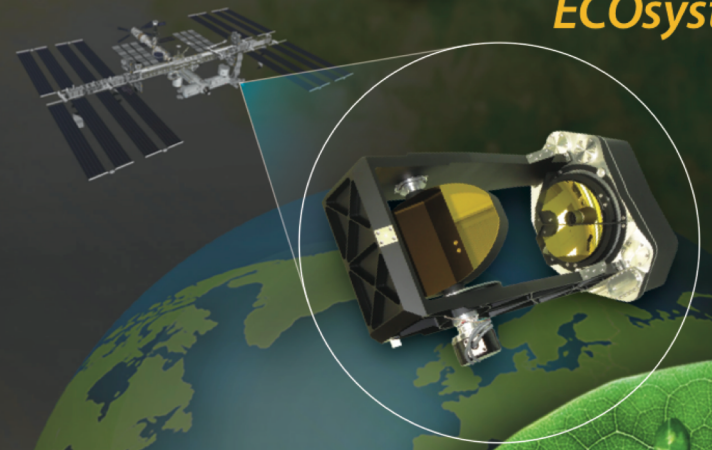
National Aeronautics and Space Administration

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

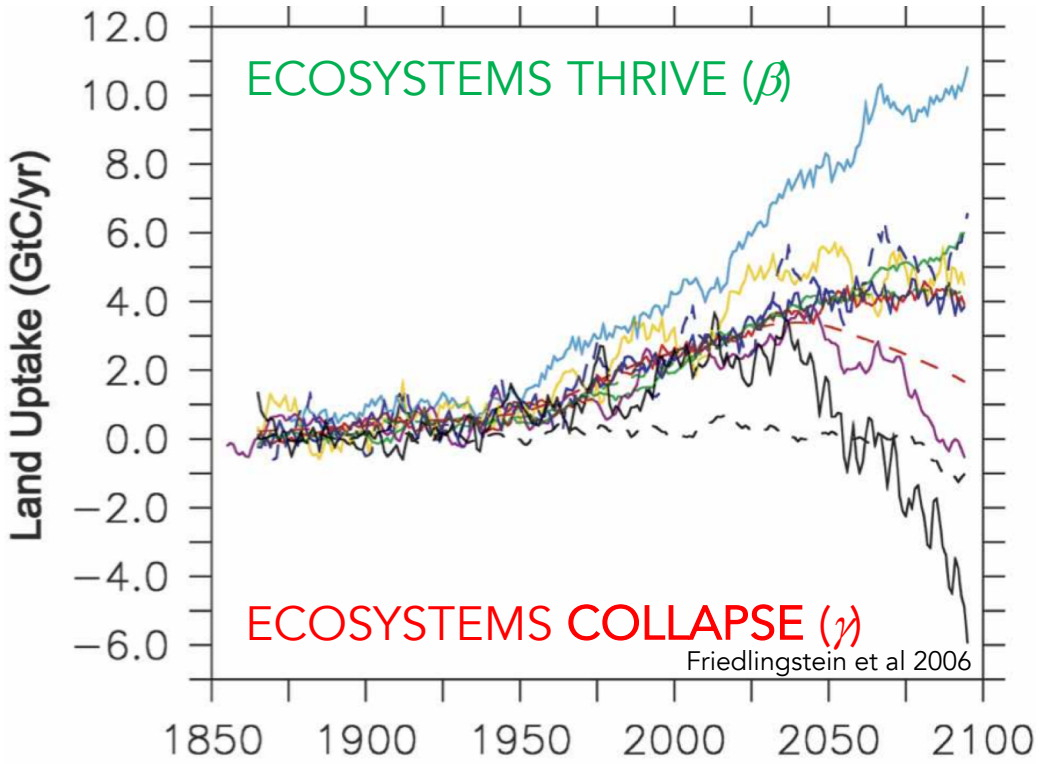
November 25, 2013

© 2014 California Institute of Technology. Government sponsorship acknowledged.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov



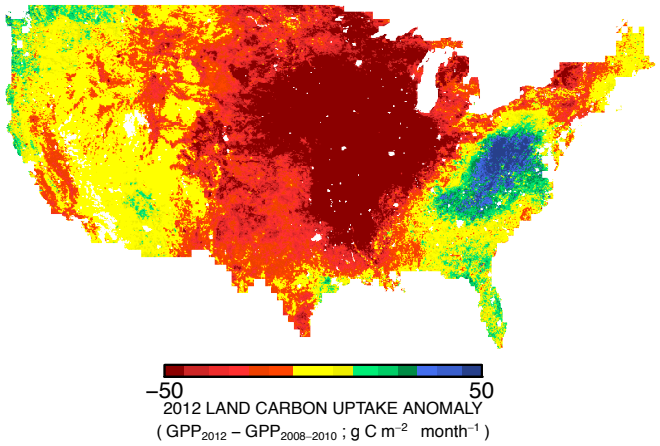
The response of the terrestrial biosphere to changing climate is one of the largest uncertainties in future climate projections.

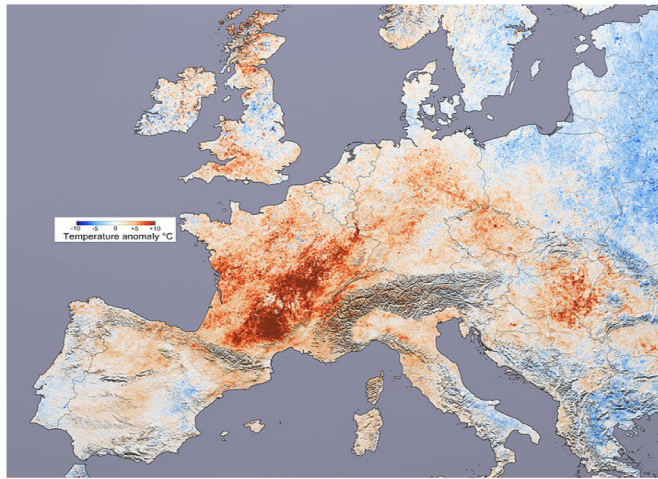
WATER

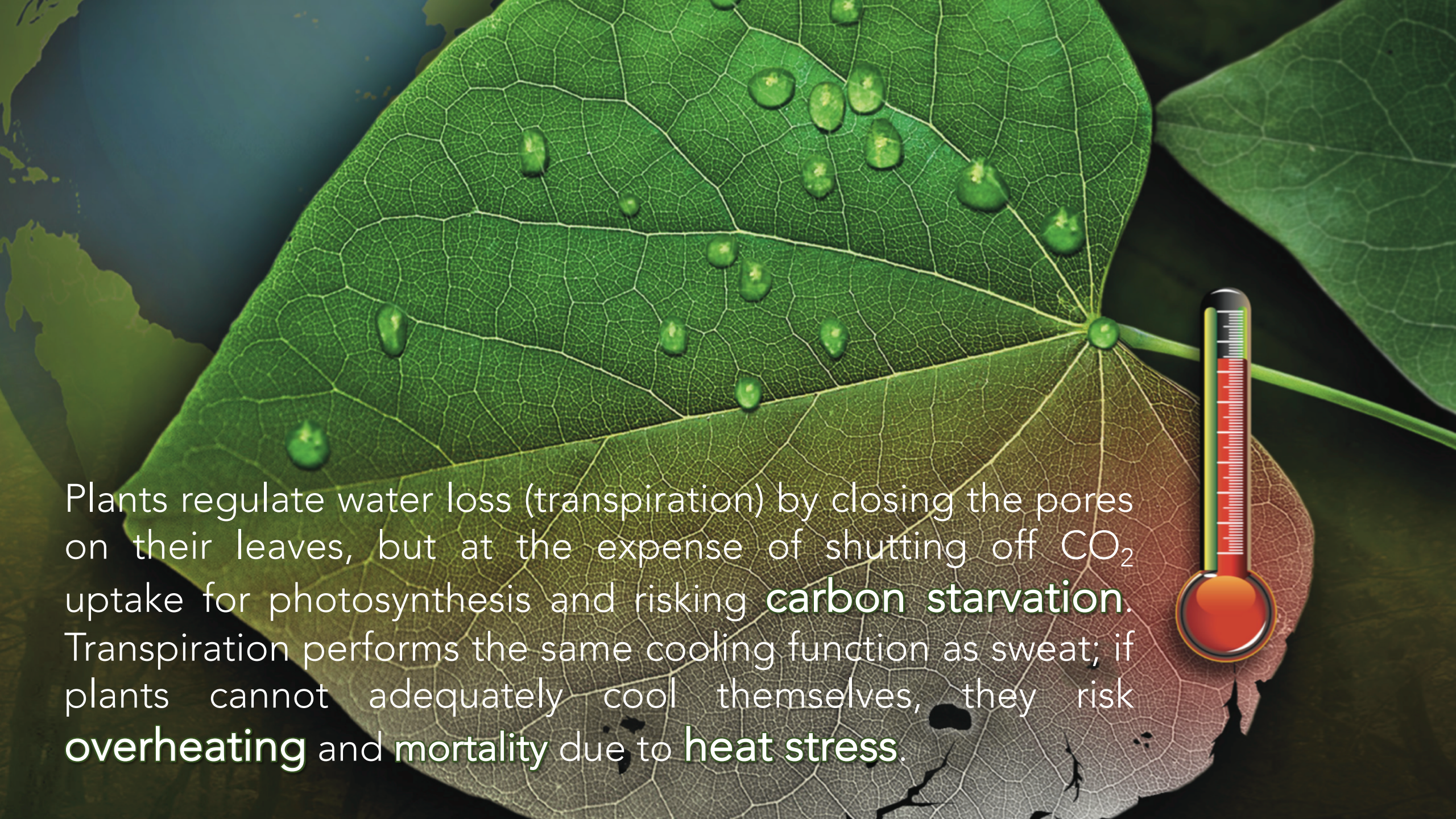
CARBON

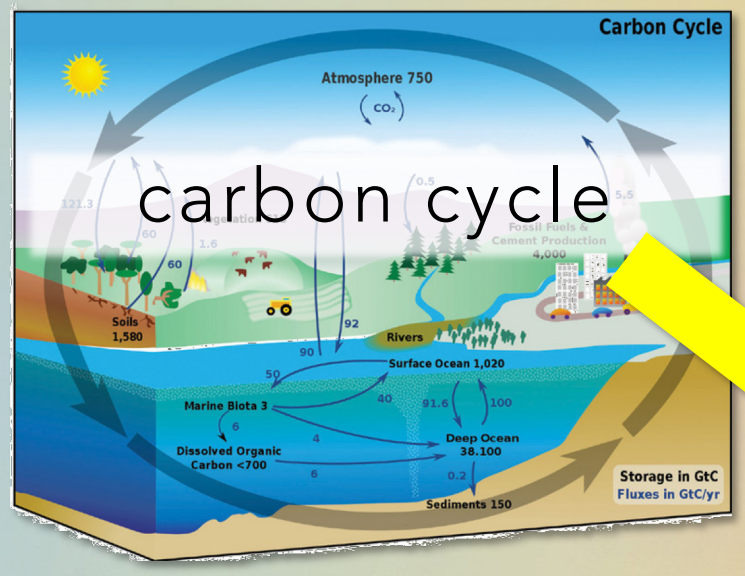
Uncertainty in our knowledge of carbon response is directly dependent on water response uncertainty

Current US drought prediction capabilities failed to predict the intensity and magnitude of the 2012 US Midwest drought

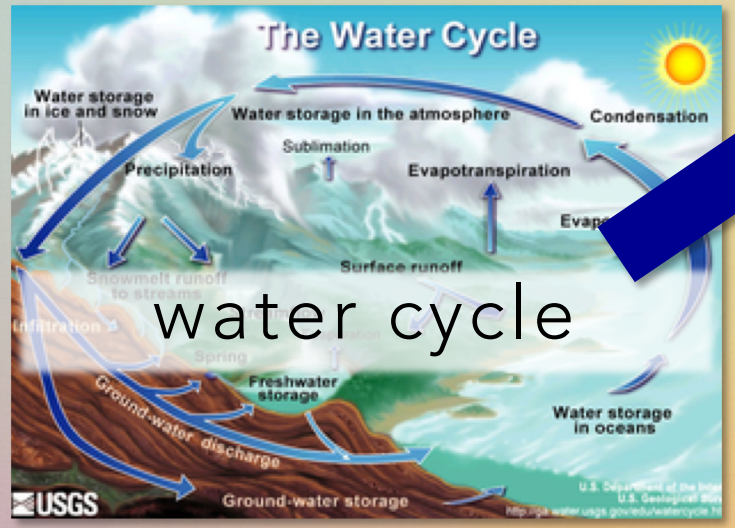




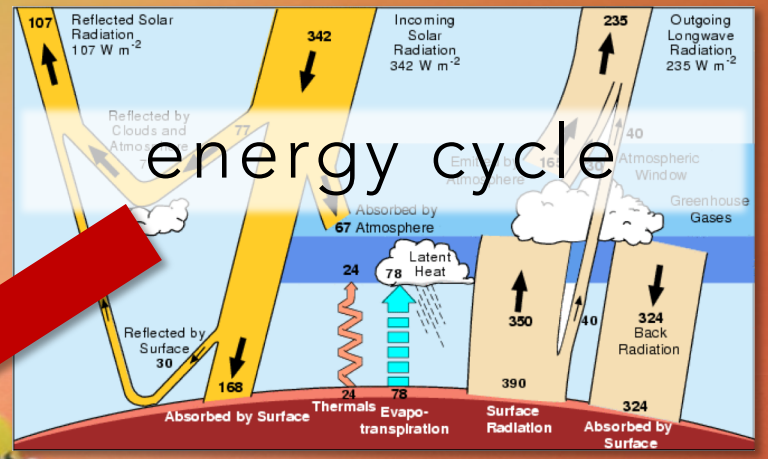

Plants regulate water loss (transpiration) by closing the pores on their leaves, but at the expense of shutting off CO_2 uptake for photosynthesis and risking **carbon starvation**. Transpiration performs the same cooling function as sweat; if plants cannot adequately cool themselves, they risk **overheating** and **mortality** due to **heat stress**.



carbon cycle



water cycle



energy cycle

ET describes the net exchange of water vapor between the land surface and the atmosphere, and is comprised of water evaporated directly from the soil or other surfaces and water transpired (i.e., used; consumptive use) by plants.

what is evapotranspiration (ET)?

Evapotranspiration is the key climate variable linking the water, energy, and carbon cycles

ET describes the net exchange of water vapor between the land surface and the atmosphere, and is comprised of water evaporated directly from the soil or other surfaces and water transpired (i.e., used; consumptive use) by plants.

what is evapotranspiration (ET)?

Evapotranspiration is the key climate variable linking the water, energy, and carbon cycles

HOW DO DIFFERENT PLANTS RESPOND TO CHANGES IN WATER AVAILABILITY?

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.

ECOSTRESS KEY SCIENCE QUESTIONS

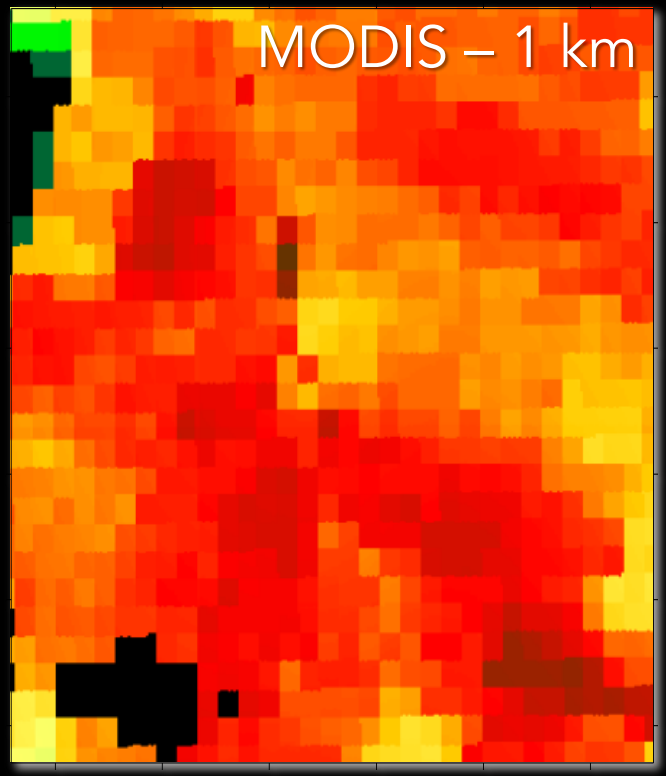
1. How is the terrestrial biosphere responding to changes in water availability?

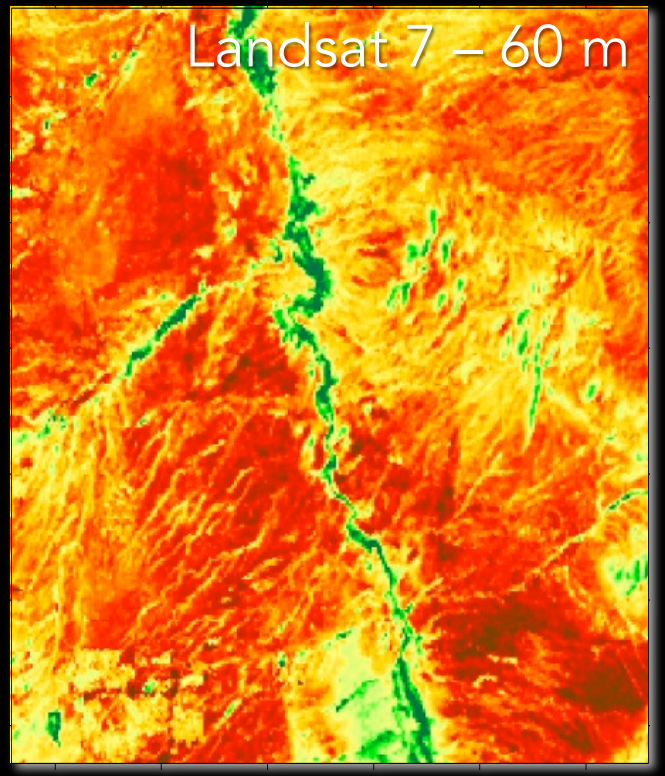
2. How do changes in diurnal vegetation water stress impact the global carbon cycle?

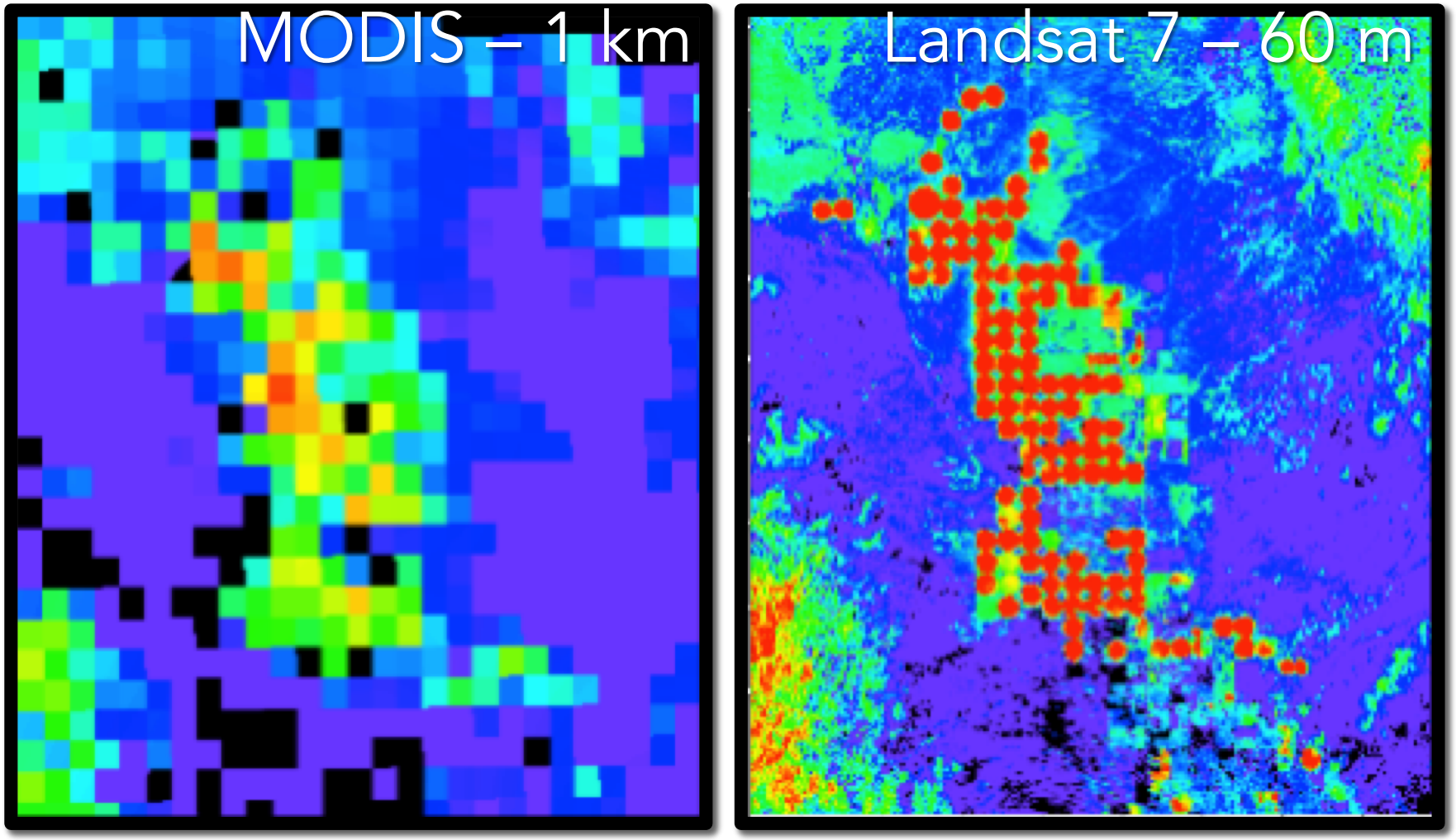
3. Can agricultural vulnerability be reduced through advanced monitoring of agricultural consumptive use and improved drought detection?

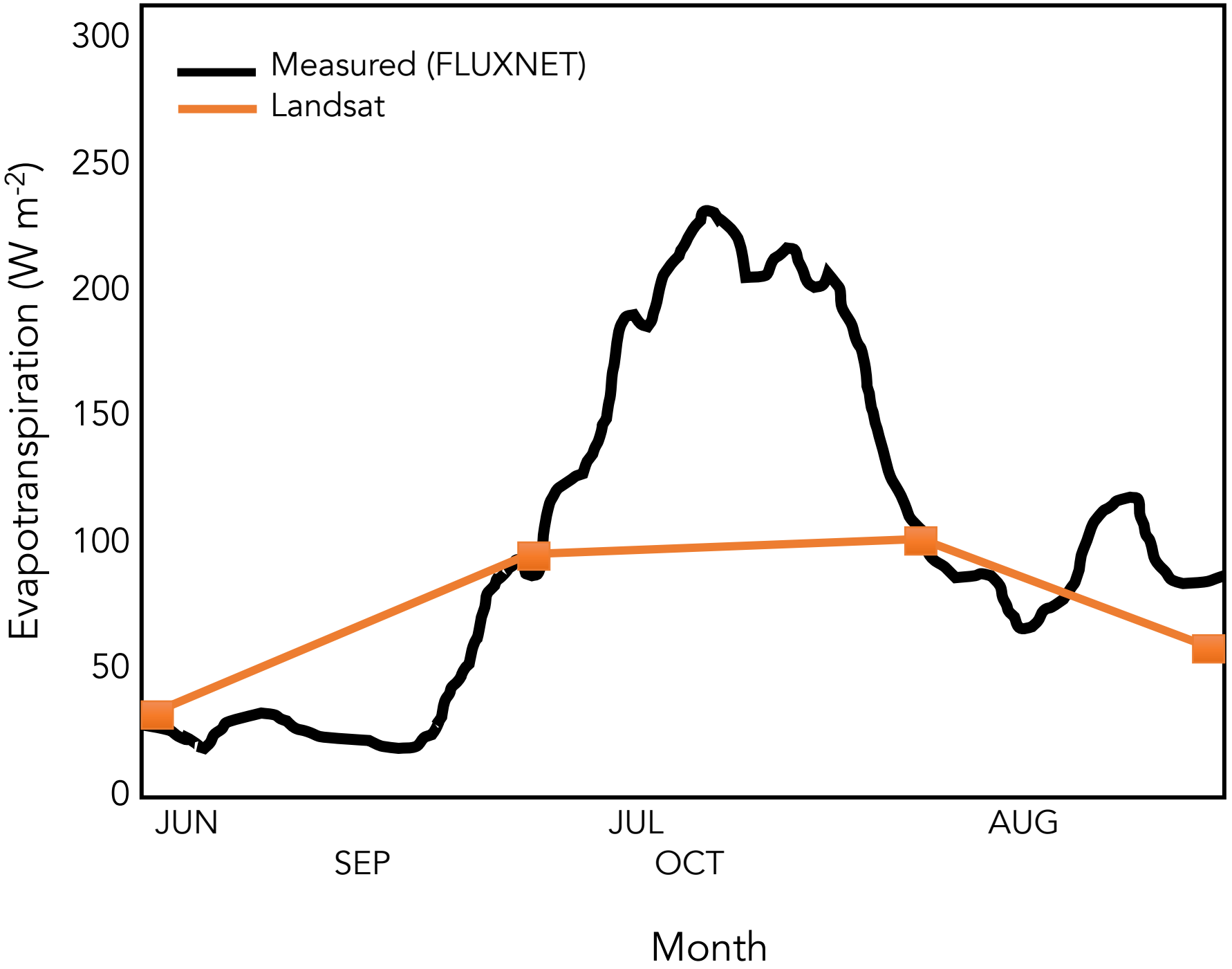
A P P R O A C H

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

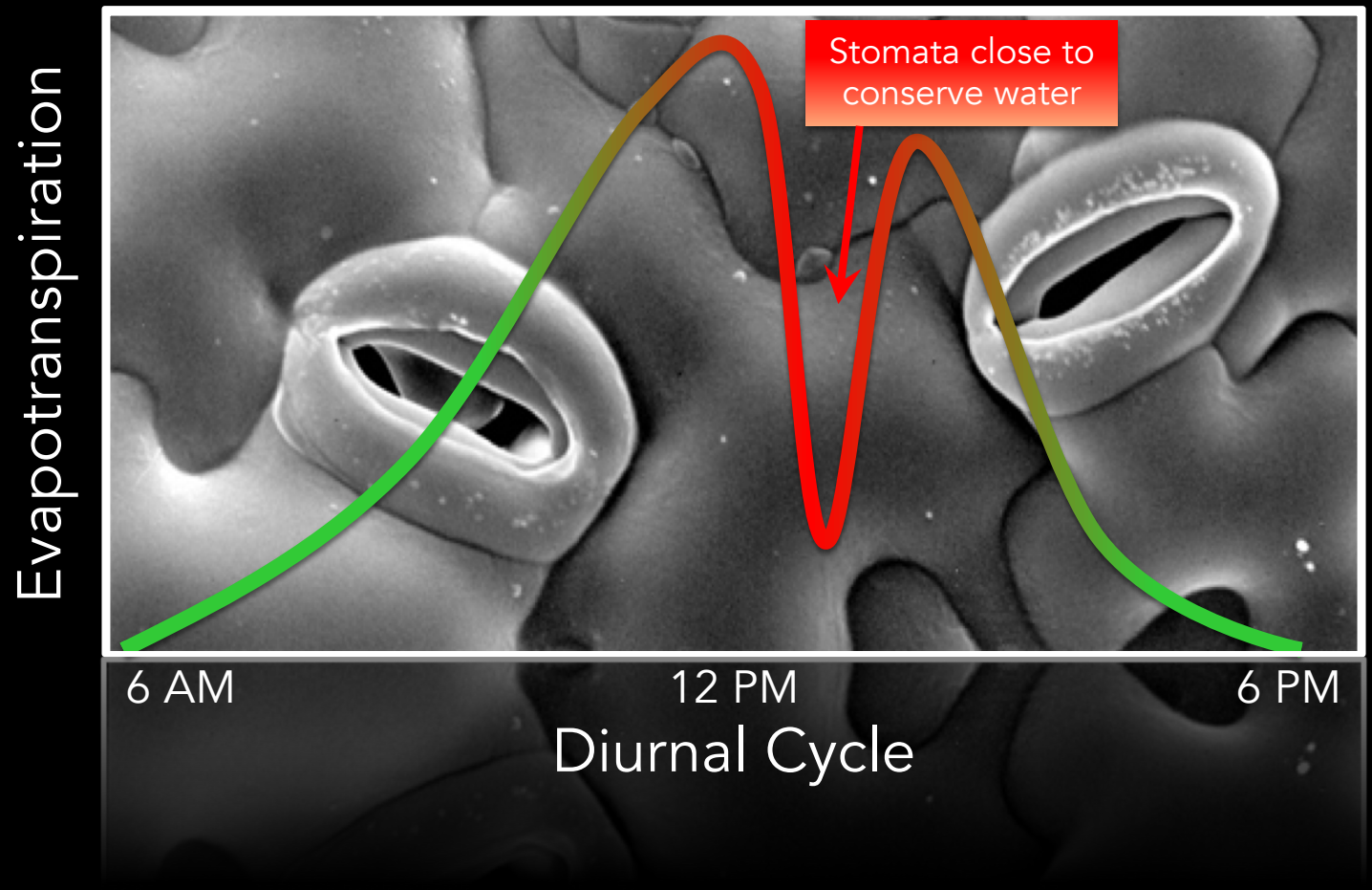

MODIS – 1 km

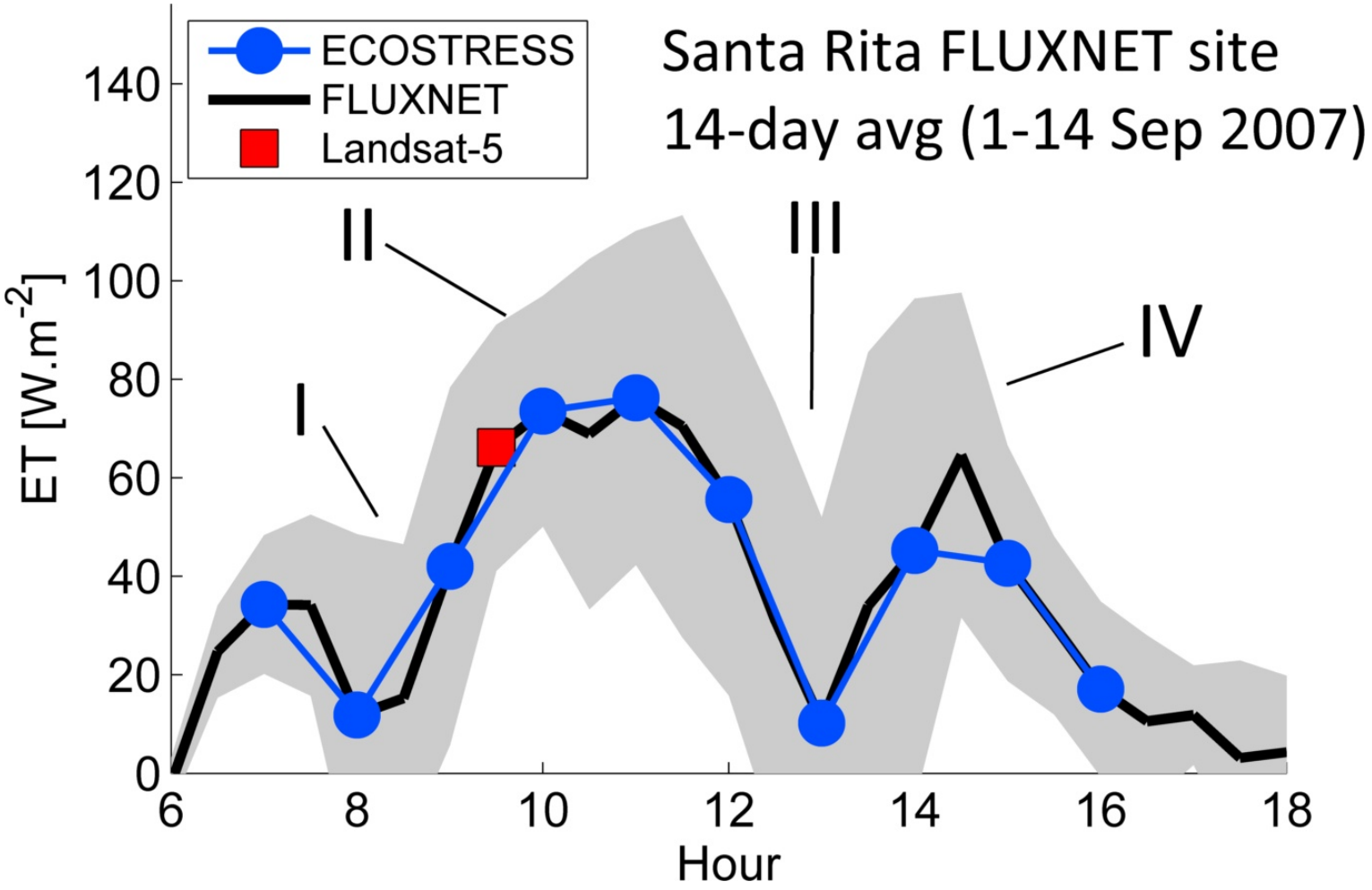

Landsat 7 – 60 m


MODIS – 1 km
Landsat 7 – 60 m


Measured (FLUXNET)
Landsat
Evapotranspiration (W m-2)
300
250
200
150
100
50
0
JUN
JUL
AUG
SEP
OCT
Month

Water Stress Drives Plant Behavior

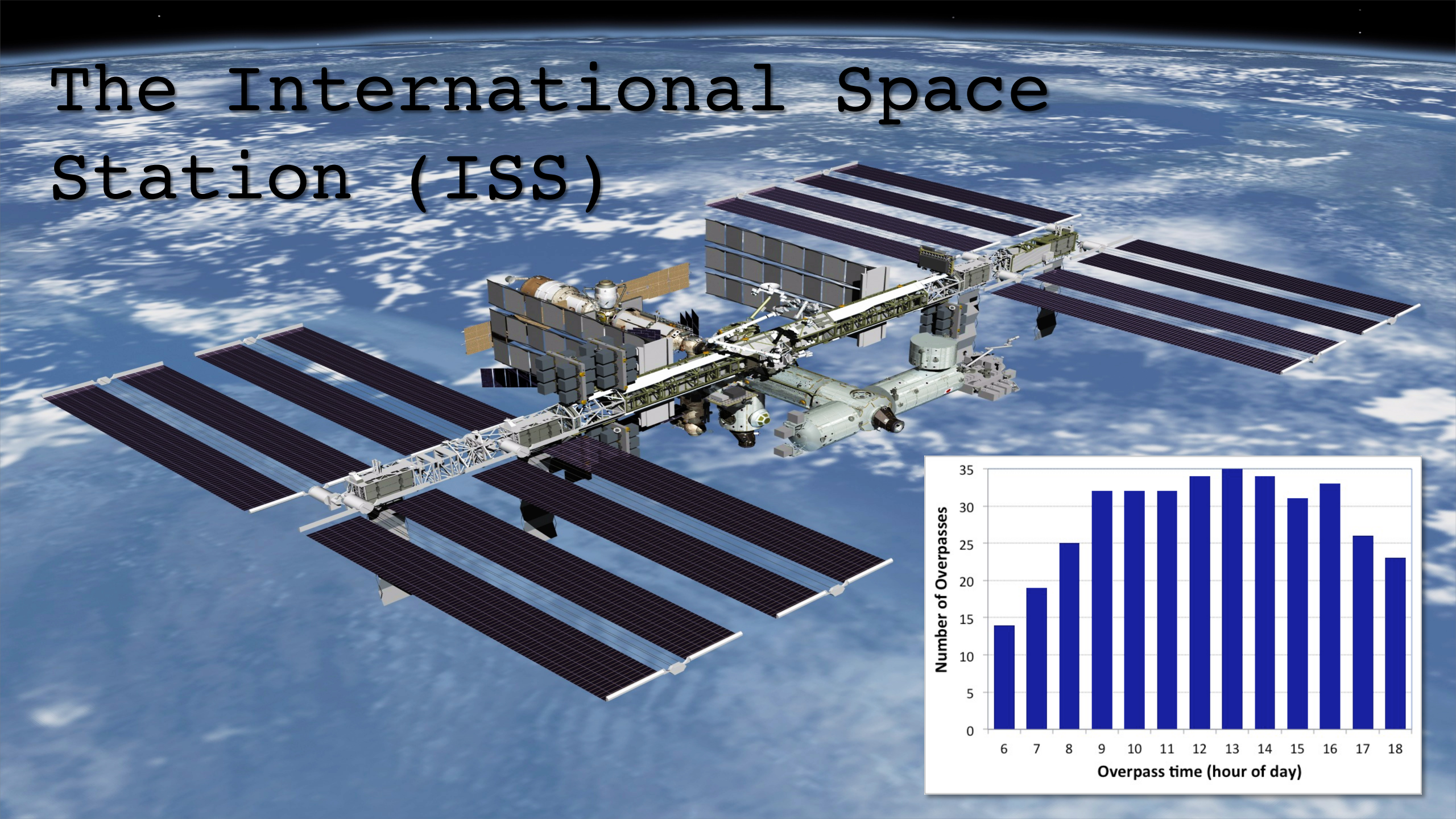


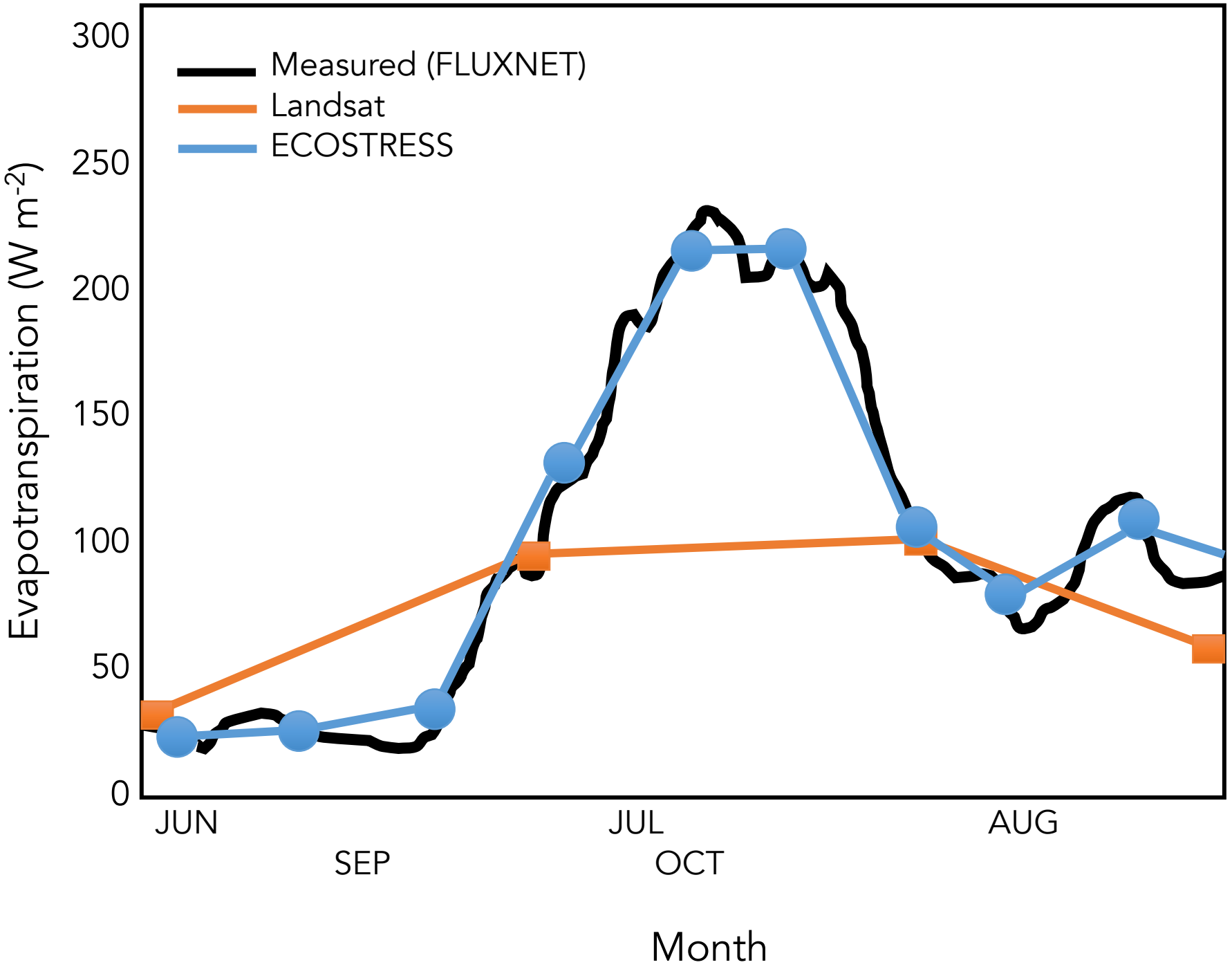


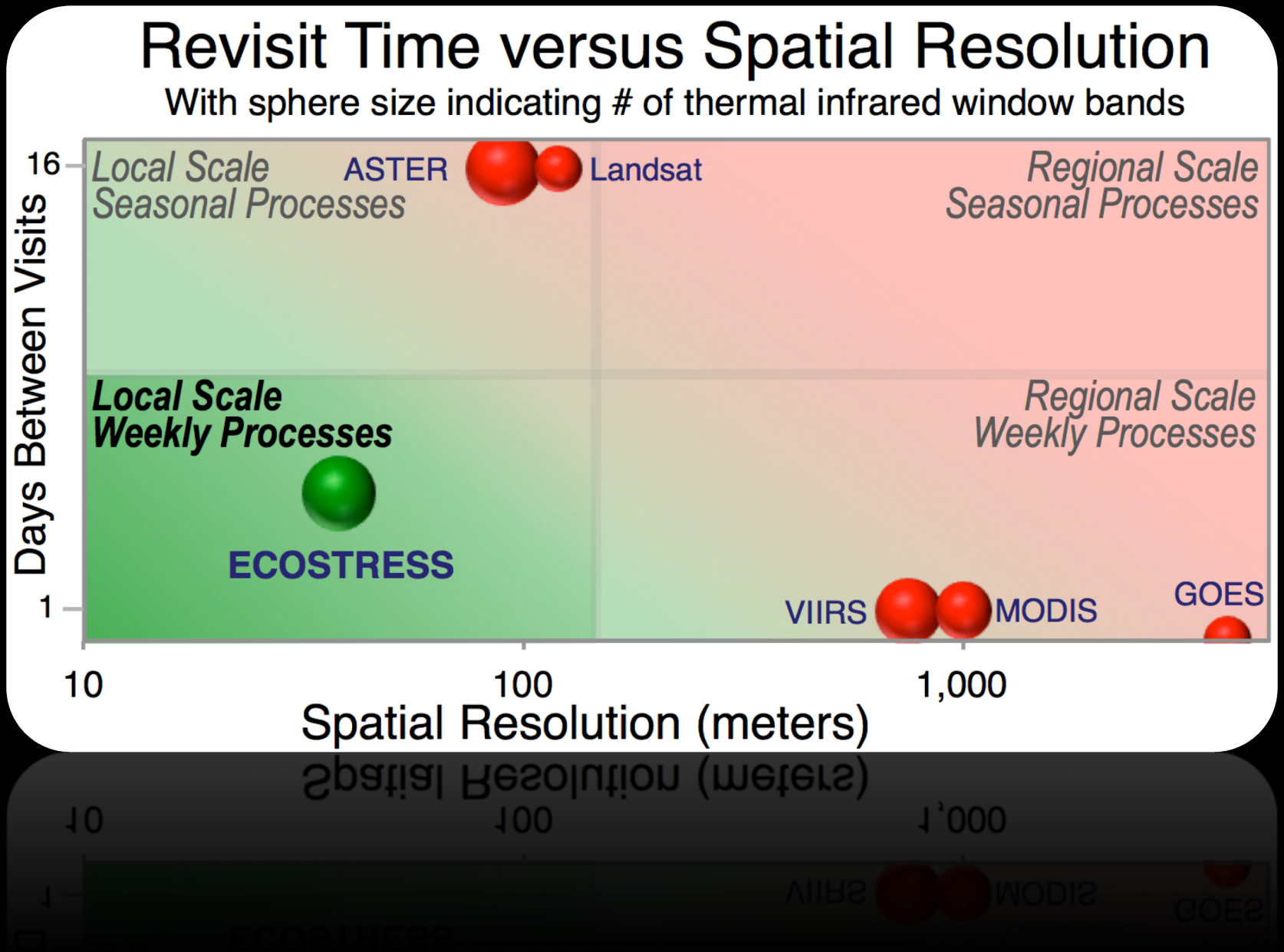
Gray shading represents mean **diurnal variation** in ET over 14-days. The afternoon decline in ET is related to water stress (clear day).

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.

The International Space Station (ISS)



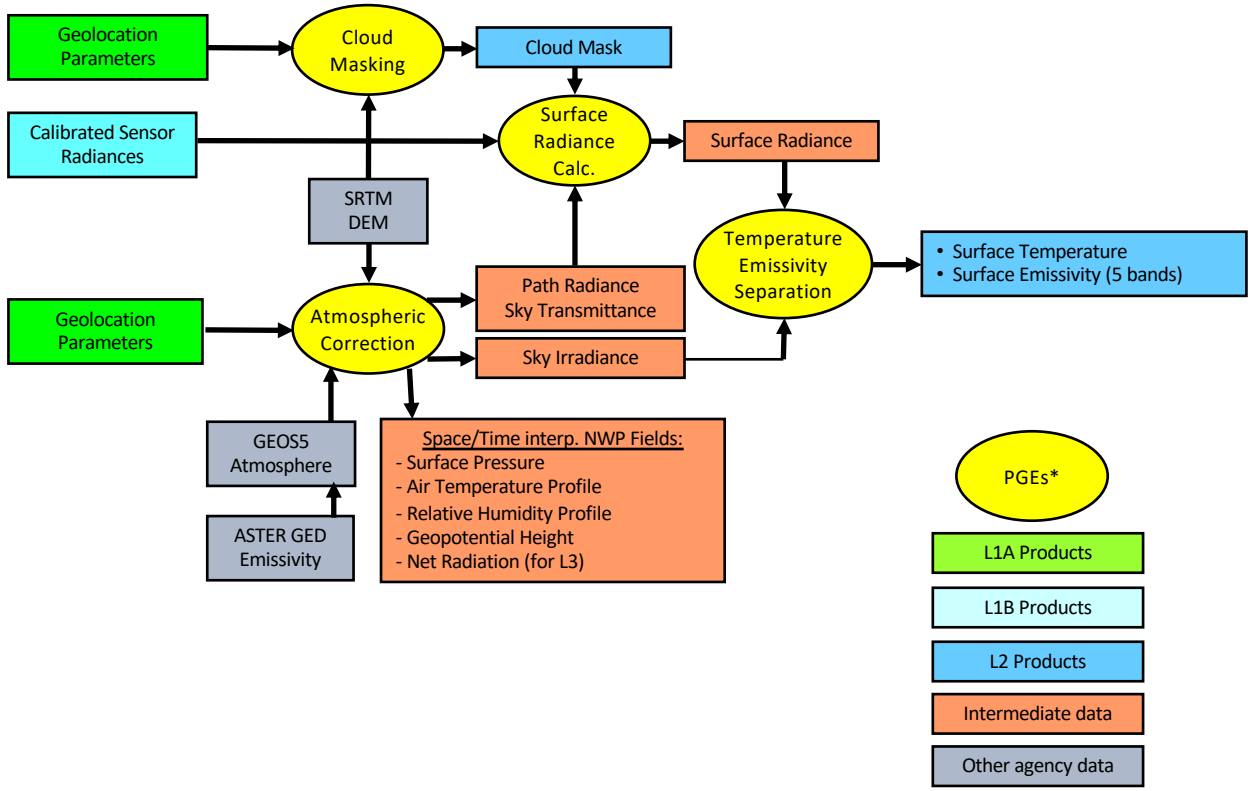

Measured (FLUXNET)
Landsat
ECOSTRESS
Evapotranspiration (W m-2)
300
250
200
150
100
50
0
JUN
JUL
AUG
SEP
OCT
Month


Revisit Time versus Spatial Resolution
With sphere size indicating # of thermal infrared window bands
Days Between Visits
16
1
Local Scale
Seasonal Processes
ASTER
Landsat
Regional Scale
Seasonal Processes
Local Scale
Weekly Processes
ECOSTRESS
Regional Scale
Weekly Processes
VIIRS
MODIS
GOES
10
100
1,000
Spatial Resolution (meters)

Science Algorithms: L2(LSTE)

The Temperature Emissivity Separation (TES) Algorithm

Hulley, G. C., C. G. Hughes, and S. J. Hook (2012), Quantifying uncertainties in land surface temperature and emissivity retrievals from ASTER and MODIS thermal infrared data, *Journal of Geophysical Research: Atmospheres*, *117*(D23).

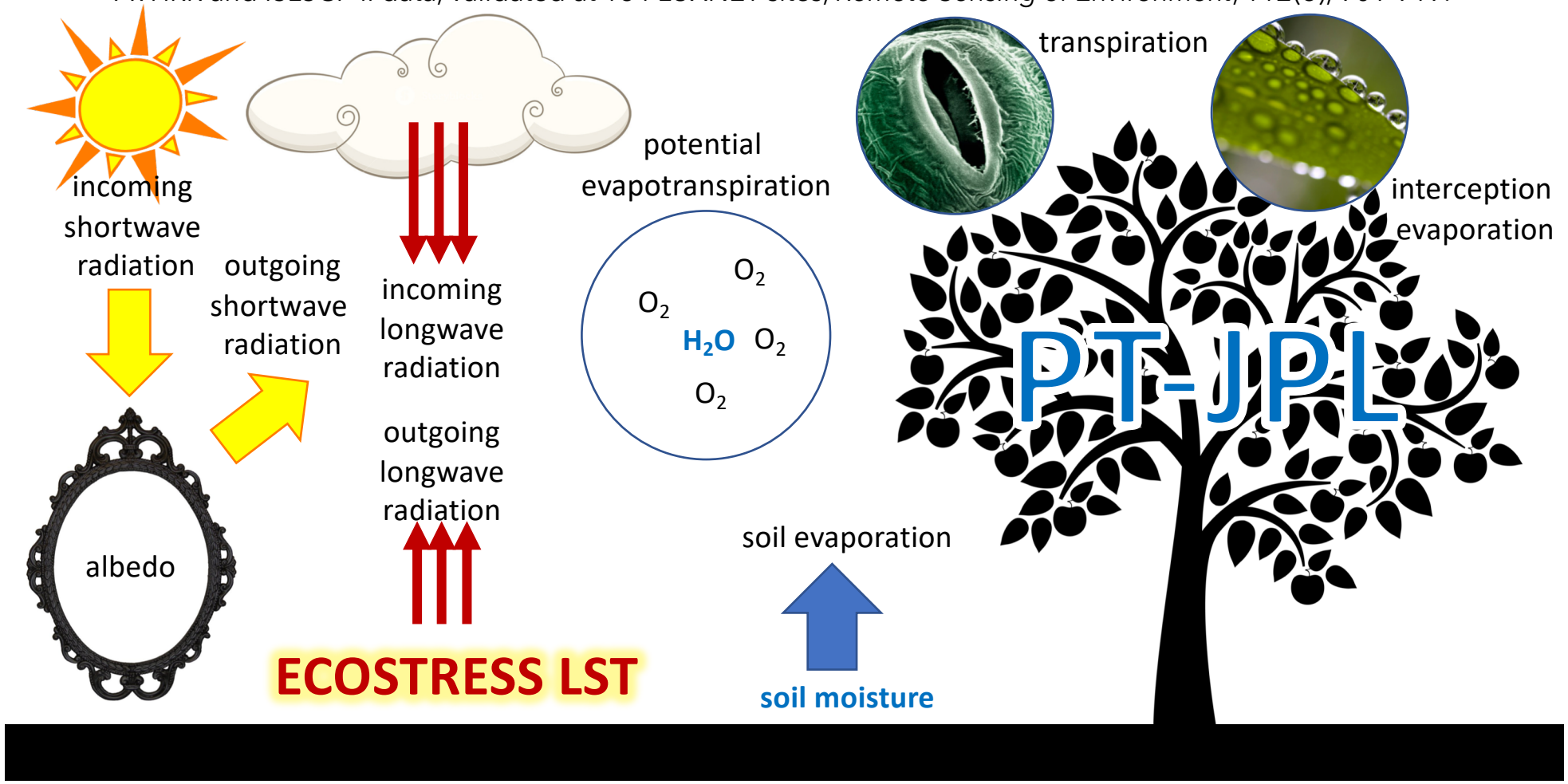


*PGE = Production Generation Executable

Science Algorithms: L3(ET_PT-JPL)

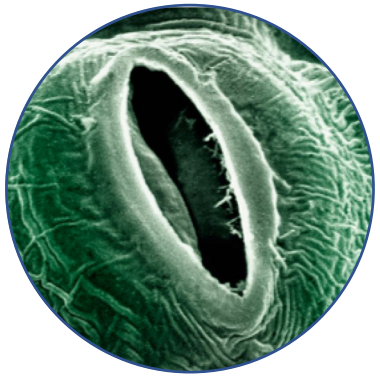
The Priestley-Taylor Jet Propulsion Laboratory (PT-JPL) Algorithm

Fisher, J. B., K. Tu, and D. D. Baldocchi (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.



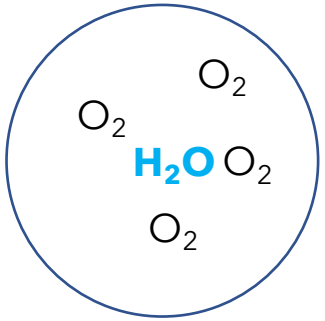
Science Algorithms: L4(ESI, WUE)

ECOSTRESS Water Use Efficiency (WUE) = Gross Primary Production (carbon in) / **ECOSTRESS Evapotranspiration (water out)**



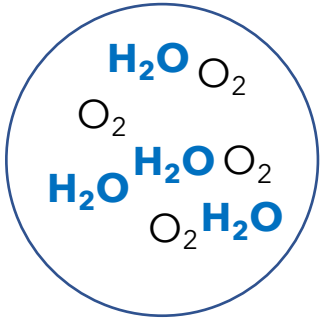
ECOSTRESS L4

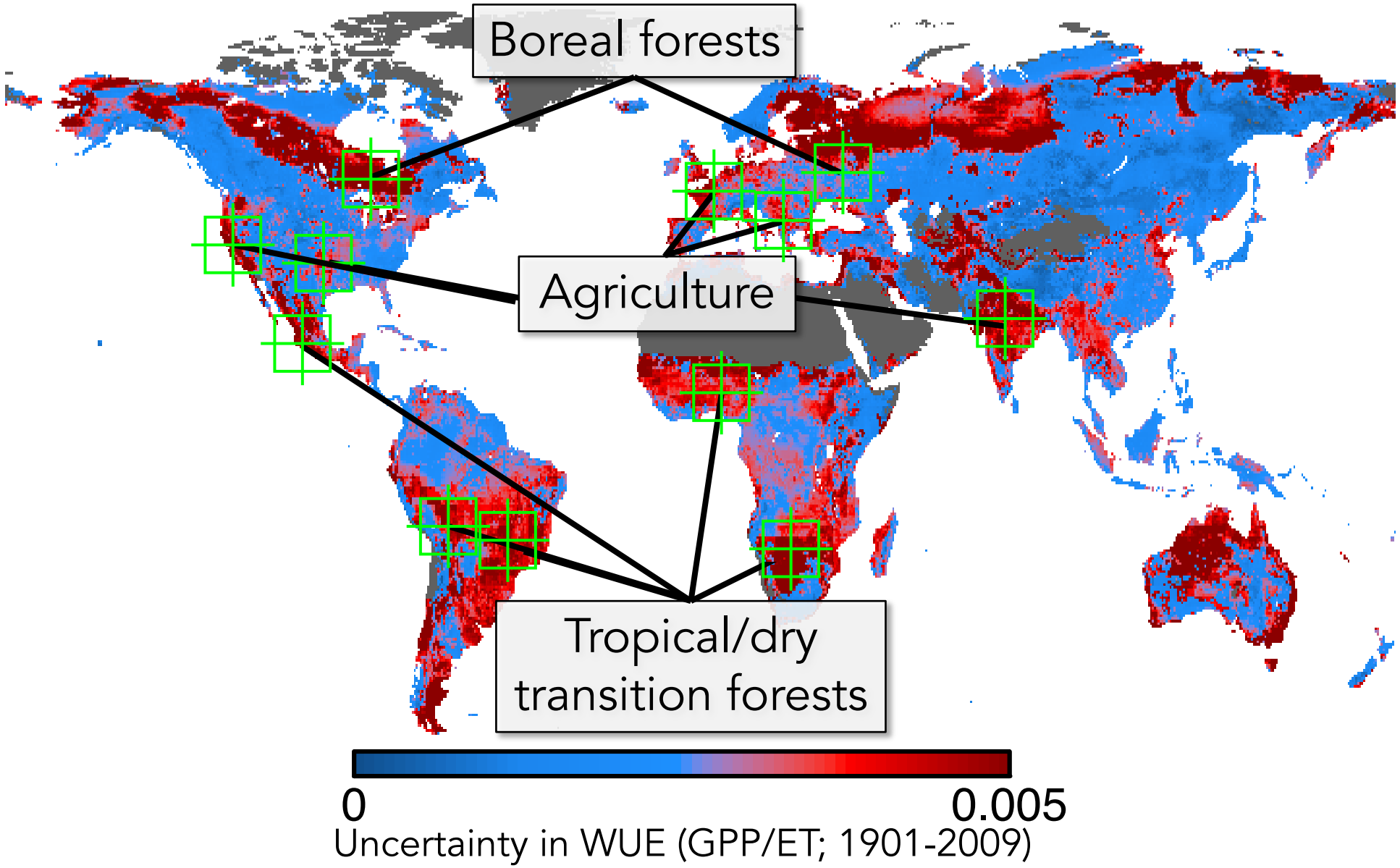
actual evapotranspiration



ECOSTRESS Evaporative Stress Index (ESI) = **actual evapotranspiration** / **potential evapotranspiration**

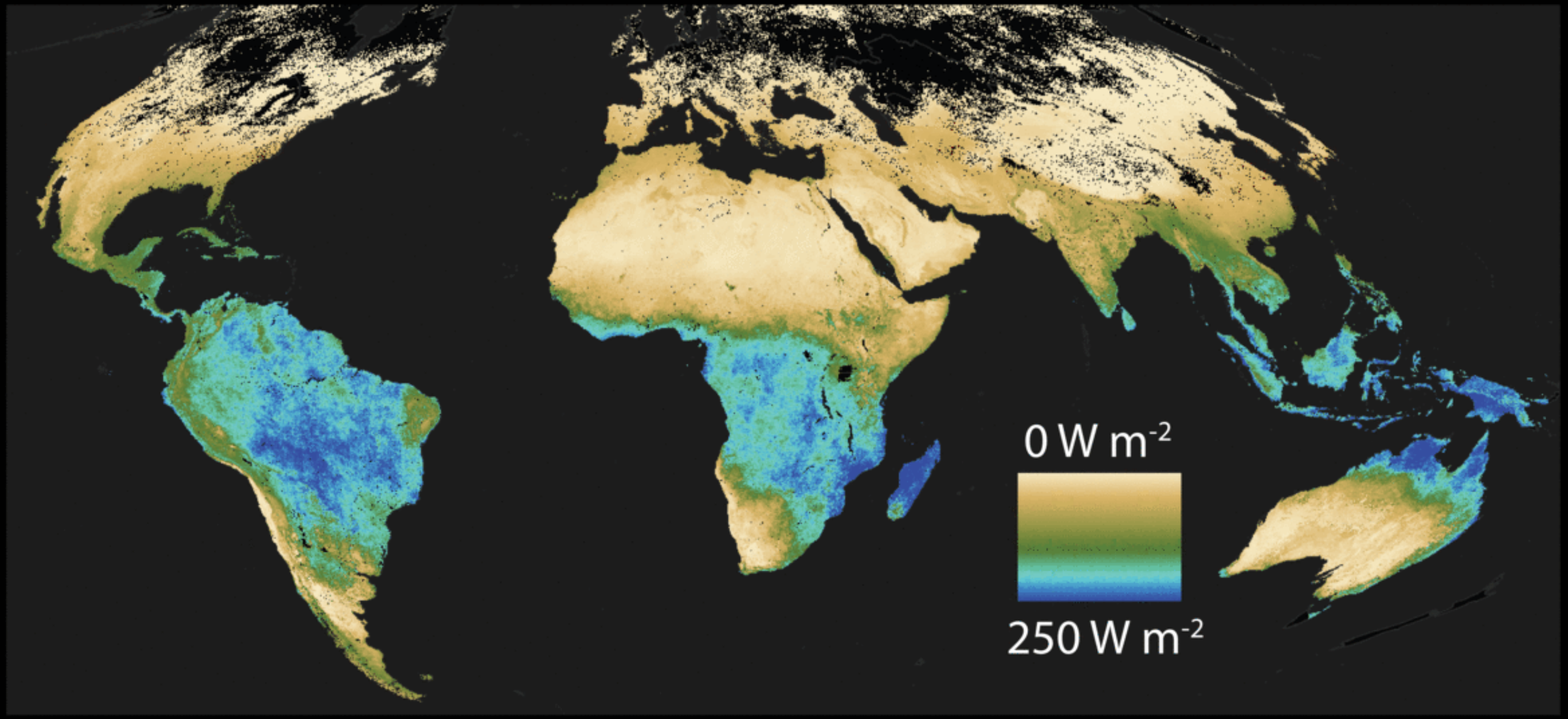
potential evapotranspiration





Nine land surface models were run with only a perturbed climate (i.e., CO_2, land use constant) over the 20th century, representing the g-response, or climate sensitivity to identify key *WUE uncertainty hotspots*.

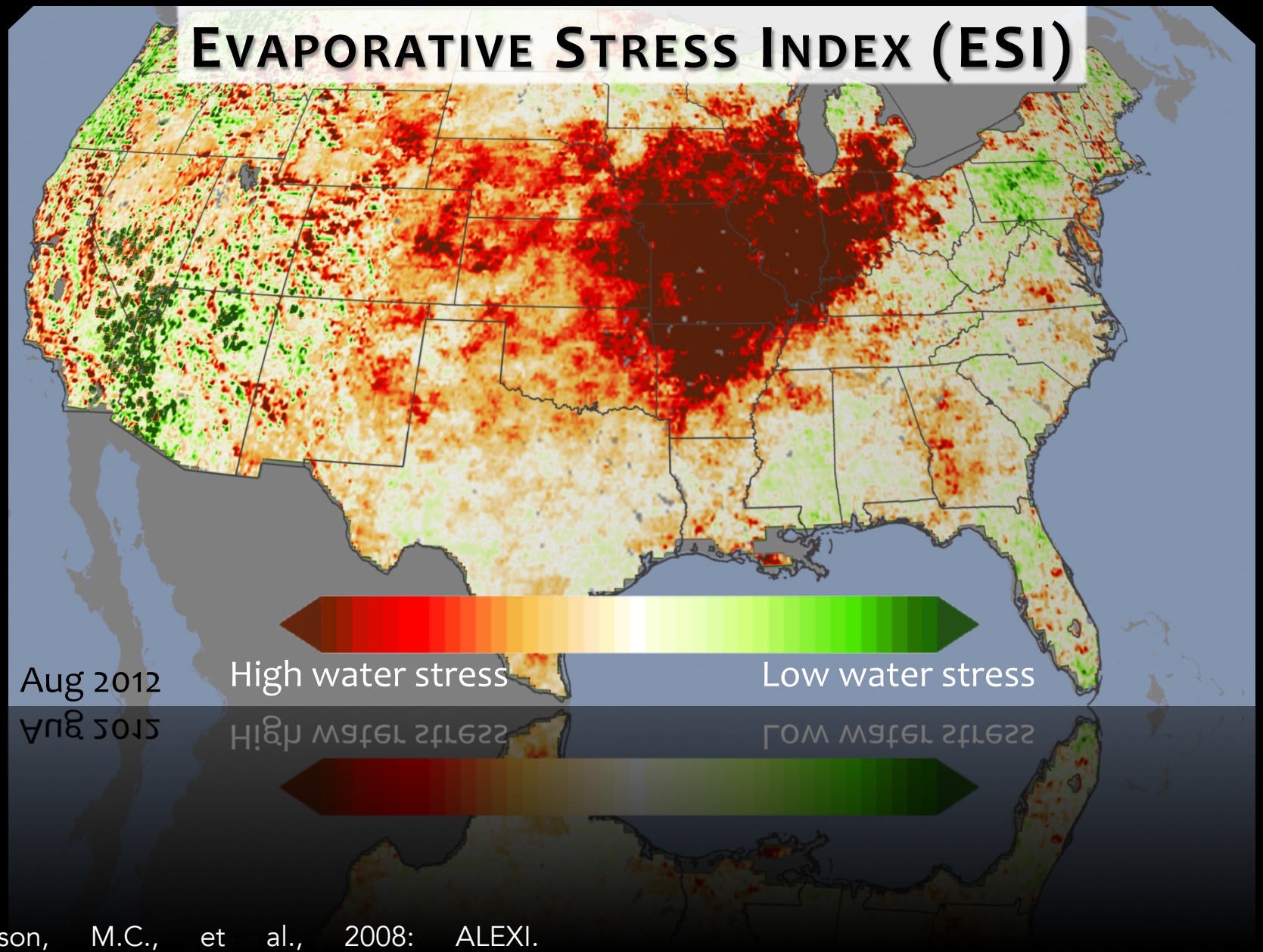
Monthly Average of PT-JPL Daily Integrated Latent Heat Flux



1 2 3 4 5 6 7 8 9 10 12 13

J F M A M J J A S O N D

Evaporative Stress Index (ESI)



Anderson, M.C., et al., 2008: ALEXI. *Remote Sensing of Environment.*

Science Algorithms: L3(ET_PT-JPL)

Geosci. Model Dev. Discuss., 8, 6809–6866, 2015
www.geosci-model-dev-discuss.net/8/6809/2015/
doi:10.5194/gmdd-8-6809-2015
© Author(s) 2015. CC Attribution 3.0 License.

Geoscientific Model Development
Discussions

This discussion paper is/has been under review for the journal Geoscientific Model Development (GMD). Please refer to the corresponding final paper in GMD if available.

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

M. F. McCabe[1], A. Ershadi[1], C. Jimenez[2], D. G. Miralles[3], D. Michel[4], and E. F. Wood[5]

Agricultural and Forest Meteorology 187 (2014) 46–61
Contents lists available at ScienceDirect
Agricultural and Forest Meteorology
journal homepage: www.elsevier.com/locate/agrformet

Multi-site evaluation of terrestrial evaporation models using FLUXNET data

A. Ershadi[a,*], M.F. McCabe[b], J.P. Evans[c,d], N.W. Chaney[e], E.F. Wood[e]

Remote Sensing of Environment 115 (2011) 801–823
Contents lists available at ScienceDirect
Remote Sensing of Environment
journal homepage: www.elsevier.com/locate/rse

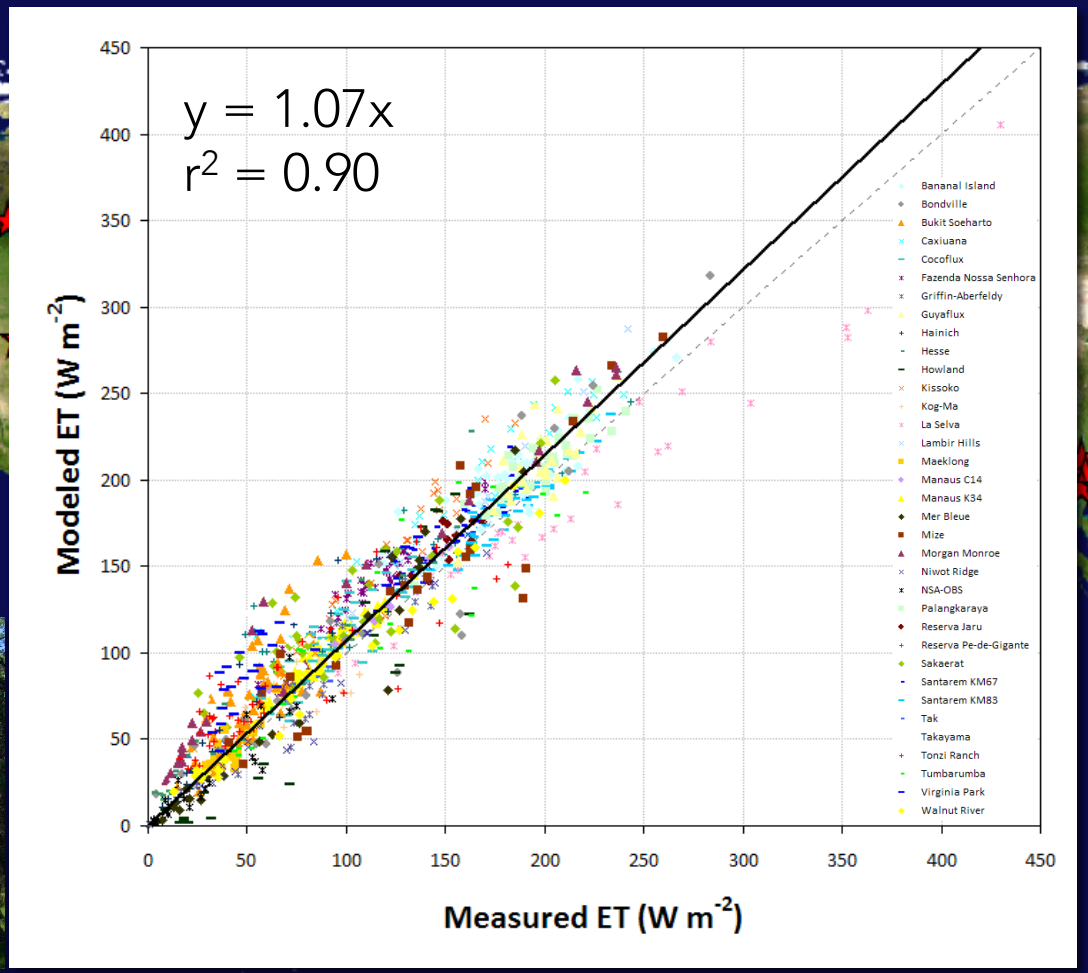
Global estimates of evapotranspiration for climate studies using multi-sensor remote sensing data: Evaluation of three process-based approaches

Raghuveer K. Vinukollu[a,*], Eric F. Wood[a], Craig R. Ferguson[a], Joshua B. Fisher[b]

Manuscript prepared for Hydrol. Earth Syst. Sci.
with version 2015/04/24 7.83 Copernicus papers of the LaTeX class copernicus.cls.
Date: 4 September 2015

The WACMOS-ET project - Part 1: Tower-scale evaluation of four observation-based evapotranspiration algorithms

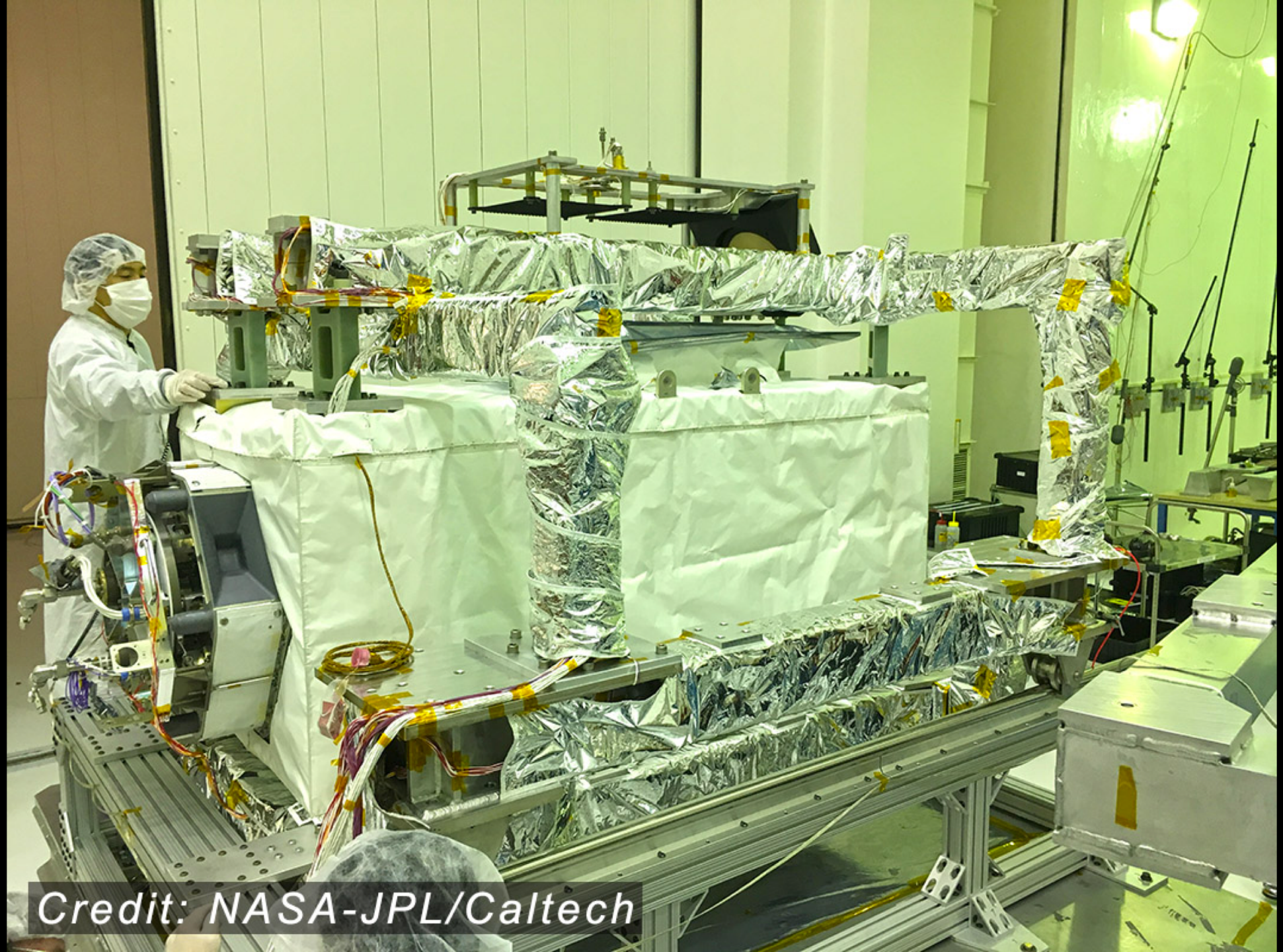
D. Michel[1], C. Jiménez[2,3], D.M. Miralles[4,5], M. Jung[6], M. Hirschi[1], A. Ershadi[7], B. Martens[5], M.F. McCabe[7], J.B. Fisher[8], Q. Mu[9], Z. Su[10], S.I. Seneviratne[1], E.F. Wood[11], and D. Fernández-Prieto[12]

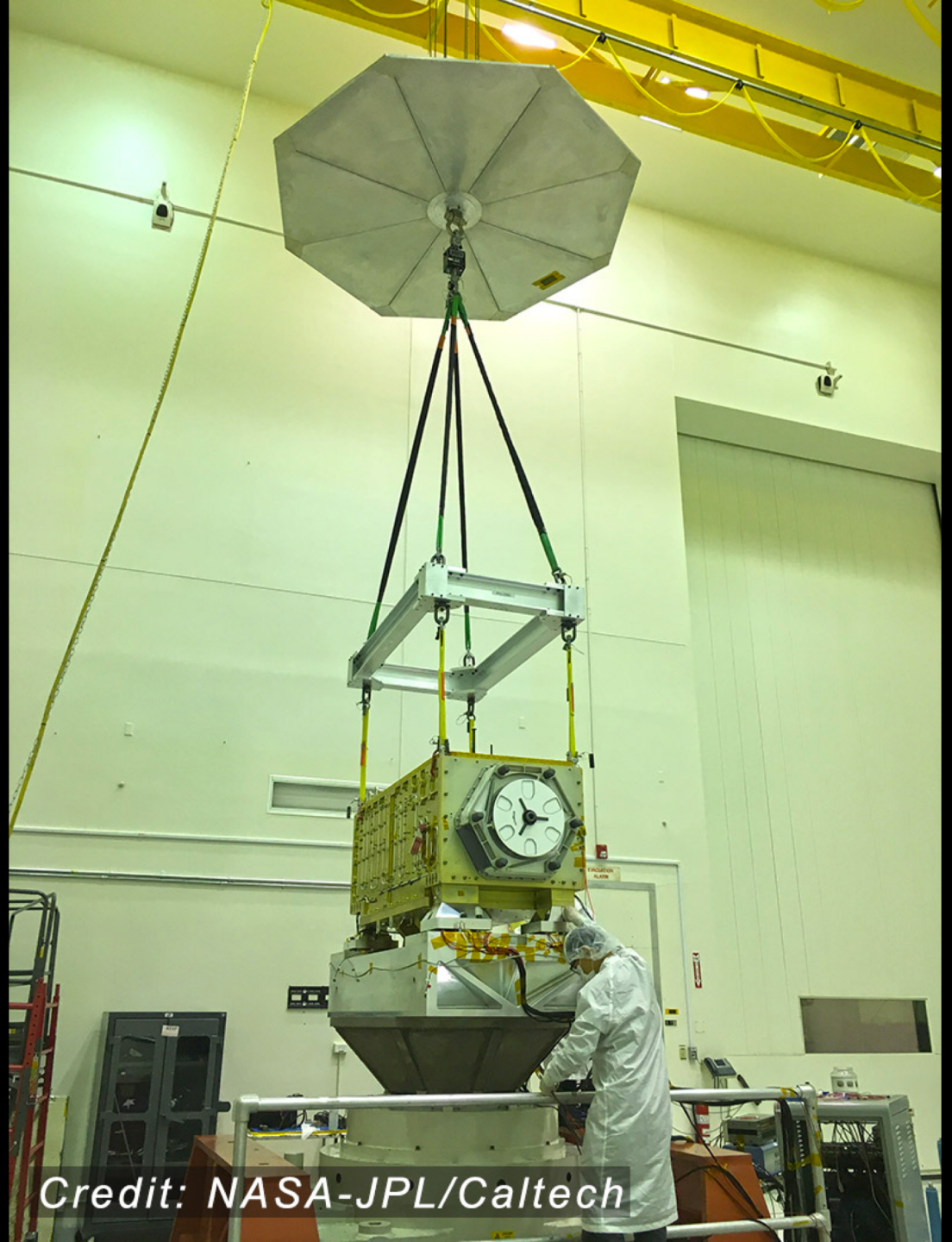


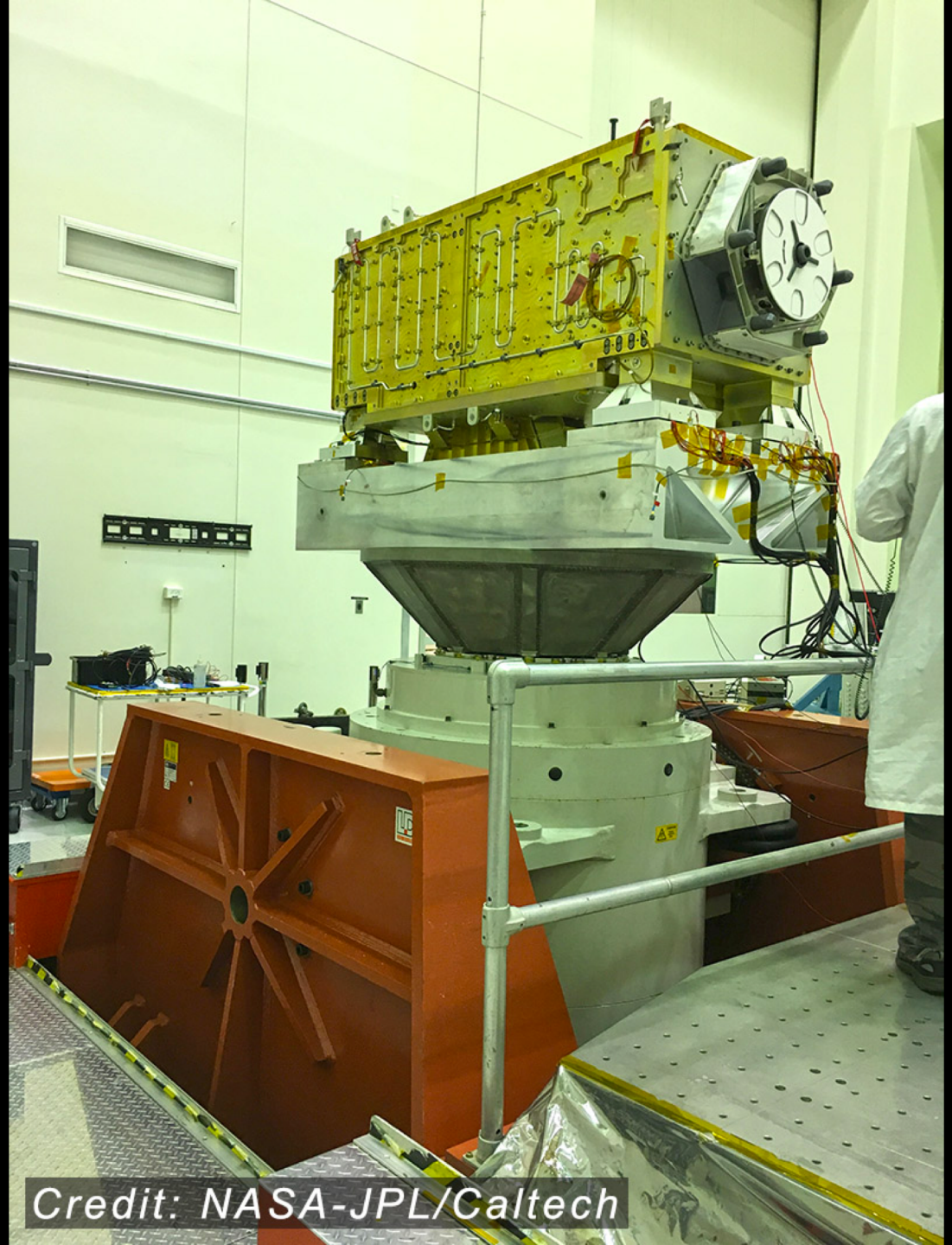
stations as independent metrics of performance, the tower-based analysis indicated that PT-JPL provided the highest overally statistical performance (0.72; 61 W m^{-2}; 0.65), followed closely by GLEAM (0.68; 64 W m^{-2}; 0.62), with values in parenthe-

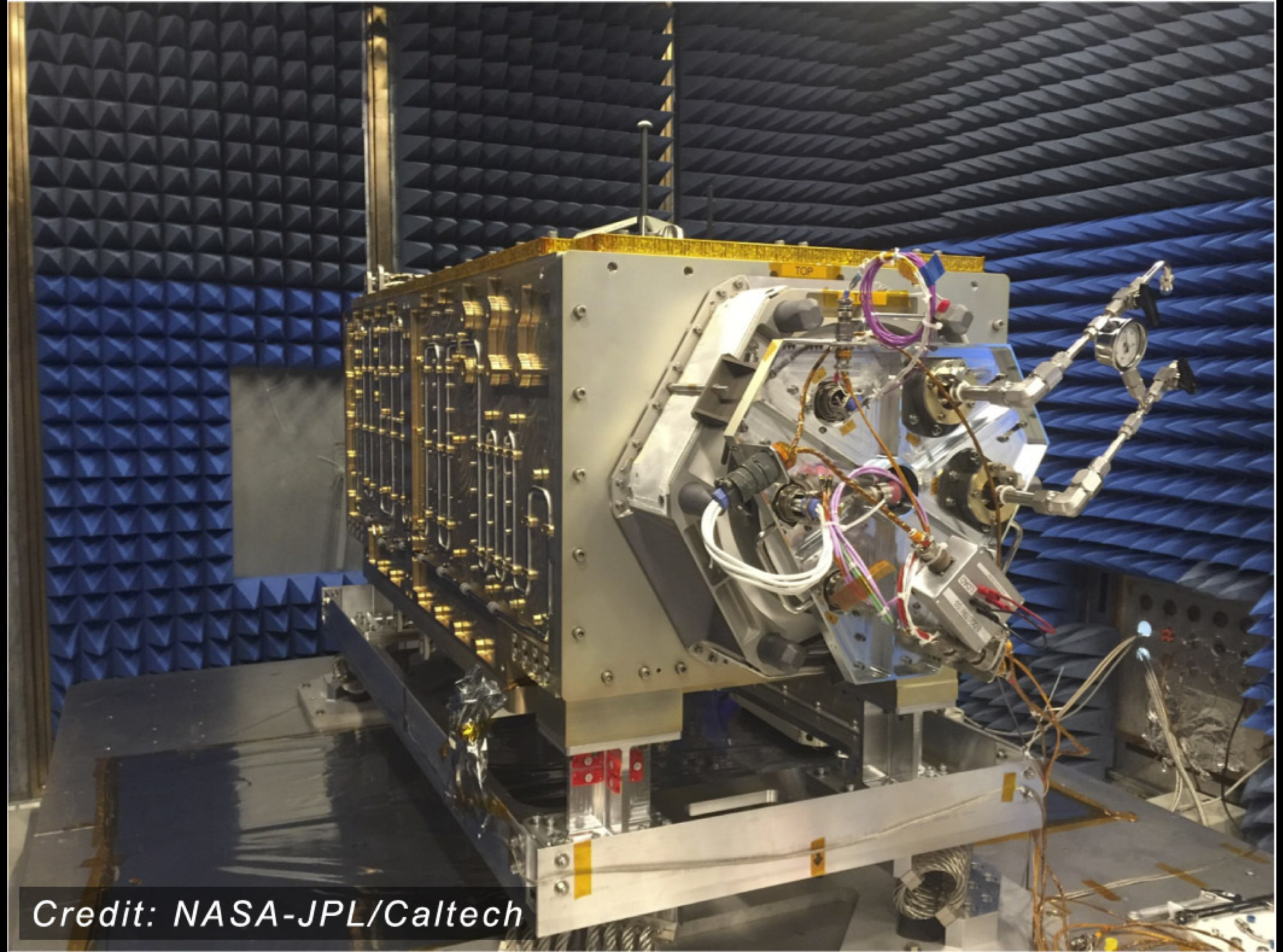
Fisher, J.B., Tu, K.P., Baldocchi, D.D., 2008. *Remote Sensing of Environment.*

Credit: NASA-JPL/Caltech


Credit: NASA-JPL/Caltech


Credit: NASA-JPL/Caltech


Credit: NASA-JPL/Caltech



Credit: NASA-JPL/Caltech

29 JUN 2018: 5.30am

CRS-15 Mission
T- 00:00:10
UPCOMING
LIFTOFF
STARTUP
THE FALCON 9 FLIGHT COMPUTERS HAVE TAKEN CONTROL OF THE COUNTDOWN
LAUNCH: CRS-15
STARTUP
MAX-Q
SECOND ENGINE STARTUP
DRAGON DEPLOY
SPACEX

TESLARATI
@_tom.cross_

Latest | Related

Four Other Things ECOSTRESS Can See
a month ago

Watching Plants' Water Use Is No Sweat for ECOSTRESS
a month ago

New NASA Mission to Detect Plant Water Use from Space
a month ago

GRACE-FO Turns on 'Range Finder,' Sees Mountain Effects
a month ago

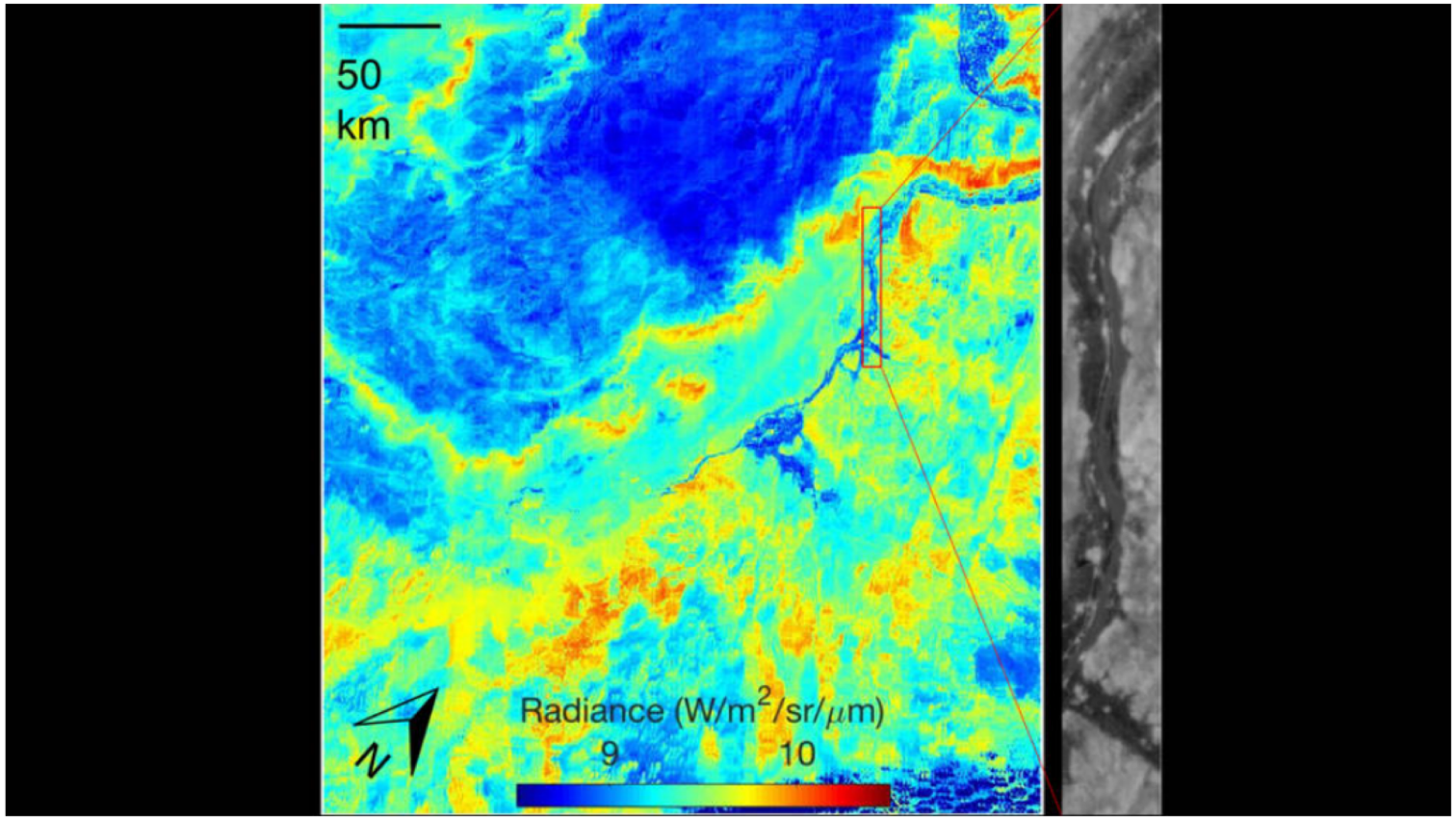
NASA's New Space 'Botanist' Arrives at Launch Site
3 months ago

Dust on Snow Controls Springtime River Rise in West
6 months ago

ECOSTRESS

July 23, 2018

NASA's 'Space Botanist' Gathers First Data



ECOSTRESS acquired this image the night of July 9 over Egypt. Yellow and red indicate generally higher temperatures. The River Nile is visible as a thin blue line on the main image. The black-and-white inset shows the level of detail available from ECOSTRESS, with the relatively cool Nile River and surrounding vegetation appearing darker.
Credits: NASA/JPL-Caltech
Full image and caption

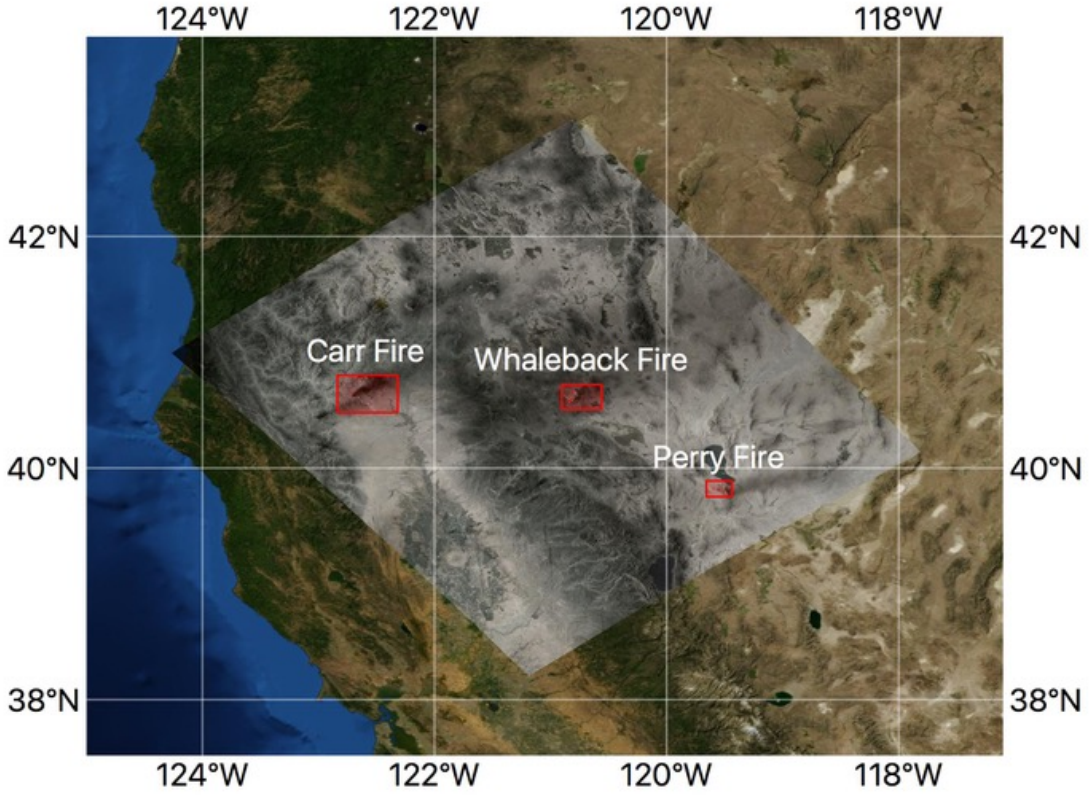
Just days after its successful installation on the International Space Station, NASA's newest Earth-observing mission, the ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS), has collected its first science data on Earth's surface temperature.

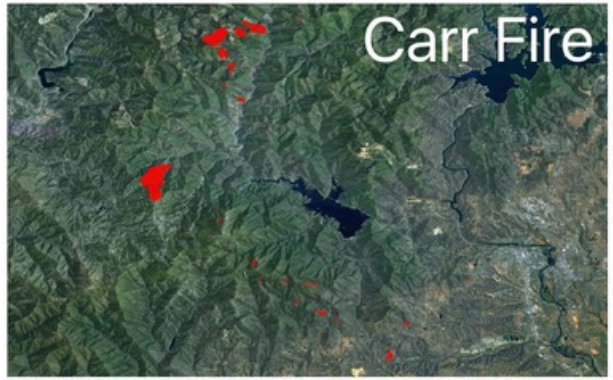
Carr, Whaleback, and Perry Fires as seen by ECOSTRESS 28 July 2018 18:45 PST

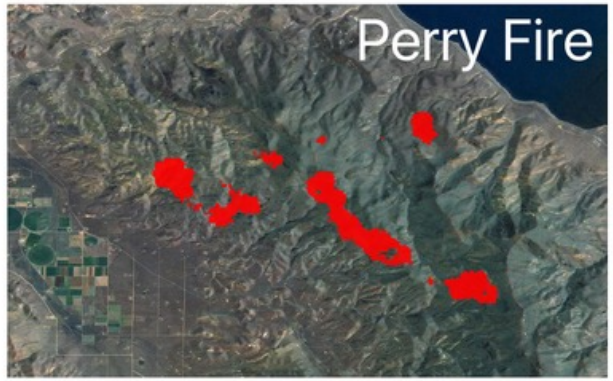
Band 4 Radiance Centered at 10.5 µm

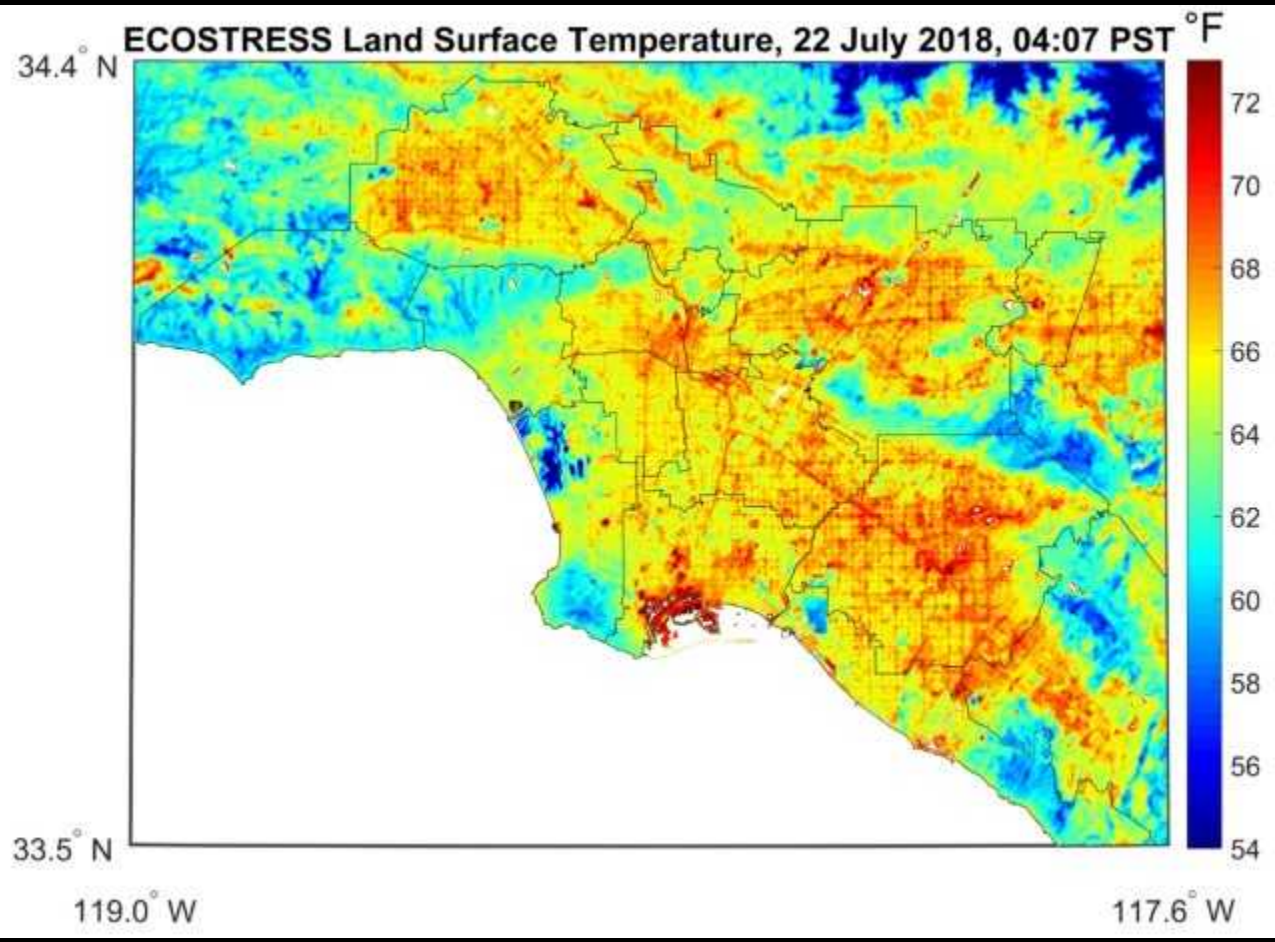
8 W m^{-2} sr^{-1} μm^{-1} 12

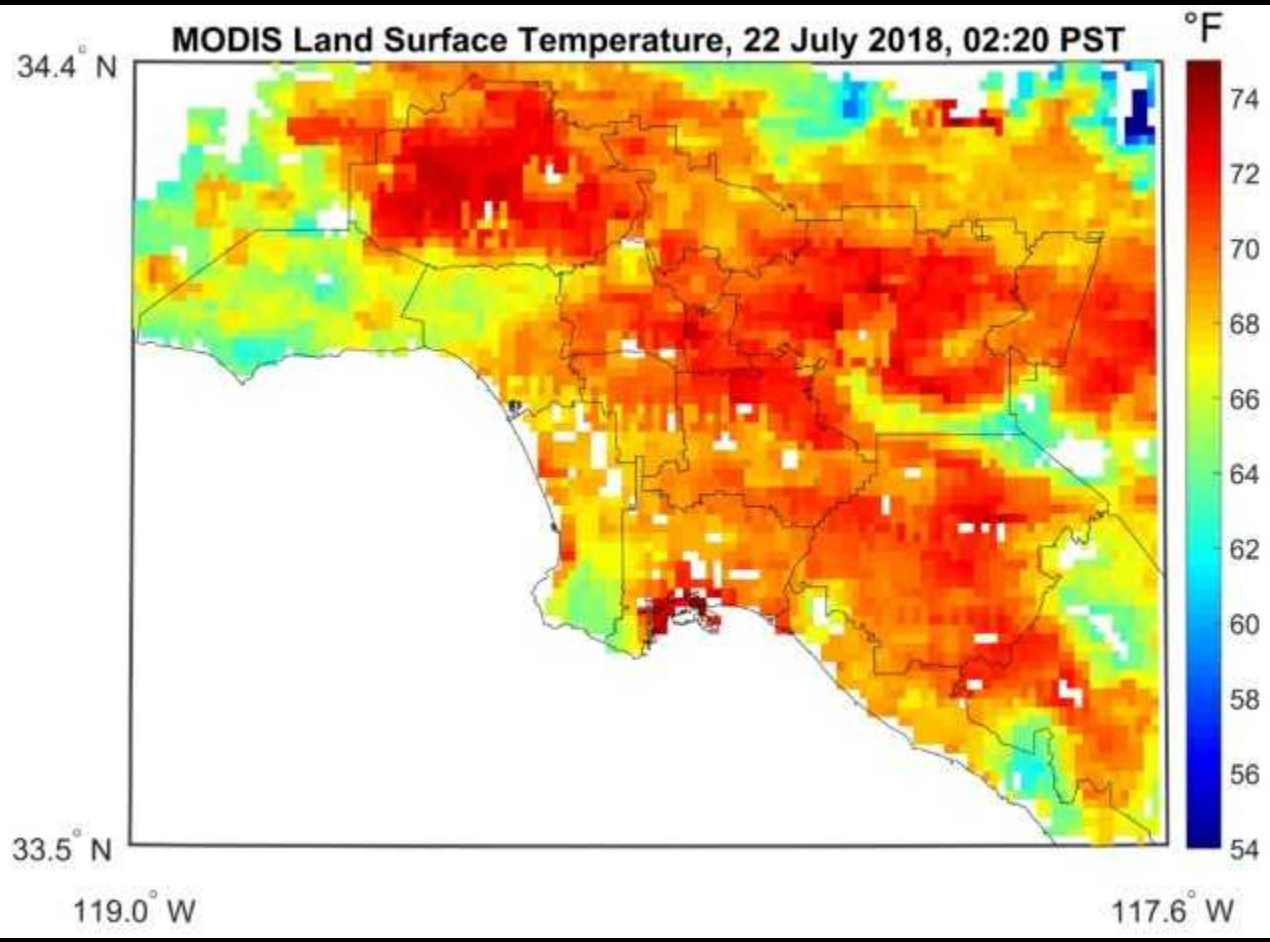
Fire > 12



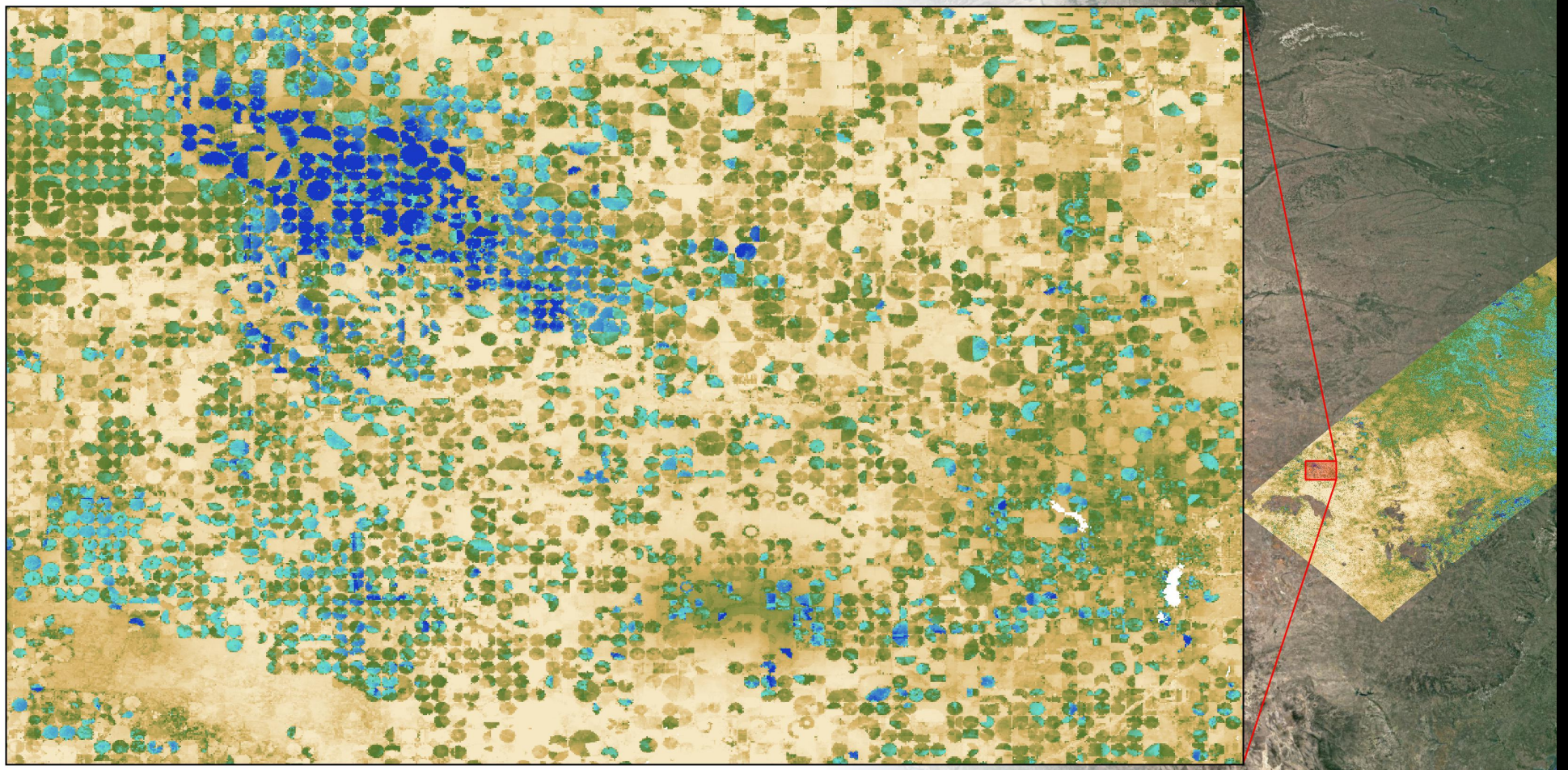





ECOSTRESS Land Surface Temperature, 22 July 2018, 04:07 PST
°F
72
70
68
66
64
62
60
58
56
54
34.4° N
33.5° N
119.0° W
117.6° W

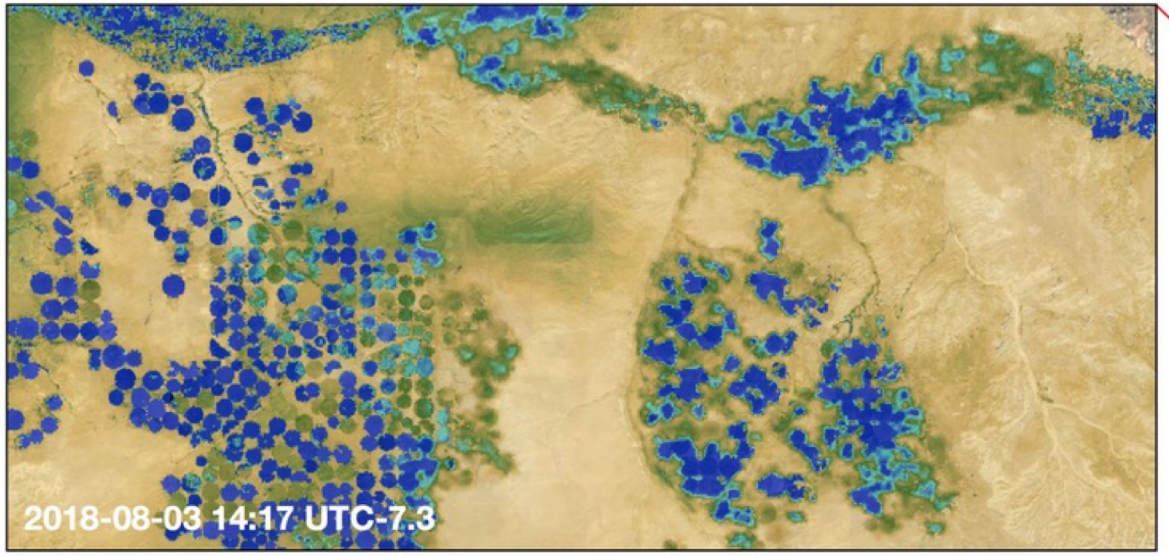

MODIS Land Surface Temperature, 22 July 2018, 02:20 PST
°F
74
72
70
68
66
64
62
60
58
56
54
34.4° N
33.5° N
119.0° W
117.6° W

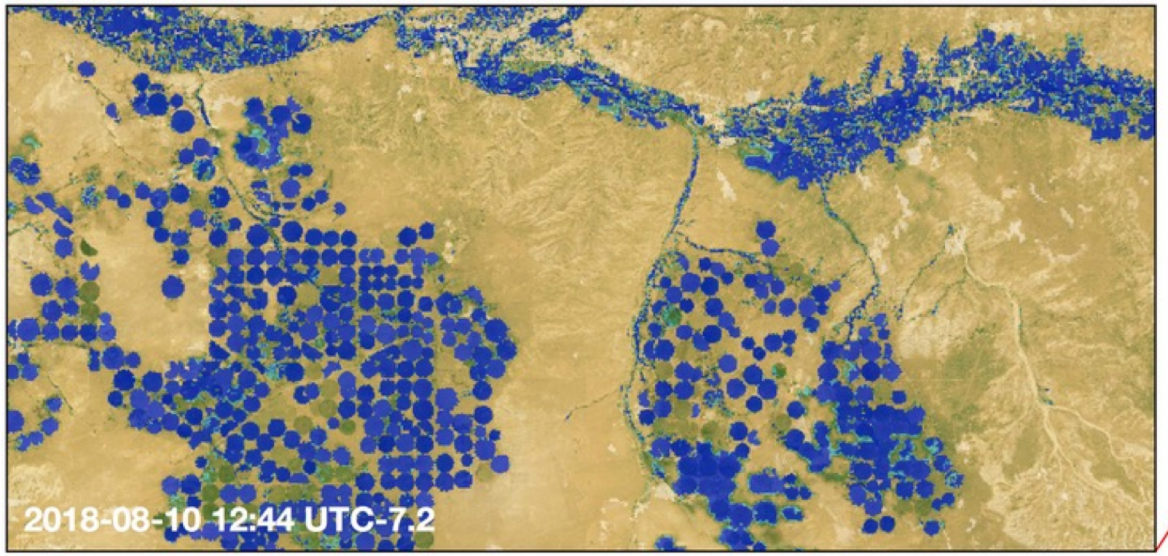
ECOSTRESS L3 (ET PT-JPL) 2018-07-29 18:19 CDT



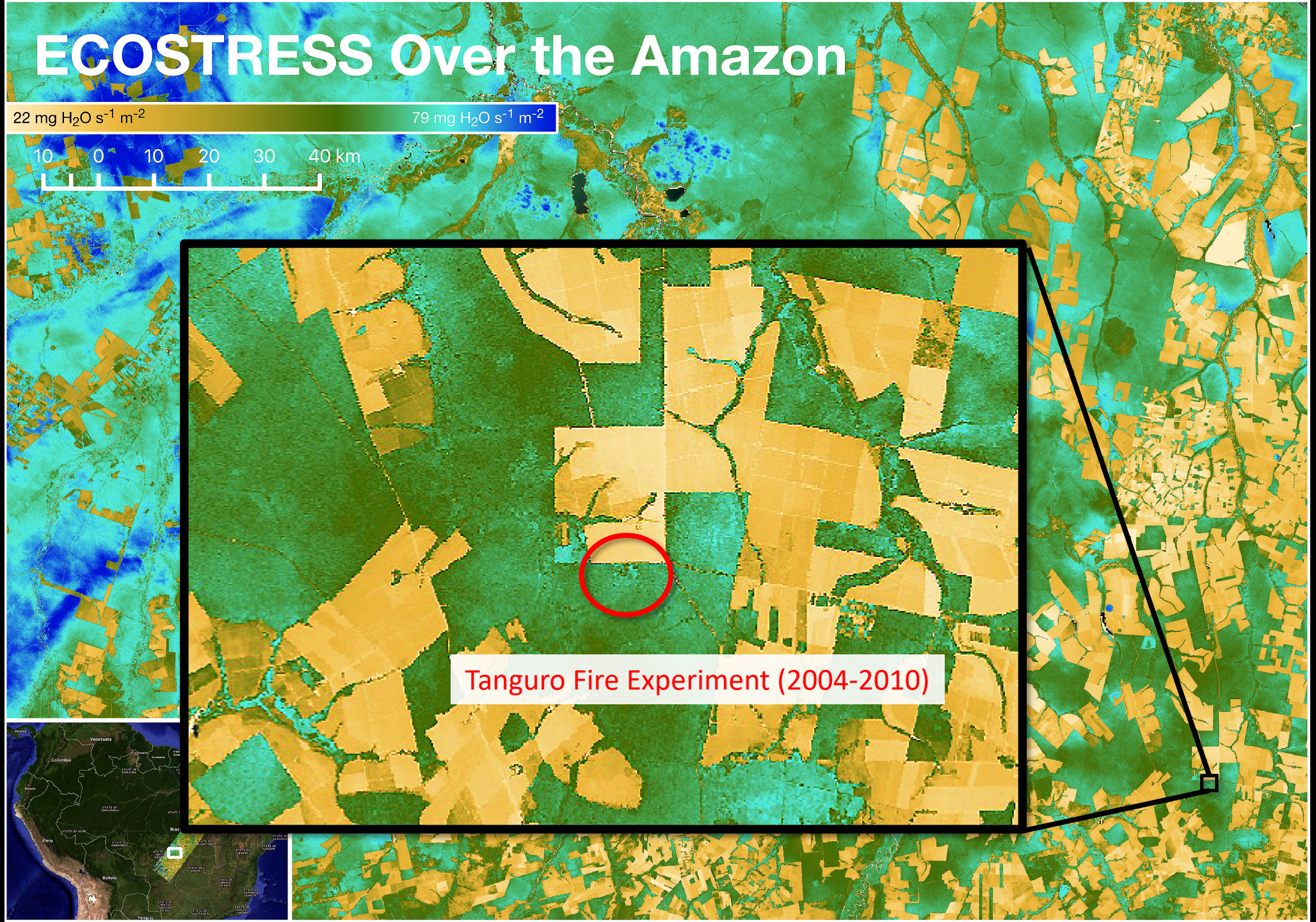
0.02 g H_2O s^{-1} m^{-2} — 0.16 g H_2O s^{-1} m^{-2}

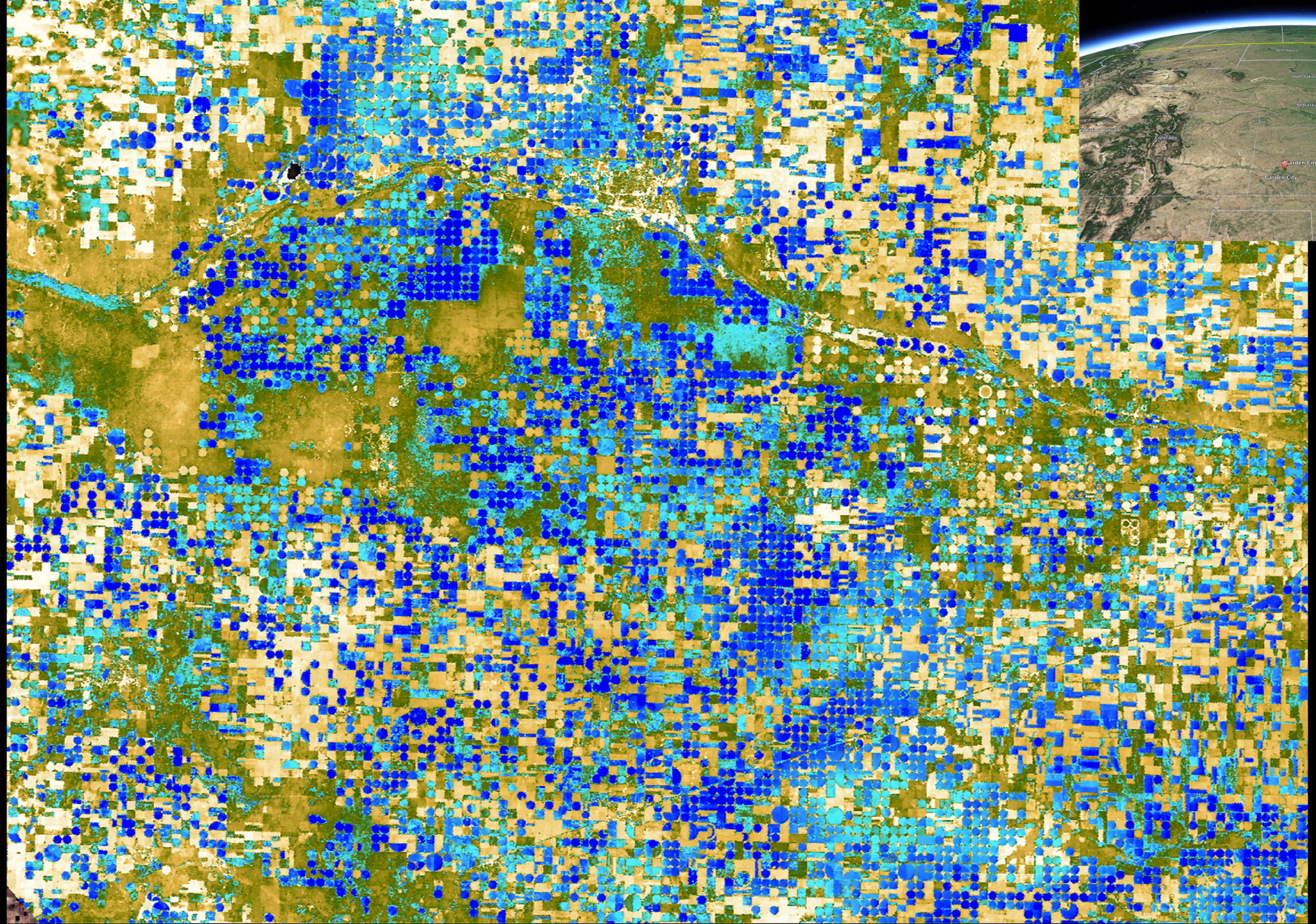
Changes in Navajo Pivot Irrigation Field ET Seen in One Week by ECOSTRESS

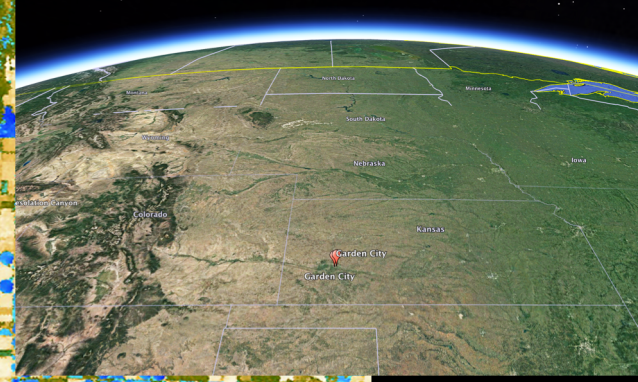


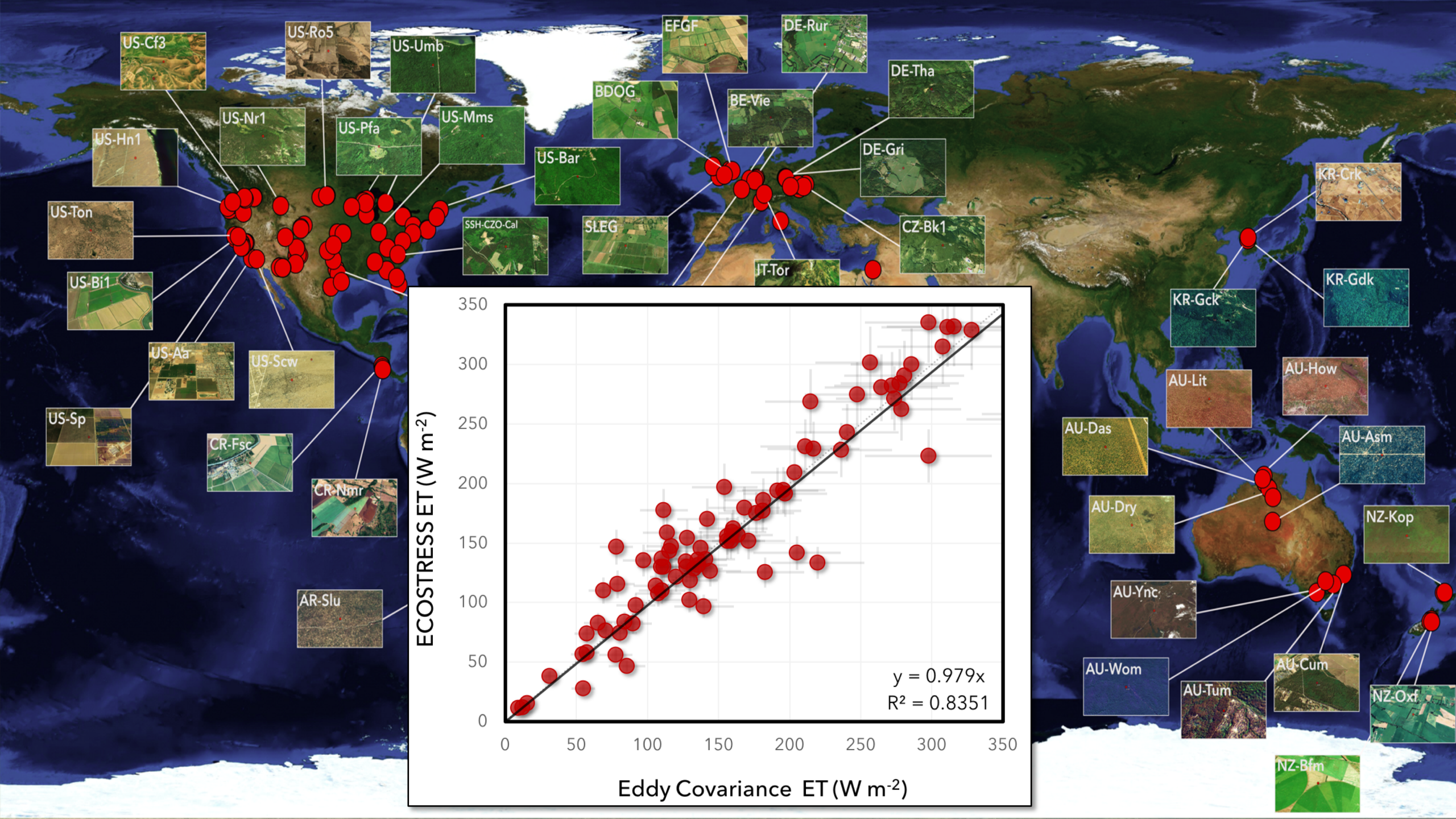


ECOSTRESS Over the Amazon






North Dakota
Minnesota
South Dakota
Nebraska
Iowa
Colorado
Kansas
Garden City
Garden City


US-Cf3
US-Ro5
US-Umb
EFGF
DE-Rur
DE-Tha
BDOG
BE-Vie
US-Nr1
US-Hn1
US-Pfa
US-Mms
US-Bar
DE-Gri
KR-Crk
US-Ton
SSH-CZO-Cal
SLEG
CZ-Bk1
IT-Tor
KR-Gdk
US-Bi1
KR-Gck
US-Aa
US-Scw
AU-How
AU-Lit
AU-Das
AU-Asm
US-Sp
CR-Fsc
AU-Dry
NZ-Kop
CR-Nmr
AU-Ync
AR-Slu
AU-Wom
AU-Cum
AU-Tum
NZ-Oxf
NZ-Bfm
ECOSTRESS ET (W m-2)
Eddy Covariance ET (W m-2)
y = 0.979x
R² = 0.8351
0
50
100
150
200
250
300
350

Jim Bridenstine @JimBridenstine · Aug 27

The #ECOSTRESS team is doing critical work to better understand how plants react to heat and water stress by measuring the temperature of Earth's vegetation. Great job!

NASA Earth and NASA JPL

THE FUTURE OF
EVAPOTRANSPIRATION
Global requirements for ecosystem functioning, carbon and climate feedbacks,
agricultural management, and water resources.