First Friday All Climate Change Talks (FFACCTS, Raleigh 9/1/2017)

Proof that some, but not all wildland fires increase surface water supplies

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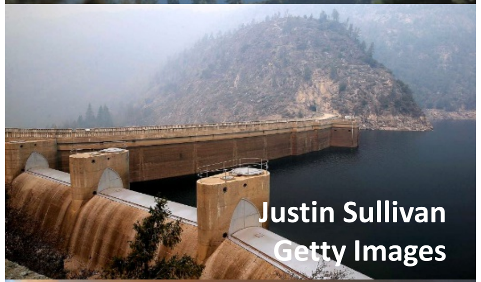
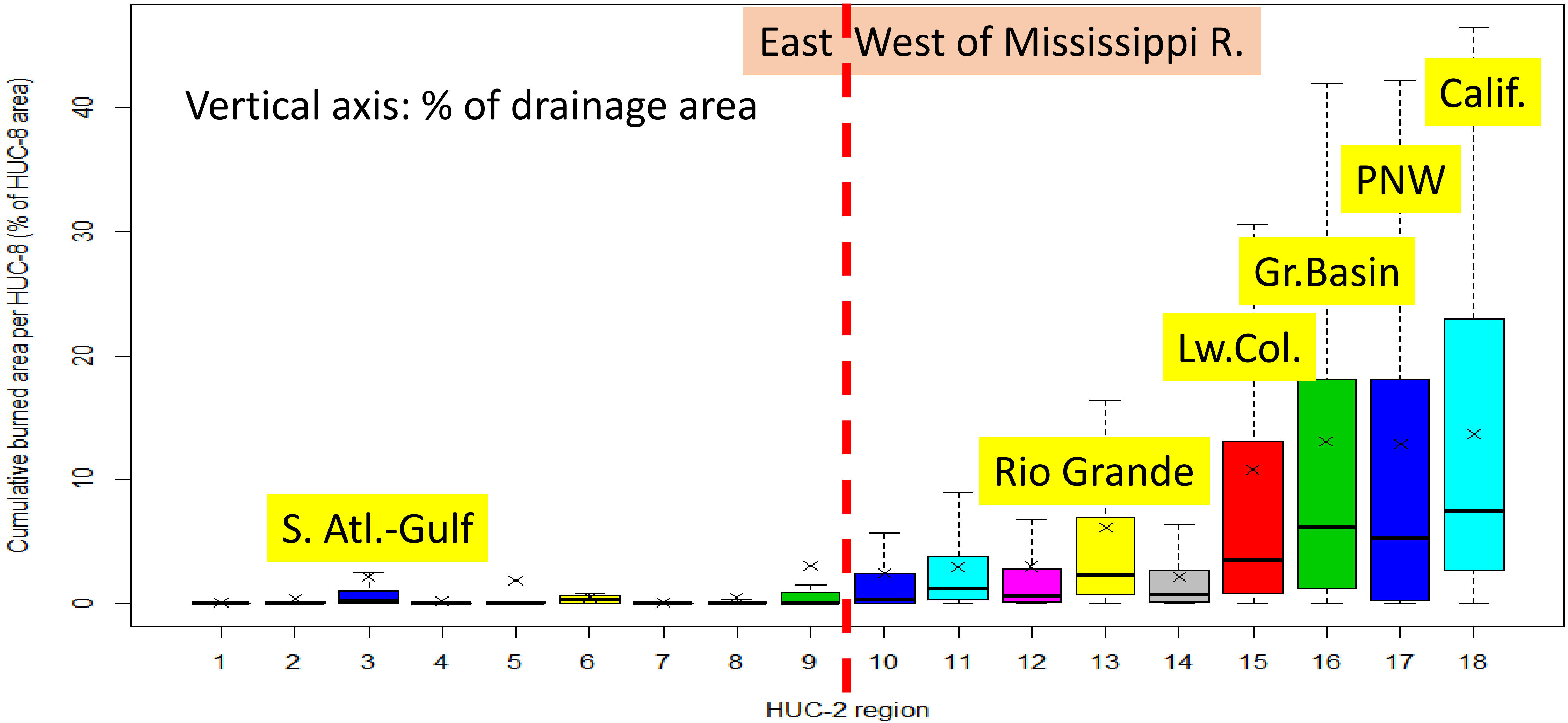
Wildland fire

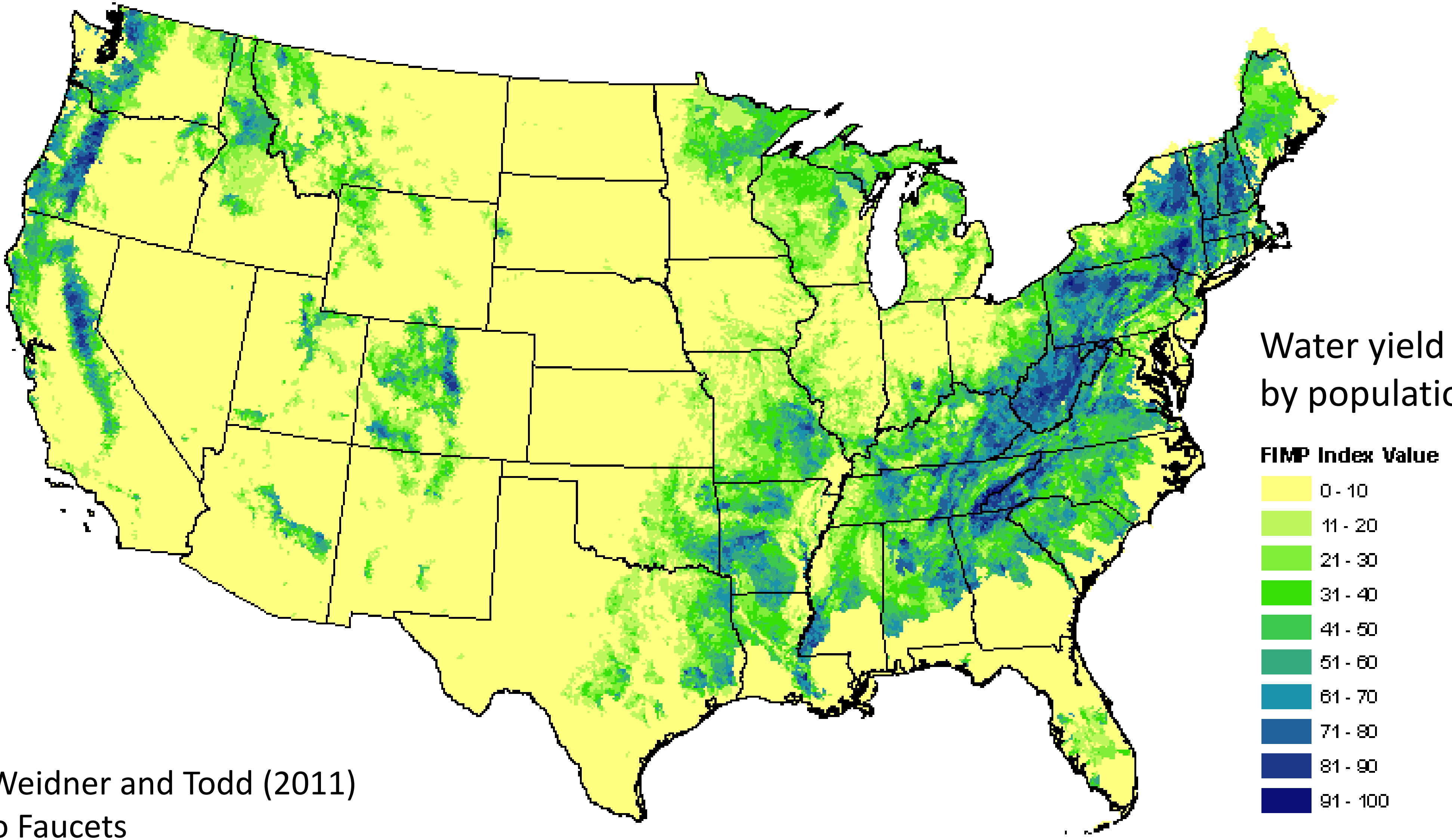
- Wildland fire = Wildfire OR prescribed fire
- Wildfire = Natural disturbance, enhances natural succession of forests, stimulates growth and biodiversity
- Prescribed fire = Low intensity, smaller
- Environmental effects (air and water contamination, landslides)
- Increased risk for water resources due to:
    - Longer wildfire seasons
    - Increasing annual area burned
    - More severe fires associated with forest densification
    - Persistent drought
    - Climate change
    - Increasingly populated wildland-urban interface



Cumulative burned area 1984-2012



Forest importance to surface drinking water (FIMP)

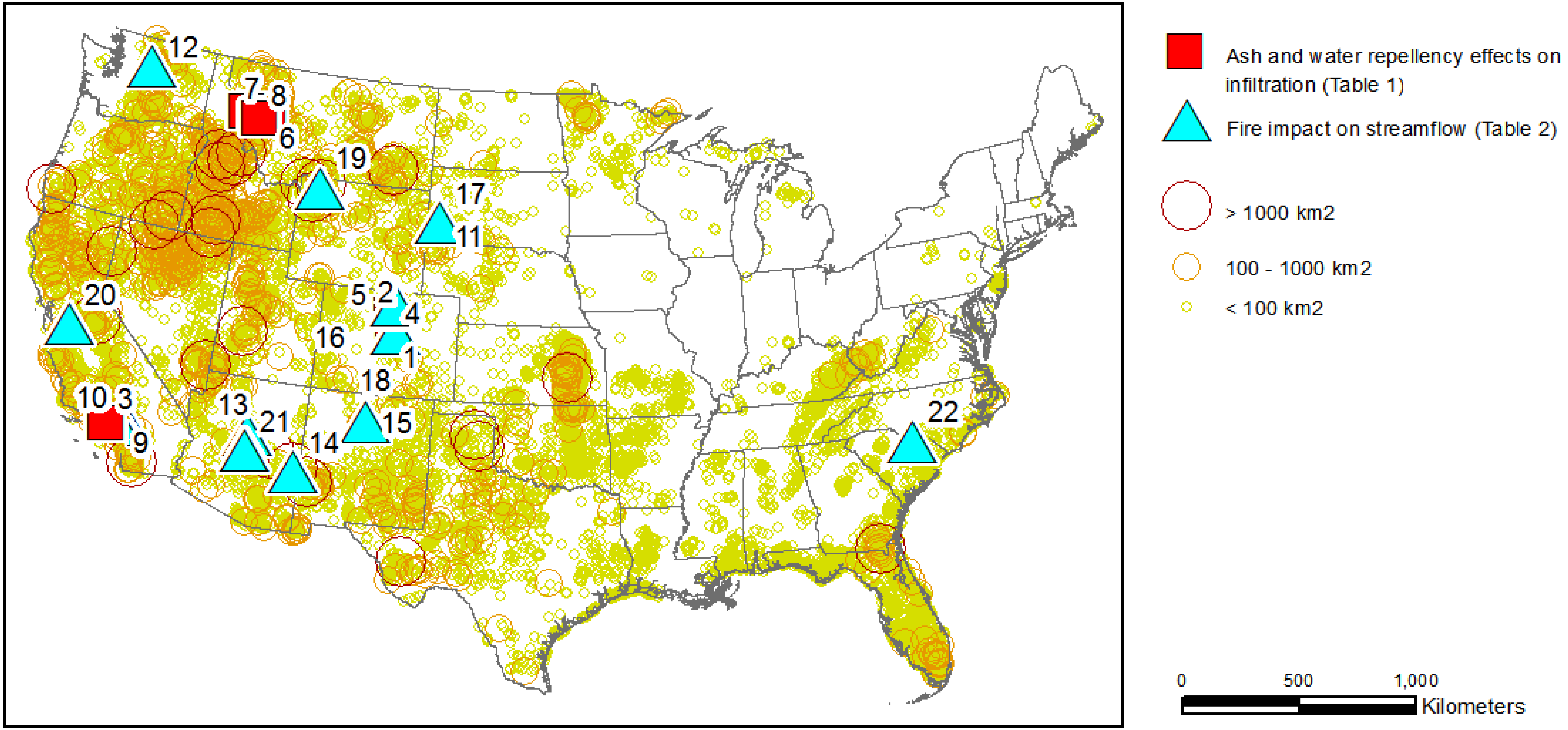


Water yield weighted by population served

Figure credit: Weidner and Todd (2011)
USFS Forests to Faucets

Wildland fire impacts on water supplies

- 50% of freshwater resources originate on forest lands
- Fire impacts last up to decades after disturbance, effects transmitted downstream
- How to distinguish streamflow changes caused by fire from those caused by variations in climate?
- National Cohesive Wildland Fire Management Strategy (implementation of 2009 Federal Land Assistance Management and Enhancement Act)
  - Assist decision making with regard to prescribed fuel treatments
  - Enhance resilience of forest watersheds
  - Maximize municipal water supplies
- Objective: CONUS assessment of wildland fire impacts (wildfire and prescribed fire) on watershed annual streamflow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20
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10 3
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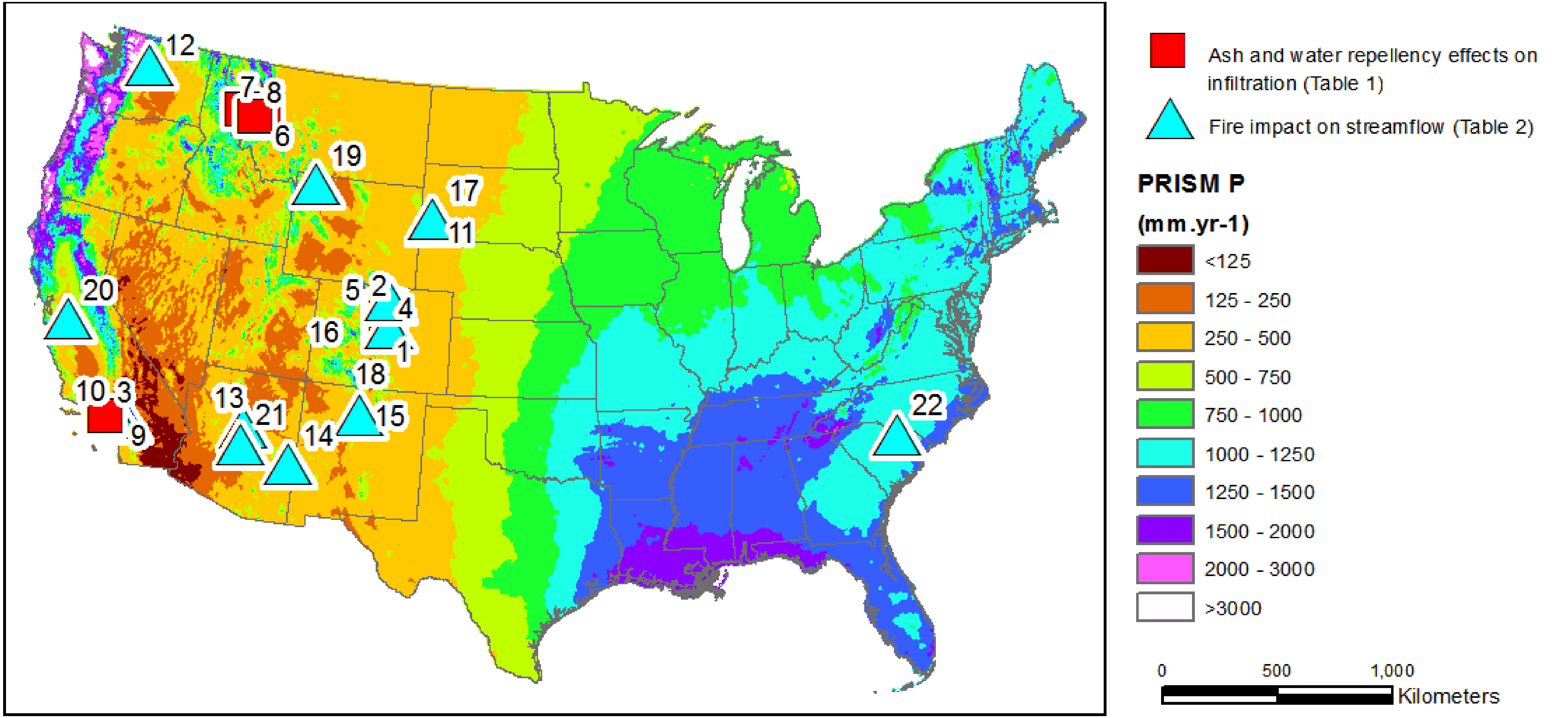
22
Ash and water repellency effects on infiltration (Table 1)
Fire impact on streamflow (Table 2)
> 1000 km2
100 - 1000 km2
< 100 km2
0
500
1,000
Kilometers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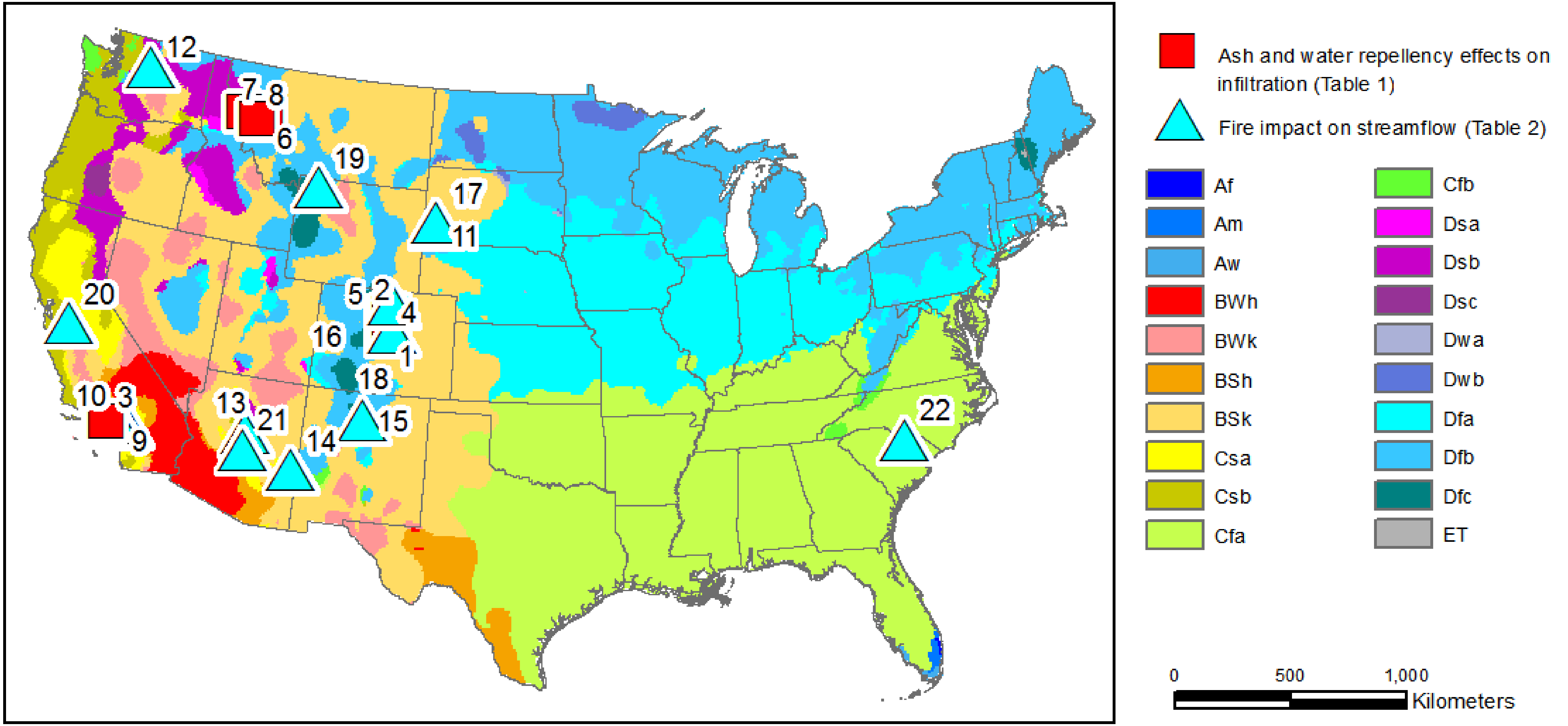
Ash and water repellency effects on infiltration (Table 1)
Fire impact on streamflow (Table 2)
PRISM P
(mm.yr-1)
<125
125 - 250
250 - 500
500 - 750
750 - 1000
1000 - 1250
1250 - 1500
1500 - 2000
2000 - 3000
>3000
0
500
1,000
Kilometers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Ash and water repellency effects on infiltration (Table 1)
Fire impact on streamflow (Table 2)
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BWh
BWk
BSh
BSk
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Cfb
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Dsb
Dsc
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Dwb
Dfa
Dfb
Dfc
ET
0
500
1,000
Kilometers

Project background

- 50% of freshwater resources originate on forest lands
- Fire impacts last up to decades after disturbance, effects transmitted downstream
- How to distinguish streamflow changes caused by fire from those caused by variations in climate?
- National Cohesive Wildland Fire Management Strategy (implementation of 2009 Federal Land Assistance Management and Enhancement Act)
    - Assist decision making with regard to prescribed fuel treatments
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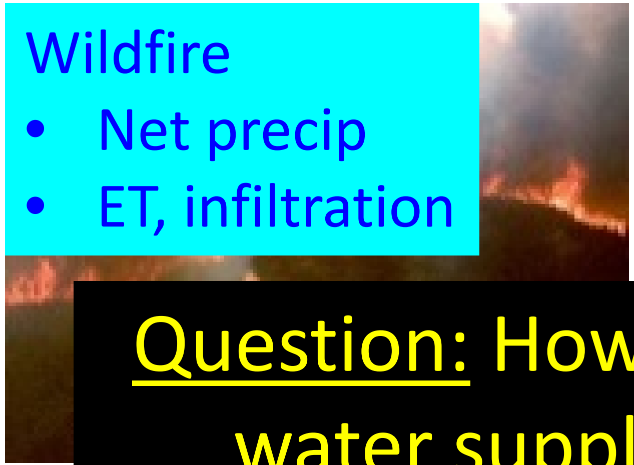
- Objective: CONUS assessment of wildland fire impacts (wildfire and prescribed fire) on watershed annual streamflow

Causes of hydrologic disturbance in forests

Wildfire
- Net precip
- ET, infiltration



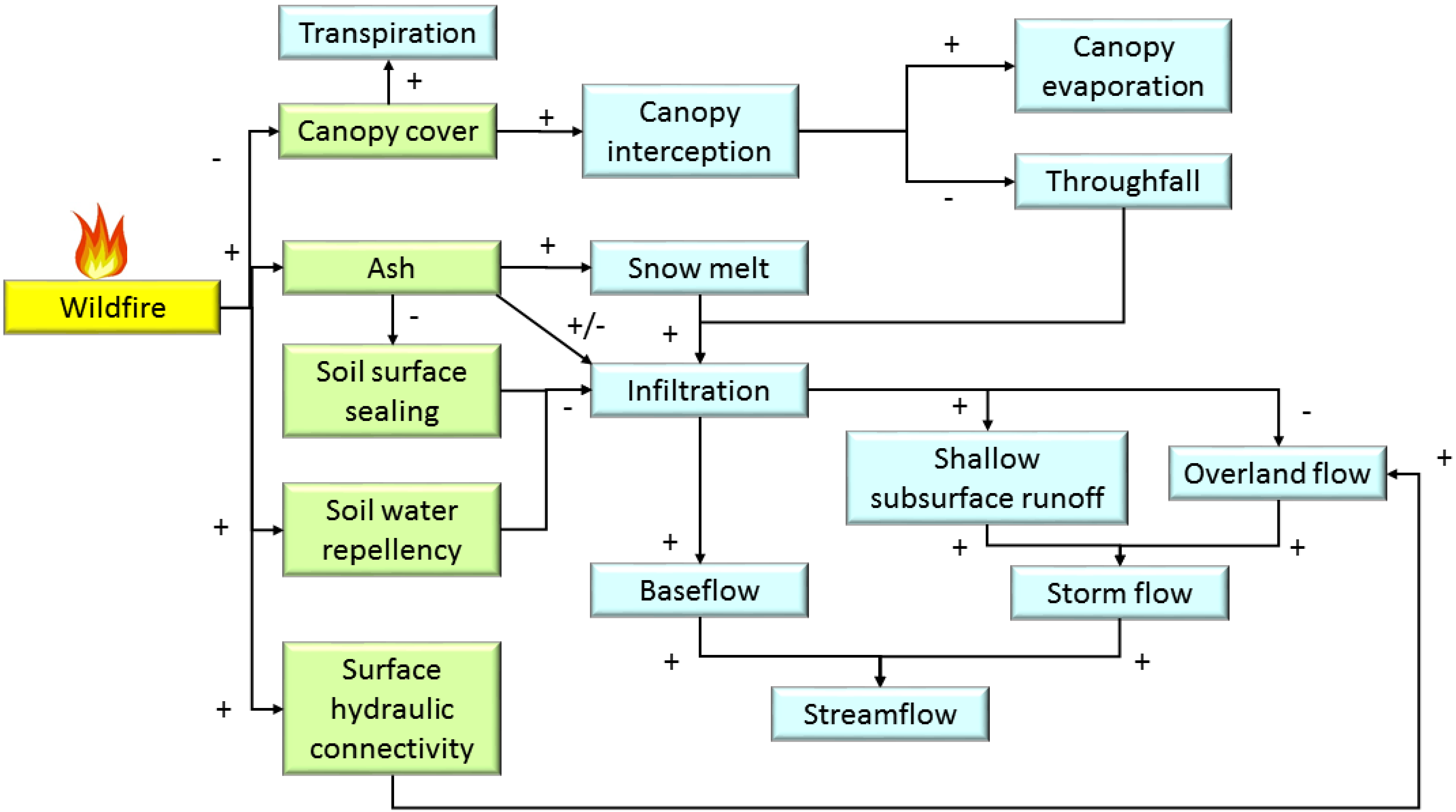
Human activity:
- Withdrawal
- River dams
- Thermal pollution

<u>Question:</u> How to distinguish wildland fire impacts on water supplies from climate variability impacts?

Climate:
- Drought
- Climate oscillations

Biological:
- Invasive species

Natural disasters:
- Volcanic eruption
- Erosion and mass movement

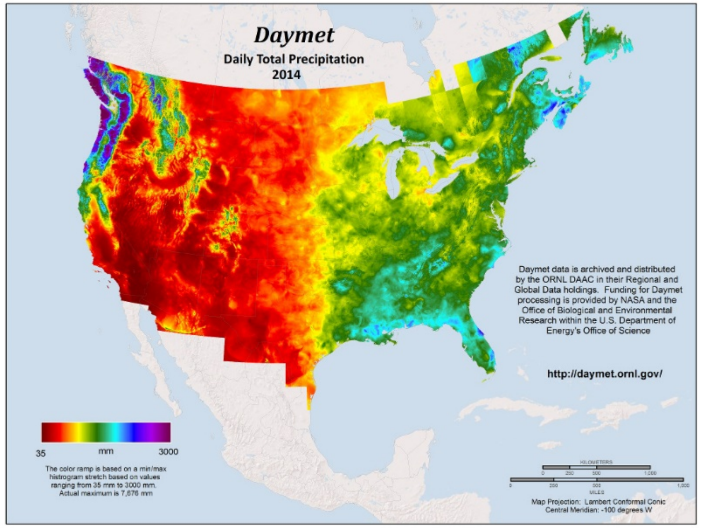

Transpiration
Canopy cover
Canopy interception
Canopy evaporation
Throughfall
Wildfire
Ash
Snow melt
Soil surface sealing
Infiltration
Soil water repellency
Shallow subsurface runoff
Overland flow
Baseflow
Storm flow
Surface hydraulic connectivity
Streamflow
+
-
+/-

Geospatial datasets

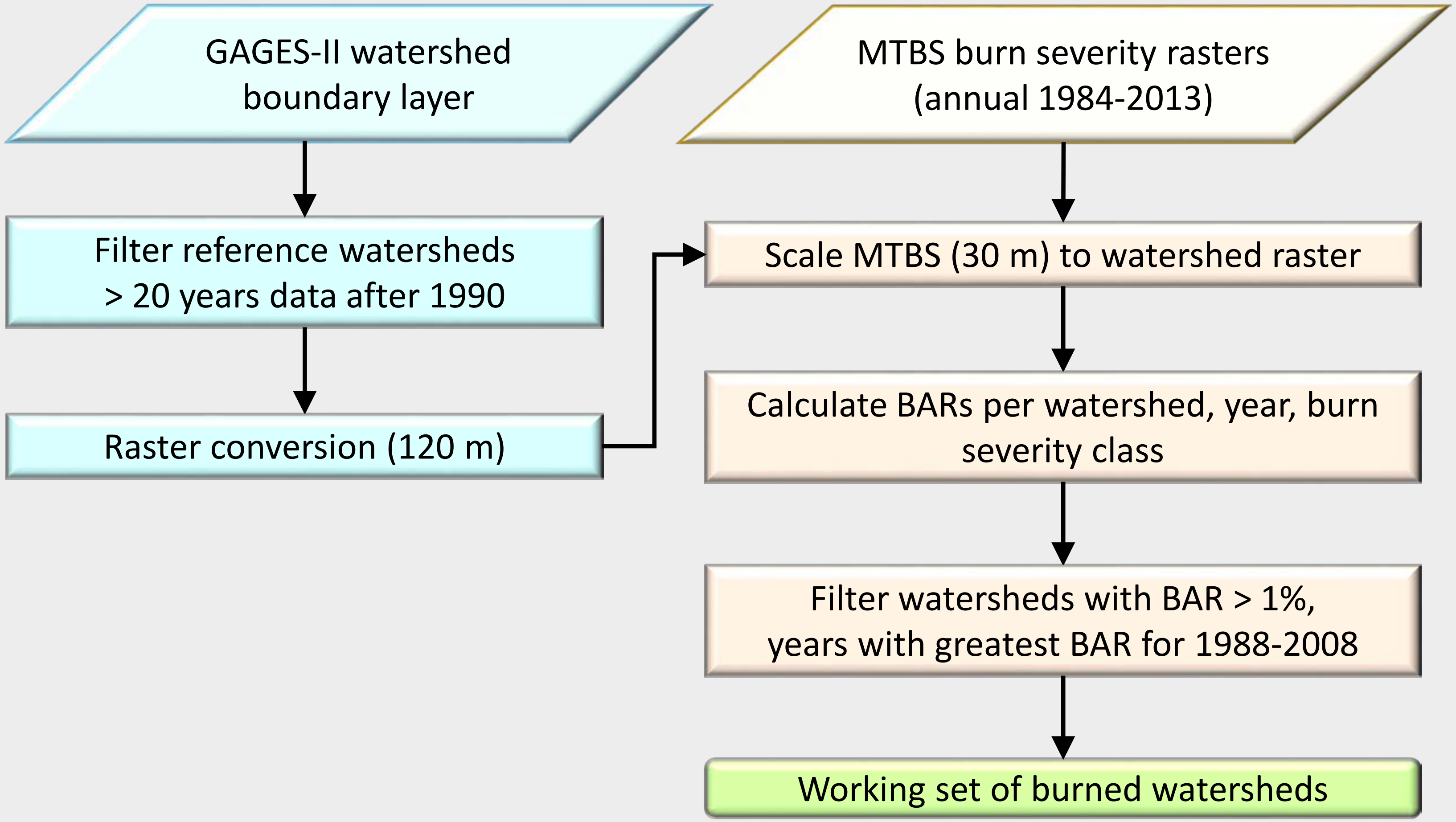
Temporal resolution

	Spatial resolution	Time resolution	Period
MTBS Burned area and burn severity	30 x 30 m	Annual	1984-2013
PRISM (Hamon PET)	4 x 4 km	Monthly	1899-2012
MODIS NDVI	236 x 236 m	Biweekly	2003-
Daymet climate	1 x 1 km	Daily	1980-
USGS GAGES-II streamflow	Point locations	Daily	1900-

Monitoring Trends in Burn Severity

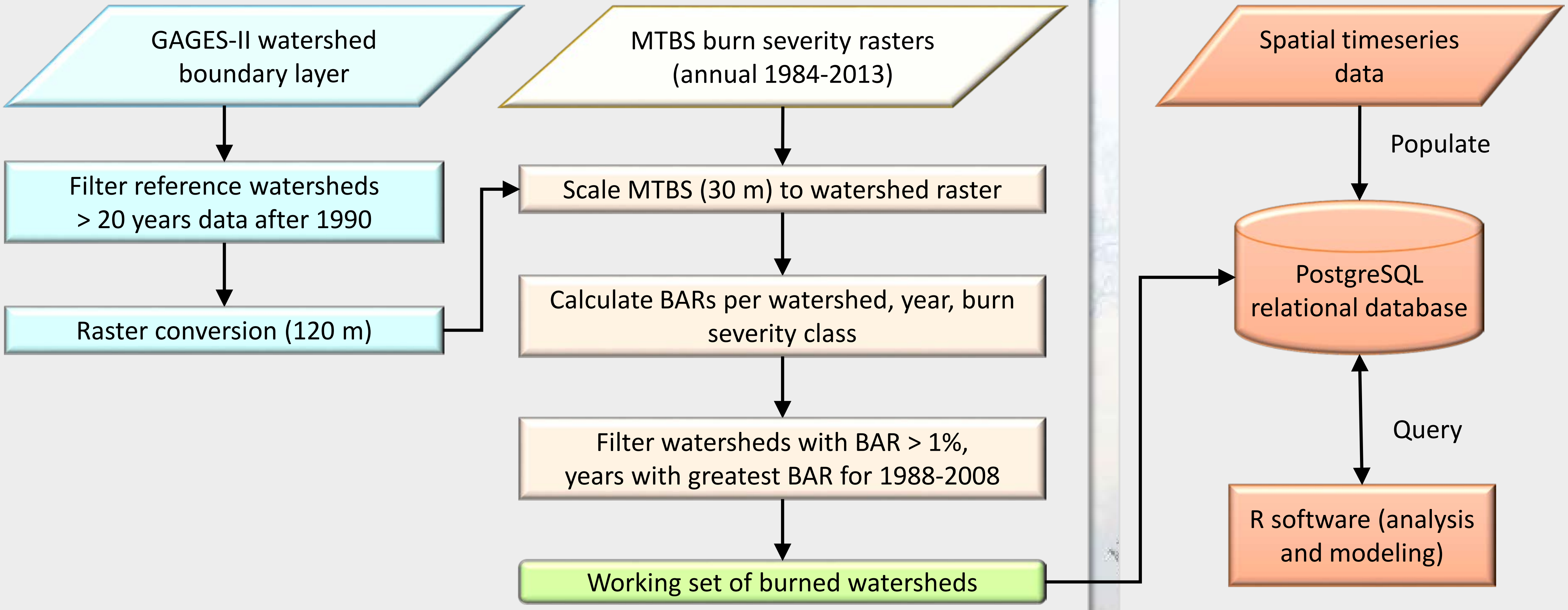


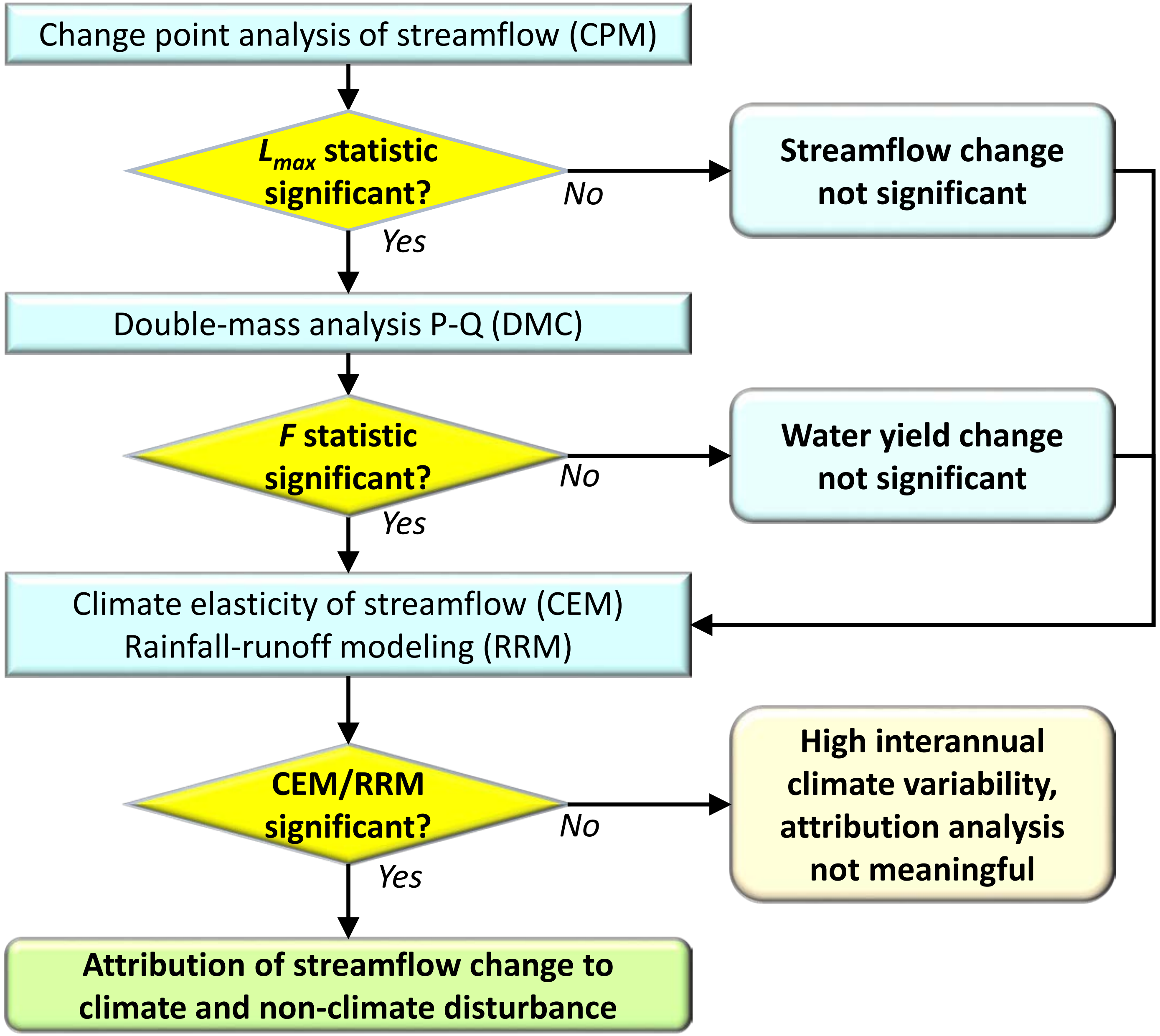
Selection of burned watersheds

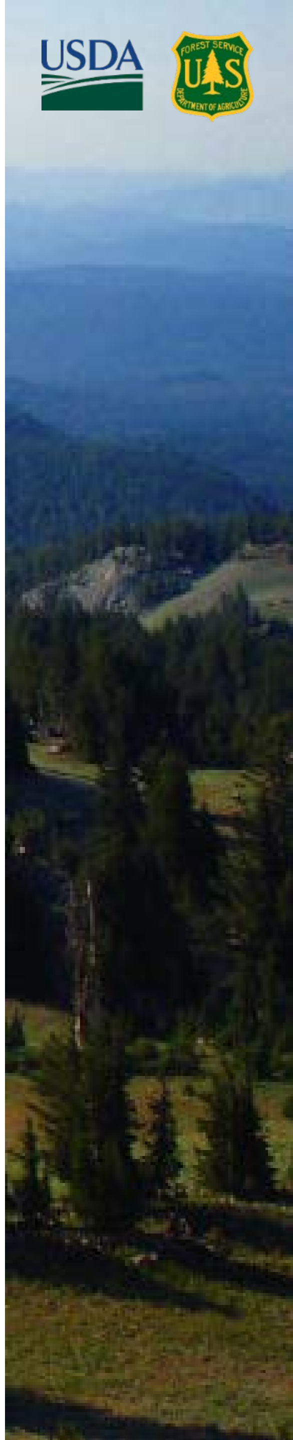


Selection of burned watersheds

Data Analysis

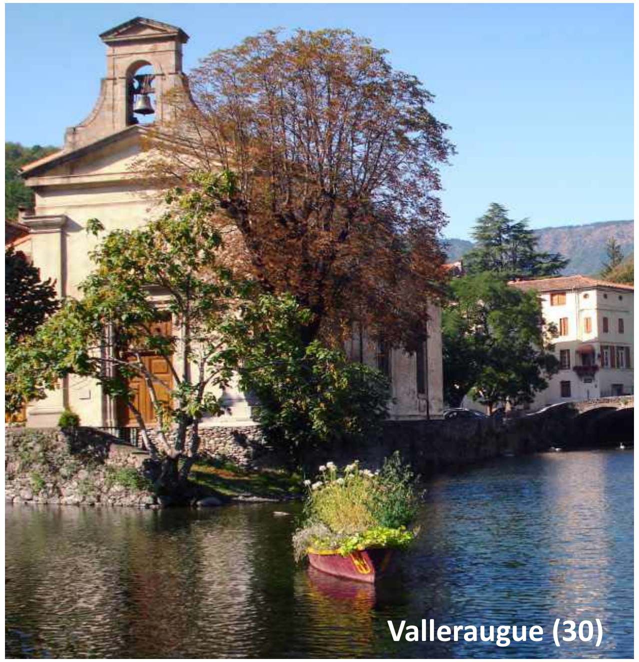



Change point analysis of streamflow (CPM)
L_{max} statistic significant?
No
Streamflow change not significant
Yes
Double-mass analysis P-Q (DMC)
F statistic significant?
No
Water yield change not significant
Yes
Climate elasticity of streamflow (CEM)
Rainfall-runoff modeling (RRM)
CEM/RRM significant?
No
High interannual climate variability, attribution analysis not meaningful
Yes
Attribution of streamflow change to climate and non-climate disturbance


USDA

Attribution of 5 year streamflow change

1. Climate elasticity model (CEM) = Predict *dQ* given *d[Climate]*
2. Rainfall runoff/reservoir model (RRM) = Predict *Q* given climate


Valleraugue (30)


Joël Berthonneau, www.trekearth.com

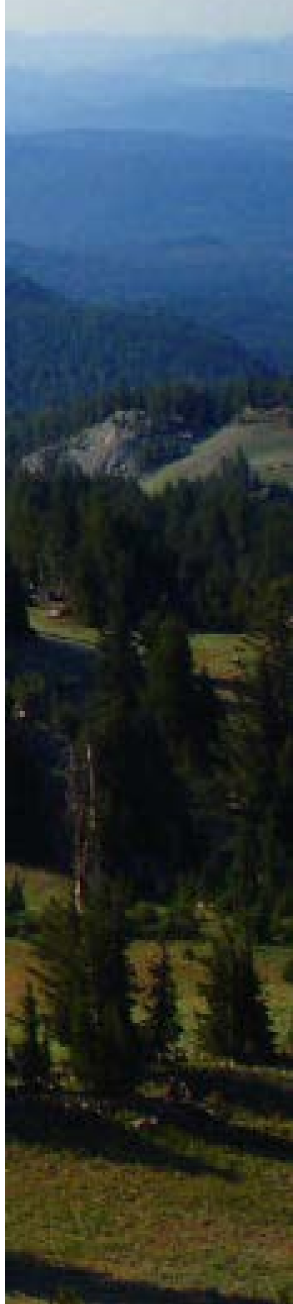
Attribution of 5 year streamflow change

Parsimonious modeling approach

$$\Delta Q = \Delta Q_{climate} + \Delta Q_{disturbance}$$

1. Select best CEM and RRM (Bayesian Information Criterion)
2. Predict $\Delta Q_{climate}$ for post-fire period
3. $\Delta Q_{disturbance} = \Delta Q - \Delta Q_{climate}$

Hallema et al., 2016a. Surface storm flow prediction on hillslopes based on topography and hydrologic connectivity. Ecological Processes, DOI: [10.1186/s13717-016-0057-1](10.1186/s13717-016-0057-1)

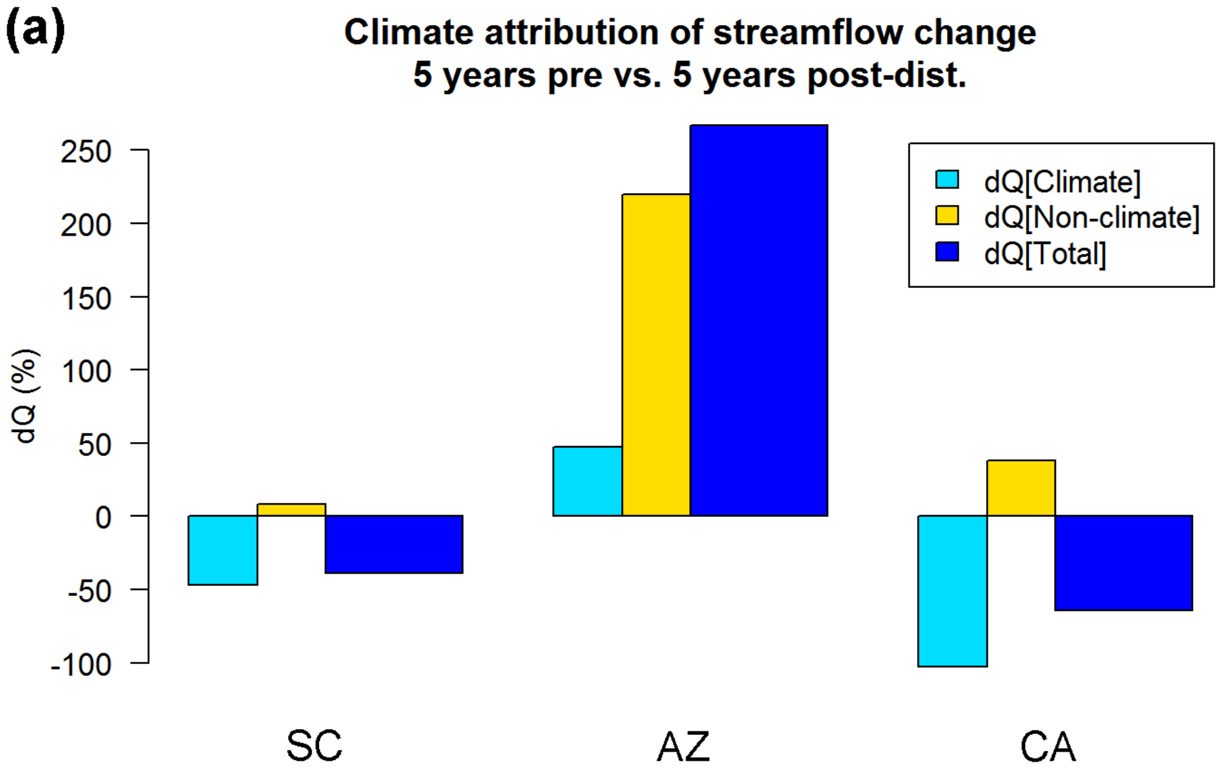


Attribution of 5 year streamflow change

Climate elasticity models (CEMs)			Rainfall-runoff models (RRMs)		
CEM_0:	$\frac{dQ}{\overline{Q}_0} = 0$	(reference)	RRM_0:	$Q = a$	(reference)
CEM_1:	$\frac{dQ}{\overline{Q}_0} = \alpha \frac{dP}{\overline{P}_0}$		RRM_1:	$Q = a + bP$	(lin. reservoir)
CEM_2:	$\frac{dQ}{\overline{Q}_0} = \alpha \frac{dP}{\overline{P}_0} + \beta \frac{dPET}{\overline{PET}_0}$		RRM_2:	$Q = a\, e^{(bP)}$	(nonlinear res.)
CEM_3:	$\frac{dQ}{\overline{Q}_0} = \alpha \frac{dP}{\overline{P}_0} + \beta \frac{d\sigma^2_{Pm}}{\sigma^2_{Pm,0}}$		RRM_3:	$Q = a\, e^{(bP\ \sigma^2_{Pm})}$	(nonlinear res.)
CEM_4:	$\frac{dQ}{\overline{Q}_0} = \alpha \frac{d(P - SWE)}{(\overline{P}_0 - \overline{SWE}_0)} + \beta \frac{dSWE}{\overline{SWE}_0}$				

Select best fit

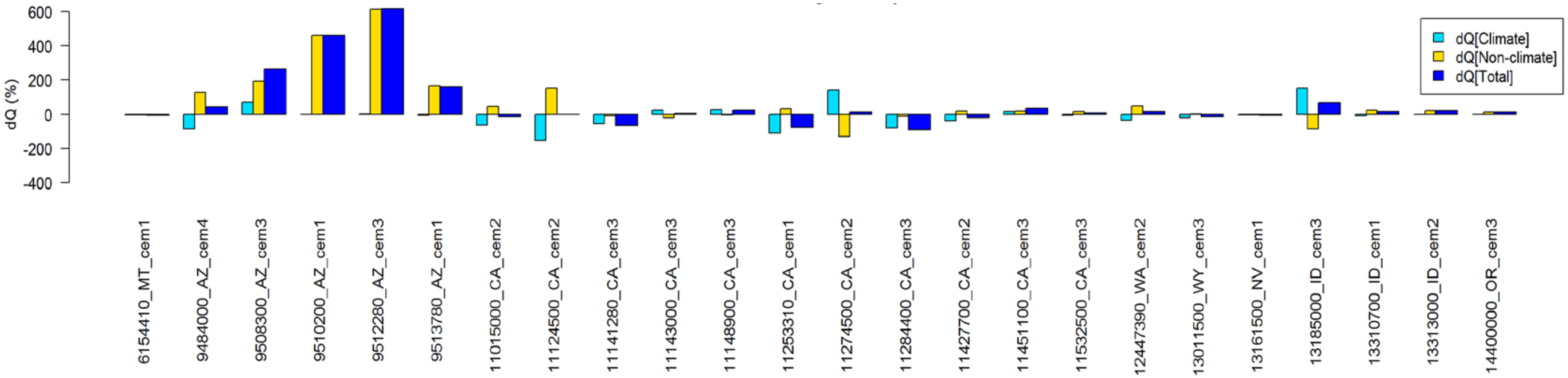
Attribution of 5 year streamflow change



- S. Carolina: Impact of low severity prescribed fires very small
- Arizona: High impact of disturbance
- California: Disturbance effects attenuated by climate trends

Hallema et al., 2016b. Assessment of wildland fire impacts on watershed annual water yield: Analytical framework and case studies in the United States. Ecohydrology, DOI: [10.1002/eco.1794](10.1002/eco.1794)

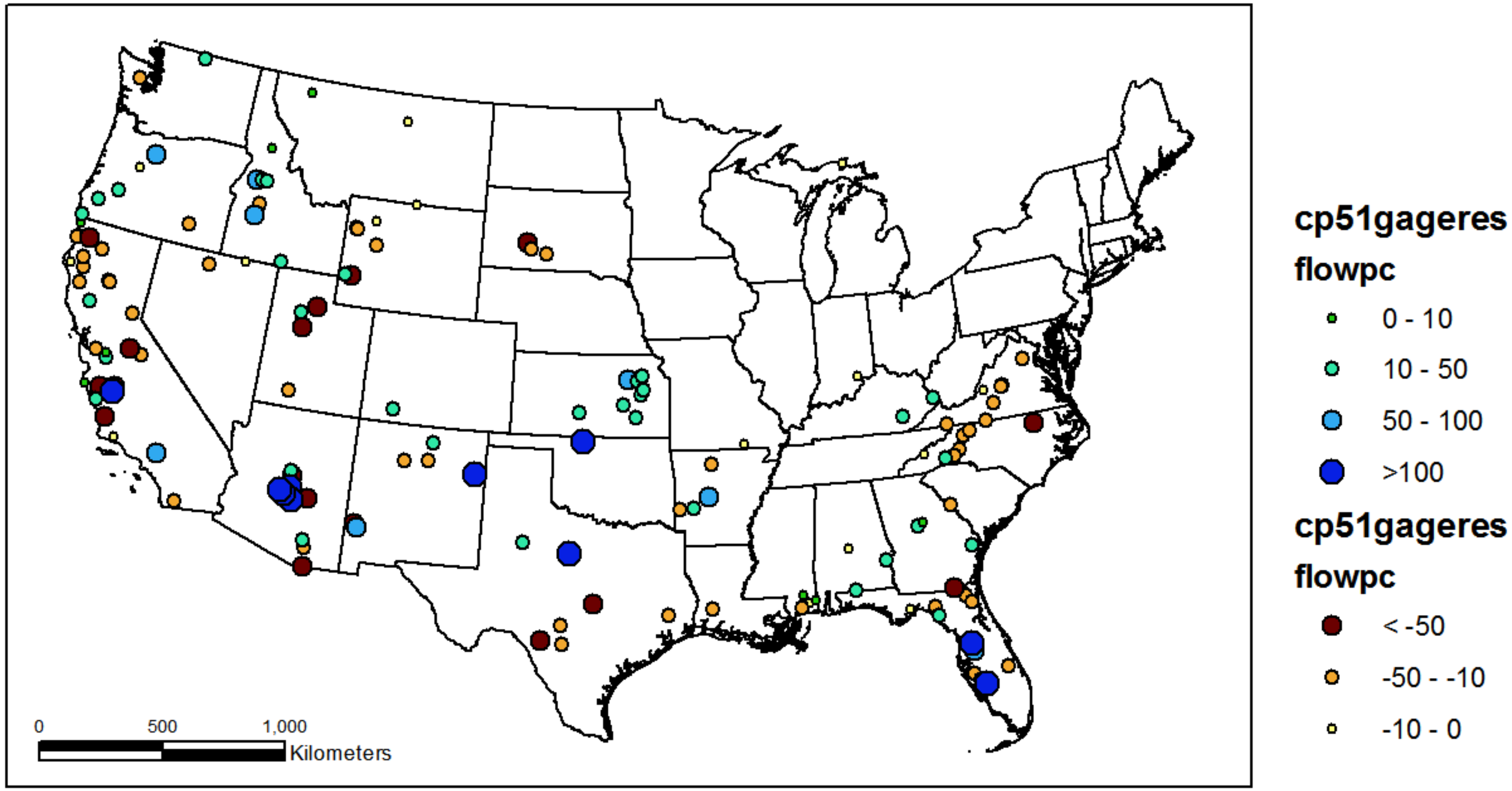
Attribution of 5 year streamflow change (25 watersheds burned >10%, mod-high severity)



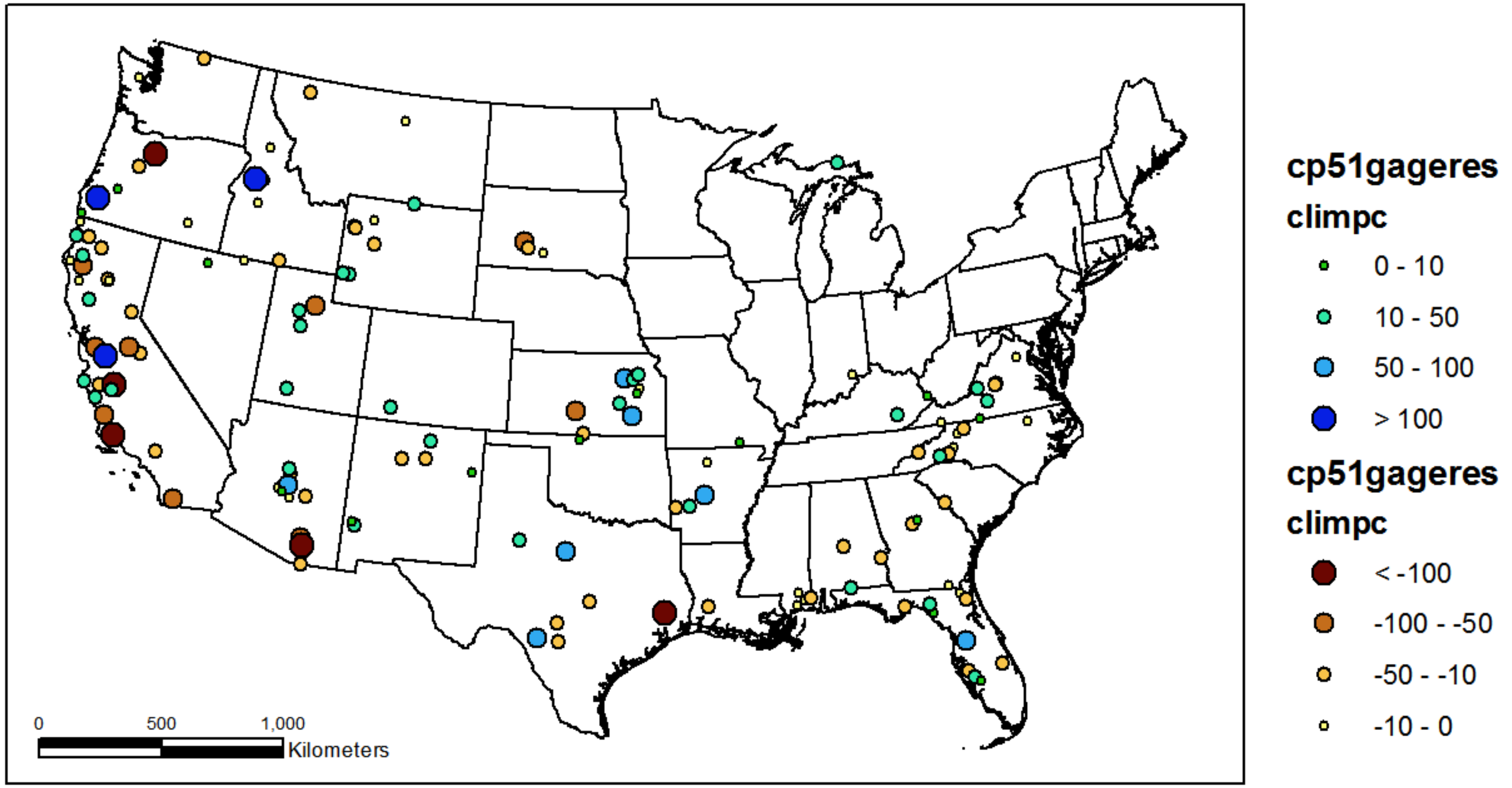
- Arizona: Dense ponderosa pine forest, high impact on streamflow
- California: Low growing chaparral vegetation, disturbance effects attenuated by climate trends

Hallema et al., 2016c. Wildland fire and climate variability impacts on annual streamflow in watersheds across the continental United States: Regional patterns and attribution analysis. Fall Meeting, American Geophysical Union, San Francisco, California, December 12-16, 2016.

% Observed change annual Q
(5y post vs. pre wildland fire, BAR>10%)

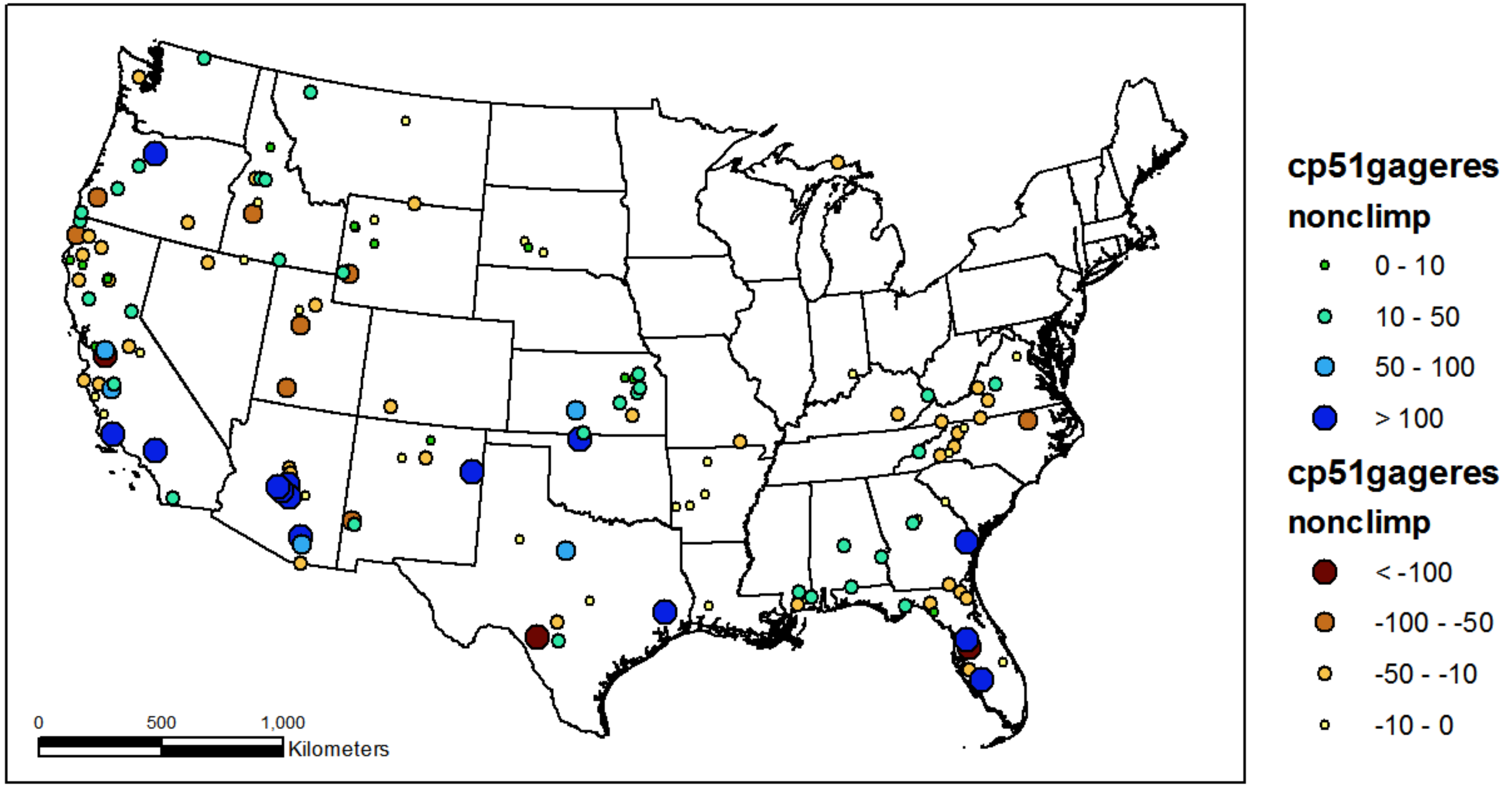


Climate contribution (%)

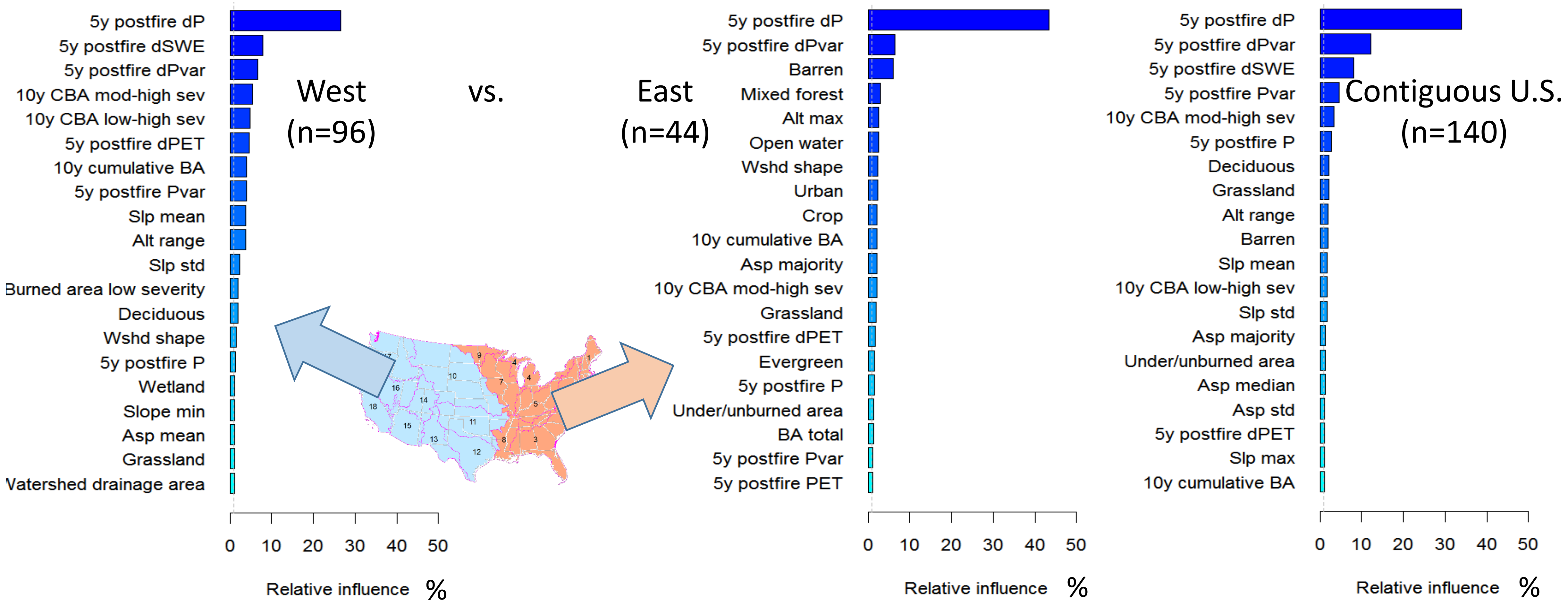


Contribution of fire disturbance (%)

$$\Delta Q_{disturbance} = \Delta Q - \Delta Q_{climate}$$



Boosted regression of 5 year post wildland fire streamflow change (dQ)



Hallema et al., 2016b. Wildland fire and climate variability impacts on annual streamflow in watersheds across the continental United States: Regional patterns and attribution analysis. Fall Meeting, American Geophysical Union, San Francisco, California, December 12-16, 2016.

Highlights

1. Western U.S.: Wildfires enhanced annual river flow, especially Lower Colorado basin. Sometimes masked by climate variability.
2. Eastern U.S.: No evidence of prescribed burning impacts on river flow
3. Sustained water supply depends on assessment of wildland fire impacts, forest interactions

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- Hallema *et al.*, 2017a. Regional patterns of post-wildfire streamflow response in the Western United States: The importance of scale-specific connectivity. *Hydrological Processes,* DOI: 10.1002/hyp.11208
- Hallema *et al.*, 2017b. Assessment of wildland fire impacts on watershed annual water yield: Analytical framework and case studies in the United States. *Ecohydrology*, DOI: 10.1002/eco.1794
- Hallema, *et al.*, 2017c. Étude de l'impact des feux de forêt et de la variabilité du climat sur les écoulements annuels des bassins versants des États-Unis. Séminaire présenté à *l'Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture*, Antony, France, le 05-01-2017.
- Hallema *et al.*, 2016a. Surface storm flow prediction on hillslopes based on topography and hydrologic connectivity. *Ecological Processes,* DOI: 10.1186/s13717-016-0057-1
- Hallema *et al.,* 2016b. Wildland fire and climate variability impacts on annual streamflow in watersheds across the continental United States: Regional patterns and attribution analysis. Fall Meeting, American Geophysical Union, San Francisco, California, December 12-16, 2016.
- Hallema *et al.,* under review. Burning forests impacts water supplies.

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- NASA Daymet

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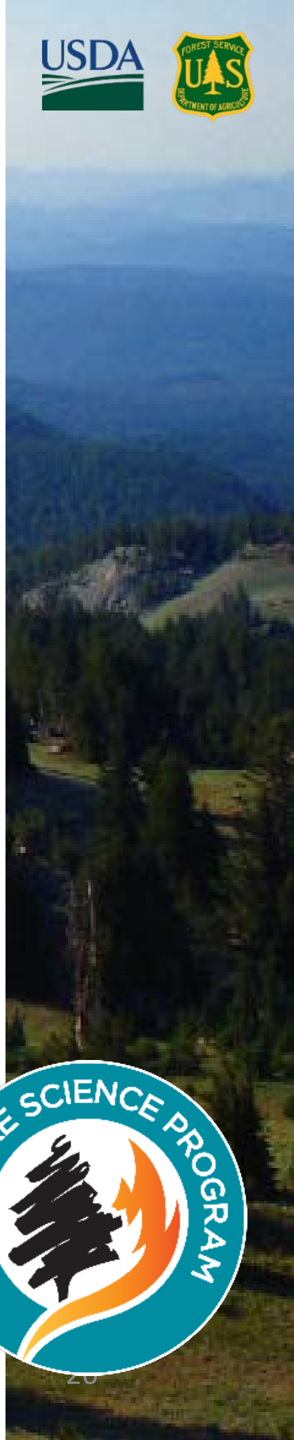

- Variability of dQ and dP considerable throughout the Pacific Northwest and California basins, which had more watersheds than most other basins
- Regression lines point to the predominantly positive correlation between dQ and dP, and a predominantly negative correlation between BAR and drainage area (i.e. the portion of the watershed burned decreased with drainage area).