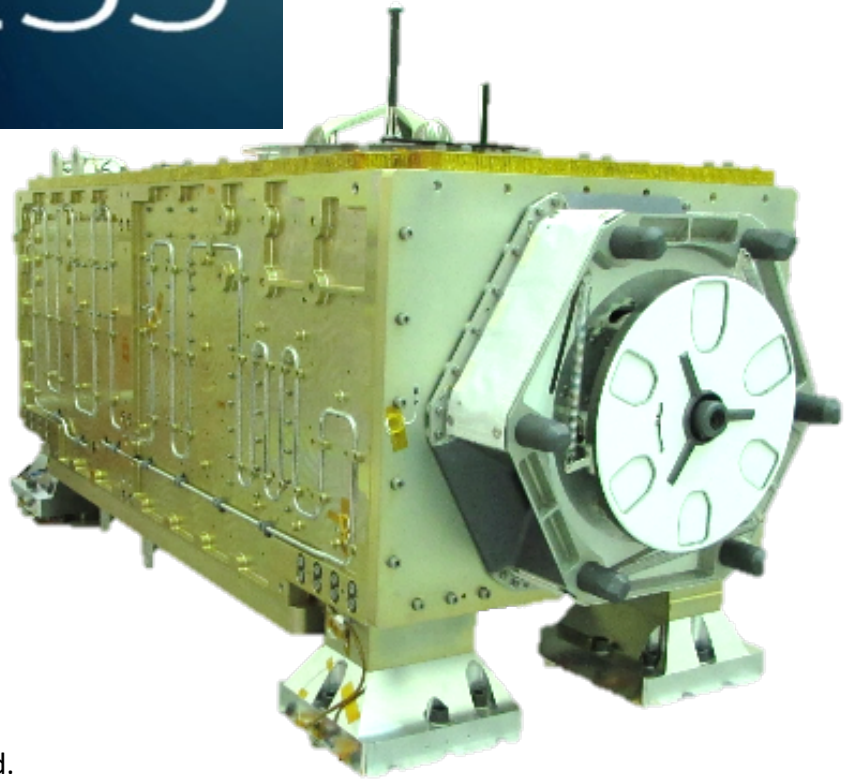
ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

ECOSTRESS



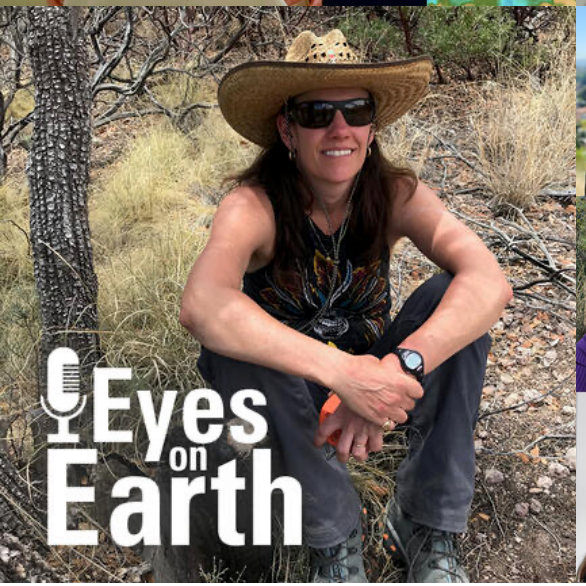
Presented by Simon J. Hook

On behalf of the
ECOSTRESS Science and Applications Team

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov



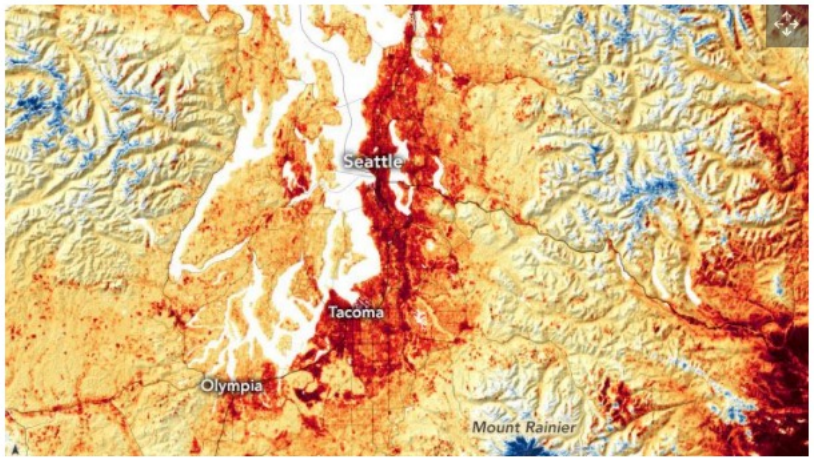
Pictures from space! Our image of the day

By Space.com Staff published about 6 hours ago

Comments (6)

PAGE 9 OF 36: IMAGE OF THE DAY — JUNE 2021

Space station sensor captures record-breaking heatwave



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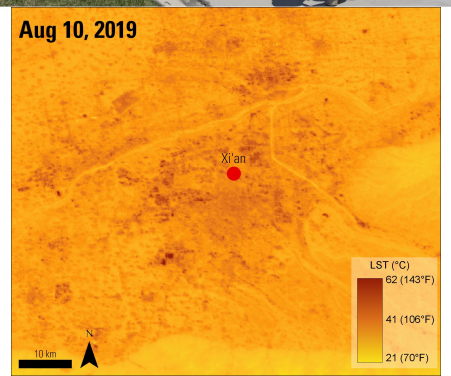
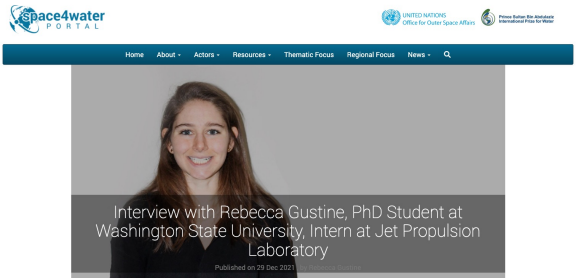
L.A.'s New Reflective Streets Bounce Heat Back into Space

The air in these neighborhoods is getting cooler — with huge implications for sweltering cities worldwide.

By: Michaela Haas

September 17, 2021 • 5 min read





MEET JPL INTERNS | MARCH 22, 2022

The JPL Interns Protecting Earth's Future

By Celeste Hoang

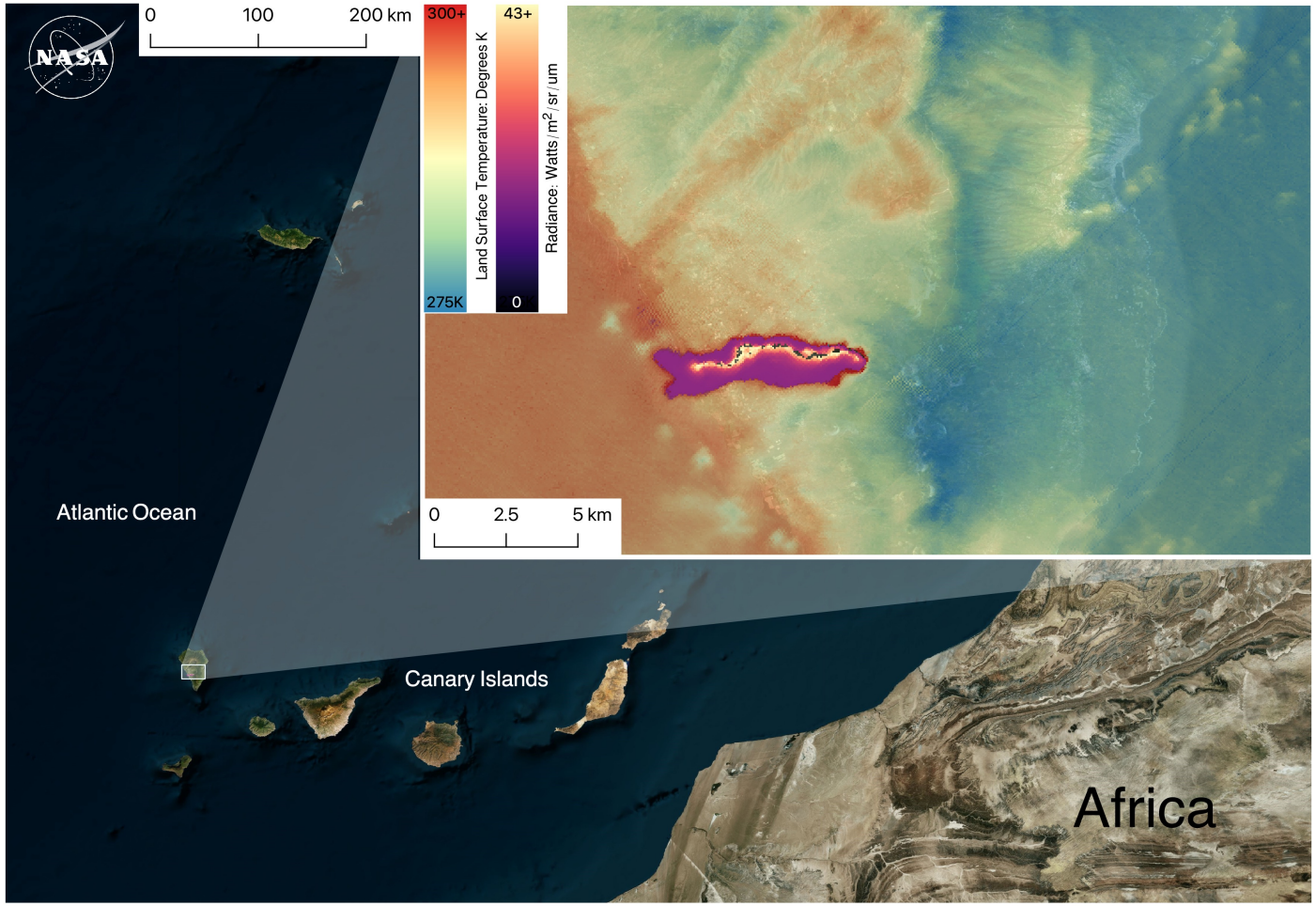
JPL interns with NASA's Earth System Observatory team. Images courtesy (from left to right): Joalda Morancy, Jonathan Vellanoweth, and Rebecca Gustine | + Expand image

ECOSTRESS maps lava flow from La Palma volcanic eruption

Background: On September 19, 2021 volcanic activity permanently altered the coastline of the small island of La Palma, located off the coast of northwestern Africa. Within seven hours of the initial eruption, the lava flow traveled about 6km to the Atlantic Coast where it continues to extend the coastline out into the ocean.

Results: This image taken by the ECOSTRESS module aboard the International Space Station captured the lava flow on September 29, 2021, after the eruption. Dark spots along the coastline represent locations where lava flowed into the ocean, increasing the surface temperature.

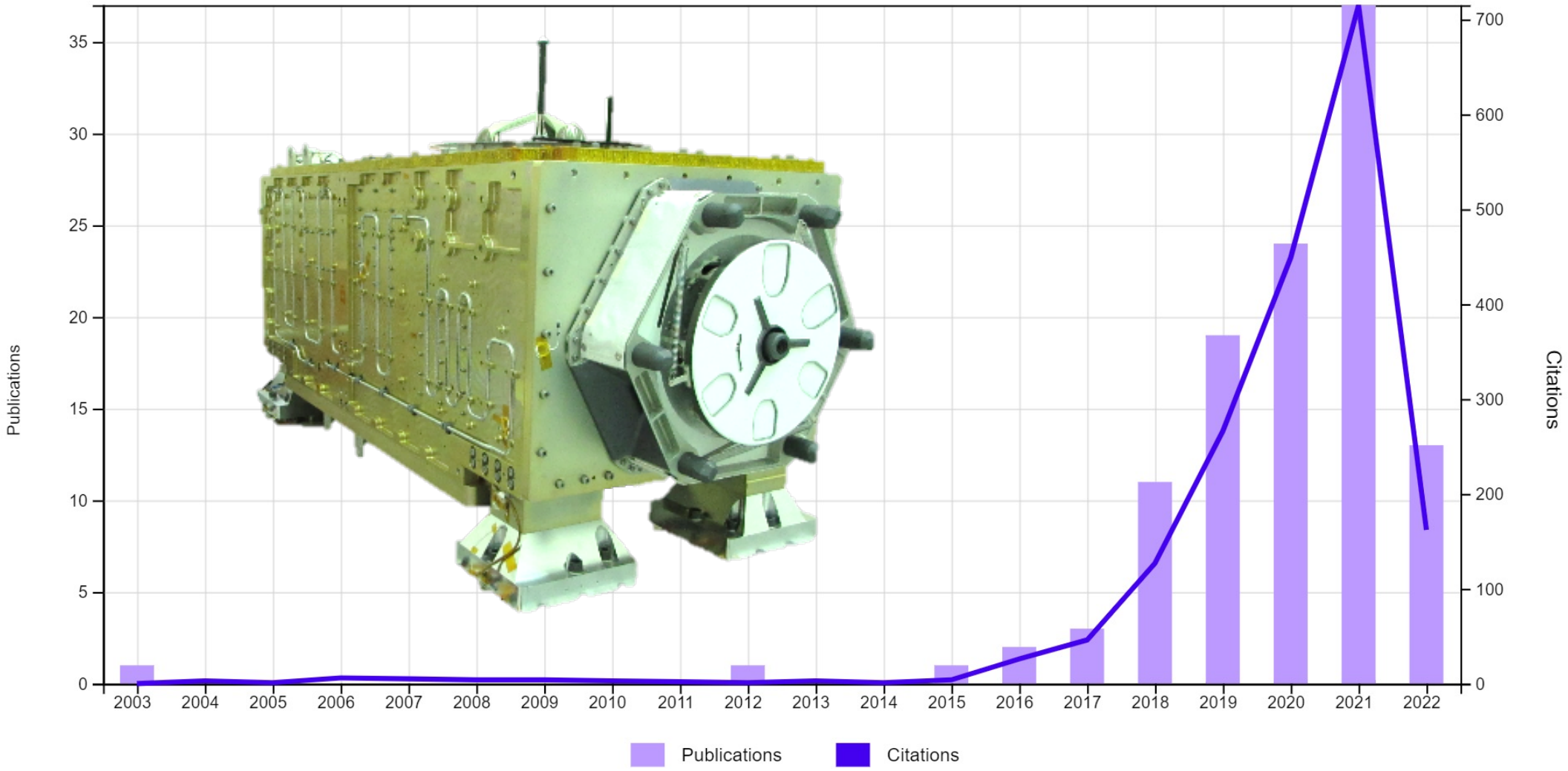
Significance: ECOSTRESS standard data products can be used to visualize and assess high temperature features associated with volcanic activity.



https://photojournal.jpl.nasa.gov/catalog/PIA24916

Credit: R. Neuren / ECOSTRESS intern

ECOSTRESS Increasing Science and Applications Contribution

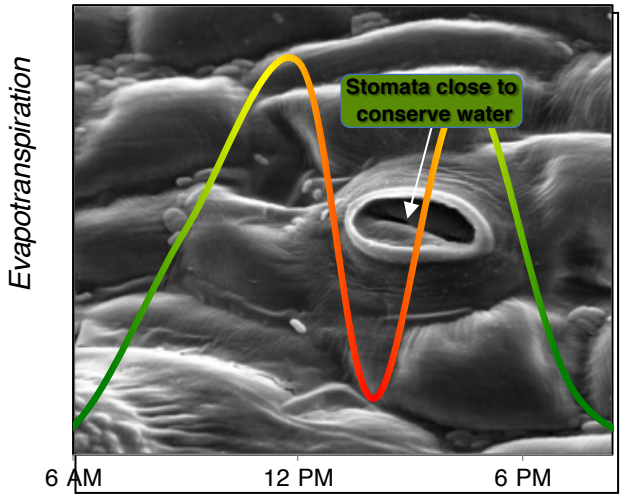


Outline

- Science
- Mission
- Latest results
- Future opportunities and measurement gaps
- Summary and conclusions

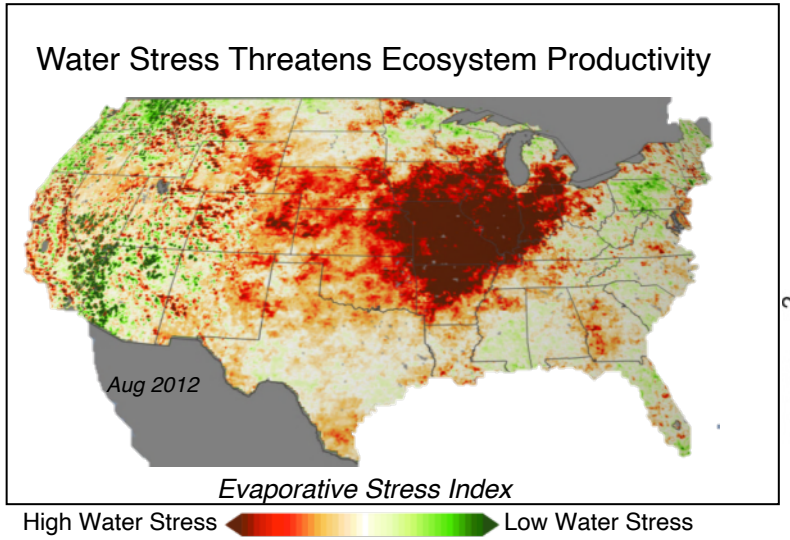
The Science

Water Stress Drives Plant Behavior

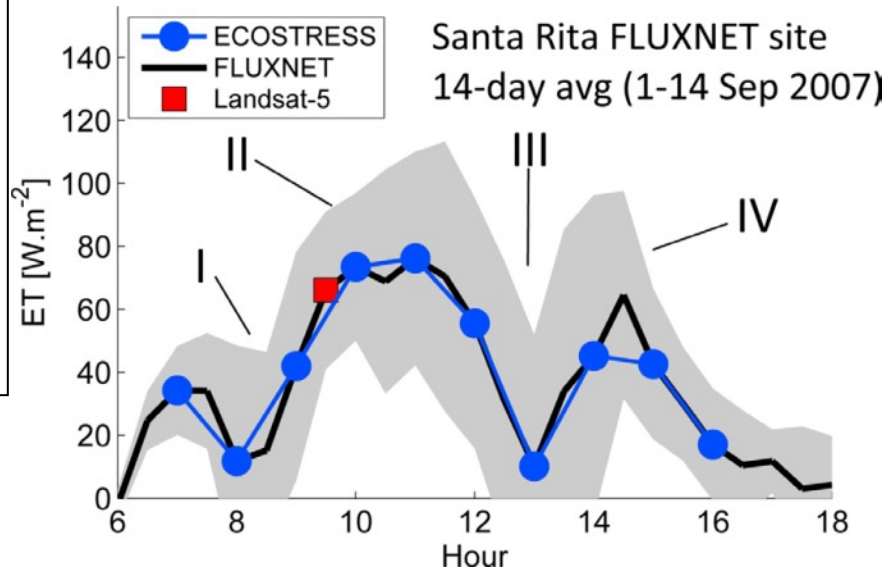


When stomata close, CO_2 uptake and evapotranspiration are halted and plants risk starvation, overheating and death.

Water Stress Threatens Ecosystem Productivity



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

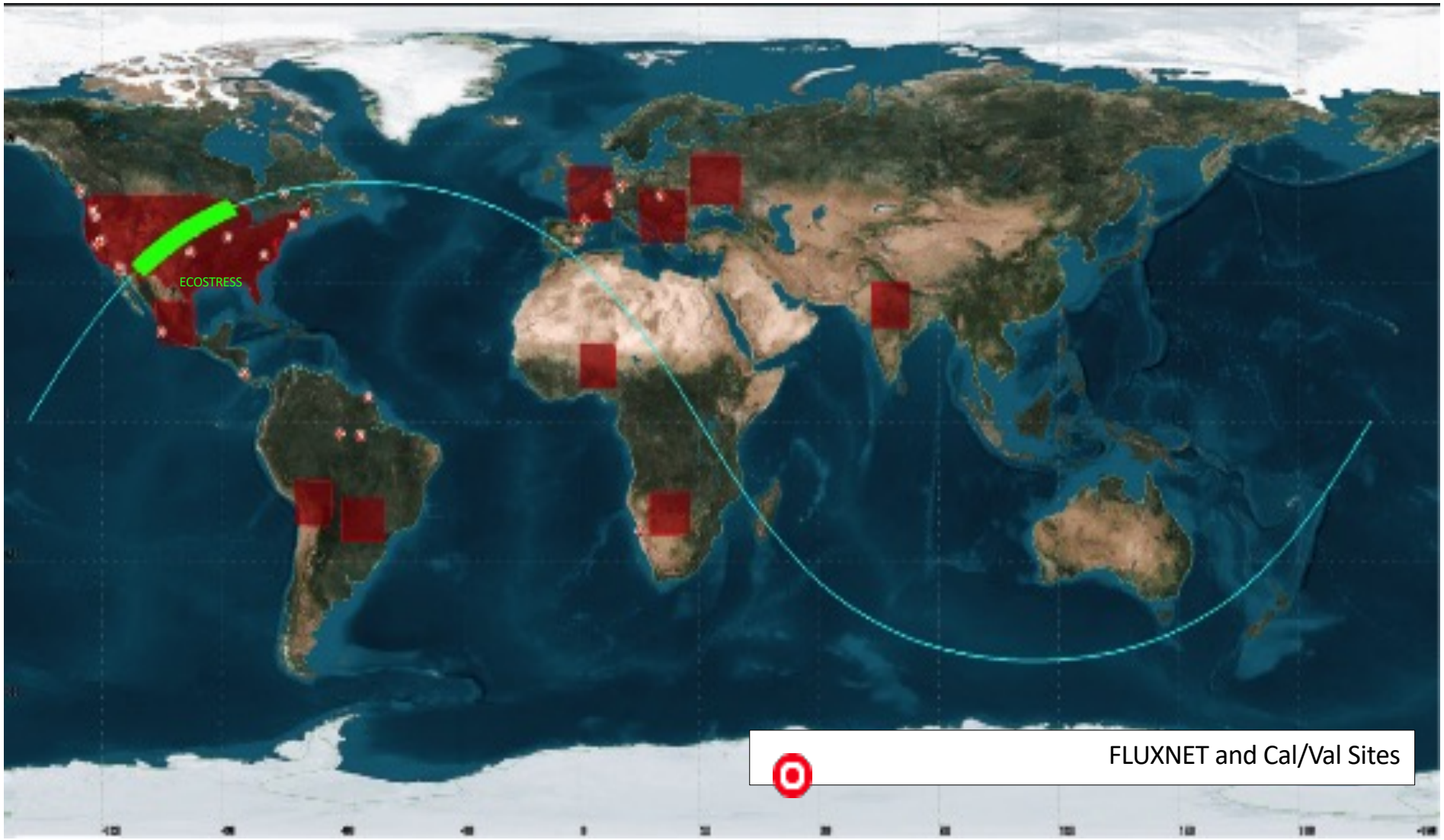


Science Objectives

- 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
- SCIENCE WAS EXPANDED TO OTHER AREAS AFTER SENIOR REVIEW

ECOSTRESS – The ISS Orbit

ECOSTRESS Planned to acquire data over hot spots or high priority targets



ECOSTRESS proposed acquisitions ~ 74 per day, **ACQUIRING 216**

Mission Overview

Primary Science Objectives:

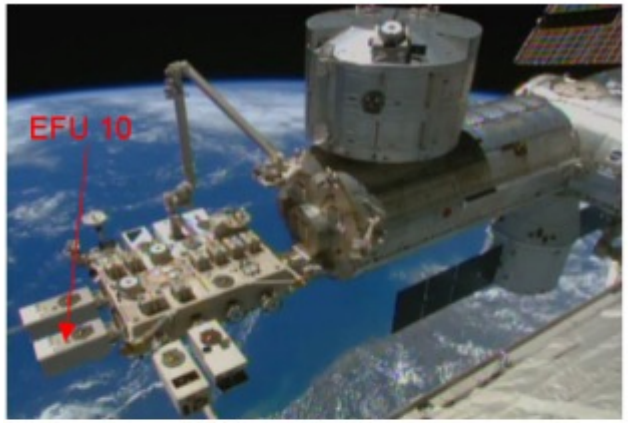
1. Identify critical thresholds of water use and water stress in critical plant biomes
2. Detect the timing, location, and predictive factors leading to plant water uptake decline and/or cessation over the diurnal cycle
3. Measure agricultural water consumptive use over the contiguous United States (CONUS)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

Overview:

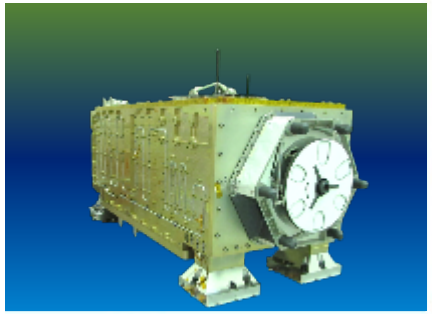
- **Cost-Capped, $29.942M Cat 3/Risk class D**
- **8–12.5 µm radiometer with a 400km swath, 69 x 38 m resolution**
- **Measure brightness temperatures of Earth at selected locations**
- **Launch in 2018** on SpX-15 and deploy on ISS JEM-EFU 10
- **First use of WiFi on JEM-EF for science payload**
- **Prime Mission Phase E:** 1 year
- **Extended Phase E: possible**

Operational Highlights:

- Planned 74 scenes per day for 365 acquisition days
- Highest spatial resolution multispectral thermal infrared radiometer NASA has ever built
- Only spaceborne instrument capable of providing data suitable for evaluating data for the Decadal Survey SBG TIR mission.

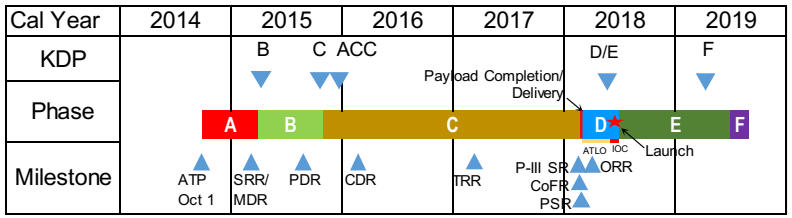


ISS JEM-EF



ECOSTRESS

Falcon-9



LATEST RESULTS

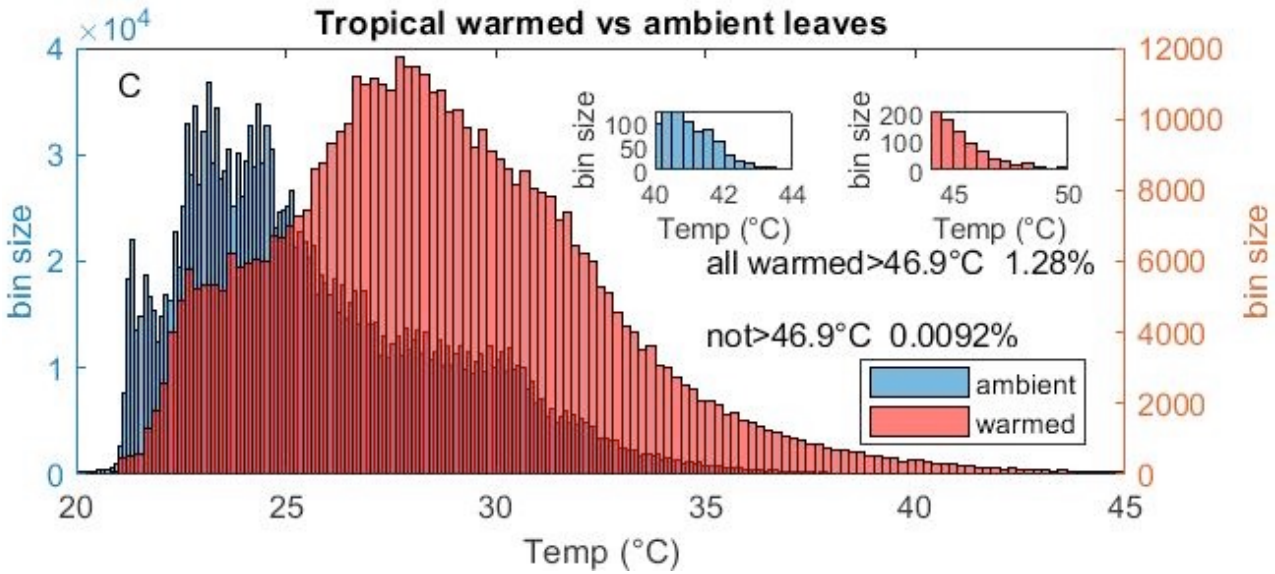
Credit: NASA

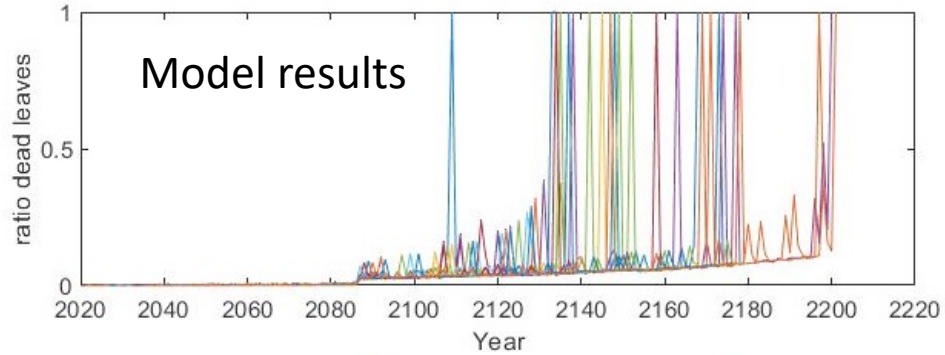
Tropical forests are approaching critical temperature thresholds

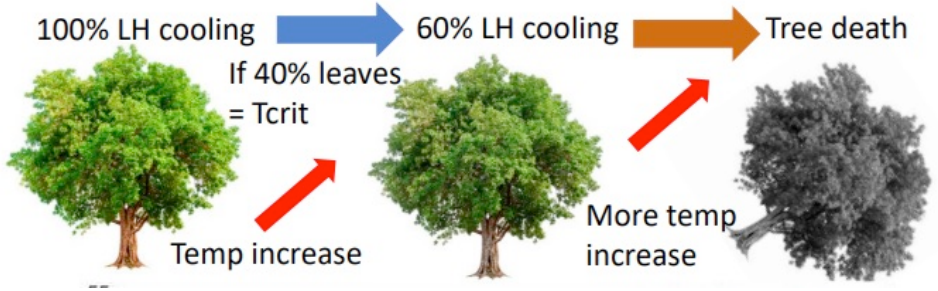
(PI: C. Doughty, NAU)

- Our goal is to understand how close peak tropical forest temperatures are to T_{crit} (46.7°C)
- Leaves currently exceeded T_{crit} 0.01% of the time and warming experiments indicate they will 1.3% of the time.
- ECOSTRESS LST across the tropics show pixels exceed 40 °C 0.01% of the time and could 1% under future warming.
- ECOSTRESS + warming experiments + simulations indicate tropical forests can withstand up to 4.0 ± 0.70°C increase in air temperatures before a potential functional collapse.

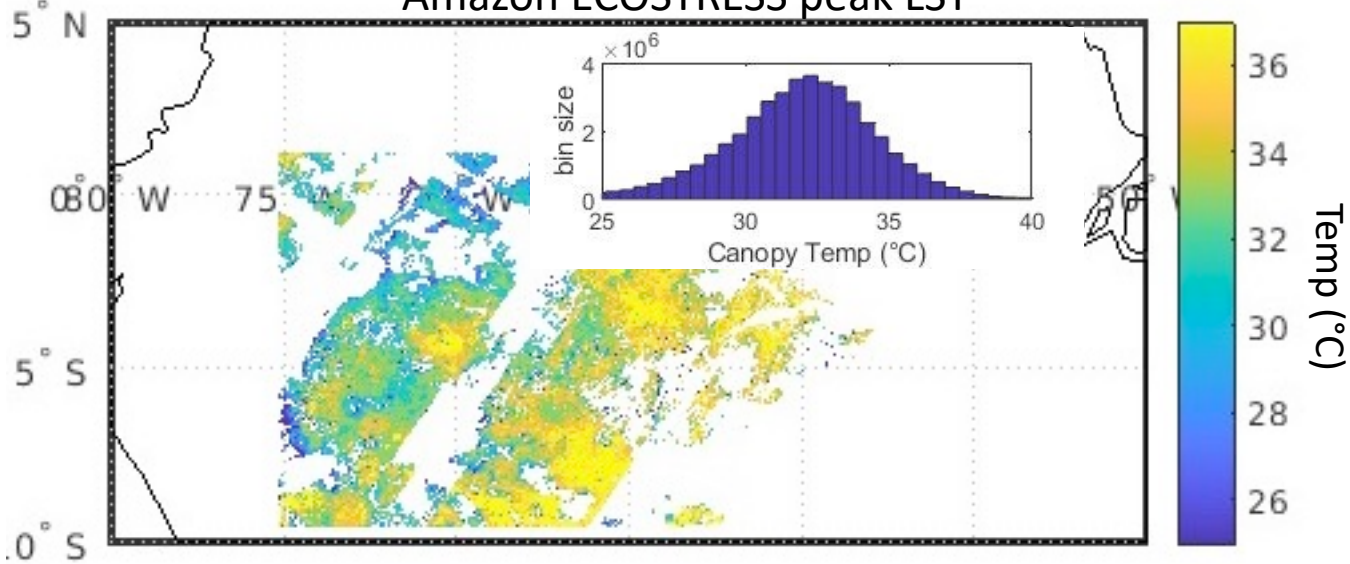
In situ measurements







Amazon ECOSTRESS peak LST



Monitoring Crop Water Use with ECOSTRESS, Landsat and VIIRS+S2

M. Anderson, J. Xue, Y. Yang, K. Knipper, W.P. Kustas, M.M. Alsina, C. Hain, J. Alfieri, J. Prueger, F. Gao

Landsat 8

Launch 2/11/2013

Polar Orbit (16 day)
2 TIR bands (100 m)

VNIR from HLS-Landsat (30 m)

ECOSTRESS

Launch 6/29/2018

ISS Orbit (~4 day)
5 TIR bands (38x69 m)

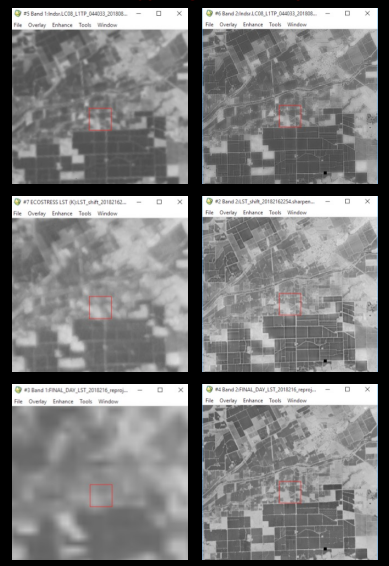
VNIR from HLS (30 m)

VIIRS

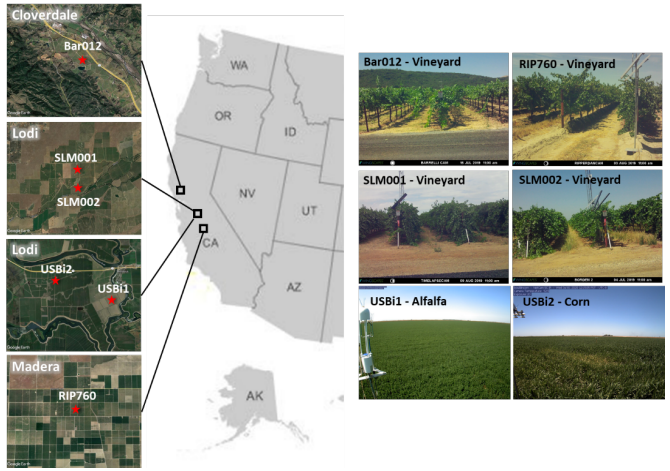
Launch 8/28/2011

Polar Orbit (~1 day)
I5 band (375 m)

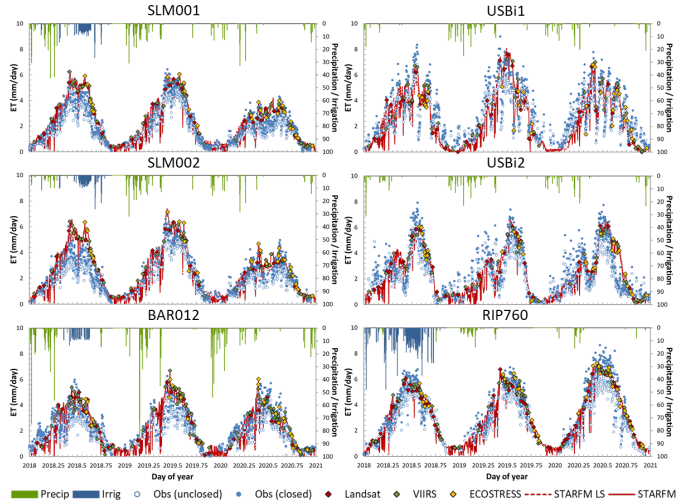
VNIR from HLS-Sentinel 2 (30 m)

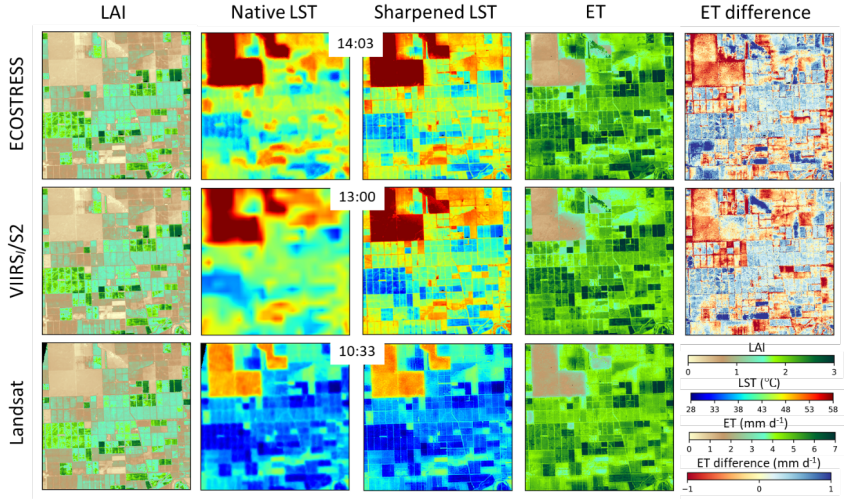


Q: Can multiple thermal sensors be combined to improve temporal sampling in high-resolution ET datasets used for water management?



- Multi-source daily ET datasets were constructed using Landsat, ECOSTRESS and VIIRS TIR data (sharpened to 30 m)
- ET timeseries extracted at 6 flux tower sites in CA agreed well with observations and demonstrated general temporal consistency between TIR sources.





- With sharpening and some constraints, ET maps from each source were typically spatially consistent.
- Benefits of additional sampling are most significant in dynamic cropping systems or in areas with high cloud cover.
- Multi-source fusion techniques developed here will be implemented in OpenET.

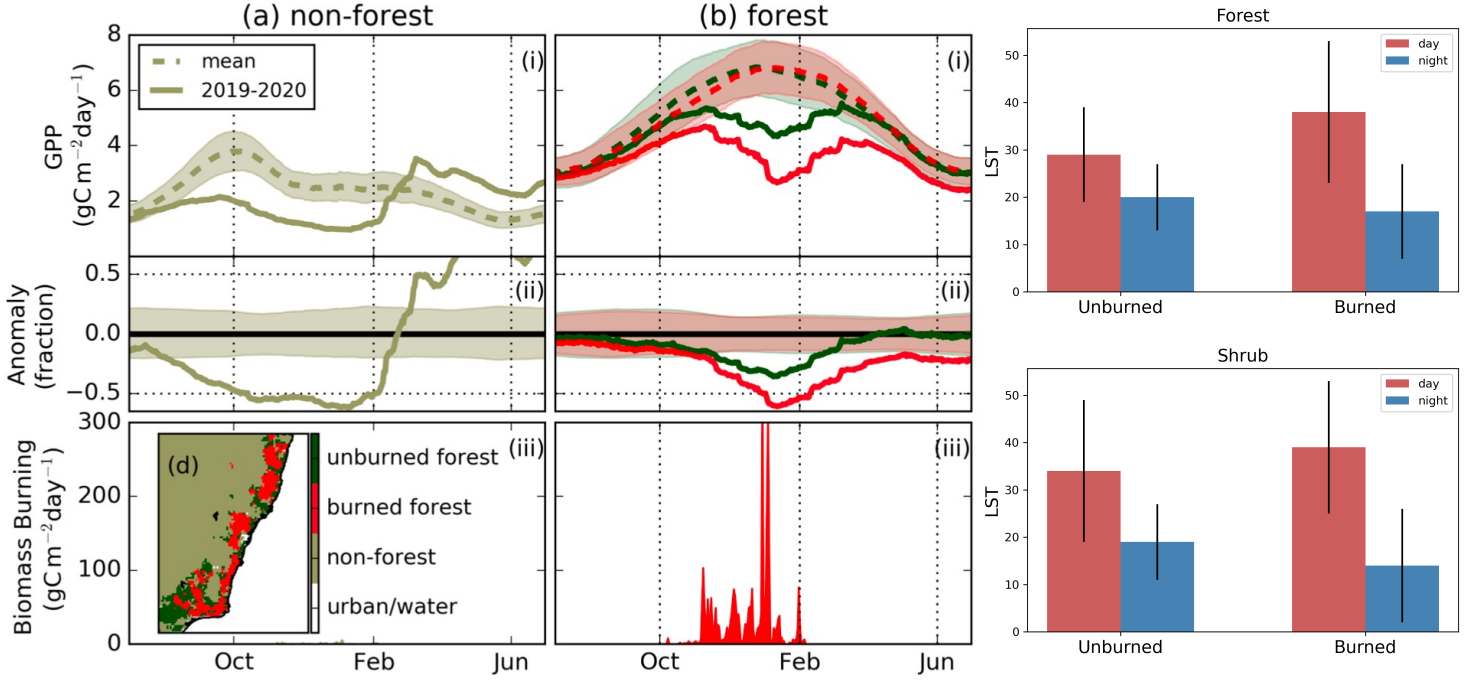
Xue, J., et al.. Improving the spatiotemporal resolution of remotely sensed ET information for water management through Landsat, Sentinel-2, ECOSTRESS and VIIRS data fusion. Irrig. Sci. 2022.

Exploit Diurnal Cycles to Evaluate Vegetation Responses to Heat and Drought Stress

(PI: C. Frankenberg; Science PI: Y. Yin; Caltech)

- ECOSTRESS allows us to observe land surface temperature at high spatial resolution across different times of the day to provide insights on both natural (left) and city (right) environment.

2019-2020 bush fire in Southeast Australia & post-fire vegetation recover / energy budget estimates from ECOSTRESS

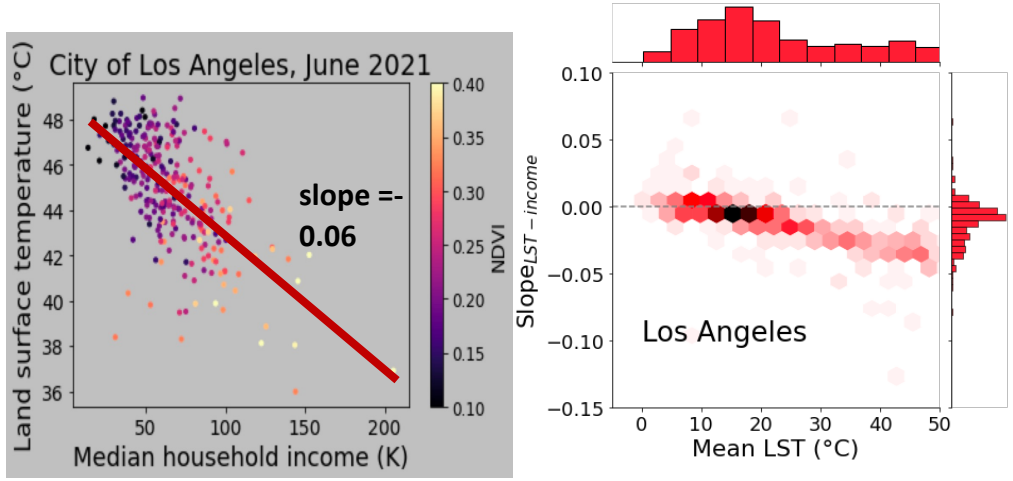


Unburned areas have much faster recover of GPP after the extreme drought; their LST is significantly lower than the burned parts during the day, whereas slightly higher in the night, hence smaller diurnal variations.

Byrne et al., 2021, AGU Advances

Yin et al., in prep

Disproportionately higher heat exposure in lower-income neighborhoods: a case study in LA



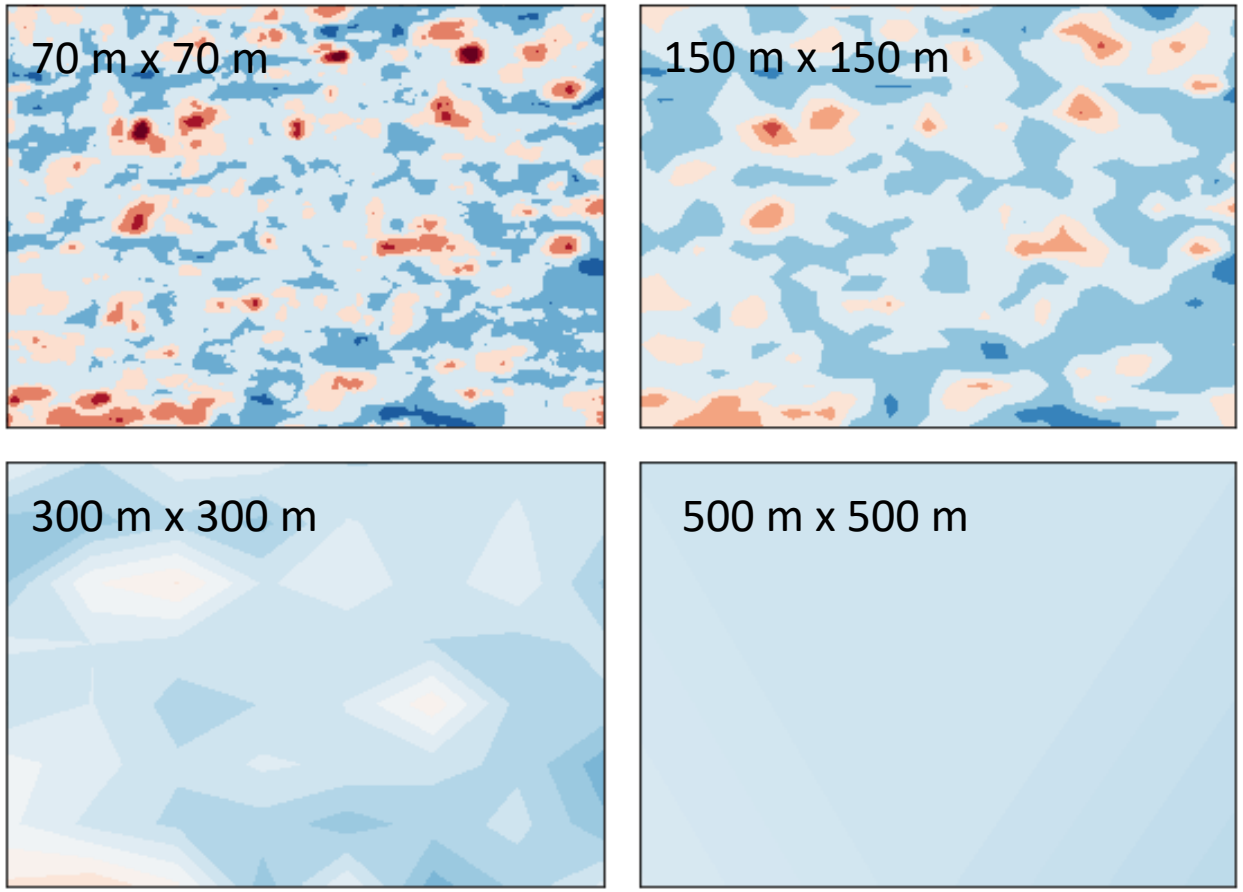
Analyzing the relative contribution of ET and surface albedo, we find that the unequal exposure is predominantly influenced by higher ET in areas with more vegetation that are associated with higher median household income. Modifying surface albedo could mitigate this pattern, in particular when water is limited.

Yin et al., to be submitted

Detecting trace gas “hot spots” over agricultural regions

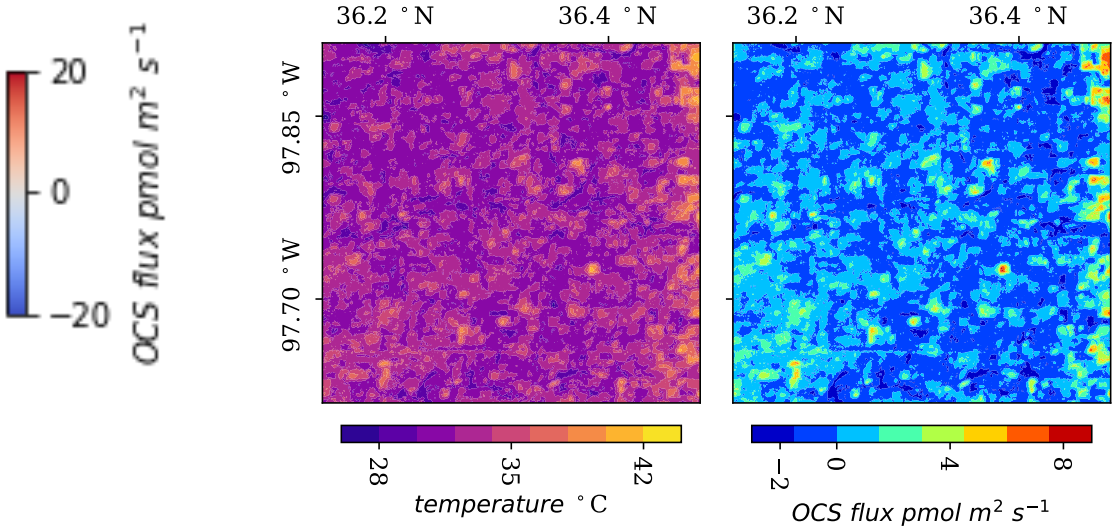
(PI: M. Whelan; Rutgers University)

- ECOSTRESS enables the detection of trace gas “hot spots” in agricultural areas where soil is actively managed
- Carbon stocks are vulnerable to changes in temperature; soil microbial communities acclimated to warmer temperatures will respond differently to diurnal temperature shifts.



Whelan et al., JGR Biogeoscience, [in review]

- e.g. carbonyl sulfide (OCS) a trace gas used for carbon cycle research are estimated using ECOSTRESS surface temperature
- Patterns of trace gas estimates are completely lost at 0.5 km.
- This approach can be applied to other trace gas flux estimates with sufficient sensitivity to temperature



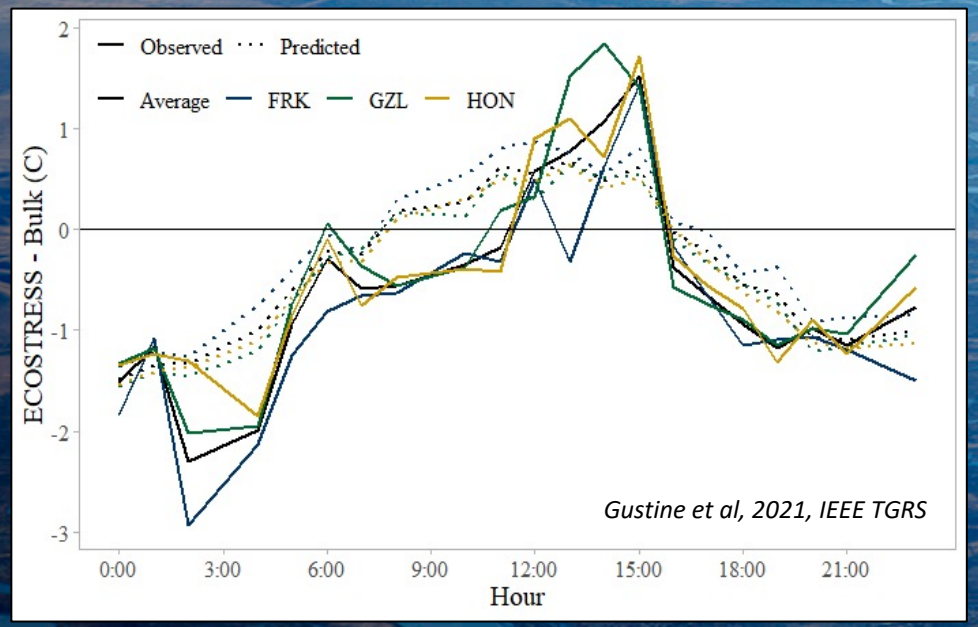
Aquatic Ecosystems

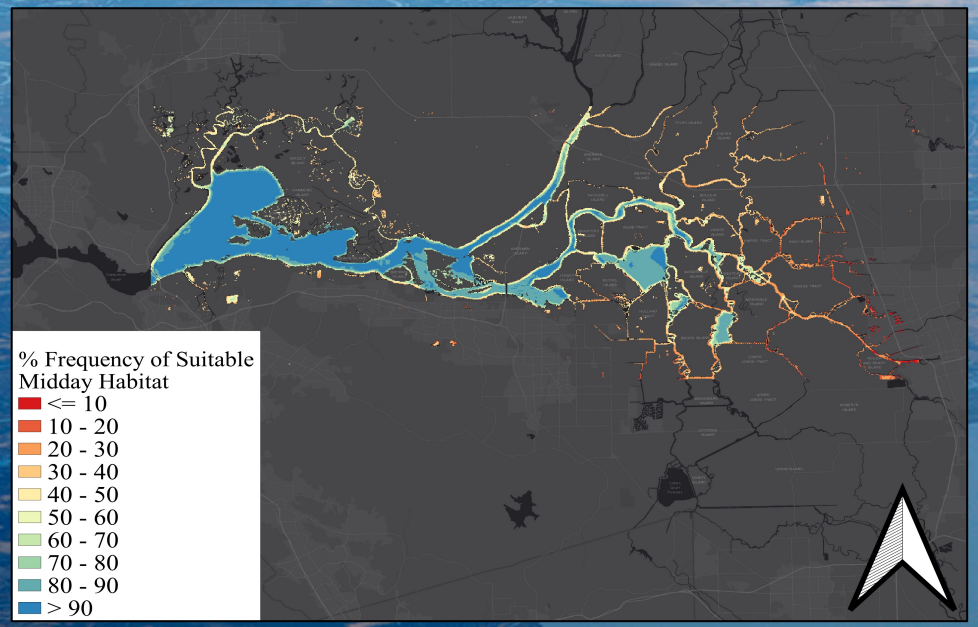
ECOSTRESS aquatic ecosystem applications in the San Francisco Estuary

Aerial view of Grizzly Bay, California
Credit: Michael Rymer

- Water temperature is a critical control on habitat suitability for vulnerable species in the San Francisco Estuary, a hub in California's water supply and infrastructure
- ECOSTRESS-derived bulk temperatures used to assess frequency of habitat suitability for the Delta smelt
- Partnering with CA resource managers to support water operations and ecosystems restoration efforts
- ECOSTRESS products to be made available in decision dashboards (baydeltalive.com)

Delta smelt, Hypomesus transpacificus,
U.S. Fish and Wildlife Service





Christine Lee, PI (JPL), Rebecca Gustine (JPL/WSU), Cassie Nickles (JPL), Gregory Halverson (JPL)

Heat and Desiccation Risk in Intertidal Shellfisheries

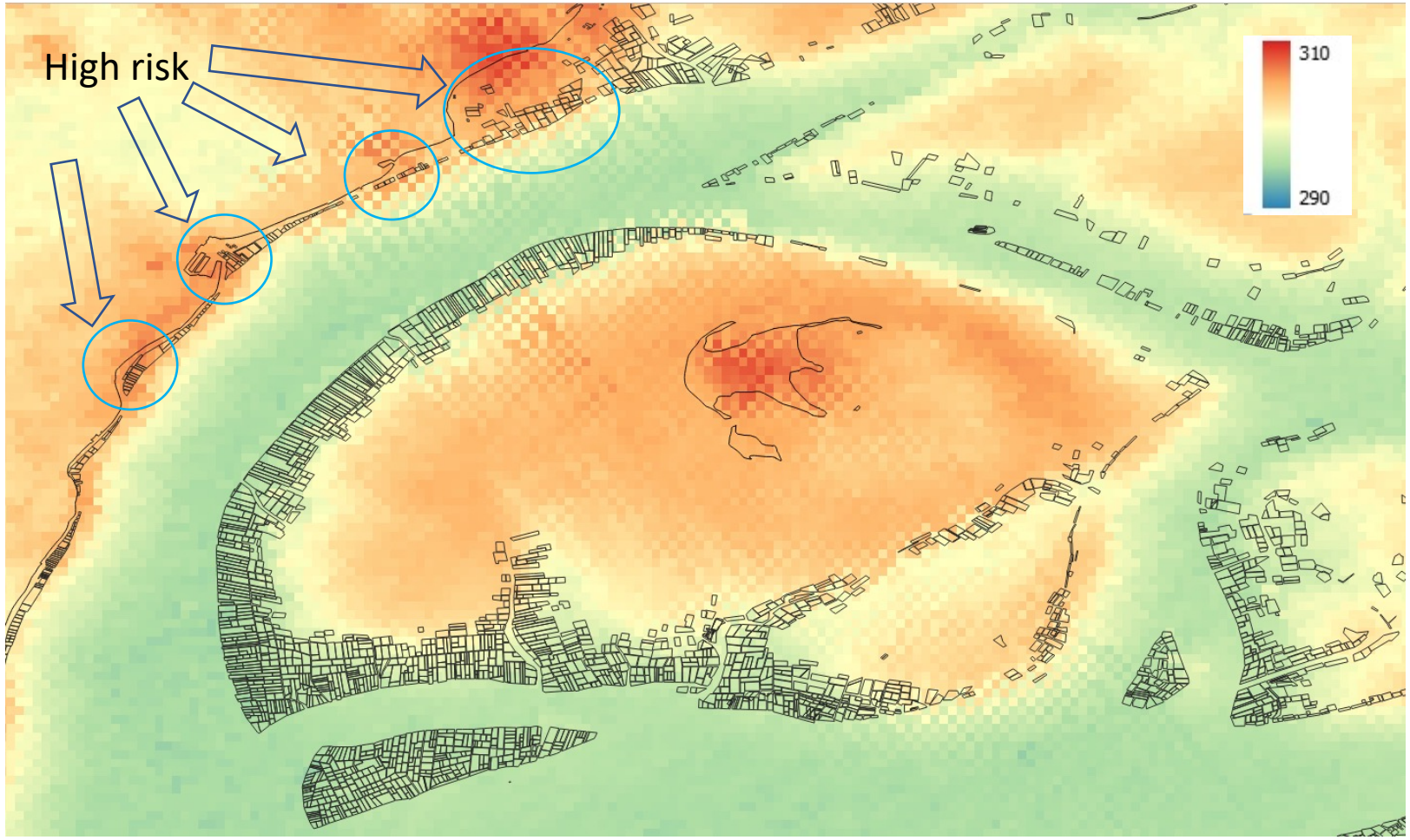
David S Wethey, University of South Carolina

The high spatial resolution of ECOSTRESS permits identification of high risk sites for oyster aquaculture at the scale of individual oyster leases in Arcachon Bay, France.

8,000 tons sold per year, with retail prices of €6.50/dozen.

Oysters suffer significant mortality at temperatures of 35C, which occur in higher risk sites in the bay in summer.

ECOSTRESS can help oyster farmers focus their efforts on the least risky sites.



80NSSC20K0074

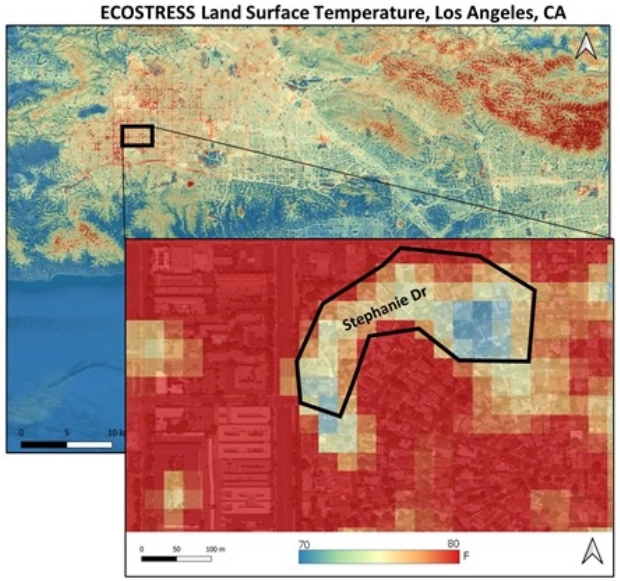
Human Health

ECOSTRESS is being used to quantify heat mitigation measures in LA and identify vulnerable populations

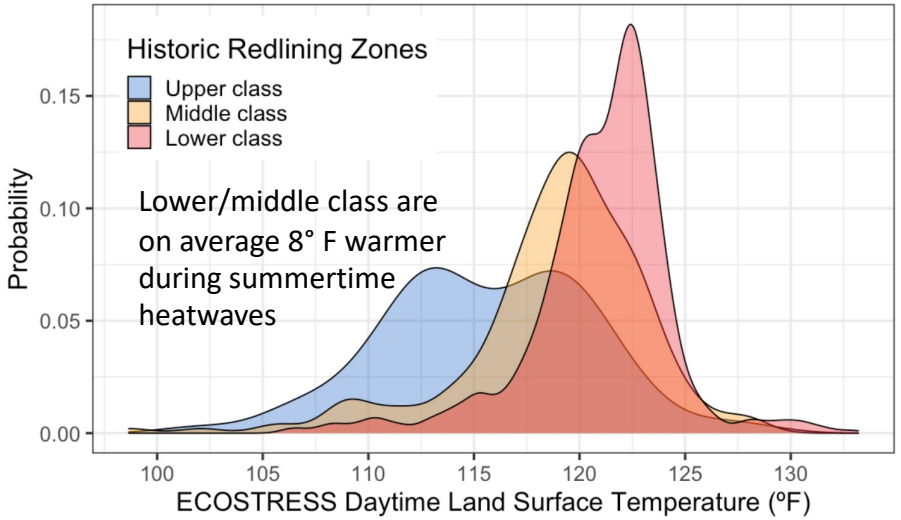
PI: G. Hulley, JPL

"I call this my 6 million dollar slide" – Greg Spotts, CSO, streetsLA

- ECOSTRESS demonstrated a 2-degree neighborhood cooling effect from cool pavement coatings applied to streets in a pilot project in Los Angeles, CA
- These results helped secure an additional 6 million dollars in funding for cooling the city through shade trees and cool pavements in underserved communities
- ECOSTRESS can be used to better understand Equity and Environment Justice concerns by quantifying the disproportionate effect of heat stress on different urban income groups



Temperature distribution of historical redlining zones in LA



ECOSTRESS Project Title: Changing landscapes, UHI and the effects on city water conservation policy

(PI: Soe W. Myint, Arizona State University)

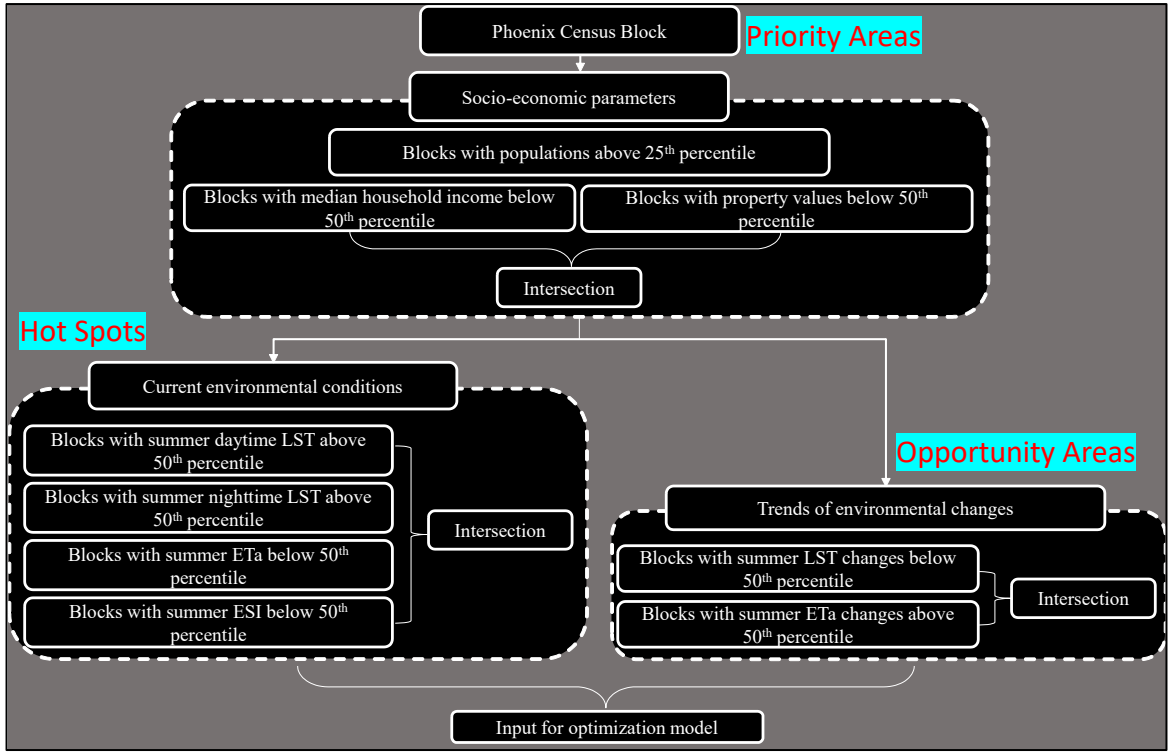
To address a classic sustainability challenge — the tradeoff between water conservation and heat mitigation in one of the most polluted or warmest cities (or rapidly growing city - Phoenix, Arizona).

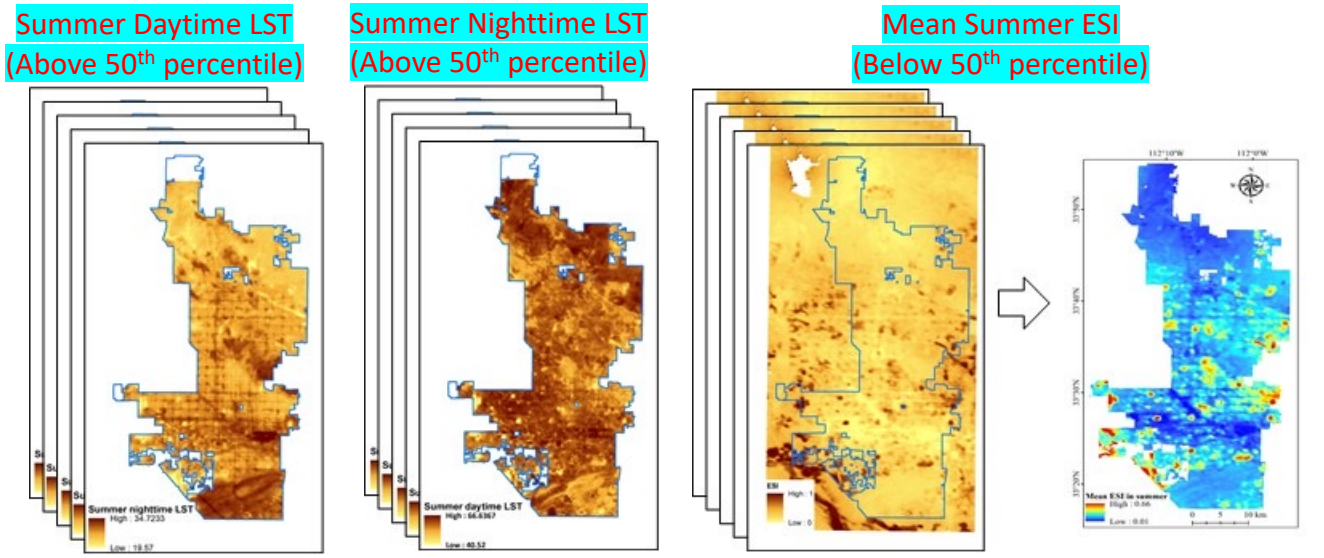
To achieve the above goal, we have set the following objectives:

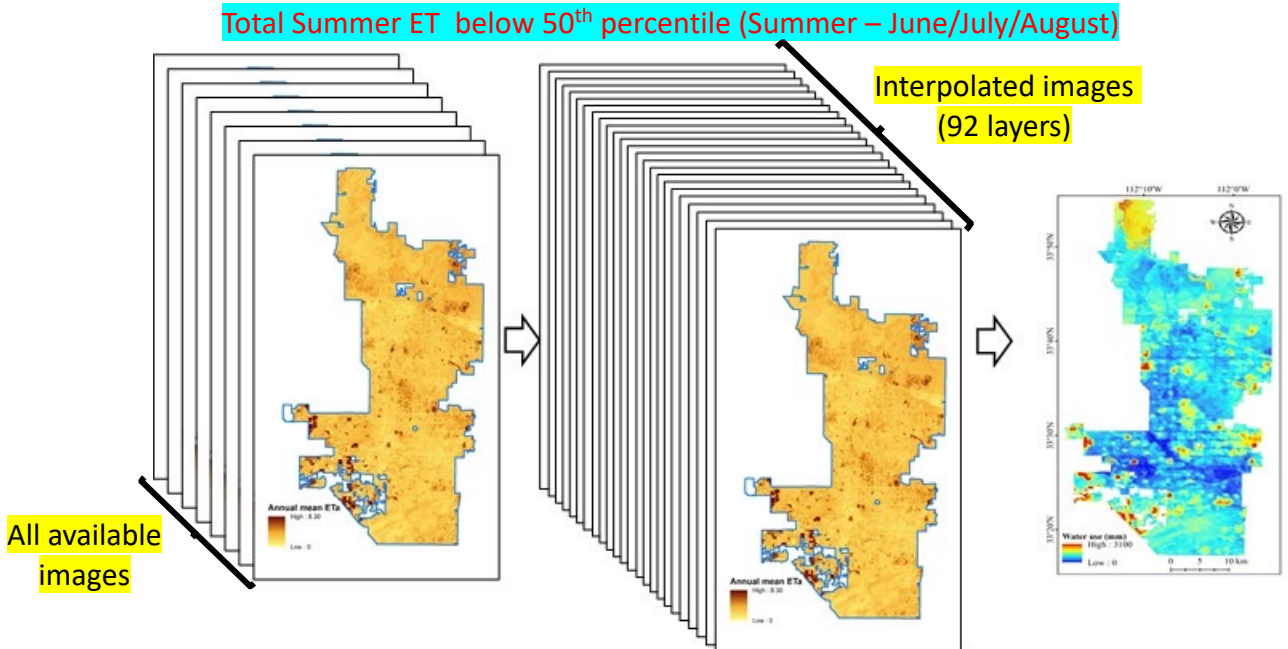
(1) Identify hotspots (dwelling districts) that require immediate attention to increase green infrastructures;

(2) Determine opportunity areas where water use can be lowered; and

(3) Develop an optimization model using the above biophysical and socio-economic parameters for an urban sustainability



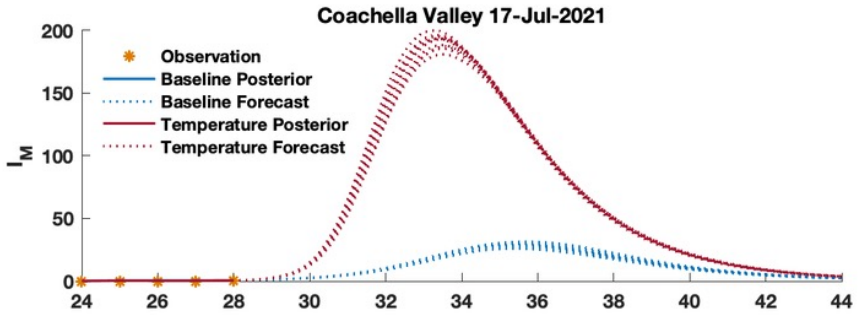




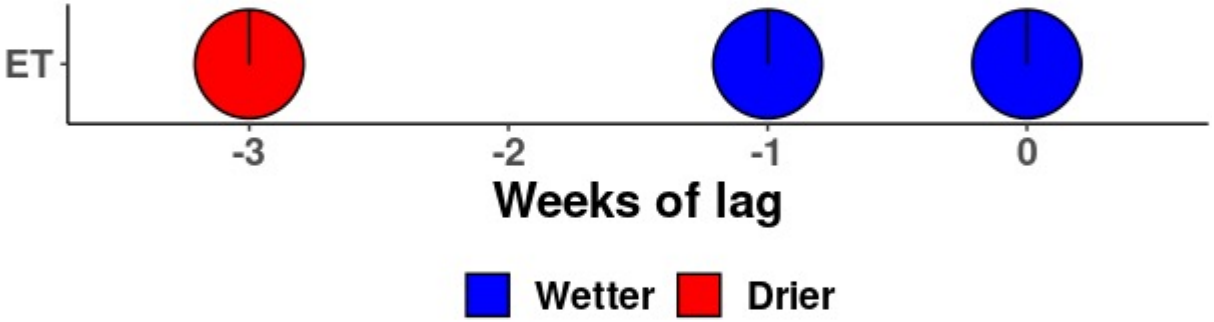
ECOSTRESS and Human Health

(PI: N. DeFelice, School of Medicine at Mt. Sinai)

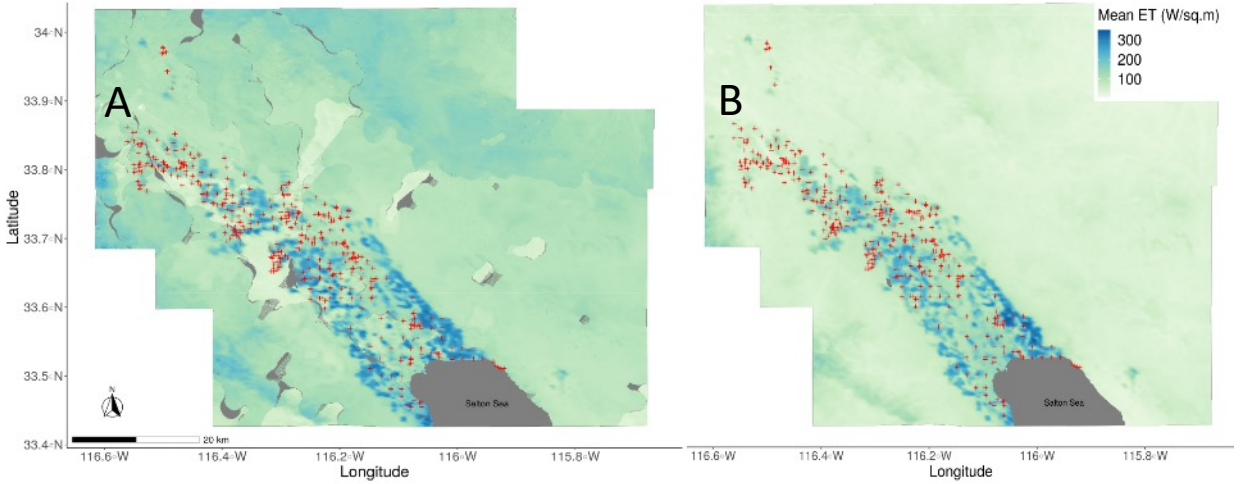
- WNV transmission is driven by an enzootic cycle between mosquito vectors and bird hosts
- Identifying key environmental conditions that facilitate and accelerate this cycle may be used to inform effective vector control
- Statistical models using ECOSTRESS', 70 m resolution, showed that drier than normal conditions followed by an increase in moisture was associated with an increase in detecting WNV infected mosquitoes for the region
- ECOSTRESS has the potential to identify changes in hydrologically rich areas where mosquitoes and birds interact during warm spring months at the start of seasonal WNV transmission



Forecasted infection rates 2021, Coachella Valley, CA.



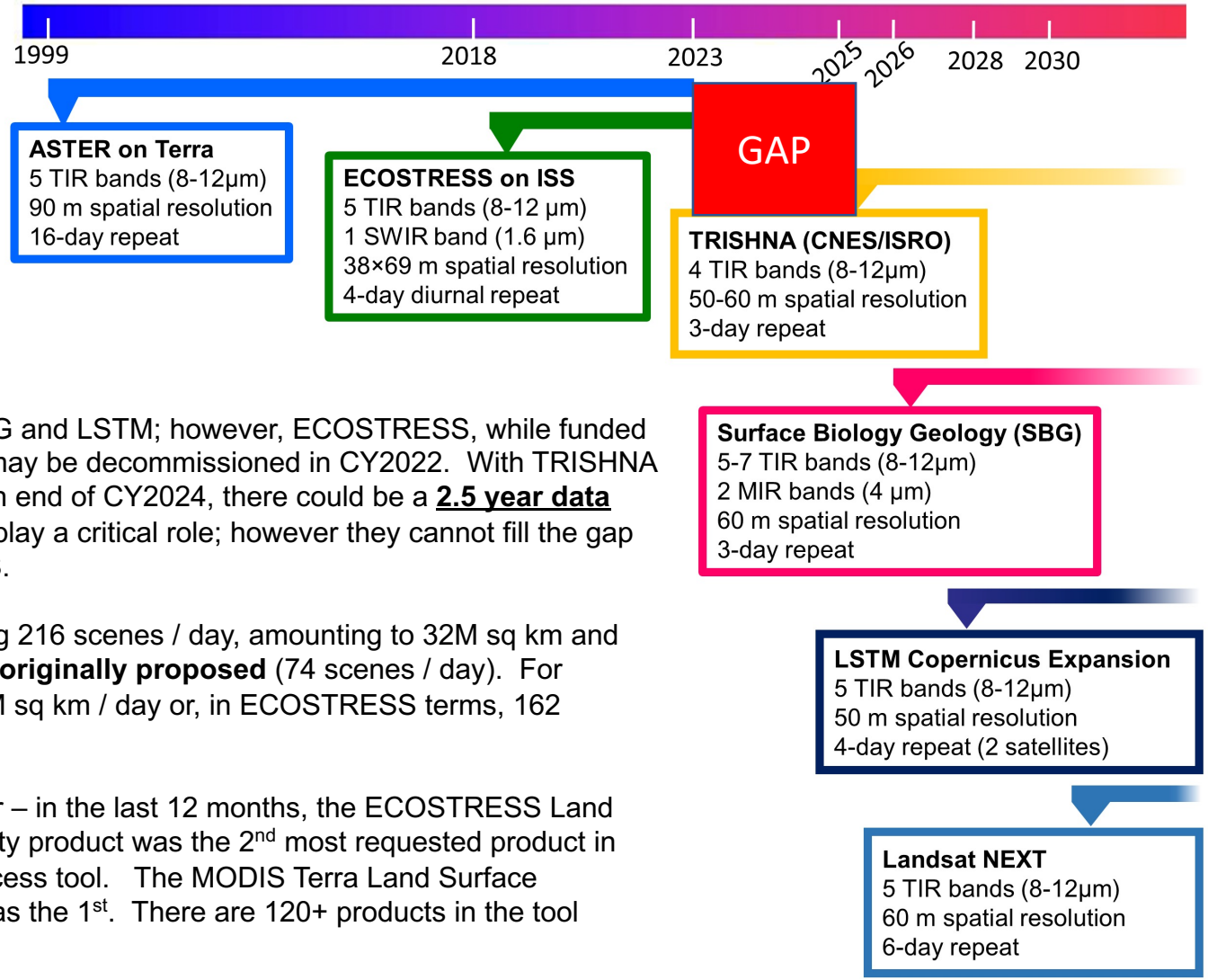
Changes in the hydrological conditions associated with the onset of detecting WNV in a localized area.



Mean evapotranspiration (ET) (W/m^2) as measured by ECOSTRESS in the Coachella Valley, CA during the early season (Panel A: March - May) and late season (Panel B: June - Aug) with trap locations (red X) for 2019.

Potential multispectral TIR data gap

High spatial resolution multispectral (3+ bands) TIR program of record



Exciting future with TRISHNA, SBG and LSTM; however, ECOSTRESS, while funded to provide data through CY2023, may be decommissioned in CY2022. With TRISHNA scheduled to launch no earlier than end of CY2024, there could be a **2.5 year data gap**. Aircraft TIR instruments will play a critical role; however they cannot fill the gap that would be left by ECOSTRESS.

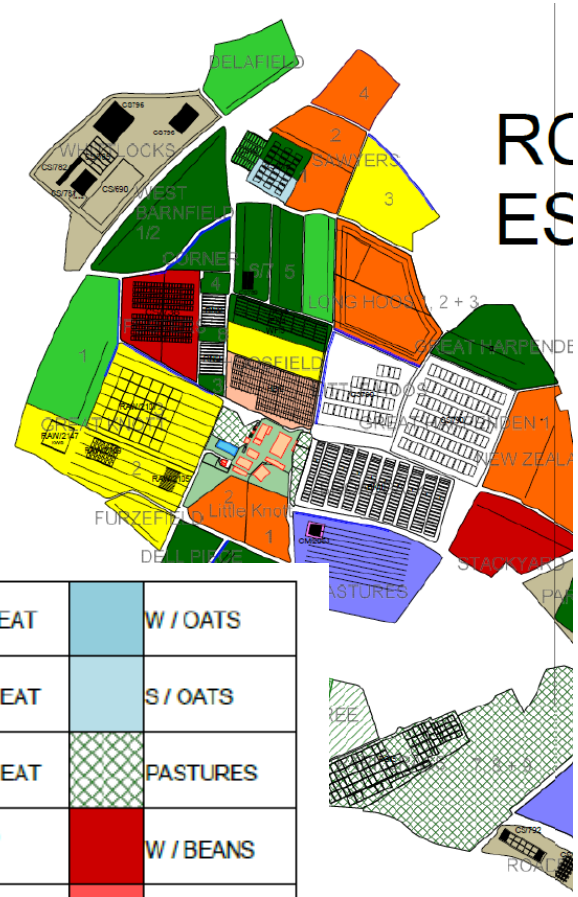
ECOSTRESS is currently acquiring 216 scenes / day, amounting to 32M sq km and **nearly 3x the number of scenes originally proposed** (74 scenes / day). For reference, Landsat-8 acquires 24M sq km / day or, in ECOSTRESS terms, 162 scenes.

ECOSTRESS is extremely popular – in the last 12 months, the ECOSTRESS Land Surface Temperature and Emissivity product was the 2nd most requested product in the LP DAAC AppEEARS data access tool. The MODIS Terra Land Surface Temperature/Emissivity product was the 1st. There are 120+ products in the tool

NASA-ESA 2021 European HyTES Campaign

2021-07-20
11:25:22

Rothamsted Research station showing the experimental fields and JPL measurements in barley field



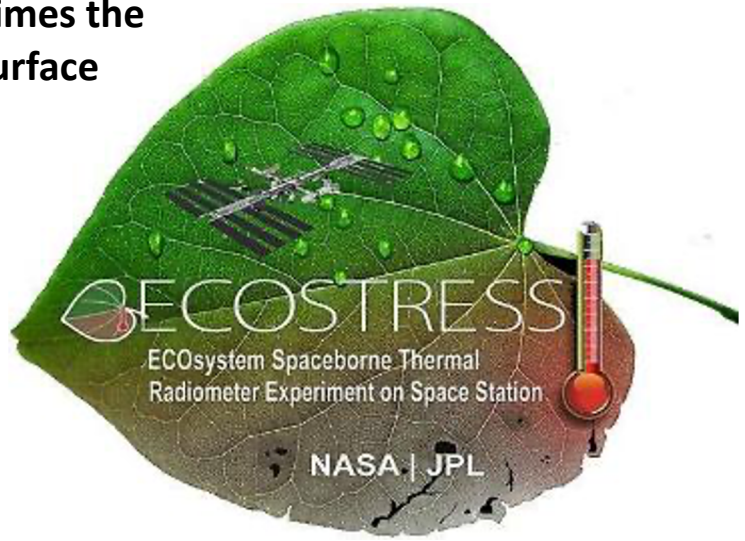
	1ST WHEAT		W / OATS
	2ND WHEAT		S / OATS
	3RD WHEAT		PASTURES
	SPRING WHEAT		W / BEANS
	WOSR		S / BEANS
	SOSR		CAMELINA
	W / BARLEY		LINSEED
	S / BARLEY	Stephen Goward, Mark Gardner, Nick Chichester-Miles, Chris Mackay, Tim Hall	Martin Gardner, Fred Ledbury, Rob Copley

ECOSTRESS Data: Quick Facts and Stats

As of 3/21/2022, 256,000+ scenes have been acquired since launch, an area over several hundred times the area of the Earth's land surface

In the last quarter, ECOSTRESS surface temperature and evapotranspiration were among top 20 of most requested products from LP DAAC AppEEARS which hosts MODIS and Landsat products

We originally planned to acquire an average of 74 scenes per day but have now acquired an average of 216 scenes per day.



Highest spatial resolution multispectral thermal infrared radiometer NASA has ever built

Only spaceborne instrument capable of providing data suitable for evaluating data for the Decadal Survey SBG TIR mission.

We originally planned to acquire ~27,000 scenes over a 1-year Mission and have now acquired 256,000+ scenes.

Successful negotiations between ISS and JAXA have secured JEM-EF site 10 for ECOSTRESS until September 2023.

Questions?