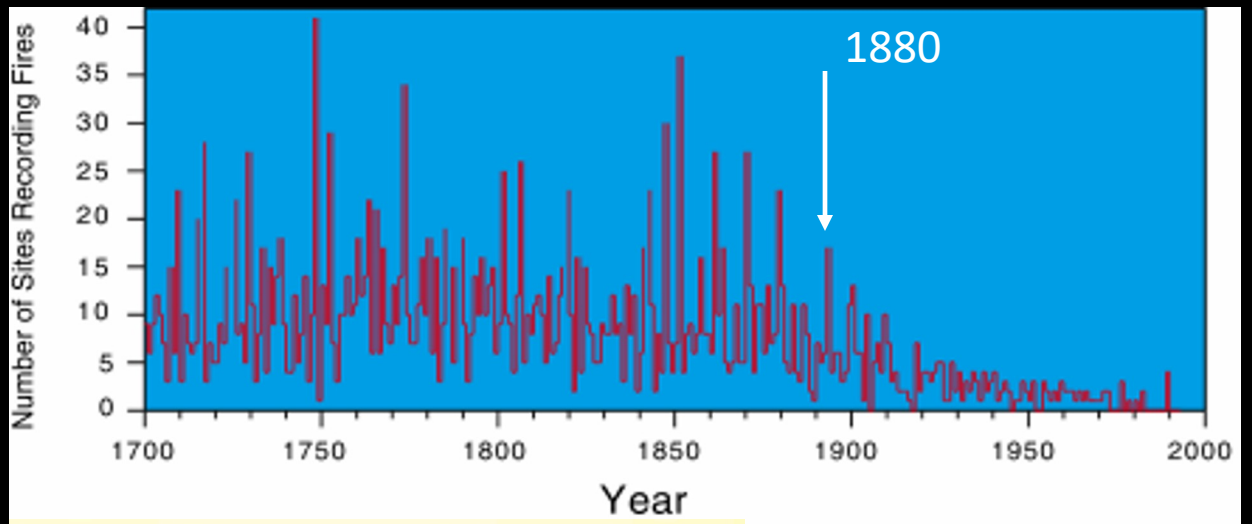
Validating ECOSTRESS in a southwestern pine-oak forest: impacts of wildfire on evapotranspiration

Helen Poulos[1], Andrew Barton[2] , George Koch[3], Tom Kolb[3], and Andi Thode[3]
[1]Wesleyan University
[2]University of Maine at Farmington
[3]Northern Arizona University

Anthropogenic Influences on Fire Regimes

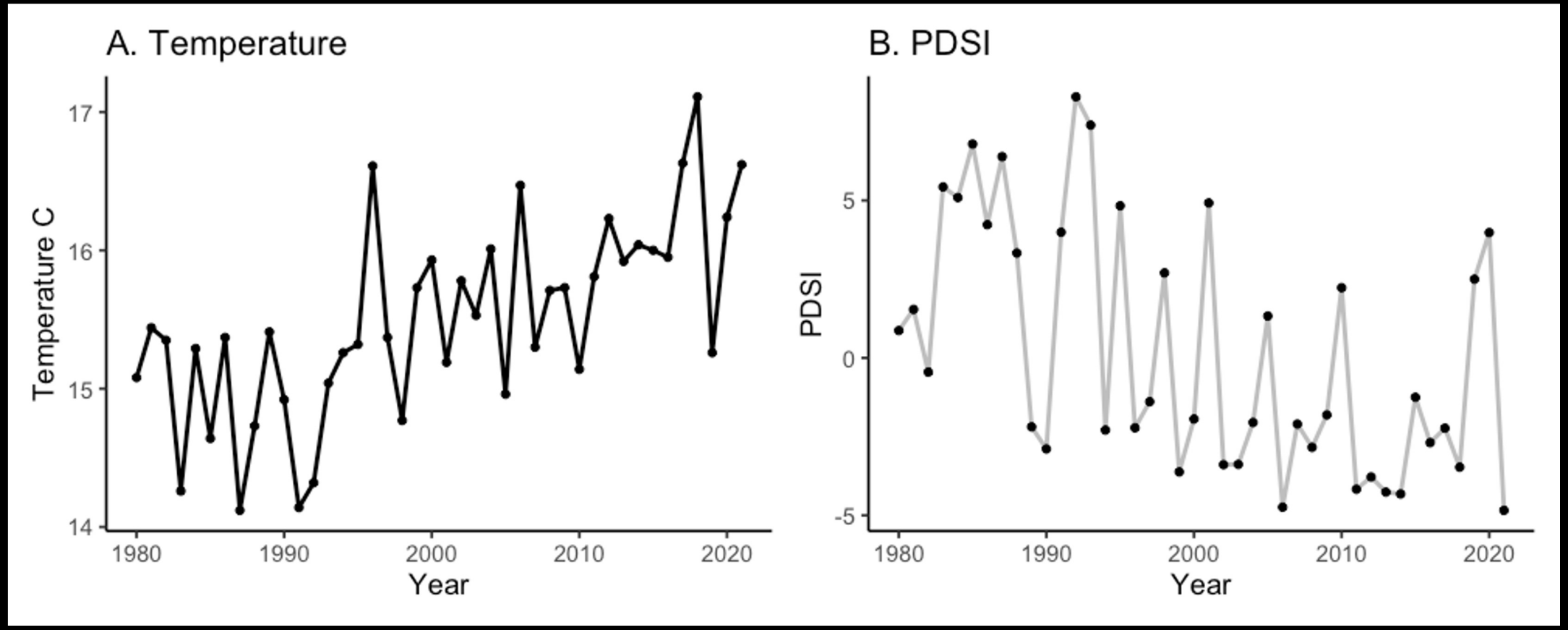


Swetnam and Betancourt 1998

Grazing

Direct Fire Suppression

22-yr Drought – Worst in 1200 yrs



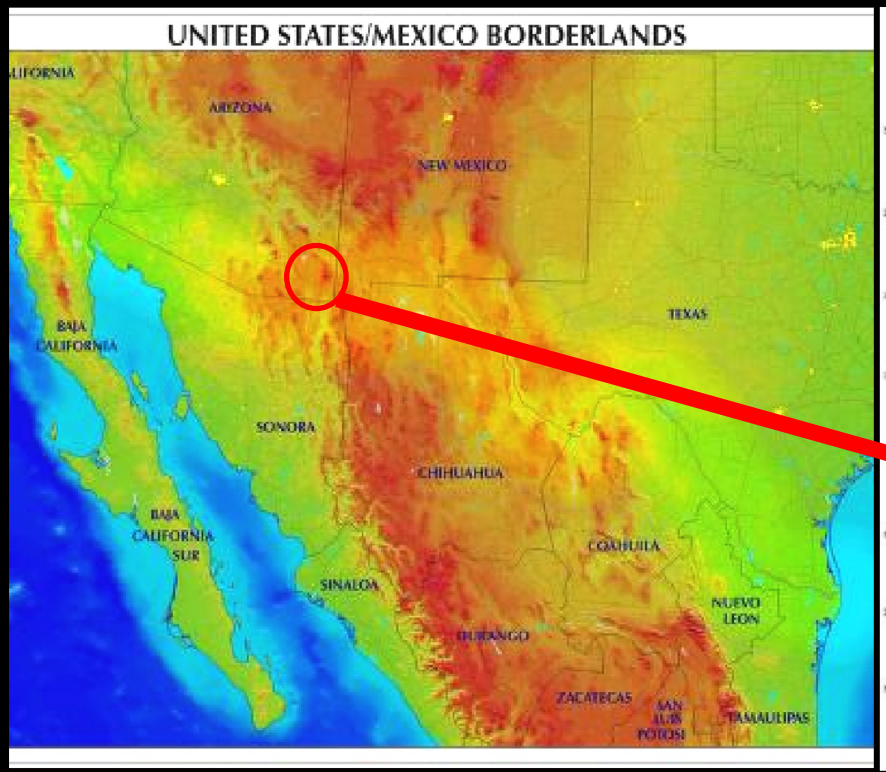
Fire Exclusion → High Fuel Loads

Climate Change → Increased Aridity

High Fuel Loads + Increased Aridity → Large Crown Fires

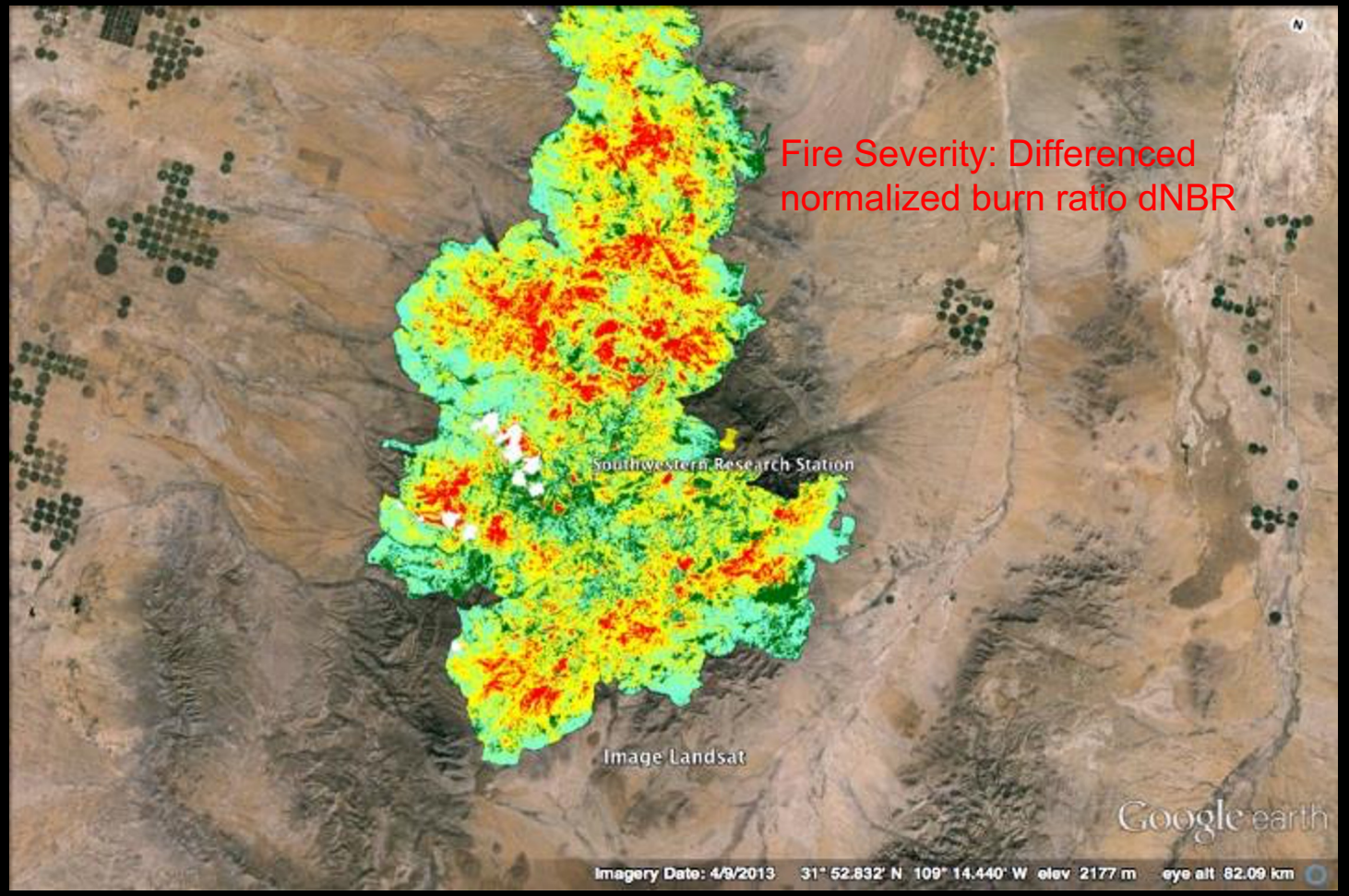
"…the fear that uncharacteristic fires may convert large areas of pine forest to other vegetation such as oak brush" (Wolfson & Thode 2014).


Chiricahua Mountains


UNITED STATES/MEXICO BORDERLANDS
ARIZONA
NEW MEXICO
TEXAS
BAJA CALIFORNIA
SONORA
CHIHUAHUA
BAJA CALIFORNIA SUR
COAHUILA
SINALOA
NUEVO LEON
DURANGO
ZACATECAS
SAN LUIS POTOSI
TAMAULIPAS


Arizona
New Mexico
Chiricahua Mountains
Mexico
Legend
Federal land
0 60 120 240 360 480
Kilometers

The massive Horseshoe II Fire of 2011, which burned over 200,000 acres



Main Project

Hypotheses:

- *Site-specific variation in diurnal, monthly, and seasonal post-fire field ET can be detected in ECOSTRESS ET products.*
- *Differences among fire severities in post-fire ET are driven by forest species composition.*
- *Post-fire ET is a good predictor of tree seedling regeneration in the wake of wildfire.*
- *ECOSTRESS ET provides good estimates of field ET.*

Wildfire severity and vegetation recovery drive post-fire evapotranspiration in a southwestern pine-oak forest, Arizona, USA

Helen Poulos, Andrew Barton, Tom Kolb, George Koch, and Andrea Thode

Remote Sensing in Ecology and Conservation. 2021. doi: 10.1002/rse2.210; NASA ECOSTRESS Grant Number: 80NSSC20K0077

Hypotheses Supported

Site-specific variation in diurnal, monthly, and seasonal post-fire field ET can be detected in ECOSTRESS ET products.

Differences among fire severities in post-fire ET are driven by forest species composition.

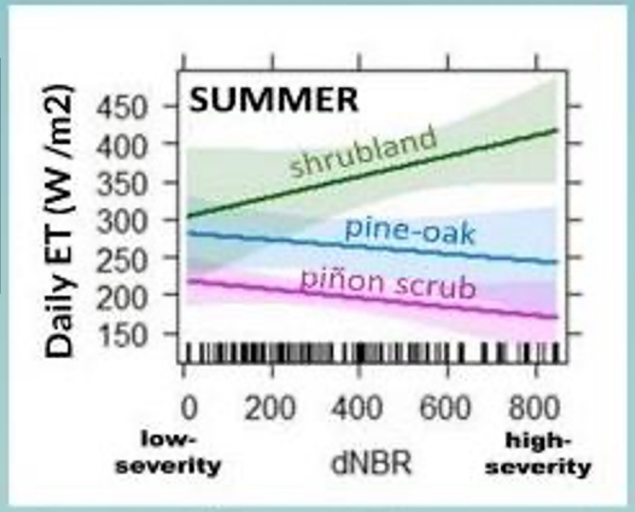


Figure 1: *Summer ET by vegetation type across the dNBR fire severity gradient. ET increases with fire severity in shrublands, which also have significantly higher ET than other vegetation types at moderate to high fire severities.*

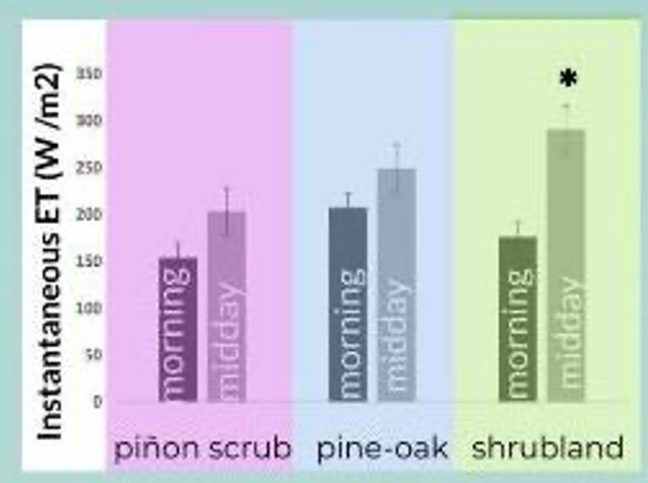
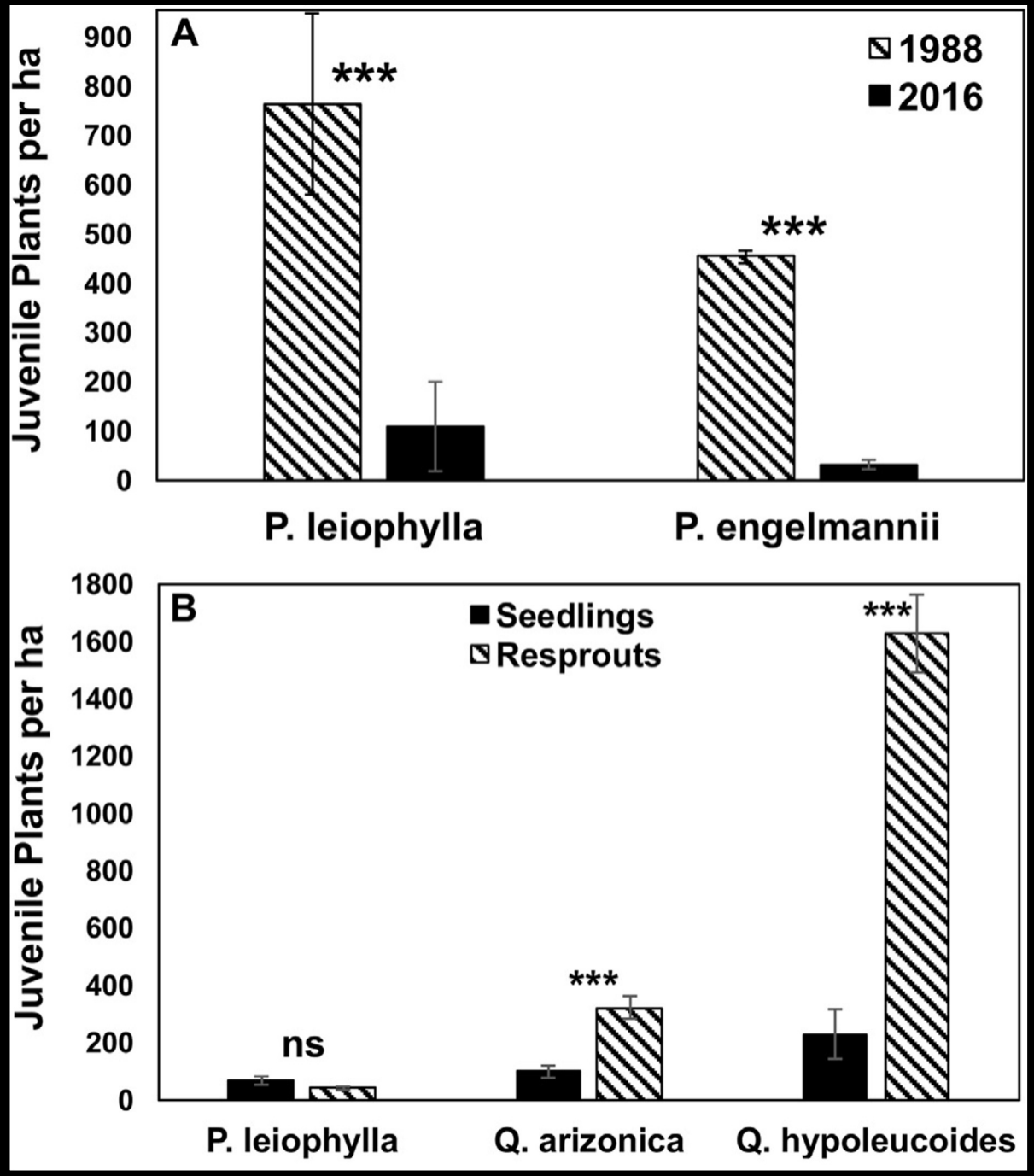


Figure 2: *Morning verssus midday ET in each post-fire vegetation type. The asterisk (*) denotes both a significant increase in ETinst from morning to midday in shrublands and the significantly higher midday ETinst of shrublands compared to other vegetation types at P < 0.01.*

Is Post-fire ET is a good predictor of tree seedling regeneration in the wake of wildfire?

Is ET a good predictor of post-fire pine regeneration?

- Long-term set of plots (1988-present) in Madrean pine-oak forest
- Historical: surface, low severity fire regime
- Modern: severe fires + drought → transition to oak shrublands
- We are tracking changes in pine regeneration
- Does ET help with understanding mechanisms curtailing pine regeneration?



1988: pre-fire, pre-drought

2016: post-fire, drought

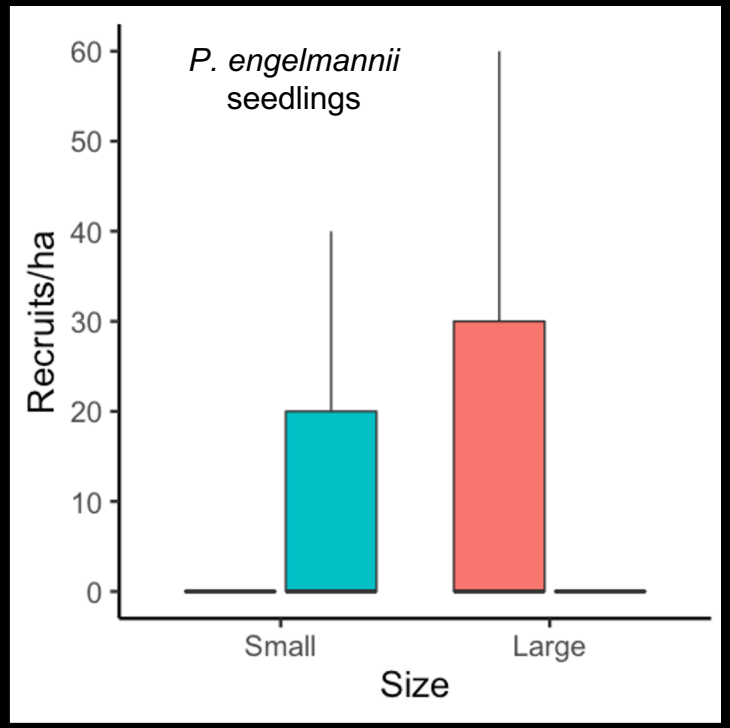
Vigorous Oak Resprouting

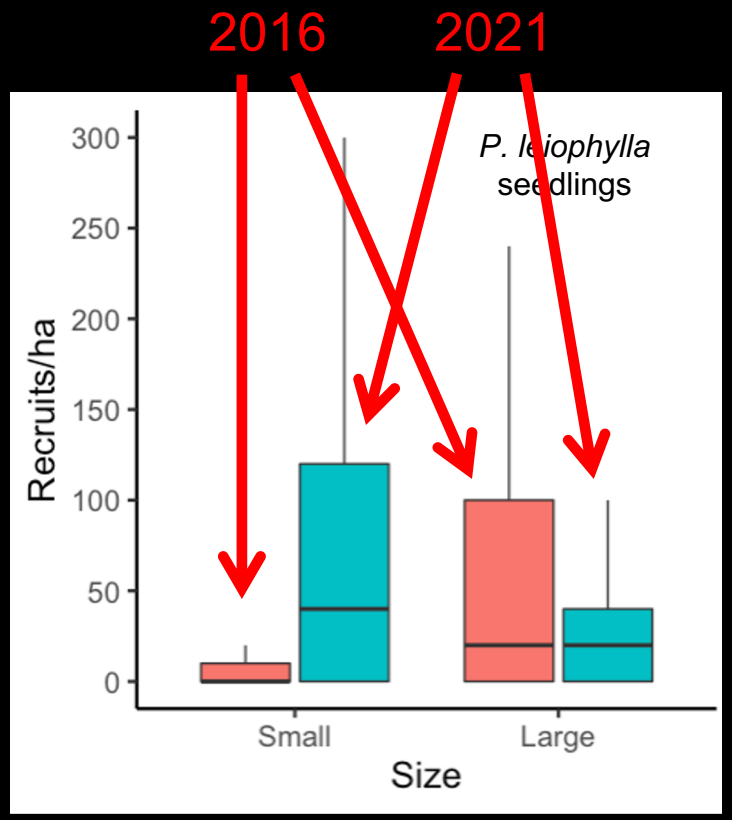
Poor Pine Regeneration

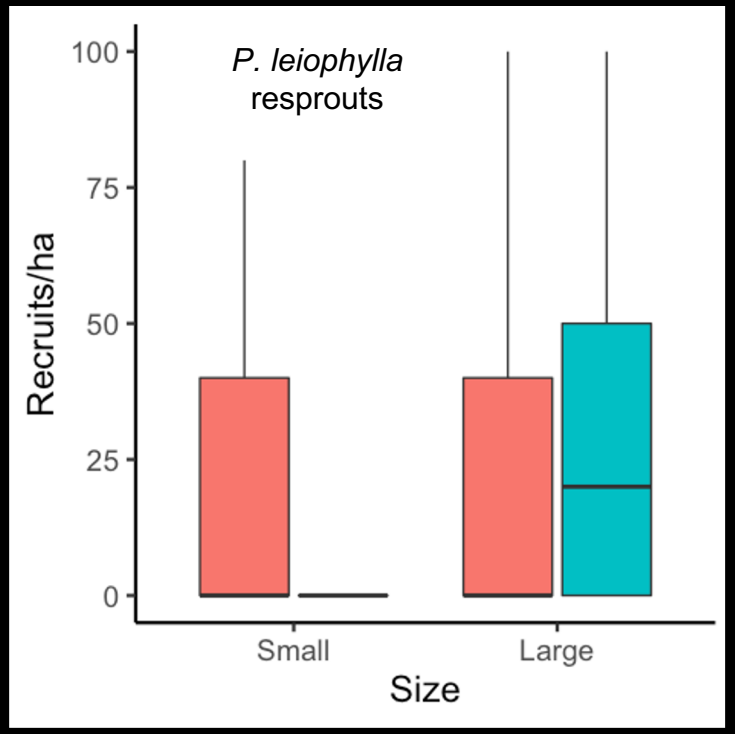
Pine-oak Forest →

Oak Shrublands

2016-2021: Pine Regeneration Did Not Improve

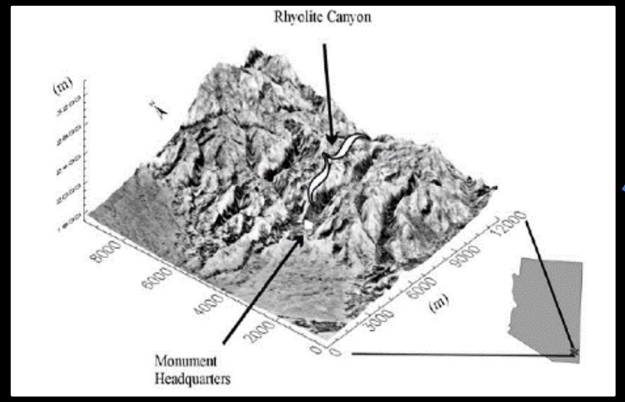




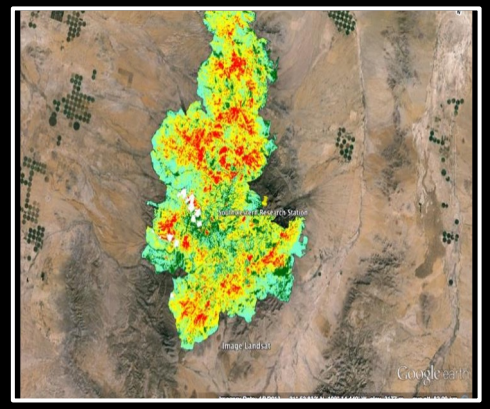


Illuminating Post-fire Pine Regeneration Patterns

Topography (Elev & TRMI)



Fire severity (dNBR)



Barton & Poulos 2018

Illuminating Post-fire Pine Regeneration Patterns

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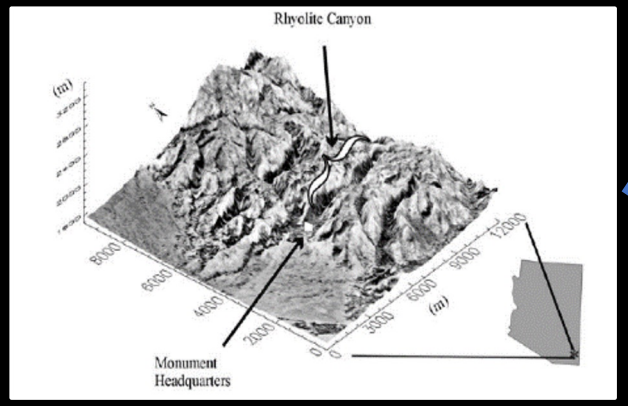

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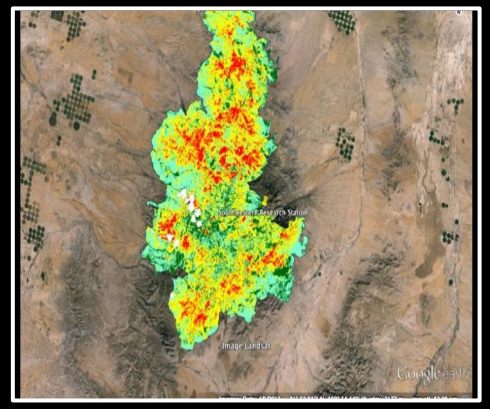


NDVI

???

ECOSTRESS ET & SoilE

MARS* Models for Pine Regeneration

MODELS	Terms Retained	GCV
P. engelmannii seedlings		
1. Elev + TRMI + dNBR		
2. Elev + TRMI + dNBR + NDVI		
3. Elev + TRMI + dNBR + ET		
4. Elev + TRMI + dNBR + SoilE		
***P. leiophylla* seedlings**		
1. Elev + TRMI + dNBR		
2. Elev + TRMI + dNBR + NDVI		
3. Elev + TRMI + dNBR + ET		
4. Elev + TRMI + dNBR + SoilE		
P. leiophylla resprouts		
1. Elev + TRMI + dNBR		
2. Elev + TRMI + dNBR + NDVI		
3. Elev + TRMI + dNBR + ET		
4. Elev + TRMI + dNBR + SoilE		

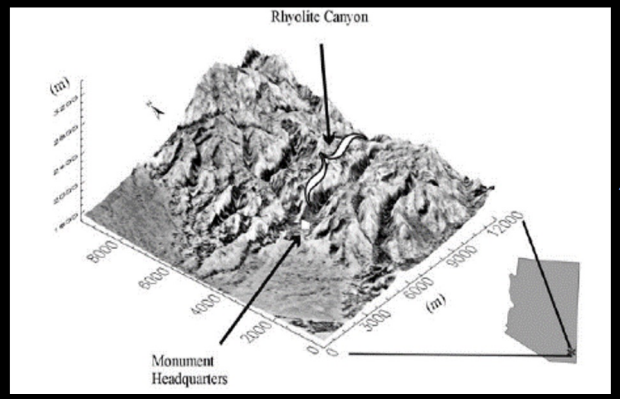
NDVI & SoilE both add explanatory value

NDVI & SoilE are strongly inversely related

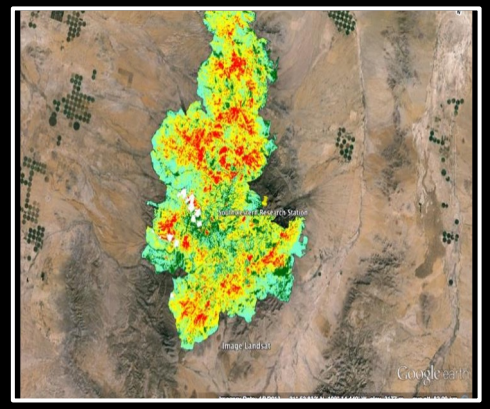
*Multivariate Adaptive Regression Splines

Illuminating Post-fire Pine Regeneration Patterns

Topography (TRMI)



Fire severity (dNBR)



30-m resolution

NDVI

70-m resolution

ECOSTRESS ~~ET~~ & SoilE

How does ECOSTRESS ET compare to field-derived ET estimates?

Field Methods

Installed 1 Bowen Ratio station at each field site for measuring **hourly and daily sub-canopy ET**

(May 2021-Sept 2022)

Installed a network of vegetation plots and 38 sap flow sensors to estimate post-fire **hourly and daily canopy ET**

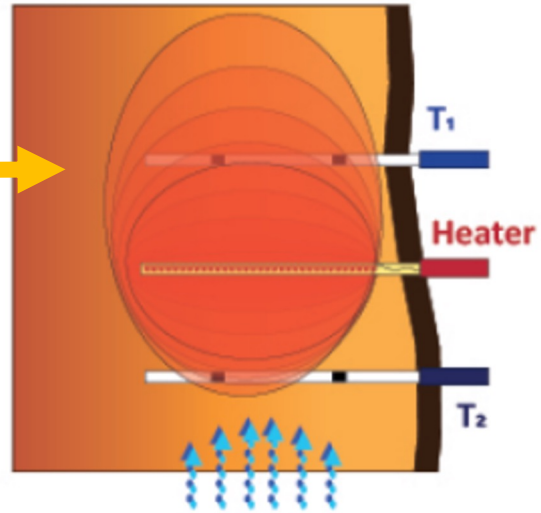
(May 2021-Sept 2022)

Estimating sub-canopy ET

- Collected 15 months of 20-minute Bowen Ratio ET data.
- Summarized hourly and daily sub-canopy ET to match with field sap flow T and ECOSTRESS overpass dates
- And precipitation, air temperature, and vapor pressure deficit data

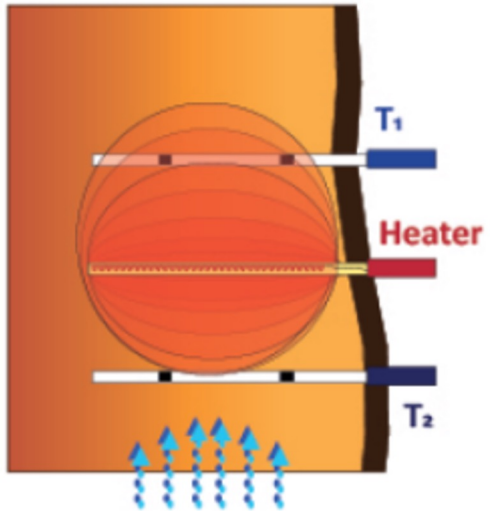
Canopy Transpiration

Sap Flow Meter Uses Heat Ratio Method

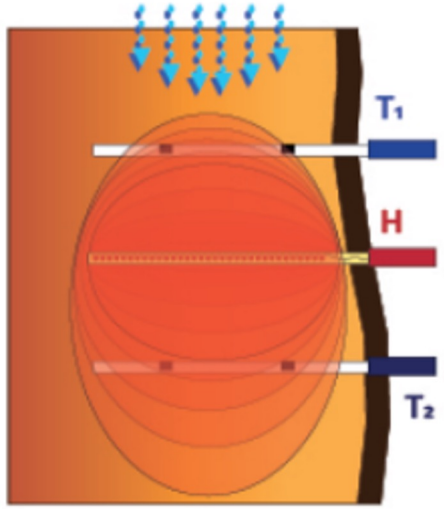


High Sap Flow

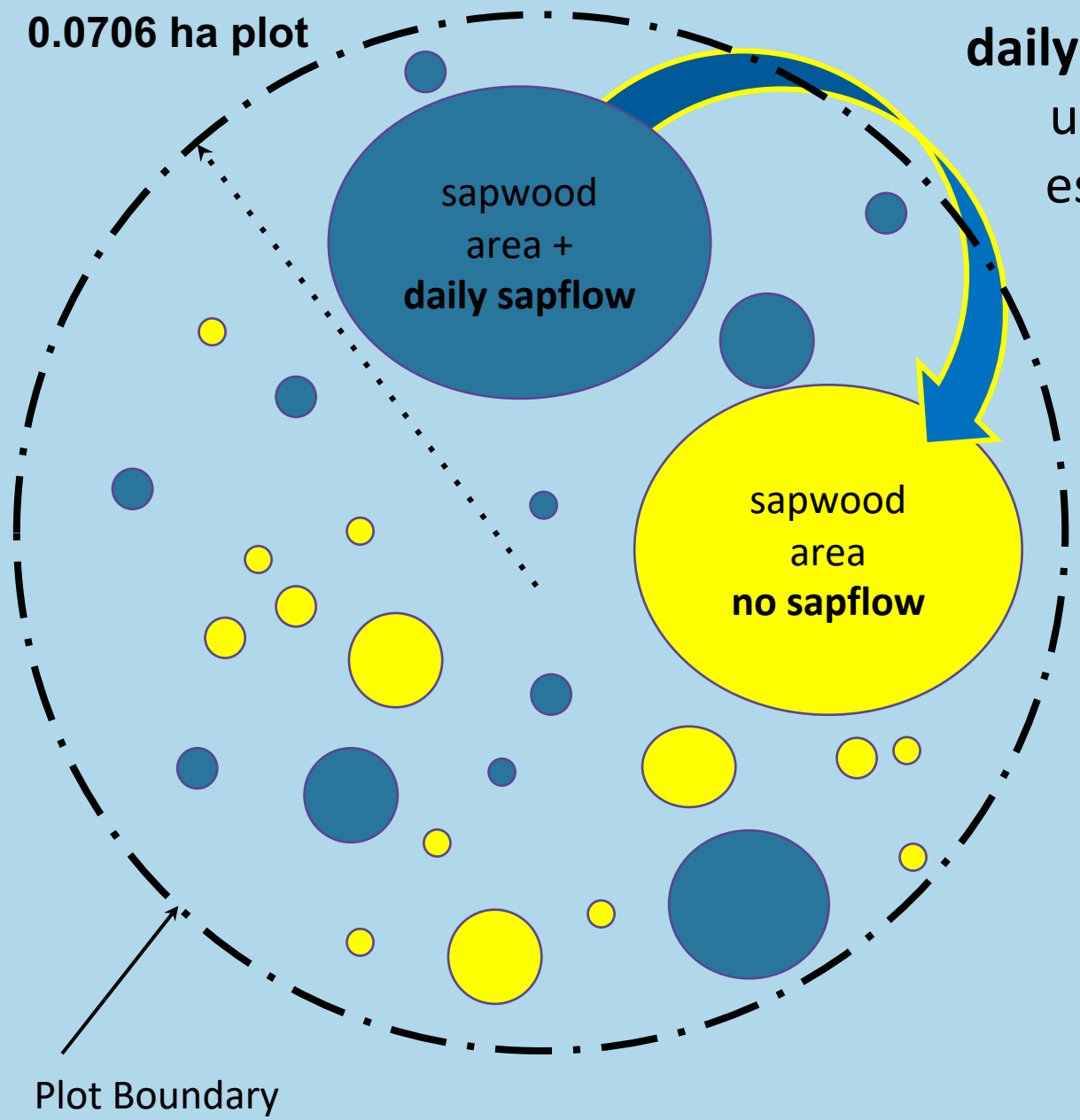
Flow Velocity (V) is logarithmically related to the ratio of temperature increases up and downstream from a heater



Low Sap Flow



Reverse Flows



Sapflow Scaling

daily regressions of sapflow for uninstrumented trees to estimate canopy sapflow

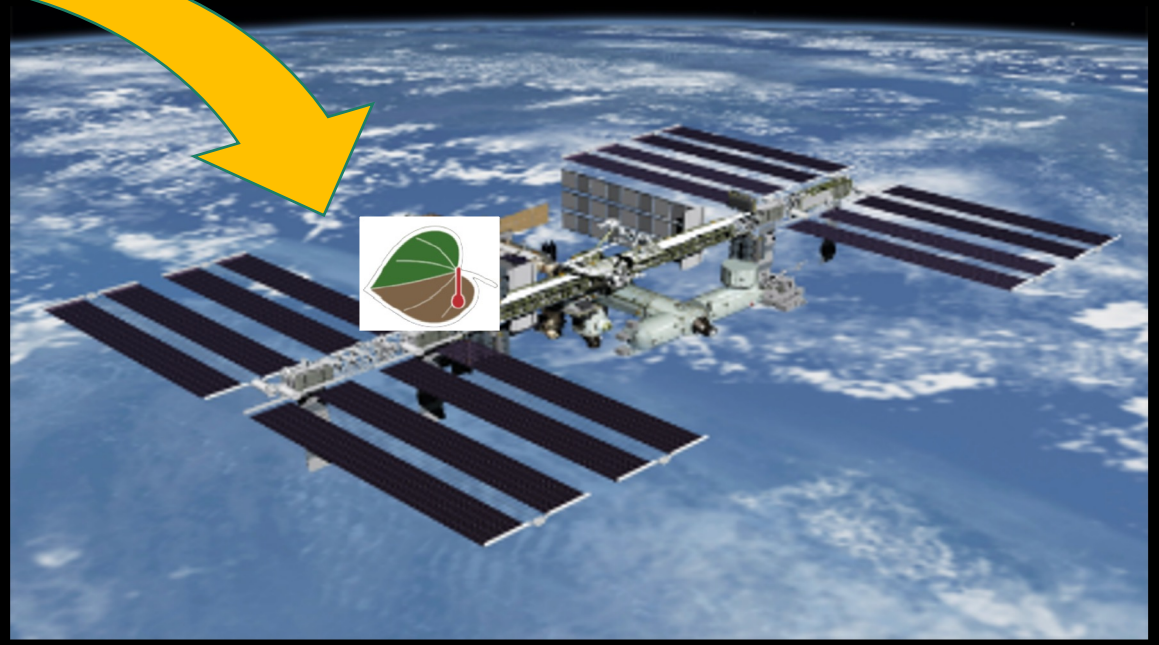
Instrumented trees
Uninstrumented trees

Total Stand ET =

Sum of subcanopy ET

+

Sum of T (instrumented and non)



Validating ECOSTRESS ET with field ET data

Does ECOSTRESS ET provides good estimates of field ET?

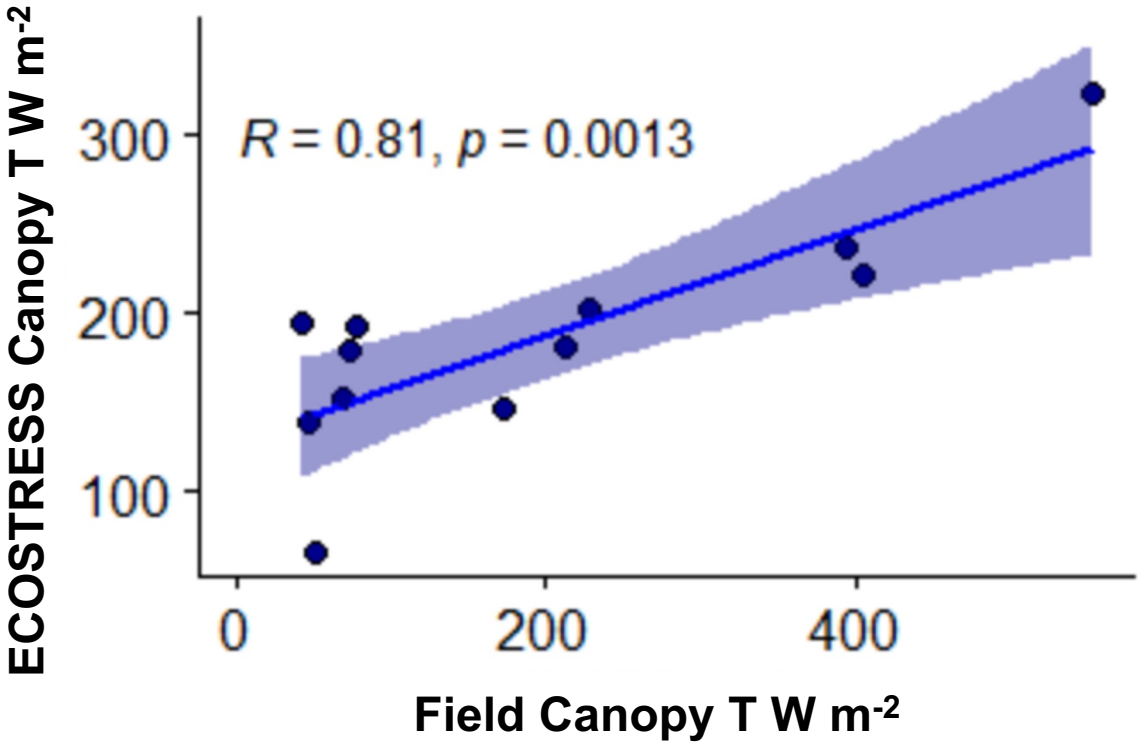
Some things we've learned

There are a lot fewer "best quality" overpasses for ECOSTRESS ET (only 24) than other products like LST (365) over 15 months, and no CanopyT data for some of those overpasses.

Metadata could be vastly improved for ECOSTRESS users. It should be clear to users that Canopy T, Soil E, and interception are in % of daily ET (not in algorithm documents).

QC Bitmask interpretations still not integrated into PT-JPL-ET products.

Best Quality Observations

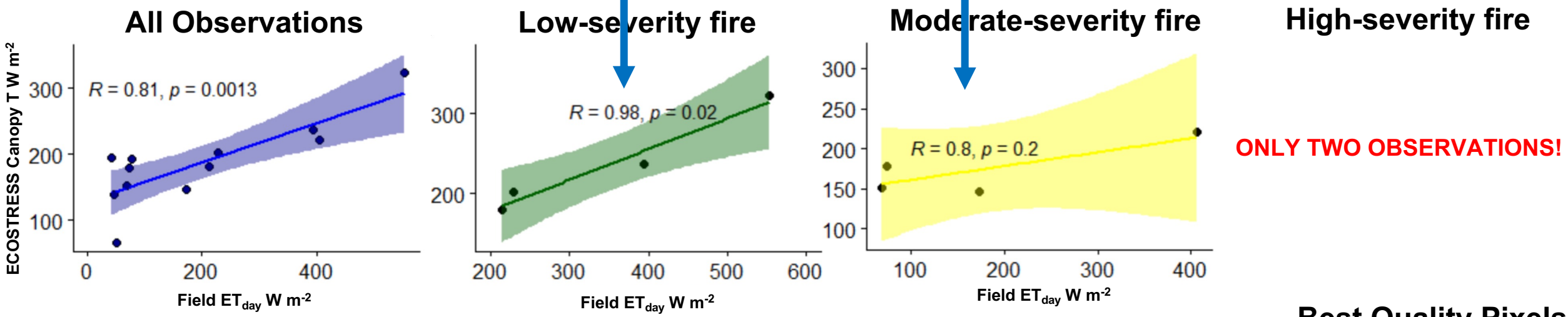


- ECOSTRESS captures field ET signal for “best quality” pixels for daylight hours

But does not perform as well with “nominal-quality” pixels

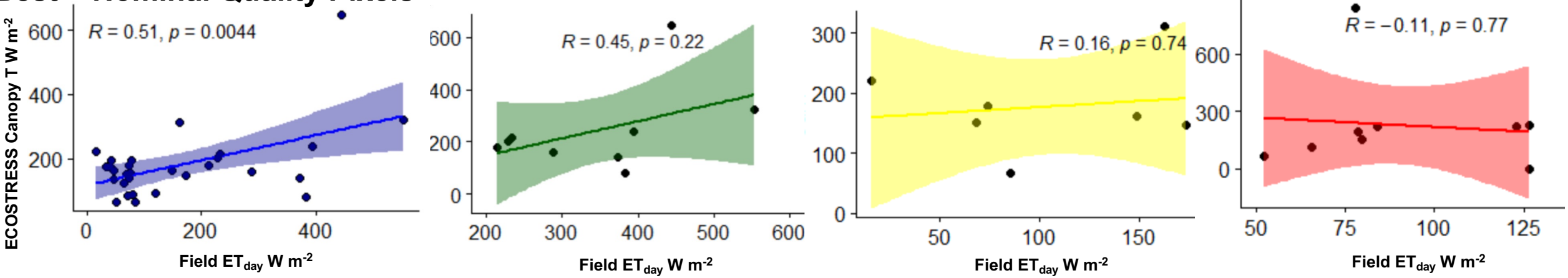
Fits are Better for areas with higher canopy cover

Best Quality Pixels



ONLY TWO OBSERVATIONS!

Best + Nominal Quality Pixels

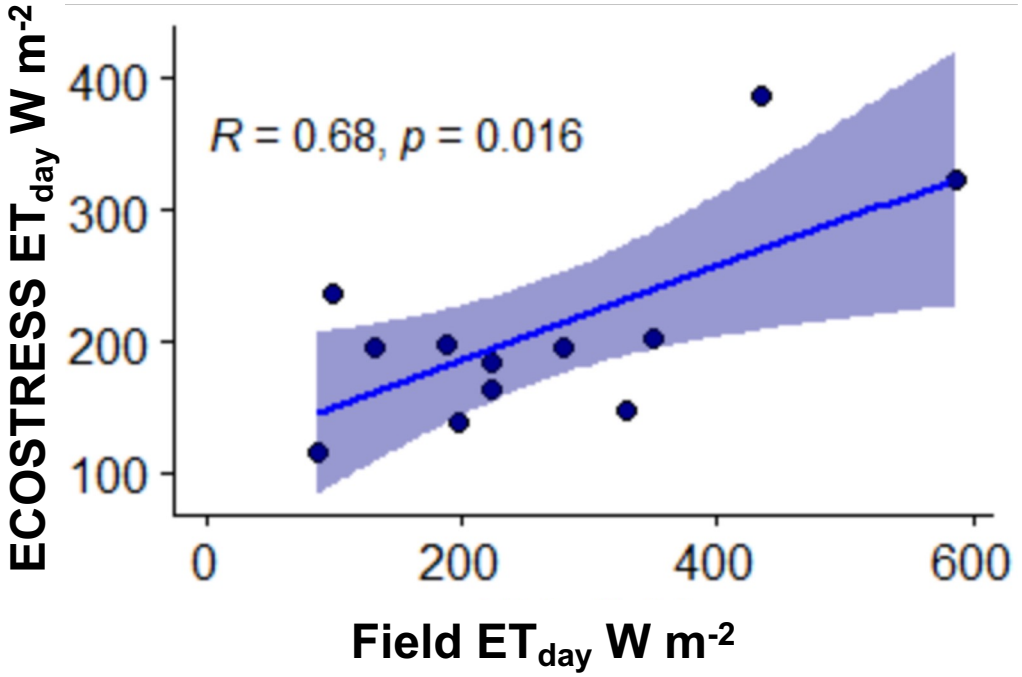


low-severity

moderate-severity

high-severity

Best Pixels
Total daily ET (canopy T + subcanopy ET)



- Better fit for Canopy T than ETday
- Much of the ET signal for the high-severity site is likely partitioned as Soil E
- Results by fire severity are similar and correlations are lower when marginal quality pixels are included
- Still working on stand ET-scaling algorithms to potentially improve line fits and ETinst validation

Validation Results Summary

- A lack of high-quality ECOSTRESS ET data limits our ability to validate the product over a 15-month period, especially at high-severity
- ECOSTRESS underestimates Canopy T and Daily ET
- Low- and moderate-severity burned areas are most accurate
- Landscape heterogeneity may influence this result: 70 m pixel size may not be good enough in these environments
- ECOSTRESS might perform better in flatter areas with more homogeneous forest cover
- We are still tweaking our scaling-algorithms and checking our results
- Collection 2 data could also improve these results

Conclusions

- ECOSTRESS is promising for wildfire applications
- We see added value from ECOSTRESS for understanding post-fire forest recovery
- BUT we need more frequent high quality ECOSTRESS ET data for good validation and calibration of the instrument

Next steps: Compare field ET to ECOSTRESS ET to evaluate the benefits of forest management on drought resiliency in northern Arizona ponderosa pine forest

Teki Sankey PI