



# **MMIF-processed WRF data for AERMOD Case Study: North ID mountain terrain**

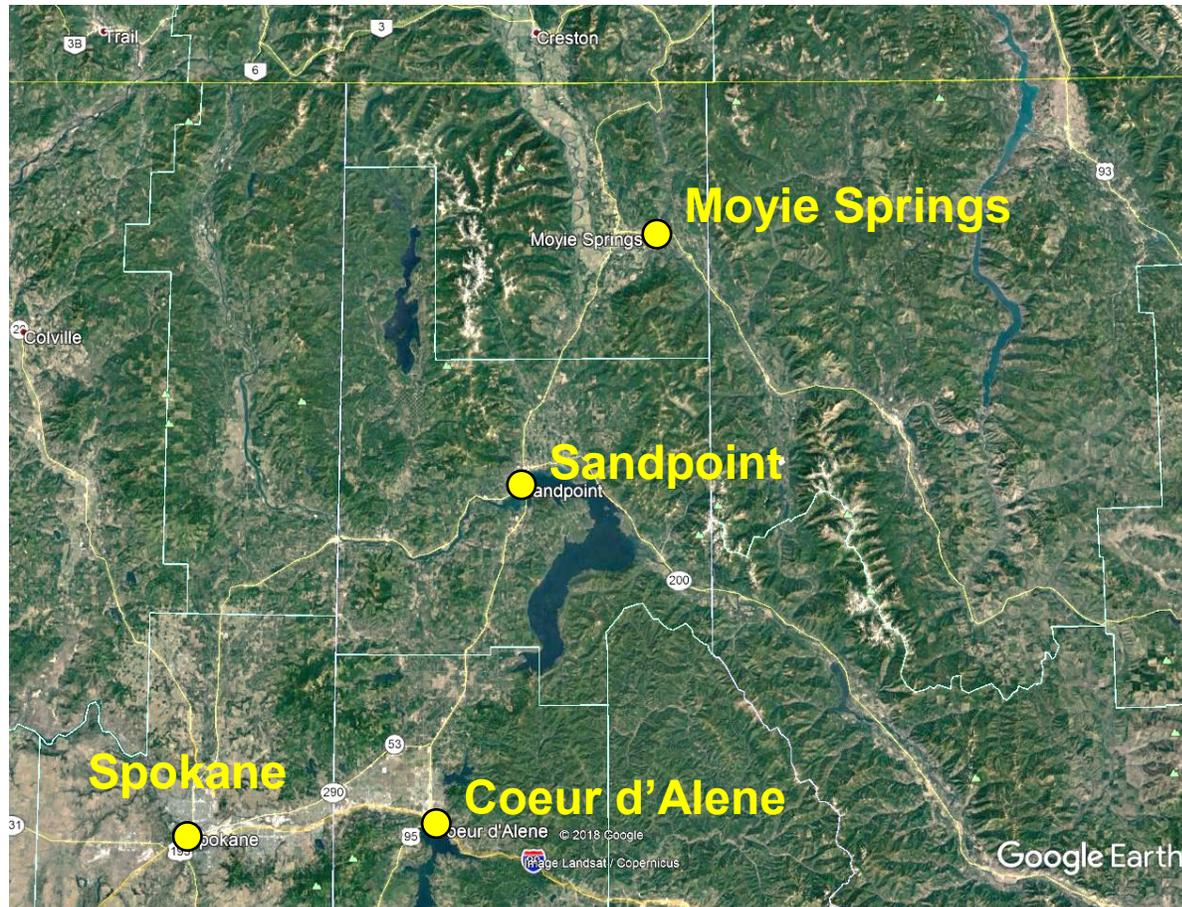
Tom Swain and Pao Baylon

IDEQ

# Outline

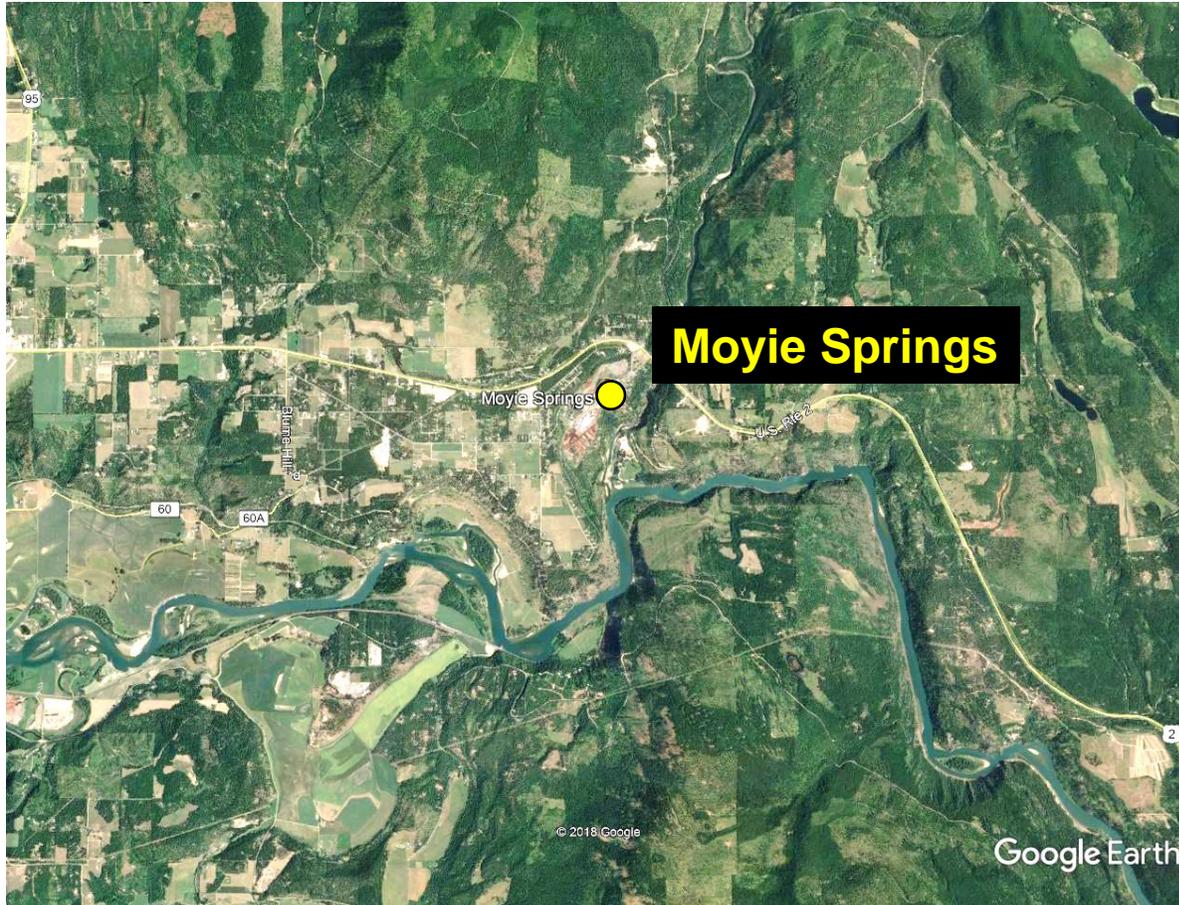
- Study Area
  - Moyie Springs
  - Sandpoint
- Part 1: Meteorological Data Analyses
- Part 2: Modeling Assessment

# Study Area and Data Availability



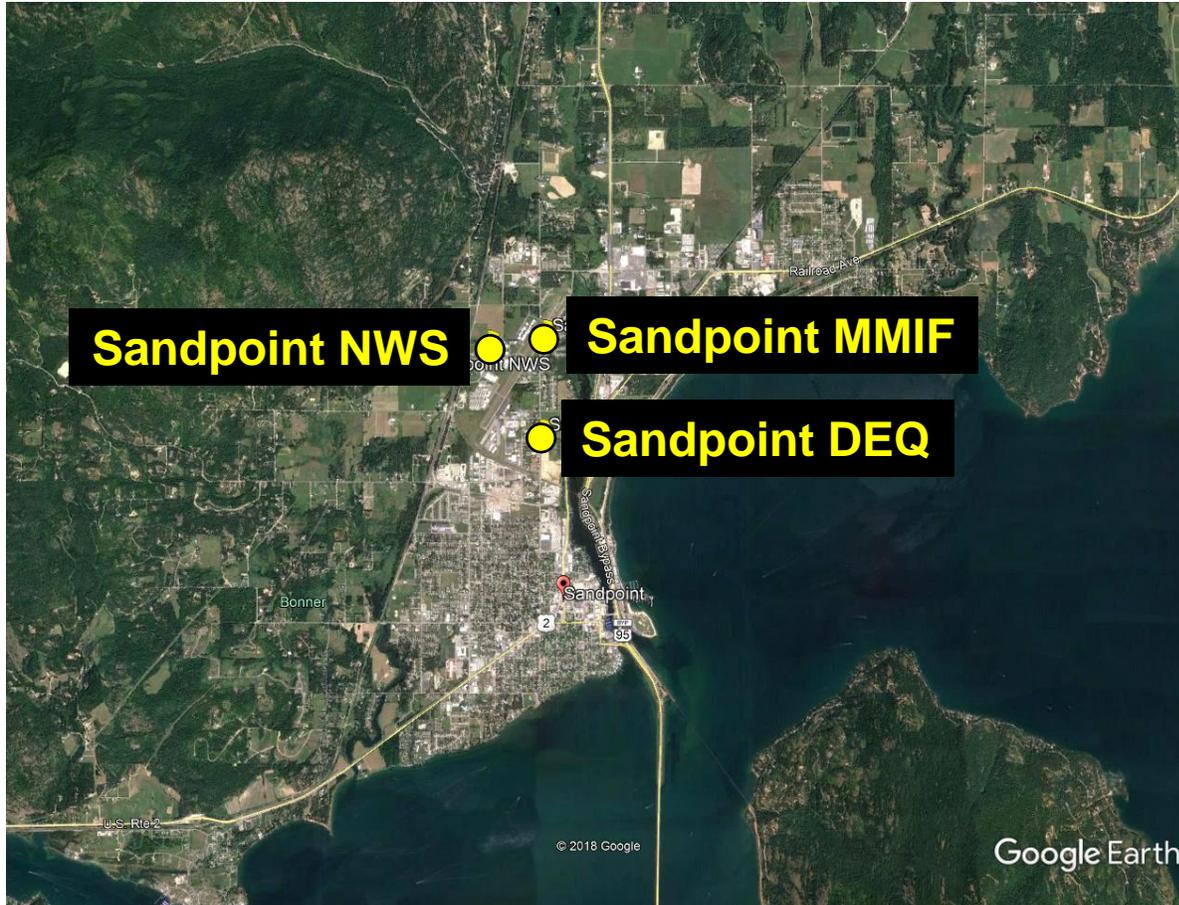
- Moyie Springs
  - WRF/MMIF 01/15-12/17
  - Onsite 12/02-11/03
- Sandpoint
  - WRF/MMIF 01/15-12/17
  - NWS 01/15-12/17
  - DEQ 01/15-03/17

# Moyie Springs, Idaho



- Remote location
- Complex terrain
- Valley drainage flows

# Sandpoint, Idaho



- Complex terrain
- Valley flows
- Body of water located east and south of the sites

# **Mesoscale Model Interface program (MMIF)**

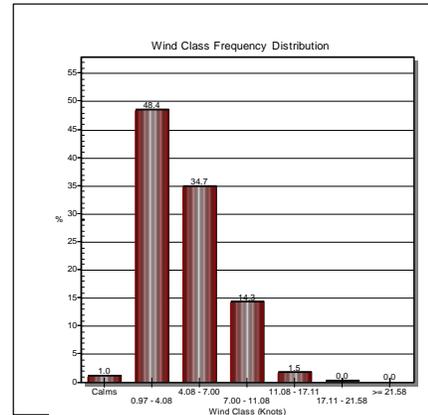
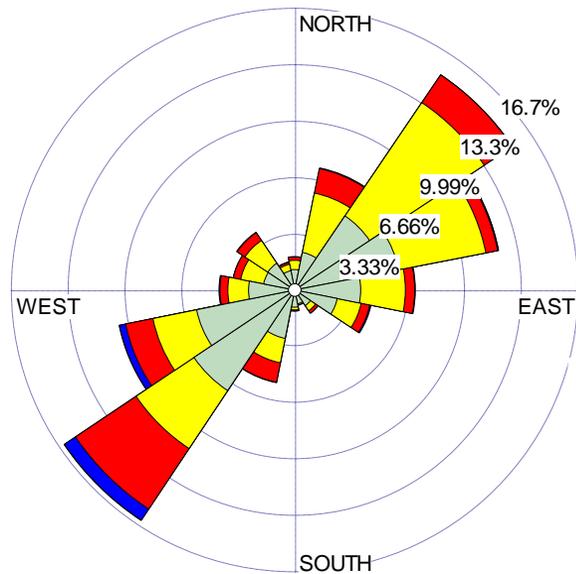
- Uses data created by the Weather Research and Forecasting (**WRF**) model.
- Processes this WRF data and creates raw meteorological input files (onsite, upper air, and surface/land use data) that can be processed by **AERMET** to create meteorological inputs that can be run with the **AERMOD** model.

# **Part 1: Meteorological Data Analyses**

# Moyie Springs Wind Roses

## WRF/MMIF (2015-2017)

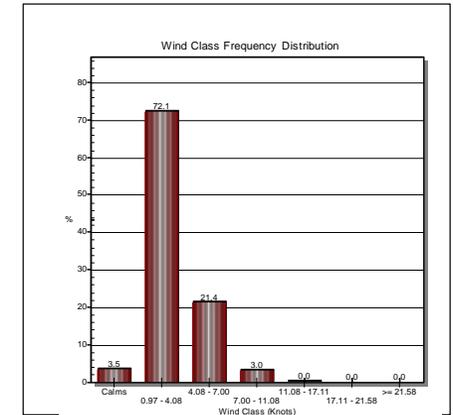
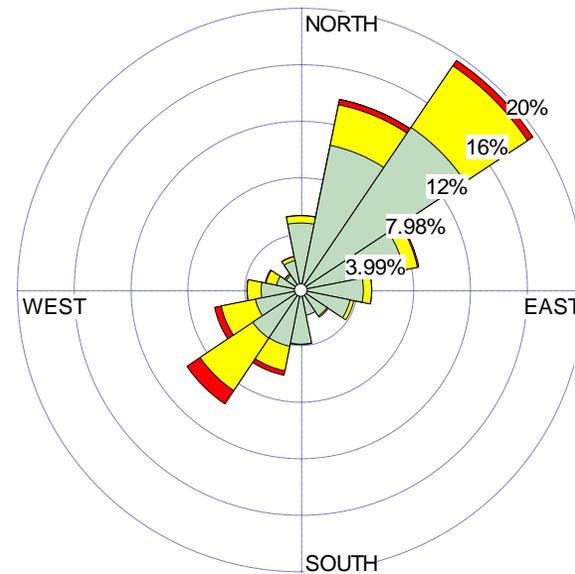
## Onsite (2002-2003)



WIND SPEED (Knots)

- >= 21.58
- 17.11 - 21.58
- 11.08 - 17.1
- 7.00 - 11.08
- 4.08 - 7.00
- 0.97 - 4.08

Calms: 1.03%



WIND SPEED (Knots)

- >= 21.58
- 17.11 - 21.58
- 11.08 - 17.1
- 7.00 - 11.08
- 4.08 - 7.00
- 0.97 - 4.08

Calms: 3.50%

WRF/MMIF data contains a much more prevalent flow from the southwest than the onsite data.

# Meteorological Data at Moyie Springs

	WRF/MMIF (2015-2017)			Onsite (2002-2003)		
	Wind Speed (m/s)	Temperature (K)	Rel Humidity (%)	Wind Speed (m/s)	Temperature (K)	Rel Humidity (%)
Maximum	10.36	311.8	100	5.96	311.1	100
Minimum	0.28	255.2	10	0.28	260	8
Mean	2.20	283.35	58.38	1.61	281.53	68.9
Missing	0.00%	0.00%	0.00%	0.29%	0.29%	0.29%
Calms	0.37%			0		

**Wind speeds from the WRF/MMIF data are greater than the onsite data.**

# Moyie Springs Diurnal Wind Roses

WRF/MMIF

Onsite

Hours 1-4

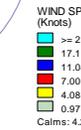
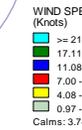
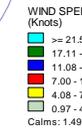
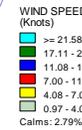
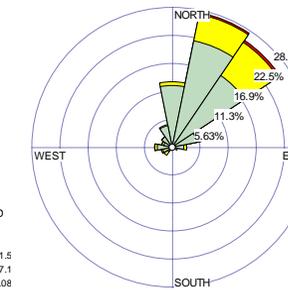
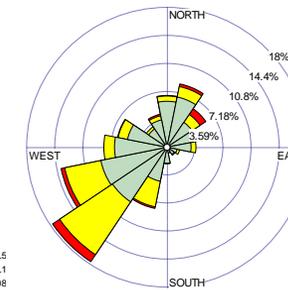
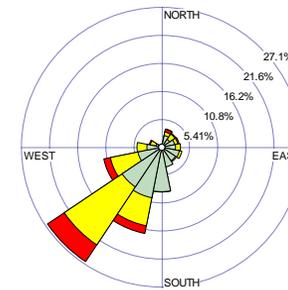
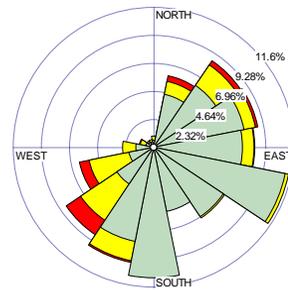
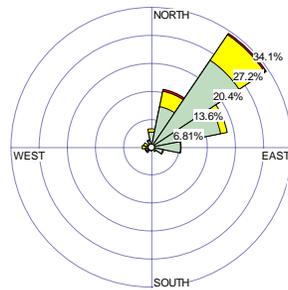
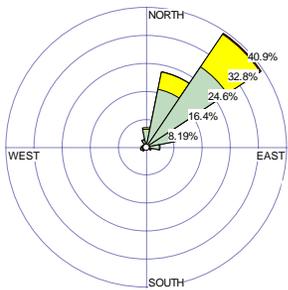
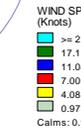
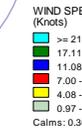
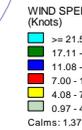
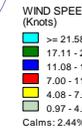
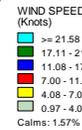
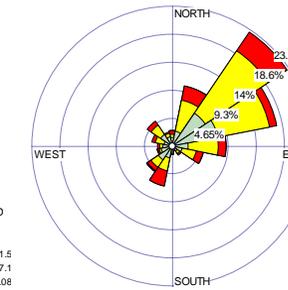
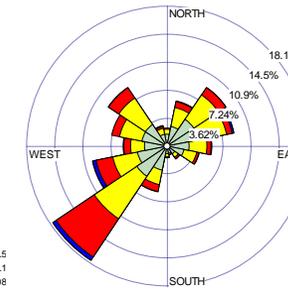
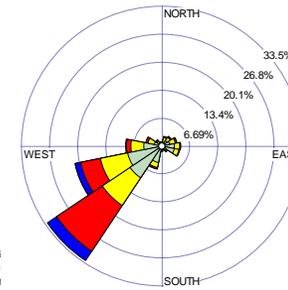
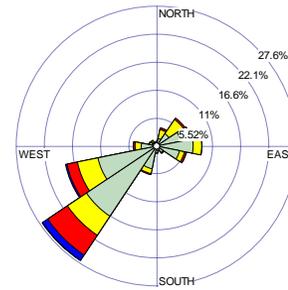
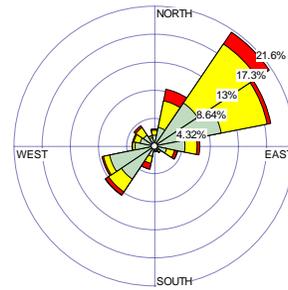
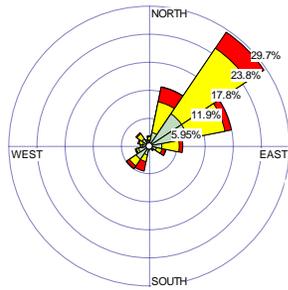
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9-12

13-16

17-20

21-24

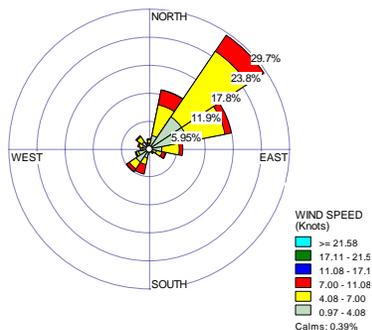


# Moyie Springs Diurnal Wind Roses

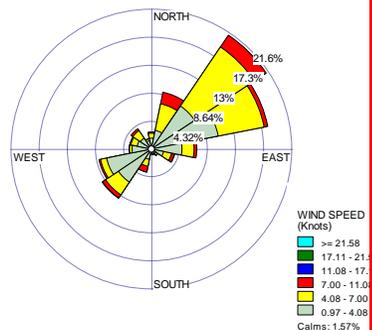
WRF/MMIF

Onsite

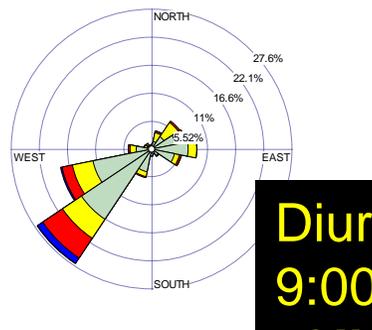
Hours 1-4



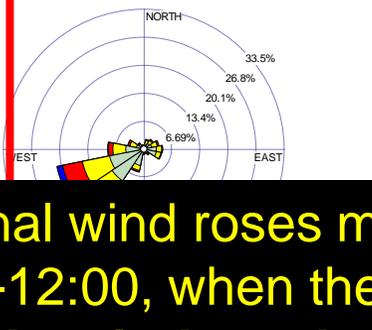
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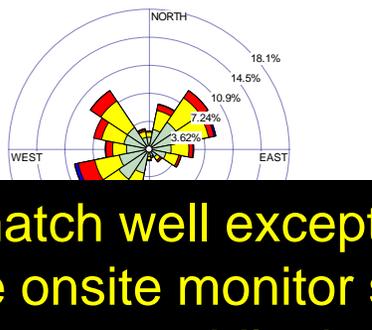
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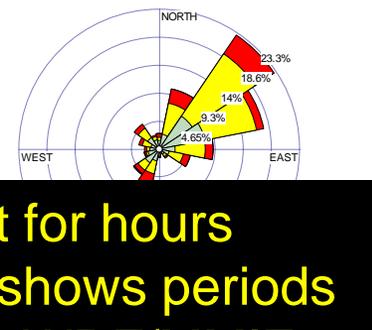
13-16



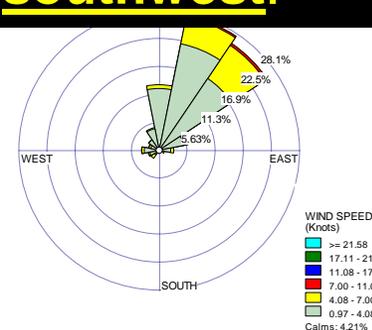
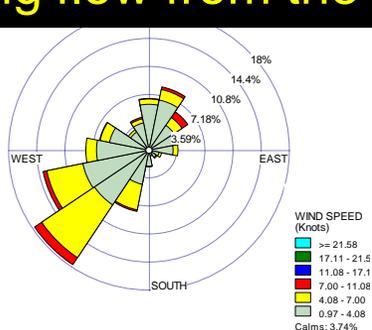
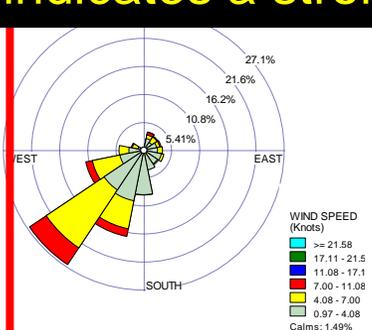
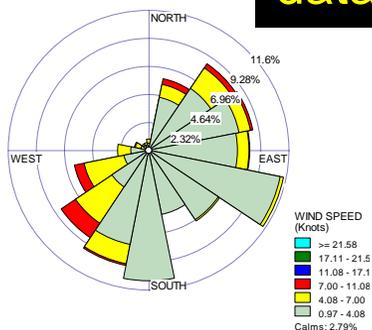
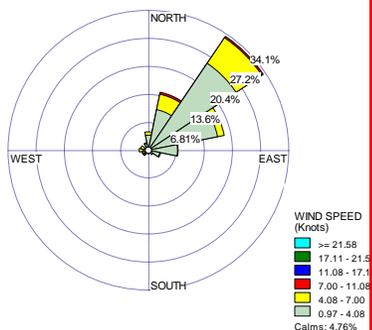
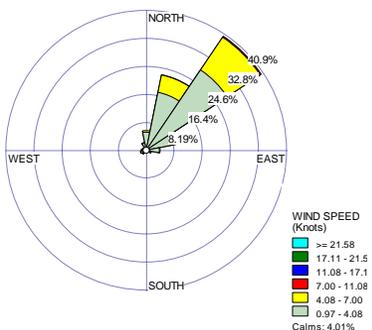
17-20



21-24



Diurnal wind roses match well except for hours 9:00-12:00, when the onsite monitor shows periods of light winds and scatter, while the WRF/MMIF data indicates a strong flow from the southwest.

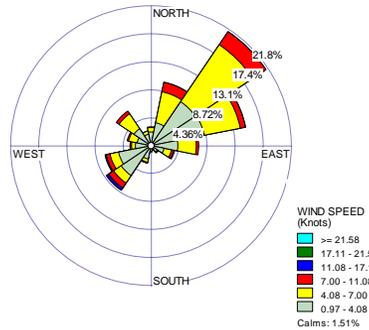


# Moyie Springs Seasonal Wind Roses

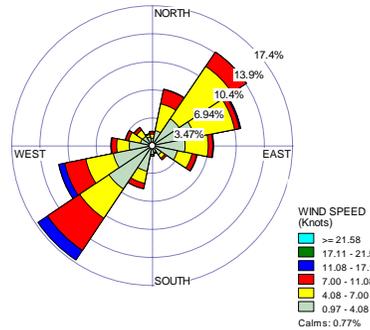
WRF/MMIF  
(2015-2017)

Onsite  
(2002-2003)

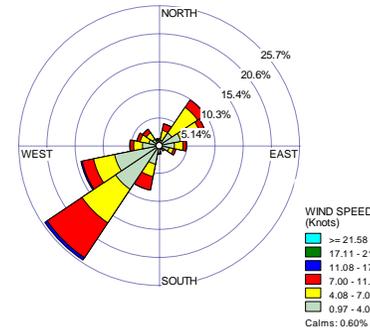
Winter



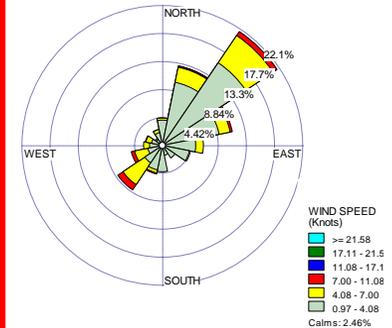
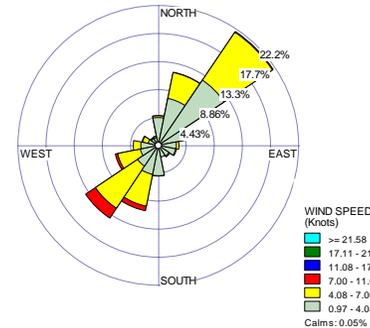
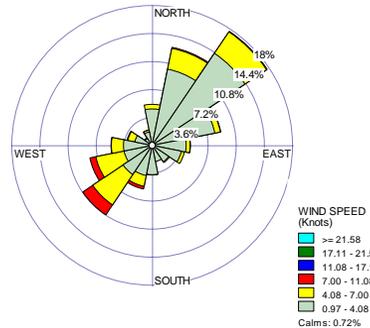
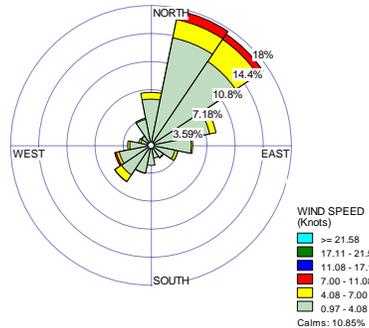
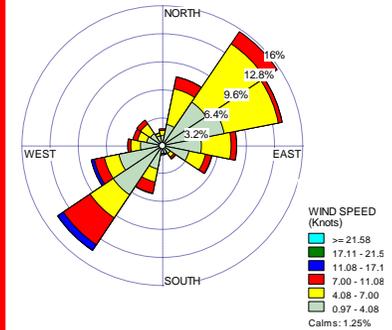
Spring



Summer



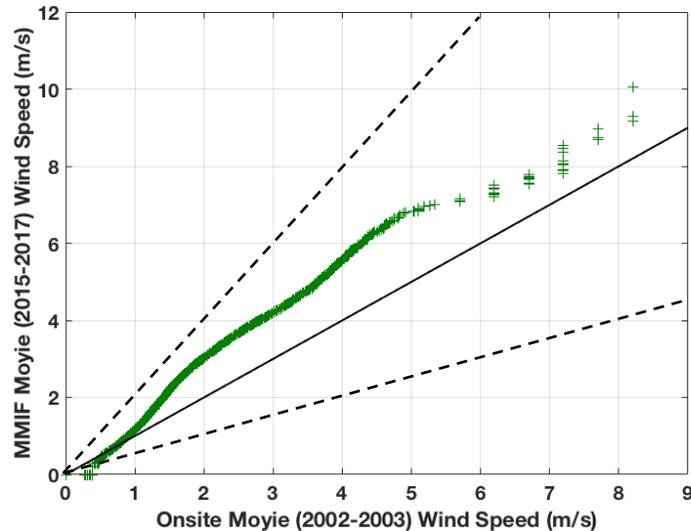
Fall



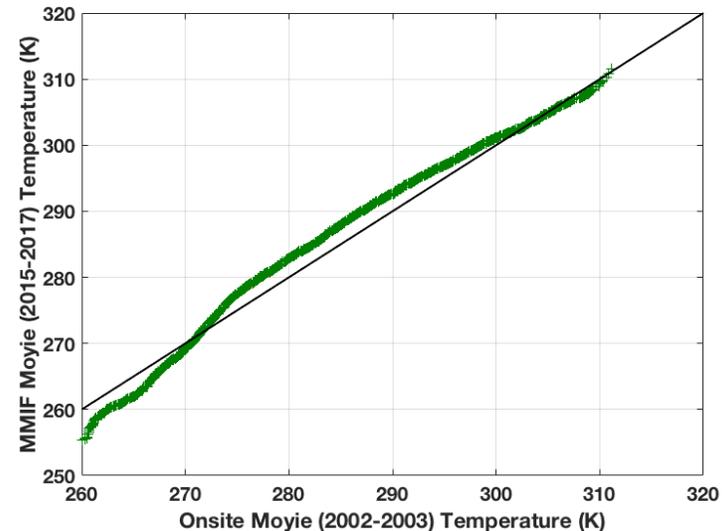
Seasonal roses match well except for autumn, when winds from the southwest are more prevalent in the WRF/MMIF data.

# Meteorological Data at Moyie Springs

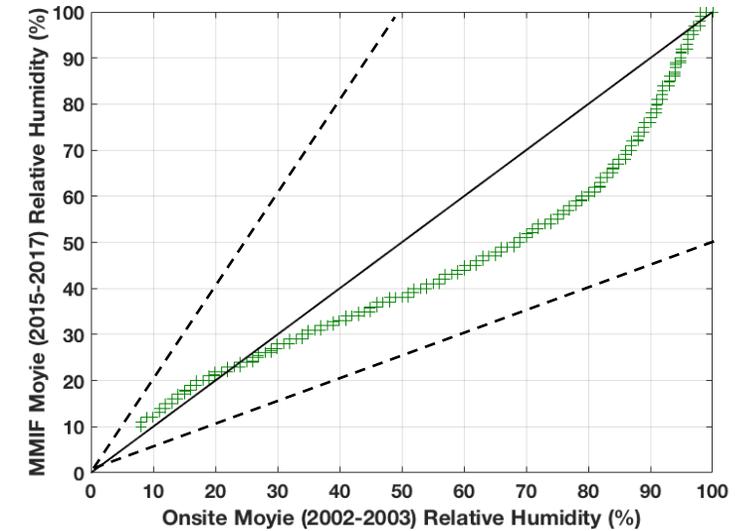
## Wind Speed



## Temperature



## Relative Humidity



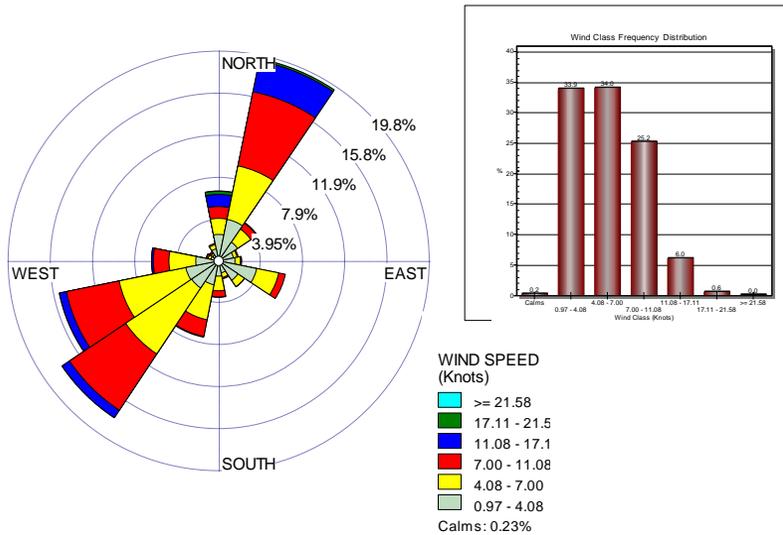
WRF/MMIF produces wind speeds greater than those in the observed data, while temperature data match fairly well. Relative humidity appears to be under-predicted.

# Sandpoint, Idaho

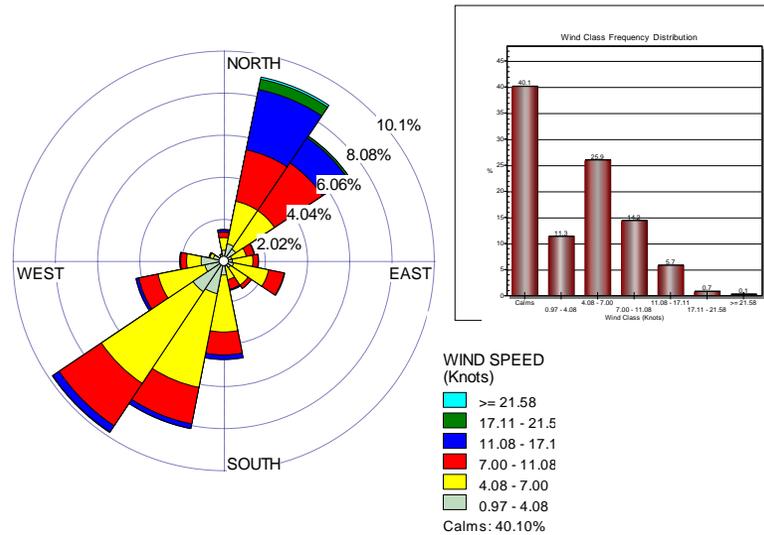


# Sandpoint Wind Roses

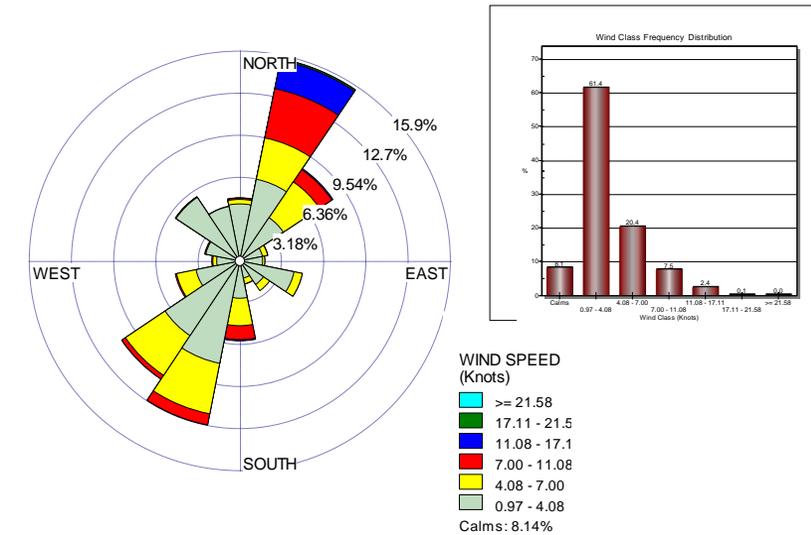
## WRF/MMIF (2015-2017)



## NWS (2015-2017)



## DEQ (2015-03/2017)



Wind roses at DEQ have a larger contingent of lower wind speeds than either the WRF/MMIF or the NWS data. However, the NWS airport contains ~40% “calm” data, which is masked in the wind roses. Data from the DEQ site is very similar to the WRF/MMIF data, except that there is a larger distribution of lighter winds.

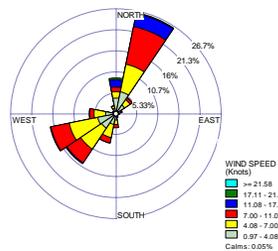
# Sandpoint Diurnal Wind Roses

WRF/MMIF

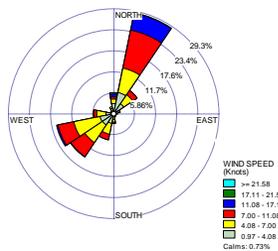
NWS

DEQ

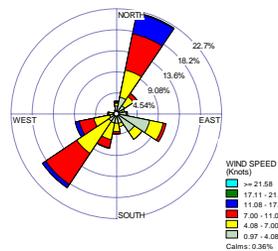
Hours 1-4



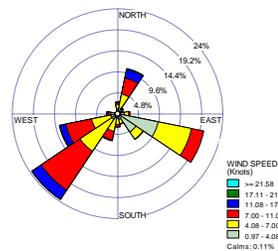
5-8



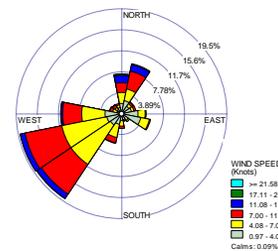
9-12



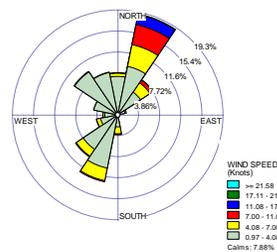
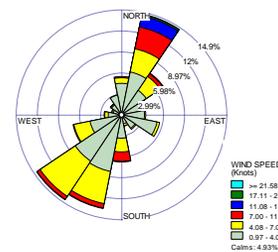
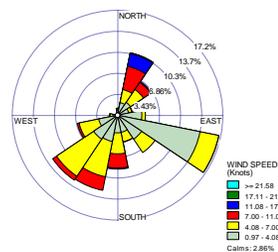
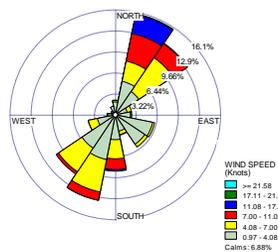
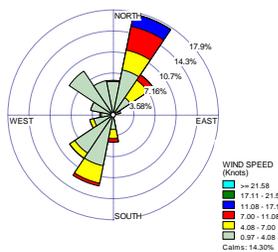
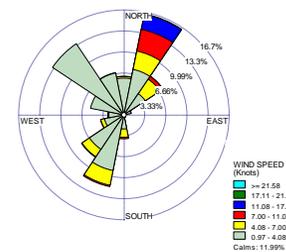
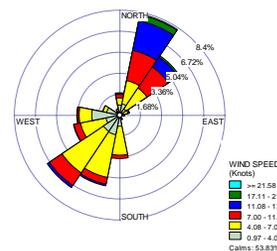
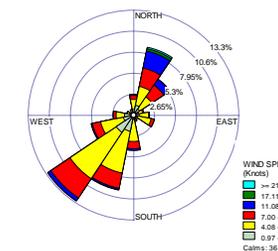
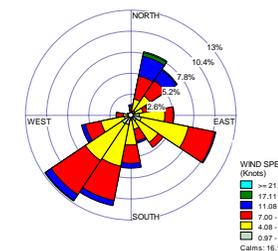
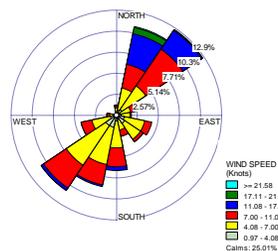
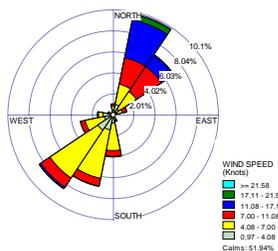
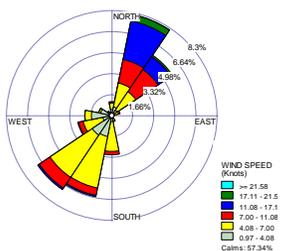
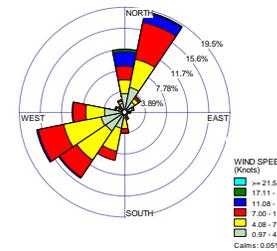
13-16



17-20



21-24



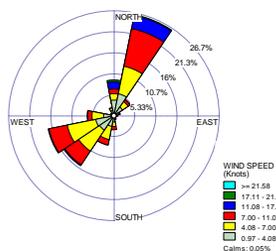
# Sandpoint Diurnal Wind Roses

WRF/MMIF

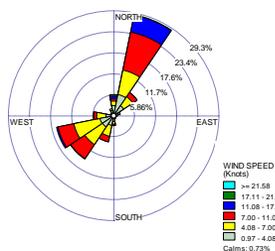
NWS

DEQ

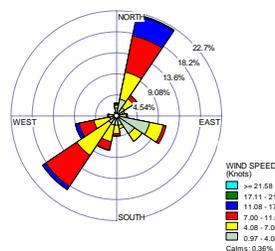
## Hours 1-4



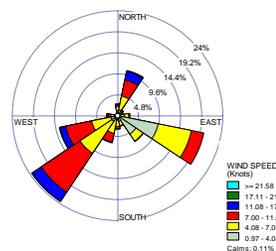
## 5-8



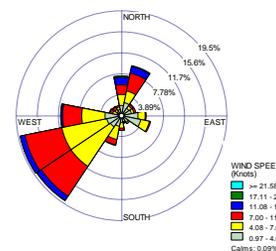
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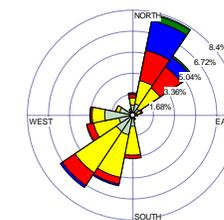
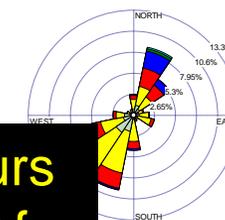
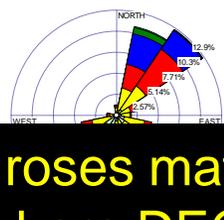
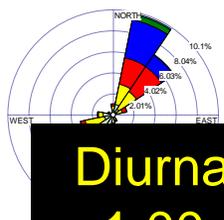
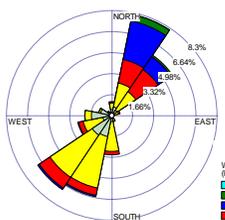
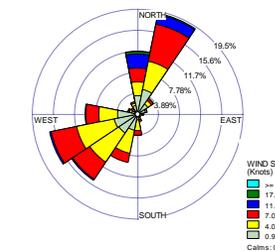
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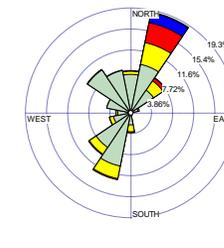
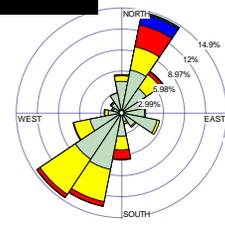
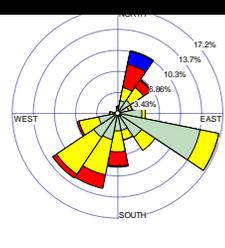
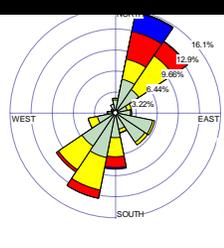
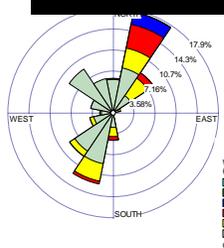
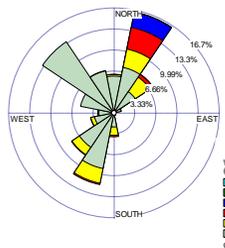
## 17-20



## 21-24



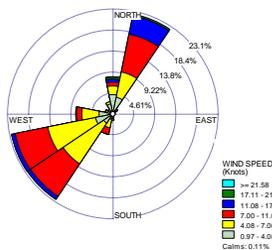
Diurnal wind roses match well, except for hours 1:00-4:00, where DEQ data shows periods of light winds from the northwest.



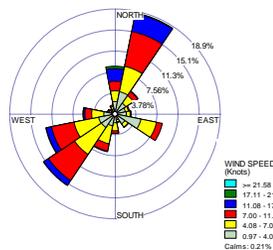
# Sandpoint Seasonal Wind Roses

WRF/MMIF

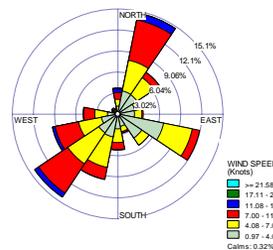
Winter



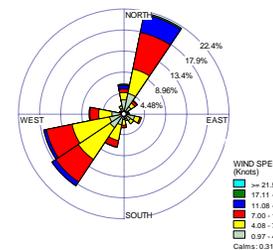
Spring



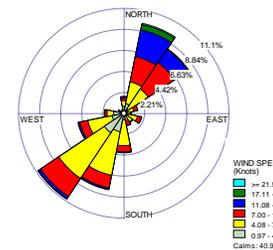
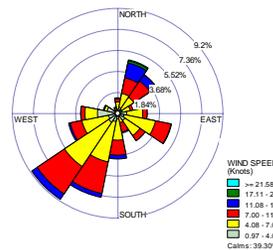
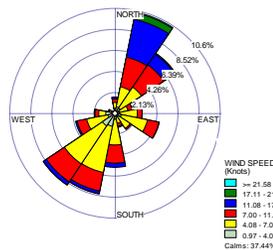
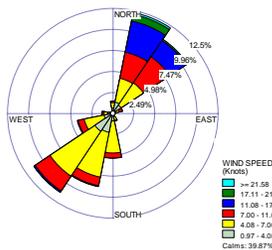
Summer



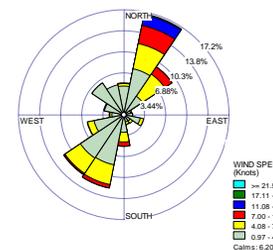
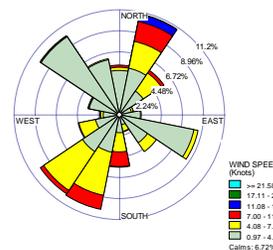
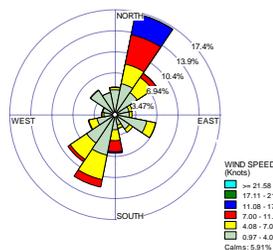
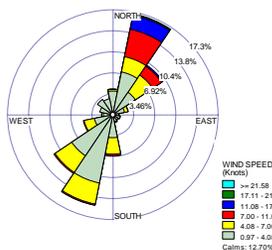
Fall



NWS



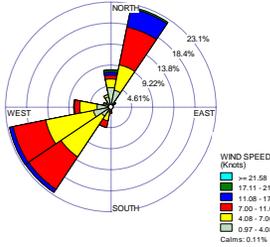
DEQ



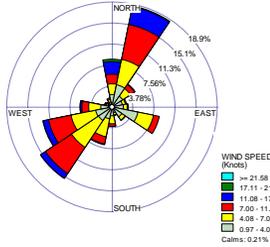
# Sandpoint Seasonal Wind Roses

WRF/MMIF

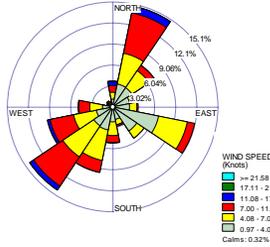
### Winter



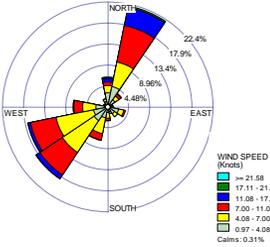
### Spring



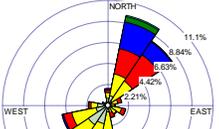
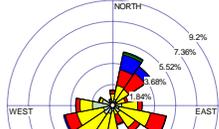
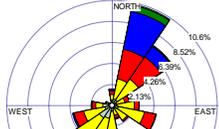
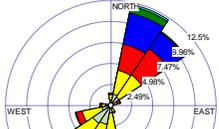
### Summer



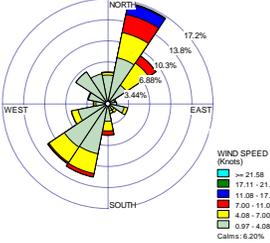
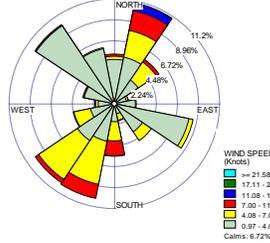
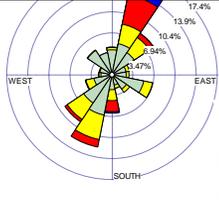
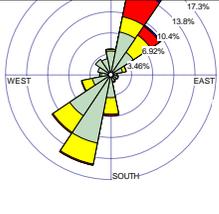
### Fall



NWS



DEQ



Seasonal roses match well except for the summer months, when the DEQ data shows more light winds from the northwest.

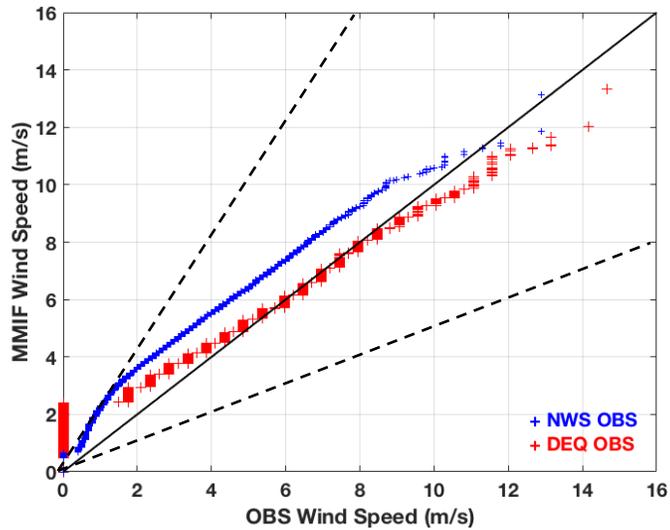
# Meteorological Data at Sandpoint

Variable	Scenario	Mean Bias	RMSE	R <sup>2</sup>
Wind Speed	MMIF-NWS	0.9251	2.1932	0.2404
	MMIF-DEQ	1.2319	2.0307	0.2834
	NWS-DEQ	0.3068	1.2172	0.7670
Temperature	MMIF-NWS	1.8662	3.4378	0.9069
	MMIF-DEQ	1.9357	3.1910	0.9061
	NWS-DEQ	0.0695	1.3235	0.9825
Relative Humidity	MMIF-NWS	-12.5762	20.9315	0.5842
	MMIF-DEQ	-14.0233	22.2378	0.5503
	NWS-DEQ	-1.4471	0.0000	1.0000

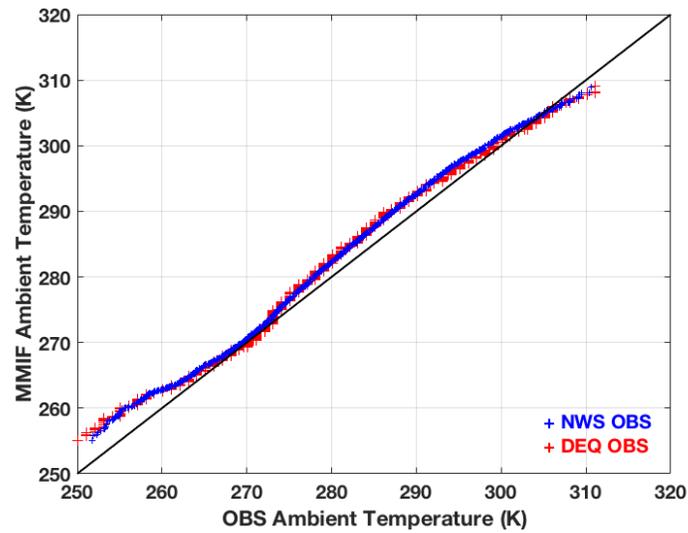
- Differences between MMIF wind speeds and observed wind speeds appear to be higher than the difference between the two observed datasets. MMIF wind speeds are weakly correlated to both observed datasets.
- MMIF tends to over-predict temperature when compared to the observations.
- MMIF tends to under-predict relative humidity when compared to the observations.

# Meteorological Data at Sandpoint

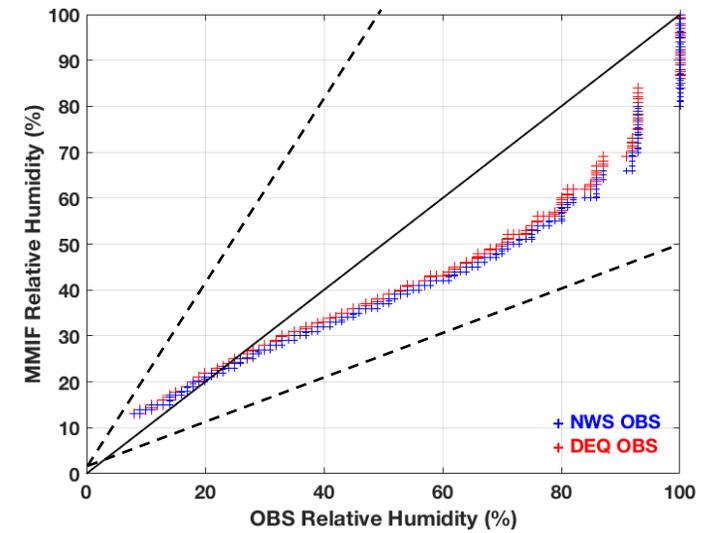
## Wind Speed



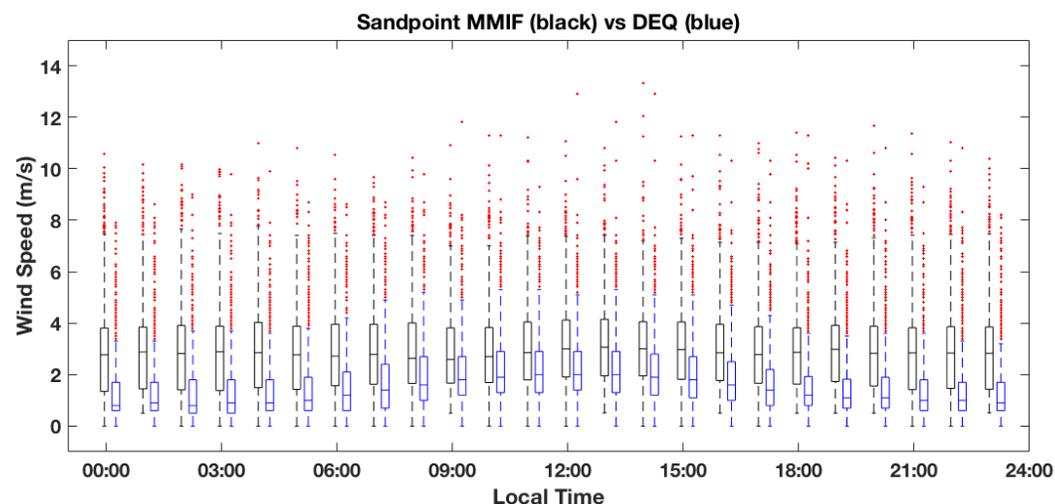
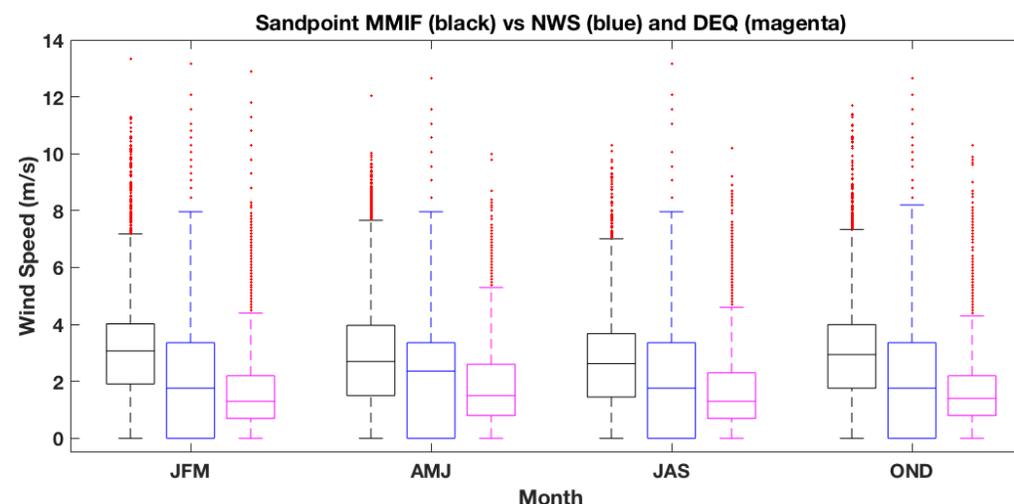
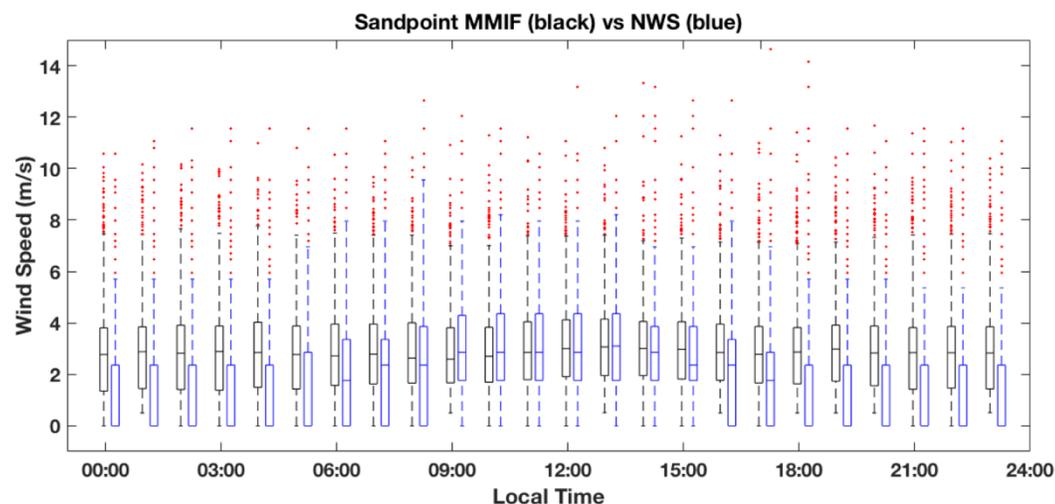
## Temperature



## Relative Humidity

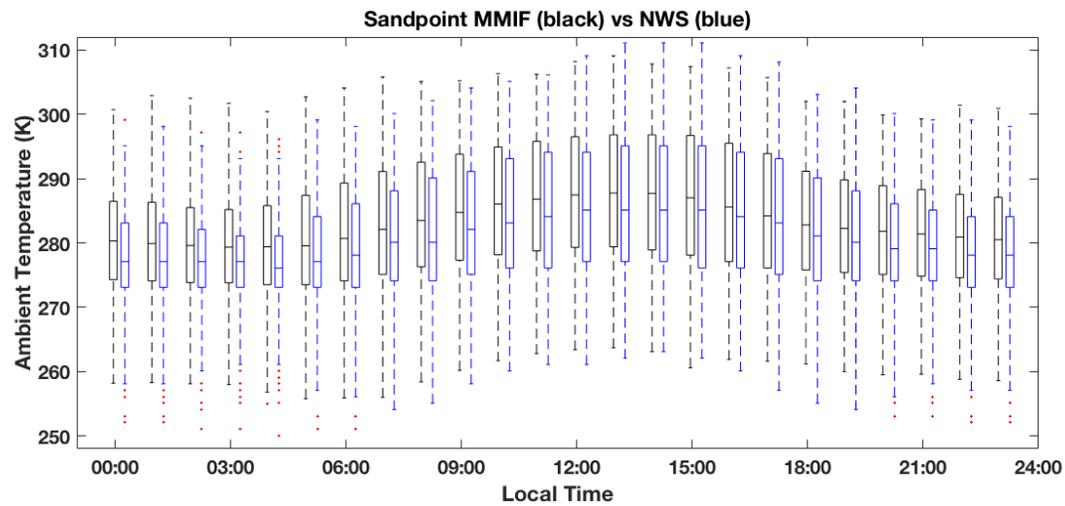
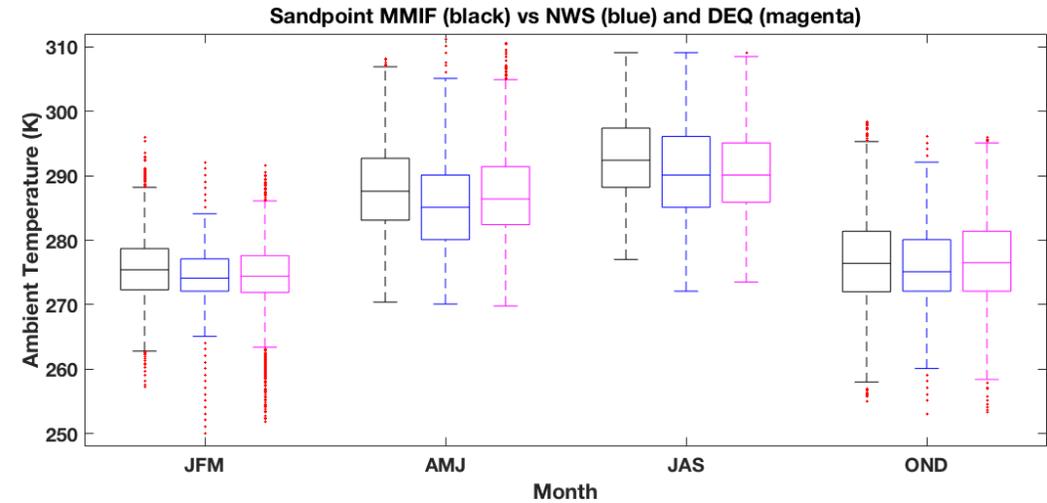
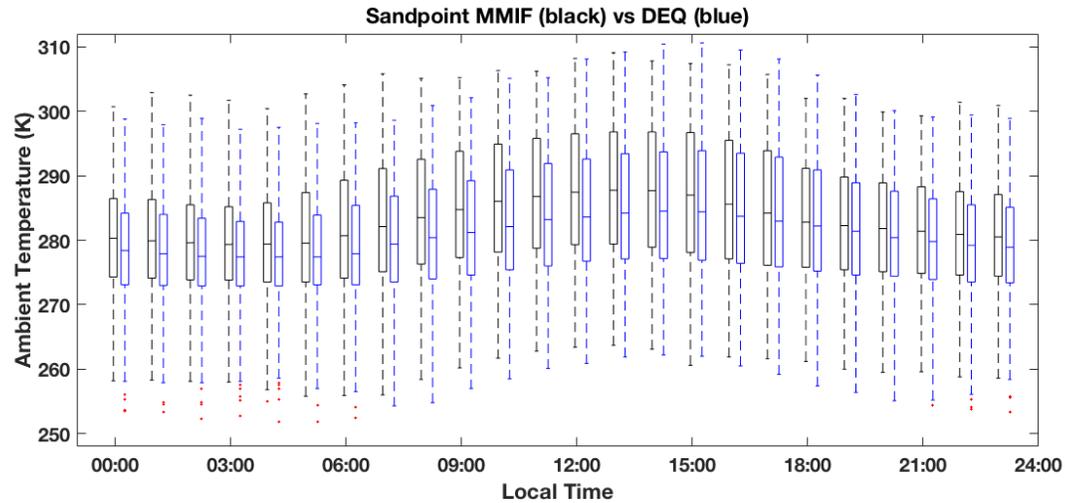


# Wind Speeds at Sandpoint



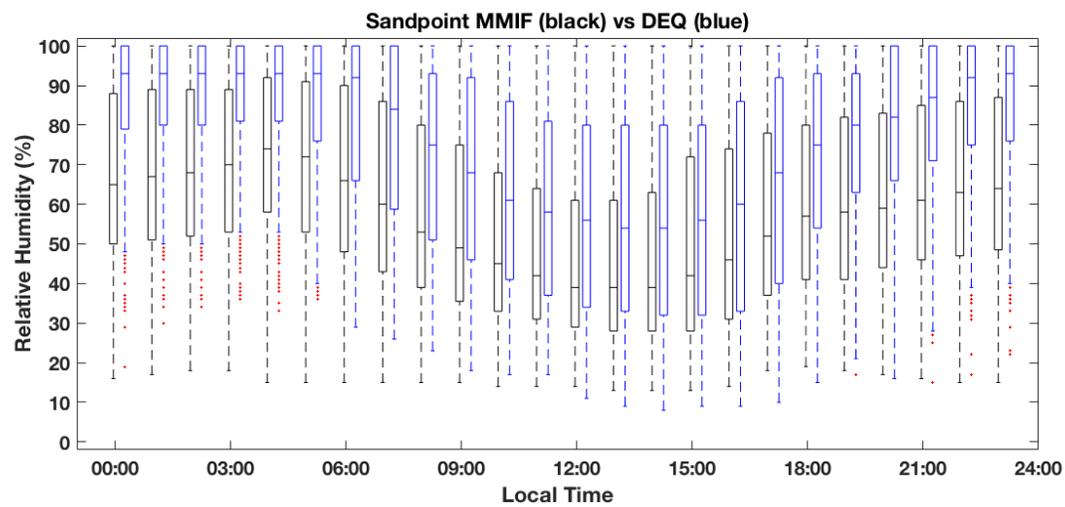
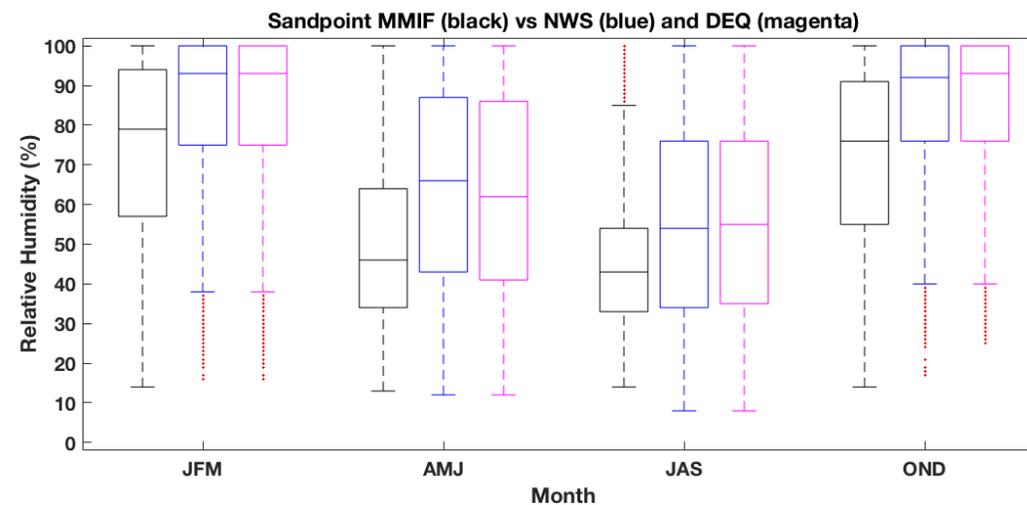
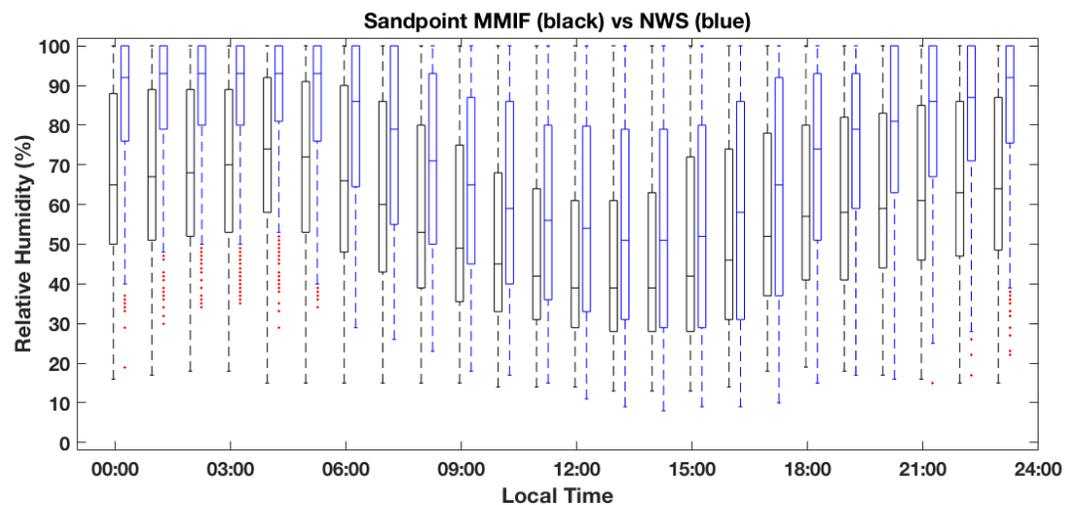
- **Daytime** MMIF wind speeds are comparable to *NWS* observations. However, **nighttime** MMIF wind speeds over-predict *NWS* measurements.
- On the other hand, MMIF wind speeds over-predict *DEQ* observations **throughout the day**.
- Seasonal box plots suggest that *NWS* wind speeds have a much wider spread than *DEQ* observations.

# Ambient Temperature at Sandpoint



- Median MMIF temperatures over-predict NWS and DEQ observations.
- Median temperatures from the three datasets at Sandpoint (MMIF, NWS, DEQ) during Winter and Fall are comparable.

# Relative Humidity at Sandpoint



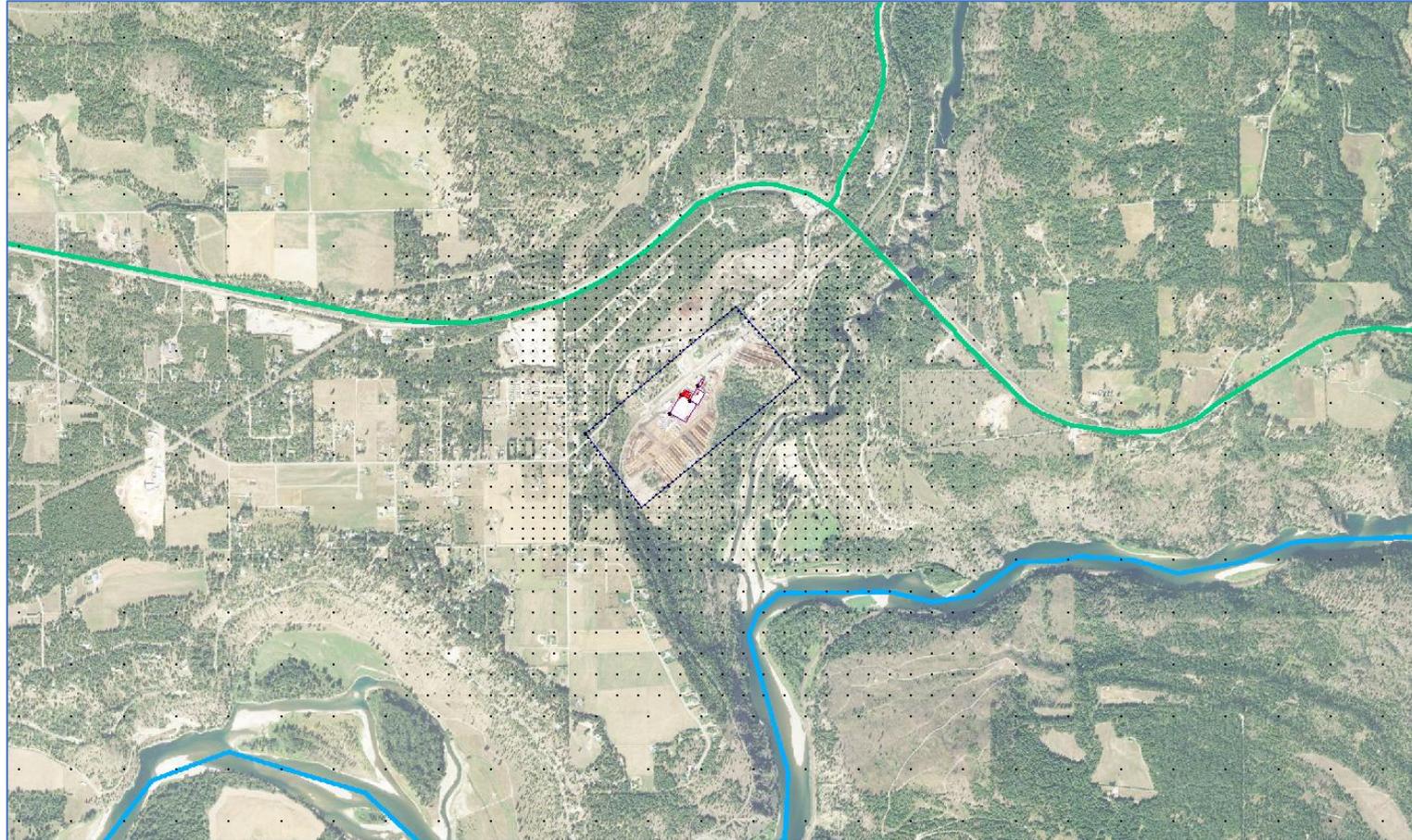
- MMIF relative humidity under-predicts observations from NWS and DEQ.
- Seasonal box plots suggest that NWS and DEQ RH measurements are comparable.

# **Part 2: Modeling Assessment**

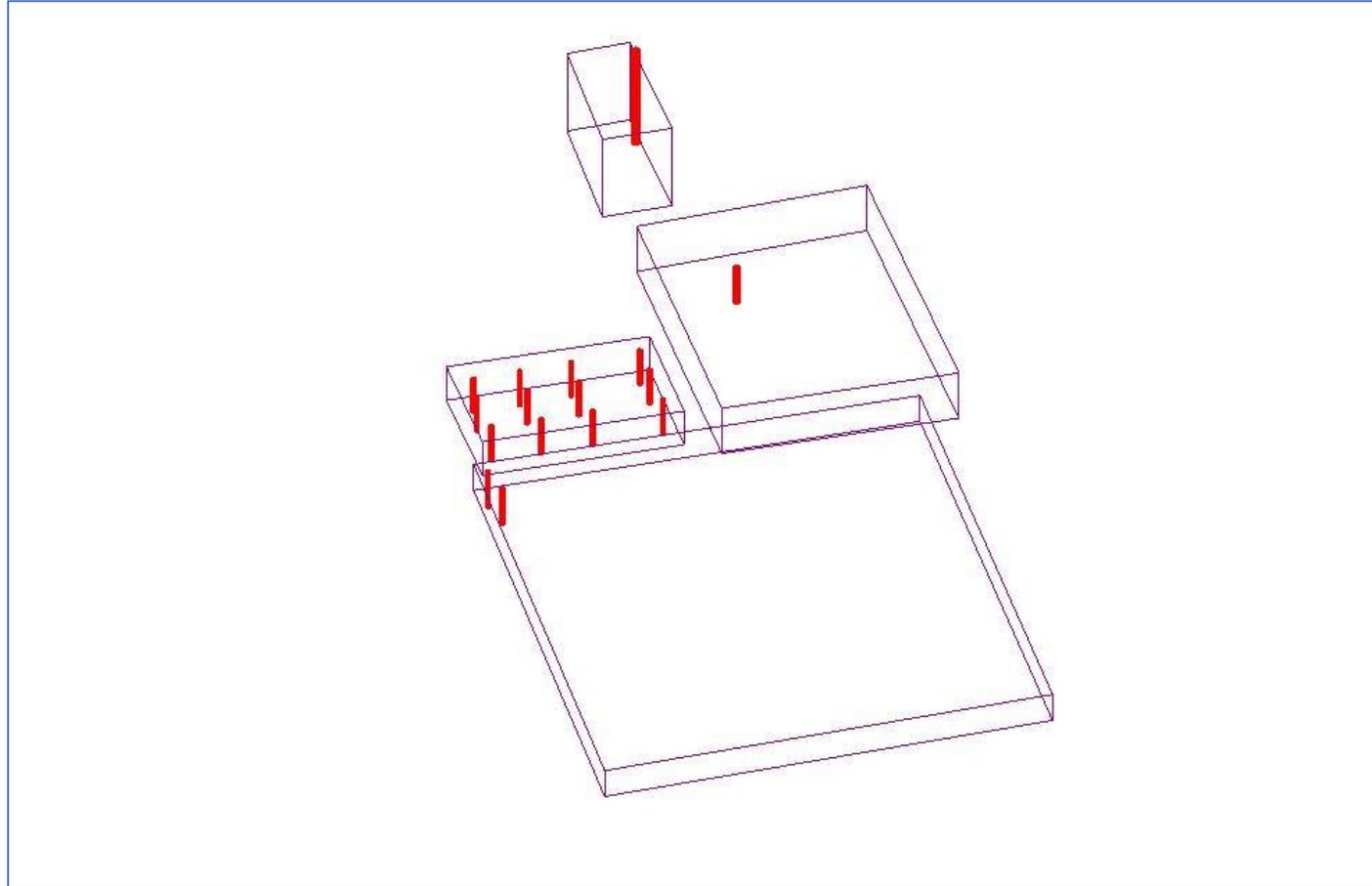
# Source Representation

- A representation of a facility was created at the location of interest in **Moyie Springs**.
- The sources, buildings, and emissions were generalized to portray a typical **lumber mill** type facility.
- Sources included a **boiler**, drying **kilns**, and a handful of **cyclones** to represent process activity emissions.
- Buildings were created to allow for typical **downwash** effect.
- An ambient **fenceline** and a **receptor grid** were created to best capture impacts from the emissions as modeled.

# Source and Receptor Location



# Source and Building Representation

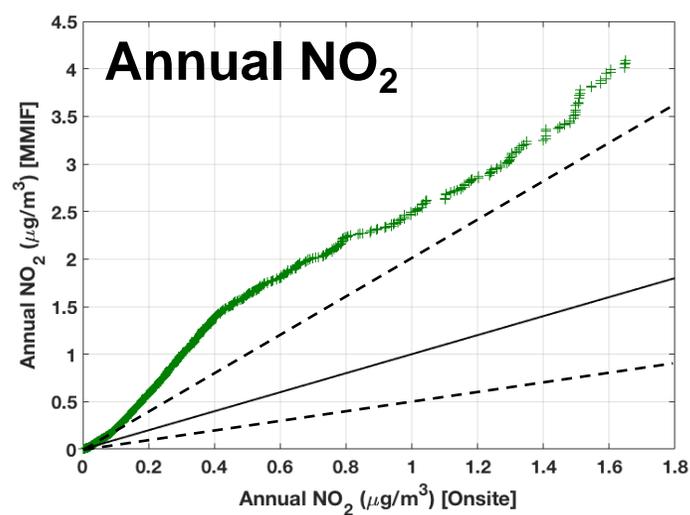
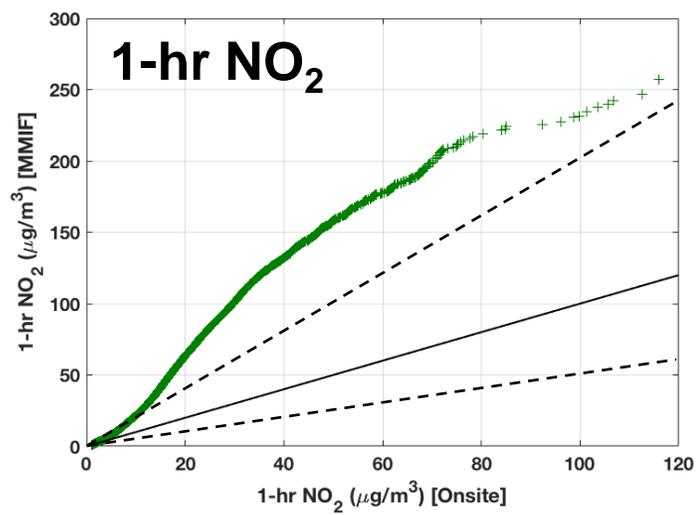
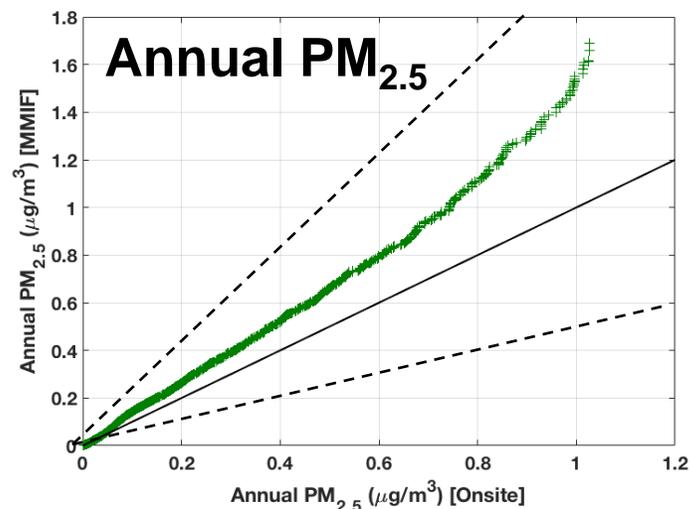
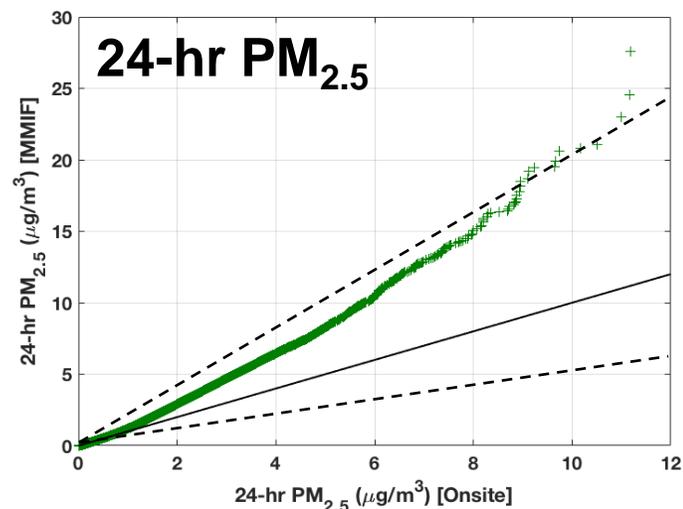


# AERMOD Modeling Results

		Moyie Springs		Sandpoint		
Pollutant	Averaging Period	WRF/MMIF	Onsite	WRF/MMIF	NWS	DEQ
		2015-2017	2002-2003	2015-2017	2015-2017	2015-2017
NO <sub>2</sub>	1-hour	201	70	208	107	114
	Annual	3.5	1.7	4.6	2.6	1.8
PM <sub>10</sub>	24-hour	18.4	8.7	16.5	10.2	14.7
PM <sub>2.5</sub>	24-hour	10	6.7	10.3	7.1	9.7
	Annual	1.54	1	1.9	1.3	1.4

WRF/MMIF data at Moyie Springs produces higher maximum concentrations than the onsite monitored data.

# Q-Q Concentration Plots at Moyie Springs



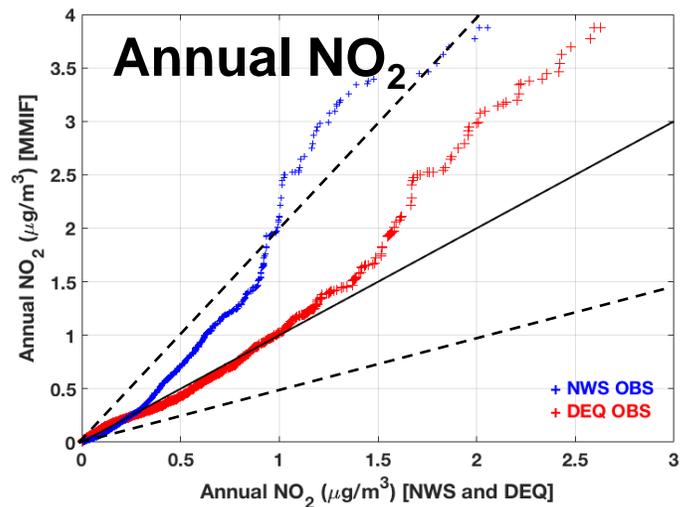
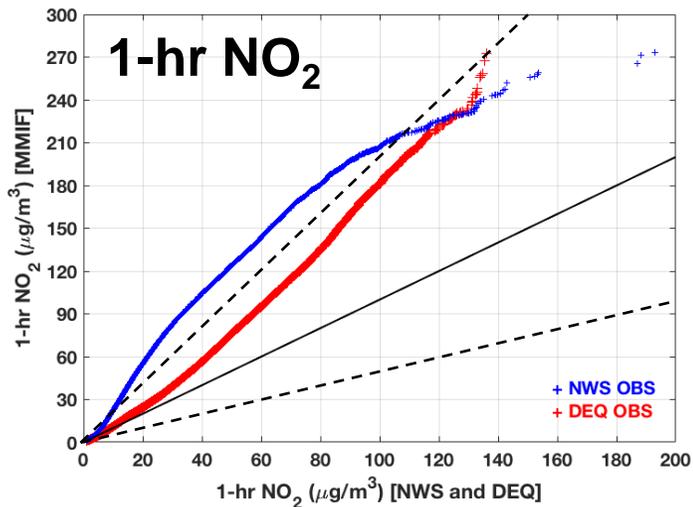
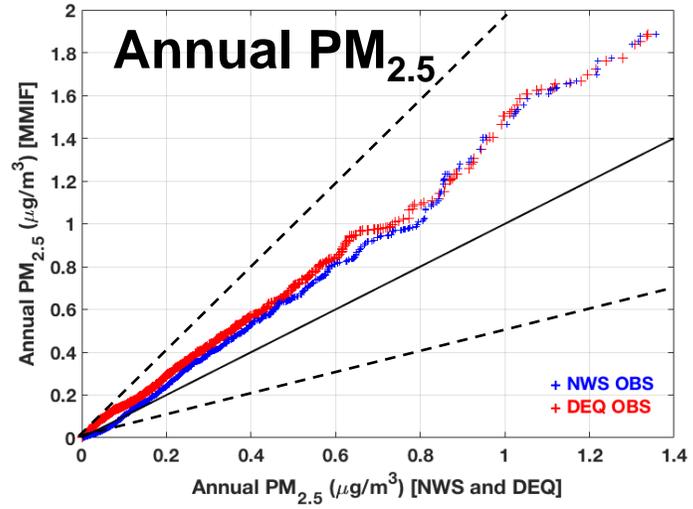
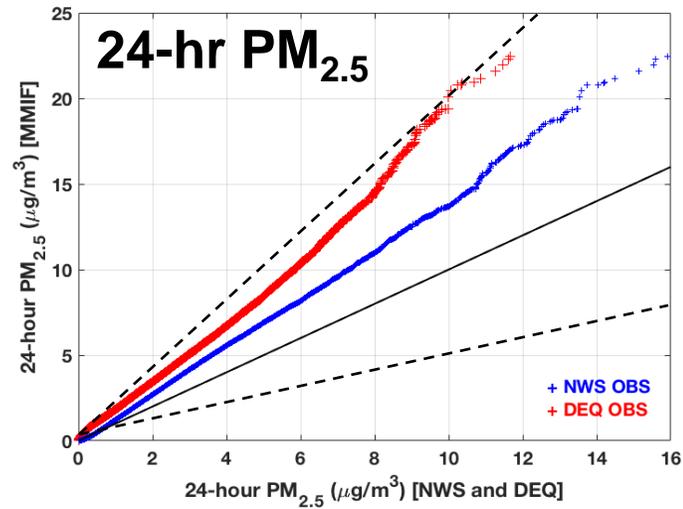
- WRF/MMIF data results in higher concentrations than the onsite data.
- Results from modeling with the onsite meteorological data should be viewed with some caution, as the onsite data processing utilized cloud cover and ceiling height data from Coeur d'Alene, Idaho (over 70 miles away) to determine stability parameters.

# AERMOD Modeling Results

		Moyie Springs		Sandpoint		
Pollutant	Averaging Period	WRF/MMIF	Onsite	WRF/MMIF	NWS	DEQ
		2015-2017	2002-2003	2015-2017	2015-2017	2015-2017
NO <sub>x</sub>	1 hour	201	70	208	107	114
	Annual	3.5	1.7	4.6	2.6	1.8
PM <sub>10</sub>	24-hour	18.4	8.7	16.5	10.2	14.7
PM <sub>2.5</sub>	24-hour	10	6.7	10.3	7.1	9.7
	Annual	1.54	1	1.9	1.3	1.4

Results for the three Sandpoint meteorological data sets also show that the WRF/MMIF data produces higher concentrations than both the NWS data and the DEQ monitored data.

# Q-Q Concentration Plots at Sandpoint

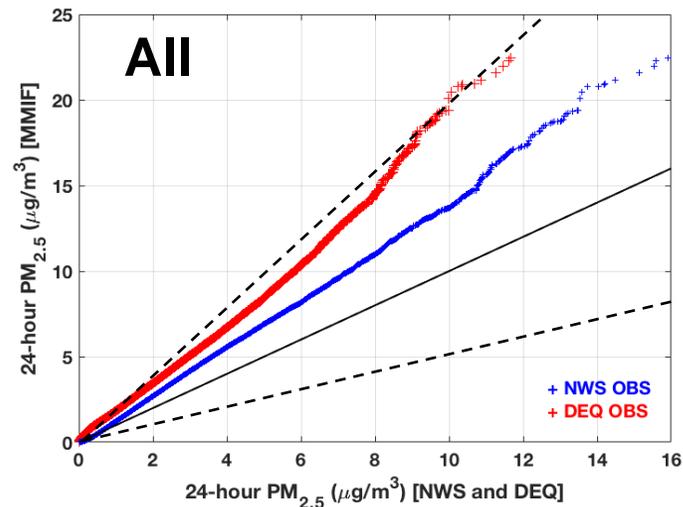
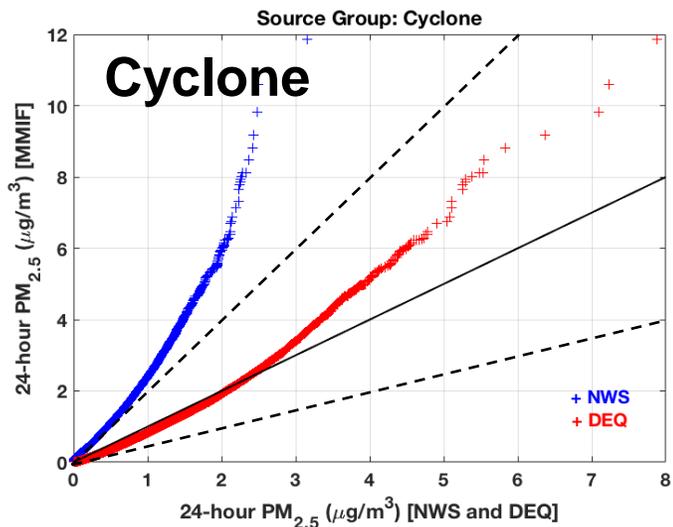
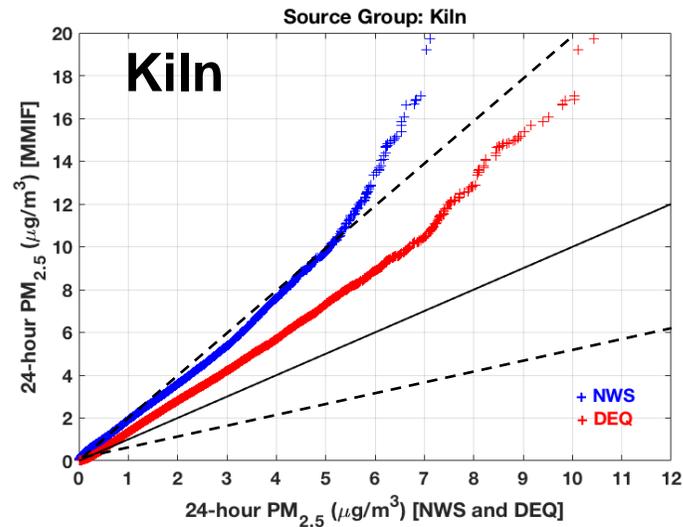
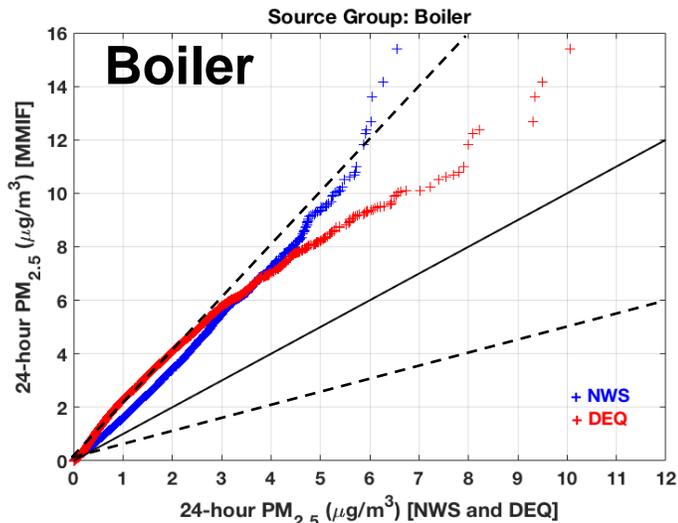


Results from the WRF/MMIF data produce higher concentrations than the two monitored meteorological data sets.

# Source Group Analyses

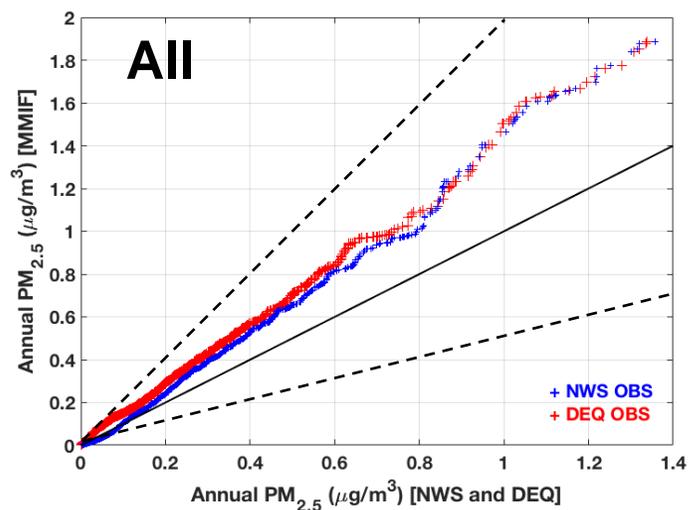
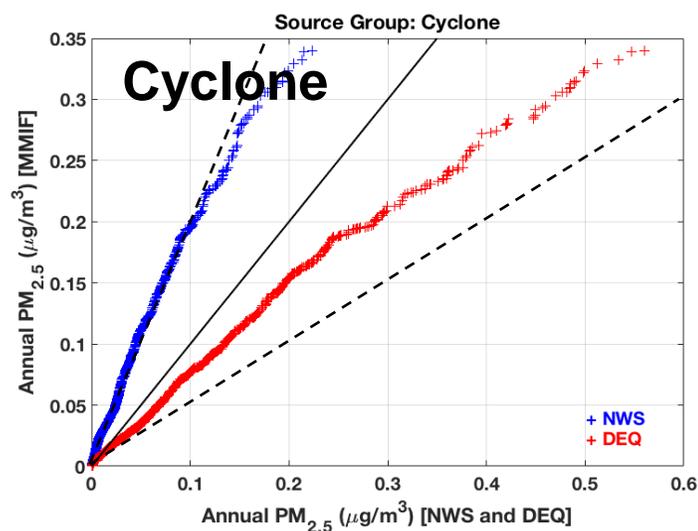
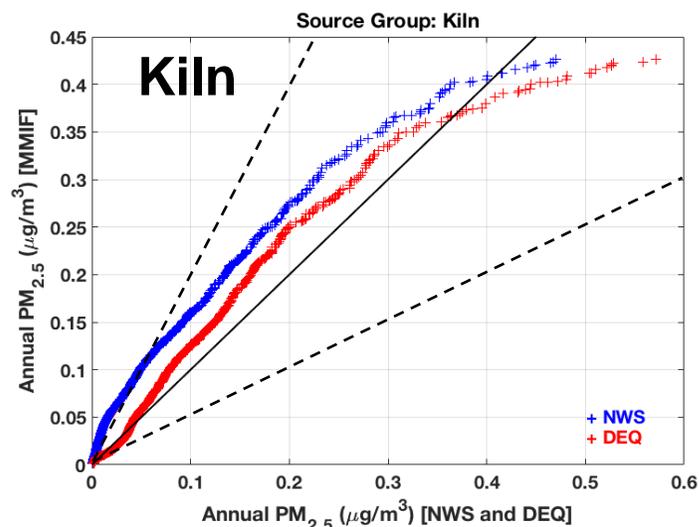
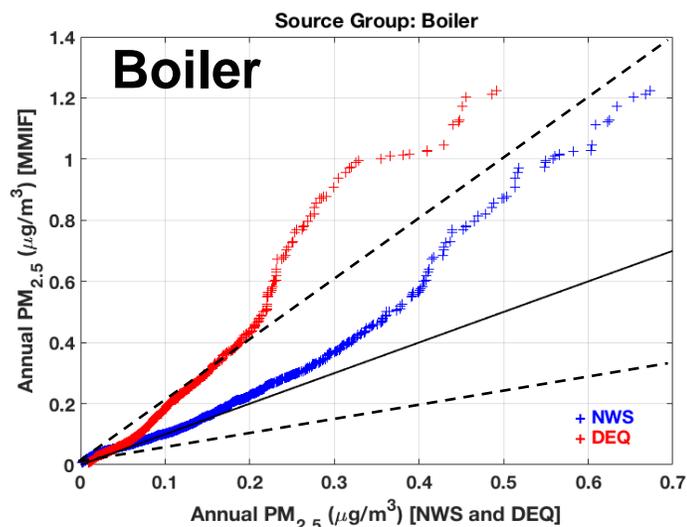
Source Group	PM <sub>2.5</sub> Averaging Period	WRF/MMIF	NWS Airport	DEQ Onsite
		2015-2017	2015-2017	2015-2017
All	24-hour	10.3	7	9.7
	Annual	1.9	1.3	1.4
Boiler	24-hour	6.51	2.82	3.18
	Annual	1.2	0.7	0.5
Kilns	24-hour	7.00	4.4	6.12
	Annual	0.43	0.47	0.57
Cyclones	24-hour	3.75	1.50	3.36
	Annual	0.34	0.22	0.56

# 24-hr PM<sub>2.5</sub> Q-Q Concentration Plots



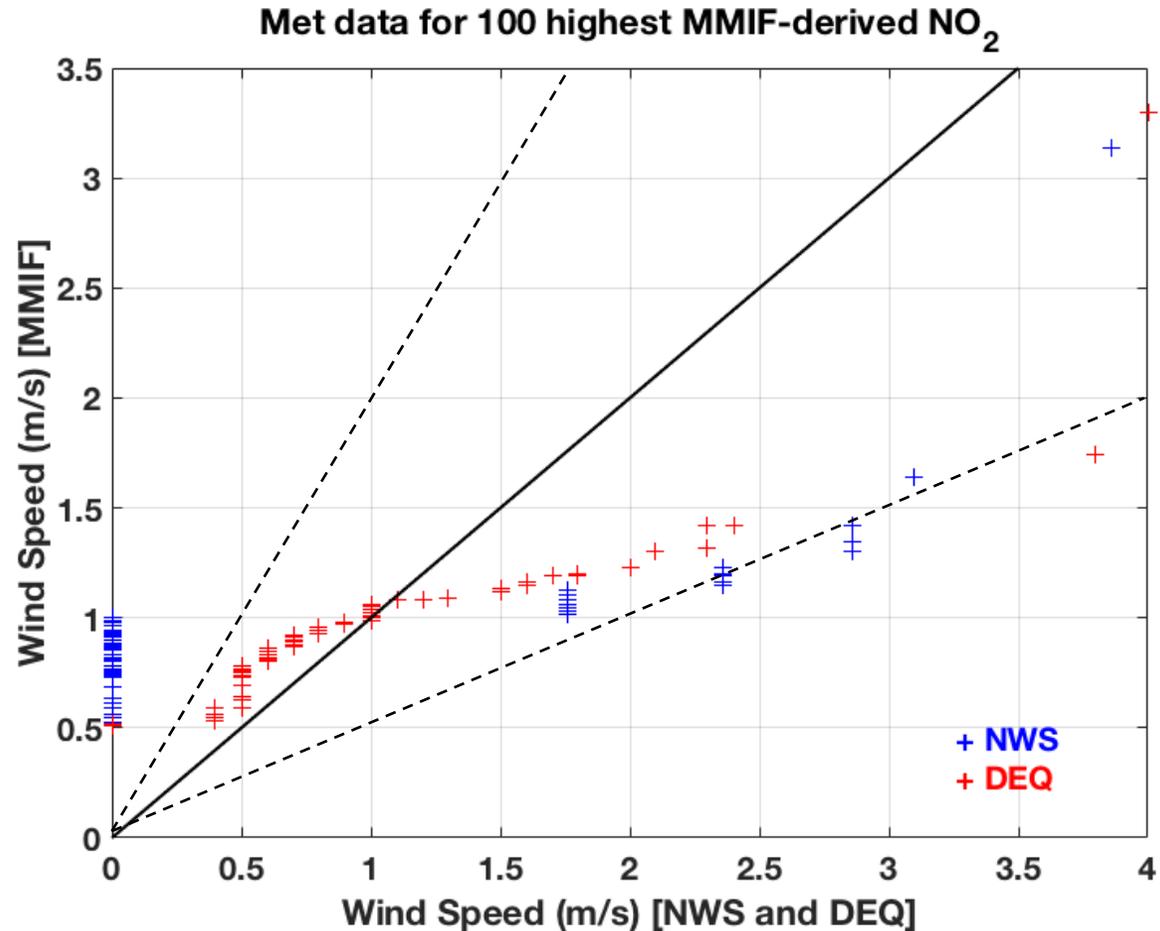
Results from the Cyclone source group show a good match for the WRF/MMIF and DEQ data sets for 24-hour PM<sub>2.5</sub> concentrations less than 3 μg/m<sup>3</sup>.

# Annual PM<sub>2.5</sub> Q-Q Concentration Plots



- In general, WRF/MMIF data produces higher concentrations than the other data sets for all three source groups.
- However, WRF/MMIF under-predicts annual PM<sub>2.5</sub> values for the less buoyant source group, Cyclones.

# Wind Speed for 100 highest MMIF-derived NO<sub>2</sub>



# Summary

- We compared **onsite** and **airport** meteorological data with **prognostic** datasets created from the WRF database.
- Some parameters (i.e., temperature, wind direction, relative humidity) have **excellent correlations**, some (i.e., wind speed) have **moderately weak correlations** and some have poor correlations.
- MMIF-driven AERMOD simulations produced maximum impacts **greater than the impacts from monitored data sets**, even though the prognostic meteorological data consistently has **wind speeds of higher value**.
- Modeling was performed with various source types typical of a lumber mill facility for numerous pollutants and averaging periods. Results from the **Cyclone source group showed a good match** for the WRF/MMIF and DEQ datasets for 24-hour  $PM_{2.5} < 3 \mu\text{g}/\text{m}^3$ . Annual results were generally higher, but were sometimes less with non-buoyant sources.

**Thanks for listening! 😊**

# **Extra Slides**

**Table 2.3. Mean bias, fractional bias, root mean square error, and R<sup>2</sup> for meteorological variables in Sandpoint, Idaho.**

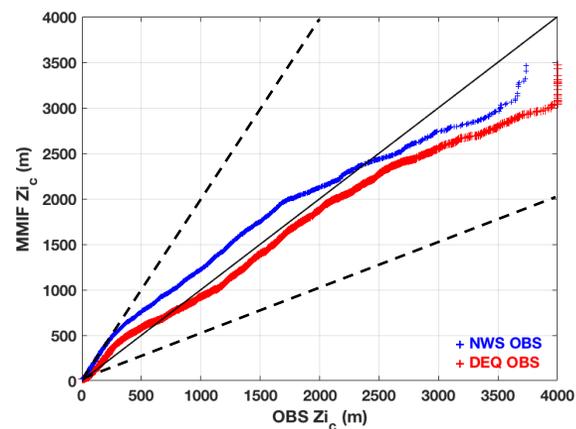
Variable	Scenario	Mean Bias	Fractional Bias	RMSE	R <sup>2</sup>
Wind Speed	MMIF-NWS	0.9251	-0.0939	2.1932	0.2404
	MMIF-DEQ	1.2319	0.0535	2.0307	0.2834
	NWS-DEQ	0.3068	0.1472	1.2172	0.7670
Ambient Temperature	MMIF-NWS	1.8662	-0.0052	3.4378	0.9069
	MMIF-DEQ	1.9357	-0.0041	3.1910	0.9061
	NWS-DEQ	0.0695	0.0011	1.3235	0.9825
Pressure	MMIF-NWS	0.0726	-6.6327e-04	1.3624	0.9613
	MMIF-DEQ	0.2003	0.0017	1.4034	0.9589
	NWS-DEQ	0.1277	0.0024	0.0000	1.0000
Relative Humidity	MMIF-NWS	-12.5762	0.0000	20.9315	0.5842
	MMIF-DEQ	-14.0233	0.0000	22.2378	0.5503
	NWS-DEQ	-1.4471	0.0000	0.0000	1.0000
Z <sub>i</sub>	MMIF-NWS	-39.1189	-0.2272	1.0089e+03	0.0470
	MMIF-DEQ	160.1586	-0.1271	941.6691	0.0466
	NWS-DEQ	199.2776	0.1008	363.1354	0.8787
Z <sub>in</sub>	MMIF-NWS	-10.3172	0.1348	306.3086	0.2531
	MMIF-DEQ	107.6649	0.1199	285.2253	0.2857
	NWS-DEQ	117.9821	-0.0149	138.5986	0.7612
L	MMIF-NWS	-0.6619	0.0087	53.4480	0.3305
	MMIF-DEQ	-2.2752	0.0312	45.8022	0.3315
	NWS-DEQ	-1.6134	0.0226	42.0033	0.4717
Cloud Cover	MMIF-NWS	0.2452	0.0000	4.4068	0.2720
	MMIF-DEQ	-1.0786	0.0000	3.8978	0.4146
	NWS-DEQ	-1.3238	0.0000	3.2456	0.5798
Heat Flux	MMIF-NWS	-21.5881	-0.1150	31.9985	0.8246
	MMIF-DEQ	1.2844	0.0362	27.9050	0.8398
	NWS-DEQ	22.8725	0.1511	31.4941	0.8808
u*	MMIF-NWS	7.4305e-04	0.1781	0.1455	0.3806
	MMIF-DEQ	0.0695	0.1676	0.1461	0.4121
	NWS-DEQ	0.0687	-0.0105	0.0722	0.7505
w*	MMIF-NWS	-0.1245	-0.1736	0.6325	0.2916
	MMIF-DEQ	0.1814	-0.0299	0.5681	0.3918
	NWS-DEQ	0.3058	0.1439	0.3498	0.8437
dθ/dz	MMIF-NWS	-6.5372e-04	-0.3460	0.0022	0.1861
	MMIF-DEQ	-0.0017	-0.5674	0.0039	0.1583
	NWS-DEQ	-0.0010	-0.2328	0.0016	0.6737
z <sub>0</sub>	MMIF-NWS	0.0946	1.2333	0.1162	0.6577
	MMIF-DEQ	-0.0075	0.0000	0.0655	0.6336
	NWS-DEQ	-0.1021	-1.2333	0.1355	0.5902
B <sub>0</sub>	MMIF-NWS	-0.2828	-0.6753	0.4310	0.8481
	MMIF-DEQ	-0.0136	0.0000	0.0000	1.0000
	NWS-DEQ	0.2692	0.6753	0.4848	0.8674
r	MMIF-NWS	-0.0289	0.0000	0.0529	0.9881
	MMIF-DEQ	-0.0118	0.0000	3.7017e-04	1.0000
	NWS-DEQ	0.0171	0.0000	0.0567	0.9856

# Meteorological Data at Sandpoint

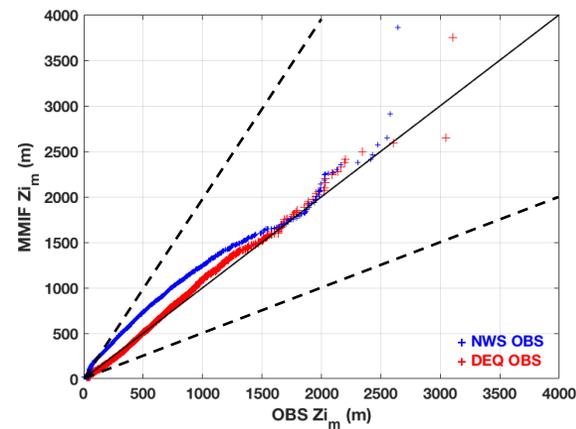
Variable	Scenario	Mean Bias	RMSE	R <sup>2</sup>
Zi <sub>c</sub>	MMIF-NWS	-39.1189	1.0089e+03	0.0470
	MMIF-DEQ	160.1586	941.6691	0.0466
	NWS-DEQ	199.2776	363.1354	0.8787
Zi <sub>m</sub>	MMIF-NWS	-10.3172	306.3086	0.2531
	MMIF-DEQ	107.6649	285.2253	0.2857
	NWS-DEQ	117.9821	138.5986	0.7612
L	MMIF-NWS	-0.6619	53.4480	0.3305
	MMIF-DEQ	-2.2752	45.8022	0.3315
	NWS-DEQ	-1.6134	42.0033	0.4717
Cloud Cover	MMIF-NWS	0.2452	4.4068	0.2720
	MMIF-DEQ	-1.0786	3.8978	0.4146
	NWS-DEQ	-1.3238	3.2456	0.5798

# Meteorological Data at Sandpoint

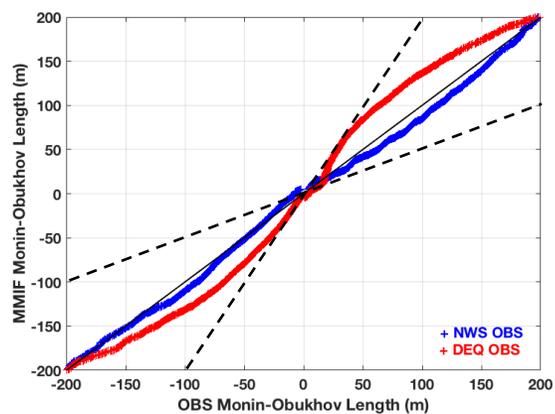
$Zi_c$



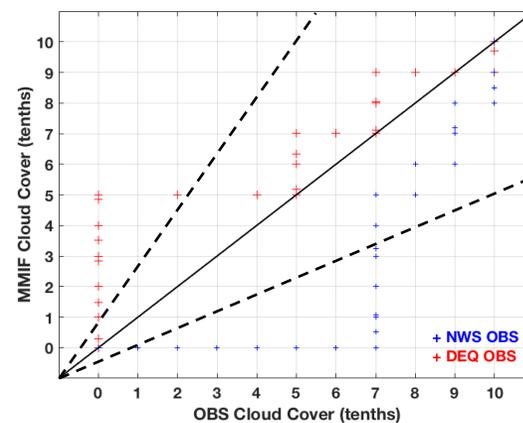
$Zi_m$



L



Cloud Cover

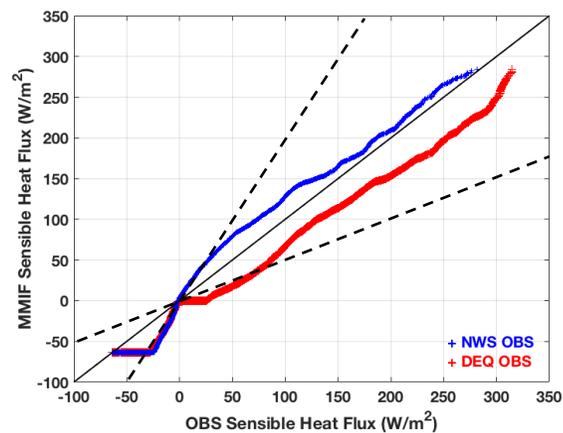


# Meteorological Data at Sandpoint

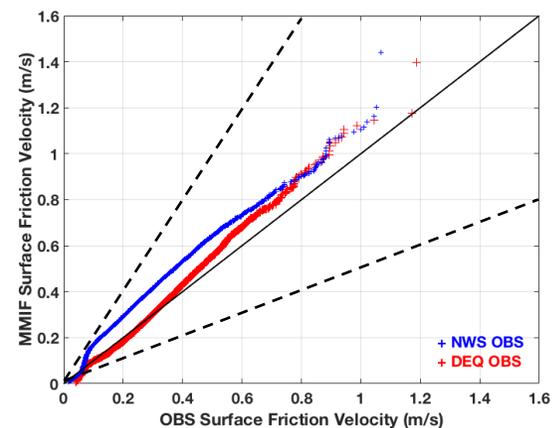
Variable	Scenario	Mean Bias	RMSE	R <sup>2</sup>
Heat Flux	MMIF-NWS	-21.5881	31.9985	0.8246
	MMIF-DEQ	1.2844	27.9050	0.8398
	NWS-DEQ	22.8725	31.4941	0.8808
u*	MMIF-NWS	7.4305e-04	0.1455	0.3806
	MMIF-DEQ	0.0695	0.1461	0.4121
	NWS-DEQ	0.0687	0.0722	0.7505
w*	MMIF-NWS	-0.1245	0.6325	0.2916
	MMIF-DEQ	0.1814	0.5681	0.3918
	NWS-DEQ	0.3058	0.3498	0.8437
dθ/dz	MMIF-NWS	-6.5372e-04	0.0022	0.1861
	MMIF-DEQ	-0.0017	0.0039	0.1583
	NWS-DEQ	-0.0010	0.0016	0.6737

# Meteorological Data at Sandpoint

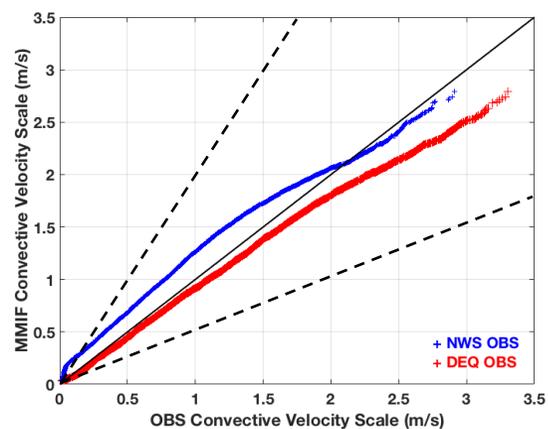
## H



## $u^*$



## $w^*$



## $d\theta/dz$

