Evaluation of Novel NASA Aerosol Fire Products Over Extreme Fire Events in the Semi-Arid Western U.S.

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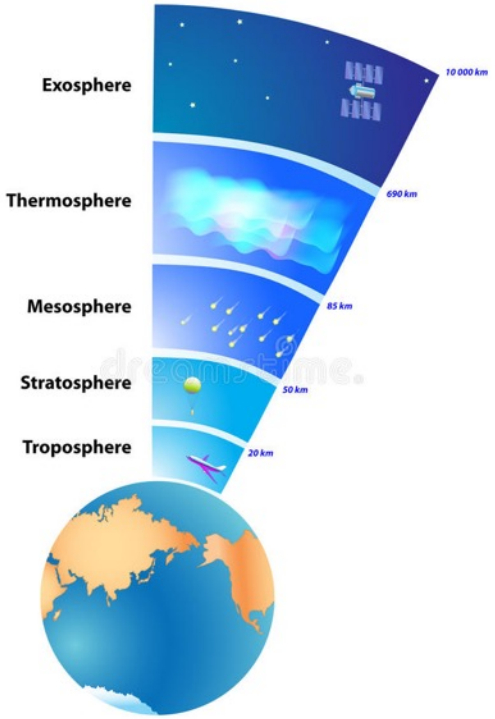
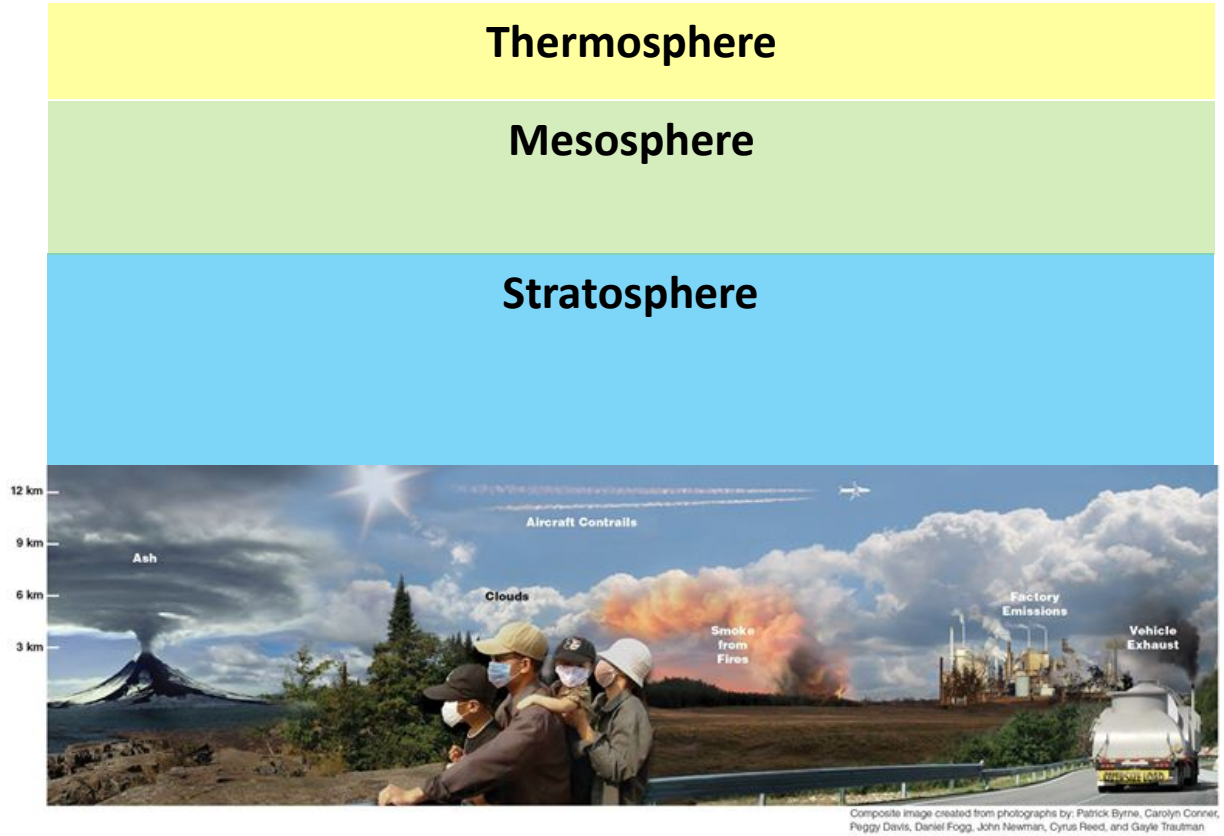
NOAA ESRL Global Monitoring Annual Conference 2019
Boulder, Colorado, USA

Motivation

Composite image created from photographs by: Patrick Byrne, Carolyn Conner, Peggy Davis, Daniel Fogg, John Newman, Cyrus Reed, and Gayle Trautman

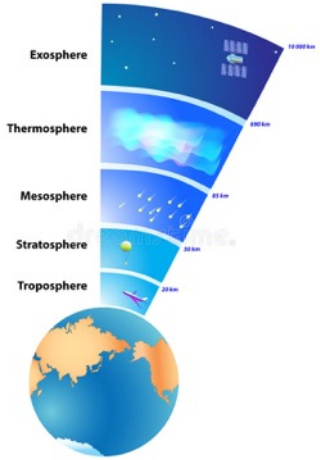
Motivation


Exosphere
10 000 km
Thermosphere
690 km
Mesosphere
85 km
Stratosphere
50 km
Troposphere
20 km


Thermosphere
Mesosphere
Stratosphere
12 km
9 km
6 km
3 km
Ash
Aircraft Contrails
Clouds
Smoke from Fires
Factory Emissions
Vehicle Exhaust
Composite image created from photographs by: Patrick Byrne, Carolyn Conner, Peggy Davis, Daniel Fogg, John Newman, Cyrus Reed, and Gayle Trautman

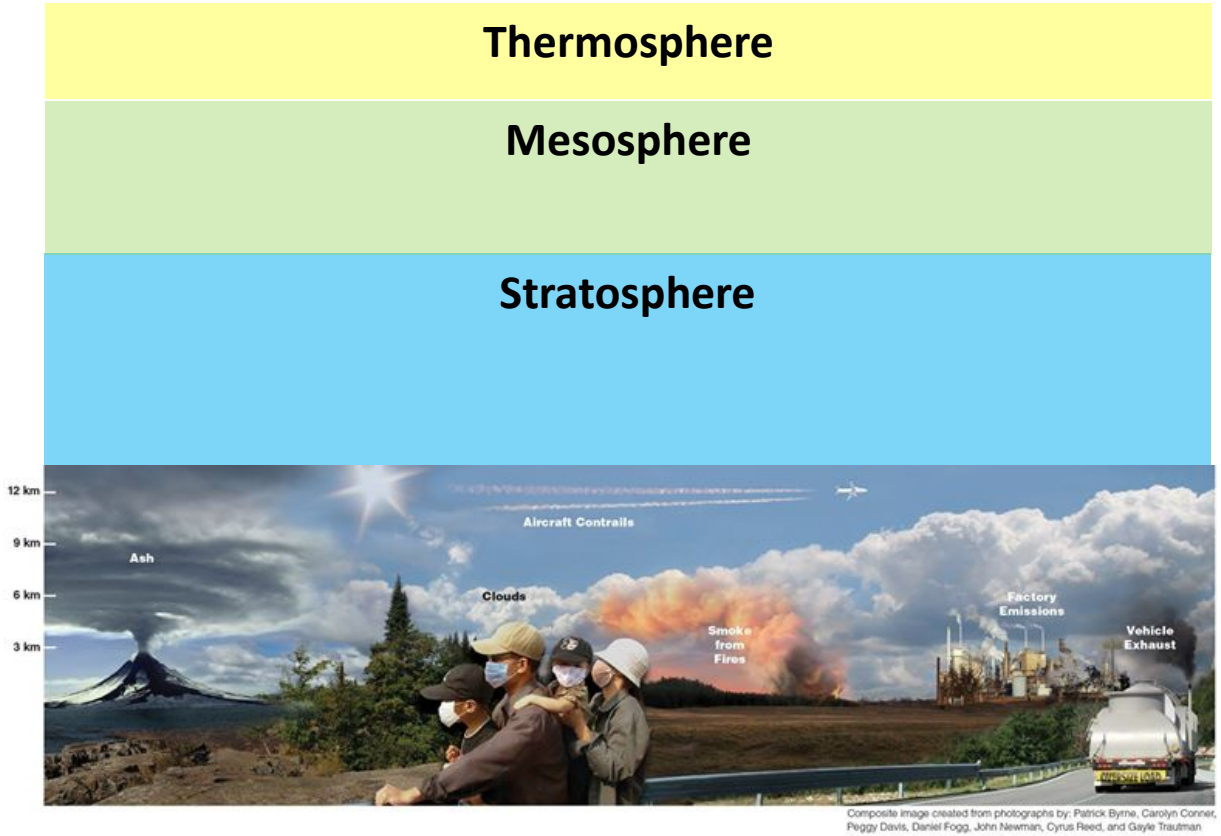
Motivation

Columnar AOD



Similar but different!

EPA
Surface $PM_{2.5}$



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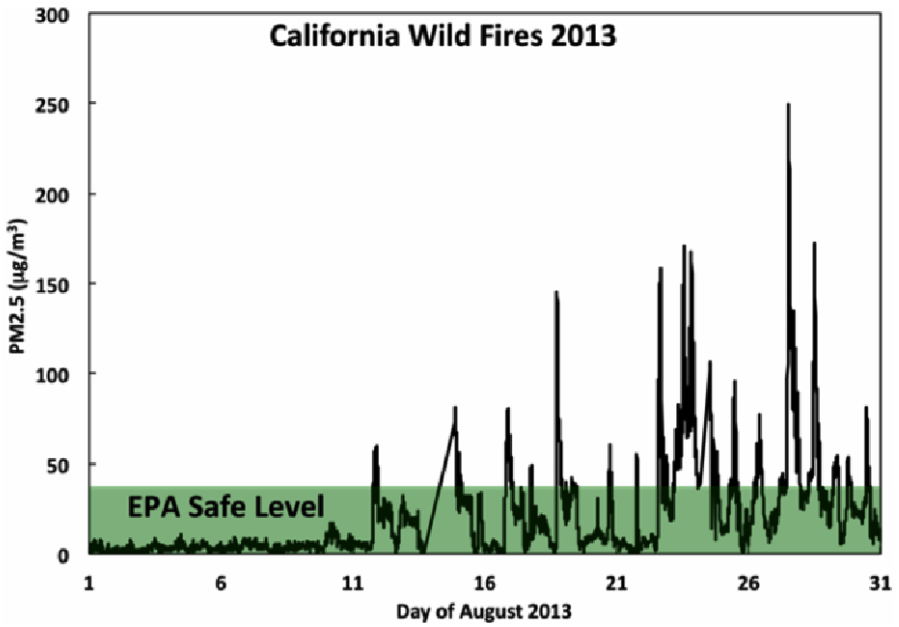
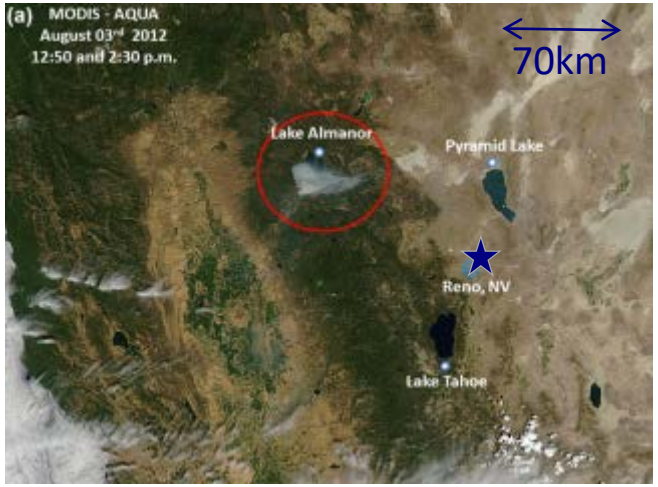
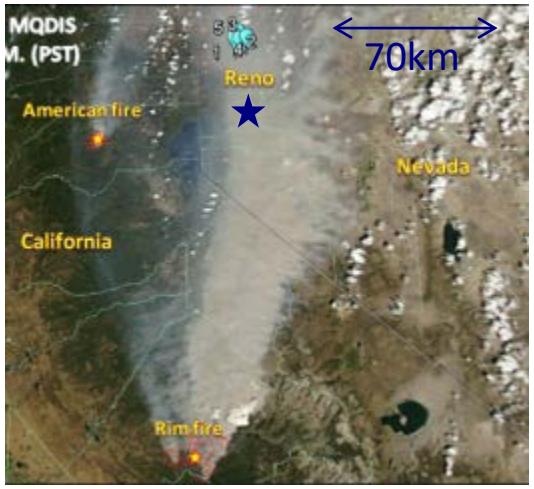


- Human health impacts of wildfire smoke exposure
- Visibility and radiative forcing impacts for climate
- Increasing drought conditions in western U.S. = more fires

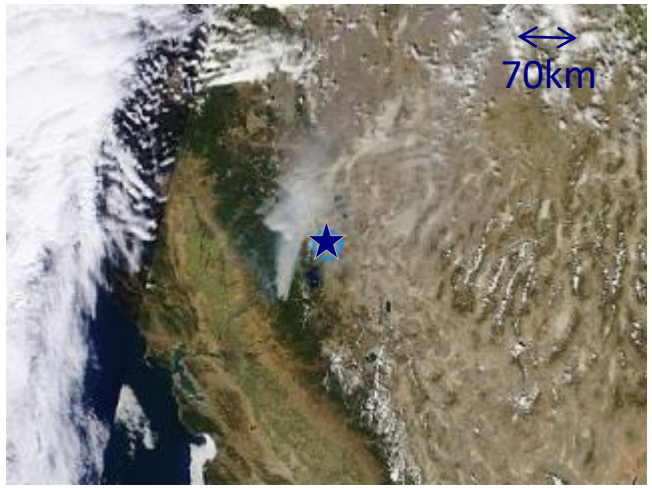
Motivation



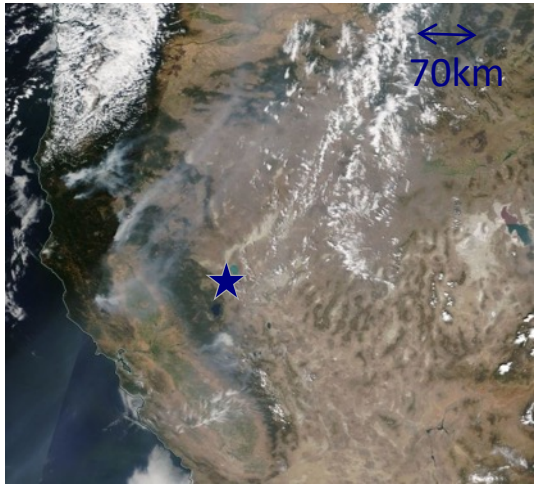
Chips Fire 2012
Aqua 3 Aug 2012



Rim Fire 2013
Aqua 22 Aug 2013



King Fire 2014
Terra 17 Sep 2014



Apocalyptical 2018
Terra 11 Aug 2018

Uncertainties in satellite-derived aerosol optical depth (AOD) from Deep-Blue and MAIAC

- **Uniformly mixed aerosols of homogeneous composition**
- **All aerosols are contained within the boundary layer**
- **Complicated transport over irregular terrain**
- **Surface reflectance issues over heterogeneous surfaces and complex topography**

Loría-Salazar et al., (2016)

Objective and Hypotheses

Objectives

1. Evaluate aerosol satellite retrievals during fires and non-fire periods using new NASA Deep-Blue Collection 6.1 and MAIAC algorithms
2. Evaluate Plume Injection Height products from NASA ASHE and MAIAC algorithms against ground-based LIDAR during the Yosemite Rim Fire (2013)
3. Create a Air Quality Fire Ratio (AQFR) using satellite-derived plume injection height (PIH) and planetary boundary layer depth (PBLH) from WRF

Hypotheses

1. Improvement on fire detection on the new Collection 6.1 Deep-Blue
2. Satellite-derived PIH is able to capture the plume top
3. The AQFR helps to diagnose surface-levels of aerosol pollution from smoke aloft

Measurements and retrievals

Aerosol Optical Depth (AOD)

- AERONET (Ground-based sun photometer)
- MODIS Deep Blue (DB) best (10 km x 10 km resolution)
- Multi-Angle Implementation of Atmospheric Correction (MAIAC) (1 km x 1 km resolution)

Plume injection height from MODIS

- Aerosol Single Scattering Albedo and Height Estimation (ASHE)
- MAIAC

LIDAR

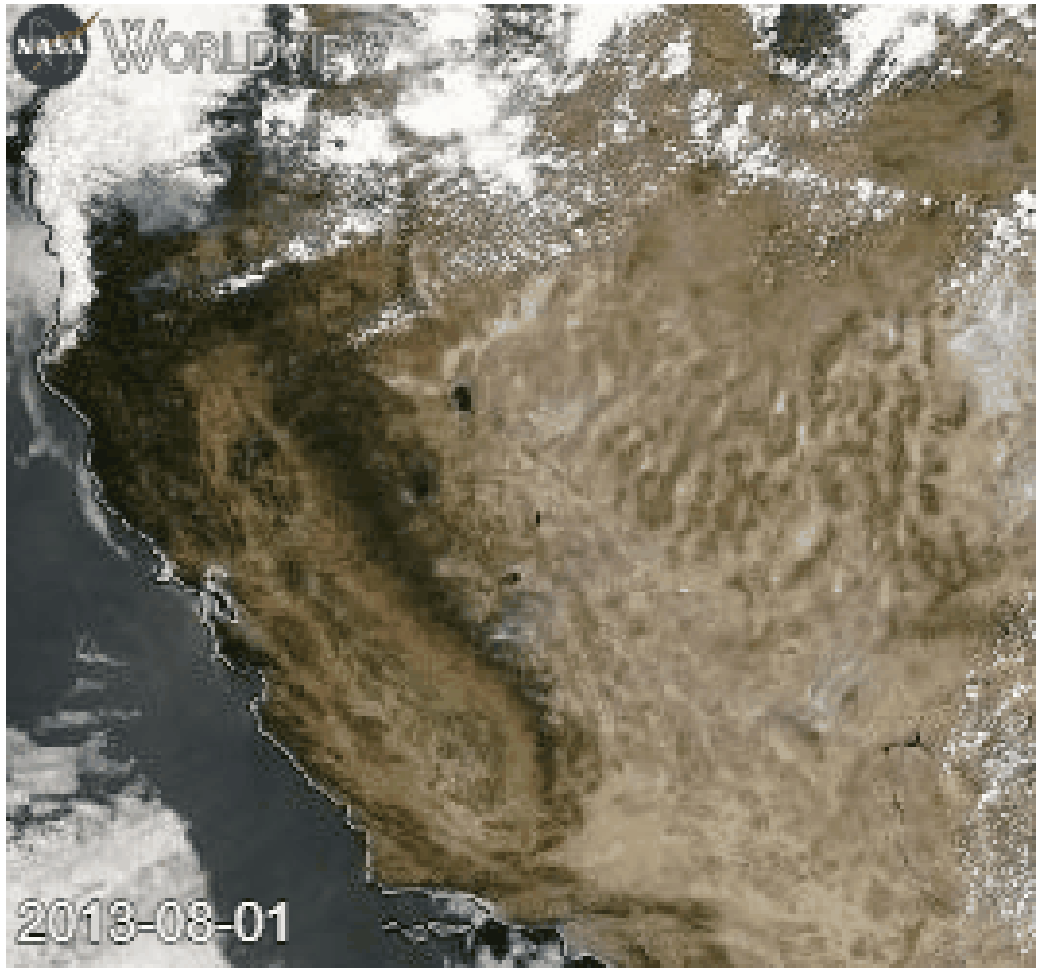
- Ground-based measurements

Weather Forecast Research (WRF) numerical model

- 12 km x 12 km horizontal resolution

Improvement DB and MAIAC AODs

Fire season, August, 2013



Study case:

- August, 2013
- Multiple fires (e.g. Yosemite Rim Fire)

MODIS DB C6.1 (?) (Pi: Christina Hsu, PhD)

- Improvement in fire detection
- Reduction in the impact of surface reflectance in the AOD

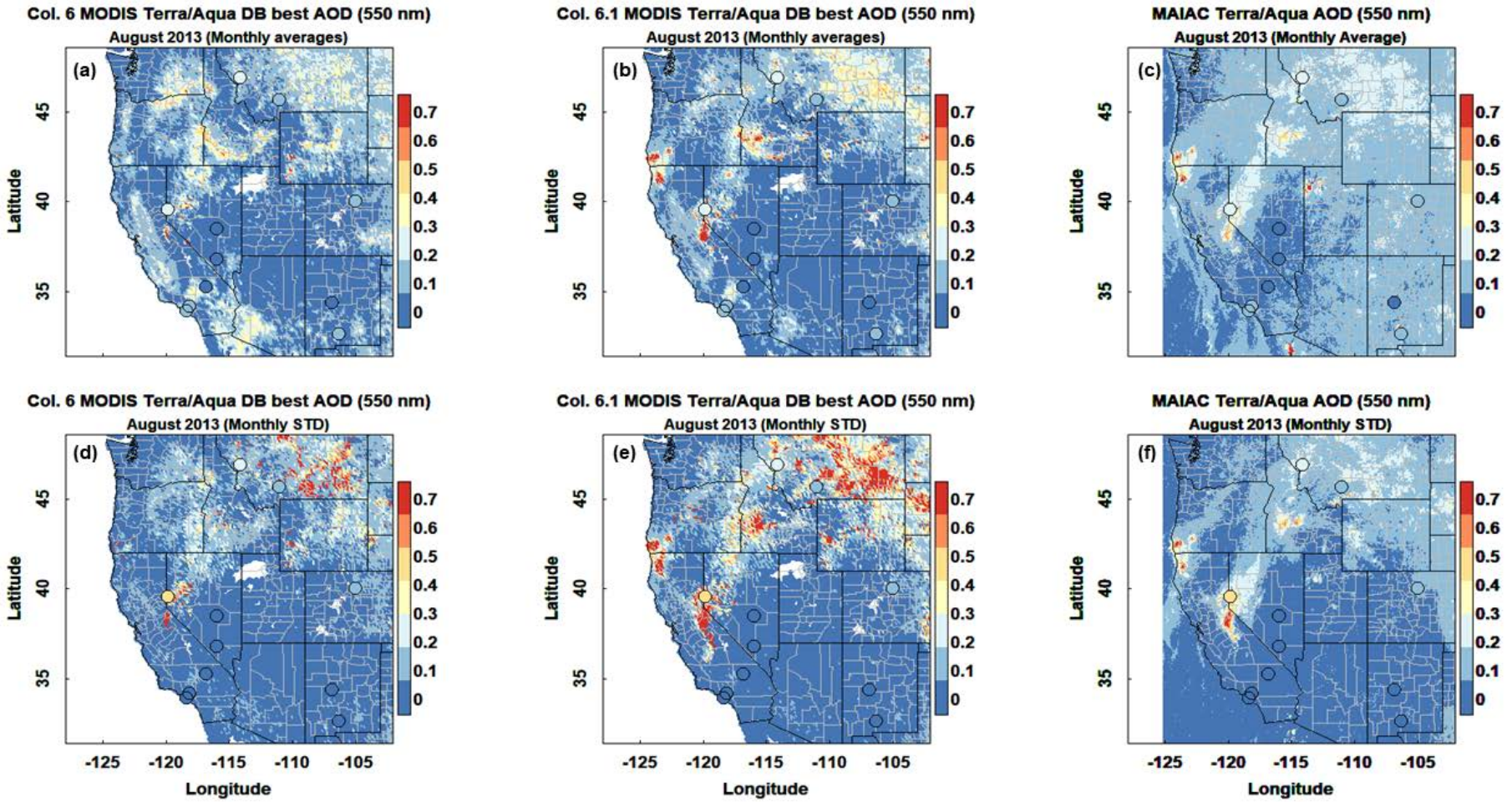
MAIAC (?) (Pi: Alexei Lyapustin, PhD)

- High-resolution AOD (1-km)
- Plume injection height
- Better characterization of surface reflectance in the AOD

Loria-Salazar et al., (submitted, JGR)

Improvement C6.1 and MAIAC AODs

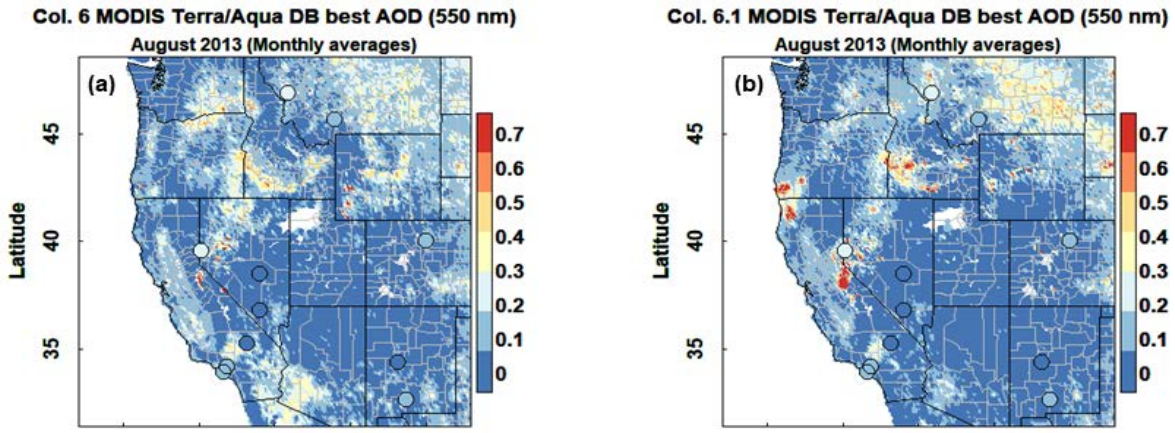
Western U.S., August, 2013



Loria-Salazar et al., (submitted, JGR)

Improvement in AOD: DB

Western U.S., August, 2013



Results:

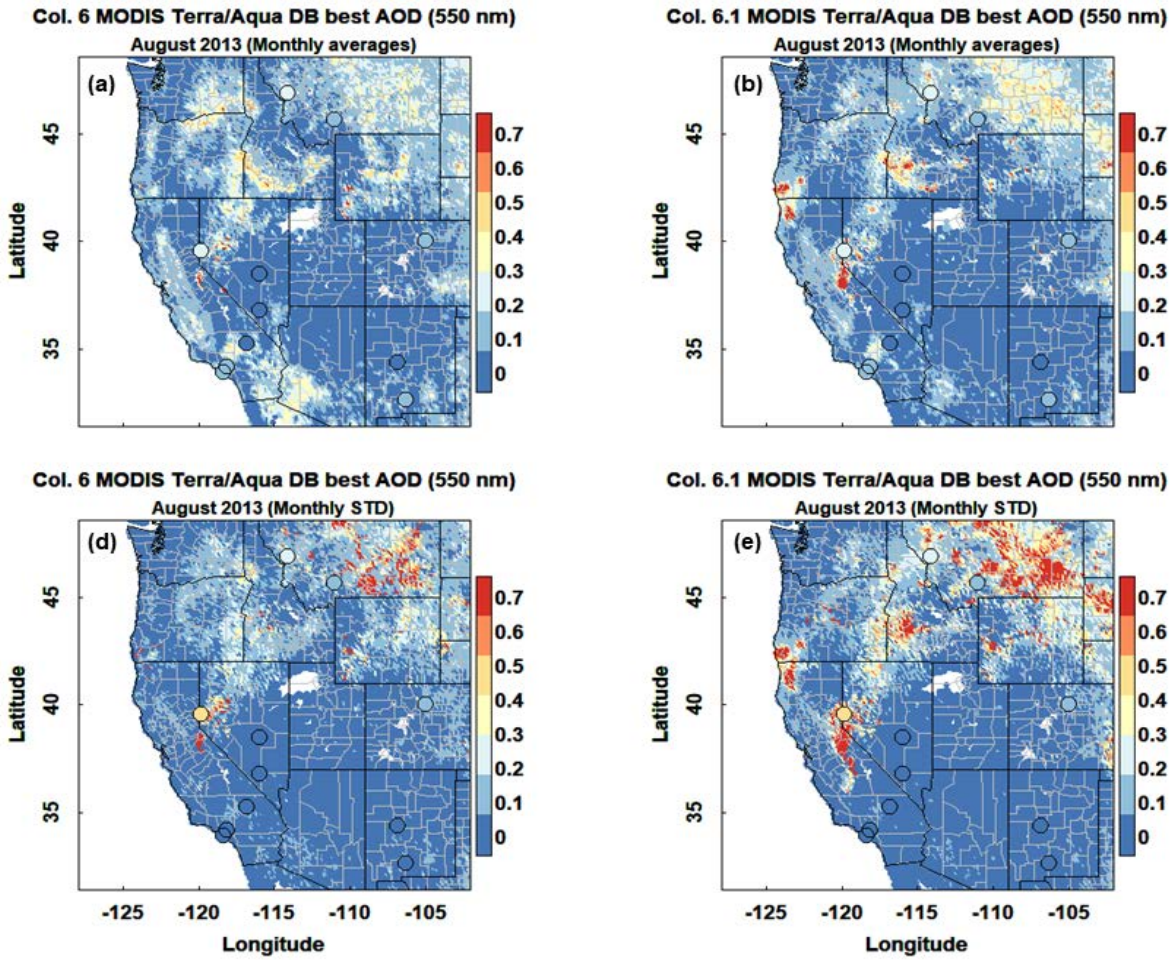
- C6 (r^2 ~0.62; p <0.01)
- C6.1 (r^2 ~0.75; p <0.01)
- Fire detection **(?)**
- Albedo **(?)**

Improvement

Loria-Salazar et al., (submitted, JGR)

Improvement in AOD: DB

Western U.S., August, 2013



Results (Fires):

- High STDs in AOD help to detect fire activity

Results (Albedo):

- Low STDs in AOD help to detect areas of albedo issues

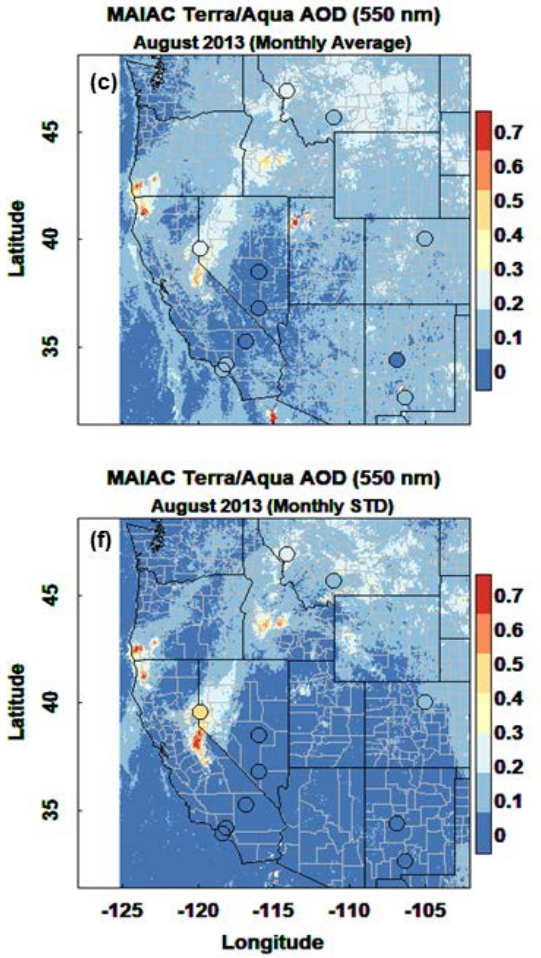
Loria-Salazar et al., (submitted, JGR)

Improvement in AOD: MAIAC

Western U.S., August, 2013

Results:

- MAIAC (r^2=0.85, p <0.01)
- **Limitations** to retrieve AOD over fire periods (underestimation).
- Low STDs in AOD help to detect areas of albedo issues



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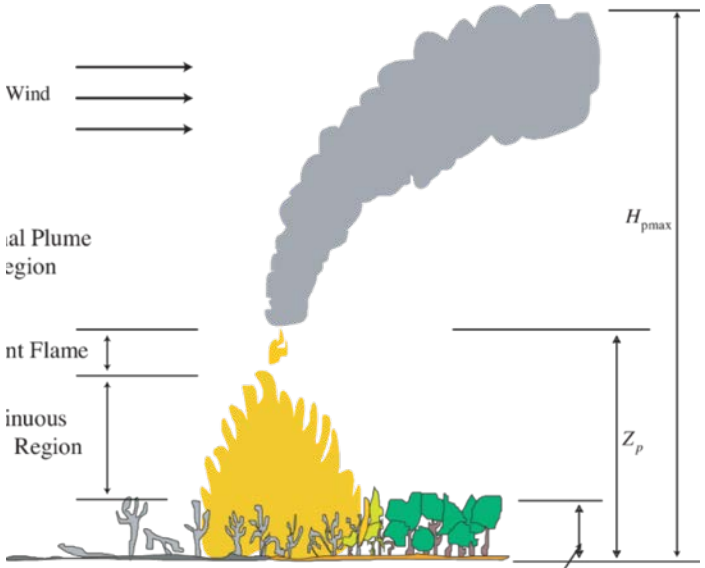
Plume Injection Height

Overview

PIH Definition



Effect of wildfire-induced thermal bubble on radio communication - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/Vegetation-fire-plume-in-a-slight-wind_fig1_242080522 [accessed 14 Nov, 2018]

Yosemite Rim fire August 2013

https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3845868.pdf

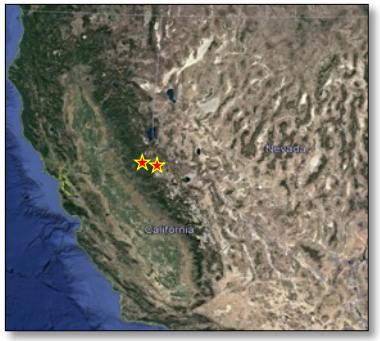
Yosemite Rim fire August 2013

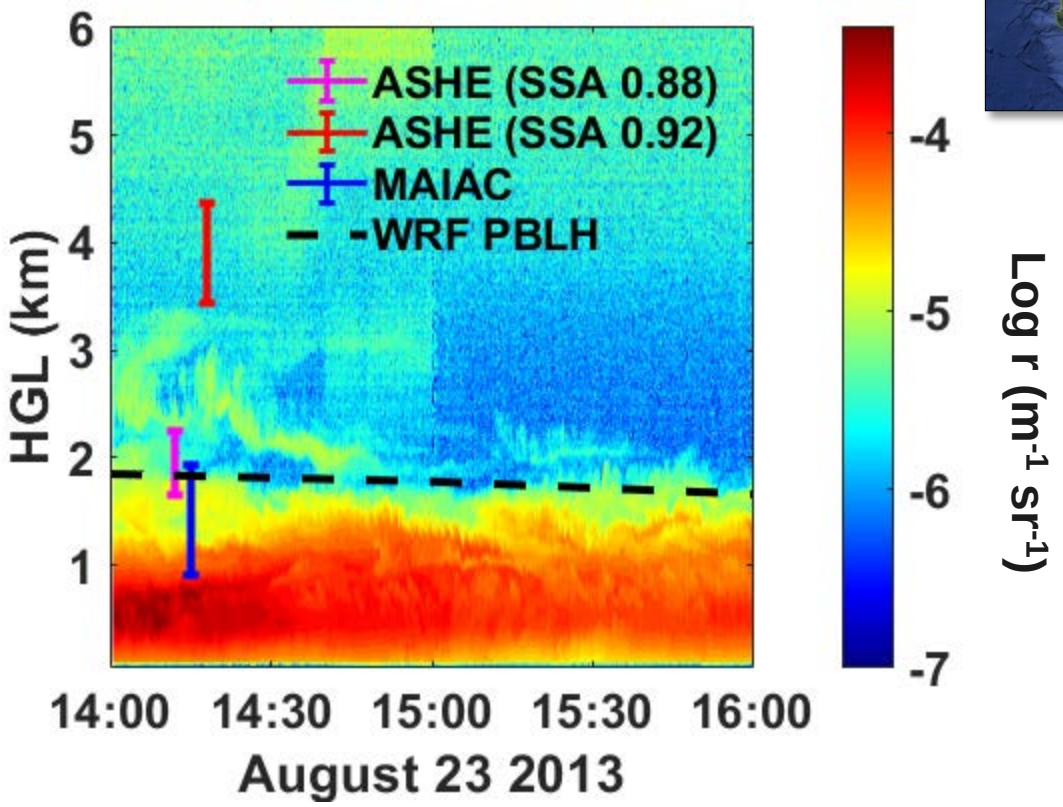
Terra MODIS visible figure

Plume Injection Height

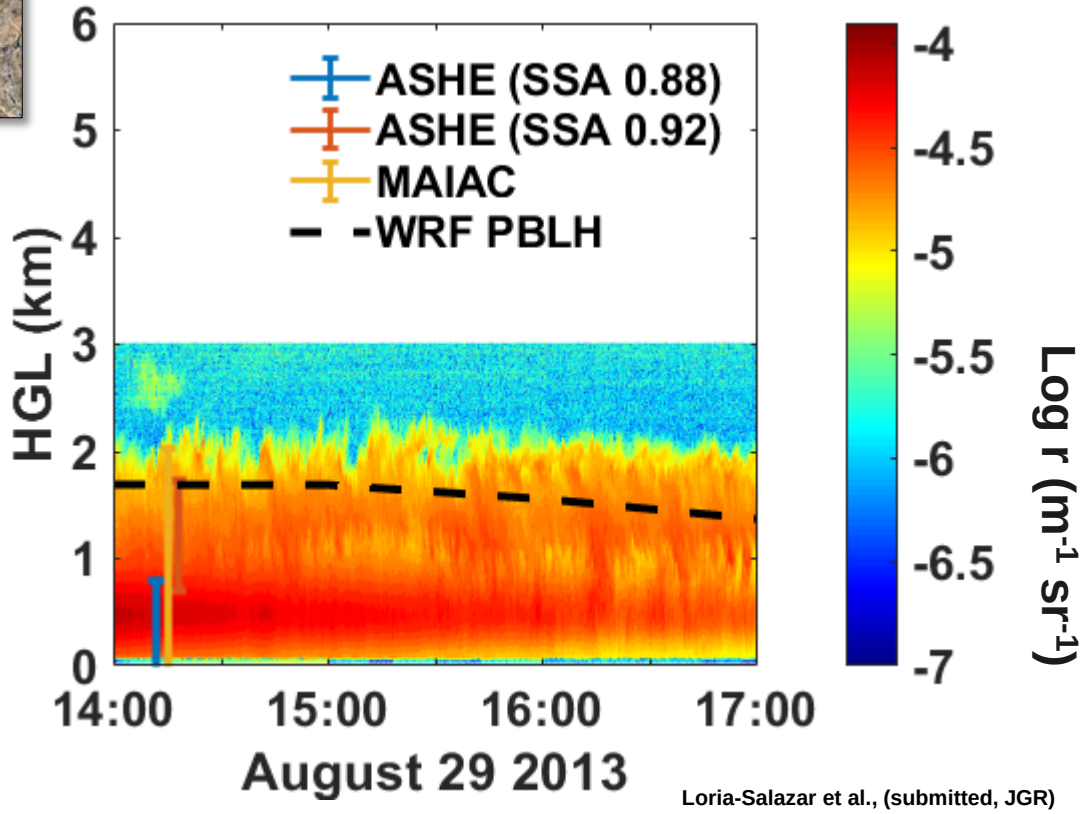
Yosemite Rim Fire, August, 2013

Dodge Ridge Ski Resort
38.2 N and -119.97 W
2010 m (ASL)





Donnell Vista
38.5 N and -119.93 W
1922 m (ASL)

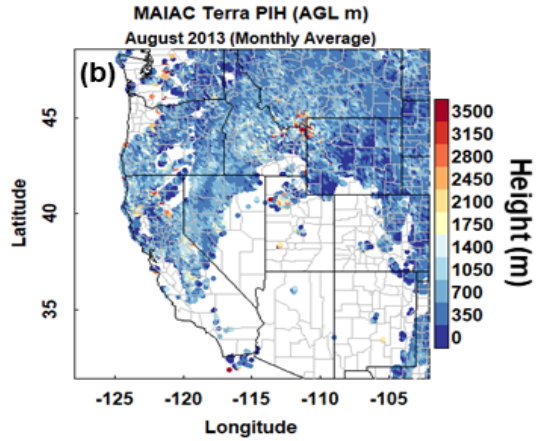


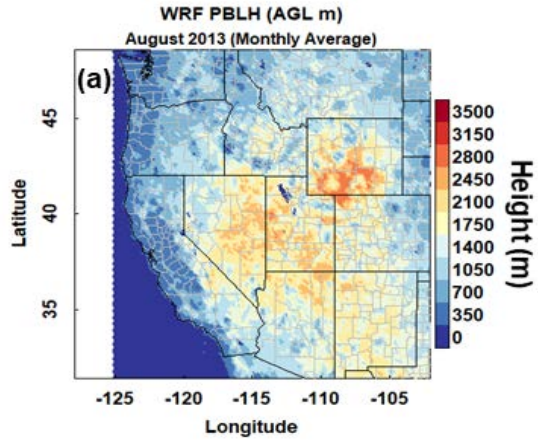
Loria-Salazar et al., (submitted, JGR)

Air Quality Fire Ratio

Western US, August, 2013

$$AQFR = \frac{PIH}{PBLH}$$





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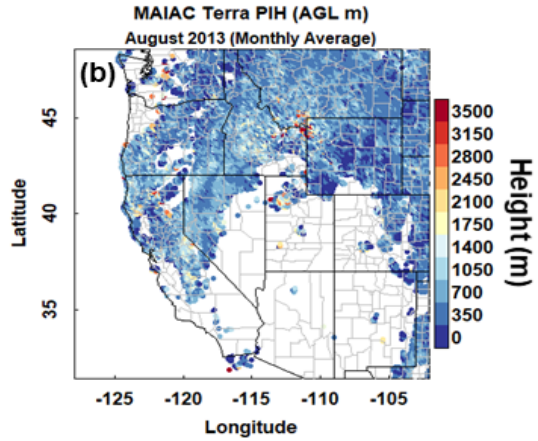
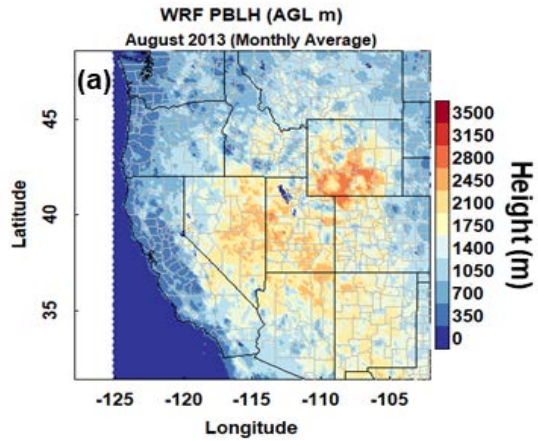




Loria-Salazar et al., (submitted, JGR)

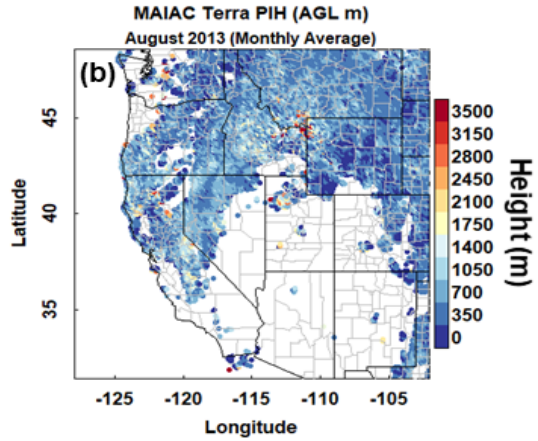
Air Quality Fire Ratio

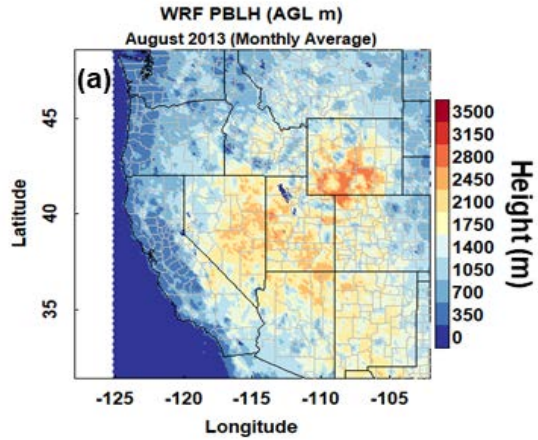
Western US, August, 2013

$$AQFR = \frac{PIH}{PBLH}$$

$AQFR \geq 1$ **Aerosol is confined within the planetary boundary layer**

$AQFR < 1$ **Aerosol is transported aloft the planetary boundary layer** **(?)**





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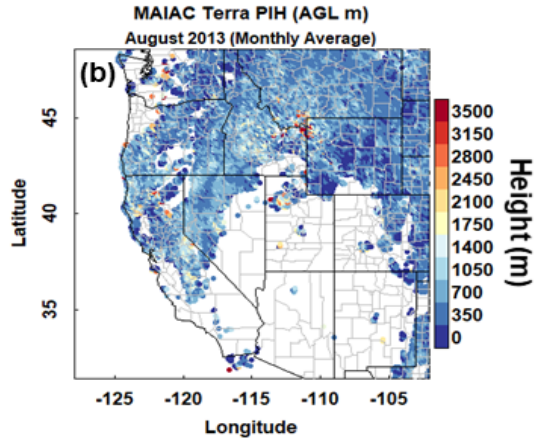
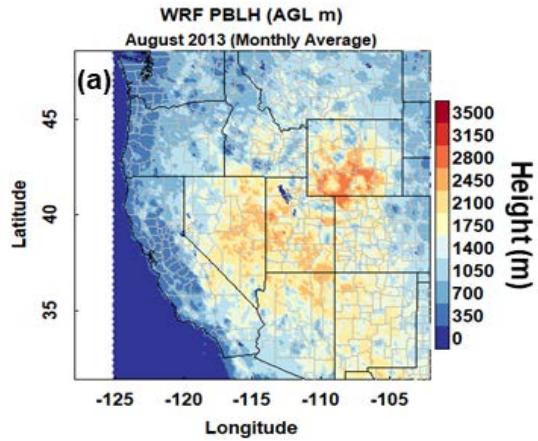


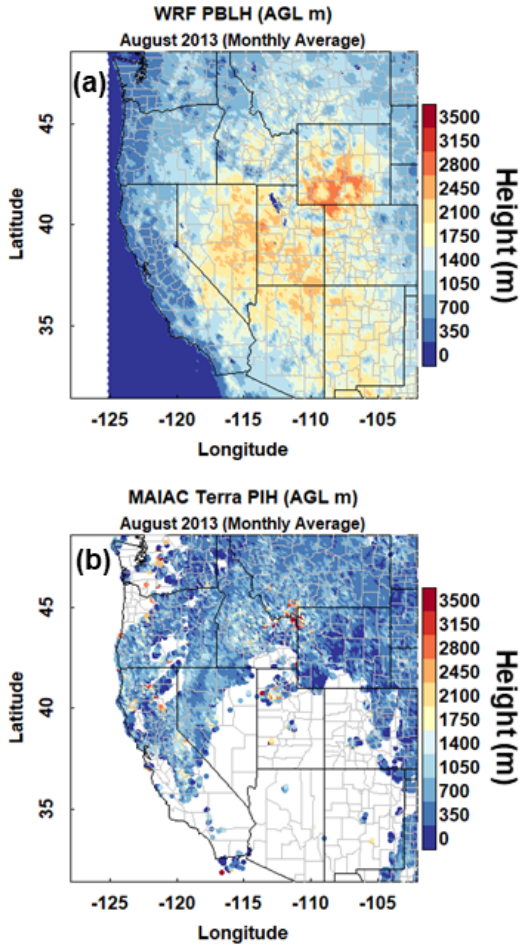


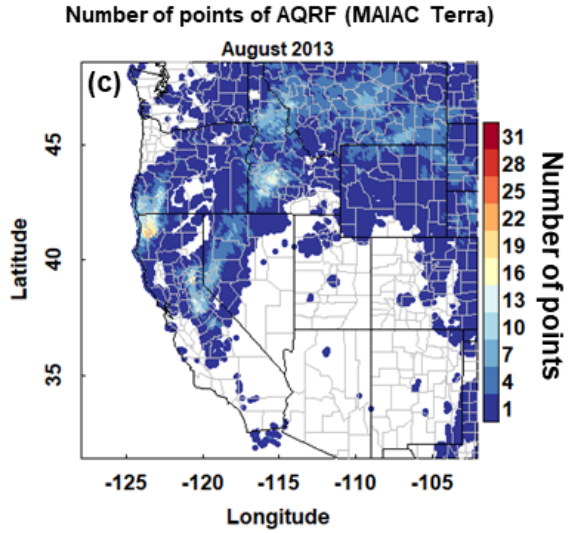
Percentage of confinement: Percentage of days when the plumes were transported within the PBLH

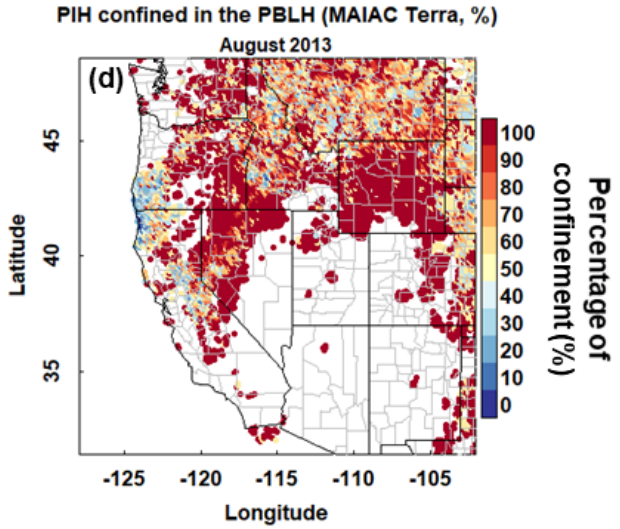
Loria-Salazar et al., (submitted, JGR)

Air Quality Fire Ratio: AM Overpass

Western US, August, 2013



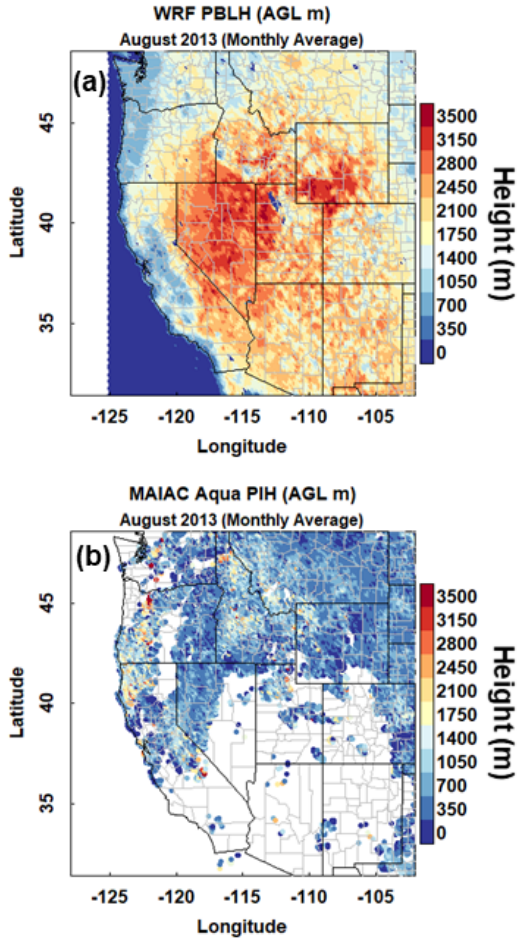


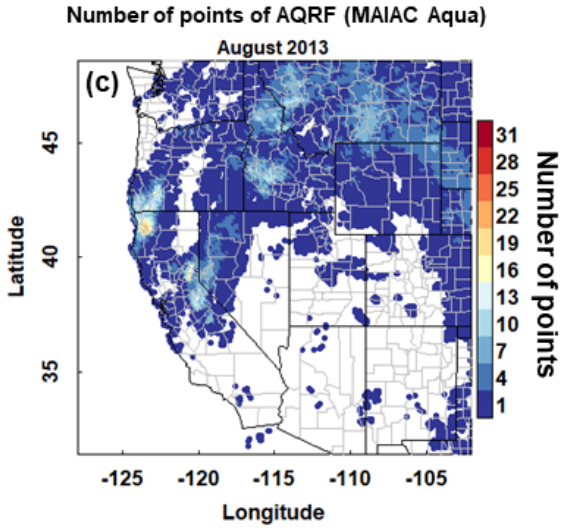


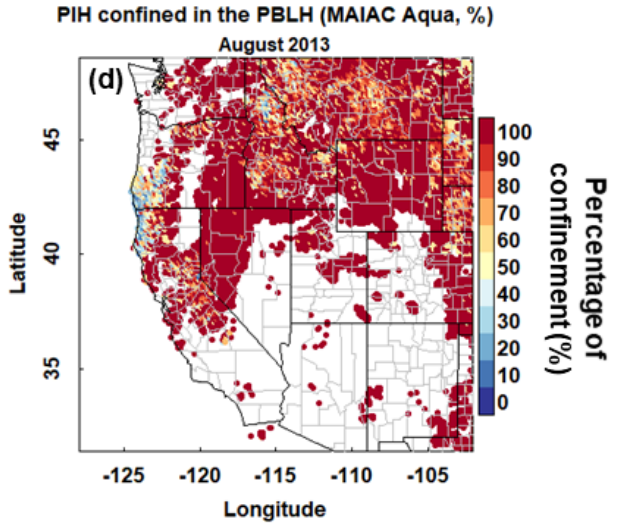
Loria-Salazar et al., (submitted, JGR)

Air Quality Fire Ratio: PM Overpass

Western US, August, 2013







Loria-Salazar et al., (submitted, JGR)

Summary

Summary

- Fire detection improvement in DB from C6 to C6.1
- MAIAC shows limitations during fire periods
- MAIAC is able to estimate PIH within 400 m and ASHE within 200 m
- The first order approximation AQFR is able to diagnose surface levels of aerosol pollution downwind from plumes aloft

Future work

1. Implementation of GOES fire products
2. Evaluate satellite-derived PIH during heterogeneous aerosol vertical profiles
3. Create new approximations of AQFR to improve fire plumes forecasting using satellite retrievals

Acknowledgments

Financial Support

- NASA Earth and Science Student Fellowship (NNX16AN94H, PI: H. A. Holmes)
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Yellowstone/UCAR

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UNR ATAQ Laboratory

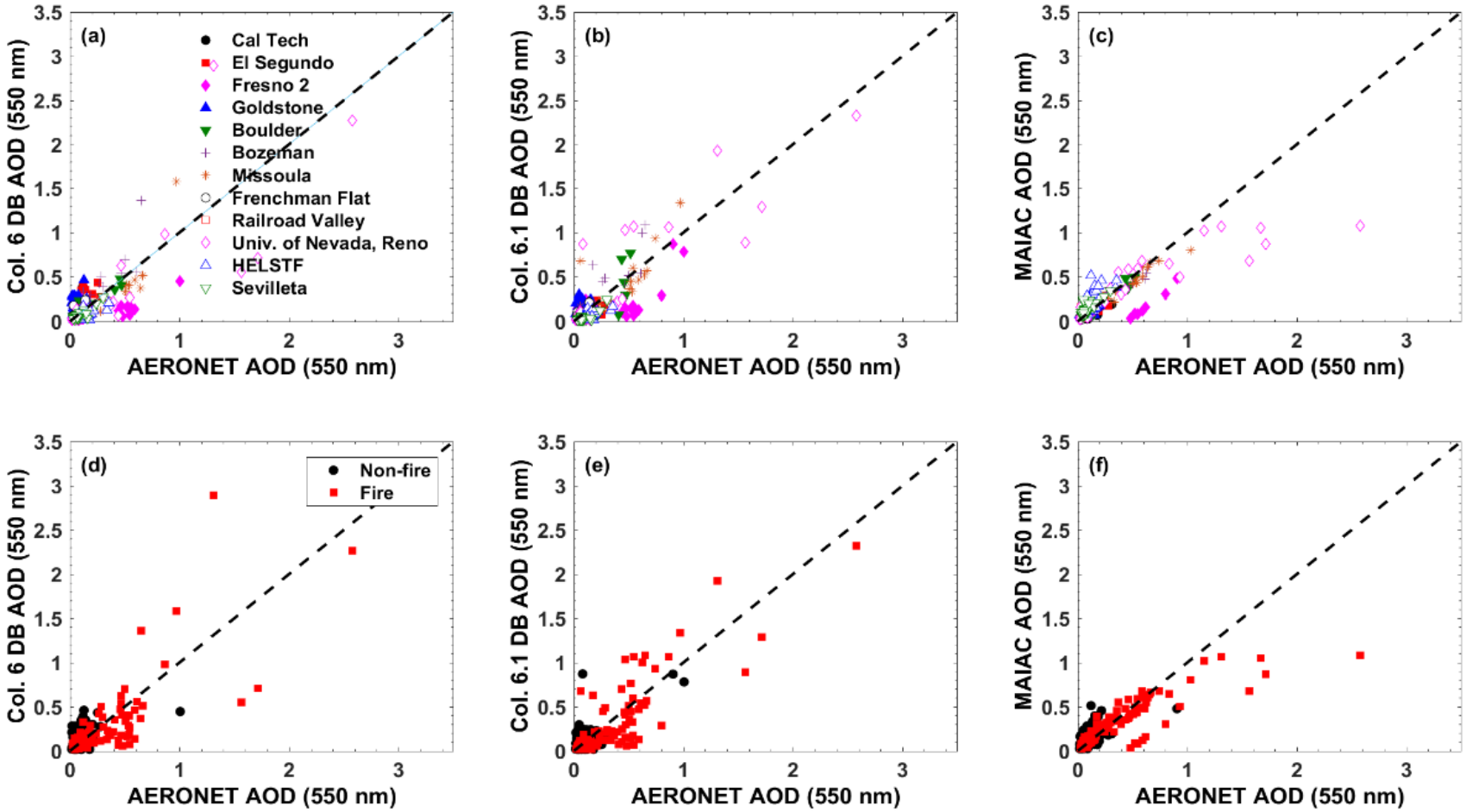
- Heather A. Holmes, PhD (PI)

UNR Patrick Arnott's Research Group

- W. Patrick Arnott, PhD (PI)

Evaluation of NASA MODIS AOD

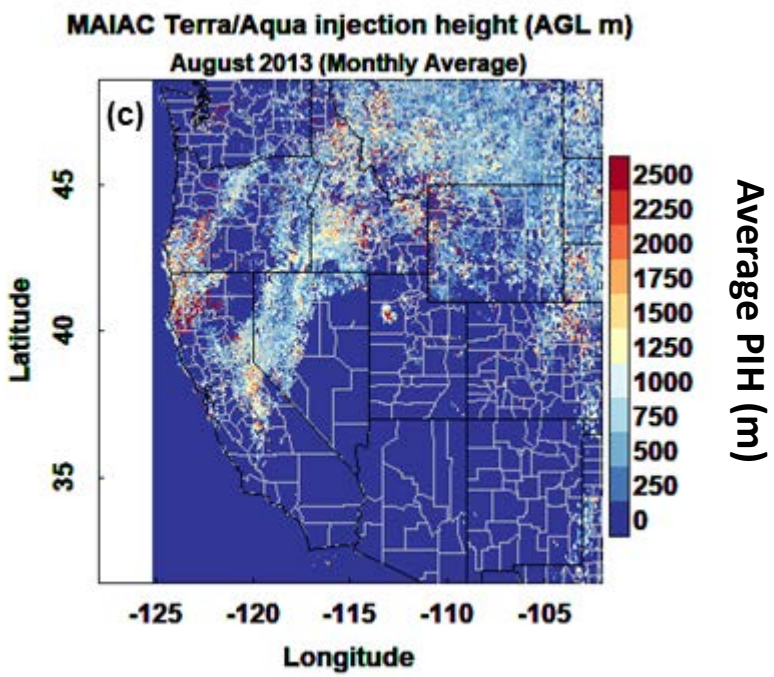
Western U.S., August, 2013

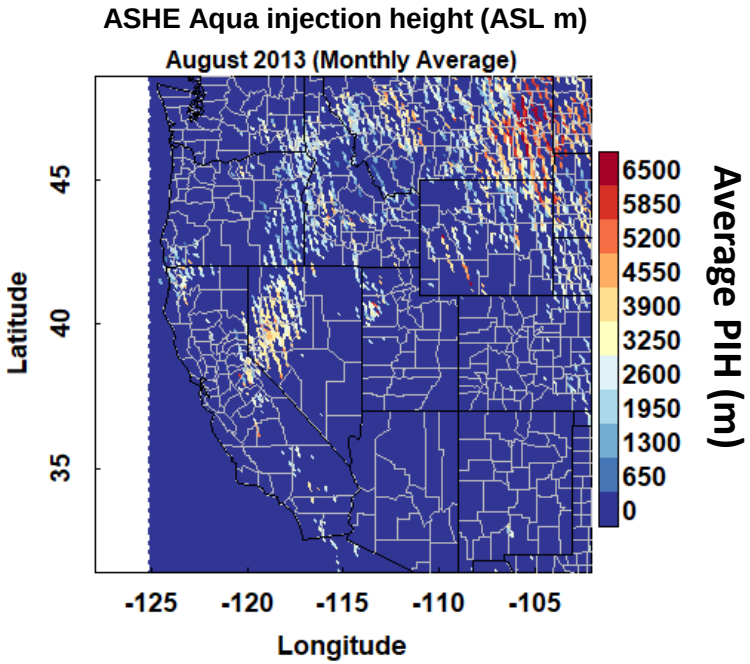


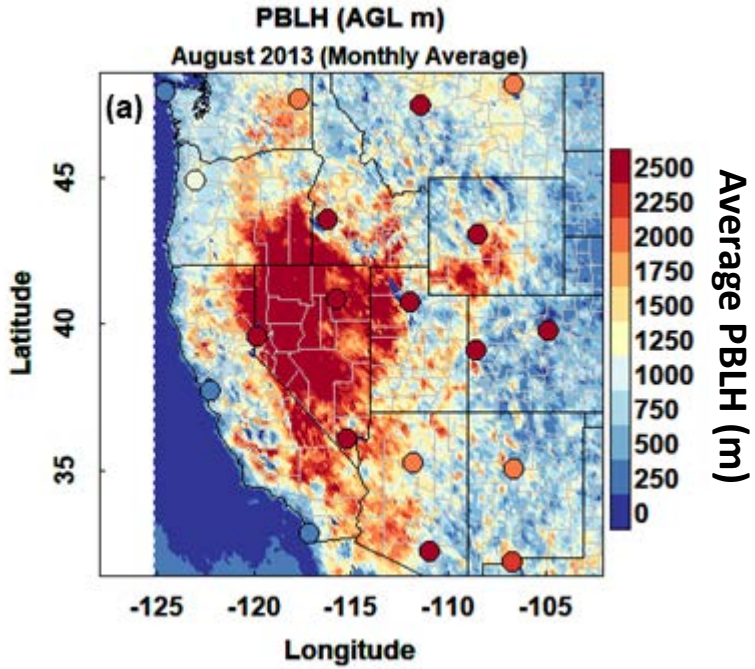
Loria-Salazar et al., (In-preparation)

Plume Injection Height

Yosemite Rim Fire, August, 2013







MODIS aerosol retrievals

Land algorithms discussion (surface characterization)

Deep-Blue (DB)

1. Pixel-based processing
2. Filters for clouds, sediments, snow, coast lines, fires, etc.
3. Short wavelengths (0.412, 0.47, 0.65 μm)
4. Surface reflectance characterization:

(i) Normalized difference vegetation index

(ii) Data base by geolocation

Hsu et al., (2013)

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Multiangle Implementation of Atmospheric Correction (MAIAC)

1. Image-based processing
2. Filters for clouds, sediments, snow, coast lines, fires, etc.
3. Short wavelength (0.47 μm) and infrared (2.1 μm)
4. Surface reflectance characterization:

Time series analysis of

(i) Surface bidirectional reflectance (BRF)

(ii) Spectral regression coefficient

Lyapustin et al., (2011)

MODIS aerosol retrievals

Land algorithms discussion (surface characterization)

Deep-Blue (DB)

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   lines, f
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Hsu et al., (2013)

Multiangle Implementation of Atmospheric Correction (MAIAC)

1. Image-based processing

now, coast

nd infrared

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(i) Surface bidirectional reflectance (BRF)
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Lyapustin et al., (2011)

Warning

Fine print: challenges retrieving on salted pans areas (e.g. Western U.S.)

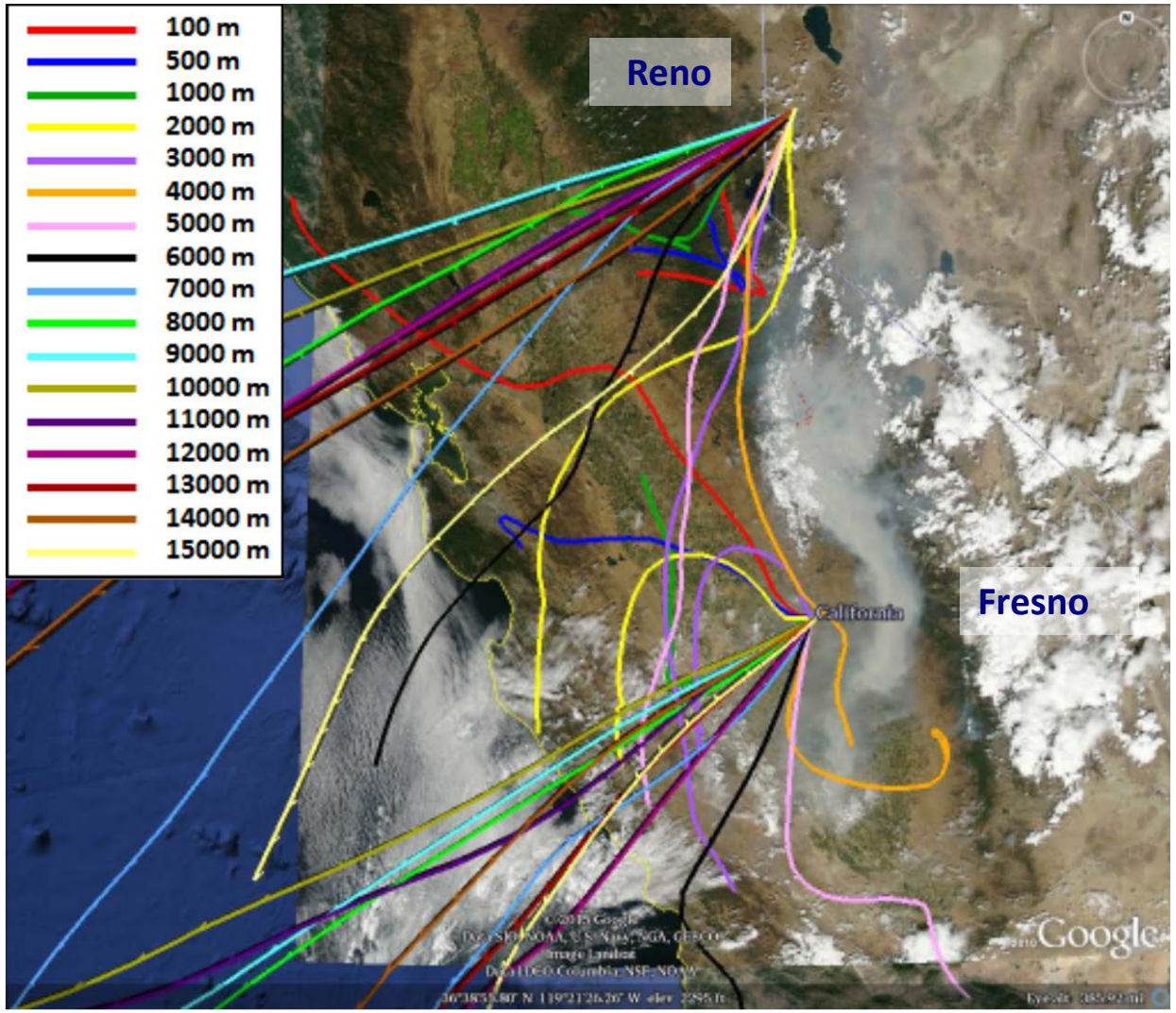
HYSPLIT Back Trajectories: 31 Aug 2013

24 hour, NAM 12-km

Reno:
100m & 2000m near plume

Fresno:
4000m & 5000m near plume

100m & 500m west of plume, clean air



Loría-Salazar et al., In-preparation

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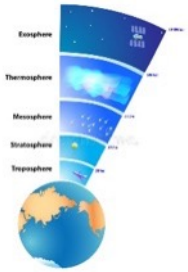

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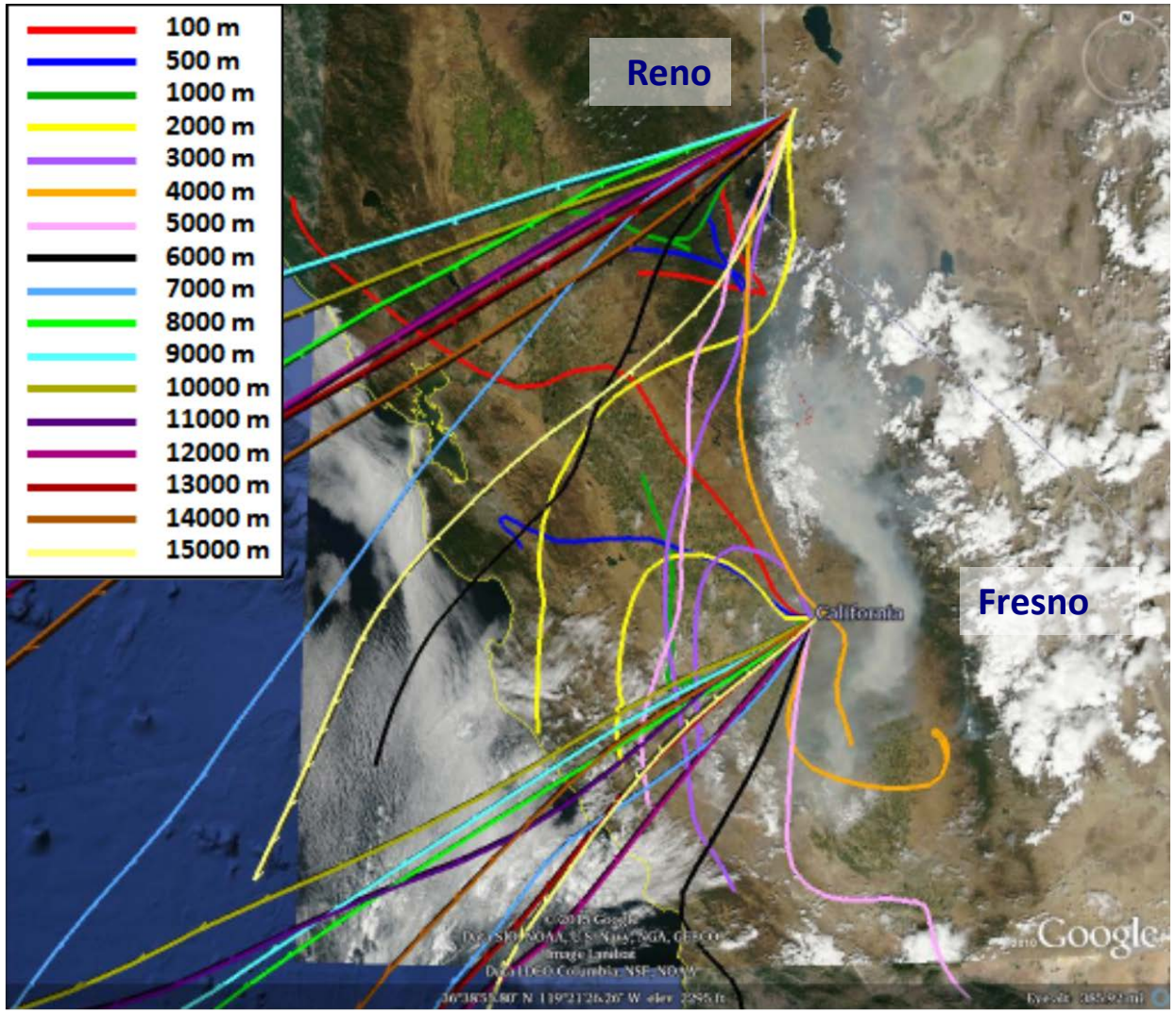

Loría-Salazar et al., In-preparation