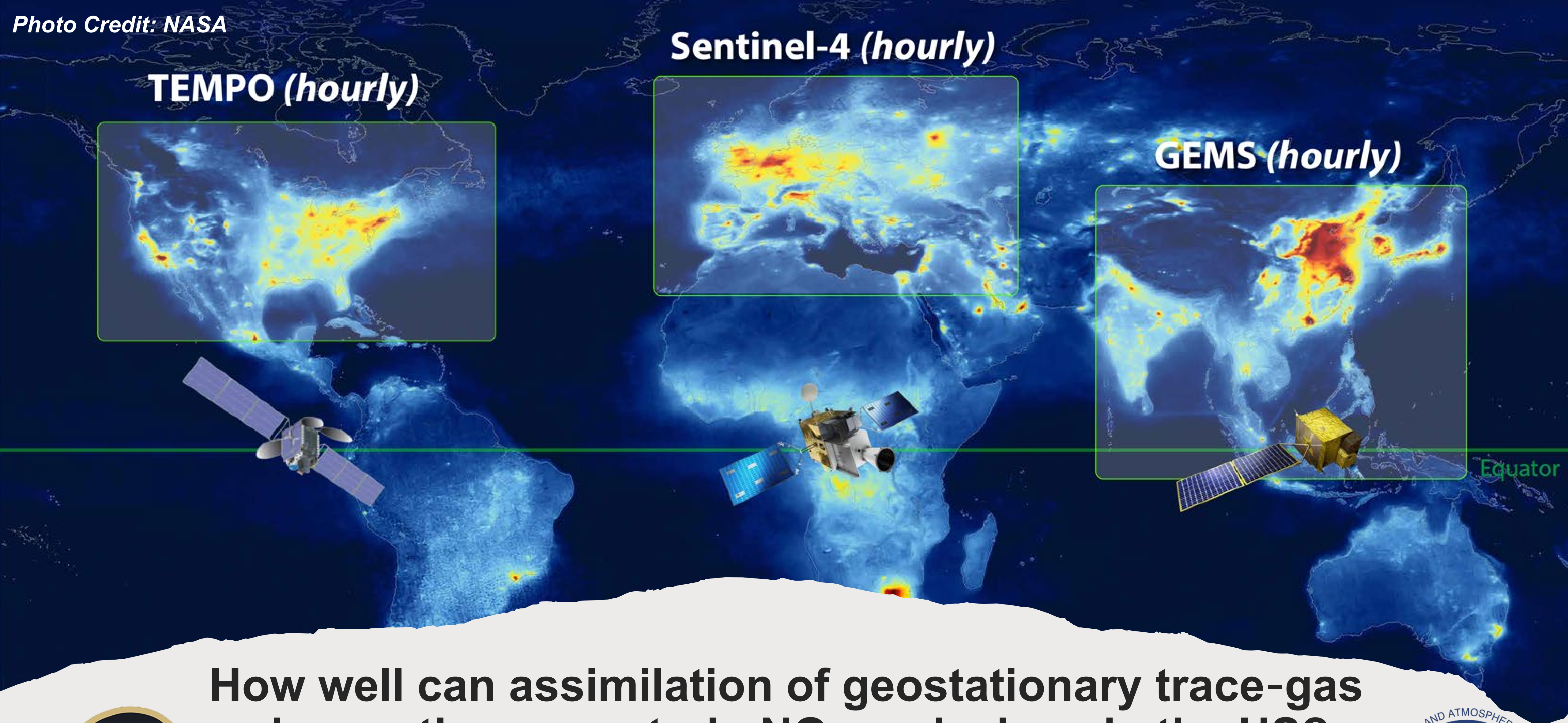

Photo Credit: NASA

How well can assimilation of geostationary trace-gas observations constrain NOx emissions in the US?

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Introduction & Objective

- NOx is precursor to Ozone (O_3) & $PM_{2.5}$ which leads to 50,000 – 80,000 premature death per year (Dedoussi et al, 2020)

- LEO satellite NO_2 observations (e.g., OMI, TROPOMI) are widely used in constraining/accessing NOx emissions (Li et al, 2021, Miyazaki et al., 2017, Qu et al., 2019)

- The geostationary instrument such as (TEMPO, GEO-XO) will provide ***high spatial-temporal resolution NO_2 measurement*** over North America in near future.

- **Objectives:**

1. Exploring the potential benefit of assimilating high spatial-temporal resolution NO_2 measurement from a geostationary instrument such as TEMPO, or NOAA's potential GEO-XO mission.
2. ***How well can GEO satellite observations constraint the NOx emissions compared to LEO satellite?***

Experimental design : OSSEs

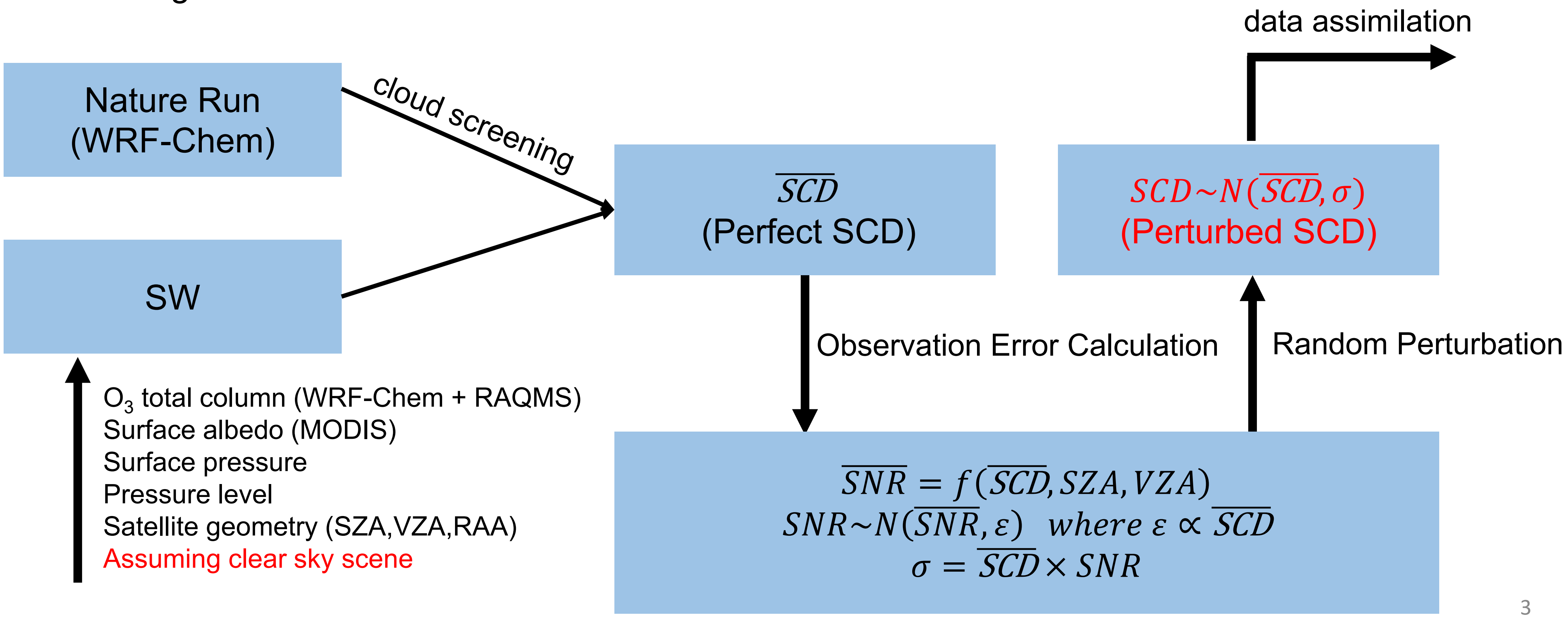
- Synthetic tropospheric TEMPO and TROPOMI NO_2 slant column density (SCD):

→ Nature Run (true atmosphere): WRF-Chem simulation with COVID-19 period emissions

→ Instrument sensitivity (scattering weight, SW): TEMPO NO2 SW LUTs (from Harvard SAO)

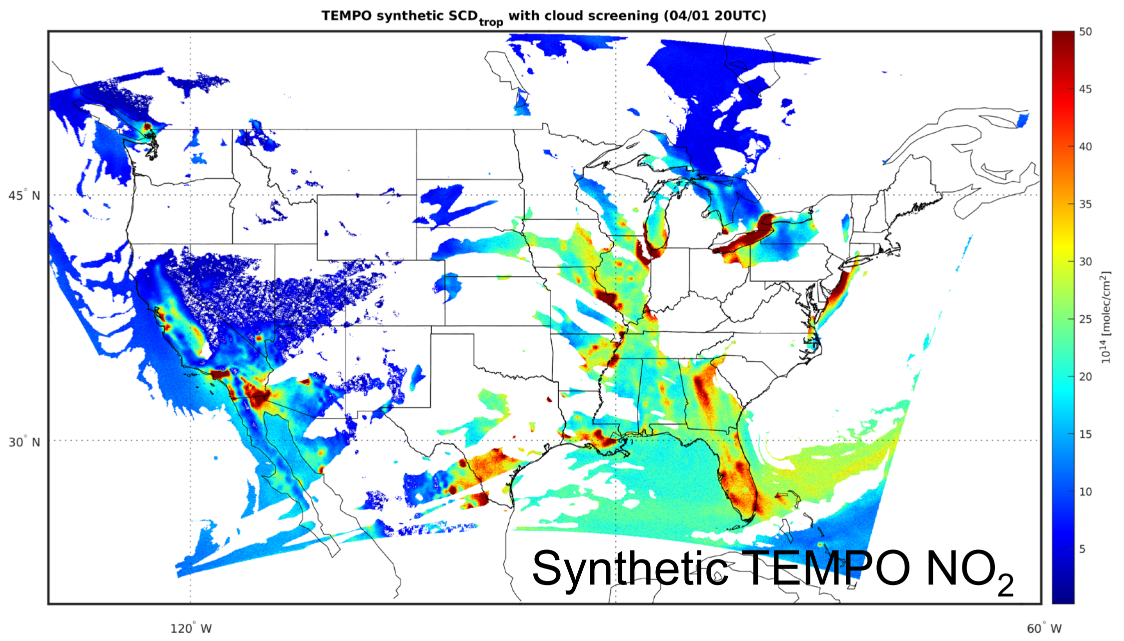
→ Accuracy (SNR, $\sigma/_{SCD}$): Predicted equation based on regression analysis of TEMPO proxy and TROPOMI data

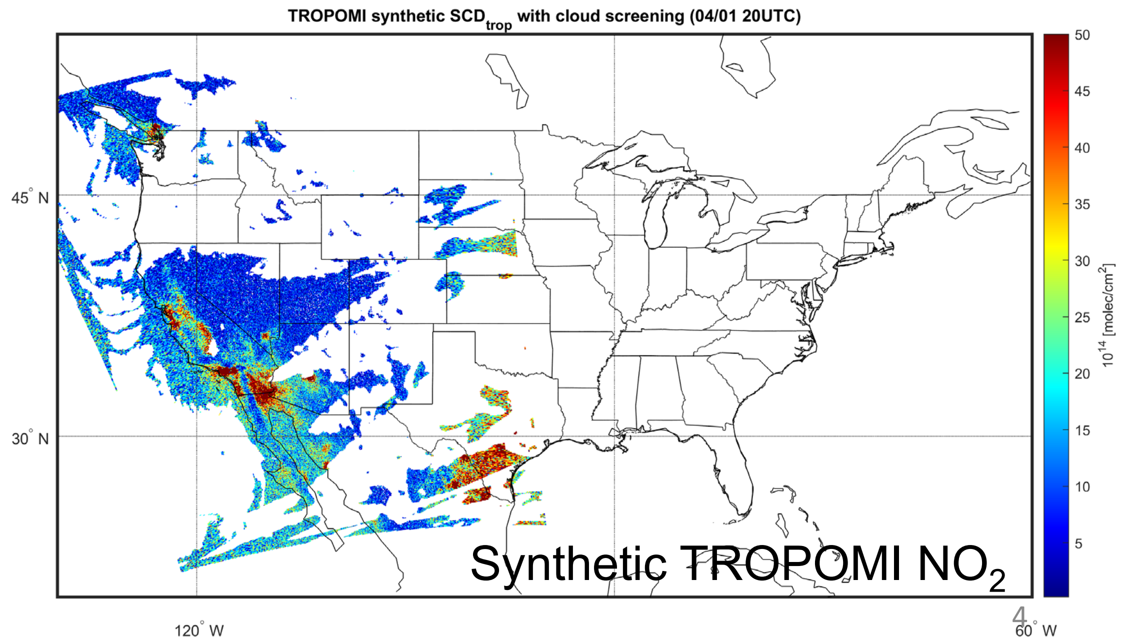
→ Cloud screening: WRF maximum cloud fraction < 0.5



TEMPO NO_2 vs. TROPOMI NO_2

	Synthetic TEMPO NO_2	Synthetic TROPOMI NO_2
Pixel resolution	2.0x 4.5 km^2	3.5 x 5.5 km^2
Spatial coverage	North America	Part of North America
Temporal coverage	Hourly (8-17 LST)	Midday (~13:30 LST)
#OBS	10^7 /hour	10^6 /day
Accuracy (SNR, $^{\sigma}/_{SCD}$)	< 0.2	> 0.2
SW vertical resolution	47	34





Experimental design: Modeling configuration

- Modeling system (forward run) : **WRF-Chem/DART** (Mizzi et al. 2016)

- **Data assimilation configurations:**

→ Independent data assimilation: TEMPO & TROPOMI NO_2 OBS only updated NOx concentration and NOx emissions

→ Multi-model ensemble: Different physics options for each ensemble member (e.g., PBL, cumulus and land surface model).

→ NOx emissions were adjusted in each DA cycle and the emissions scaling factors were propagated with time.

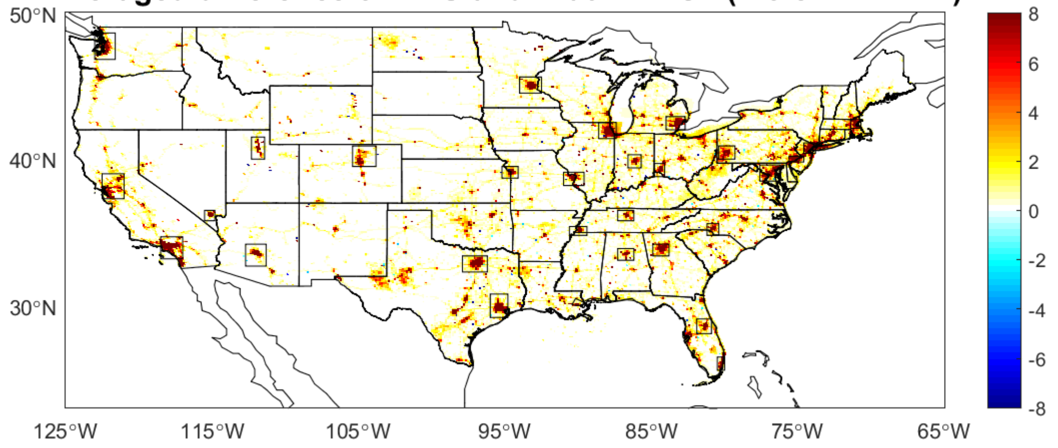
→ Assimilating super-observation (12x12 km) of TEMPO and TROPOMI NO_2 raw data (inverse-variance weighting)

- Simulation time periods: 2020/04/01 - 2020/04/06 (6 days)

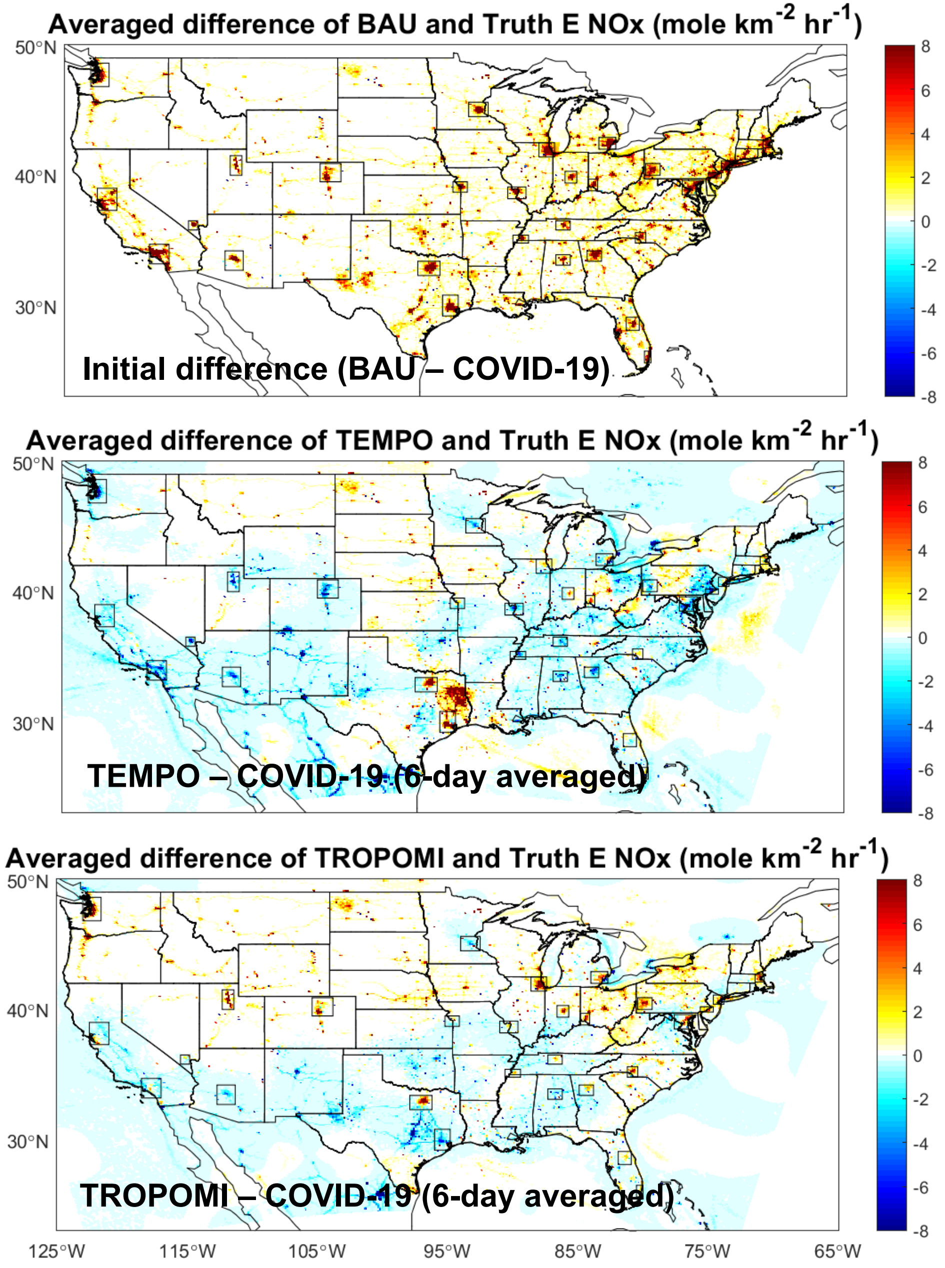
Experiments	Descriptions
TEMPO	Assimilating synthetic TEMPO NO_2
TROPOMI	Assimilating synthetic TROPOMI NO_2

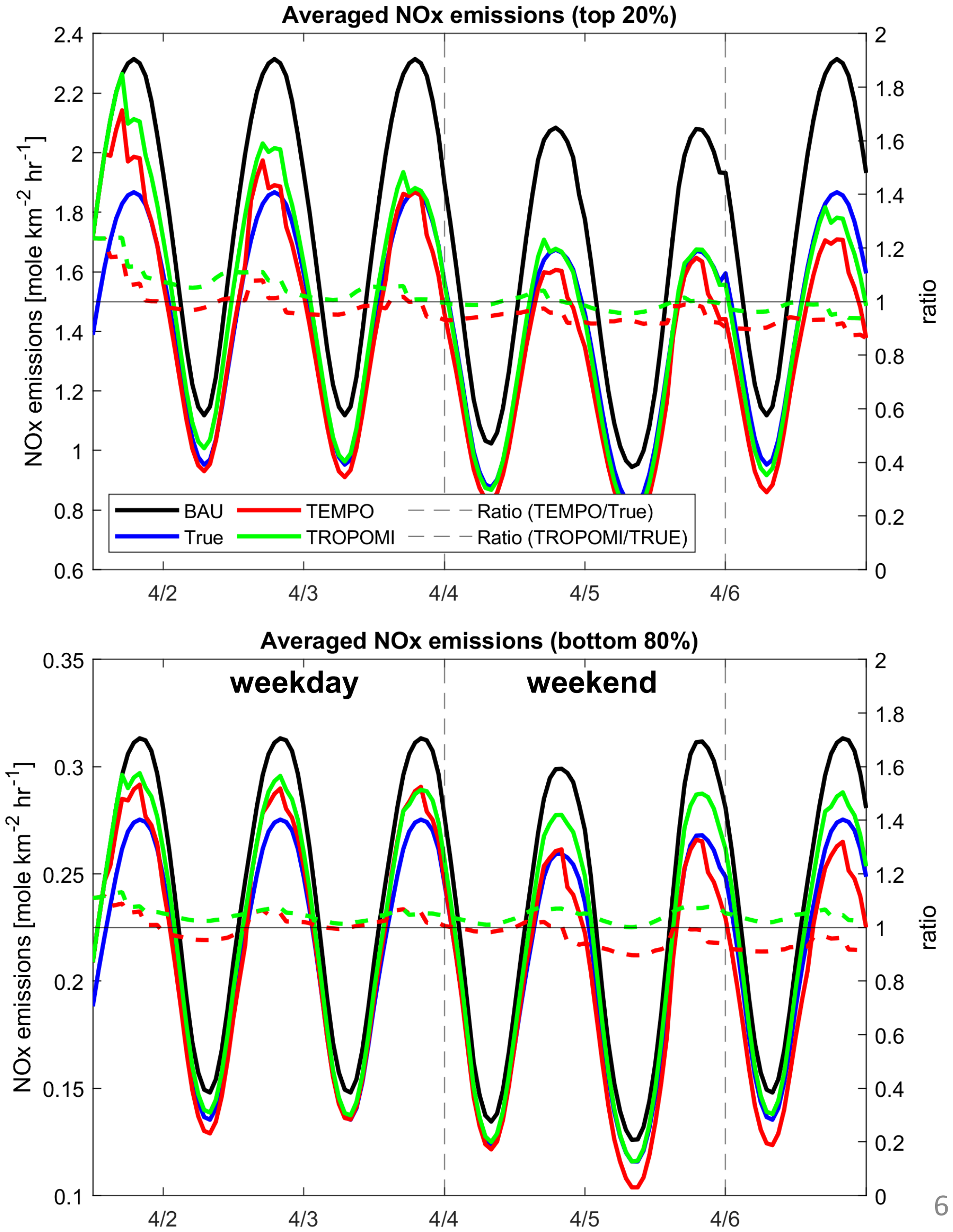
Model Configurations	
Model version	WRF-Chem v4.2.2
Emissions (BAU)	**Forward run**
Emissions (COVID-19)	**True emissions (Harkins et al., 2021)**
Biogenic emissions	MEGAN2.1
Fire emissions	FINN1.5
IC/BC	MET: NAM, CHEM: RAQMS
Gas phase chemistry	RACM_ESRL
Aerosol module	MADE/SORGAM
Resolutions	12 km with 51 vertical layers

Data assimilation configurations	
Filter type	EAKF (Anderson, 2003)
Ensemble members	10
DA cycle	3-hours
DA window	±1.5 hours
Horizontal (vertical) localization half width for NO_2	300km (off)



Result- NOx emissions adjustment





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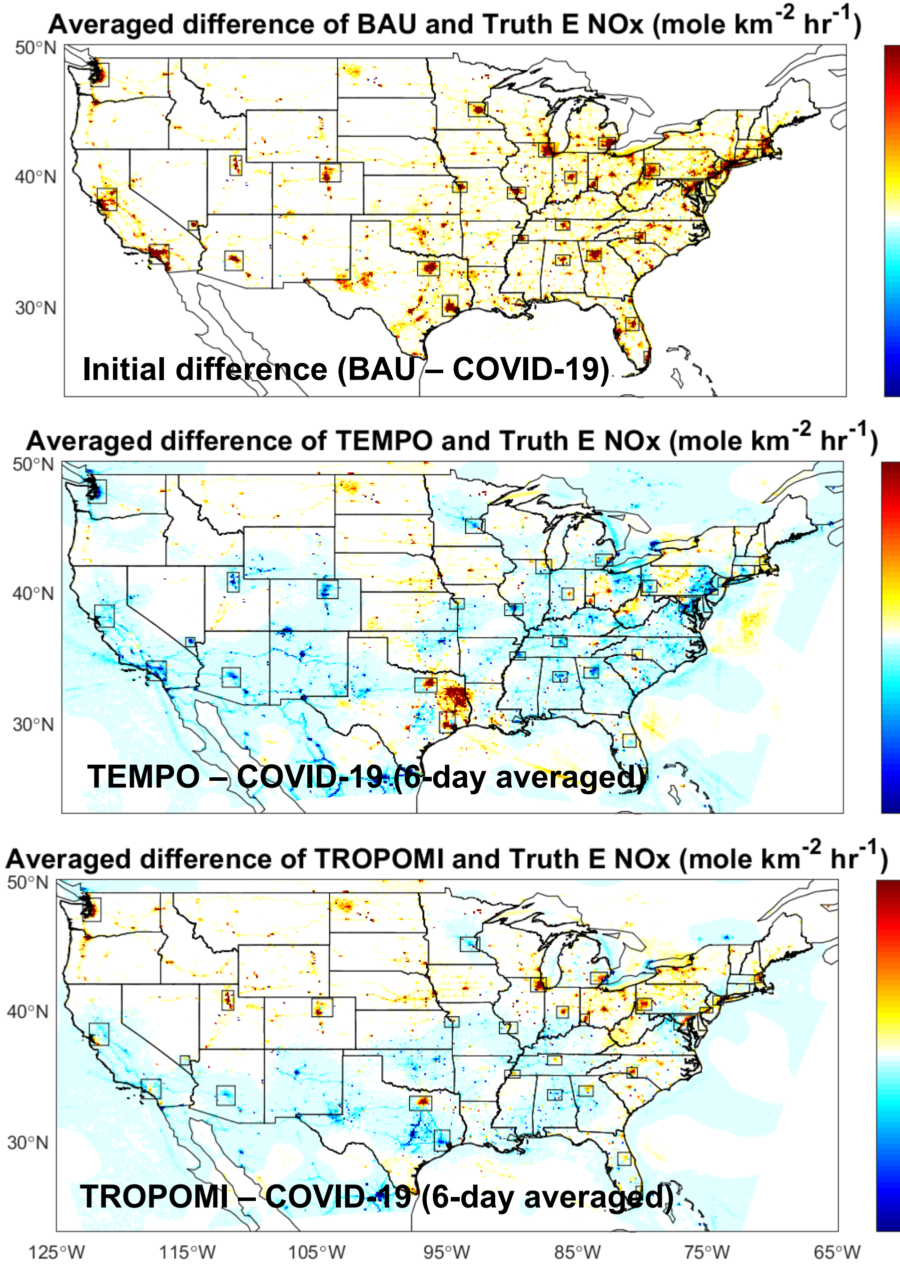
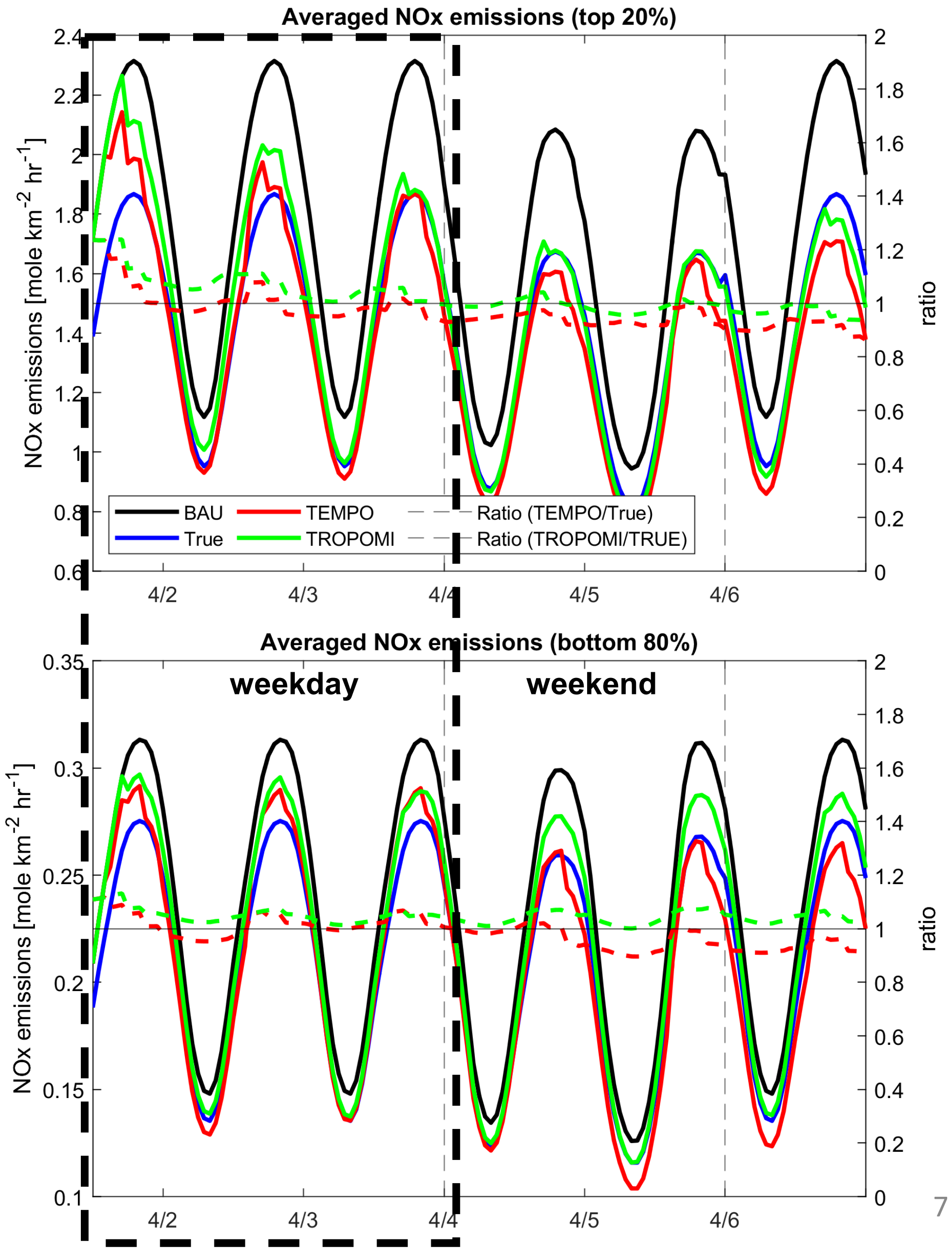
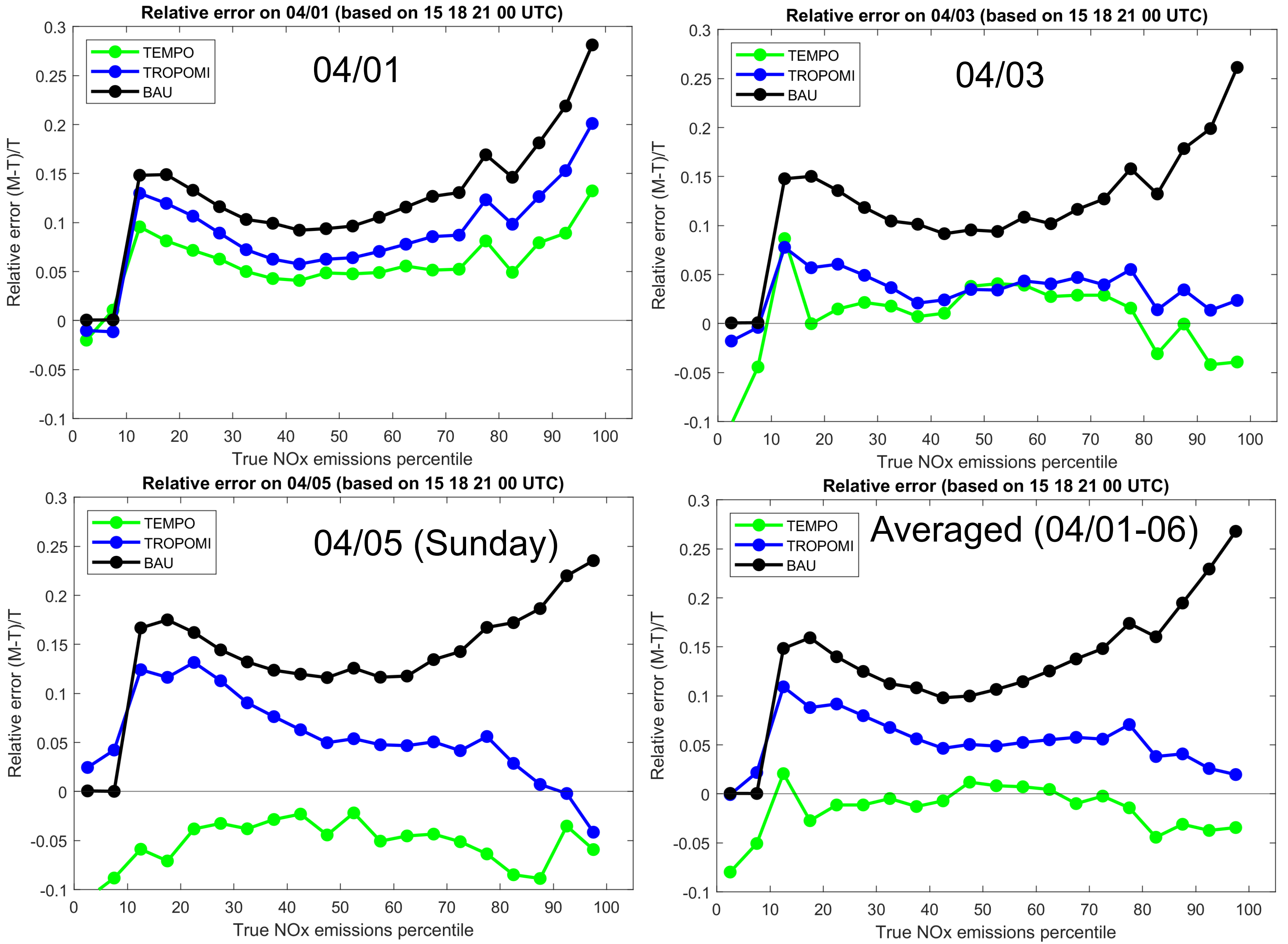




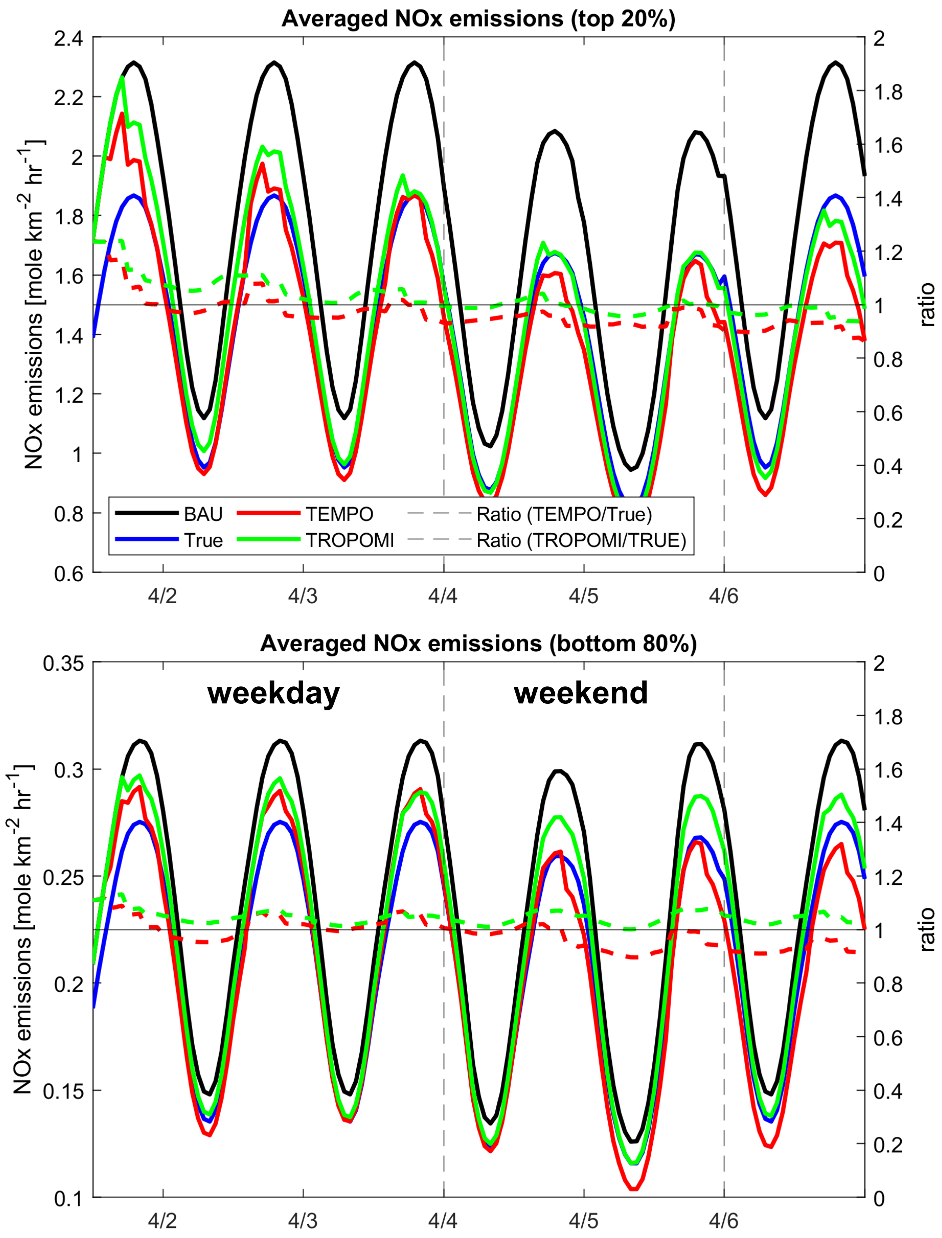
Result- NOx Emissions Relative Error



- Relative error = $\frac{e_{mod} - e_{tr}}{e_{tr}}$
- Speed of convergence:
  TEMPO > TROPOMI
- Top 20% of TEMPO estimated NOx are biased low.
- The weekend show higher bias.

Conclusion and Future Works

- TEMPO experiment can retrieve true NOx emissions much faster than TROPOMI experiment.
- The NOx emissions in most of the urban region are also better constrained in the TEMPO NO_2 experiment.
- The estimated NOx emissions in TEMPO experiment are biased low (under investigation)
- We expect that future geostationary satellite observations could improve the skill of top-down emission estimates and our ability to track the impact of specific emissions regulations on changes in air quality.



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Q & A

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