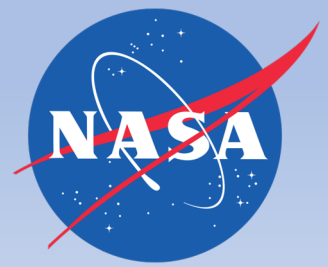
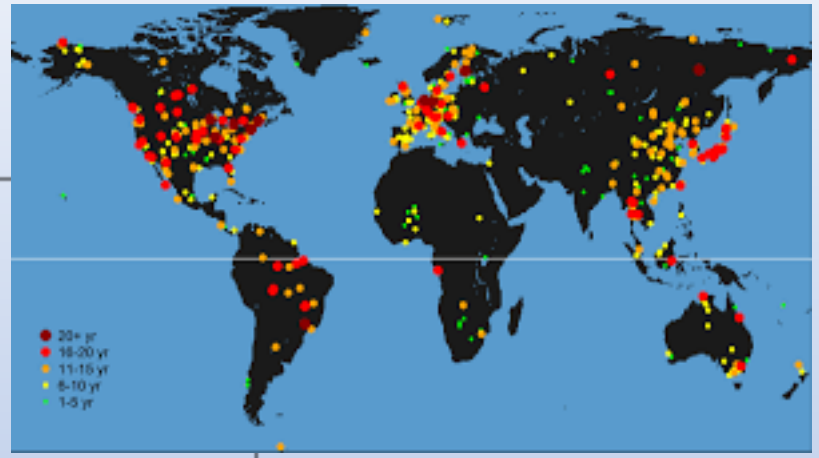
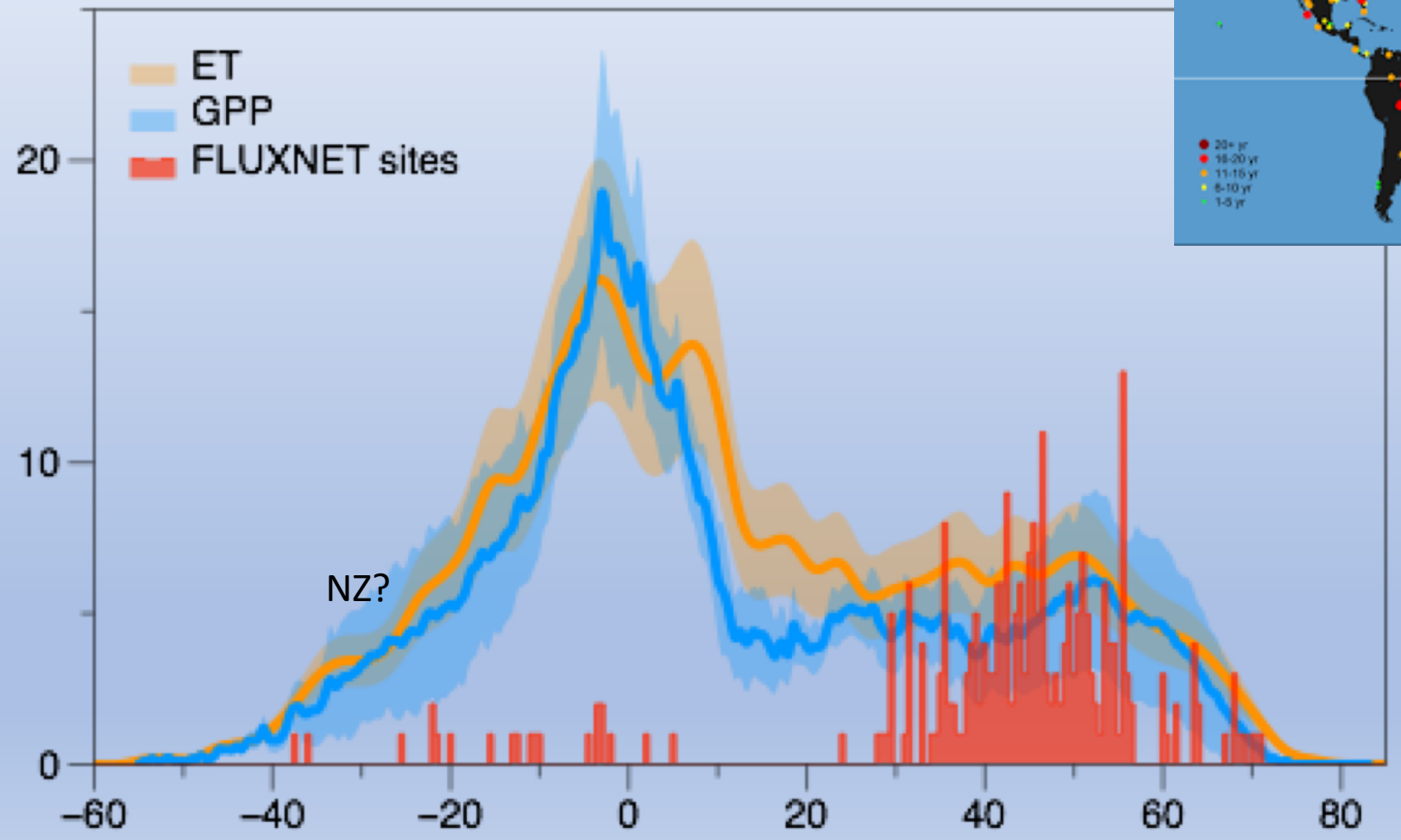
The data gap and the contribution of space

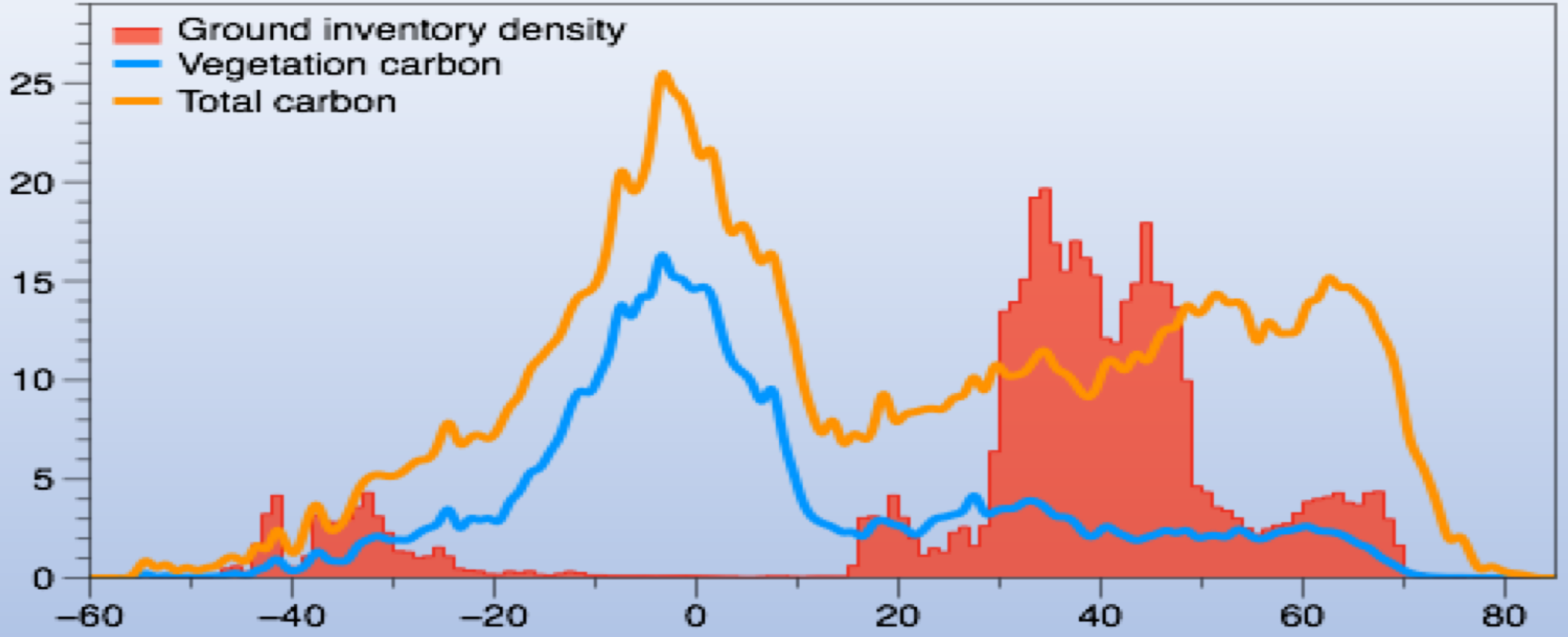


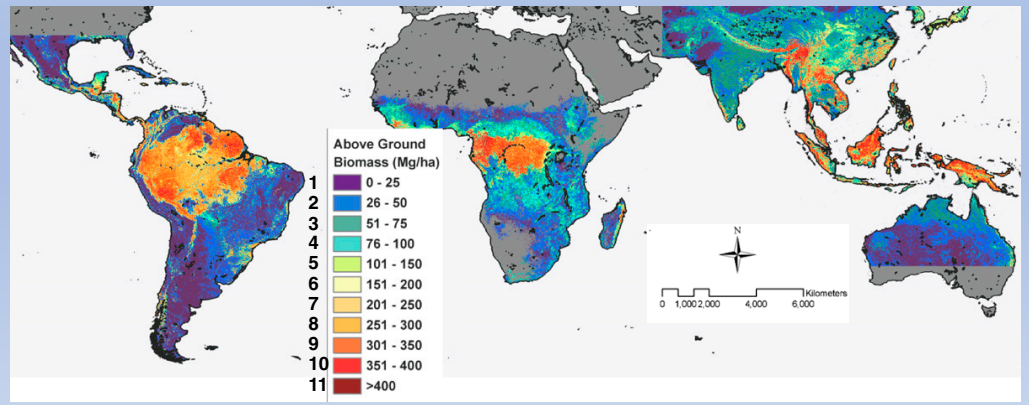
The Data Gap: ET and GPP



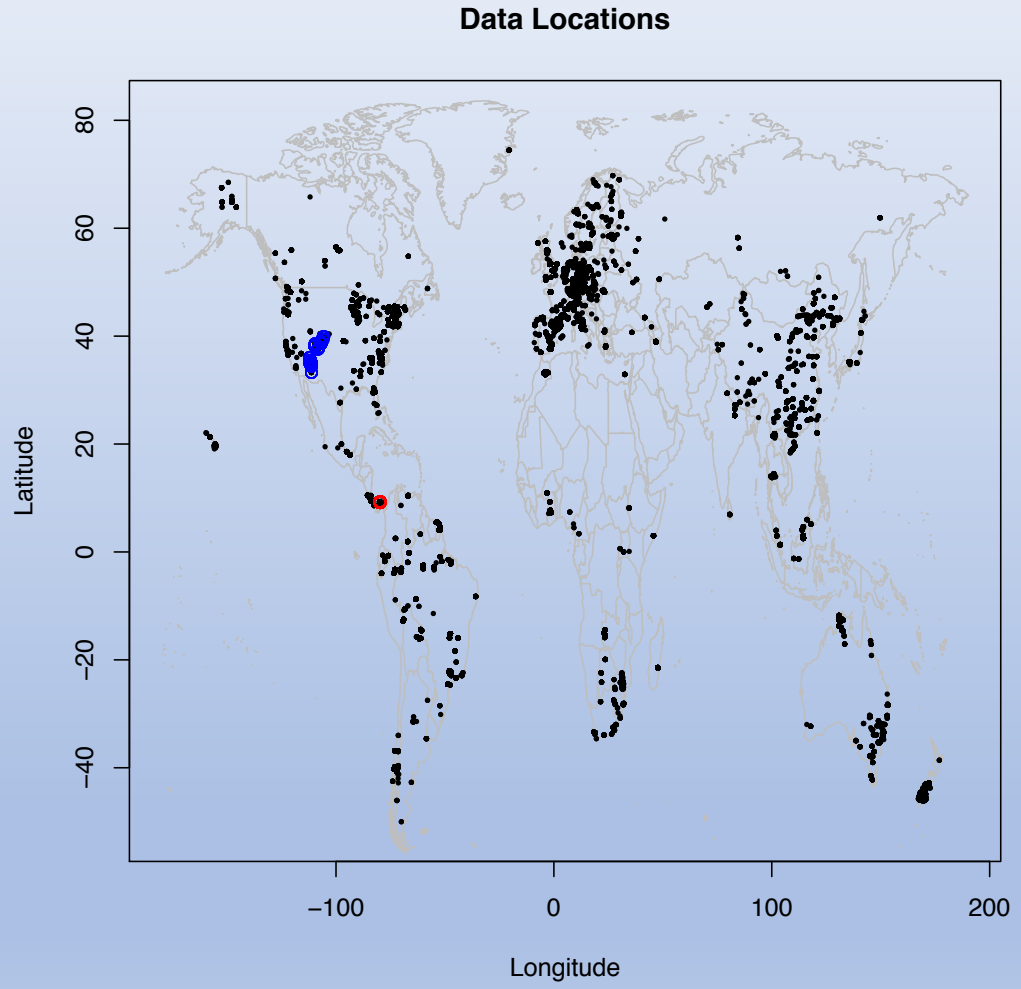


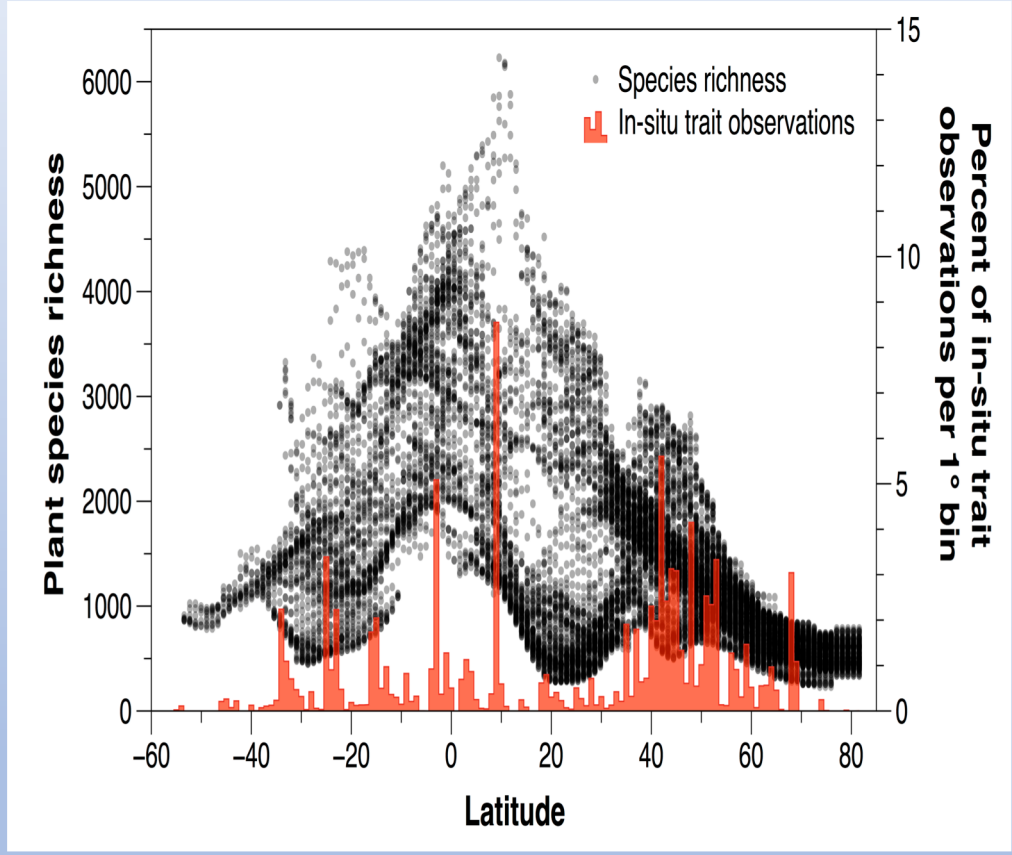
Biomass, forest structure and carbon storage





Plant functional traits: the biodiversity gap

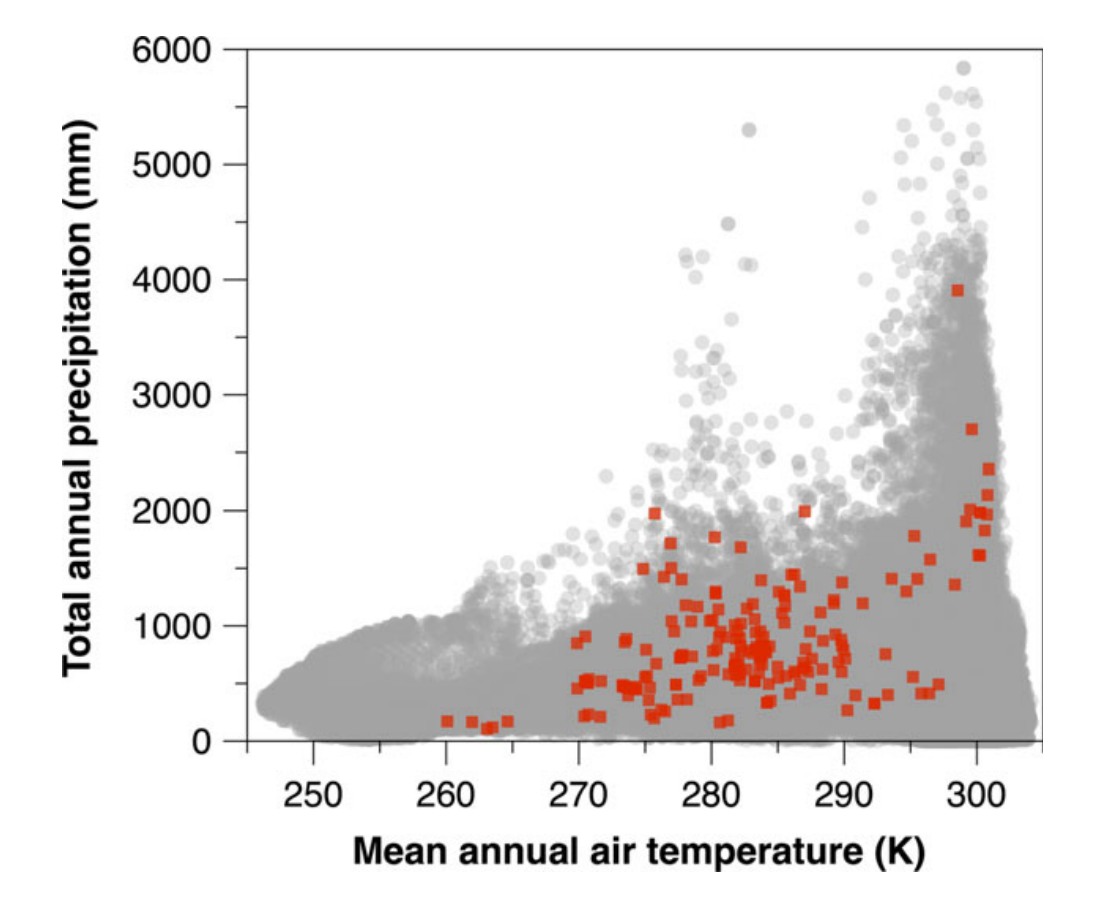




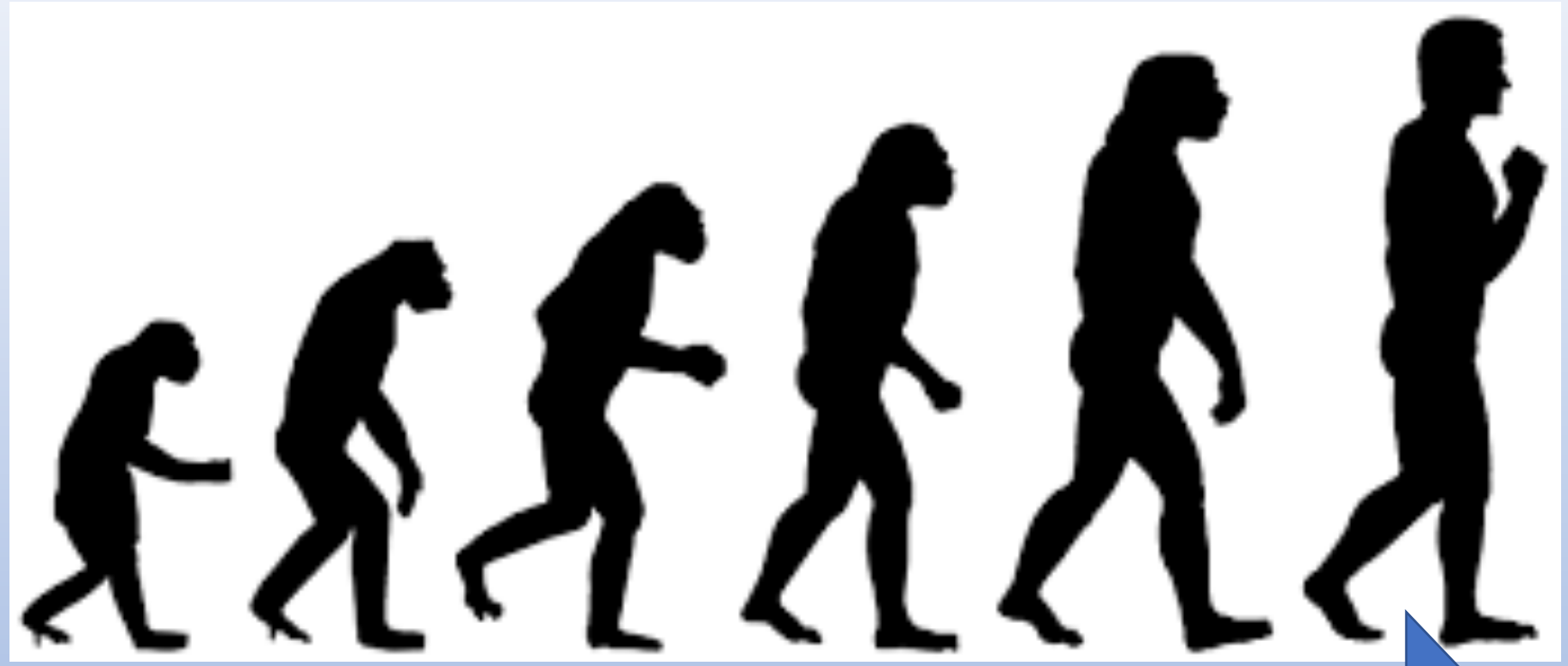
Change—the biggest gap

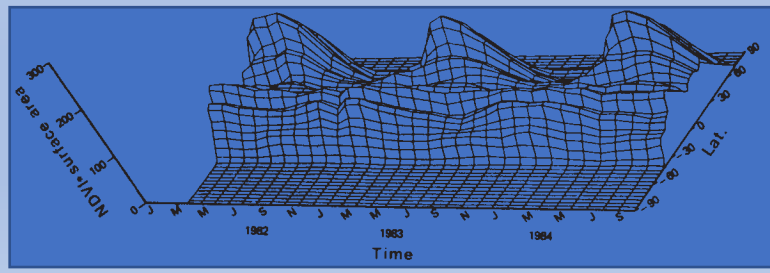
- Current data are mainly static-estimates of diversity are compiled from data collected over decades as if species diversity and distribution was static or stationary.
- Pat Comer--2 x 10^6, 2% resampled.
- Case studies of change and compilations are based on very limited and very biased sampling.

Spanning but not sampling the diversity of life

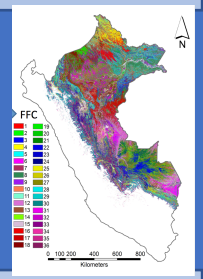


The evolution of global ecology



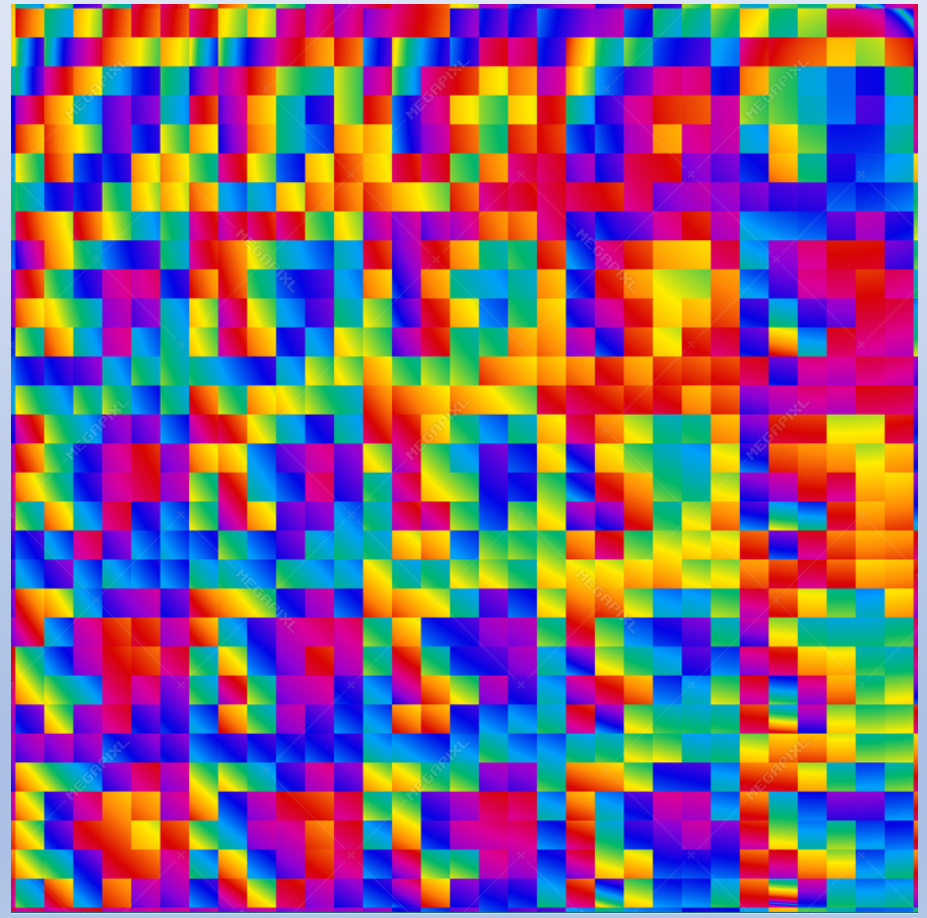


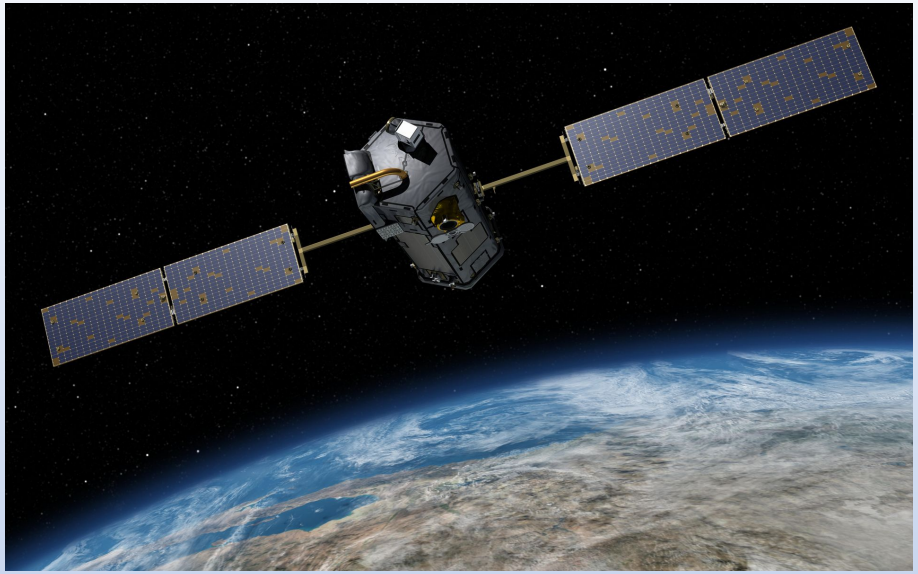
Green slime -> Life in its diversity

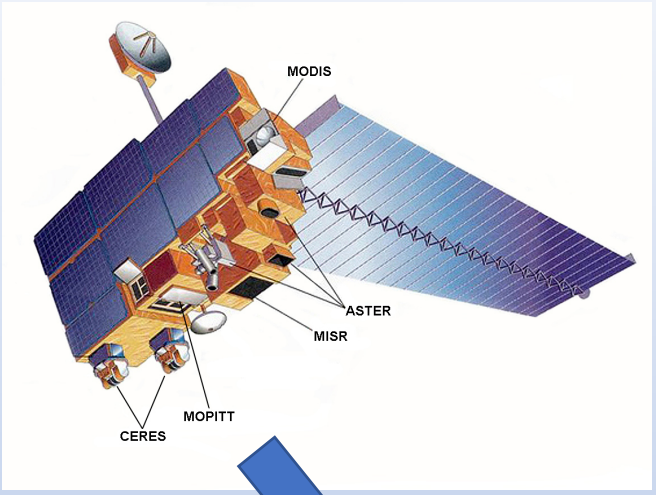


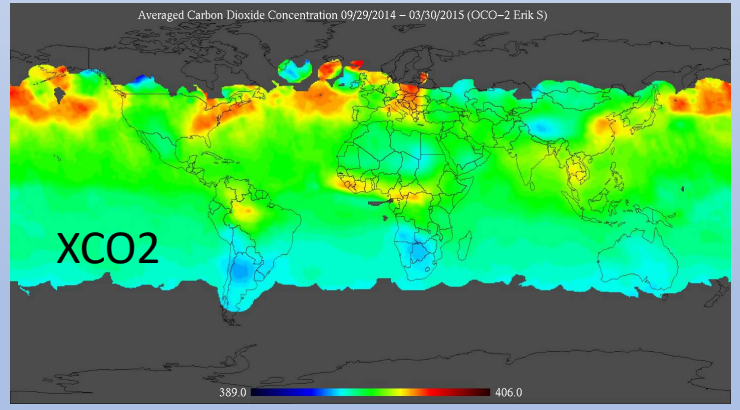
Traditional remote sensing has seen the world as shades of green

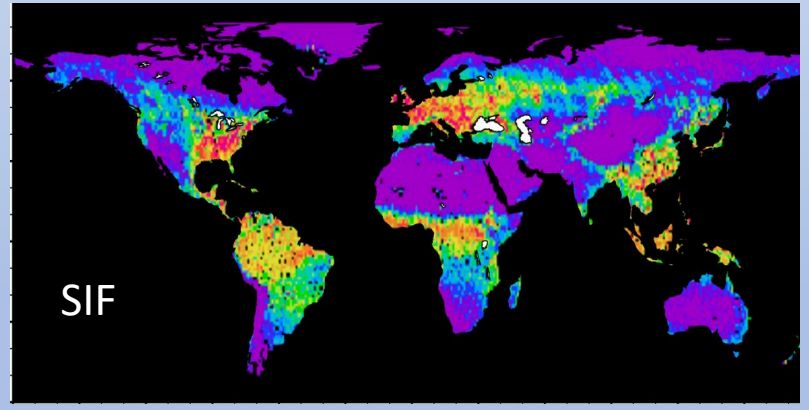
Spectroscopy sees vegetation in living color

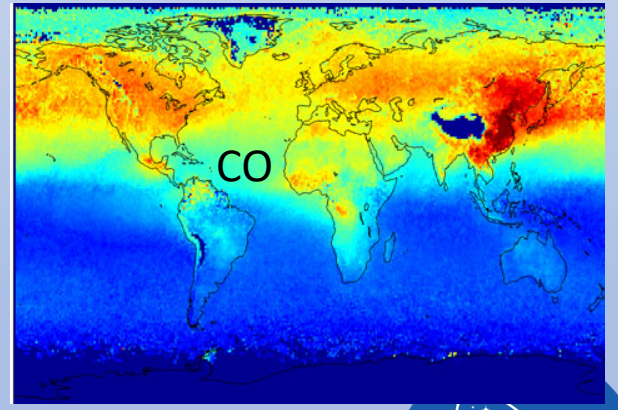






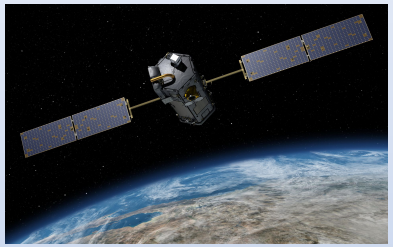


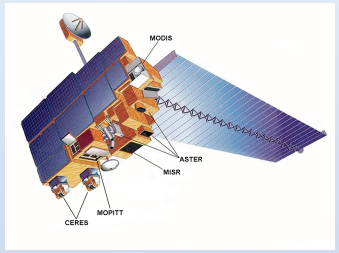


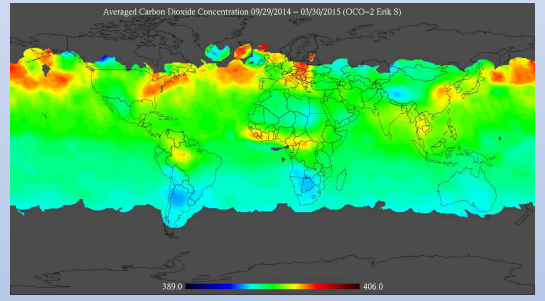


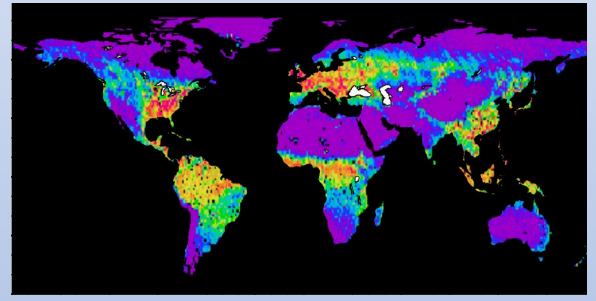
Flux towers in the sky

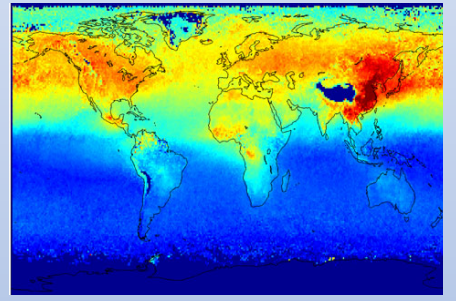
Carbon Arithmetic







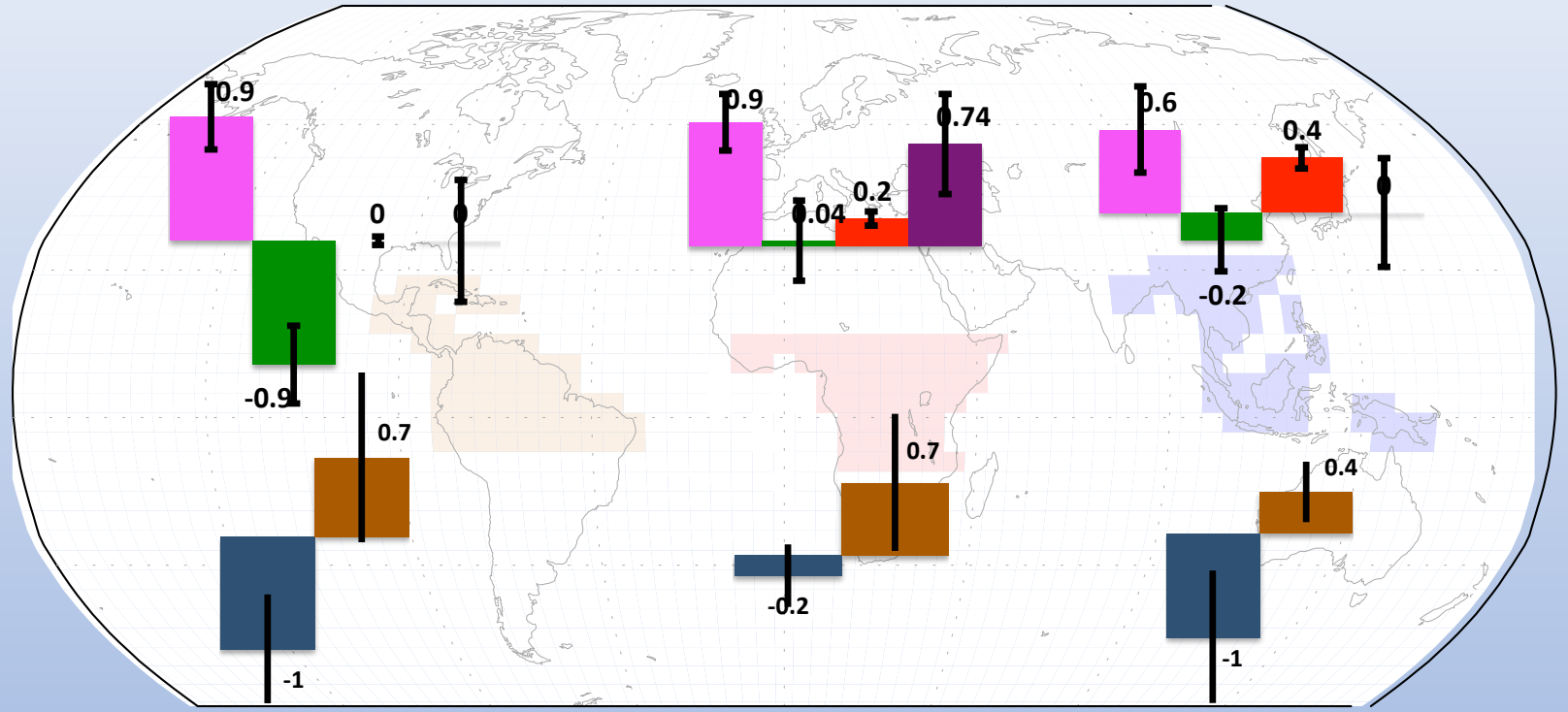




NBP from XCO2 - GPP from SIF - Fire from CO. = Respiration

R_{eco}

Three Continents, Three Explanations

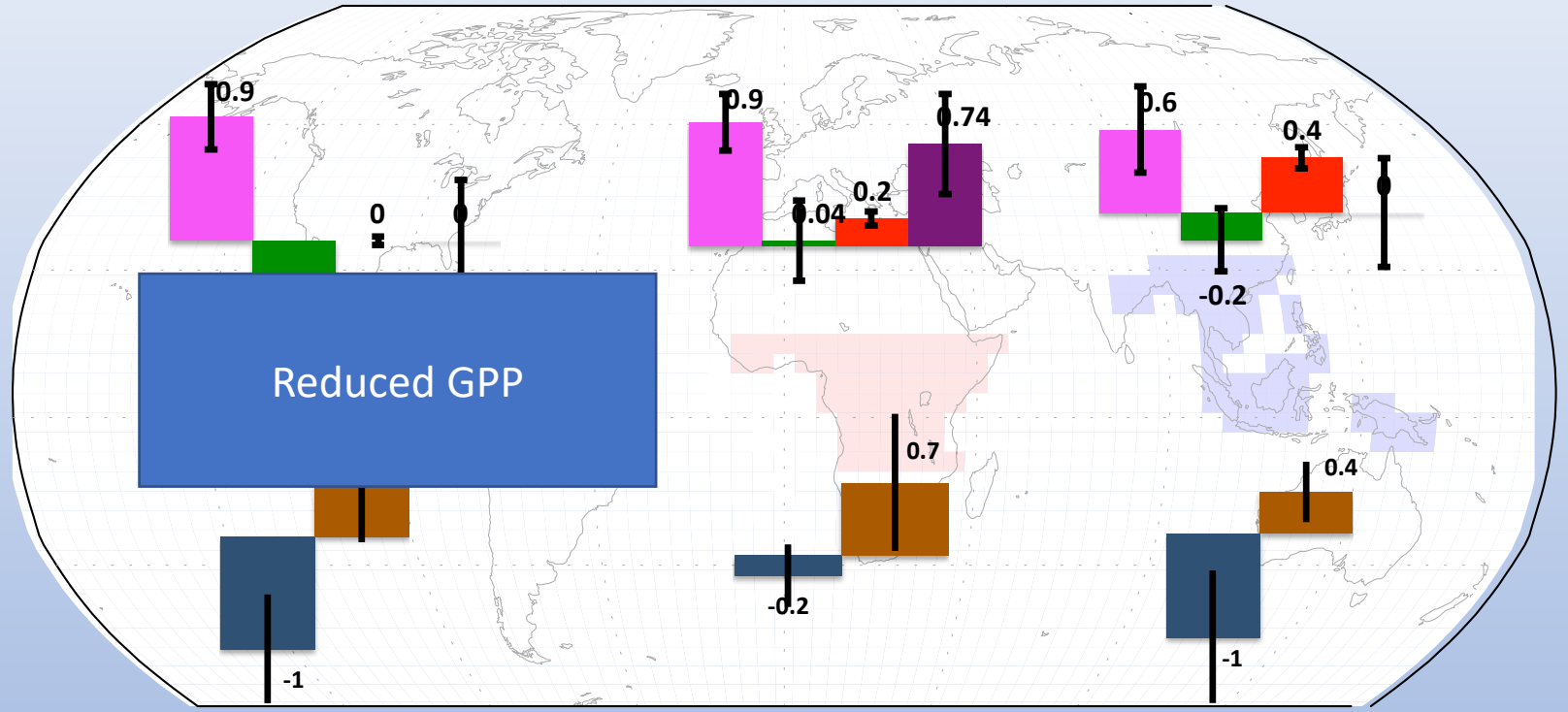


2015-2011

- ΔNBE, GtC
- ΔGPP, GtC
- ΔFire, GtC
- Δ(respiration), GtC
- ΔT, K
- Δprecip, mm/day

- Trop. S. America
- Trop. Africa
- Tropical Asia

Three Continents, Three Explanations

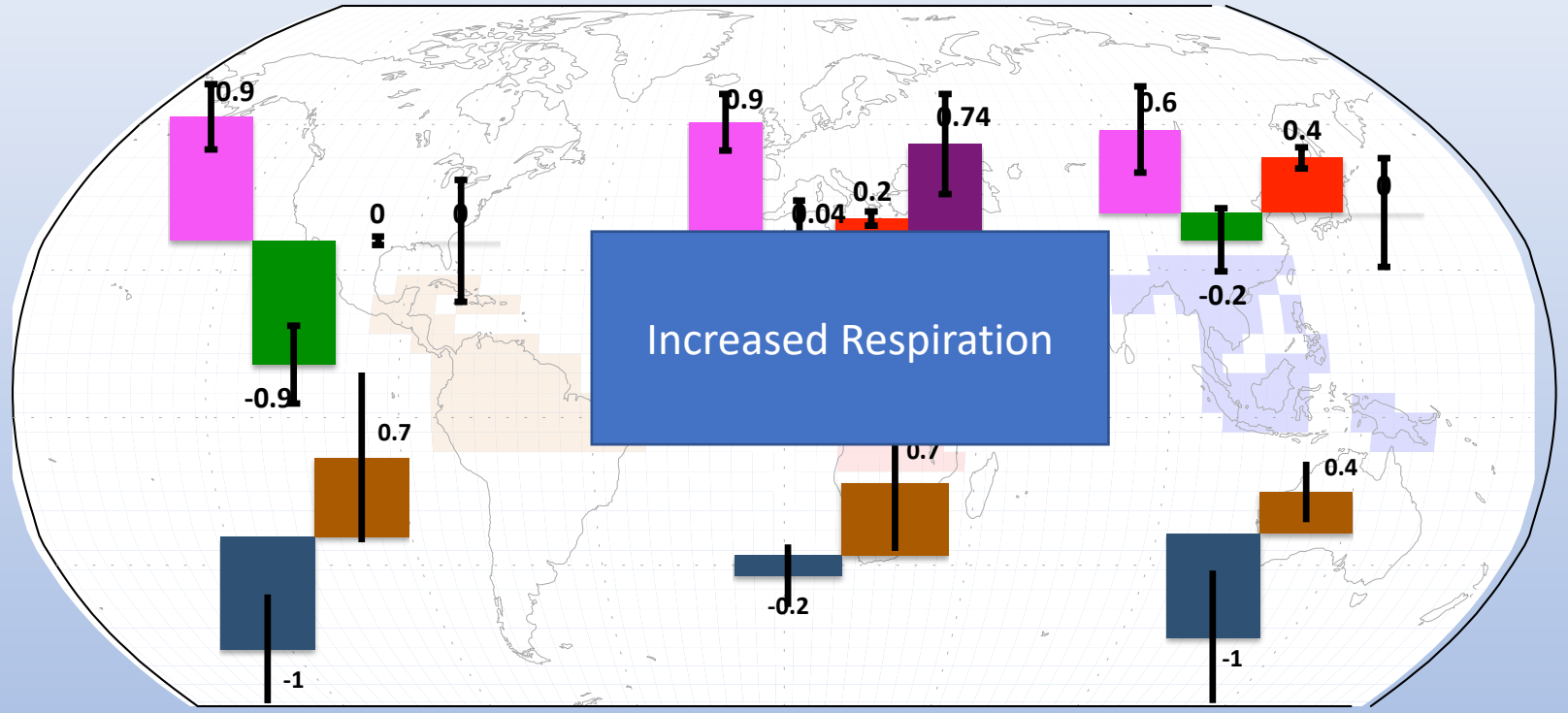


Trop. S. America
Trop. Africa
Tropical Asia

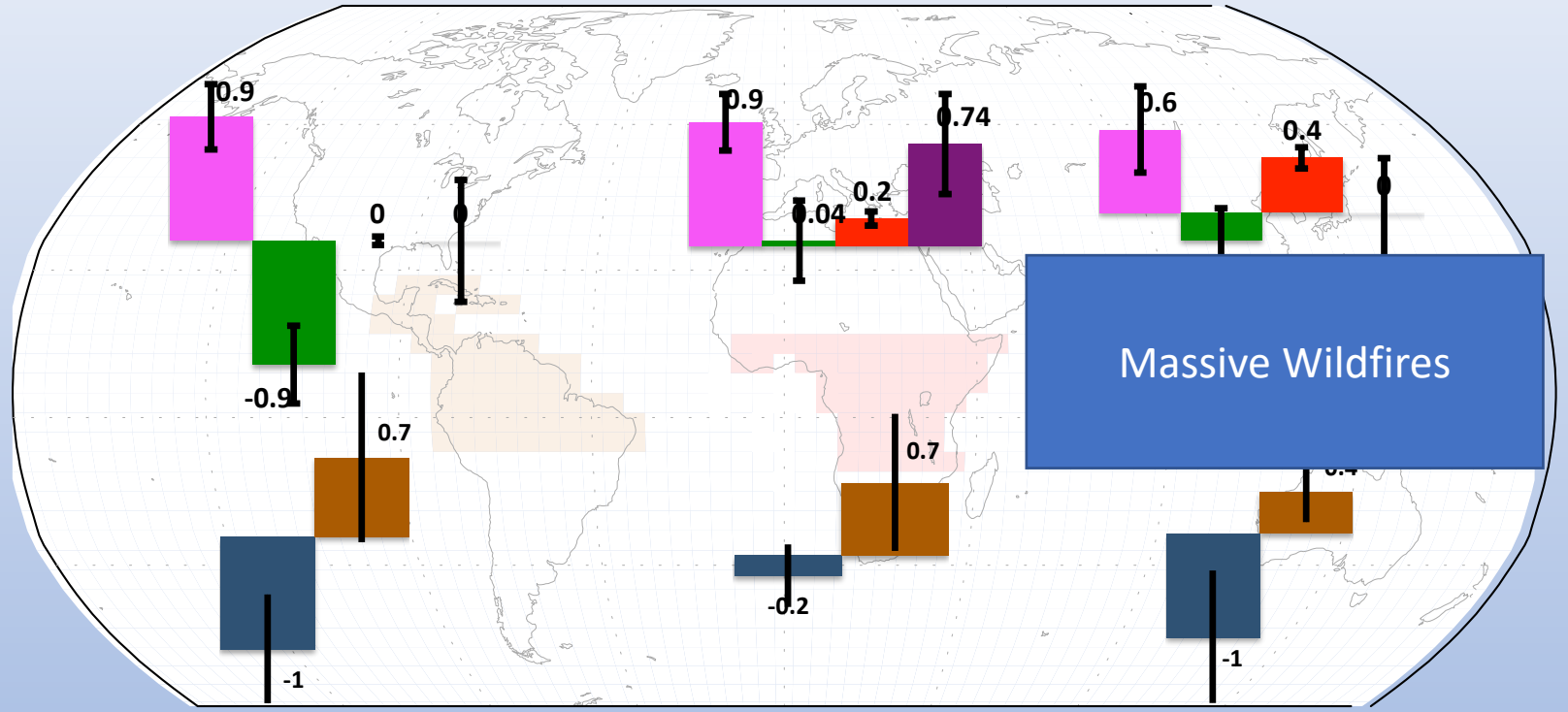
2015-2011
ΔNBE, GtC
ΔGPP, GtC
ΔFire, GtC
Δ(respiration), GtC

ΔT, K
Δprecip, mm/day

Three Continents, Three Explanations



Three Continents, Three Explanations



2015-2011

- ΔNBE, GtC
- ΔGPP, GtC
- ΔFire, GtC
- Δ(respiration), GtC
- ΔT, K
- Δprecip, mm/day

- Trop. S. America
- Trop. Africa
- Tropical Asia

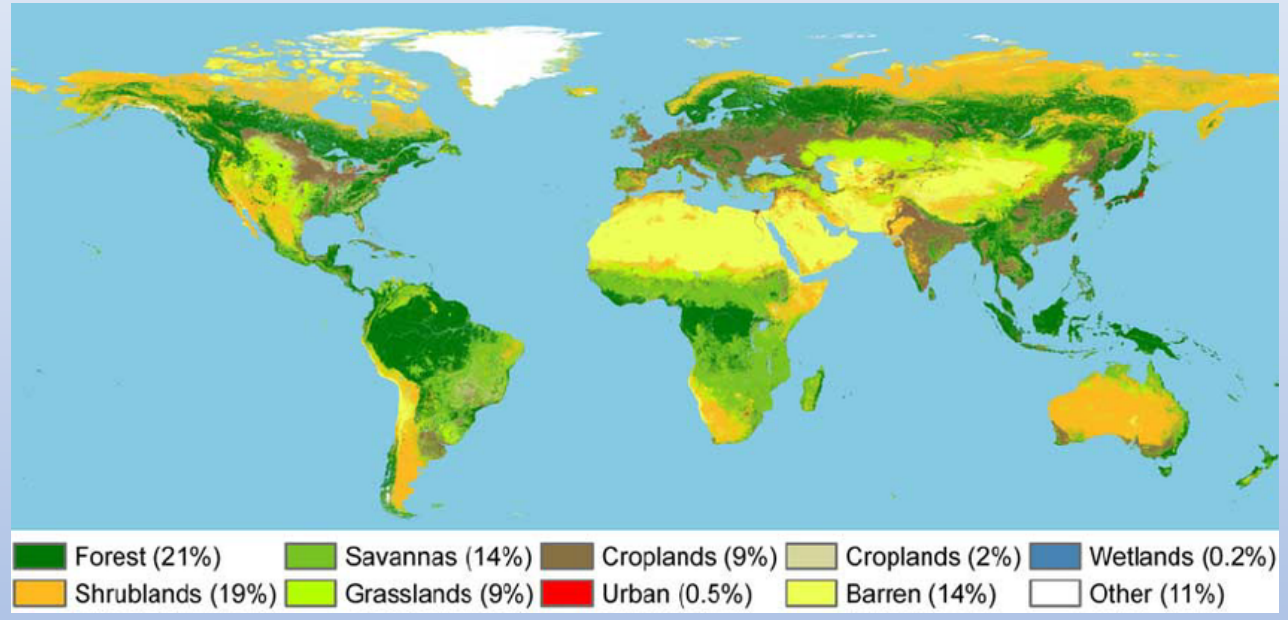
Why do the tropical continents differ in their response to El Nino?

Why do carbon cycle responses (GPP, R_{eco}, Fire) vary between continents?
<u>Source of variation</u>
Climate: Does flux vary as a response to specific temperature ands rainfall extremes?
Disturbance and land use: Does flux vary because of vulnerability established by prior disturbance regimes?
Environment and evolution: Does the sensitivity of fluxes to climate vary because of inherent ecosystem and biogeographic characteristics?

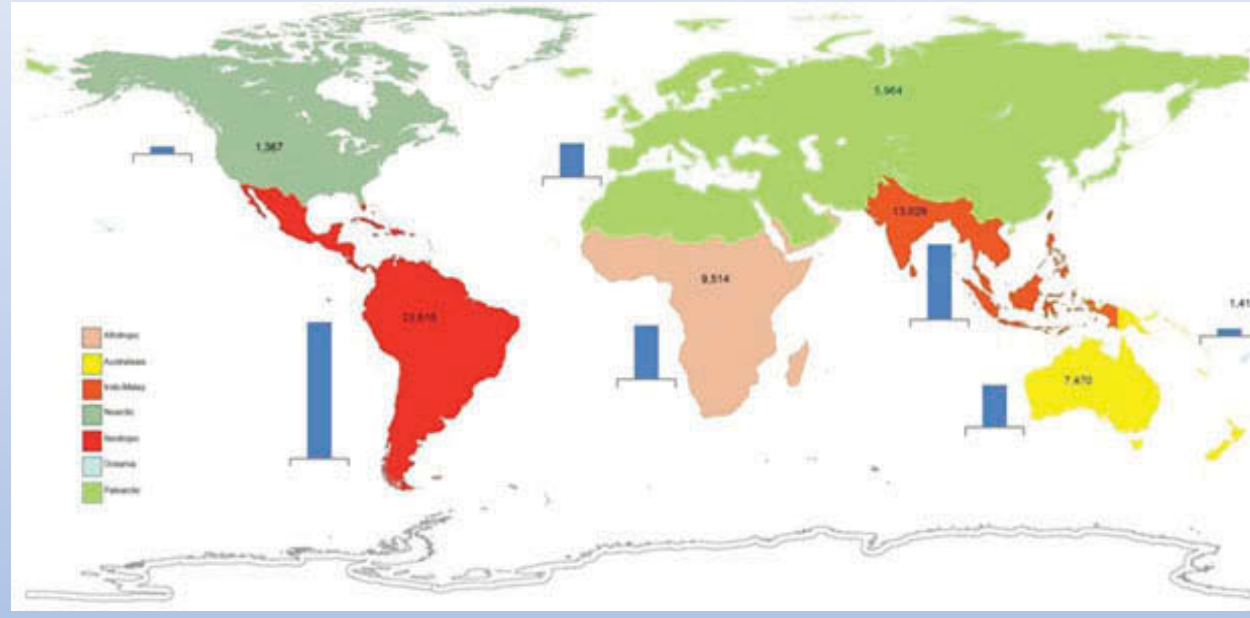
Why do the tropical continents differ in their response to El Nino?

Why do carbon cycle responses (GPP, R_{eco}, Fire) vary between continents?
Source of variation
Climate: Does flux vary as a response to specific temperature ands rainfall extremes?
Disturbance and land use: Does flux vary because of vulnerability established by prior disturbance regimes?
Environment and evolution: Does the sensitivity of fluxes to climate vary because of inherent ecosystem and biogeographic characteristics?

The tropics are heterogeneous?

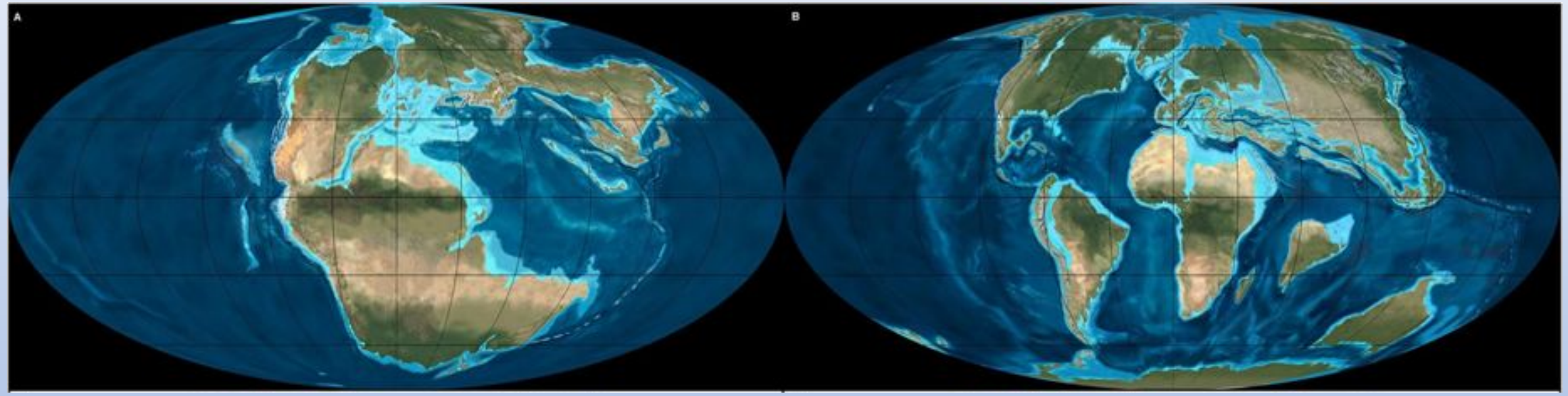


20 biomes



60,000 tree species

Many tropical lineages diverged in deep time:
Is function fully convergent or does it reflect lineage?



Triassic-Jurassic Earth (200 MY)

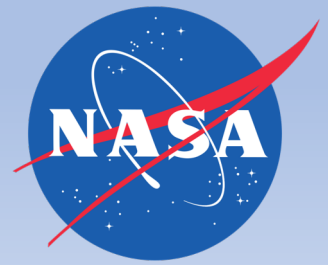
Cretaceous-Paleogene (60 MY)

Surface Biology and Geology: a Designated Mission: 2024

What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space

Overall Science Context

- Understanding **alterations to surface characteristics and landscapes** (e.g., snow cover, snow melt, landslides, earthquakes, eruptions, urbanization, land-cover and land use) and the implications for applications such as risk management and resource management;
- Assessing the **evolving characteristics and health of terrestrial vegetation and aquatic ecosystems**, which is important for understanding key consequences such as crop yields, carbon uptake, and biodiversity; and
- Examining **movement of land and ice surfaces** to determine, in the case of ice, the likelihood of rapid ice loss and significantly accelerated rates of sea-level rise, and in the case of land, changes in strain rates that impact and provide critical insights into earthquakes, volcanic eruptions, landslides, and tectonic plate deformation.

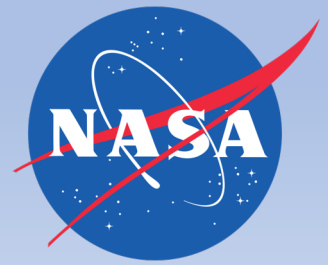


Specific to SBG

QUESTION E-1. What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space?
E-1a. Quantify the global distribution of the functional traits, functional types, and composition of vegetation and marine biomass, spatially and over time.

QUESTION H-2. How do anthropogenic changes in climate, land use, water use, and water storage, interact and modify the water and energy cycles locally, regionally and
H-2b. Quantify the magnitude of anthropogenic processes that cause changes in radiative forcing, temperature, snowmelt, and ice melt, as they alter downstream water quantity and quality globally and what are the short- and long-term consequences?
H-2a. Quantify how changes in land use, water use, and water storage affect evapotranspiration rates, and how these in turn affect local and regional precipitation systems, groundwater recharge, temperature extremes, and carbon cycling.

QUESTION S-2. How do geological disasters directly impact the earth system and society following an event?
S-2b. Assess surface deformation (<10 mm), extent of surface change (<100 m spatial resolution) and atmospheric contamination, and the composition and temperature of volcanic products following a volcanic eruption (hourly to daily temporal sampling).



Targeted Observable – 18 Surface Biology and Geology

TO-18 **Surface Biology & Geology**	• Surface geology & biology • Active geologic processes • Ground & water temperature • Gross Primary Production (GPP) • Snow spectral albedo • Functional traits of terrestrial vegetation and inland & near-coastal aquatic ecosystems	- **H-1c**, 2a, 2b, 3a, 3b, 3c, 4a, 4c, 4d - W-3a - **S-1a**, 1c, 2b, 4b, 4c, 7a - E-1a, **1c**, 1d, **2a, 3a**, 5a, 5b, 5c - C-3a, 3c, 3d, 6b, 7e, 8f	***ESAS 2007:*** HyspIRI ***POR:*** ASTER/Terra, MODIS, Landsat, AIRS, PACE, Hyperion, ECOSTRESS	POR does not include hyperspectral imagery in the visible or shortwave infrared	***Similar to:*** **HyspIRI, combination of ASTER, MODIS, Landsat, AIRS; airborne instrument AVIRIS-NG** • Hyperspectral imagery in the visible and shortwave infrared and multi- or hyperspectral imagery in the thermal infrared • Spatial resolution of 30-60 m (vis-SWIR) and 60 m (TIR) with 14-19 day (SWIR) and 5 day (TIR) temporal resolution

DESIGNATED
PROGRAM ELEMENT

Maximum development cost
$650M

Surface Biology and Geology: a core mission for Earth System Science

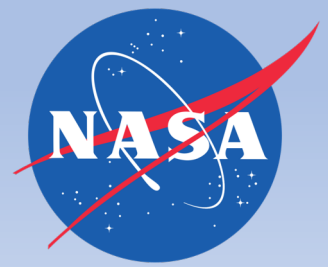
Question: What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space (National Academies 2018)?

Objective: Quantify the distribution of the functional traits, functional types and composition of terrestrial and shallow aquatic vegetation … spatially and over time (National Academies, 2018).

Candidate measurement approach: Hyperspectral imagery in the visible and shortwave infrared and multi- or hyperspectral imagery in the thermal infrared

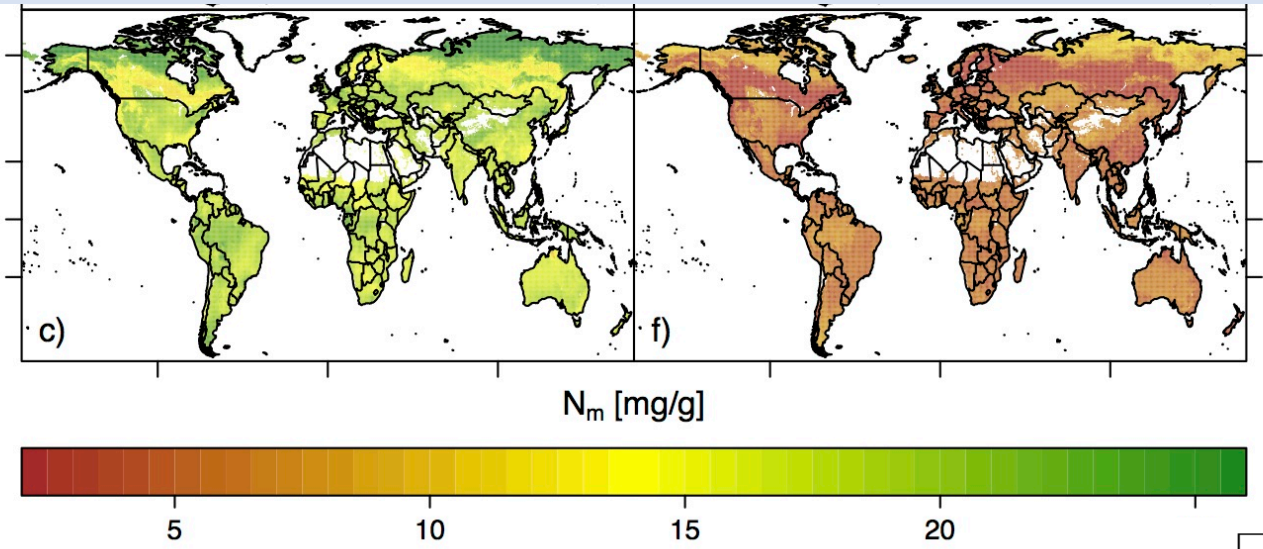
The previous recommendation: 2007

Mission to observe distribution and changes in ecosystem function. An optical sensor with spectral discrimination greatly enhanced beyond that of Landsat and MODIS is required to detect and diagnose changes in ecosystem function, such as water and nutrient cycling and species composition. Such observations include nutrient and water status, presence of and responses to invasive species, health of coral reefs, and biodiversity. The panel proposes a hyperspectral sensor with pointability for observing disturbance events, such as re and drought, when and where they occur at higher than normal frequency.



A spaceborne imaging spectrometer will radically improve our knowledge of Plant Functional Traits

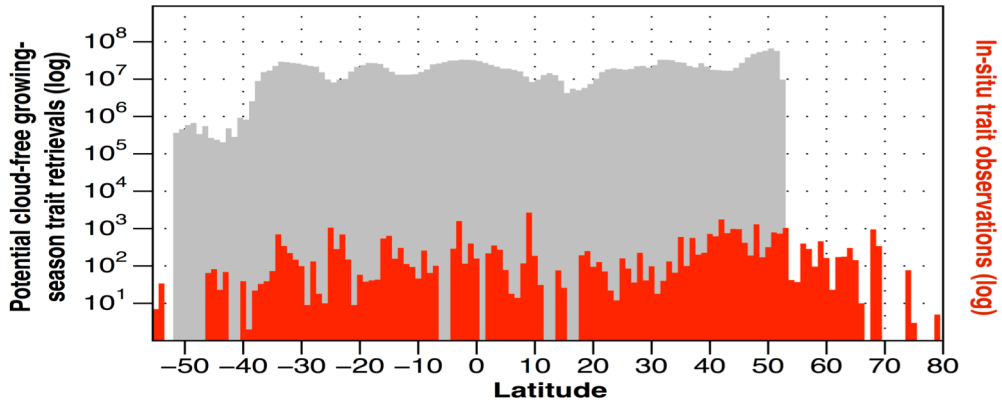
Scaling up from *in situ* for a focal Plant Functional Trait using TRY: ± 25%



Current best estimates of uncertainty, per pixel, from imaging spectroscopy are lower than TRY estimates

Functional Trait	Units	Normalized Uncertainty, Retrieved (Singh et al 2015)
LMA	g/m^2	11%
Nitrogen	% dry mass	16%
Chlorphyll	ng/mg	8%
Lignin	% dry mass	12%
Phosphorus	% dry mass	16%

A spaceborne imaging spectrometer will increase the number of trait observations by 6 orders of magnitude



Level 1 requirements from the Decadal Survey SATM

H-1c. Quantify rates of snow accumulation, **snowmelt, ice melt, and sublimation** from snow and ice worldwide at *scales driven by topographic variability*.

H-2a. Quantify how changes in land use, water use, and water storage affect evapotranspiration rates, and how these in turn affect local and regional precipitation systems, groundwater recharge,

E-1a. Quantify the global distribution of the **functional traits, functional types, and composition of vegetation and marine biomass**, *spatially and over time*.

S-2b. Assess surface deformation (<10 mm), **extent of surface change (<100 m spatial resolution) and atmospheric contamination, and the composition and temperature of volcanic products following a volcanic eruption** (*hourly to daily temporal sampling*)

Bold text drives us towards specific spectroscopic characteristics,
Italic text defines sampling strategy and active pointing for revisit cadence

Level 1 requirements

H-1c. Quantify rates of snow accumulation, **snowmelt, ice melt, and sublimation** from snow and ice worldwide at *scales driven by topographic variability*.

H-2a. Quantify how changes in land use, water use, and water storage affect evapotranspiration rates, and how these in turn affect local and regional precipitation systems, groundwater recharge,

E-1a. Quantify the global distribution of the **functional traits, functional types, and composition of vegetation and marine biomass**, *spatially and over time*.

S-2b. Assess surface deformation (<10 mm), **extent of surface change (<100 m spatial resolution) and atmospheric contamination, and the composition and temperature of volcanic products following a volcanic eruption** (*hourly to daily temporal sampling*)

Required data products

Snow albedo and light-absorbing impurities

Land Surface Temperature and ET

Functional traits, types, composition

Volcanic gases, temperature, surface composition change

Instrument and mission requirements

ECOSTRESS

DESIS

HISUI

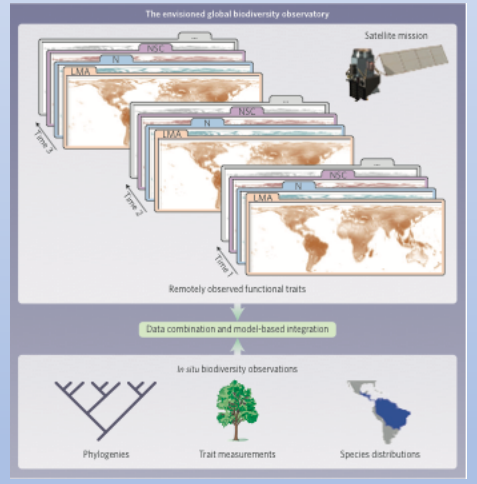
EMIT

EnMAP

HISUI

SBG

CHIME



GEDI

BIOMASS

NISAR