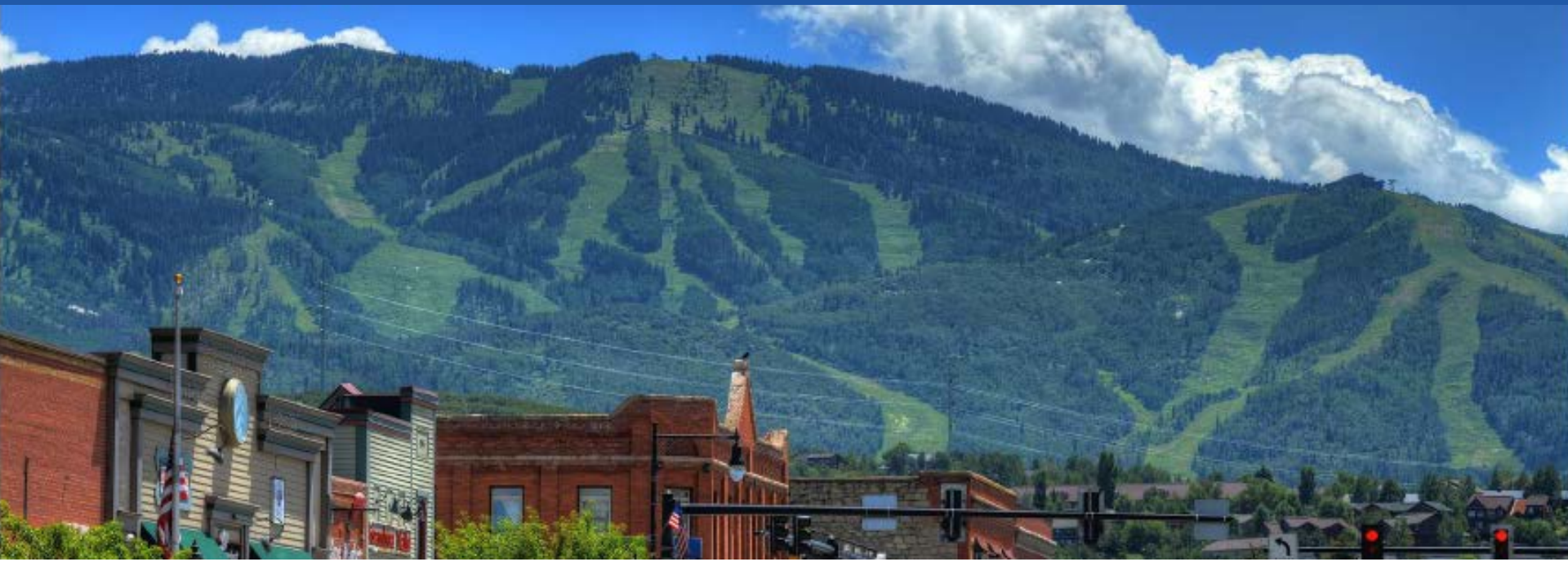
Impacts of Increasing Aridity and Wildfires on Aerosol Loading in the Intermountain Western U.S.



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Storm Peak Laboratory

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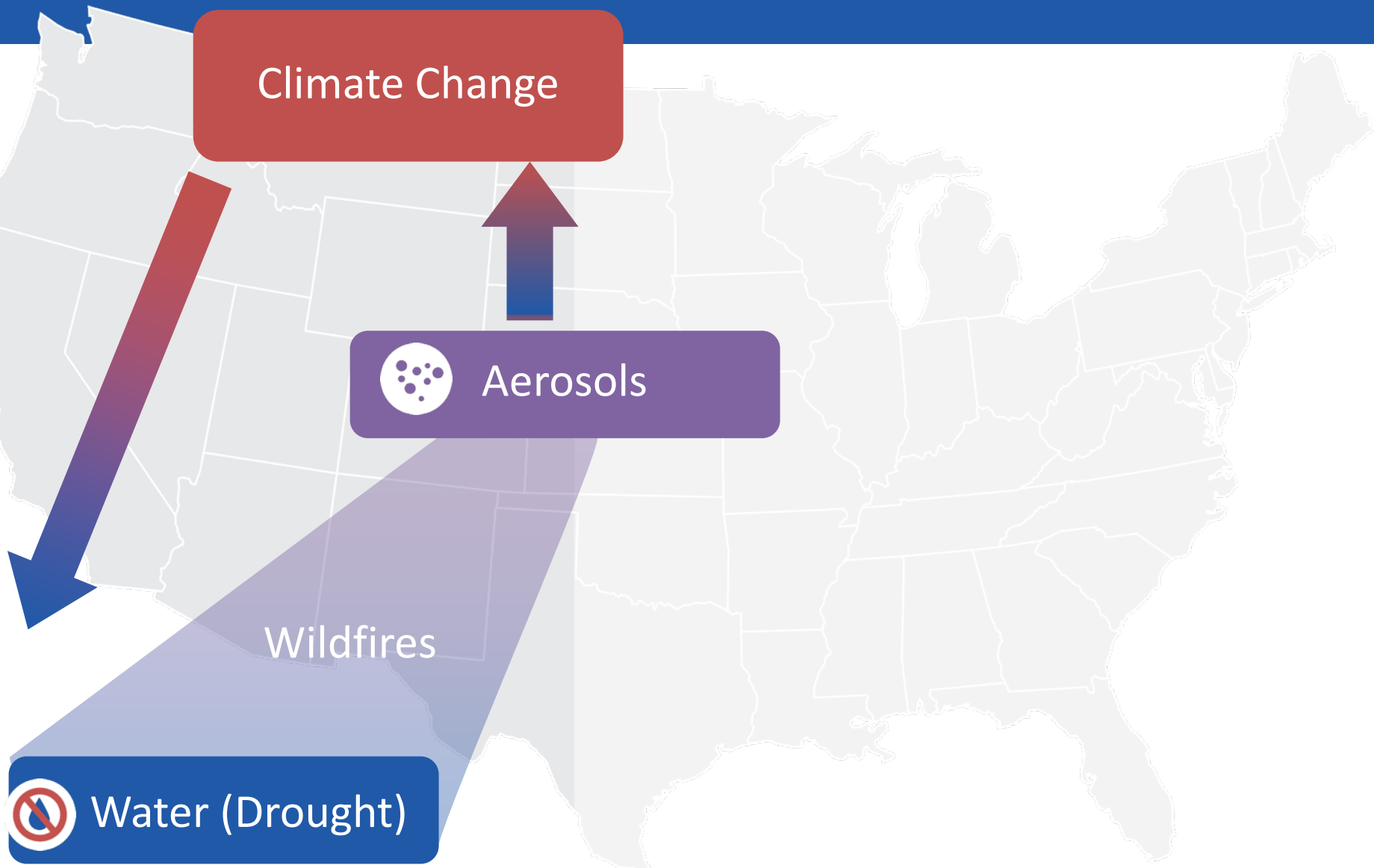
Framework

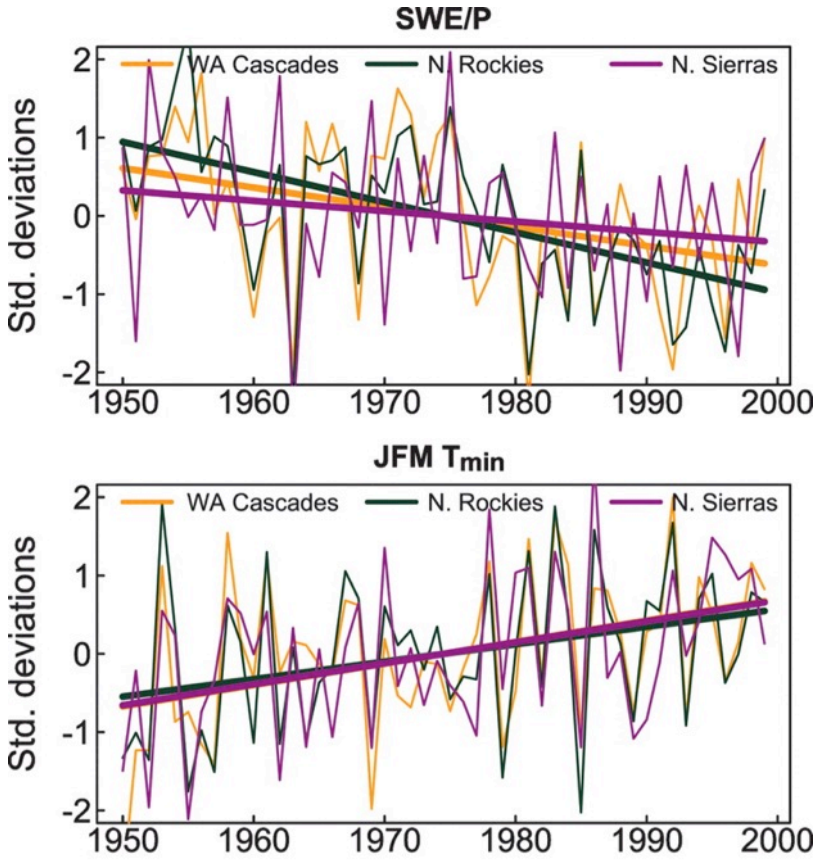


Increasing land surface aridity in Western U.S.

Mote et al., 2004, *BAMS* & Barnett et al., 2008, *Science*

- Winter precipitation falling as rain instead of snow, earlier snow melt
- Warming over most of the region that has exacerbated drier summer conditions

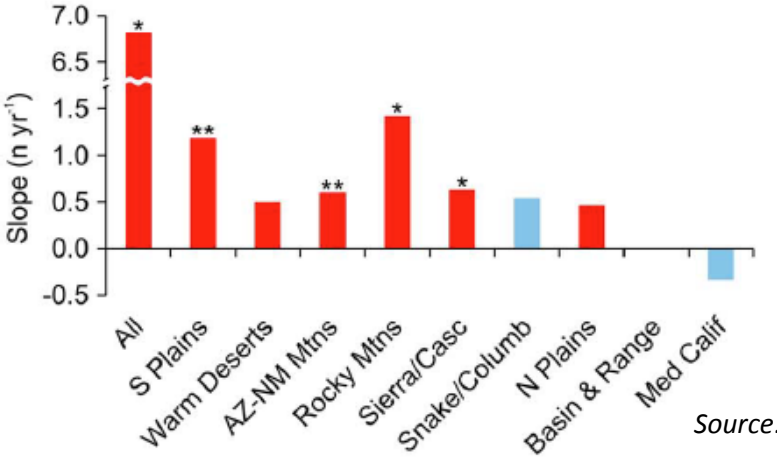
1945–55 to 1990s	Observed SWE
Cascades	–29.2%
Rockies	–15.8%
California	–2.2%
Interior	–21.6%



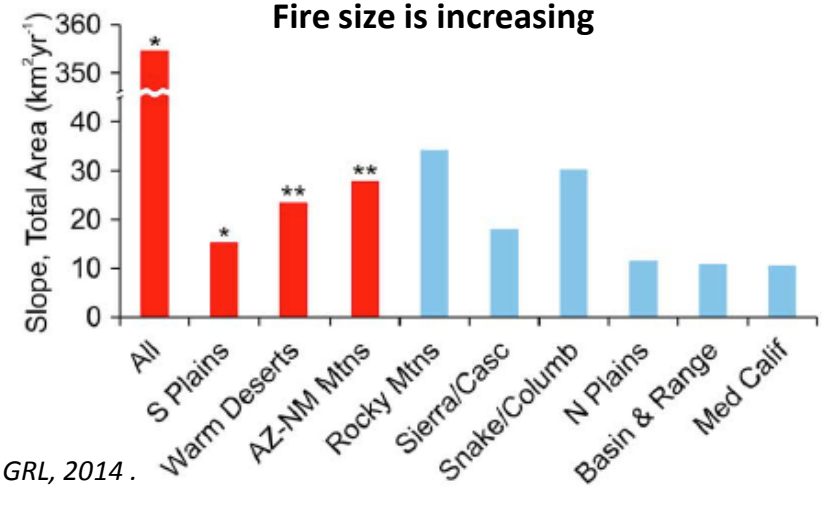
Observed time series of selected variables (expressed as unit normal deviates)

Increasing Wildfires in Western U.S.

Number of fires increasing

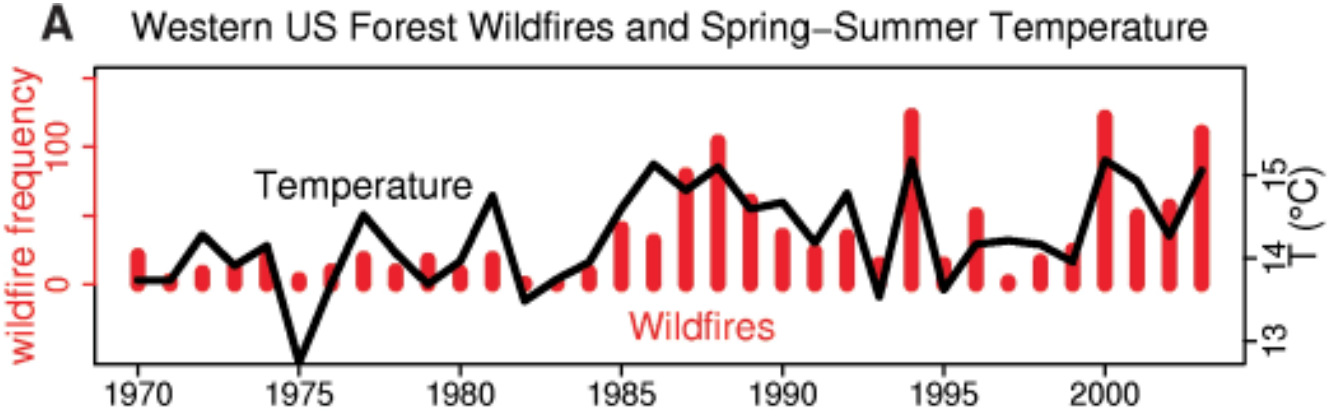


Fire size is increasing



Source: Dennison et al., GRL, 2014 .

Wildfire activity strongly associated with spring snowmelt timing, which is sensitive to changes in temperature.

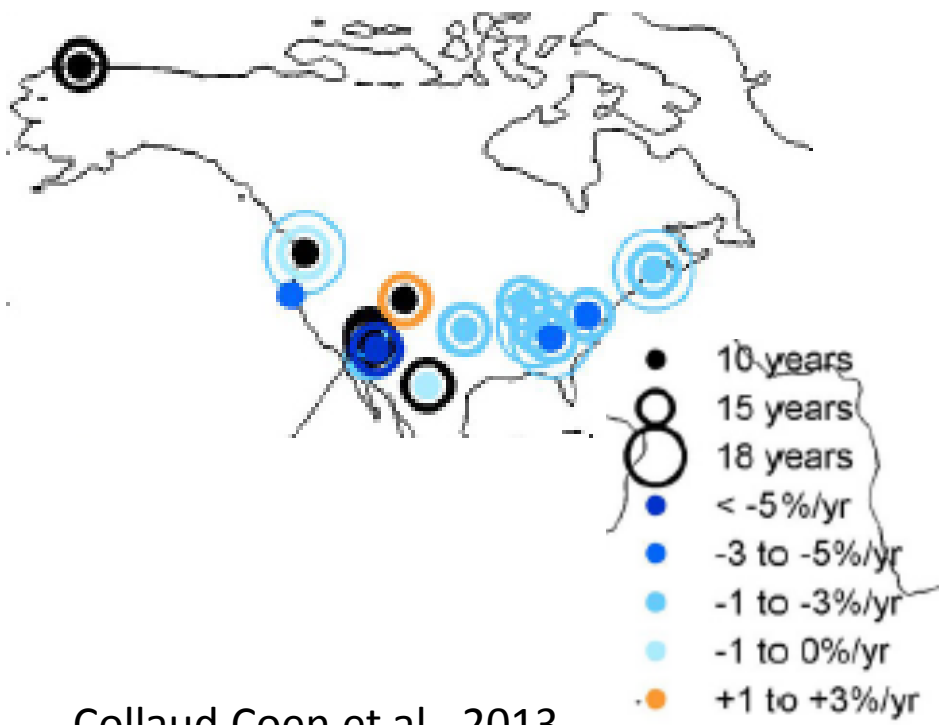


Source: Westerling et al., Science 2006

Increasing Aerosol Loading in the Intermountain West

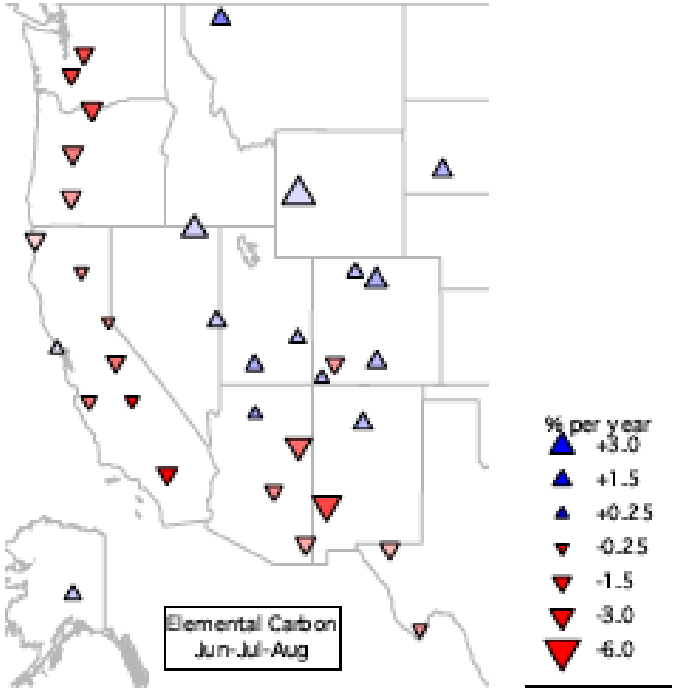
Unlike the rest of the U.S., visibility has not improved in the intermountain region during the last two decades and, in fact, certain types of aerosols are increasing (e.g., Hand et al., 2013).

Trend in Aerosol Scattering



Collaud Coen et al., 2013

Trend in Elemental Carbon (1990-2004)



Murphy et al., 2011

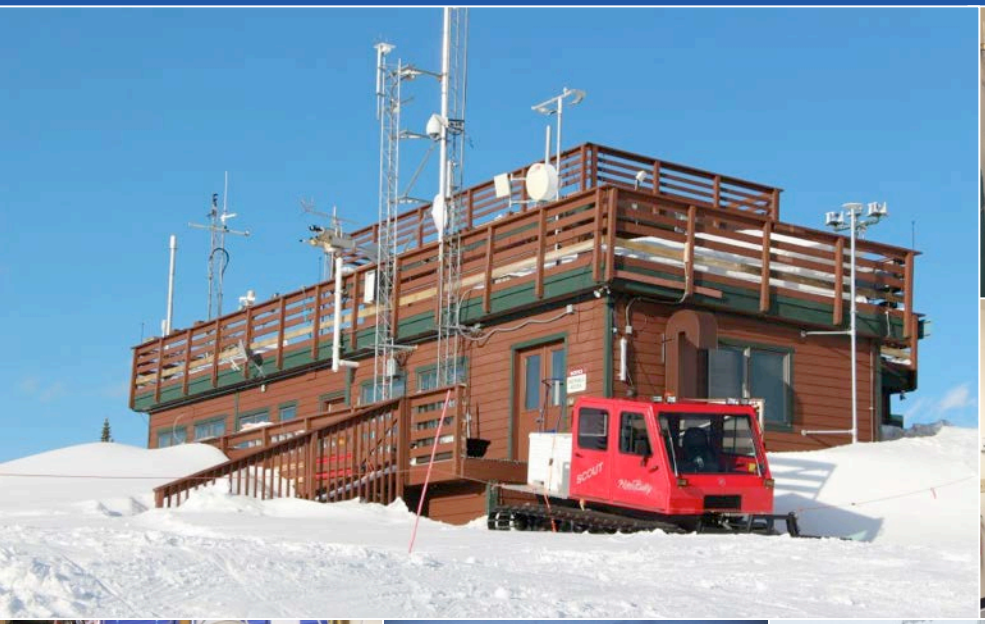
Research Question

Is the increasing aerosol loading in the remote Intermountain Western U.S. due to drought/wildfires?

And what should we expect in the future?

Aerosol, Cloud, and Trace Gases Research and Education Facility

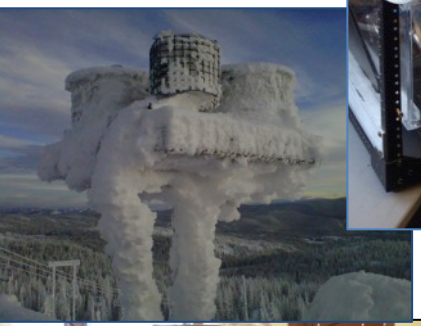
Storm Peak Laboratory

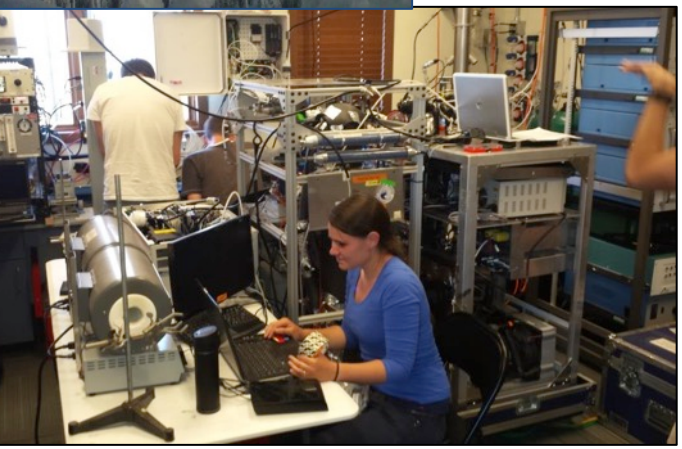


- Located on Steamboat Springs Ski Resort
- Elevation: 3220 m (10,530 ft)
- Pressure: ~ 690 mb
- In cloud ~25% of time in winter
- Mixed Phase Clouds
- 9 Person Bunkhouse
- Full Kitchen, Running Water
- Facility and Guest Instruments
- Wet Chemistry Lab
- Over 100 publications to date

DRI
Desert Research Institute

DRI/SPL Partnership with NOAA ESRL





Storm Peak Laboratory collaboration with NOAA ESRL and is used by all four divisions.

- Long term partner of GMD - Aerosol Group
  - Frequently used to test new instruments. (e.g. CLAP vs. PSAP, and inlet study)
- Used by PSD to test equipment for icing in Arctic
- Used by CSD for field deployments
  - PALMS as part of extensive FIN3
  - Selected as ground site for FIREX
- Used by GSD as a site for GPS water vapor

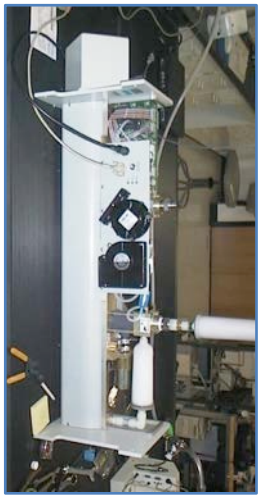
Aerosol Instrument at Storm Peak Laboratory used to detect fires

Visible Multifilter Rotating Shadowband Radiometer (vis-MFRSR)
USDA monitoring network
Data from 1999-2013
Calibrated using Langley plots (Michalsky et al., 2001)
Cloud screening (Michalsky et al., 2013)
Daily AOD calculated from measurements that passed cloud screening

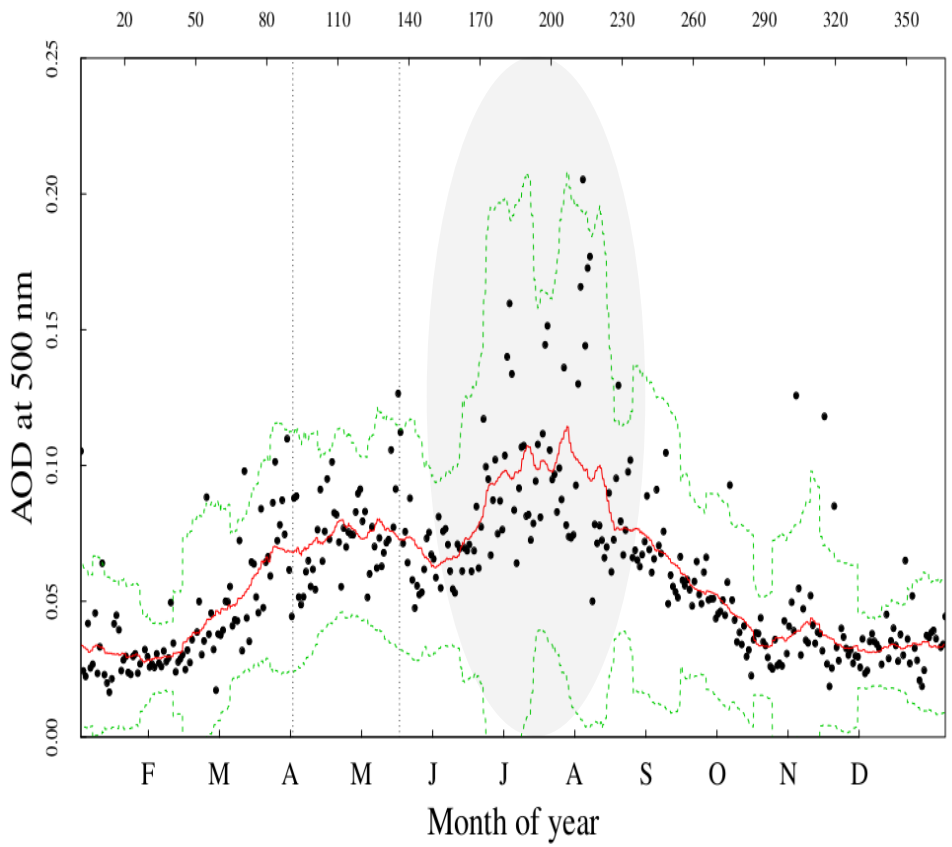
Ångström Exponent

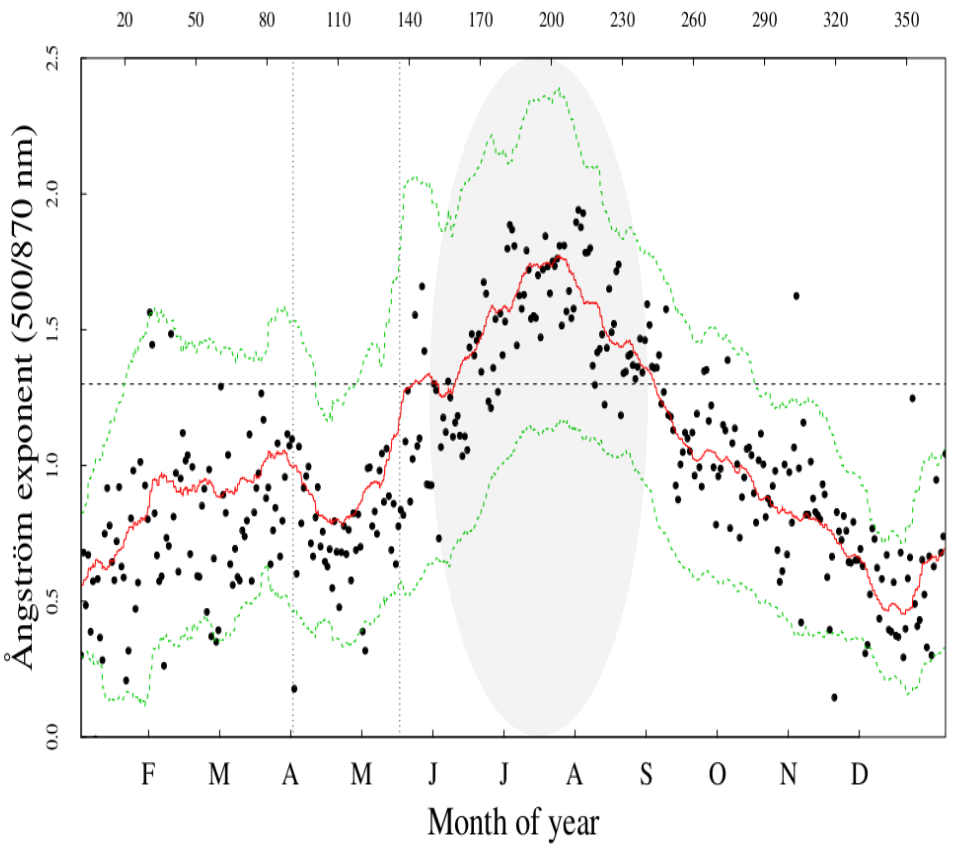
$$\alpha_{Inst} = \ln(\sigma_{sp,\lambda 2}/\sigma_{sp,\lambda 1})/\ln(\lambda 1/\lambda 2)$$

MFRSR $\lambda 1$=500 nm, $\lambda 2$=870 nm;



Seasonality of AOD at Storm Peak Laboratory 1999-2013





Used α>1.3 to separate combustion sources from dust (Clarke and Kapustin, 2010; *Science*)

Research Question

Is the increasing aerosol loading in the remote Intermountain Western U.S. due to drought/wildfires ?

Need:

More stations besides Storm Peak Lab

Hydrologists

More Sites with Aerosol Data in Intermountain West

Relatively Remote:
High Elevation
Away from Major Urban Area
Over 10 years of data

AOD Data

NASA

NOAA

SURFRAD

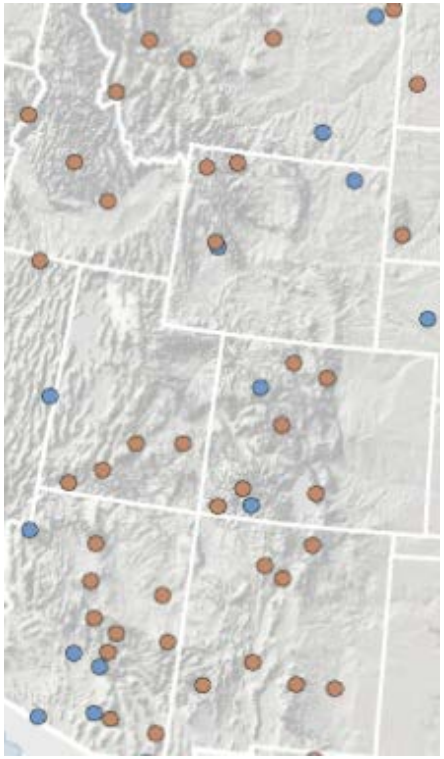
Only Found 1 more site with AOD Climatology

Sevilleta National Wildlife Refuge - Doug Moore

More Sites with Aerosol Data in Intermountain West

Relatively Remote:
High Elevation
Away from Major Urban Area

IMPROVE Site
IMPROVE Protocol Site



AOD Data

AERONET
AEROSOL ROBOTIC NETWORK

NASA

NOAA

SURFRAD

Only Found 1 more site with AOD Climatology

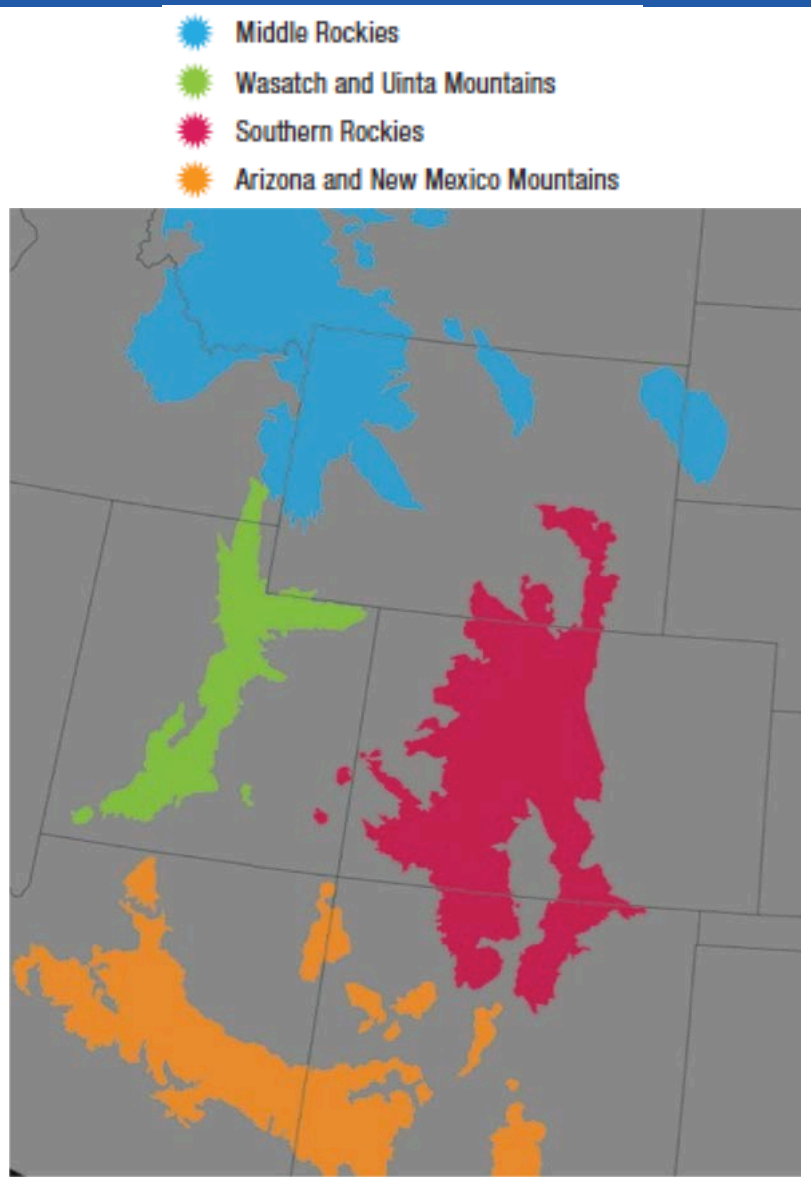
Sevilleta National Wildlife Refuge - Doug Moore

30 YEARS OF IMPROVING VISIBILITY
IMPROVE
1985 - 2015

Link between Aerosol Loading and Drought ?

Hydrologic Model

- High Elevations in the Intermountain West
- Summertime Aridity = PET/P
- Variable Infiltration Capacity model
  - (Livneh et al., 2013)
  - 1988-2013
- EPA Level 3 Ecoregions
- 1/16° (~6km) latitude-longitude grid



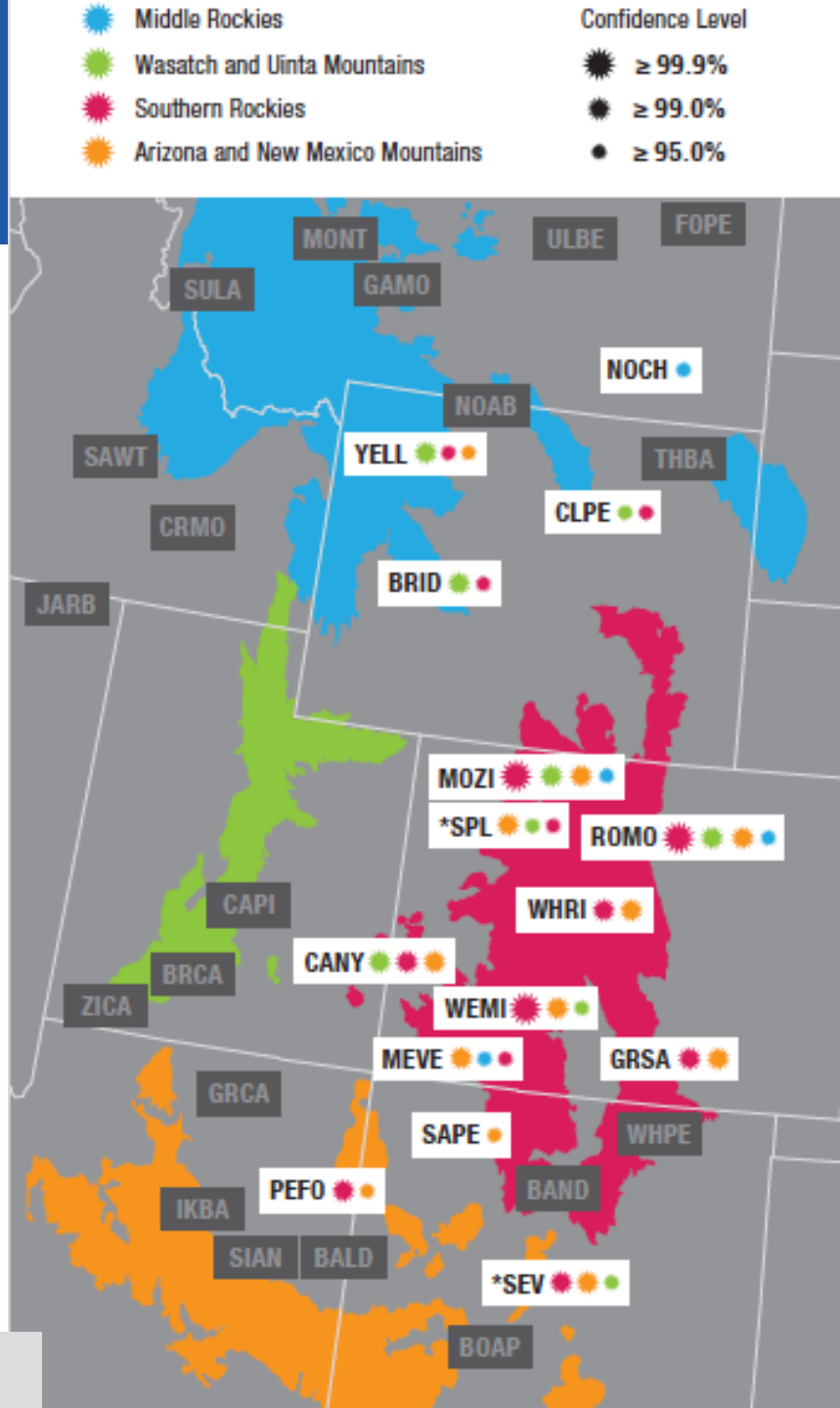
Link between Aerosol Loading and Drought

12 IMPROVE sites
2 AOD sites

Demonstrated a correlation [$p<0.05$] between surface level summertime organic aerosol loading and aridity.

Organic aerosol loading had the greatest correlation with aridity.

Southern Rockies Area



Link between Aerosol Loading and Fire Area

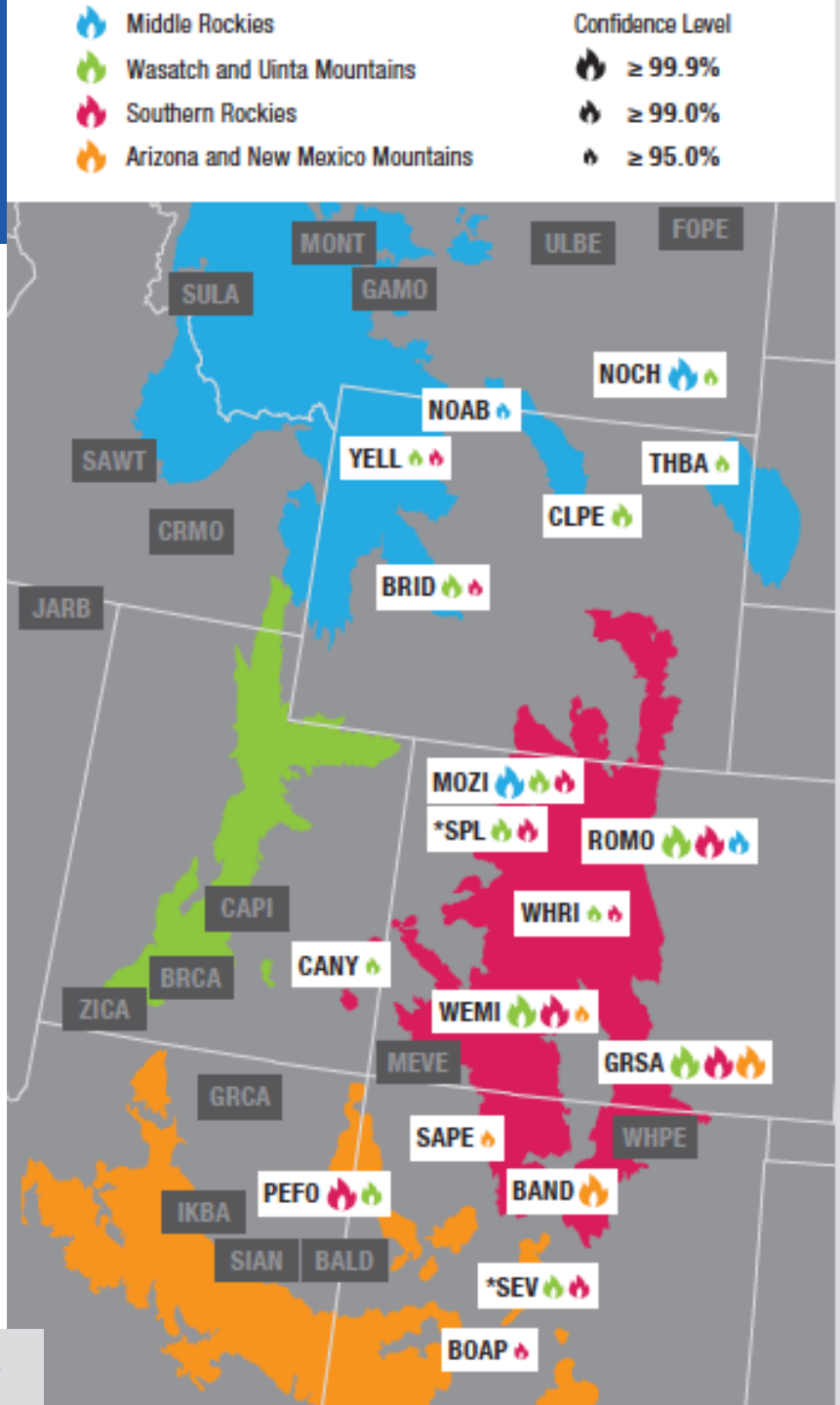
Fire Area reported by Monitoring Trends in Burn Severity project for Level 3 Ecoregions.

Generated from Landsat surface reflectance

16 IMPROVE sites
2 AOD sites

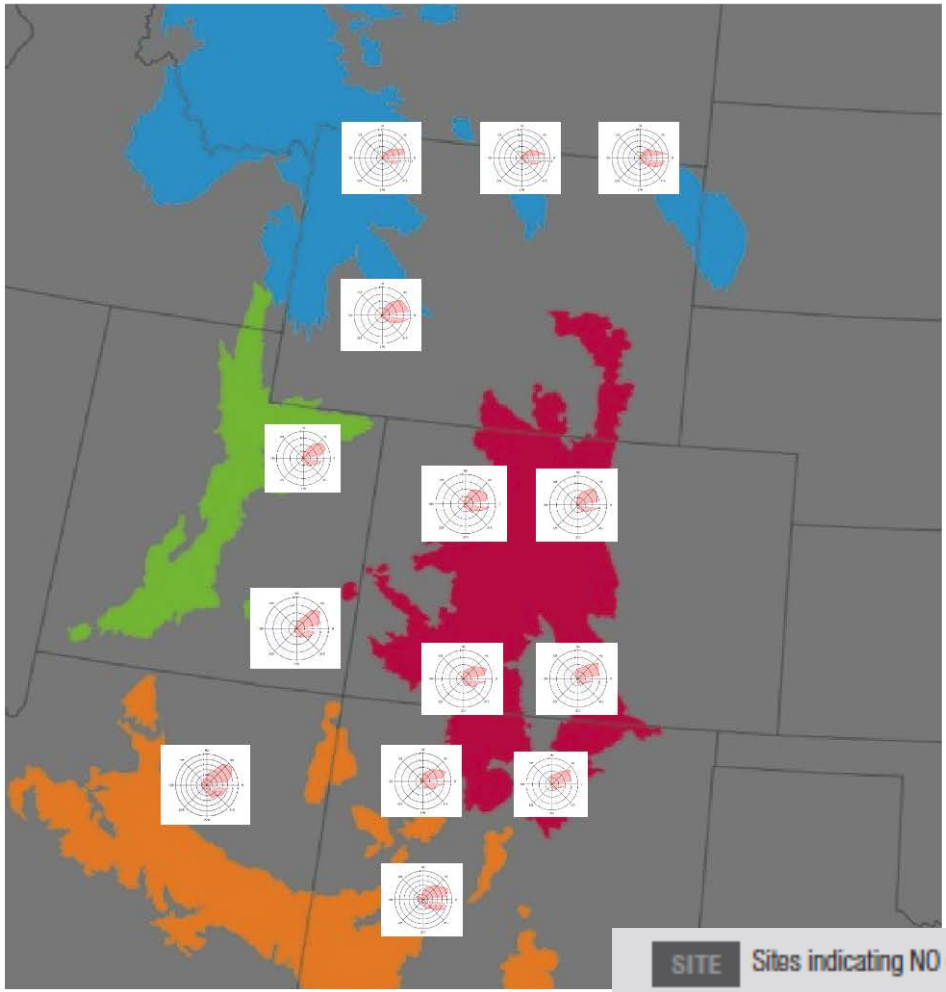
Demonstrated a correlation [$p<0.05$] between surface level summertime organic aerosol loading and fire area burned.

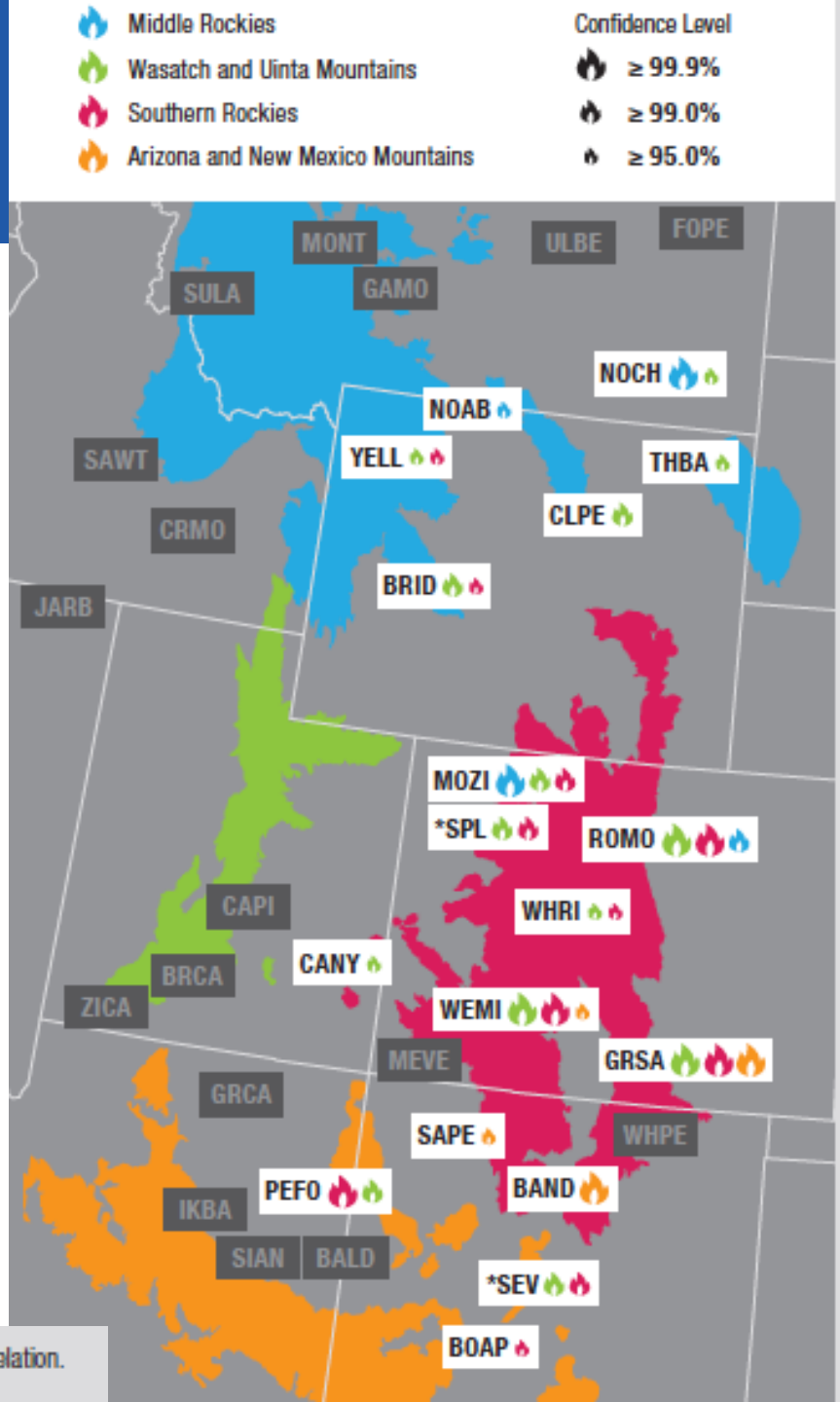
Southern Rockies Area
Middle Rockies Area



Flow Helps Explain Pattern

NCEP Reanalysis Data
700 mb level





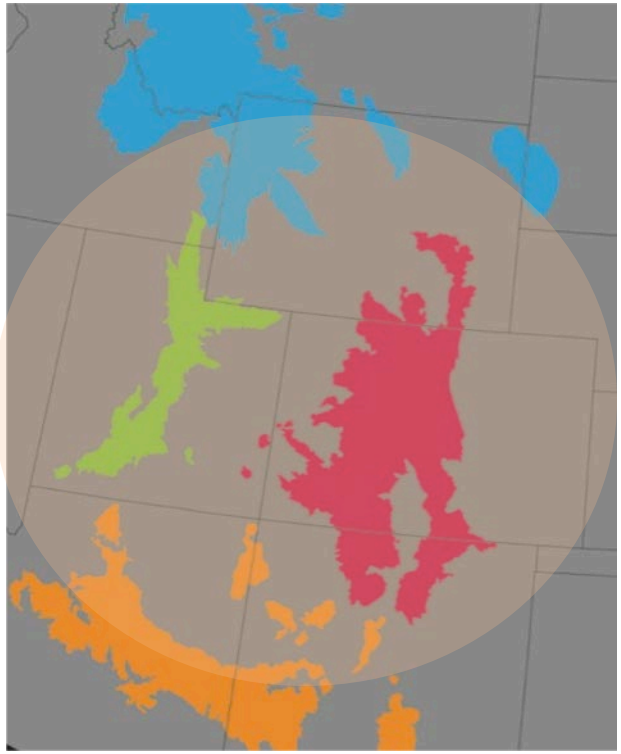
Future Prediction

Prior work estimated wildfire activity and resulting OC for 2050 from 15 Global Climate Models (Yue et al. 2013; “Rocky Mt. Forest”).

Representing mainly mixed and /or coniferous forest.

GCMs predicted a fire area increase of 2.69 times
increasing summer OC by 46% by 2050

From the data presented we expect an increase in:
OC of 24±3% and 34±3%
for Southern Rockies & Wasatch/Uinta Mts. by 2050



Summary

- Dataset highlights wide scale implications of a warmer drier climate on aerosol loading in the Western U.S.
- Summer AOD and surface OC correlates with large scale aridity and Fire Area burned
- Results provide quantifiable constraints on the influence of drought and resulting wildfires on aerosol loading suitable for evaluating climate model performance

Acknowledgements

Storm Peak Laboratory/DRI:
Melanie Wetzel, P. Tyson Atkins, Randy Borys

UV- B Monitoring
& Research Program

More Information:

Hallar et al., Atmos. Chem. Phys., 15, 13665-13679, 2015
Hallar et al. Environ. Research Lett 12.1 (2017): 014006.