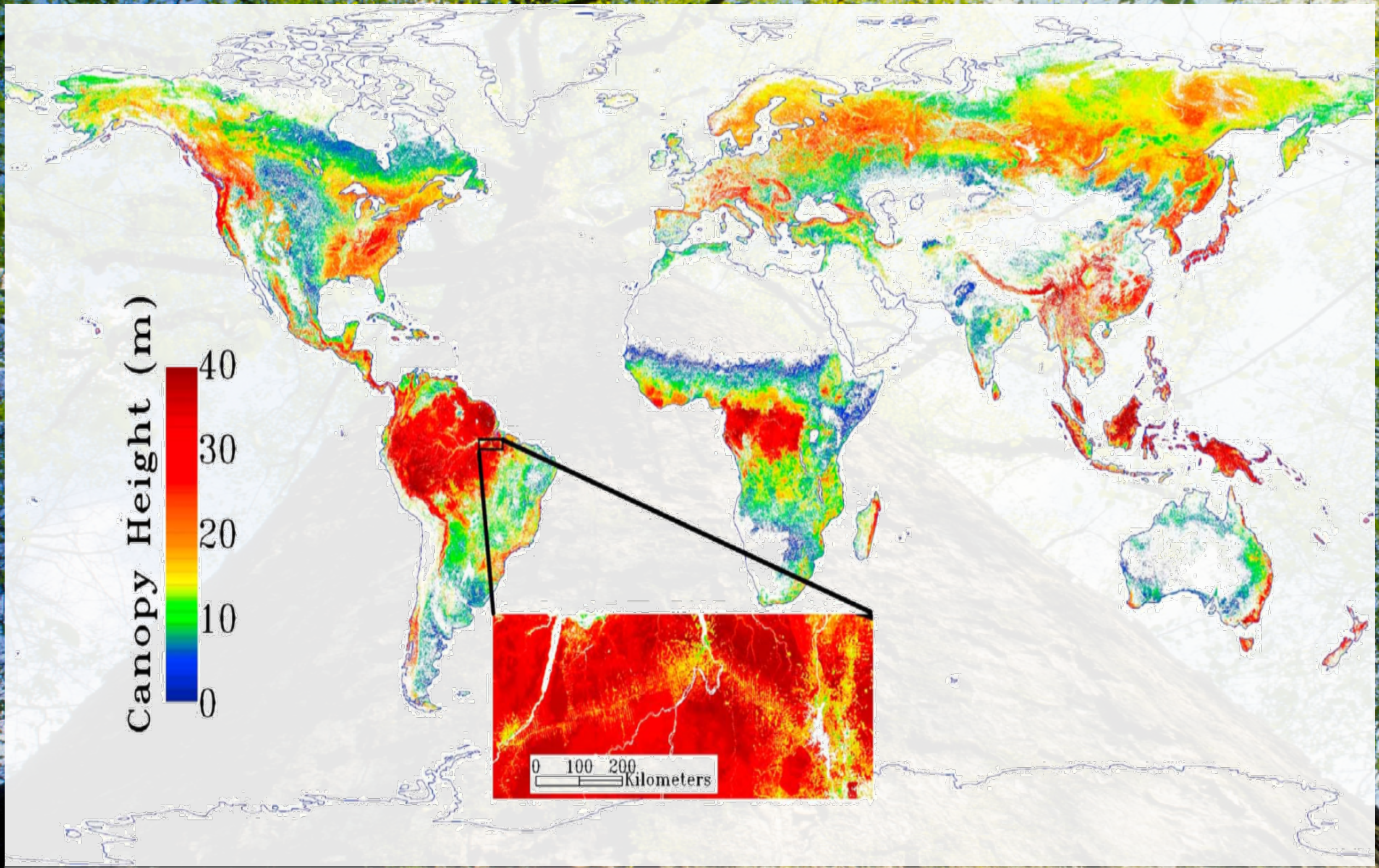
WHAT IS AN ECOSYSTEM?


PHYSIOLOGICAL FUNCTION
TRAIT COMPOSITION
PHYSICAL STRUCTURE

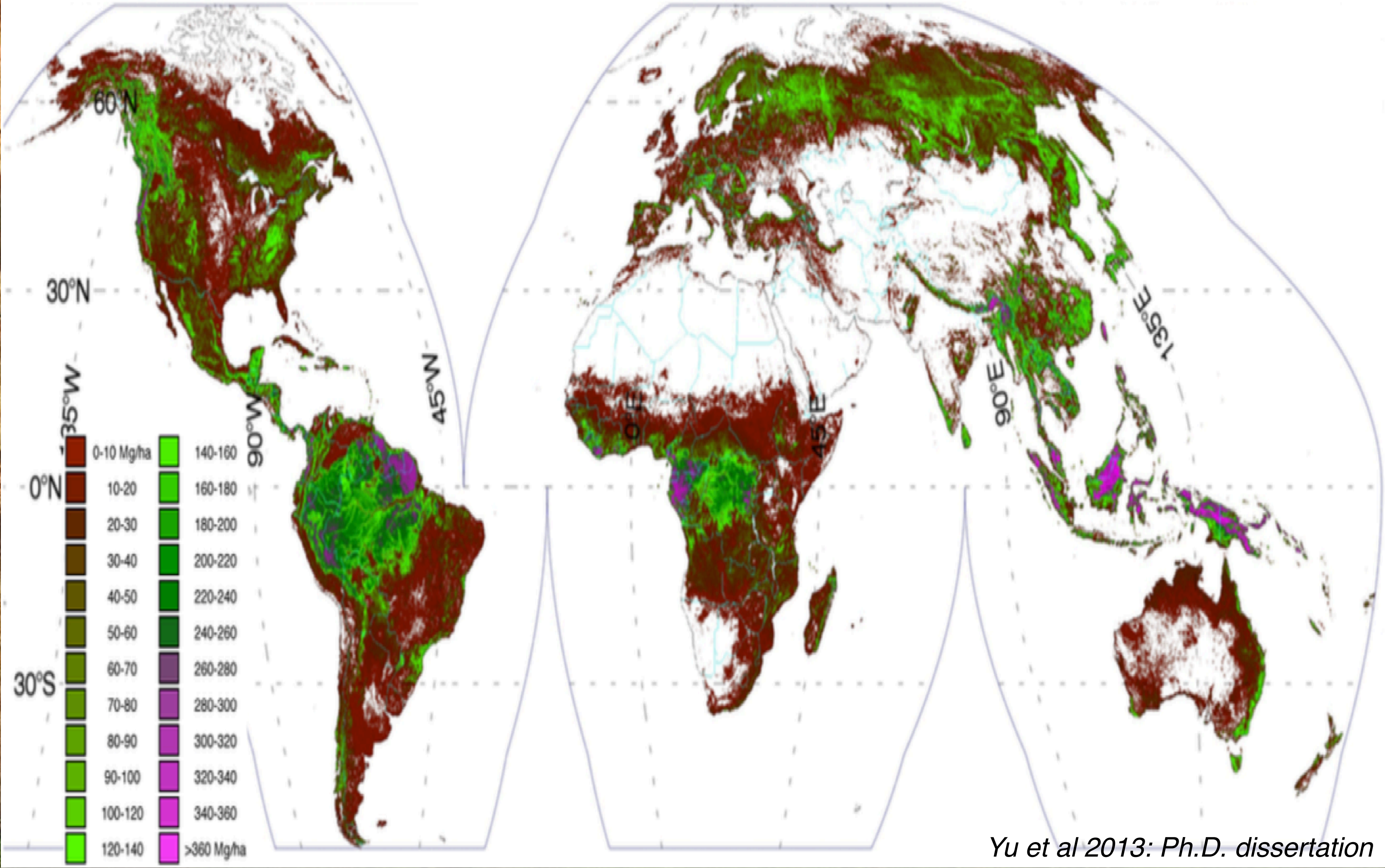
WHAT CAN WE OBSERVE GLOBALLY?

Structure: Canopy Height



Simard, M., Pinto, N., Fisher, J.B., Baccini, A., 2011. Mapping forest canopy height globally with spaceborne LiDAR. *Journal of Geophysical Research–Biogeosciences* 116: G04021, DOI:10.1029/2011JG001708.

Structure: Biomass

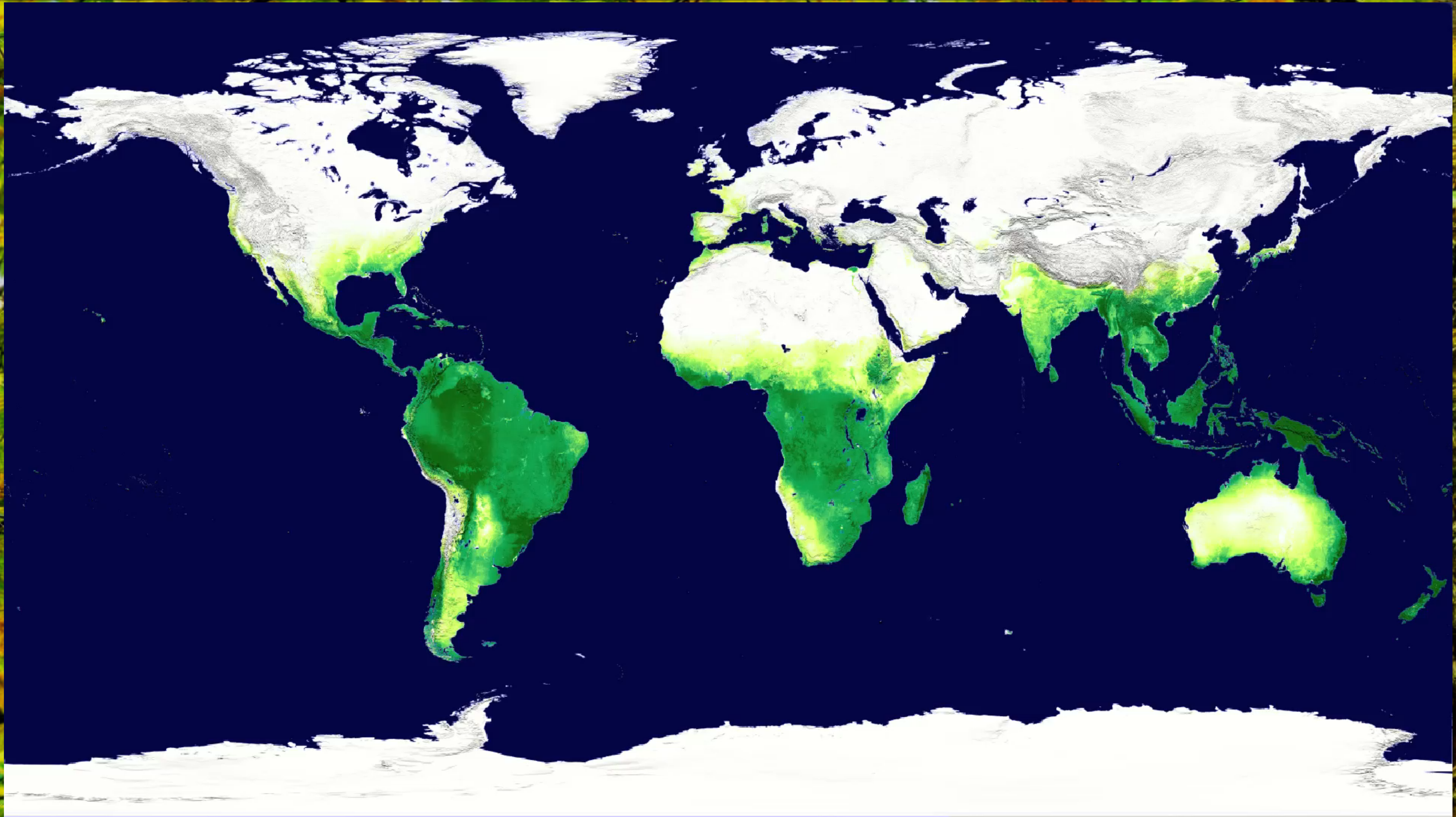


Yu et al 2013: Ph.D. dissertation

Saatchi, S.S., et al., 2011. Benchmark map of forest carbon stocks in tropical regions across three continents. *Proceedings of the National Academy of Sciences* 108(24): 9899-9904.

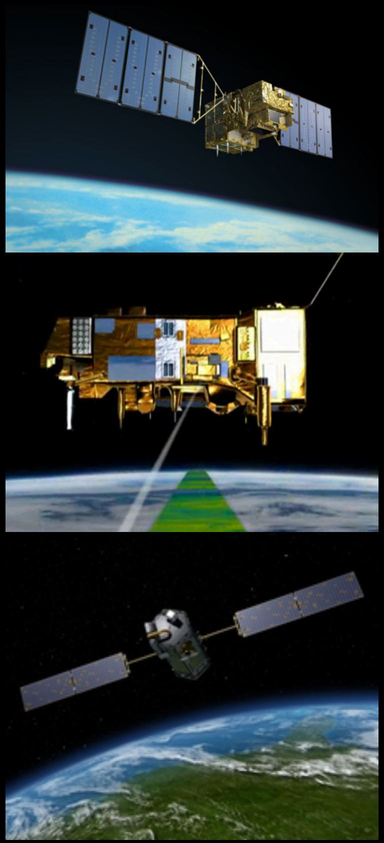
Structure: Leaf Area Index

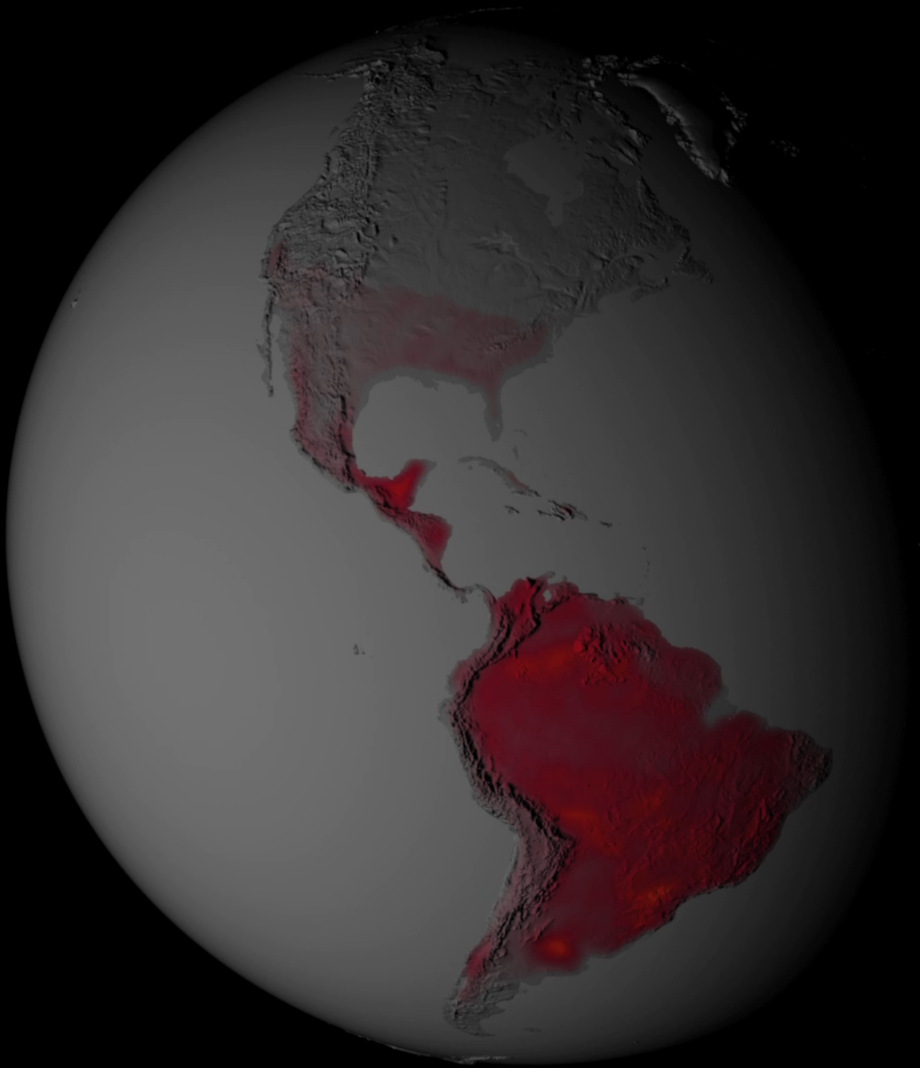
Function: Gross and Net Primary Production



NDVI, EVI, SAVI → fAPAR, LAI → GPP, NPP

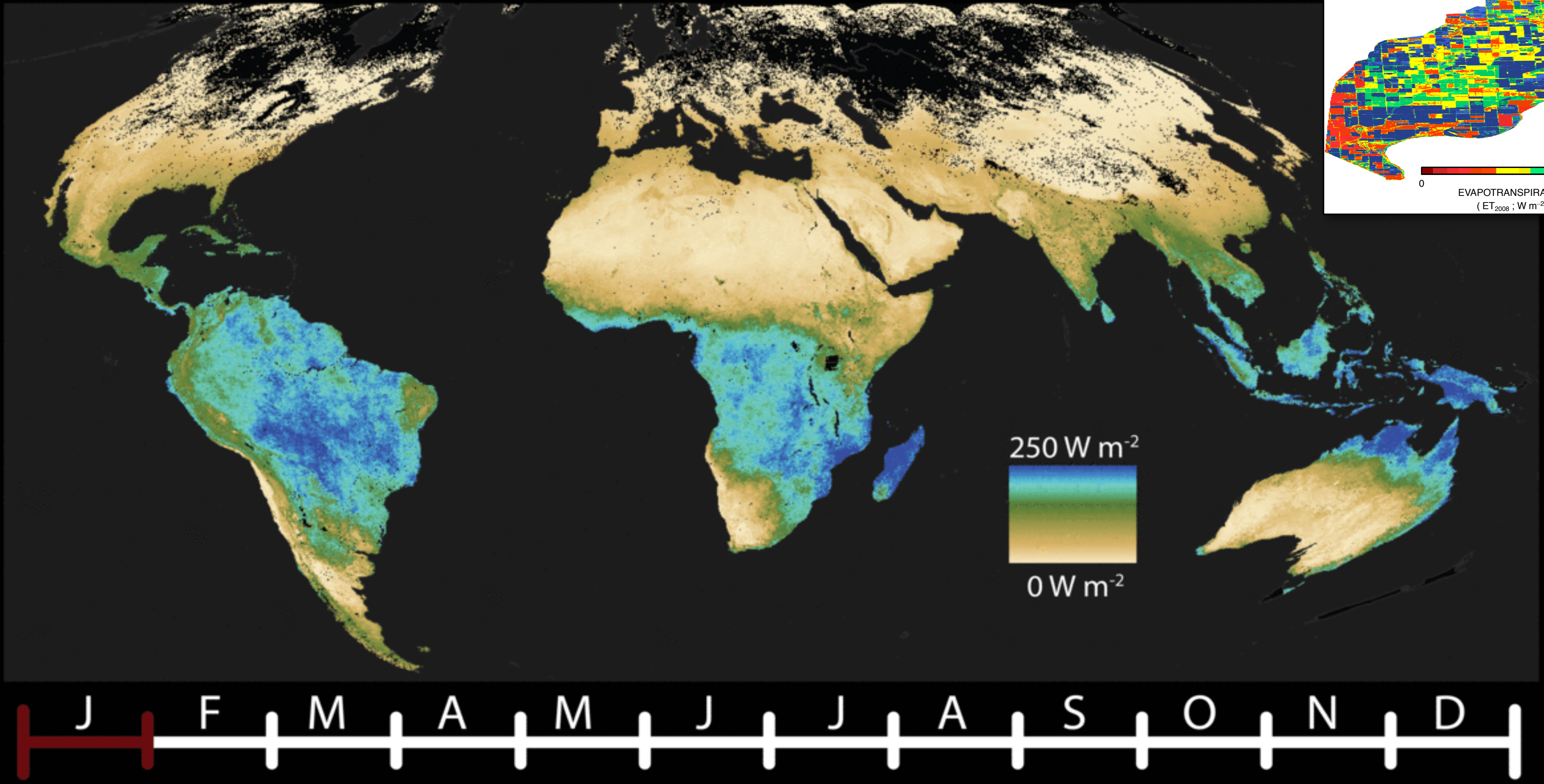
Function: Fluorescence → GPP

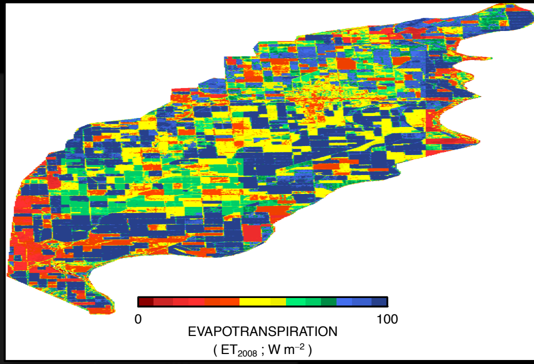




Frankenberg, C., Fisher, J.B., et al., 2011. New global observations of the terrestrial carbon cycle from GOSAT: patterns of plant fluorescence with gross primary productivity. *Geophysical Research Letters*.

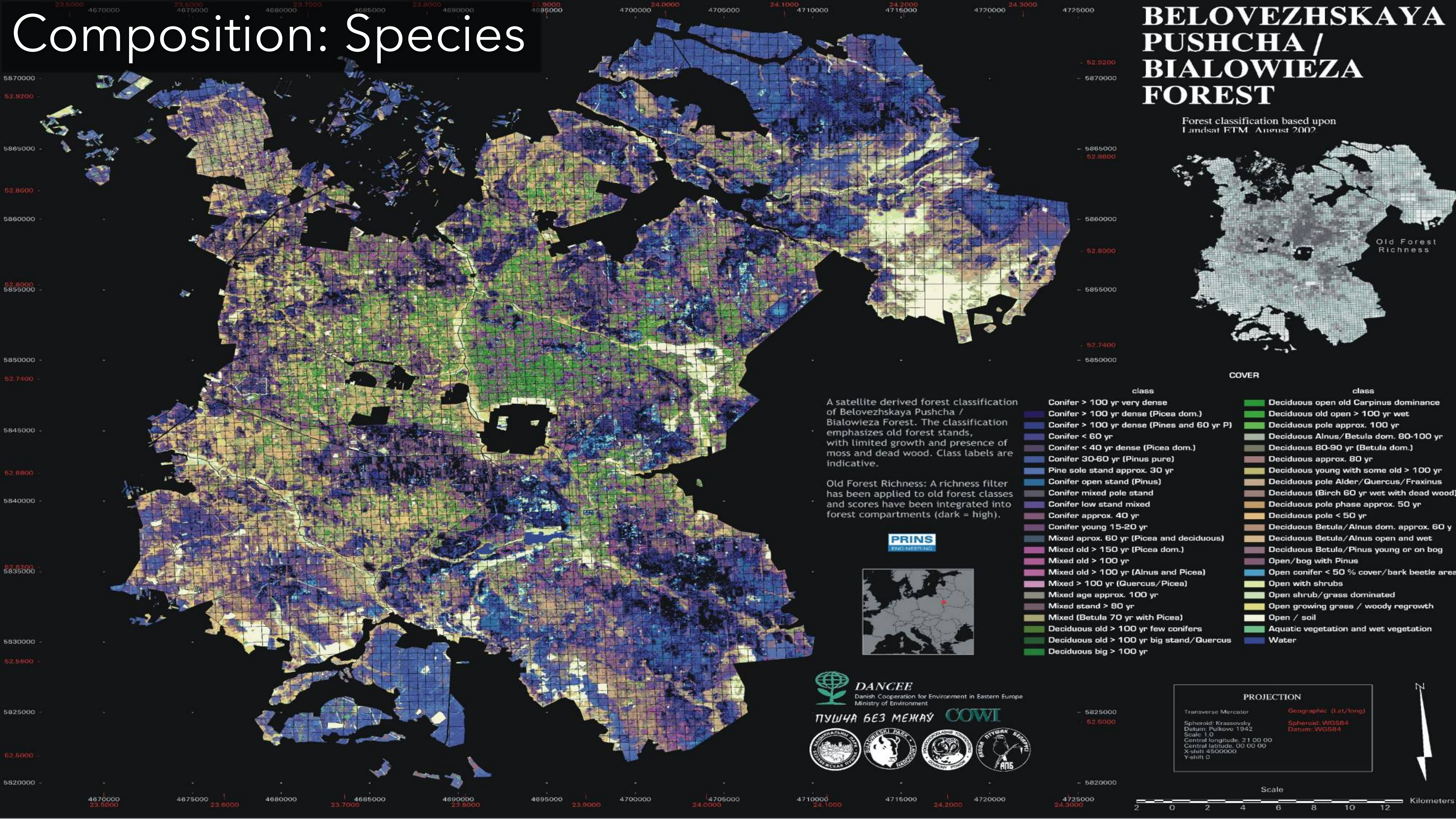
Function: Evapotranspiration



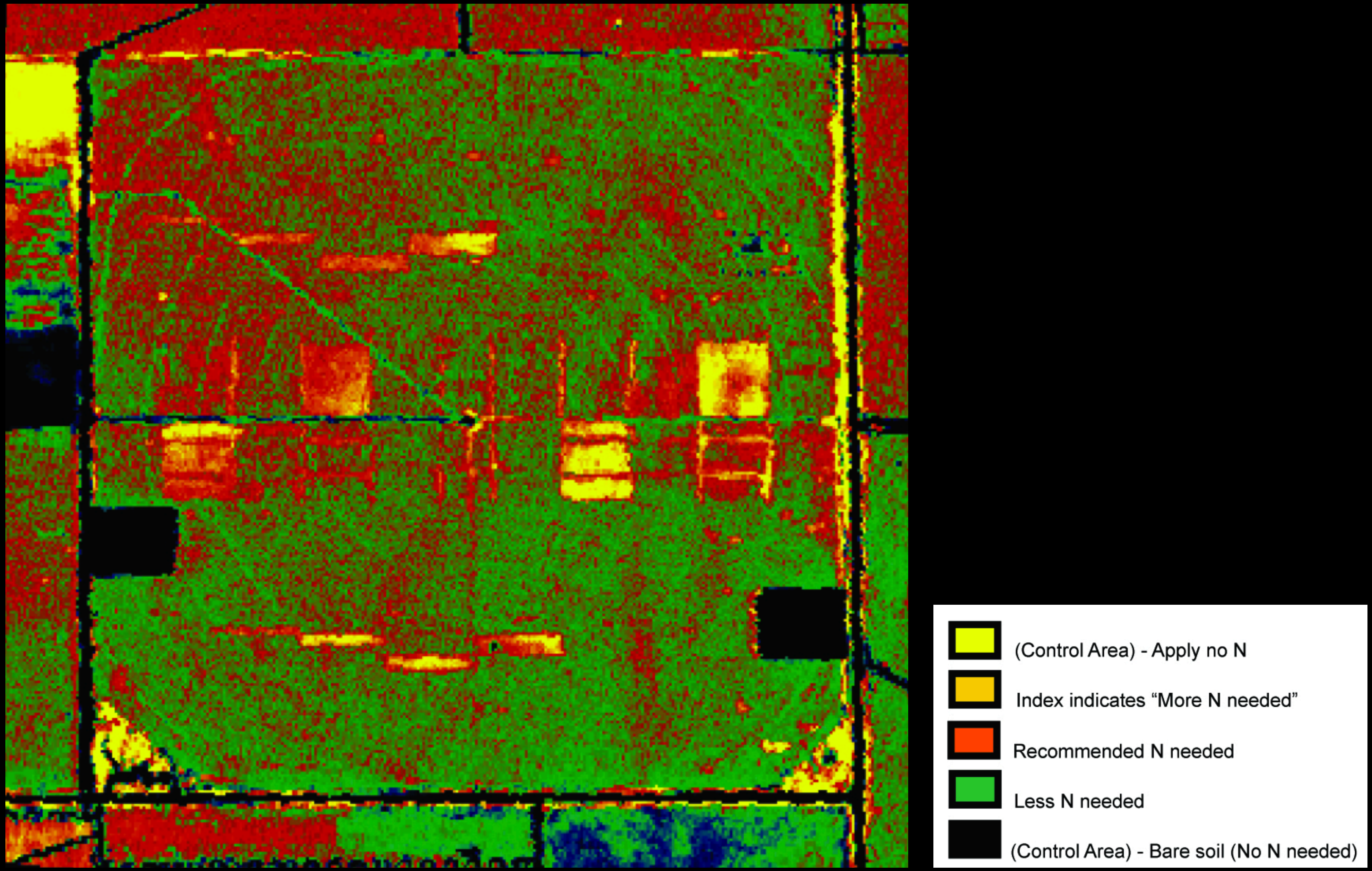


Fisher, J.B., et al., 2008. Global estimates of the land-atmosphere water flux based on monthly AVHRR and ISLSCP-II data, validated at 16 FLUXNET sites. *Remote Sensing of Environment* 112(3): 901-919.

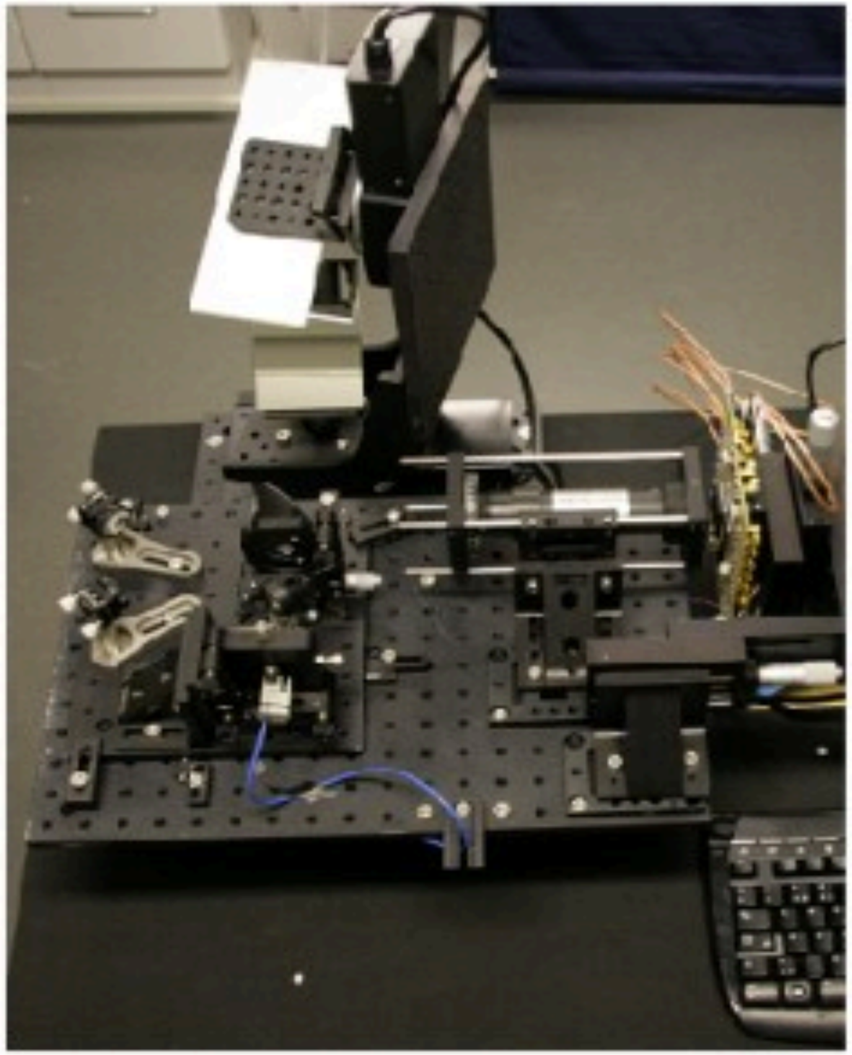
Composition: Species

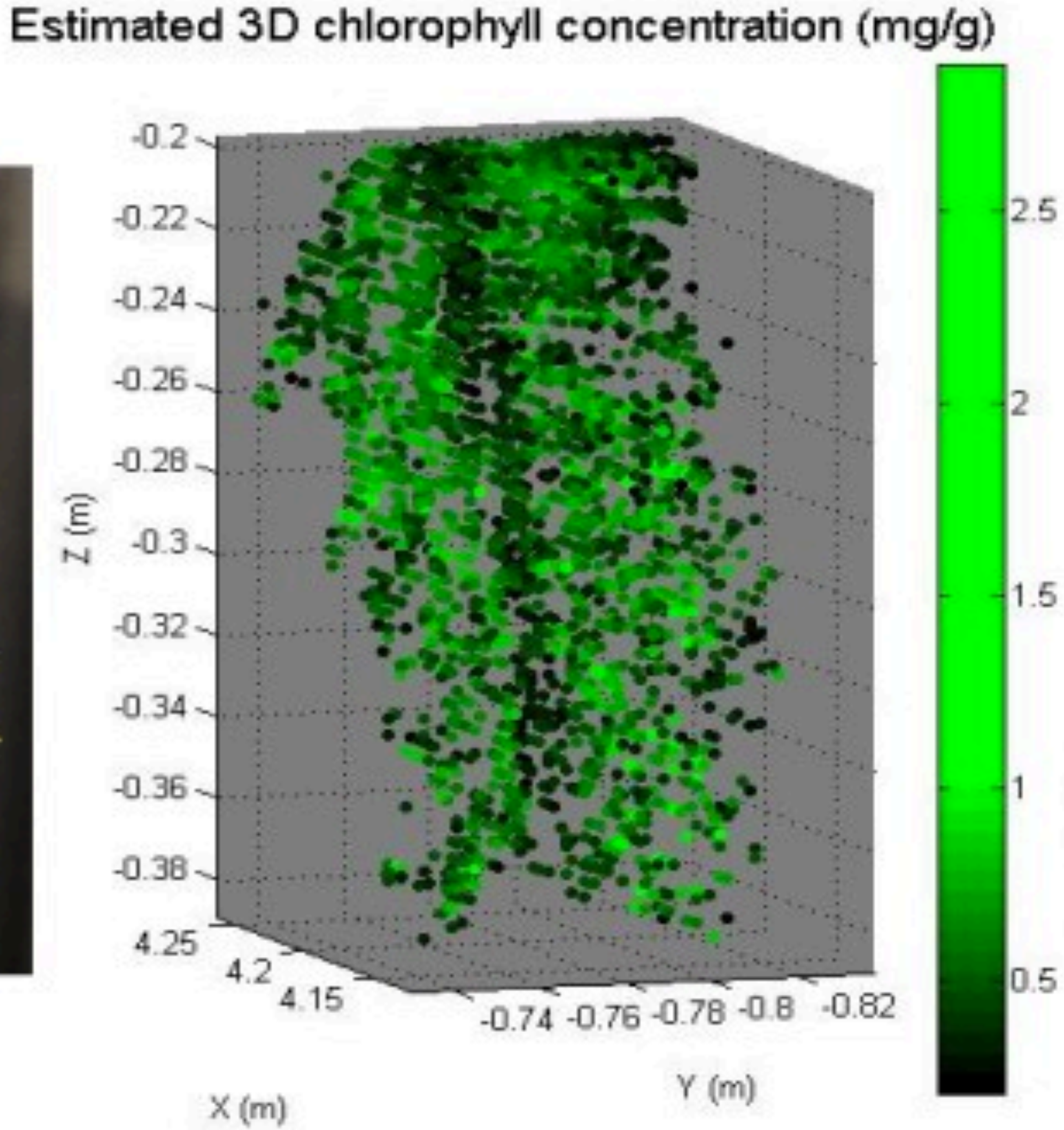


Composition: Canopy Nutrients

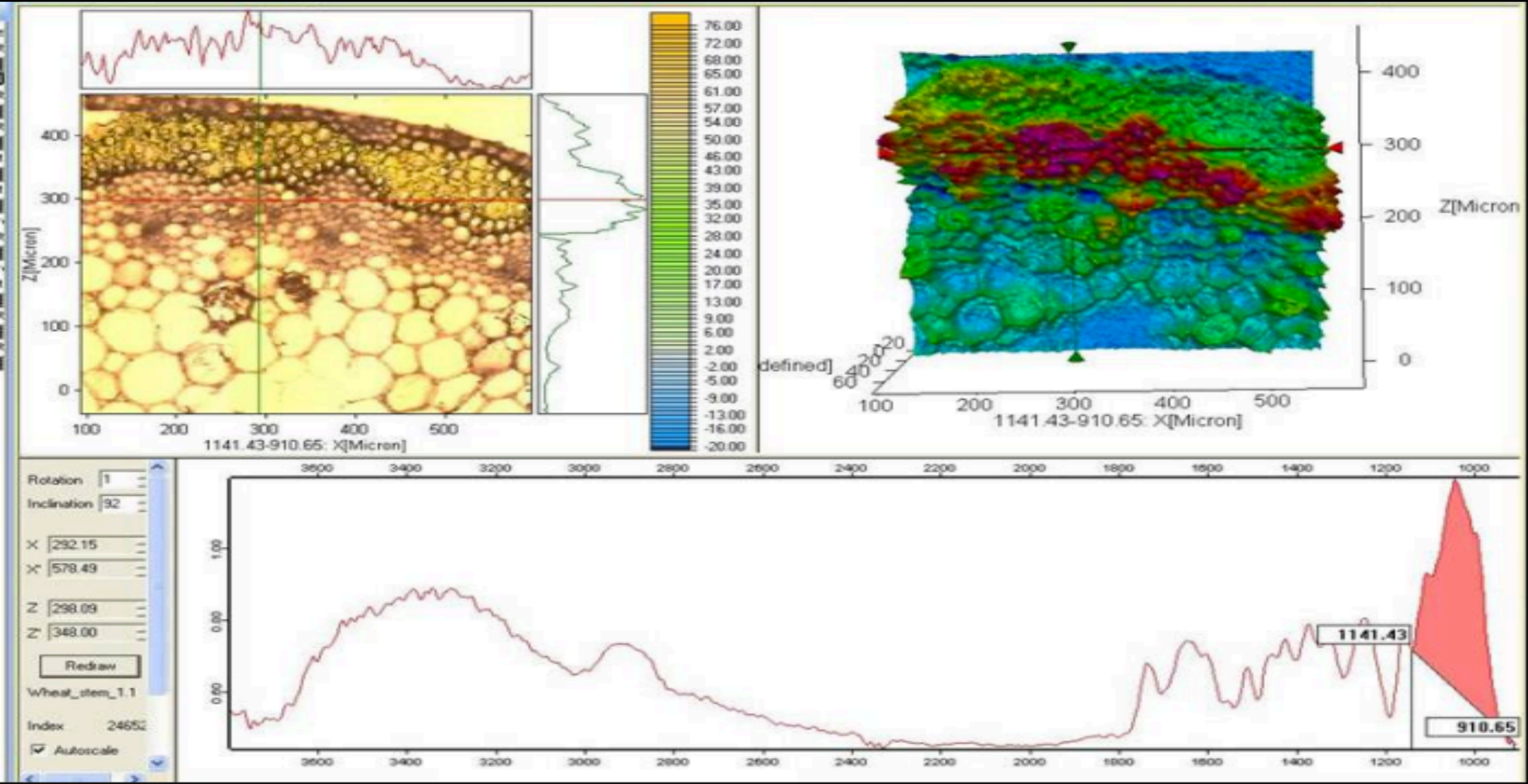


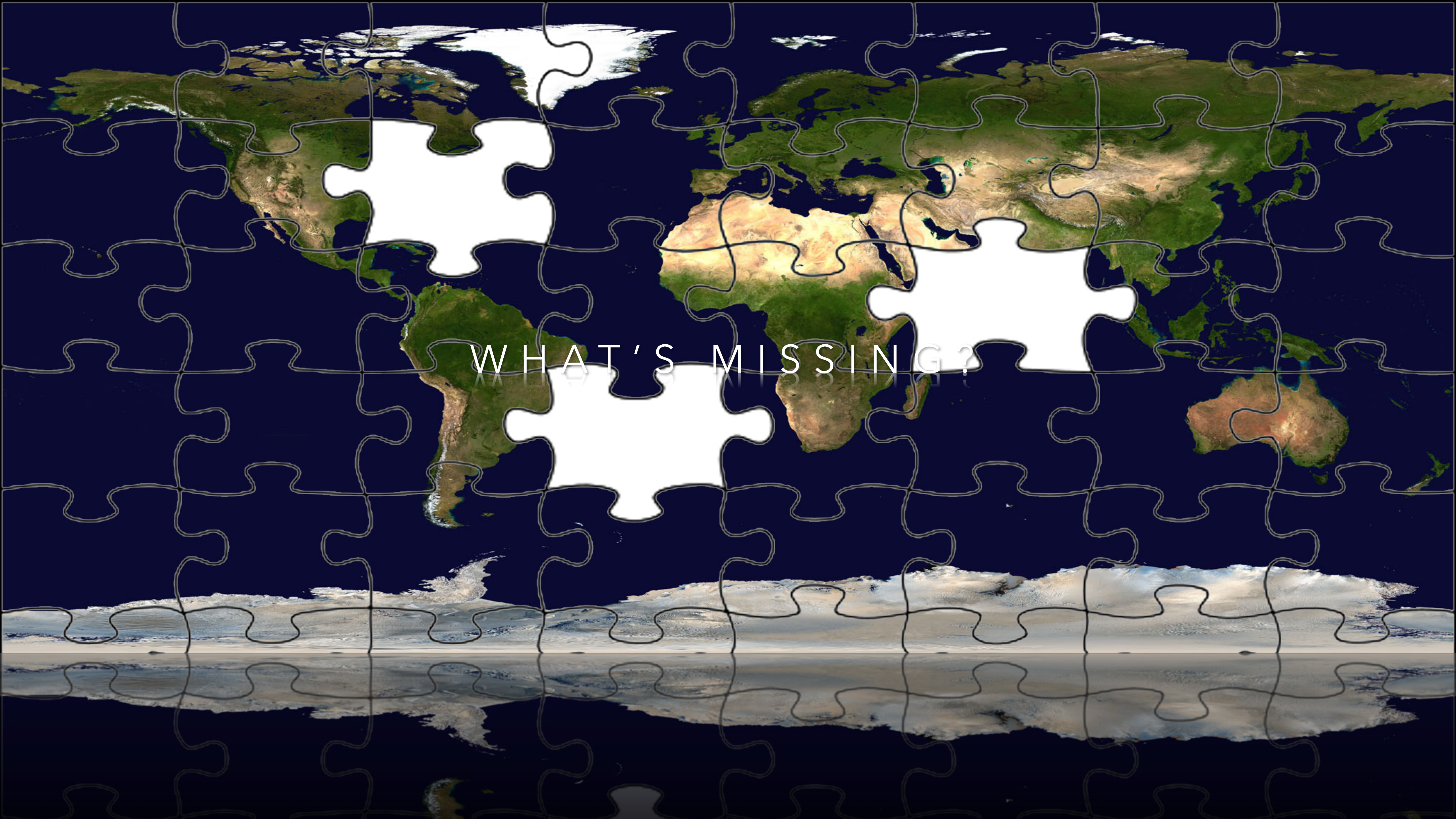
Composition: Chlorophyll Content





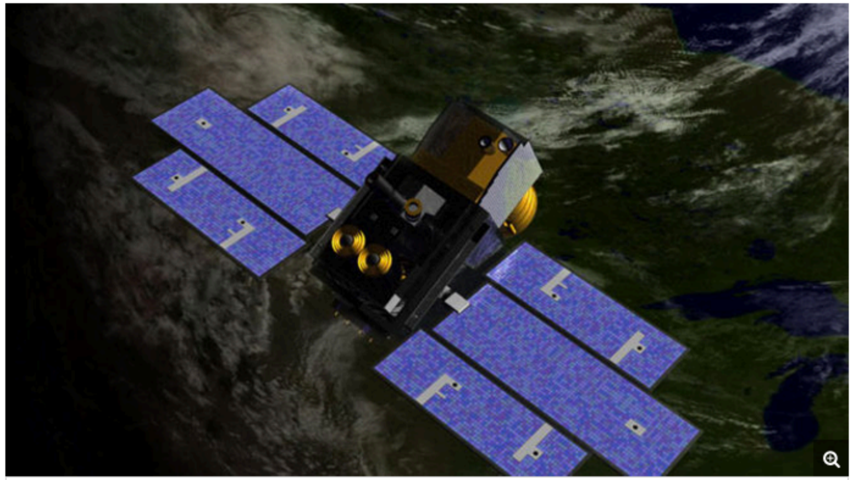
Composition: Lignin




WHAT'S MISSING?

Fire and Ice: Satellite Burns Up in Earth's Atmosphere to End Polar Mission

By SPACE.com Staff | August 31, 2010 04:07pm ET



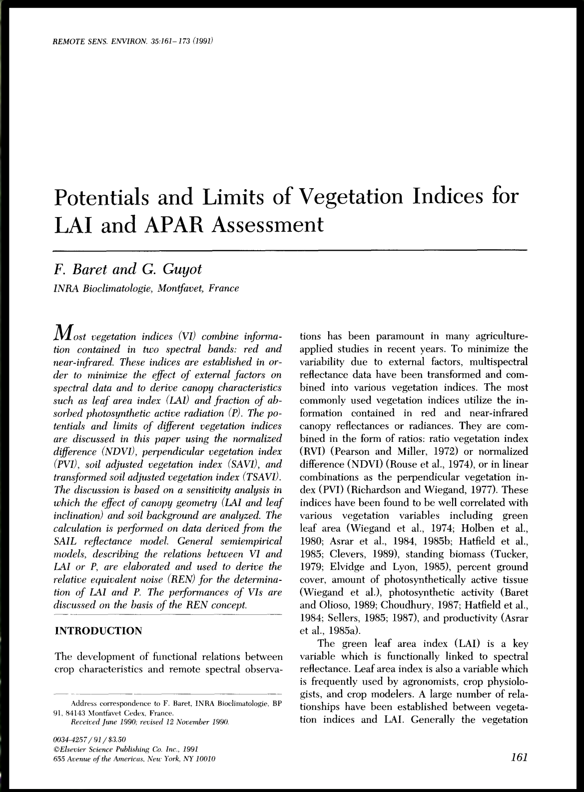
Artist's concept of ICESat.

Credit: NASA

A NASA satellite that spent seven years studying Earth's polar regions ended its successful mission Monday by plunging back to Earth on purpose to burn up in the atmosphere.

Some debris from the Ice, Cloud, and land Elevation satellite ? known as ICESat ? fell into the Barents Sea north of Norway and Russia at approximately 5 a.m. EDT (0900 GMT) Monday, according to the Orbital Debris Program Office at NASA's Johnson Space Center in Houston.

The agency lowered the orbit of ICESat in July and formally decommissioned the satellite in preparation for its re-entry into Earth's atmosphere. But the craft's lasting legacy will be its impact on the understanding of ice sheet and sea ice dynamics, NASA officials said. [Images: Ice of the Antarctic]



REMOTE SENS. ENVIRON. 35:161–173 (1991)

Potentials and Limits of Vegetation Indices for LAI and APAR Assessment

F. Baret and G. Guyot

INRA Bioclimatologie, Montfavet, France

Most vegetation indices (VI) combine information contained in two spectral bands: red and near-infrared. These indices are established in order to minimize the effect of external factors on spectral data and to derive canopy characteristics such as leaf area index (LAI) and fraction of absorbed photosynthetic active radiation (P). The potentials and limits of different vegetation indices are discussed in this paper using the normalized difference (NDVI), perpendicular vegetation index (PVI), soil adjusted vegetation index (SAVI), and transformed soil adjusted vegetation index (TSAVI). The discussion is based on a sensitivity analysis in which the effect of canopy geometry (LAI and leaf inclination) and soil background are analyzed. The calculation is performed on data derived from the SAIL reflectance model. General semiempirical models, describing the relations between VI and LAI or P, are elaborated and used to derive the relative equivalent noise (REN) for the determination of LAI and P. The performances of VIs are discussed on the basis of the REN concept.

INTRODUCTION

The development of functional relations between crop characteristics and remote spectral observations has been paramount in many agriculture-applied studies in recent years. To minimize the variability due to external factors, multispectral reflectance data have been transformed and combined into various vegetation indices. The most commonly used vegetation indices utilize the information contained in red and near-infrared canopy reflectances or radiances. They are combined in the form of ratios: ratio vegetation index (RVI) (Pearson and Miller, 1972) or normalized difference (NDVI) (Rouse et al., 1974), or in linear combinations as the perpendicular vegetation index (PVI) (Richardson and Wiegand, 1977). These indices have been found to be well correlated with various vegetation variables including green leaf area (Wiegand et al., 1974; Holben et al., 1980; Asrar et al., 1984, 1985b; Hatfield et al., 1985; Clevers, 1989), standing biomass (Tucker, 1979; Elvidge and Lyon, 1985), percent ground cover, amount of photosynthetically active tissue (Wiegand et al.), photosynthetic activity (Baret and Olioso, 1989; Choudhury, 1987; Hatfield et al., 1984; Sellers, 1985; 1987), and productivity (Asrar et al., 1985a).

The green leaf area index (LAI) is a key variable which is functionally linked to spectral reflectance. Leaf area index is also a variable which is frequently used by agronomists, crop physiologists, and crop modelers. A large number of relationships have been established between vegetation indices and LAI. Generally the vegetation

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Received June 1990; revised 12 November 1990.

0034-4257/91/$3.50

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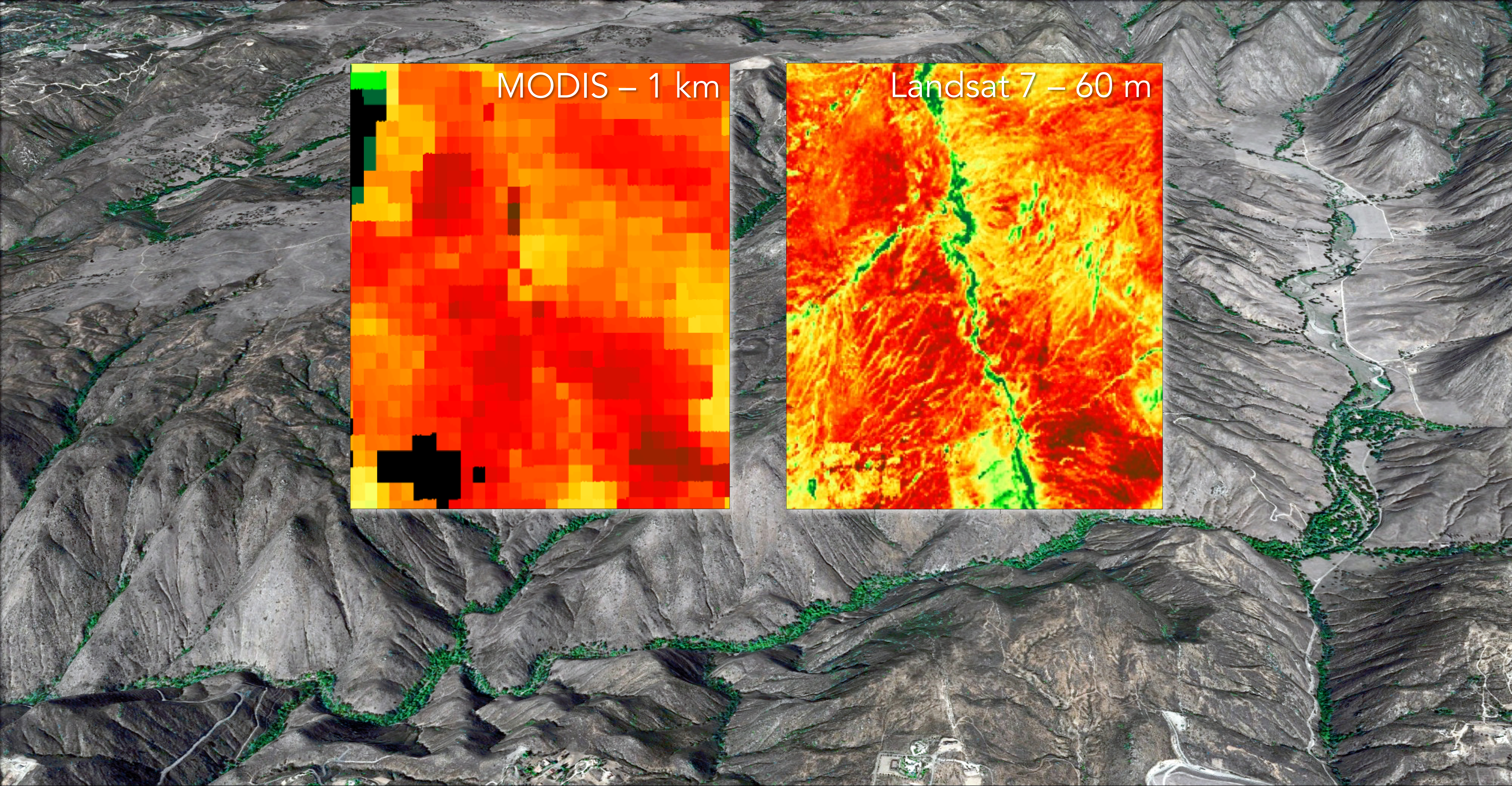
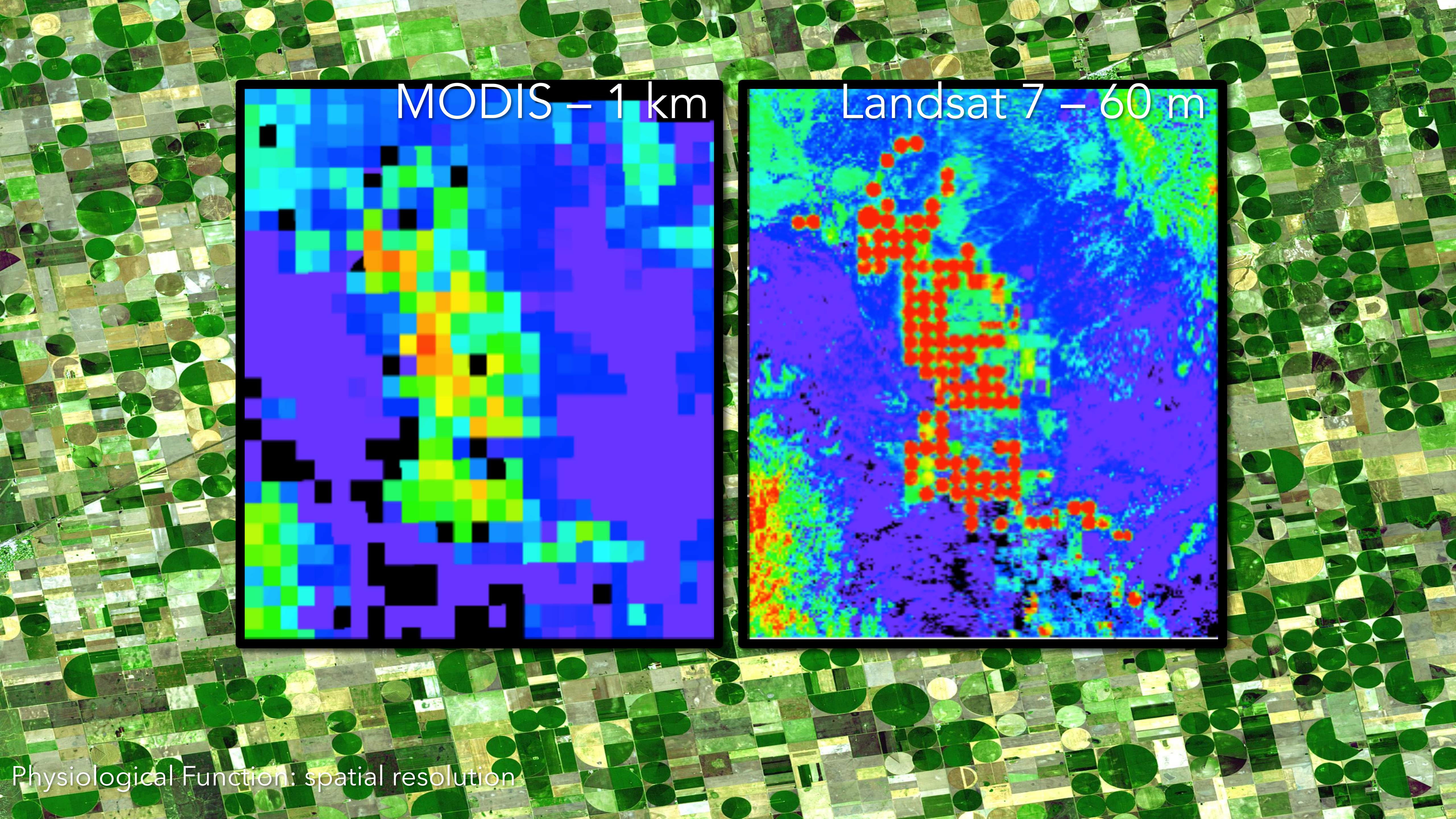
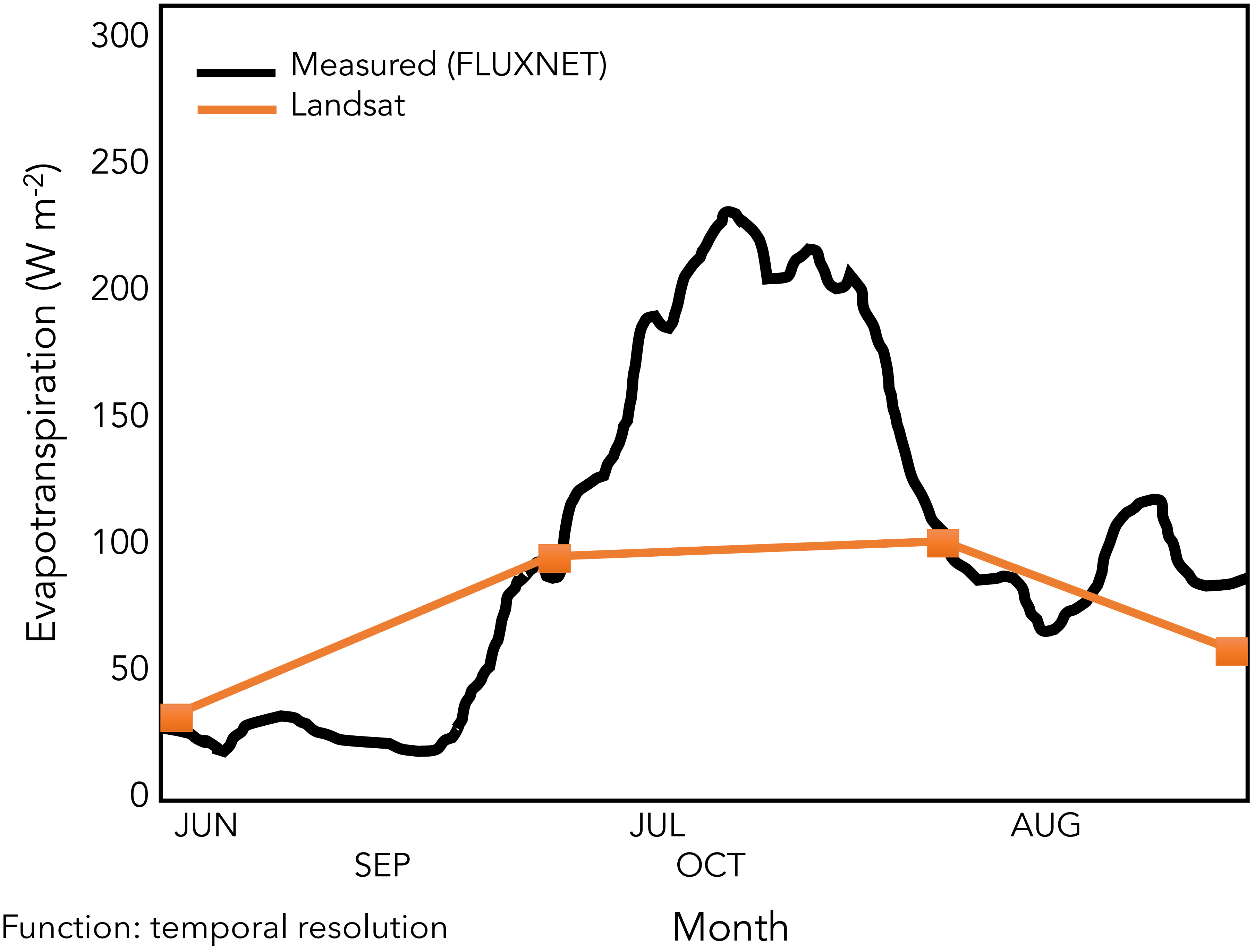


Physiological Function: spatial resolution

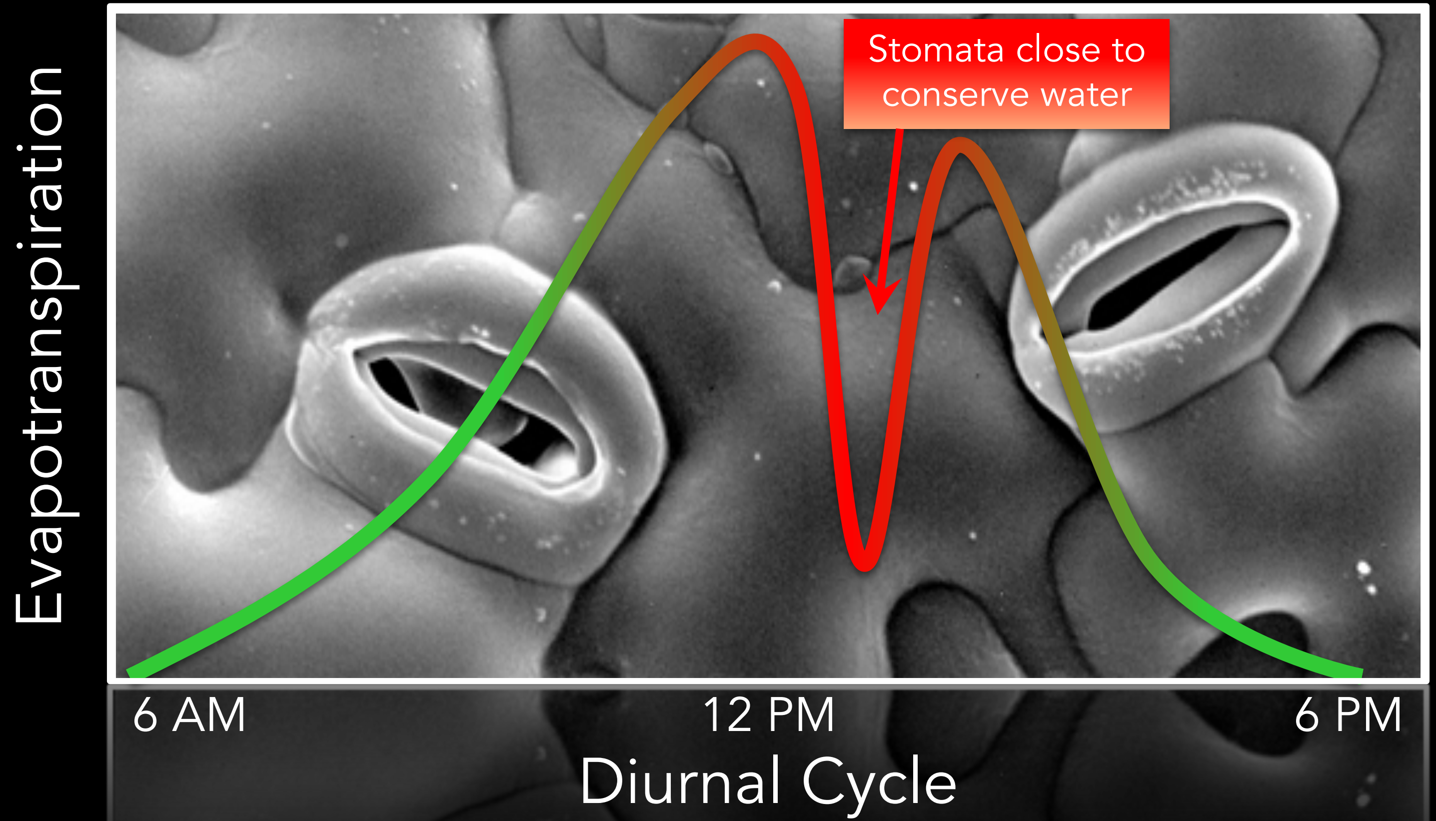


Physiological Function: spatial resolution

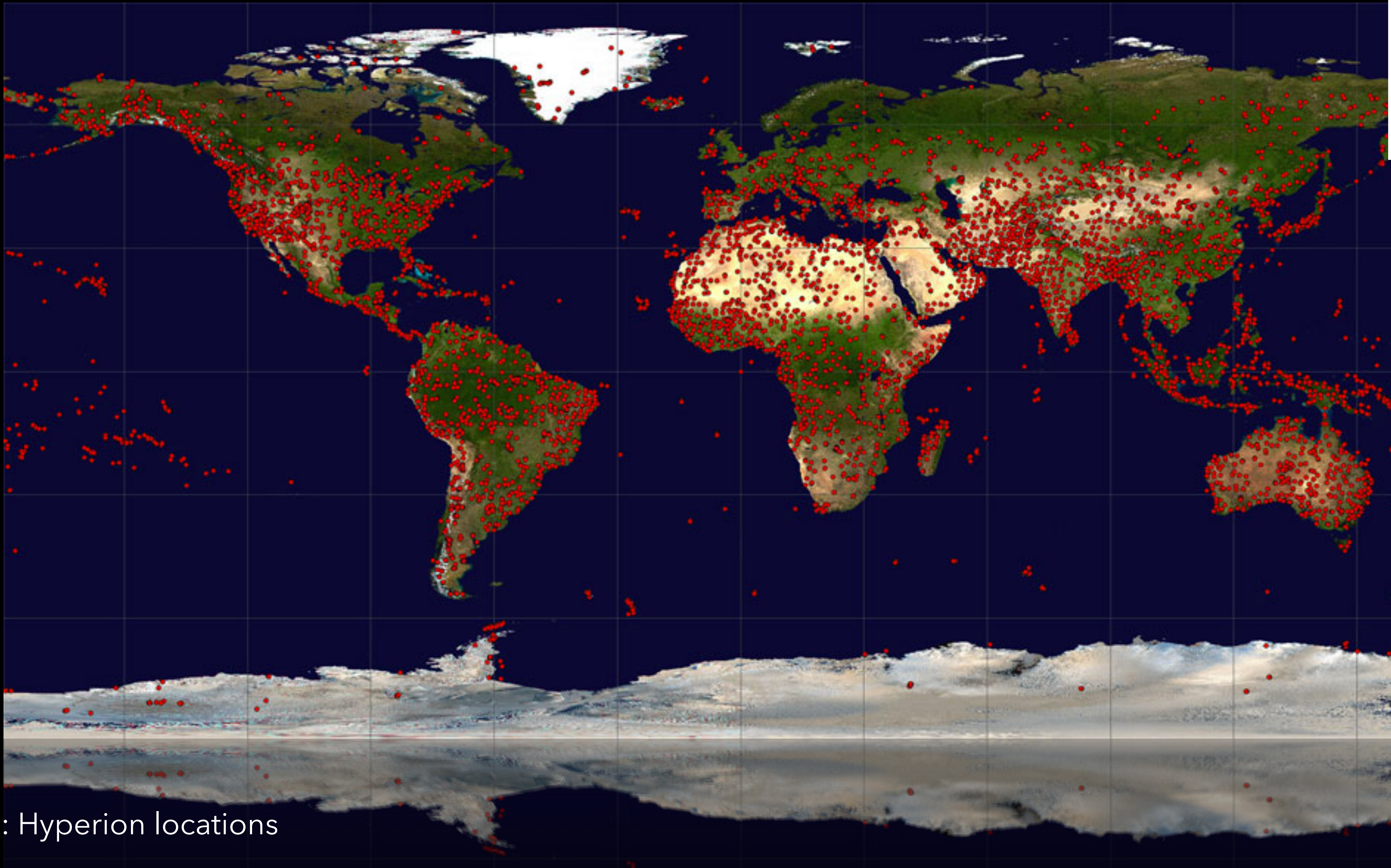


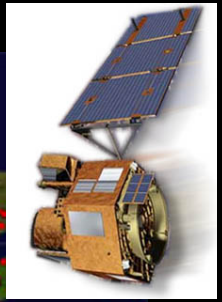
Physiological Function: temporal resolution

Water Stress Drives Plant Behavior

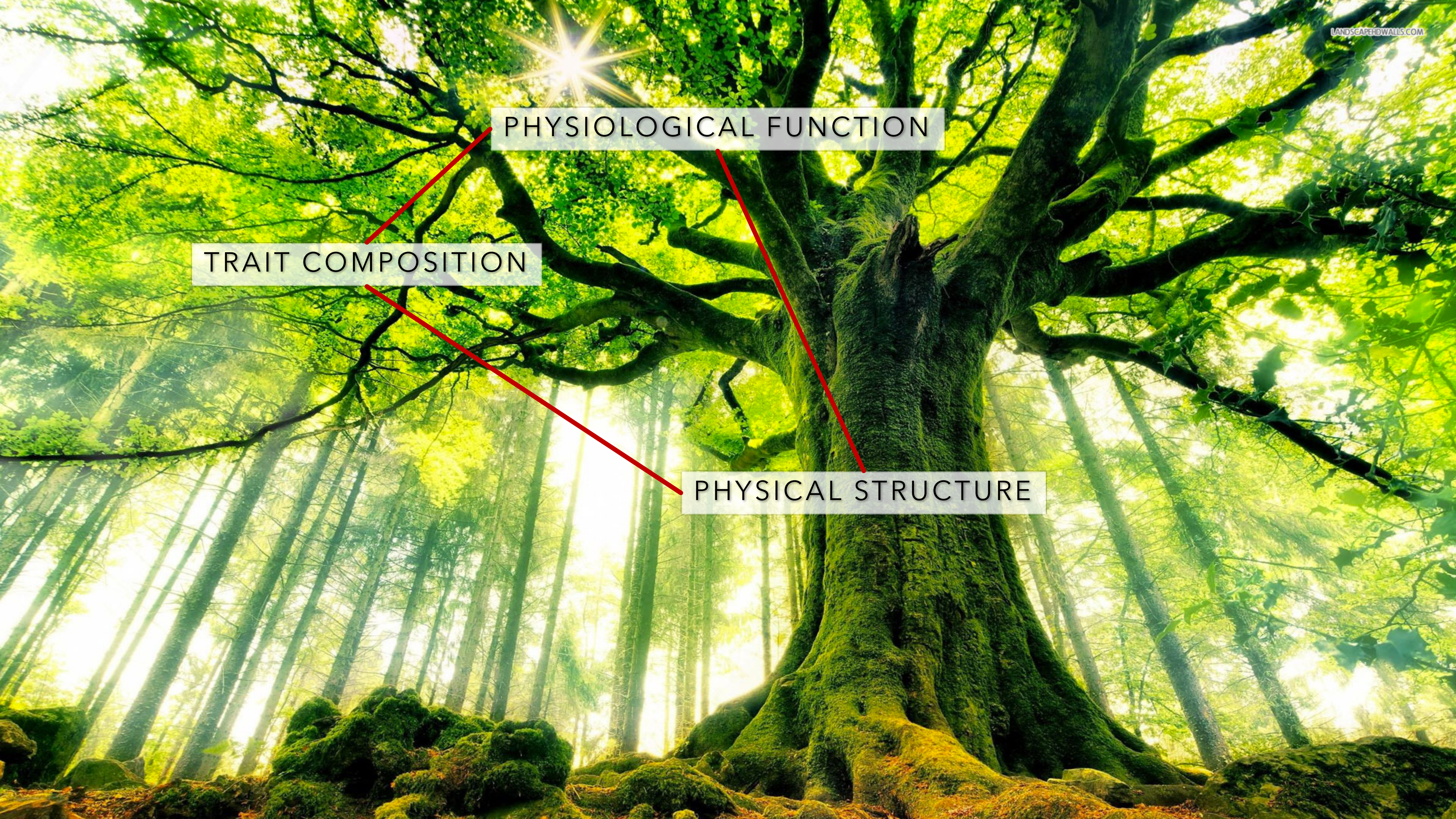


Physiological Function: temporal resolution

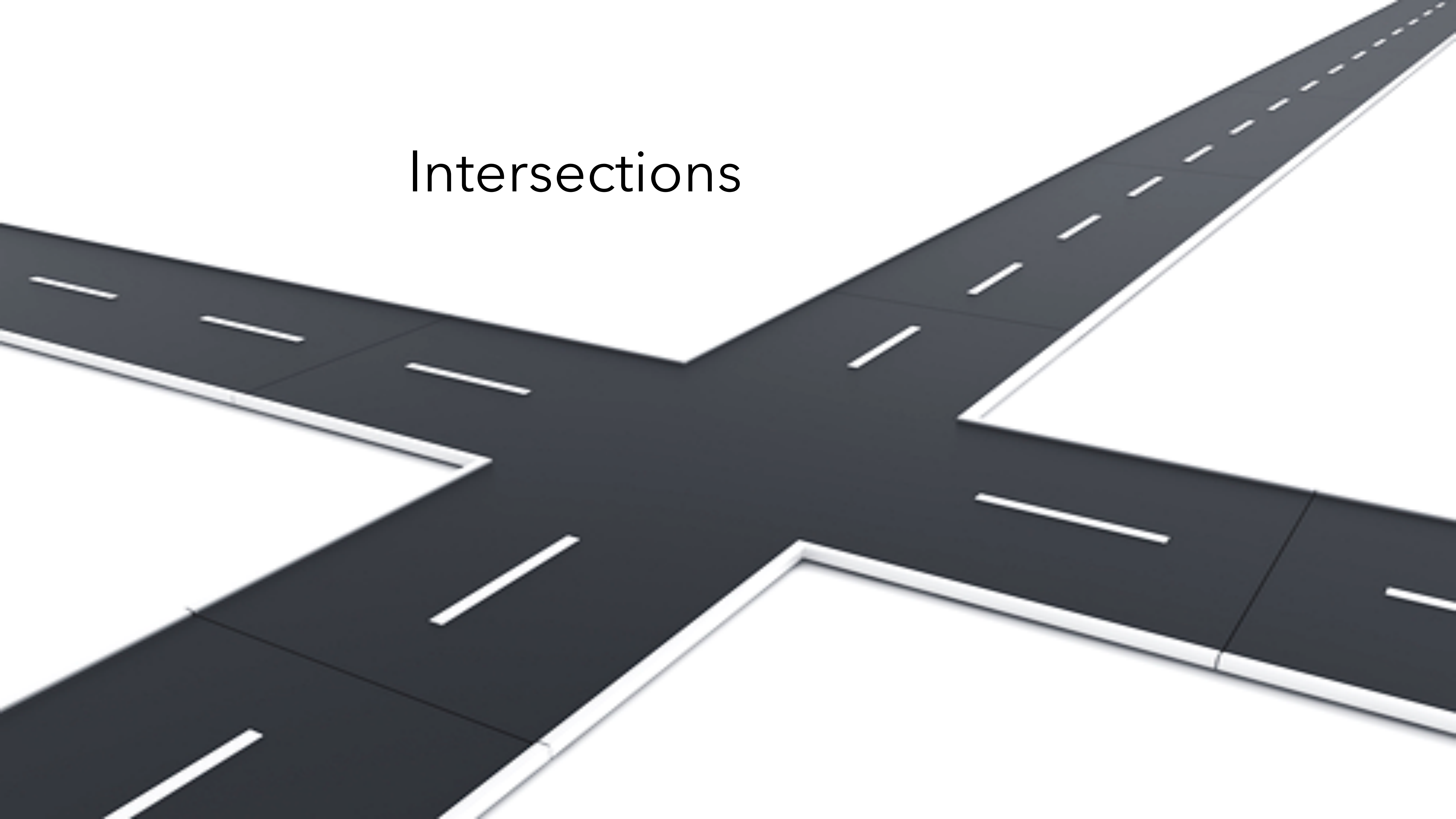




Traits: Hyperion locations


PHYSIOLOGICAL FUNCTION
TRAIT COMPOSITION
PHYSICAL STRUCTURE

Intersections



$$GPP \times ET^{-1} = WUE$$

$$\mathrm{GPP} \times \Delta\mathrm{BIOMASS}^{-1}$$

$$=$$

$$\mathrm{CUE}$$

$$\text{NUTRIENTS} \times \Delta\text{BIOMASS}^{-1}$$

$$=$$

$$\text{NUE}$$

f(productivity, water use, C storage, canopy traits)

=

C sink potential

$$f(\text{productivity, water use, structure, canopy traits})$$

$$=$$

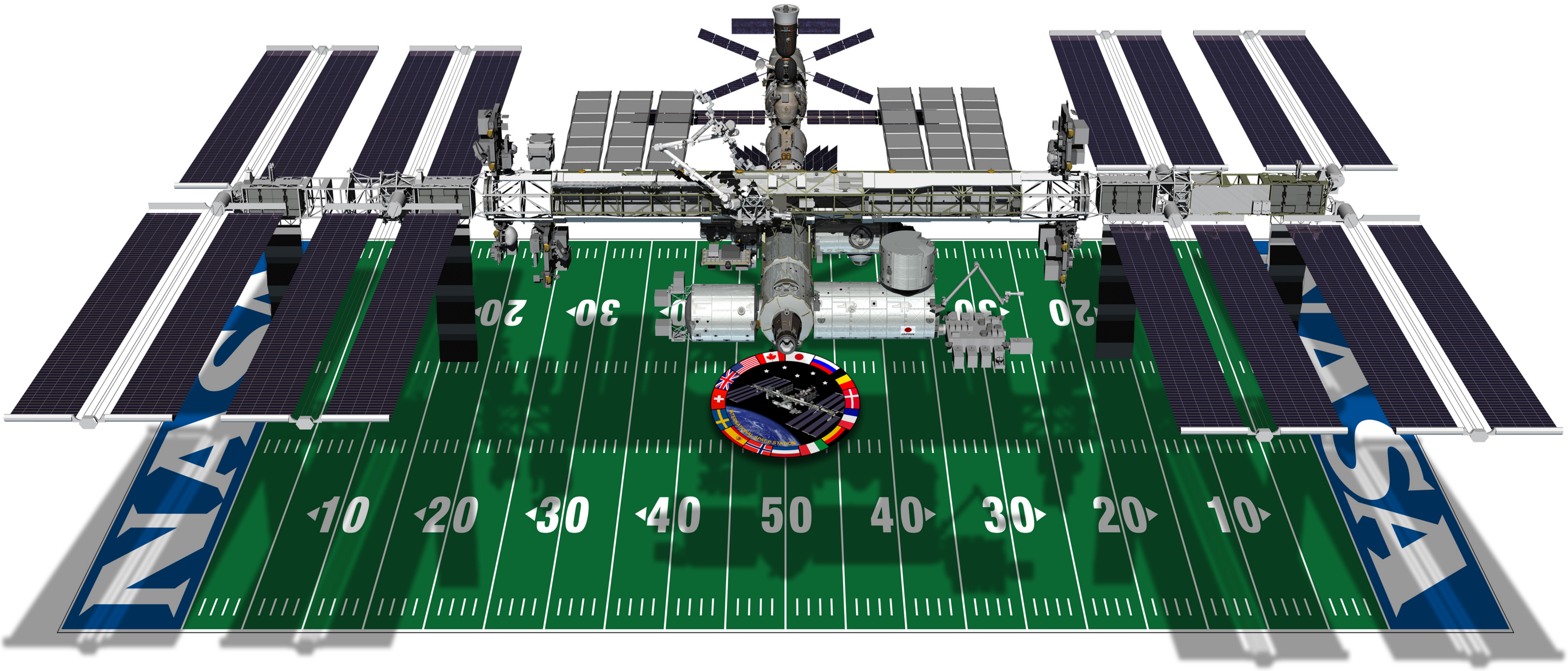
Disturbance Ecology

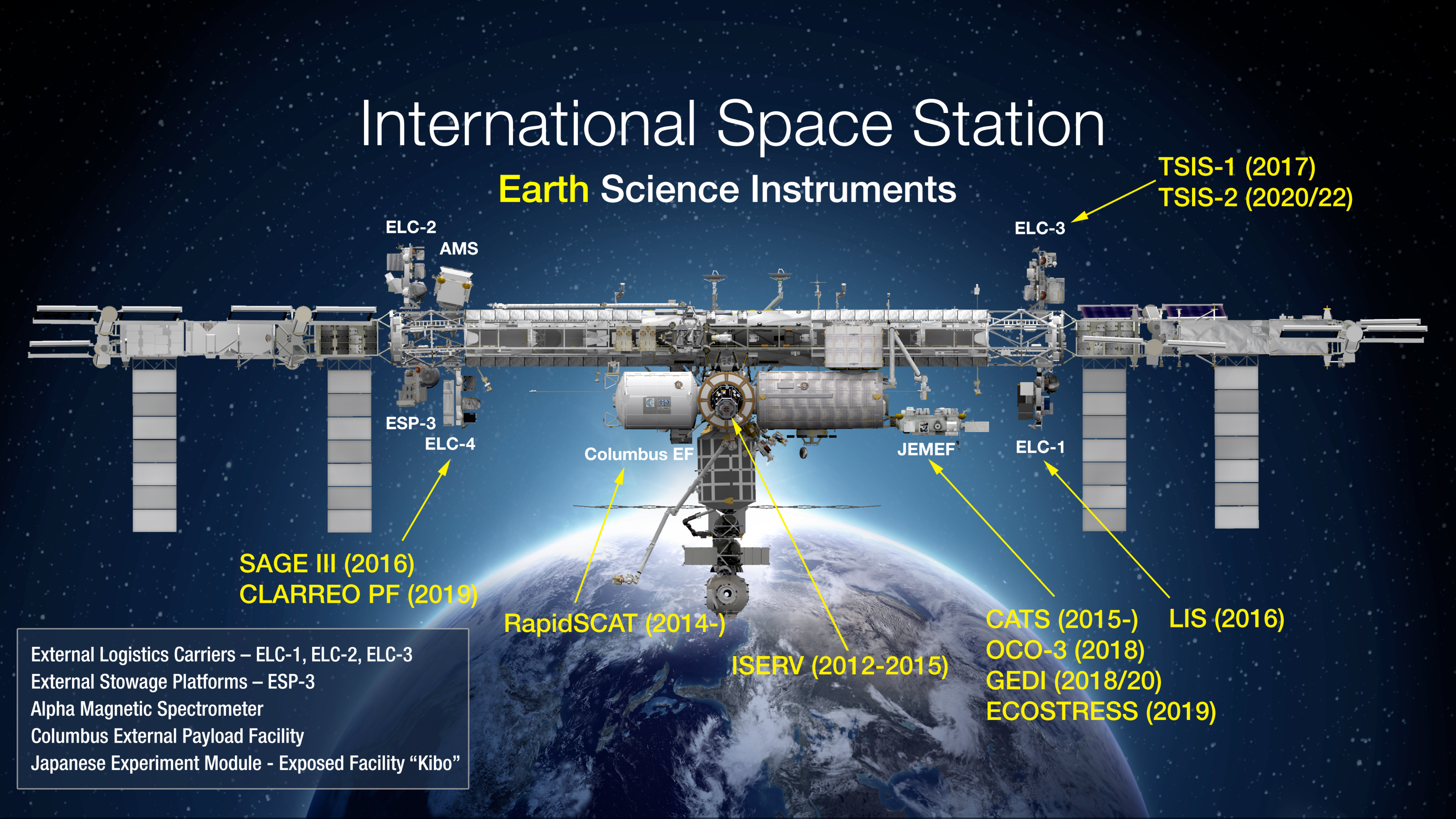
Satellite missions are traditionally independent of one another, with different timelines.

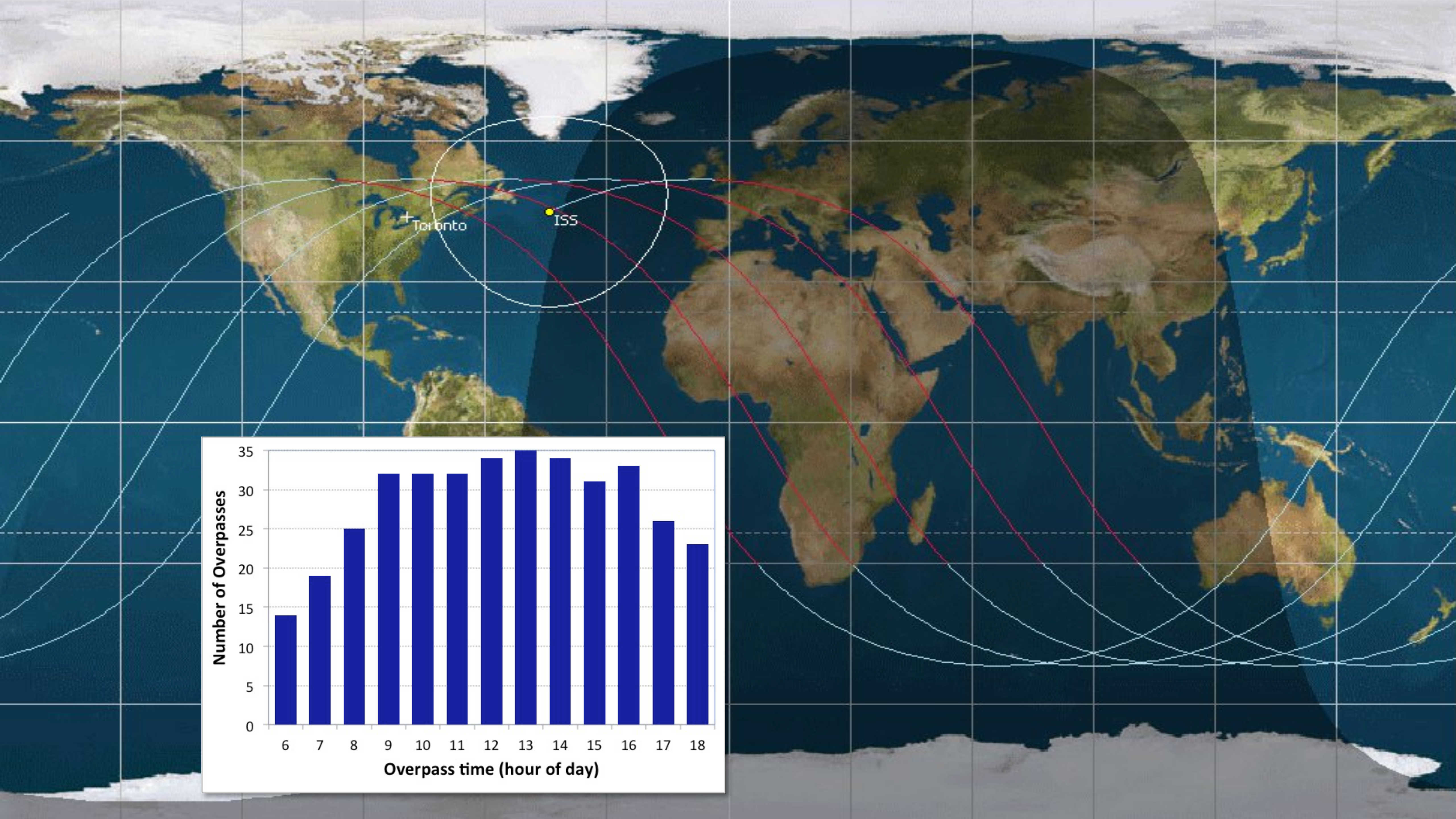

LANDSCAPEHDWALLS.COM


The International Space
Station (ISS)

National Aeronautics and Space Administration




International Space Station
Earth Science Instruments
TSIS-1 (2017)
TSIS-2 (2020/22)
ELC-2
AMS
ELC-3
ESP-3
ELC-4
Columbus EF
JEMEF
ELC-1
SAGE III (2016)
CLARREO PF (2019)
RapidSCAT (2014-)
ISERV (2012-2015)
CATS (2015-)
OCO-3 (2018)
GEDI (2018/20)
ECOSTRESS (2019)
LIS (2016)
External Logistics Carriers – ELC-1, ELC-2, ELC-3
External Stowage Platforms – ESP-3
Alpha Magnetic Spectrometer
Columbus External Payload Facility
Japanese Experiment Module - Exposed Facility “Kibo”


Toronto
ISS
Number of Overpasses
Overpass time (hour of day)
0
5
10
15
20
25
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35
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7
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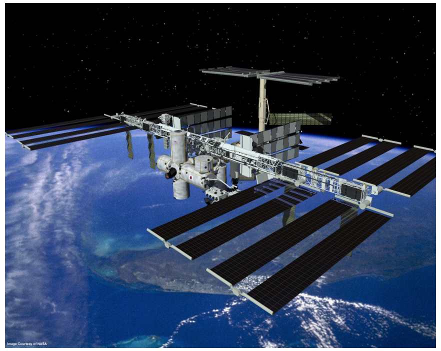
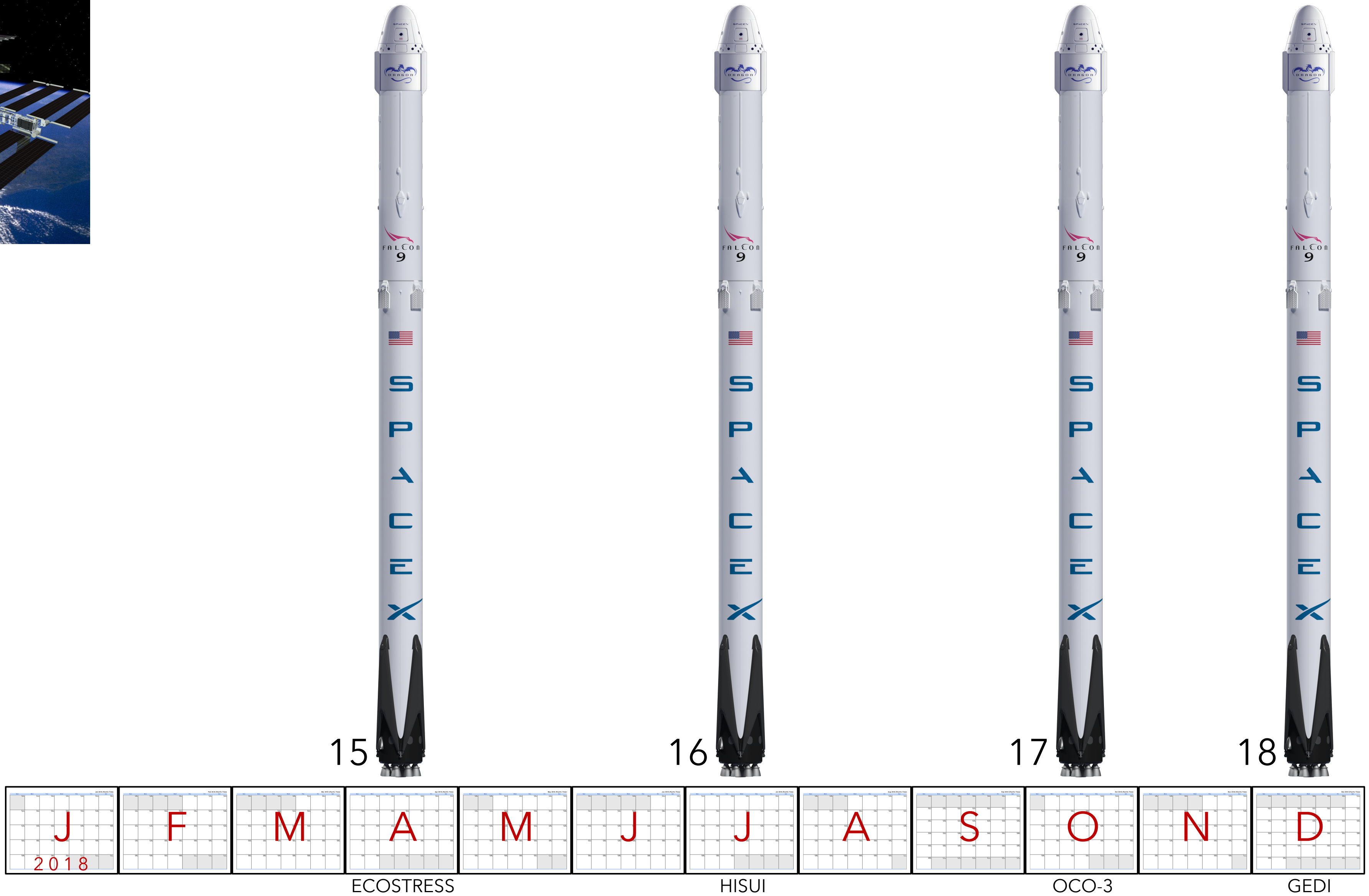
18

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ECOSTRESS
HISUI
OCO-3
GEDI

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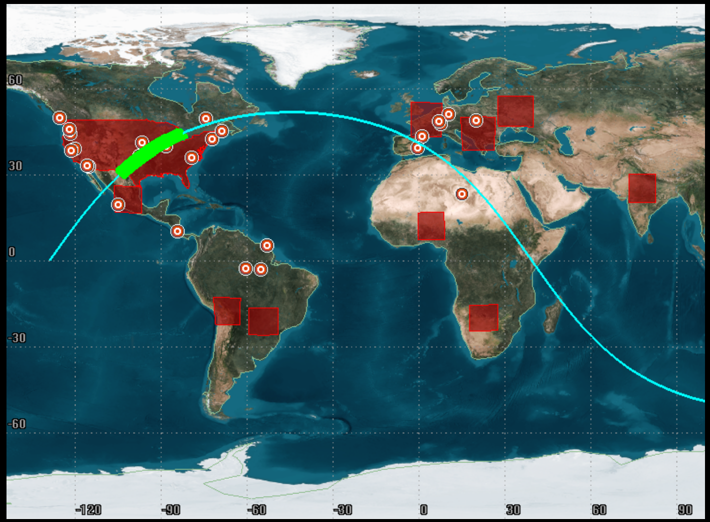
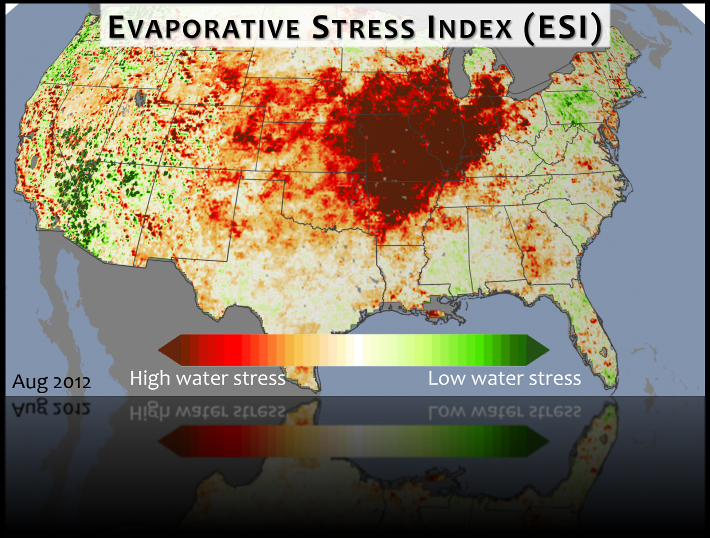
ECOSTRESS

- **Instrument:** Thermal Radiometer
- **Spatial resolution:** 70 m
- **Spectral bands:** 5 (8-12.5 µm)
- **Lead:** JPL, NASA
- **L2 product(s):** Land Surface Temperature & Emissivity
- **L3 product(s):** Evapotranspiration (incl. components: soil evaporation, canopy transpiration, interception evaporation)
- **L4 product(s):** Water Use Efficiency; Evaporative Stress Index

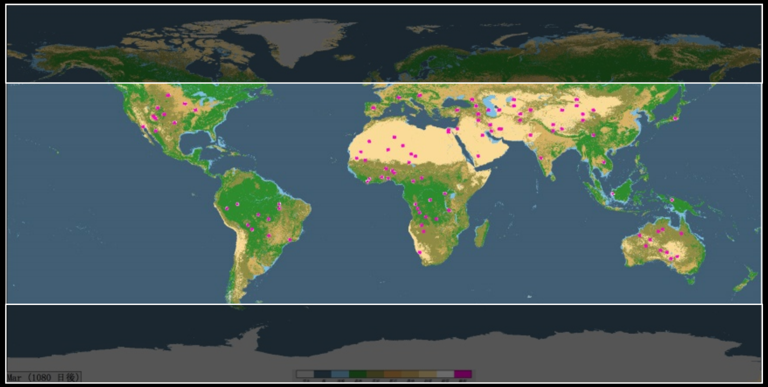




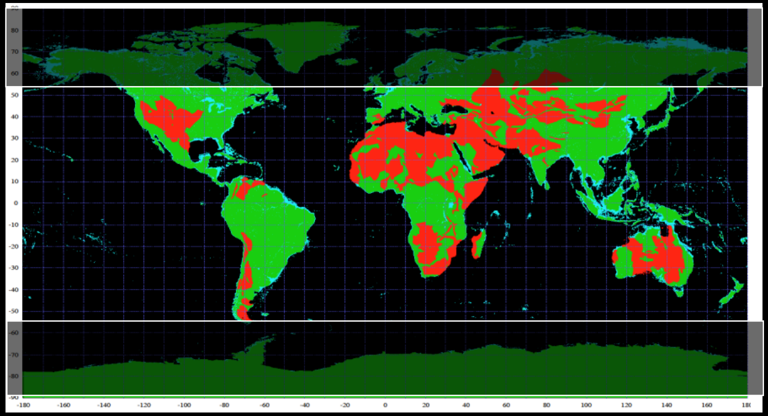

HISUI
Hyperspectral Imager SUIte
翡 翠

HISUI

- **Instrument:** Hyperspectral Imager
- **Spatial resolution:** 30 m
- **Spectral bands:** 185 (0.4–2.5 µm)
- **Lead:** Japan Space Systems
- **L2 product(s):** Atmospherically corrected surface spectral reflectance
- **Notes:** Data will be partially directly transmitted to ground stations (10 GB/day = 30,000 km2). The rest (300 GB/day = 900,000 km2) will be recorded in removal media and shipped back to Earth by cargo ships 3-4 times per year.
- **Notes:** Ability to do SIF.



Tentative DARs for Verification Observation



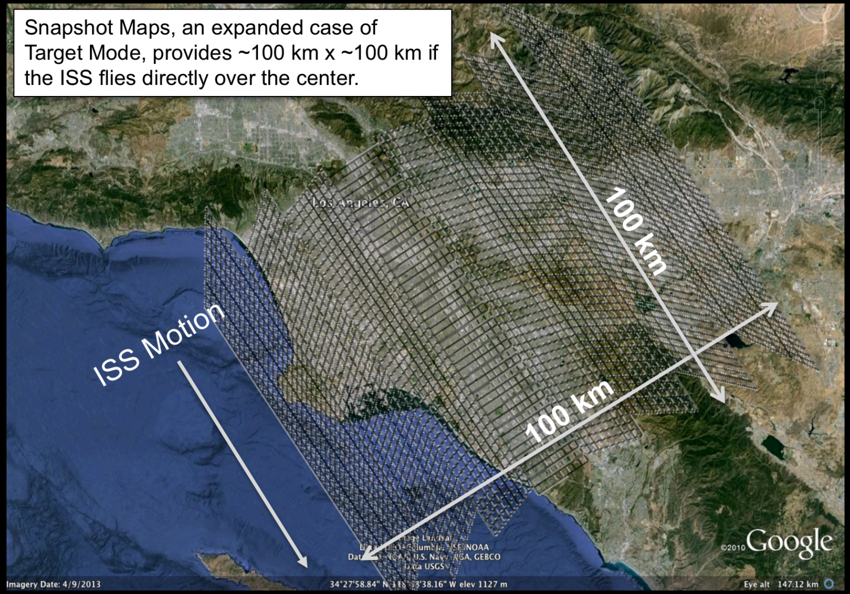
Red = Priority areas for oil/gas/metal resources, **Green** = Other land, **Light blue** = Coastal zones shallower than 30 m.

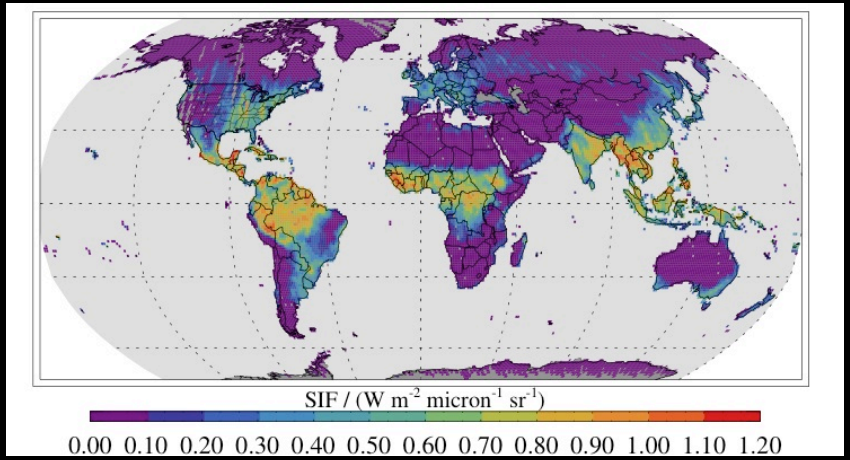
OCO-3

ORBITING CARBON OBSERVATORY

OCO-3

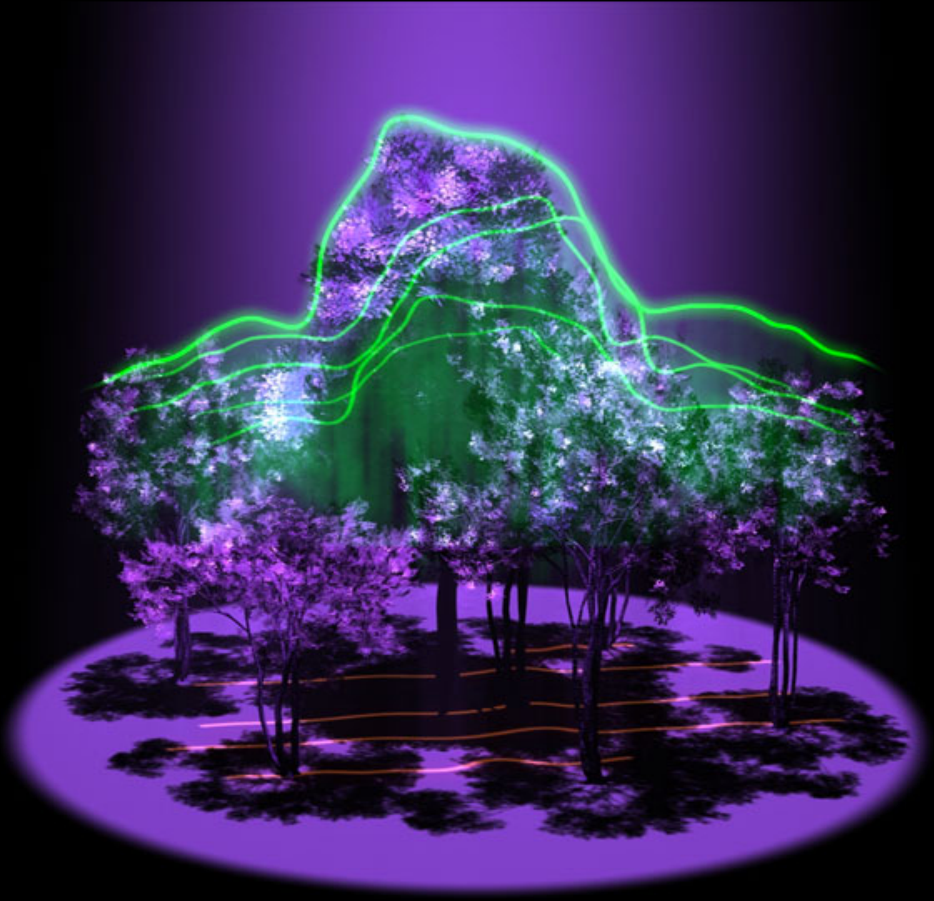
- **Instrument:** 3 Grating Spectrometers
- **Spatial resolution:** 3 km
- **Spectral bands:** 3 (0.765-2.06 μm)
- **Lead:** JPL, NASA
- **L2 product(s):** XCO_2, Solar Induced Fluorescence (SIF)
- **Note(s):** Ability to do "mapping mode", i.e., 100 km^2





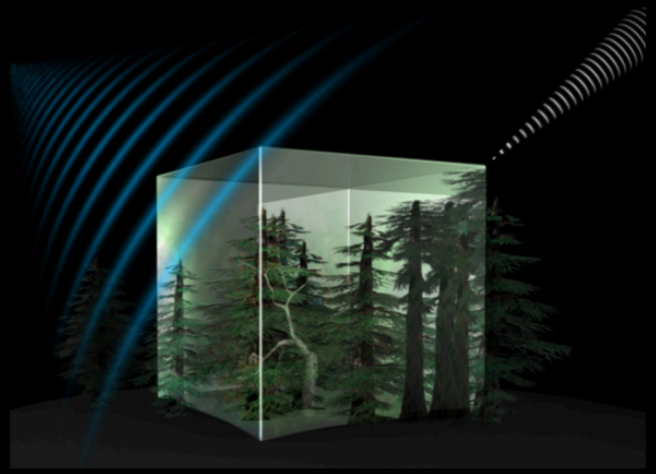
GEDI LIDAR

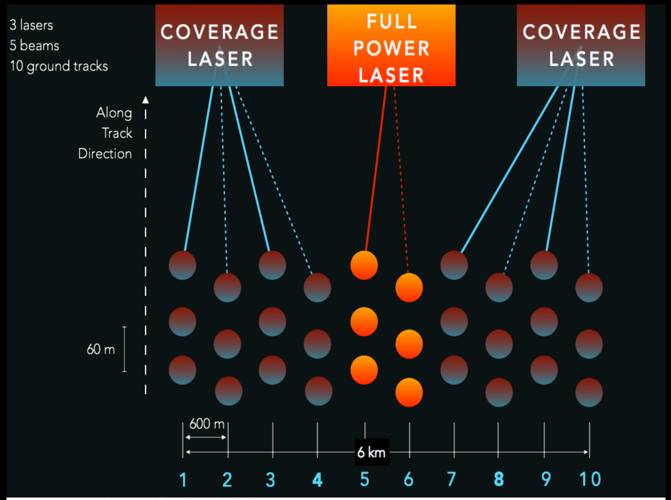
GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

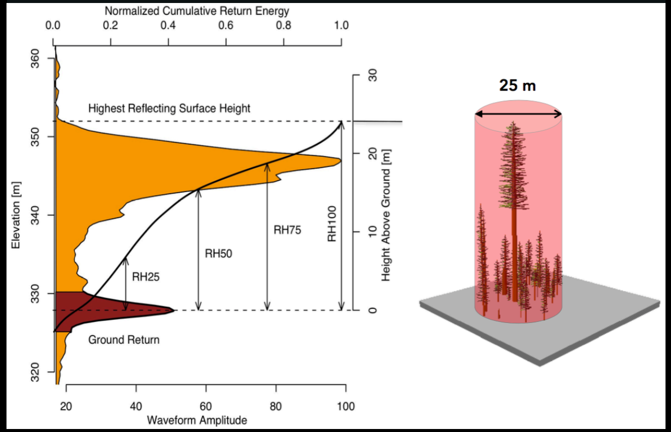


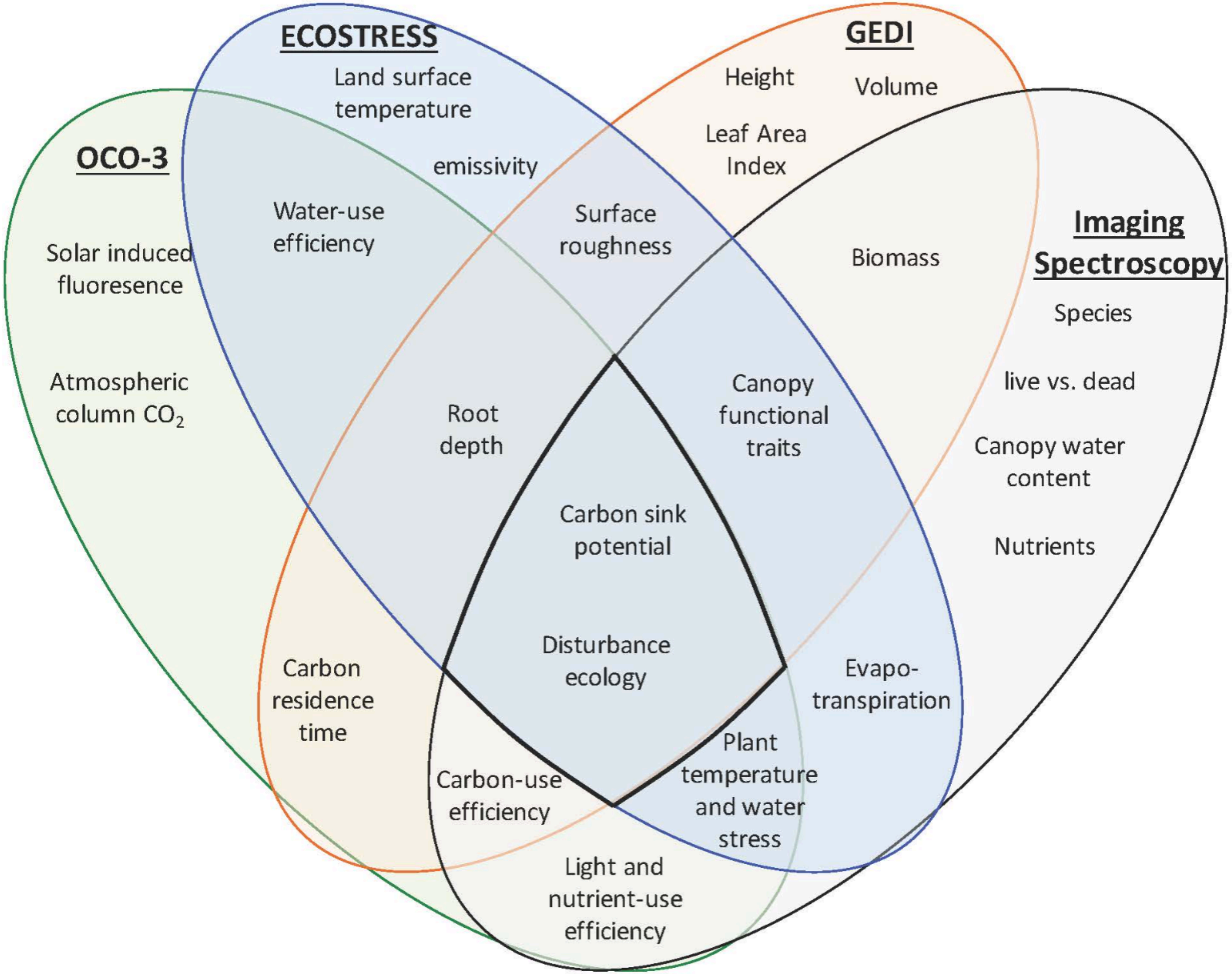
GEDI

- **Instrument:** Multi-beam waveform LiDAR
- **Spatial resolution:** 25 m
- **Lead:** UMD, NASA
- **L2/3 product(s):** Canopy Height, Canopy Profile Metrics, Habitat Metrics
- **L4 product(s):** Aboveground Carbon Stock, Change, and Flux
- **Note(s):** 15,000,000,000 land surface laser observations in 2 years

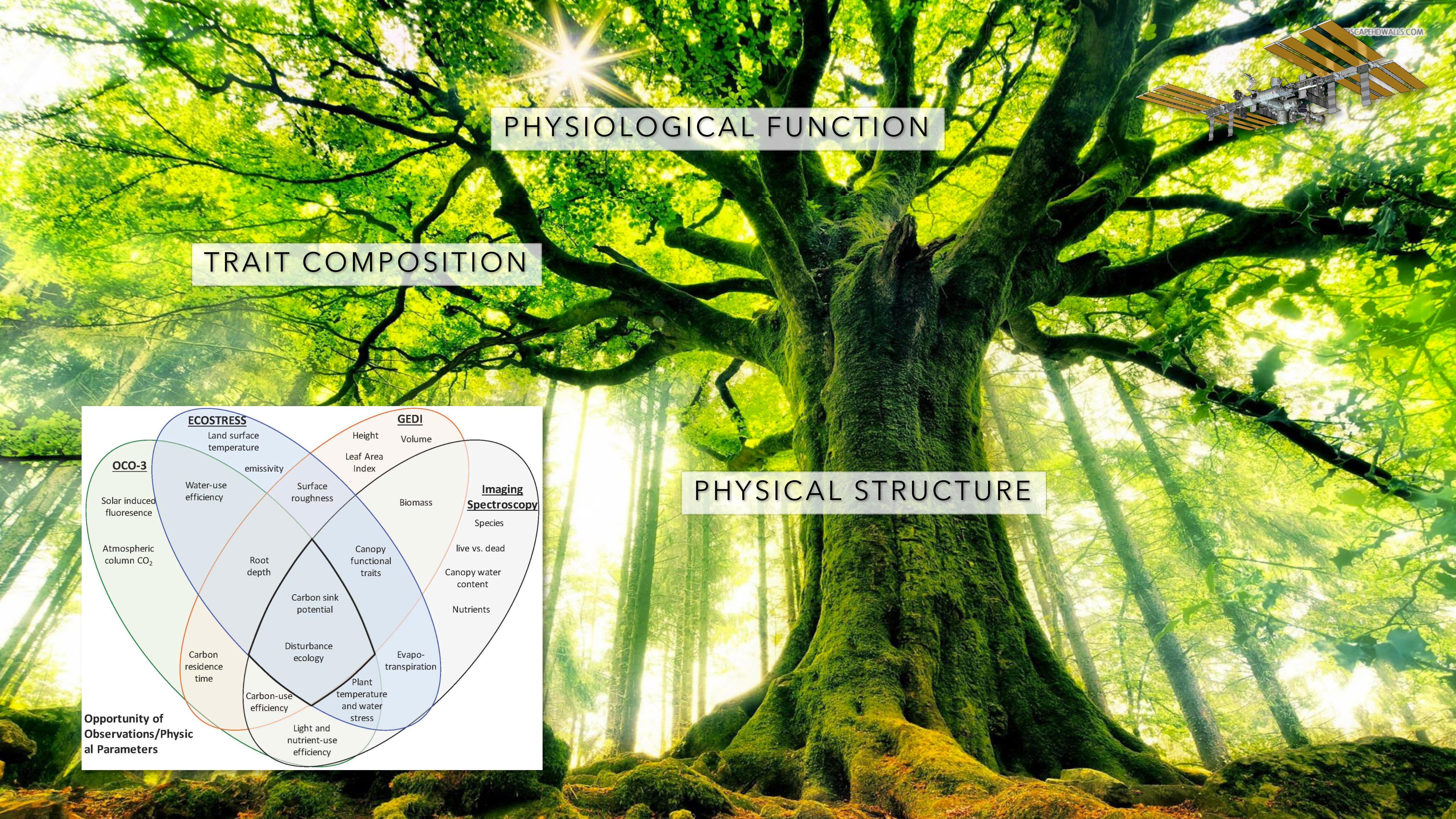








ECOSTRESS
Land surface temperature
emissivity
GEDI
Height
Volume
Leaf Area Index
OCO-3
Water-use efficiency
Surface roughness
Imaging Spectroscopy
Solar induced fluoresence
Biomass
Species
Atmospheric column CO_2
Root depth
Canopy functional traits
live vs. dead
Canopy water content
Carbon sink potential
Nutrients
Disturbance ecology
Carbon residence time
Evapo-transpiration
Plant temperature and water stress
Carbon-use efficiency
Light and nutrient-use efficiency


PHYSIOLOGICAL FUNCTION
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Nutrients
Disturbance ecology
Carbon residence time
Evapo-transpiration
Plant temperature and water stress
Carbon-use efficiency
Light and nutrient-use efficiency
Opportunity of Observations/Physical Parameters

Conclusions: Open Road

- Holistic view of terrestrial ecosystems must include structure, function, and composition;
- Integrated view requires integrated observations matched to the characteristics of the observed;
- Systematic barriers reduce likelihood of “full” missions simultaneously capturing all components;
- ISS reduces barrier to entry–key platform to synergize observations of fundamental ecosystem properties;
- We will have simultaneous observations of structure from GEDI (canopy height, biomass), function from ECOSTRESS (evapotranspiration) and OCO-3 (fluorescence), and composition from HISUI (TBD);
- The synergies between these measurements is an open road–where will it take us?