# Preliminary Evaluation of an Alternative Implementation Of AERMOD's Penetrated Plume Treatment

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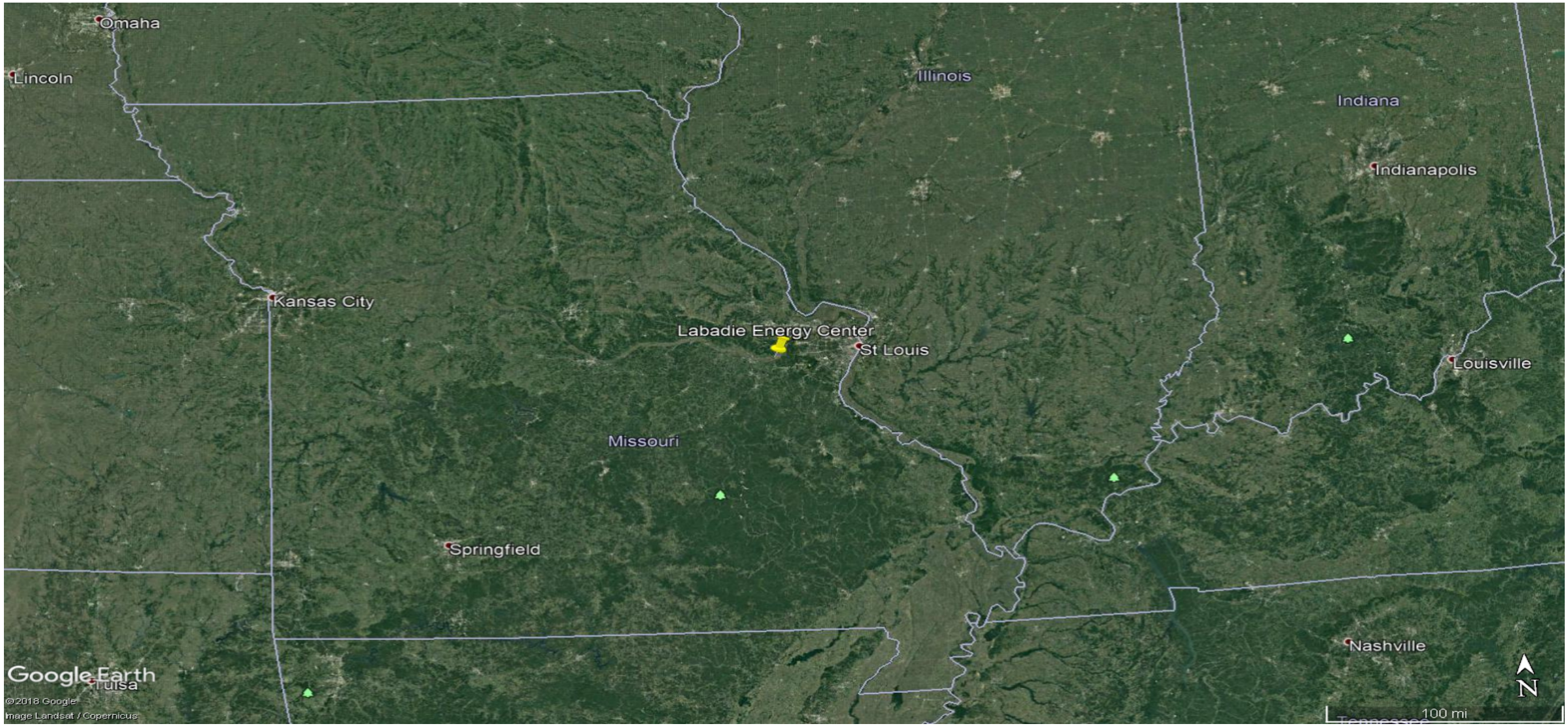
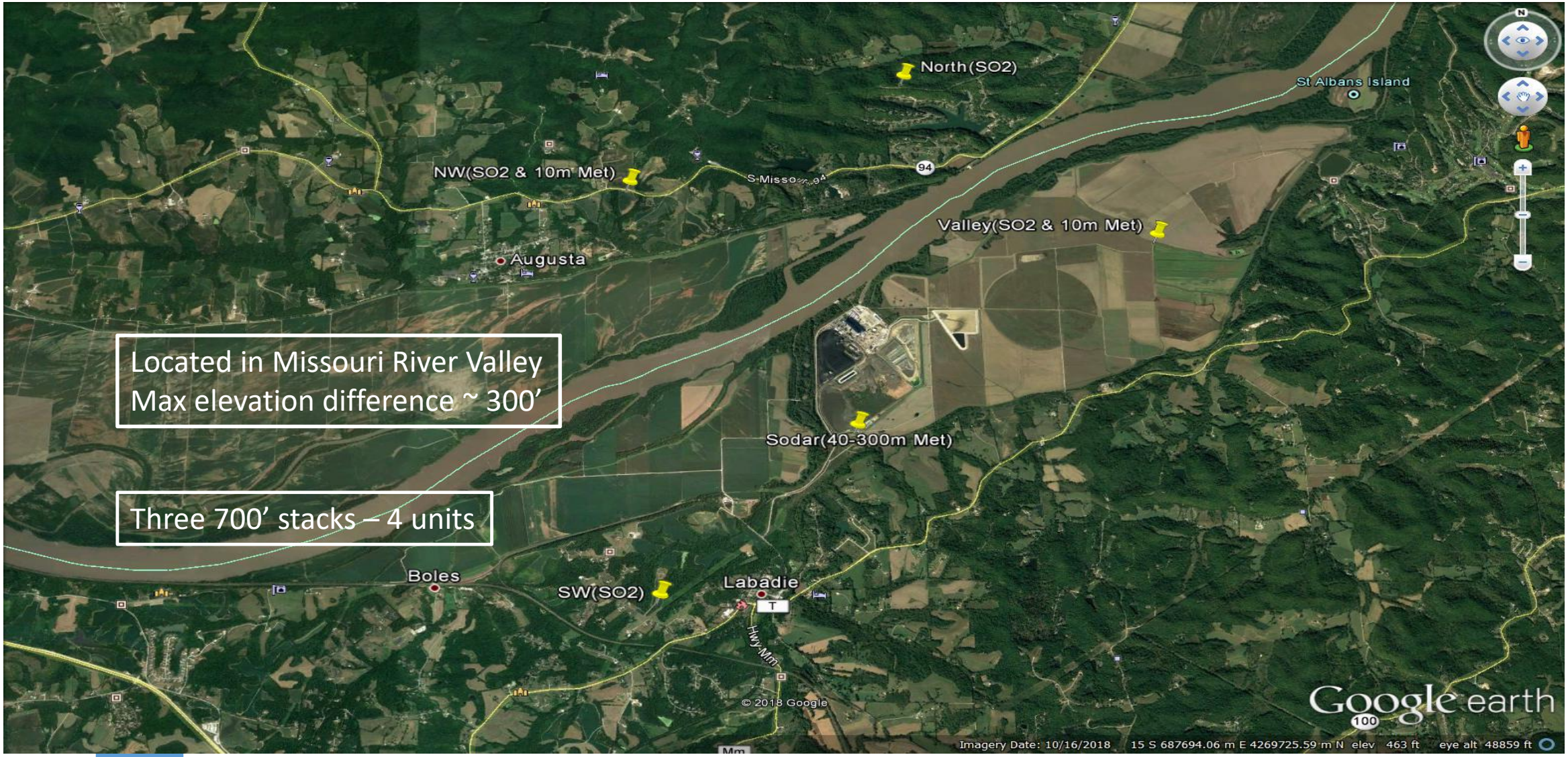
# Labadie Energy Center Location



# Labadie Ambient Monitoring System

- Ameren operates an ambient monitoring network around the Labadie Energy Center.
  - 4 $SO_2$ monitoring sites
  - 2 10m meteorological towers
    - 10m wind speed and direction including sigma-theta
    - 2m and 10m temperature and 2m relative humidity
    - 10m vertical wind speed and sigma
    - Solar radiation, precipitation and station pressure.
  - SODAR with a vertical range of 40m – 300m
    - Wind speed and direction with turbulence (i.e. sig-w, sig-theta …)
    - Virtual temperature

# Labadie Ambient Monitoring System




Located in Missouri River Valley
Max elevation difference ~ 300’

Three 700’ stacks – 4 units

# Determination of Best Performing Meteorology

- Utilize default AERMOD with various onsite meteorological scenarios in combination with NWS KSUS surface (Chesterfield Airport, MO) and KILX upper air (Lincoln, IL) data.  Evaluation used 2017-18 meteorological data.
  - Individual 10m tower data with turbulence at the NW and Valley sites
  - Individual 10m tower data without turbulence and Ustar at the NW and Valley sites
  - NWS KSUS without any onsite data and Ustar
  - Individual 10m tower data with turbulence at the NW and Valley sites with SODAR data including turbulence(20m layers to 300m)
  - Individual 10m tower data with turbulence at the NW and Valley sites with SODAR wind speed and direction only without turbulence(20m layers to 300m)
- Best AERMOD performance resulted with the use of the Valley 10m data set with turbulence and SODAR wind speed and direction only(20m layers to 300m).

# AERMET Meteorology on Default AERMOD Modeled High Days

| Date/time | Hour | WS (m/s) | WD(deg) | Mixing Height(m) | Stable/ Unstable(L) | Pen Fraction | Dominant Plume Type |
|---|---|---|---|---|---|---|---|
| 18022211 | 11 | 1.91 | 28.9 | 374 | -7.5 | .97-.86 | pen |
| 18060609 | 9 | 1.07 | 26.8 | 300 | -2.9 | 1 | pen |
| 17052708 | 8 | 1.02 | 44.3 | 488 | -1.7 | .79-.63 | pen |
| 18120911 | 11 | 2.57 | 28.7 | 283 | -7.9 | 1 | pen |
| 18071912 | 12 | 2.04 | 193 | 470 | -27.4 | .82-.64 | pen |
| 17022310 | 10 | 1.28 | 27.1 | 323 | -1.8 | 1 | Pen |
| 17112611 | 11 | 1.65 | 252.8 | 460 | -9.2 | .81-.65 | pen |
| 17053109 | 9 | 0.72 | 271.7 | 492 | -1 | 1.0-.94 | Pen |
| 18111114 | 14 | 1.26 | 254.3 | 349 | -12 | 1 | Pen |
| 17062709 | 9 | 0.92 | 264.8 | 559 | -3 | .9-.75 | Pen |

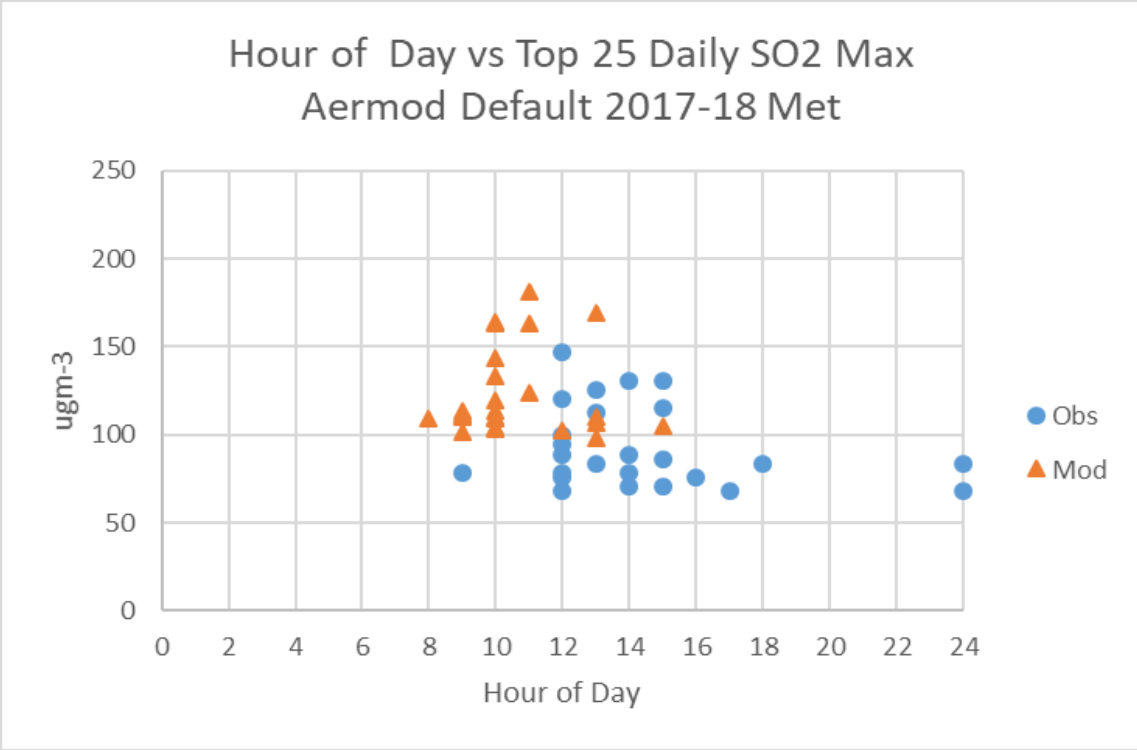
Note: Valley met 2017-18

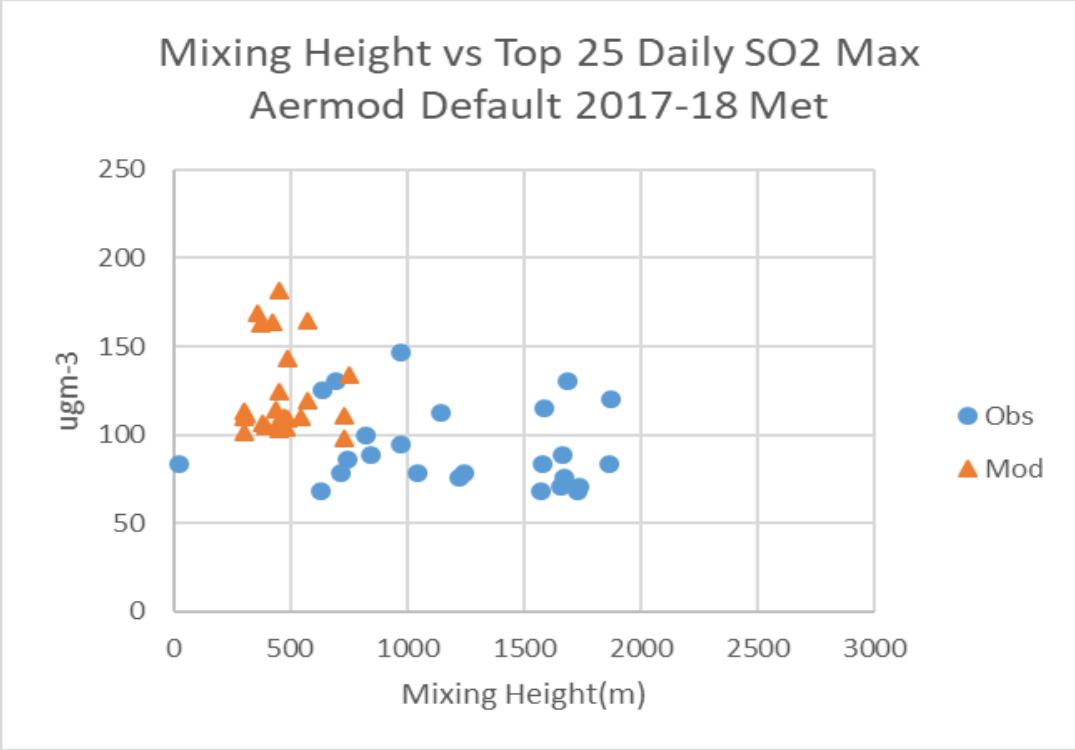
# AERMET Meteorology on Observed High Days

| Date/time | Hour | WS (m/s) | WD(deg) | Mixing Height(m) | Stable/ Unstable(L) | Pen Fraction | Dominant Plume Type |
|---|---|---|---|---|---|---|---|
| 18031412 | 12.0 | 4.17 | 262.1 | 971 | -21.8 | .37-.22 | Dir |
| 18041015 | 15.0 | 2.66 | 253.9 | 1690 | -8.5 | 0 | Dir |
| 18020214 | 14.0 | 1.54 | 321.6 | 695 | -2.9 | .44-.28 | Ind |
| 17111613 | 13.0 | 1.42 | 59.2 | 636 | -6 | .3-.14 | Ind |
| 18091812 | 12.0 | 2.68 | 265.2 | 1873 | -16.4 | 0.01 | Dir |
| 17080915 | 15.0 | 1.9 | 327 | 1586 | -9.4 | 0.02 | Dir |
| 17091413 | 13.0 | 1.68 | 304.7 | 1144 | -5.3 | .1-.08 | Ind |
| 18093012 | 12.0 | 1.72 | 218.9 | 821 | -7.4 | 0.24 | Ind |
| 18041712 | 12.0 | 3.09 | 4.6 | 971 | -9.1 | .05-.02 | Dir-Ind |
| 17101912 | 12.0 | 2.85 | 270 | 846 | -16.4 | .16-.12 | Ind |

Note: Valley 2017-18 met

# Modeled and Monitored $SO_2$ Concentrations by Time of Day Mixing Height



# Alternative Penetrated Plume Treatment – "PENMOD"

- **Check on the mixing height for the current hour as well as the next hour to determine how the effective dispersion parameters for the penetrated plume should be computed. Note: only invoked under unstable conditions and stack height below the mixing height.**

Current and the next hour's mixing height are both below the penetrated plume final height

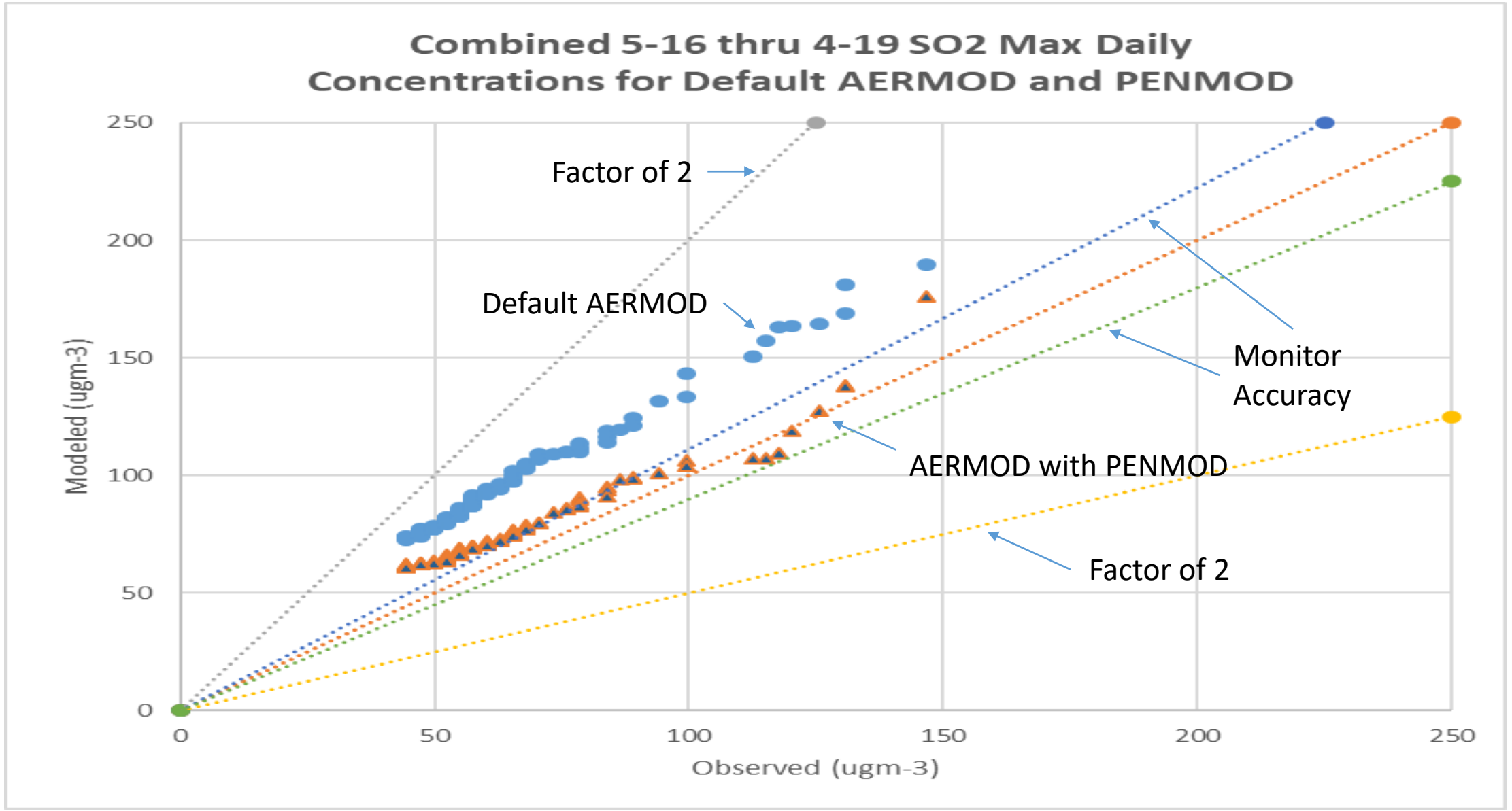
Utilize Effective parameters at penetrated plume height for sigma calculations

Current mixing height is below the penetrated plume height, but the next hours mixing height rises above that height

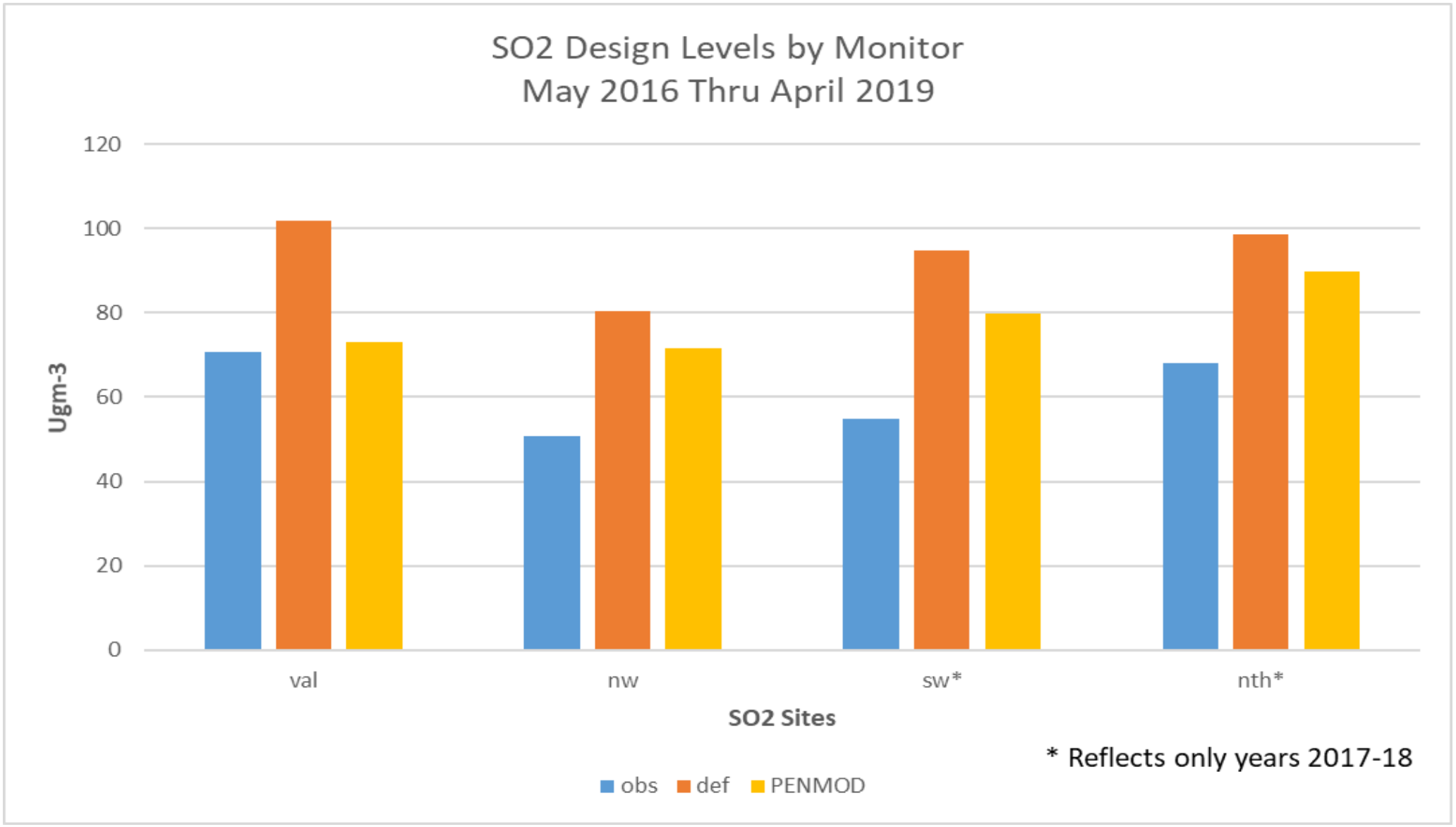
Utilize a weighted average of the effective parameters at penetrated plume height and AERMODs default determination of the effective parameters based on the time the next hours mixing height reaches the penetrated plume height. A linear rise in mixing height is assumed between hours.

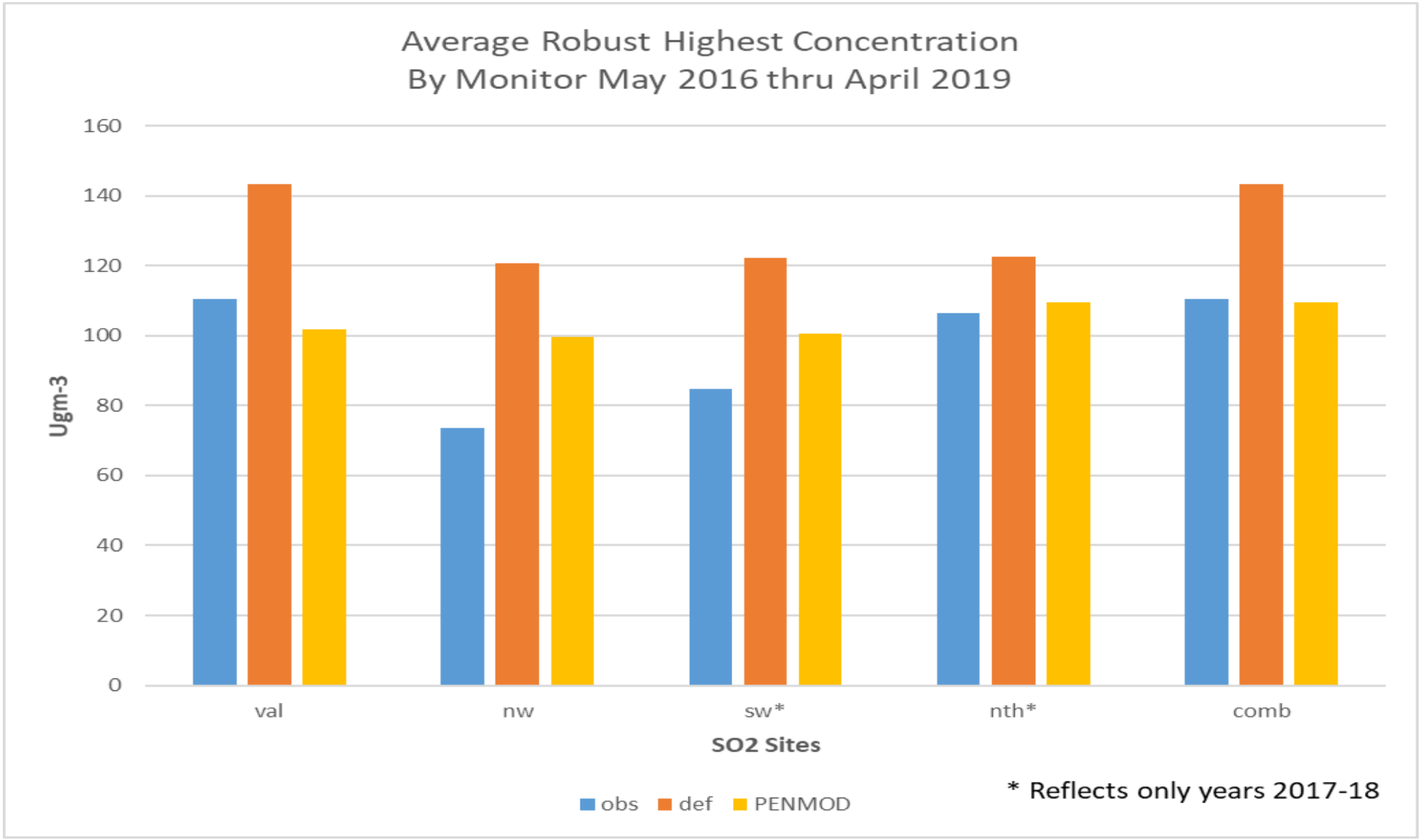
# Application of the Alternative Penetrated Plume Treatment

- Utilizing 3 years of ambient data from the Labadie Network – May 2016 thru April of 2019
- Following comparisons were made between default AERMOD and AERMOD with “PENMOD”
  - Q-Q plots for each monitor and combined
  - Design Value comparisons
  - Robust Highest concentrations and Robust 4$^{th}$ Highest concentrations
  - Fractional Bias and other statistics
  - EPA’s Model Evaluation Methodology (MEM)

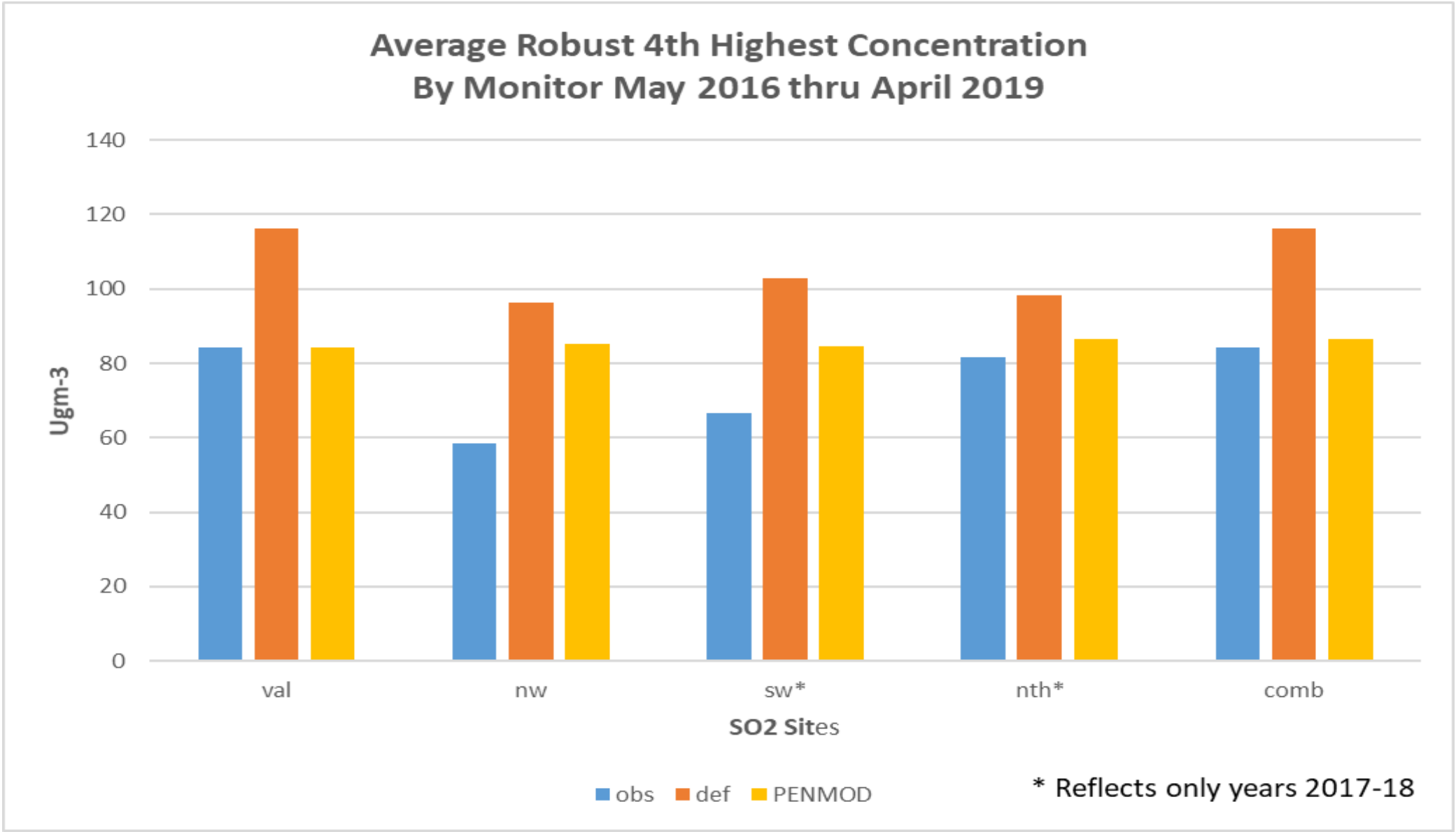



**Note: All monitor location concentrations combined as one monitor**


SO2 Design Levels by Monitor
May 2016 Thru April 2019
120
100
80
60
40
20
0
Ugm-3
val
nw
sw*
nth*
SO2 Sites
* Reflects only years 2017-18
obs
def
PENMOD




**comb – highest concentration between monitors**



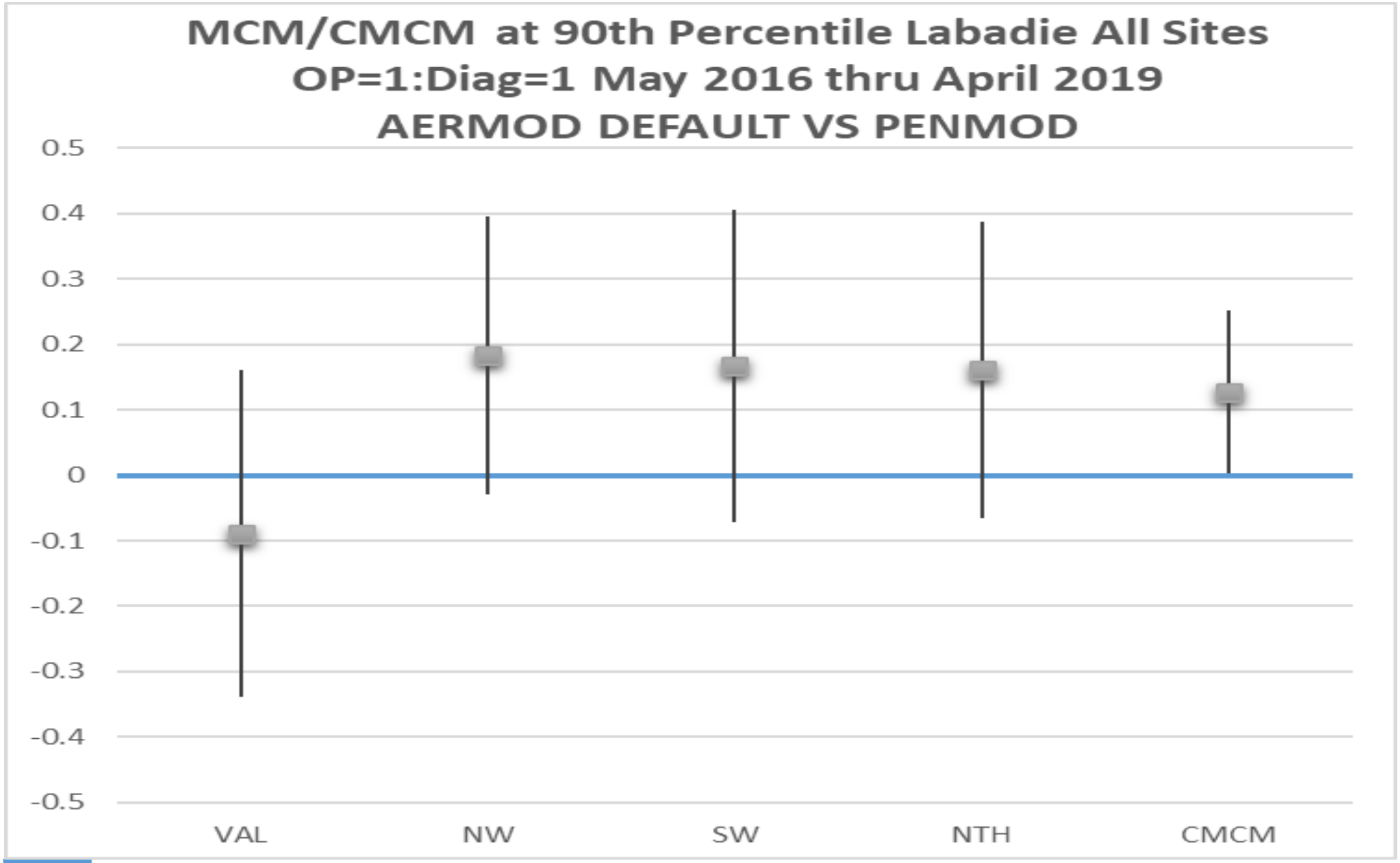

**comb – highest concentration between monitors**

# Fractional Bias – Modeled/Observed Comparison of AERMOD Default with AERMOD PENMOD Modification

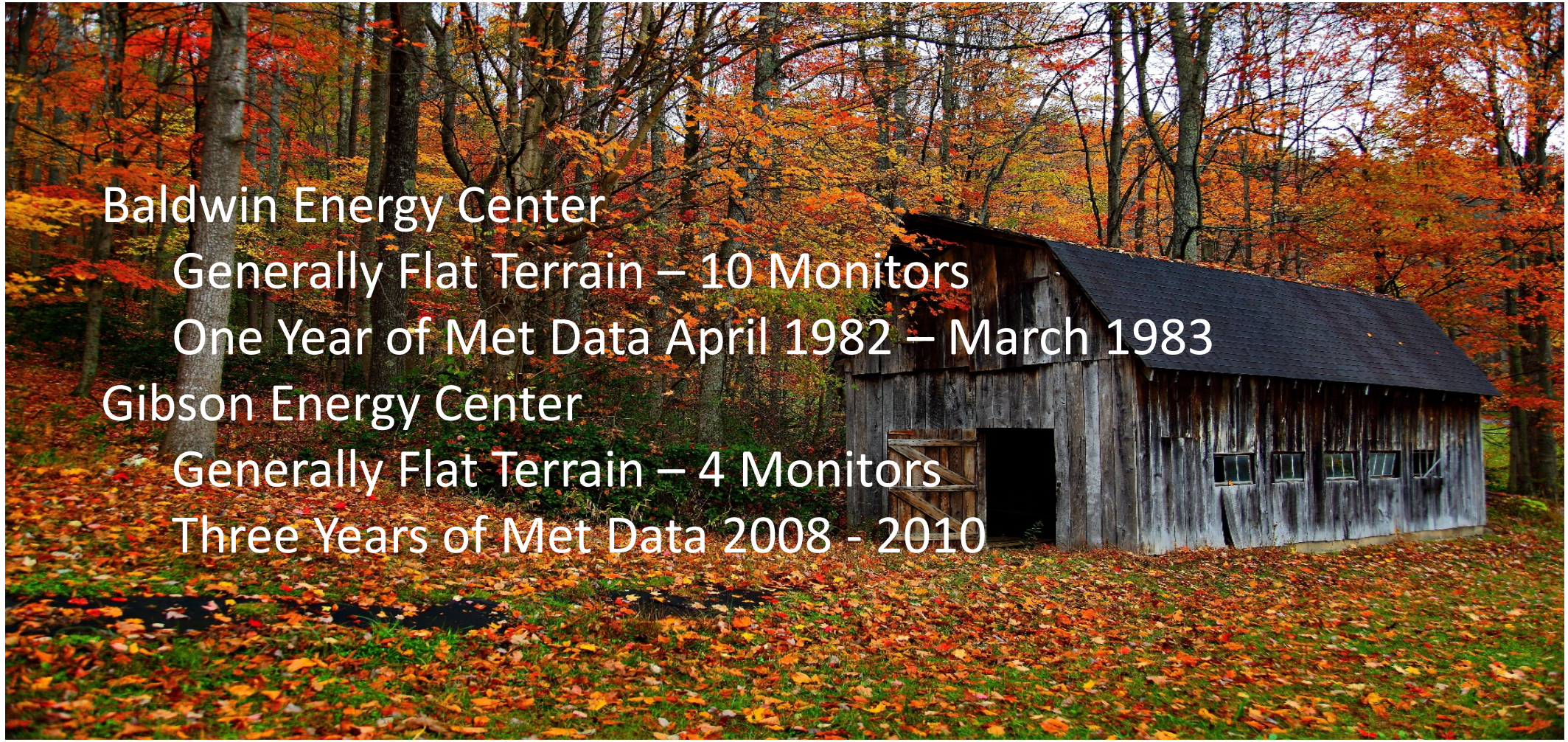
| Site | Aermod Default Frac Bias | Aermod Default Ratio Mod/Obs Concentrations | Aermod PENMOD Frac Bias | PENMOD Ratio Mod/Obs Concentrations |
|---|---|---|---|---|
| val | -0.330 | 1.395 | -0.025 | 1.025 |
| nw | -0.546 | 1.750 | -0.332 | 1.398 |
| sw* | -0.466 | 1.607 | -0.252 | 1.288 |
| nth* | -0.344 | 1.416 | -0.178 | 1.195 |
| comb | -0.322 | 1.383 | -0.073 | 1.076 |

*** Based on data from January 2017 thru April 2019**

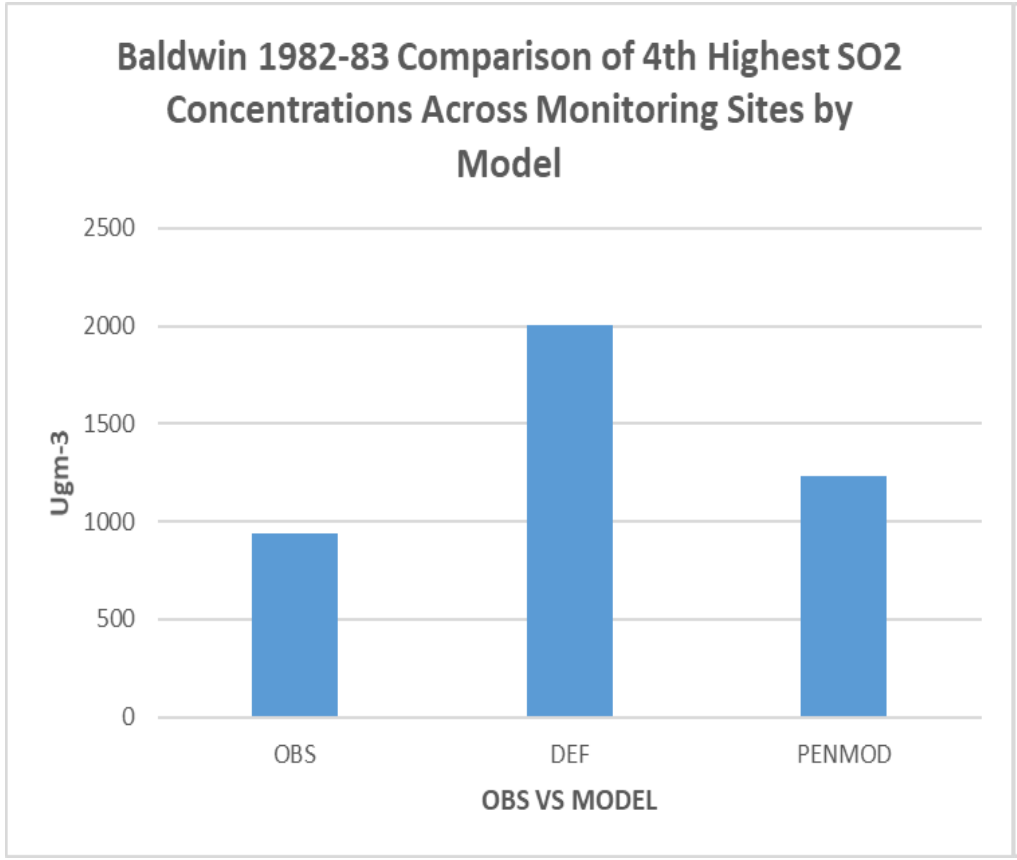
**Comb – all site location concentrations combined as one monitor**

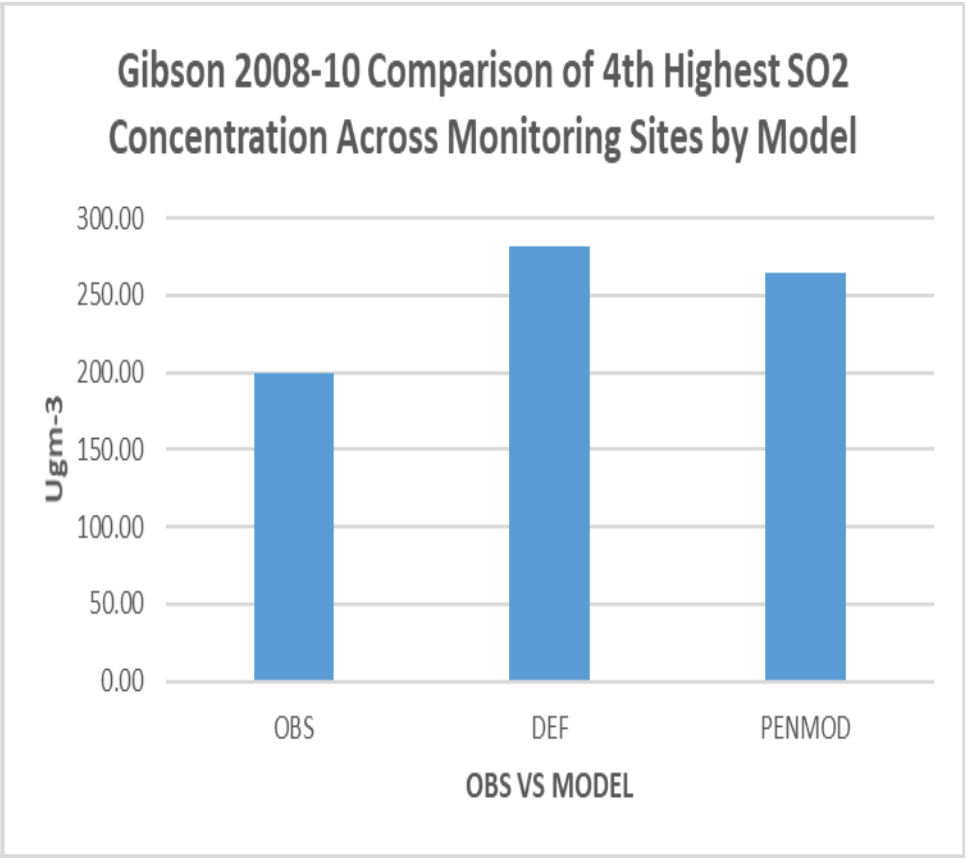

MCM/CMCM at 90th Percentile Labadie All Sites
OP=1:Diag=1 May 2016 thru April 2019
AERMOD DEFAULT VS PENMOD
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
VAL
NW
SW
NTH
CMCM

# Other PENMOD Evaluations



# Comparison of 4th High Max $SO_2$ at Monitoring Sites by Model Baldwin and Gibson



# Conclusion – Next Steps

- The current implementation of AERMOD's penetrated plume treatment dominates the higher modeled concentrations for elevated point sources ultimately over predicting the observed concentrations.

- The actual higher observed concentrations appear to not be the result of the entrainment of the penetrated plume under low mixing heights, but occur under higher mixing heights and most likely the impacts from the direct and indirect AERMOD plumes or other processes not accounted for in AERMODs implementation.

- The PENMOD modification reduces this over prediction by giving consideration to whether for a given hour you would expect the penetrated plume to actually be entrained into the mixed layer or whether you would expect it to remain in the stable layer above.

- We will continue to evaluate this alternative with other datasets and the Labadie Energy Center monitoring network as the dataset grows.