EMC- 2019-003 Fuel Treatments and Hydrologic Implications in the Sierra Nevada

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EMC Science Questions

1. *How will variability in forest treatments affect sub-basin and basin scale discharge?*
2. *What key variables determine hydrologic response to differing mitigation strategies?*
3. *How will downstream aquatic habitat be impacted by upstream forest treatments?*
4. *To what degree does sediment flux vary due to upstream forest mitigations?*
5. *To what degree can remote sensing information quantify treatment impacts on forest structure?*
6. *What key metrics best quantify system change and can be easily integrated into a predictive framework for evaluating habitat and hydrologic response in California watersheds?*

Today’s Update

1. Research Goals
   (primary focus on questions 1, 2, 5 and 6)
2. Methods
3. Results
4. Conclusions
5. Deliverables and Outcomes
6. Future Work

Research Goals

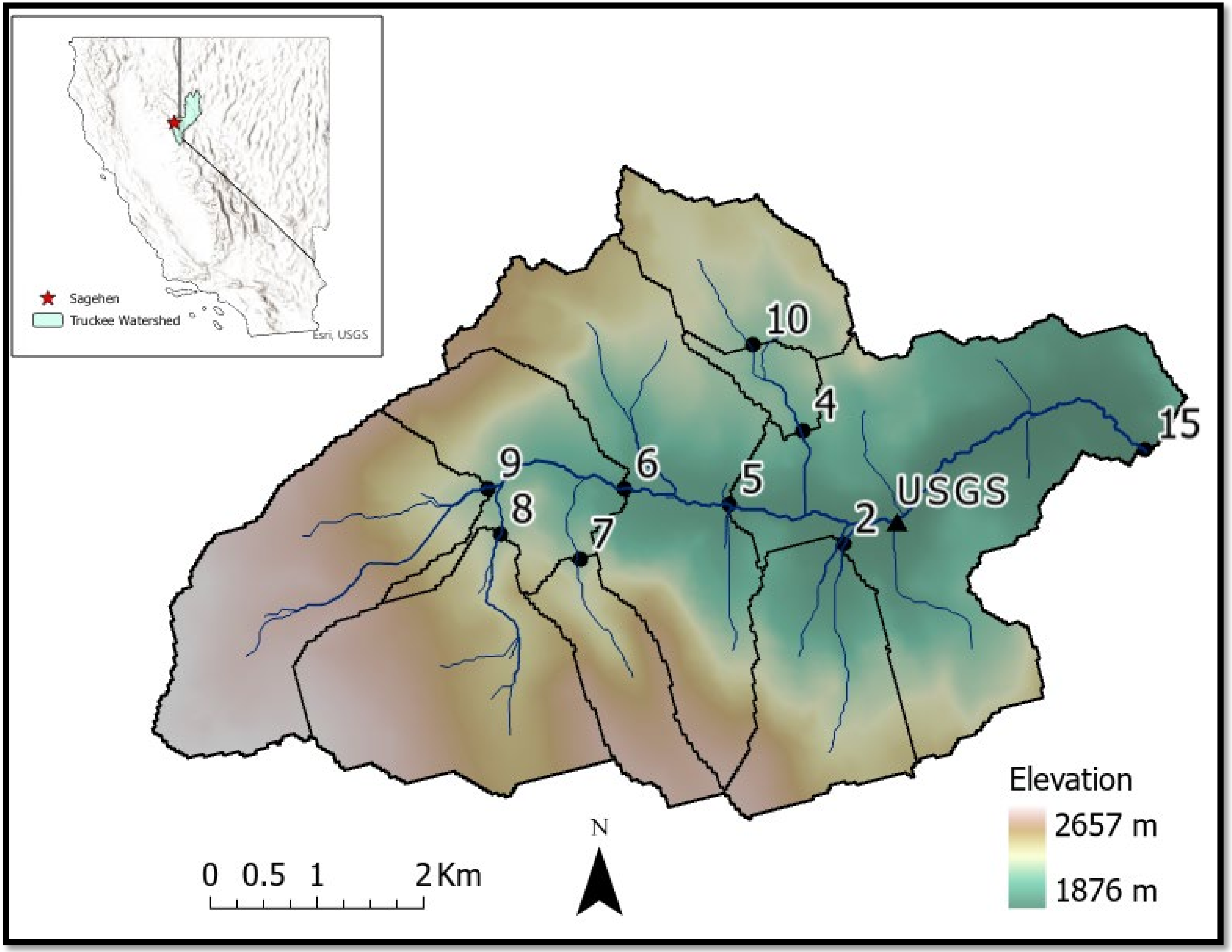
Using the Sagehen experimental watershed in the Sierra Nevada, we investigated

1. The impact of forest treatments on annual runoff (water yield) at various spatial scales

2. The impact of forest treatments on annual evapotranspiration (ET) at various spatial scales

Our tools: Field data, remote sensing, and high-resolution modeling

Sagehen Basin- Eastern Sierra Nevada, California



Area: ~30 km^2

Average slope: 18%

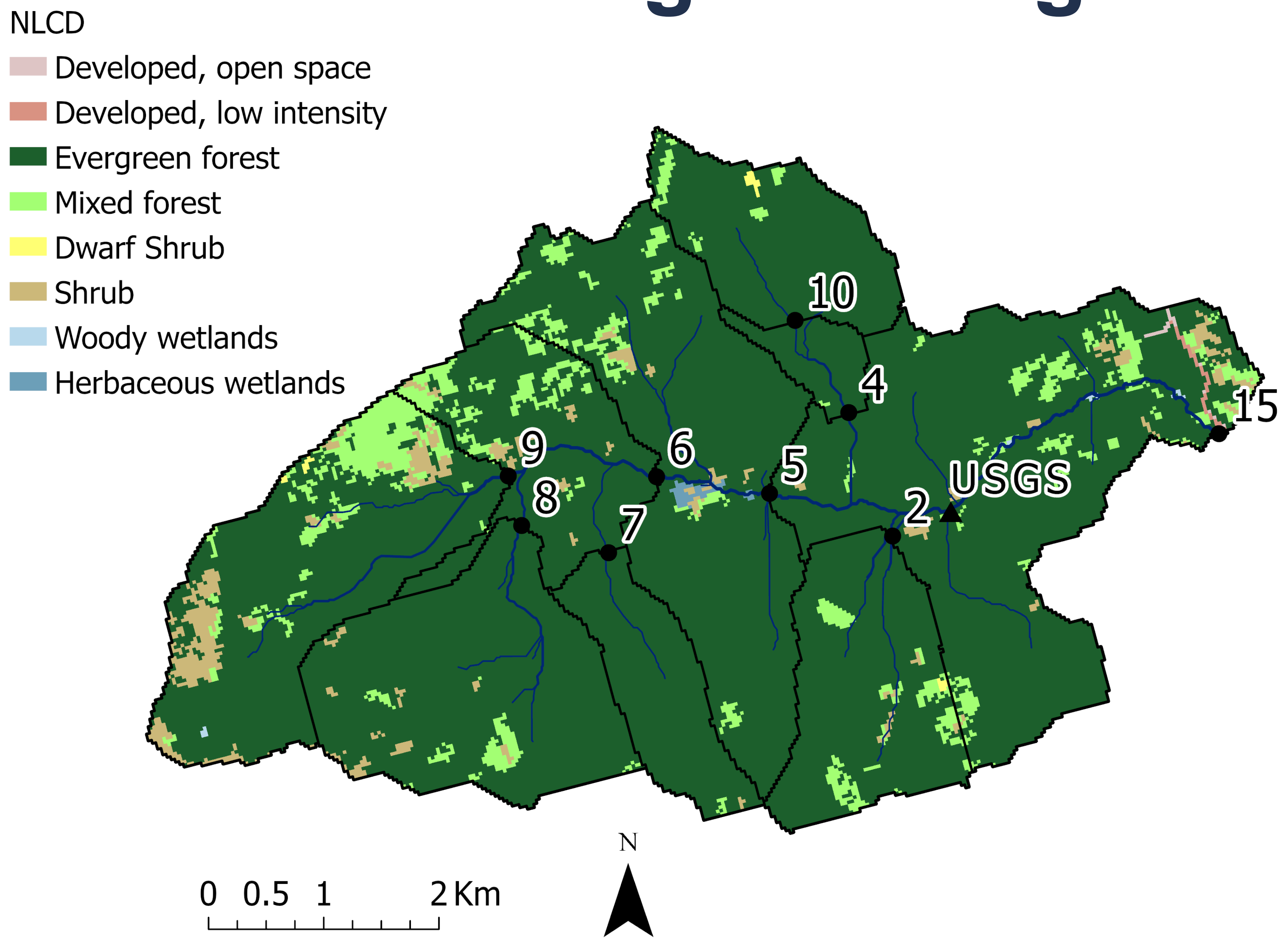
Average Precipitation: 800 mm

Snowfall: 80% of precipitation

Peak flow: May

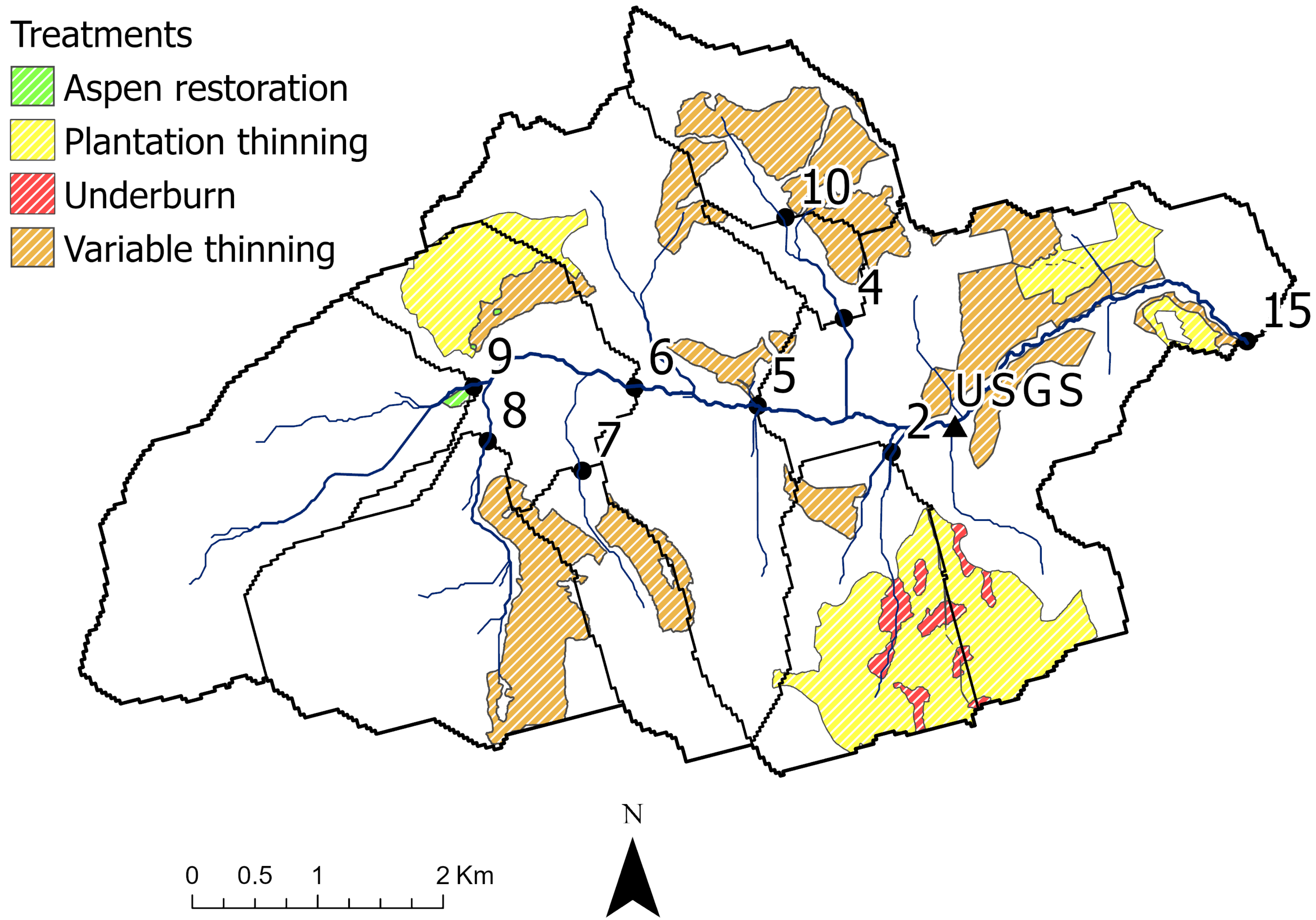
Min flow: September

Sagehen vegetation



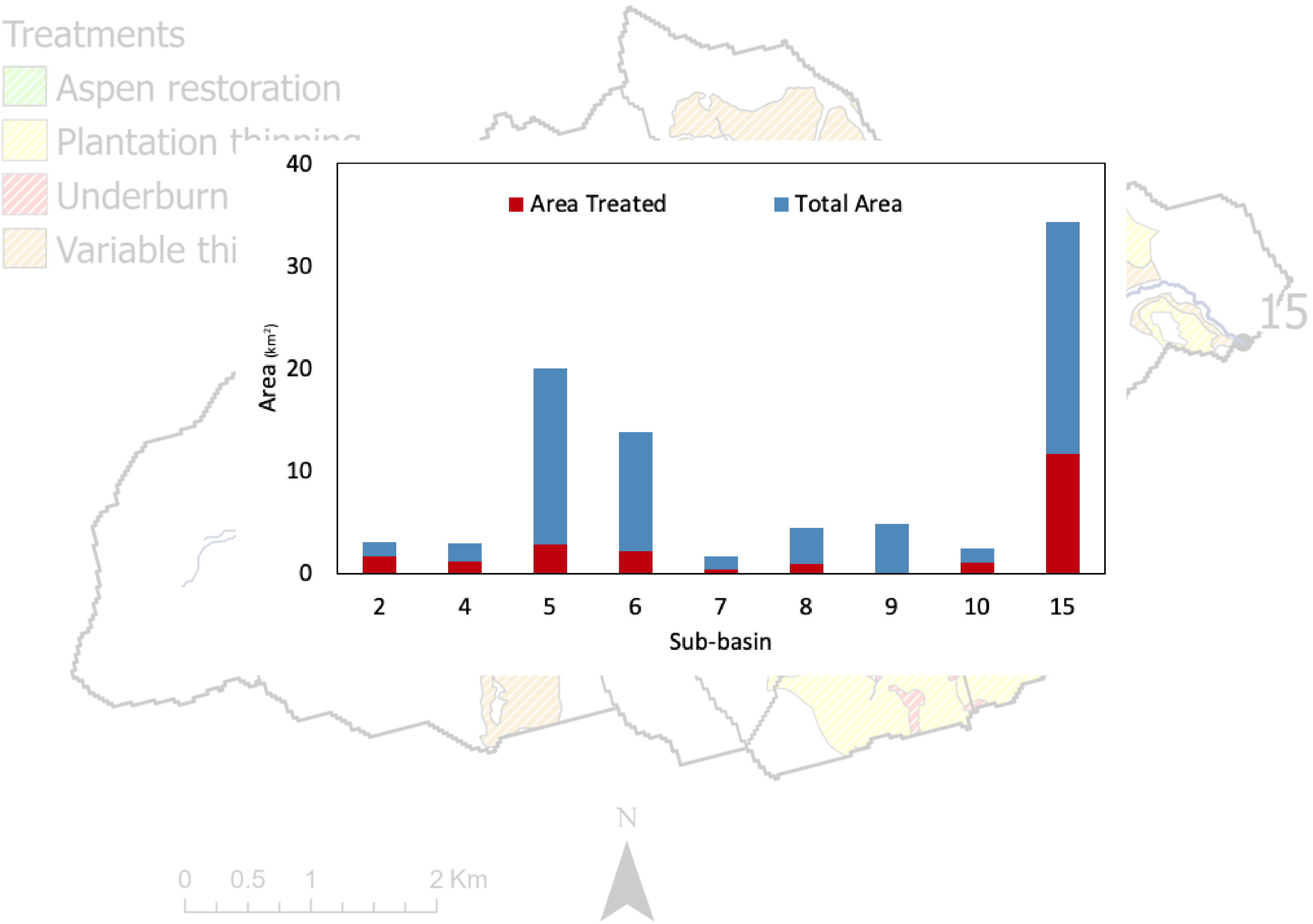
- 65% of Sagehen covered by vegetation
- 80% of vegetation evergreen forest
- **Jeffrey pine** and lodgepole pine (lower elevation)
- **Red fir** and white pine (higher elevations)

Treatment areas



Sub-basin	Area (km^2)	% Treated
2	3.02	56%
4	2.95	38%
5	19.96	14%
6	13.79	16%
7	1.71	24%
8	4.48	19%
9	4.87	0.4%
10	2.36	41%
15	34.22	34%

Treatment areas



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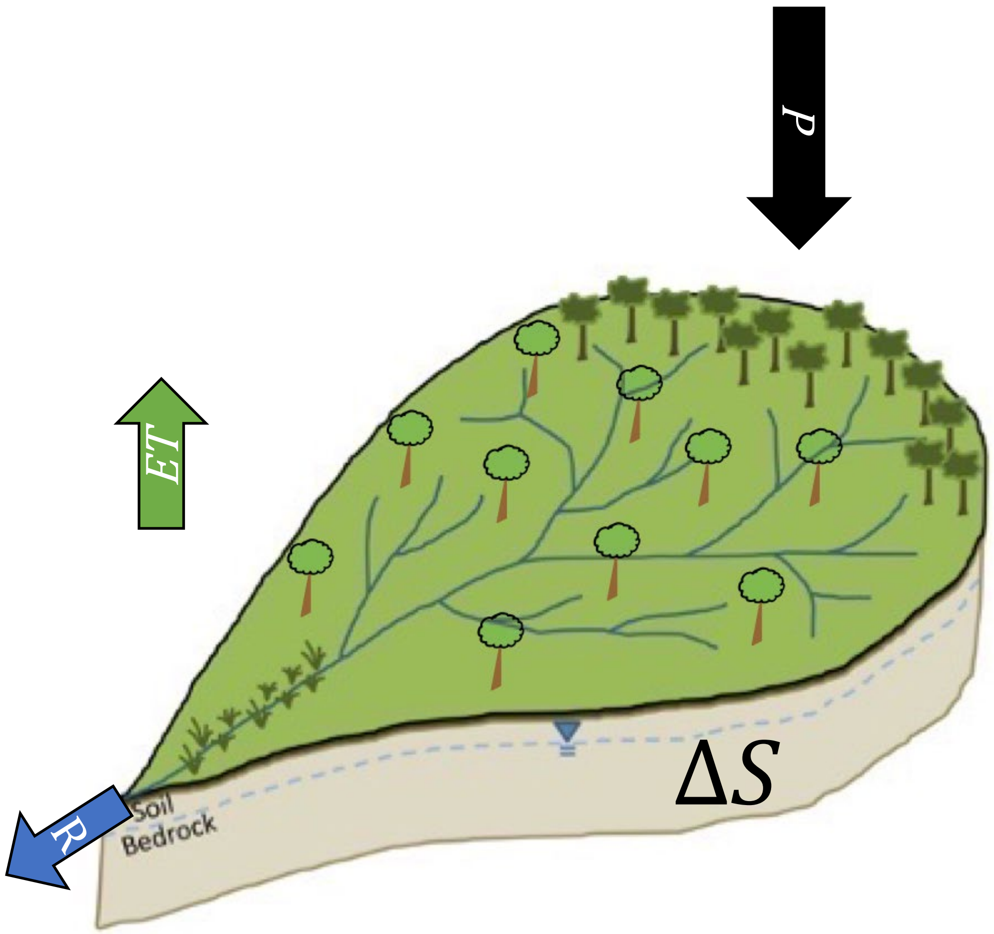
Goal 1 Methods

Investigating the impact of treatment on annual runoff

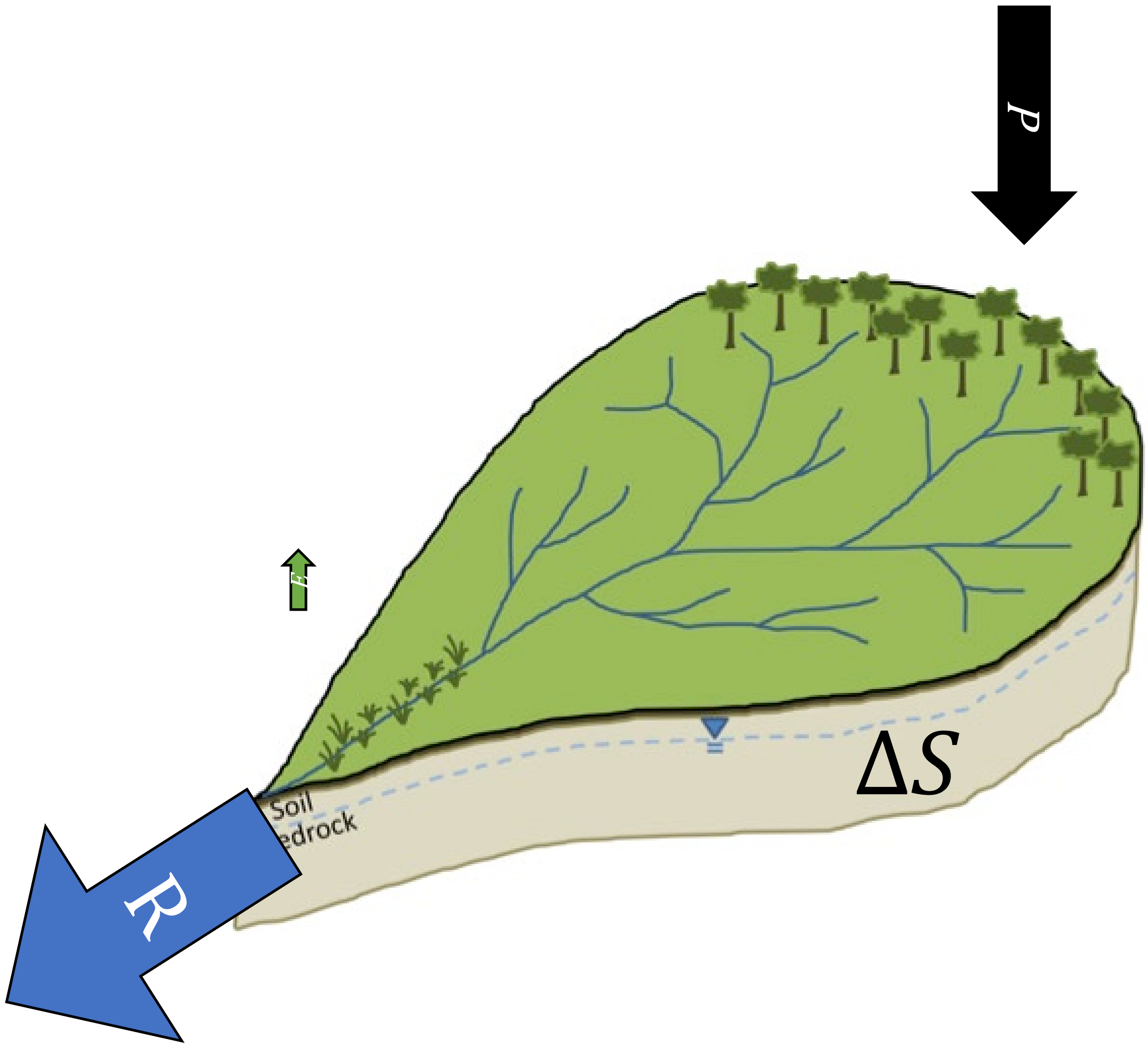
1. Annual water budgets at basin and sub-basin scale

2. Linear regression between precipitation and water yield at basin and sub-basin scale

Pre-treatment

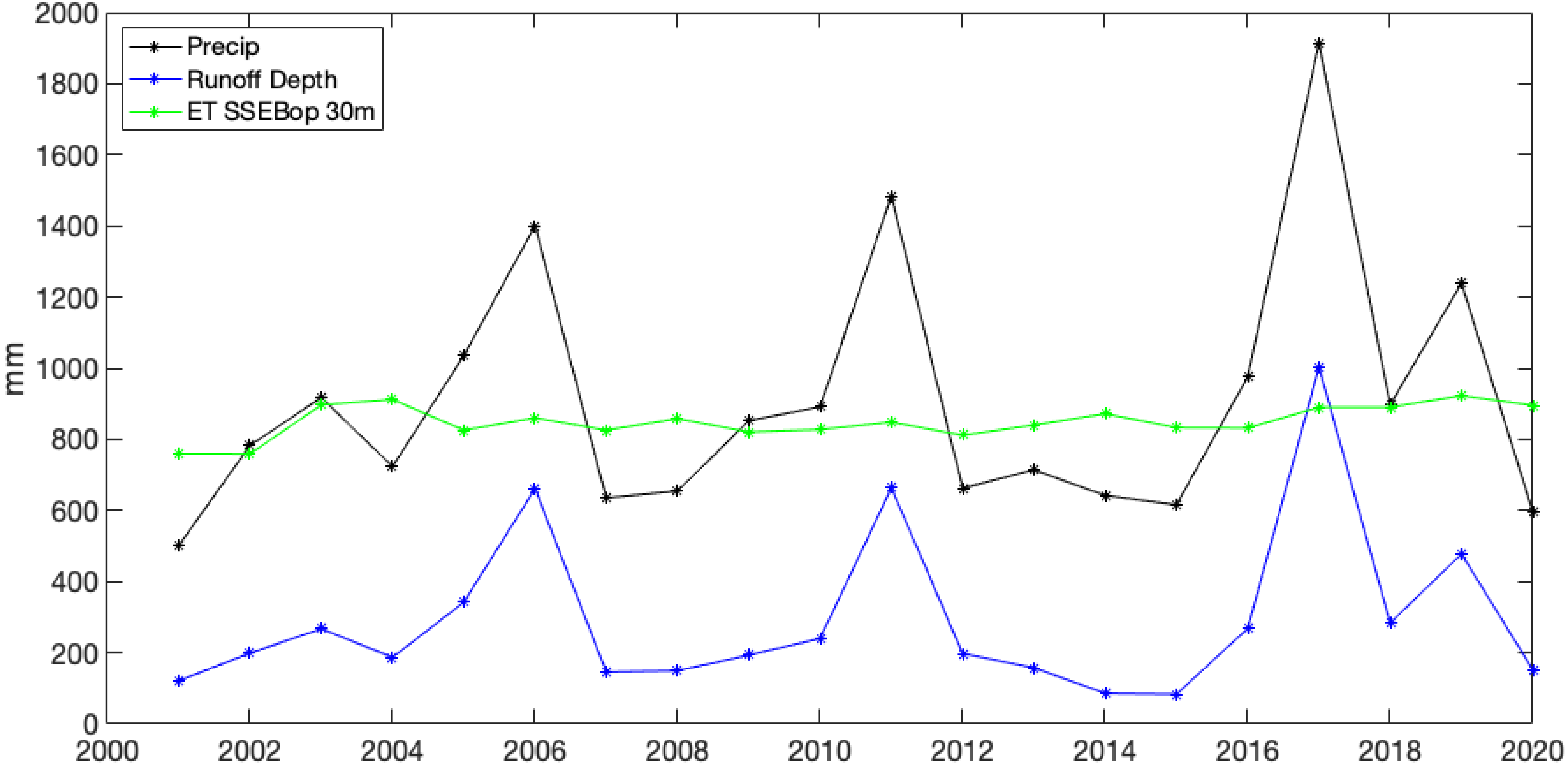


Post-treatment

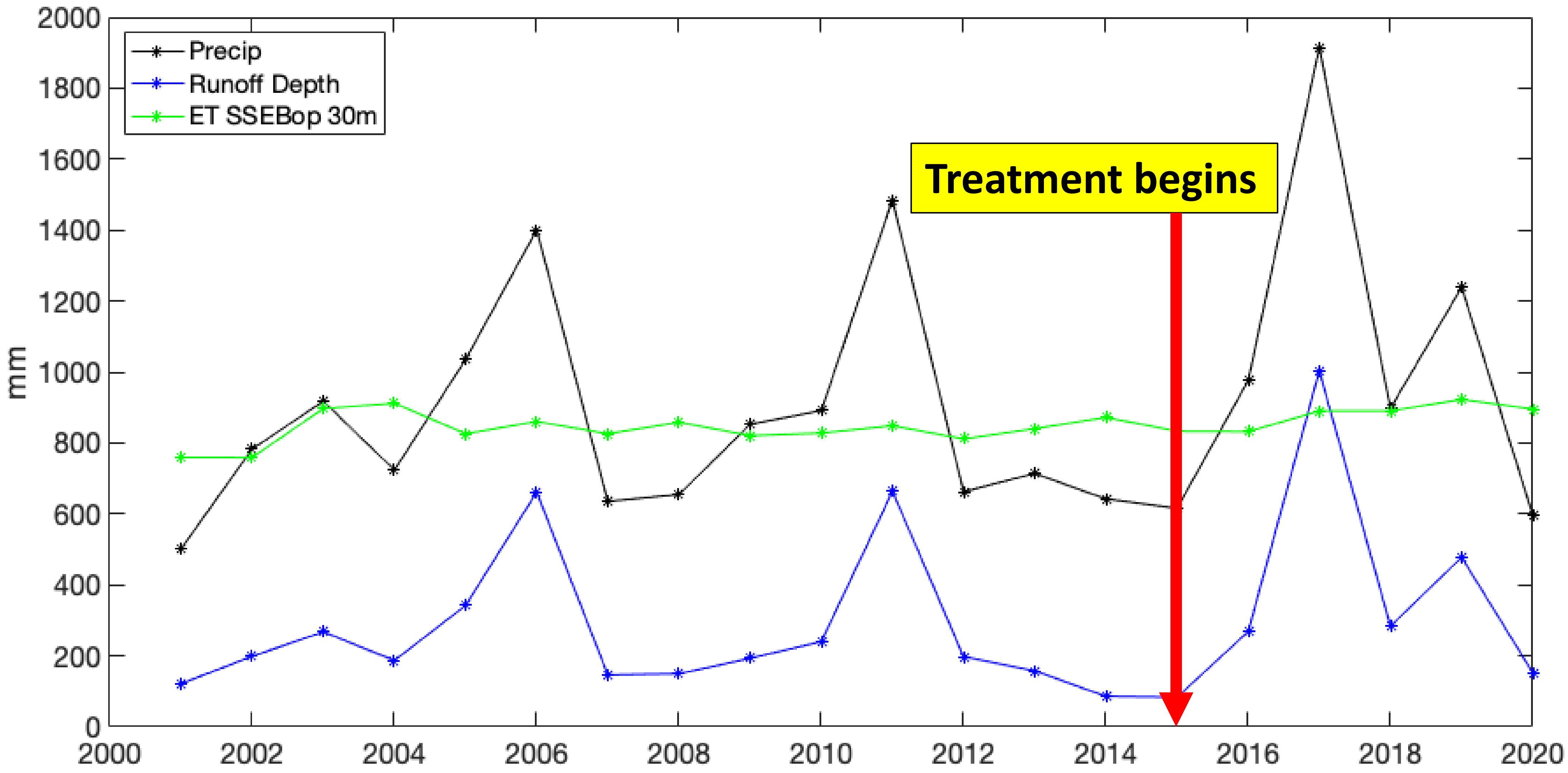


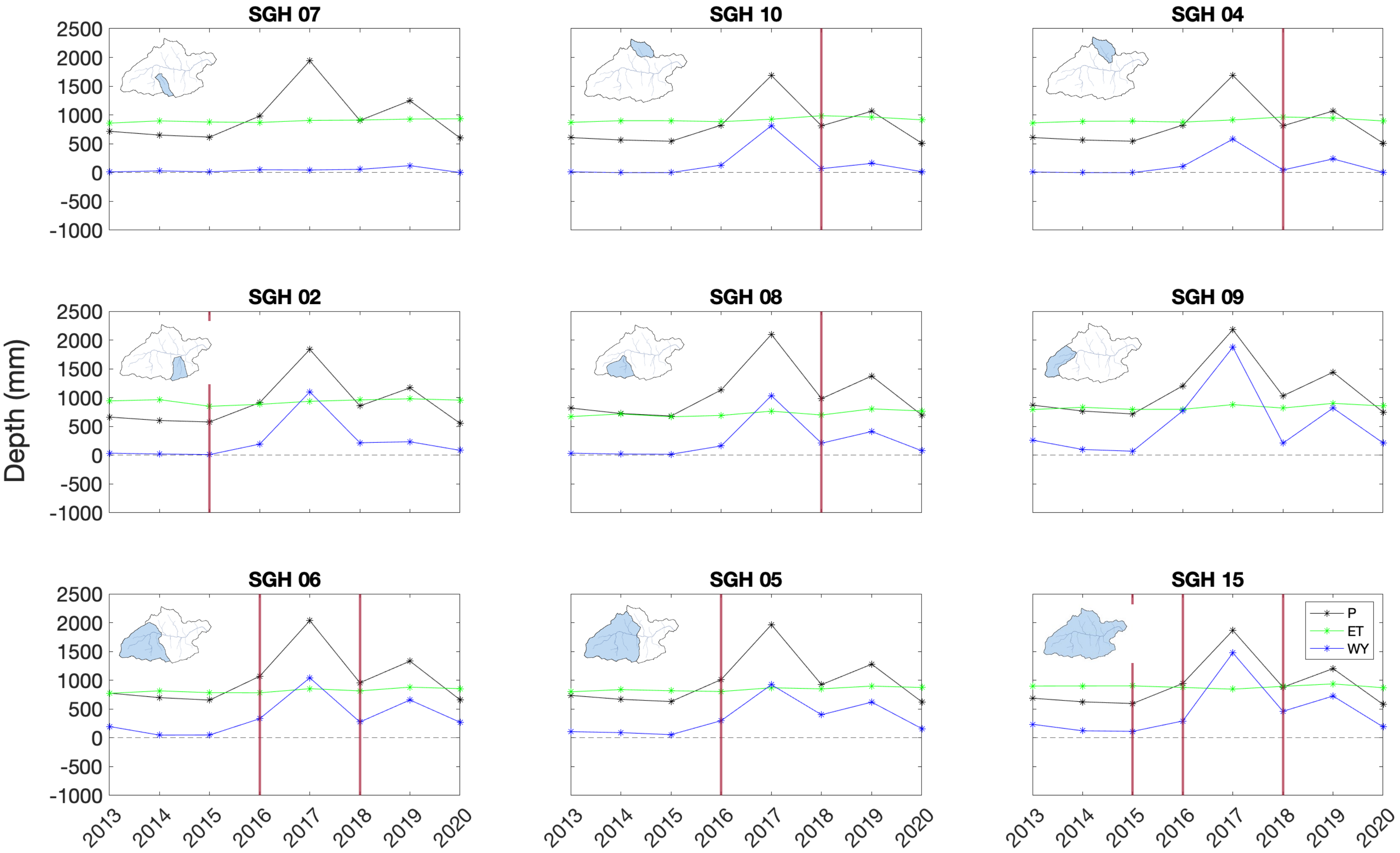
Sagehen Water Budget

High variability in P and R, low variability in ET

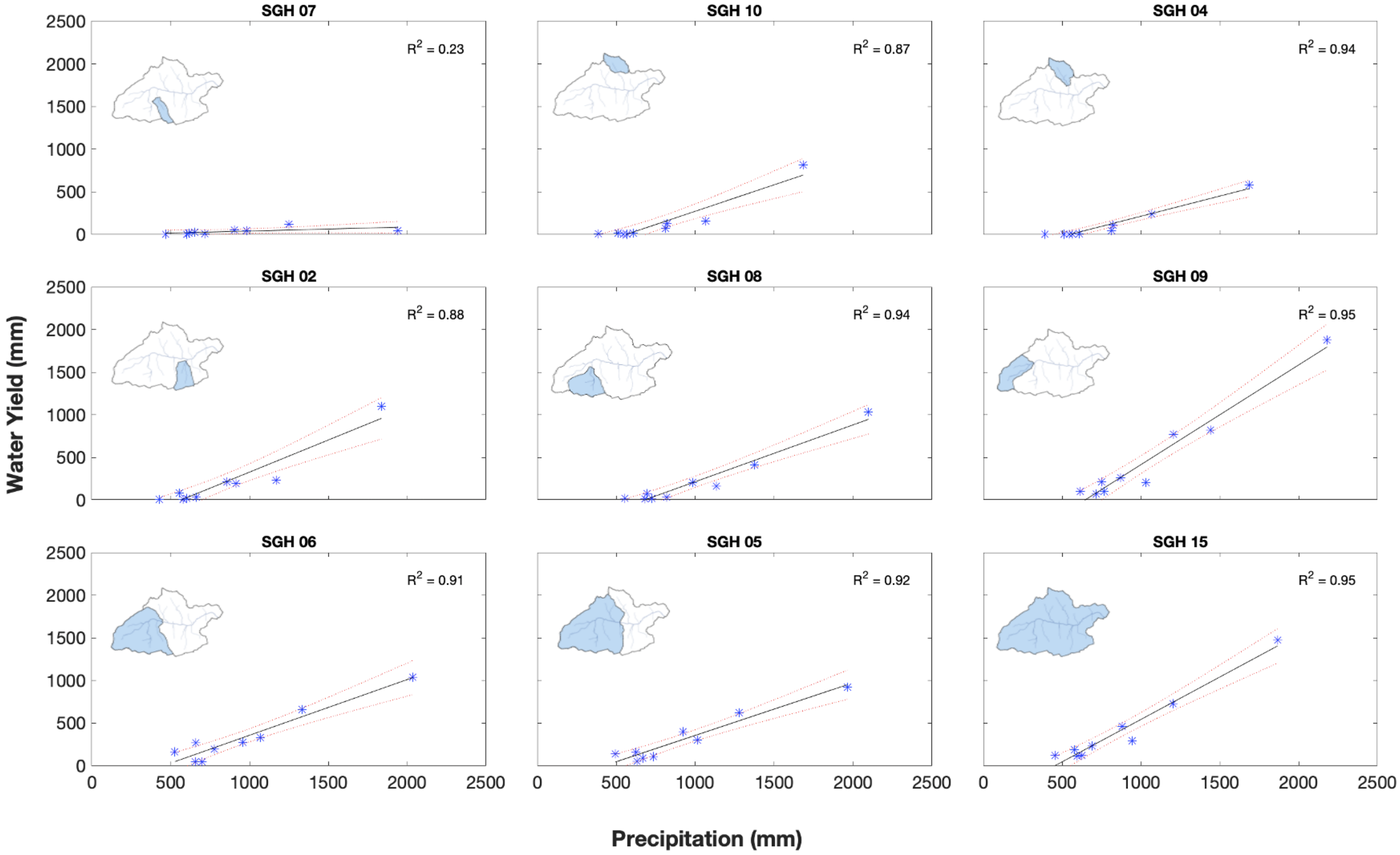


Sagehen Water Budget
Minimal variability in ET even after treatment




SGH 07
SGH 10
SGH 04
SGH 02
SGH 08
SGH 09
SGH 06
SGH 05
SGH 15
Depth (mm)
2500
2000
1500
1000
500
0
-500
-1000
2013
2014
2015
2016
2017
2018
2019
2020
P
ET
WY

≥ 85% of variability in sub-basin runoff predicted by precipitation



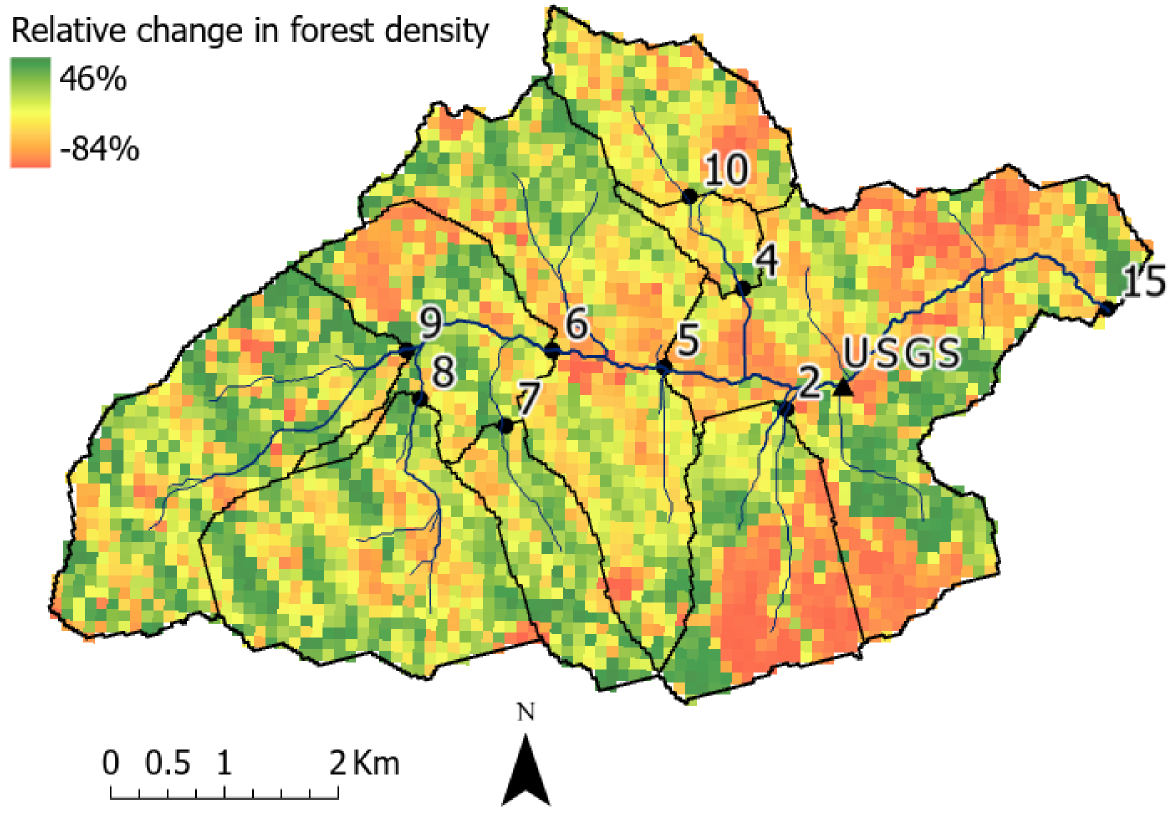
Goal 2 Methods

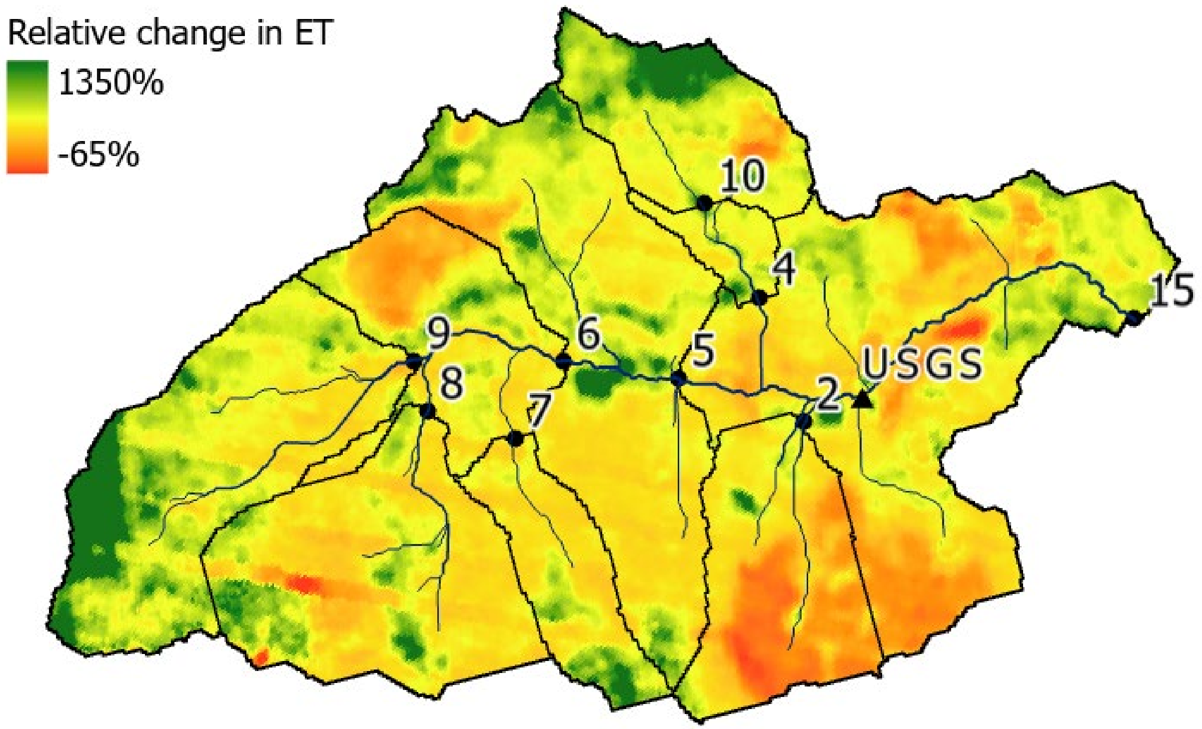
Investigating the impact of forest treatments on annual ET

Pixel scale analysis (100m x 100m)

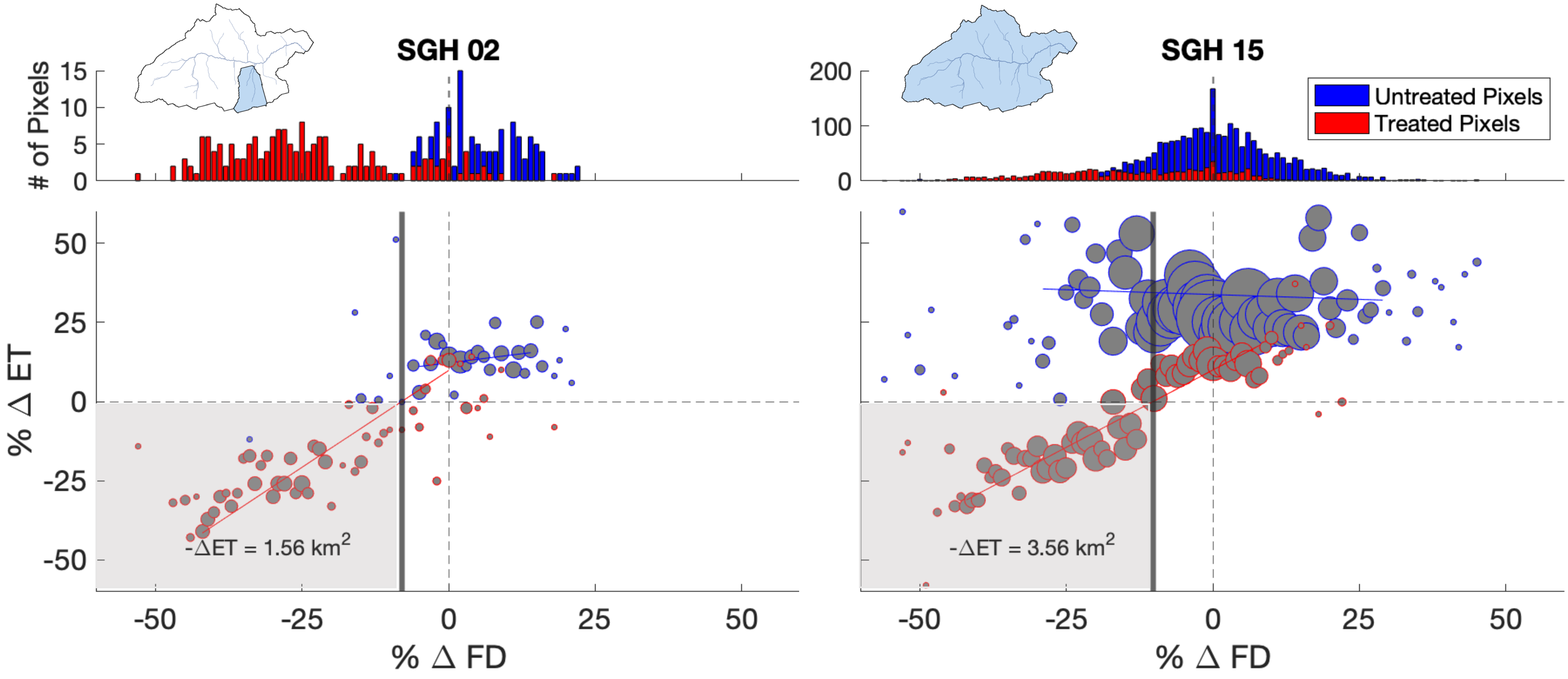
1. Compare change in forest density pixel data to change in ET pixel data between 2018 and 2014
2. Group pixels to treated and untreated categories and compare change in forest density to change in ET in both groups
3. Run a linear regression analysis to explore the relationship between change in forest density and change in ET

Relative change in forest density between 2014 and 2018 visually similar to relative change in ET





Linear relationship between change in forest density and change in ET within treated pixels



Conclusions from current work

1. During the study period annual ET at sub-basin and basin scale was nearly constant despite treatment

2. At sub-basin and basin scale precipitation accounts for $\geq$ 85% of water yield variability. There was no measurable increase in water yield due to forest treatment

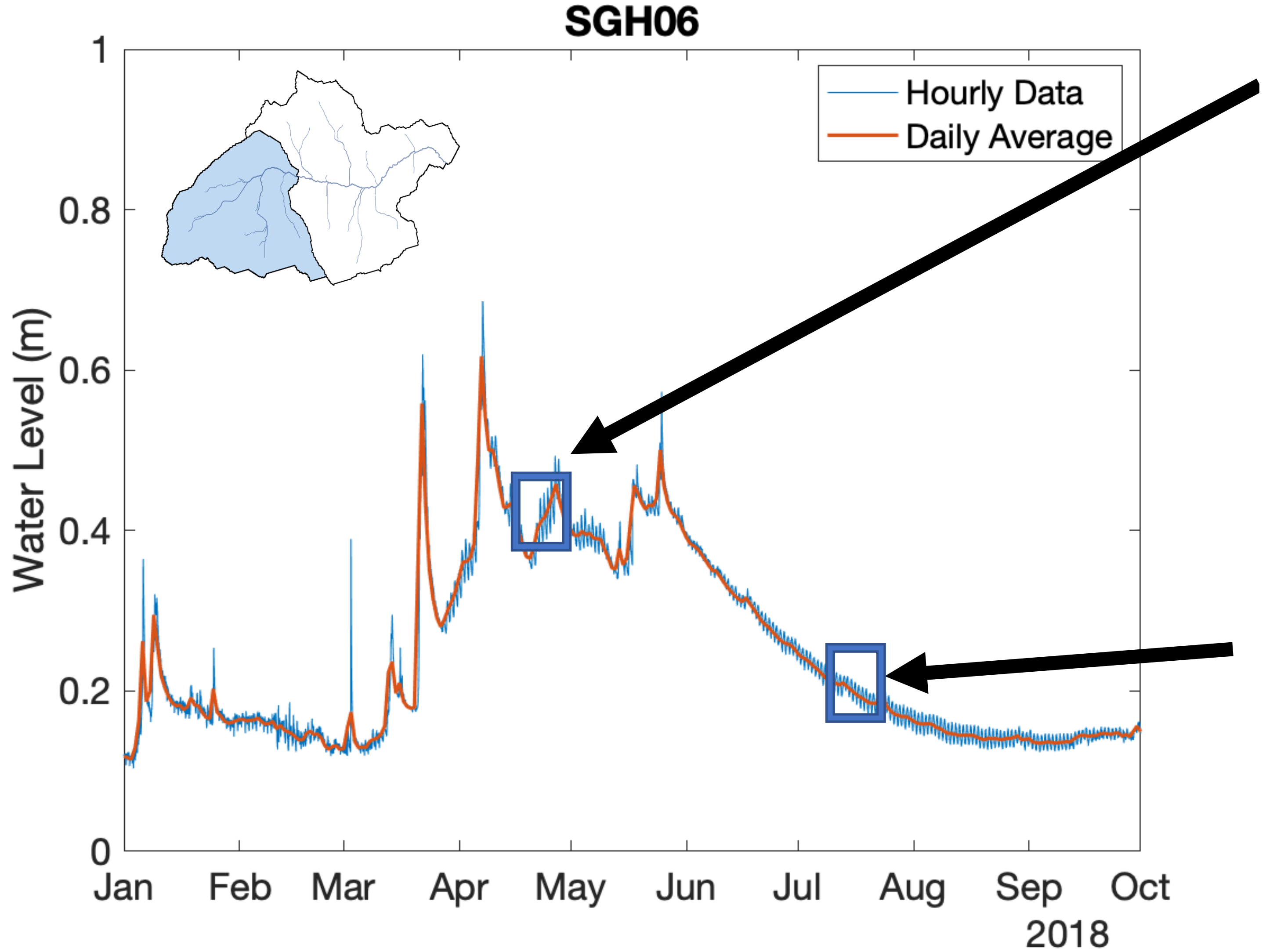
3. At pixel scale forest treatment reduced ET across ~50% of sub-basin SGH 02 but only 10% of the Sagehen watershed. This scale of impact was too small to influence water yield.

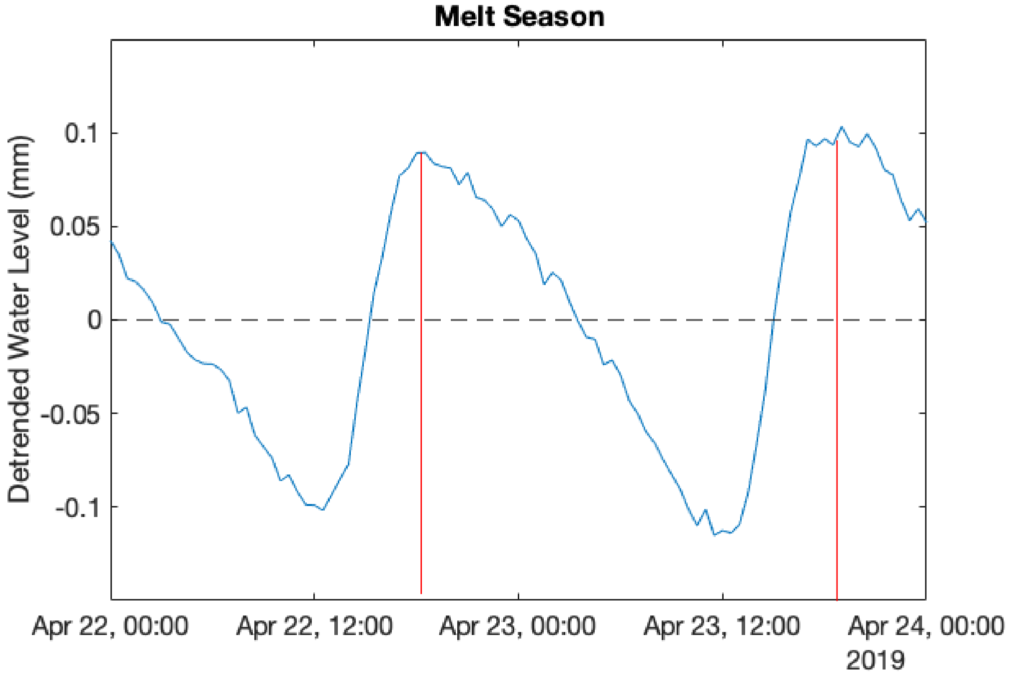
Ongoing work: Evaluating the diel (24 hr) cycle

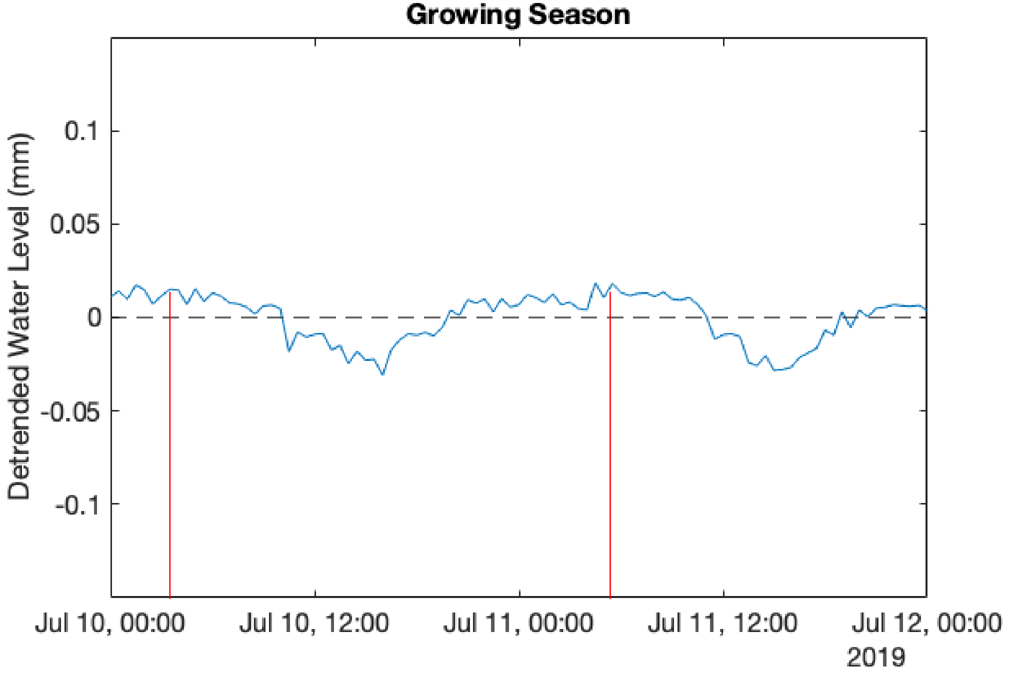
- Goal: use hourly stream stage data to understand watershed scale behavior

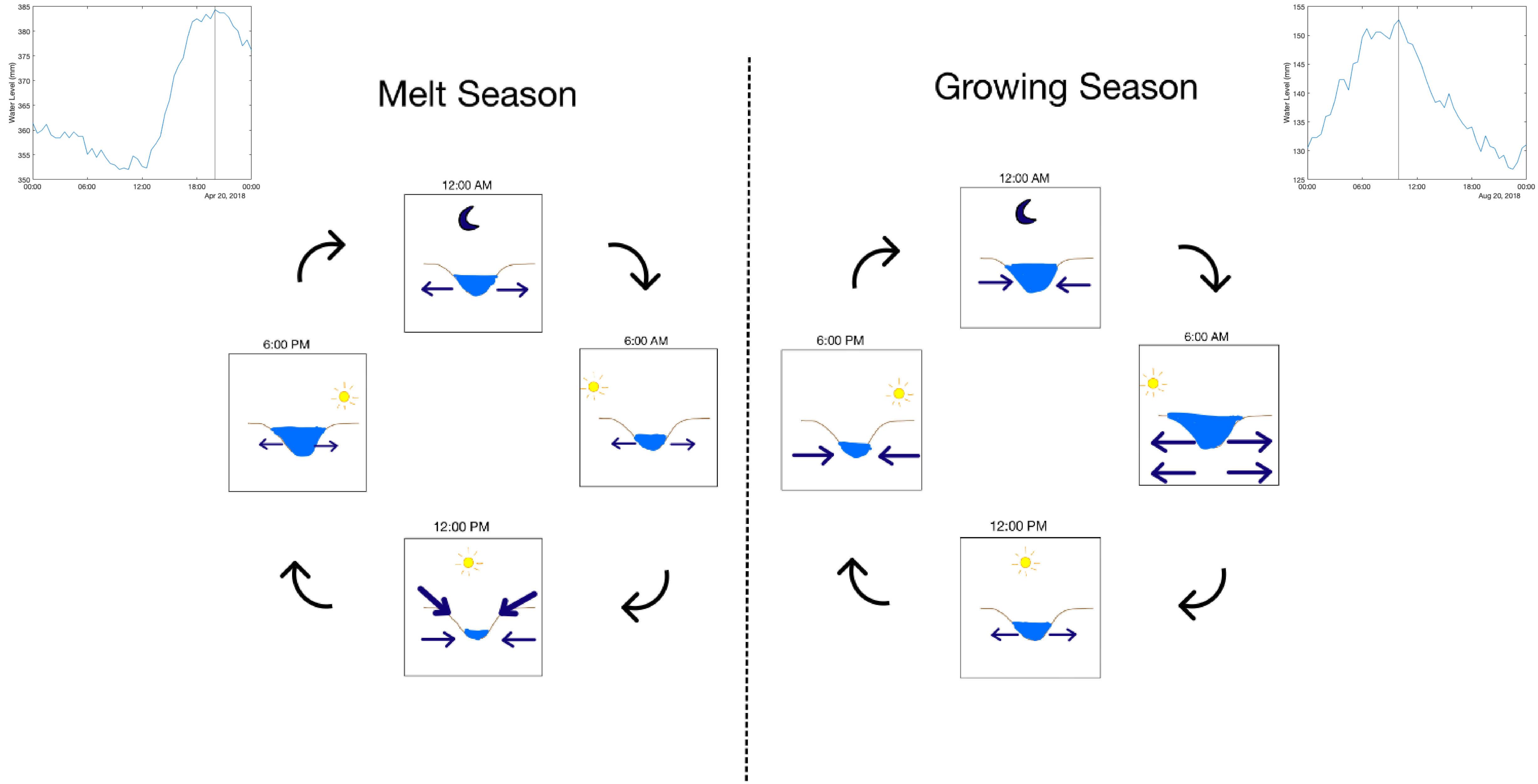
- Goal: quantify daily stream stage variability using the Diel Cycle Index and see how climate change may change this metric

Diel (24 hr) fluctuations in stream stage








Melt Season
Growing Season
Water Level (mm)
385
380
375
370
365
360
355
350
00:00
06:00
12:00
18:00
00:00
Apr 20, 2018
155
150
145
140
135
130
125
Aug 20, 2018
12:00 AM
6:00 AM
12:00 PM
6:00 PM


Melt Season
Transition
Growing Season
Change in Stream Stage (mm/hr)
Temp (F)
SGH06
DCI
Signficant DCI
Max Change in Stream Stage
(mm)
Mar
Apr
May
Jun
Jul
Aug
2018
Stream Stage (mm)
00:00
06:00
12:00
18:00

Using hourly stream stage data to understand watershed scale behavior

1. What can we learn about watershed hydrology by studying the DCI signal?

2. How does the DCI signal vary across space?

3. How does the DCI signal vary across time?

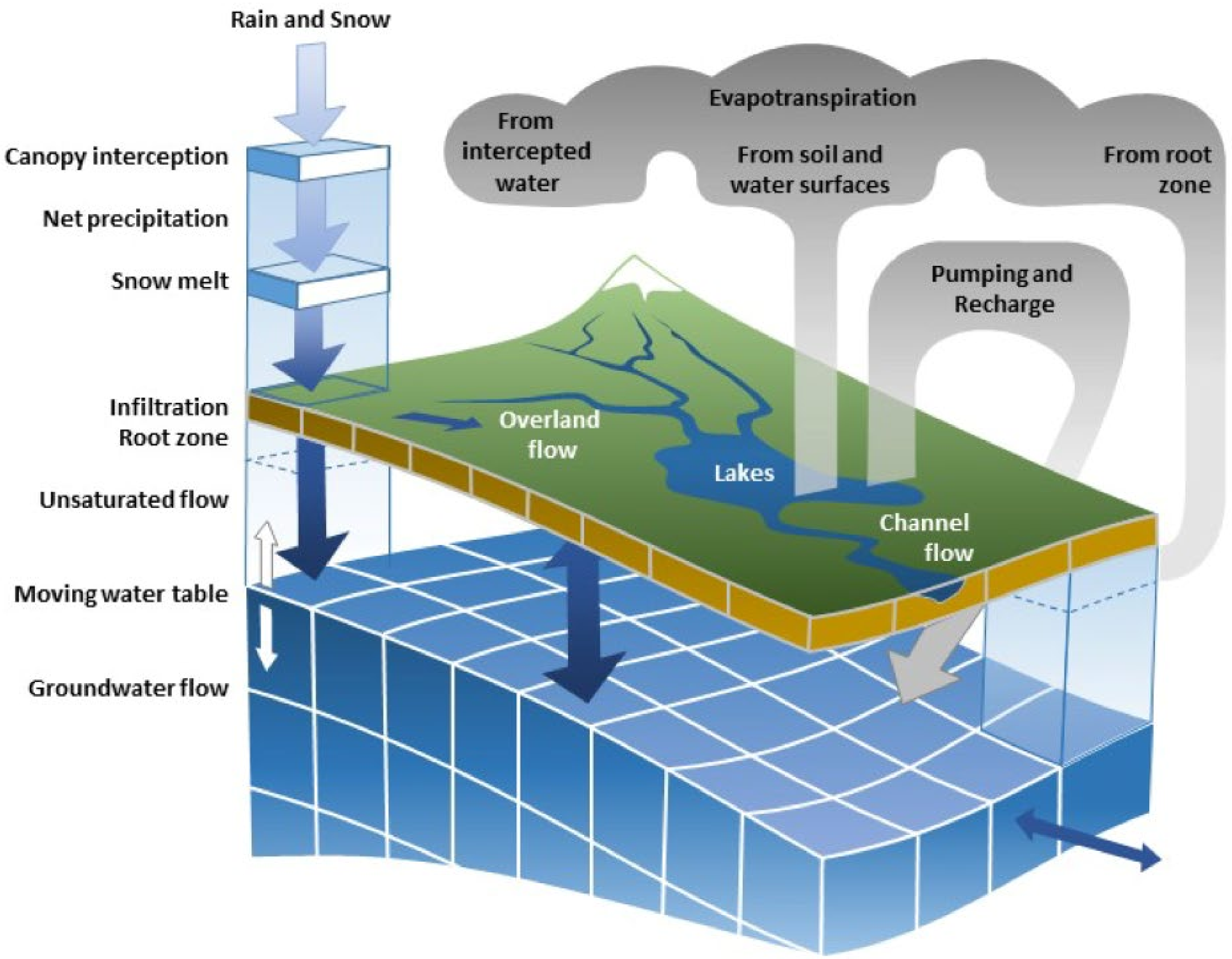
Ongoing work: High-resolution modeling

- Goal: Model development and parameterization to represent a range of fuel treatment options.
  - How well does this model replicate previous forest treatments?
- Goal: Model the interactions of vegetation with the hydrologic process.
  - How much of the forest do we need to treat to start to see hydrologic change (impact on runoff)?
    - For example, if we applied X% of forest treatment to the basin, how does that impact streamflow?

MIKE SHE Model

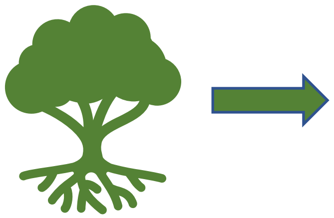
- Physics based, 3D, fully distributed modeling framework

- Includes important features for modeling eco-hydrology in high mountain basins:
  - Snow melt/accumulation
  - Subsurface flow processes – in both saturated and unsaturated zones
  - Quantitative vegetation representation (LAI, rooting depth)

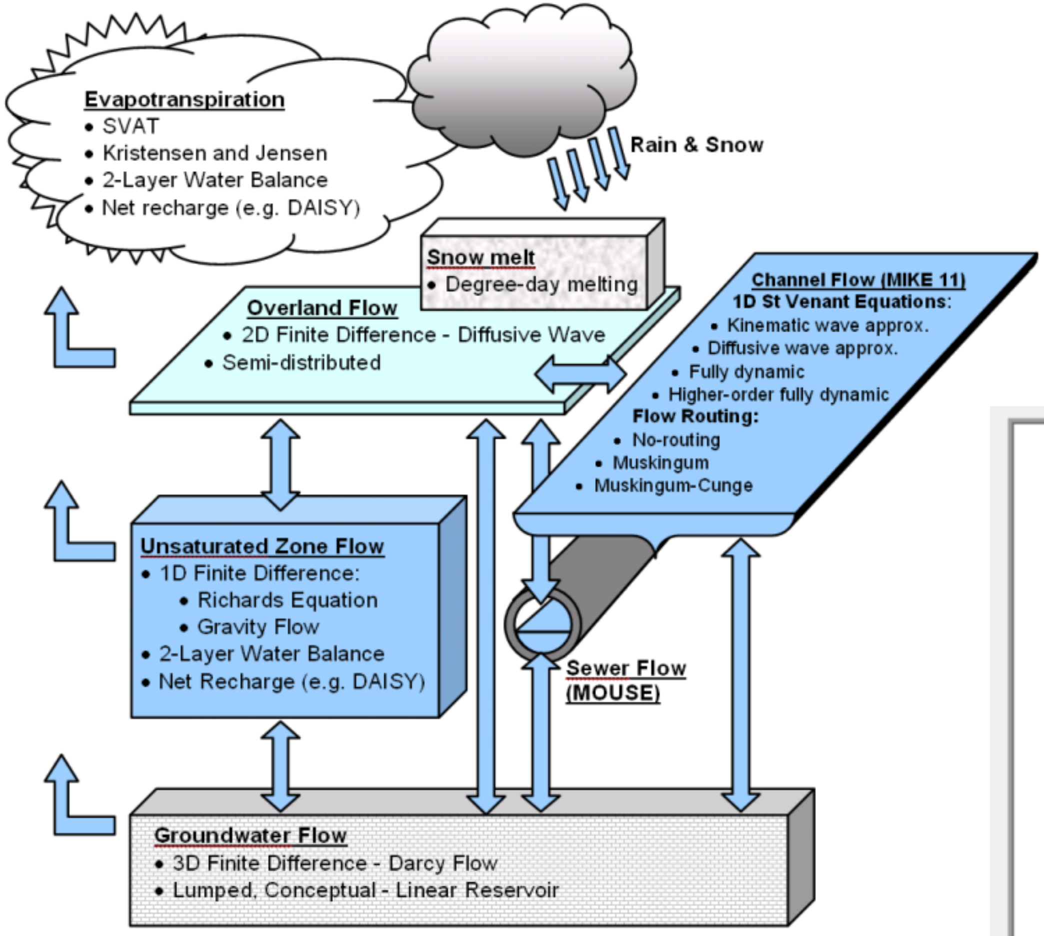


Conceptual figure taken from the MIKE SHE Manual

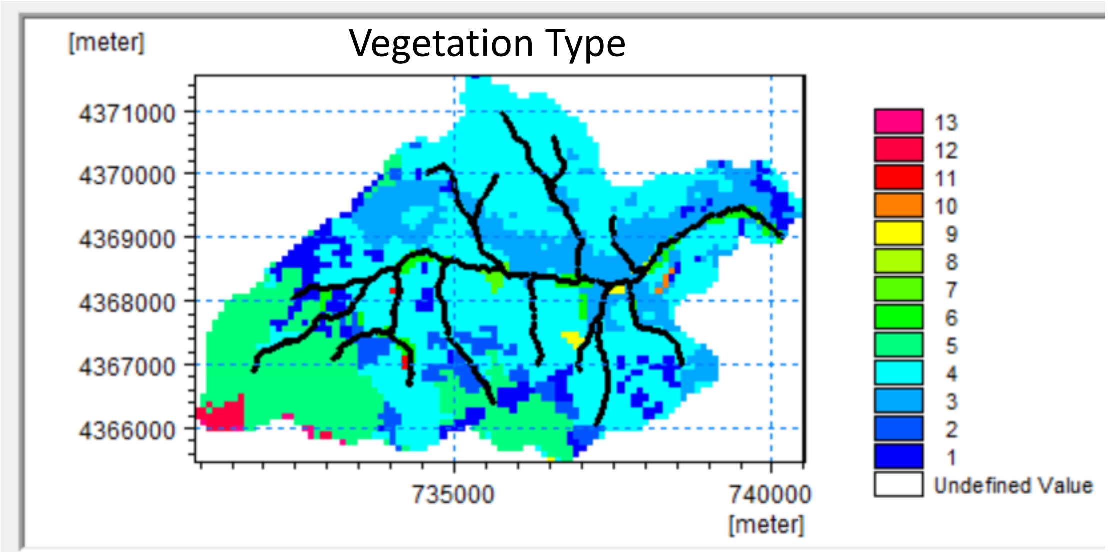
Model Setup / Framework



Vegetation Change (e.g., forest treatments)



- Frame the model based off the dominant hydrologic processes in the watershed.
- Our focus: the impact of vegetation change on ET and ultimately runoff at the basin and sub-basin scales.



Presentations and Products

Publications

1. Boden, et al. (2022). *A multi-scale assessment of forest treatment impacts on evapotranspiration and water yield in the Sierra Nevada*. *(submission August 2022)*
2. Boden, et al. (2022) *Impact of forest treatment on water yield in a Sierra Nevada watershed.* [Master's thesis, Colorado School of Mines]. ProQuest Dissertations Publishing. *(in queue for publication)*

Conference presentations

1. Rocky Mountain Hydrologic Research Center – *Fall Meeting*	October 2021
2. American Geological Society- *Annual Meeting*	December 2021
3. Colorado School of Mines- *Thesis Defense*	April 2022
4. Colorado State University- *Hydrology Days*	April 2022
5. University of Colorado- *Hydrology Symposium*	May 2022
6. American Geological Society – *Annual Meeting*	Dec. 2022 *(abstract submitted)*

Thank you!

Questions?

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