Assessing the capability of TEMPO to retrieve pollution gradients in complex environments

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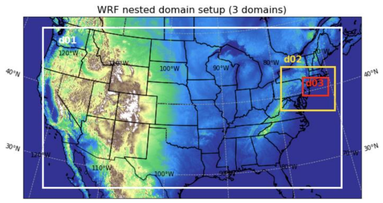
Introduction

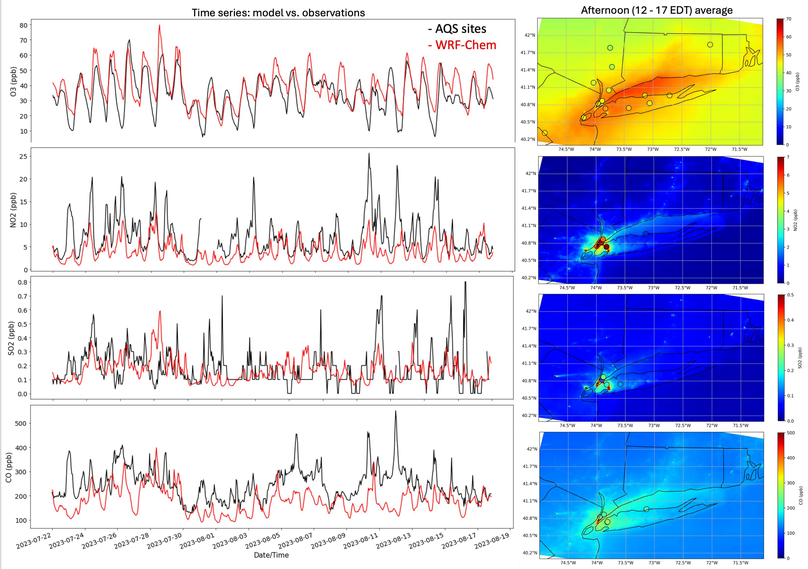
NASA's Tropospheric Emissions: Monitoring of Pollution (TEMPO) geostationary sensor is expected to greatly improve observations and our understanding of spatiotemporal pollution variability in North America and the processes driving them. We perform a high spatial resolution WRF-Chem model simulation at 1.33 km × 1.33 km resolution during the AGES+ 2023 summer campaign to improve our understanding of regional air quality and examine pollutant transport in coastal regions and along the urban/rural interface. We assess model capability in reproducing observed spatiotemporal structure and variability of NO_2 and O_3 concentrations using ground-based airborne in situ and remote-sensing observations as well as TEMPO version 3 tropospheric NO_2 column retrievals. This work represents a preliminary effort to combine ground-based and airborne in-situ and remote-sensing measurements, high spatial resolution CTM simulations, and TEMPO retrievals to gain a better understanding of processes driving large pollution gradients in coastal environments and along the urban/rural interface.

WRF-Chem evaluation



Microphysics	Thompson scheme
Cumulus	Modifed Tiedtke scheme
Long/shortwave radiation	RRTMG
Boundary-layer	YSU scheme
Surface-layer	Revised MM5 Monin-Obukhov scheme
Land-surface	Noah land surface model
Chemistry/aerosol scheme	T1_MOZART chemistry & GOCART aerosols
Biogenic/fire emissions / dry deposition	MEGAN / FINN 2.5 2023 / Wesely scheme
IC/BC	WACCM
Meteorology	HRRR @ 3 km

We conducted a WRF-Chem nested simulation for summer 2023 at 12, 4, & 1.33 km horizontal resolution. Using HRRR (3 km) IC meteorological fields and NEMO EPA NEI 2019 (1 km) anthropogenic emissions for d02 & d03.



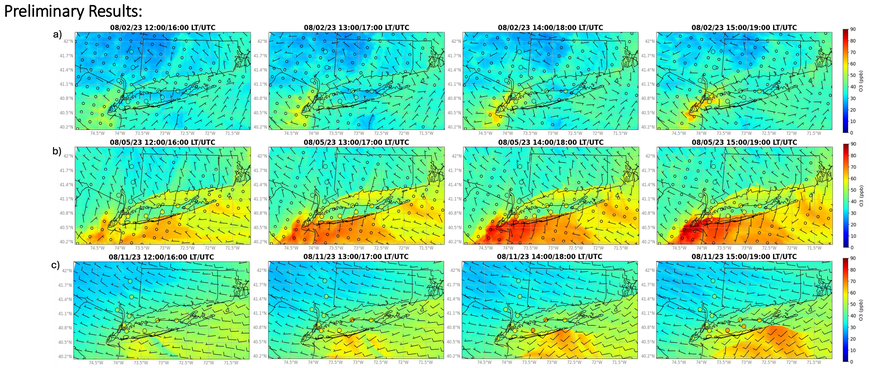
Afternoon (12 – 17 EDT) model vs. observations (ppb)

	R	MB	NMB (%)	RMSE	MAE
O_3	0.6	4.5	9.9	9.6	7.7
NO_2	0.5	-2.5	-52.8	3.2	2.8
SO_2	0.3	-0.1	-33.9	0.1	0.1
CO	0.5	-39.7	-17.2	63.2	51.0

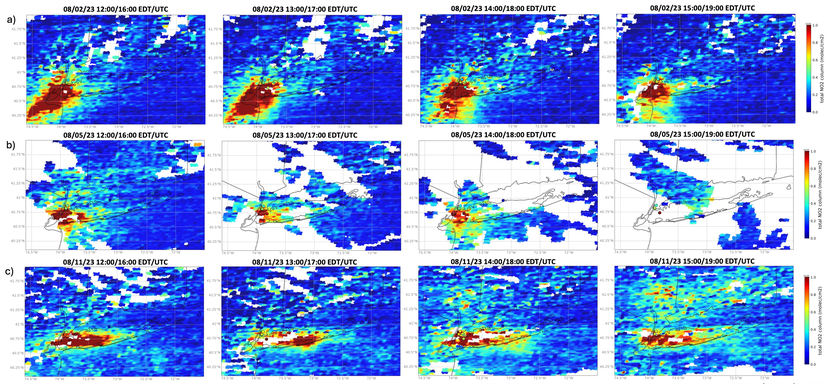
(Top left) Time series of the full simulation period comparison of model simulated vs. AQS observed species (O_3, NO_2, SO_2, CO). (Top right) Spatial distribution of afternoon (12 – 17 EDT) species. (Table) statistics for afternoon hour averages.

O_3 gradients along the coast

Preliminary Results:



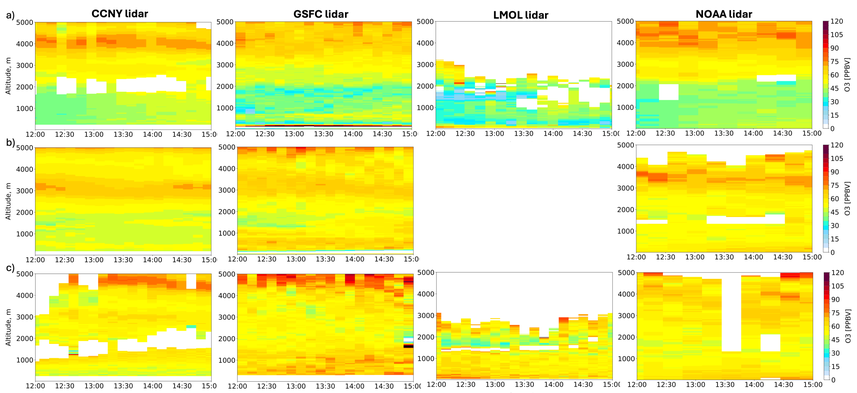
(Top) Simulated progression of three surface O_3 enhancements over the coast. a) 08/02/2023 depicts low winds, b) 08/05/2023 onshore flow, sharp O_3 gradients, and c) 08/11/2023 offshore flow.



(Top) TEMPO NO_2 tropospheric column progression for the 3 O_3 enhancement cases: a) 08/02/2023, b) 08/05/2023, c) 08/11/2023. AQS surface NO_2 observations (ppb) overlayed for a qualitative comparison.

Tropospheric O_3 Lidar Network (TOLNet) O_3 lidars deployed:

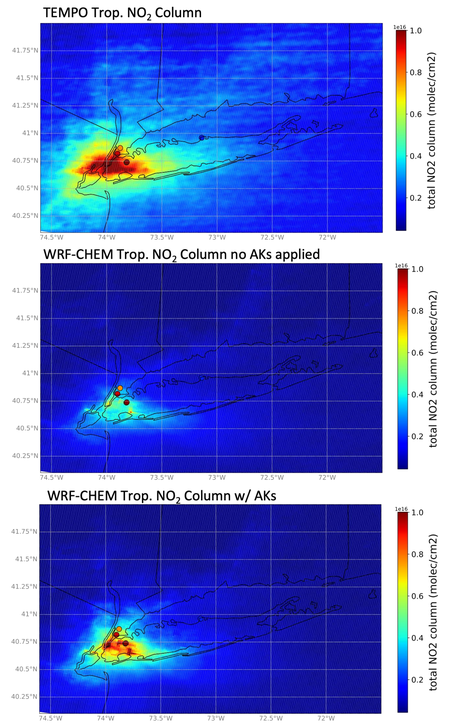
- CCNY lidar – New York, NY
- GSFC lidar – Old Field, NY
- LMOL lidar – Sherwood Island, CT
- NOAA lidar – Guilford, CT



(Top) Lidar curtains for the 3 O_3 enhancement cases: a) 08/02/2023, b) 08/05/2023, c) 08/11/2023. Columns (left to right) CCNY, GSFC, LMOL, and NOAA lidar systems.

Tropospheric NO_2 columns

Preliminary Results:



(Left) Direct comparison of the TEMPO tropospheric column and the simulated WRF-Chem tropospheric column average during the STAQS measurement period (August 1 – 18, 2023).

We oversampled (Sun et al., 2018) the TEMPO L2 V3 NO_2 column to customized 1.33 km L3 grid.

Calculated tropospheric averaging kernel to apply to model column:

$$W / AMF = AK$$

W represents the scattering weight, AMF is the air mass factor (Eskes & Boersma, 2003).

AQS surface NO_2 observations (ppb) overlayed for a qualitative comparison.

Conclusion

- **Preliminary results:** On average, TEMPO NO_2 tropospheric columns are captured along the Long Island Sound but individual cases must be closely evaluated.
- Th is study aim s to grasp how well TEMPO-measured pollution quantities can be used synergistically to refine our understanding of O_3 formation and chemistry in complex environments.
- A more in-depth analysis of the impact of land-water gradients and emissions transport in these complex environments, with a focus on tropospheric O_3 profile retrievals, will be investigated in future work.

Data and References

- Eskes, H. J. and Boersma, K. F.: Averaging kernels for DOAS total-column satellite retrievals, Atmos. Chem. Phys., 3, 1285–1291, https://doi.org/10.5194/acp-3-1285-2003, 2003.
- Sun, K., et al.: A physics-based approach to oversample multi-satellite, multispecies observations to a common grid, Atmos. Meas. Tech., 11, 6679–6701, https://doi.org/10.5194/amt-11-6679-2018, 2018.

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