HyspIRI Thermal & ECOSTRESS

Presented at:

HyspIRI Symposium

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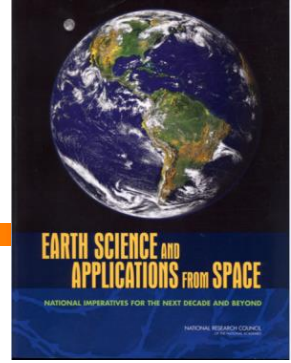
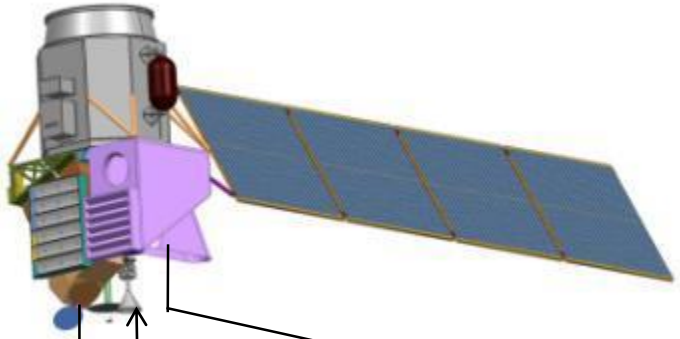
Outline

- HyspIRI Thermal
- ECOSTRESS (ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station)
- Summary and Conclusions

NRD Decadal Survey
HyspIRI Mission Concept



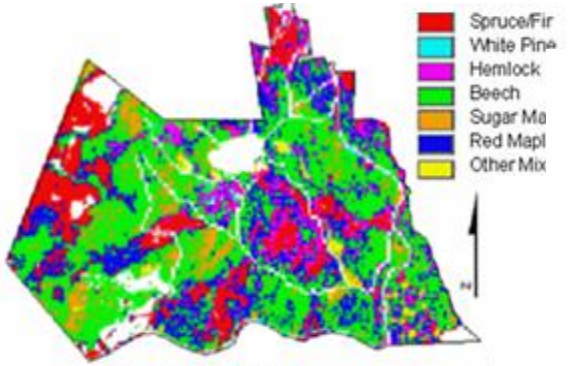


Visible ShortWave InfraRed (VSWIR) Imaging Spectrometer

Multispectral Thermal InfraRed (TIR) Scanner

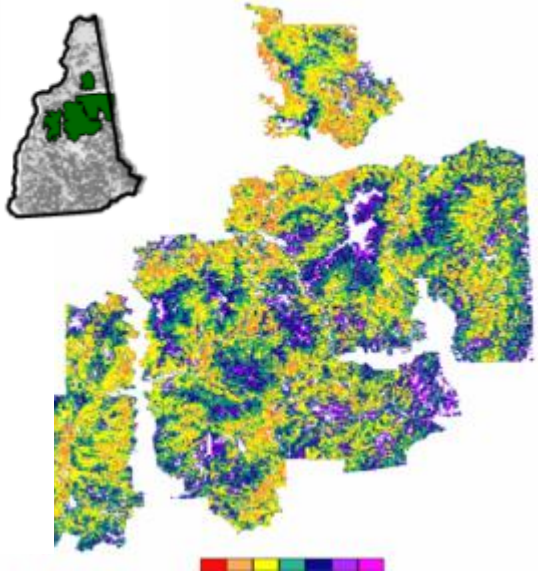
IPM Low Latency Data

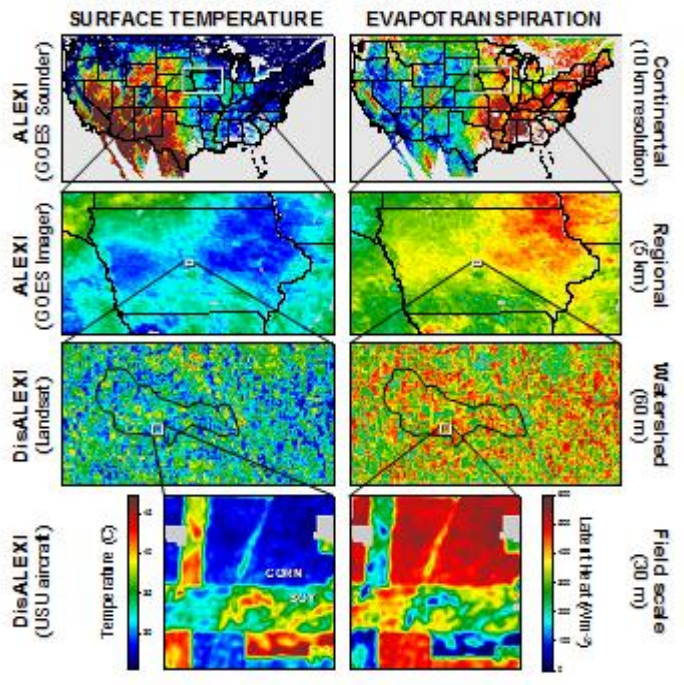
Map of dominant tree species, Bartlett Forest, NH



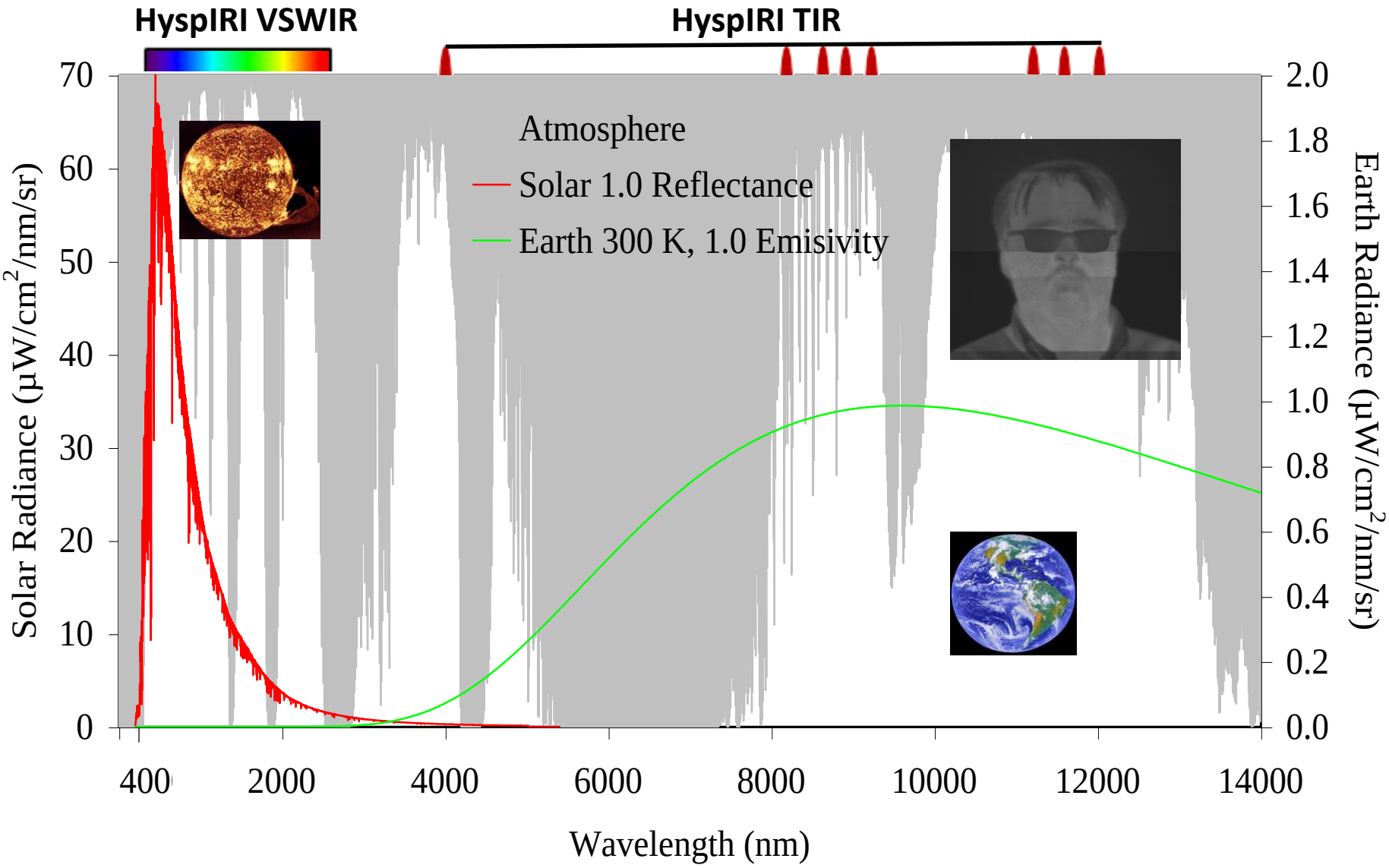
Soil C:N Ratio

White Mountain National Forest, NH





HyspIRI Measures the Optical Spectrum



HyspIRI Thermal Infrared (TIR) Multispectral Science Measurements

Science Questions:

TQ1. Volcanoes/Earthquakes

– How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?

• TQ2. Wildfires

– What is the impact of global biomass burning on the terrestrial biosphere and atmosphere, and how is this impact changing over time?

• TQ3. Water Use and Availability

– How is consumptive use of global freshwater supplies responding to changes in climate and demand, and what are the implications for sustainable management of water resources?

• TQ4. Urbanization/Human

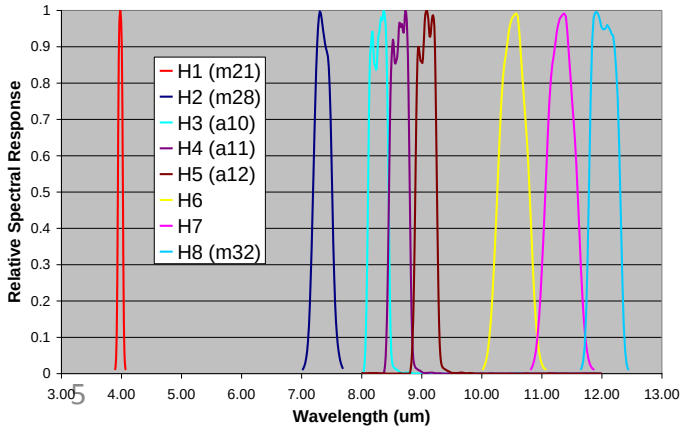
– How does urbanization affect the local, regional and global environment? Can we characterize this effect to help mitigate its impact on human health and welfare?

• TQ5. Earth surface composition and change

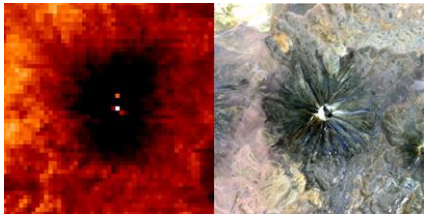
– What is the composition and temperature of the exposed surface of the Earth? How do these factors change over time and affect land use and habitability?

Measurement:

- 7 bands between 7.5-12 µm and 1 band at 4 µm
- 60 m resolution, 5 days revisit
- Global land and shallow water

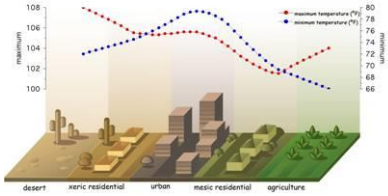


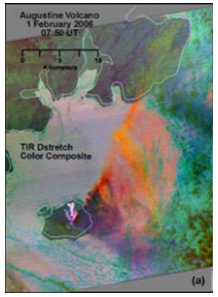
Andean volcano heats up



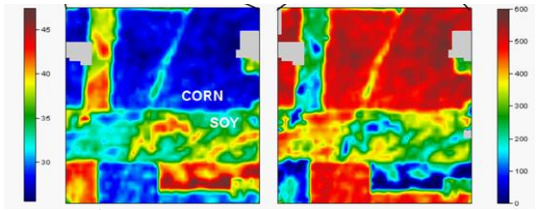
Volcanoes

Urbanization





Water Use and Availability



Surface Temperature

Evapotranspiration

Recent and Upcoming Activities

HyspIRI VSWIR
380 to 2510 nm in
≤10-nm spectral bands
30 m spatial resolution
16 day revisit
Swath width=185 km

+

HyspIRI TIR
8 spectral bands
between 4 and 12 um
60 m spatial resolution
5 day revisit
Swath width=600 km

Updates

1. Exploring increasing swath width so have 4-day revisit
2. Exploring adding SWIR band instead of one of TIR bands
3. Reports (ECOSTRESS STM and HyspIRI Workshop)
4. HyspIRI airborne campaign and HyTES airborne campaigns

ECOSTRESS
5 spectral bands between
8 and 12 um
38x69 m spatial resolution
4 day revisit
Swath width=400 km
Launch=2017

ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

Project Overview

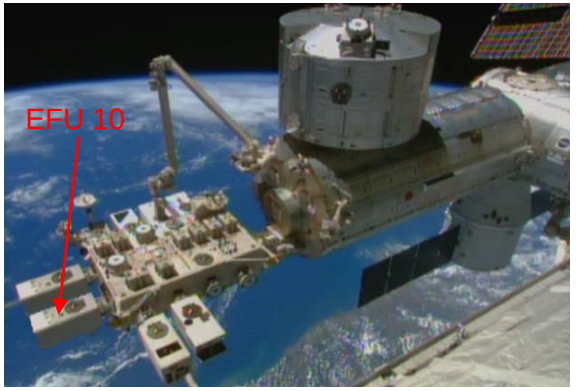
ECOSTRESS is an Earth Venture Instrument-2 on the ISS

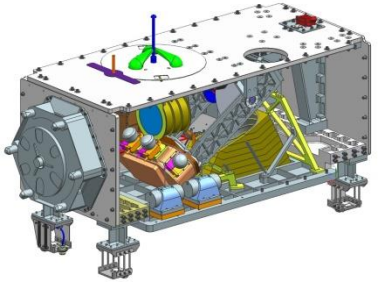
Primary Science Objectives

- Identify critical thresholds of water use and water stress in key climate-sensitive biomes
- Detect the timing, location, and predictive factors leading to plant water uptake decline and cessation over the diurnal cycle
- Measure agricultural water consumptive use over the contiguous United States (CONUS) at spatiotemporal scales applicable to improve drought estimation accuracy

Features:

- $29.9M RY Cat 3/Risk class D per NPR 7120.5E/ NPR 8705.4
- 8–12.5 µm Radiometer with a 400km swath, ~60-m resolution
- Measure brightness temperatures of Earth at selected location
- May 2017 Payload delivery date, Ready for launch August 2017
- Deployed on the ISS on JEM-EFU 10
- Operational life: 1 year after 30 days on-orbit checkout



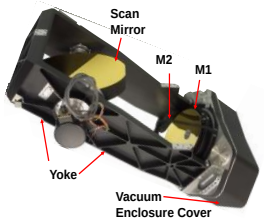


Cal Year	2014	2015	2016	2017	2018
Phase	A	B	C	D	F
Milestone	Start Oct 1	SRR/ MDR	PDR	CDR	TRR	PSR	ORR	Launch

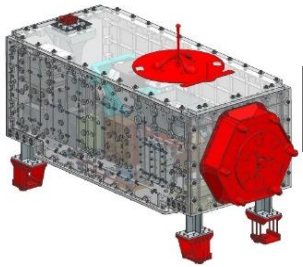
Delivery

Mission Concept

Prototype PHyTIR Instrument

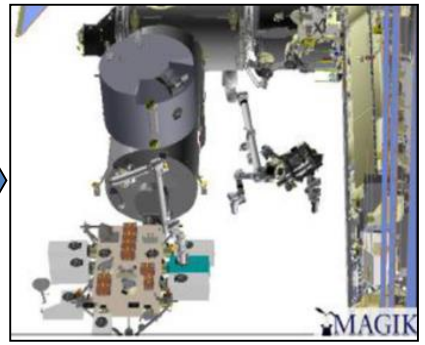


ECOSTRESS Payload

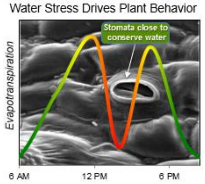


Dragon-Trunk Falcon-9 LV

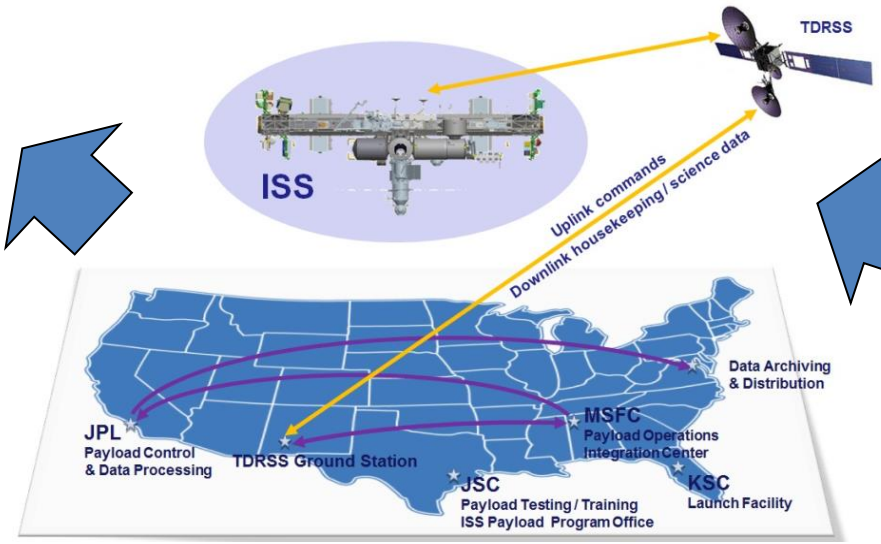
Installation on JEM-EF



Science Data Processing



MOS and Ground and Space Network

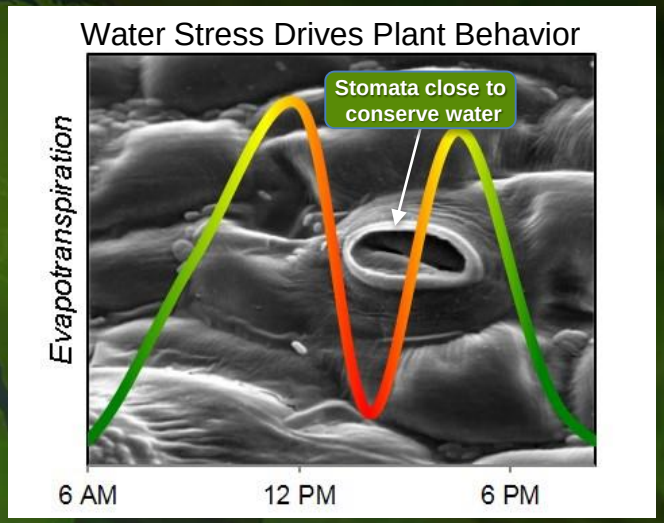


Data Collection

Science Overview

*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 (ET) from the International Space Station (ISS).*

Water stress is quantified by the Evaporative Stress Index, which relies on evapotranspiration measurements.

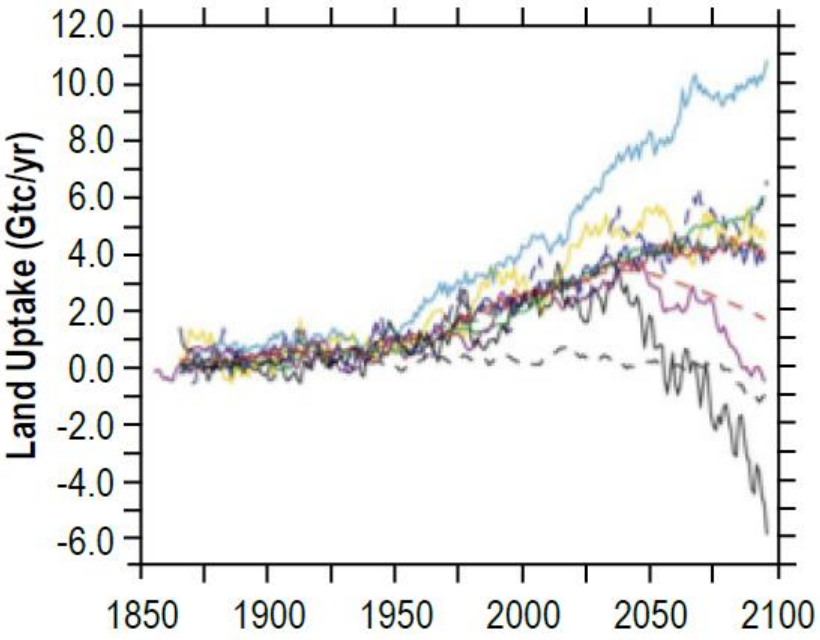


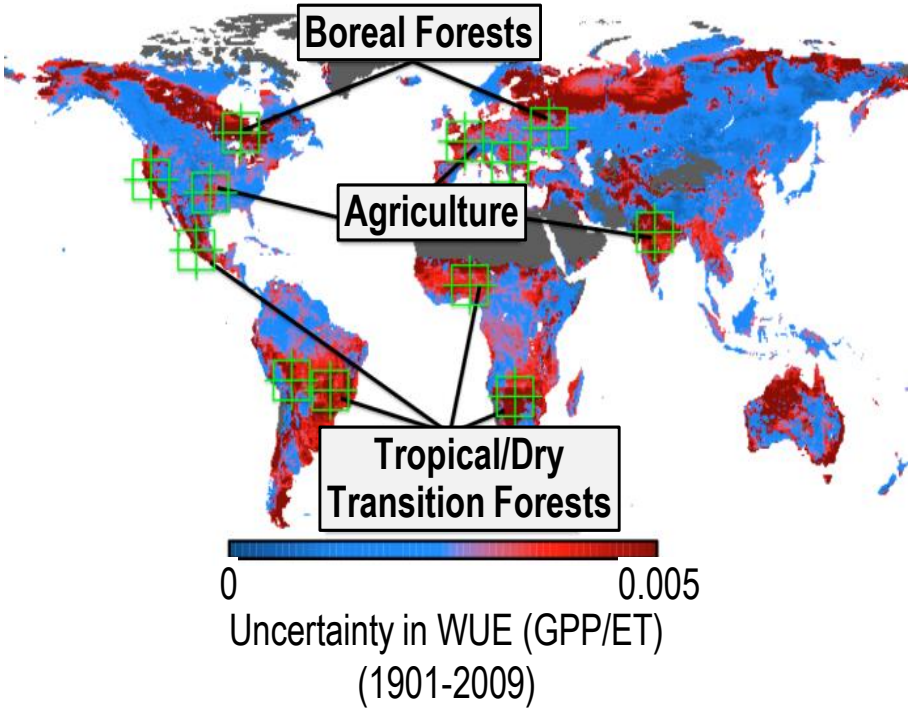
When stomata close, CO_2 uptake and evapotranspiration are halted and plants risk starvation, overheating and death.

Science Objectives

- Identify **critical thresholds of water use and water stress** in key climate-sensitive biomes
- Detect the timing, location, and predictive factors leading to plant **water uptake decline** and/or cessation over the **diurnal cycle**
- Measure **agricultural water consumptive use** over the contiguous United States (CONUS) at spatiotemporal scales applicable to improve drought estimation accuracy

Q1. How is the terrestrial biosphere responding to changes in water availability?

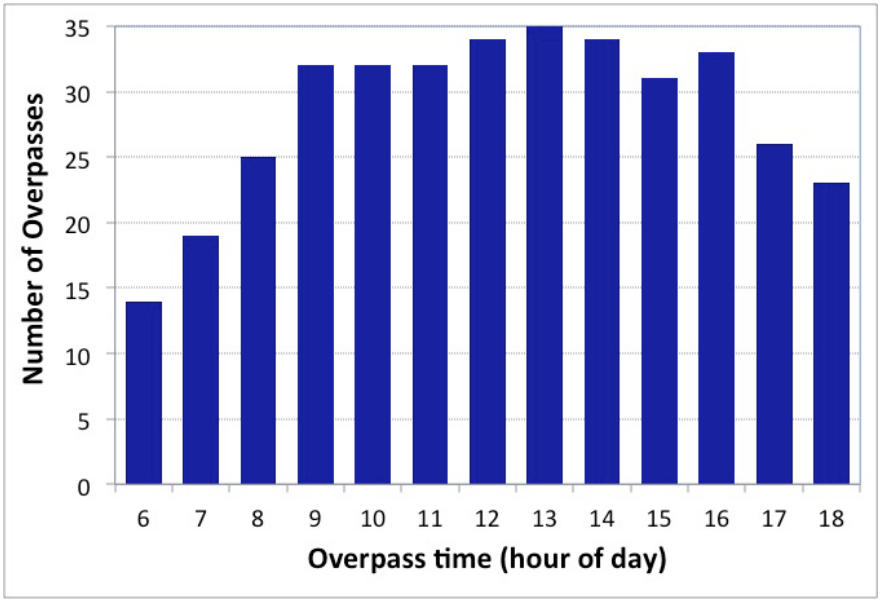




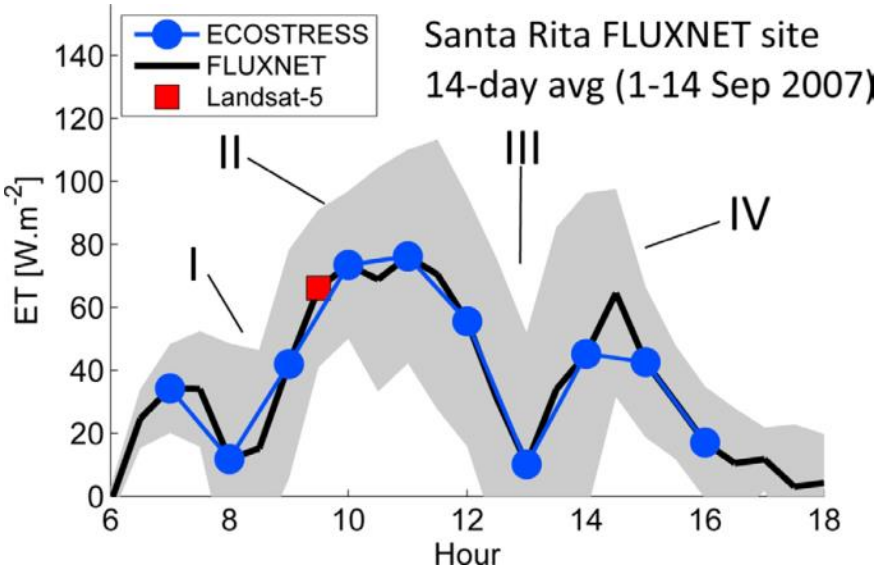
Uncertainty in our knowledge of carbon response is directly dependent on water response uncertainty and how plants use water under drying conditions.

Red areas (“hotspots”) are where global models disagree on water use efficiency (WUE) based biome changes with climate change. ECOSTRESS will reduce this uncertainty with measurements for WUE (GPP/ET).

Q2. How do changes in diurnal vegetation water stress impact the global carbon cycle?



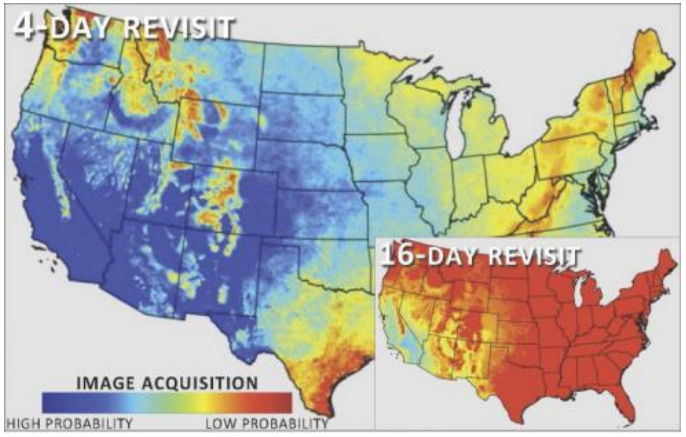
ECOSTRESS acquires numerous samples throughout the day over 1 year (at 50° latitude shown, for example).



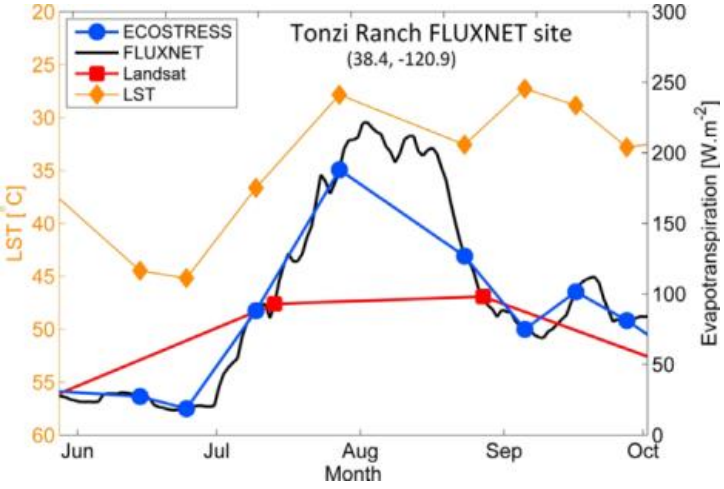
ECOSTRESS's diurnal sampling measures the shape of the daily ET cycle. The afternoon decline in ET is related to water stress (clear day).

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

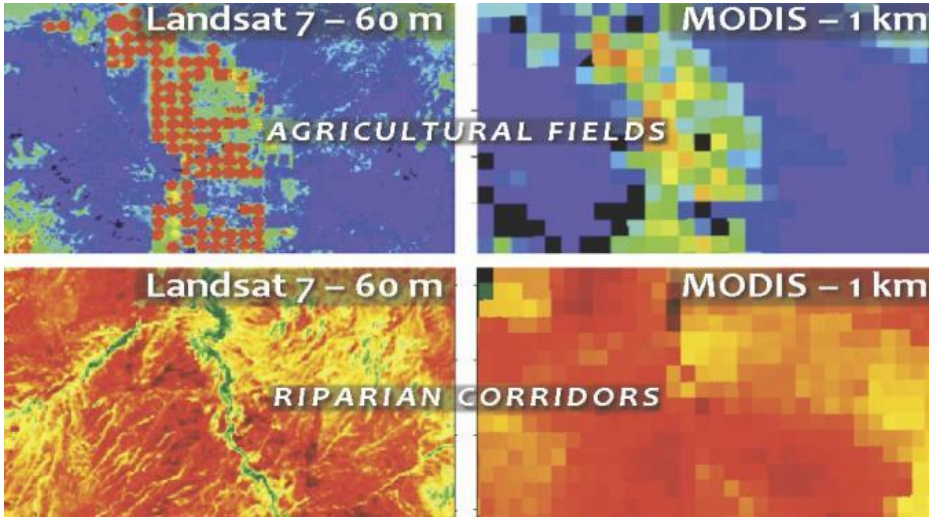
Q3. Can agricultural vulnerability be reduced through advanced monitoring of agricultural water consumptive use and improved drought estimation?



Probability of producing valid ET estimates when satellite revisit time is 16 days (lower-right inset) vs. 4 days



ECOSTRESS's spatial resolution will distinguish fine-scale landscape heterogeneity such as agricultural systems (top) and riparian corridors (bottom) similar to Landsat (left), whereas MODIS (right) does not.



ECOSTRESS's temporal resolution provides a *9-fold* decrease in ET error relative to Landsat.

L1 Science Requirements and Margins

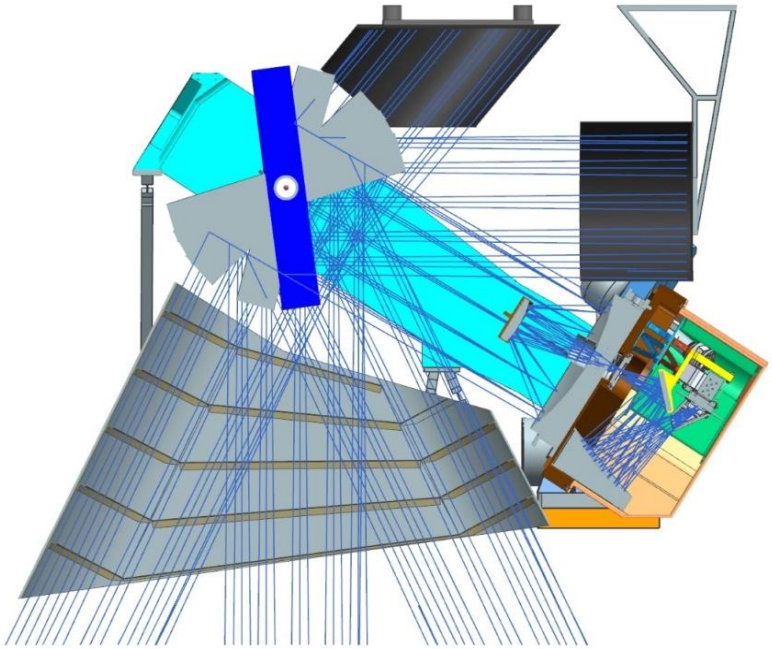
Parameter	Science Requirement (from PLRA)	Current Best Estimate @ 400 km
Ground Sample Distance (m) Crosstrack x Downtrack at nadir	≤ 100 x ≤100	68.5 x 38.5
Swath width (ISS nominal altitude range is 385 to 415 km)	≥ 360	402
Wavelength range (µm)	8-12.5	8-12.5
Number of bands	≥ 3	5
Radiometric accuracy (K @300K)	≤ 1	0.5
Radiometric precision (K @300K)	≤ 0.3	0.15
Dynamic Range (K)	270-335	200-500
Data collection	CONUS, twelve 1,000 x1,000km key climate biomes and twenty-five FLUXNET sites. On average 1 hour of science data per day.	1.5 hours per day of science data

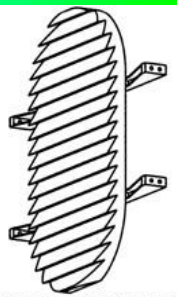
Baseline = Threshold

ECOSTRESS Science Data Products

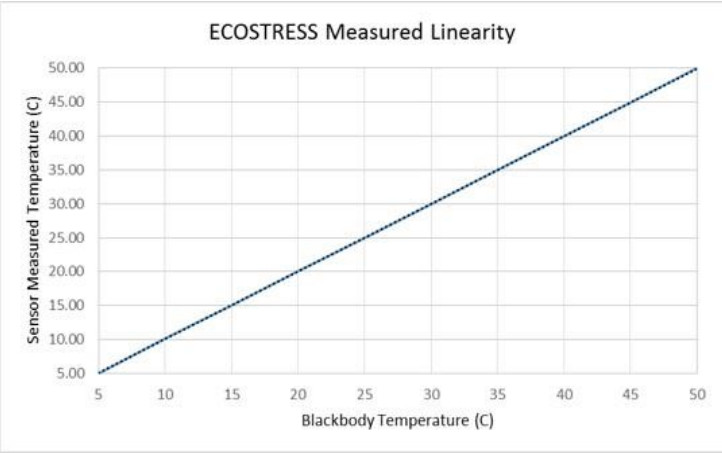
Data Product	Description	Initial Availability to NASA DAAC	Median Latency in Product Availability to NASA DAAC after Initial Delivery	NASA DAAC Location
Level 0	Raw collected telemetry	6 months after IOC	12 weeks	To be assigned by NASA SMD/ESD
Level 1	Calibrated Geolocated Radiances	6 months after IOC	12 weeks	To be assigned by NASA SMD/ESD
Level 2	Surface temperature and emissivity	6 months after Level 1 data products are available	12 weeks	To be assigned by NASA SMD/ESD
Level 3	Evapotranspiration	2 months after Level 2 data products are available	12 weeks	To be assigned by NASA SMD/ESD
Level 4	Water use efficiency and evaporative stress index	2 months after Level 3 data products are available	12 weeks	To be assigned by NASA SMD/ESD

Science Measurement: L1 Brightness Temperature at Sensor

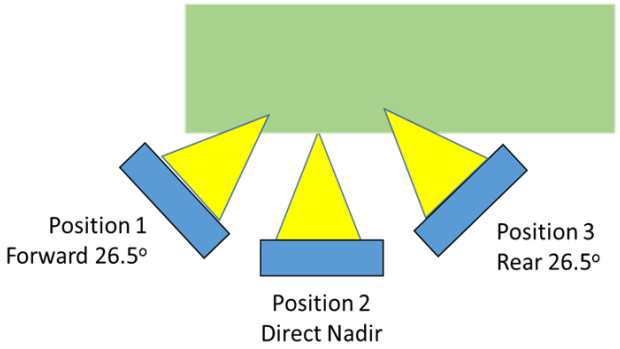




Band	Center (µm)
1	8.28
2	8.63
3	9.07
4	11.35
5	12.05
6	1.6



Actual Temp (C)	Measured Temp (C)	ΔT(C)
50	50.00	0
45	44.85	0.15310
40	39.94	0.06220
35	34.98	0.02400
30	29.98	0.01560
25	24.88	0.12260
20	20.03	-0.02640
15	15.09	-0.09190
10	10.19	-0.18880
5	5.00	0



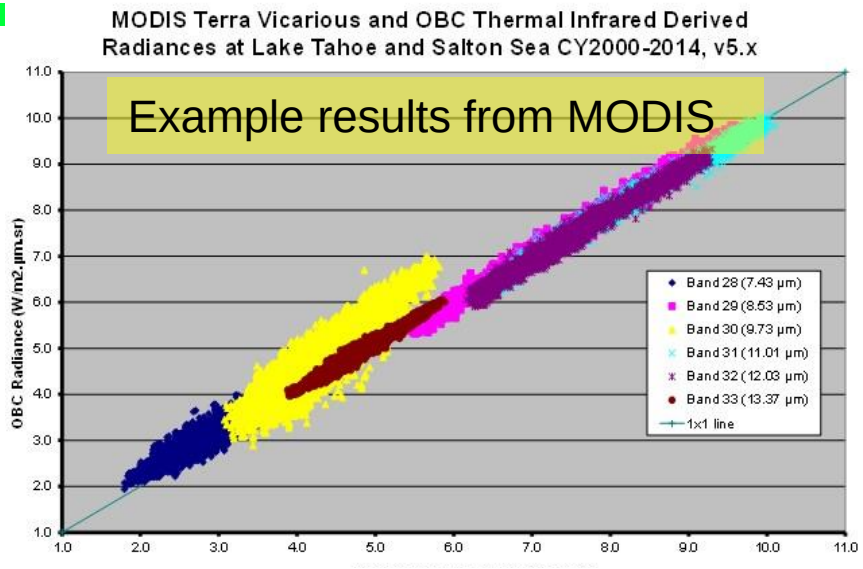
2-point calibration using measurements from this blackbody (5°C and 50°C)

Scene temperature of 25°C measured at each FOV position

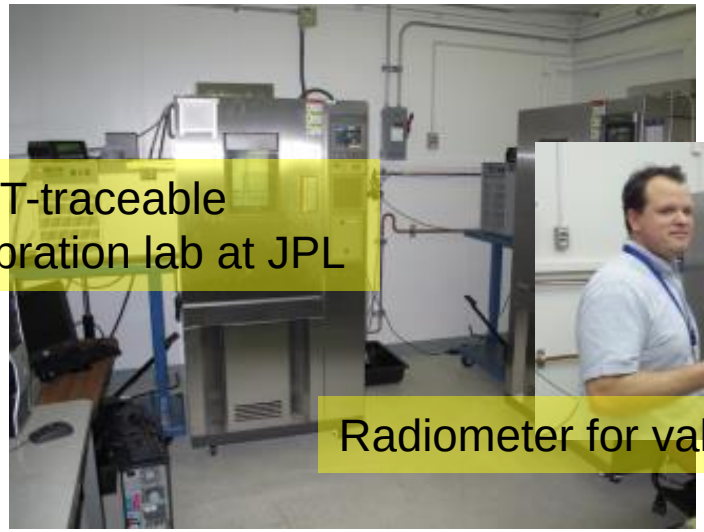
	# Bands	Accuracy	Precision	Uncertainty
PLRA	3	1	0.3	1.04
Measured Capability	5	0.5	0.2	0.54

Brightness Temperature at Sensor : On-orbit Validation

Validation site at Lake Tahoe

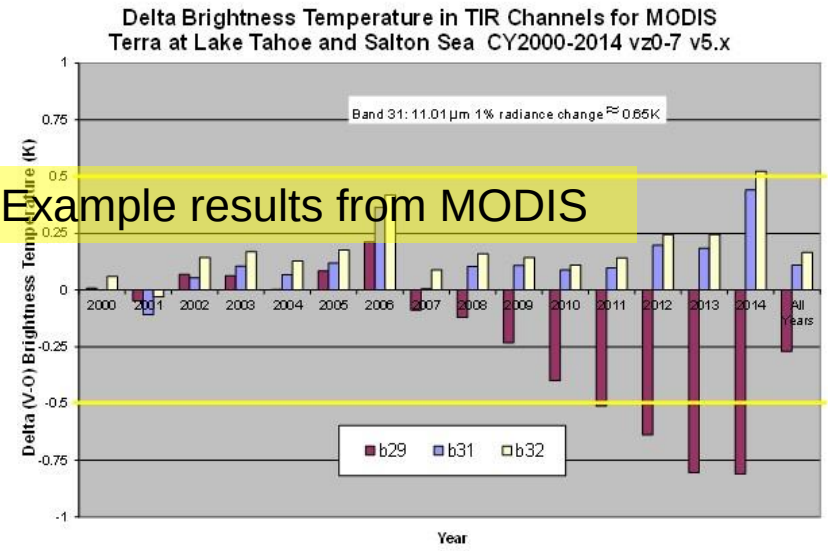


Example results from MODIS



NIST-traceable calibration lab at JPL

Radiometer for validation



Example results from MODIS

Science Measurement: L2 Surface Temperature and Emissivity

L1 Brightness Temperature at Sensor

Calibration

Atmospheric Profiles Water vapor scaling

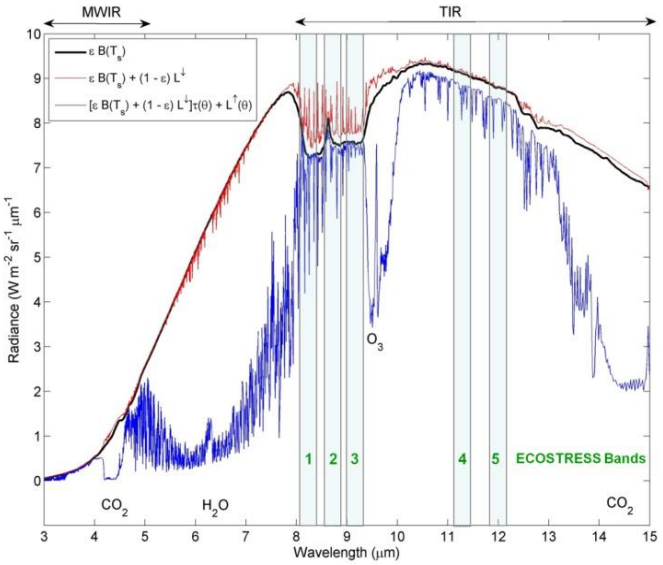
Atmospheric Correction

Emissivity Calibration

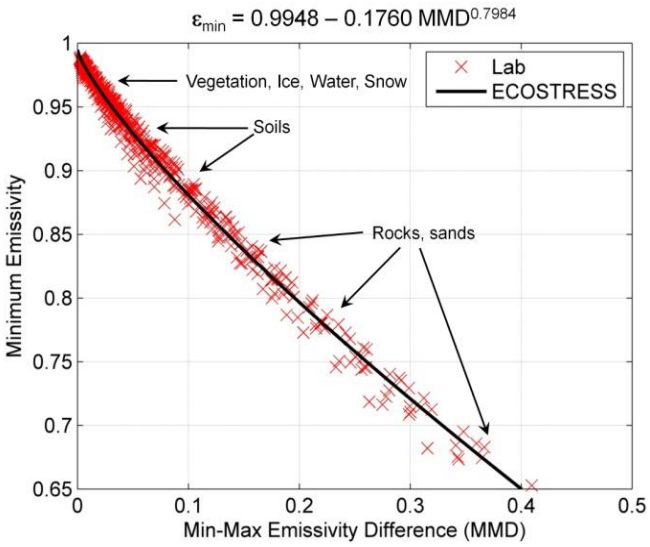
T-E Separation Day/Night or TES

L2 Temperature and Emissivity

Radiative Transfer

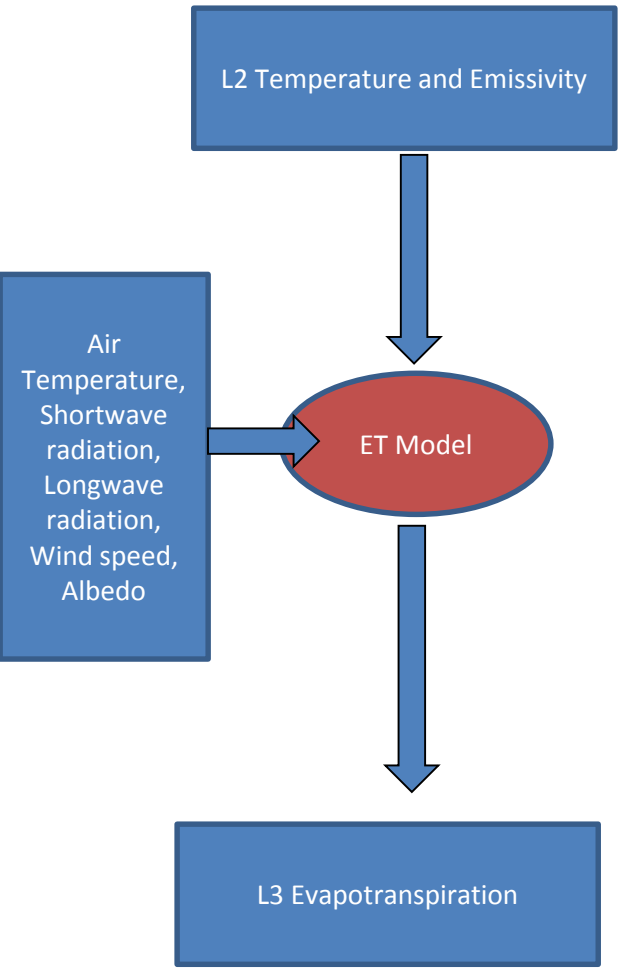


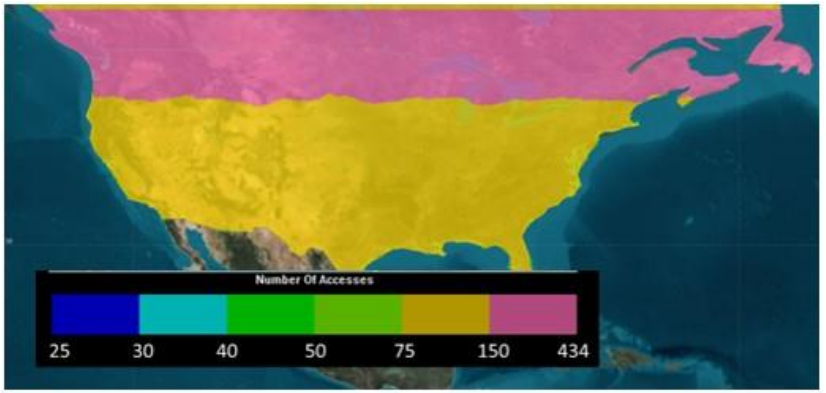
Emissivity Calibration



Input Parameter	Input Uncertainty	(Accuracy, Precision, Uncertainty) [K]
Air temperature	1.5K	(0.15, 0.01, 0.15)
Relative humidity	20%	(0.21, 0.18, 0.28)
Ozone	x2	(0.11, 0.02, 0.11)
T-E separation	0.1 K NEΔT	(0.10, 0.11, 0.15)
	Modeled case	**(0.30, 0.21, 0.37)**
	Nominal Capability	**(2.00, 0.30, 2.02)**

L3 Evapotranspiration





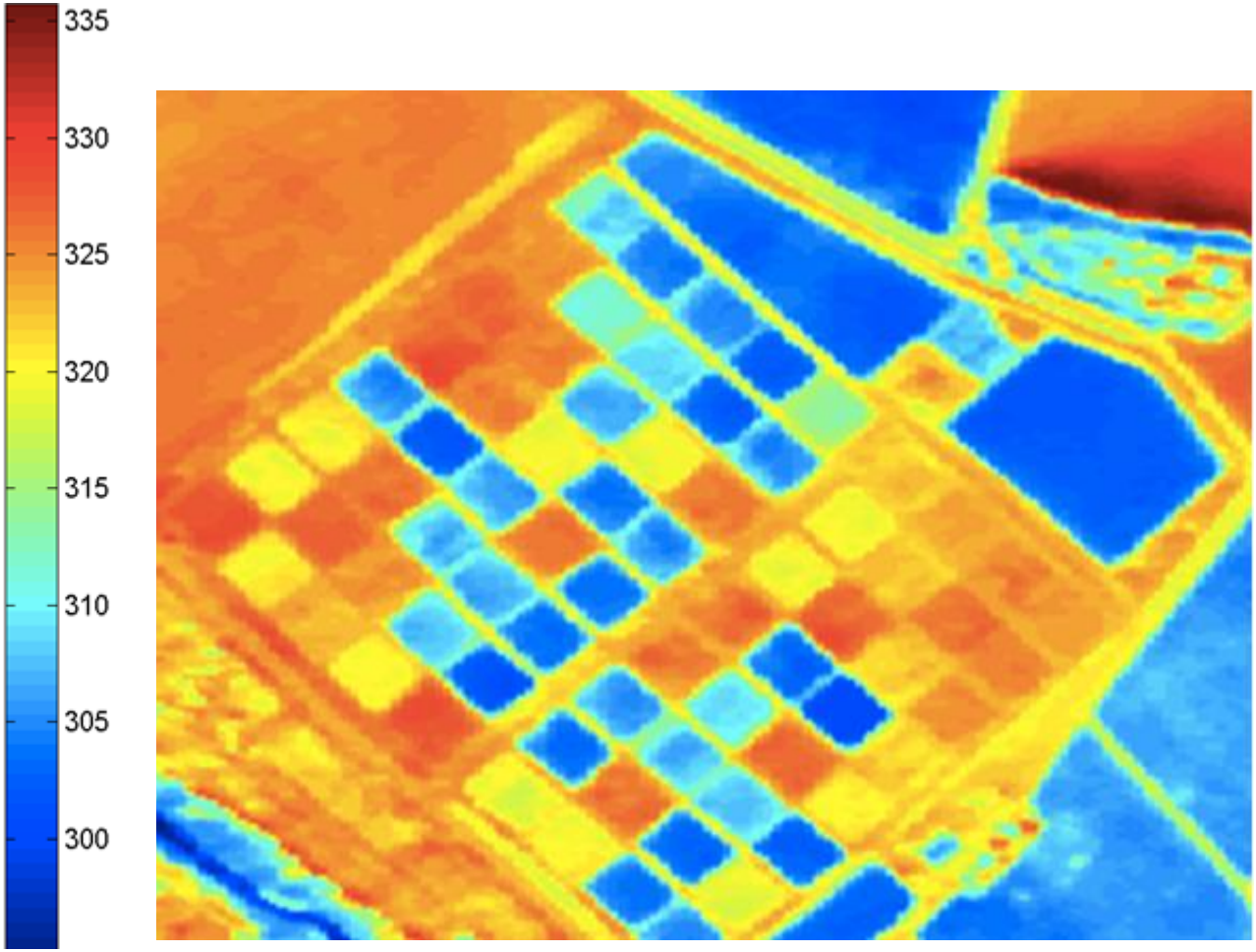
ECOSTRESS CONUS Number of Views
1 Year Simulation - Sunrise to Sunset

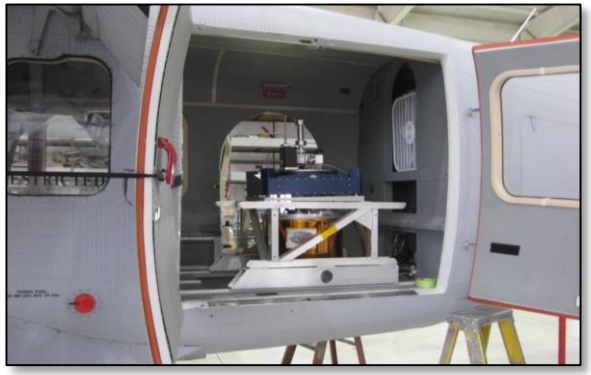
Analysis from 9 CONUS sites

Input Parameter	Input Uncertainty	[Accuracy, Precision, Uncertainty]
L2 Land Surface Temp.	± 1K	[±0.09, 0.04, 0.1 (6%)] mm per day
Air temperature	± 1K	[±0.25, 0.1, 0.27 (15%)] mm per day
Shortwave radiation	± 50Wm^2	[±0.14, 0.06, 0.16 (9%)] mm per day
Longwave radiation	± 20Wm^2	[±0.05, 0.03, 0.06 (4%)] mm per day
Wind speed	± 25%	[±0.01, 0.12, 0.12 (7%)] mm per day
Albedo	± 10%	[±0.03, 0.06, 0.07 (4%)] mm per day
	Modeled case	**[0.30, 0.18, 0.35 (18%)] mm per day**
	Nominal Capability	**[15,0.5,16]**

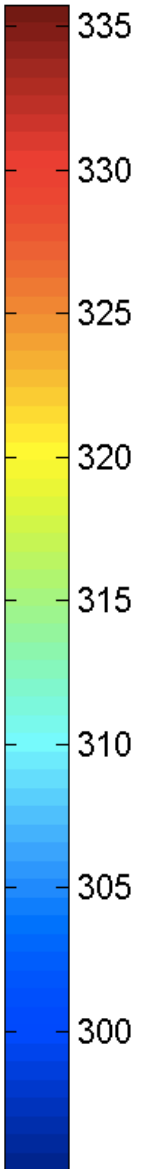
HyTES Validation

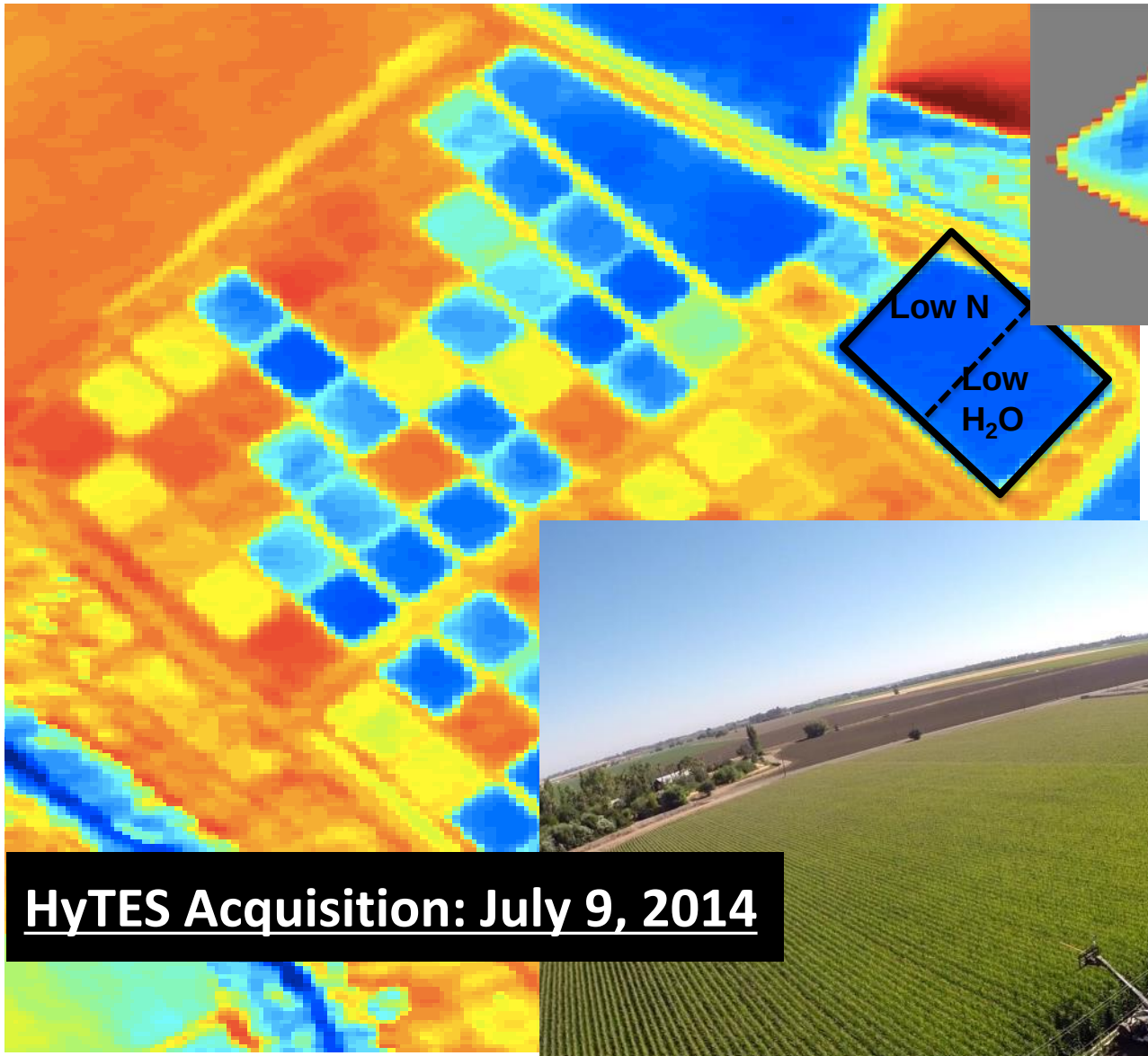
HyTES Image Acquired on 9 JUL 2014

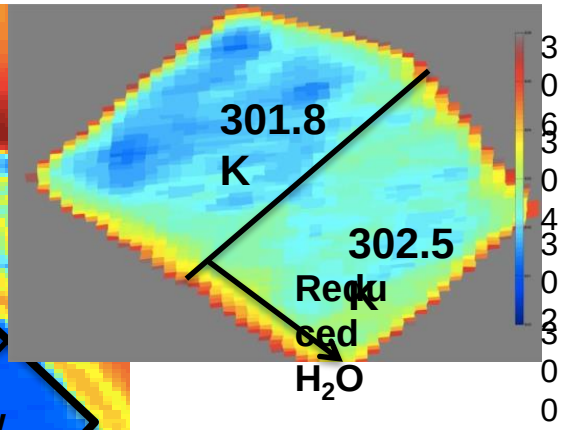




Detection of Crop Stress from Reduced Watering







HyTES Acquisition: July 9, 2014

Summary

- The ECOSTRESS mission will help answer three key science questions:
  - How is the terrestrial biosphere responding to changes in water availability?
  - How do changes in diurnal vegetation water stress impact the global carbon cycle?
  - Can agricultural vulnerability be reduced through advanced monitoring of agricultural water consumptive use and improved drought estimation?
- ECOSTRESS has a clearly defined set of data products and mature algorithms
- Opportunity for creating HyspIRI-like datasets using ECOSTRESS, HyTES and MASTER

ECOSTRESS will launch in 2017 and provide highest spatial resolution thermal infrared data ever from the International Space Station. The experiment is focused on plants but data useful for many applications

Movie Time