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

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Fire Exclusion

Climate Change

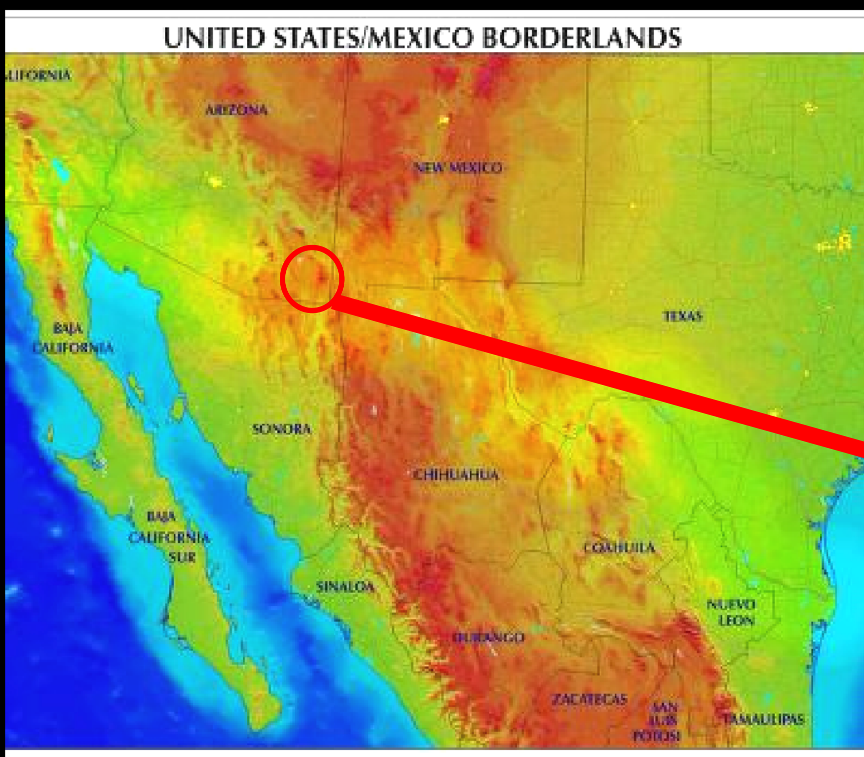
High
Fuel Loads

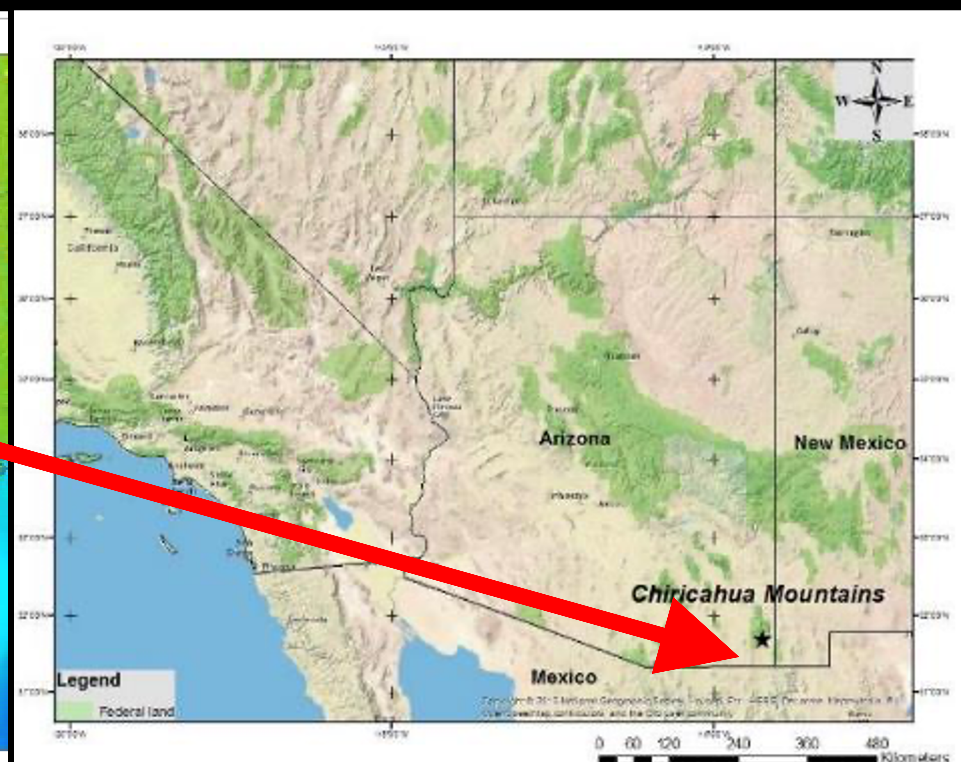
Increased
Aridity

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).

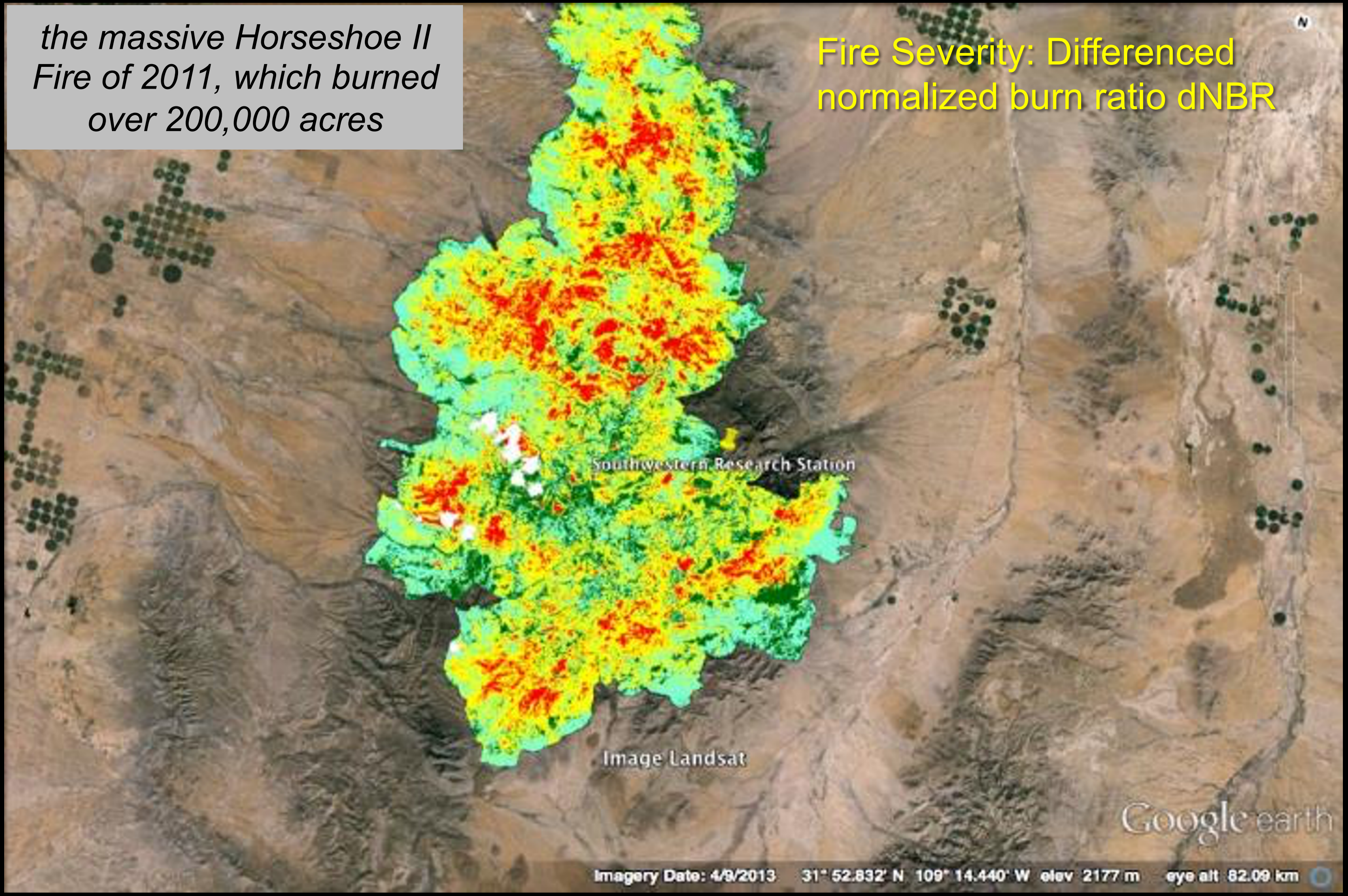

Chiricahua Mountains


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

Fire Severity: Differenced normalized burn ratio dNBR



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

- Fire severity was a significant positive driver of post-fire ET during the growing season.
- Shrublands had significantly higher daily and midday ET than other pine-dominated vegetation types.
- This ET pattern may explain the prolific post-fire vigor and high cover of shrublands in the wake of high-severity fire.
- This contrasts results from other high-severity fire sites because of the high post-fire vegetation cover in shrublands.

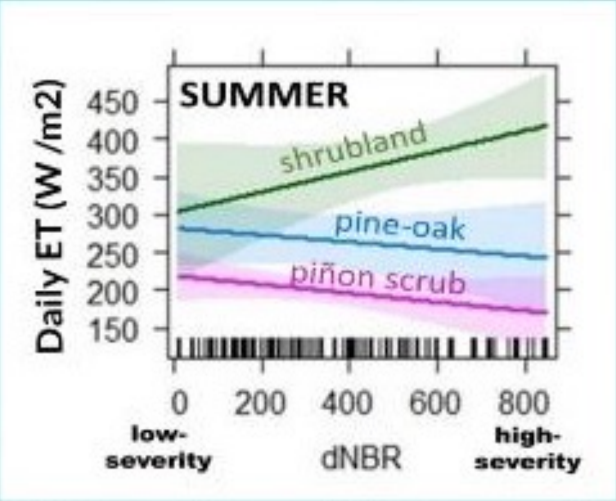


Figure 1: *Summer ET by vegetation type across the dNBR fire severity gradient. ET increases with fire severity in shrublands, which also have significantly higher ET than other vegetation types at moderate to high fire severities.*

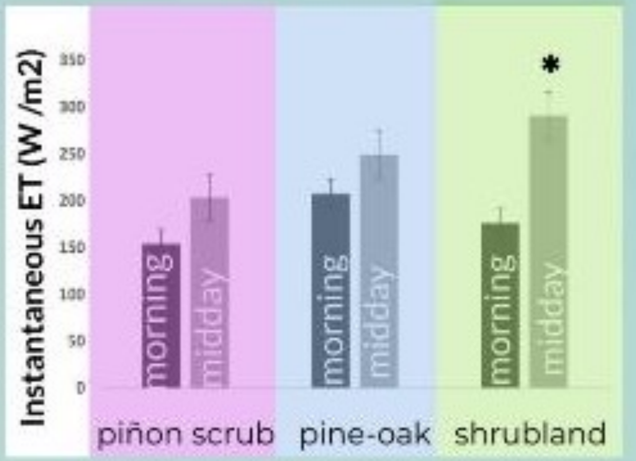


Figure 2: *Morning verssus midday ET in each post-fire vegetation type. The asterisk (*) denotes both a significant increase in ETinst from morning to midday in shrublands and the significantly higher midday ETinst of shrublands compared to other vegetation types at P < 0.01.*

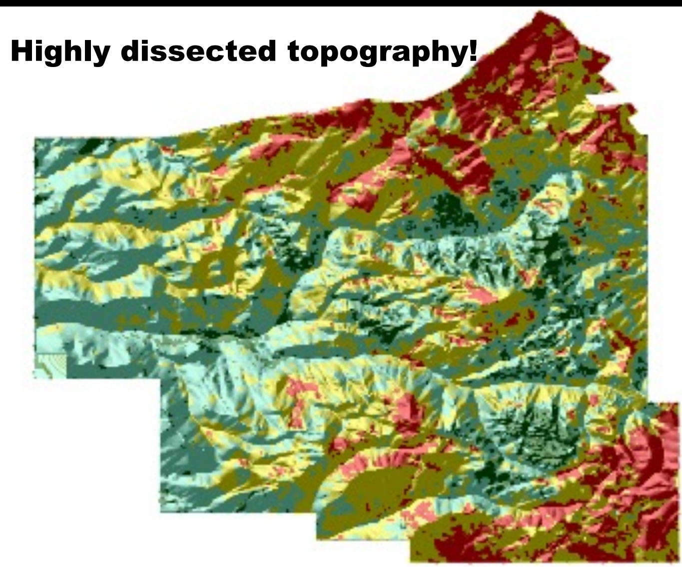
Validating ECOSTRESS across the fire severity gradient

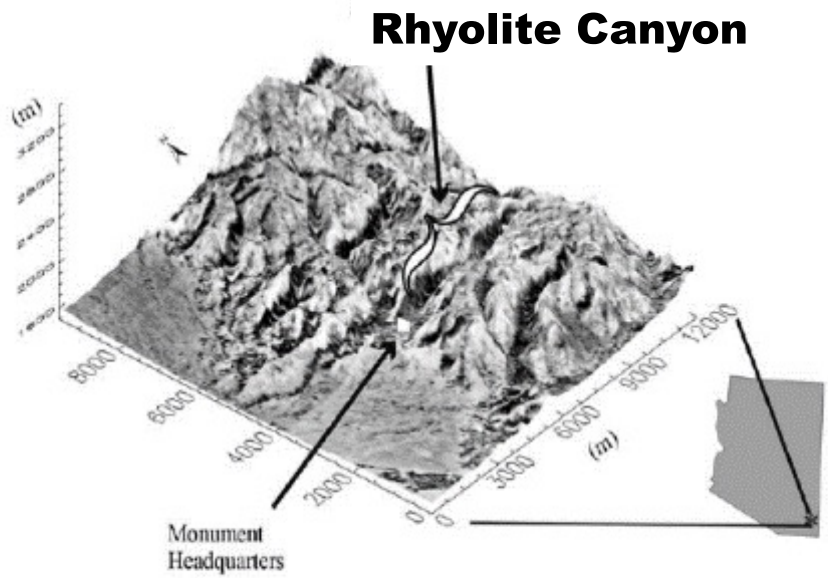
Hypotheses:

- *Site-specific variation in diurnal, monthly, and seasonal post-fire field ET can be detected in ECOSTRESS ET products.*
- *ECOSTRESS ET provides good estimates of field ET.*
- *Field ET data will corroborate the results of our first paper by demonstrating significantly higher ET at high-severity sites.*
- Differences among fire severities in post-fire ET are closely tied to forest structure and species composition.

Site Selection

Criterion 1: minimize topographic effects on ET by working within a single canyon that we can access by foot.





Criterion 2: Sites were covered by pine-oak forest prior to the HSII Fire

Criterion 3: Sites centered within relatively homogeneous fire severity classes (from Landsat MTBS maps)

Field Methods

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

(April 2021)

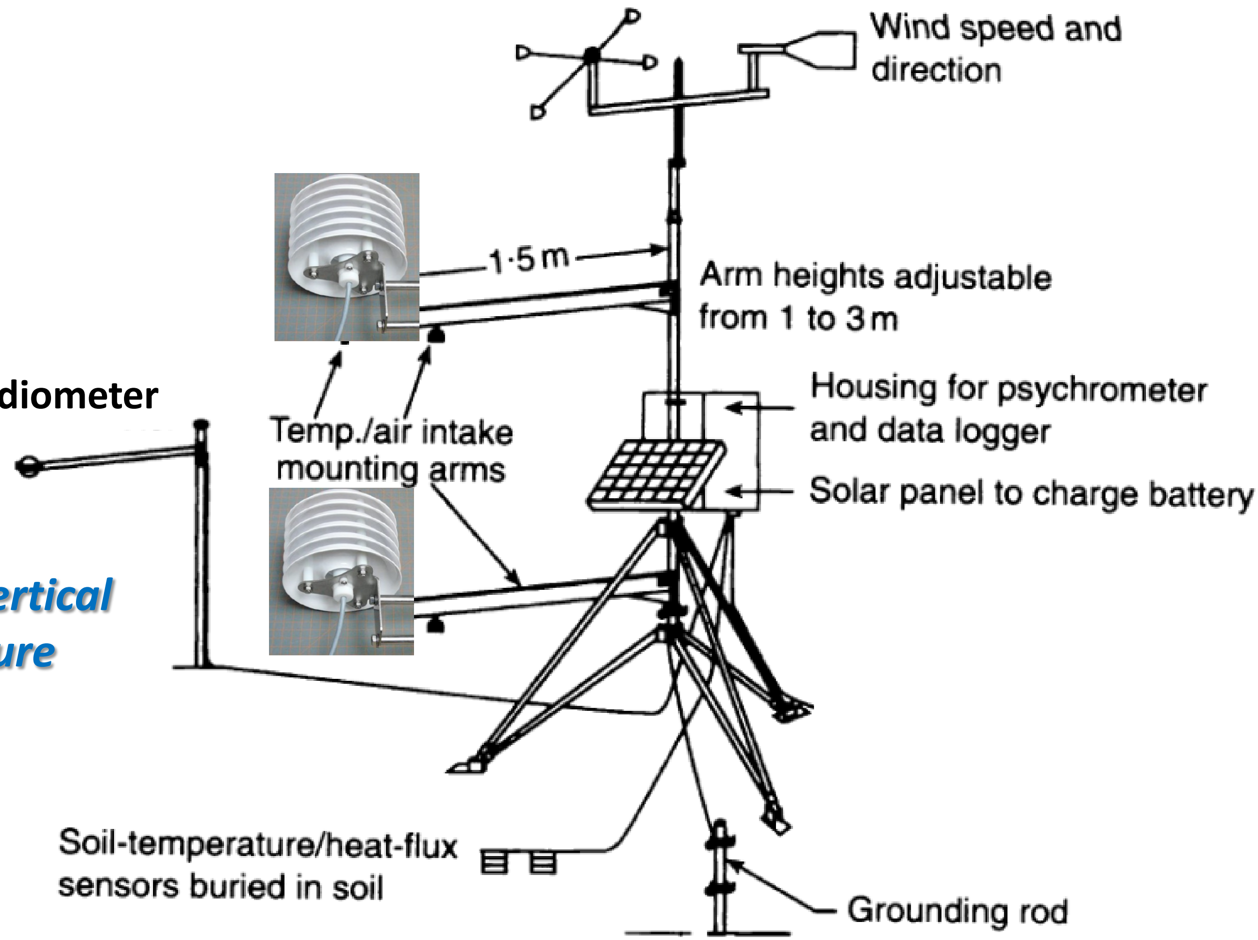
Installed a network of vegetation plots and 38 sap flow sensors to estimate post-fire **hourly and daily canopy ET**

(May 2021)

Sub-canopy ET

Sub-canopy ET: Bowen Ratio Method

Fig. 4 System of Bowen ratio measurement (Blight 1997)

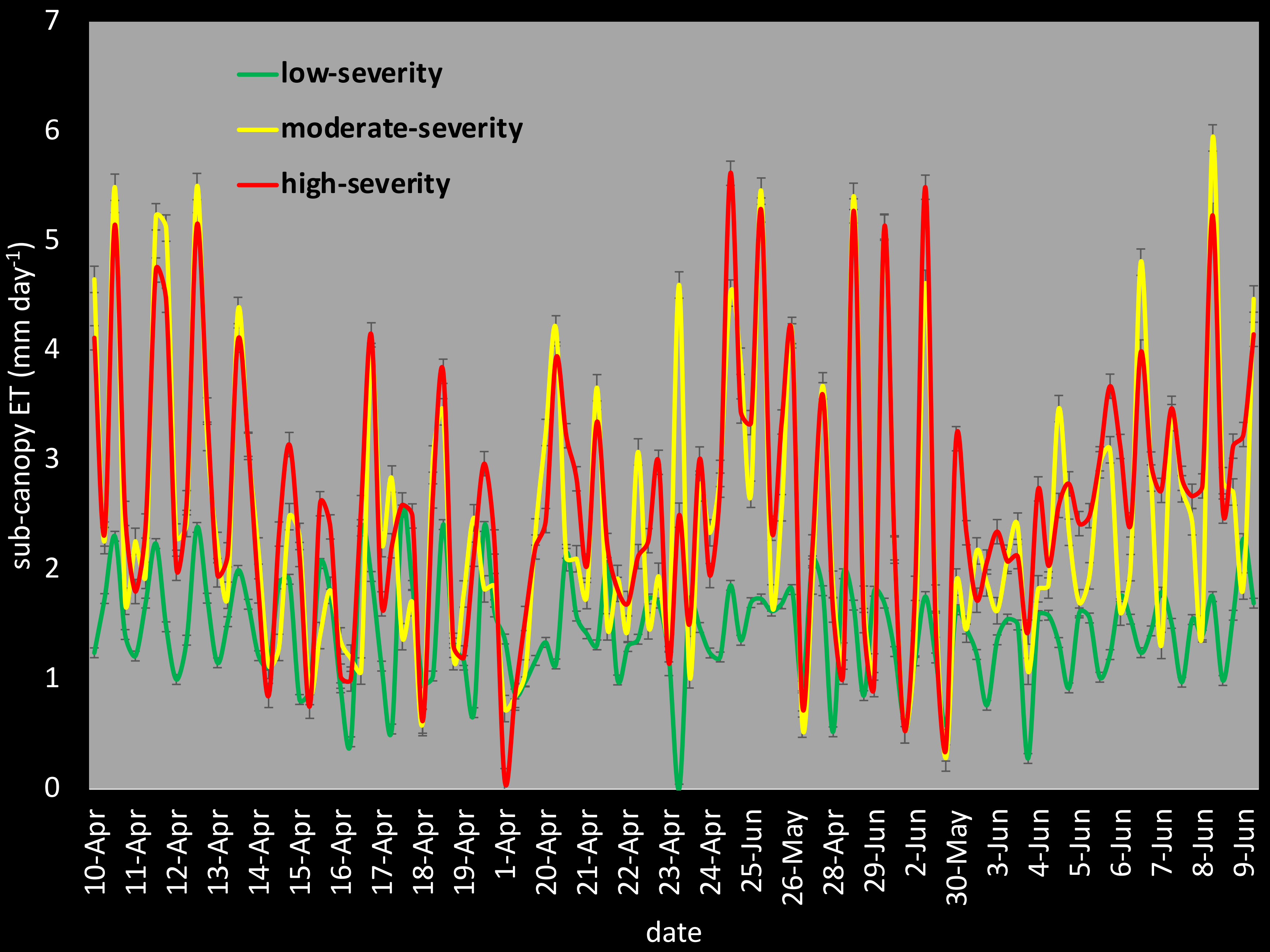


B is calculated using vertical gradients of temperature and humidity

3 stations 1 low-, 1 moderate-, 1 high-severity

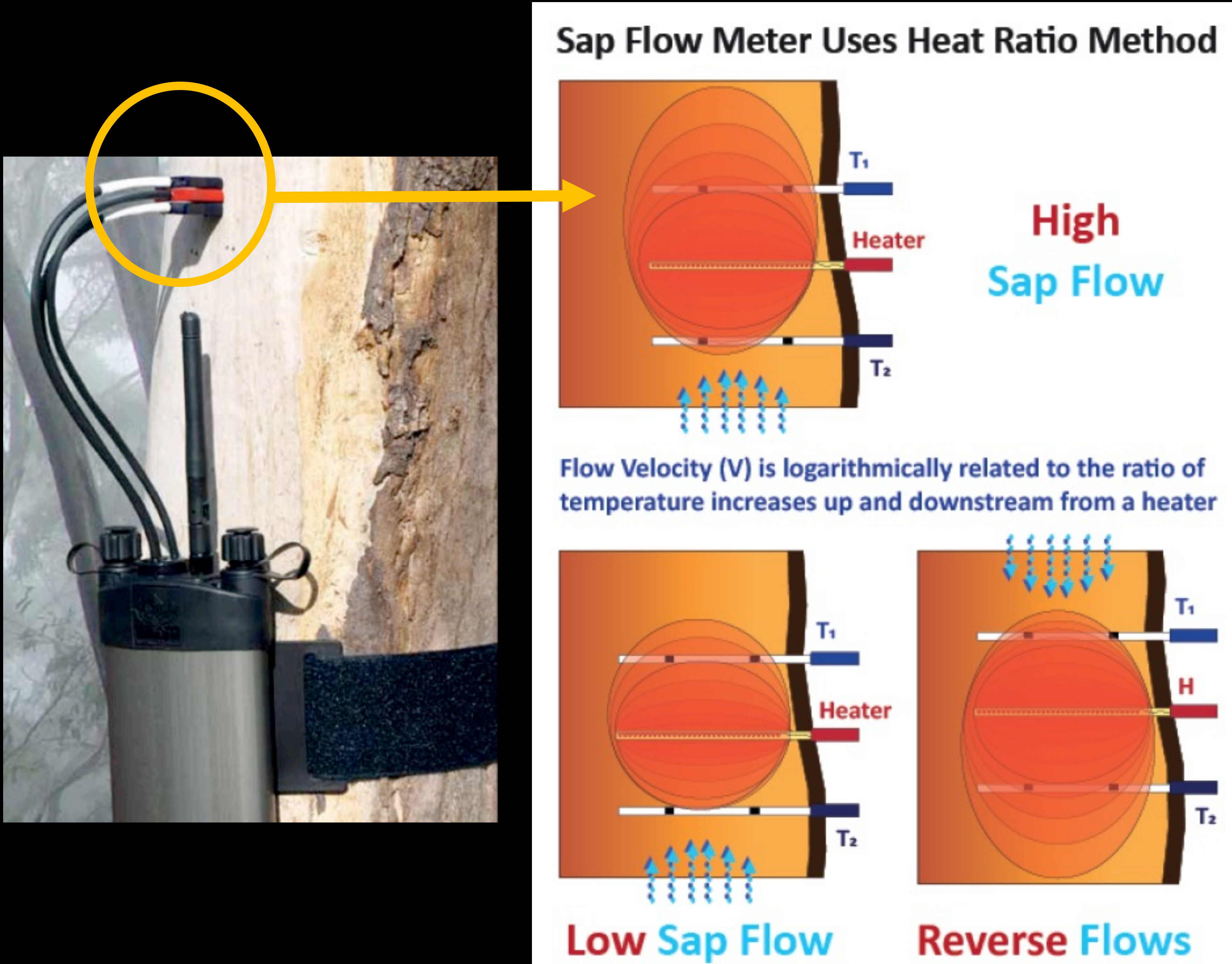
Estimating sub-canopy ET

- Gap-filling Bowen Ratio ET data using linear regression via Penman-Monteith-derived PET
- Summarizing hourly and daily sub-canopy ET to match with field sap flow T and ECOSTRESS overpasses



low-severity
moderate-severity
high-severity
sub-canopy ET (mm day^{-1})
0
1
2
3
4
5
6
7
date
10-Apr
11-Apr
12-Apr
13-Apr
14-Apr
15-Apr
16-Apr
17-Apr
18-Apr
19-Apr
1-Apr
20-Apr
21-Apr
22-Apr
23-Apr
24-Apr
25-Jun
26-May
28-Apr
29-Jun
2-Jun
30-May
3-Jun
4-Jun
5-Jun
6-Jun
7-Jun
8-Jun
9-Jun

Canopy Transpiration


Sap Flow Meter Uses Heat Ratio Method
T1
Heater
T2
High
Sap Flow
Flow Velocity (V) is logarithmically related to the ratio of temperature increases up and downstream from a heater
T1
Heater
T2
Low Sap Flow
T1
H
T2
Reverse Flows

Sapflow Sensor Network

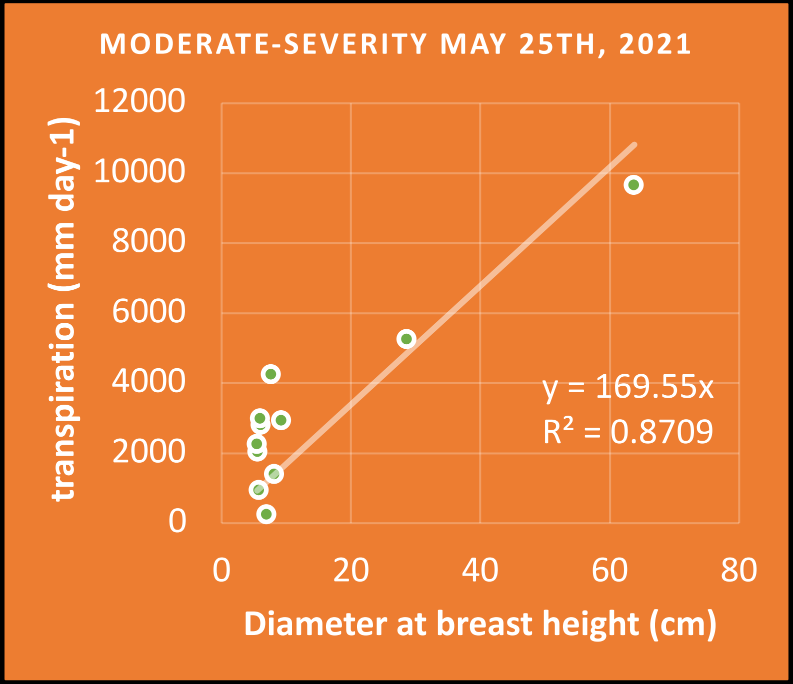


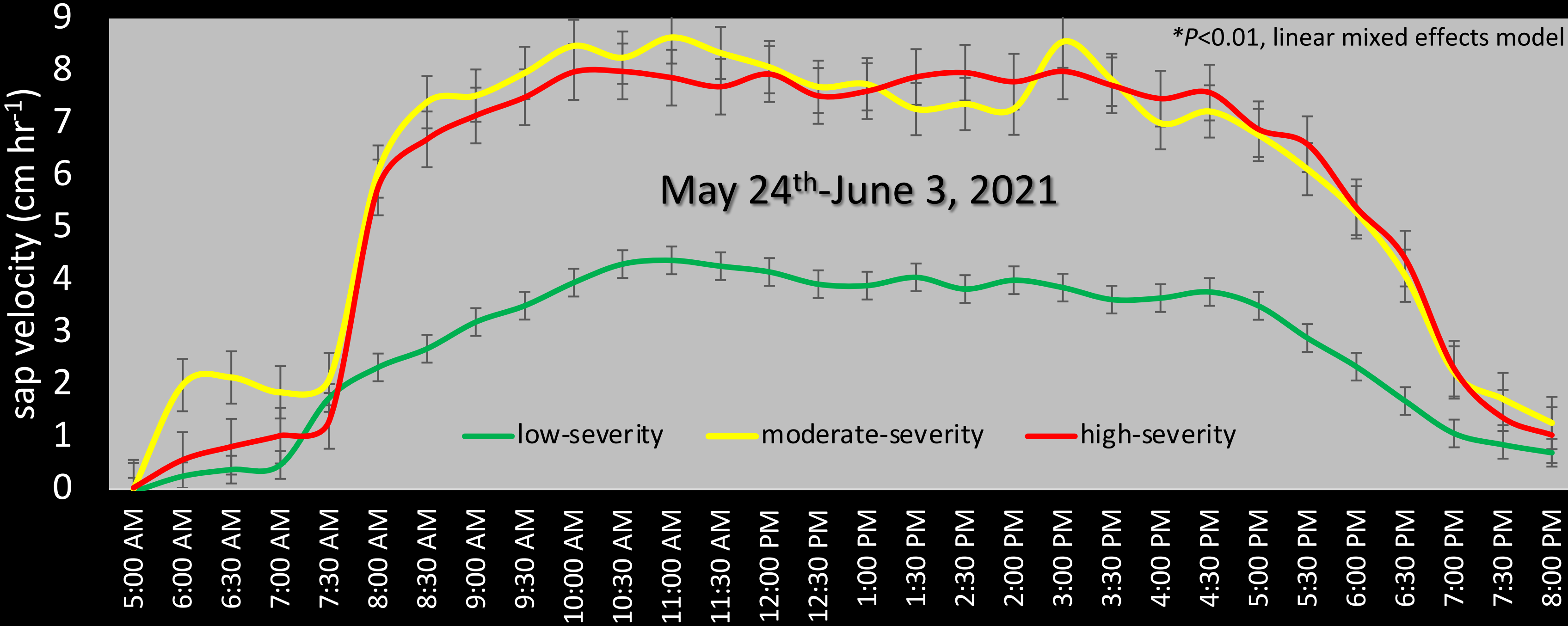
Estimating canopy transpiration from sap flow

- Sapwood depth
- Bark thickness
- Measured all “canopy” trees > 2 cm DBH in a 15-m radius plot

Workflow development

- Estimating Daily flows with taper functions after setting zero nighttime flow rates.
- Scaling daily flows of instrumented trees to the stand-scale for comparison with ECOSTRESS via daily transpiration-tree diameter regressions at each fire severity

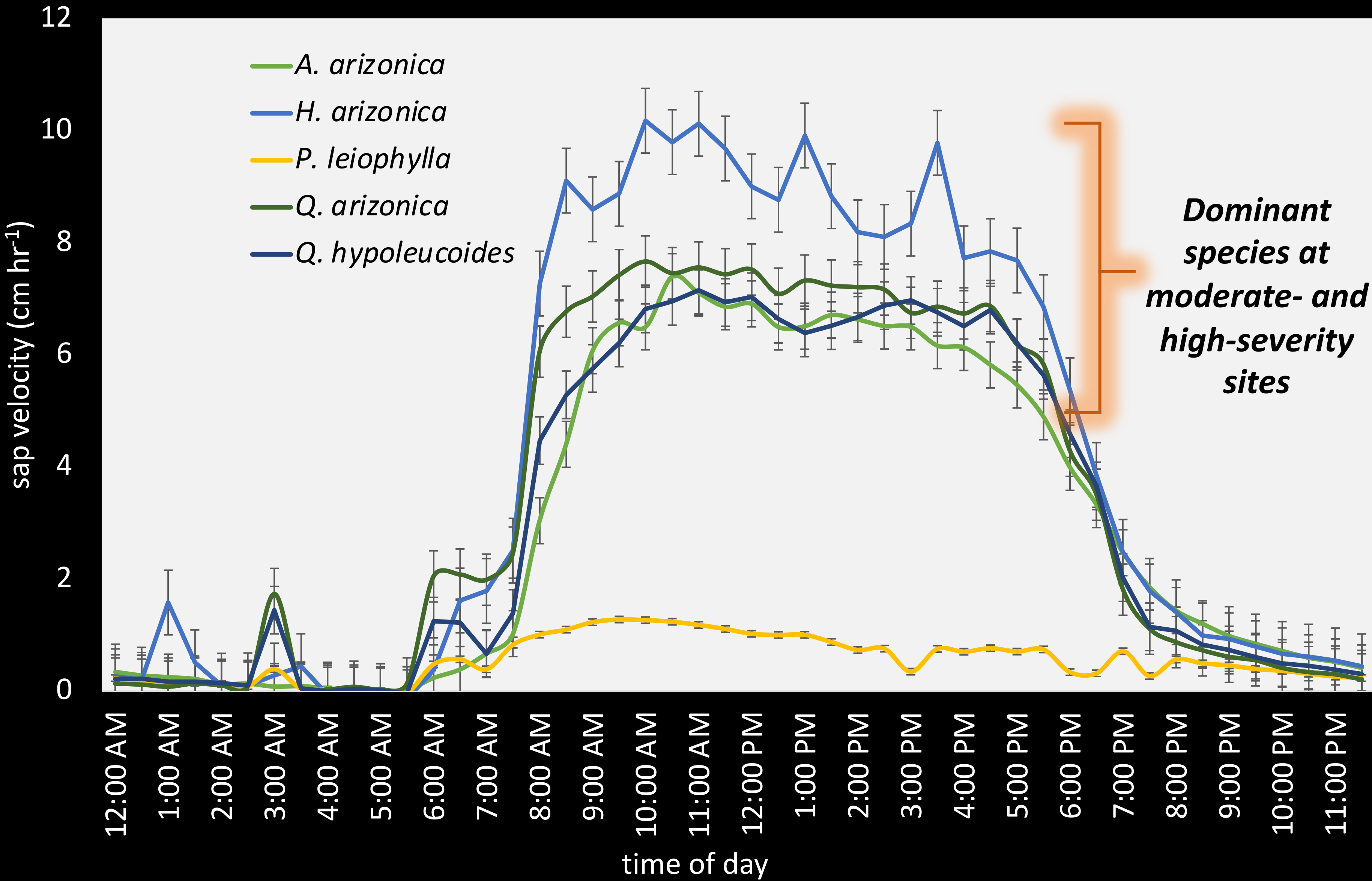




low-severity

moderate-severity

high-severity

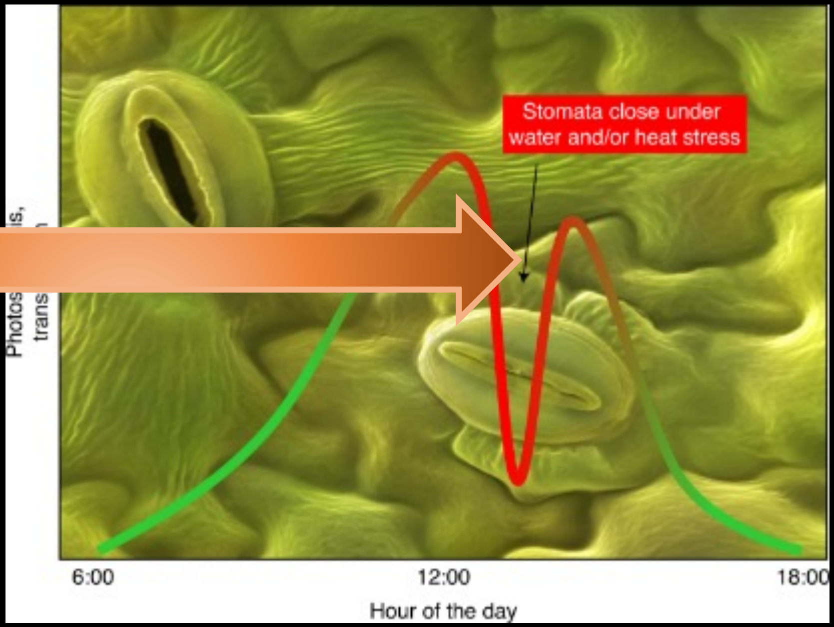

A. arizonica
H. arizonica
P. leiophylla
Q. arizonica
Q. hypoleucoides
Dominant species at moderate- and high-severity sites
sap velocity (cm hr-1)
time of day
0
2
4
6
8
10
12
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM

May 24-June 3
2 ECOSTRESSS passes over these 8 days

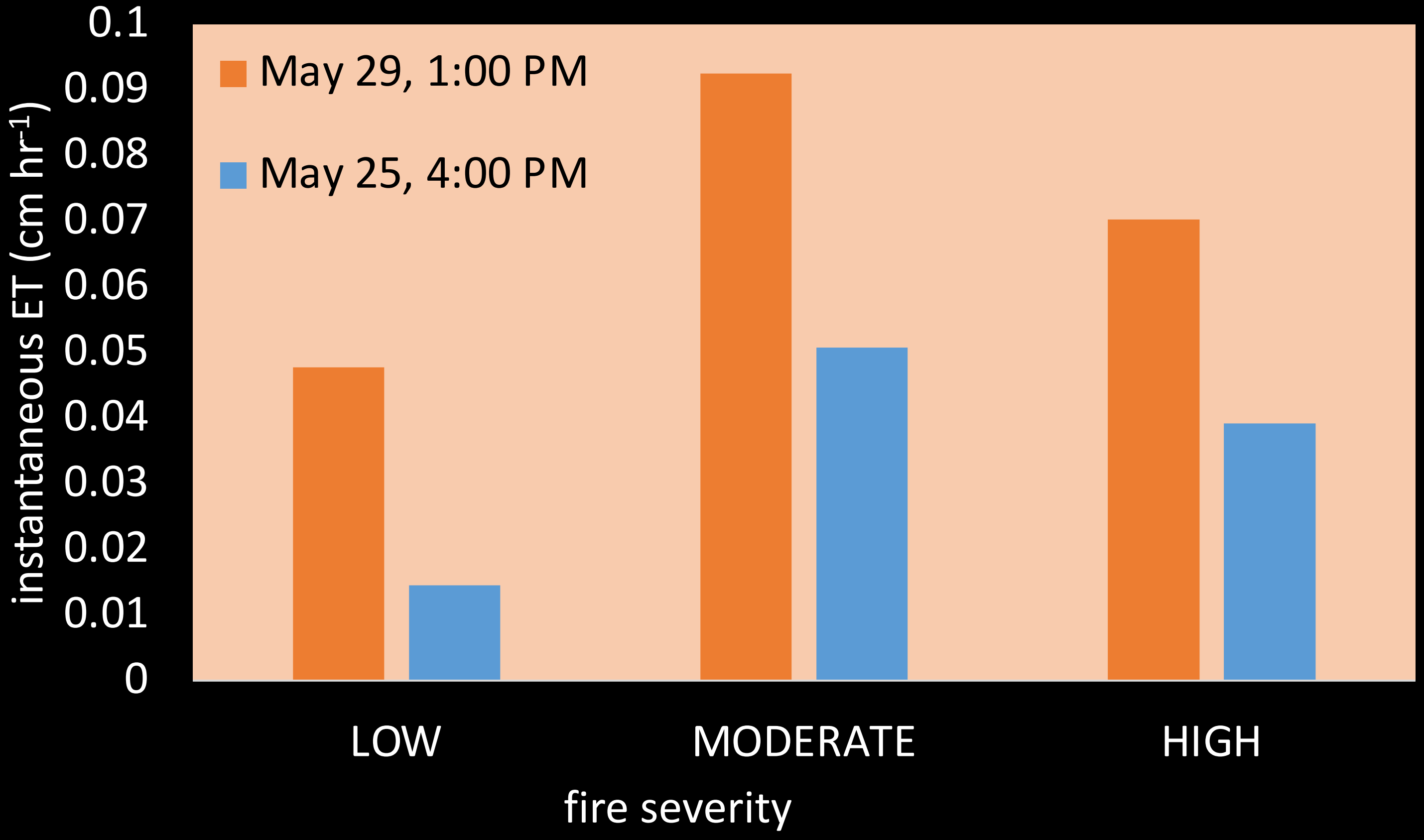
May 25th @ 4:00 PM, 2021
May 29th @ 1:00 PM, 2021

Compare field vs. ECOSTRESS values

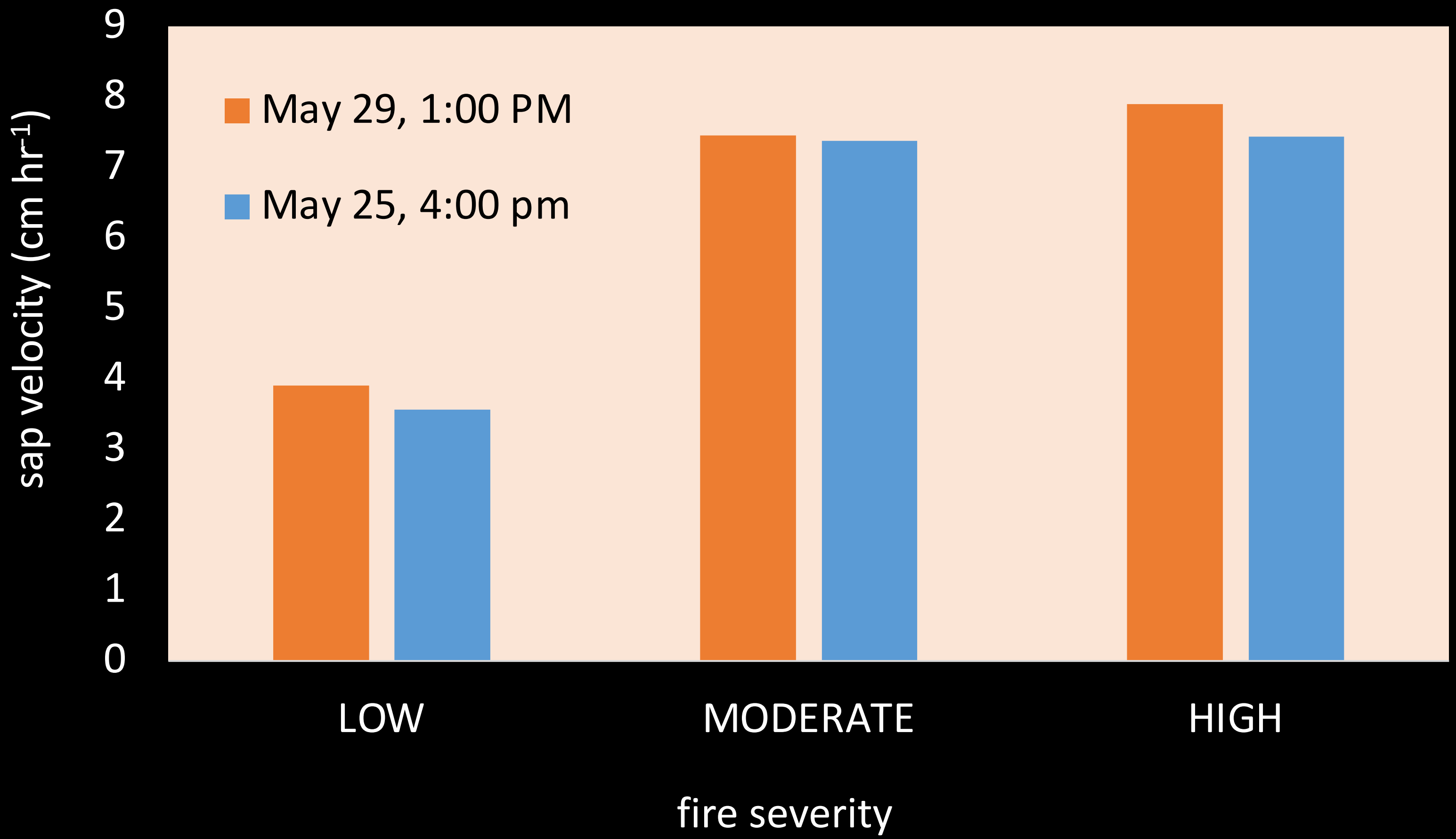
- daily ET
- Instantaneous ET



Instantaneous field sub-canopy ET



Instantaneous field ET from sap flow sensors



Scaled daily transpiration rates

fire severity	**DOY**	***ECOSTRESS daily ET***	**field canopy T**	**field sub-canopy ET**	*total field ET*
		ET (mm day^{-1} ha^{-1})			
low	149	***8.8***	12.8	2.3	15.1
low	145	***7.6***	12.1	0.7	12.8
moderate	149	***6.8***	14.0	3.4	17.5
moderate	145	***5.3***	9.6	2.5	12.1
high	149	***4.8***	37.7	4.5	42.2
high	145	***5.3***	19.0	1.9	20.9

Conclusions

1. Post-fire field ET is higher at moderate- and high-severity fire sites.
2. Plants growing in the wake of moderate- and high-severity fire have high instantaneous and daily transpiration rates.
3. Plants growing at moderate- and high-severity fire sites continue to transpire into the afternoon.
4. Field results corroborate our earlier ECOSTRESS imagery-based paper on post-fire ET.

The post-fore vegetation matrix matters!

low-severity

moderate-severity

high-severity

...But big, tall trees ≠ higher instantaneous or daily transpiration rates!

Next steps

- Fine-tune tree-to-stand ET scaling for species-specific differences in sap flow.
- Continue to acquire field data to evaluate diurnal and seasonal ET
- Continue to acquire ECOSTRESS imagery to validate
  - PT-JPL-ET
  - disALEXI-ET
  - LST (moderate and high severity sites)
- Filter out mixed pixel ECOSTRESS scenes
- Use plot data we collected from 51 plots to understand how ECOSTRESS influences post-fire regeneration

Thank you!