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

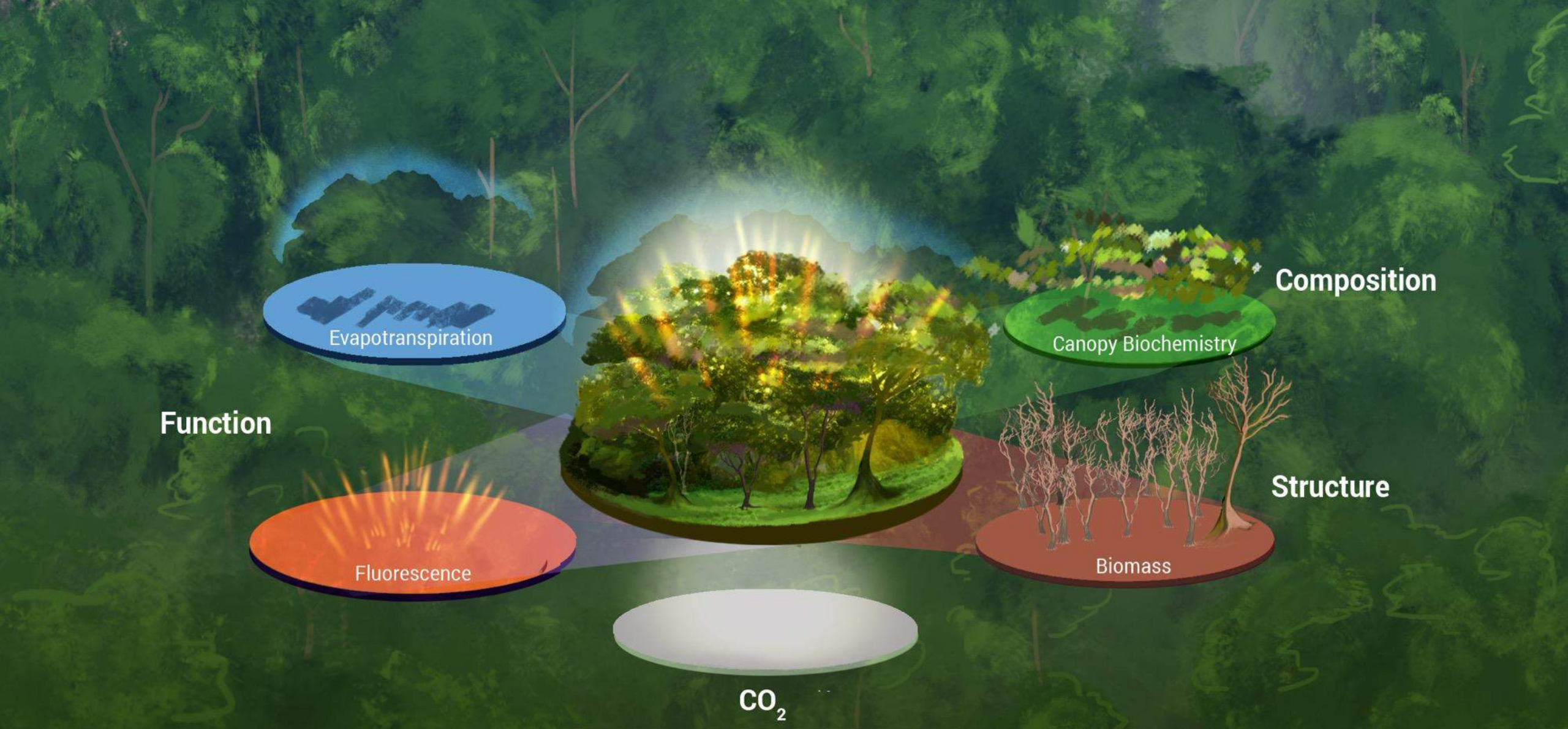
**JOSHUA B. FISHER**[1], E. NATASHA STAVROS[1], RYAN PAVLICK[1], SIMON J. HOOK[1], ANNMARIE ELDERING[1], RALPH DUBAYAH[2], TSUNEO MATSUNAGA[3], SHAWN SERBIN[4], DAVID SCHIMEL[1]

[1] Jet Propulsion Laboratory, California Institute of Technology
[2] University of Maryland
[3] Japanese National Institute for Environmental Studies
[4] Brookhaven National Laboratory



© 2019 All rights reserved.

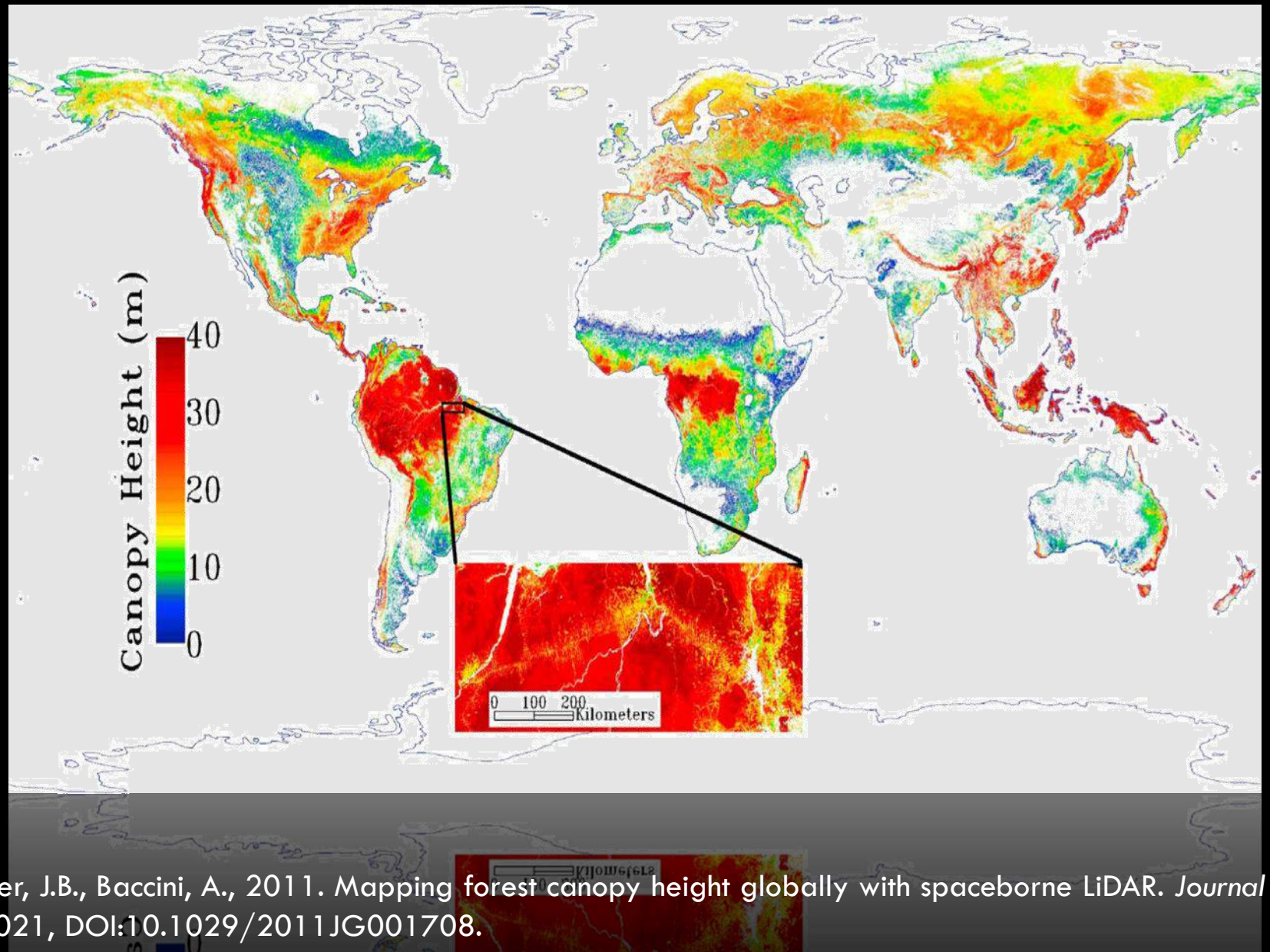
# WHAT IS AN ECOSYSTEM?




# STRUCTURE – COMPOSITION – FUNCTION

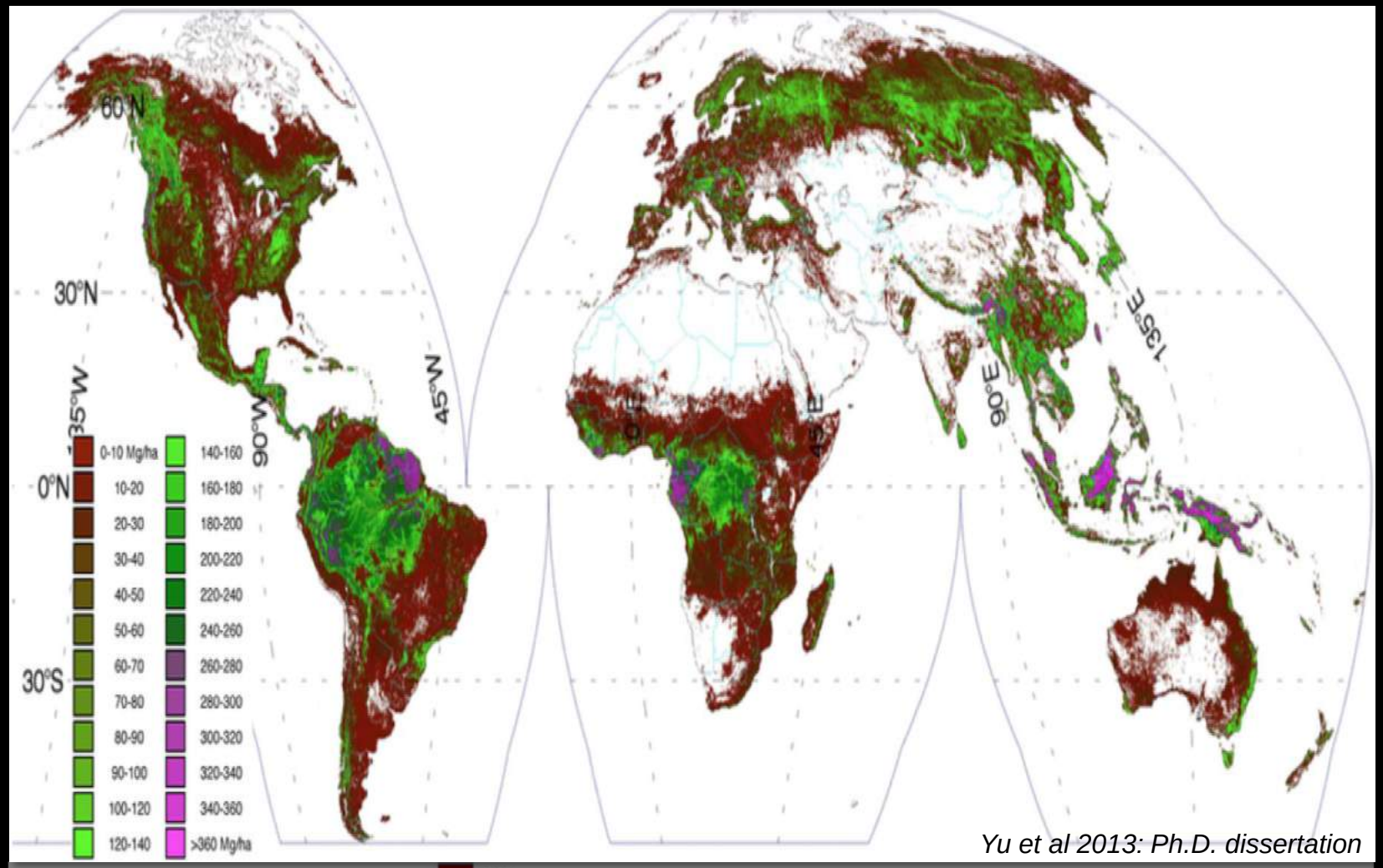
# WHAT CAN WE OBSERVE GLOBALLY?

# 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

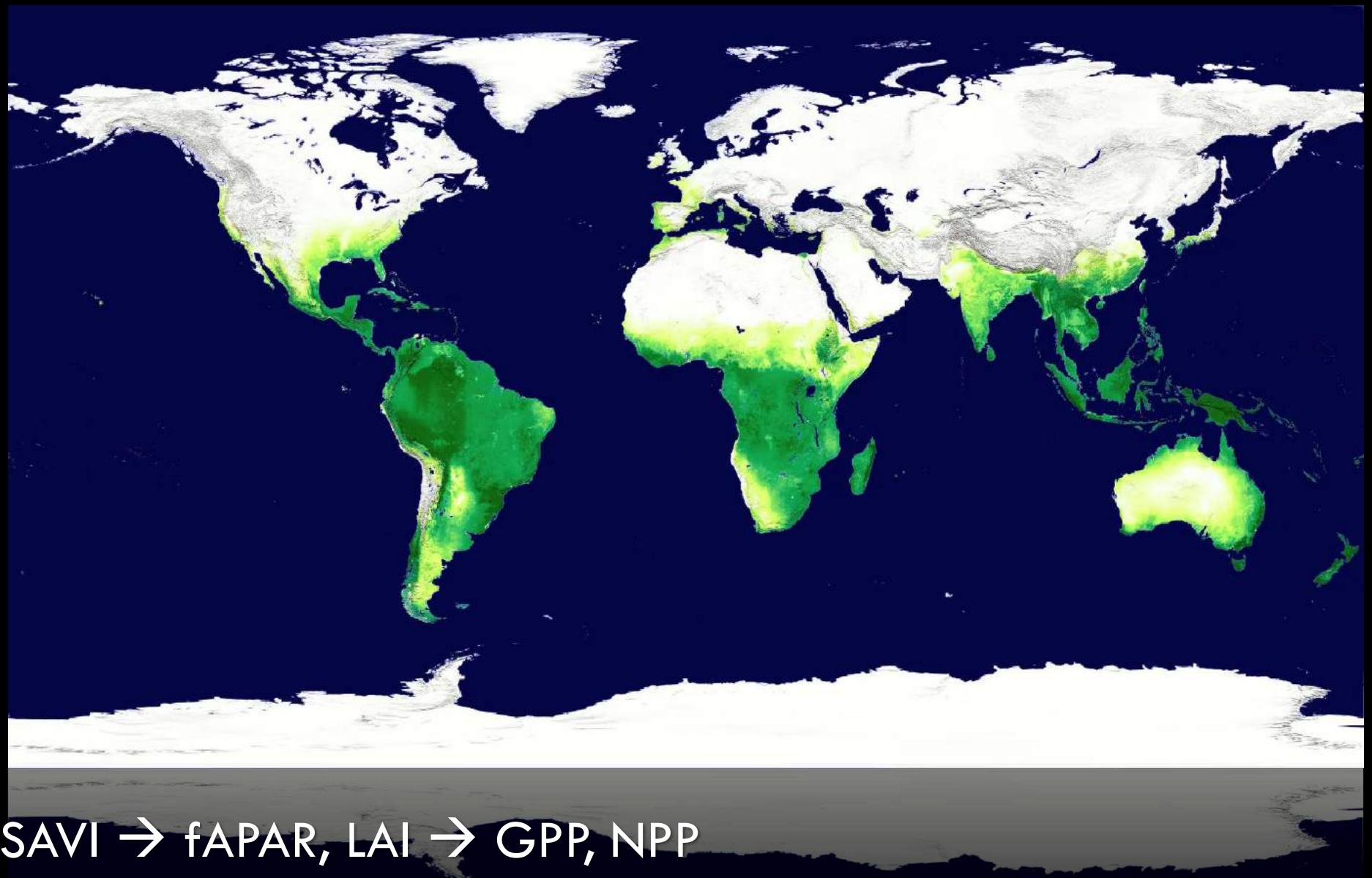



*Yu et al 2013: Ph.D. dissertation*

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.

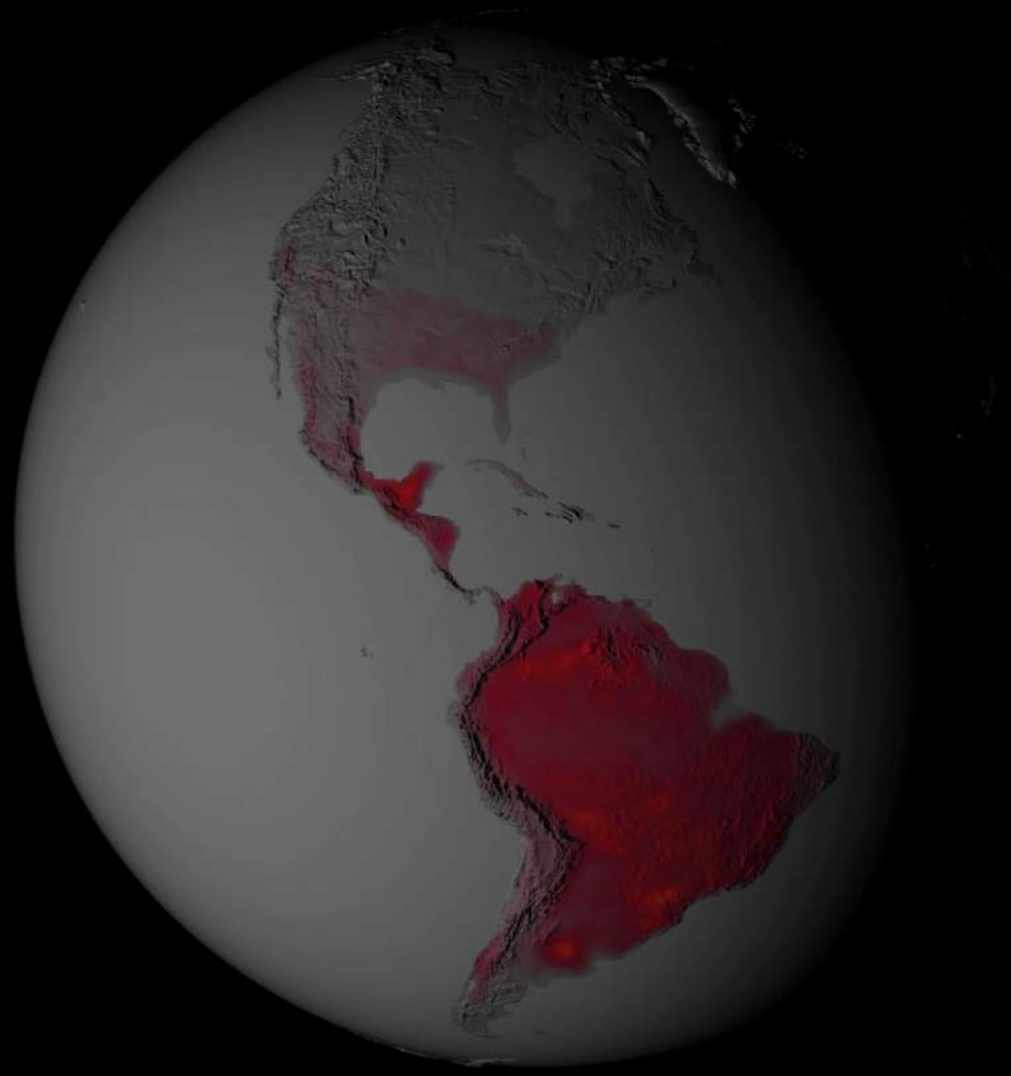
# Structure: Leaf Area Index

# Function: Gross and Net Primary Production



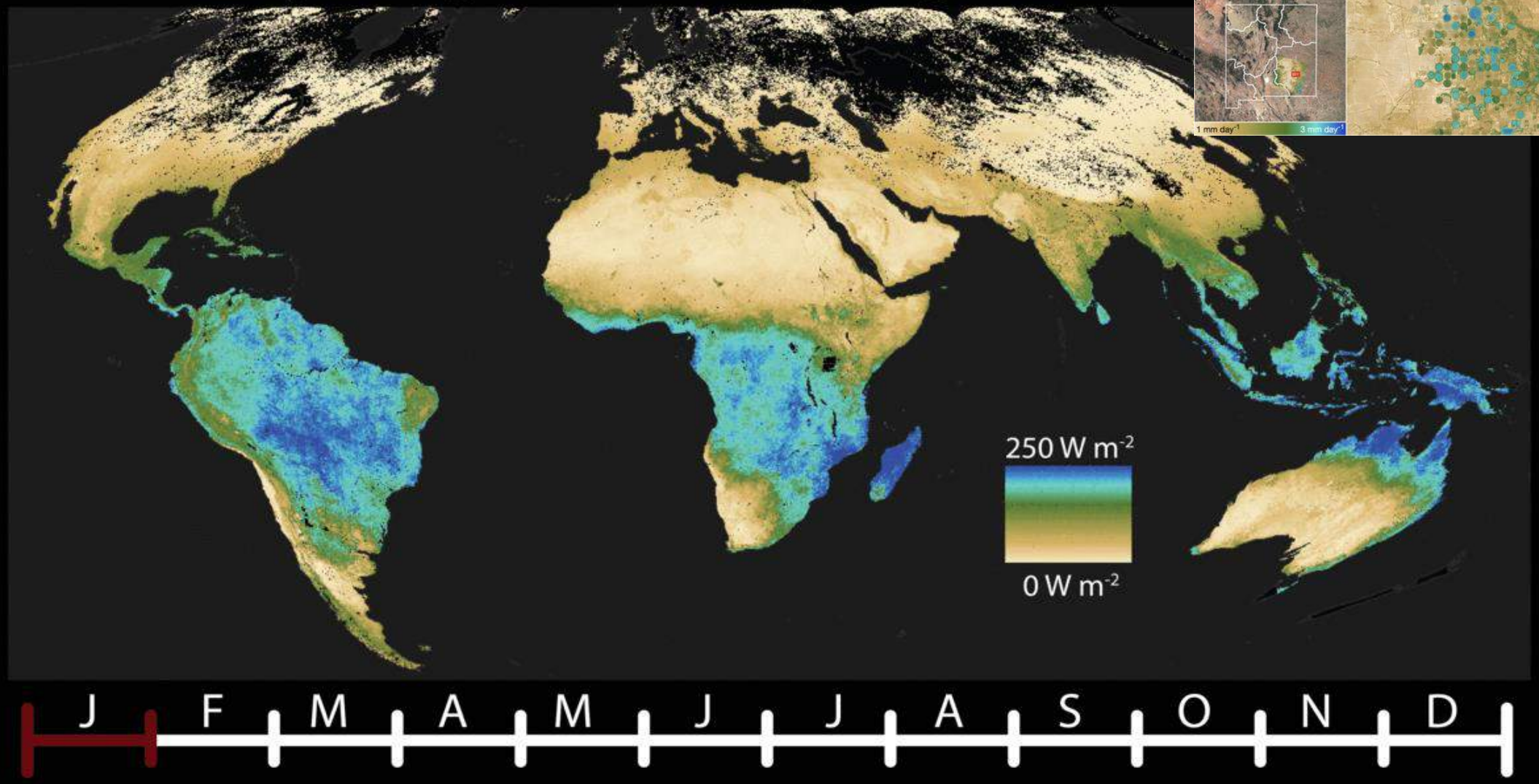
NDVI, EVI, SAVI → fAPAR, LAI → GPP, NPP

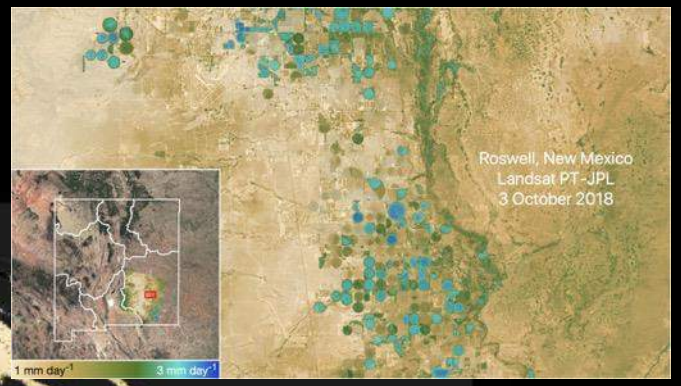
# Function: Fluorescence → GPP



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*.
Joiner, J., et al., 2011. First observations of global and seasonal terrestrial chlorophyll fluorescence from space. *Biogeosciences*.

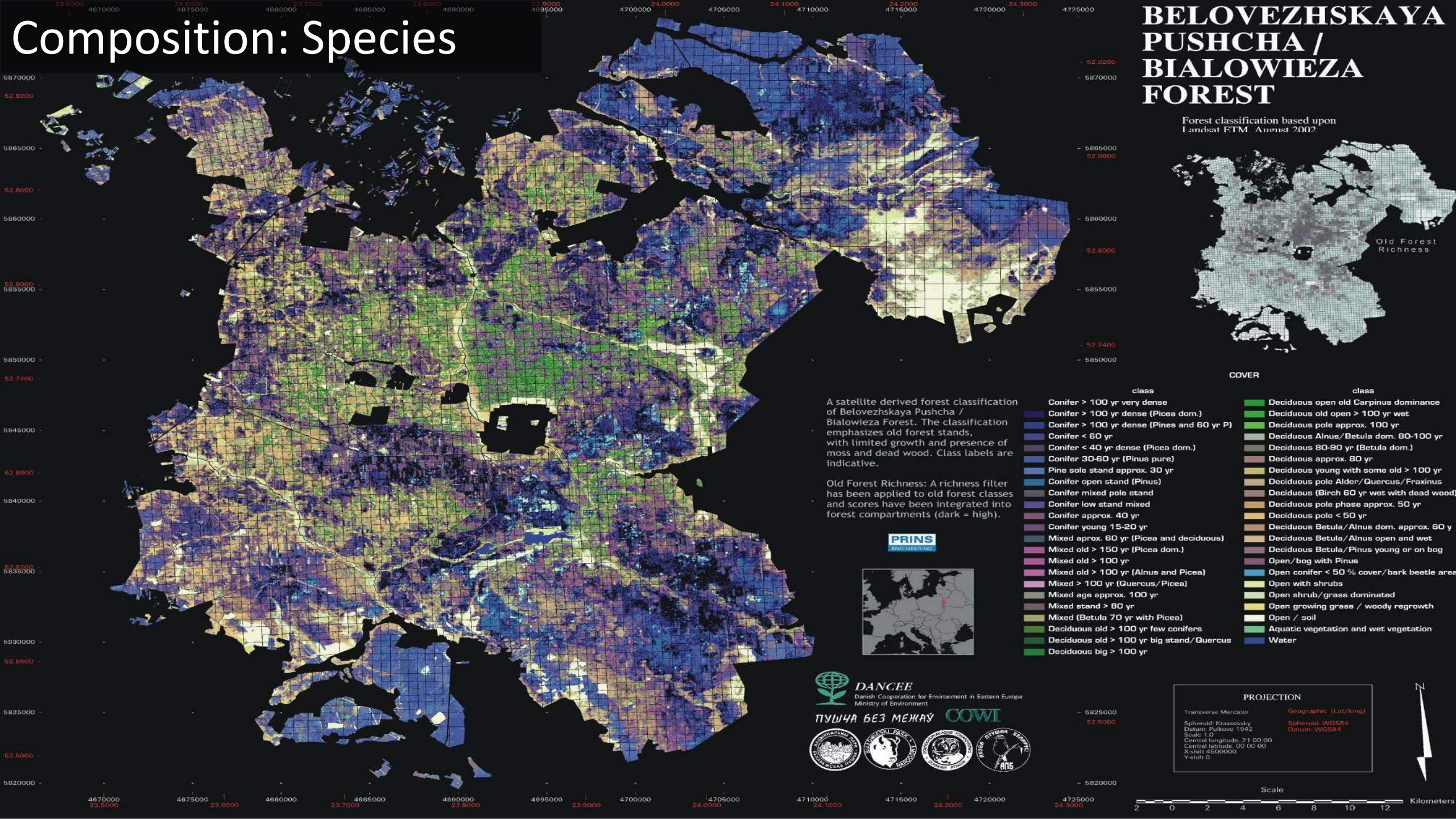
# Function: Evapotranspiration




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

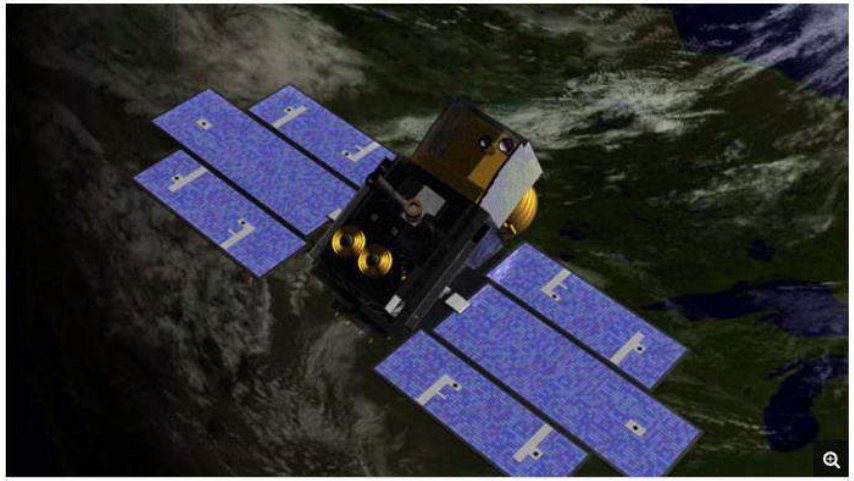


WHAT'S MISSING?

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

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

0
0
0
0
0
MORE



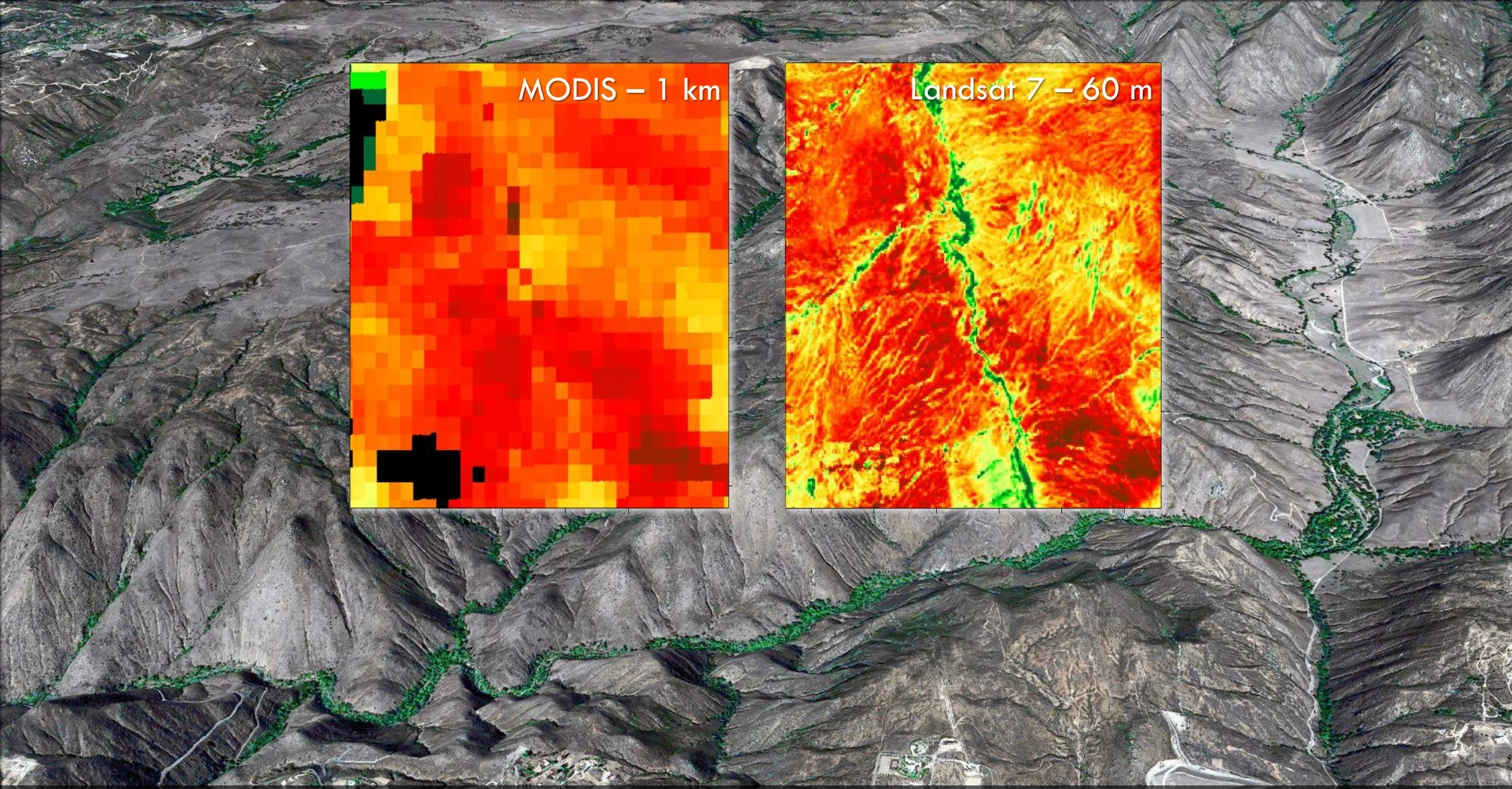
Artist's concept of ICESat.

Credit: NASA

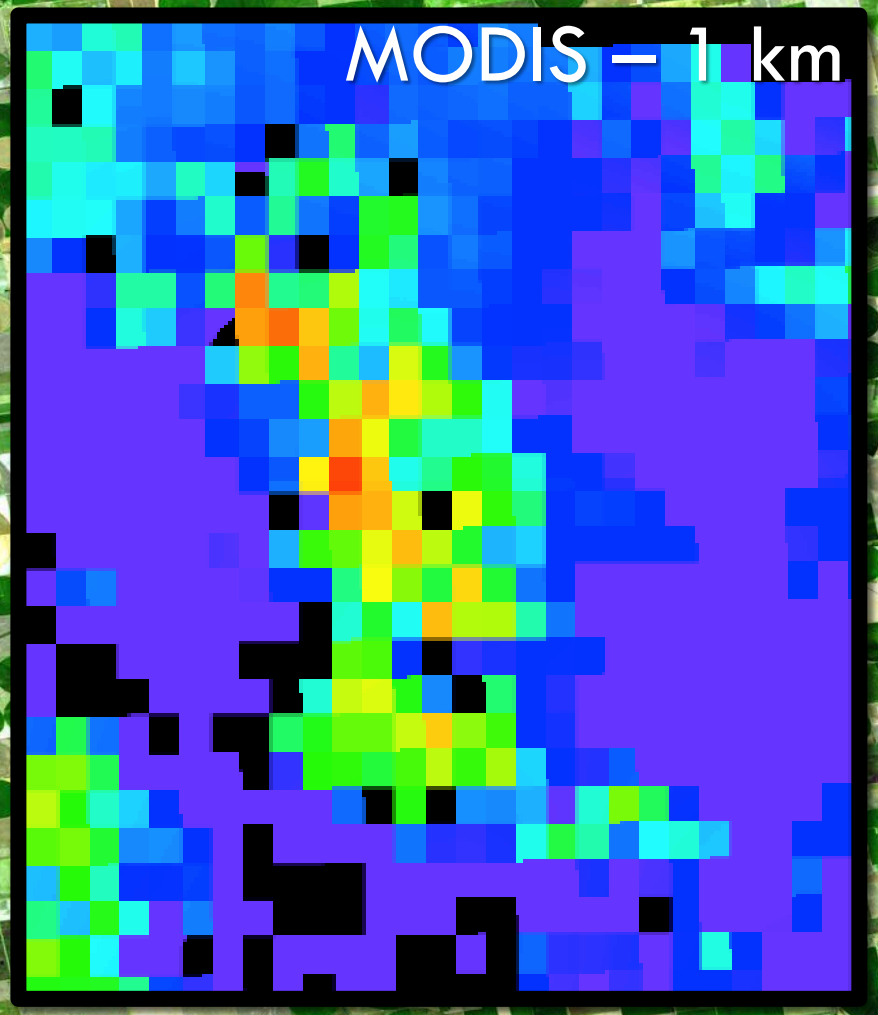
A NASA satellite that spent seven years studying Earth's polar regions ended its successful mission Monday by plunging back to Earth on purpose to burn up in the atmosphere.

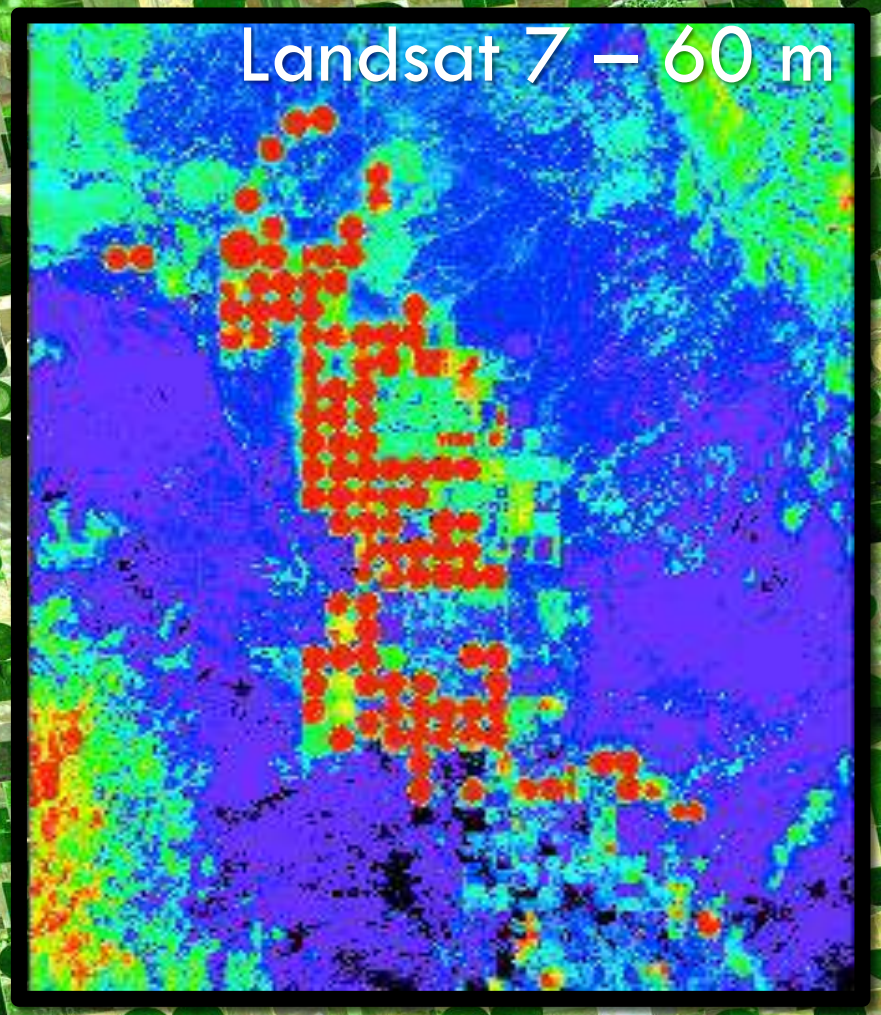
Some debris from the Ice, Cloud, and land Elevation satellite ? known as ICESat ? fell into the Barents Sea north of Norway and Russia at approximately 5 a.m. EDT (0900 GMT) Monday, according to the Orbital Debris Program Office at NASA's Johnson Space Center in Houston.

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]

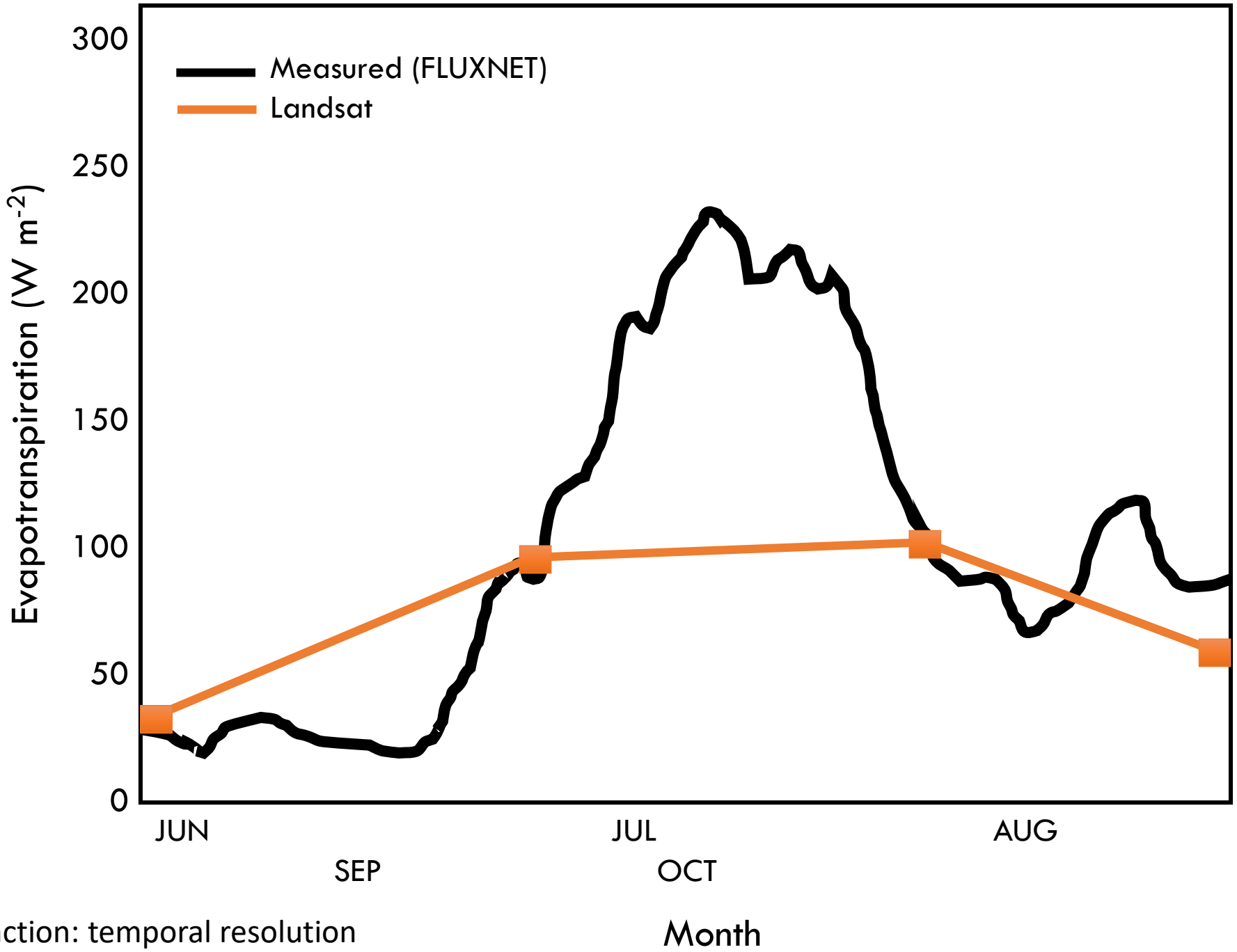



Physiological Function: spatial resolution



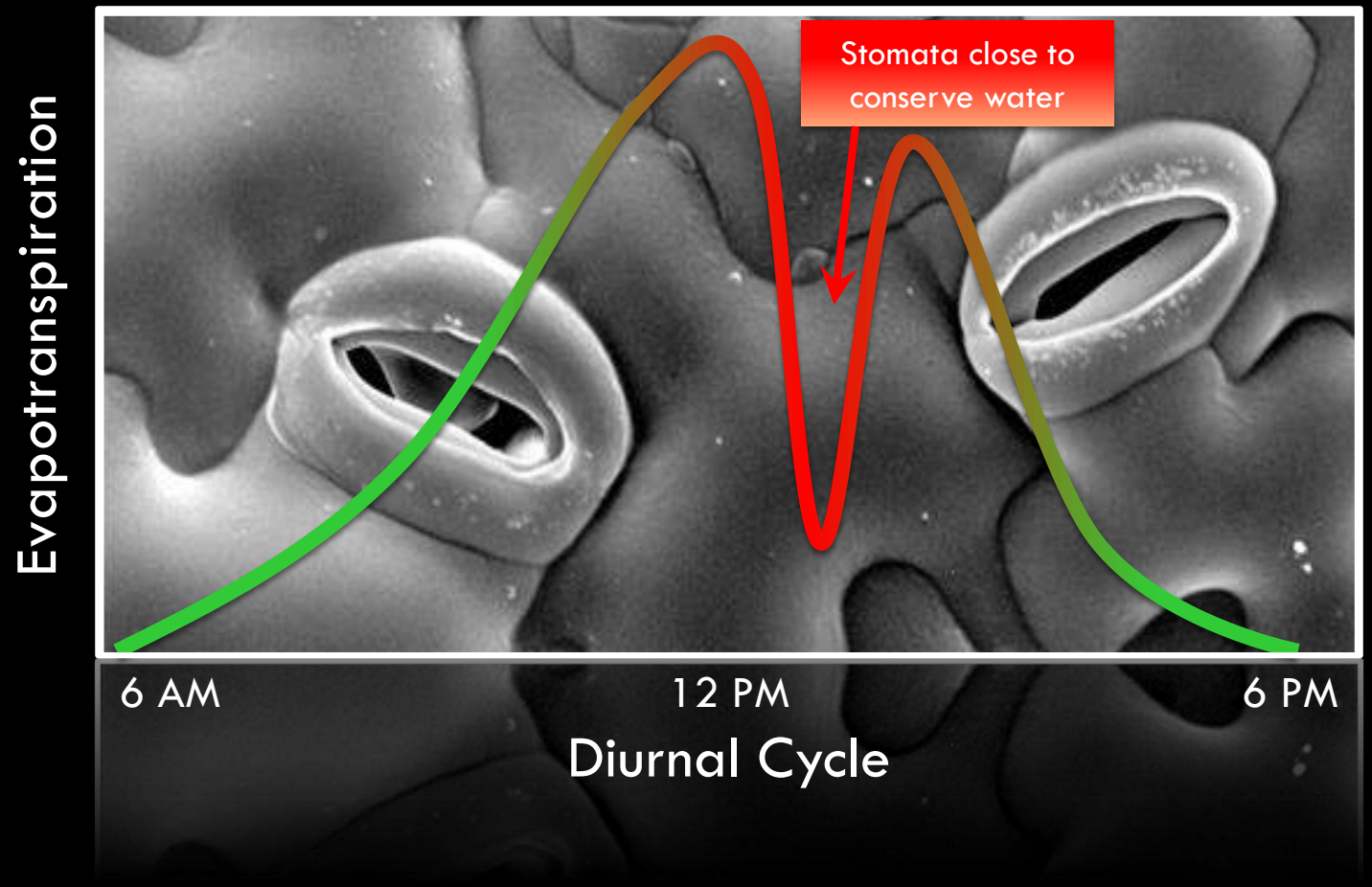




Physiological Function: spatial resolution

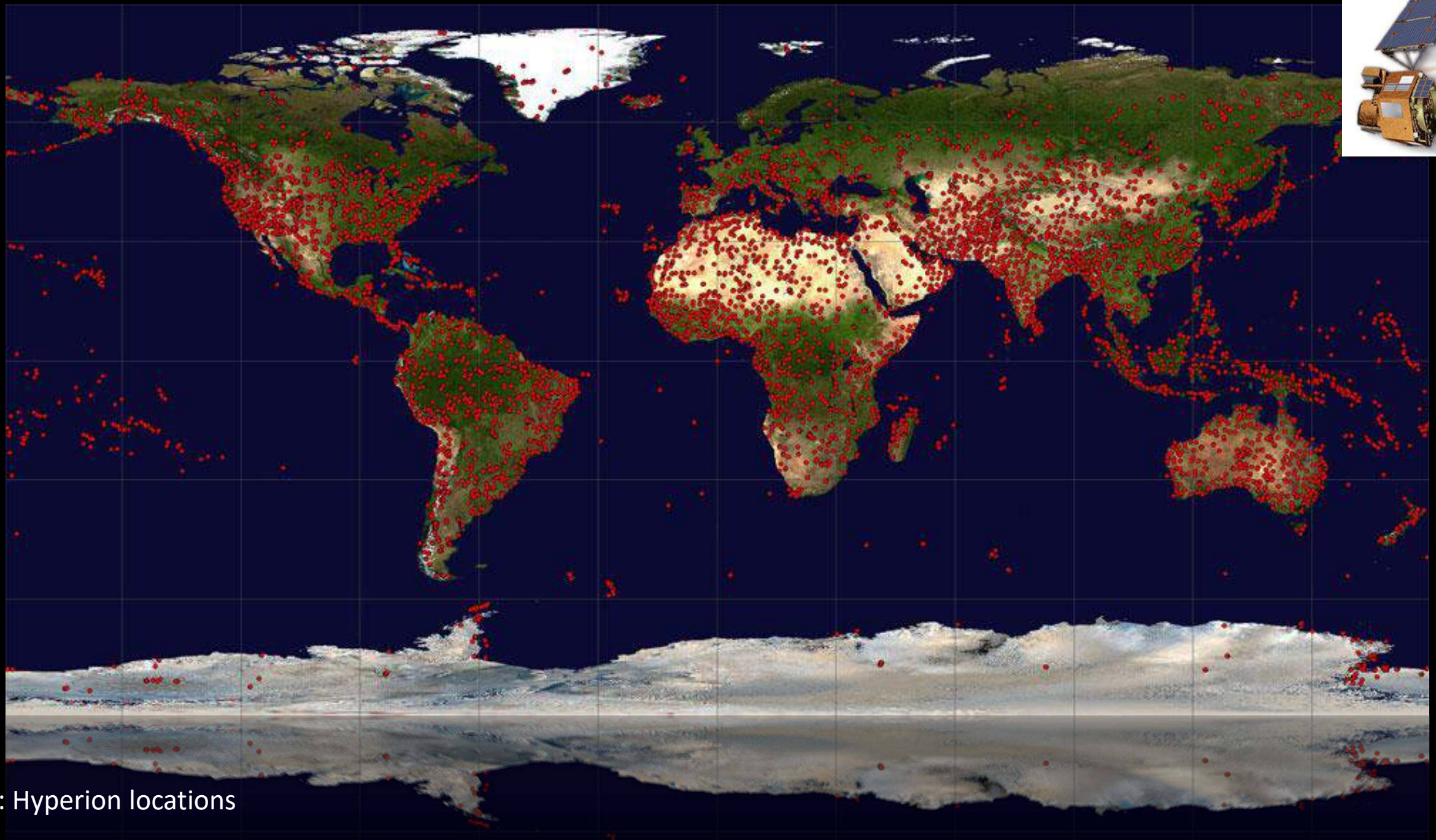



Physiological Function: temporal resolution

# Water Stress Drives Plant Behavior




Physiological Function: temporal resolution



Traits: Hyperion locations

# Intersections

$$GPP \times \Delta BIOMASS^{-1} = CUE$$

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

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

=

C sink potential

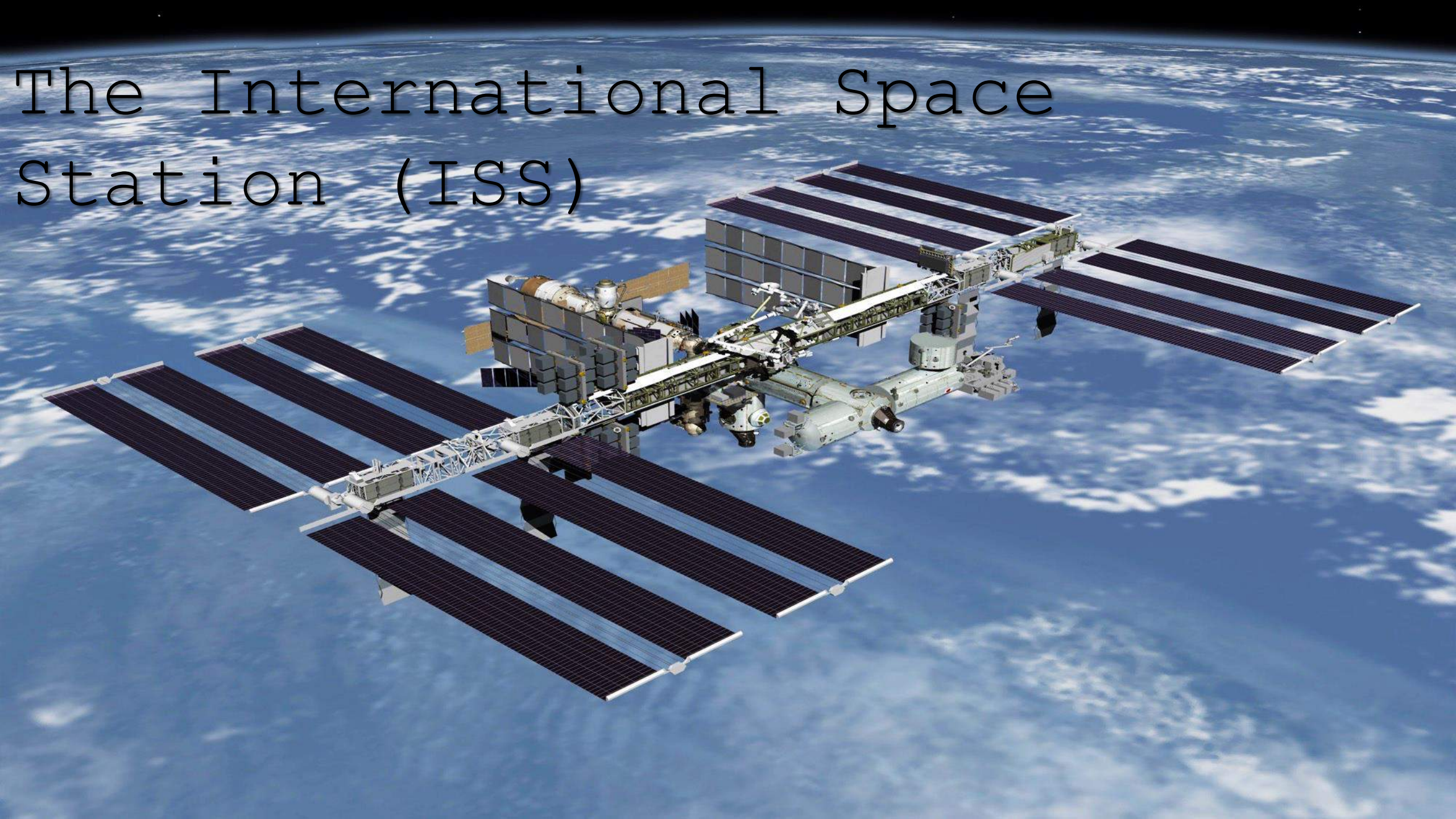
$f$(productivity, water use, structure, canopy traits)

=

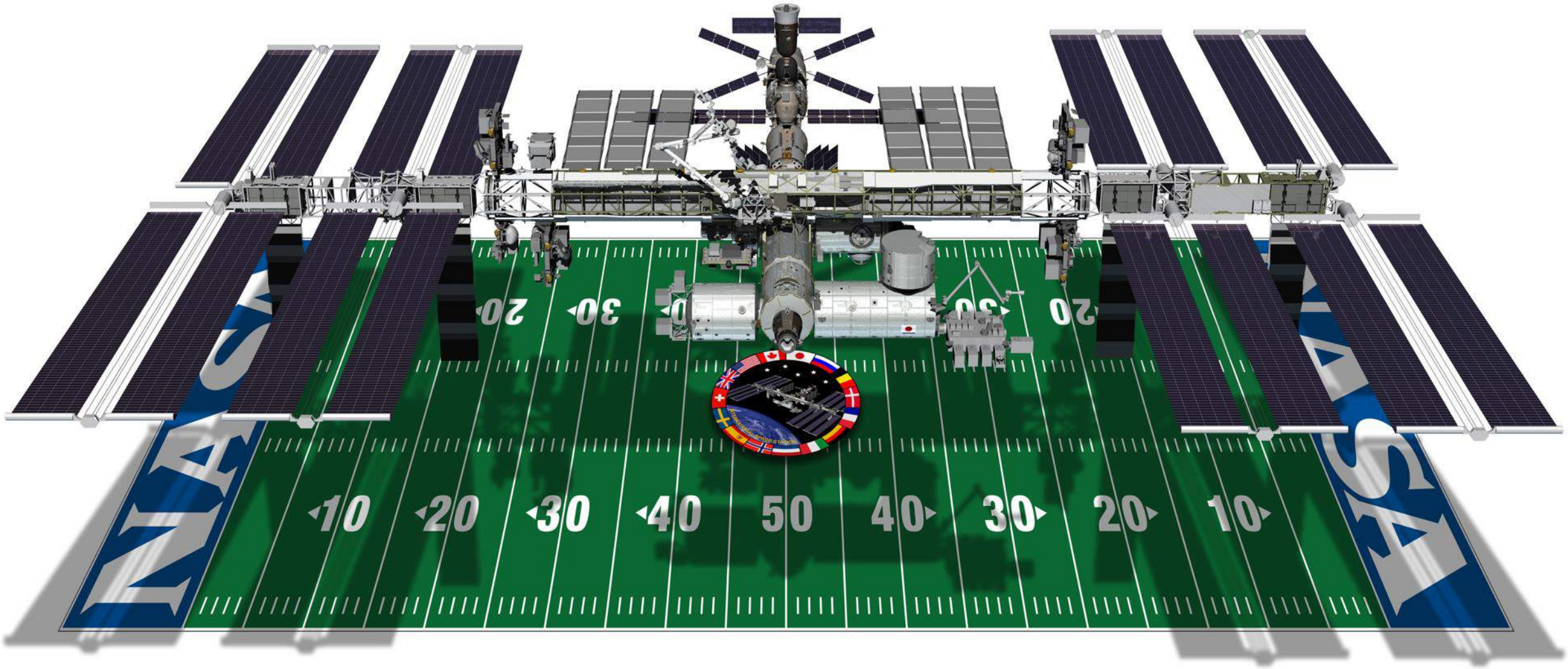
Disturbance Ecology

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

# The International Space Station (ISS)



National Aeronautics and Space Administration

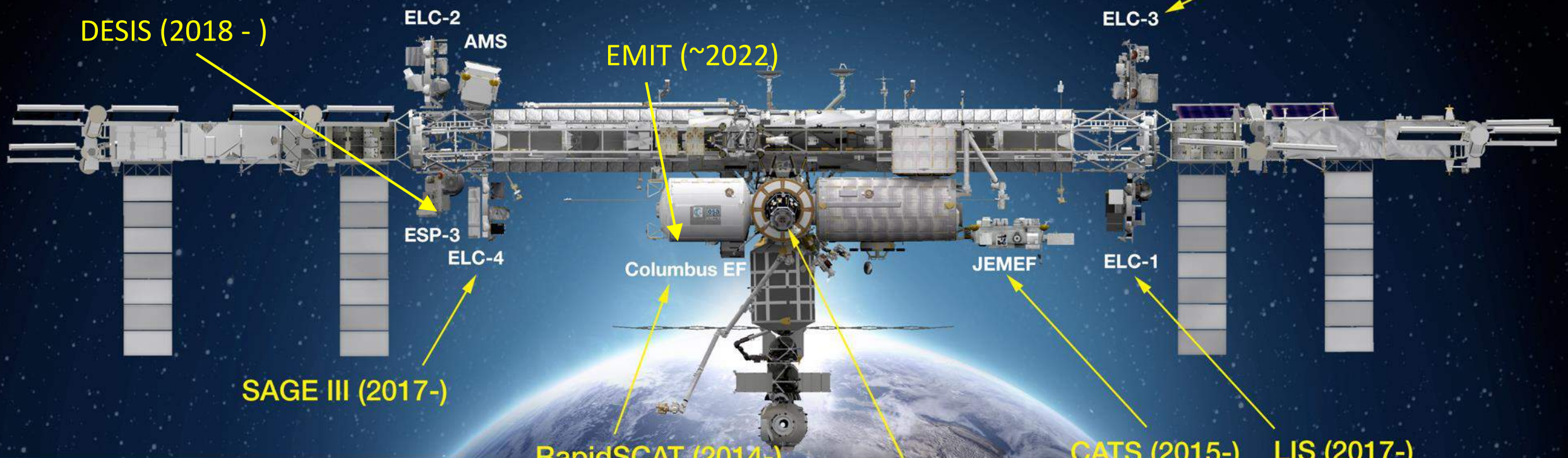



www.nasa.gov

JPL Halloween Costume Contest 2017

# International Space Station

## Earth Science Instruments




DESIS (2018 - )

EMIT (~2022)

TSIS-1 (2018)

SAGE III (2017-)

RapidSCAT (2014-)

ISERV (2012-2015)

ICARUS (2019 - )

CATS (2015-)

LIS (2017-)

GEDI (2019)

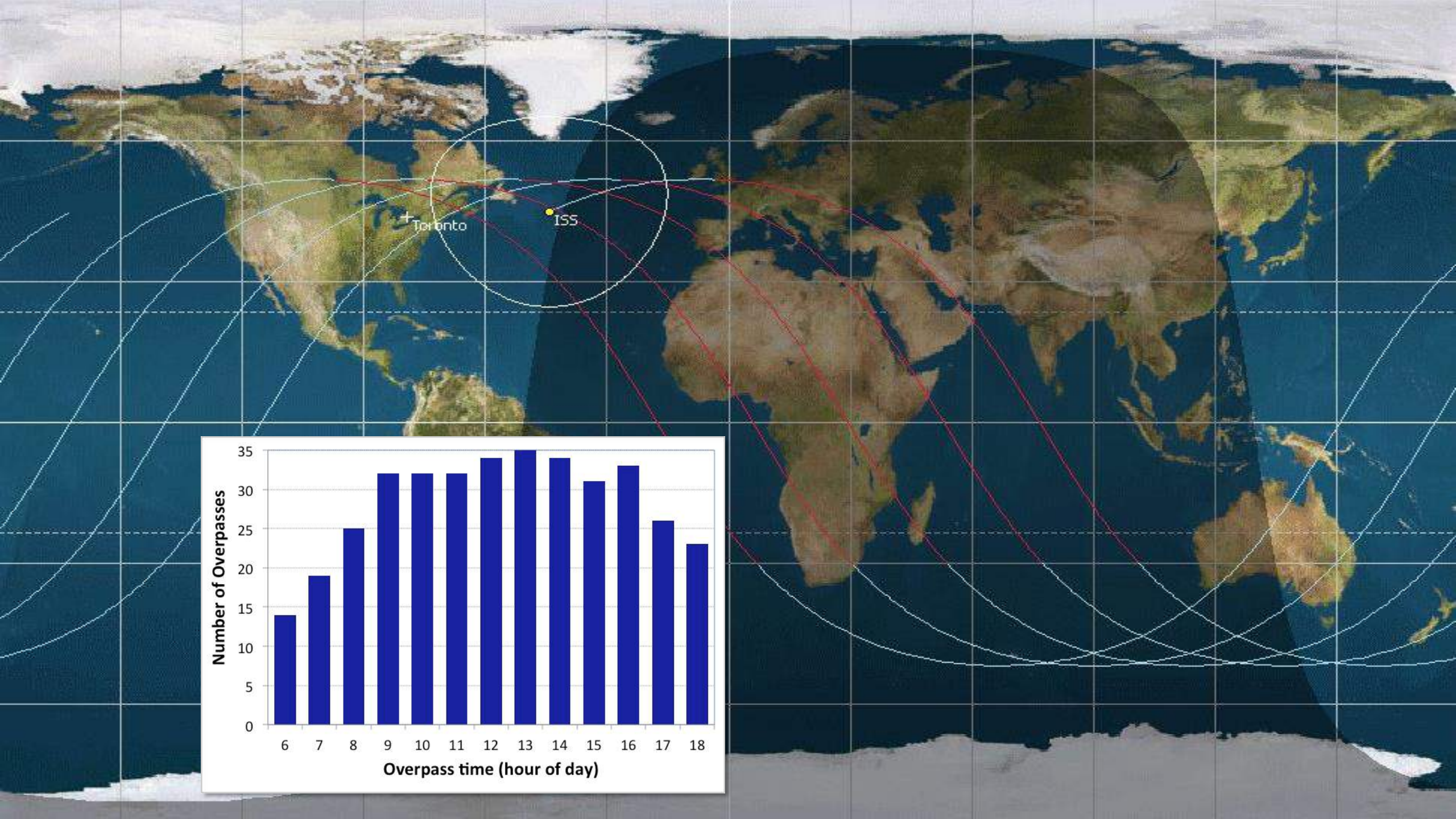
ECOSTRESS (2019)

HICO (2009-2014)

OCO-3 (2019)

HISUI (~2019)

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
0
5
10
15
20
25
30
35
6
7
8
9
10
11
12
13
14
15
16
17
18
Overpass time (hour of day)

J 2018
J
A
S
O
N
D
J 2019
F
M
A
M
J
J
A
S
O
N
D
ECOSTRESS
DESIS
GEDI
OCO-3
HISUI
TESLARATI
@_tom.cross_

ECOSTRESS!

# ECOSTRESS

## *ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station*

An Earth Venture Instrument-2 Proposal

*Submitted in response to*

AO NNH12ZDA006O EVI2

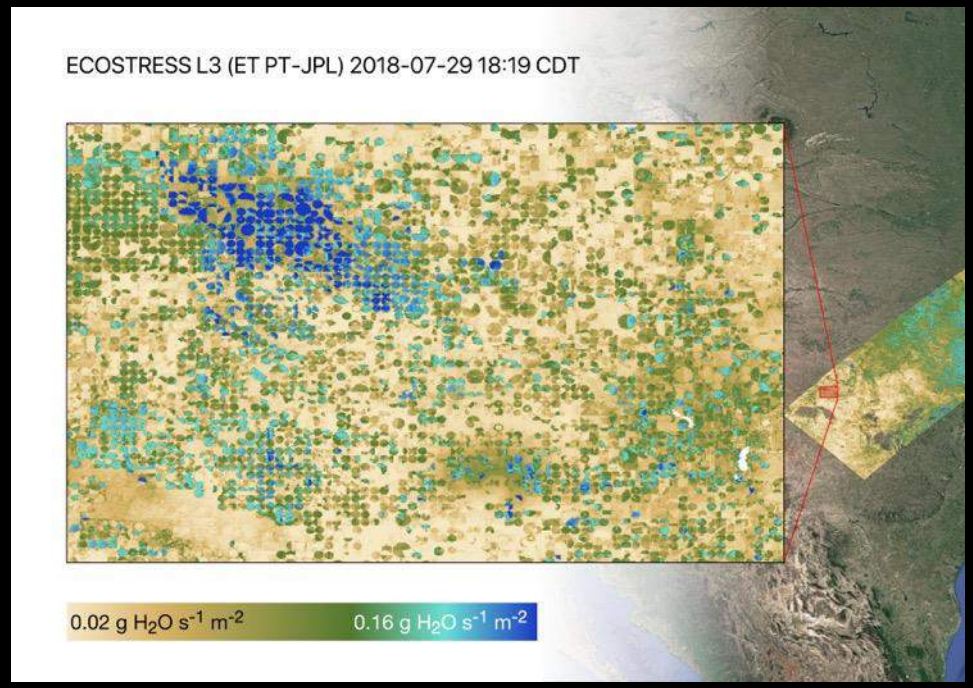
*Prepared for*

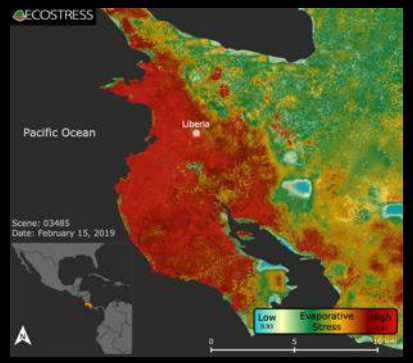
National Aeronautics and
Space Administration
Science Mission Directorate

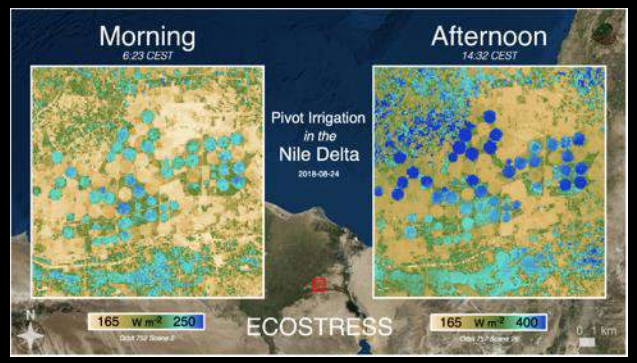
November 25, 2013

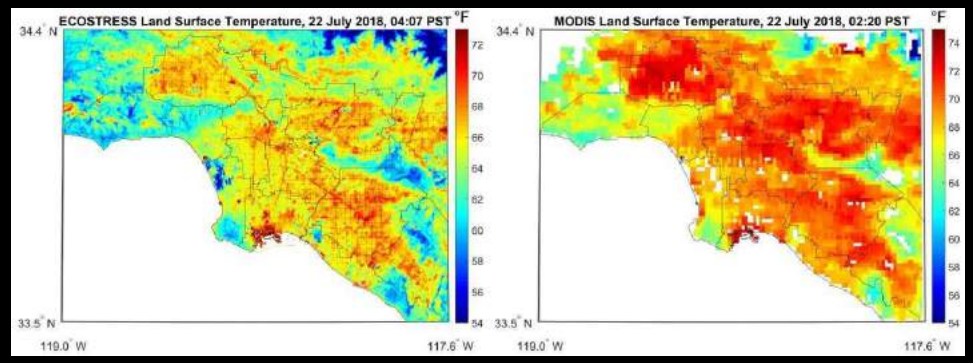
# ECOSTRESS

- **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



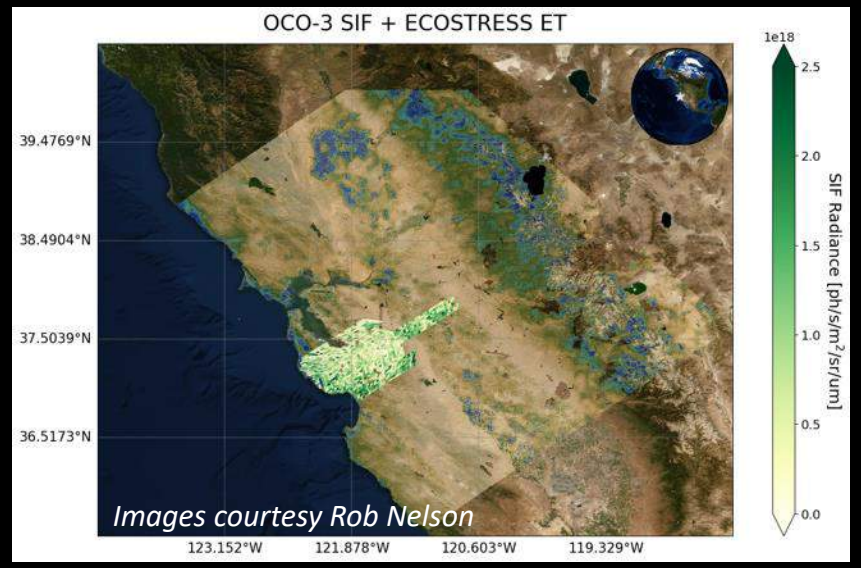



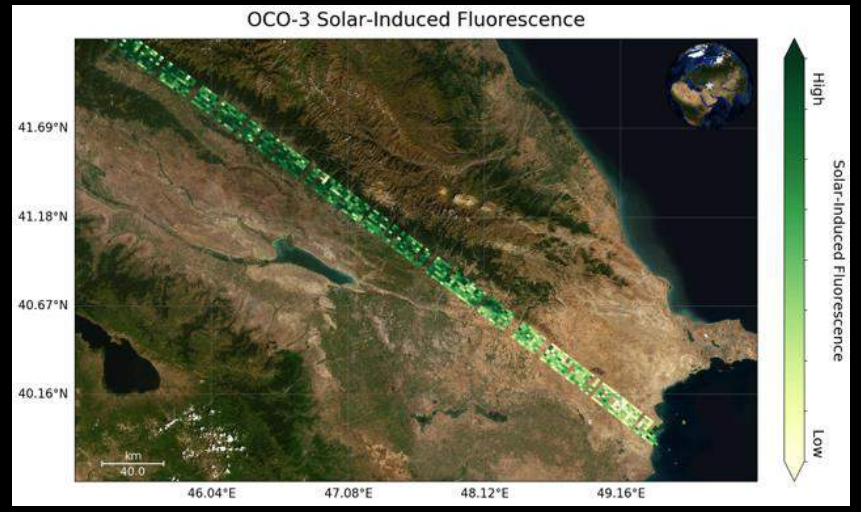



OCO-3
ORBITING CARBON OBSERVATORY

# 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 $km^2$



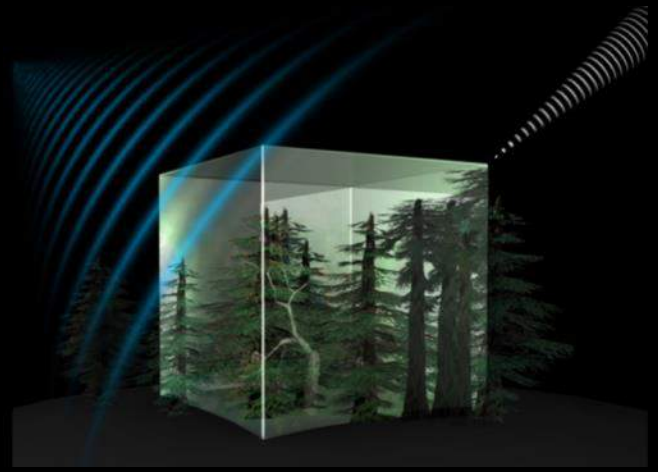


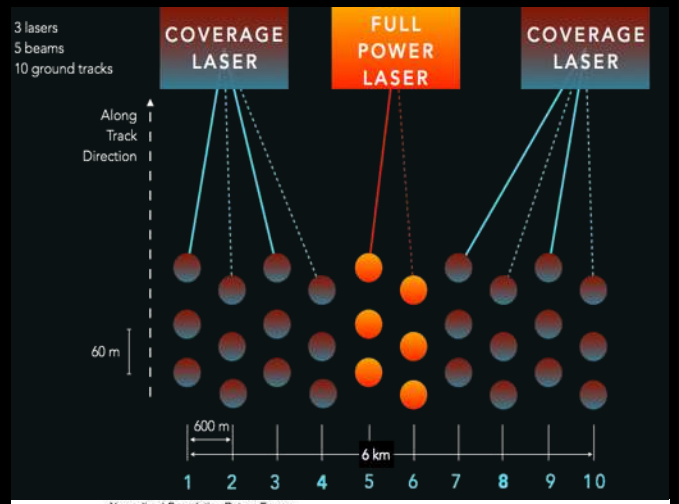
GEDI LIDAR

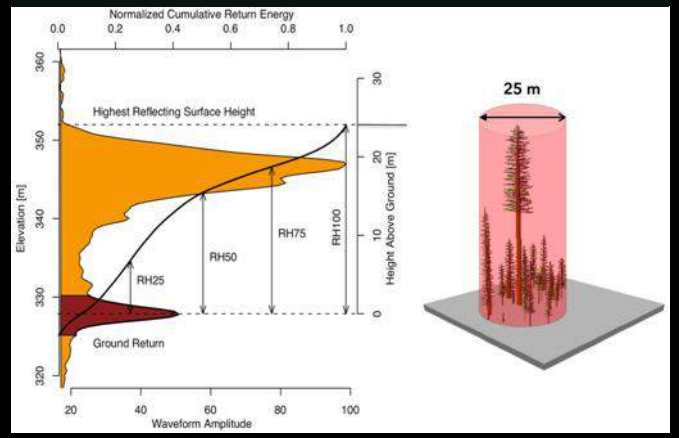
# GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION

# 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

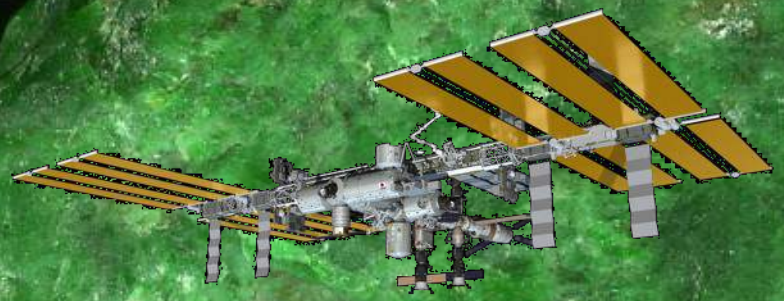




# HISUI

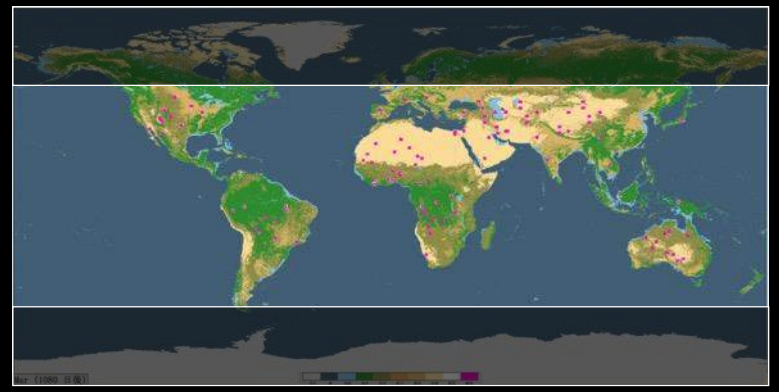
## Hyperspectral Imager SUIte



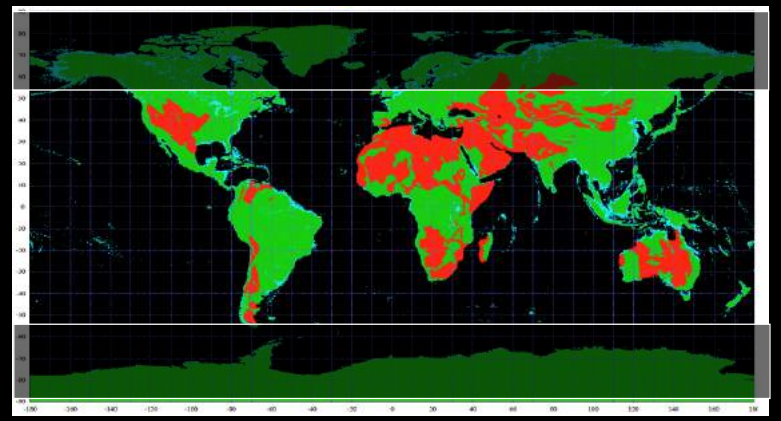
翡　翠

# HISUI

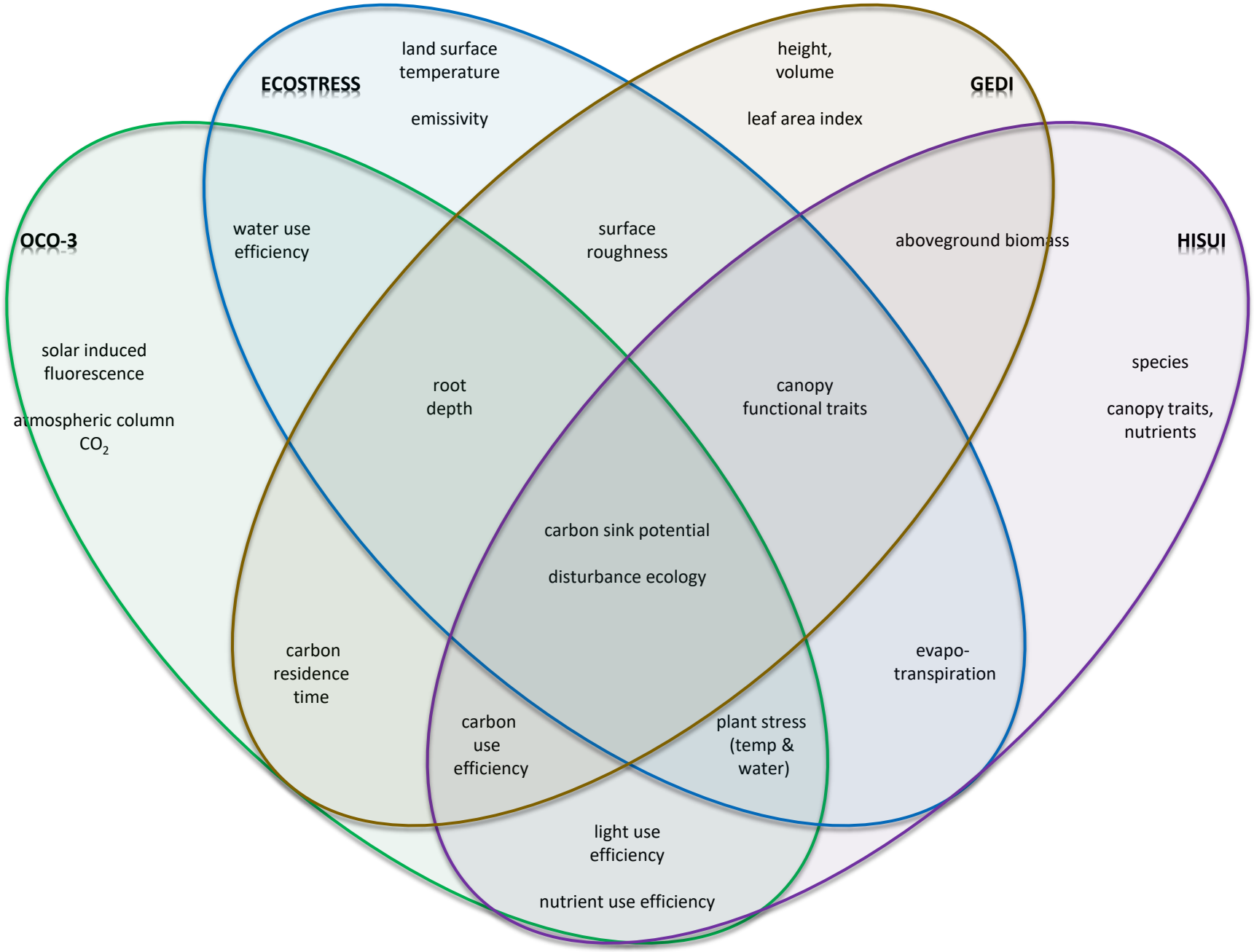
- **Instrument:** Hyperspectral Imager
- **Spatial resolution:** 30 m
- **Spectral bands:** 185 (0.4–2.5 μm)
- **Lead:** Japan Space Systems
- **L2 product(s):** Atmospherically corrected surface spectral reflectance
- **Notes:** Data will be partially directly transmitted to ground stations (10 GB/day = 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-like product.



Tentative DARs for Verification Observation



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




*Stavros et al. 2017*

# Conclusions: Open Road

- Holistic view of terrestrial ecosystems must include structure, function, and composition;
- 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 now have simultaneous observations of structure from GEDI (canopy height, biomass), function from ECOSTRESS (evapotranspiration) and OCO-3 (fluorescence), and composition from HISUI (traits);
- The synergies between these measurements is an open road—where will it take us?

• Stavros, E.N., Schimel, D., Pavlick, R., Serbin, S., Swann, A., Duncanson, L., Fisher, J.B., Fassnacht, F., Ustin, S., Dubayah, R., Schweiger, A., Wennberg, P., 2017. ISS observations offer insights into plant function. *Nature Ecology & Evolution* 1(0194): 1-4.