

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

PI
SCIENCE LEAD
SCIENCE TEAM

Simon Hook (JPL)
Joshua B. Fisher (JPL)
Rick Allen (U. Idaho)
Martha Anderson (USDA)
Andy French (USDA)
Chris Hain (UMD)
Glynn Hulley (JPL)
Eric Wood (Princeton U.)

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

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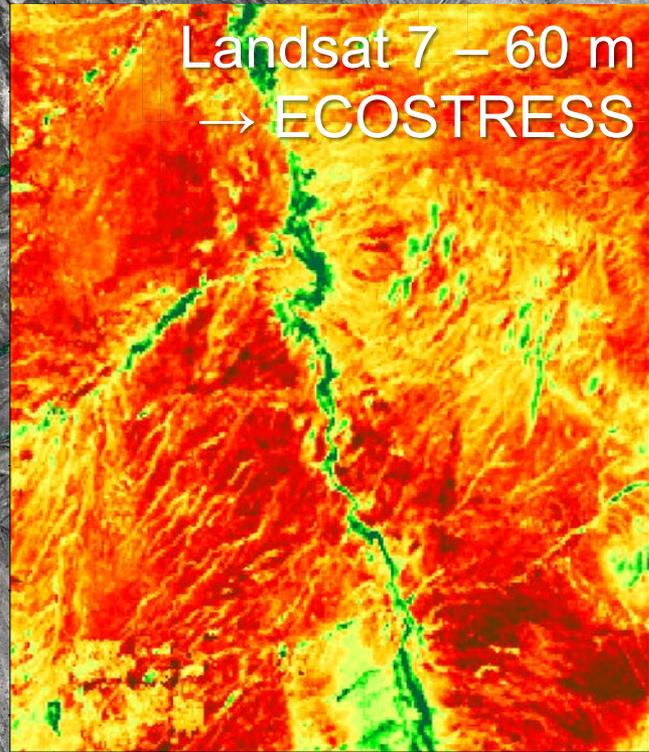
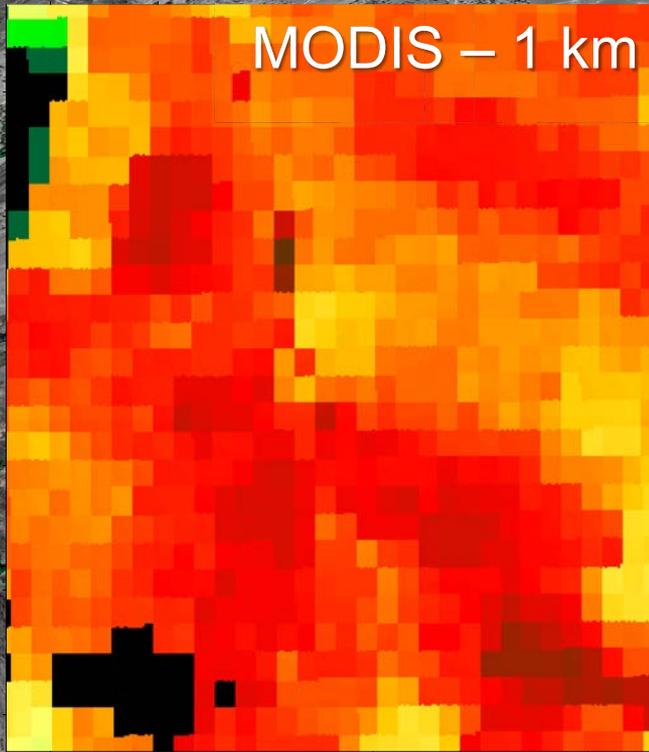
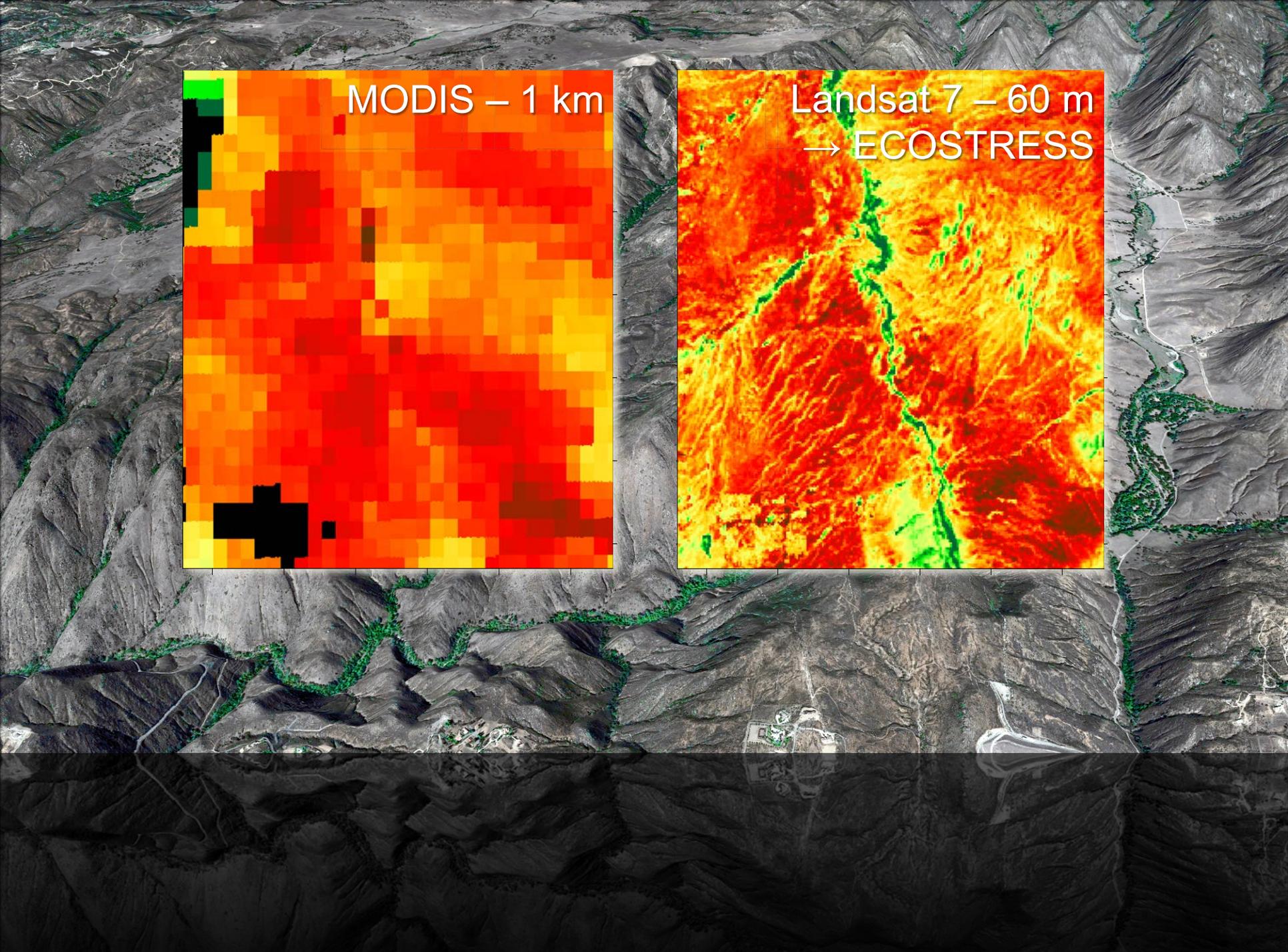


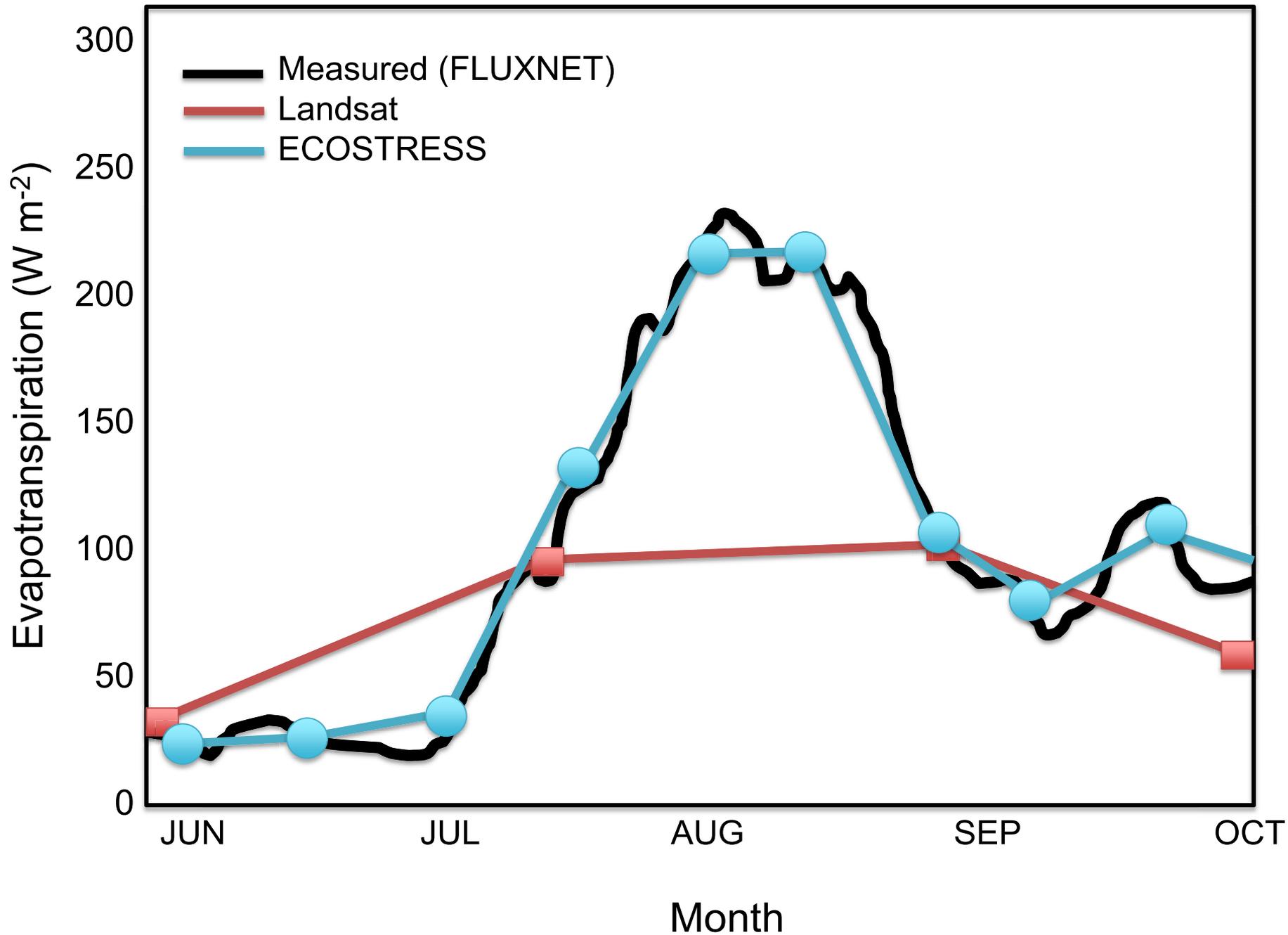
HOW DO DIFFERENT PLANTS RESPOND TO
CHANGES IN WATER AVAILABILITY?

WHICH PLANTS DIE
FIRST?

How plants respond to changes in water availability can be expressed in terms of **Water Use Efficiency (WUE)**, defined as the amount of carbon fixed per unit water used (gross primary production, GPP, divided by ET). Some plants have high WUE and can fix a large amount of carbon using a small amount of water; other plants are less efficient. Low WUE plants risk **replacement** with increasing droughts.

What we need: accurate, high spatial, high temporal, diurnal cycle, global, ET.

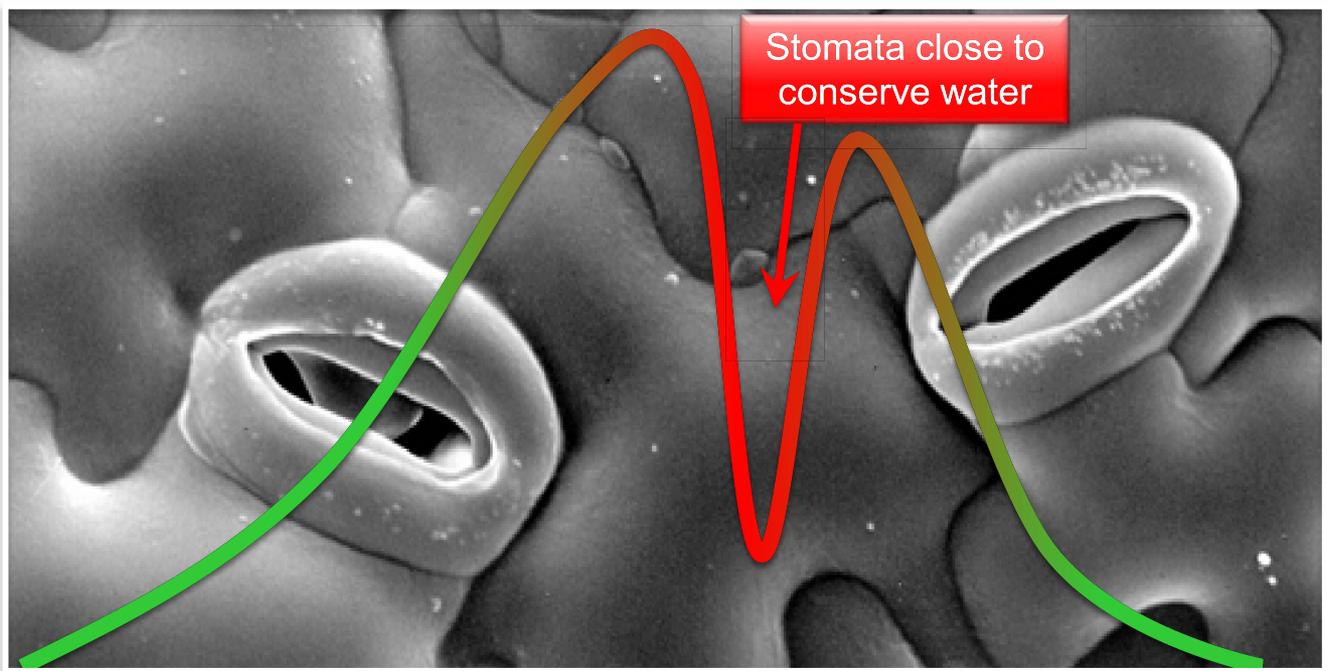






Water Stress Drives Plant Behavior

Evapotranspiration



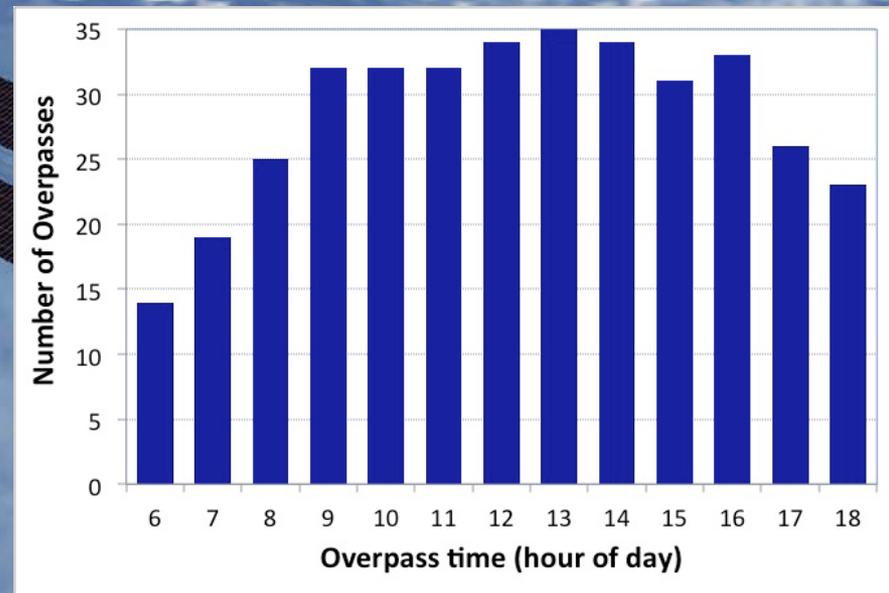
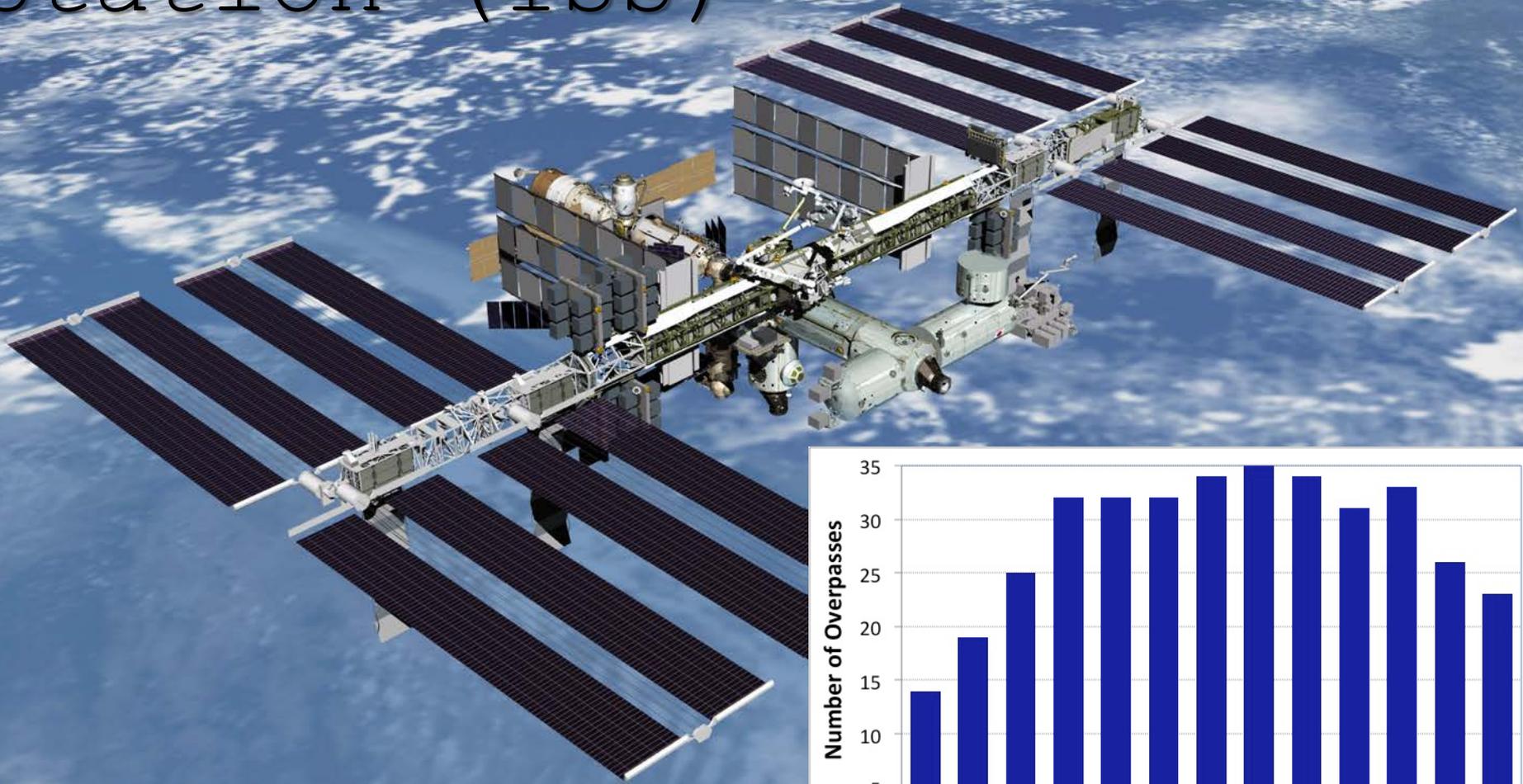
6 AM

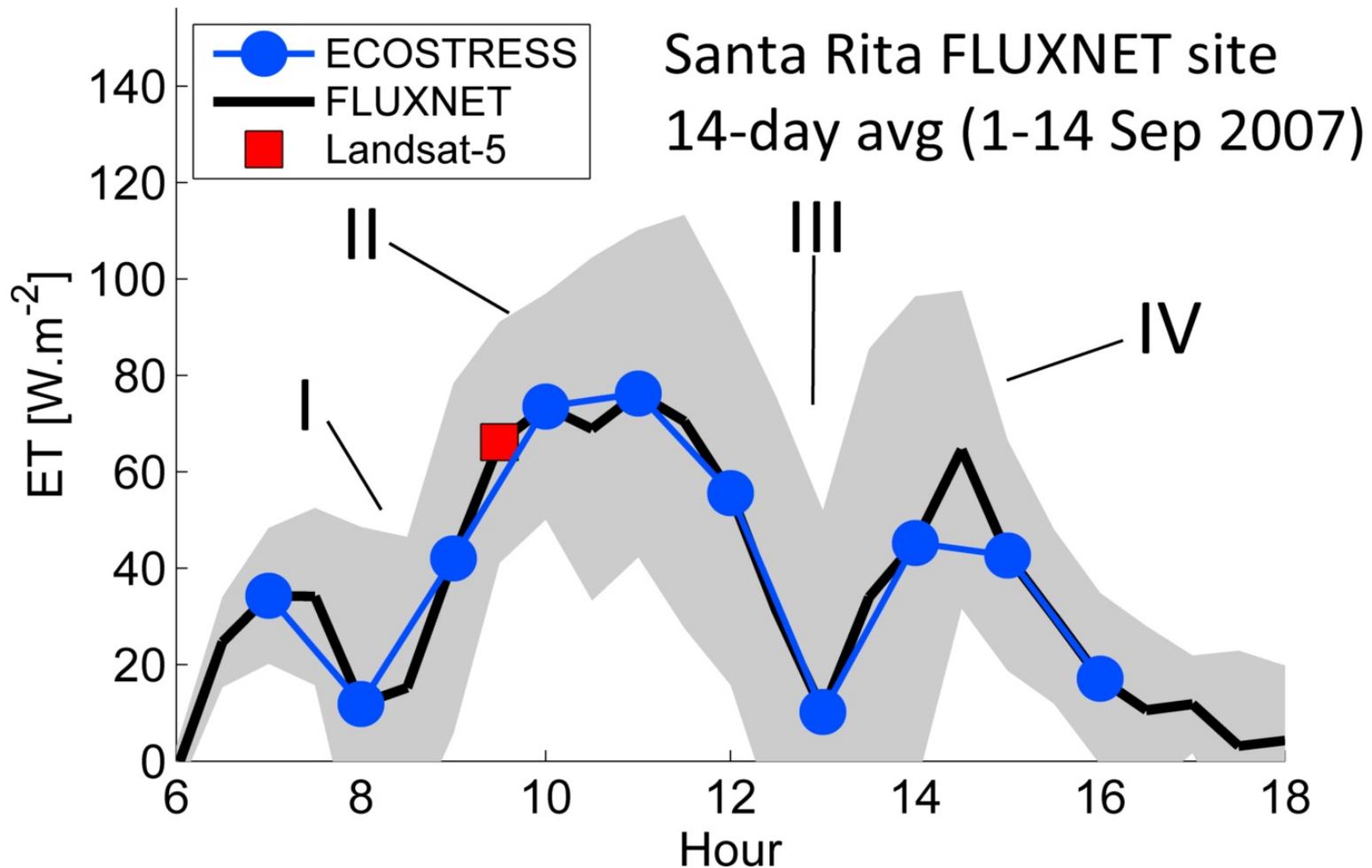
12 PM

6 PM

Diurnal Cycle

The International Space Station (ISS)



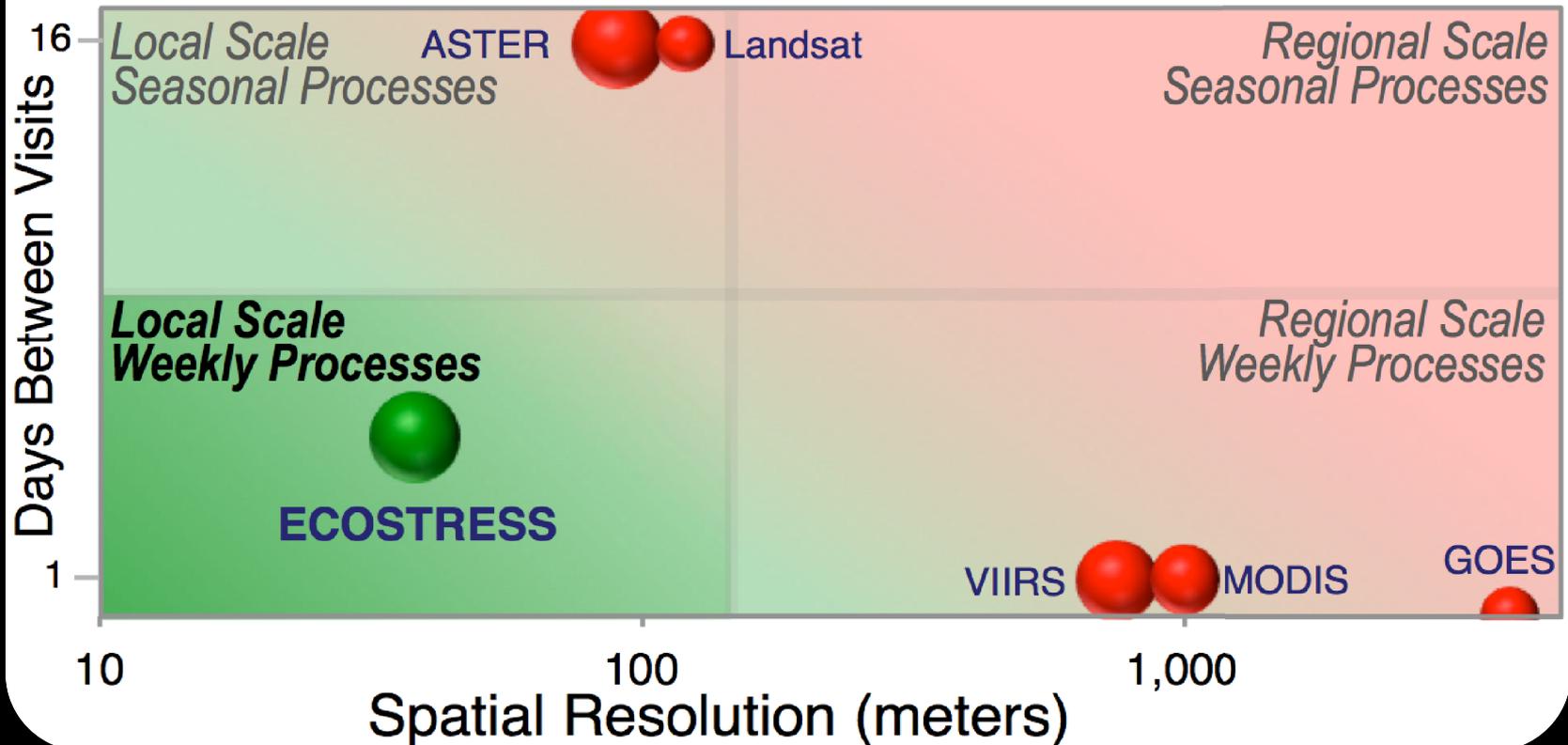


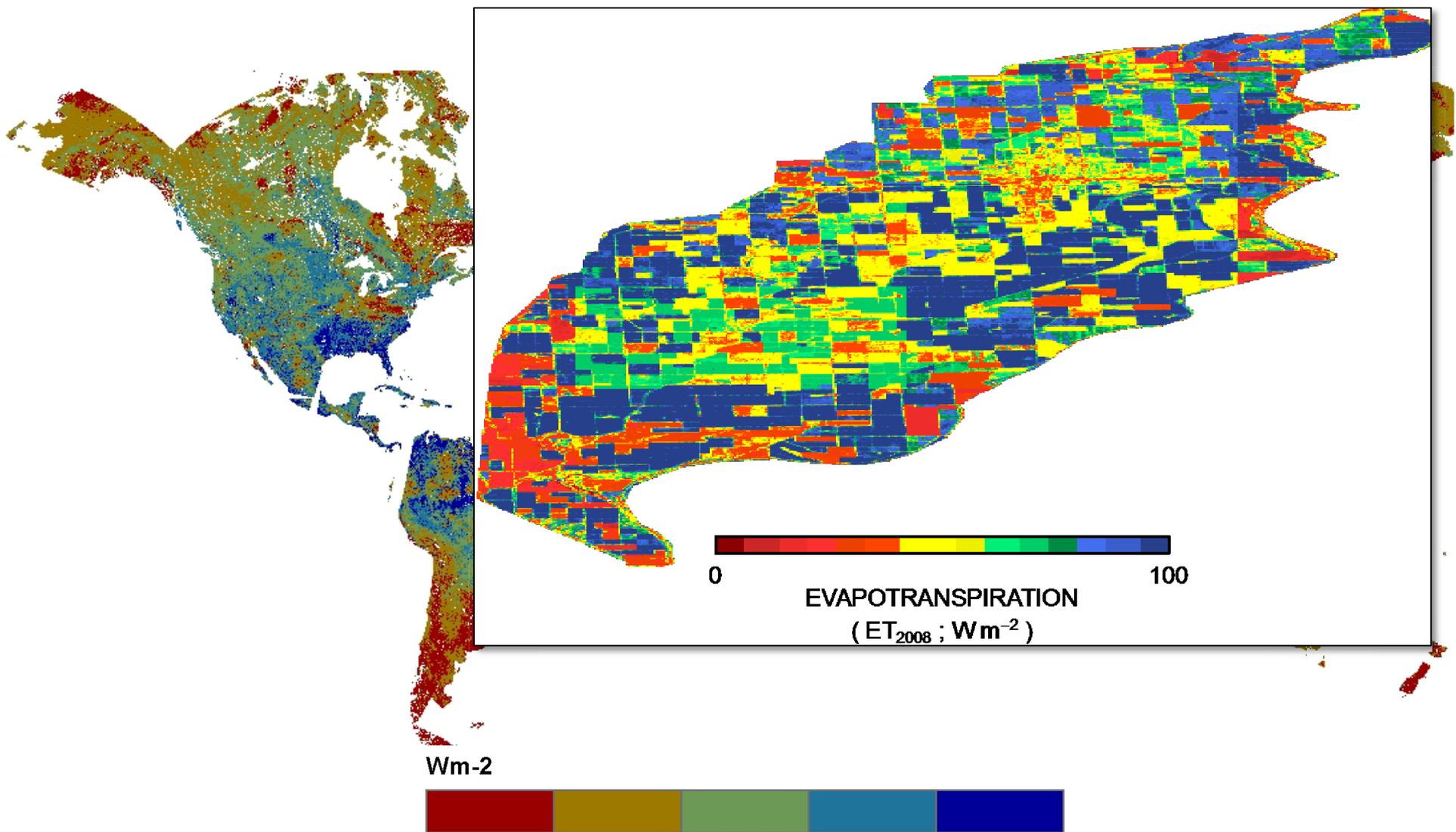
Gray shading represents mean **diurnal variation** in ET over 14-days. The afternoon decline in ET is related to water stress (clear day).

- I Xylem refilling after initial water release.
- II ET at maximum/potential rate in the morning.
- III Stomata shut down water flux in the afternoon.
- IV ET resumes at maximum/potential in early evening when demand is reduced.

Revisit Time versus Spatial Resolution

With sphere size indicating # of thermal infrared window bands





Current JPL ET:

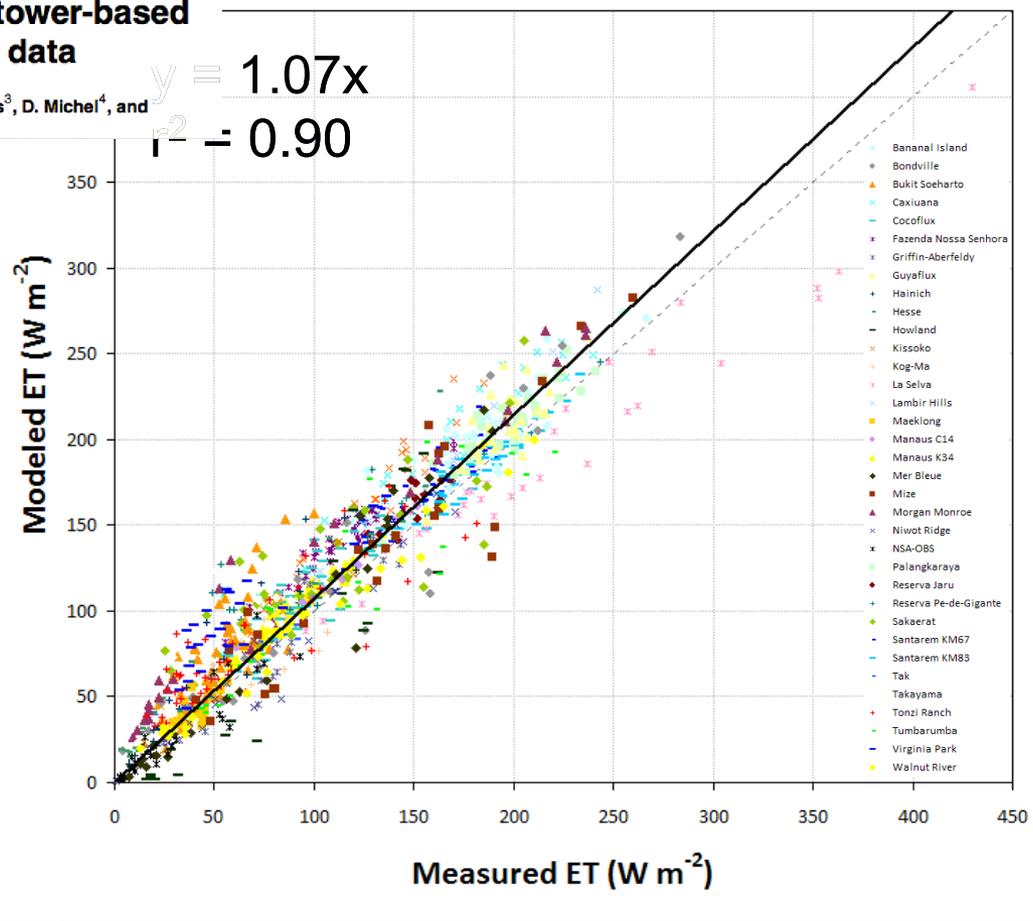
- Global, 1 km, daily
- Running multiple algorithms: PT-JPL, PM-MOD16, SEBS, PMBL

stations as independent metrics of performance, the tower-based analysis indicated that **PT-JPL provided the highest overall statistical performance (0.72; 61 W m⁻²; 0.65)**, followed closely by GLEAM (0.68; 64 W m⁻²; 0.62), with values in parenthe-

The GEWEX LandFlux project: evaluation of model evaporation using tower-based and globally-gridded forcing data

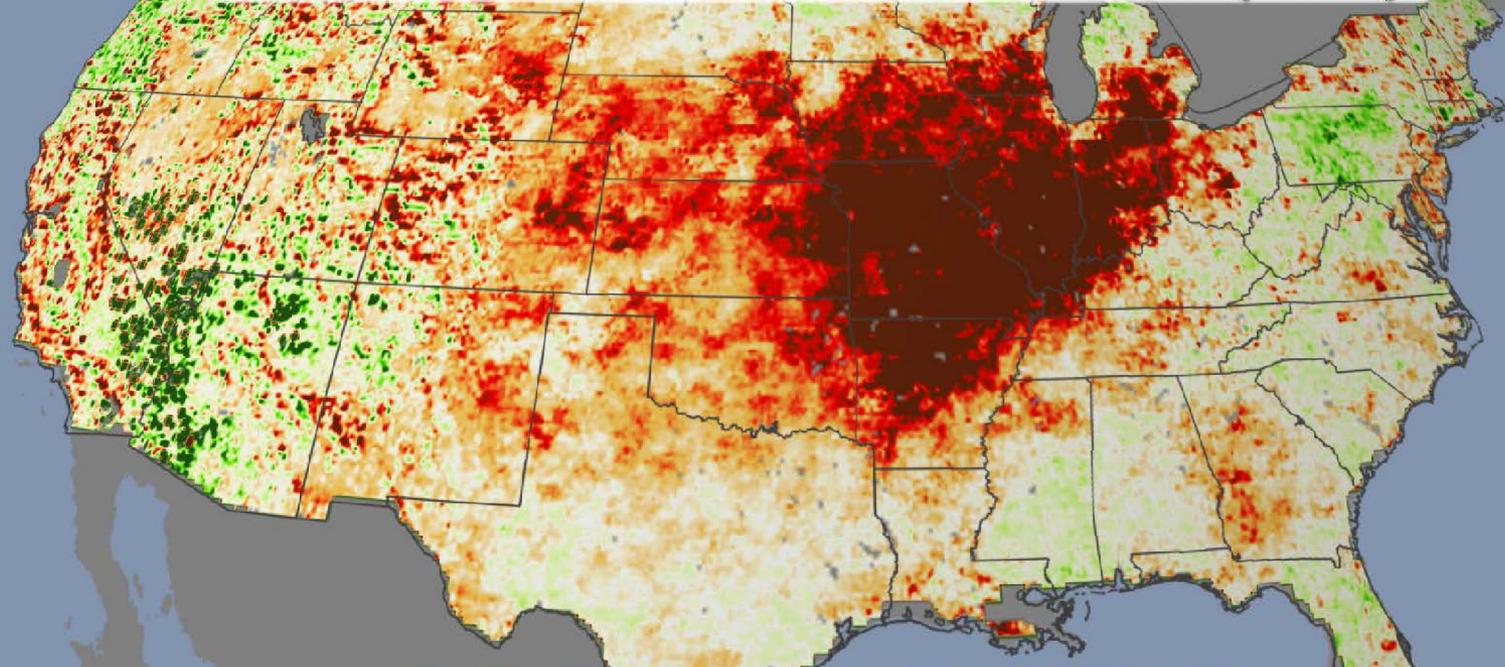
M. F. McCabe¹, A. Ershadi¹, C. Jimenez², D. G. Miralles³, D. Michel⁴, and E. F. Wood⁵

$$y = 1.07x$$
$$r^2 = 0.90$$



PT-JPL ET VALIDATION

EVAPORATIVE STRESS INDEX (ESI)



Aug 2012

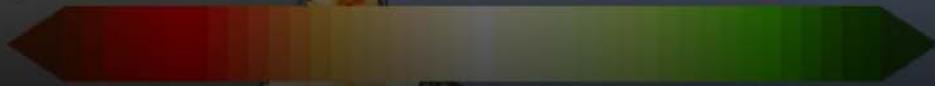
High water stress

Low water stress

Aug 2012

High water stress

Low water stress



New global observations of the terrestrial carbon cycle from GOSAT: Patterns of plant fluorescence with gross primary productivity

Christian Frankenberg,¹ Joshua B. Fisher,¹ John Worden,¹ Grayson Badgley,¹ Sassan S. Saatchi,¹ Jung-Eun Lee,¹ Geoffrey C. Toon,¹ André Butz,² Martin Jung,³ Akihiko Kuze,⁴ and Tatsuya Yokota⁵

Received 30 June 2011; revised 11 August 2011; accepted 16 August 2011; published 14 September 2011.

[1] Our ability to close the Earth's carbon budget and predict feedbacks in a warming climate depends critically on knowing where, when and how carbon dioxide is exchanged between the land and atmosphere. Terrestrial gross primary production (GPP) constitutes the largest flux component in the global carbon budget, however significant uncertainties remain in GPP estimates and its seasonality. Empirically, we show that global spaceborne observations of solar induced chlorophyll fluorescence – occurring during photosynthesis – exhibit a strong linear correlation with GPP. We found that the fluorescence emission even without any additional climatic or model information has the same or better predictive skill in estimating GPP as those derived from traditional remotely-sensed vegetation indices using ancillary data and model assumptions. In brief, we summarize the generally

strong linear correlation between fluorescence and GPP models weakens, attributable to discrepancies between croplands (18–48% higher fluorescence) and high-latitude needleleaf for

that retrievals of chlorophyll fluorescence provide direct global observational constraints for GPP and open an entirely new viewpoint on the global carbon cycle. We anticipate that global fluorescence observations, with consolidated plant physiology, will be a step-change in carbon cycle research and enable an unprecedented robustness in the understanding of the current

GOSAT, Patterns of plant fluorescence with gross primary productivity (GPP) and its seasonality. Currently there are two explicit

[2] Gross primary production (GPP) is the largest flux component in the global land carbon flux [Zhao and Running, 2010; Beer et al., 2010]. Currently there are two explicit

by the American Geophysical Union.

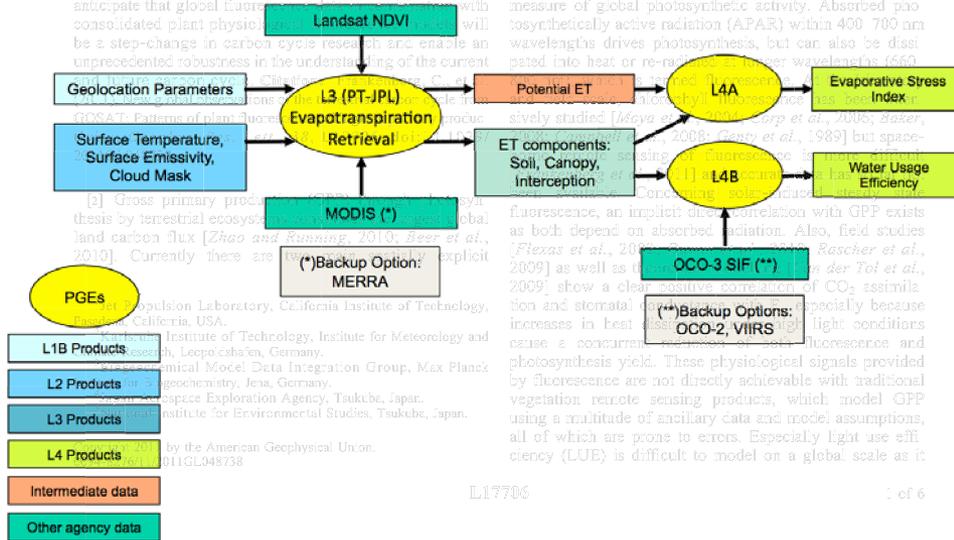
approaches to quantify GPP globally: 1) meteorology-driven full land surface carbon cycle models [Friedlingstein et al., 2006; Sitch et al., 2008]; and, 2) remote sensing-driven [Zhao and Running, 2010] and/or flux tower based [Beer et al., 2010; Jung et al., 2011] semi-empirical models focused on GPP or net primary production (NPP). Significant uncertainties related with the first approach are due to differing model sensitivities to meteorological parameters and uncertain global meteorological data sets [Friedlingstein et al., 2006; Sitch et al., 2008]. Uncertainties with the second approach exist because GPP cannot directly be estimated from the remote sensing measurements but is also modeled as a function of leaf area index (LAI) and fraction of absorbed photosynthetically active radiation (FAPAR) or greenness indices such as the normalized difference or enhanced vegetation indices (NDVI, EVI) [Zhao et al., 2008]. These indices are often contaminated by atmospheric conditions, and may contribute a misleading signal when vegetation becomes stressed, e.g. green canopies that are not photosynthesizing [Zhao et al., 2008].

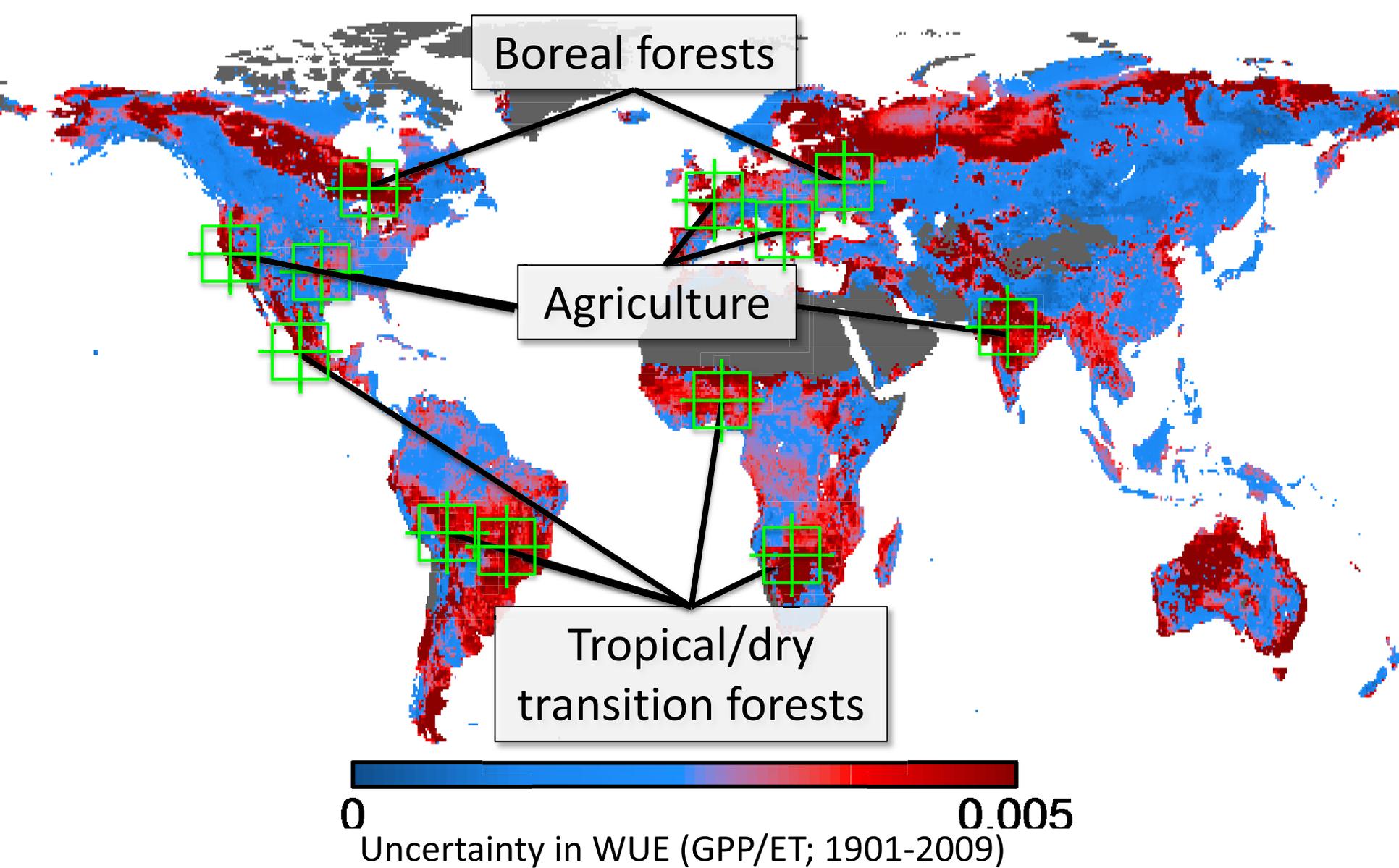
[3] Remote sensing of solar-induced chlorophyll fluorescence (F_s) [Krause and Weis, 1991], as intended with the FLEX satellite mission, offers a direct physiology-based measure of global photosynthetic activity. Absorbed photosynthetically active radiation (APAR) within 400–700 nm wavelengths drives photosynthesis, but can also be dissipated into heat or re-radiated at longer wavelengths (650–750 nm) [Krause and Weis, 1991]. This process has been extensively studied [Meyer and Schepers, 2006; Baker, 2008; Genty et al., 2008; Genty et al., 1989] but space-

fluorescence, an implicit correlation with GPP exists as both depend on absorbed radiation. Also, field studies [Flexas et al., 2006; Rascher et al., 2009] as well as laboratory studies [Genty et al., 2009] show a clear positive correlation of CO₂ assimilation and stomatal conductance, especially because increases in heat and light conditions cause a concurrent decrease in fluorescence and photosynthesis yield. These physiological signals provided by fluorescence are not directly achievable with traditional vegetation remote sensing products, which model GPP using a multitude of ancillary data and model assumptions, all of which are prone to errors. Especially light use efficiency (LUE) is difficult to model on a global scale as it



L3/L4 Data Flow

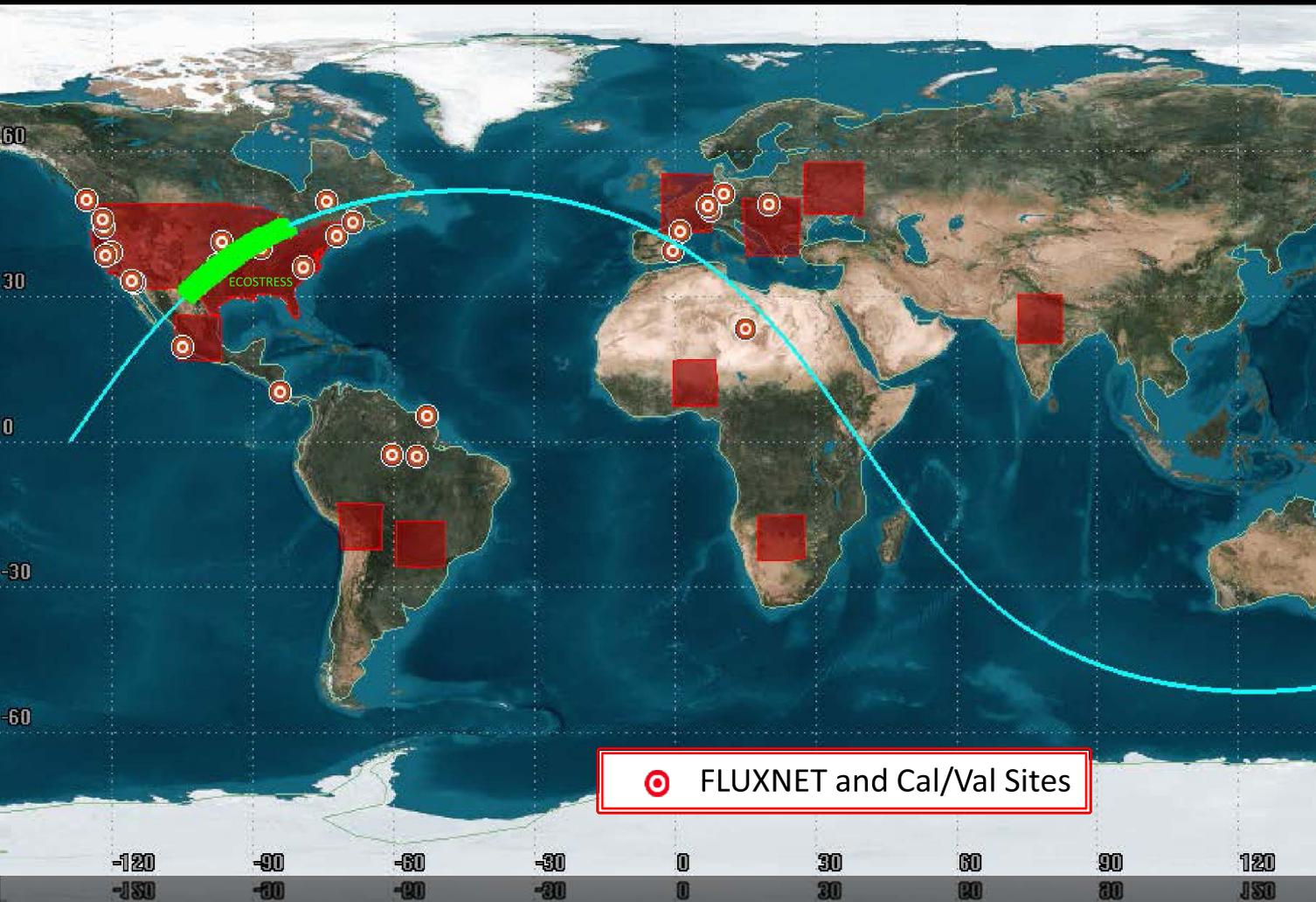




0 0.005
Uncertainty in WUE (GPP/ET; 1901-2009)

Nine land surface models were run with only a perturbed climate (i.e., CO₂, land use constant) over the 20th century, representing the γ -response, or climate sensitivity to identify key *WUE uncertainty hotspots*.





🎯 FLUXNET and Cal/Val Sites

Table F.1-2. ECOSTRESS targets include all of CONUS, 1,000 km regions centered on climate hotspots and agricultural regions, and validation sites. ENF: Evergreen Needleleaf Forest; EBF: Evergreen Broadleaf Forest; WSA: Woody Savanna; SAV: Savanna; CRO: Cropland; DBF: Deciduous Broadleaf Forest; Cal/Val: Radiance at sensor, LST Calibration/Validation site.

Site	Biome Type	Latitude	Longitude
Climate Hotspot Regions			
Boreal North America	ENF	47.0	-87.0
Boreal Eurasia	ENF	47.0	45.0
Tropical/Dry Transition 1	EBF	-12.0	-87.0
Tropical/Dry Transition 2	EBF/WSA	-16.0	-50.0
Tropical/Dry Transition 3	EBF/WSA	20.0	-103.0
Tropical/Dry Transition 4	WSA/SAV	9.0	4.0
Tropical/Dry Transition 5	WSA/SAV	-23.0	22.0
Agricultural Regions			
Agricultural North America 1	CRO	35.7	-121.0
Agricultural North America 2	CRO	41.5	-98.7
Agricultural Eurasia 1	CRO	44.2	18.0
Agricultural Eurasia 2	CRO	25.0	78.0
Agricultural Eurasia 3	CRO	47.0	0.0
FLUXNET and Calibration/Validation Sites			
Campbell River, Canada	ENF	49.9	-125.3
Hartheim, Germany	ENF	47.9	7.6
Howland Forest, ME, USA	ENF	45.2	-68.7
Metolius, OR, USA	ENF	44.5	-121.6
Quebec Boreal, Canada	ENF	49.7	-74.3
Tatra, Slovak Republic	ENF	49.1	20.2
Wind River Crane, WA, USA	ENF	45.8	-122.0
Guyatlux, French Guyana	EBF	5.3	-52.9
La Selva, Costa Rica	EBF	10.4	-84.0
Manaus K34, Brazil	EBF	-2.6	-60.2
Santarem KM87, Brazil	EBF	-2.9	-56.0
Santarem KM83, Brazil	DBF	-3.0	-55.0
Chamela, Mexico	DBF	19.5	-105.0
Duke Forest, NC, USA	DBF	36.0	-79.1
Hainich, Germany	DBF, Cal/Val	51.1	10.5
Harvard Forest, MA, USA	DBF	42.5	-72.2
Hesse Forest, France	DBF	48.7	7.1
Tonzi Ranch, CA, USA	DBF/WSA	38.4	-121.1
ARM S. Great Plains, OK, USA	CRO, Cal/Val	36.6	-97.5
Aurade, France	CRO	43.5	1.1
Bondville, IL, USA	CRO, Cal/Val	40.0	-88.3
El Saler-Sueca, Spain	CRO	39.3	-0.3
Mead 1, 2, 3 NE, USA	CRO	41.2	-96.5
Salton Sea, CA	Cal/Val	33.3	-115.7
Lake Tahoe, CA	Cal/Val	39.2	-120.0
Gobabeb, Namibia	Cal/Val	23.5	15.1
Algodones Dunes, CA	Cal/Val	33.0	-115.1

ECOSTRESS KEY SCIENCE QUESTIONS

1. HOW IS THE TERRESTRIAL BIOSPHERE RESPONDING TO CHANGES IN WATER AVAILABILITY?
1. HOW DO CHANGES IN DIURNAL VEGETATION WATER STRESS IMPACT THE GLOBAL CARBON CYCLE?
1. CAN AGRICULTURAL VULNERABILITY BE REDUCED THROUGH ADVANCED MONITORING OF AGRICULTURAL CONSUMPTIVE USE AND IMPROVED DROUGHT DETECTION?

ECOSTRESS SCIENCE OBJECTIVES

1. IDENTIFY **CRITICAL THRESHOLDS** OF WATER USE AND WATER STRESS IN KEY CLIMATE SENSITIVE BIOMES (E.G., TROPICAL/DRY TRANSITION FORESTS, BOREAL FORESTS);
1. DETECT THE TIMING, LOCATION, AND PREDICTIVE FACTORS LEADING TO PLANT WATER UPTAKE DECLINE AND/OR CESSATION OVER THE **DIURNAL CYCLE**;
1. MEASURE AGRICULTURAL WATER **CONSUMPTIVE USE** GLOBALLY AT SPATIOTEMPORAL SCALES APPLICABLE TO IMPROVING DROUGHT ESTIMATION ACCURACY.

COMMUNITY INVOLVEMENT

NASA ROSES

EARLY ADOPTERS

APPLIED SCIENCES

ECOSTRESS:

A technology that will help us
understand how plants react to
our changing planet



Olivia Mansion



ECOSTRESS

ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

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*ECOSTRESS will provide critical insight into **plant–water dynamics** and how **ecosystems change with climate** via **high spatiotemporal resolution thermal infrared radiometer measurements of evapotranspiration from the International Space Station (ISS)**.*

ECOSTRESS Science Data Products

L2	Surface Temperature Surface Emissivity
L3	Evapotranspiration
L4	Water Use Efficiency Evaporative Stress Index

November 25, 2013

ECOSTRESS AND BEYOND...

- 2017
- → HypsIRI →
- → Landsat/SLI →