University of Nevada, Reno

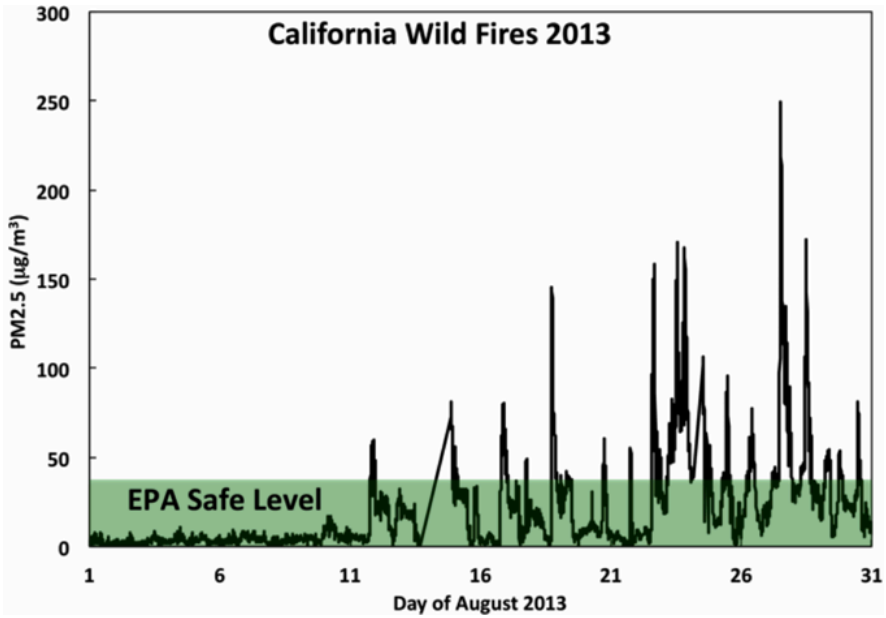
Spatial evaluation of surface $PM_{2.5}$ estimates using columnar aerosol optical depth from MODIS retrievals in the western U.S.

S. Marcela Loría-Salazar, Heather A. Holmes, W. Patrick Arnott, James C. Barnard
Atmospheric Sciences Program, Department of Physics, University of Nevada, Reno

05 October 2015
14th Annual CMAS Conference
UNC-Chapel Hill, Chapel Hill, North Carolina, USA

University of Nevada, Reno

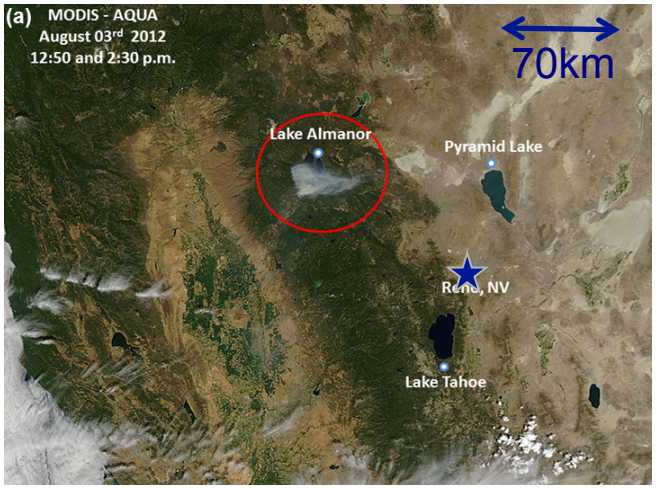
Motivation



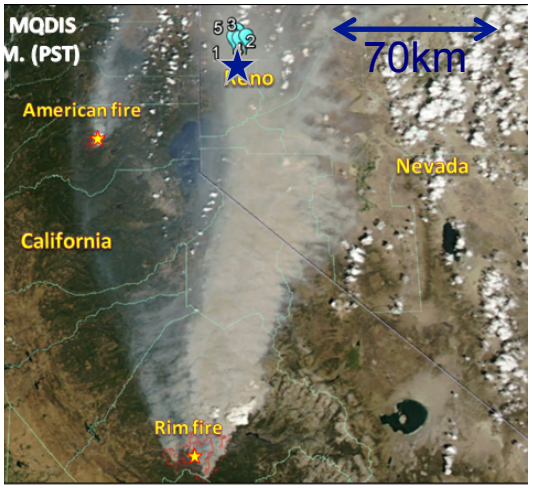
- Human health impacts of wildfire smoke exposure
- Visibility and radiative forcing impacts for climate
- Increasing drought conditions in western U.S. = more fires

University of Nevada, Reno

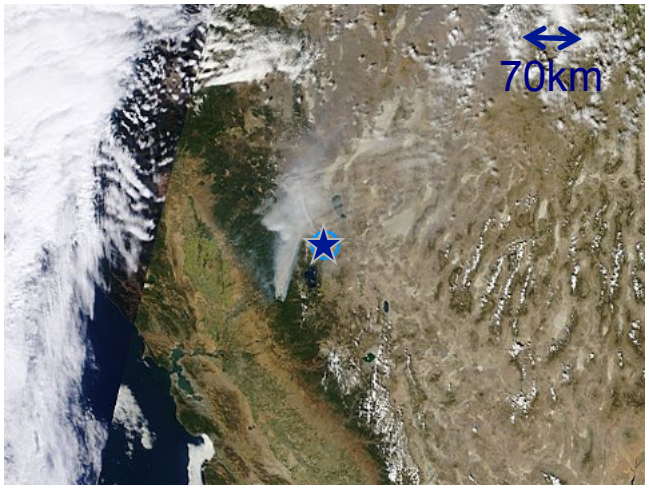
Motivation



Chips Fire 2012
Aqua - 3 Aug 2012



Rim Fire 2013
Aqua –22 Aug 2013



King Fire 2014
Terra- 17 Sep 2014

Uncertainties in aerosol optical depth (*AOD*) satellite remote sensing algorithm

- Uniformly mixed aerosols of homogeneous composition
- All aerosols are contained within the boundary layer
- Surface reflectance: Dark Target (dark) & Deep Blue (bright)

University of Nevada, Reno

Objectives and Hypotheses

Objectives

- Determine uncertainty of satellite *AOD* using ground-based *AOD*
- Investigate the relationship between columnar *AOD* & $PM_{2.5}$
- Use models and upper air data to understand aerosol transport from wildfire smoke plumes
- Develop daily, spatially-resolved surface *PM* concentration fields

Hypotheses

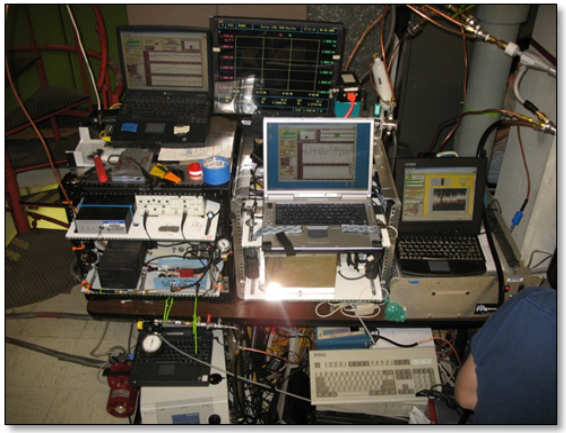
- Complex atmospheric transport will lead to uncertainties in satellite retrieval algorithms
- Columnar *AOD* and surface $PM_{2.5}$ will not be linearly correlated
- Wildfire smoke will improve sensitivity of satellite retrieval

University of Nevada, Reno

Approach

- Collect MODIS satellite retrievals for *AOD*
- Collect NASA AERONET ground-based sunphotometry *AOD* data
- Collect $PM_{2.5}$ concentration data from monitoring networks
- Collect balloon sounding data
- UNR Photoacoustic and Integrated Nephelometer (PIN) measurements
- Evaluate spatial satellite retrivals for *AOD* using AERONET data
- Investigate atmospheric physics using balloon and PIN data

Cimel CE-318 Sun photometer



Photoacoustic and Integrated Nephelometer

Beta Attenuation Monitor ($PM_{2.5}$)

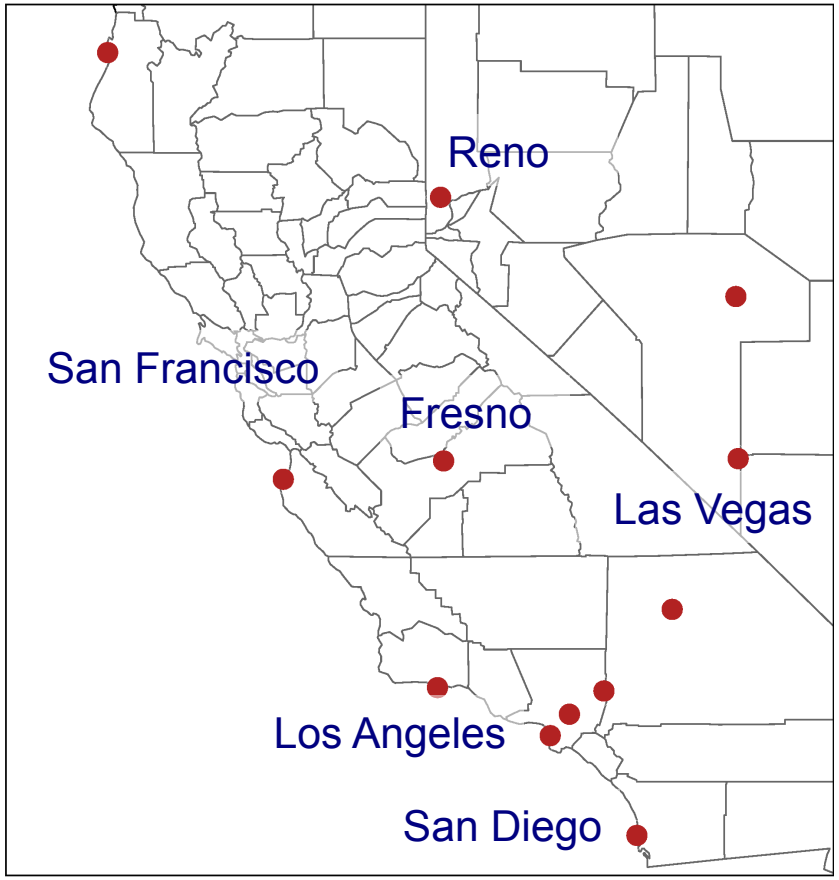
University of Nevada, Reno

Satellite Domain and *AOD* Monitors

Satellite Domain

- 10-km horizontal resolution
- One swath two times per day

AERONET Locations



- 12 *AOD* monitors
- Hourly data during daylight

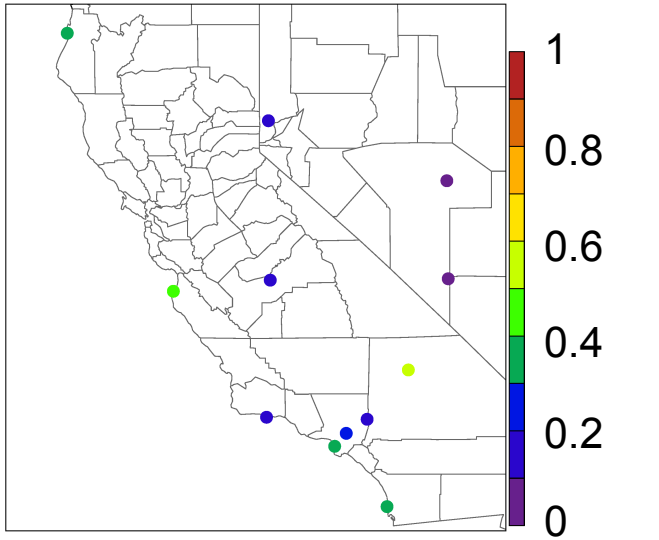
University of Nevada, Reno

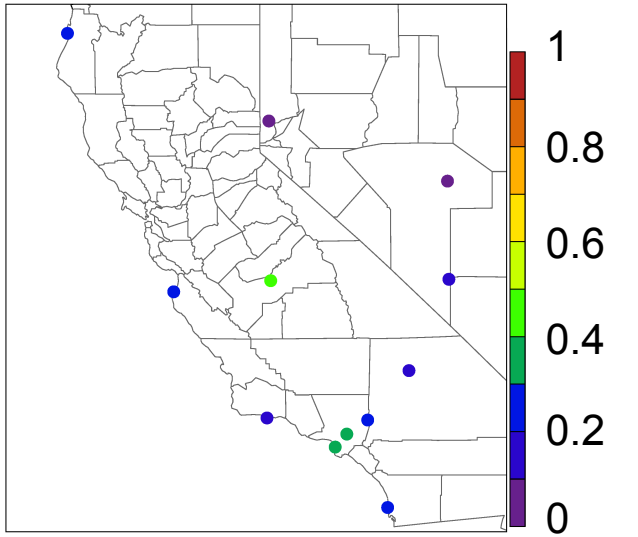
Spatial R^2 and Normalized Mean Bias (NMB)

Terra (AM): Three Years, Non-fire Periods

Dark Target | **Deep Blue**

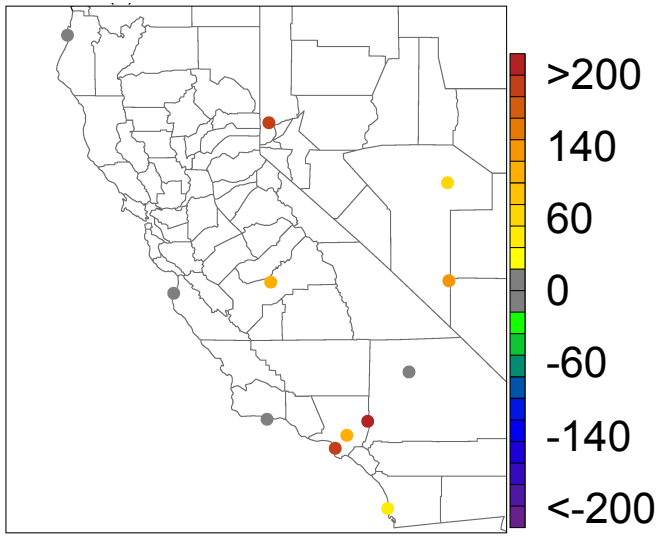
Correlation (R^2)

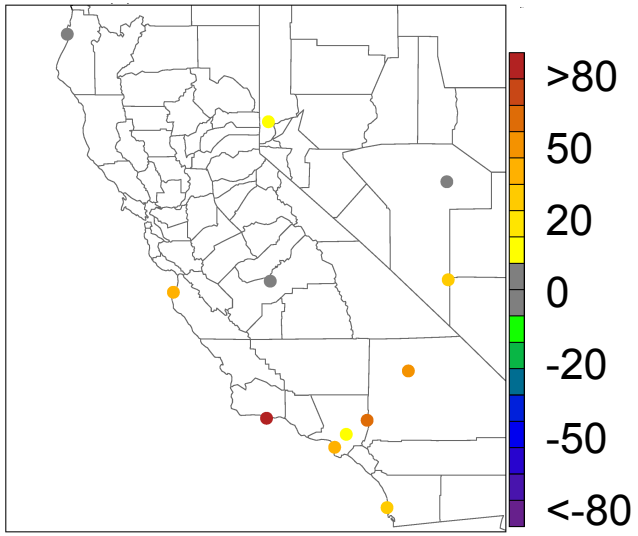




Bias (NMB %)

$$NMB = \frac{\sum_{1}^{n}(P - O)}{\sum_{1}^{n}(O)} * 100$$





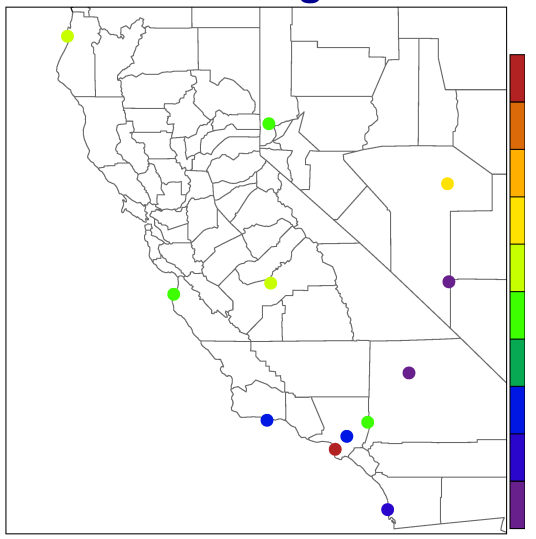
University of Nevada, Reno

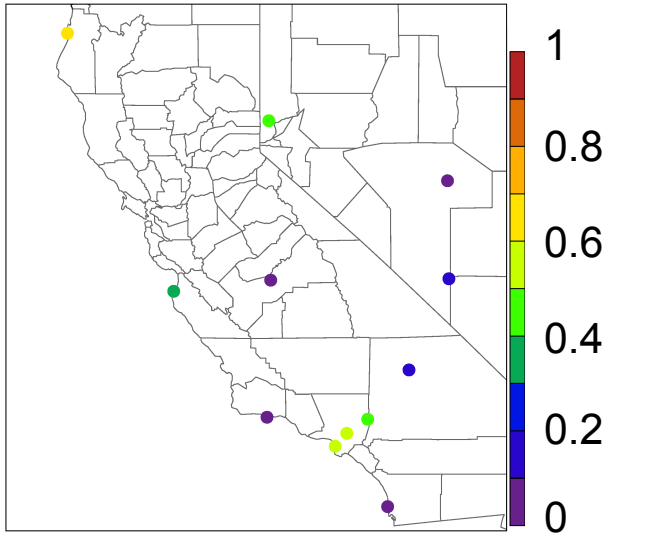
Spatial R^2 and Normalized Mean Bias (NMB)

Terra (AM): Three Years, Fire Periods

Dark Target | **Deep Blue**

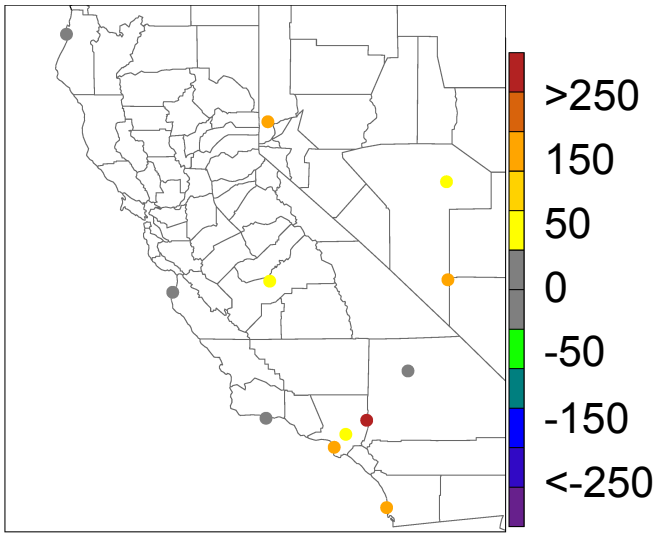
Correlation (R^2)

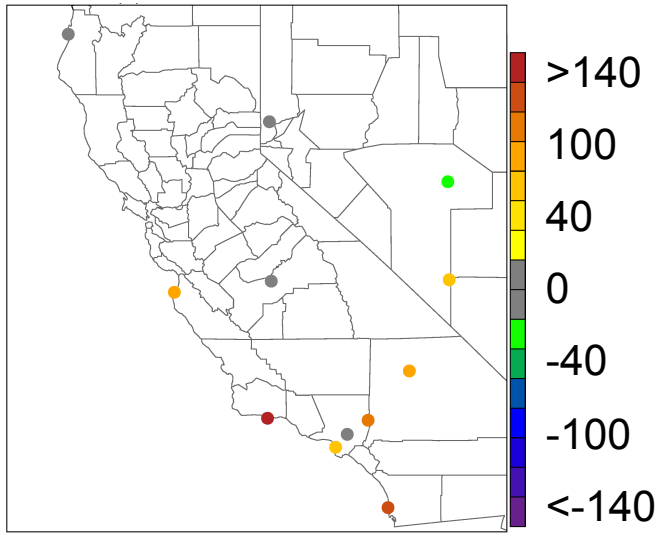




Bias (NMB %)

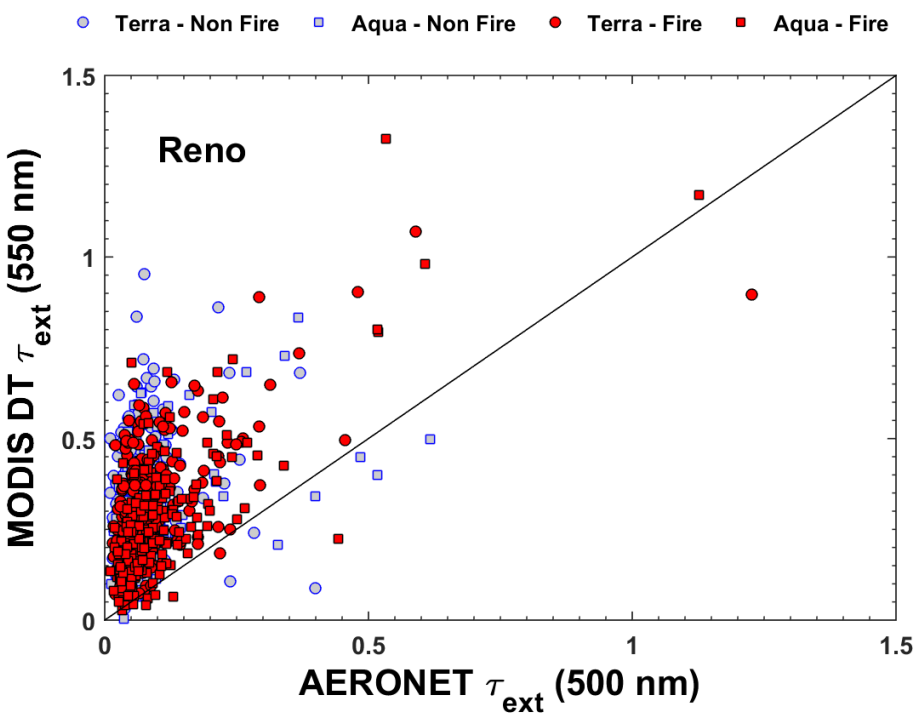
$$\mathrm{NMB} = \frac{\sum_{1}^{n}(P-O)}{\sum_{1}^{n}(O)} * 100$$



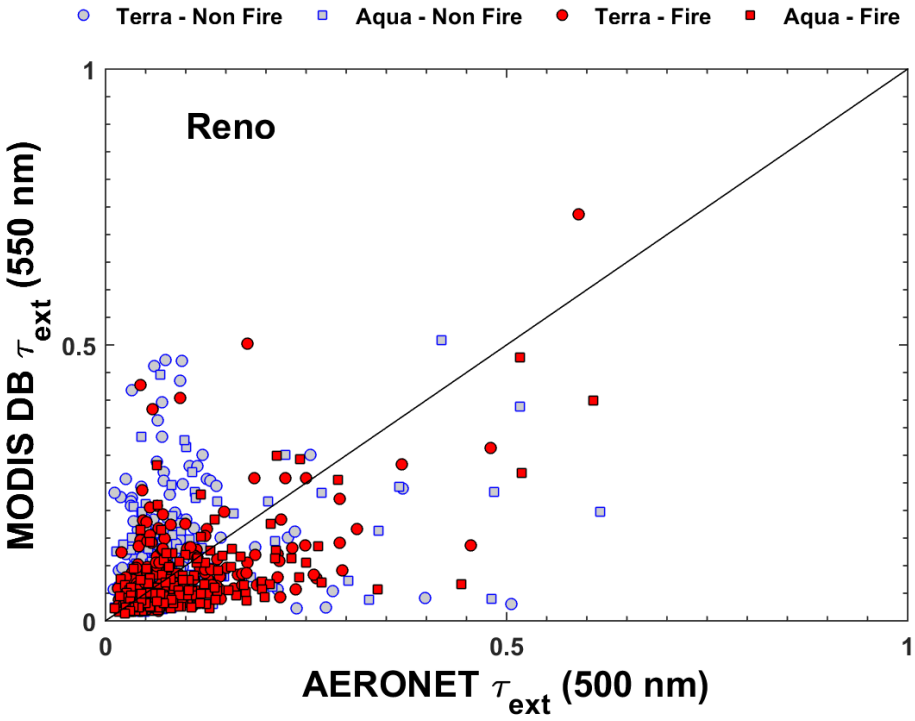


Reno: AERONET versus MODIS *AOD*

Dark Target



Deep Blue

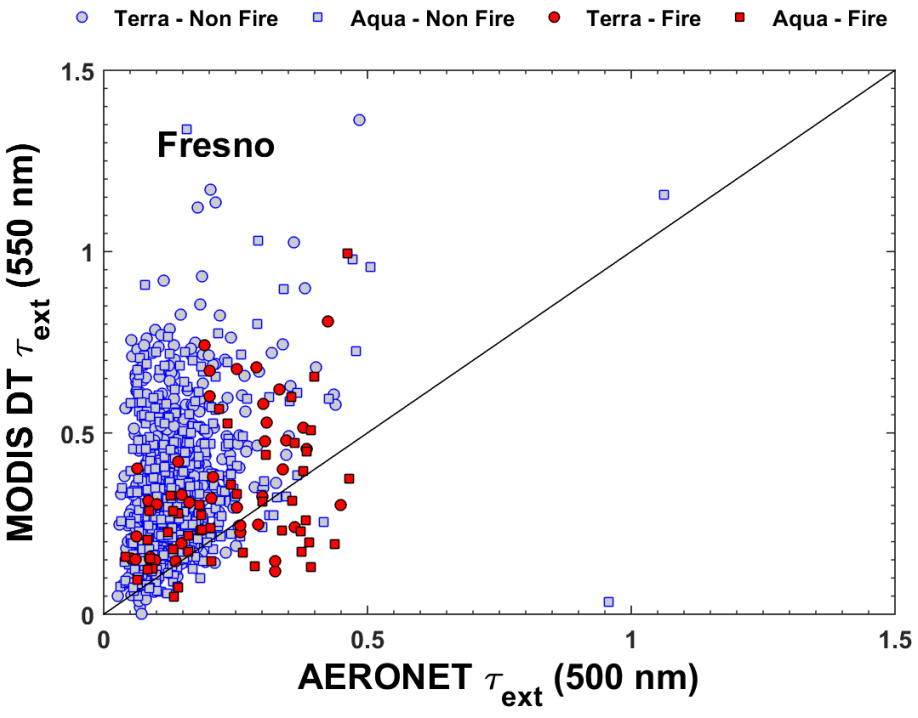


- Deep Blue for bright surfaces, Reno = Desert
- Deep Blue under predicts *AOD* for fire periods

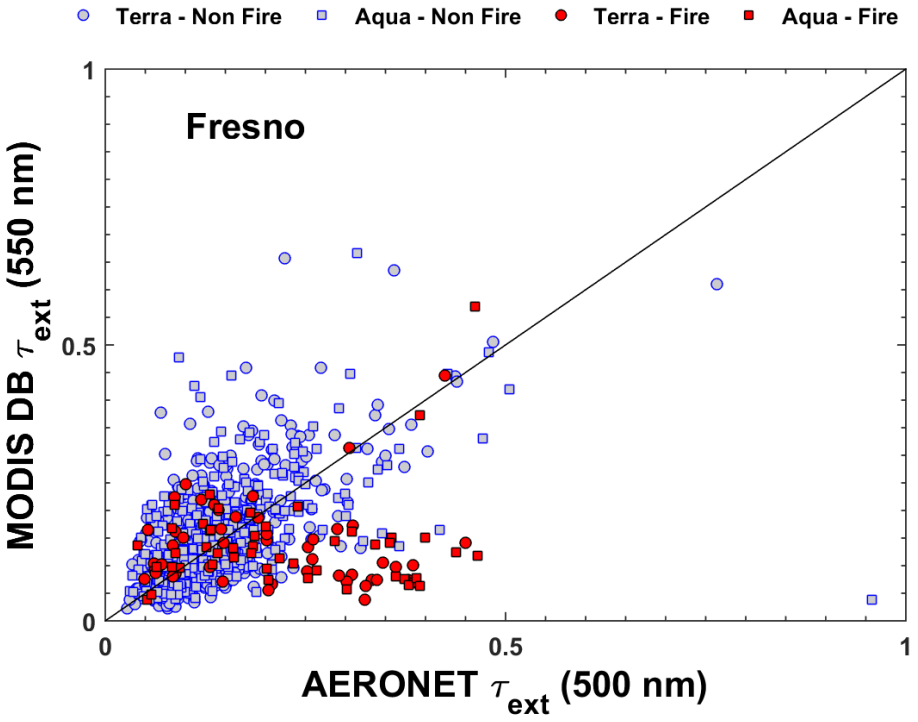
University of Nevada, Reno

Fresno: AERONET versus MODIS *AOD*

Dark Target

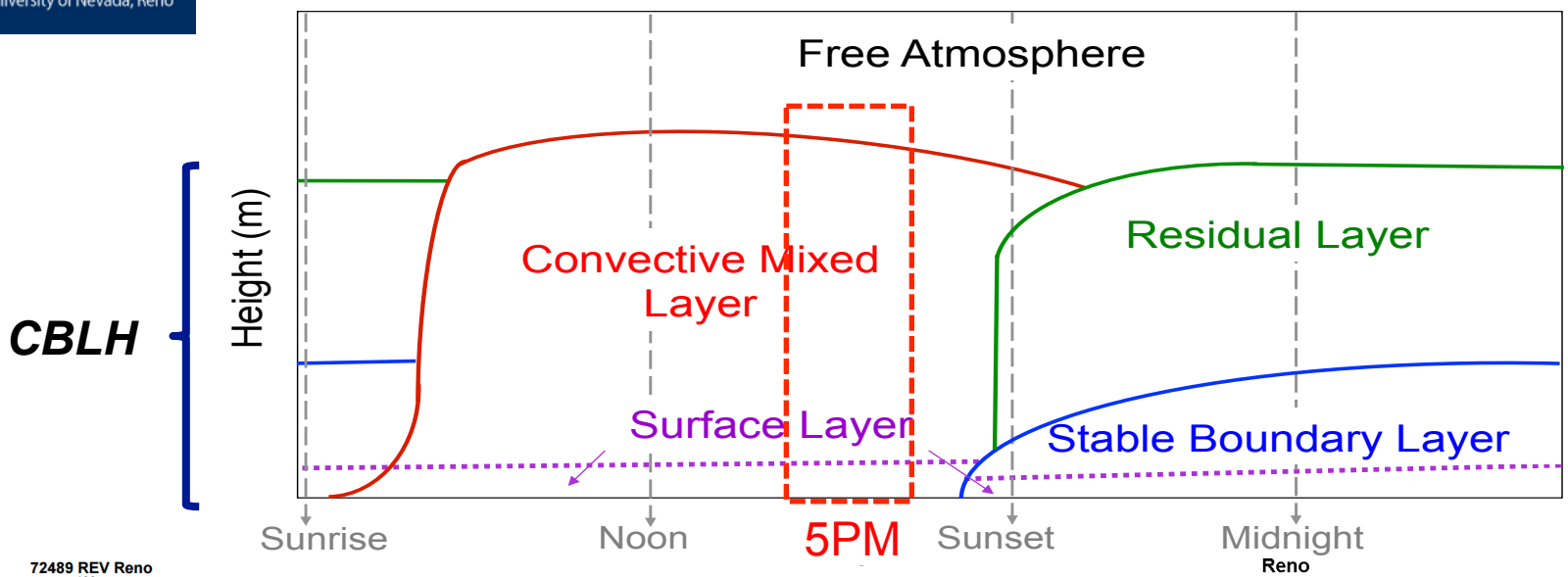


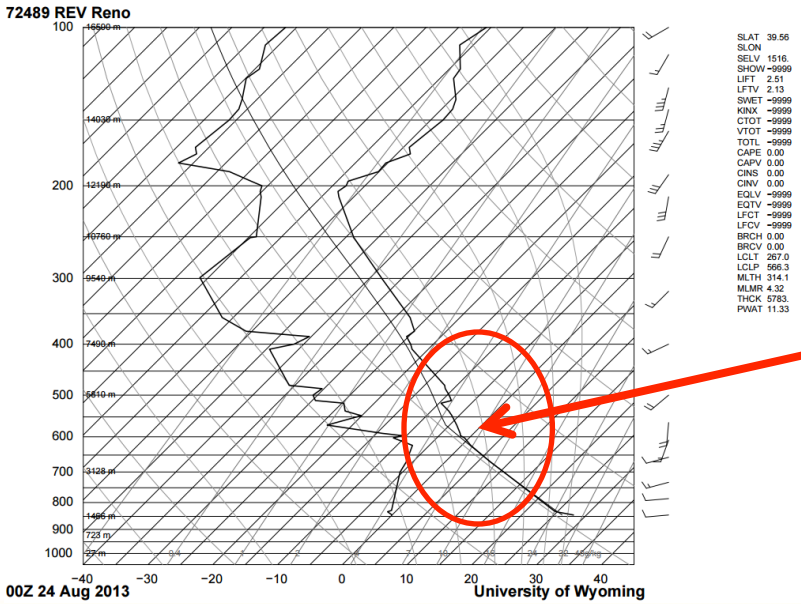
Deep Blue

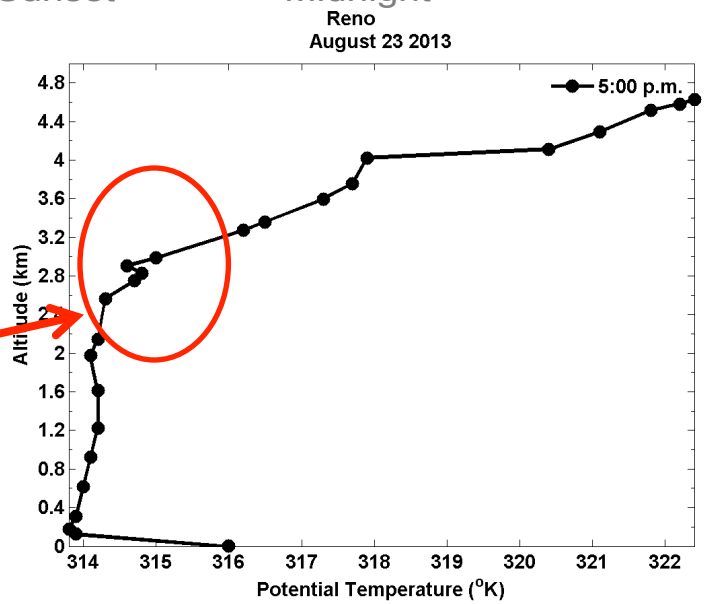


- Deep Blue better correlation, Fresno = Desert?
- Deep Blue under predicts *AOD* for fire periods

Convective Boundary Layer Height (*CBLH*)







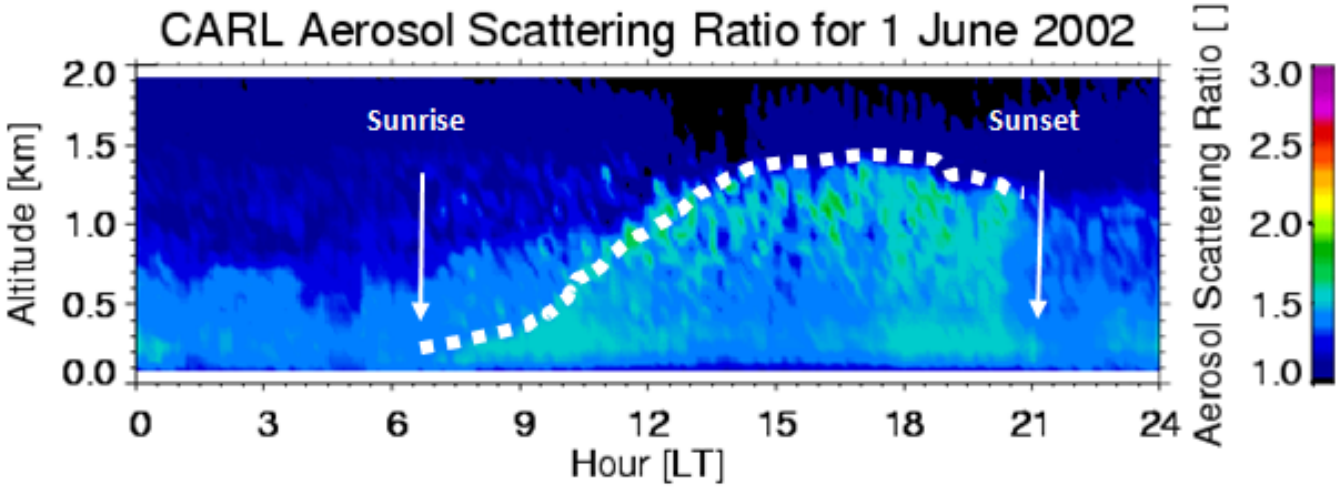
University of Nevada, Reno

Apparent Optical Height (*AOH*)

Estimates the height that aerosols can reach in the atmosphere

- In-situ photoaccoustic and reciprocal nephelometer: Surface β_{ext}
- Ground-based sunphotometry: Columnar *AOD* (τ_{ext})

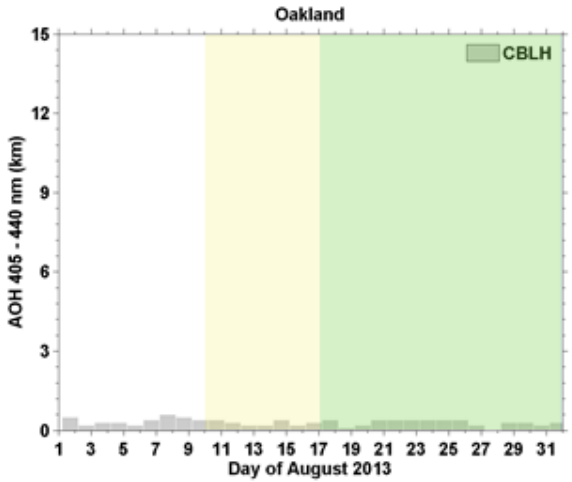
$$\mathrm{AOH}(\lambda) = \tau_{\mathrm{ext}}(\lambda)/\beta_{\mathrm{ext}}(\lambda)$$

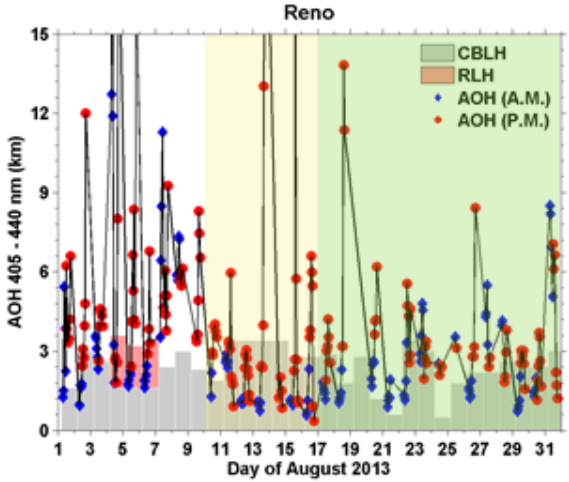


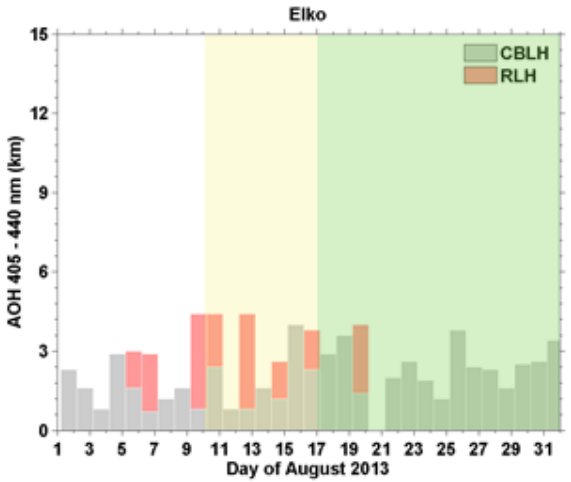
Raman Lidar Picture of the Convective Mixed Layer at the DOE ARM site in North Central Oklahoma. (Courtesy of Dr. David Turner)

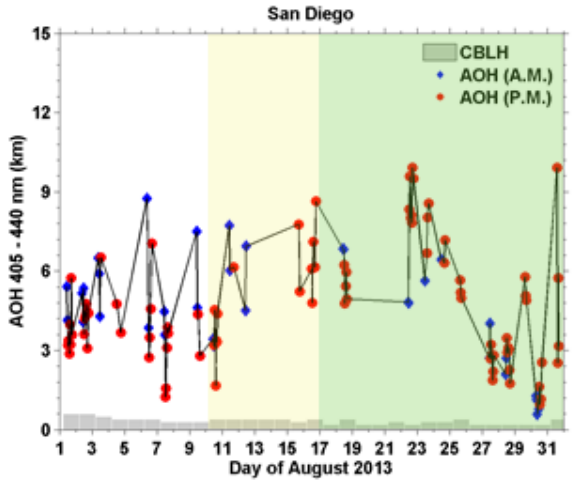
University of Nevada, Reno

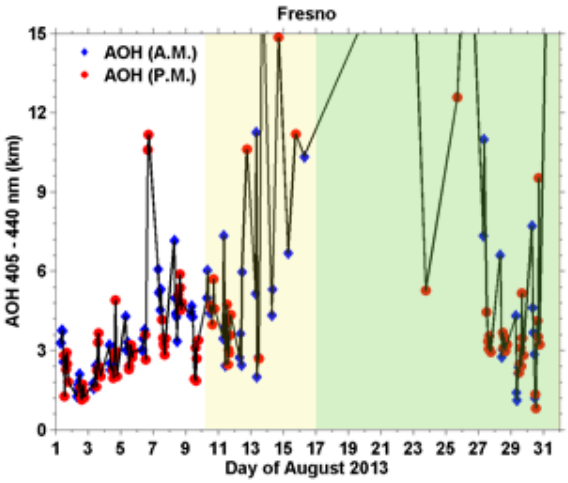
Vertical Profiles: *CBLH* and *AOH*

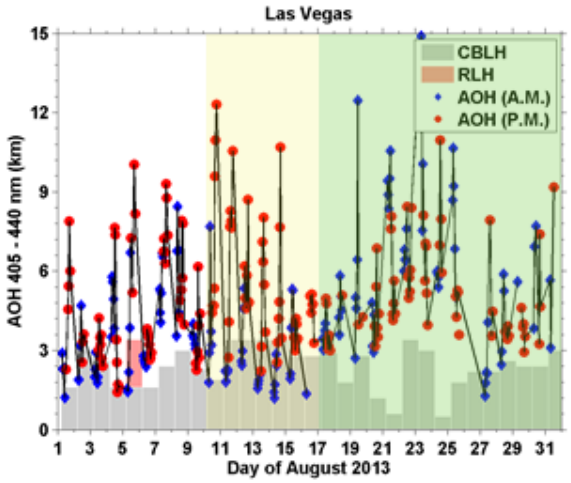








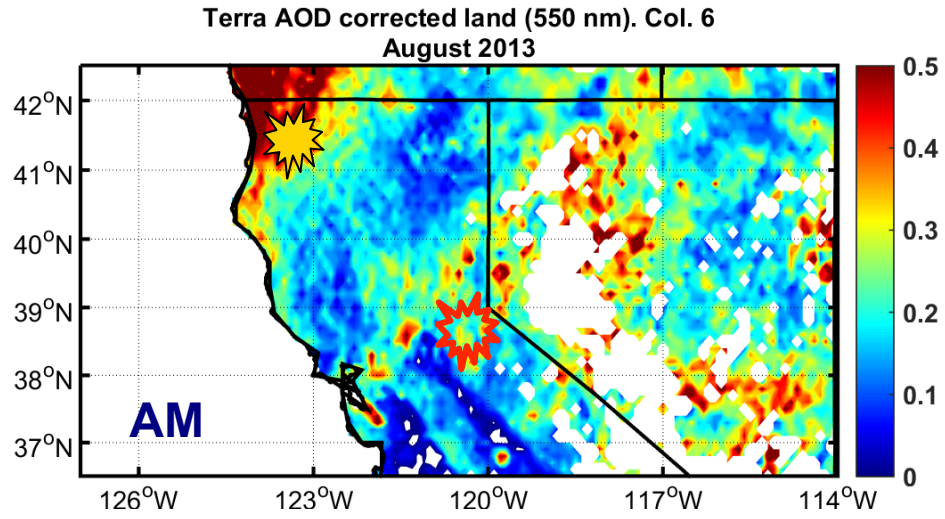


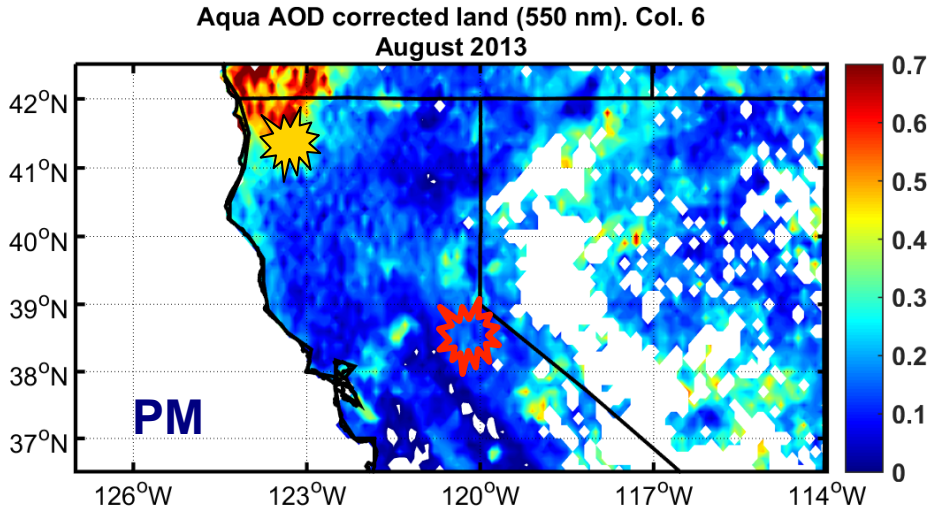


University of Nevada, Reno

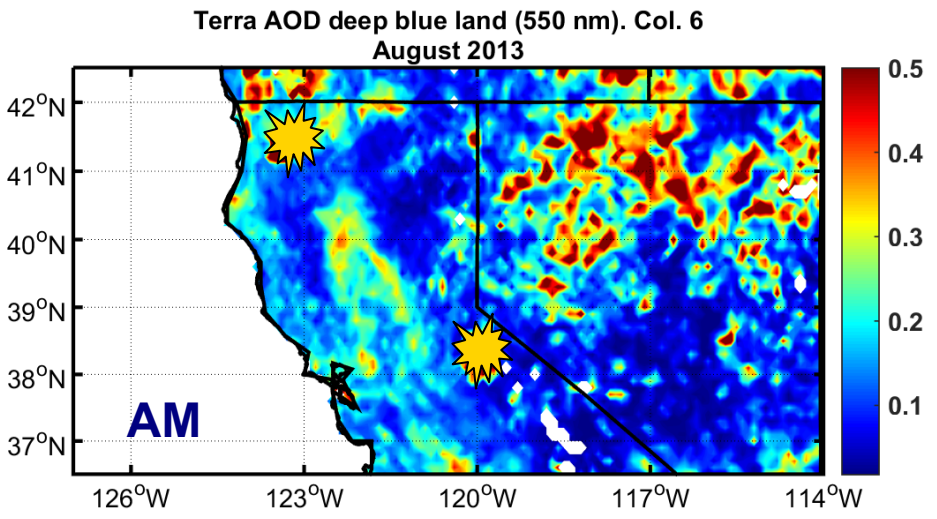
MODIS AOD: August 2013 - Rim Fire

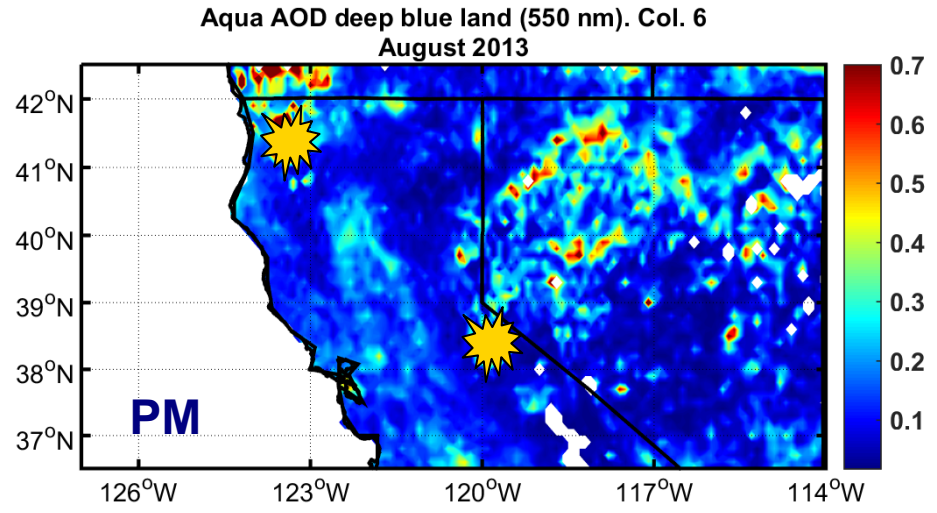
Dark Target





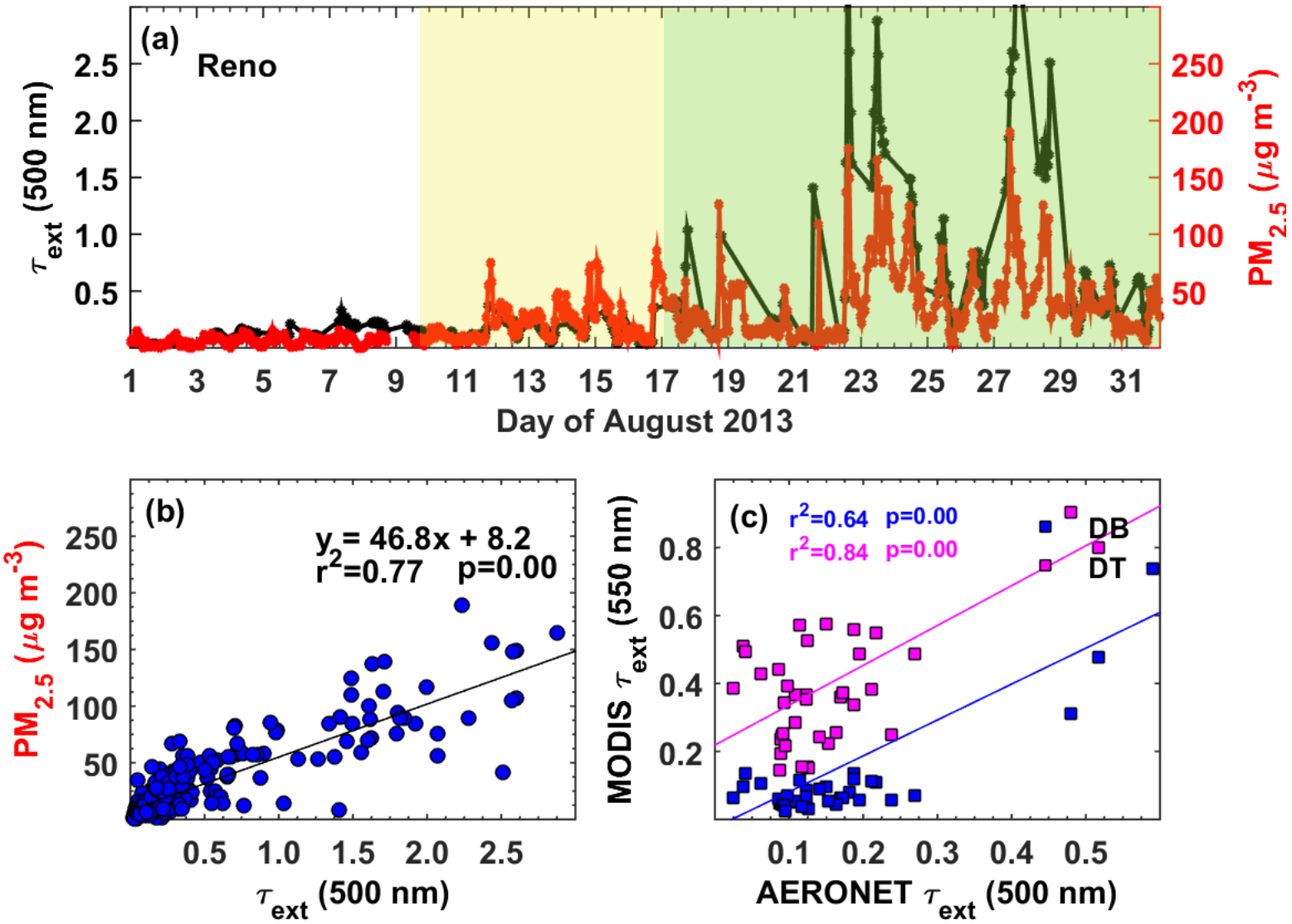
Deep Blue





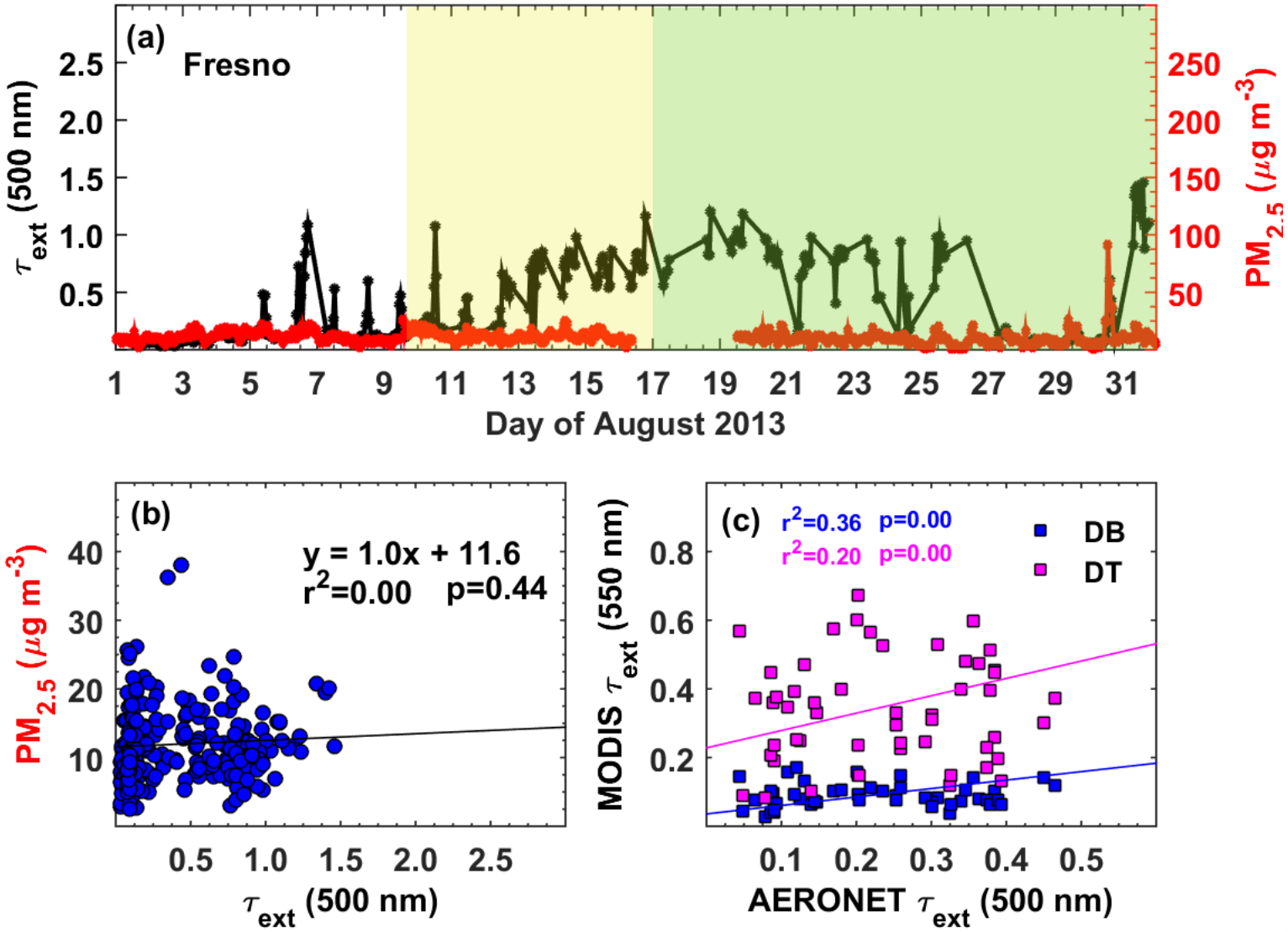
University of Nevada, Reno

Reno: $PM_{2.5}$, AERONET and MODIS *AOD*



University of Nevada, Reno

Fresno: $PM_{2.5}$, AERONET and MODIS *AOD*



University of Nevada, Reno

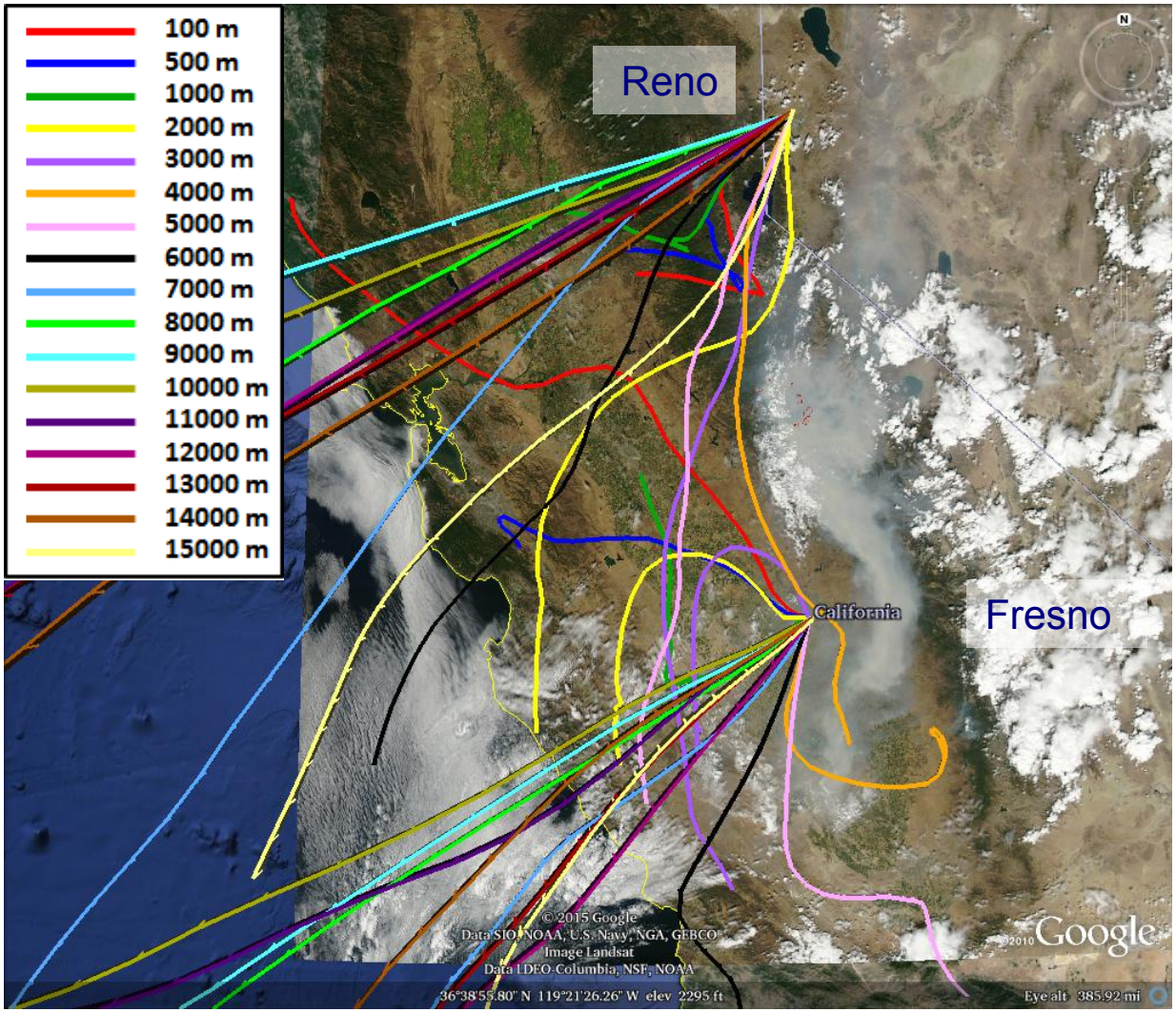
HYSPLIT Back Trajectories: 31 Aug 2013

24 hour, NAM 12-km

Reno:
100m & 2000m
near plume

Fresno:
4000m & 5000m
near plume

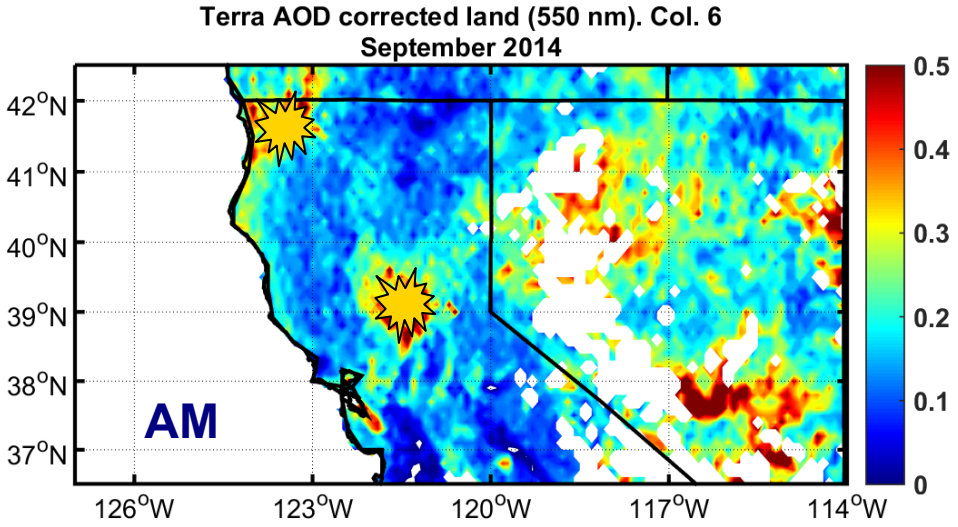
100m & 200m
west of plume,
clean air

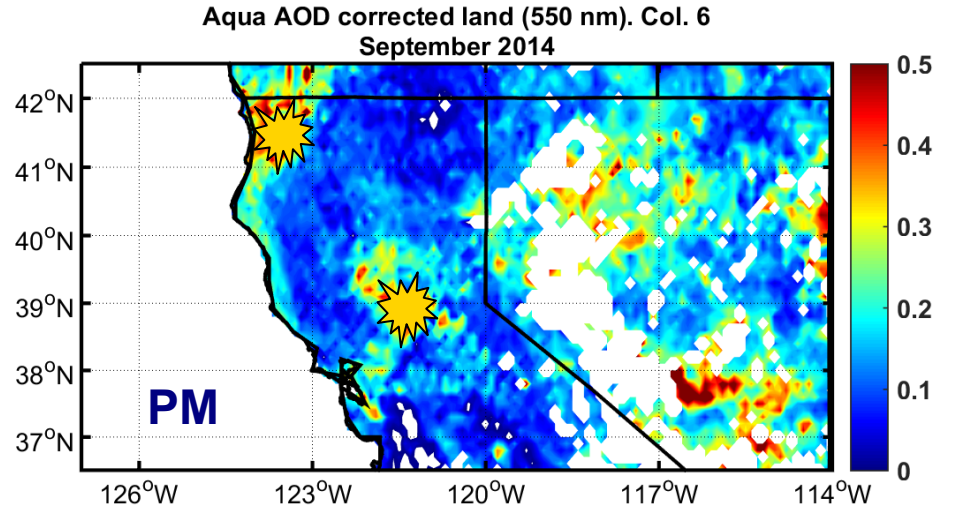


University of Nevada, Reno

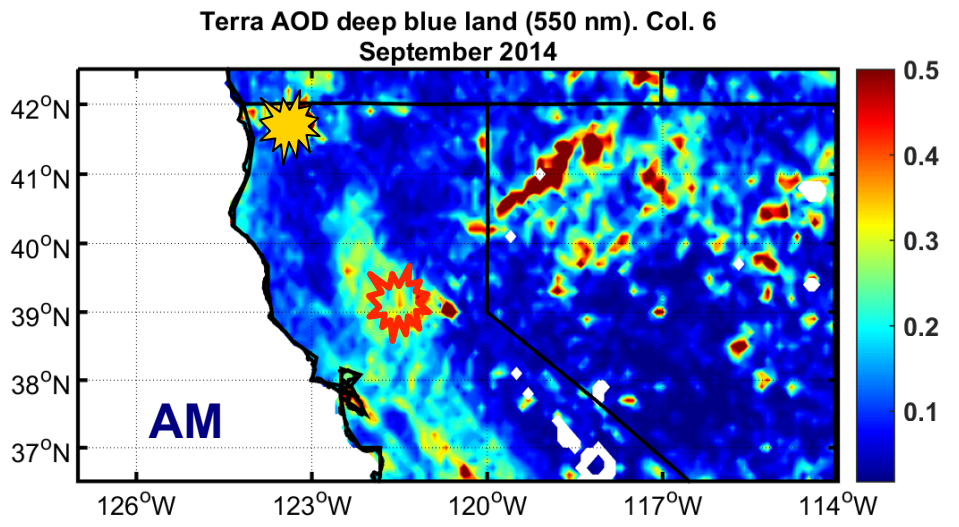
MODIS AOD: September 2014 - King Fire

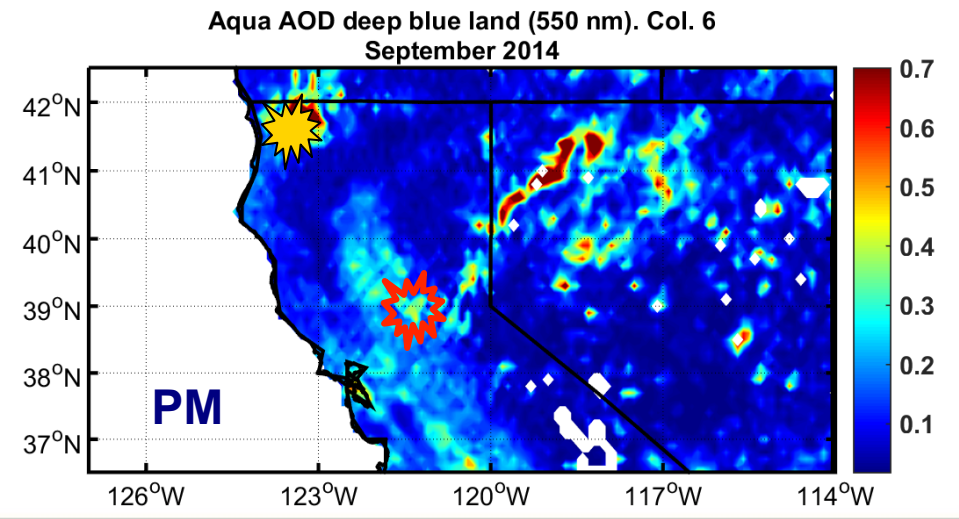
Dark Target





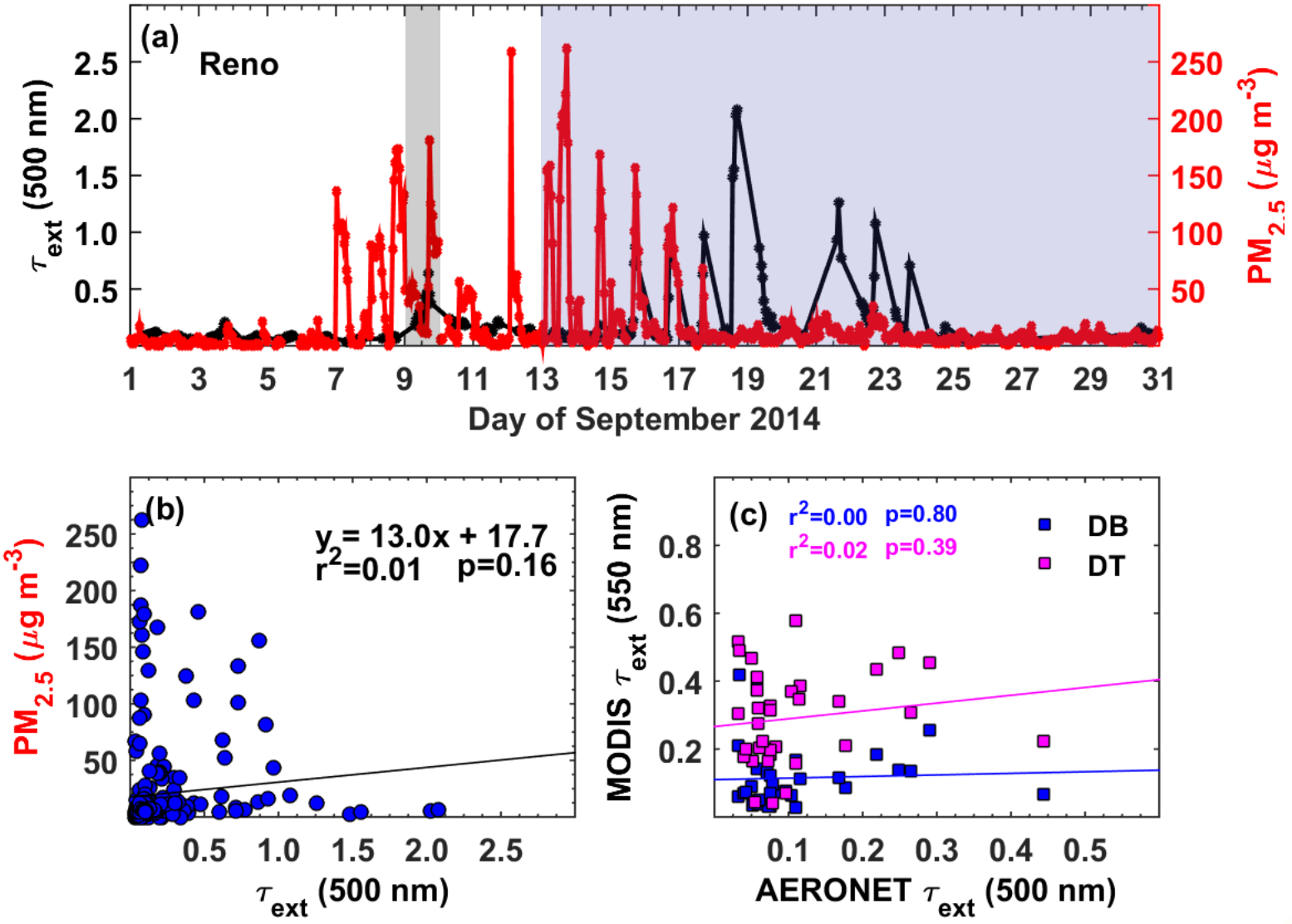
Deep Blue





University of Nevada, Reno

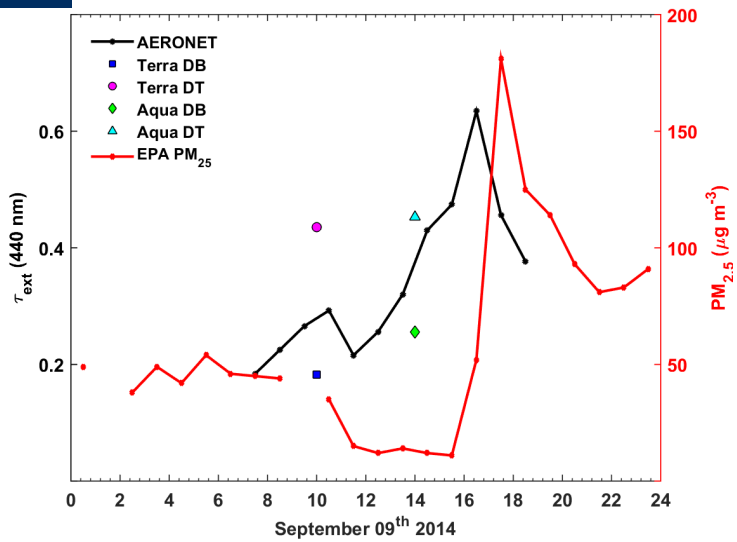
Reno: $PM_{2.5}$, AERONET and MODIS *AOD*

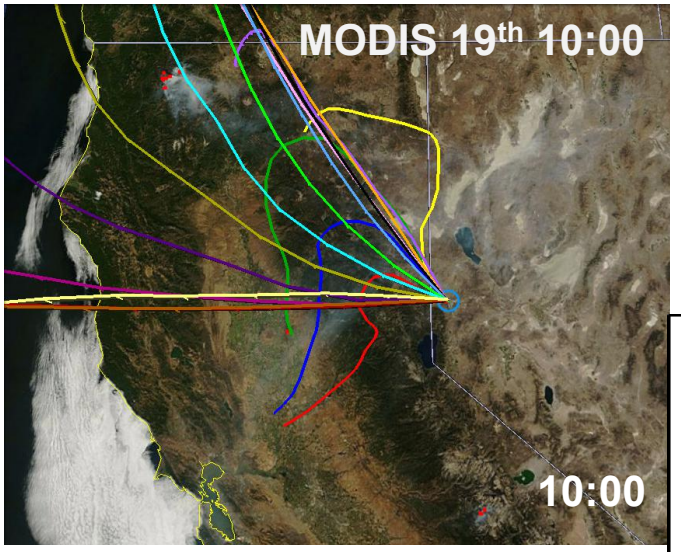


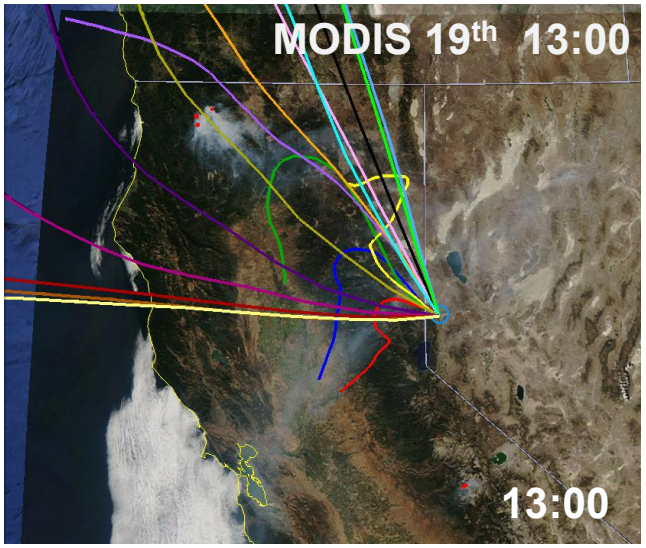
University of Nevada, Reno

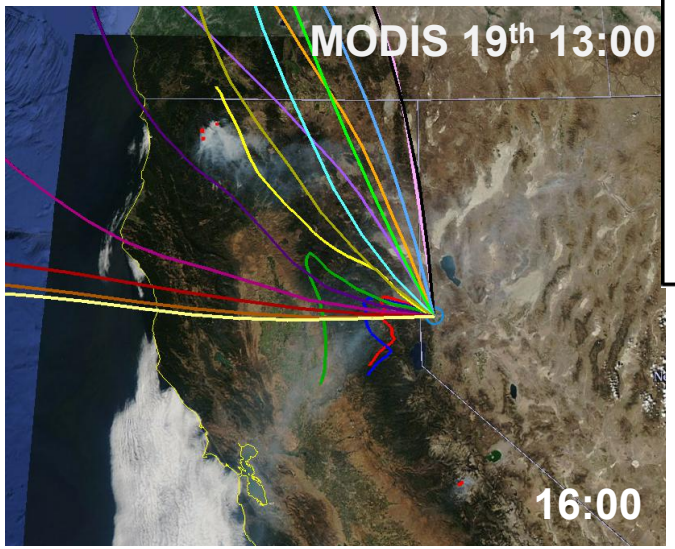
HYSPLIT Back Trajectories: 9 Sep 2014

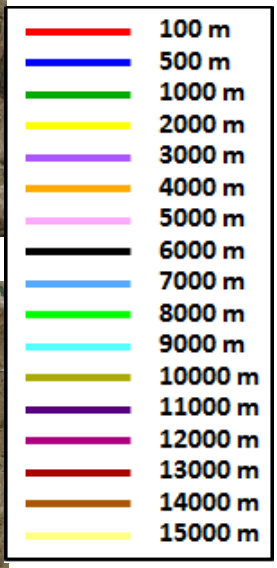
Reno 24 hour, NAM 12-km











University of Nevada, Reno

Conclusions

Summary

- *AOD* satellite retrievals have high uncertainty in the western U.S. due to complex terrain, bright surface, heterogeneous aerosol profiles
- Aerosols above the CBL, enhanced by smoke plume injection above CBL
- Wildfire smoke improves the correlation between AERONET & MODIS but does not improve the bias
- Surface $PM_{2.5}$ is not linearly correlated with columnar *AOD*

Future Directions

- Data fusion of MODIS *AOD* and $PM_{2.5}$ observations, with and without calibration using AERONET to estimate surface $PM_{2.5}$ [AGU]
- Statistically quantify uncertainties in MODIS *AOD* using AERONET data, and attribute to parameterizations in retrieval algorithm [AGU]
- Use spatial surface $PM_{2.5}$ concentrations to estimate wildfire smoke exposure in California and Nevada