Smoke at Ohanapecosh Campground in Mount Rainier National Park
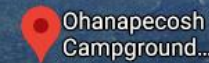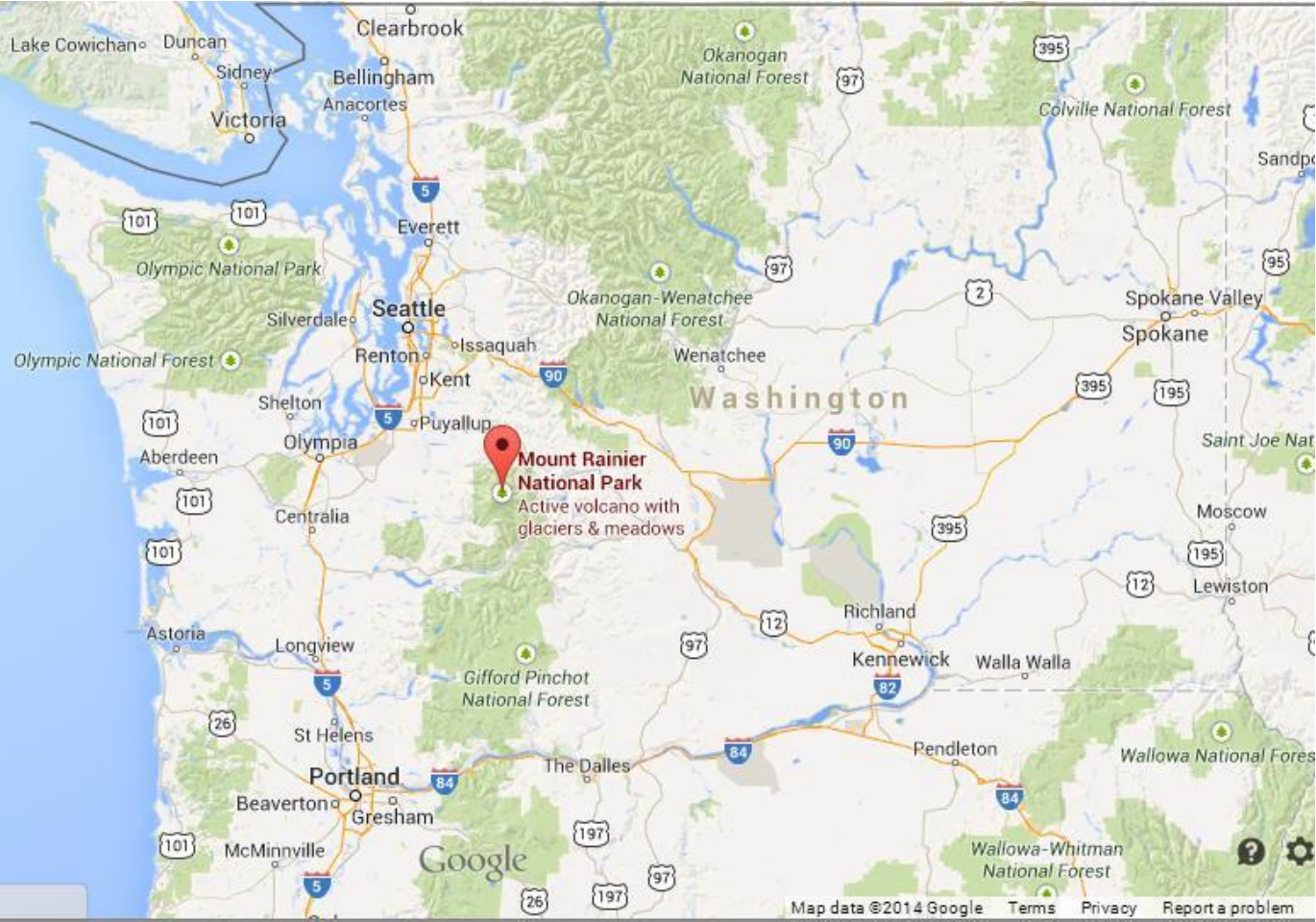
Summer 2020 Findings

Sean Hickey

Lake Cowichan Duncan Clearbrook
Sidney Bellingham Okanogan National Forest
Victoria Anacortes Colville National Forest
Sandpo...
101 101 Everett Olympic National Park
Silverdale Seattle Okanogan-Wenatchee National Forest Spokane Valley Spokane
Olympic National Forest Renton Issaquah Wenatchee
Shelton Kent Washington Saint Joe Nat...
Olympia Puyallup Moscow
Aberdeen Centralia **Mount Rainier National Park**
Active volcano with glaciers & meadows Richland Lewiston
Astoria Longview Kennewick Walla Walla
St Helens Gifford Pinchot National Forest Pendleton
Portland The Dalles Wallowa National Fores...
Beaverton Gresham Wallowa-Whitman National Forest
McMinnville Google
Map data ©2014 Google Terms Privacy Report a problem

165 Mt Rainier National Park 410
Liberty Cap 123
Point Success 410 123
PARADISE
706 Longmire Ohanapecosh Campground...
123

Some background

- Buildup of smoke during evenings at Ohanapecosh Campground as a result of campfire burning

- Smoke buildup suspected to be largely meteorologically driven

- Short-term exposure to high amounts of fine particles (i.e. smoke) can be dangerous!

Photo taken by Jeremiah Johnson 2013

Broad Objectives & Goals of Research

1. To better understand how the meteorology and geography of Ohanapecosh relate to smoke build up in the campground.

2. To develop a tool that can forecast nightly $PM_{2.5}$ concentrations at the campground
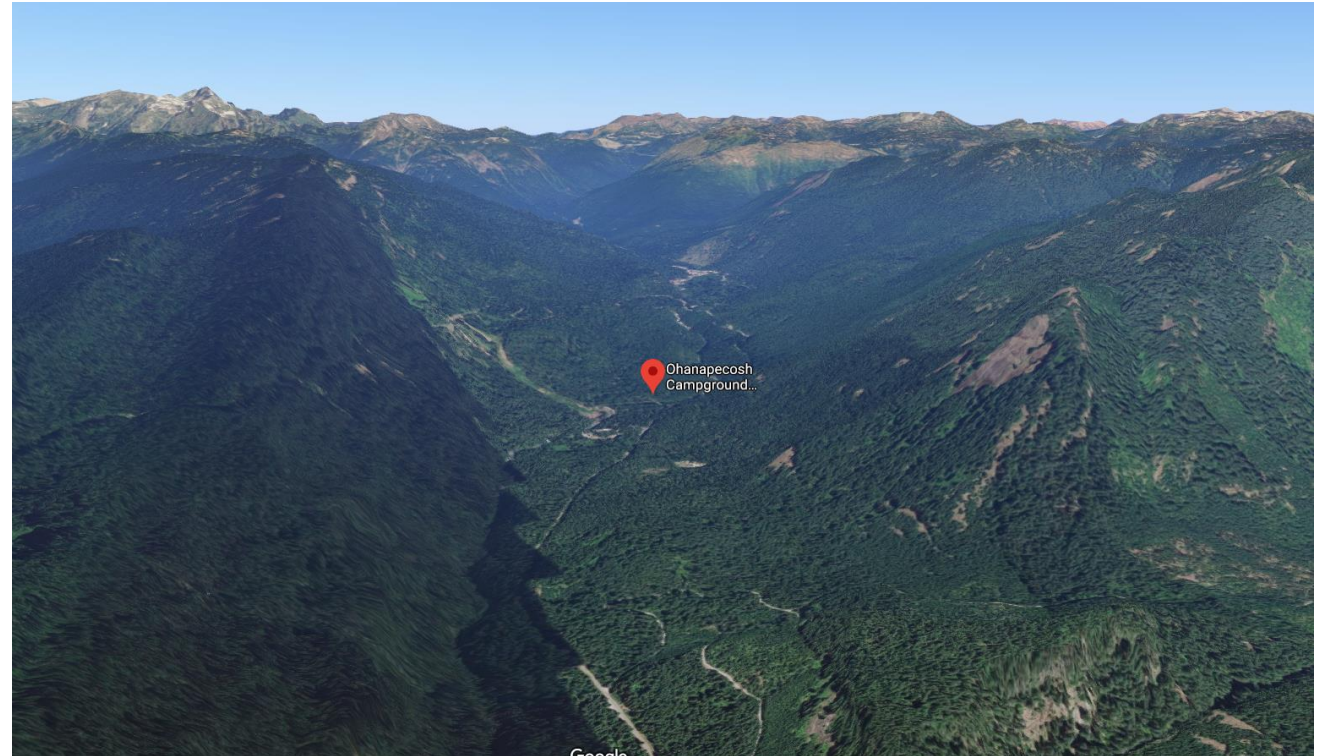
Investigation 1

What influenced PM$_{2.5}$ levels in the campground at night?

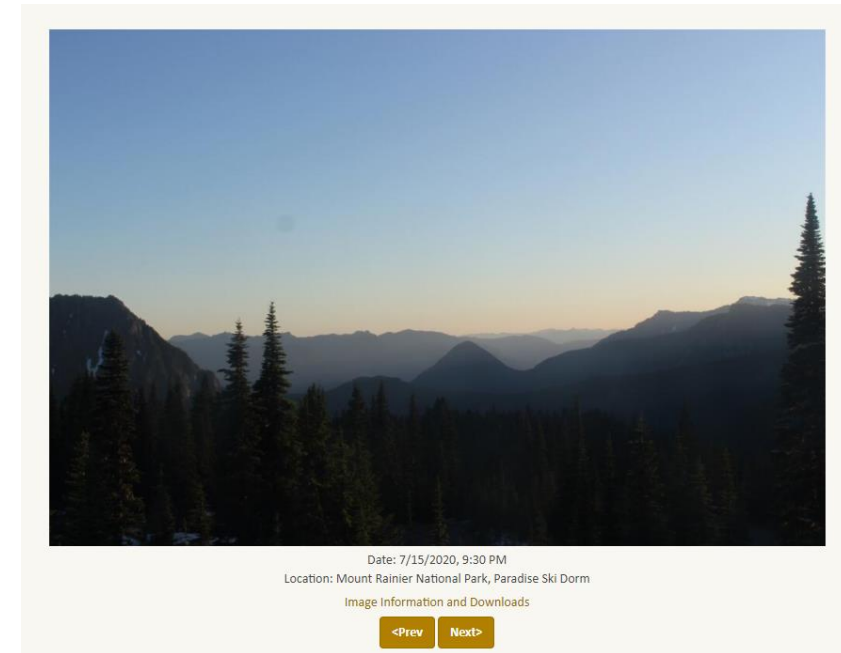## Data Used:

MetOne E-BAM PM2.5 concentrations
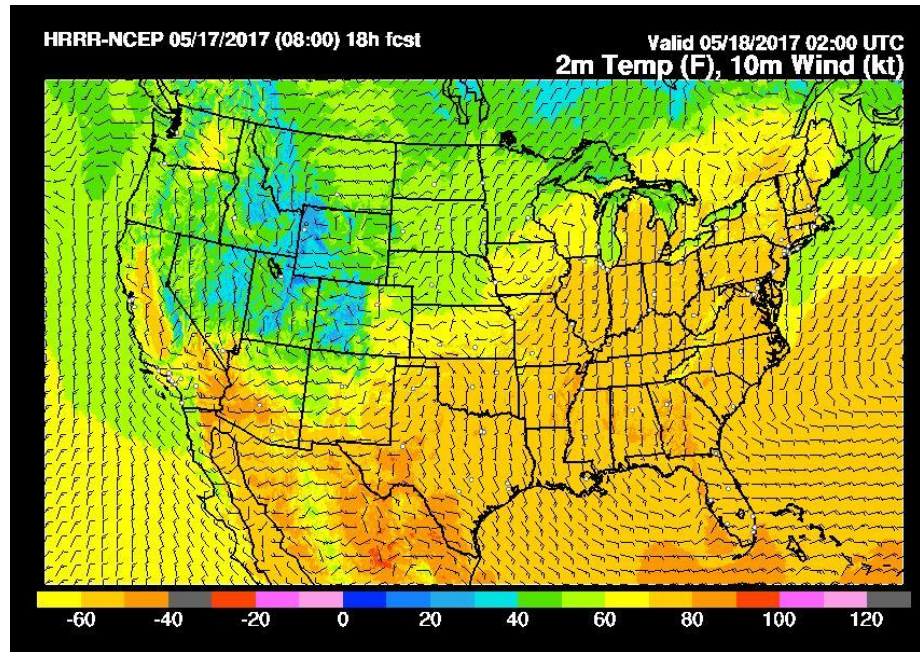
North American Mesoscale Modeled Meteorological Data (12 km resolution)

Visibility webcam at the park to detect cloud presence.

Characteristics of PM2.5 data

- 213 nights of PM2.5 data and meteorological data from summer 2009, 2010, 2013

- Peaks in smoke generally occurred from ~9pm-1am.

- Daily average PM2.5 never exceeds EPA daily limit (35 µg·m³),

- Nightly average from 9pm-1am exceeded 35 µg·m³ on 65/213 nights
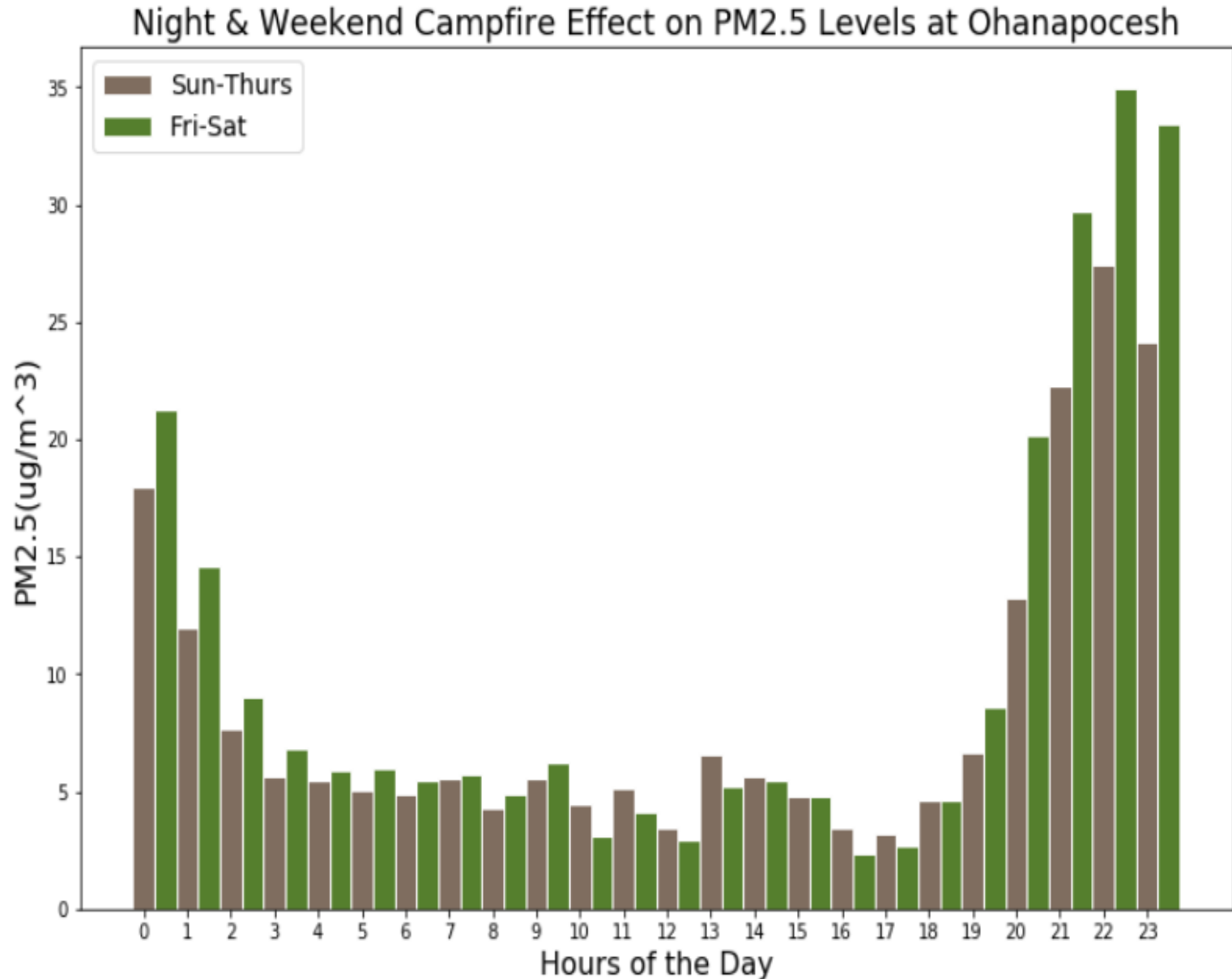
Variables Used

- NAM Meteorological Data
  - Temperature
  - Relative humidity
  - Mixing height
  - Wind speed
- The presence of clouds
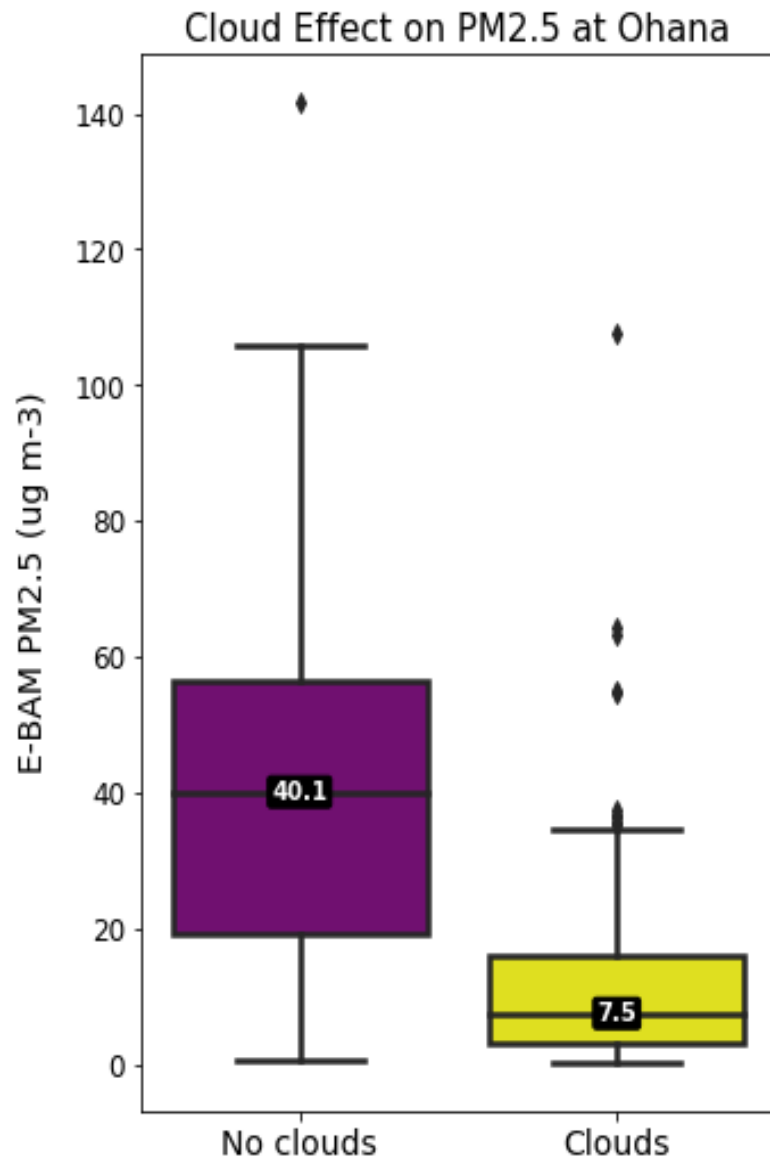- $PM_{2.5}$ from the previous night
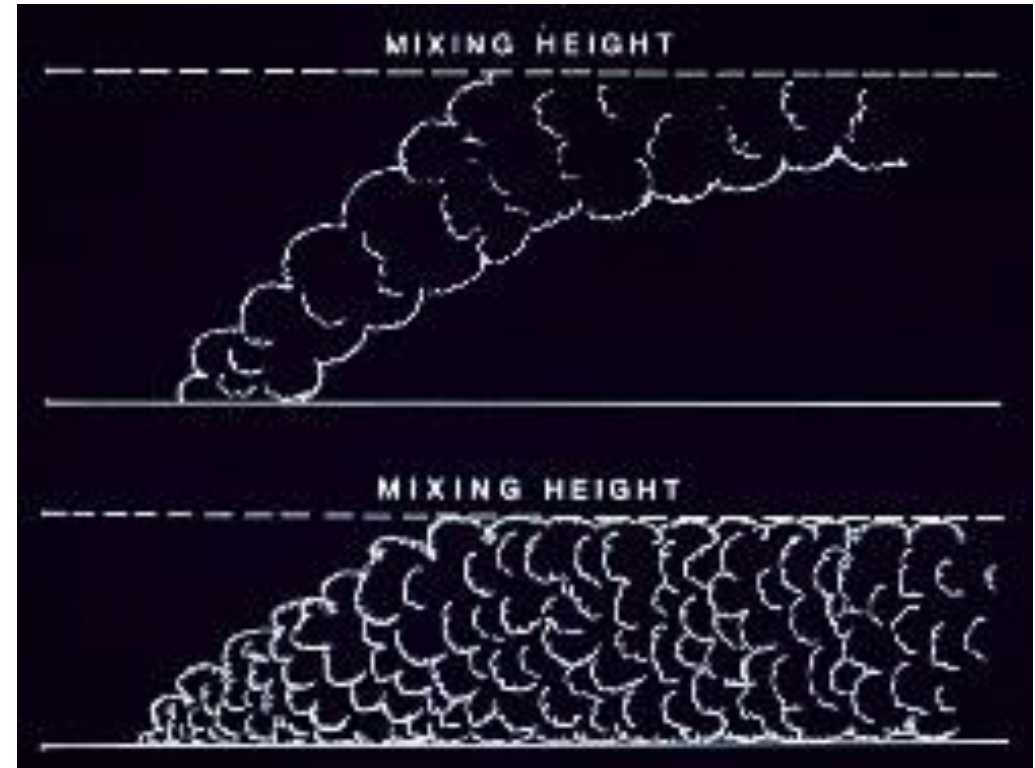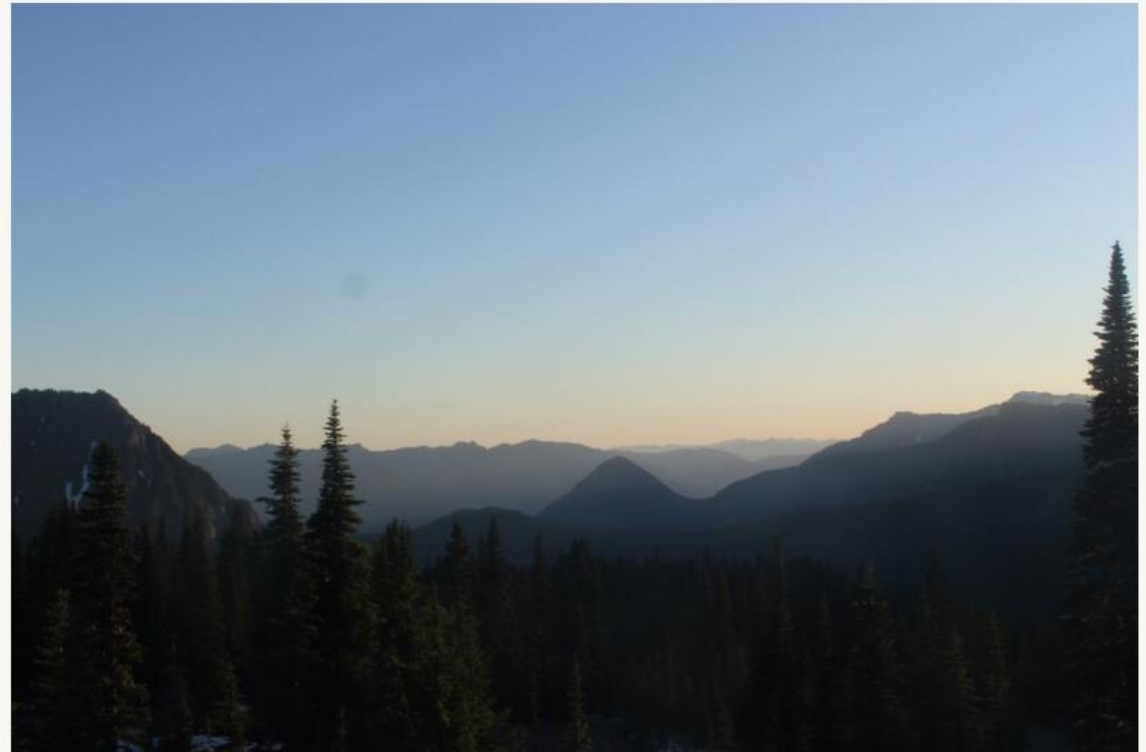
Preparing Data for Analysis

- Grouped dataset by night (from 9pm-1am)

- Developed new time-lagged variables

- Transformed $PM_{2.5}$ data to get normal distribution using Box-Cox Transformation

$$\left\{ y = \frac{x^\lambda - 1}{\lambda} \text{ where } \lambda \neq 0 \right.$$

Distribution Without Box-Cox Transformation

Distribution With Box-Cox Transformation
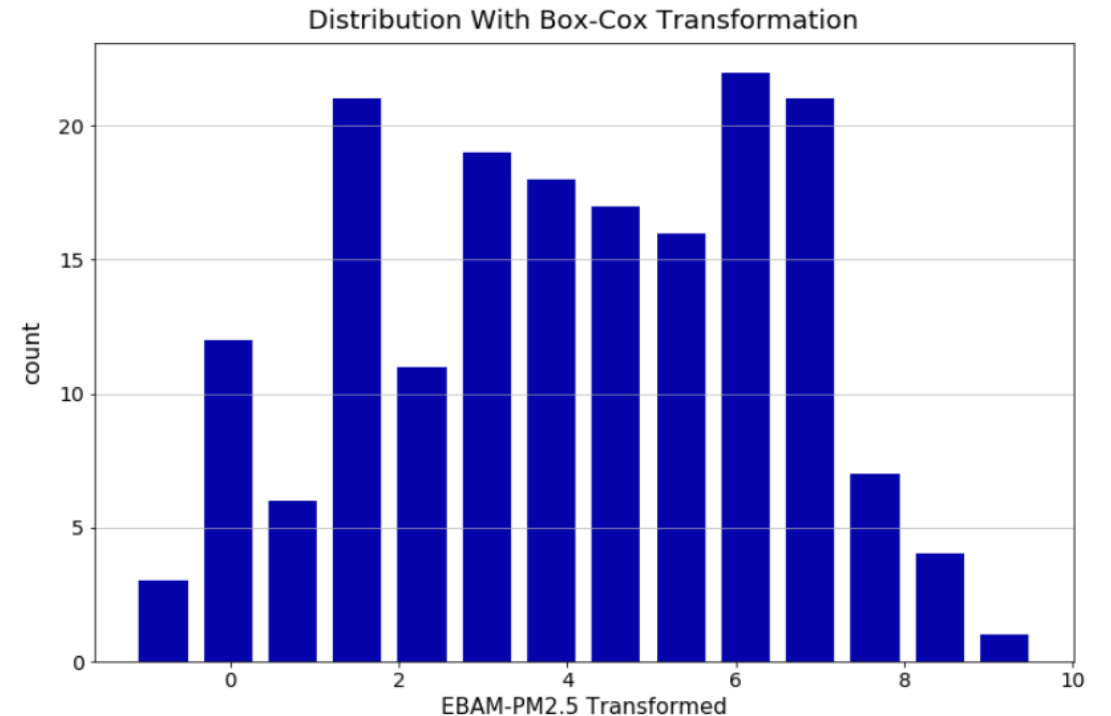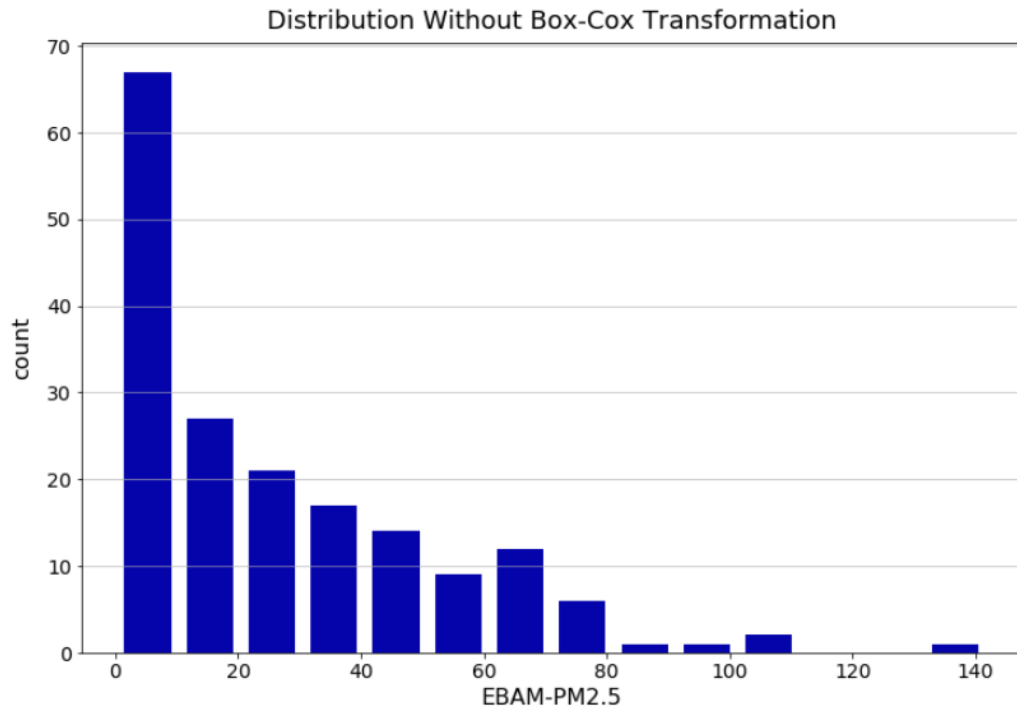
The strongest indicator:

Date: 7/15/2020, 9:30 PM
Location: Mount Rainier National Park, Paradise Ski Dorm
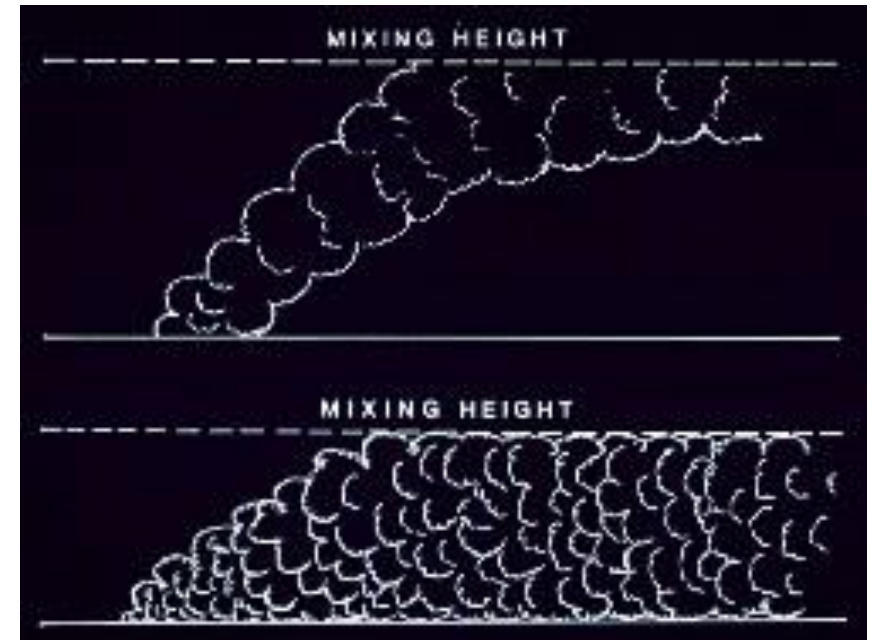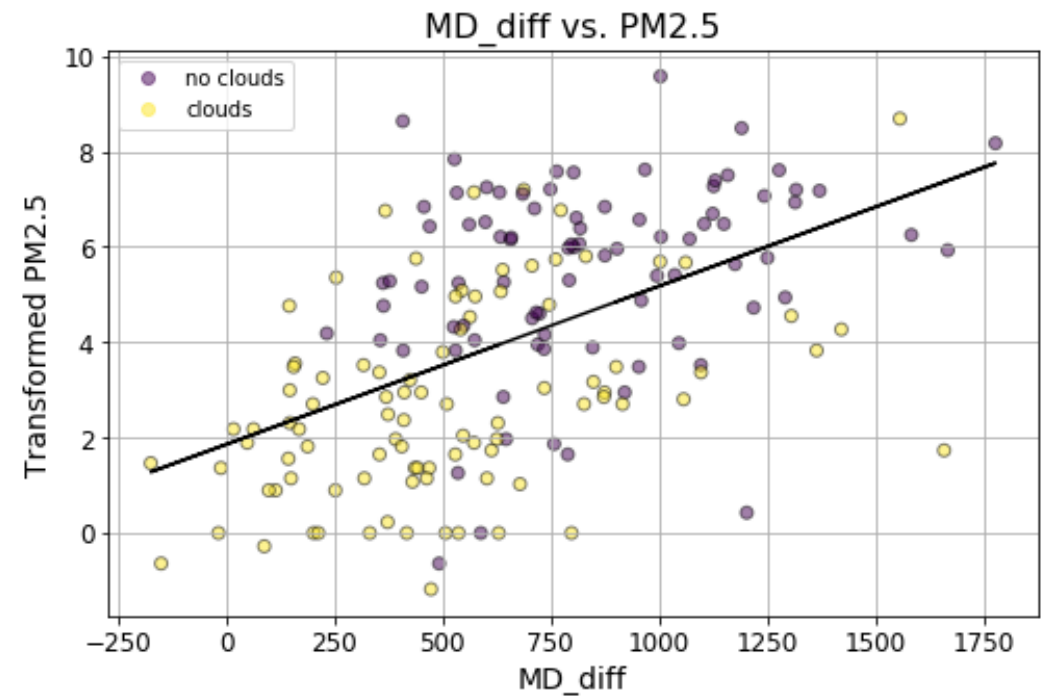Image Information and Downloads

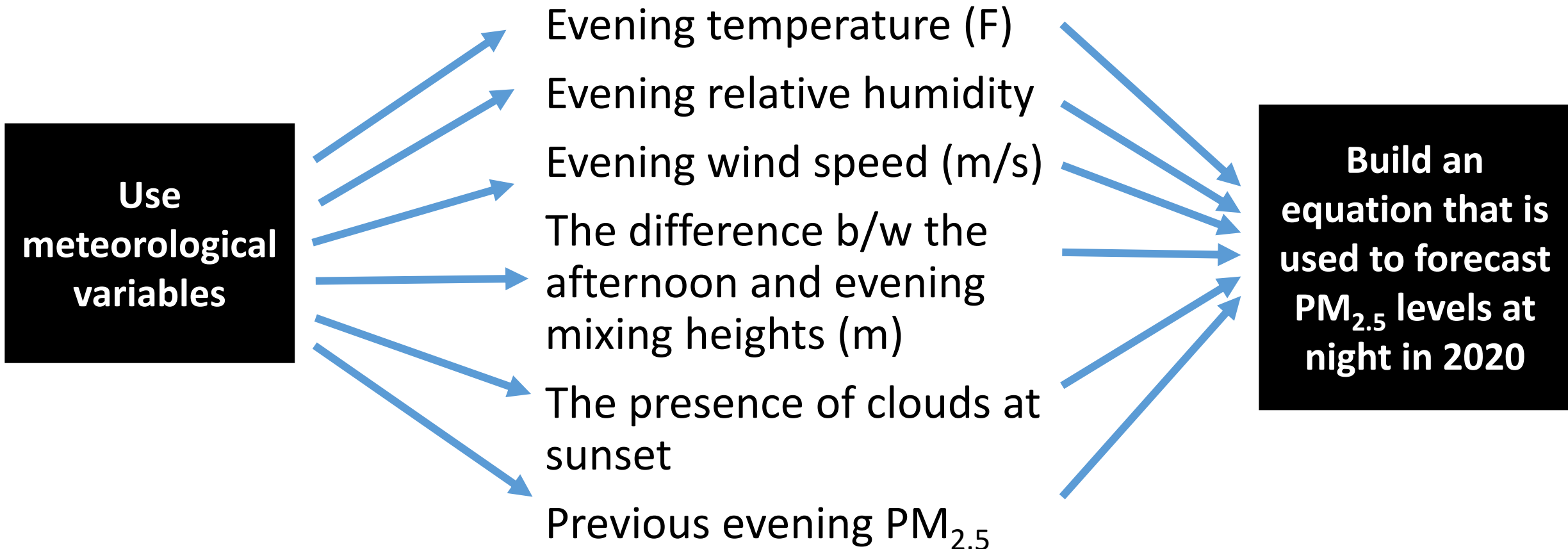<Prev   Next>

PM$_{2.5}$ is noticeably higher at the campground when:

- There are clear skies in the late afternoon and evening
- It is warm at night
- It is dry at night
- Wind speeds are low
- There is a large difference between the afternoon and evening mixing height

Multi-variate regression between meteorological data and E-BAM PM$_{2.5}$ from 2009-2013

Use meteorological variables

Evening temperature (F)

Evening relative humidity

Evening wind speed (m/s)

The difference b/w the afternoon and evening mixing heights (m)

The presence of clouds at sunset

Previous evening PM$_{2.5}$

Build an equation that is used to forecast PM$_{2.5}$ levels at night in 2020

Used data collected in summer 2020 to evaluate the model built from historical data:

- PurpleAir PM2.5
- Daily NOAA/NWS Forecast
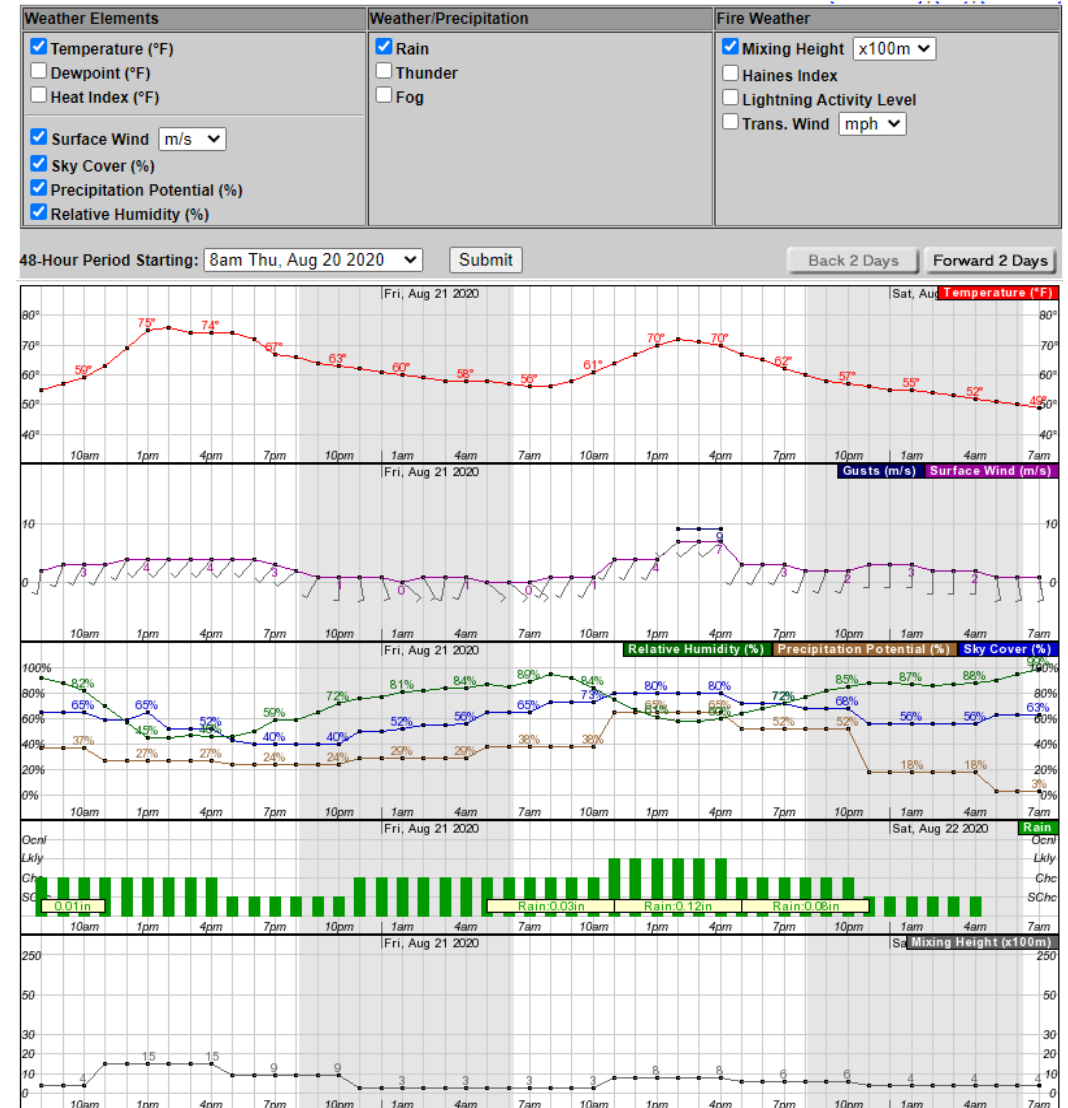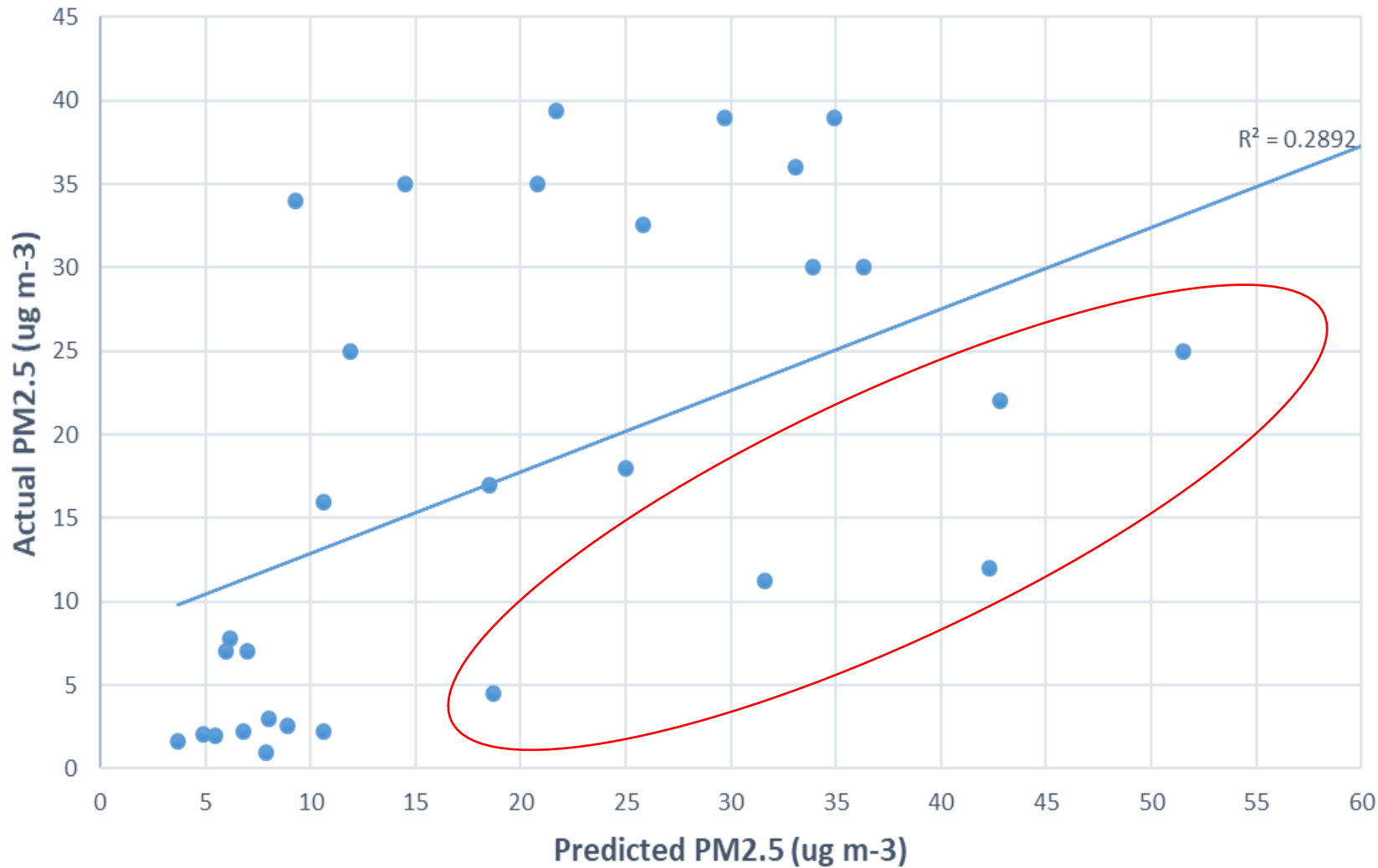
Results:

- $R^2 = 0.525$ for 2009-2013 data;
- $R_2 = 0.289$ when tested on data collected in 2020
- Mean Absolute Error = 10.49 $\mu g \cdot m^3$

Model is good at predicting when concentrations will be low!

78 of 200 campsites were closed during the sampling period in 2020 due to maintenance at the campground → this could lead to over prediction…

The model predicted general trends fairly well considering the closures...

More data needed

Predicted PM2.5 vs Actual: Summer 2020

PM2.5 (ug m-3)

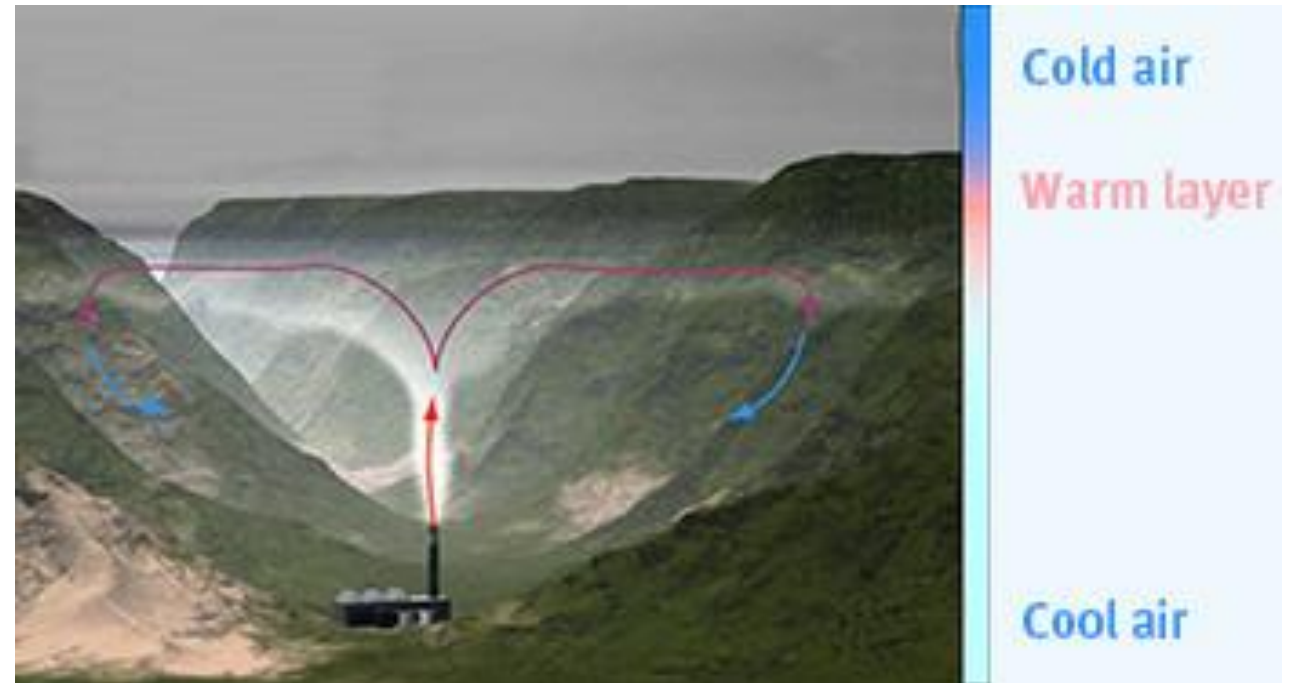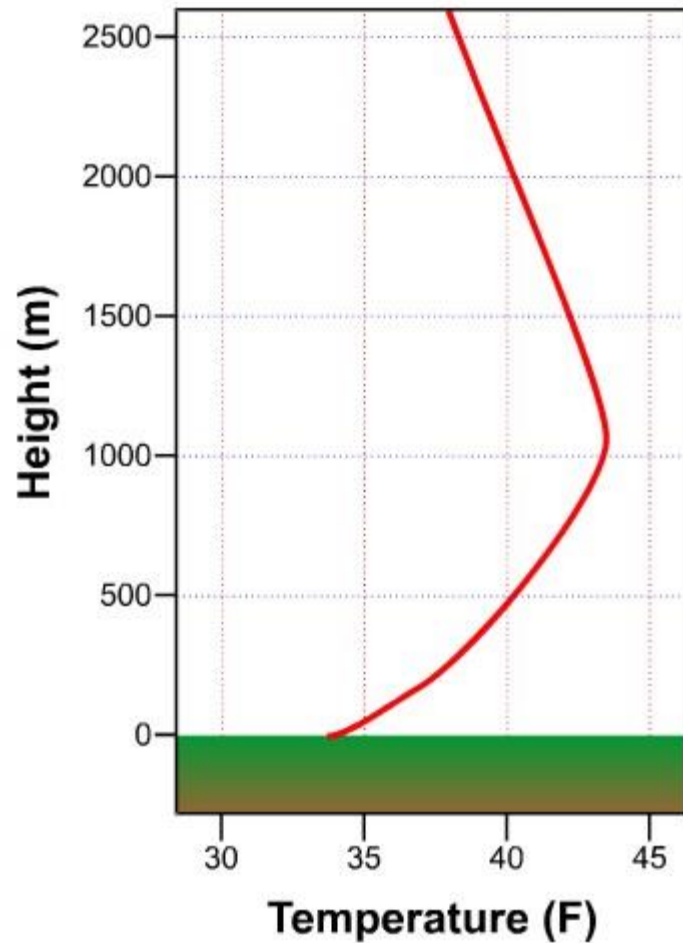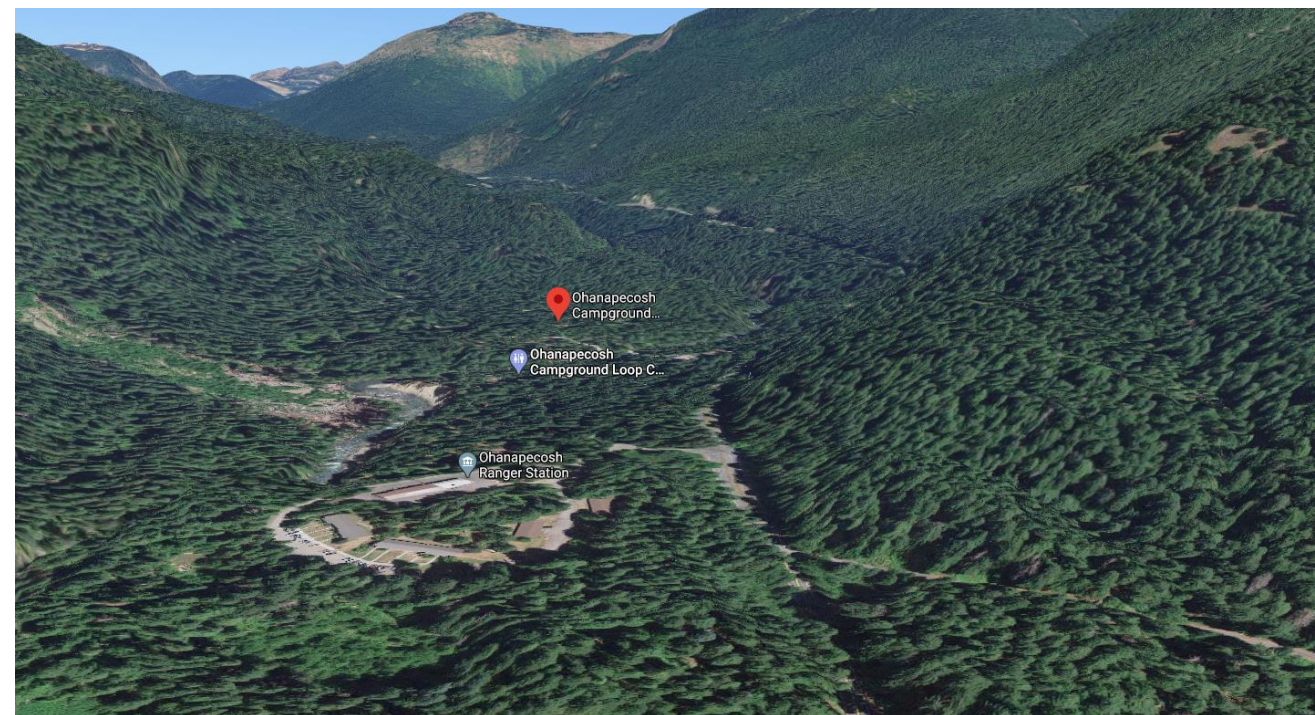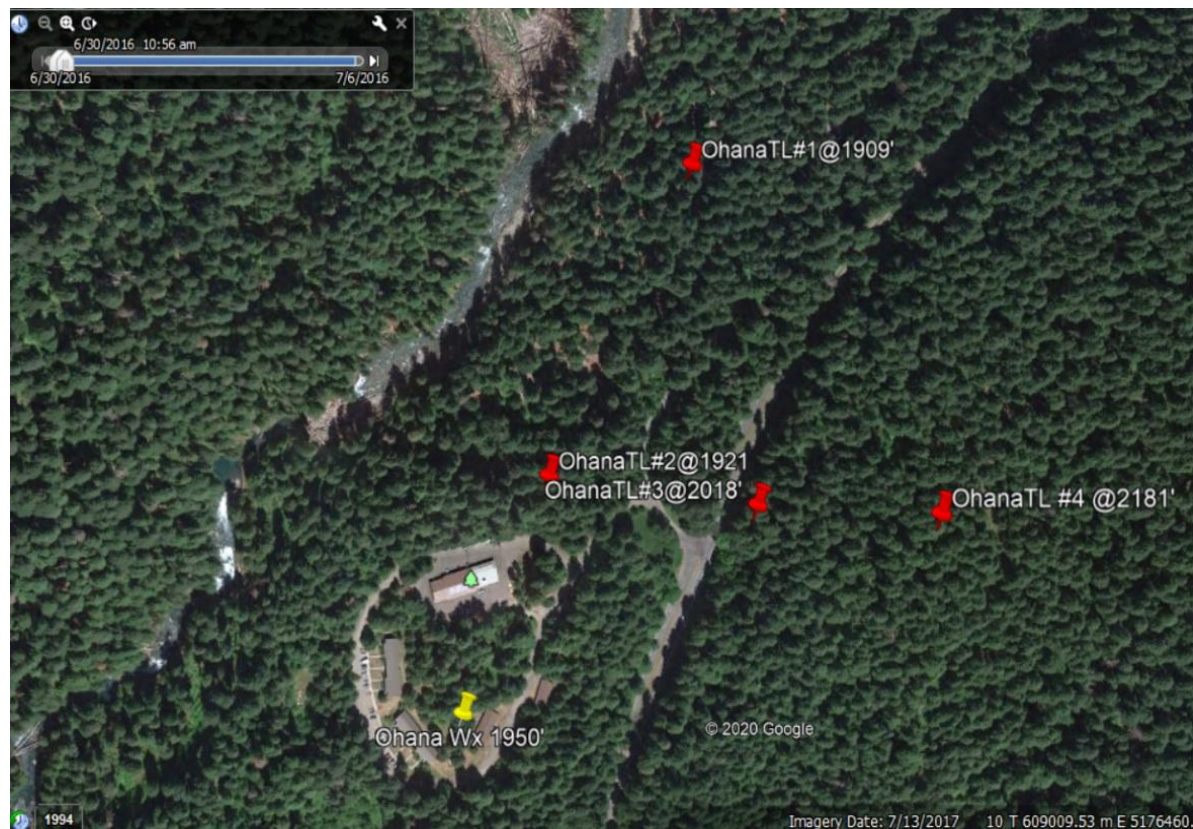Model Predicted PM2.5 — Purple Air Reported PM2.5
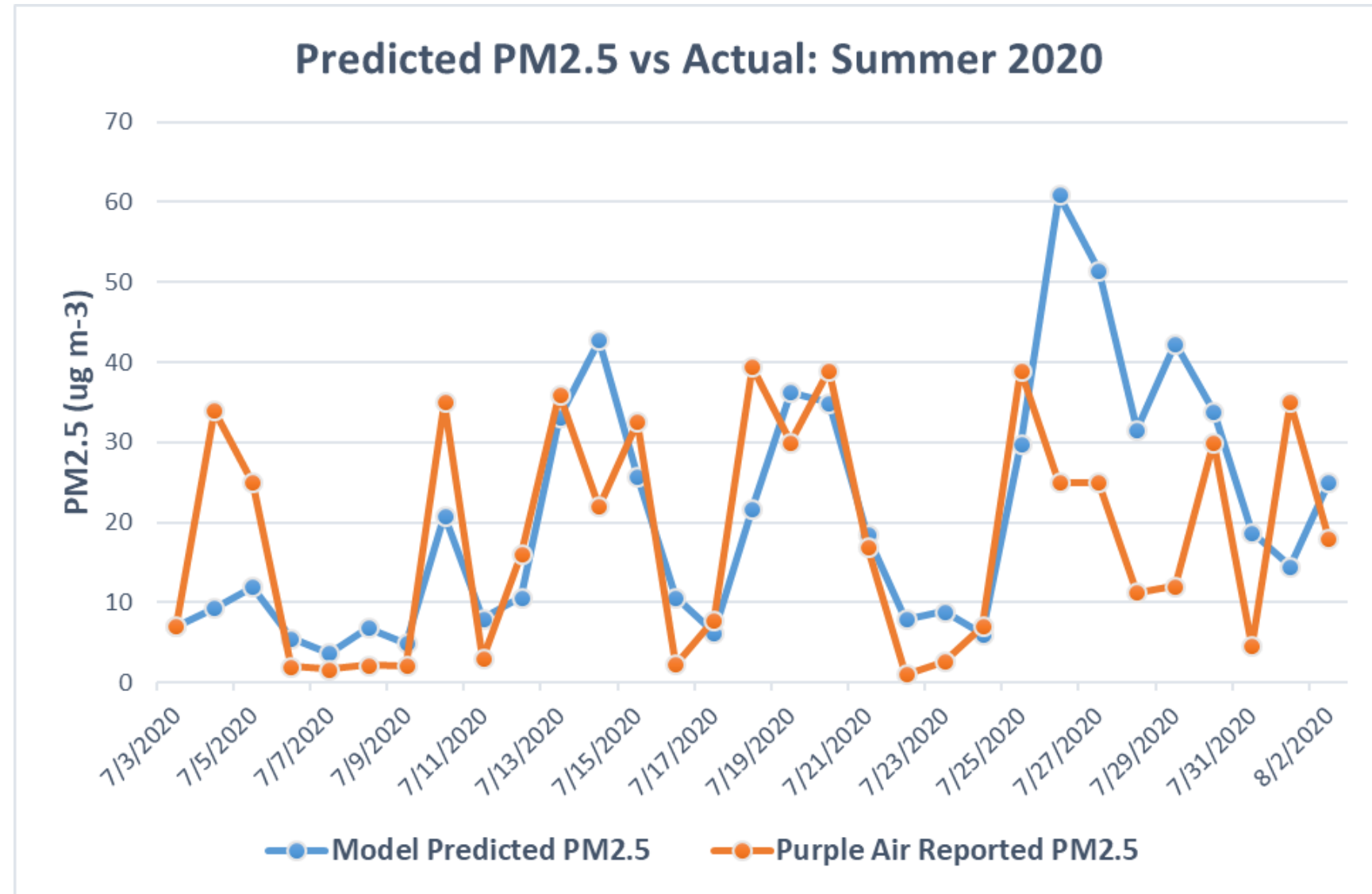
A Spreadsheet for Park Officials

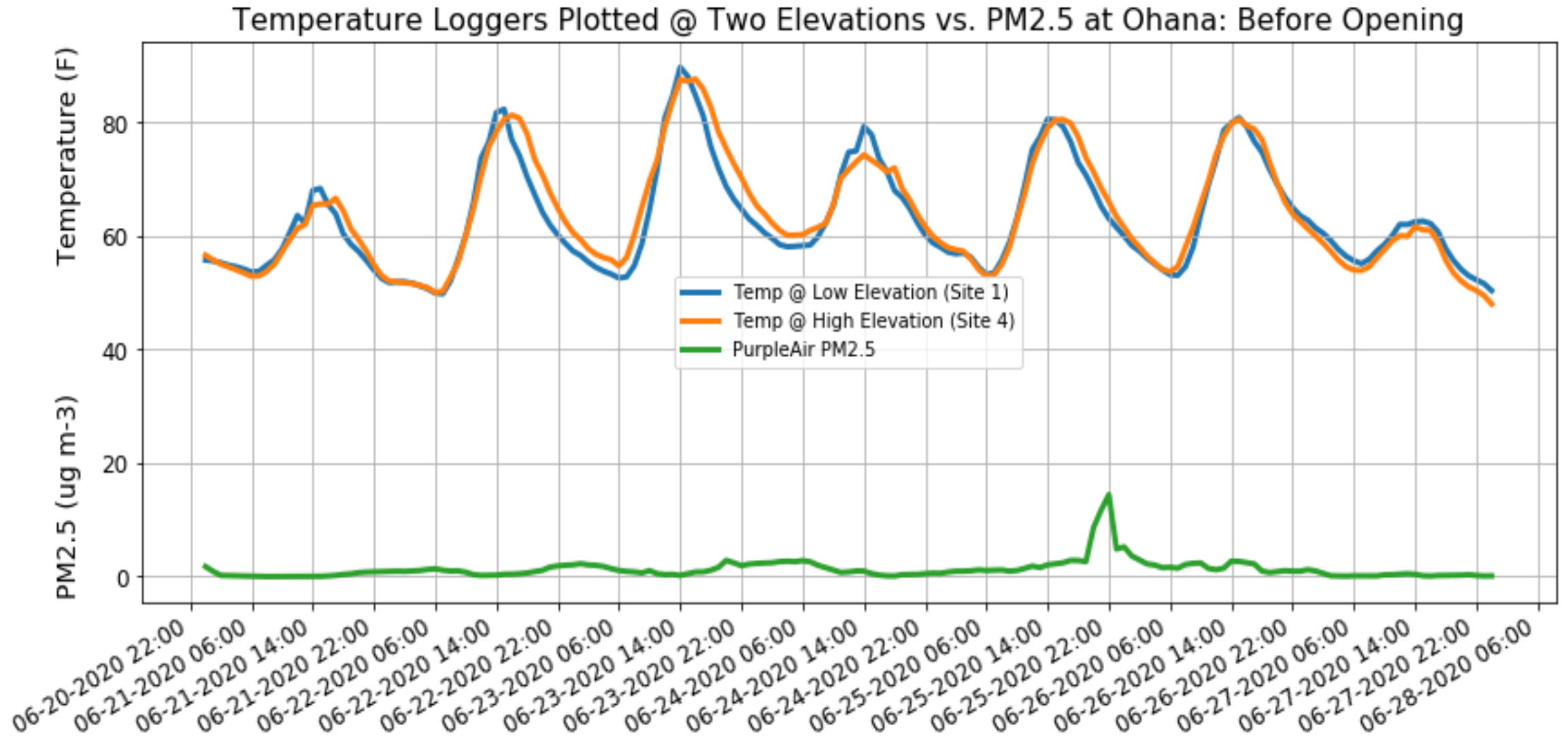| Forecast	Date	RH_night	T_night	WS_night	MD_diff	clouds_20	pm25_prev_day	Predicted PM2.5	Actual PM2.5	Error +/-	Abs. Error			
NAM12	07/03/2020	90	50	2.5	264	1	34	7.0	7	0.02	0.02		coef	
NAM12	07/04/2020	88	51	2.2	776	1	7	9.3	34	-24.70	24.70	constant	3.124	
NAM12	07/05/2020	90	51	2.2	847	1	34	11.9	25	-13.08	13.08	RELHUMID	-0.0272	
NAM12	07/06/2020	93	50	3.5	388	1	25	5.5	2	3.55	3.55	AIRTEMP_F	0.052	
NAM12	07/07/2020	97	48	3	256	1	2	3.7	1.6	2.14	2.14	WS_ms	-0.3143	
NAM12	07/08/2020	91	53	2.7	543	1	1.6	6.8	2.2	4.60	4.60	MD_diff	0.0013	
NAM12	07/09/2020	95	53	2.7	230	1	2.2	4.9	2.1	2.78	2.78	clouds_20	-0.8461	
NAM12	07/10/2020	81	51	1.2	967	0	2.1	20.8	35	-14.17	14.17	pm25_prev_day	0.0148	
NAM12	07/11/2020	94	52	3.5	654	1	35	8.0	3	4.95	4.95	Lambda	0.242	
NAM12	07/12/2020	85	48	2.8	544	0	3.2	10.6	16	-5.41	5.41			
NAM12	07/13/2020	67	50	1.9	1509	0	16	33.1	36	-2.94	2.94			
NAM12	07/14/2020	47	53	2.4	1343	0	36	42.8	22	20.83	20.83			
NAM12	07/15/2020	68	57.5	2.8	945	0	22	25.8	32.6	-6.84	6.84	**Error**		
NOAA	07/16/2020	90	56	2.2	500	1	32.6	10.6	2.25	8.34	8.34	MAE-NAM12	8.16	
NOAA	07/17/2020	87	52	3	450	1	2.25	6.2	7.8	-1.61	1.61	MAE-NOAA	12.10	
NOAA	07/18/2020	70	58	2.6	800	0	7.8	21.7	39.4	-17.65	17.65	MAE-ALL	10.49	
NOAA	07/19/2020	74	63	0.5	700	0	39.4	36.3	30	6.30	6.30			
NOAA	07/20/2020	78	64	1	900	0	30	34.9	39	-4.10	4.10			
NOAA	07/21/2020	80	59	0.5	500	1	39	18.5	17	1.50	1.50			
NOAA	07/22/2020	90	55	2.5	400	1	17	7.9	1	6.87	6.87			
NOAA	07/23/2020	85	53	2	600	1	1	8.9	2.6	6.34	6.34			
NOAA	07/24/2020	90	50	3.2	600	1	2.6	6.0	7	-1.00	1.00			
NOAA	07/25/2020	72	57	0.89	1000	0	7	29.7	39	-9.34	9.34			

Investigation 2

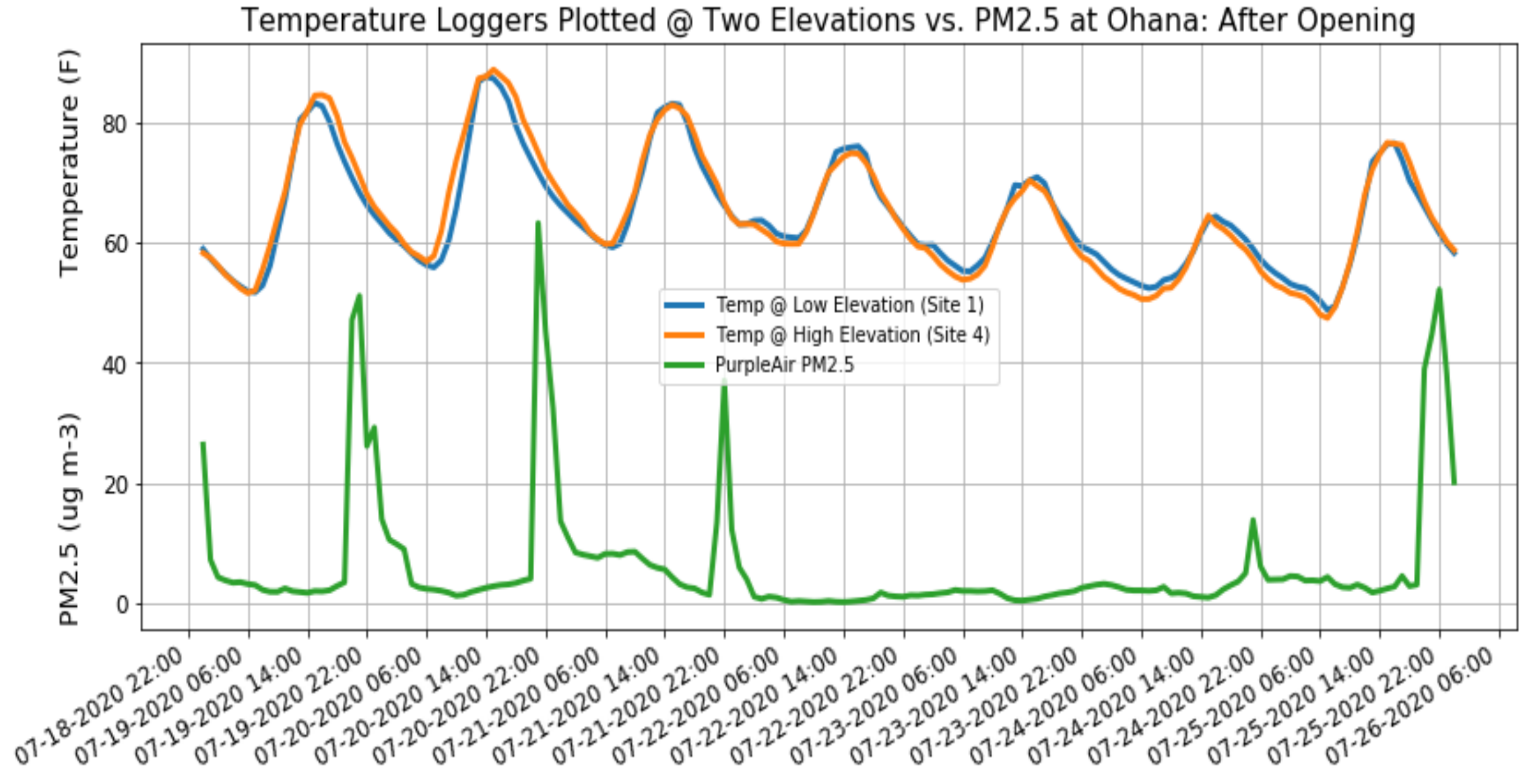## Check for inversions & their effect: Temploggers + PM$_{2.5}$ Collection
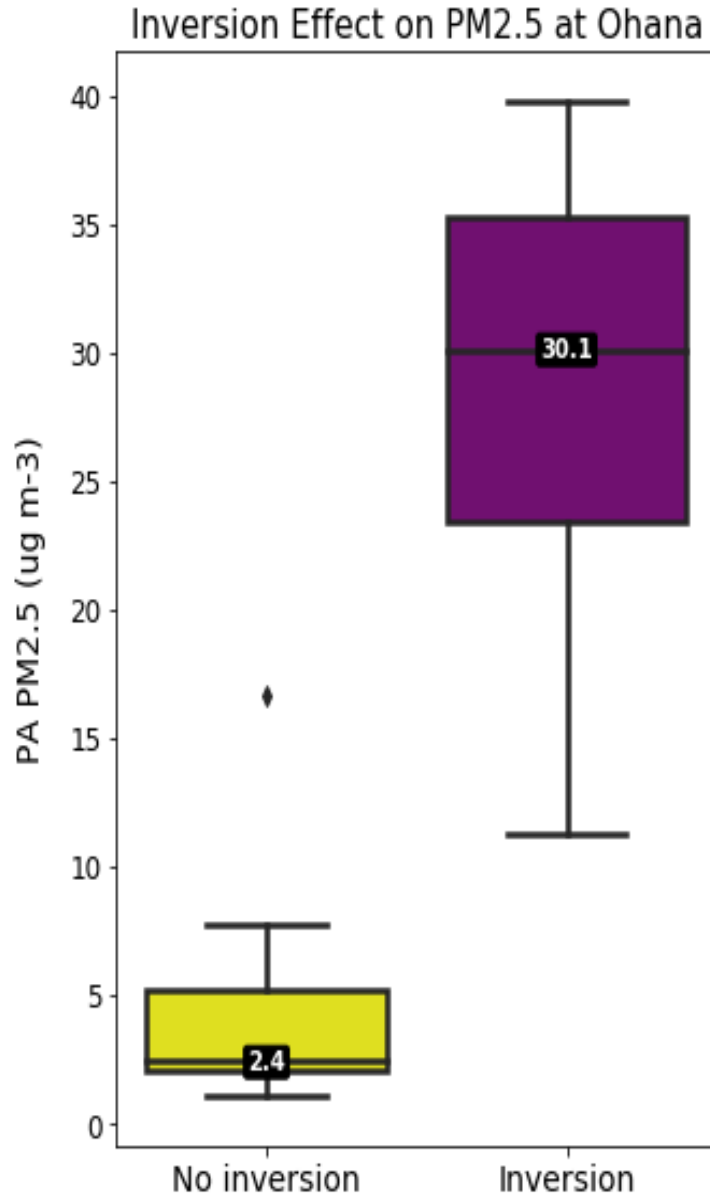
6/30/2016   7/6/2016

OhanaTL#1@1909'

OhanaTL#2@1921
OhanaTL#3@2018'
                                    OhanaTL #4 @2181'

Ohana Wx 1950'

© 2020 Google

1994

Imagery Date: 7/13/2017   10 T 609009.53 m E 5176460.

Ohanapecosh
Campground...

Ohanapecosh
Campground Loop C...

Ohanapecosh
Ranger Station

Orange over blue = Inversion

Temperature Loggers Plotted @ Two Elevations vs. PM2.5 at Ohana: Before Opening

Legend:
- Temp @ Low Elevation (Site 1)
- Temp @ High Elevation (Site 4)
- PurpleAir PM2.5

Orange over blue = Inversion

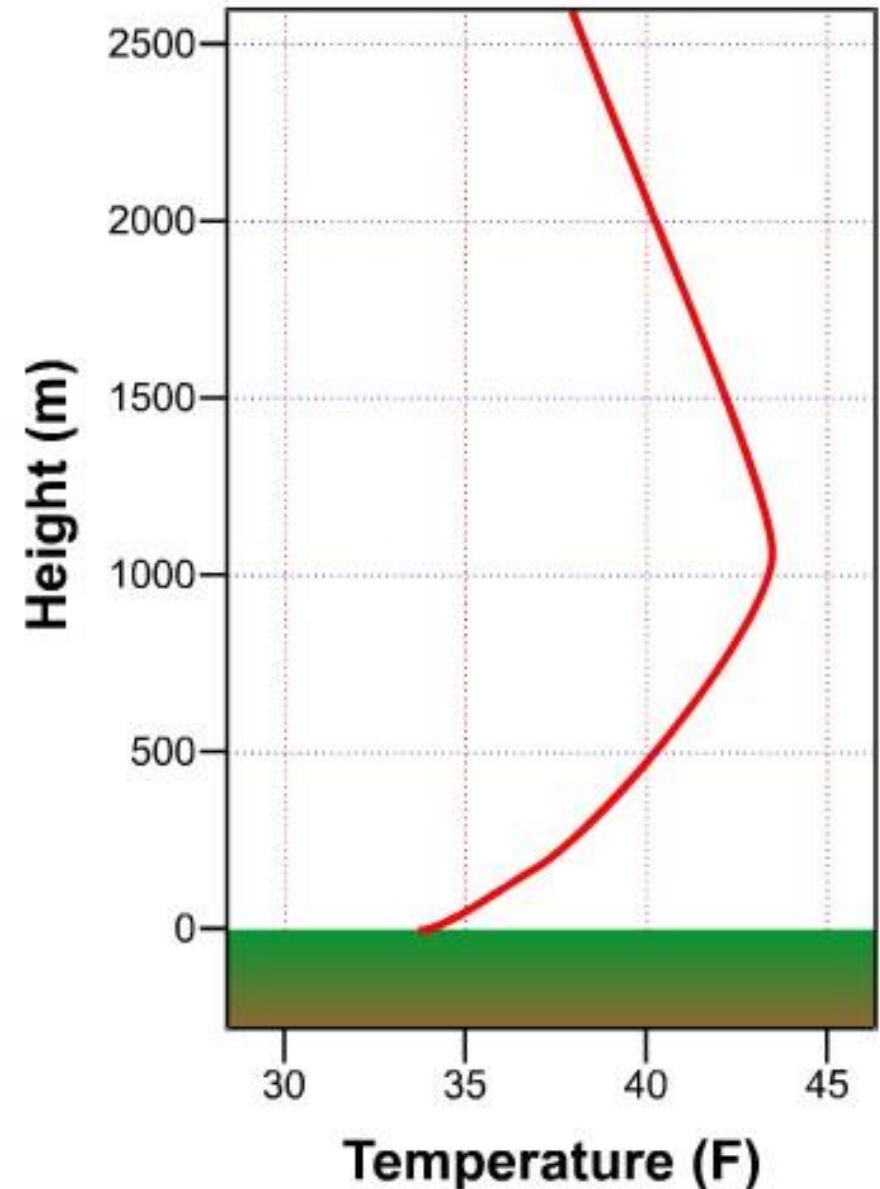Temperature Loggers Plotted @ Two Elevations vs. PM2.5 at Ohana: After Opening

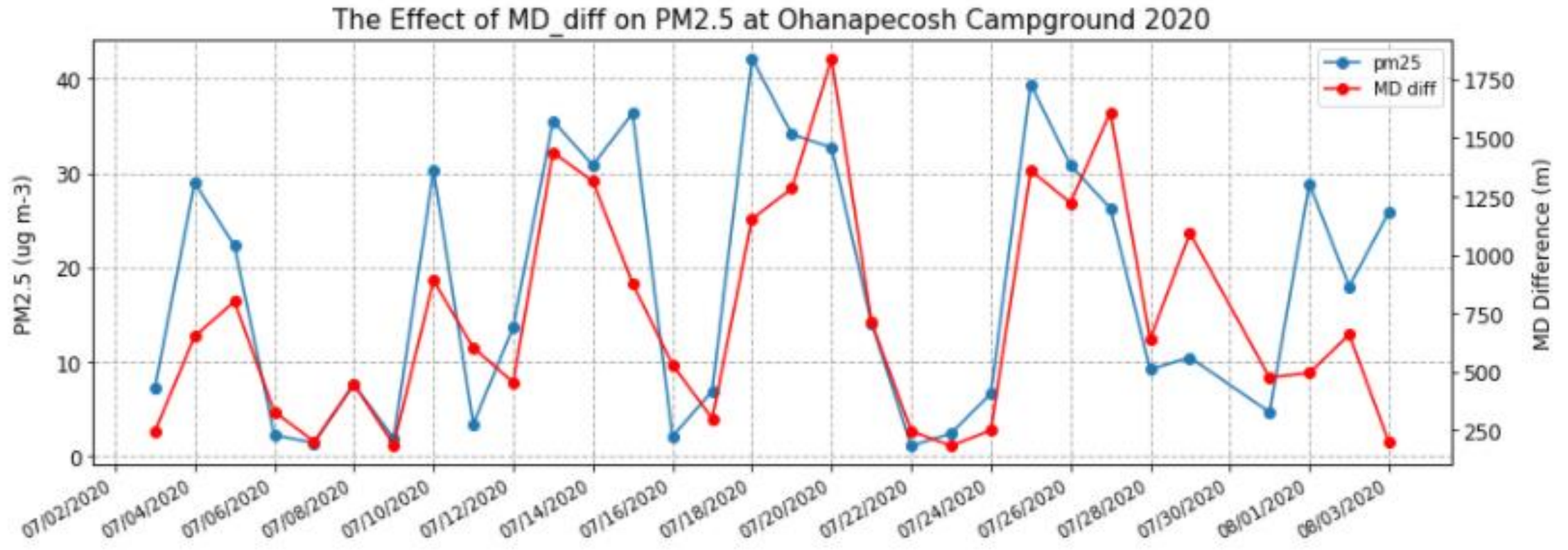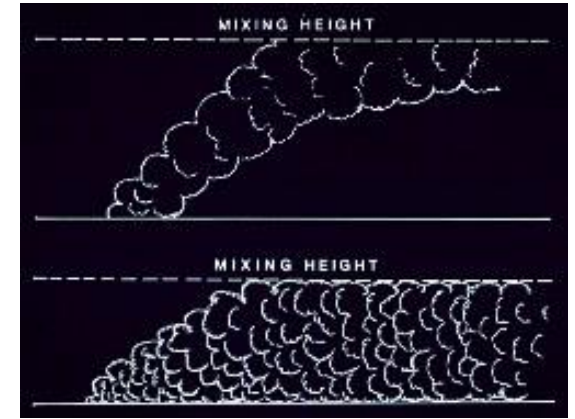Inversion Effect on PM2.5 at Ohana

Conclusions

- 20 of 33 nights after campground opened experienced inversions
- PM2.5 was significantly higher on these nights
- Clouds can prevent inversions from forming
- Clouds correctly predicted whether an inversion would occur 72% of the time (24/33 nights)
  - Clouds present at sunset = no inversion
  - Clear skies at sunset = inversion

Relationship b/w Clouds & Inversions

- The Earth's surface cools more rapidly on clear nights and more slowly on cloudy nights

- During the day, clouds can absorb longwave radiation (infrared) from the ground.

- At night, clouds prevent the ground from cooling off quickly because they supply the ground with radiation they absorbed before, keeping the air temperature at the surface warmer than the overlying air and preventing the inversion

- The opposite is true on clear nights. The ground cools off quickly, and the air just above the ground loses its heat to the ground by conduction throughout the night, resulting in the air near the surface being cooler than the air above it, creating an inversion.

Reference: https://www.ag.ndsu.edu/publications/crops/air-temperature-inversions-causes-characteristics-and-potential-effects-on-pesticide-spray-drift

Difference in afternoon and evening mixing depth a good predictor of Inversions?

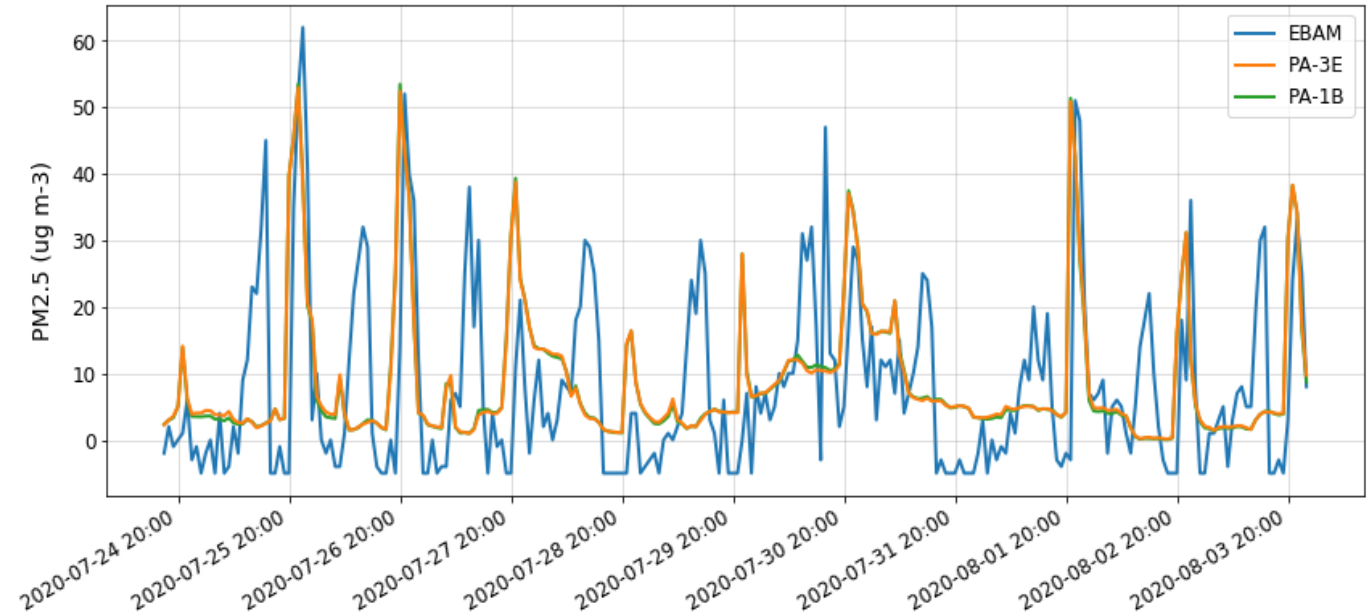The Effect of MD_diff on PM2.5 at Ohanapecosh Campground 2020
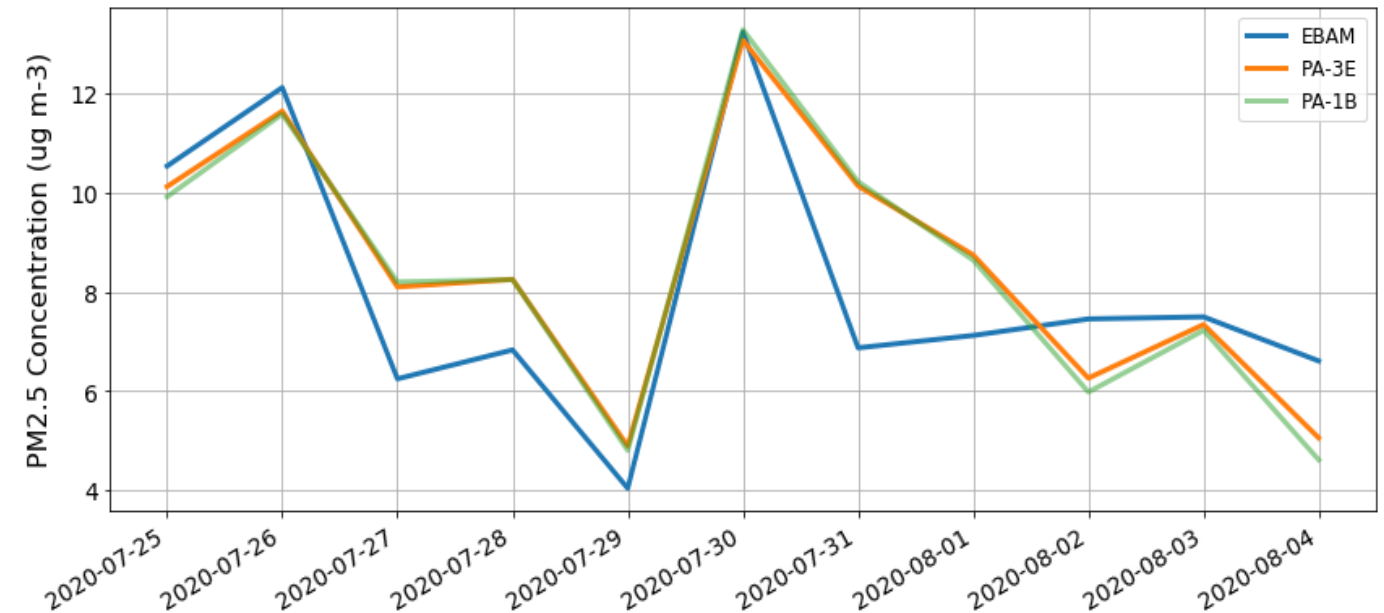
Investigation 3

Compare low-cost Purple Air Sensors with MetOne E-BAM

Hourly E-BAM Concentrations vs 2-PurpleAir Sensors at Ohana: 07/24/2020-08/03/2020

Daily E-BAM & PurpleAir Concentrations at Ohanapocesh Campground: 07/25/20-08/04/20

Thanks for listening!

Any questions?

Plots
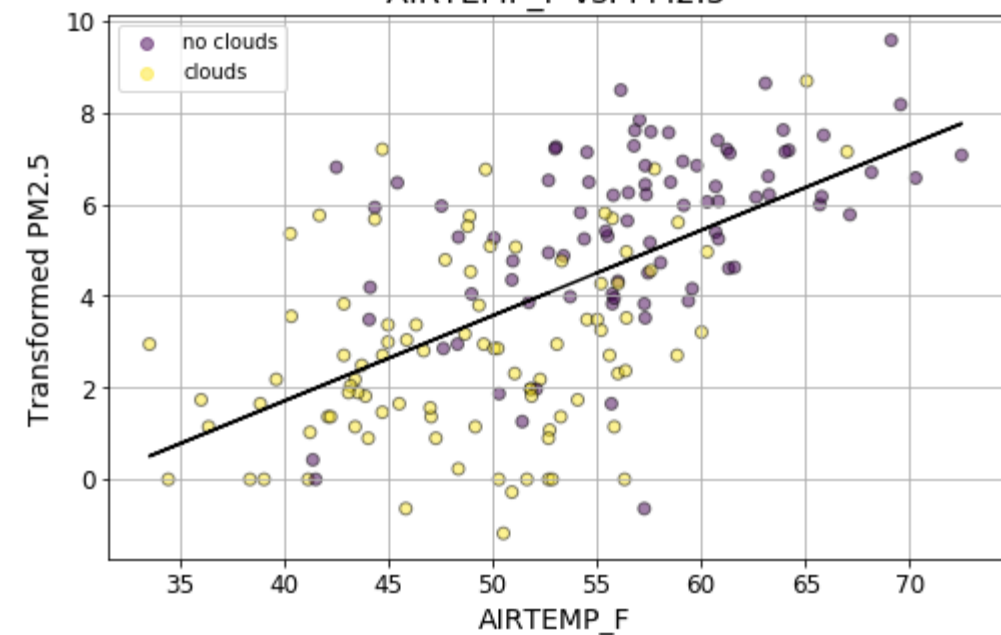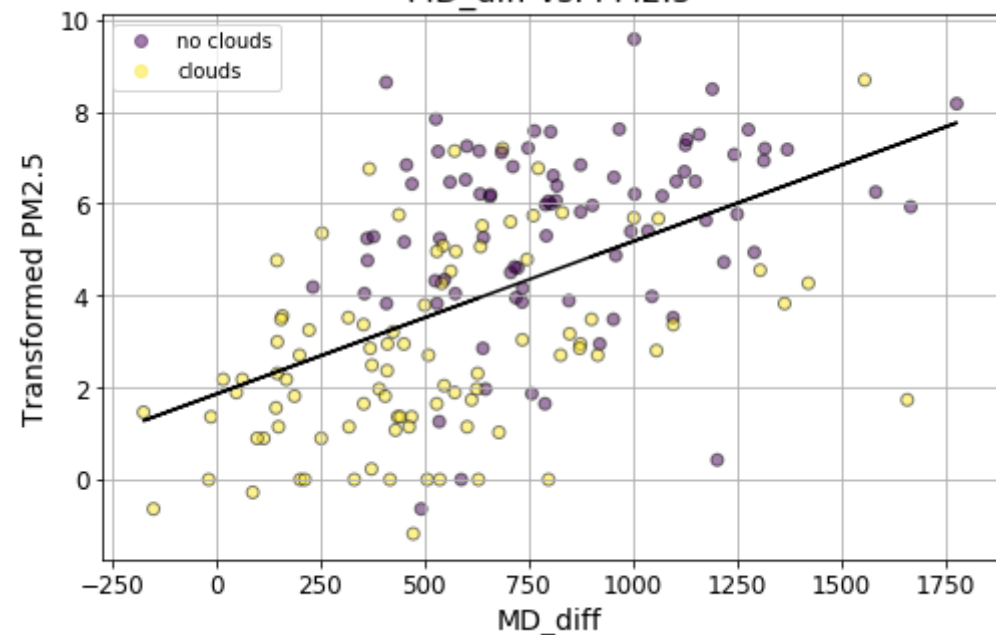
Box-Cox
transformed

Cloud Relationship with Temperature
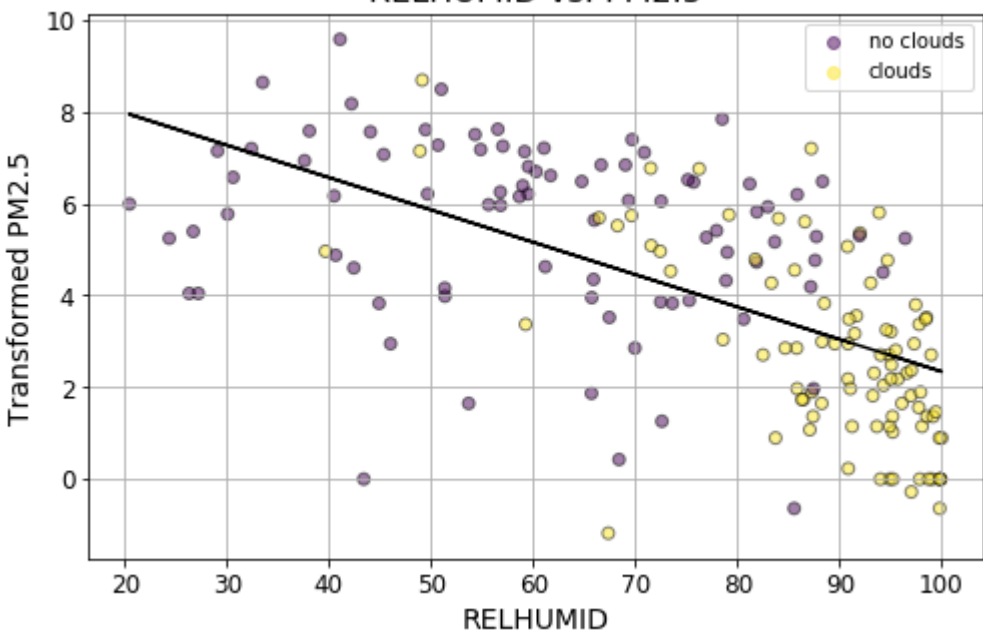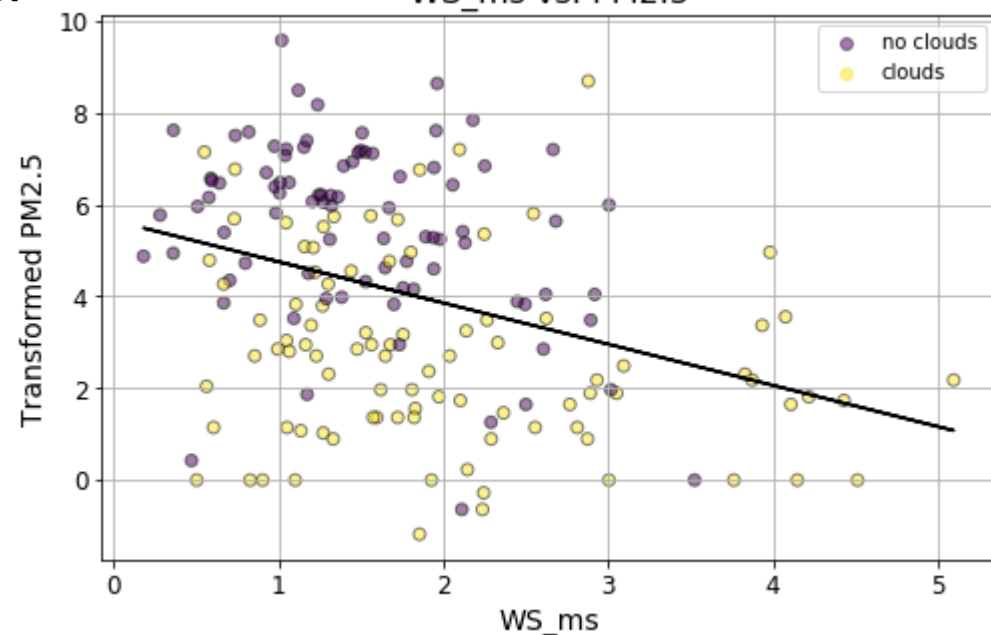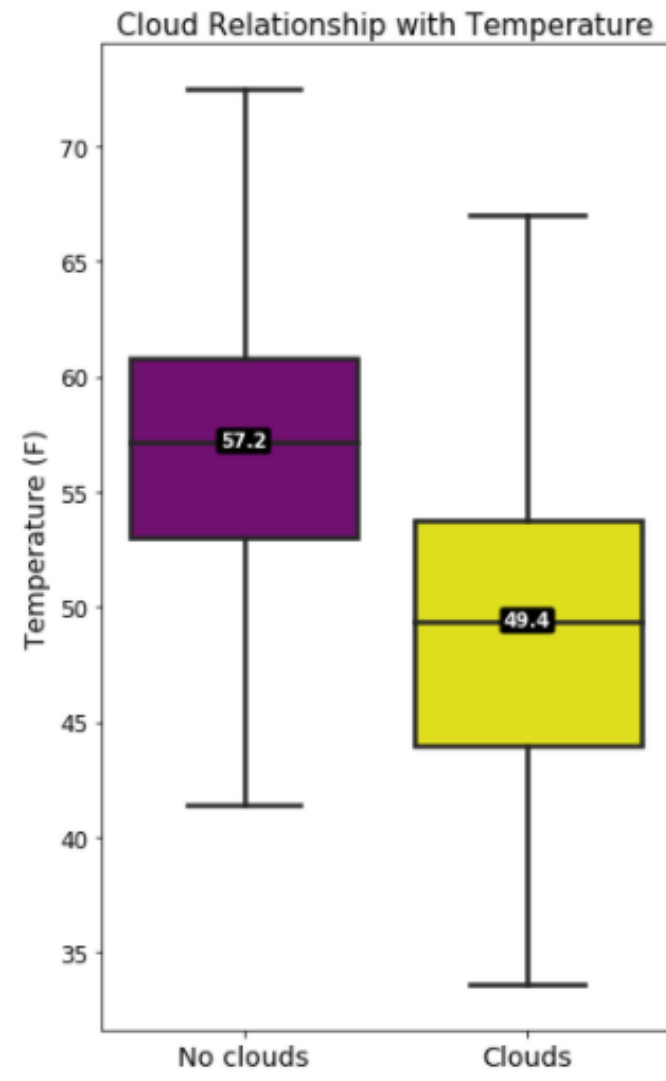
Regional Campfire Ban Decision-Making Flowchart

What AQI category does the park (and its immediately surrounding regions) fall under according to AirNow.gov?

Can one or more current readings validate AirNow forecast?:
- Nearby AirNow PM2.5 station
- Tahoma Woods PM2.5 nephelometer
- Regional PurpleAir Sensors

Can field validation of unhealthy air quality be provided?
- Difficulty breathing?
- Eye-irritation?
- Reduced visibility distinct from fog (webcam)?
- Smoke present?

If the case to support poor air quality in the park is:
- <u>Weak</u> – follow the above procedures again at 11:30am
- <u>Supportive</u> – refer to the corresponding procedures
- <u>Worse than forecasted</u> – refer to the corresponding procedures and provide a final update at 11:30am

Moderate	Unhealthy for Sensitive Groups	Unhealthy	Very Unhealthy	Hazardous
AQI (50-100) $PM_{2.5}$ (12.1-35.4 ug/m^3)	AQI (101-150) $PM_{2.5}$ (35.5-55.4 ug/m^3)	AQI (151-200) $PM_{2.5}$ (55.5-150.4 ug/m^3)	AQI (201-300) $PM_{2.5}$ (150.5-250.4 ug/m^3)	AQI (301-500) $PM_{2.5}$ (>254.5 ug/m^3)
• Recommend groups to not use campfires if anyone in the group is sensitive to poor air quality • Encourage small groups to keep campfires small or to combine with other groups • Encourage groups to completely extinguish campfires upon completion	• Prohibit individual campfires and setup group campfire locations in the major campgrounds • Require all campfires to be completely extinguished by 11pm	• Prohibit the use of campfires across the park.	• Prohibit the use of campfires across the park.	• Prohibit the use of campfires across the park.