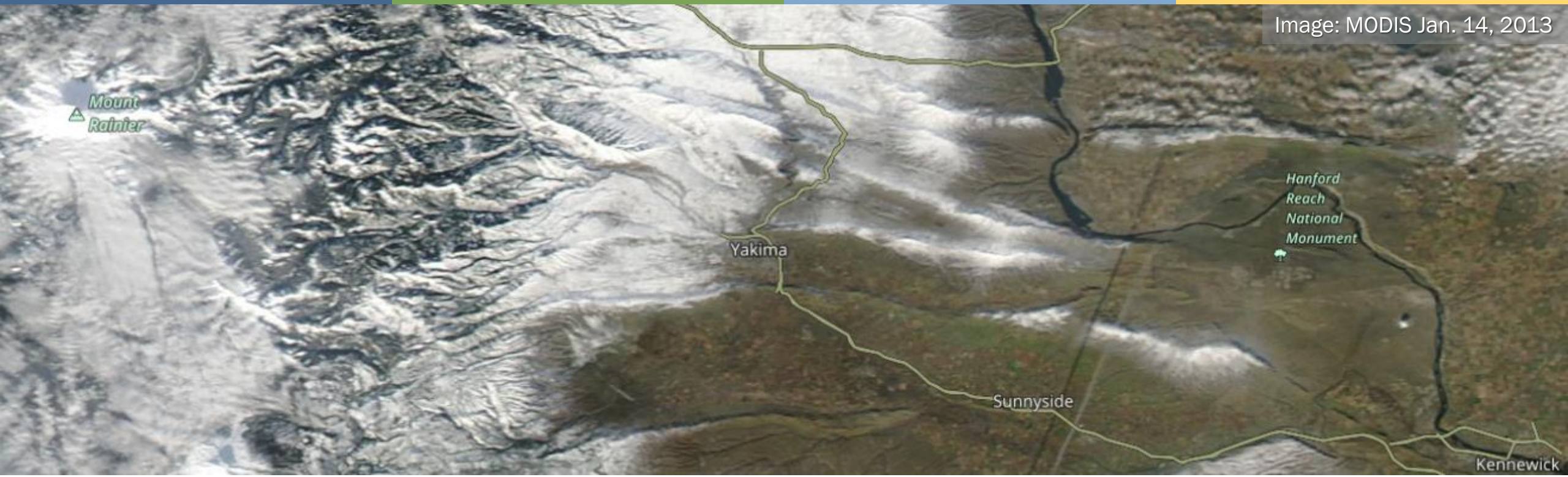

Yakima wintertime PM2.5 modeling update 4/3 km EMAQ

Looking at the Nov. 2019 simulations

Farren Thorpe, Tesfamichael Ghidey, Beth Friedman, Shuang Xia

NW-AIRQUEST Mtg.

June 28, 2022

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Overview

- Previous YAWNS work (2013)
- Review EMAQ setup/configuration
- Recent follow-up to modeling work, with new case study (2019)
- Discussion of model performance for PM2.5 in Yakima
- PM2.5 speciation results
- Emissions reduction scenarios

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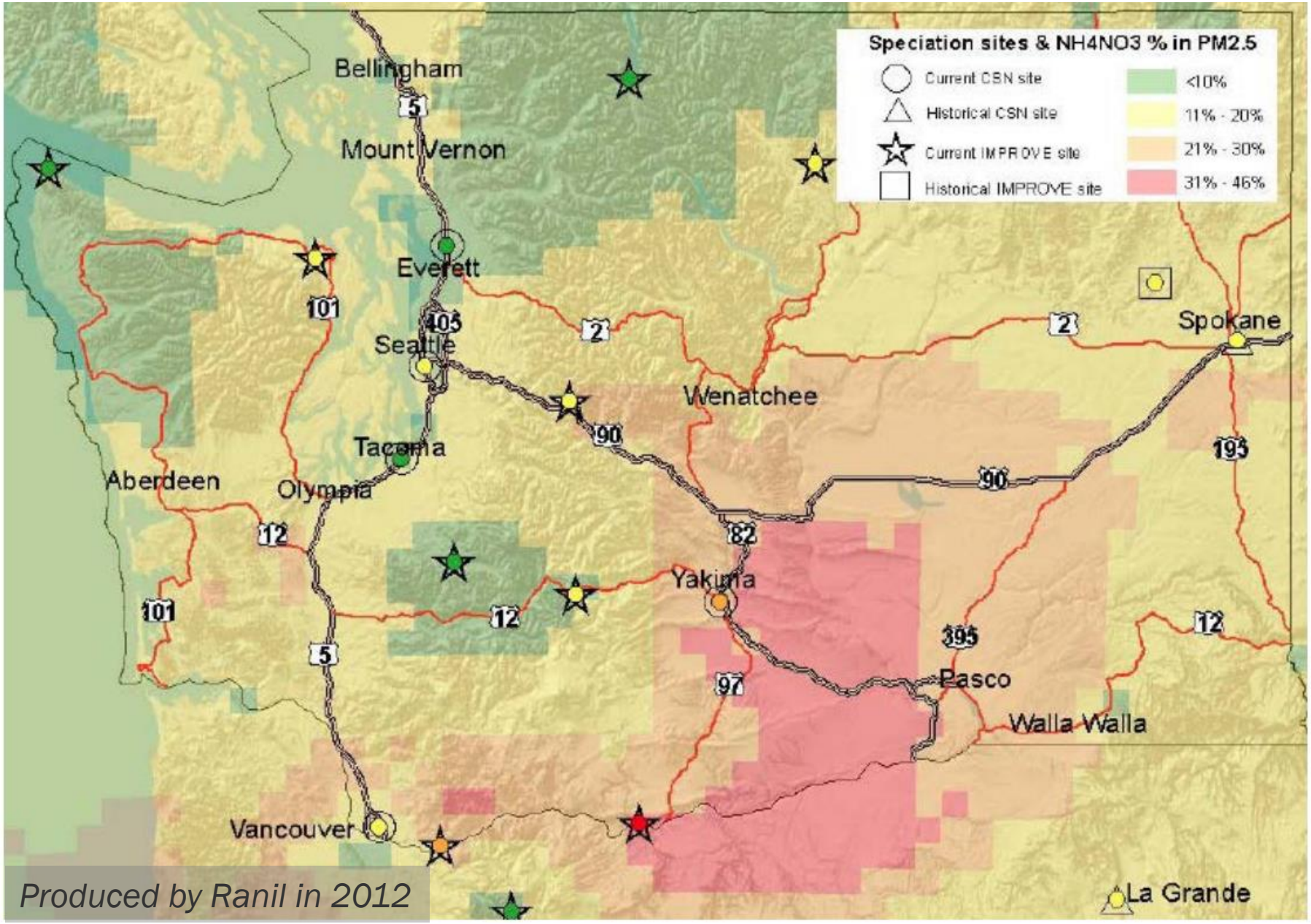
Ammonium Nitrate contribution to total PM2.5



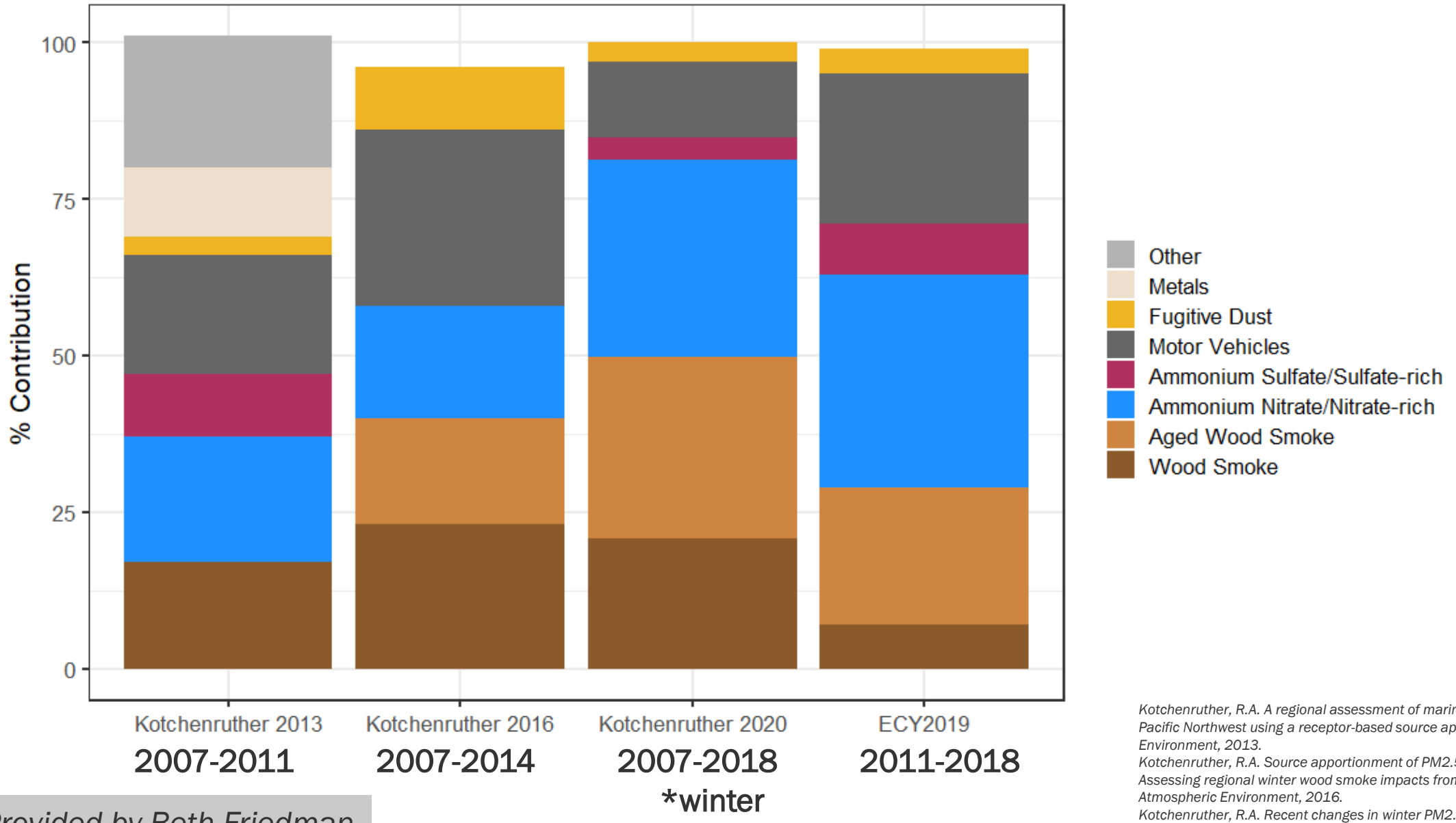
Produced by Ranil in 2012

Yakima often has PM2.5 issues during the winter, but not just due to wood-smoke.

WSU and CWU were contracted by Ecology to perform a Yakima Air Wintertime Nitrate Study (YAWNS) to understand why particulate nitrate is a problem in the area.

Multi-pollutant monitoring campaign conducted in January of 2013.

Source apportionment of PM2.5 in Yakima



Provided by Beth Friedman

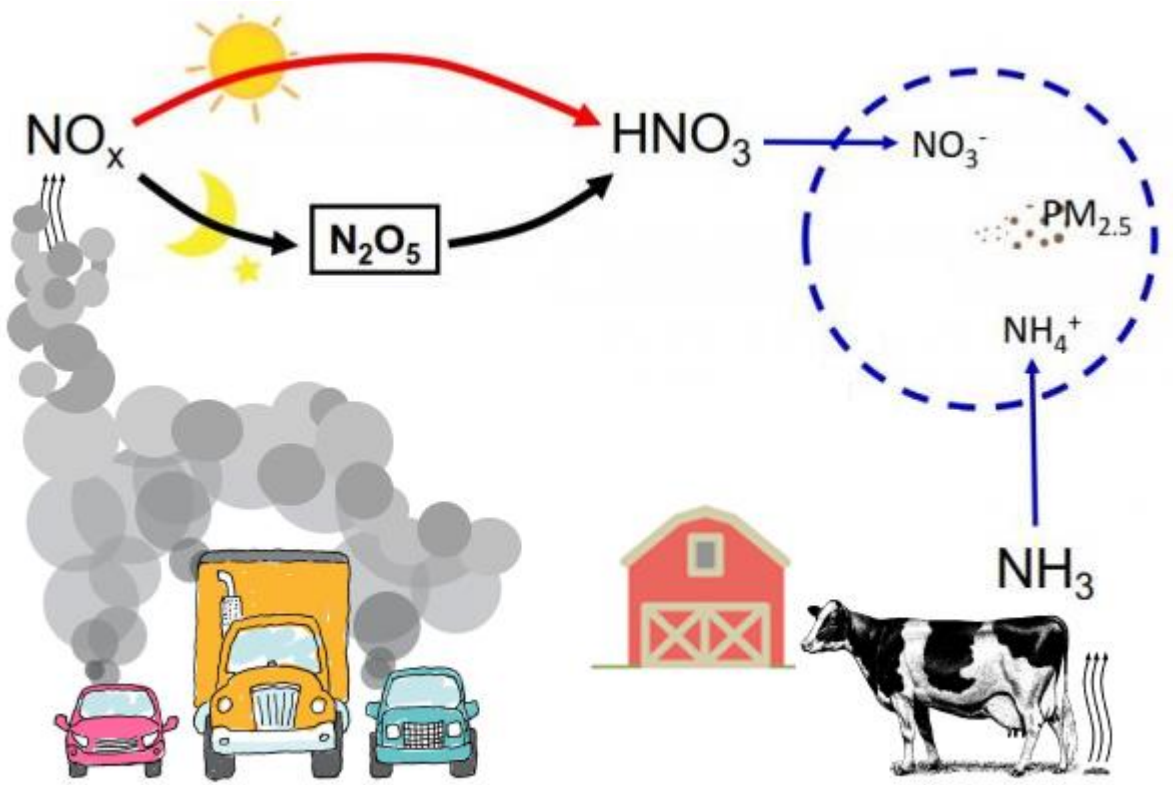
Kotchenruther, R.A. A regional assessment of marine vessel PM2.5 impacts in the U.S. Pacific Northwest using a receptor-based source apportionment method. Atmospheric Environment, 2013.

Kotchenruther, R.A. Source apportionment of PM2.5 at multiple Northwest U.S. sites: Assessing regional winter wood smoke impacts from residential wood combustion. Atmospheric Environment, 2016.

Kotchenruther, R.A. Recent changes in winter PM2.5 contributions from wood smoke, motor vehicles, and other sources in the Northwest U.S. Atmospheric Environment, 2020.

YAWNS Conclusions

- High nitrate levels are likely caused by ammonia from agricultural activities interacting with NOx from motor vehicles during the right weather conditions.
- Air from both upper and lower Yakima valleys gradually mix together in typical conditions. However, mixing is restricted during cold, stagnant periods
- Need to determine what kind of actions will help reduce aerosol nitrate in Yakima.

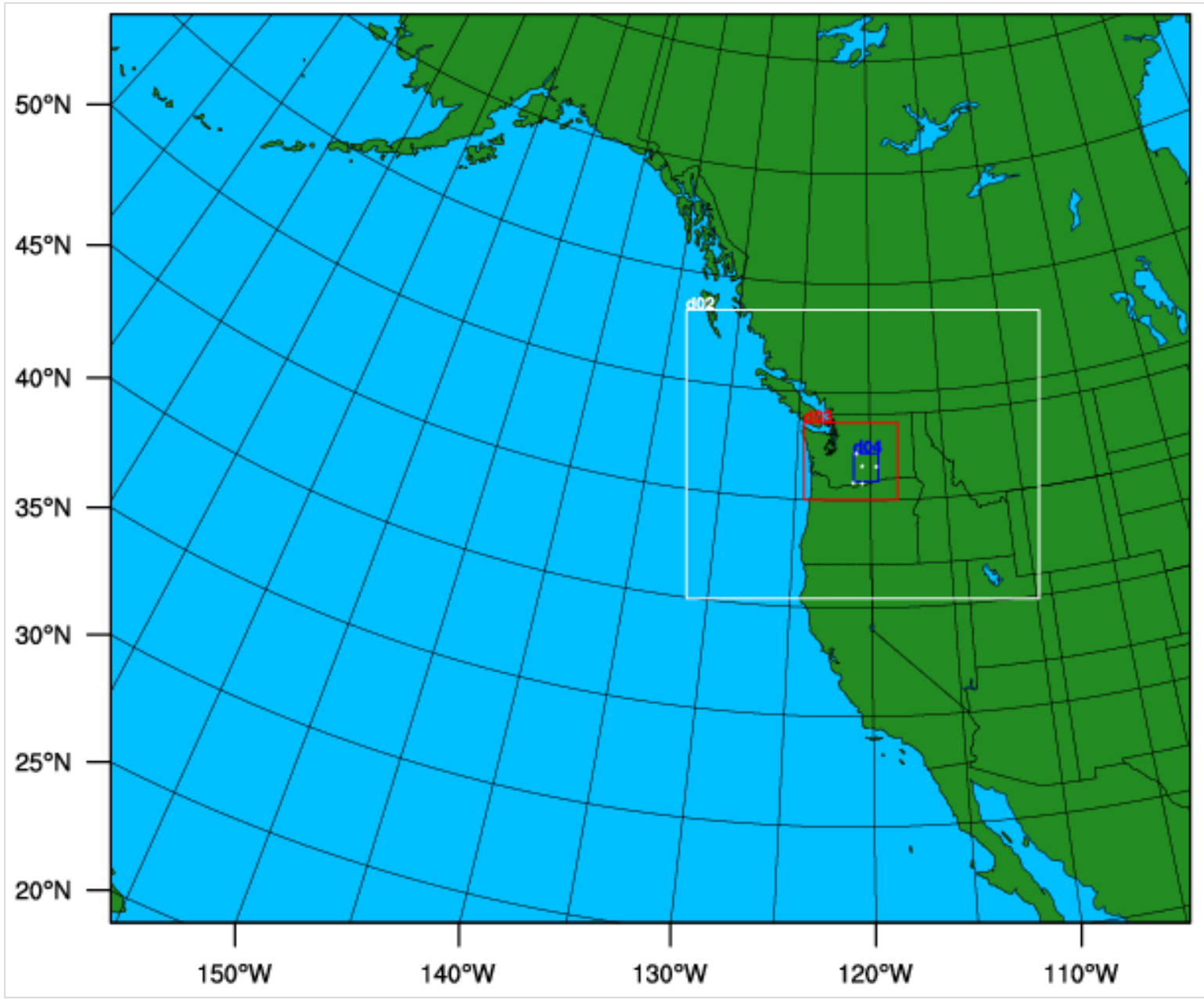


EMAQ Setup

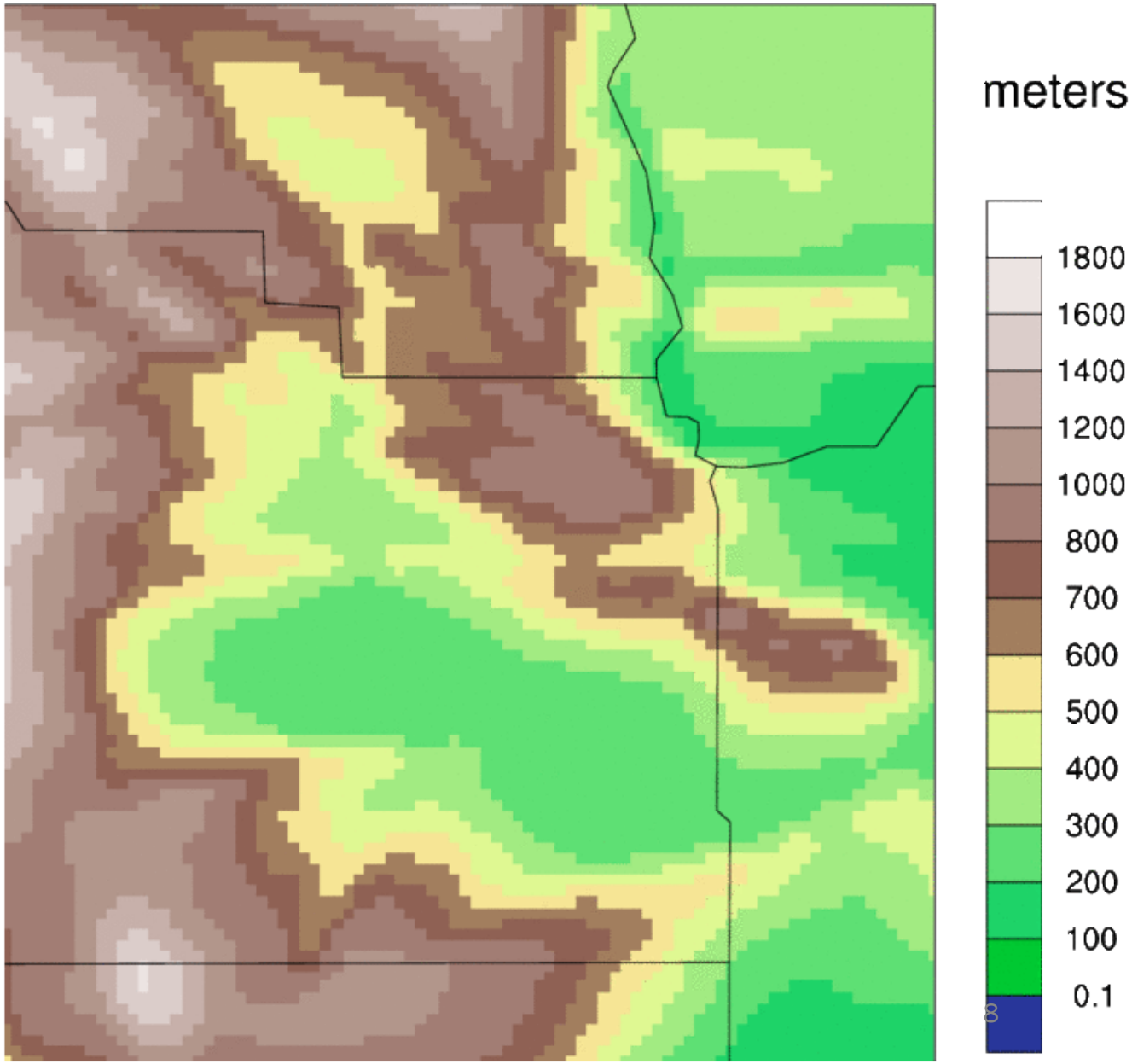
- Met: WRF ARW v3.7.1; MCIP v4.4
- Emis: SMOKE v4.5
- EI: biogenic (BEIS 3.61/BELD 4.1); area (2014, no road dust); onroad/nonroad (2014 adjusted to “2019”); point (2016);
- bcon: Boundary conditions derived from MOZART monthly avg. (static daily, no diurnal profile)
- CTM: CMAQ v5.2; CB05; AERO6
- linux: Computing Resources: 24 Virtual CPUs; 320 GB RAM; Scientific Linux 7.9

EMAQ WRF Domains

Horiz. Resol^{n}. (km)	Number of Grid Points	
	W->E	S->N
36	151	127
12	148	121
4	118	97
1.33	94	106



Yakima EMAQ 4/3km Modeling Domain UGAs (left) and terrain (right)



Emissions – Spatial Distribution

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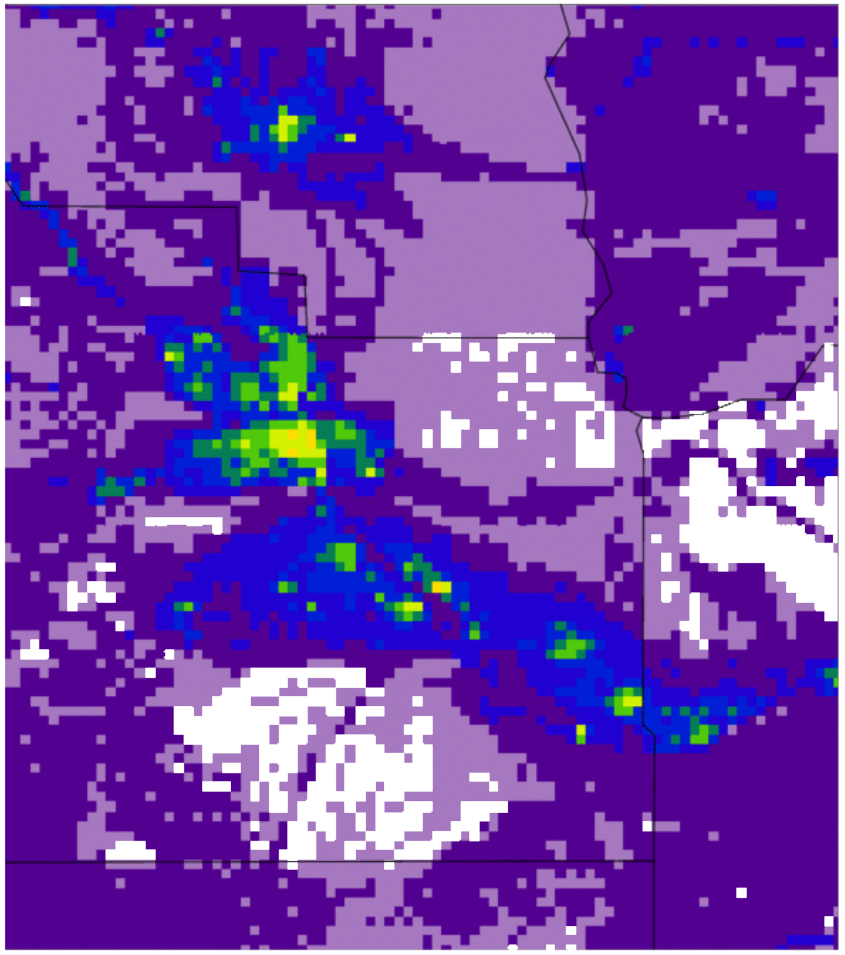
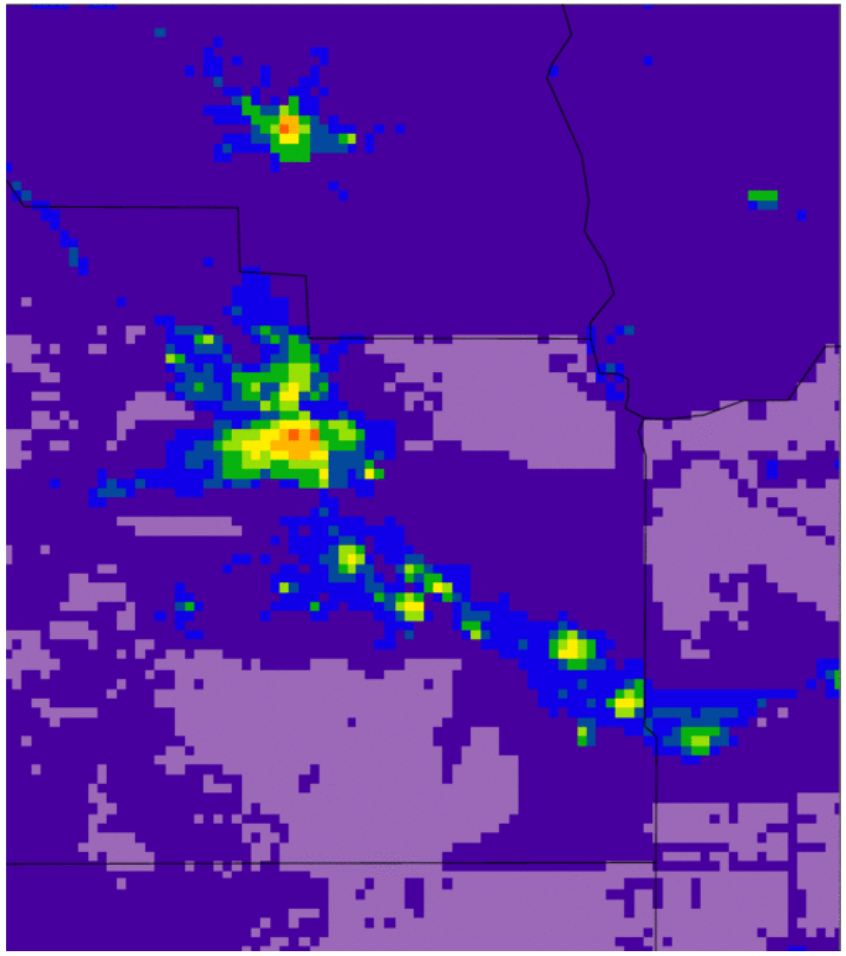
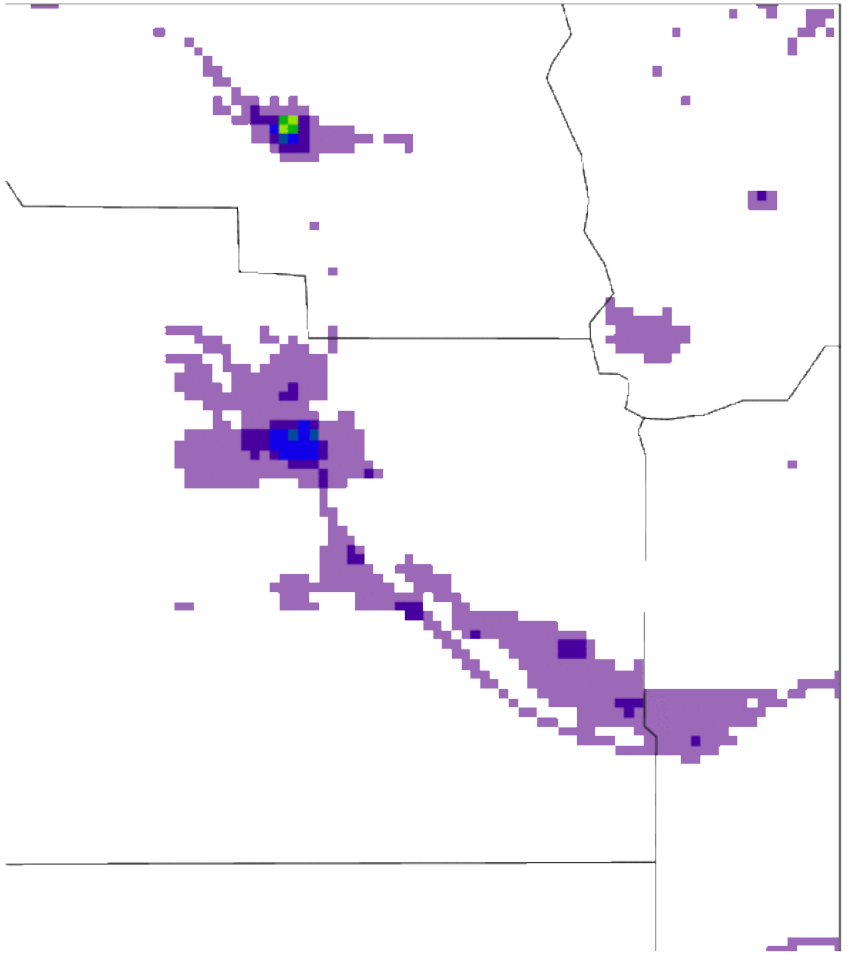
PM2.5



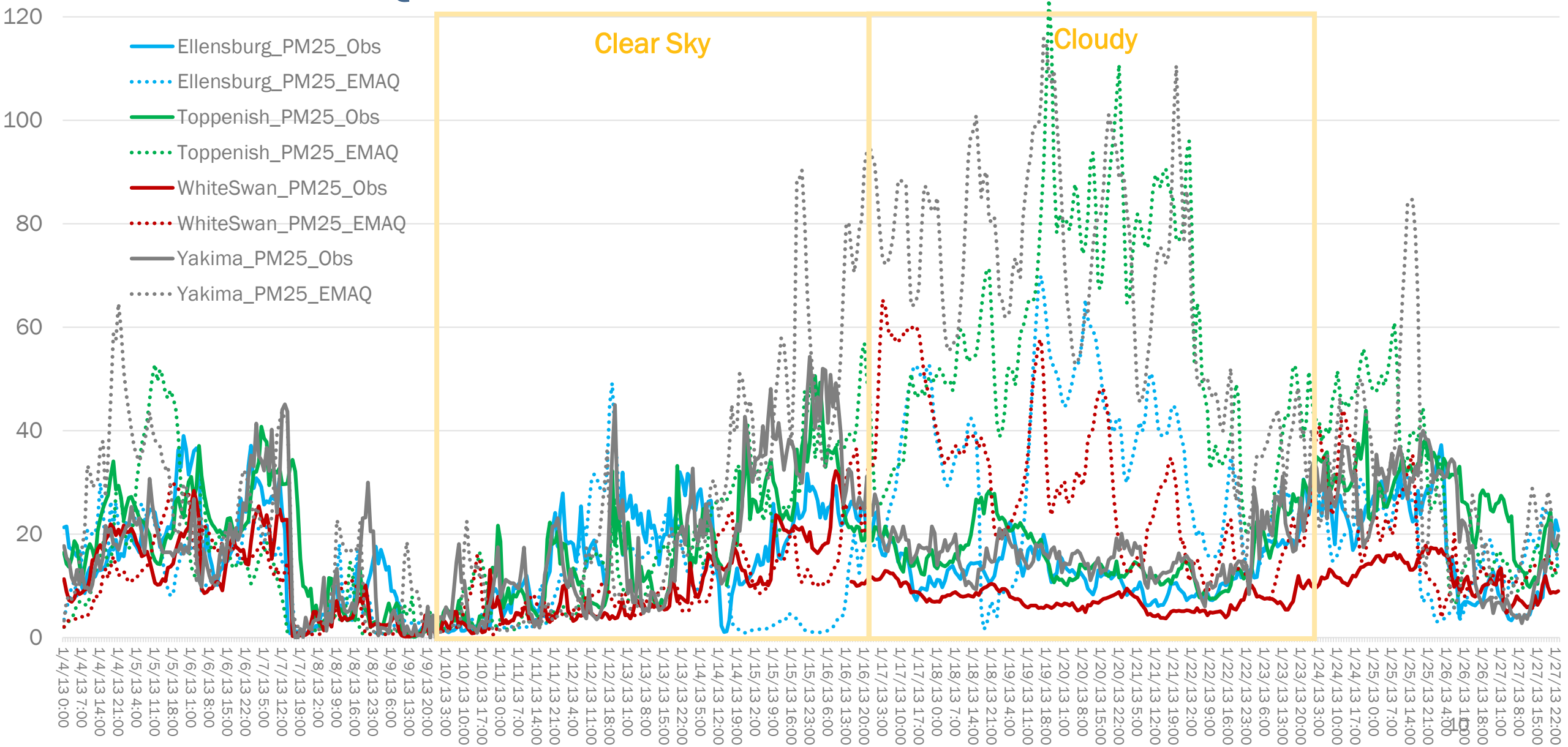
CO



NOx



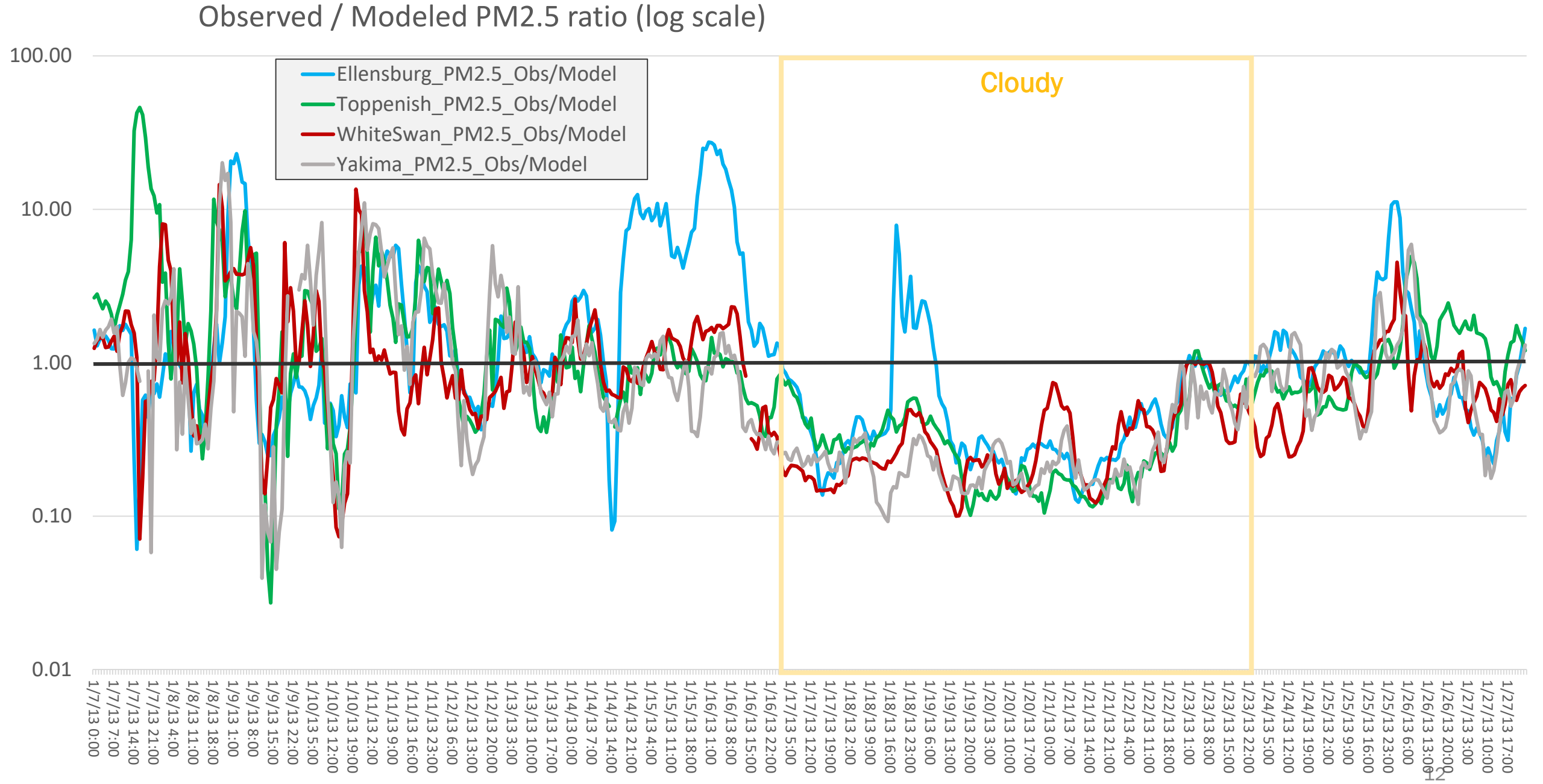
2013 EMAQ PM2.5 Performance (µg/m³)



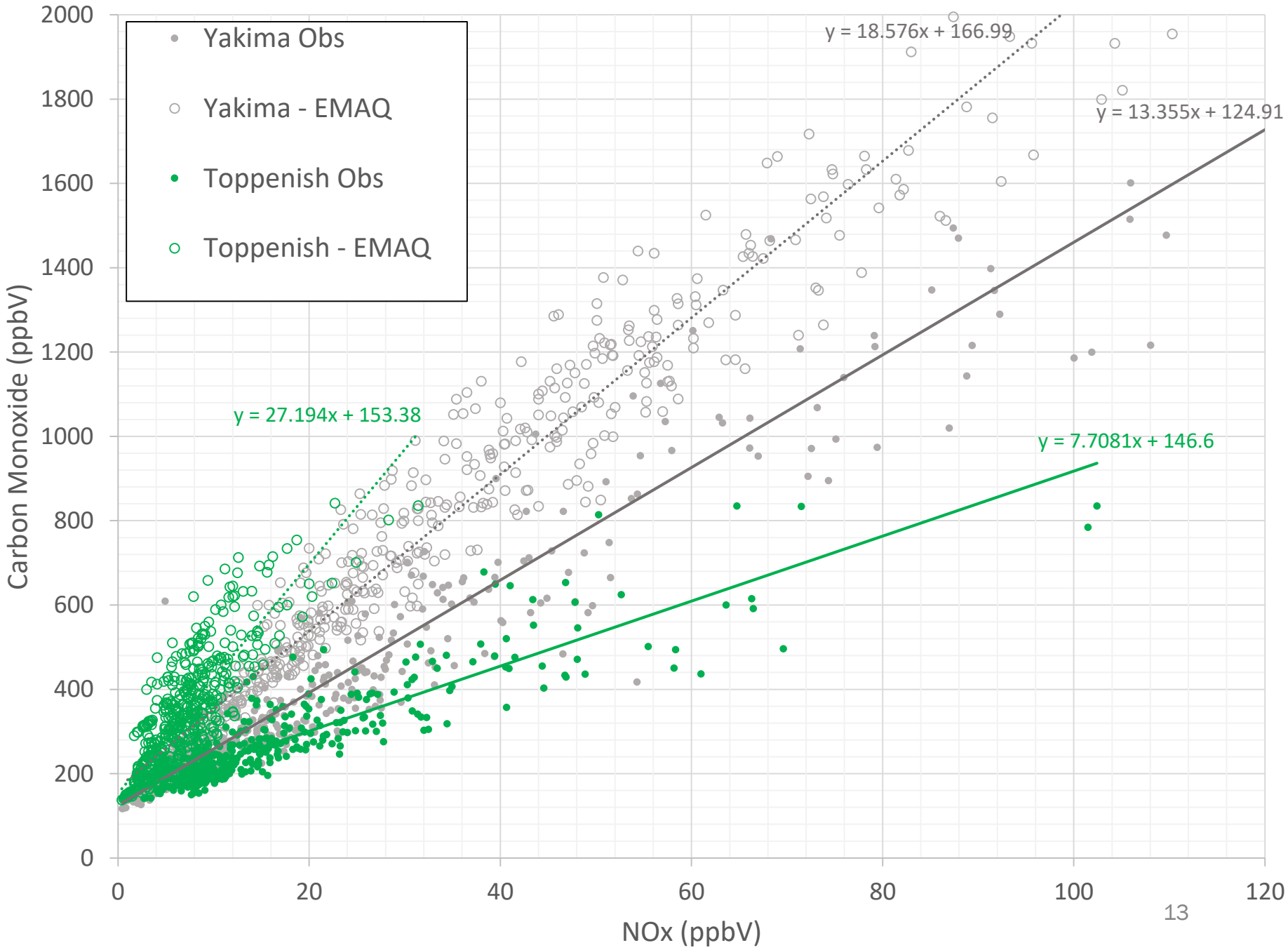
Two periods with a mesoscale stagnation episode:

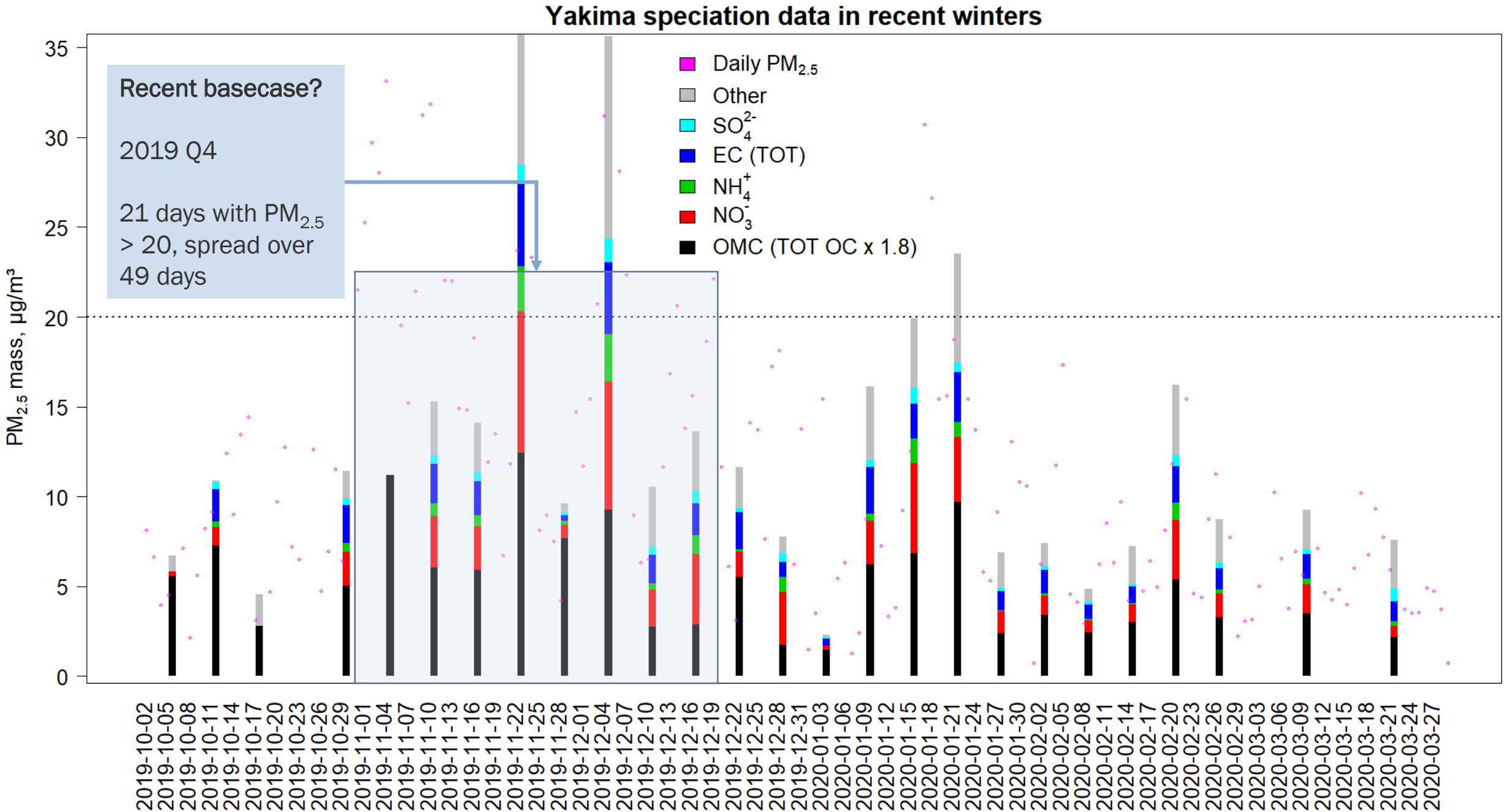
- Clear Sky period, 10 – 16 January, 2013;
  - Night was characterized by elevated levels of both primary and secondary PM components
  - Diurnal cycle of the mixing layer followed a typical pattern

- Persistent Cloud period, 17 – 23 January, 2013;
  - Persistent low levels of all primary pollutants;
  - Meteorology driven; T & RH relatively flat
  - secondary PM remained high, especially particulate nitrate
  - Low-level cloud enhanced surface mixing and increased dilution of primary pollutants


Observed / Modeled PM2.5 ratio (log scale)
Ellensburg_PM2.5_Obs/Model
Toppenish_PM2.5_Obs/Model
WhiteSwan_PM2.5_Obs/Model
Yakima_PM2.5_Obs/Model
Cloudy
100.00
10.00
1.00
0.10
0.01
1/7/13 0:00
1/7/13 7:00
1/7/13 14:00
1/7/13 21:00
1/8/13 4:00
1/8/13 11:00
1/8/13 18:00
1/9/13 1:00
1/9/13 8:00
1/9/13 15:00
1/9/13 22:00
1/10/13 5:00
1/10/13 12:00
1/10/13 19:00
1/11/13 2:00
1/11/13 9:00
1/11/13 16:00
1/11/13 23:00
1/12/13 6:00
1/12/13 13:00
1/12/13 20:00
1/13/13 3:00
1/13/13 10:00
1/13/13 17:00
1/14/13 0:00
1/14/13 7:00
1/14/13 14:00
1/14/13 21:00
1/15/13 4:00
1/15/13 11:00
1/15/13 18:00
1/16/13 1:00
1/16/13 8:00
1/16/13 15:00
1/16/13 22:00
1/17/13 5:00
1/17/13 12:00
1/17/13 19:00
1/18/13 2:00
1/18/13 9:00
1/18/13 16:00
1/18/13 23:00
1/19/13 6:00
1/19/13 13:00
1/19/13 20:00
1/20/13 3:00
1/20/13 10:00
1/20/13 17:00
1/21/13 0:00
1/21/13 7:00
1/21/13 14:00
1/21/13 21:00
1/22/13 4:00
1/22/13 11:00
1/22/13 18:00
1/23/13 1:00
1/23/13 8:00
1/23/13 15:00
1/23/13 22:00
1/24/13 5:00
1/24/13 12:00
1/24/13 19:00
1/25/13 2:00
1/25/13 9:00
1/25/13 16:00
1/25/13 23:00
1/26/13 6:00
1/26/13 13:00
1/26/13 20:00
1/27/13 3:00
1/27/13 10:00
1/27/13 17:00

2013 CO/NOx


Yakima Obs
Yakima - EMAQ
Toppenish Obs
Toppenish - EMAQ
y = 18.576x + 166.99
y = 13.355x + 124.91
y = 27.194x + 153.38
y = 7.7081x + 146.6
Carbon Monoxide (ppbV)
NOx (ppbV)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
20
40
60
80
100
120


Yakima speciation data in recent winters
Recent basecase?
2019 Q4
21 days with PM2.5 > 20, spread over 49 days
Daily PM2.5
Other
SO4 2-
EC (TOT)
NH4 +
NO3 -
OMC (TOT OC x 1.8)
PM2.5 mass, µg/m³
0
5
10
15
20
25
30
35
2019-10-02
2019-10-05
2019-10-08
2019-10-11
2019-10-14
2019-10-17
2019-10-20
2019-10-23
2019-10-26
2019-10-29
2019-11-01
2019-11-04
2019-11-07
2019-11-10
2019-11-13
2019-11-16
2019-11-19
2019-11-22
2019-11-25
2019-11-28
2019-12-01
2019-12-04
2019-12-07
2019-12-10
2019-12-13
2019-12-16
2019-12-19
2019-12-22
2019-12-25
2019-12-28
2019-12-31
2020-01-03
2020-01-06
2020-01-09
2020-01-12
2020-01-15
2020-01-18
2020-01-21
2020-01-24
2020-01-27
2020-01-30
2020-02-02
2020-02-05
2020-02-08
2020-02-11
2020-02-14
2020-02-17
2020-02-20
2020-02-23
2020-02-26
2020-02-29
2020-03-03
2020-03-06
2020-03-09
2020-03-12
2020-03-15
2020-03-18
2020-03-21
2020-03-24
2020-03-27

EMAQ WRF Performance

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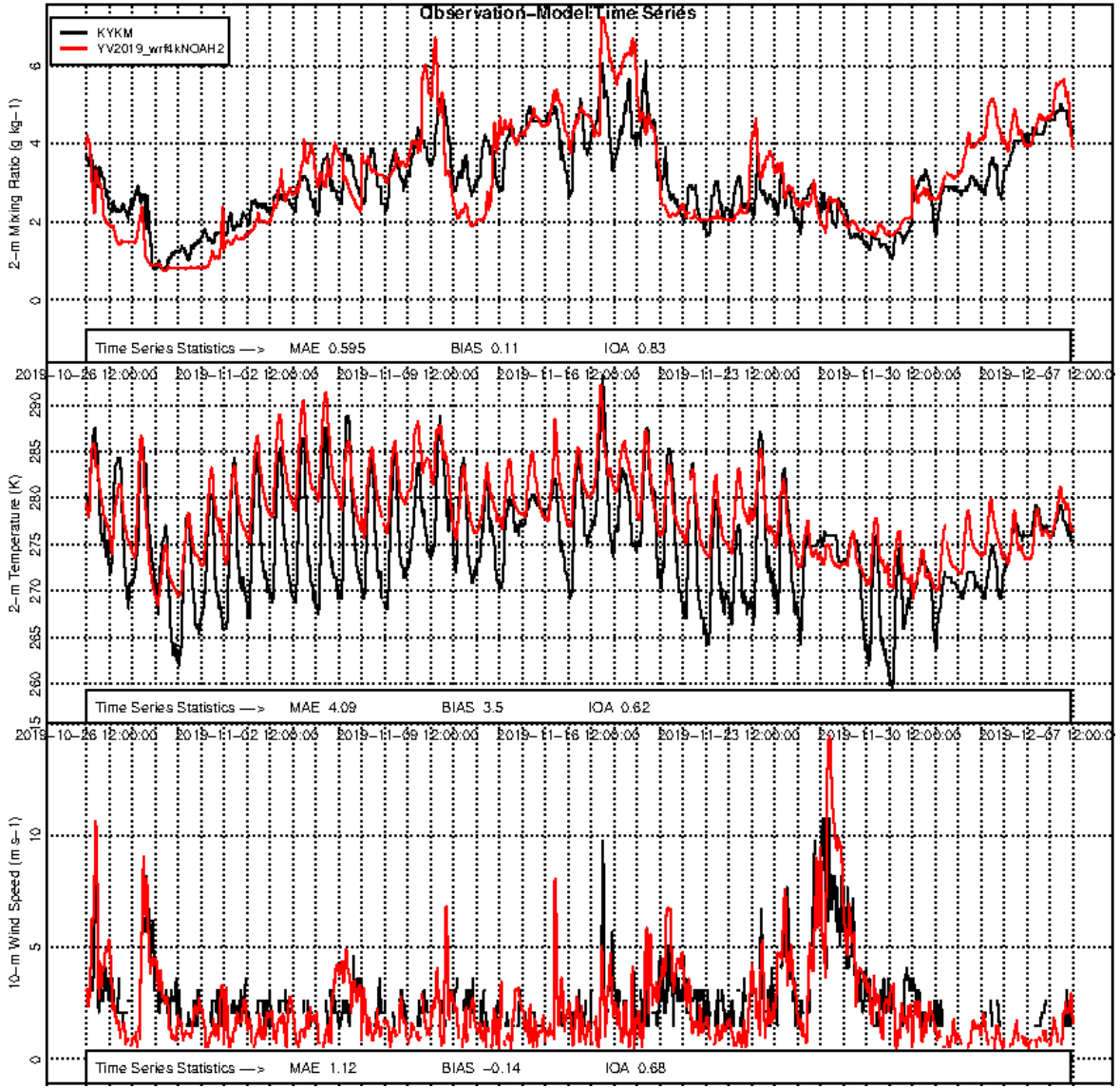
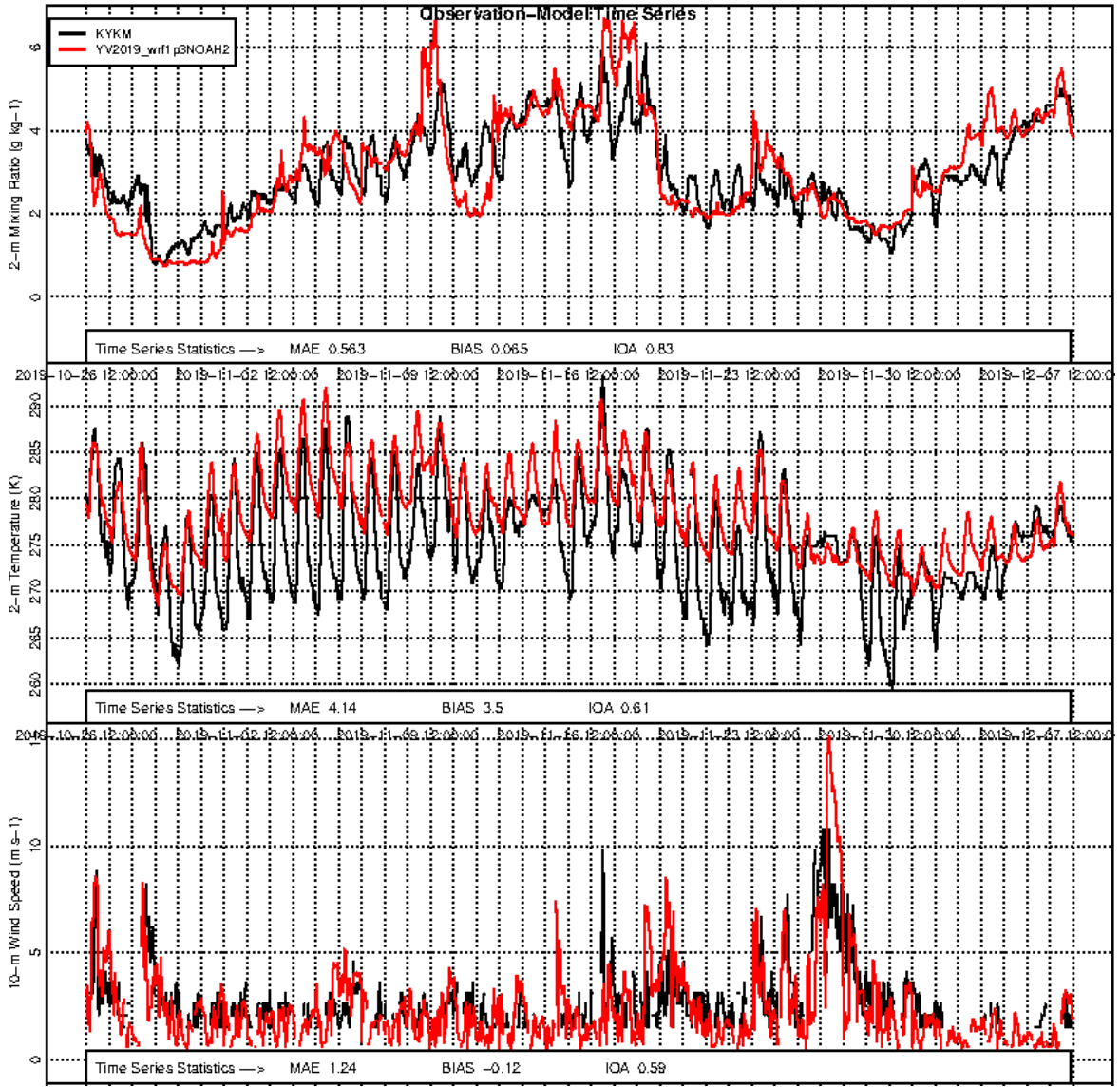
4 km domain: Q(g/kg), T(K), WS(m/s)



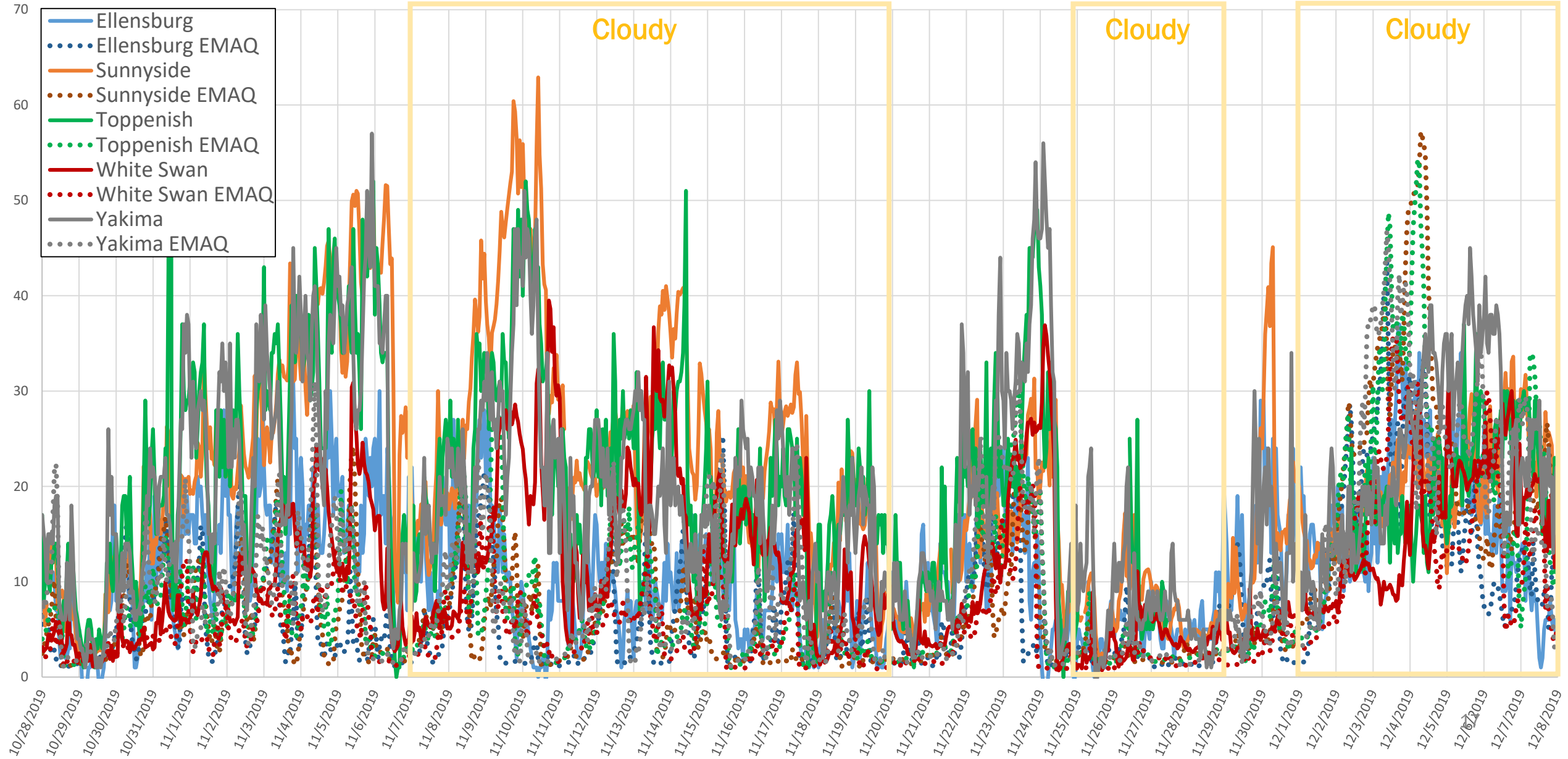
1.3 km domain: Q, T, WS



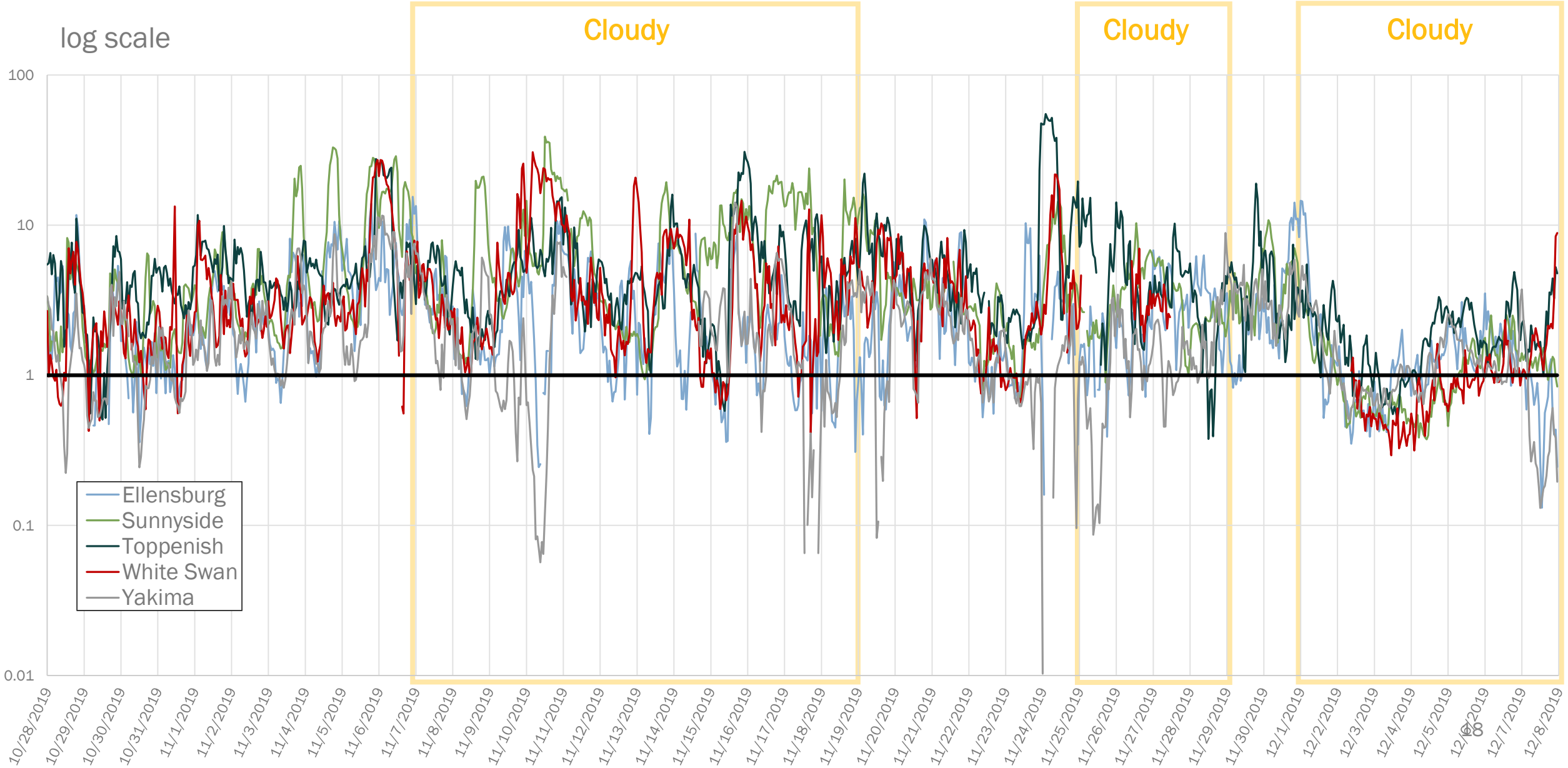
WRF Performance

- Performed within the target benchmarks for humidity and wind speed
- Poor performance in temperature
- A mixed performance in wind direction: better in bias, but poor in mean error due to wide variability and divergence
- Observational Nudging is the only and next plan for a possible reproduction of WRF variables to observations more accurately

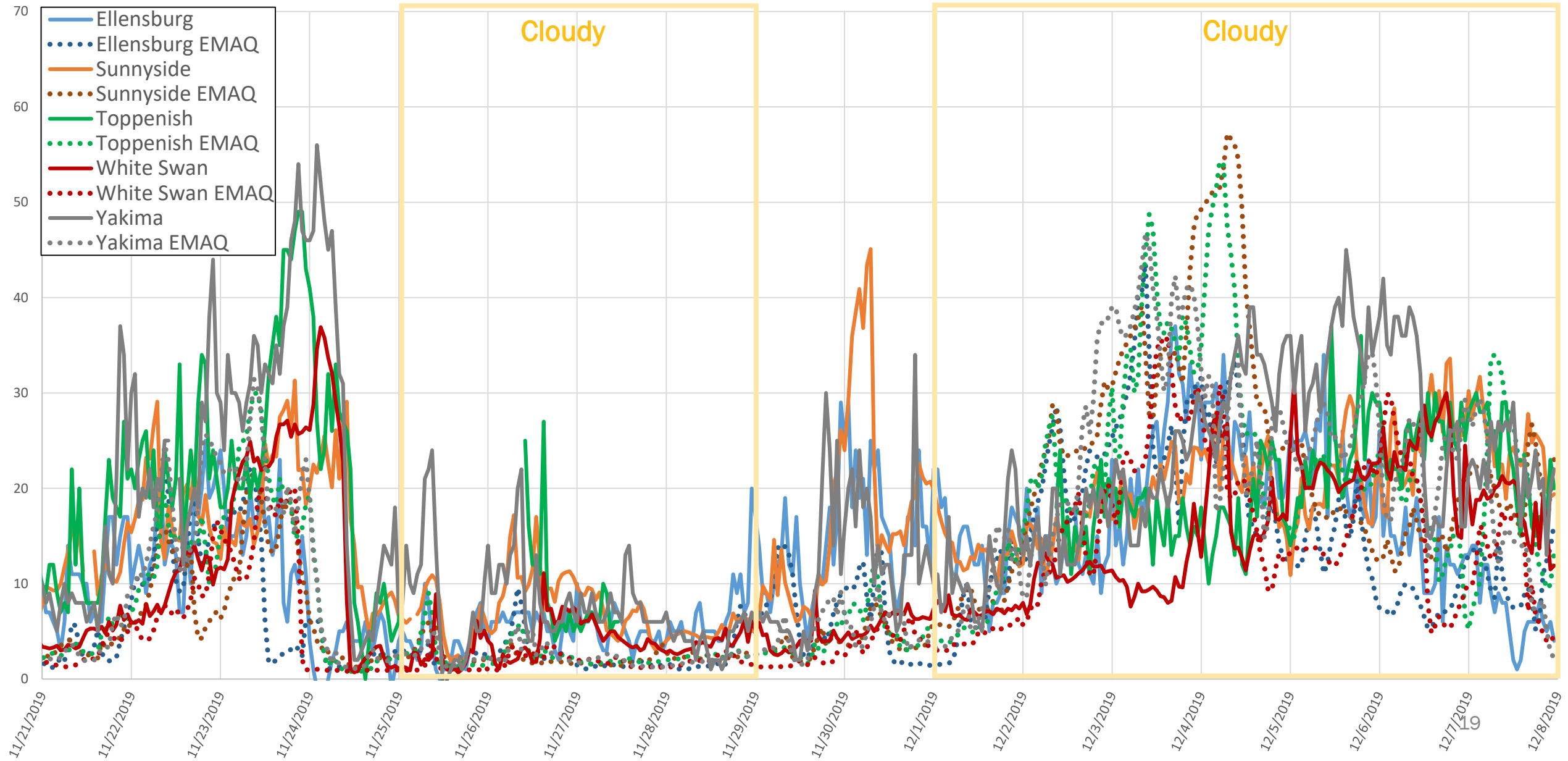
2019 EMAQ (Base) PM2.5 Performance (µg/m³)



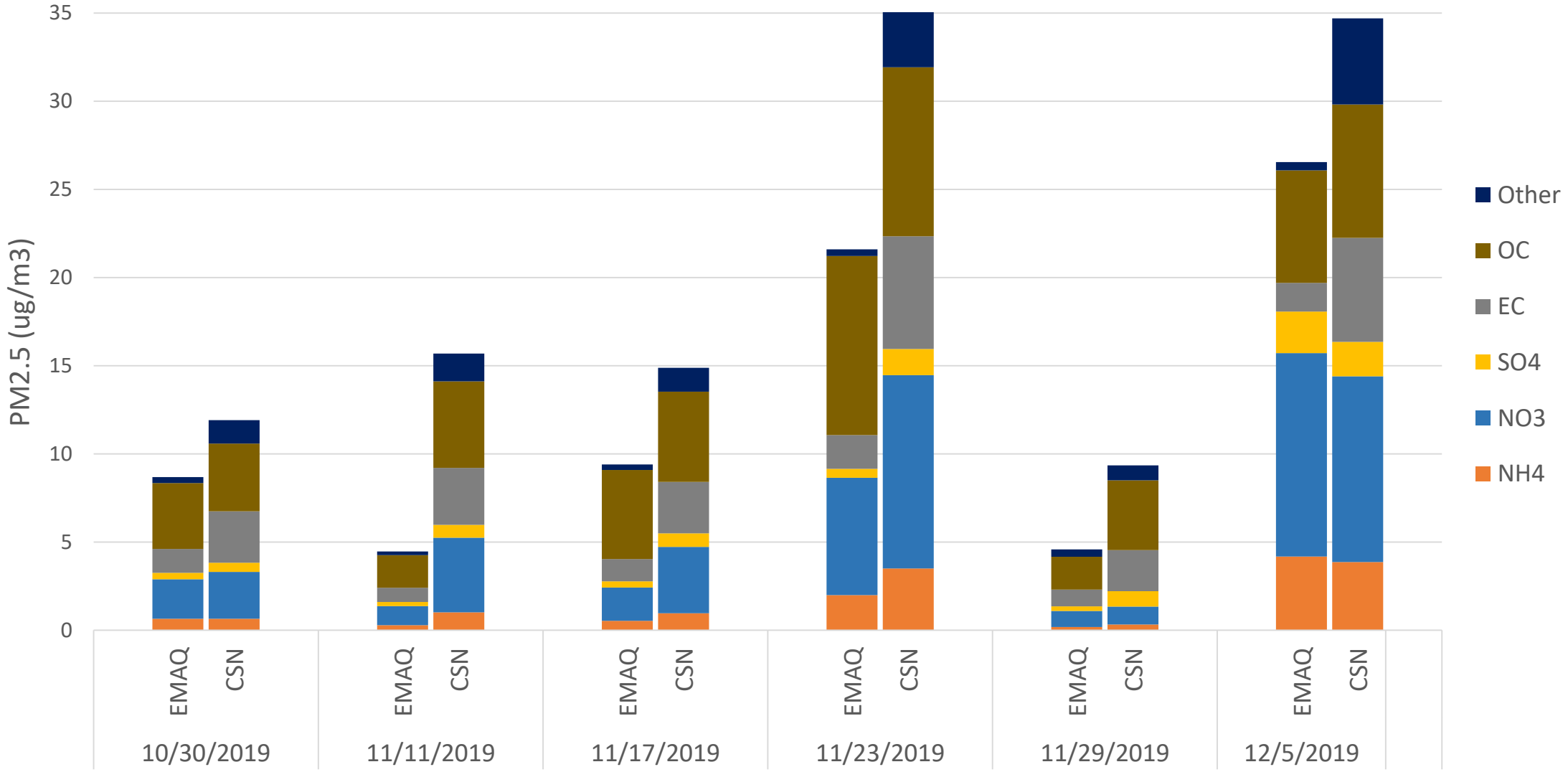
2019 EMAQ (Base) PM2.5 Obs/Model



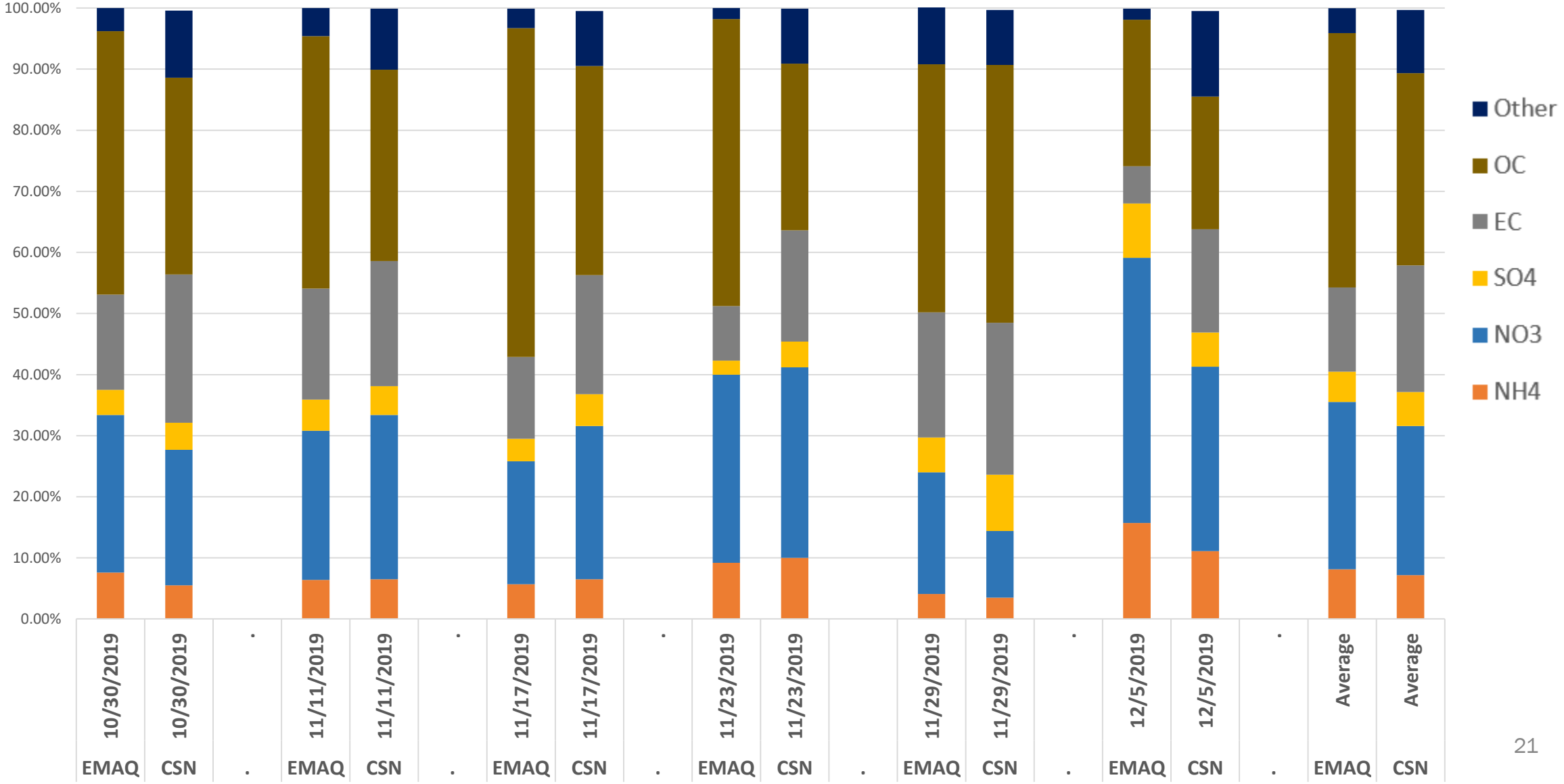
2019 EMAQ (Base) PM2.5 Performance (µg/m³)



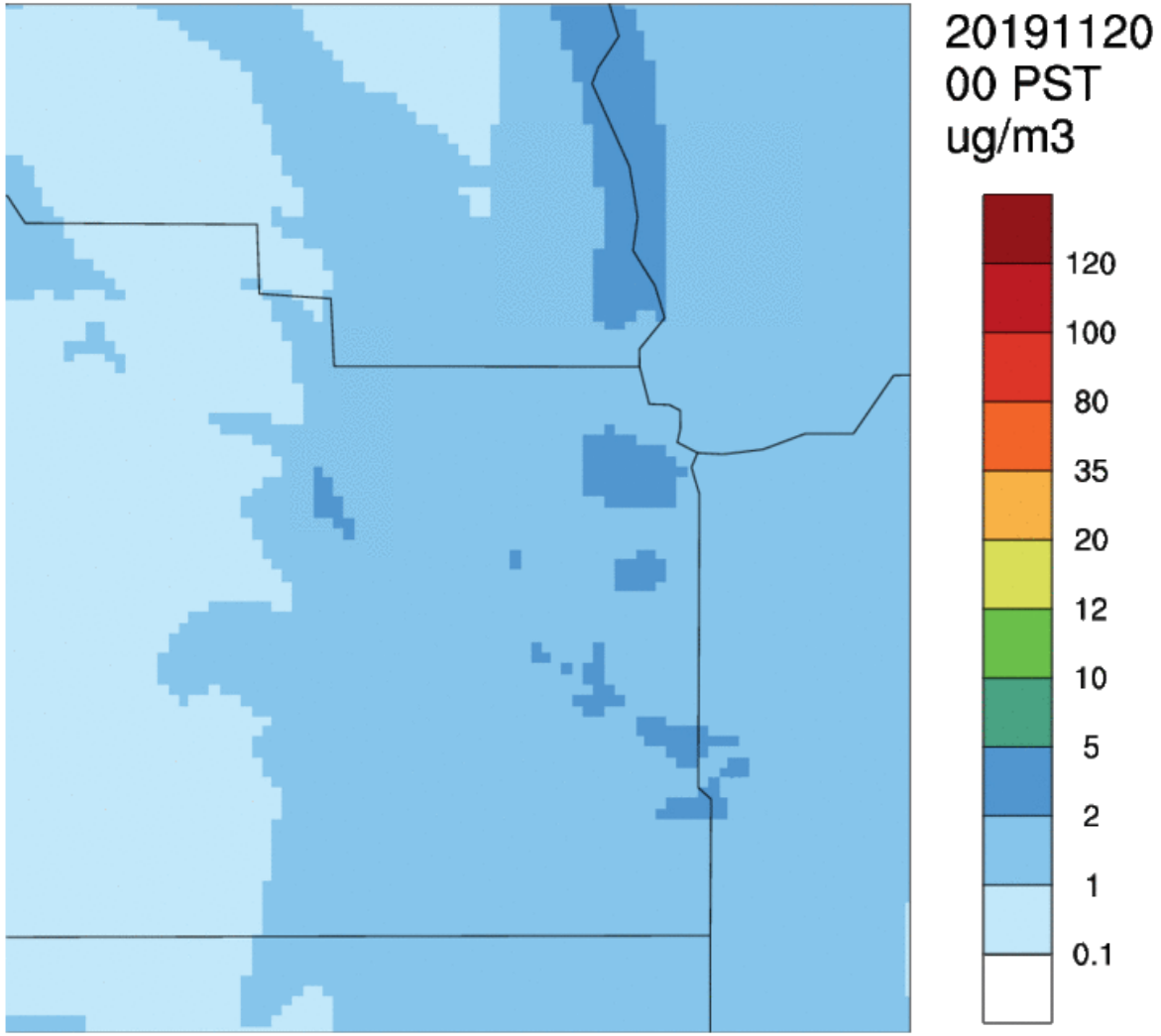
EMAQ PM2.5 Speciation Performance (Yakima)



EMAQ PM2.5 Speciation Performance (Yakima)



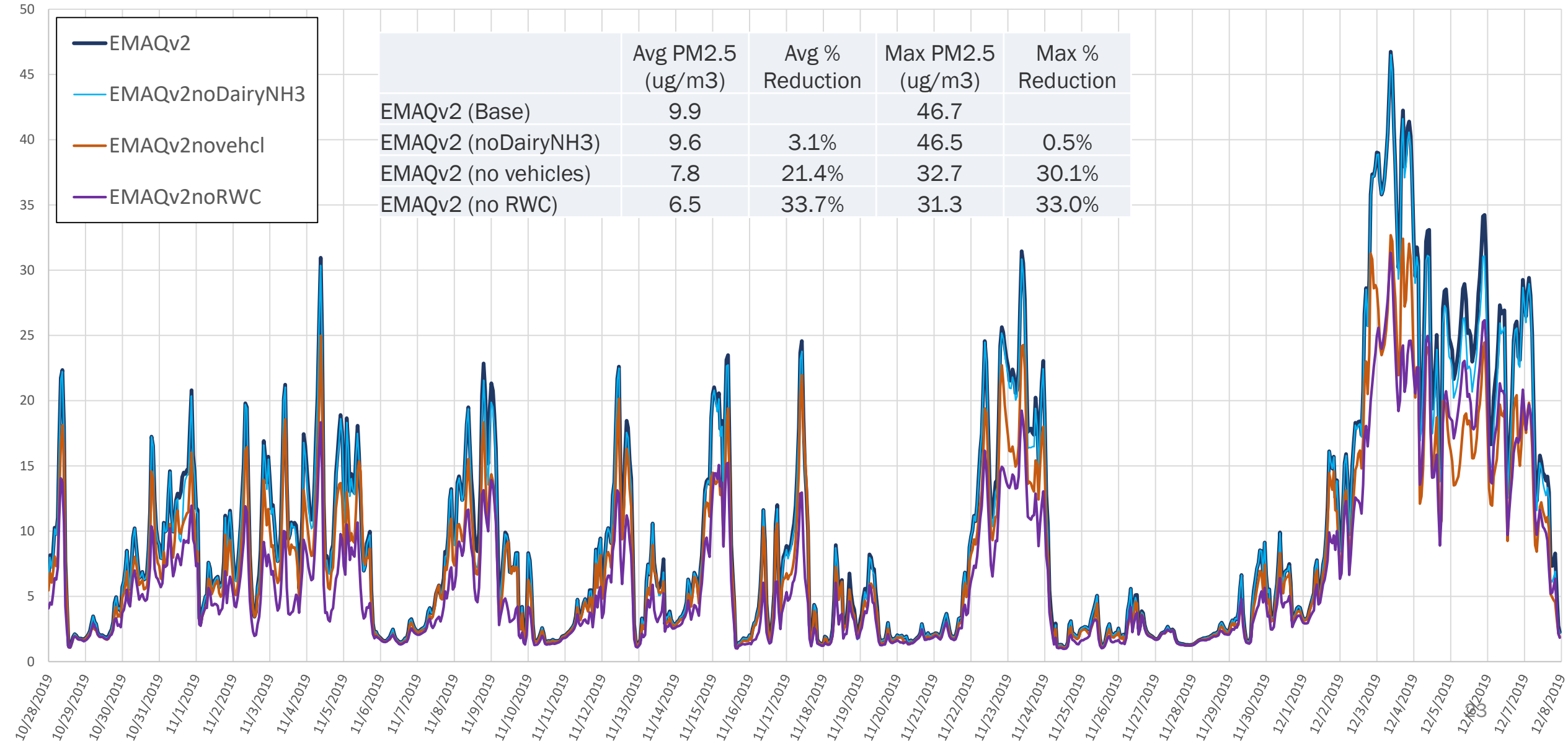
EMAQ PM2.5 Surface PM2.5
Base Case (Updated) Animation



Brute Force Emissions Reduction Scenarios

- EMAQ Base Case (not shown)
- EMAQv2 Base Case (Updated)
- EMAQv2 No Dairy NH3 Scenario
- EMAQv2 No Vehicles Scenario
- EMAQv2 No RWC Scenario

2019 EMAQ Scenarios PM2.5 Yakima (µg/m³)

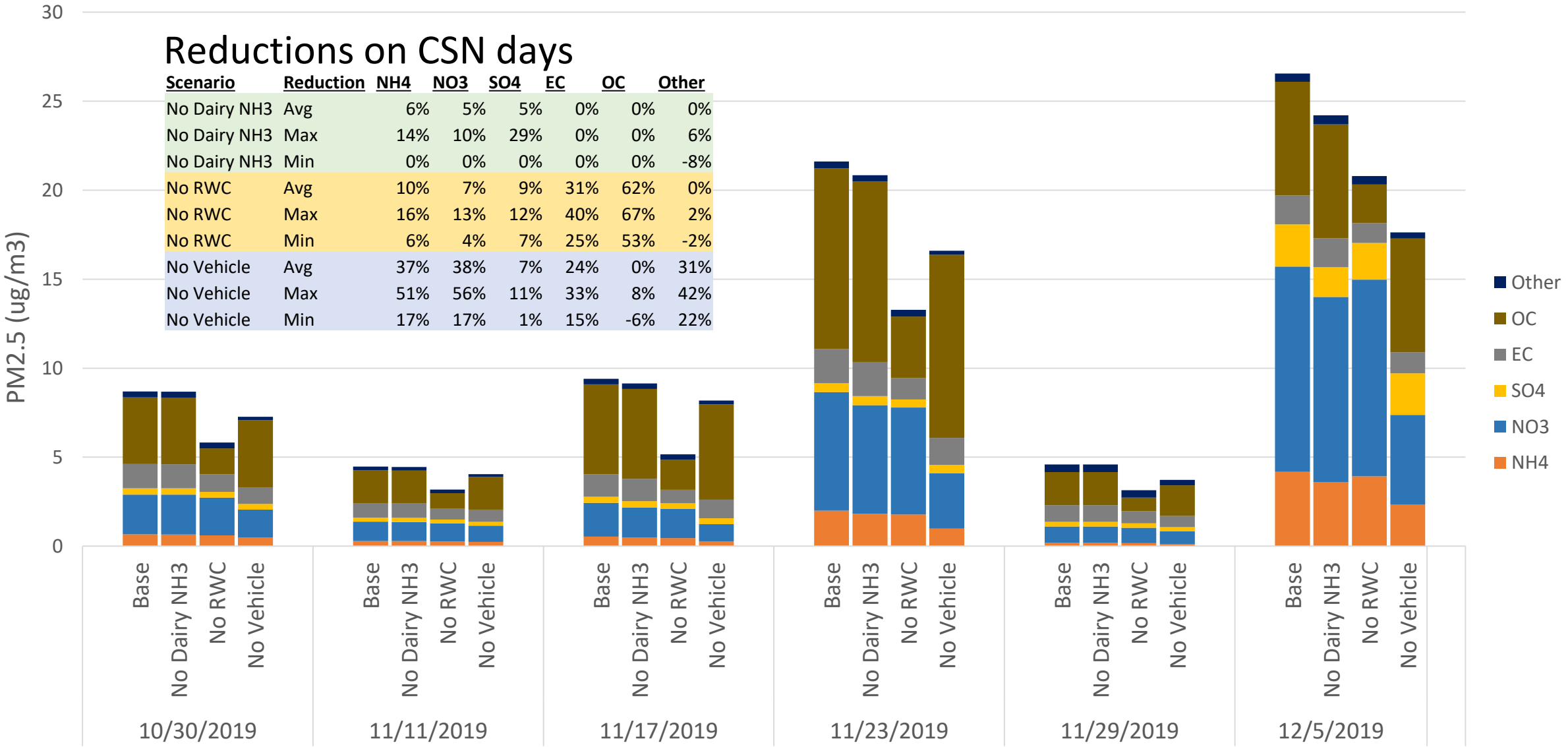


	Avg PM2.5 (ug/m3)	Avg % Reduction	Max PM2.5 (ug/m3)	Max % Reduction
EMAQv2 (Base)	9.9		46.7	
EMAQv2 (noDairyNH3)	9.6	3.1%	46.5	0.5%
EMAQv2 (no vehicles)	7.8	21.4%	32.7	30.1%
EMAQv2 (no RWC)	6.5	33.7%	31.3	33.0%

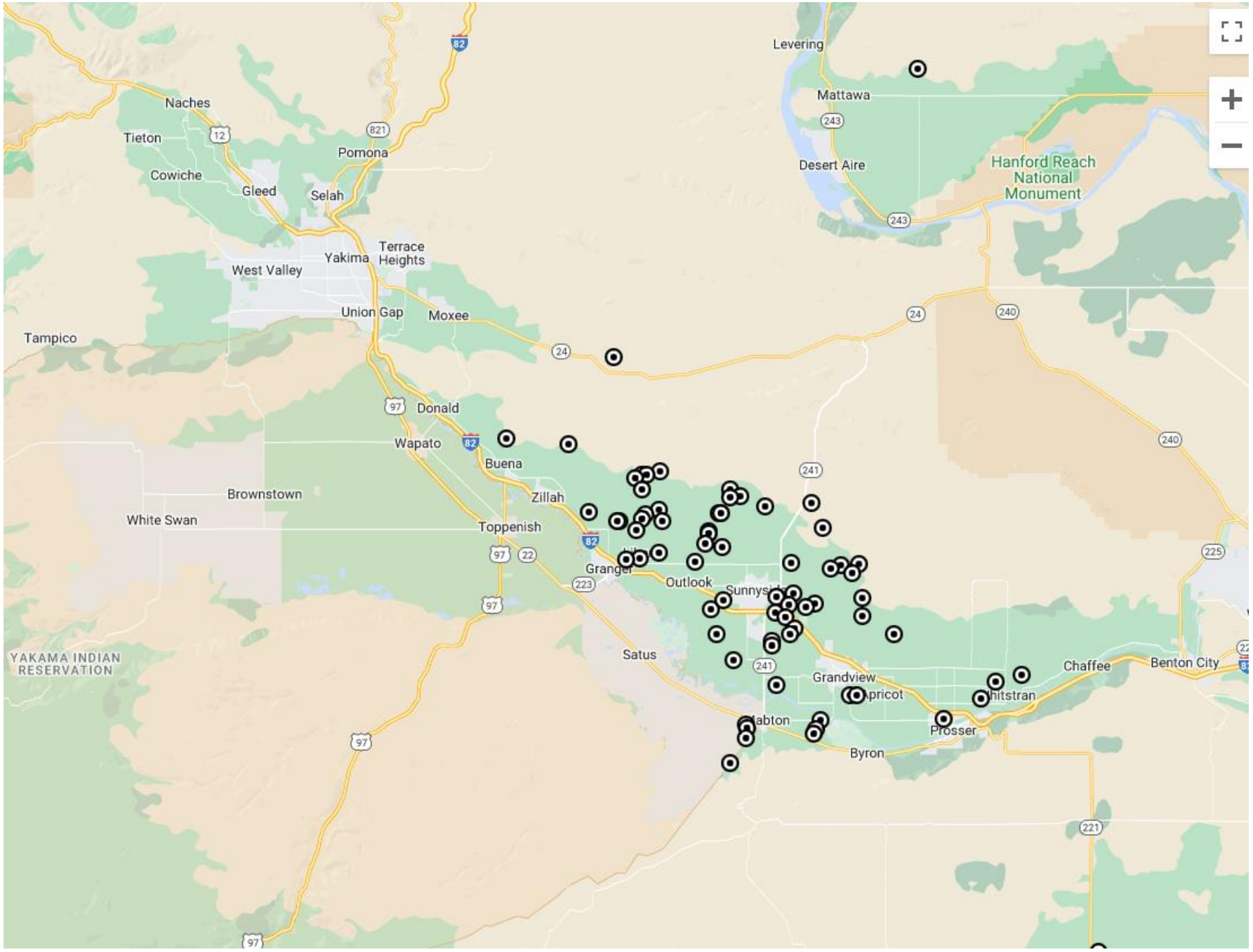
EMAQ PM2.5 Scenarios Speciation (Yakima)

Reductions on CSN days

Scenario	Reduction	NH4	NO3	SO4	EC	OC	Other
No Dairy NH3	Avg	6%	5%	5%	0%	0%	0%
No Dairy NH3	Max	14%	10%	29%	0%	0%	6%
No Dairy NH3	Min	0%	0%	0%	0%	0%	-8%
No RWC	Avg	10%	7%	9%	31%	62%	0%
No RWC	Max	16%	13%	12%	40%	67%	2%
No RWC	Min	6%	4%	7%	25%	53%	-2%
No Vehicle	Avg	37%	38%	7%	24%	0%	31%
No Vehicle	Max	51%	56%	11%	33%	8%	42%
No Vehicle	Min	17%	17%	1%	15%	-6%	22%



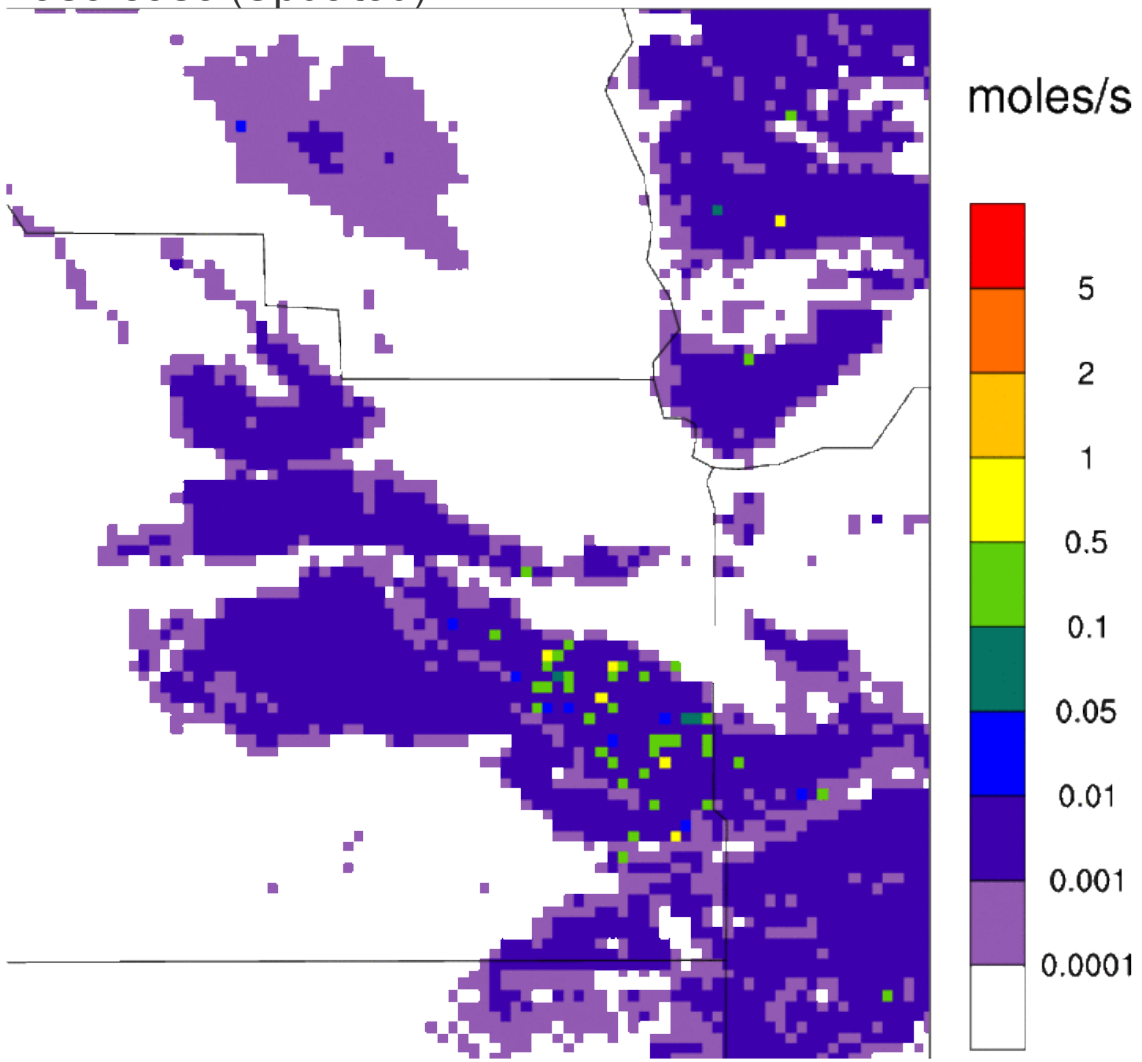
Ag Points (Dairies, etc.)



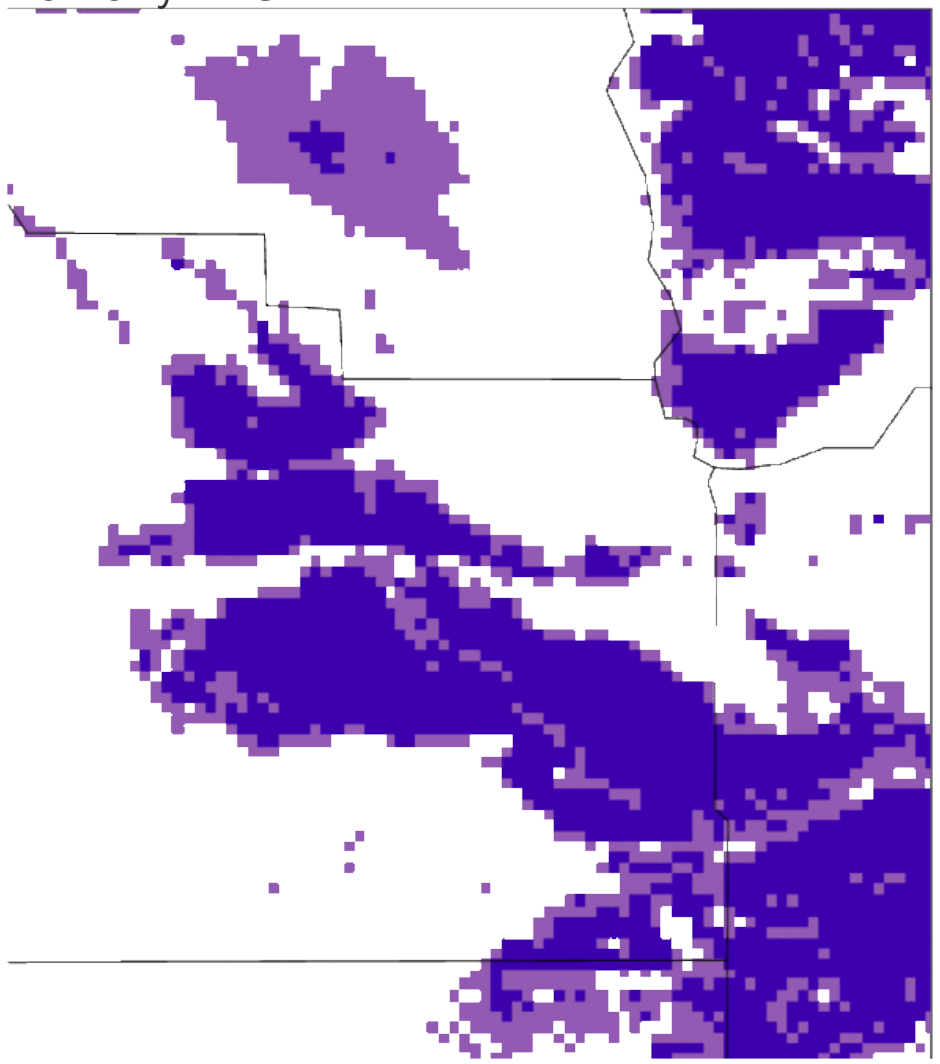
NH3 Emissions

Avg NH3 Emissions = 0.00202 vs 0.00053 moles/sec

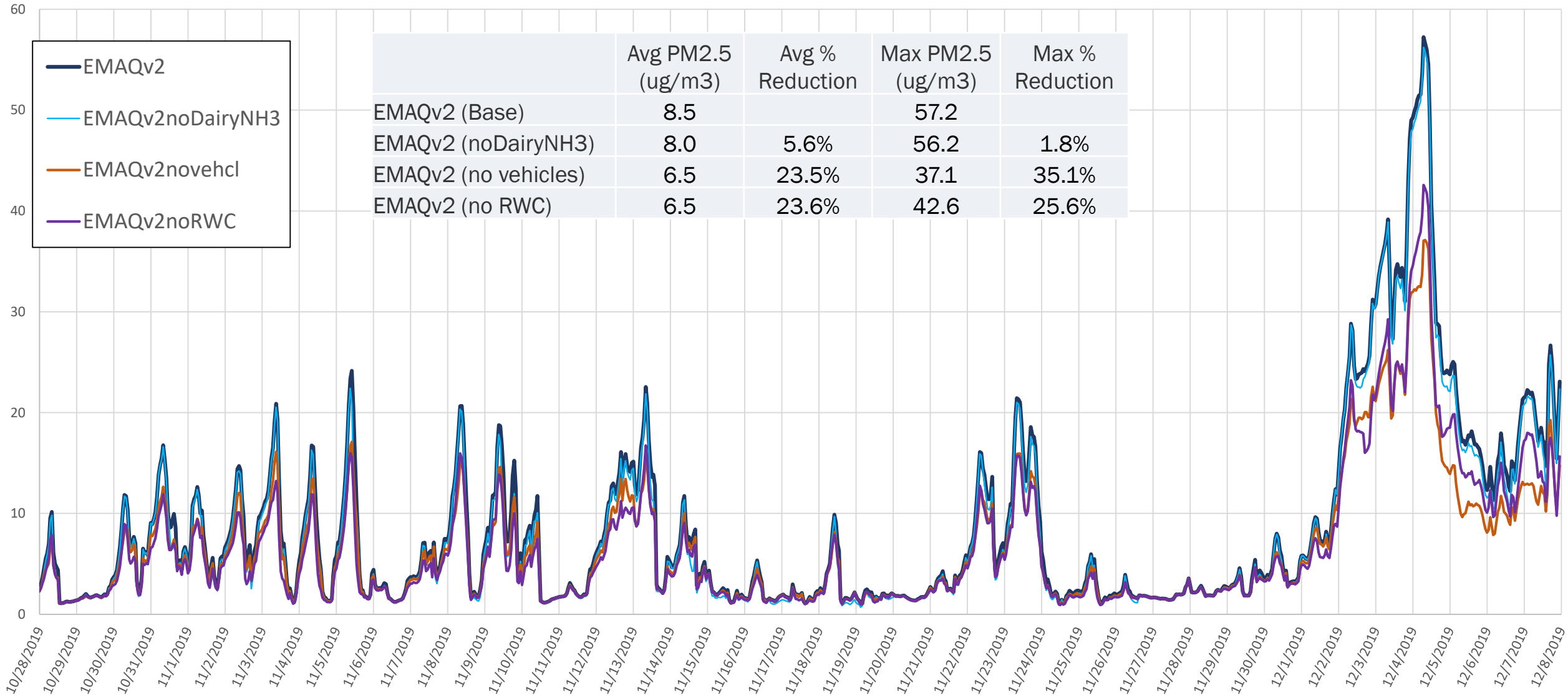
Base Case (Updated)



No Dairy NH3



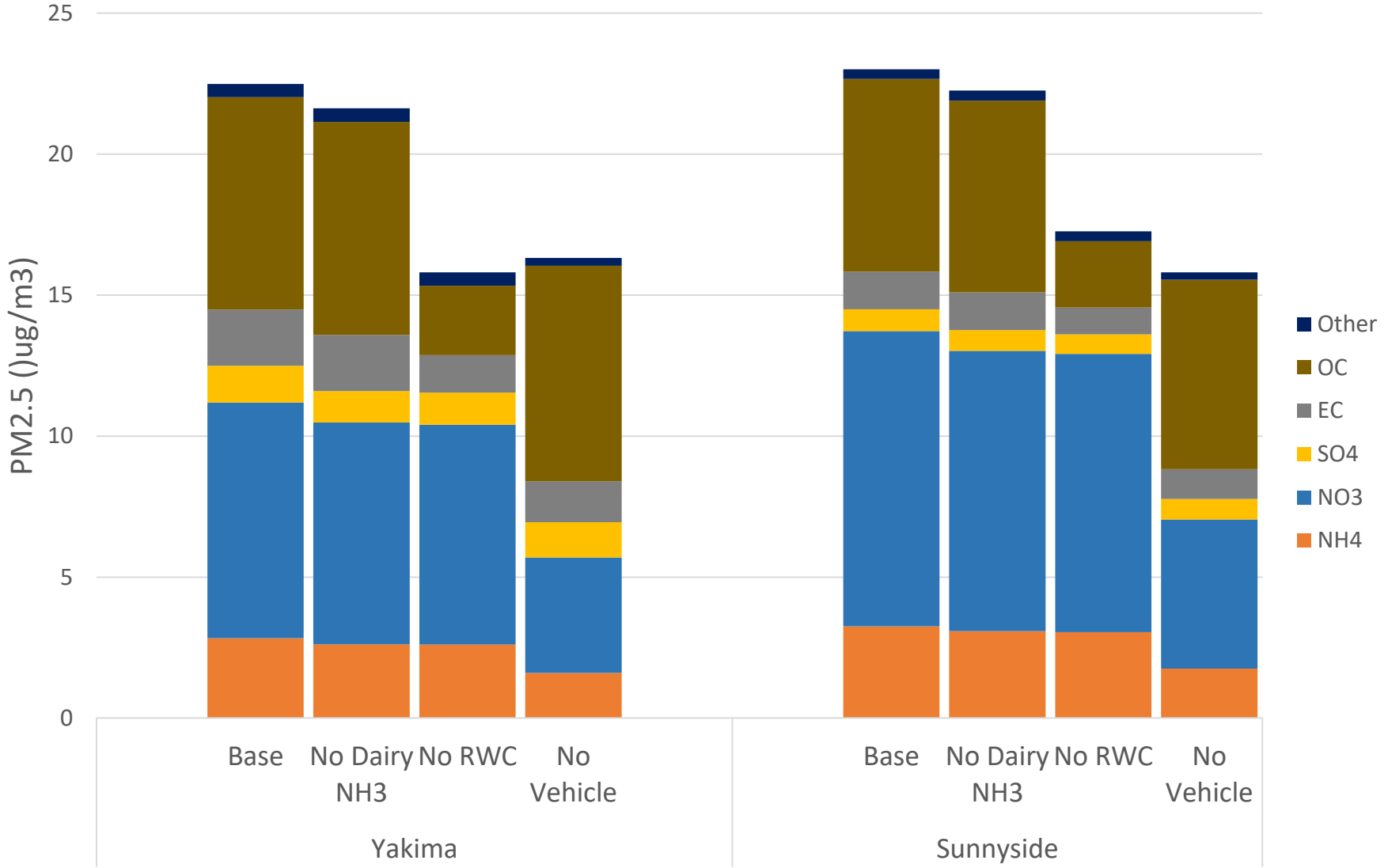
2019 EMAQ Scenarios PM2.5 Sunnyside (µg/m³)



	Avg PM2.5 (ug/m3)	Avg % Reduction	Max PM2.5 (ug/m3)	Max % Reduction
EMAQv2 (Base)	8.5		57.2	
EMAQv2 (noDairyNH3)	8.0	5.6%	56.2	1.8%
EMAQv2 (no vehicles)	6.5	23.5%	37.1	35.1%
EMAQv2 (no RWC)	6.5	23.6%	42.6	25.6%

Dec 1 – 7, 2019 EMAQ Speciation

Results suggest NOx-limited regime for secondary PM2.5 production



Next Steps

- Other model emissions reductions scenarios
  - Dust? Point Sources? Nonroad? Combination?
- Try observational nudging in WRF 1.33km
  - Compiler issues may require virtual machine
- Solicit feedback/ideas from leadership and locals

Image: Mt. Adams from Nob Hill; Yakima Herald-Republic

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Thank you

Questions?