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science down to earth and deliver it into your hands.

From TEMPO Columns to Surface Air Quality

The NASA Health and Air Quality Applied Sciences Team (HAQAST)

3rd Generation; 2021-2025

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Special thanks to:

Kristen Foley and Todd Plessel at EPA for sharing EQUATES data from CMAQ

Luke Valin at EPA for helpful conversations

Madankui Tao, Columbia University, and Arlene Fiore, MIT

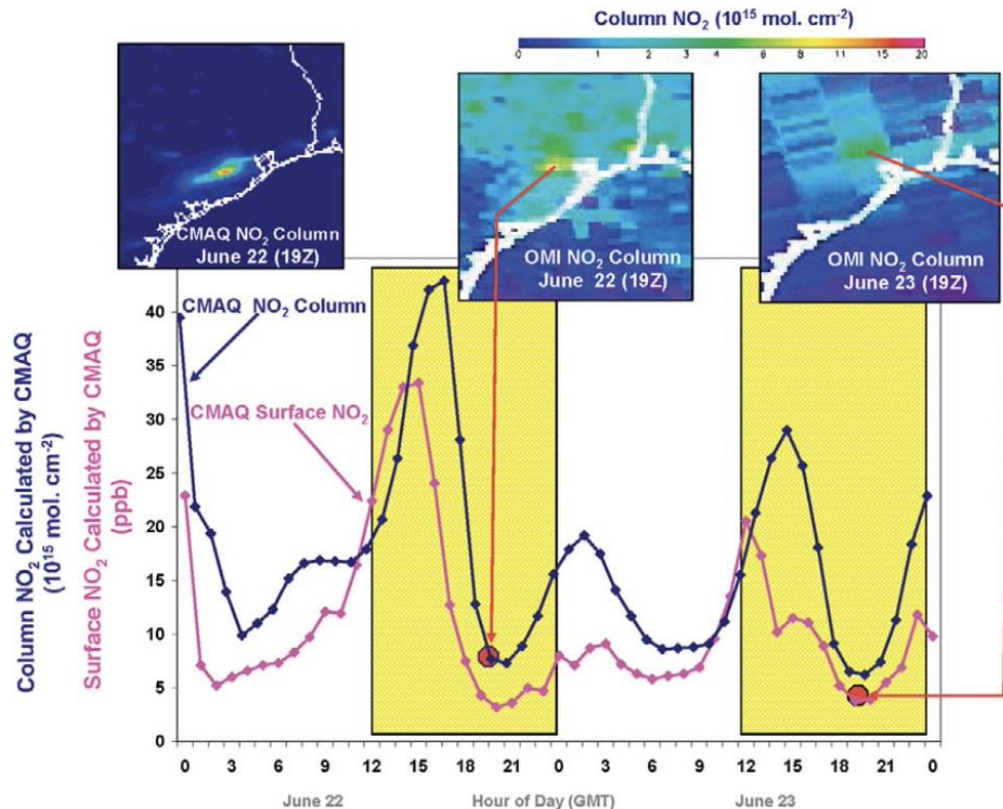
Summer Acker & Brandon Wolf, UW-Madison

TEMPO can inform variability in near-surface air quality

- Morning Maximum
- Mid-day Minimum
- Evening Secondary Max
- **column** lags **surface** ~2 hours

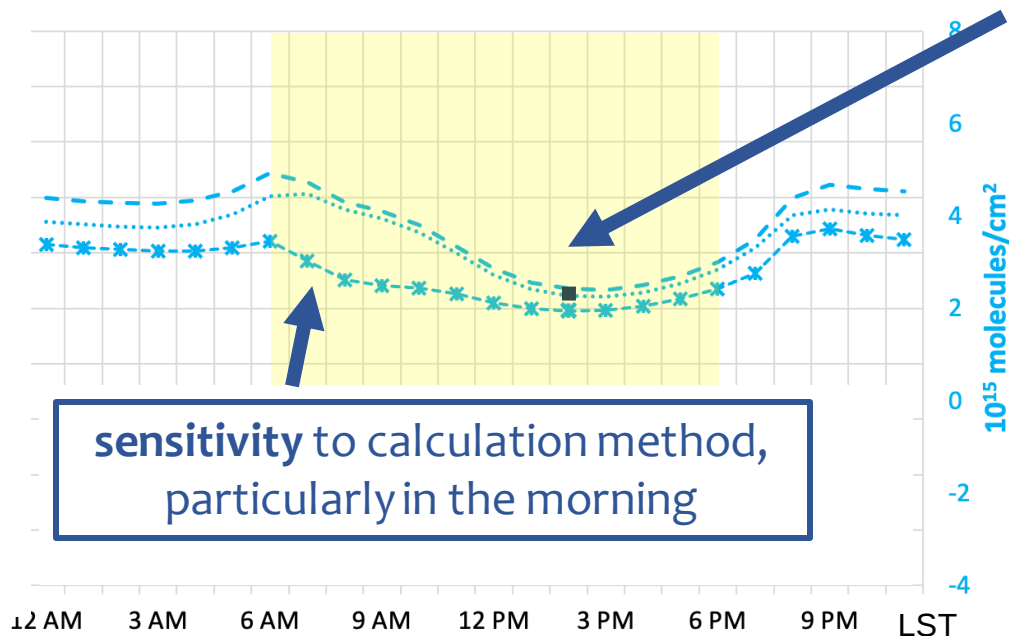
Based on 2 days of CMAQ modeling over Houston, TX

Fishman et al. (2008): Remote Sensing of Tropospheric Pollution from Space,
doi:[10.1175/2008BAMS2526.1](https://doi.org/10.1175/2008BAMS2526.1)



No standard approach to modeling “TEMPO-like” columns

little impact of calculation method at TROPOMI overpass



sensitivity to calculation method, particularly in the morning

column NO_2 :

TROPOMI tropospheric column

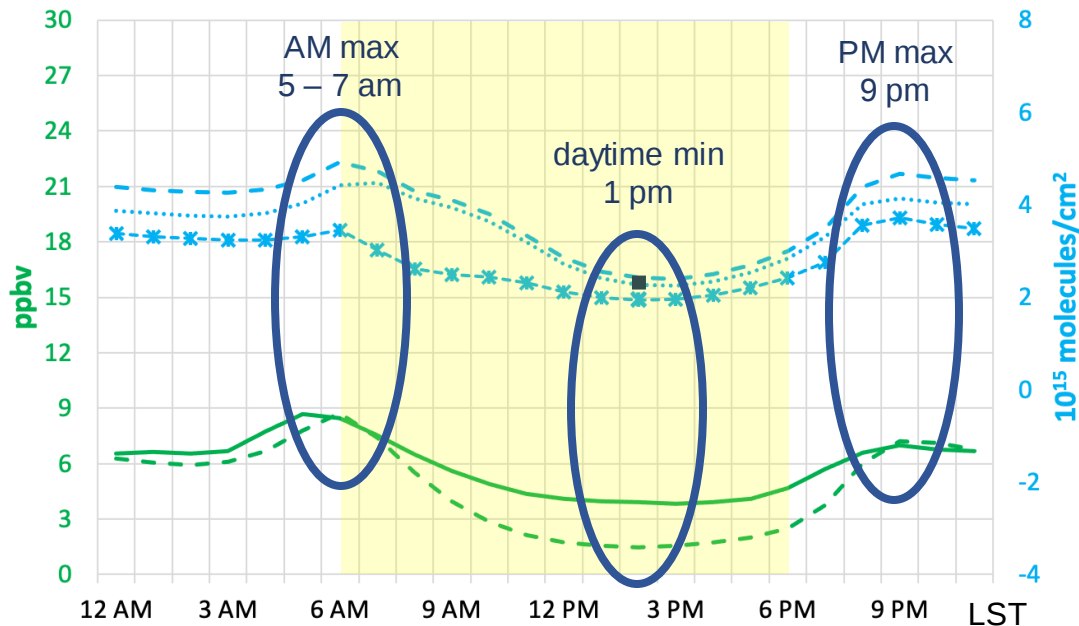
model column sum (to 50 hPa),
analogous to Fishman et al. (2008)

model column sum (to 200 hPa),
analogous to M. Tao et al. (in review)

model column weighted with the
TROPOMI averaging kernel

CMAQ-simulated hourly NO_2 vertical column density (VCD), averaged over locations of US ground monitors for July 2019

**TEMPO will cover mid-day min;
probably will get AM max;
probably not get the PM max**



CMAQ-simulated hourly NO₂ vertical column density (VCD), averaged over locations of US ground monitors for July 2019

NO₂ at the surface:

Surface monitors (AQS)

Model @ Surface (CMAQ/EQUATES)

NO₂ Vertical Column Density (VCD):

TROPOMI tropospheric column

model column sum (to 50 hPa),
analogous to Fishman et al. (2008)

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model column weighted with the
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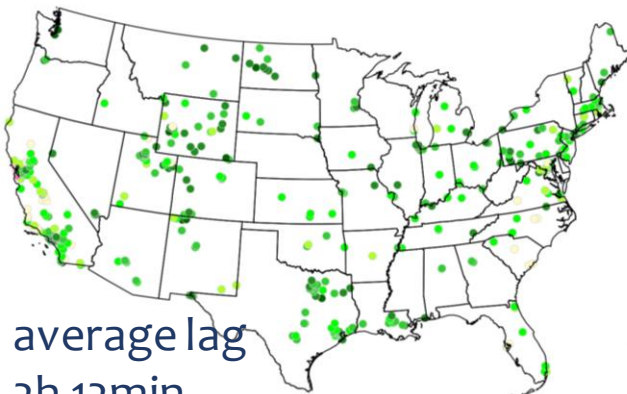


Temporal alignment of NO₂ column and surface will vary through the day

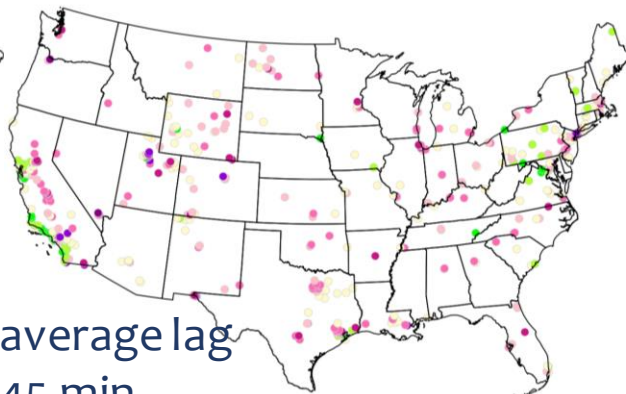
AM max

daytime min

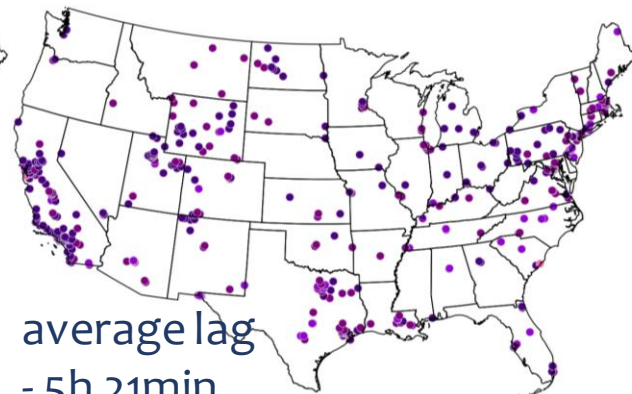
PM max



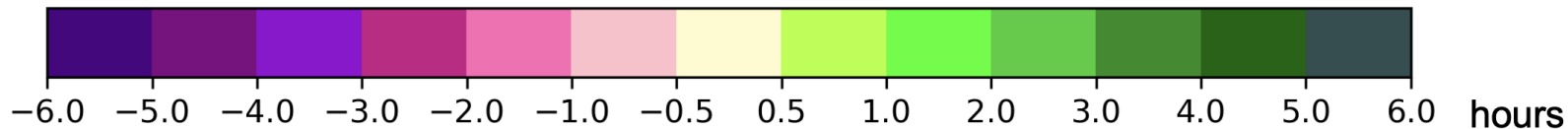
average lag
2h 12min



average lag
45 min



average lag
-5h 21min



← surface lags column

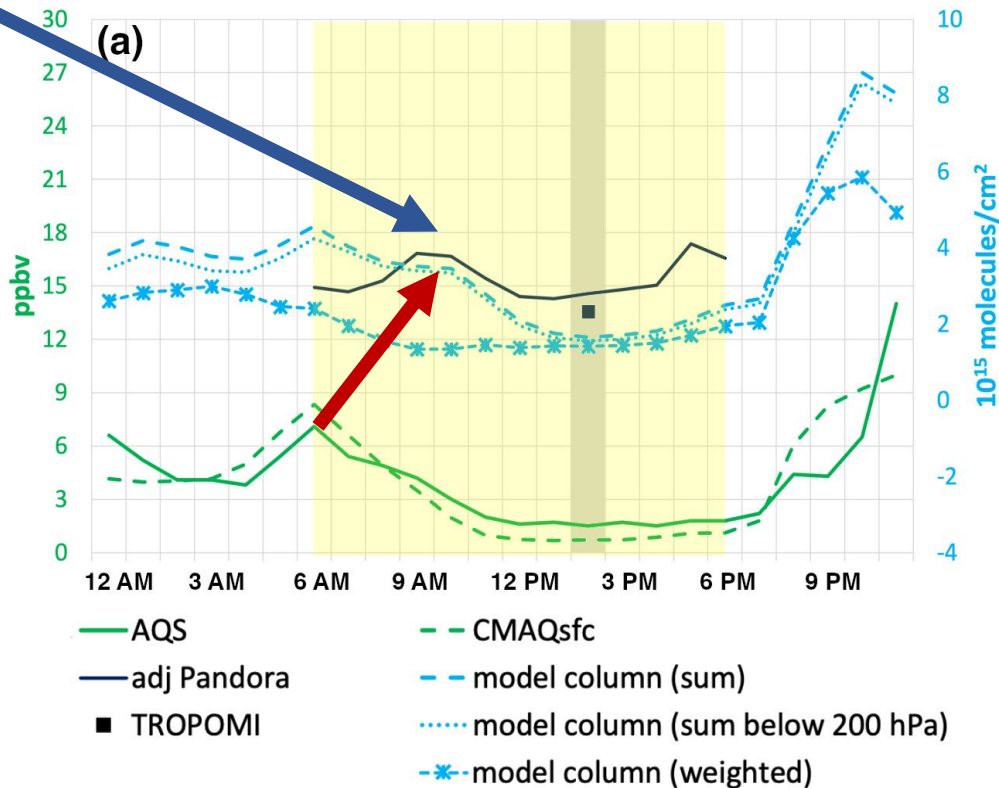
column lags surface →

Based on CMAQ-modeled surface (all times) vs. column (daylight hours only)

Pandora provides ground-based column NO_2 observations in a growing network

example day, Greenbelt MD (7/25/2019)

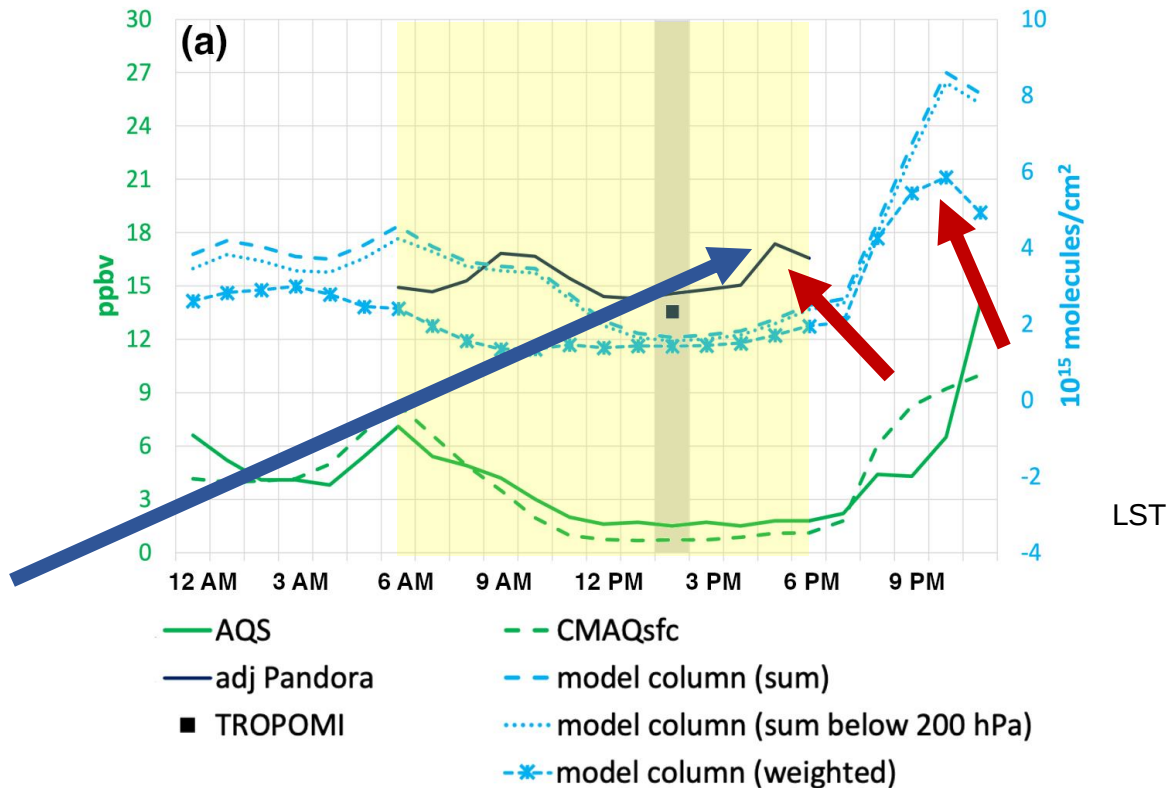
Pandora shows column maximum **lagging** surface maximum in morning (~3 hours)



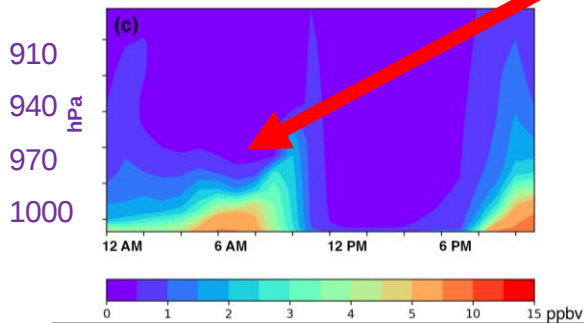
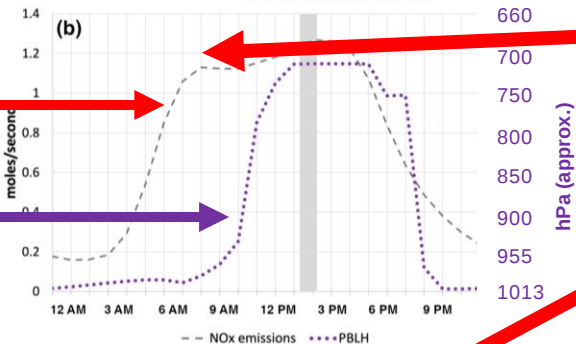
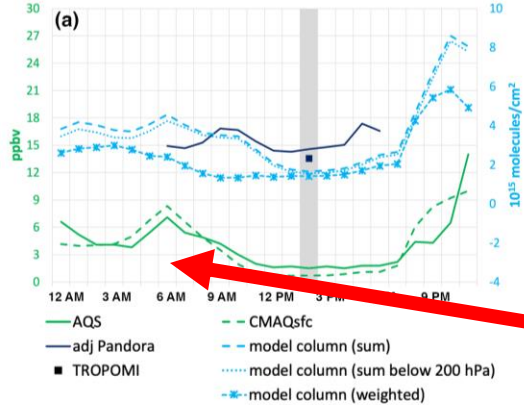
Patterns vary site-by-site, day-by-day

example day, Greenbelt MD (7/25/2019)

Column maximum
precedes surface
maximum in
evening ... but results
depend on treatment
of night-time column
vs. night-time surface



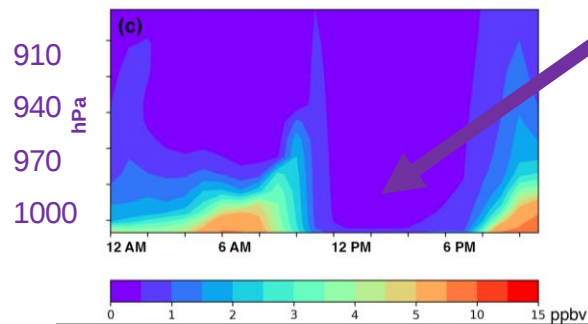
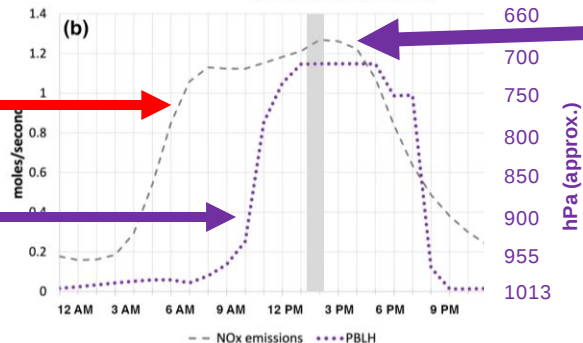
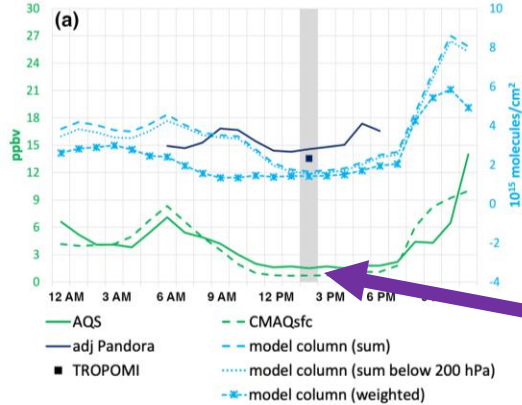
NO_x emissions
PBLH



Early Morning:
NO_x emissions rise,
with surface NO₂
building up in morning

NO_x emissions

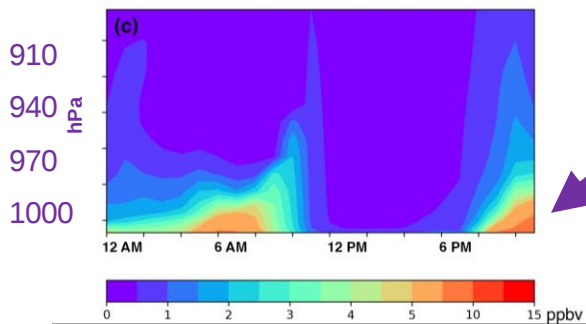
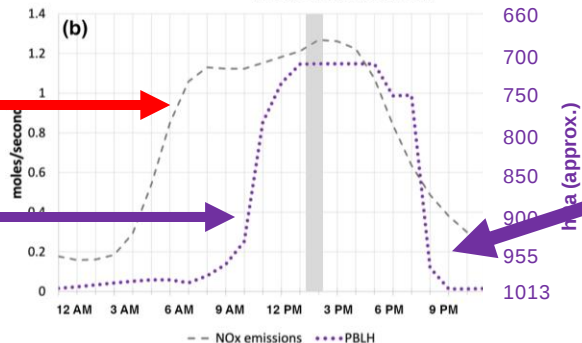
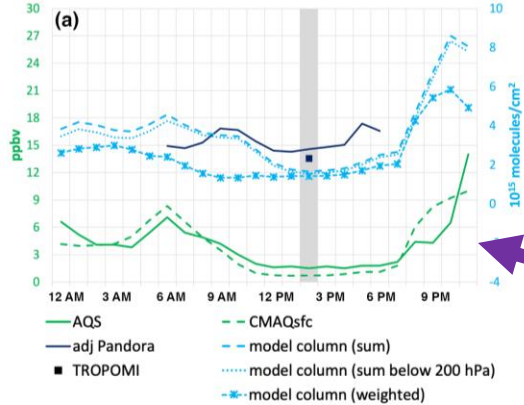
PBLH



Late Morning:
Boundary Layer (PBLH)
expands, with NO₂
dispersing

NO_x emissions

PBLH



Evening:
PBLH collapses, with
NO₂ rising at surface



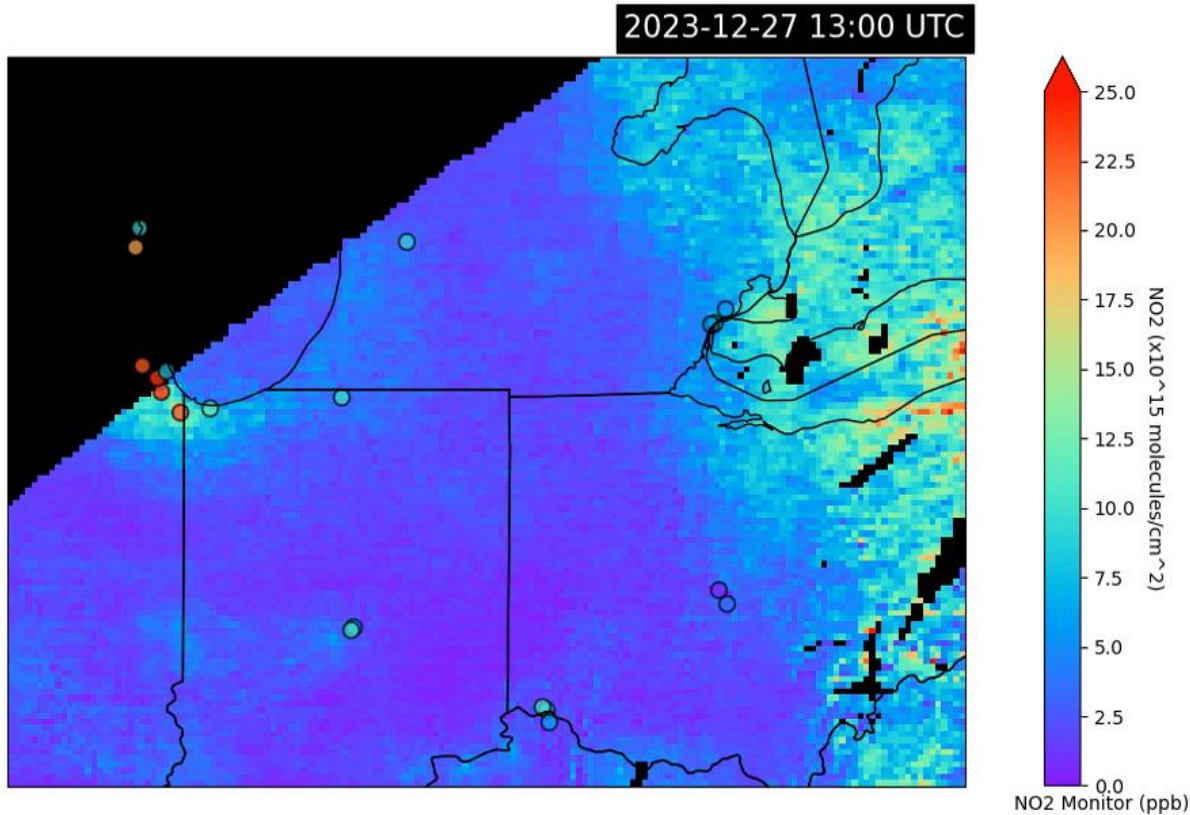
How-to's for ...

Loops over a specific region
(+ overlaid with wind vectors,
+ overlaid with AQS
monitors)

Creating TEMPO NO₂ L2 and
L3 maps

Creating timeseries from
TEMPO → csv (for Excel or
similar)

Converting TEMPO NetCDF
→ GeoTIFF file for GIS



TEMPO NO₂ over the Great Lakes with AQS Monitors (12/27-29, 2023)



Monica Harkey, Tracey Holloway, et al., "Simulated Surface-Column NO₂ Connections for Satellite Applications." In prep for *JGR-Atmospheres*.

Eliot J. Kim, Tracey Holloway, Ajinkya Kokandakar, Monica Harkey, Stephanie Elkins, Daniel L. Goldberg, Colleen Heck, "A Comparison of Regression Methods for Inferring Near-Surface NO₂ with Satellite Data." In revision for *JGR-Atmospheres* + [PDF] from techrxiv.org.

Alicia Hoffman, Timothy H Bertram, Tracey Holloway, Monica Harkey (2024) "Assessment of Nocturnal NO_x Heterogeneous Reaction Mechanisms in the Community Multiscale Air Quality (CMAQ) Model." *JGR-Atmospheres*, 129, 10.

Jennifer McGinnis, Tracey Holloway, Jenny Bratburd, Madankui Tao, and Arlene Fiore (2023) "Satellite Data to Inform Ozone Sensitivity: A Practical Methodology Using Google Earth Engine" EM, The Magazine for Environmental Managers, A&WMA. December 2023.

Hollowaygroup.org/tutorials + HAQAST.org/data-and-tools/