Remote-sensing guided modeling of dynamic post-fire watershed changes in SWAT+

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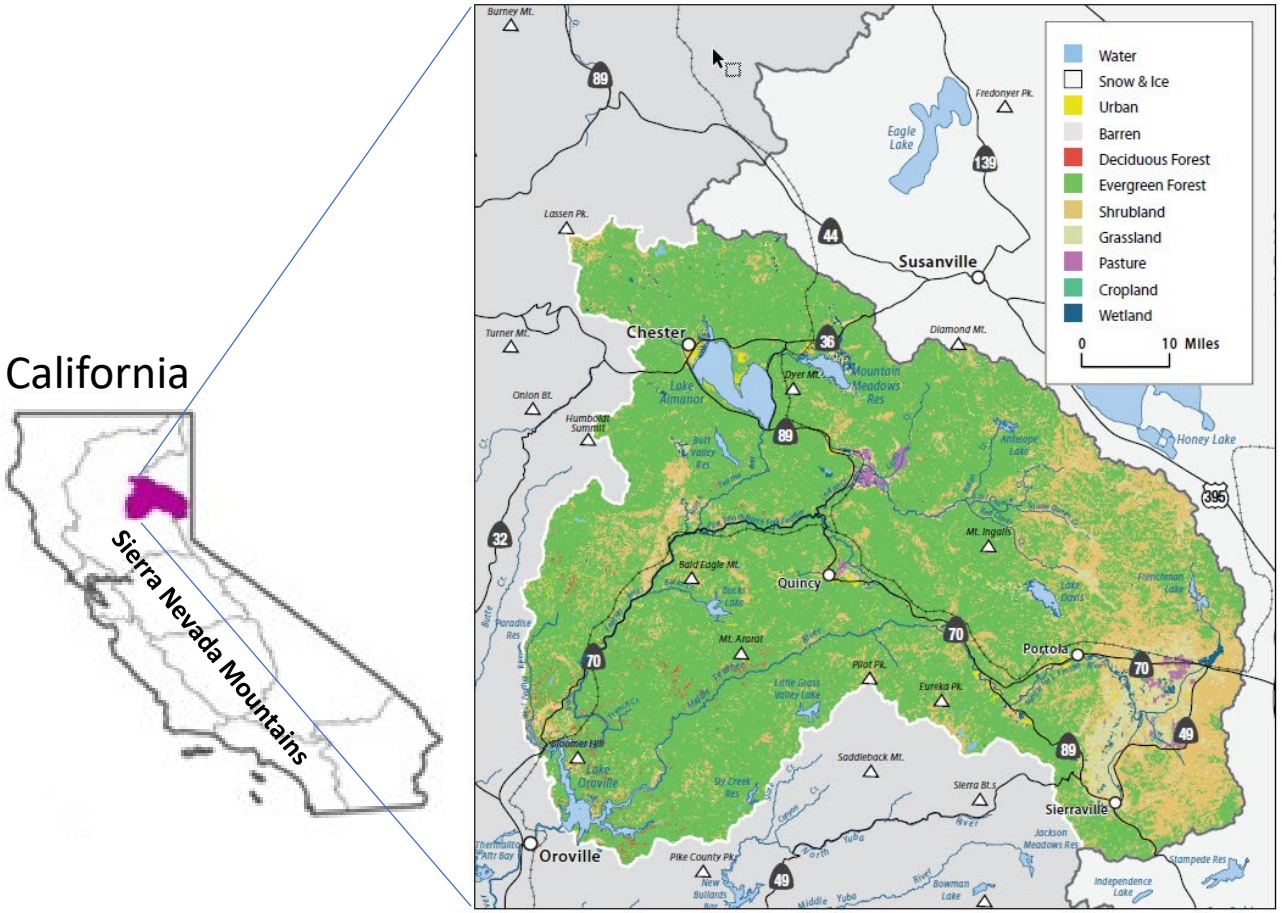
CALIFORNIA DEPARTMENT OF WATER RESOURCES

Objectives

- Identifying burn severity intervals using the remote-sensing based vegetation cover loss
- Translating fire purturbation to the model focusing on shifts in vegetation classifications and hydrologic soil and routing parameters
- Dynamic multi-year wildfire integration using DTL
- Testing the water budget sensitivities to fire

Study area

Upper Feather River Watershed



https://sacriver.org/explore-watersheds/feather-river-subregion/upper-feather-river-watershed/

- Area: 9400 km^2
- Elevation range: 270-2900 m
- Climate: Mediterranean
- Precipitation: 1078mm

- 70% is composed of mixed conifer forest

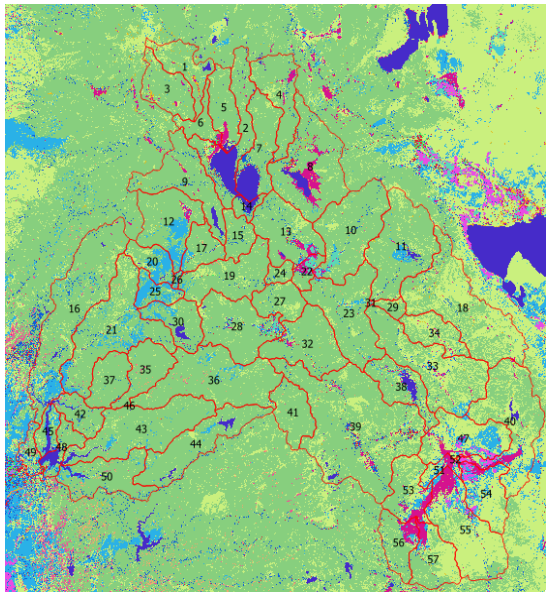
- The North Complex Fire (Aug. 17–Dec. 3, 2020)
- The Dixie Fire (July 13–Oct. 25, 2021)

Model set up

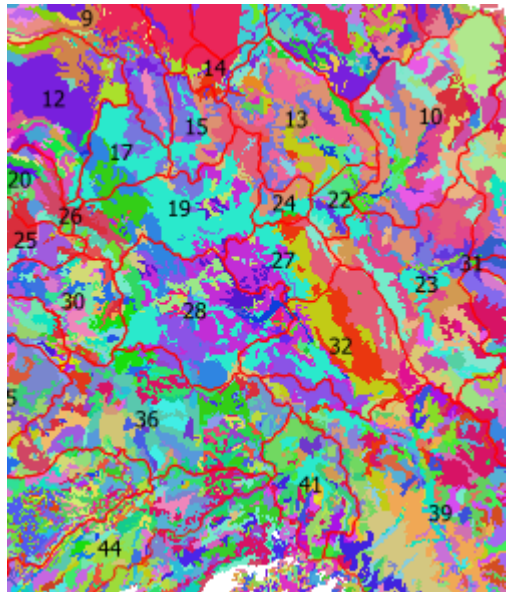
QSWAT+ 2.3.3

SWAT+ Editor v2.2.2

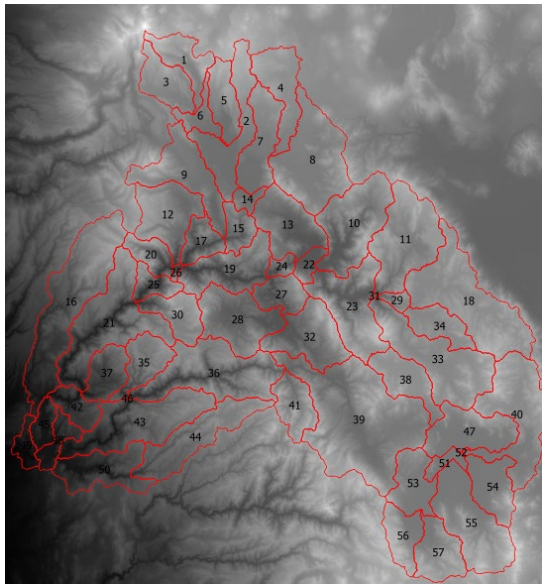
Spatial inputs



NLCD 2001 Land use



SURGO soil data



SRTM DEM 30 m

Meteorological inputs

- Precipitation (PRISM data)
- maximum and minimum temperature
- daily time step

Sensitivity analysis

- Manual: one parameter at a time
- Automatic: Sobol algorithm (SWAT+ Toolbox)

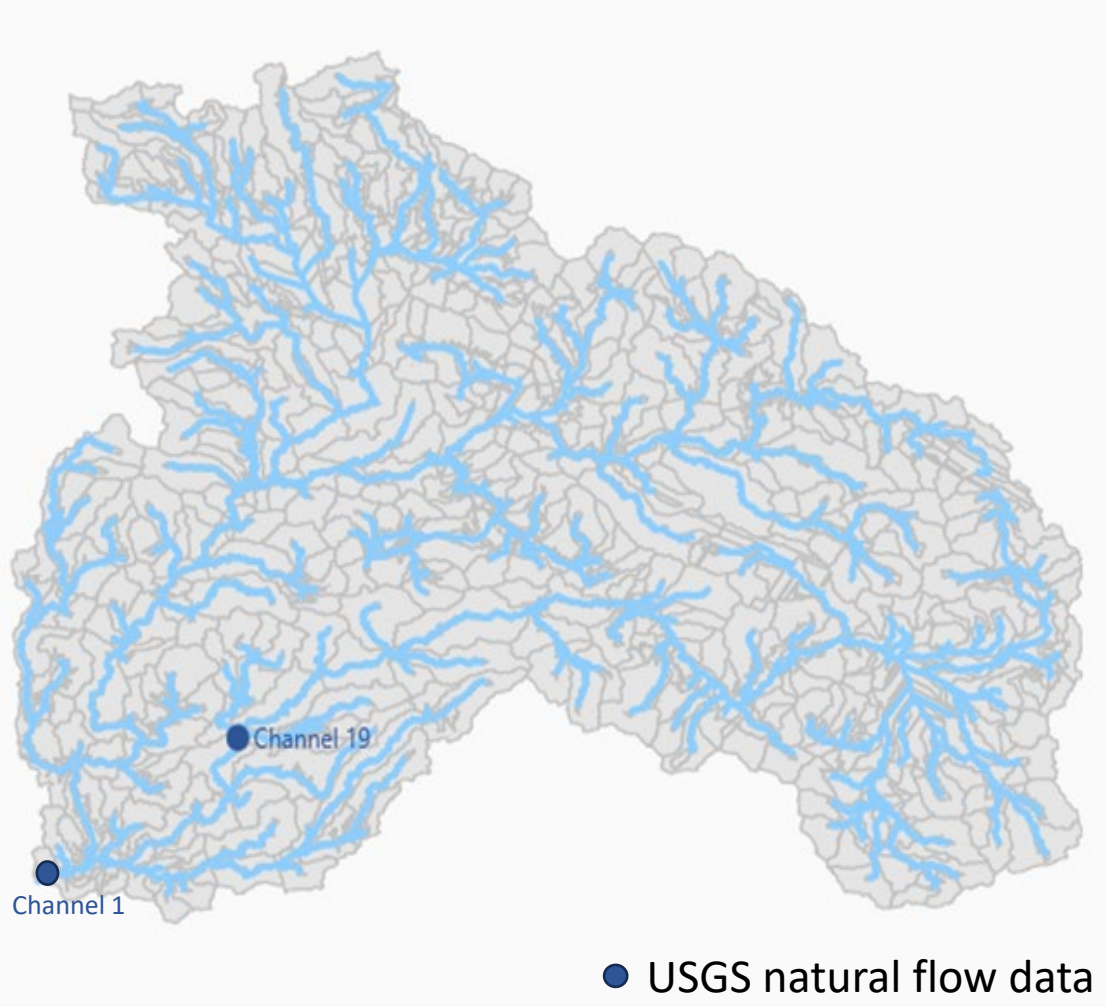
Multi-gauge calibration/validation

- Channel-19: 1946-1986 (5 years warmup period)
- Channel-1: 1997_2022 (5 years warm up period)

Multi-variable calibration

- Discharge
- Leaf Area Index (VIIRS LAI) 2016-2022

Upper Feather River Watershed

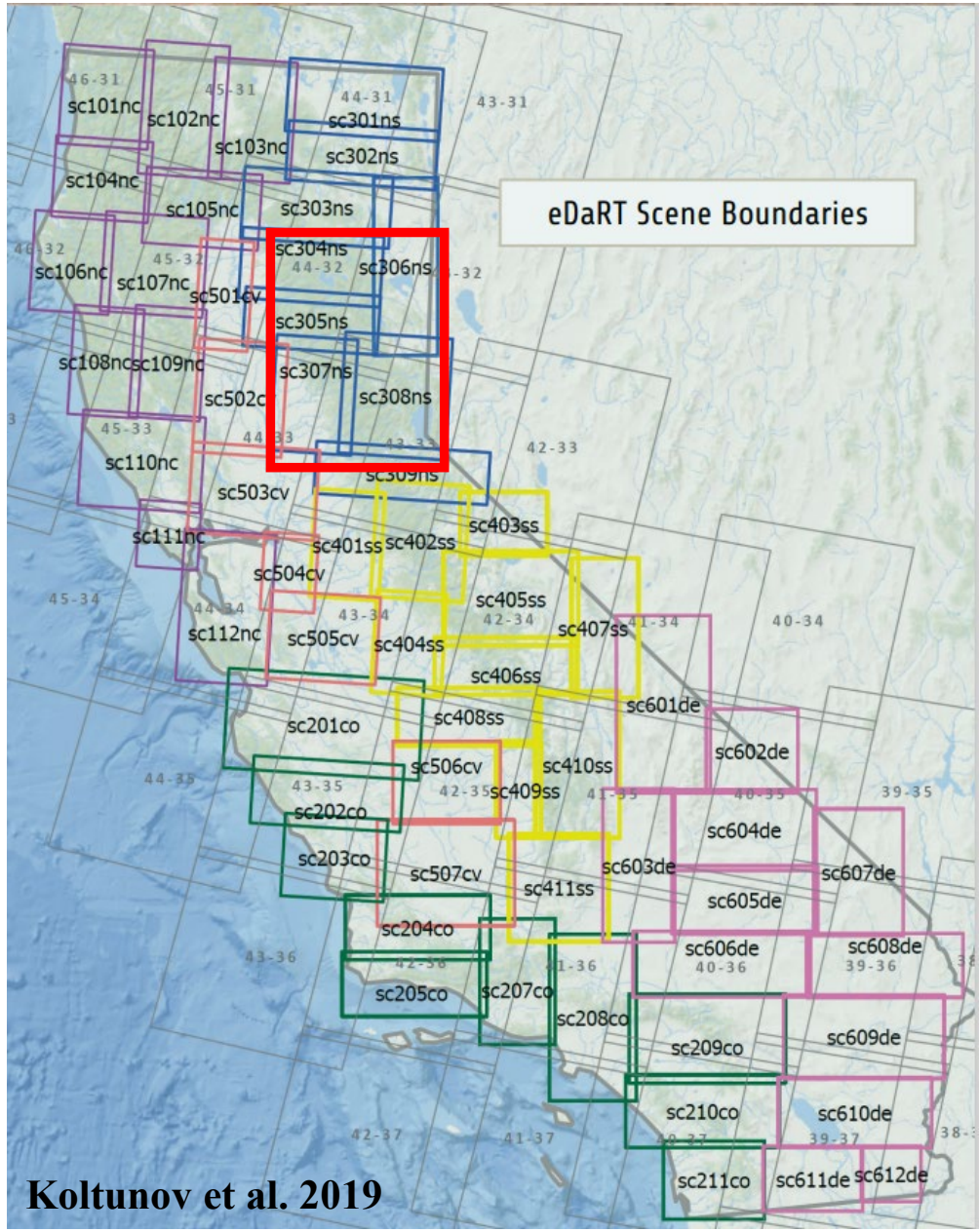


Modified plant database

Parameter	Definition (unit)	Default (Range)	FRSE	FRSD	FRST
bm_e	Radiation-use efficiency (kg biomass /ha/(MJ/m^2))	15 (10-90)	14	15	14
lai_min	Initial leaf area index (m2/m2)	0.75	1.2	-	1
lai_pot	Maximum potential leaf area index (none)	5 (5-10)	3.1	2	3.25
frac_hu$_1$	Fraction of the growing season or the total potential heat units corresponding to the 1st point on optimal leaf area development curve (fraction)	0.15 (0-1)	0.1	0.02	0.09
frac_hu$_2$	Fraction of the growing season heat units corresponding to the 2nd point on optimal leaf area development curve (fraction)	0.40 (0-1)	0.29	0.15	0.30
lai_max$_1$	Fraction of the maximum leaf area index corresponding to the 1st point on optimal leaf area development curve (fraction)	0.05 (0-1)	0.14	0.10	0.14
lai_max$_2$	Fraction of the maximum leaf area index corresponding to the 1st point on optimal leaf area development Curve (fraction)	0.95 (0-1)	0.87	0.88	0.87
dlai_rate	Exponent that governs the LAI decline rate	1	0.57	0.53	0.57
tmp_opt	Optimal temperature for plant growth (◦C)	30 (11-38)	20	24	25
tmp_base	Minimum temperature for plant growth (◦C)	10 (0-18)	2.5	-	-
bio_leaf	Leaf to biomass fraction (none)	0.3	0.02	-	0.035

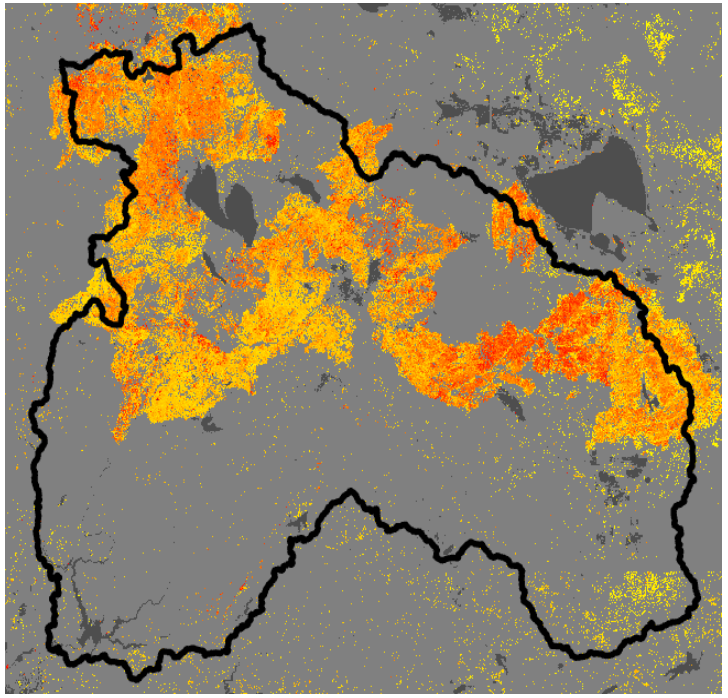
Informing SWAT+ about fire severity

- Ecosystem Disturbance and Recovery Tracker (eDaRT; Koltunov et al. 2020).
- Landsat image processing system
- Primary output: disturbance events detection (30 m) (timing, confidence, and magnitude).
- Magnitude of impact: % canopy cover loss estimated via Mortality Magnitude Index (MMI) model (Slaton et al. 2024).
- 5 eDaRT scenes used to cover the study area.



% Canopy Cover Loss (ΔCC) and psot-fire landcover transitions

% Canopy Cover Loss



Δ Canopy Cover	Burn severity
≤ 1%	Unburned
1-10%	Low
11-40%	Low-mod
41-75%	Moderate
76-100%	High

- Intervals defined using a training sample of burned pixels and ancillary data

Modeling Post-Fire Changes

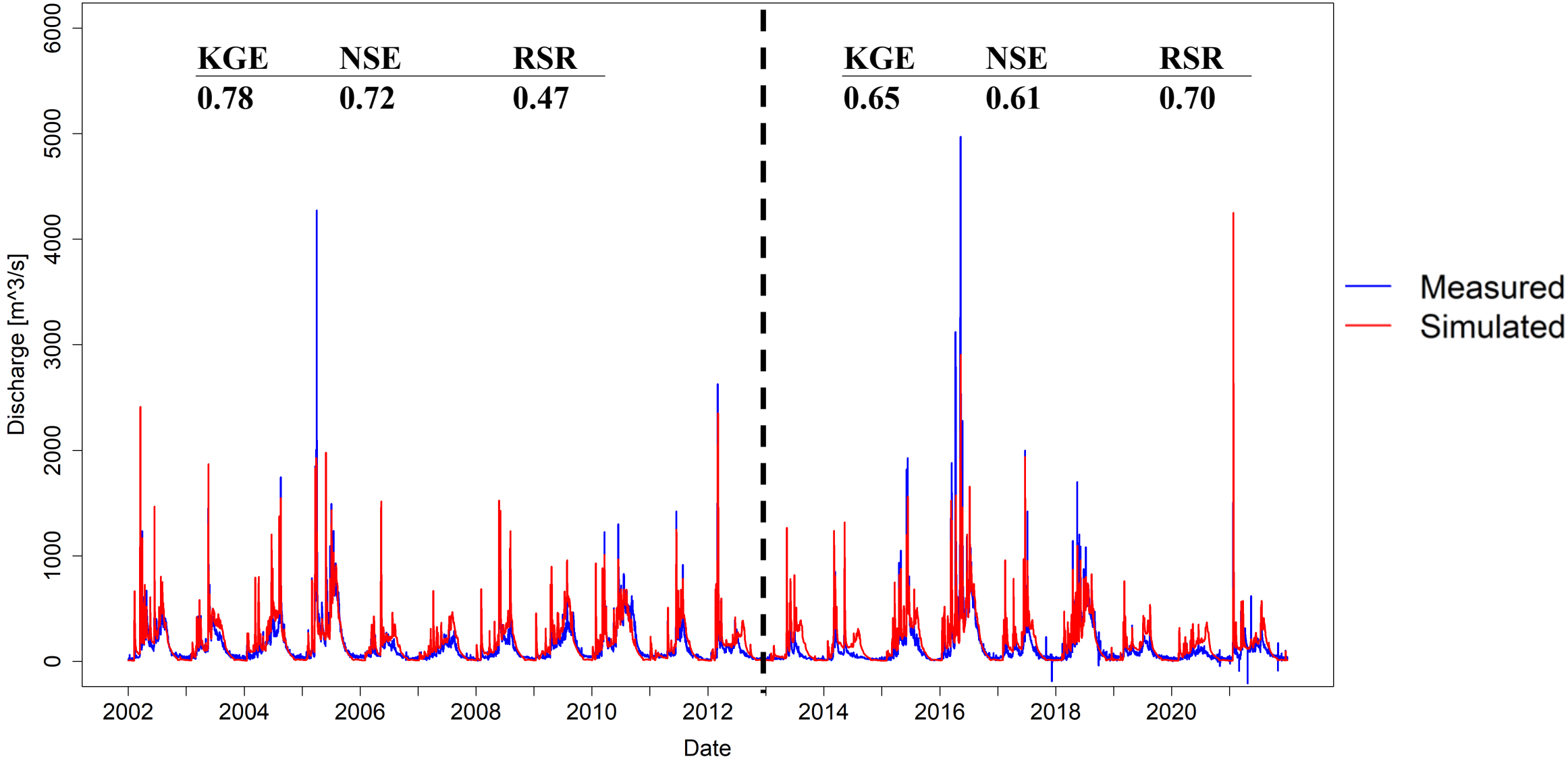
SWAT+ experiment

- Reduced the biomass and residue
- Adjusted soil characteristics
- Land cover transitions in moderate and high severity
- Adjusted maning overland flow

Post fire parameter adjustments

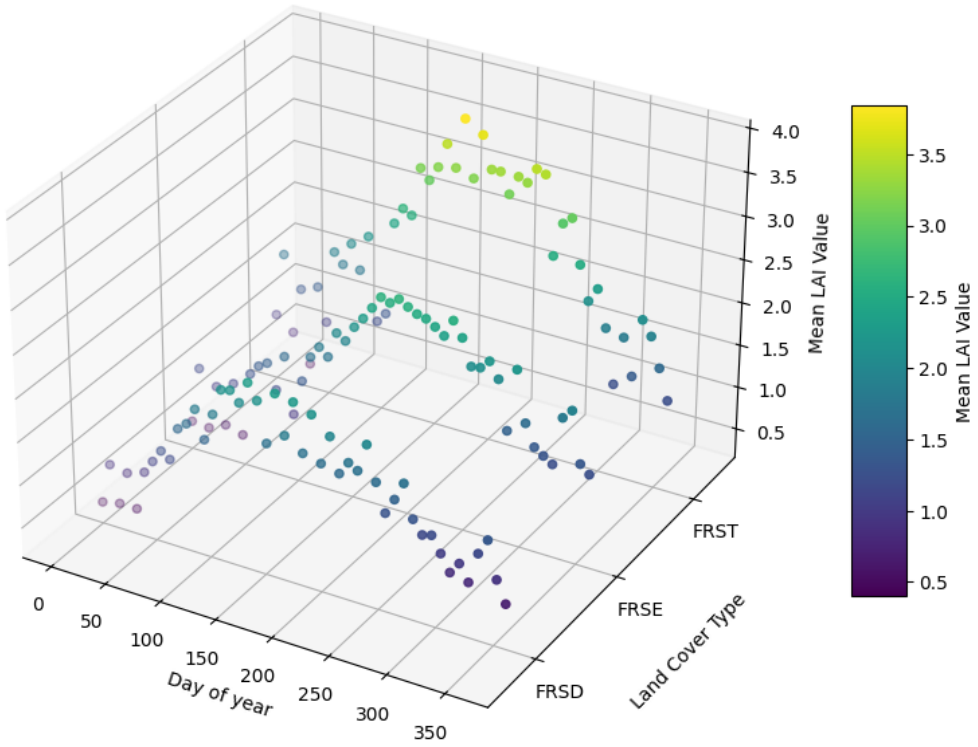
MMI	Fire severity	Above ground biomass and residue	CN2	OV-N	land use transition based on fire severity		
					FRSE/FRSD/FRST →	RNGB →	RNGE →
0	no fire	-	-	-	-	-	-
1-10	low	5.5	5	-	-	-	-
11-41	low-moderate	26	10	0.6	-	RNGE	-
41-75	moderate	58	15	0.13	RNGE	RNGE	-
76-100	high	88	20	0.01	BARR	BARR	BARR

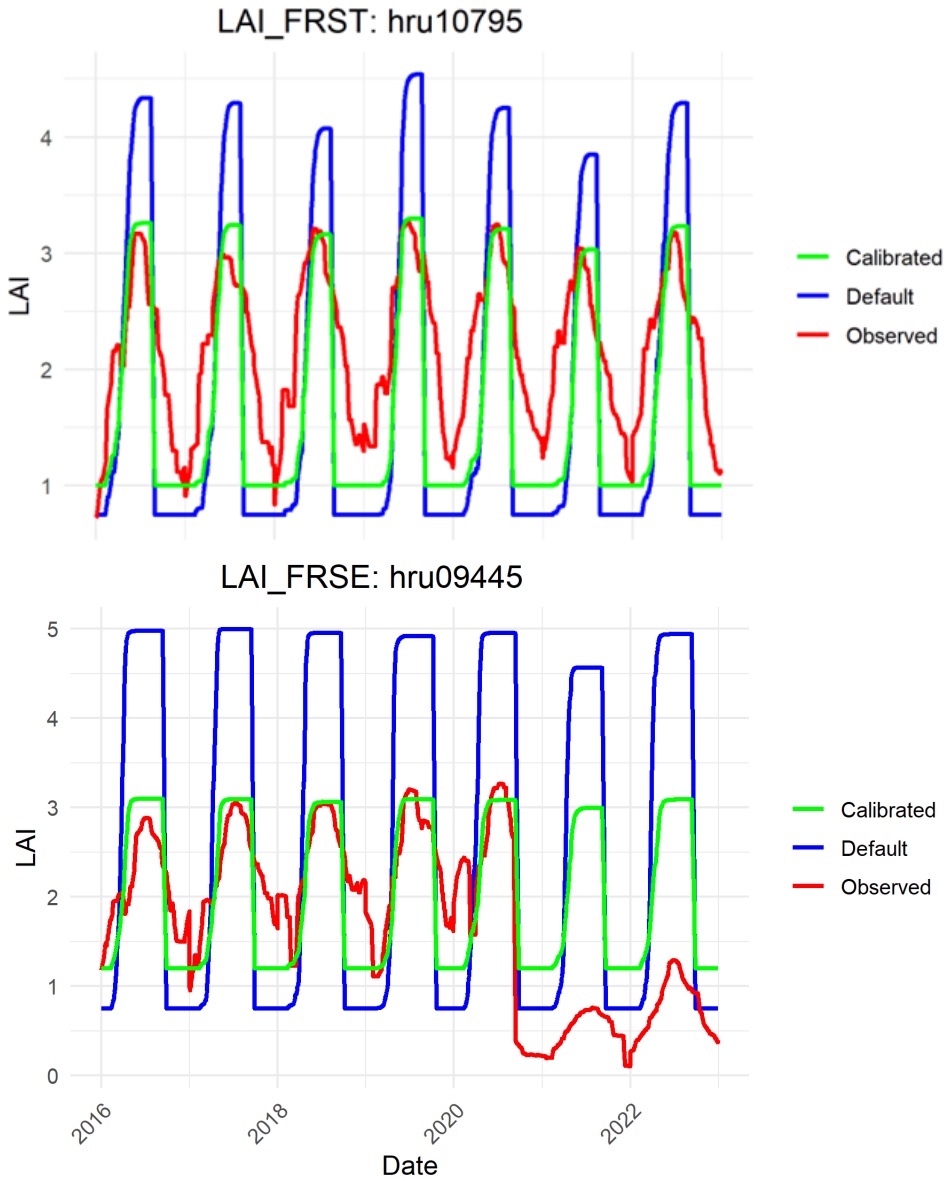
Result of best parameter set calibration and validation (Outlet)



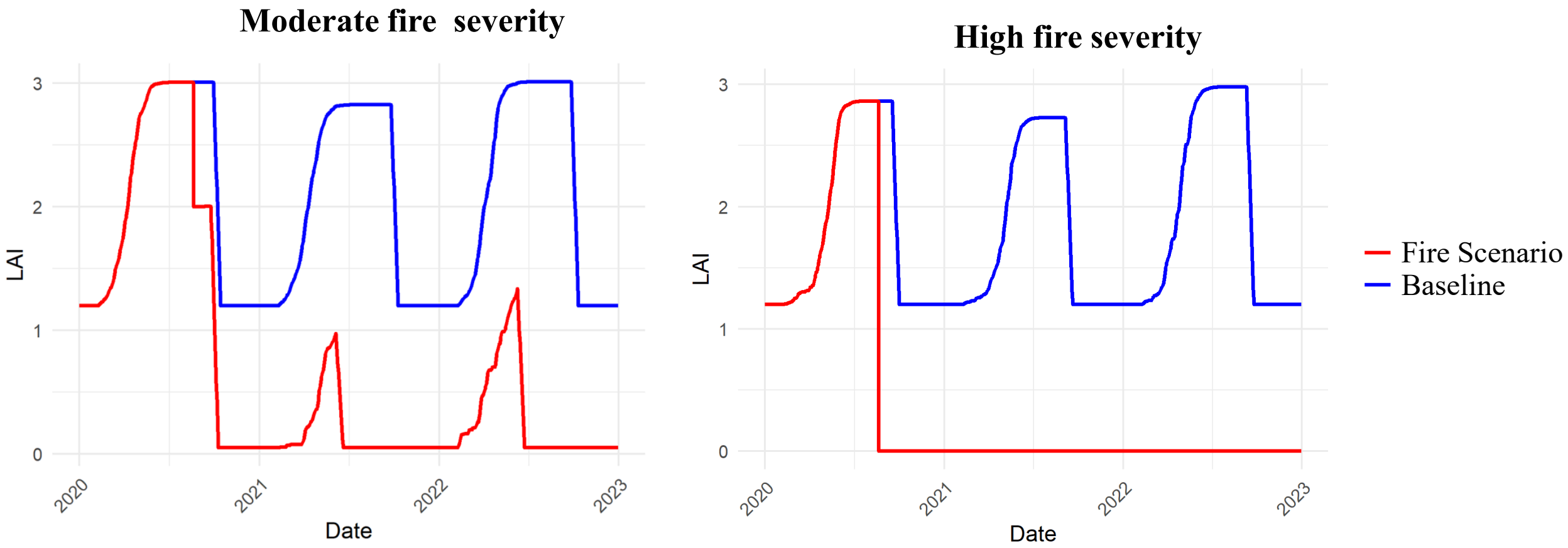
Result of LAI Calibration (baseline)

Mean VIIRS LAI (2016-2022) for Selected Forest Land Cover Types

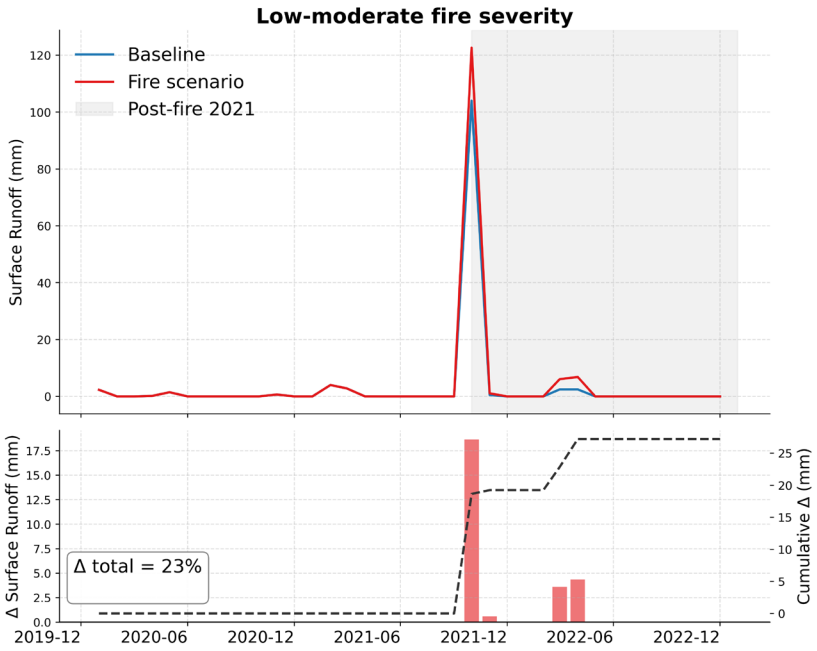


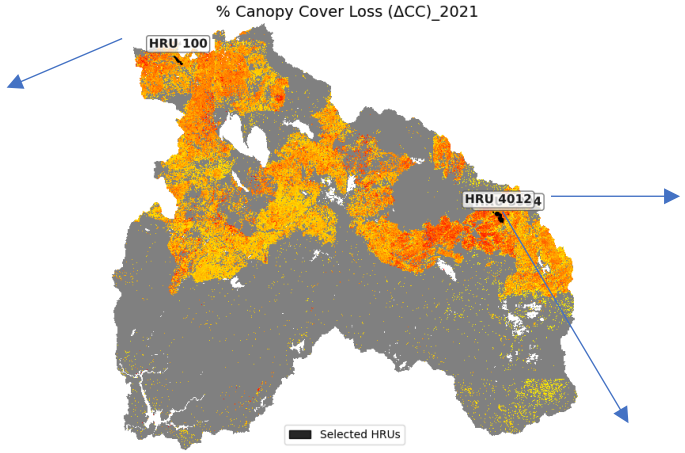


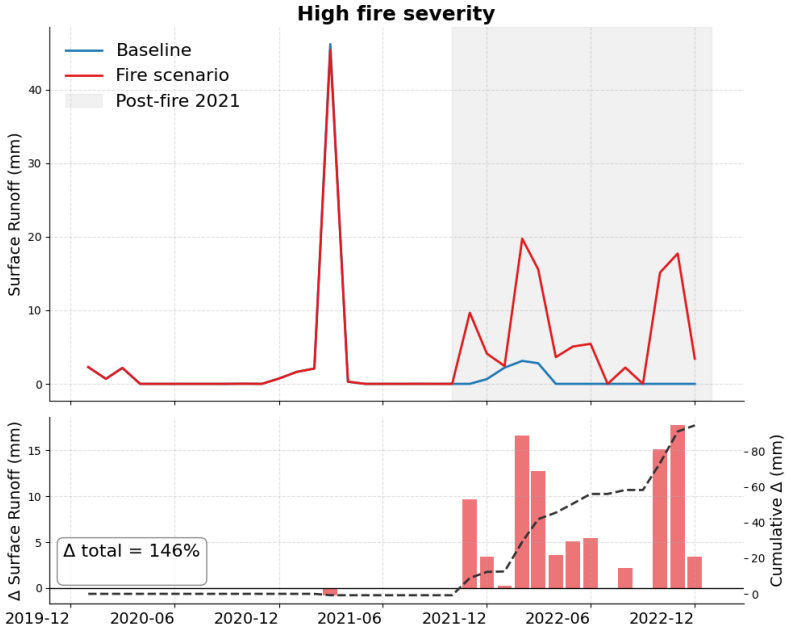
SWAT+ LAI (baseline vs fire scenario)

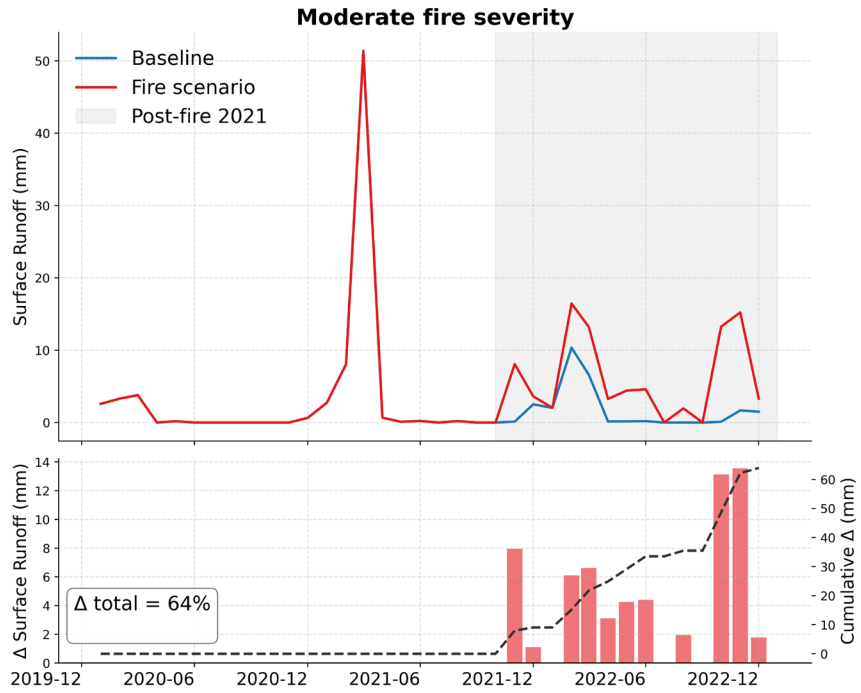


Runoff

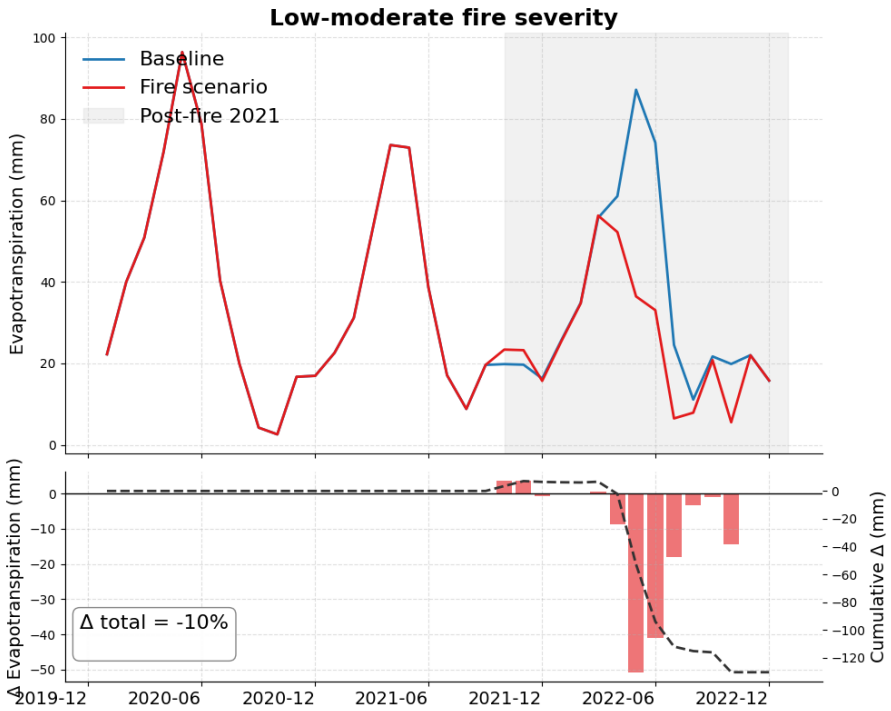

Low-moderate fire severity
Baseline
Fire scenario
Post-fire 2021
Surface Runoff (mm)
Δ Surface Runoff (mm)
Cumulative Δ (mm)
Δ total = 23%
2019-12
2020-06
2020-12
2021-06
2021-12
2022-06
2022-12

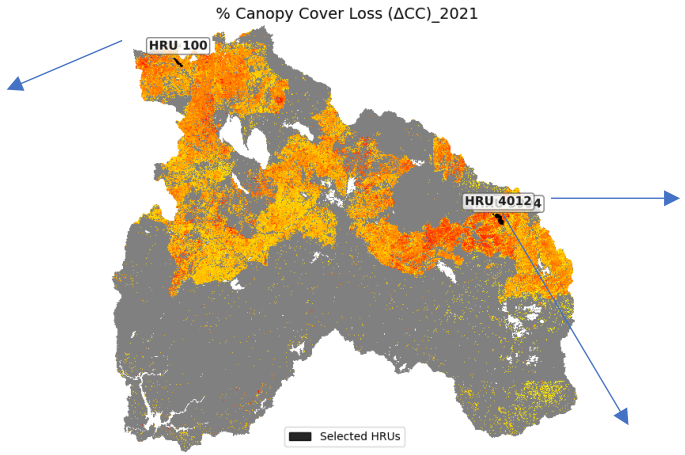

% Canopy Cover Loss (ΔCC)_2021
HRU 100
HRU 40124
Selected HRUs

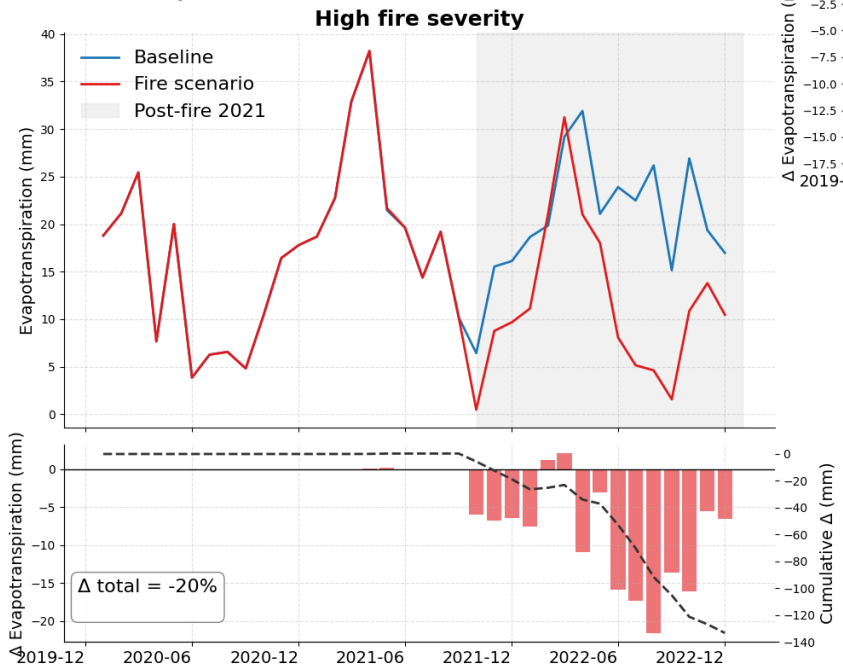

High fire severity
Baseline
Fire scenario
Post-fire 2021
Surface Runoff (mm)
Δ Surface Runoff (mm)
Cumulative Δ (mm)
Δ total = 146%
2019-12
2020-06
2020-12
2021-06
2021-12
2022-06
2022-12

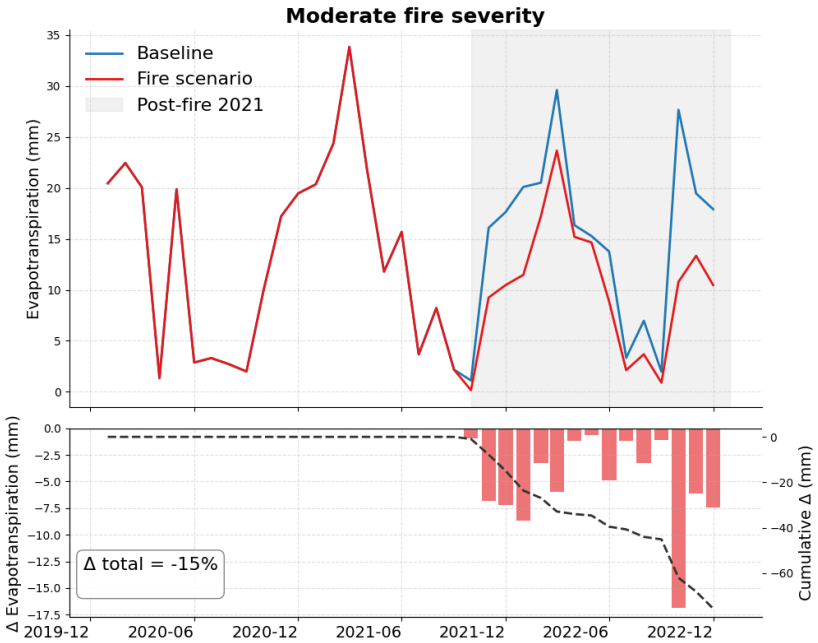

Moderate fire severity
Baseline
Fire scenario
Post-fire 2021
Surface Runoff (mm)
Δ Surface Runoff (mm)
Cumulative Δ (mm)
Δ total = 64%
2019-12
2020-06
2020-12
2021-06
2021-12
2022-06
2022-12

Evapotranspiration

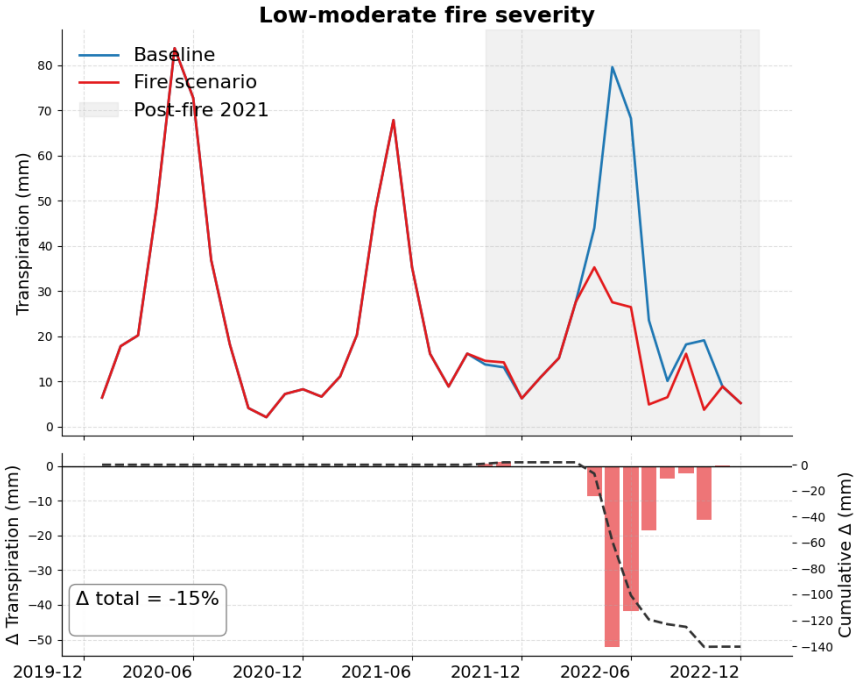


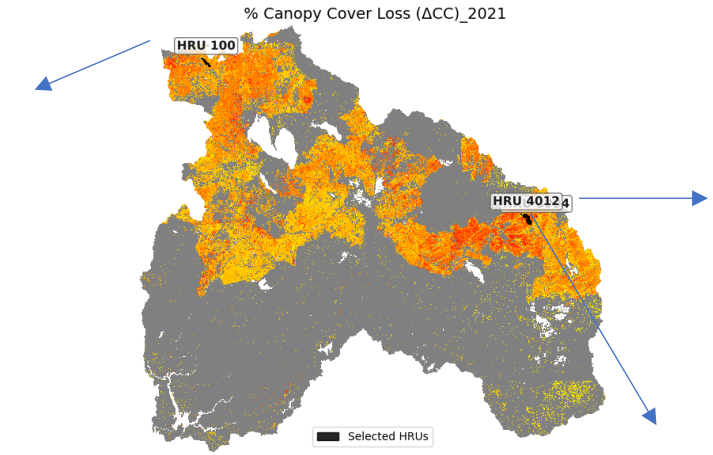


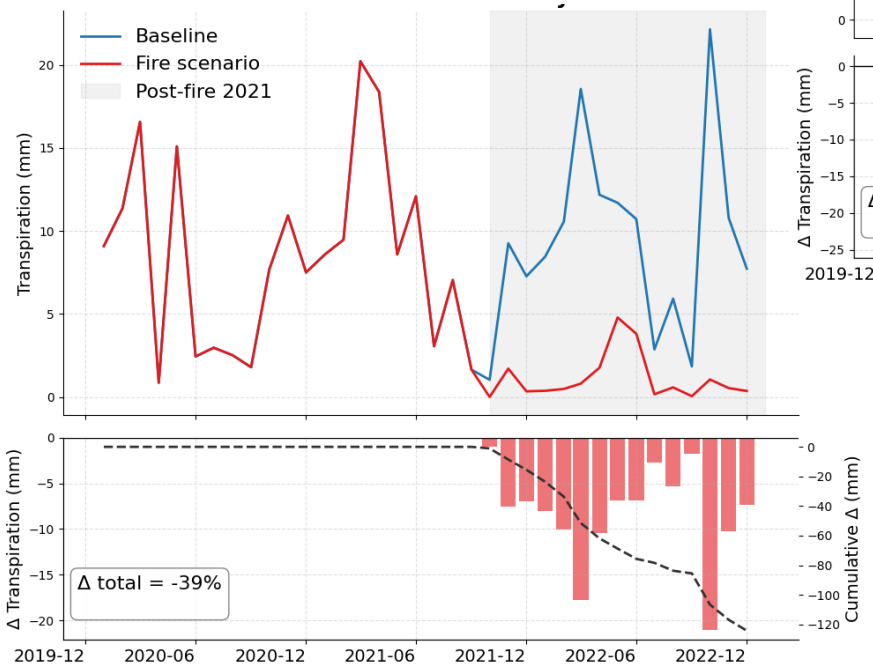


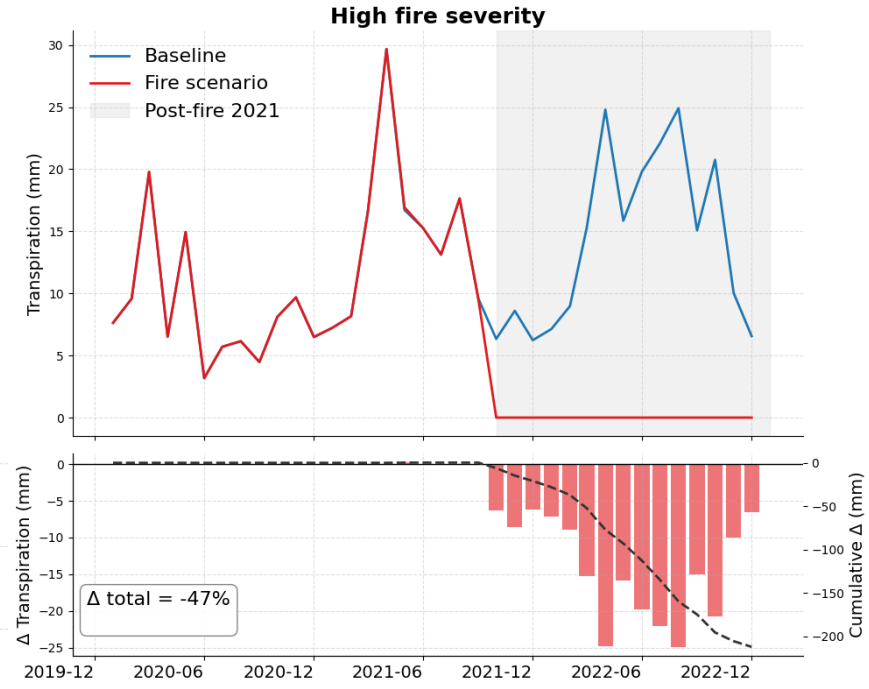


Transpiration









Conclusion

- The fire-aware simulation improved the representation of post fire LAI
- Enhancement at HRU level regarding simulating the surface runoff, ET and its partitions.
- The post-fire scenario showed little to no increase in basin-scale streamflow
- There is shortcoming in scaling fire effects from hru to basin.

Thank you

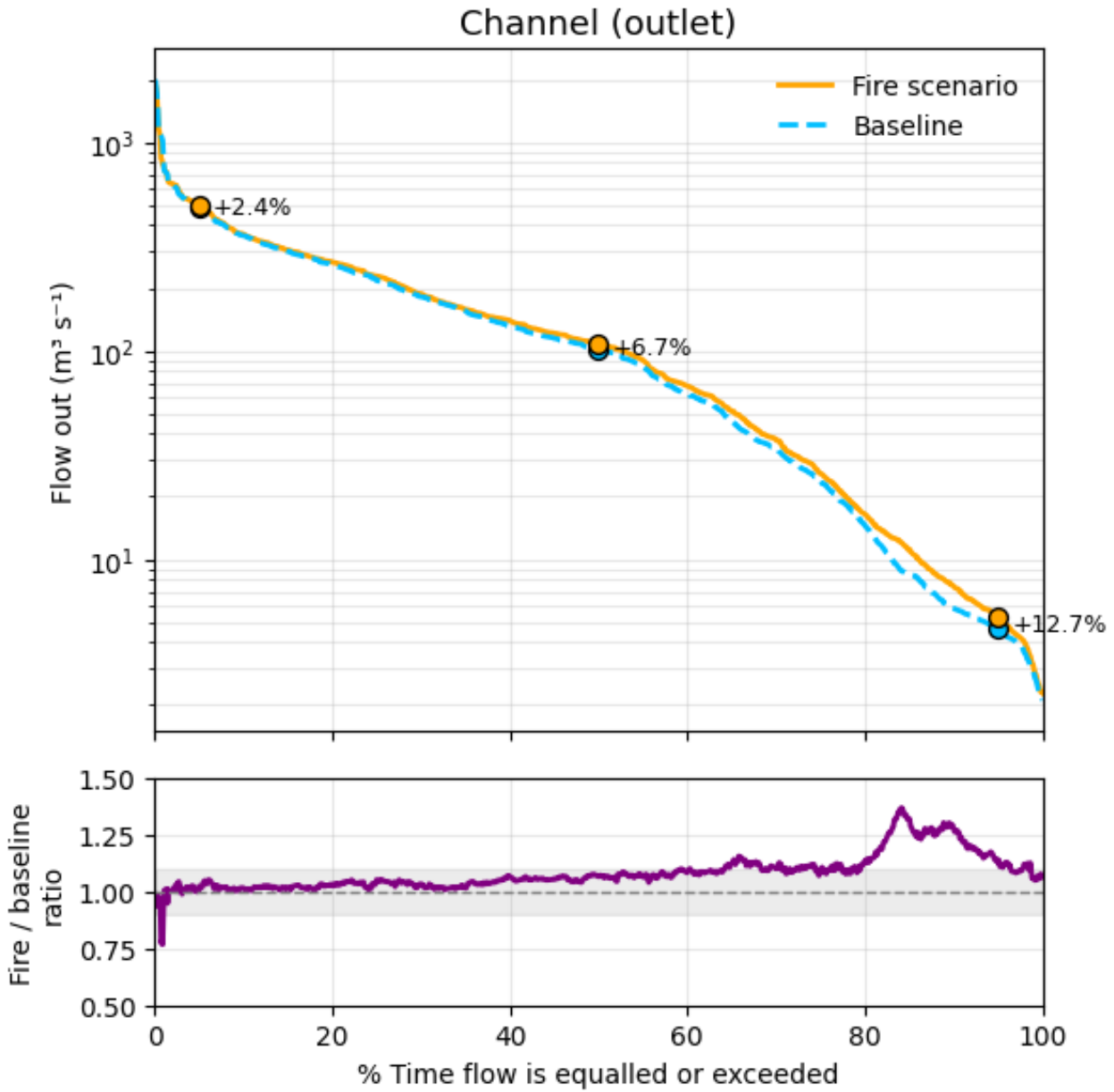
Questions?

- fkordrostami@ucdavis.edu

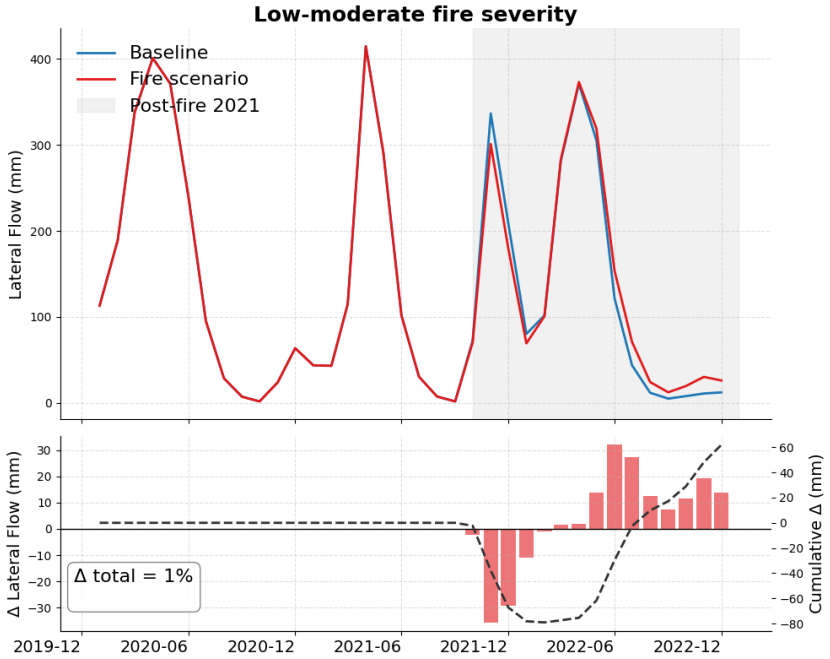
Basin outflow

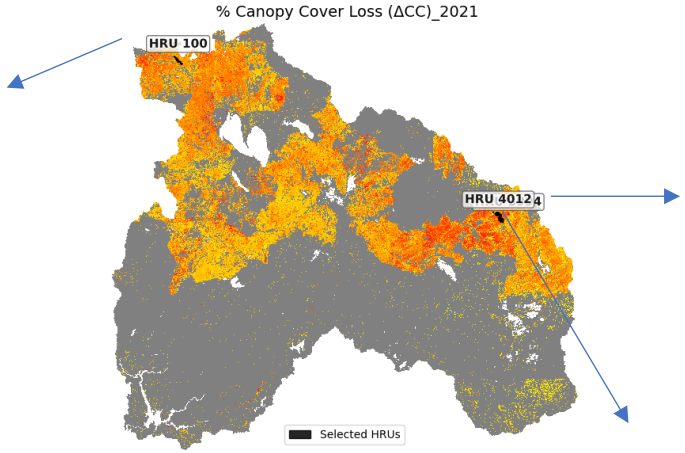
- Mean %Δ: 8.90 %

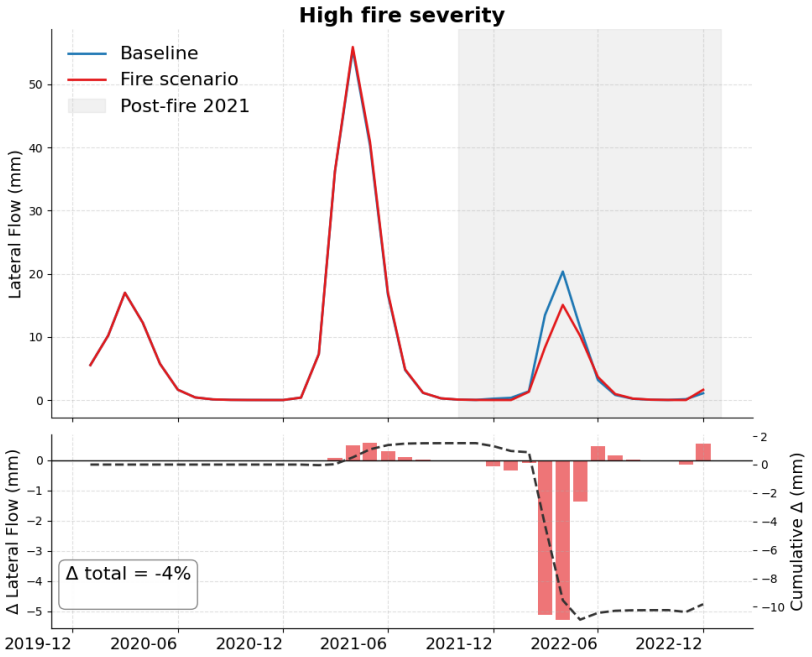
- The effect of wildfire on peak flows, and low flows was most evident in headwater catchments and was dampened at the outlet of basins (Wampler et al., 2023)

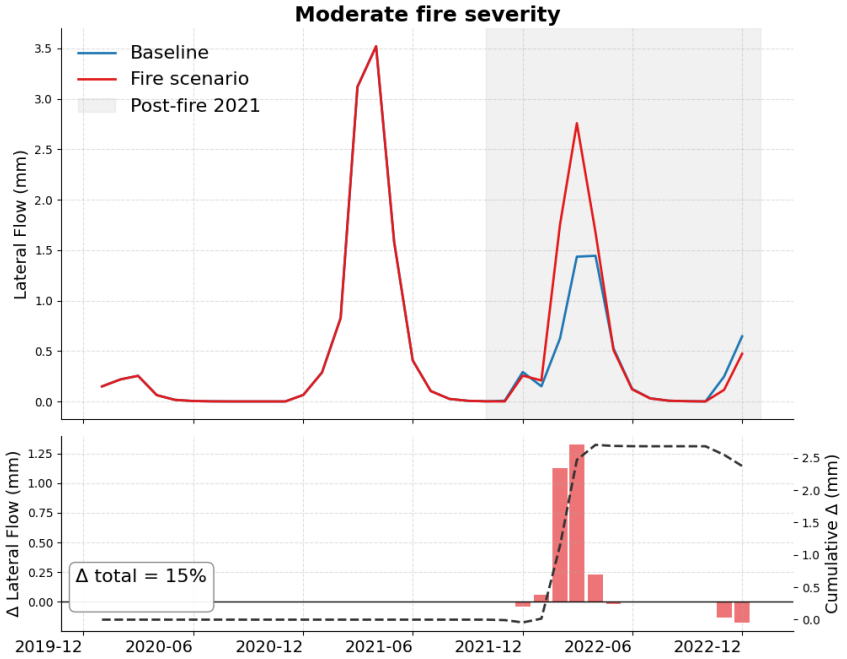


Lateral flow

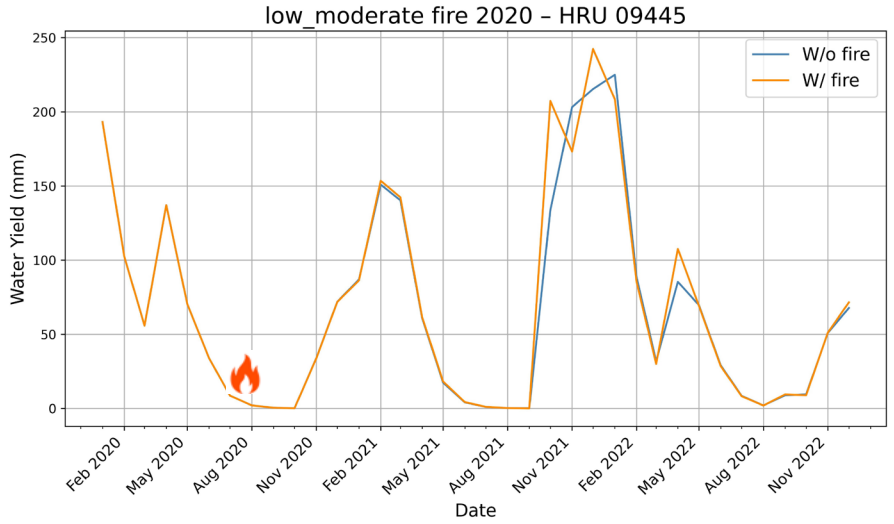


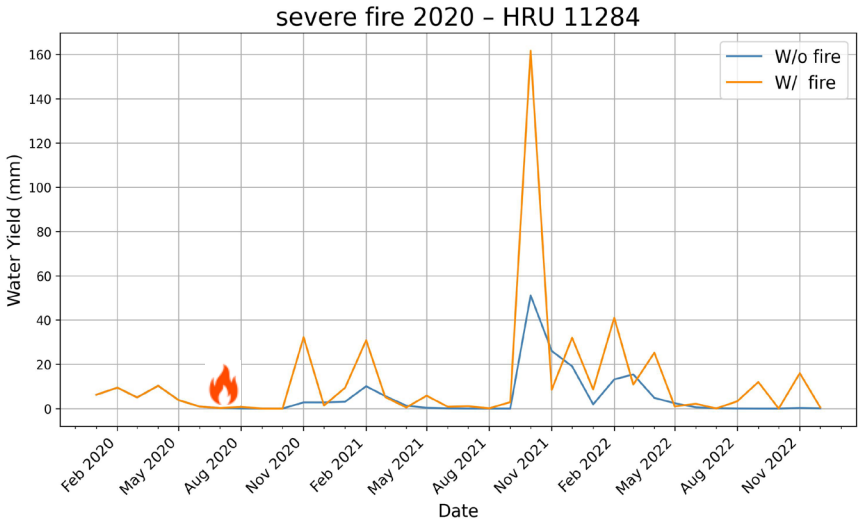


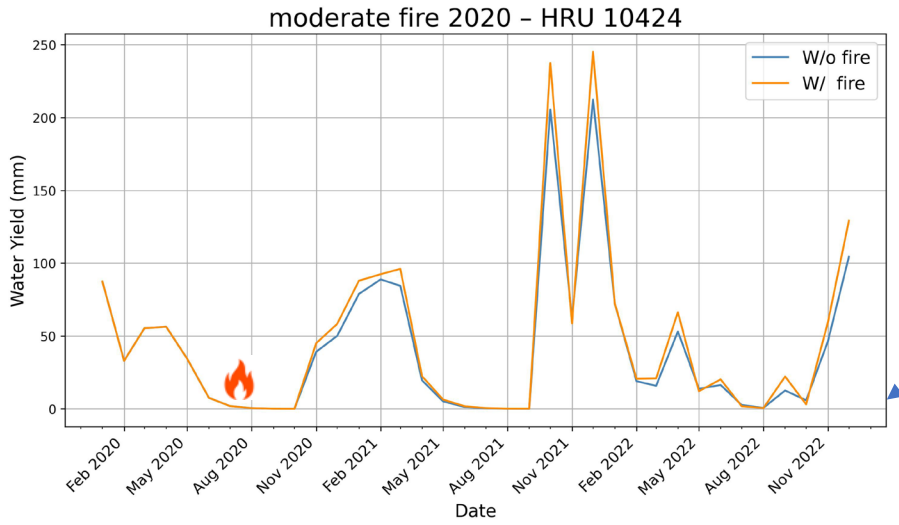


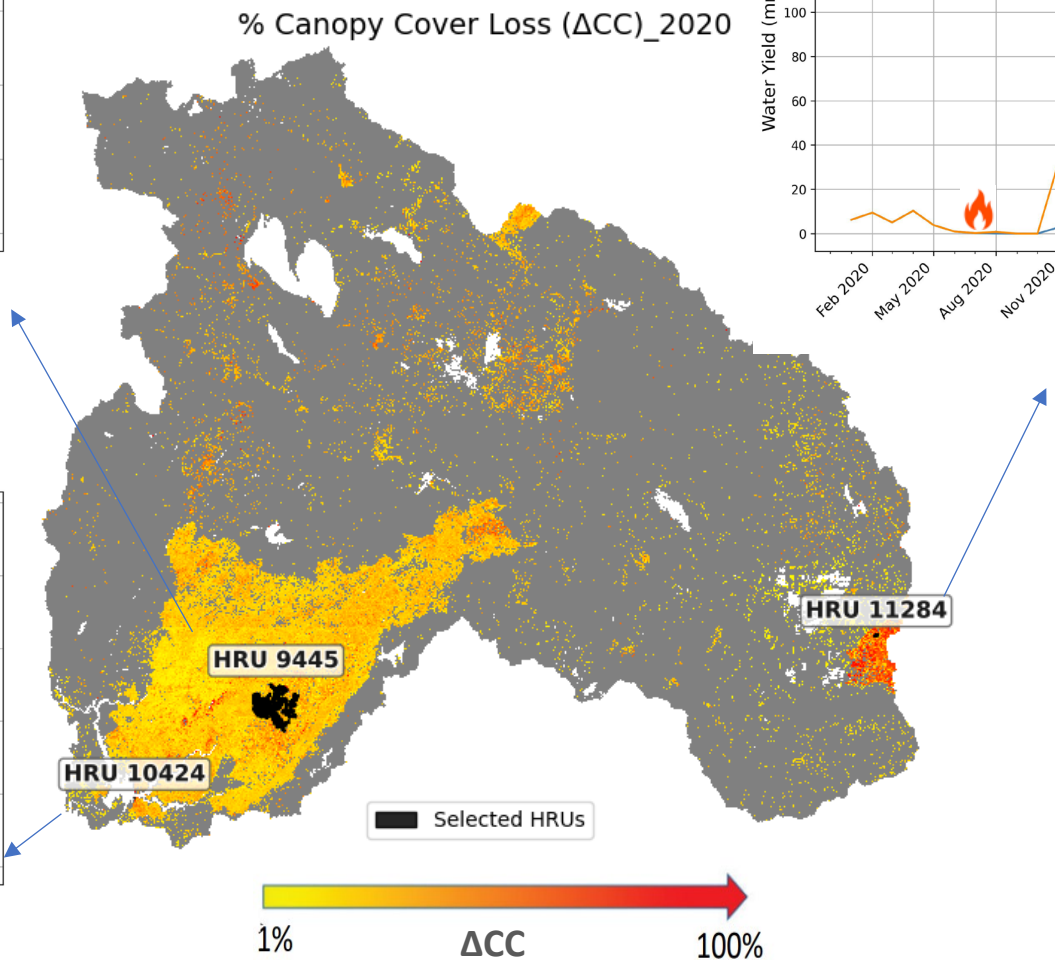


Water yield

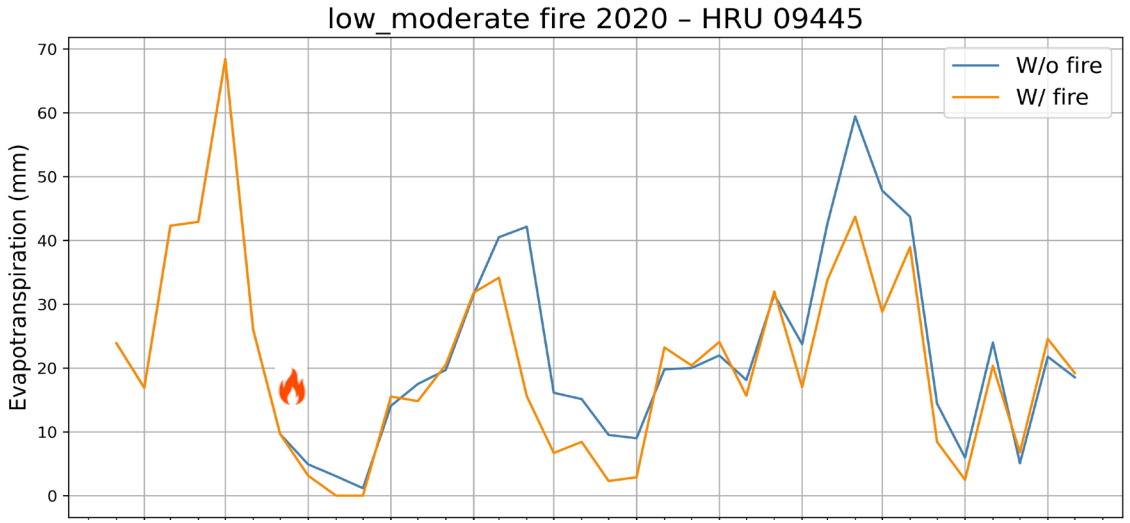

low_moderate fire 2020 – HRU 09445
W/o fire
W/ fire
Water Yield (mm)
Date
Feb 2020
May 2020
Aug 2020
Nov 2020
Feb 2021
May 2021
Aug 2021
Nov 2021
Feb 2022
May 2022
Aug 2022
Nov 2022

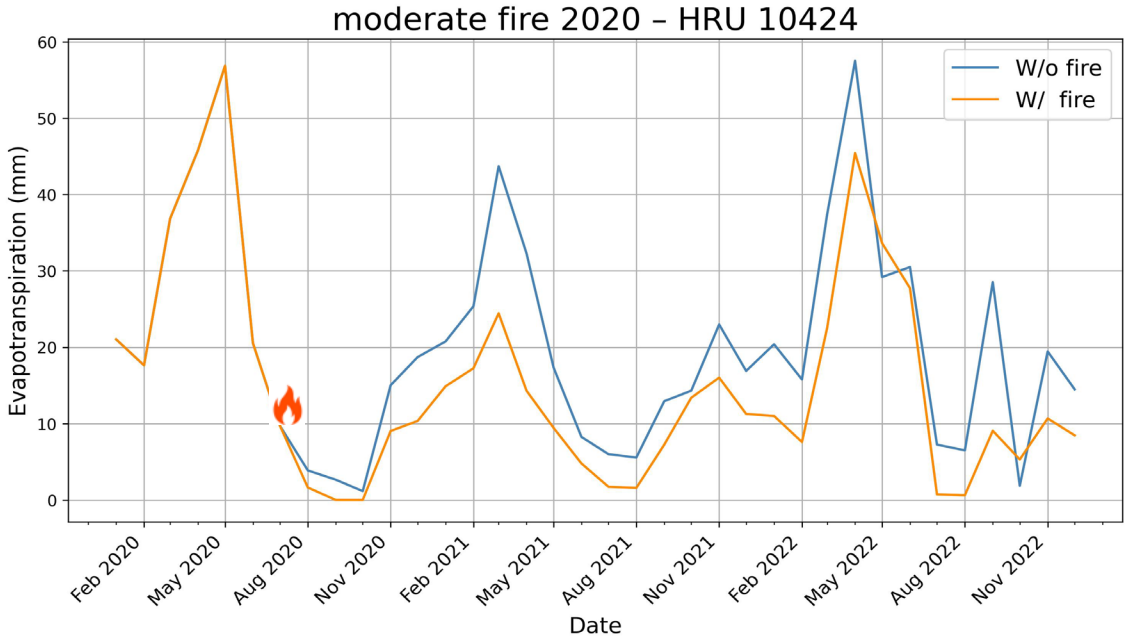

severe fire 2020 – HRU 11284
W/o fire
W/ fire
Water Yield (mm)
Date

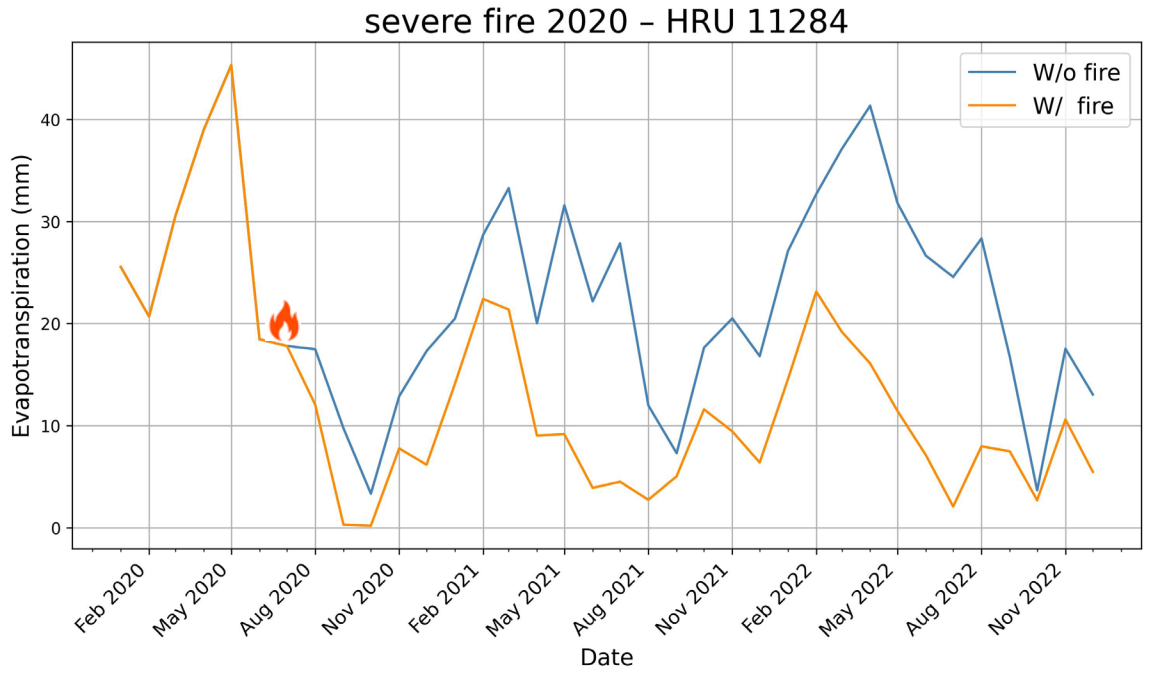

moderate fire 2020 – HRU 10424
W/o fire
W/ fire
Water Yield (mm)
Date


% Canopy Cover Loss (ΔCC)_2020
HRU 9445
HRU 10424
HRU 11284
Selected HRUs
1%
ΔCC
100%

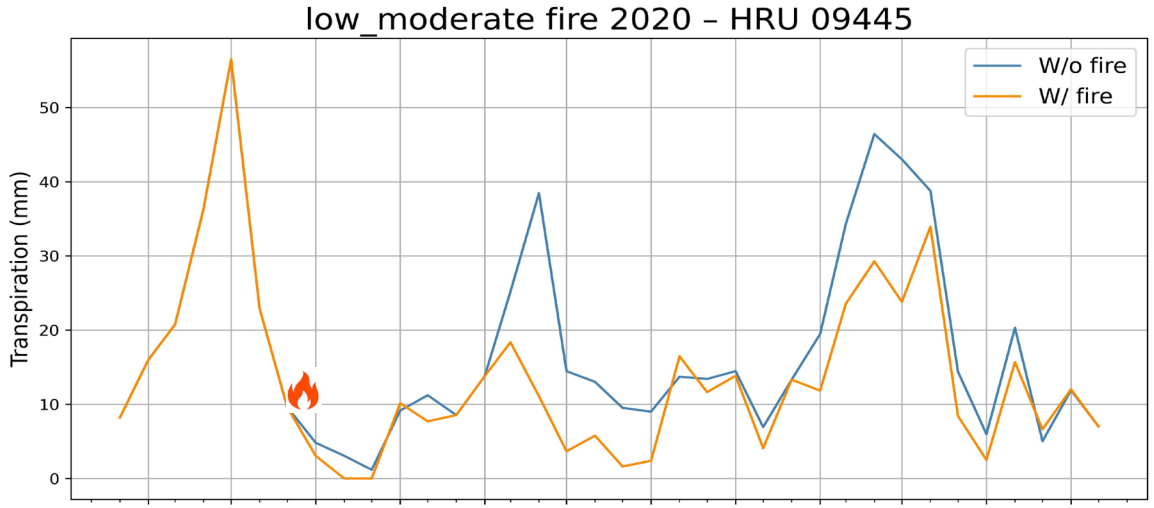
Evapotranspiration

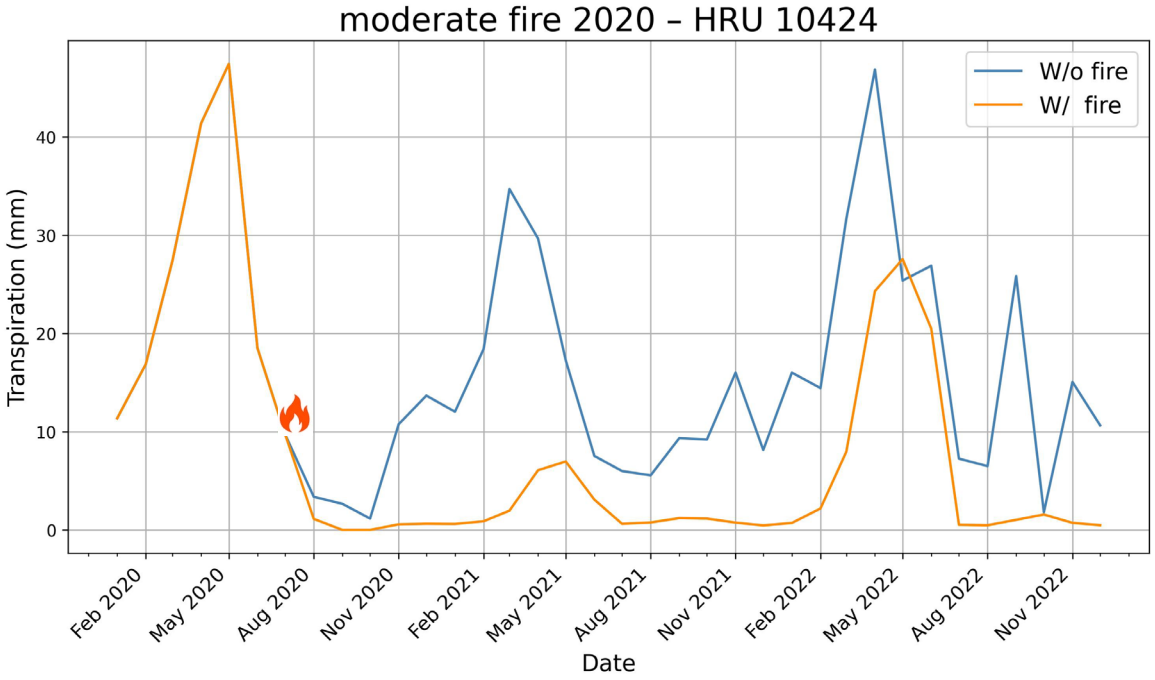


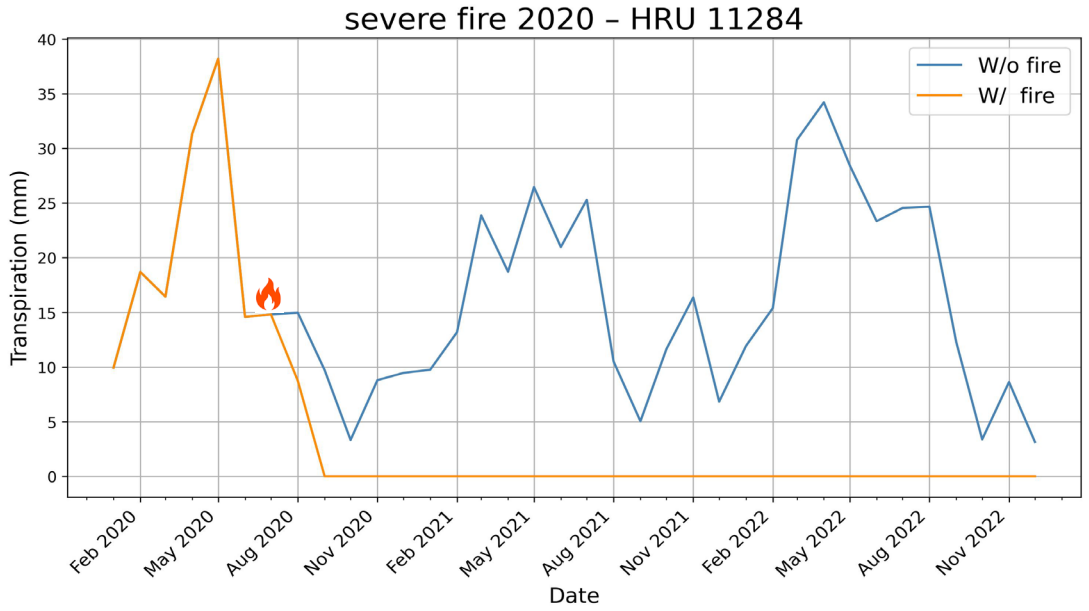




Transpiration







Justification for wb divergent before fire event in 2021

The shaded region represents the post-fire simulation period, beginning on the scheduled ignition date (October 1, 2021), when SWAT+ management operations were triggered. Prior to this date, both baseline and fire scenarios were identical.

“Slight pre-ignition divergence in transpiration may reflect indirect carryover from upstream 2020 burn effects included in the fire scenario run.
Although HRU 4012 itself was unaffected by the 2020 fire, basin-level hydrologic feedbacks (e.g., altered groundwater recharge or lateral flow routing) could have slightly modified local soil moisture conditions prior to the 2021 ignition.”

1. How to add the second DTL;

“Scen_fire21”

scen_lu.dtl - Notepad

File Edit Format View Help

```
scen_fire_dtl Generated by f.kordrostami on 02.06.2025
1

        DTBL_NAME          CONDS        ALTS        ACTS
  scen_fire20               2            1           4119
 COND_VAR      OBJ       OBJ_NUMB   LIM_VAR      LIM_OP  LIM_CONST  ALT1
  jday         null      0          null         -       233        =
  year_cal     null      0          null         -       2020       =
 ACT_TYP       OBJ       OBJ_NUM    ACT_NAME      ACT_OPTION CONST  CONST2 FILE_POINTER  OUT1
  lu_change    hru       23       rngb_burn1_chg   null       0      0      rngb_burn1_lum   y
  lu_change    hru       24       rngb_burn1_chg   null       0      0      rngb_burn1_lum   y
  lu_change    hru       25       rngb_burn1_chg   null       0      0      rngb_burn1_lum   y
  lu_change    hru       102      frse_burn1_chg   null       0      0      frse_burn1_lum   y
```

scen_dtl.upd - Notepad

File Edit Format View Help

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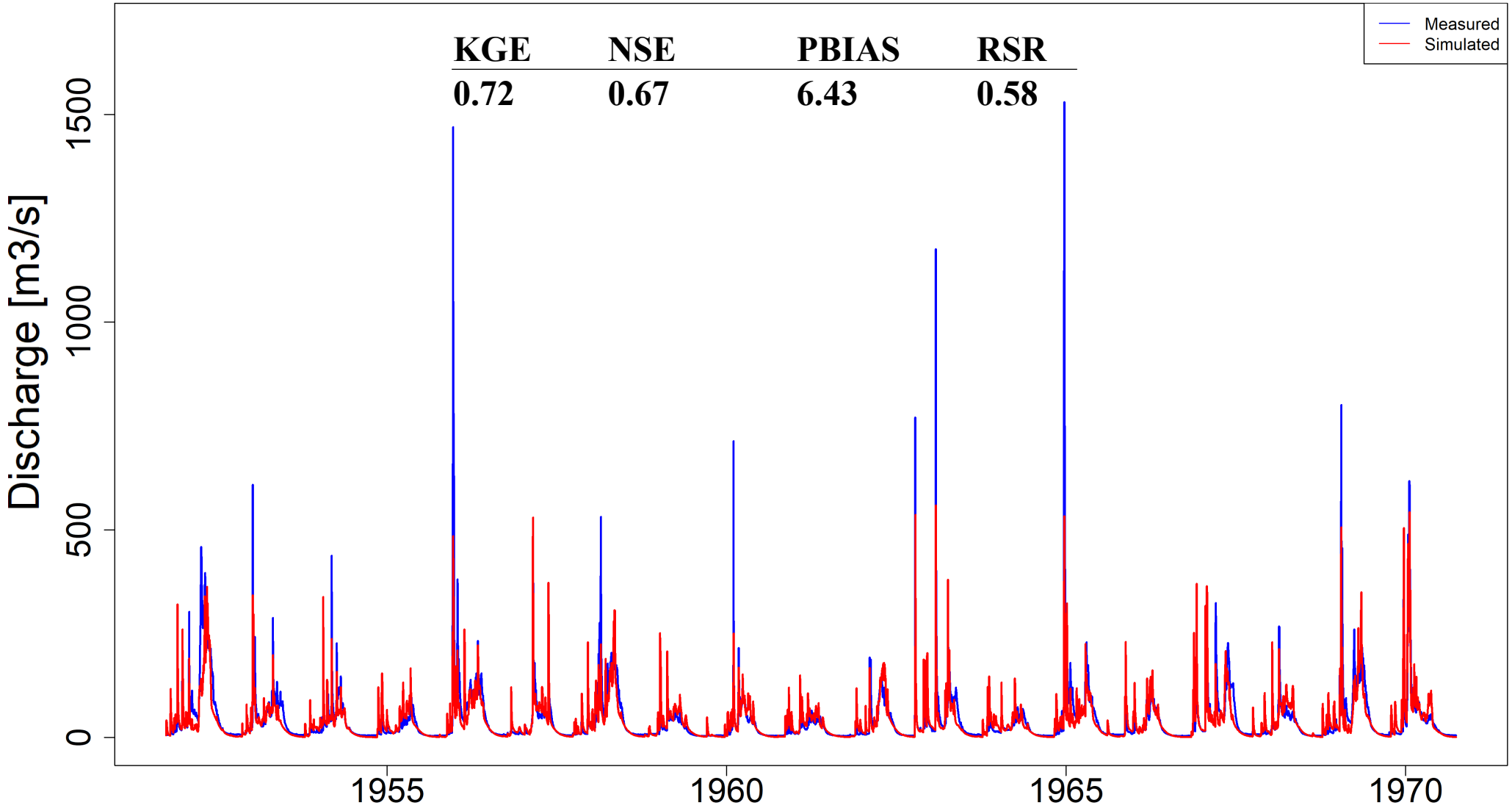
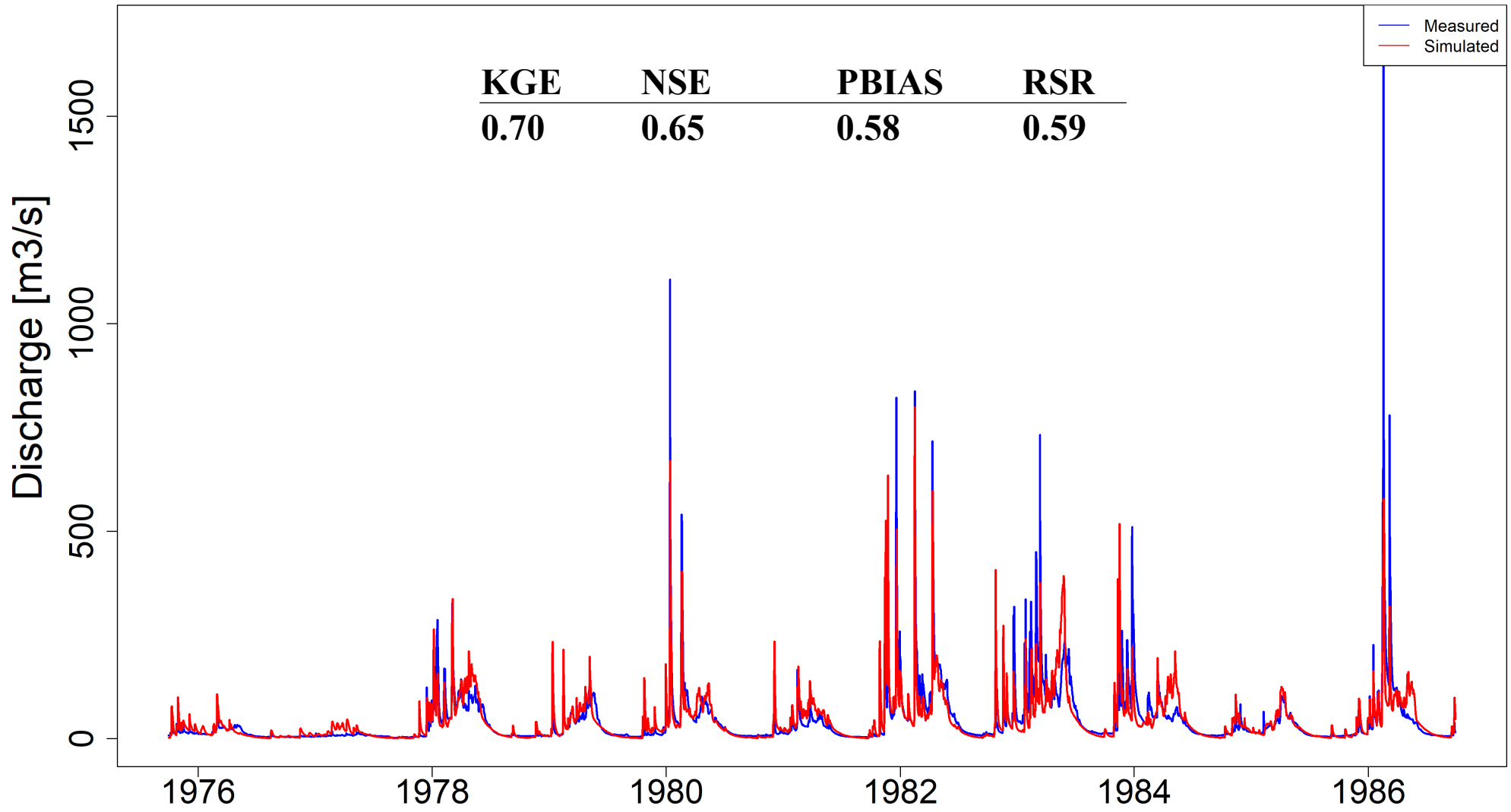
scenario dtl
1
MAX_HITS    NAME                    DTABLE
  1         frsd_burn1_chg        scen_fire20
```

Result of calibration (channel 19)



Result of validation (channel 19)



SWAT+ ,MODIS, OpenET(evergreen forest)