Rapid Refreshing of Anthropogenic NO_x Emissions to Support NWS O_3 Forecasting

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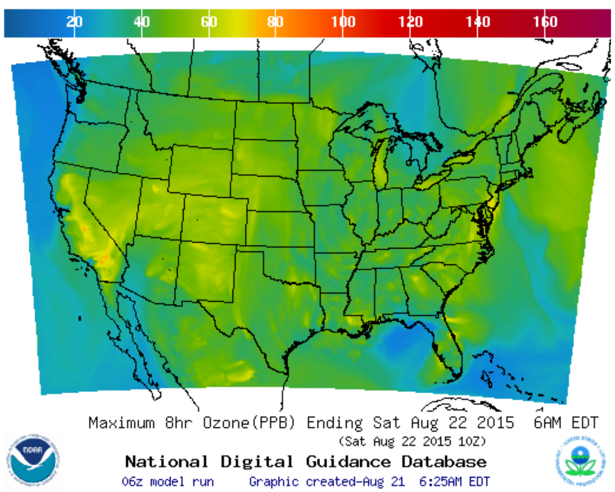
NOAA National Air Quality Forecast Capability (NAQFC)

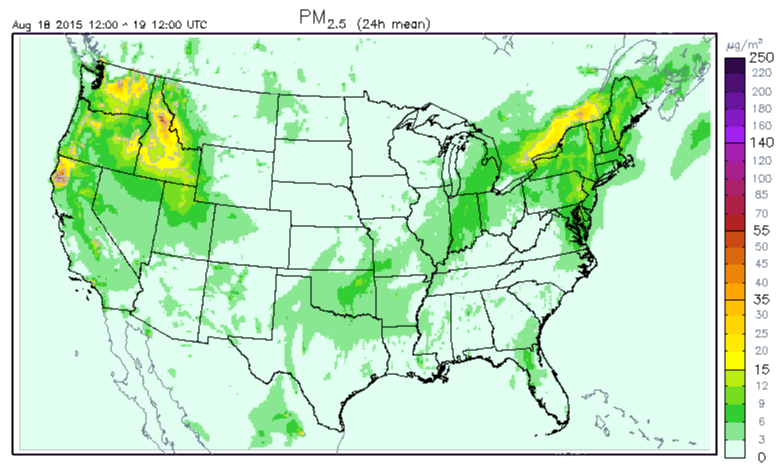
- Developed by OAR/Air Resources Laboratory; Operated by National Weather Service (NWS) (PM: I. Stajner).

- Provides national numeric air quality guidance for ozone (operational product) and $PM_{2.5}$ (particulate matter with diameter < 2.5 μm);

O_3 Forecasting



$PM_{2.5}$ Forecasting



http://airquality.weather.gov/

<u>**NAQFC is one of the major gateways to disseminate NOAA satellite observations and model prediction of air quality to the public.**</u>

Challenges in NAQFC Emission Forecasting

- **Time lag is a major obstacle for NAQFC emission forecasting.**

Forecasters want: ***emission of tomorrow;***

Data availability: ***emission data 4+ years old*****.**
(three years labor, one year QA, post-processing and release).

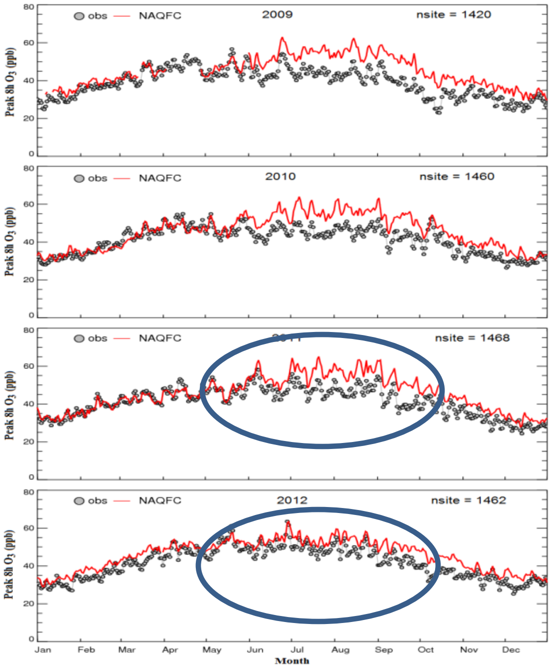
How to overcome this problem?

- **NAQFC Practices:**

Option 1, no update (2007-2011) - Dear price paid;

Option 2, use EPA emission projection (2012-2015).

Option 3, emission data assimilation (2016-?).



(Tong et al., Atmos. Environ. 2015)

Impact of the Great Recession on US Air Quality

- **Starting – Ending time: December 2007 – October 2009;**

- **Cause: Bursting of the housing bubble in 2007, followed by a subprime mortgage crisis in 2008;**

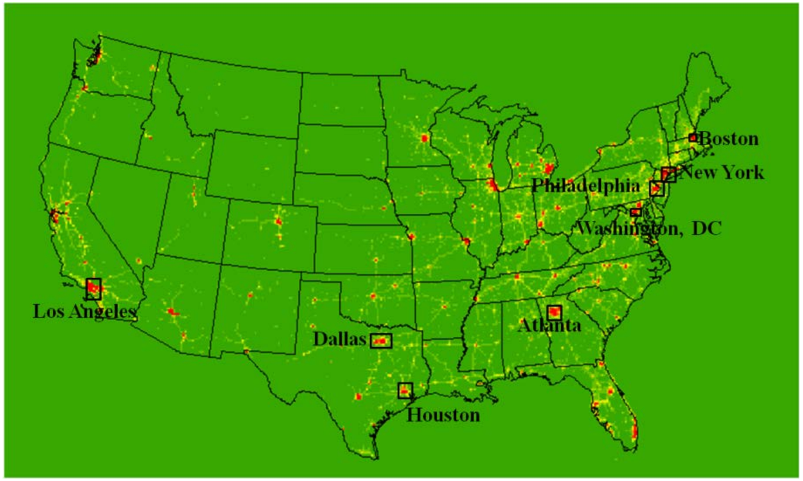
- **Impacts:**
  - **Unemployment rate: 4.7% in Nov 2007 → 10.1% in Oct 2009.**
  - **Income level: dropped to 1996 level after inflation adjustment;**
  - **Poverty rate: 12% → 16% (50 millions);**
  - **GDP: contract by 5.1%;**

- **Worst economic recession since the Great Depression**

Question: What does it mean to Air Quality (and Emissions)?

Methodology

- **Emission Indicator – Urban NOx in Summer**
  - Short lifetime → proximity to emission sources
  - Urban NO2 dominated by local sources;
  - High emission density → low noise/signal ratio;
- **NOx Data sources**
  - Satellite remote sensing (OMI-Aura NO2).
  - Ground monitoring (EPA AQS NOx);
  - Emission data (NOAA National Air Quality Forecast Capability operational emissions);
- **Deriving the trend:** $(Y2-Y1)/Y1 \times 100\%$
- **Selection of urban areas**

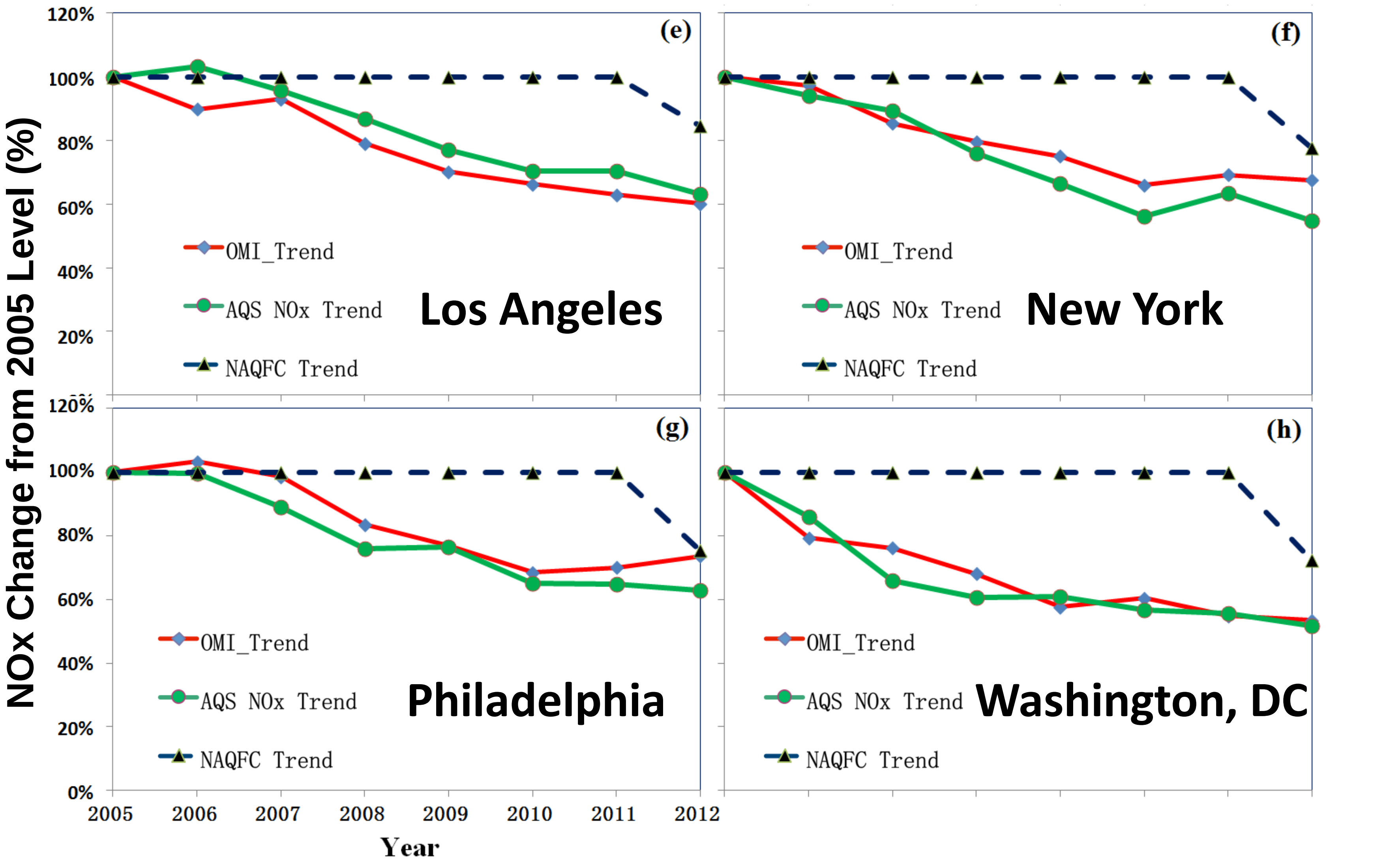


NOx Changes
Prior to, during and after the Recession

Stage	Sources	Atlanta	Boston	Dallas	Houston	Los Angeles	New York	Philadel-phia	Washing-ton, DC	Mean
Before	OMI SP	-11.7	-9.4	-7.5	-5.7	-3.3	-7.5	-0.6	-12.3	-7.3
	AQS	-9.9	-2.1	-5.2	0.7	-2.0	-5.5	-5.5	-18.7	-6.0
During	OMI SP	-5.5	-7.5	-8.9	-7.9	-13.1	-6.2	-11.7	-13.0	-9.2
	AQS	-17.5	-7.0	-13.0	-14.0	-10.3	-13.6	-7.0	-3.7	-10.8
After	OMI SP	-6.0	-3.3	-2.1	0.4	-5.0	-3.2	-1.2	-2.3	-2.8
	AQS	1.4	-6.1	0.1	0.2	-6.4	-5.4	-6.1	-5.3	-3.4

- Distinct regional difference;
- Average NOx changes are consistent for OMI and AQS data;
- -6%/yr - -7%/yr prior to Recession;
- -9%/yr - -11%/yr during Recession;
- -3%/yr after Recession (Recovery?).

Inter-Comparison of OMI, AQS and NAQFC



Feasibility Study: Emission Data Assimilation

(Project funded by OAR USWRP program, PM: J. Cortinas)

Can satellite data be used to rapidly refresh NOx emission?

Approach: Replace EPA projection factors by observation-based factors

Use both satellite and ground observations;

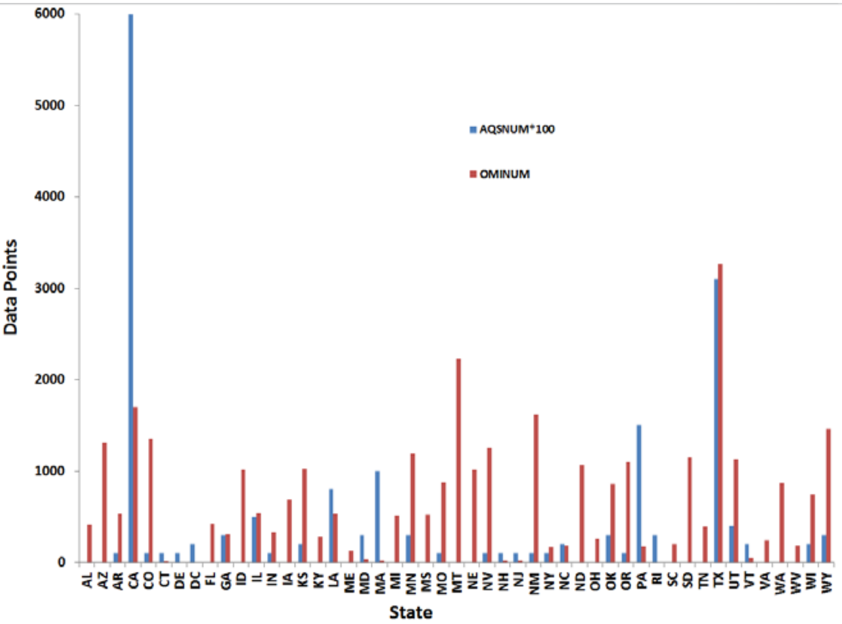
Optimal data fusion algorithm.

$$AF = \frac{\Delta S \times f_S + \Delta G \times f_G}{N_S \times f_S + N_G \times f_G}$$

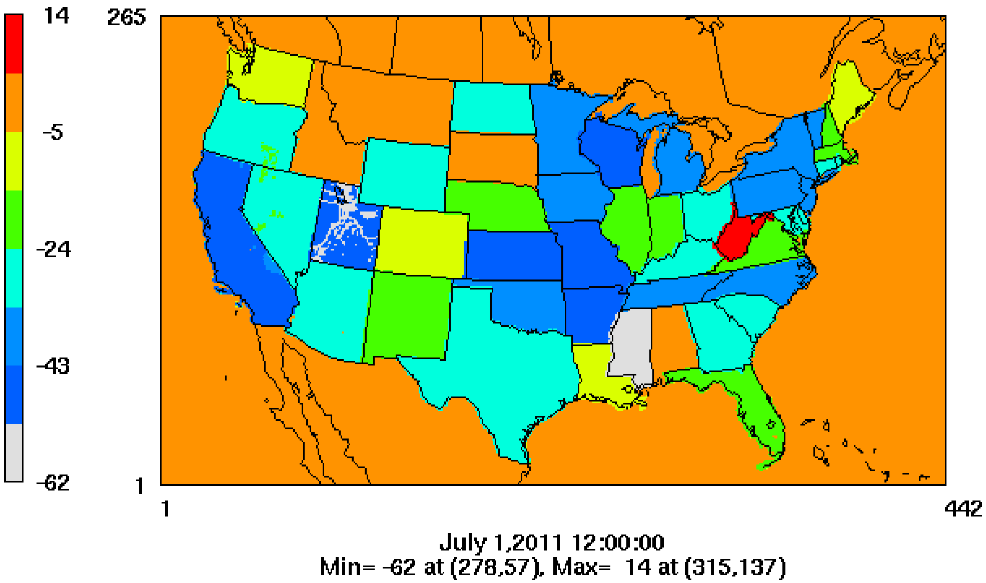
ΔS and N_S - changing rate and data number of satellite data;
ΔG and N_G -- rate and number of ground data;
f_S and f_G -- weighting factors for satellite and ground data;

Why both satellite and ground observations?

Comparison of OMI and AQS (x100) Samples



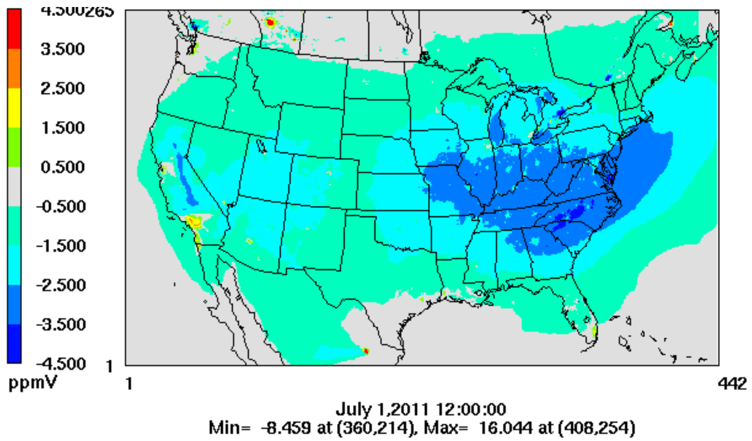
State-level Projection Factors from OMI and AQS



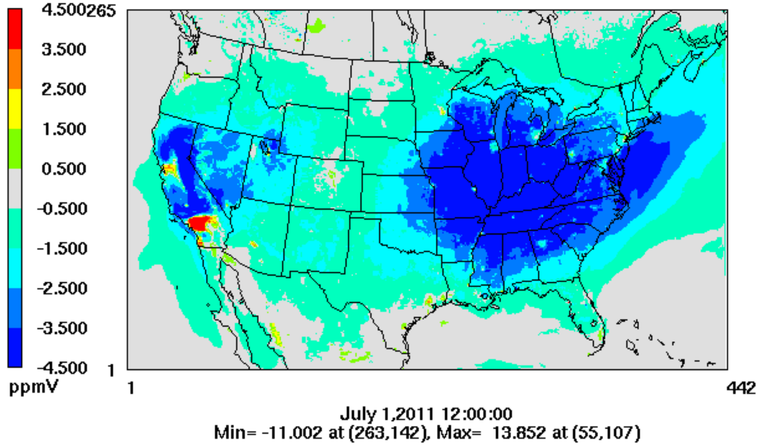
OMI Preprocessing: 1) Quality filter; 2) Set a cut-off value; 3) Calculate lower and higher 25% percentiles

Performance Evaluation of NAQFC O_3 Forecasting

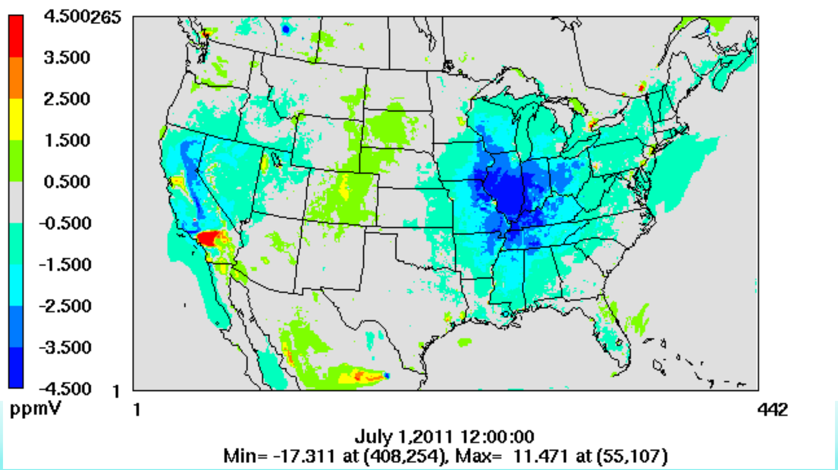
Effect of Using EPA Projection



Effect of Using New Factors



Difference



Model Performance Evaluation

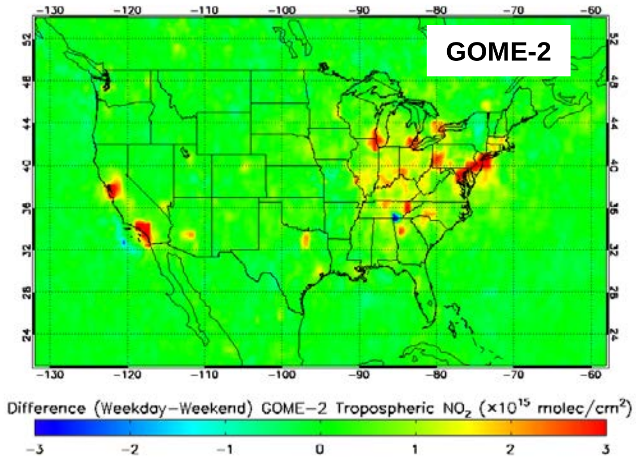
Performance Metrics

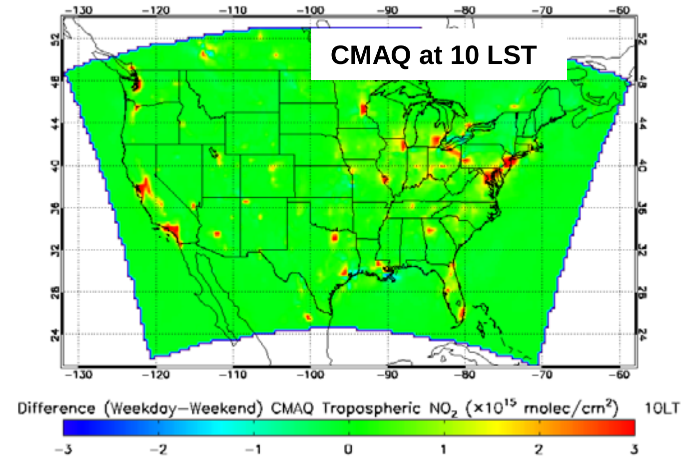
			MOD_MEAN			RMSE			NME			MB			NMB			R		
TYPE	COUNT	OBS_MEA	BASE	NEI2012	JPSS	BASE	NEI2012	JPSS	BASE	NEI2012	JPSS	BASE	NEI2012	JPSS	BASE	NEI2012	JPSS	BASE	NEI2012	JPSS
Hourly		AQS	NEI2005	PROJ2012	NOx_EDA	NEI2005	PROJ2012	NOx_EDA	NEI2005	PROJ2012	NOx_EDA	NEI2005	PROJ2012	NOx_EDA	NEI2005	PROJ2012	NOx_EDA	NEI2005	PROJ2012	NOx_EDA
CONUS	15930	40.09	52.37	52	51.58	23.25	23.07	22.68	43.11	42.83	41.94	12.28	11.91	11.49	30.63	29.71	28.67	0.57	0.56	0.58
NE	2055	39.83	40.41	39.94	39.57	14.38	14.39	14.27	26.71	26.82	26.42	0.59	0.11	-0.25	1.47	0.28	-0.63	0.61	0.61	0.62
SE	2805	45.7	58.11	57.38	56.97	24.01	23.8	23.17	40.39	40.42	39.12	12.41	11.68	11.28	27.16	25.56	24.67	0.51	0.5	0.53
UM	3615	46.74	57.94	57.54	56.02	23.11	22.82	22.09	35.38	34.86	33.75	11.2	10.8	9.27	23.96	23.09	19.84	0.48	0.48	0.49
LM	2190	32.35	53.15	52.99	52.16	27.32	27.17	26.4	68.74	68.32	66.09	20.8	20.64	19.81	64.31	63.8	61.23	0.57	0.56	0.58
RM	1560	43.38	55.25	55.09	55.34	22.83	22.61	22.73	37.63	37.28	37.54	11.87	11.71	11.96	27.36	27	27.57	0.56	0.57	0.57
PC	2160	39.06	54.24	54.57	55.61	26.63	26.63	26.85	49.62	49.78	49.83	15.18	15.52	16.55	38.87	39.72	42.37	0.65	0.66	0.68

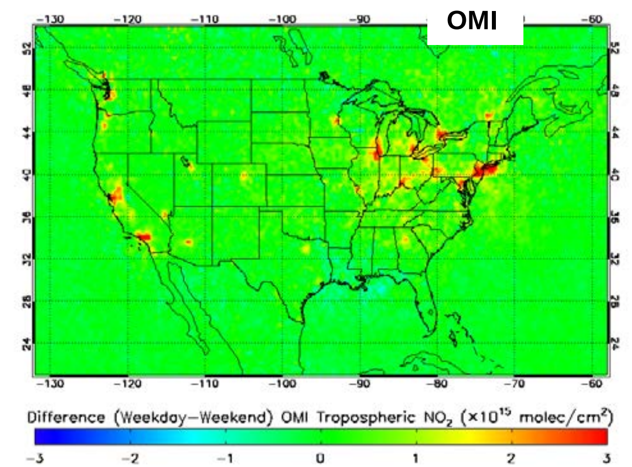
			MOD_MEAN			RMSE			NME			MB			NMB			R		
Max 8hr		AQS	NEI2005	PROJ2012	NOx_EDA	NEI2005	PROJ2012	NOx_EDA	NEI2005	PROJ2012	NOx_EDA	NEI2005	PROJ2012	NOx_EDA	NEI2005	PROJ2012	NOx_EDA	NEI2005	PROJ2012	NOx_EDA
CONUS	1062	48.57	59.32	58.44	58.32	21.85	21.52	21.44	31.73	31.19	31.11	10.75	9.87	9.74	22.13	20.32	20.06	0.52	0.51	0.52
NE	137	47.36	46.35	45.22	45.16	11.29	11.61	11.57	18.78	18.91	18.83	-1.02	-2.15	-2.21	-2.15	-4.53	-4.66	0.77	0.77	0.75
SE	187	56.42	63.83	62.52	62.77	19.62	19.19	18.91	25.75	25.51	25.07	7.4	6.1	6.34	13.12	10.8	11.24	0.51	0.49	0.53
UM	241	55.32	64.33	63.25	61.94	20.83	20.49	20.15	25.04	24.71	24.57	9.01	7.93	6.61	16.28	14.33	11.96	0.48	0.47	0.46
LM	146	39.47	62.72	62.09	61.45	29.32	28.95	28.23	60.42	59.25	57.61	23.25	22.61	21.97	58.89	57.28	55.66	0.43	0.4	0.43
RM	104	51.88	61.85	60.98	61.65	21.11	20.61	20.98	26.16	25.35	25.93	9.97	9.1	9.77	19.21	17.53	18.83	0.44	0.45	0.45
PC	144	49.61	63.96	63.9	65.3	25.75	25.62	26.42	34.75	34.34	35.44	14.36	14.3	15.69	28.94	28.82	31.63	0.52	0.53	0.54

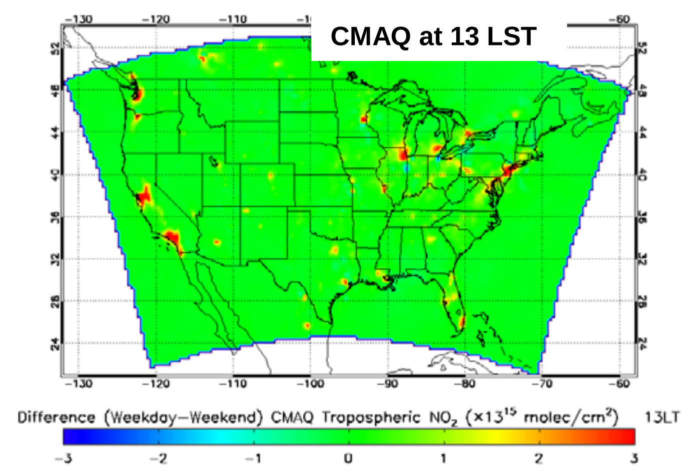
Prediction with the new assimilated emission data outperforms the current operational system.

Observed and Modeled Weekday/Weekend Difference in Tropospheric NO_2









(Courtesy: S. Kondragunta)

Summary & Future Plan

- Satellite observations can be used to detect emission changes consistent with ground observations;
- Demonstrate the feasibility of assimilating satellite and ground observations to rapidly update anthropogenic emissions;
- The assimilated emission data can improve NAQFC forecasting capability, outperforming the current operational system.
- Future plans include testing with GOME-2 and OMPS NO2 products beyond monthly means (e.g., daily change, over land and ocean).