A Satellite Constrained Meteorological Modeling Platform for LADCO States SIP Development

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Annual Project Review: 19 September 2022

Project Goals

• Primary goal is to support the modeling needs of the Lake Michigan Air Directors Consortium (LADCO) through development, verification, and delivery of a satellite-constrained modeling platform that can be used for air quality assessments of ozone in the Lake Michigan region

- Ozone non-attainment events occur periodically, especially along the Lake Michigan shoreline, so those states are required by the Clean Air Act to demonstrate strategies to mitigate these ozone exceedance events

- Meteorological modeling is very challenging due to the influence of lake/land breeze circulations on the transport and chemistry along the Lake Michigan shoreline

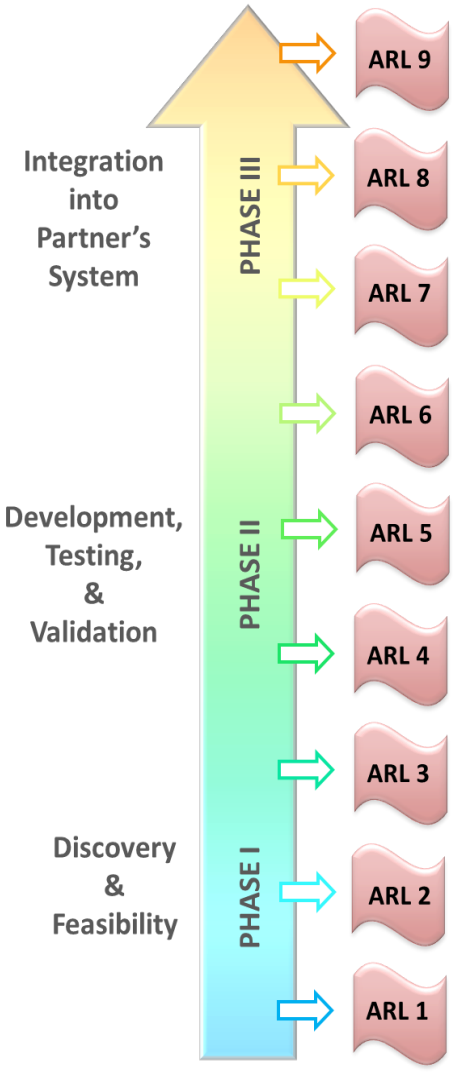
• End goal is to deliver a well-tested modeling platform to LADCO that leverages NASA satellite observations and land surface modeling and data assimilation capabilities

Milestones During the Entire Project

Project Steps by Project Year Quarter	*Year 1*				*Year 2*				*Year 3*			
	Q1	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*
Generate SPoRT LIS soil moisture analyses												
Conduct WRF physics/satellite data sensitivity tests												
Generate 2017 CLAVR-x satellite cloud climatologies												
Conduct WRF/SPoRT-LIS nudging experiments												
Develop and test WRF cloud optical thickness bias correction methodology												
Develop 2017 NEI emissions surrogates												
Conduct preliminary 2017 SIP assessment modeling												
Conduct final 2017 SIP assessment modeling												
Evaluate 2017 SIP model simulations												
Generate 2016 meteorological fields												
Generate 2016 CLAVR-x satellite cloud climatologies												
Develop 2016 NEI emissions surrogates												
Generate 2016 cloud optical thickness bias corrections												
Perform 2016 SIP assessment modeling												
Evaluate 2016 SIP model simulations												
ARL Level	**3**			**4**		**5**		**6**		**7**		**8**

- We have completed all of our project milestones, with the remaining task being to work on paper revisions.

Project Application Readiness Level



- Start-of-Project ARL = #3 *(01 October 2018)*
- Goal ARL = #8
- Current ARL = #8

At the start of this project, each of the components that we were planning to use to enhance the accuracy of the LADCO meteorological modeling platform had been tested and validated independently. This allowed us to place the initial readiness level at ARL-3.

The readiness level of this project was raised to ARL-8 earlier this year because we had accomplished all the project goals and because collaborators at LADCO had successfully used the modeling platform during their State Implementation Plan (SIP) modeling efforts.

The modeling platform developed during this project has proven useful for our collaborators.

WRF Model Sensitivity Simulations

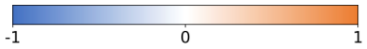
EXPERIMENT	SST	GVF	SOIL	Nudging
EPA	--	--	--	--
YNT	--	--	--	--
YNT-SST	✓	--	--	--
YNT-GVF	--	✓	--	--
YNT-SOIL	--	--	✓	--
YNT-N2KM	--	--	--	✓
YNT-SST-SOIL	✓	--	✓	--
YNT-GVF-SST	✓	✓	--	--
YNT-GVF-SOIL	--	✓	✓	--
YNT-GVF-SOIL-SST	✓	✓	✓	--
YNT-SSN	✓	--	✓	✓
YNT-SSNG	✓	✓	✓	✓

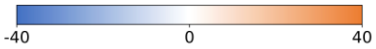
All simulations cover a seven-week period during 2017

- "EPA" simulations follow the EPA operational forecasting model configuration, including the Pleim-Xu land surface model (LSM), Morrison 2-moment cloud microphysics, and ACM2 PBL parameterization schemes
- "YNT" simulations use the YSU PBL, Noah LSM, and Thompson microphysics, respectively
- "SST" refers to the high-resolution, real-time GLSEA SST dataset
- "SOIL" refers to high-resolution soil moisture/temperature analyses provided by NASA SPoRT
- "GVF" refers to the high-resolution VIIRS green vegetation fraction dataset
- "N2KM" refers to nudging temperature, moisture, and horizontal winds above 2 km

WRF Model Verification

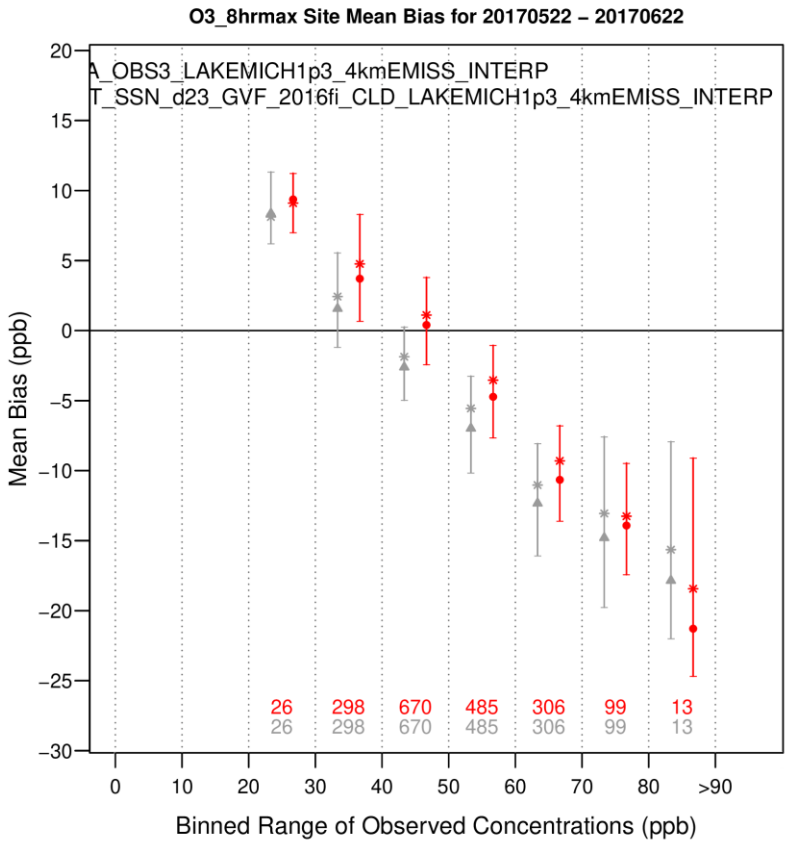
Bias				% RMSE Change vs. EPA		
a) 2-m Temperature [K]				**b)** 2-m Temperature [K]		
Simulation	12 km	4 km	1.3 km	12 km	4 km	1.3 km
EPA	-0.12	-0.40	0.16	2.03	2.23	3.00
YNT	0.16	0.47	0.55	13.08	0.45	-25.18
YNT_SST	0.17	0.48	0.56	12.44	-0.13	-25.58
YNT_SOIL	-0.39	-0.19	-0.22	11.95	-4.62	-30.41
YNT_N2KM	0.25	0.58	0.67	12.44	-0.18	-24.68
YNT_GVF	-0.28	-0.02	-0.03	12.54	-1.88	-27.91
YNT_SSNG	-0.56	-0.32	-0.38	10.62	-5.20	-29.71
YNT_SSN	-0.29	-0.07	-0.09	9.00	-7.44	-31.91
d) 2-m Mixing Ratio [g/kg]				**e)** 2-m Mixing Ratio [g/kg]		
Simulation	12 km	4 km	1.3 km	12 km	4 km	1.3 km
EPA	0.91	1.28	1.35	1.85	2.03	2.07
YNT	0.19	0.00	-0.20	-19.96	-28.69	-29.85
YNT_SST	0.20	0.00	-0.20	-20.66	-29.19	-30.48
YNT_SOIL	0.24	0.10	-0.02	-20.12	-29.14	-31.40
YNT_N2KM	0.22	0.05	-0.14	-19.69	-28.10	-28.88
YNT_GVF	0.30	0.17	0.02	-20.12	-28.69	-30.77
YNT_SSNG	0.36	0.28	0.24	-22.33	-29.83	-31.54
YNT_SSN	0.27	0.14	0.04	-21.20	-29.83	-32.03
g) 10-m Wind Speed [m/s]				**h)** 10-m Wind Speed [m/s]		
Simulation	12 km	4 km	1.3 km	12 km	4 km	1.3 km
EPA	0.05	-0.17	-0.14	1.52	1.51	1.63
YNT	0.45	0.34	0.36	6.26	2.19	-3.32
YNT_SST	0.46	0.34	0.36	6.52	2.52	-2.40
YNT_SOIL	0.38	0.24	0.23	5.07	1.26	-4.49
YNT_N2KM	0.42	0.32	0.34	4.61	0.60	-5.05
YNT_GVF	0.60	0.54	0.60	10.87	7.97	4.06
YNT_SSNG	0.53	0.47	0.49	8.04	5.25	-0.25
YNT_SSN	0.36	0.23	0.22	3.82	-0.20	-6.52

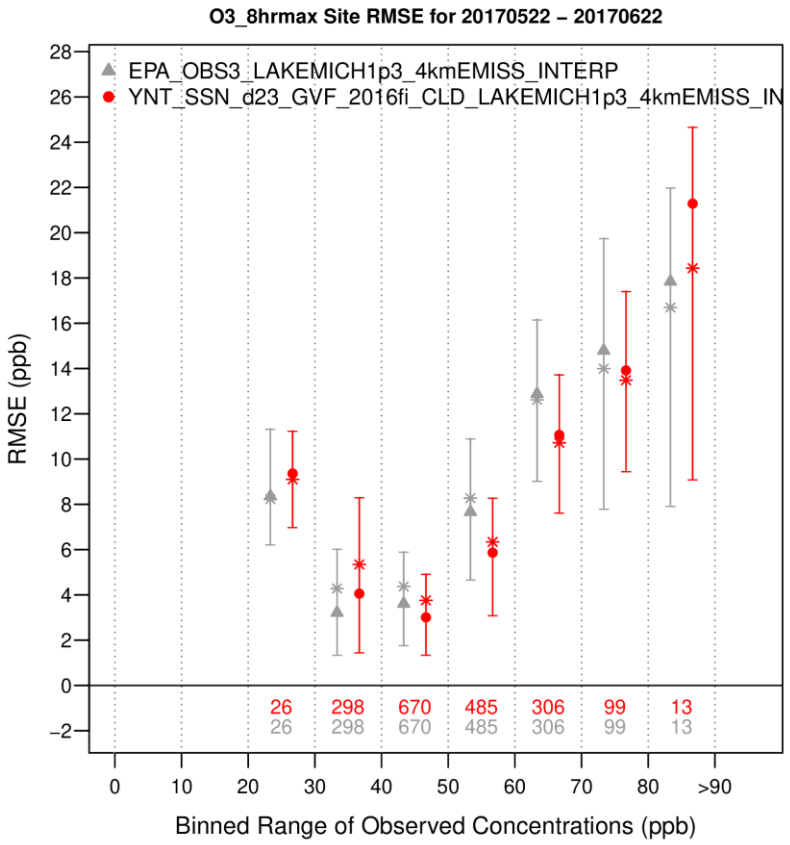




- Figure shows bias and RMSE percentage changes in 2-m temperature, 2-m mixing ratio, and 10-m wind speed for each configuration relative to the EPA baseline configuration on the 12, 4, and 1.3-km resolution domains
- Performance of YNT simulations mixed on the 12-km domain, but much better than the EPA model configuration on the 1.3-km domain
- Soil moisture and soil temperature analyses obtained from the NASA SPoRT LIS (YNT-SOIL) were the most important individual input surface dataset

CMAQ Model Verification





- "EPA" is baseline and "YNT" is the optimized configuration
- Binned box and whisker plots for 8-h ozone maximum concentration at AQS sites on the 1.3-km resolution domain from 22 May – 22 June 2017 (LMOS field campaign time period)
- Systematic high biases for lower ozone concentrations (< ~40 ppbv) and a low biases for higher ozone concentrations (> 50 ppbv) are evident in both simulations.
- YNT simulation has lower biases and RMSE between 40-80 ppbv.
- EPA Baseline shows lower biases and RMSE in the 80-90 ppbv bin.

Publications

- Otkin, J. A., L. Cronce, J. Case, R. Pierce, M. Harkey, A. Lenzen, D. Henderson, Z. Adelman, T. Nergui, G. Good, D. Bizot, and C. R. Hain, 2022: Evaluation of high-resolution model simulations in the Lake Michigan region. To be submitted to Atmospheric Chemistry and Physics.

- Pierce, R. B, M. Harkey, A. Lenzen, L. Cronce, J. A. Otkin, J. L. Case, D. S. Henderson, Z. Adelman, T. Nergui, and C. Hain, 2022: High-resolution CMAQ simulations of ozone exceedance events during the Lake Michigan Ozone Study. To be submitted to Atmospheric Chemistry and Physics.