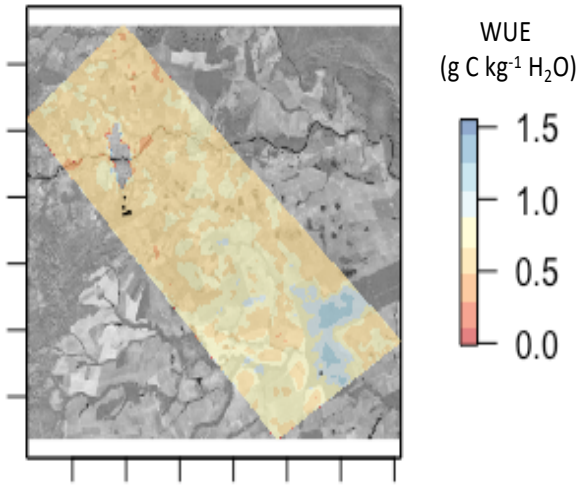
Merging ECOSTRESS with field data in the highest uncertainty water use efficiency regions in the world

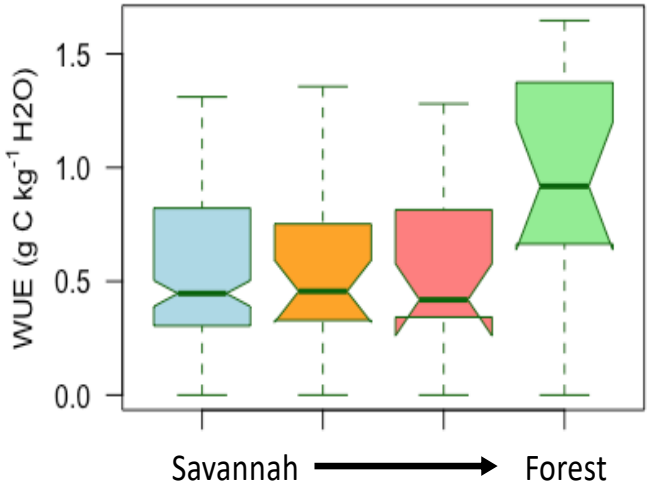
Chris Doughty, Jenna Keany, Brittany Schweiger, Greg Goldsmith, Imma Oliveras, Yadvinder Malhi, Joshua B. Fisher

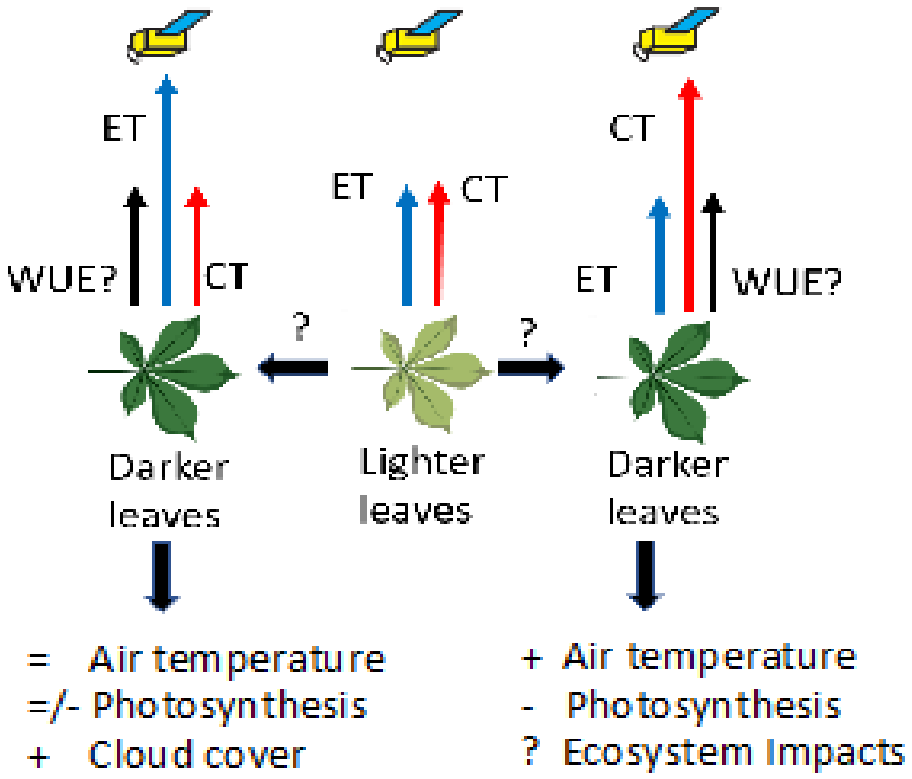
Mean WUE – Savannah to Forest Transition

Nova Xavantina, Brazil



WUE from 7/21/2018 - 6/9/2020



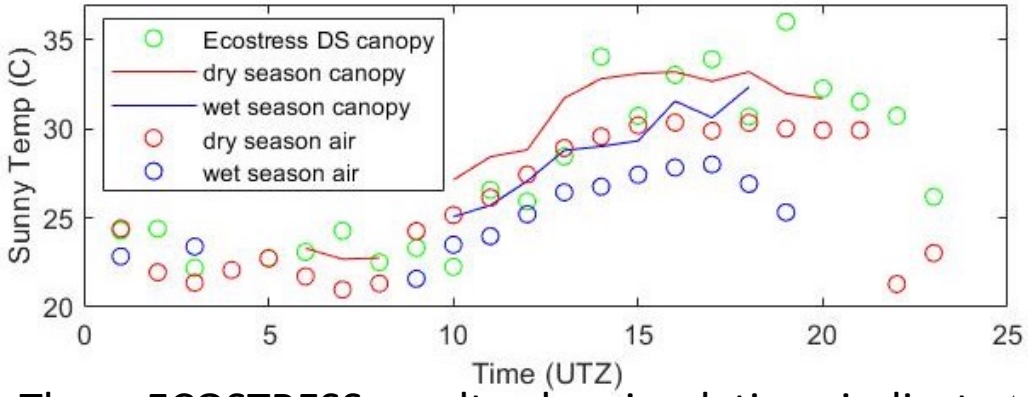


NAU Northern Arizona University
Ecological and Environmental Informatics

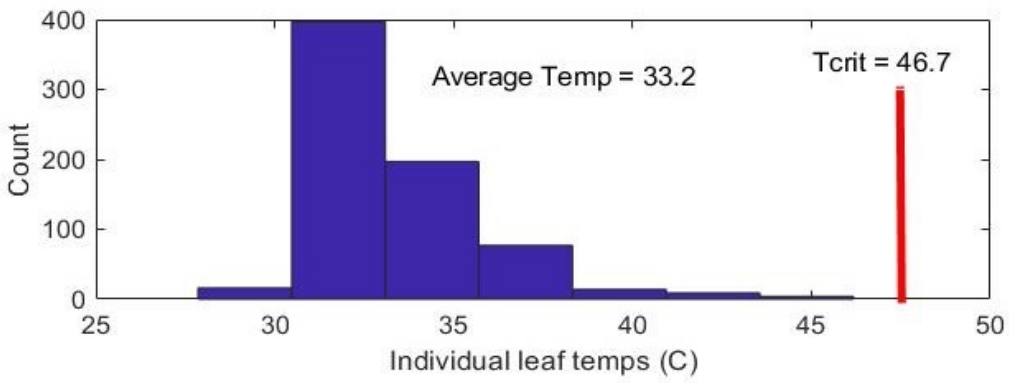
Testing whether tropical forests are within critical temperature thresholds

Chris Doughty, Jenna Keany, Brittany Schweiger, Greg Goldsmith, Imma Oliveras, Yadvinder Malhi, Joshua B. Fisher,

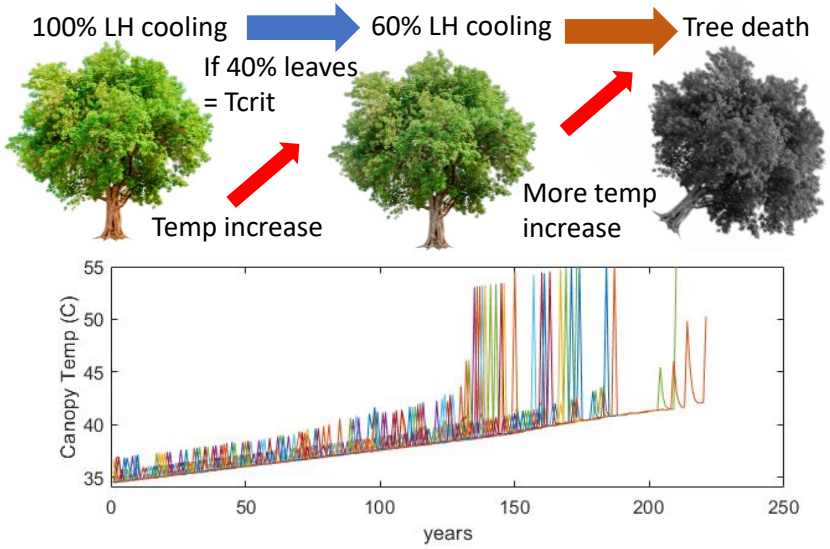
1.ECOSTRESS matches well with pyrgeometer and mean leaf thermocouple data in tropical forests.

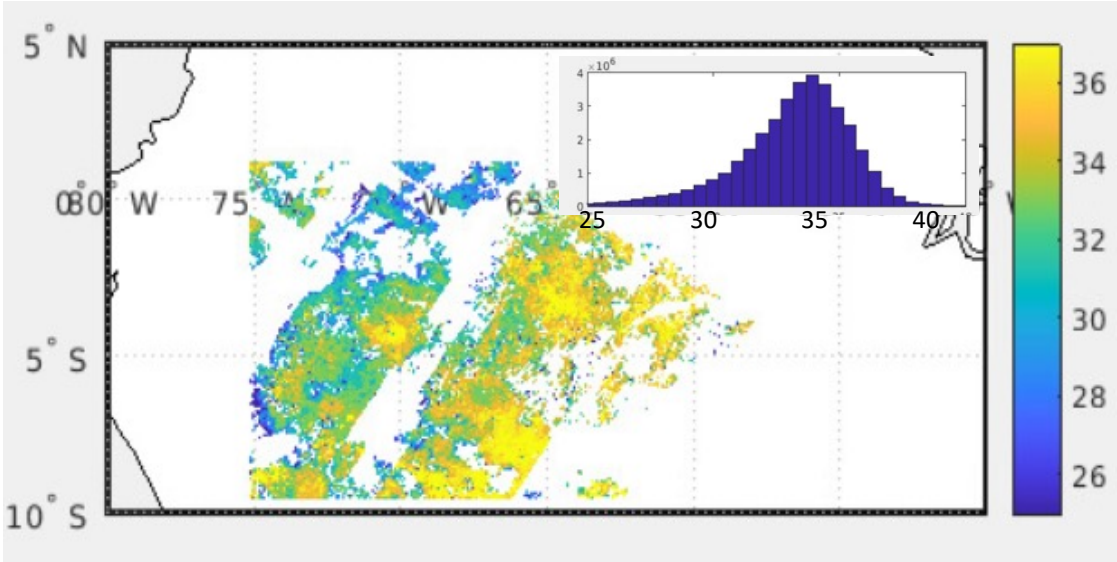


2. During warm, dry periods, canopy temperatures average ~33.5C with a long hot tail close to critical temperature thresholds



3. These ECOSTRESS results plus simulations indicate tropical forests can withstand up to 4.7 ± 0.90°C increase in air temperatures before a potential collapse





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Click Here for Full Article

Are tropical forests near a high temperature threshold?

Christopher E. Doughty[1] and Michael L. Goulden[1]

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ORIGINAL ARTICLE

Plant, Cell & Environment WILEY

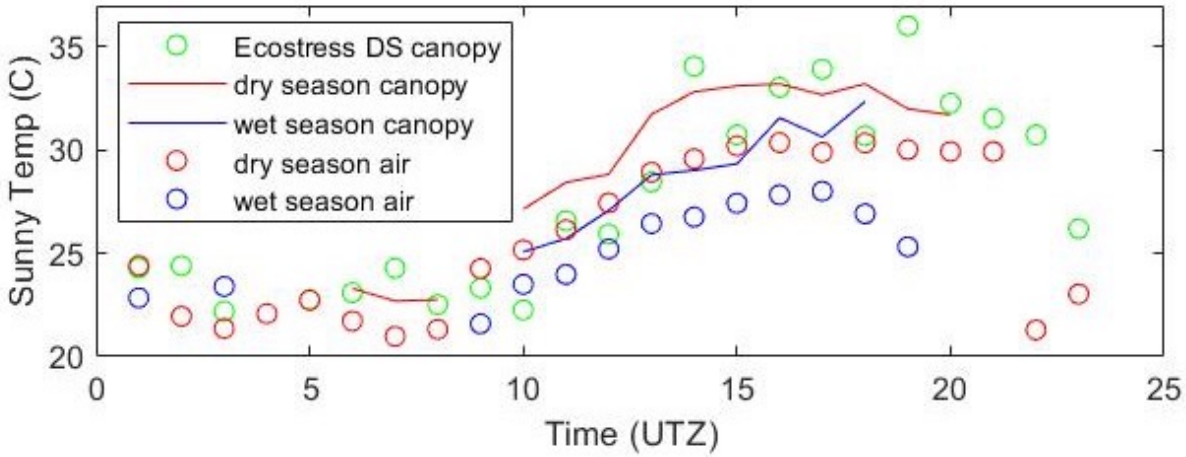
Leaf heat tolerance of 147 tropical forest species varies with elevation and leaf functional traits, but not with phylogeny

Martijn Slot[1] | Daniela Cala[1,2] | Jorge Aranda[1] | Aurelio Virgo[1] | Sean T. Michaletz[3] | Klaus Winter[1]

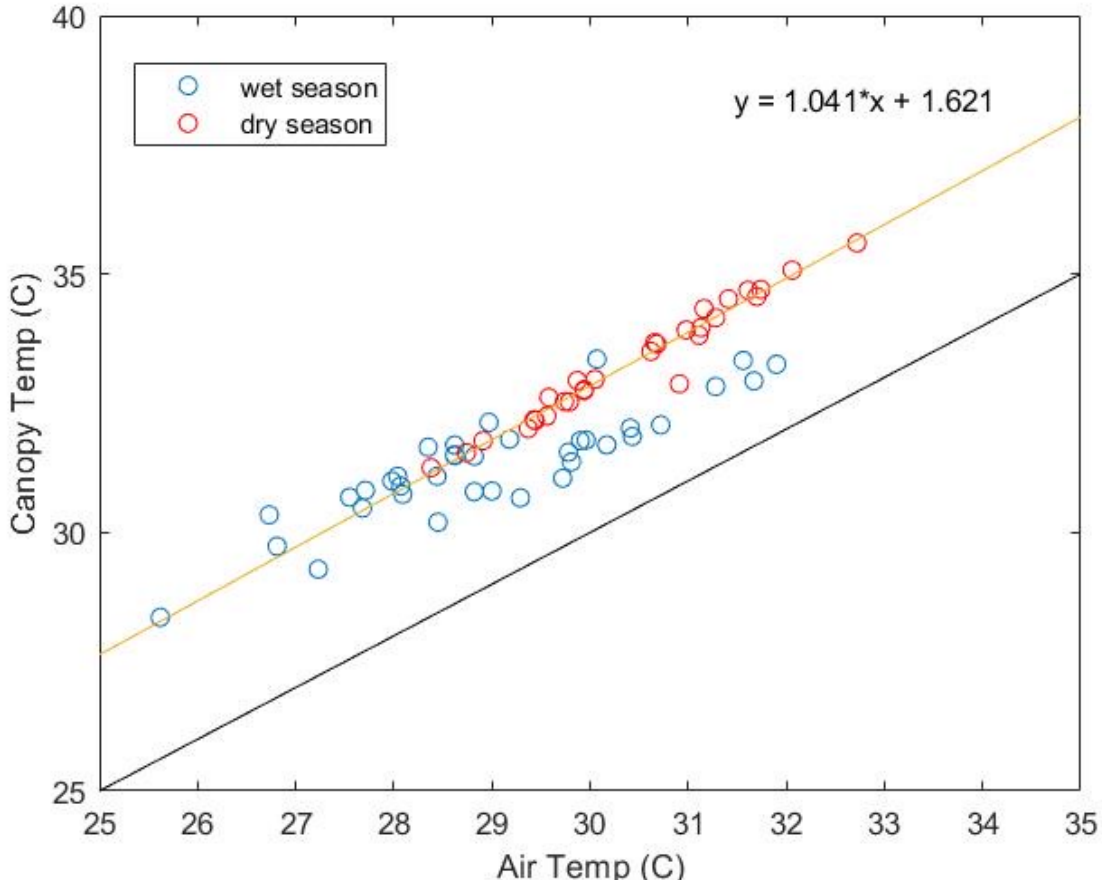
Among 147 tropical tree species, the average T_{crit} was 46.7°C (5th–95th percentile: 43.5–49.7°C)

What are current "peak temperatures" in the tropics and how close will tropical forests come to Tcrit in a future warmer world?

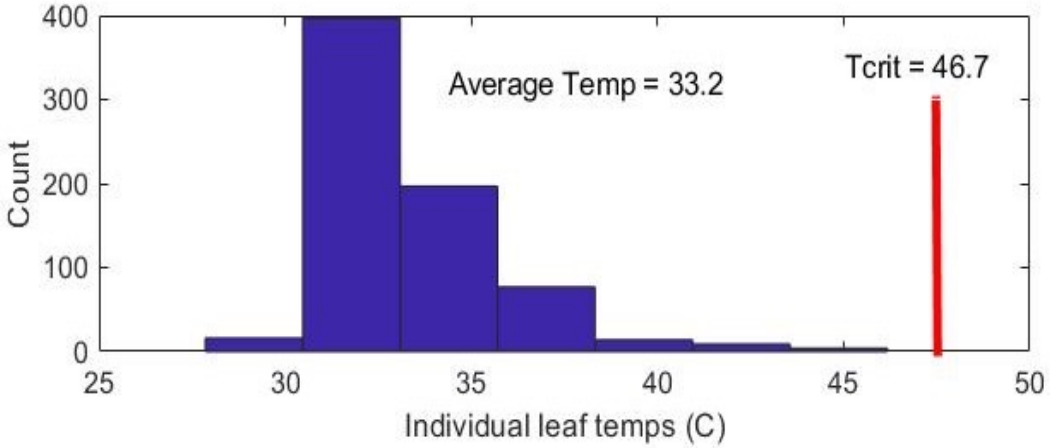
Compare ECOSTRESS to downward facing pyrgeometer and leaf thermocouples



- Canopy temperatures average 2-3C warmer than air temperatures during sunny periods in tropical forests

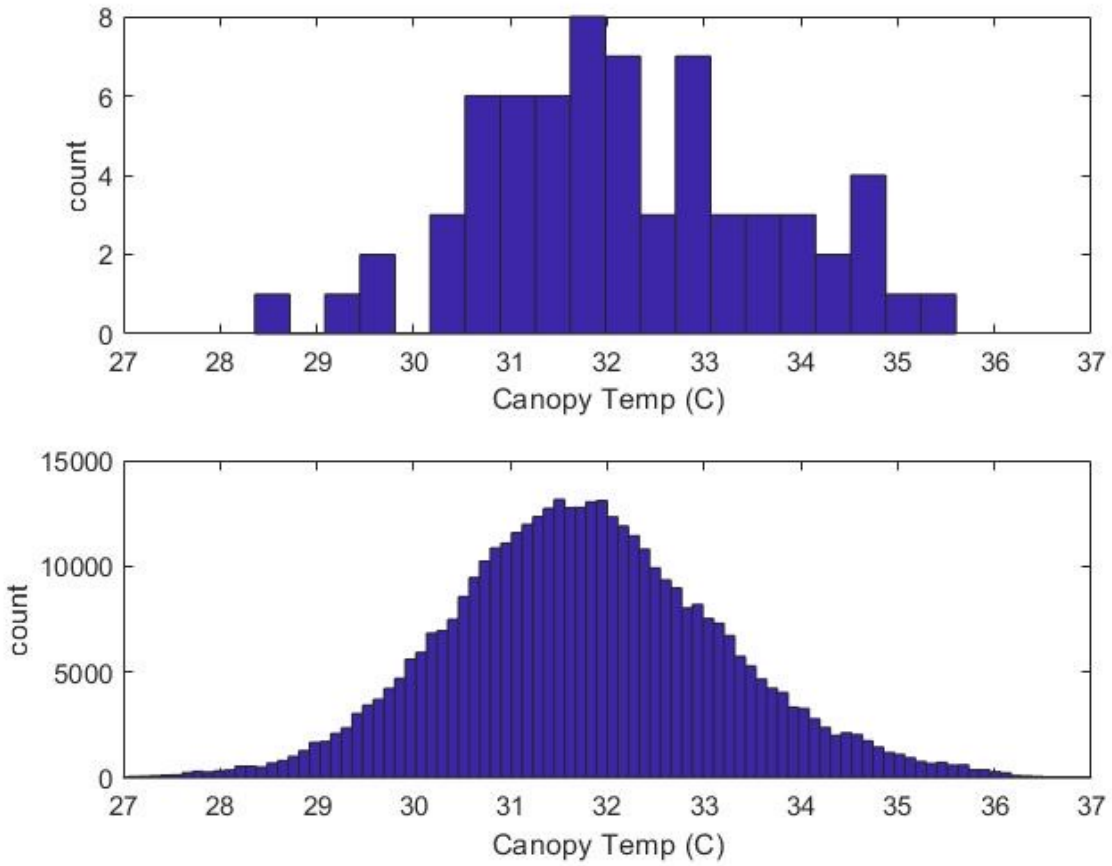


- For a given canopy temperature, there is a distribution of individual leaf temperatures with a long hot tail

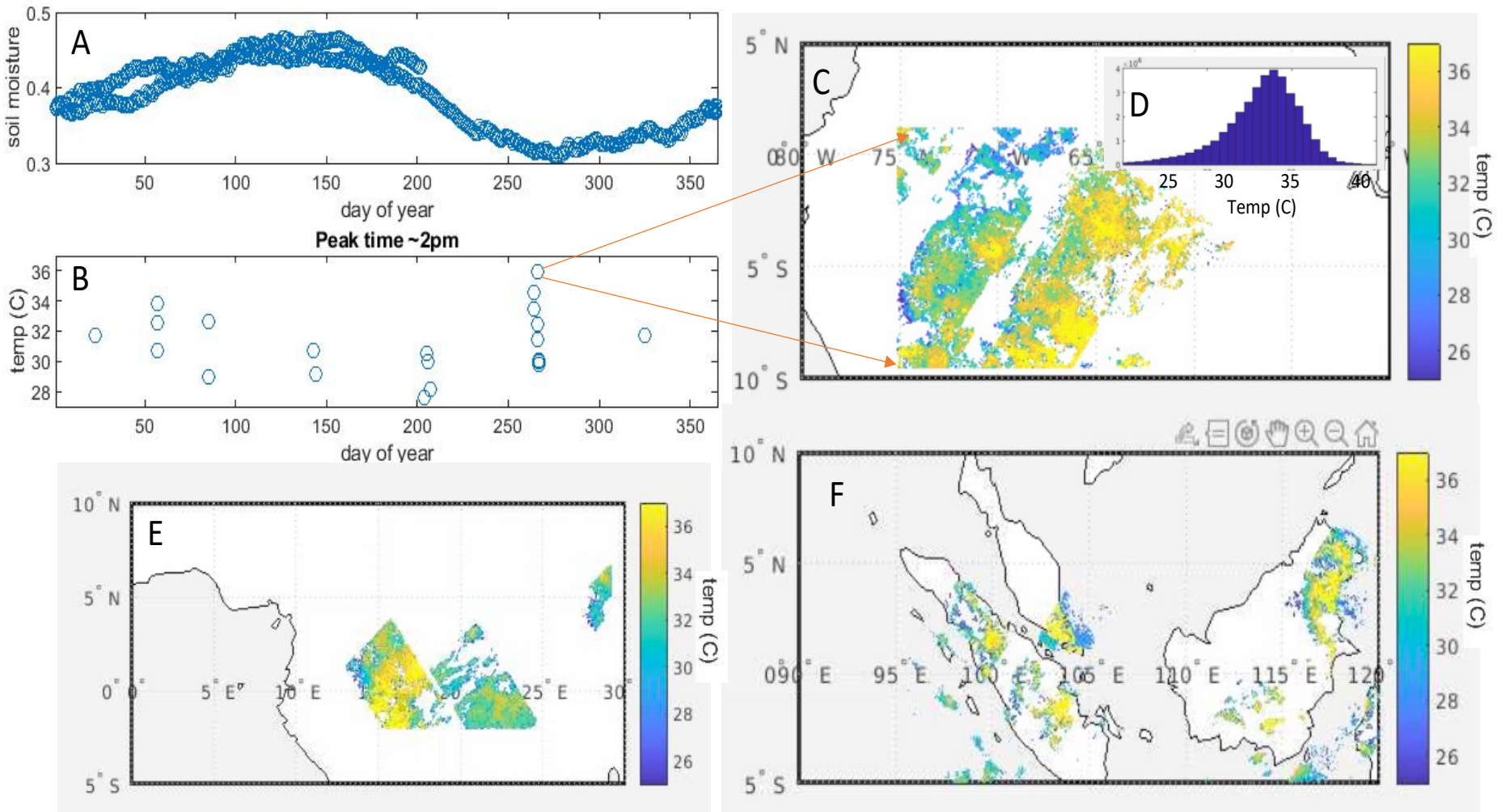


Temporal averaging removes the long tail

- Does ECOSTRESS with its higher spatial resolution also show a higher temperature distribution?



Temperature trends across the tropics during warm dry periods

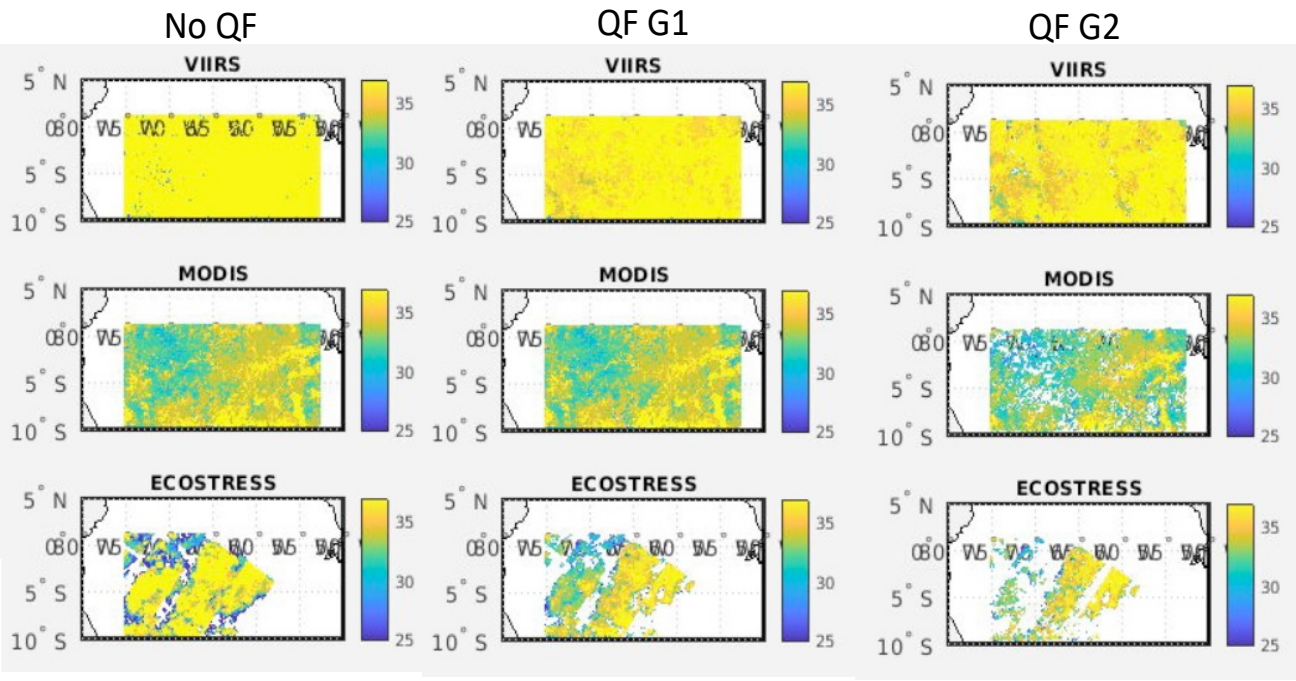


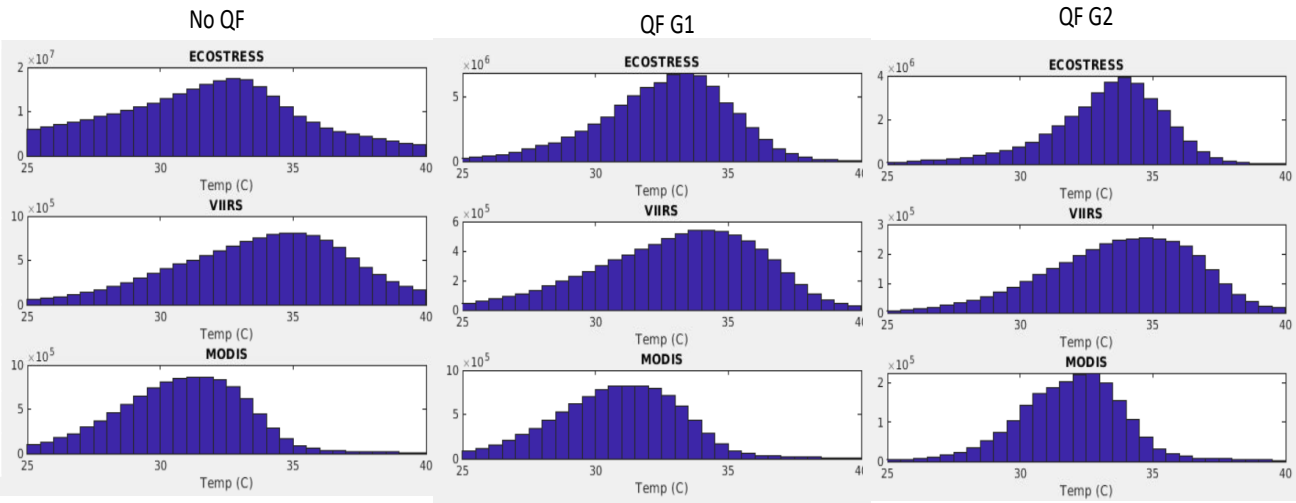
Canopy temperatures average 33-34C during warm, dry periods with a hot tail >40C

	≥ 38.0 °C		≥ 40.0 °C		≥ 45.0 °C	
	Current	+2 °C	Current	+2 °C	Current	+2 °C
South America	0.50%	5%	0.10%	1%	0.00%	0.10%
Central Africa	0.60%	2%	0.06%	0.60%	0%	0.01%
SE Asia (Borneo)	3%	8%	1%	3%	0.01%	0.30%

MODIS and VIIRS show similar trends to ECOSTRESS

	VIIRS	% of data	MODIS	% of data	ECOSTRESS	% of data	ECOSTRESS (reduced resolution)
No QF median	35.2	100%	31.2	100%	32.7	100%	30.7
QF 1 median	34.1	18%	31.2	27%	33.5	12%	32.8
QF 2 median	34.7	8%	32.7	6%	33.9	6%	33.1
No QF %>40C	0.06	100%	0.003	100%	0.03	100%	0.030
QF 1 %>40C	0.019	18%	0.003	27%	0.002	12%	0.0008
QF 2 %>40C	0.026	8%	0.004	6%	0.001	6%	0.0006





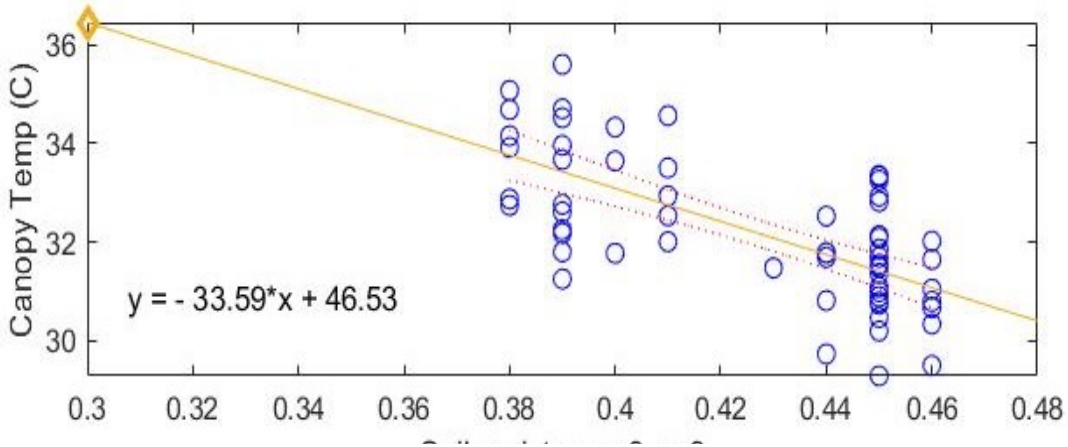
Quality flags are complicated

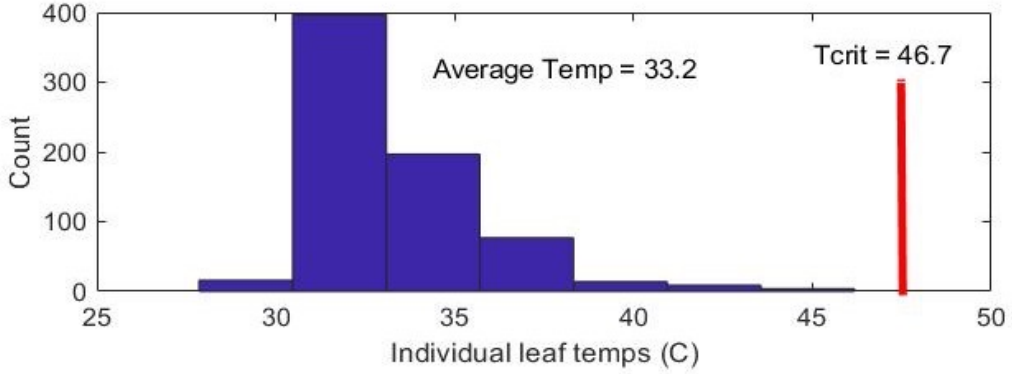
Flag #	Sensor	% of all data	Selected	Mandatory QA flags	Cloud/ocean flag	Iterations	Atmospheric Opacity	MMD	Emissivity accuracy	LST accuracy	Data quality flag
3520	ES	0.05	1,2	Pixel produced, best quality	Not set.	Fast	0.2 - 0.3 (Nominal value)	<0.03 (Vegetation, snow, water, ice)	>0.02 (Poor performance)	>2 K (Poor performance)	Good quality L1B data
3522	ES	0.06	1	Pixel produced, but cloud detected	Not set.	Fast	0.2 - 0.3 (Nominal value)	<0.03 (Vegetation, snow, water, ice)	>0.02 (Poor performance)	>2 K (Poor performance)	Good quality L1B data
11745	VI	0.03	1	*	Pixel within 2 pixels of nearest cloud	Fast	0.2 - 0.3 (Nominal value)	<0.03 (Vegetation, snow, water, ice, some soils)	0.01 - 0.015 (Good performance)	>2 K (Poor performance)	Good data quality of L1B bands 14, 15, 16
12001	VI	0.01	1	*	Pixel within 2 pixels of nearest cloud	Fast	0.1 - 0.2 (Nominal value)	<0.03 (Vegetation, snow, water, ice, some soils)	0.01 - 0.015 (Good performance)	>2 K (Poor performance)	Good data quality of L1B bands 14, 15, 16
15841	VI	0.06	1	*	Pixel within 2 pixels of nearest cloud	Fast	0.2 - 0.3 (Nominal value)	<0.03 (Vegetation, snow, water, ice, some soils)	<0.01 (Excellent performance)	>2 K (Poor performance)	Good data quality of L1B bands 14, 15, 16
32225	VI	0.07	1,2	*	Pixel within 2 pixels of nearest cloud	Fast	0.2 - 0.3 (Nominal value)	<0.03 (Vegetation, snow, water, ice, some soils)	<0.01 (Excellent performance)	1.5 - 2 K (Marginal performance)	Good data quality of L1B bands 14, 15, 16

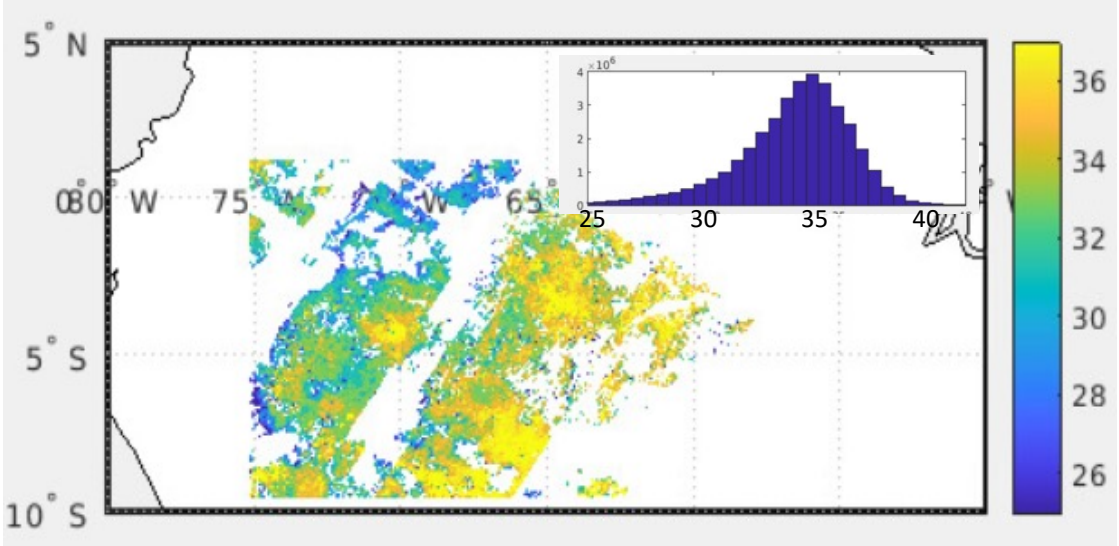
- LST accuracy often poor (~3C) in the tropics >90%
- MMD classified as vegetation low often <10%

Simple model

- We created a simple model to simulate canopy temperatures under future climate change that assumes:
- a long tail distribution of leaf temperatures,
- leaf death at Tcrit
- evaporative cooling as a linear function of the total number of leaves.

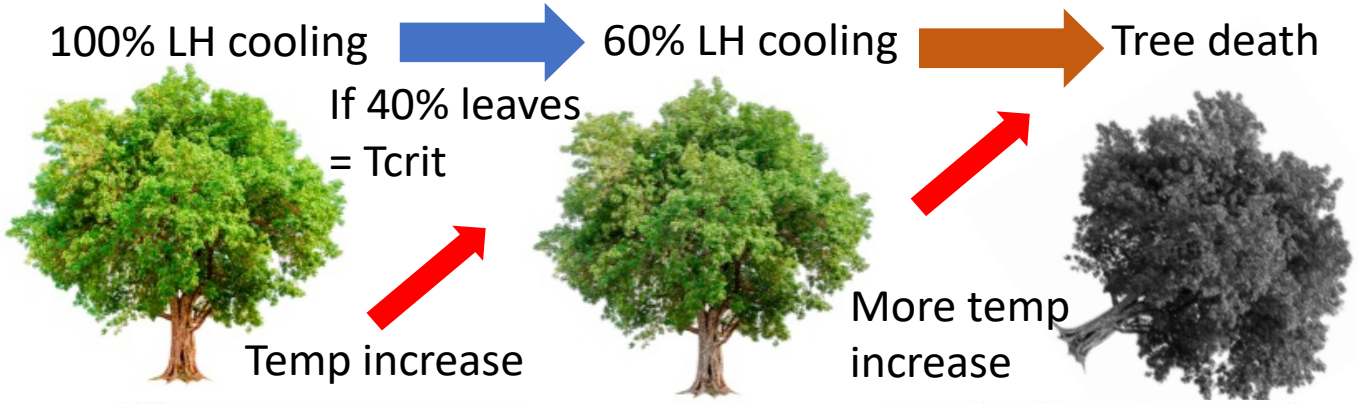


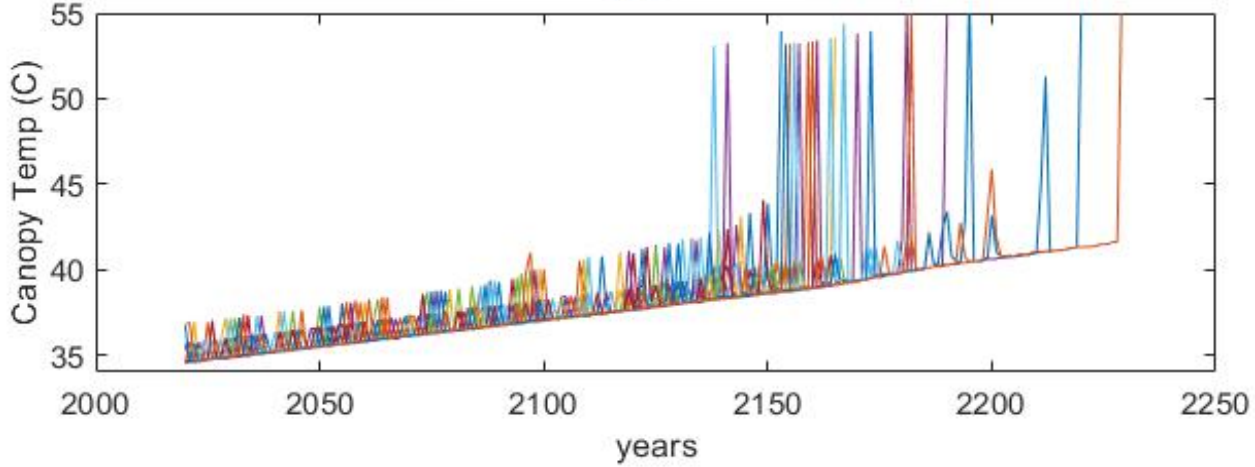


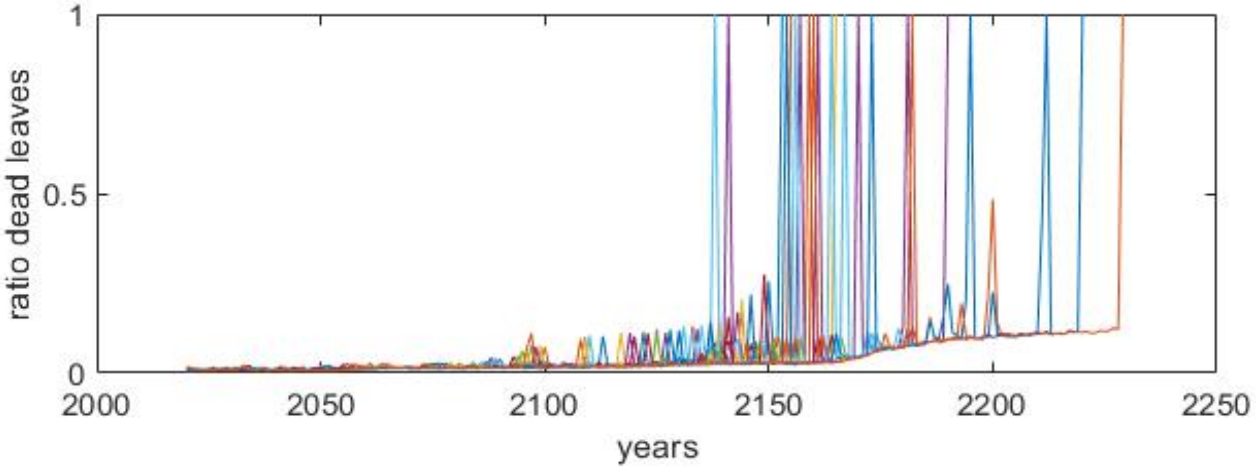


Simple model

- **Tropical forests can, on average, withstand up to 4.7 ± 0.90°C (N=30 model runs) increase in air temperatures before a potential collapse**

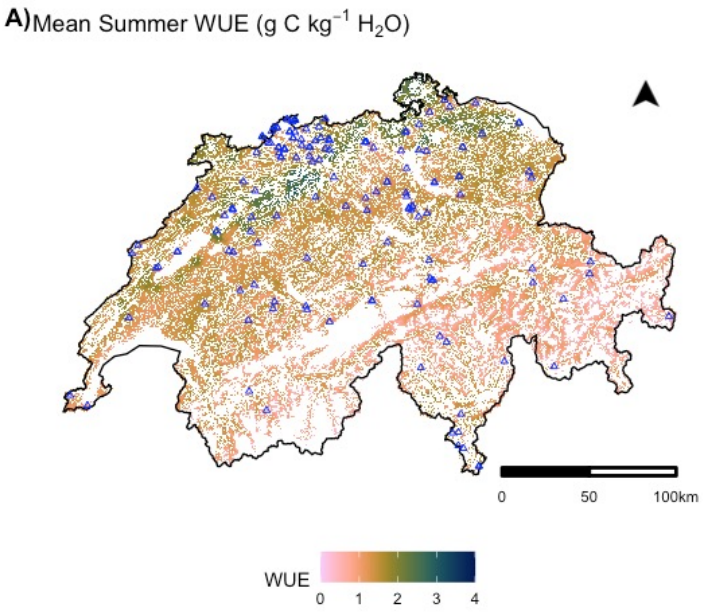






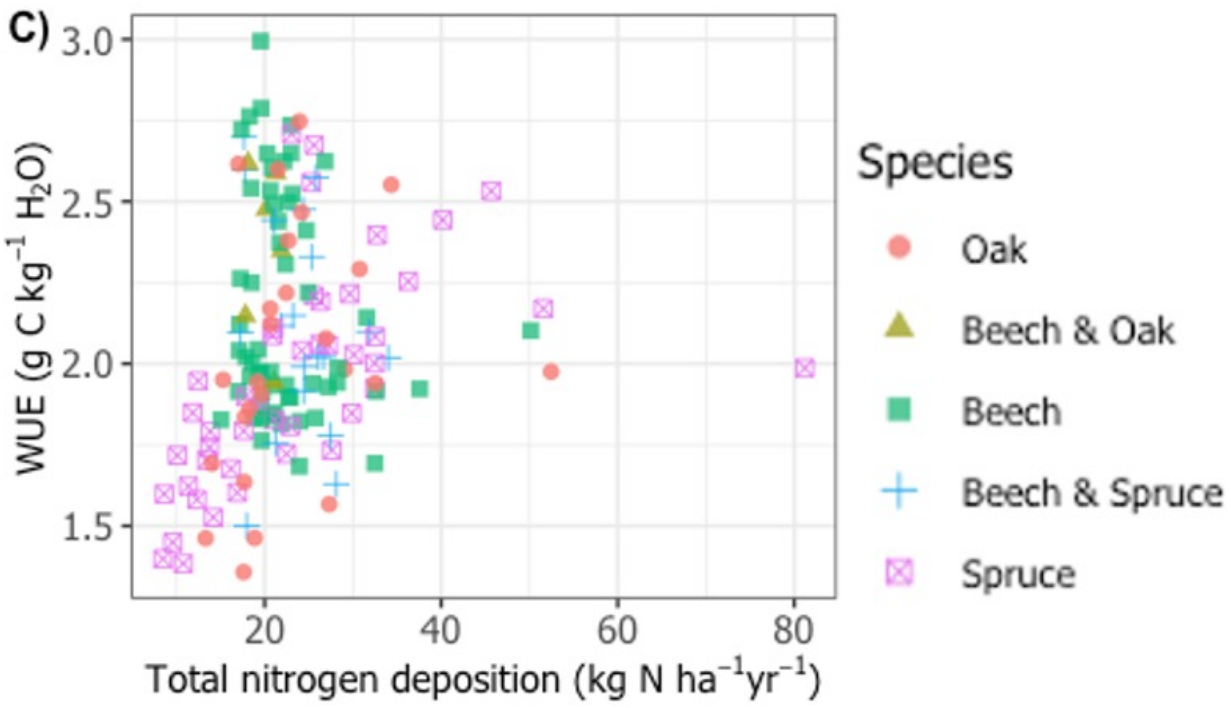
Other ongoing projects

Mapping Water-Use Efficiency in Swiss Forests



A undergraduate thesis from Chapman University student Brandon Bernardo has developed high resolution maps of water-use efficiency to inform decision-making by regional land managers.

Water-Use Efficiency Is Impacted By Pollution



Brandon's work reveals the impacts of anthropogenic nitrogen deposition on forest function. He recently presented his results at the Ecological Society of America.

Thank You

NASA Award Number, 80NSSC20K0216

Questions?

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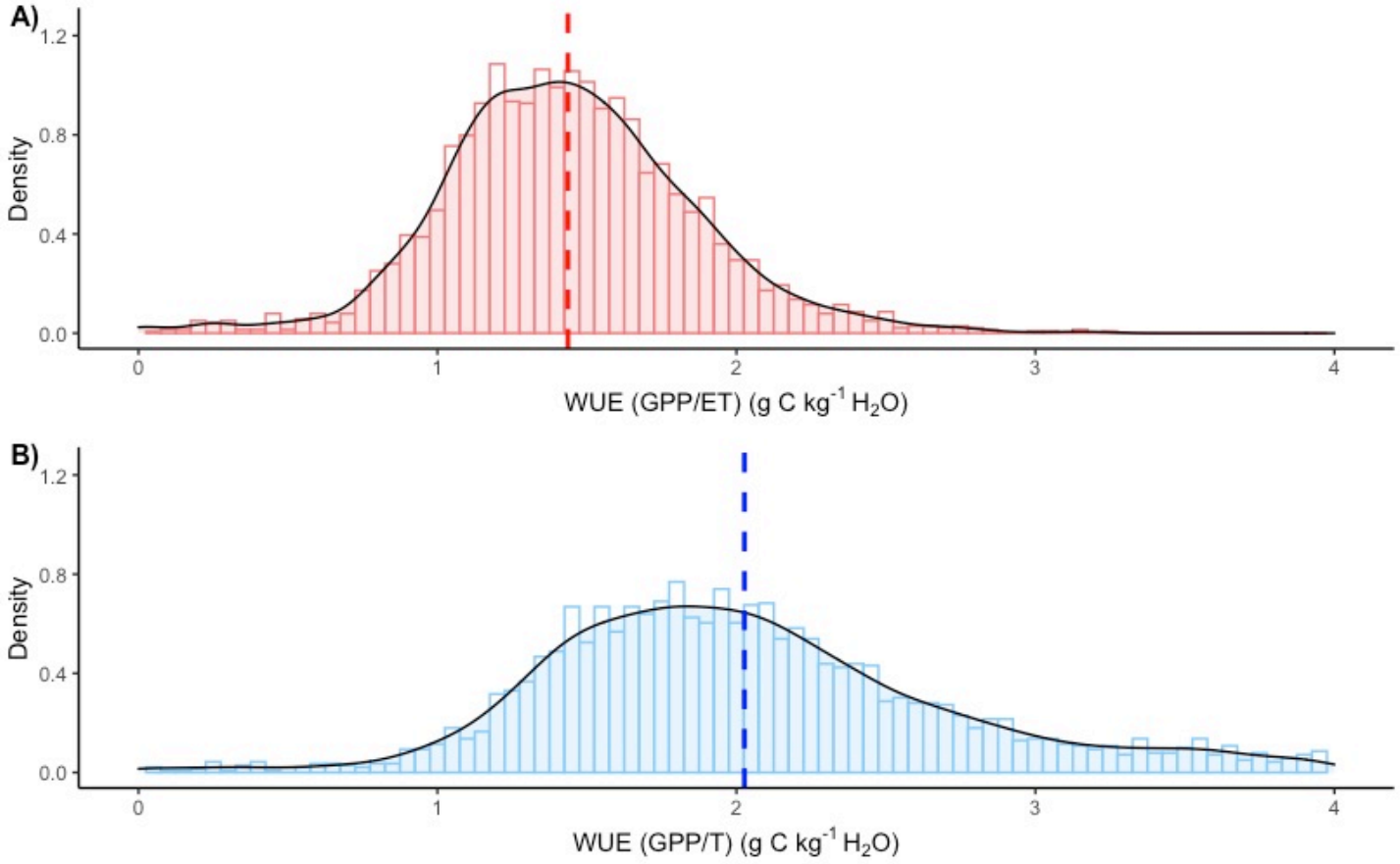
Testing New Calculations of Water-Use Efficiency



The research has also allowed us to compare different approaches to calculating WUE, which we hope will inform algorithm development moving forward.