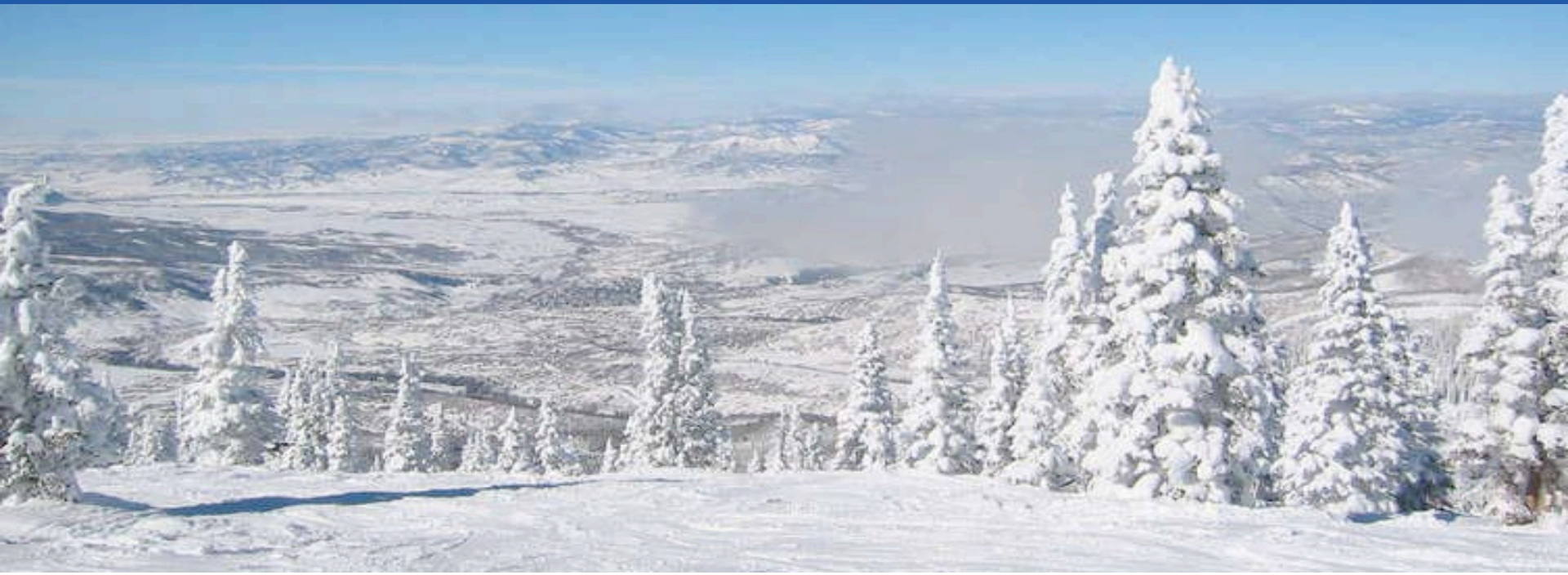
Multiyear Measurements of Aerosols at Storm Peak Laboratory, a Colorado Mountain-Top Site



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Storm Peak Laboratory

DRI
Desert Research Institute

Aerosol, Cloud, and Trace Gases Research and Education Facility

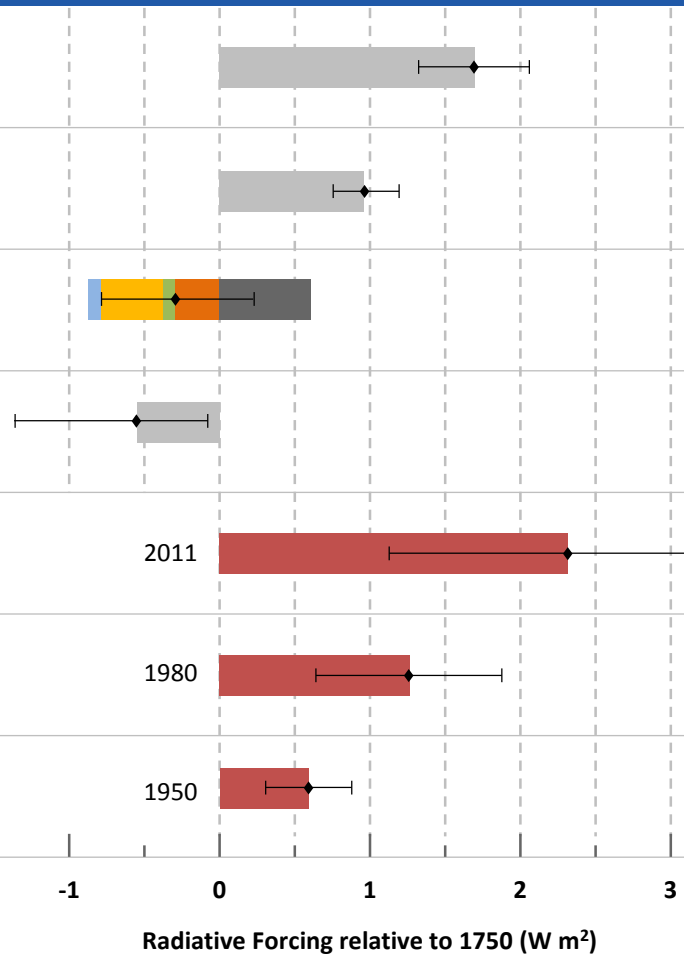
Storm Peak Laboratory

- 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

DRI
Desert Research Institute

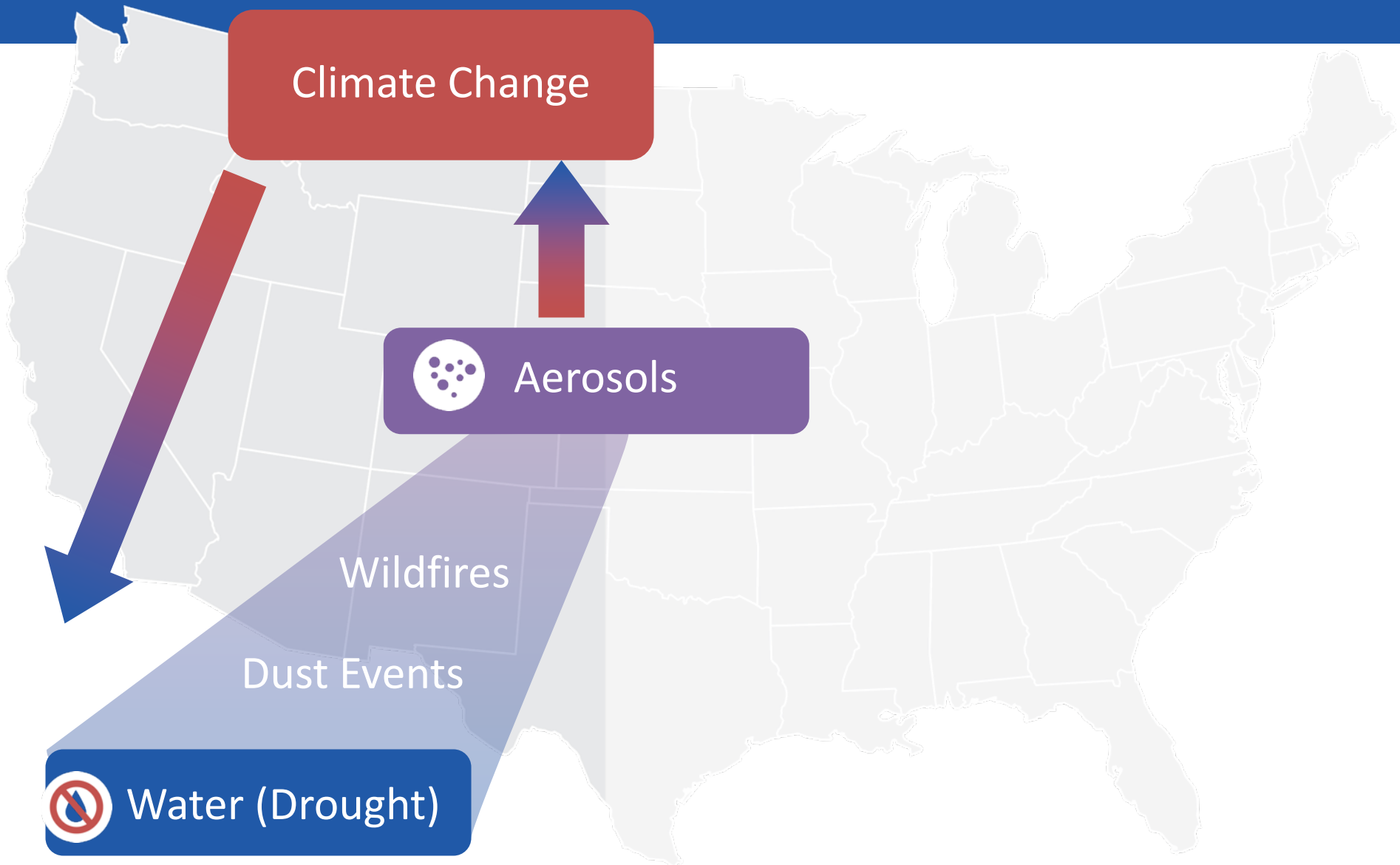
Climate Emission Drivers

Emitted Compound	Radiative Forcing by Emissions and Drivers	Level of Confidence
CO_2		Very High
CH_4		High
Aerosols and precursors Mineral Dust, Sulphate, Nitrate, Organic Carbon, Black Carbon		High
Cloud adjustments due to aerosols		Low
Man's impact relative to the year 1750	2011	High
	1980	High
	1950	Medium

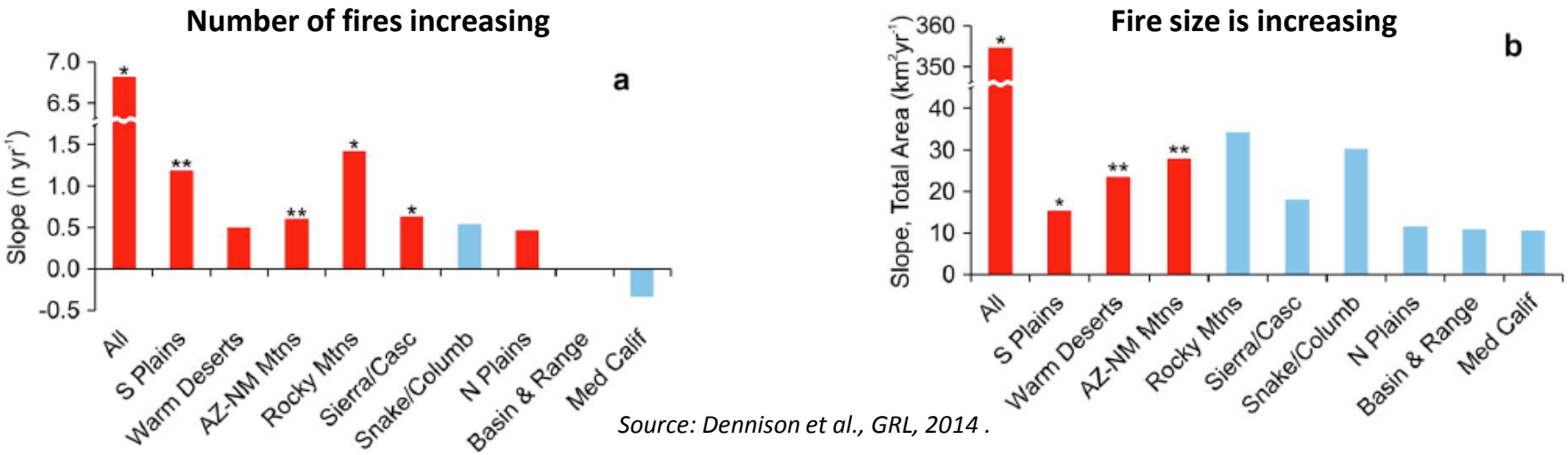


ipcc
INTERGOVERNMENTAL PANEL ON climate change

Framework

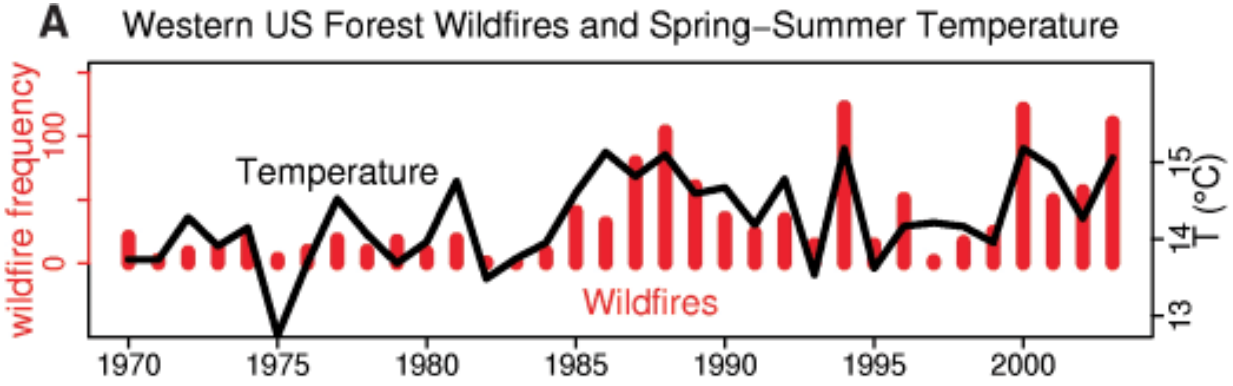

Climate Change
Aerosols
Wildfires
Dust Events
Water (Drought)

Increasing Wildfires in Western U.S.



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 Dust in Western U.S.

Phoenix, AZ dust storm in July 2012.

Photograph by Ross D. Franklin, AP

Source: Center for Snow & Avalanche Studies

Neff et al., 2008; Nature Geoscience

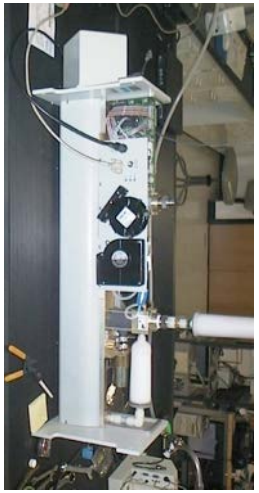
"dust load levels increased by 500% above the late Holocene average following the increased western settlement of the U.S. during the 19th century. …caused by the expansion of livestock grazing in the early 20th century."

Painter et al., 2007, Nature

Frequency of dust deposition and radiative forcing doubled when the Colorado Plateau experienced intense drought.

Instrument at Storm Peak Laboratory

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



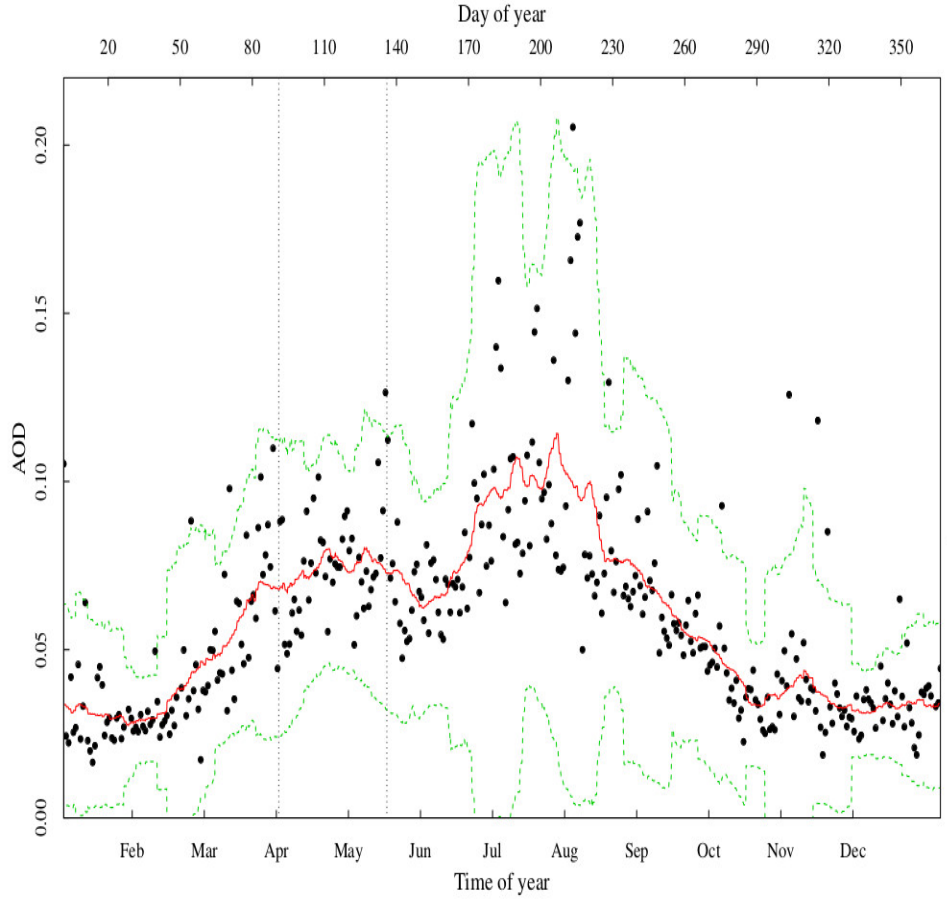
TSI integrating nephelometer (Model 3563, St. Paul, Minnesota)
Data from 2011-2014
Calibrated with particle-free air and CO_2
Zero checks on filtered air were performed hourly

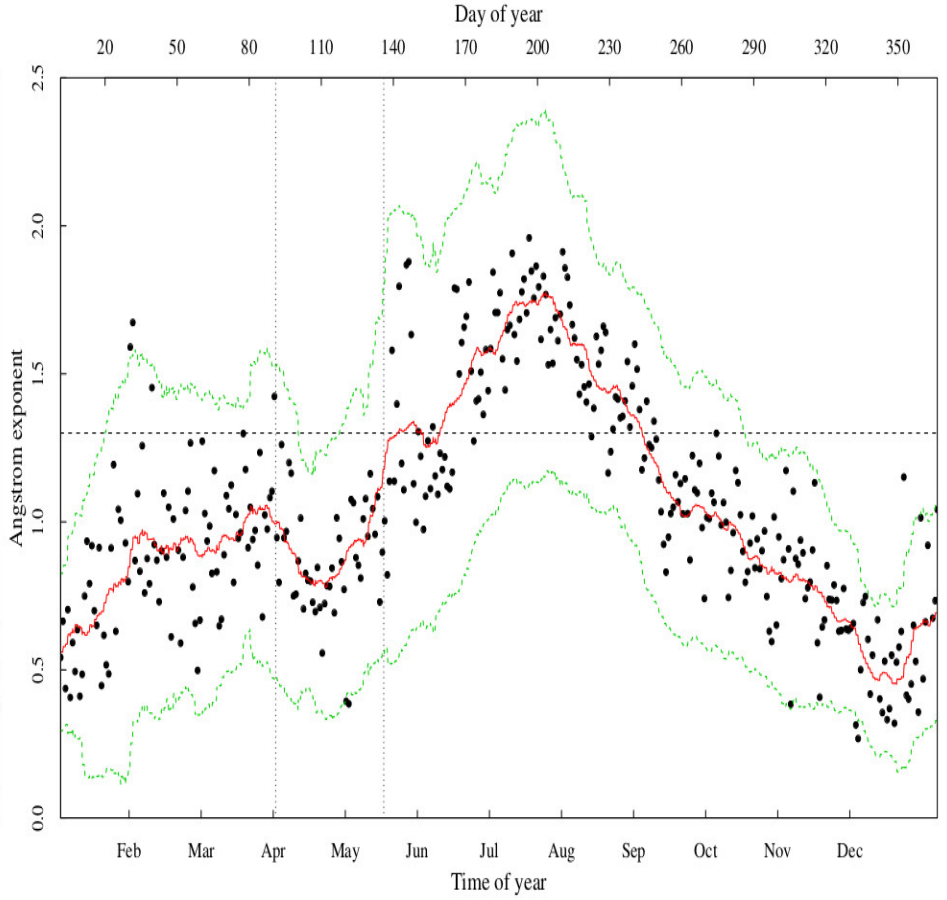
Ångström Exponent

$$\alpha_{Inst} = \ln(\square_{sp,\square 2}/\square_{sp,\square 1})/\ln(\square 1/\square 2)$$

MFRSR $\square 1$=500 nm, $\square 2$=870 nm;
Nephelometer $\square 1$=450 nm, $\square 2$=700 nm.

Seasonality of AOD at Storm Peak Laboratory 1999-2013



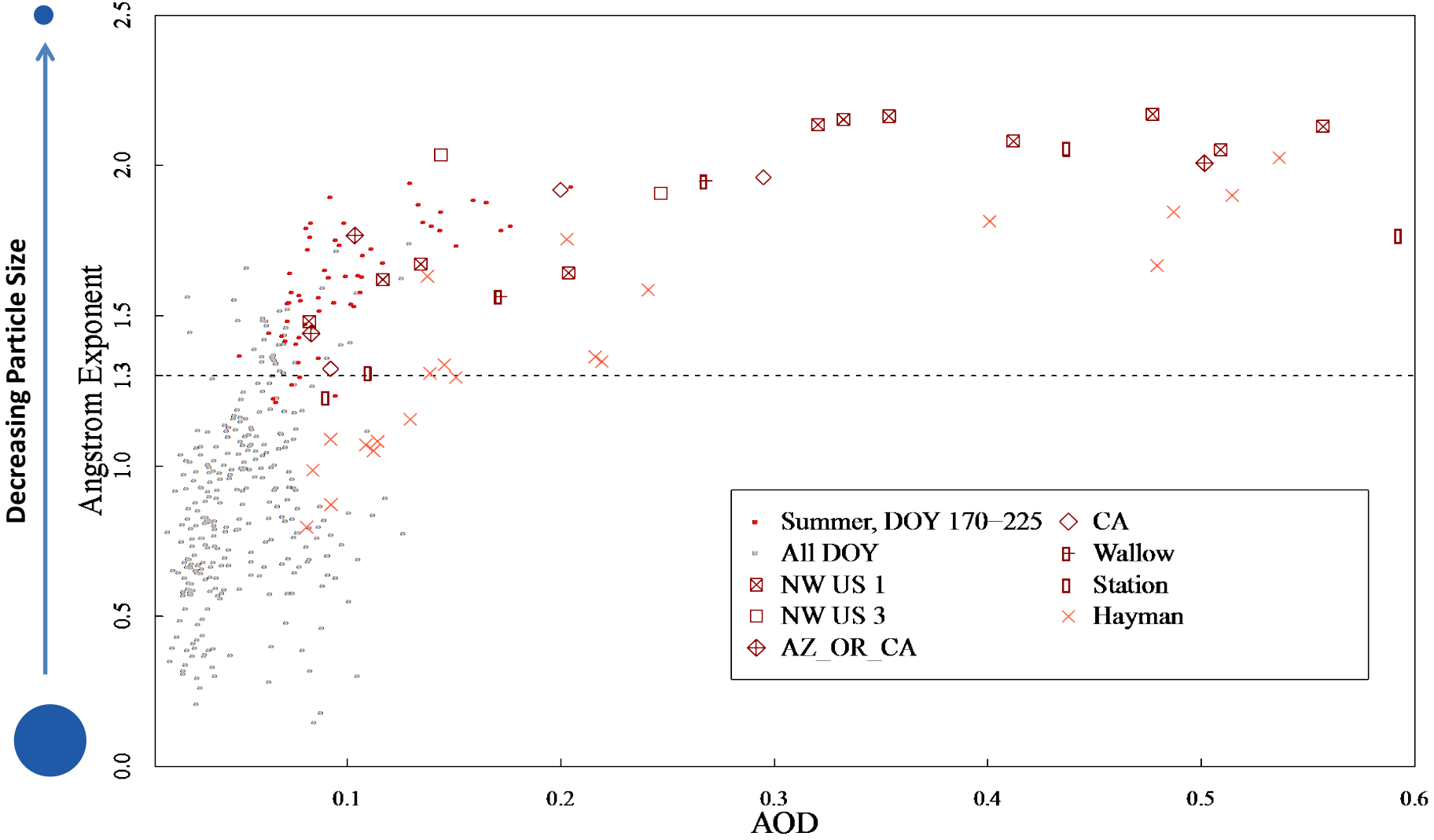


Fires observed at Storm Peak Laboratory

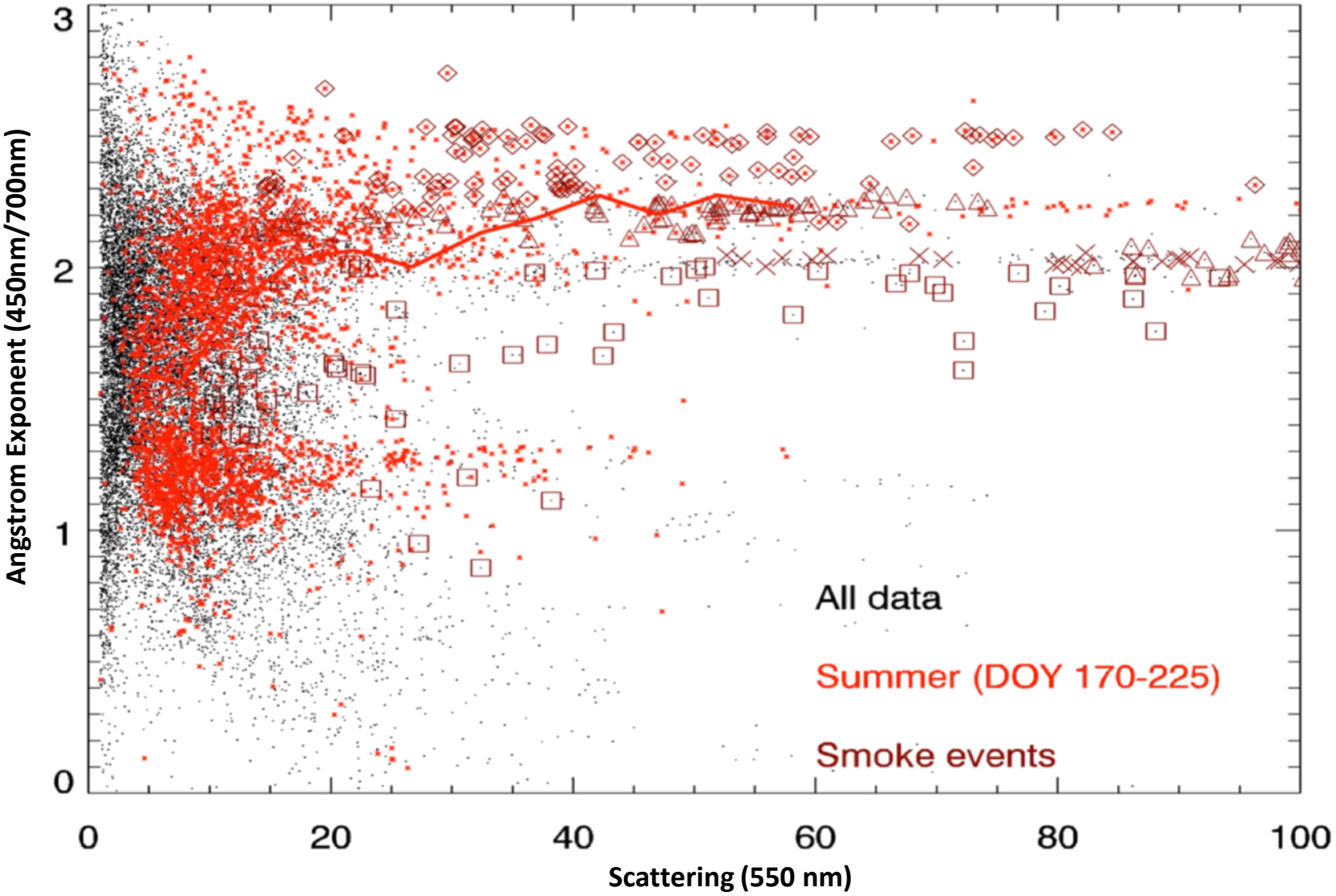
Start Time (UTC)	End Time (UTC)		MFRSR Data Available	Nephelometer Data Available
FIRE EVENT		**Origin**		
July 27, 2000	August 6, 2000	NW US 1	X	
June 15, 2002	July 10, 2002	Hayman	X	
July 30, 2002	Aug 3, 2002	AR,OR, CA	X	
Sept 4, 2006	Sept 9, 2006	CA	X	
Aug 29, 2009	Sept 3, 2009	Station Fire	X	
June 4, 2011 0700	June 8, 2011 0000	Wallow	X	X
June 30, 2012 0700	July 5, 2012 0700	Waldo/ High Park		X
Aug 10, 2012 0700	Aug 18, 2012 0700	NW US 2		X
Sept 21, 2012 0700	Sept 23, 2012 0700	NW US 3	X	X

Identified by MODIS - Val Martin et al., ACP, 2013

Observation of Fires at Storm Peak Laboratory 1999-2013



Observation of Fires at Storm Peak Laboratory 2011-2013

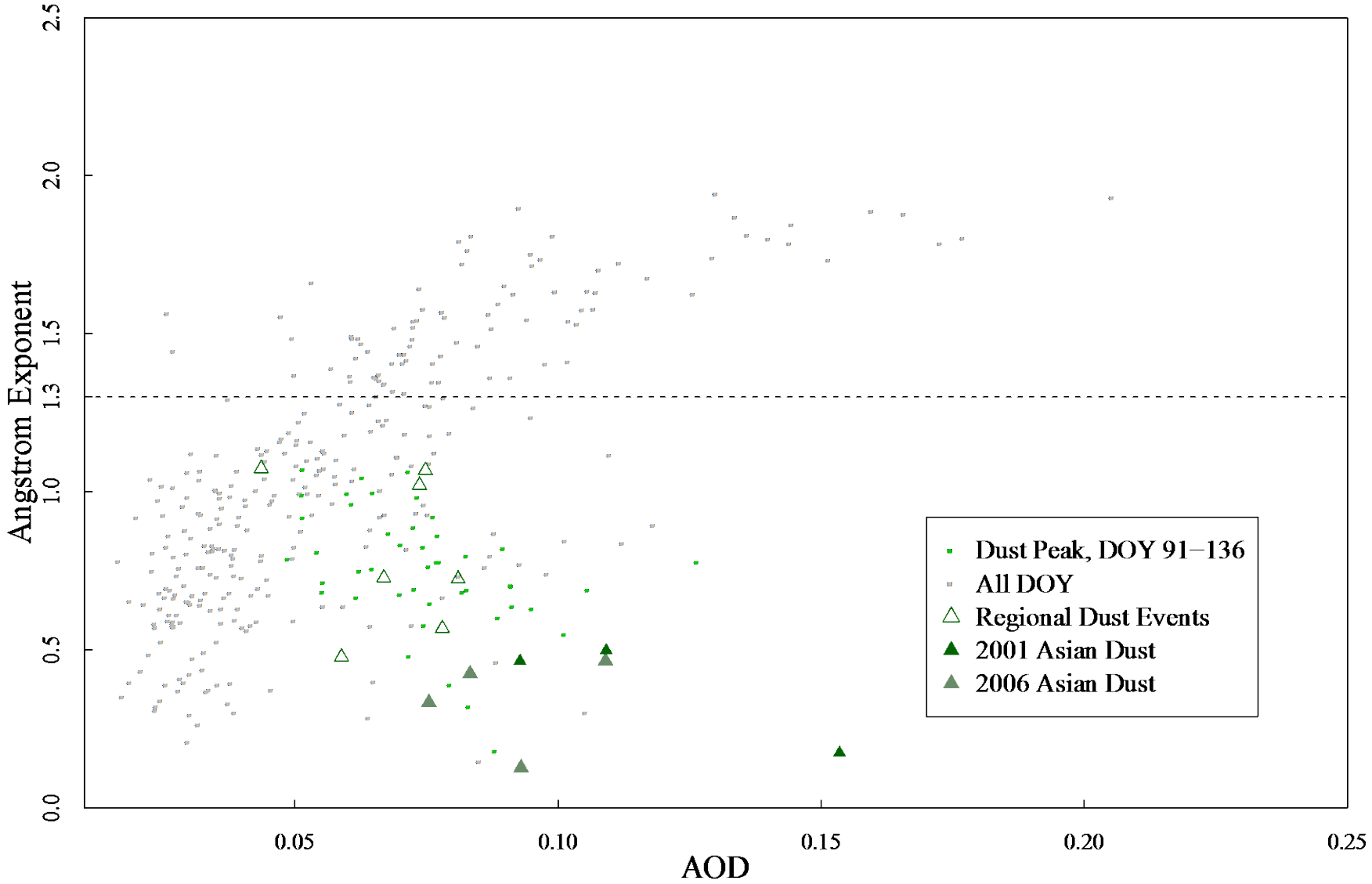


Dust observed at Storm Peak Laboratory

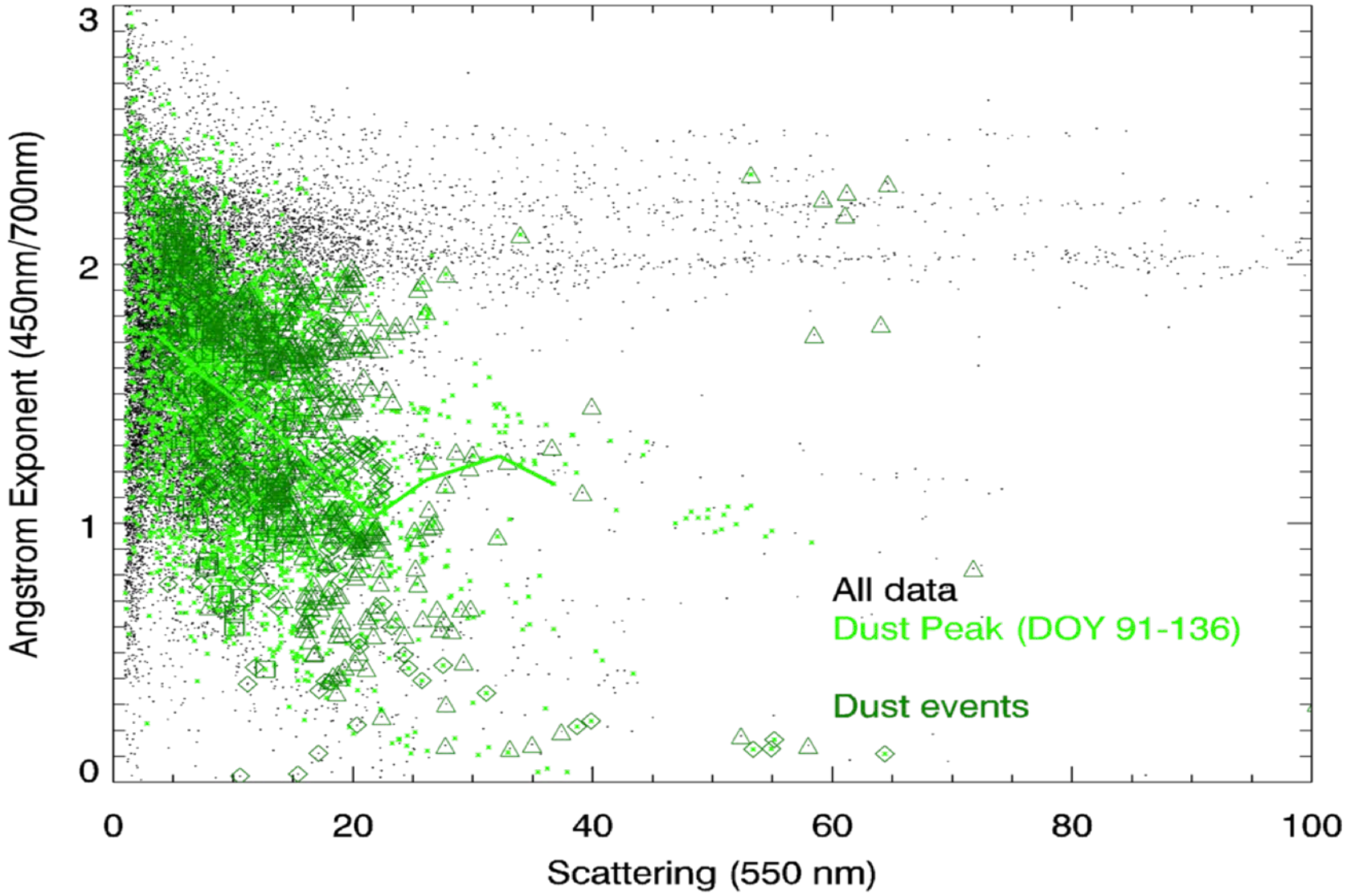
Start Time (UTC)	End Time (UTC)		MFRSR Data Available	Nephelometer Data Available
DUST EVENT				
April 15, 2001 1200	April 16, 2001 1200	Asian	X	
April 27, 2006	May 1, 2006	Asian	X	
Regional Events		**Wind Dir. at CSAS**		
April 19, 2007 1900	April 20, 2007 0700	201	X	
April 16, 2008 1900	April 17, 2008 0700	219	X	
April 4, 2009 0500	April 5, 2009 0700	206	X	
April 13, 2010 0800	April 13, 2010 1300	188	X	
May 22, 2010 0900	May 24, 2010 1500	192	X	
April 22, 2011 2200	April 24, 2011 0000	258		X
May 1, 2011 1200	May 4, 2011 0600	279		X
May 5, 2011 0900	May 11, 2011 0600	206	X	X
May 27, 2011 1800	May 29, 2011 1200	243		X
March 7, 2012 0900	March 8, 2012 0900	197		X
March 20, 2012 0900	March 22,2012 0000	193		X
March 27, 2012 1800	March 29, 2012 1200	207		X
April 2, 2012 2000	April 3, 2012 1000	198		X
April 7, 2012 1800	April 11, 2012 1400	201		X
May 20, 2012 0000	May 23, 2012 1400	213		X
May 24, 2012 1400	June 1, 2012 0000	217*		X
May 25, 2013 0000	May 25, 2013 1800	207		X

* Average of 3 consecutive dust events at CSAS

Observation of Dust at Storm Peak Laboratory 1999-2013



Observation of Dust at Storm Peak Laboratory 2011-2013



Summary

Dataset highlights wide scale implications of a warmer drier climate on aerosol loading in the Western U.S.

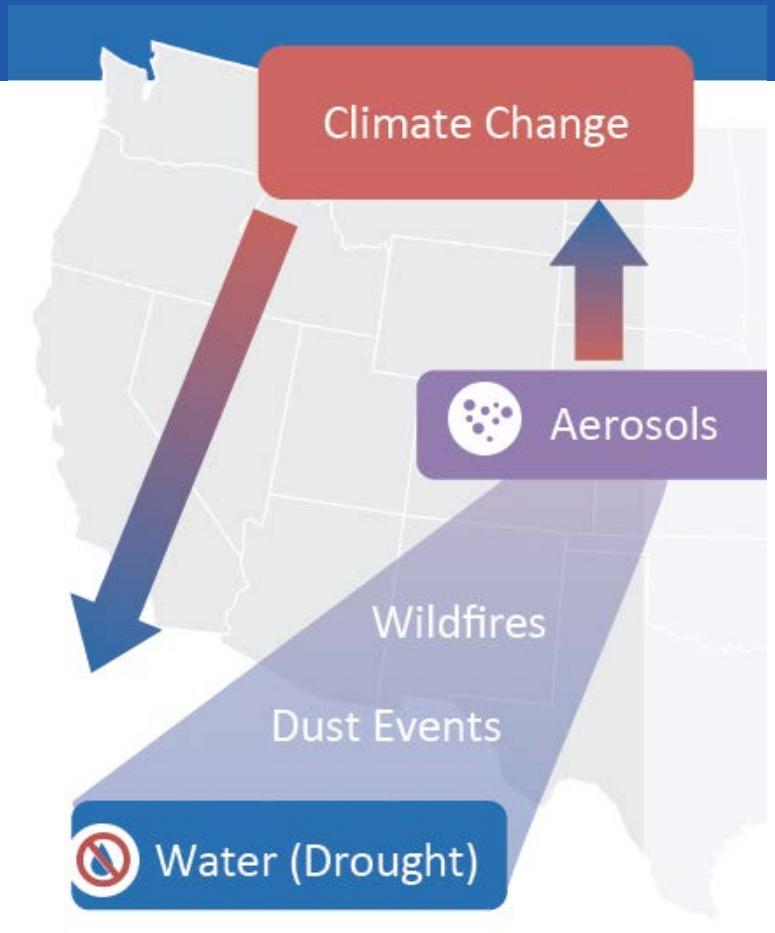
Spring AOD is dominated by dust aerosols

Summer AOD dominated by aerosols associated with biomass-burning

Supported with nephelometer measurements at surface

Median contribution to spring and summer AOD by dust and biomass-burning is comparable.

Summer AOD correlates with large scale aridity



Acknowledgements

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