

Kalman Filter Bias Correction for AIRPACT PM_{2.5} Forecasts

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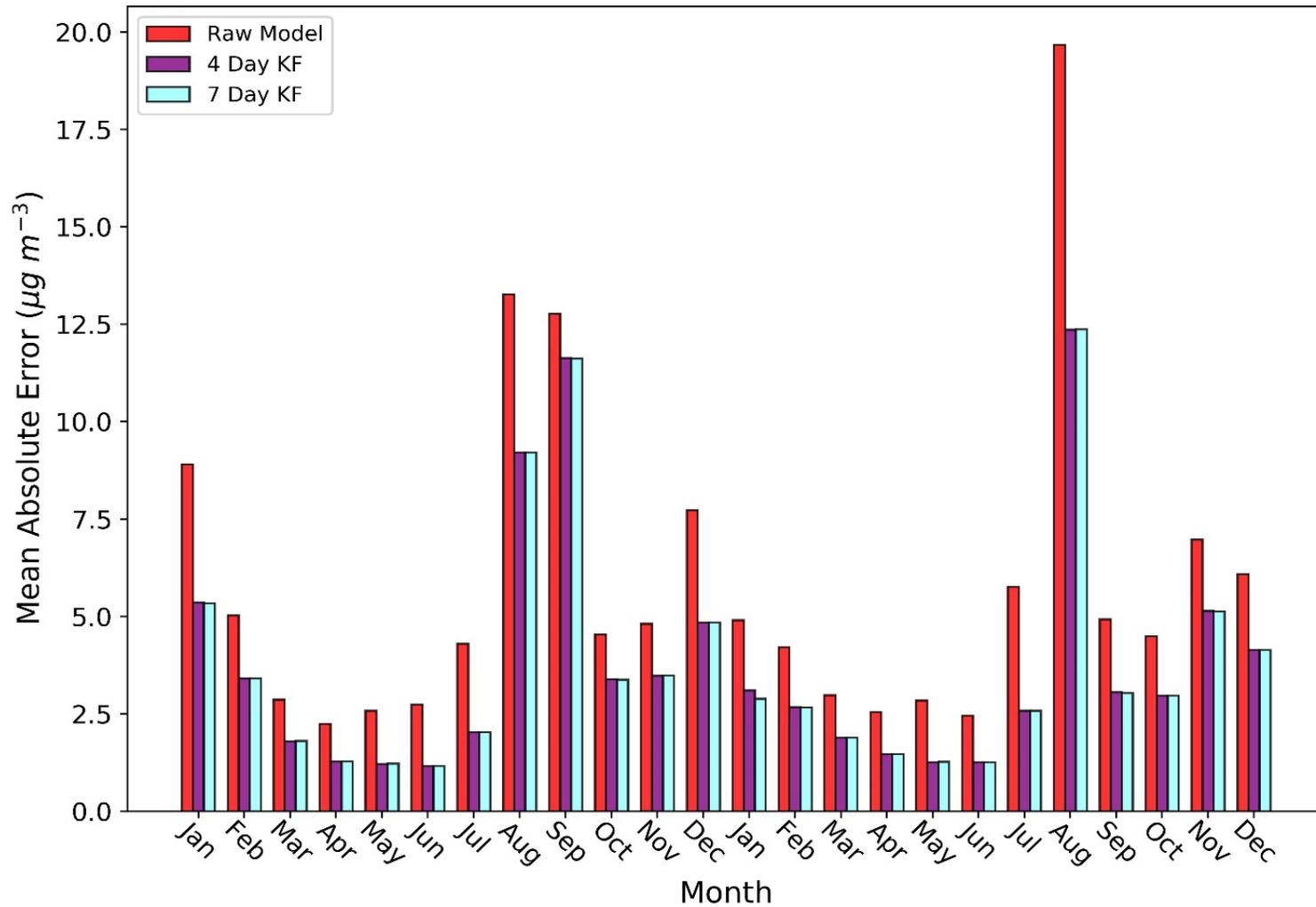
NW-AIRQUEST Annual Meeting

Kalman Filter Method

- Tested both 4-Day and 7-Day Training Period for a Kalman Filter
 - The Kalman Filter uses the biases from the training period to predict the biases of the rolling 24-hour averaged PM_{2.5}
 - The observations used are reported via AIRNow
 - $Bias = AIRPACT_{24h,PM_{2.5}} - AIRNow_{24h,PM_{2.5}}$
 - The AIRPACT 24-hr PM_{2.5} values are extracted at site locations
 - The Kalman Filter
 - $Bias_t = [1 - Bias_{t-1}]K_t + \epsilon_t$
 - Where $Bias_t$ is the predicted bias, $Bias_{t-1}$ is the bias at the previous time step, K_t is the Kalman Gain, and ϵ_t is a noise term based on the variance of the bias
 - $KF_t = AIRPACT_t - Bias_t$
 - Where KF_t is the bias corrected PM_{2.5}, and $AIRPACT_t$ is the rolling 24-hour averaged PM_{2.5}

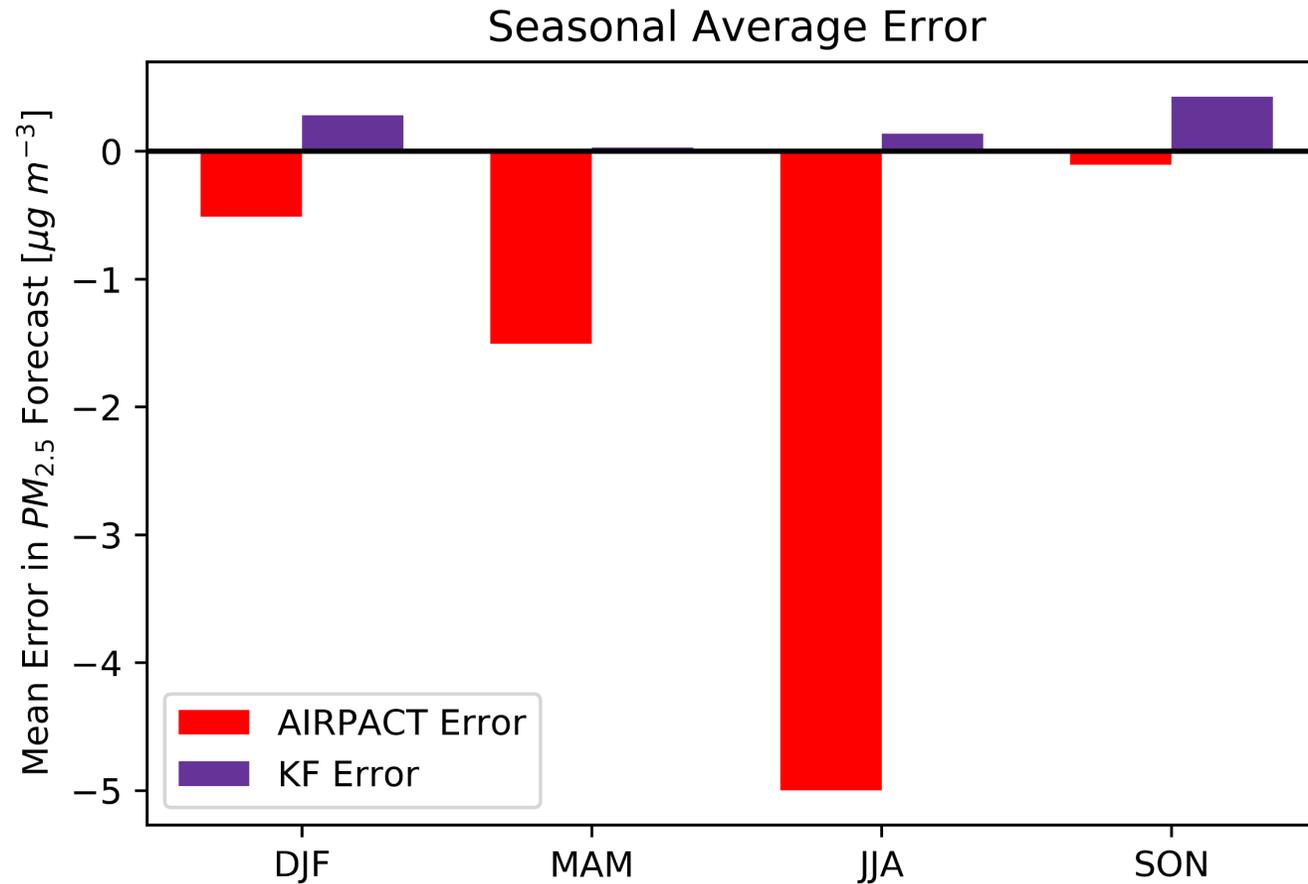
Mean Bias (%) for 4 & 7 Day Training Periods by Month (2017 & 2018 combined)

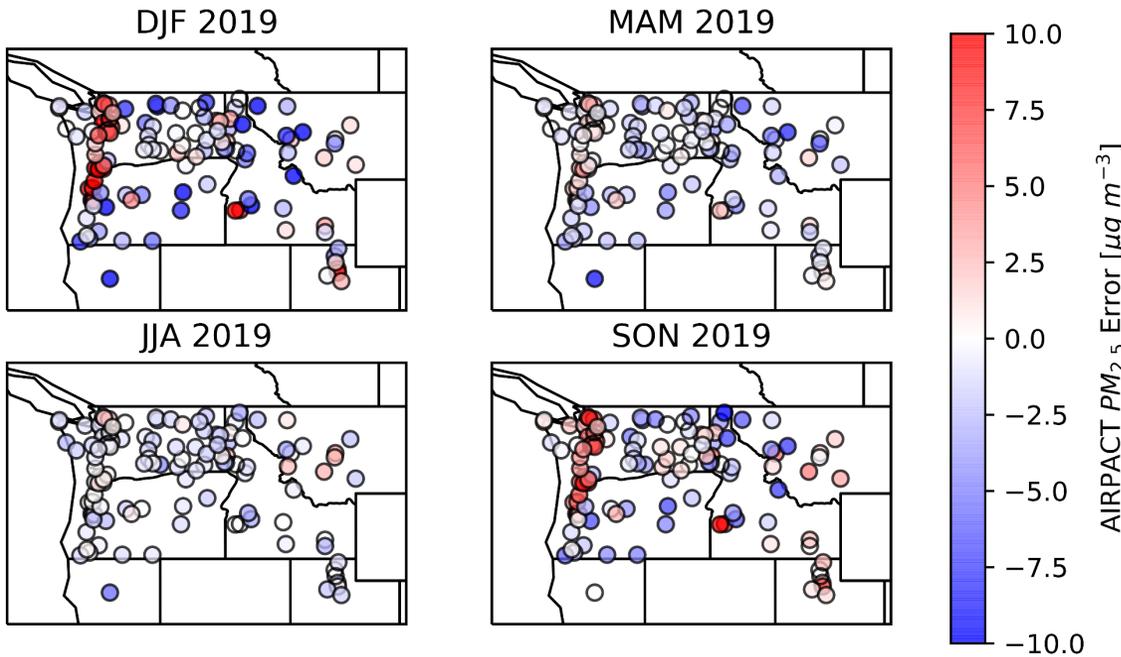
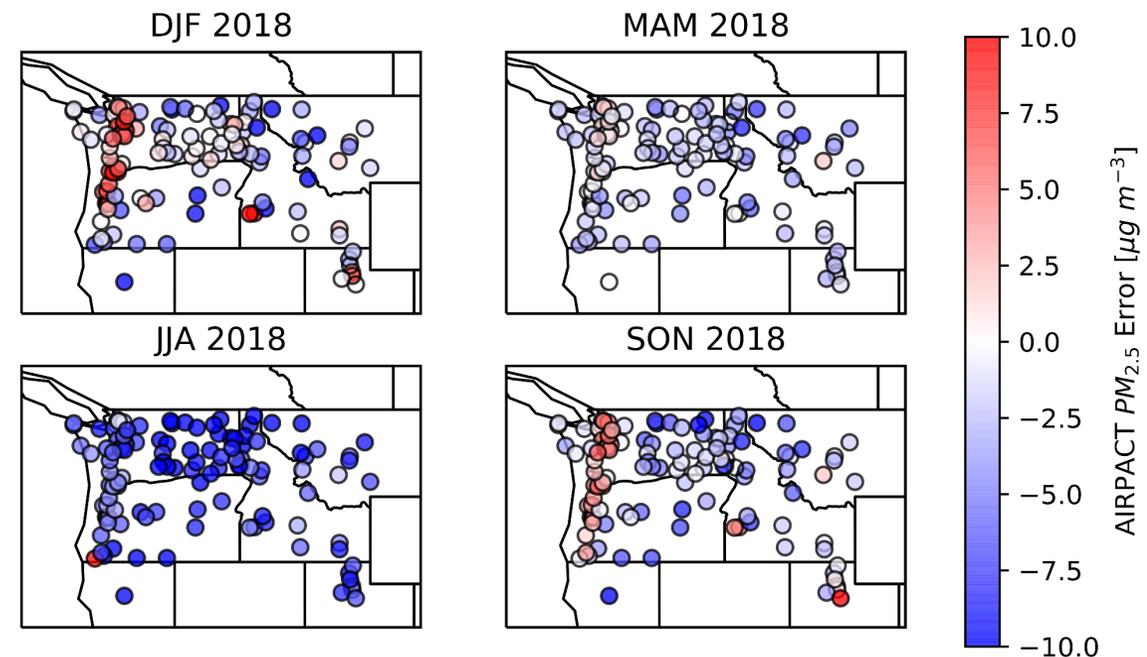
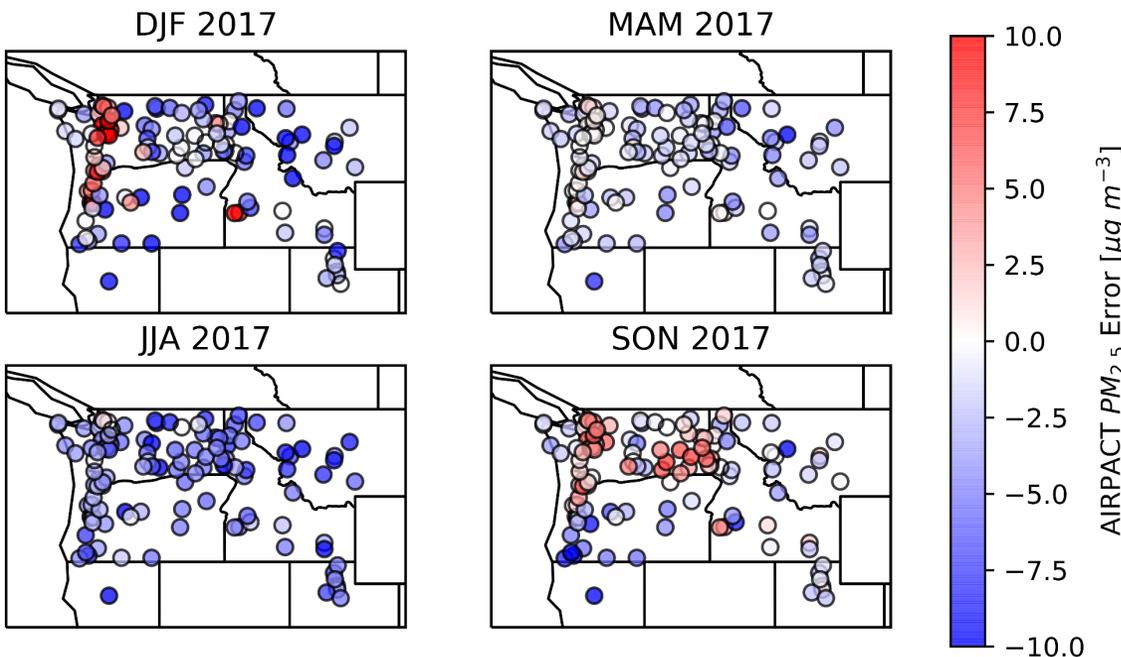
Month	Mean Observed PM _{2.5} (ug/m ³)	Raw AIRPACT	7 day Kalman Filter	4 day Kalman filter
January	9.7	-25%	-3%	3%
February	6.4	-18%	3%	3%
March	4.7	-32%	2%	2%
April	4.1	-50%	-1%	-3%
May	4.5	-54%	0%	-1%
June	4.2	-57%	0%	0%
July	7.6	-62%	-2%	-3%
August	23.5	-62%	2%	2%
September	15.3	-13%	6%	6%
October	7.7	-14%	2%	2%
November	9.2	-8%	4%	4%
December	9.5	7%	1%	1%
Average	8.9	-32.1%	1.1%	1.3%



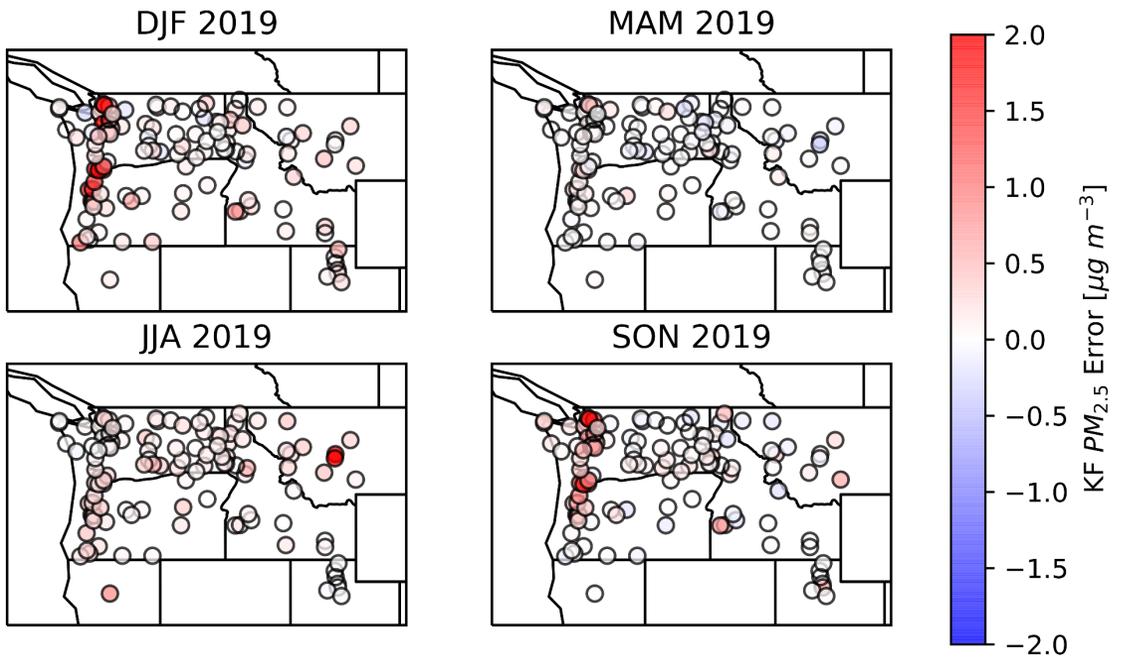
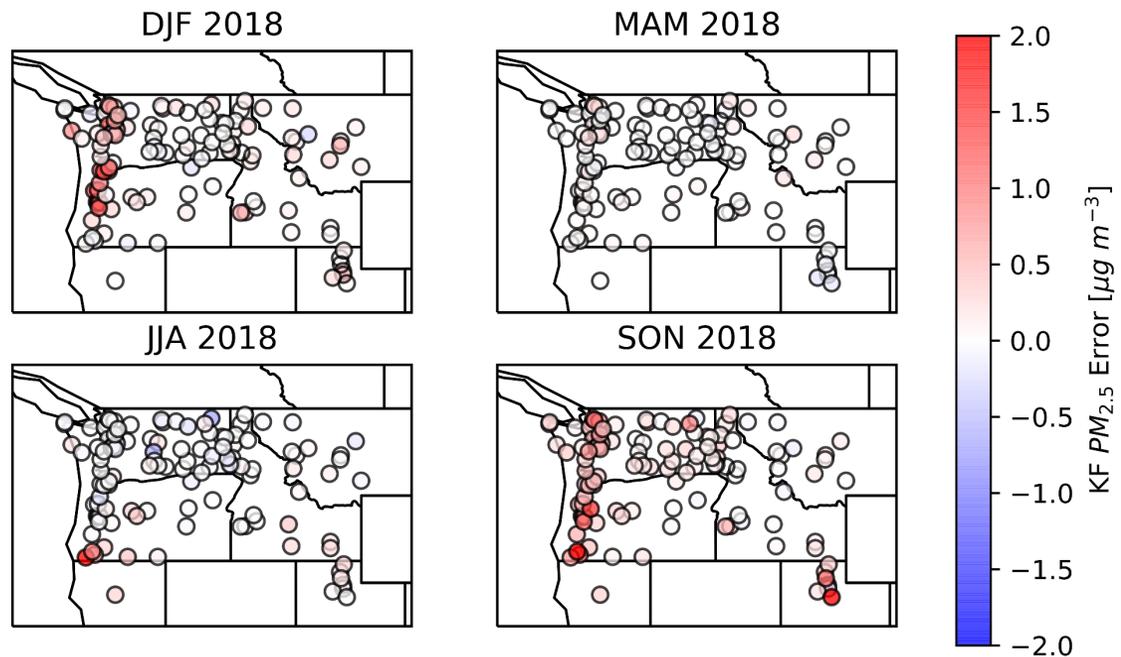
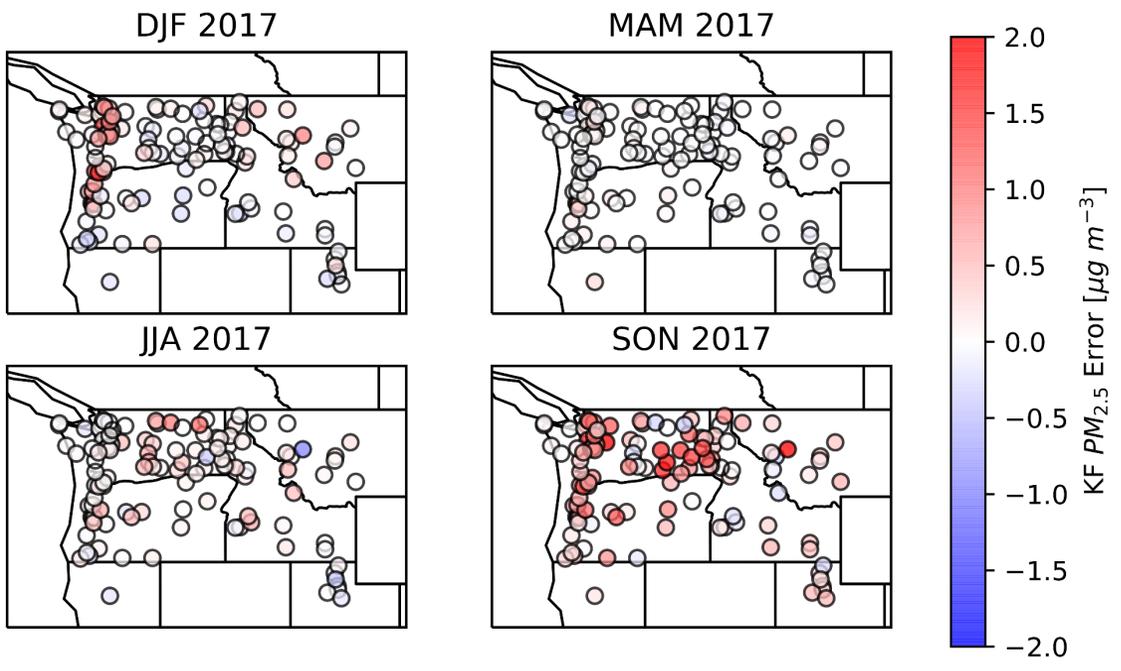
- The Monthly Mean Absolute Error for AIRPACT, 4-Day KF, 7-Day KF based on the averages of the 24-hour $PM_{2.5}$ in 2017 and 2018
- Annual Absolute Error Averages [$\mu\text{g m}^{-3}$]:
 - 2017
 - AIRPACT: 5.98
 - 4-Day KF: 4.07
 - 7-Day KF: 4.07
 - 2018
 - AIRPACT: 5.66
 - 4-Day KF: 3.05
 - 7-Day KF: 4.07

Bar Chart of Seasonal Mean Bias (2017 & 2018 combined)



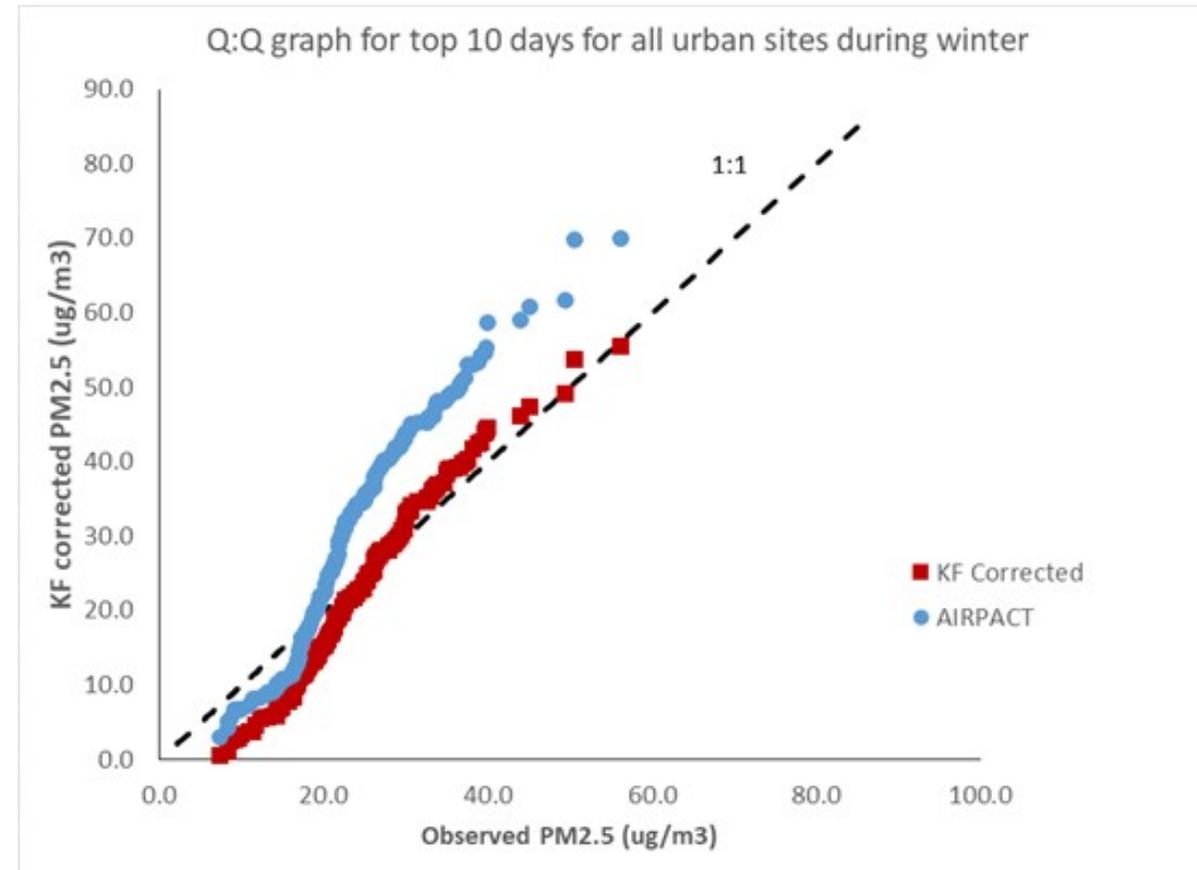
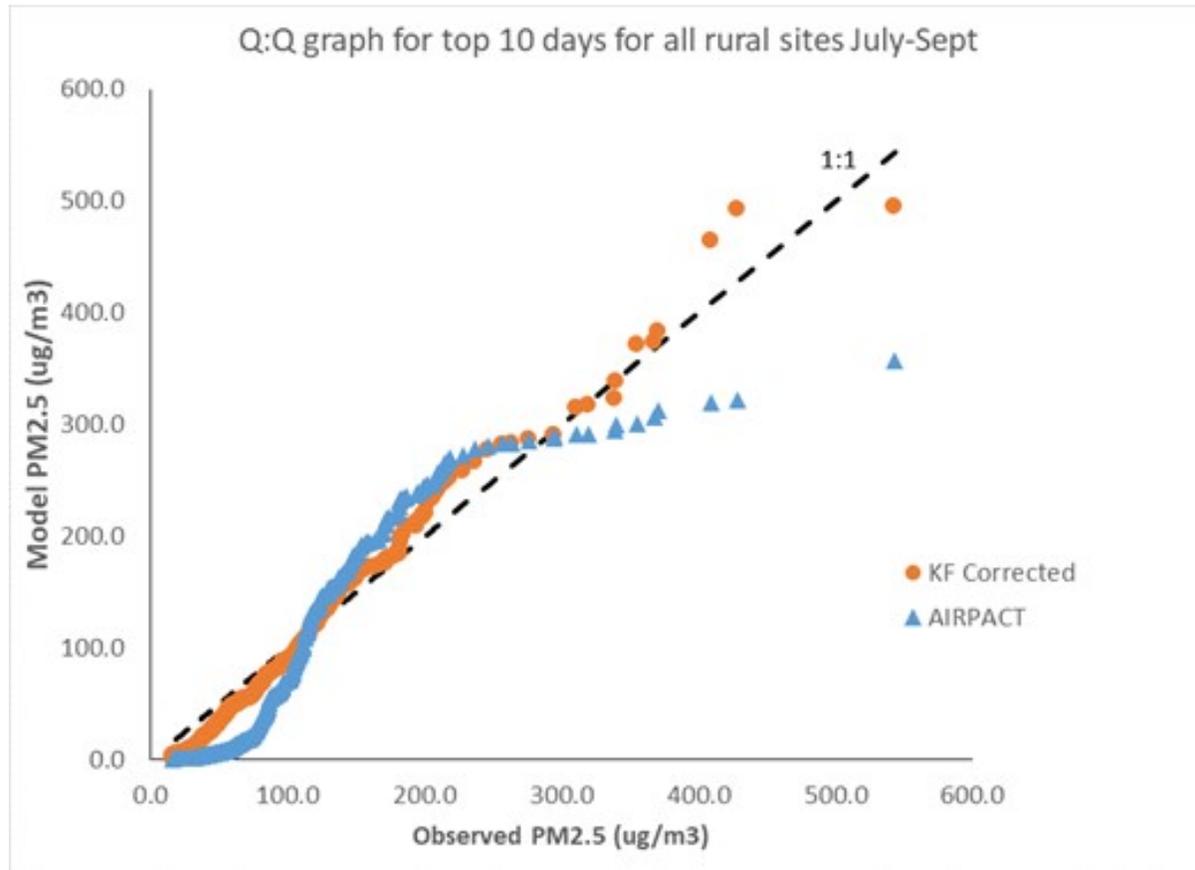


AIRPACT Seasonal Bias
 (range: -10 to + 10)
 for 2017, 2018, 2019
 winter spring
 summer fall



4-Day KFBC Seasonal Bias
 (range: -2 to +2)
 for 2017, 2018, 2019
 winter spring
 summer fall

Ranked PM_{2.5} Daily Averages for the worst 10 days from 2017 & 2018

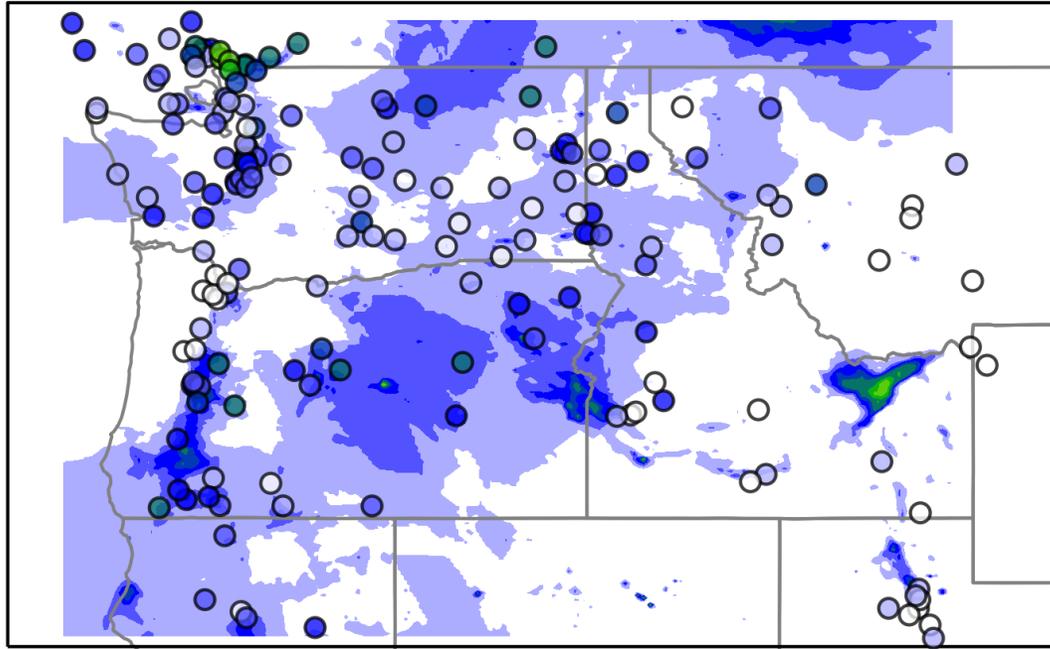


Methods of interpolation tested

- Grid Applied Gaussian Kriging: This method uses a gaussian variogram model, to interpolate the Kalman Filter predicted bias to a grid cell using the 10 closest sites to that grid cell. This bias interpolation is subtracted from the original AIRPACT forecast. (2017, 2018, 2019)
- Grid Applied Linear Kriging: Uses a linear variogram model to interpolate the KF predicted bias to a grid cell using the 10 closest sites to that grid cell, this bias interpolation is subtracted from the 24 hour averaged AIRPACT grid. (2017, 2018, 2019)
- Grid Applied Cubic Spline: Uses a cubic spline to interpolate the KF bias, which is then subtracted from the original AIRPACT forecast (2017)

N.B.: Consultation with Jill Schulte (ECY) and Sara Strachan (IDEQ)

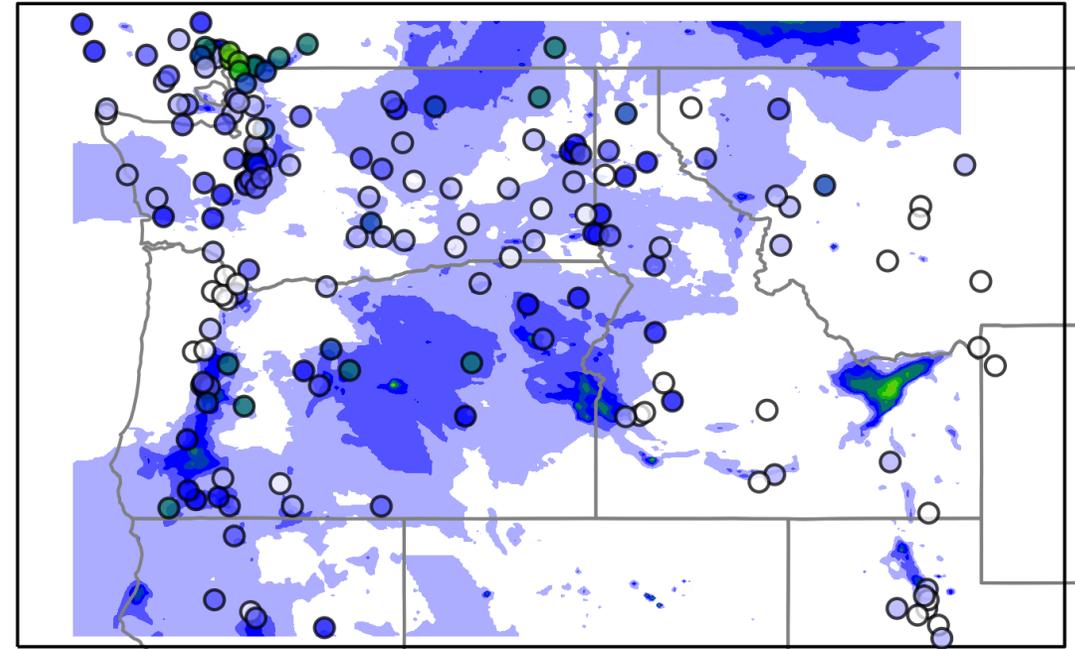
March 12



Grid Applied Linear Kriging Method:

- Variogram Model: Linear
- Using 10 closest points
- Krig the Kalman Filter Predicted bias, and subtract from the original model forecast

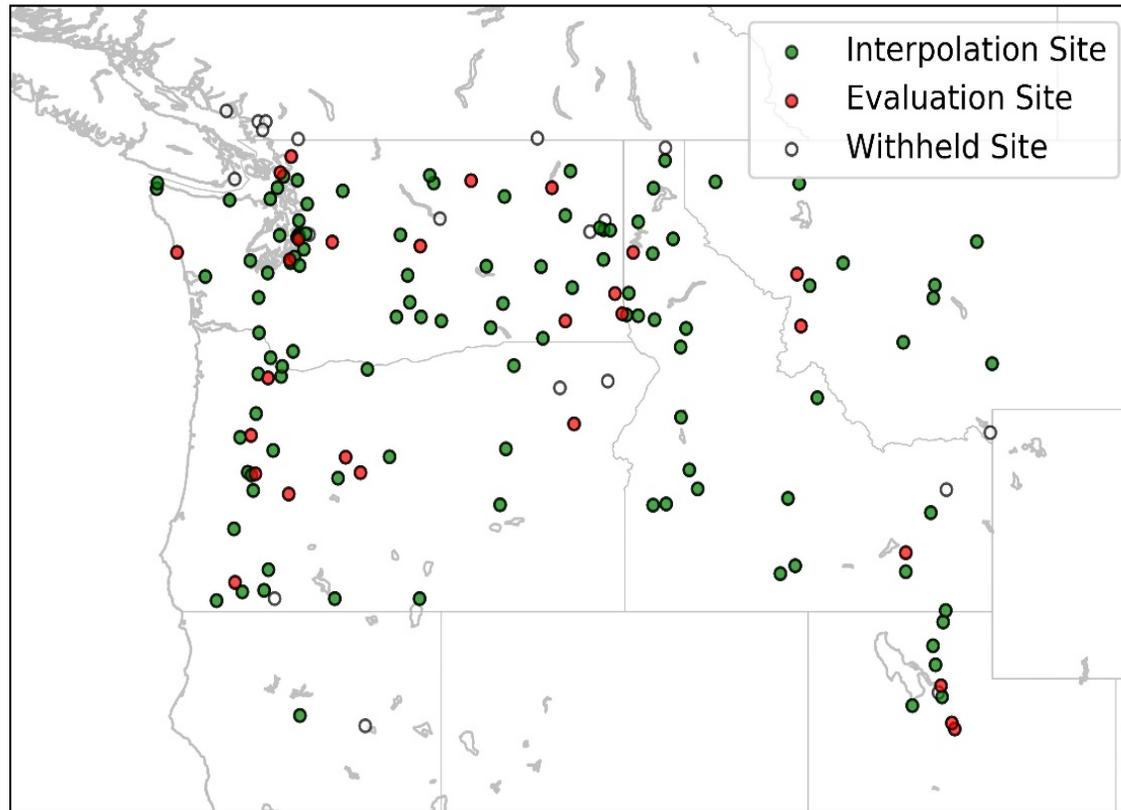
March 12



Grid Applied Gaussian Kriging Method:

- Variogram Model: Gaussian
- Using 10 closest points
- Krig the Kalman Filter Predicted bias, and subtract from the original model forecast

Testing the interpolation method



- Green Points were used to interpolate raw model values, these are the same points that were used in the Kalman Filter post-processing
- Red points were used to test how well the interpolation method did
- 20% of the observation sites were withheld as test points (Red)
- 107 points were used to interpolate
- 24 sites were used to evaluate the interpolation
 - 11 Rural
 - 9 Suburban
 - 4 Urban
- Open Points are used, along with the others, operationally.

Interpolation of KF Bias Correction for 2017

PM_{2.5} ug/m³	Cubic Spline		Gaussian Kriging		Linear Kriging	
Month	MAE	MB	MAE	MB	MAE	MB
Jan-17	9.0	3.1	6.0	1.1	5.3	1.9
Feb-17	4.8	2.1	5.8	-0.4	3.6	1.7
Mar-17	2.9	1.5	2.6	0.8	2.4	1.2
Apr-17	2.2	1.5	2.0	0.4	1.7	0.6
May-17	2.7	1.9	2.0	0.9	2.0	0.9
Jun-17	2.5	1.8	2.4	0.3	2.0	0.7
Jul-17	3.6	2.3	2.9	0.5	2.9	0.6
Aug-17	16.3	0.2	12.5	1.6	9.0	2.2
Sep-17	20.4	-7.5	13.2	3.3	12.2	3.5
Oct-17	4.7	2.0	3.6	1.2	3.4	1.5
Nov-17	5.0	1.1	5.1	-1.0	3.5	1.4
Dec-17	9.0	3.3	6.3	2.7	5.7	3.6
AVERAGE	6.9	1.1	5.4	0.9	4.5	1.6

Interpolation Method By Site Type

	Grid Applied Gaussian Kriging		Grid Applied Linear Kriging	
	MAE [$\mu\text{g m}^{-3}$]	MB [$\mu\text{g m}^{-3}$]	MAE [$\mu\text{g m}^{-3}$]	MB [$\mu\text{g m}^{-3}$]
Rural Sites Average	4.10	1.84	3.58	2.43
Suburban Sites Average	3.13	0.78	2.69	1.35
Urban Sites Average	3.12	1.98	3.03	1.75

- Rural Sites: Linear preforms better
- Suburban Sites: Linear preforms better
- Urban: About the same performance, which makes sense due to density of monitors.

Daily Running and Website

- 4-Day Kalman Filter
- Linear Kriging Method is the main interpolation method used.
- Two other interpolation methods are also being run.
- Now online: Side-by-side display:
 - http://lar.wsu.edu/airpact/bias_correction.php#
 - 24-hr AIRPACT PM2.5
 - KFBC w/ Linear Kriging Interpolation for 24-hr PM2.5
- Integration of KFBC into performance stats in AIRPACT6.

Summary and Conclusions

- The KF Bias Correction provides significantly better PM_{2.5} forecasts.
- **This method decreases the bias in PM_{2.5} concentrations from near -50% to ±6%.**
- The system works well for both winter and wildfire seasons.

The End