Seeing the Daily Cycle: *Examining Diurnal Patterns in TEMPO and Pandoras*

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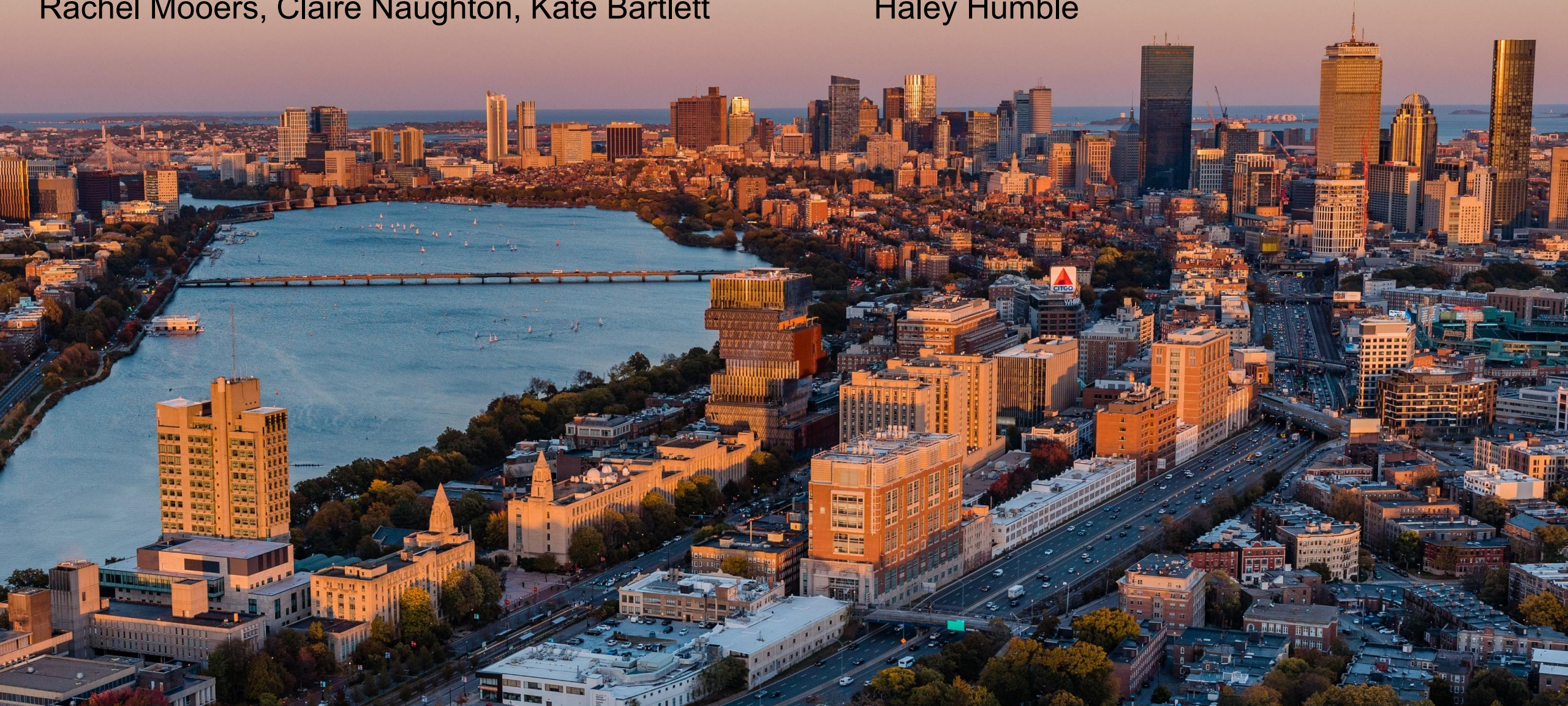
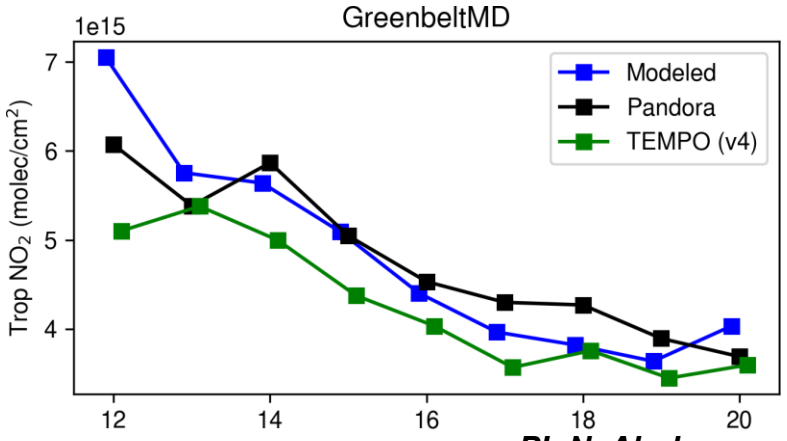
John Lin, University of Utah
Haley Humble

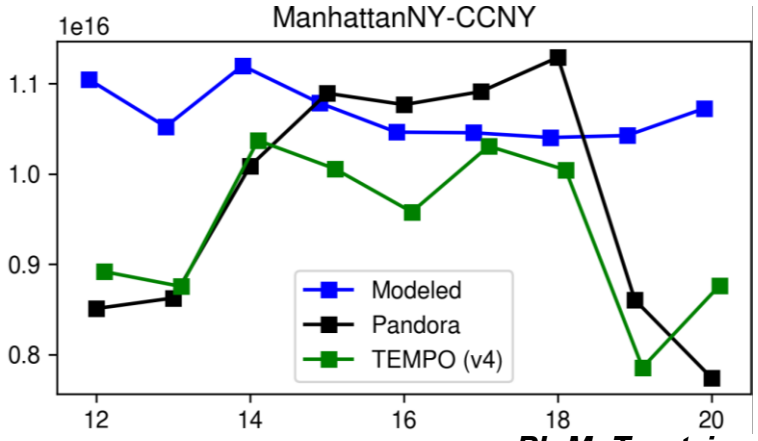


Agreement (and Disagreement) Between Pandora, TEMPO, and GEOS-CF

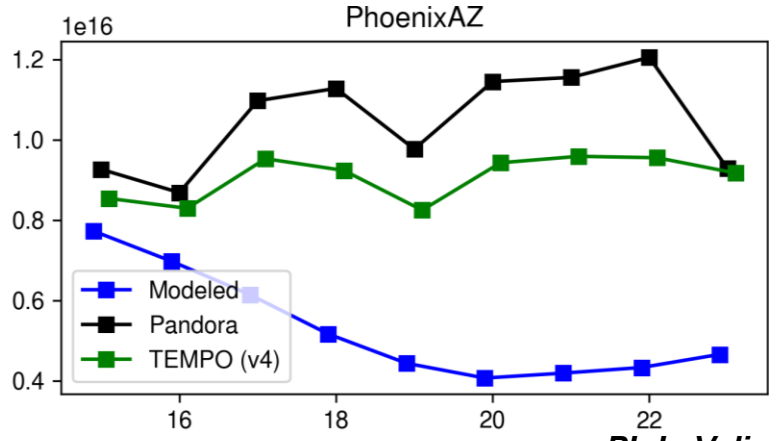
October 2025 (All coincidently sampled for: TEMPO Quality Flag = 0, Cloud Fraction < 0.1)



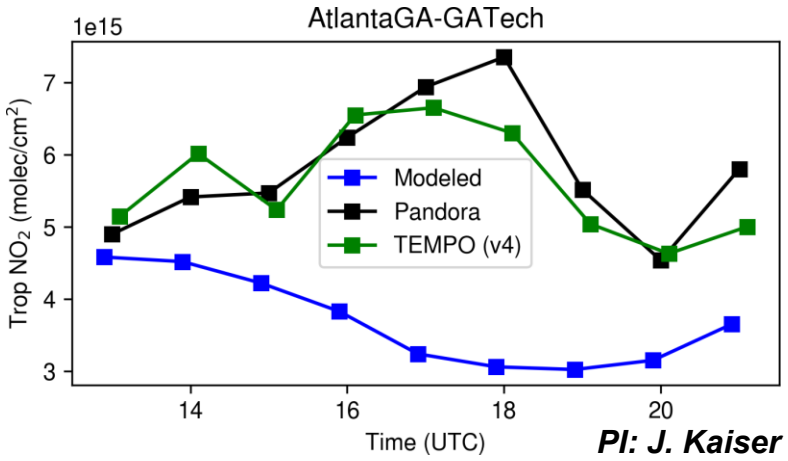
PI: N. Abuhassan



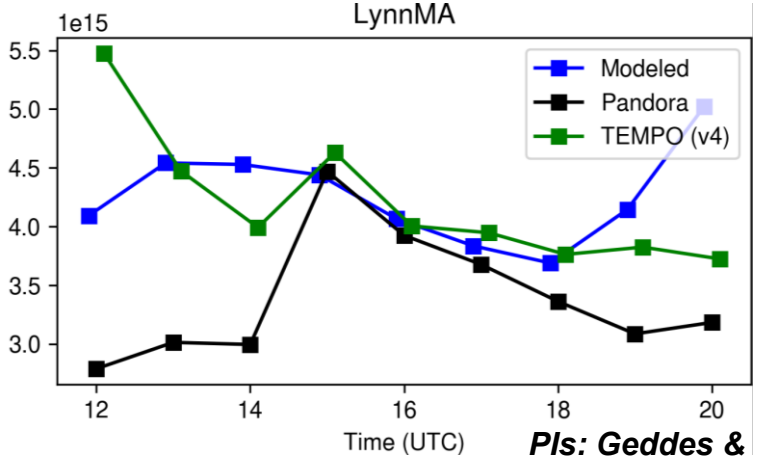
PI: M. Tzortziou



PI: L. Valin



PI: J. Kaiser

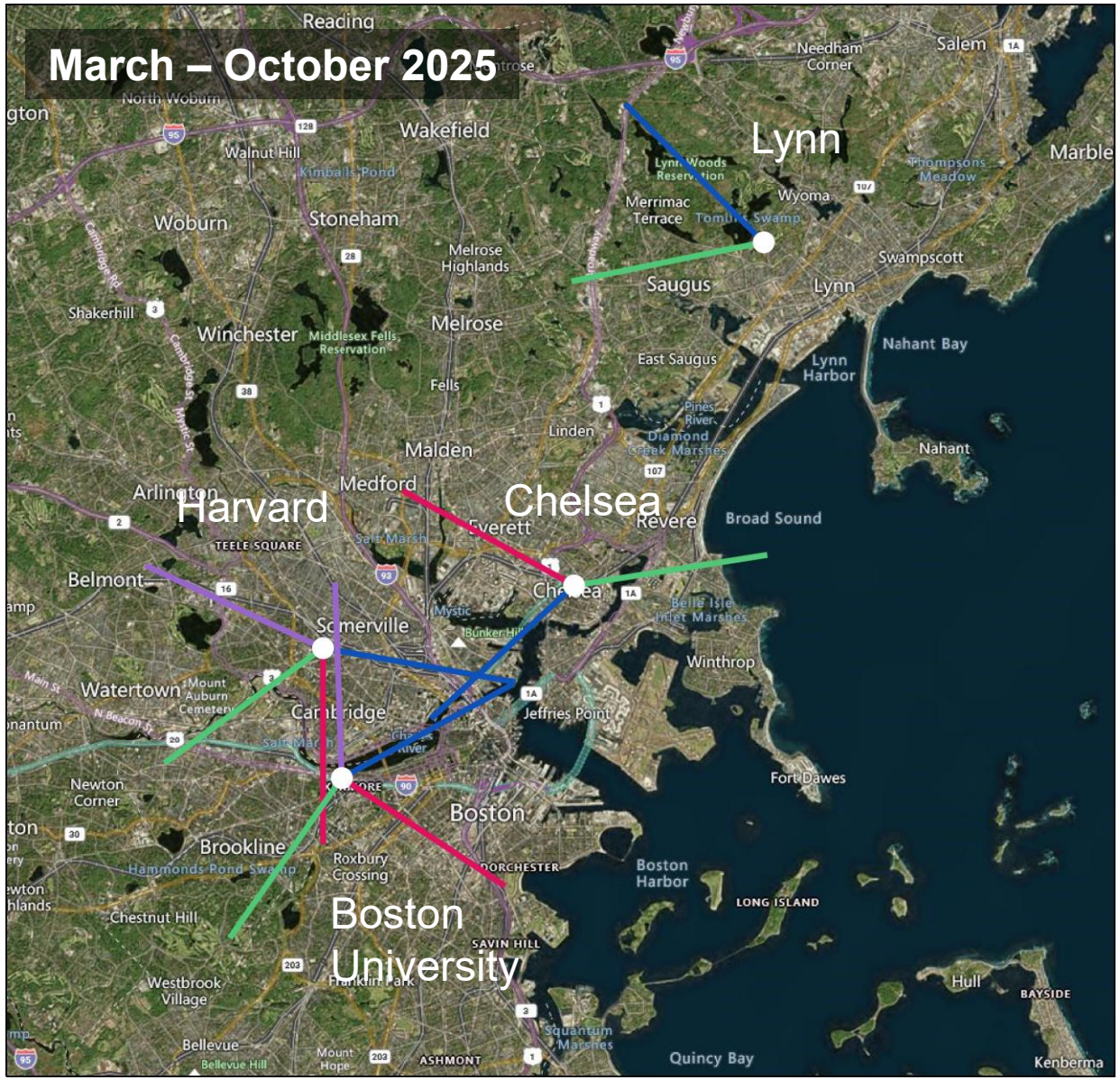


PIs: Geddes & Gonzalez Abad

Encouraging agreement in urban areas between Pandora and TEMPO!

Remaining instances of disagreement require detailed study…

Multi-Azimuth Mapping Experiment in Boston



Schedule

- 00:04
- 00:19
- 00:34
- 00:49

Detailed multi-axis scan (13 zenith angles) in up to four different azimuth directions every hour

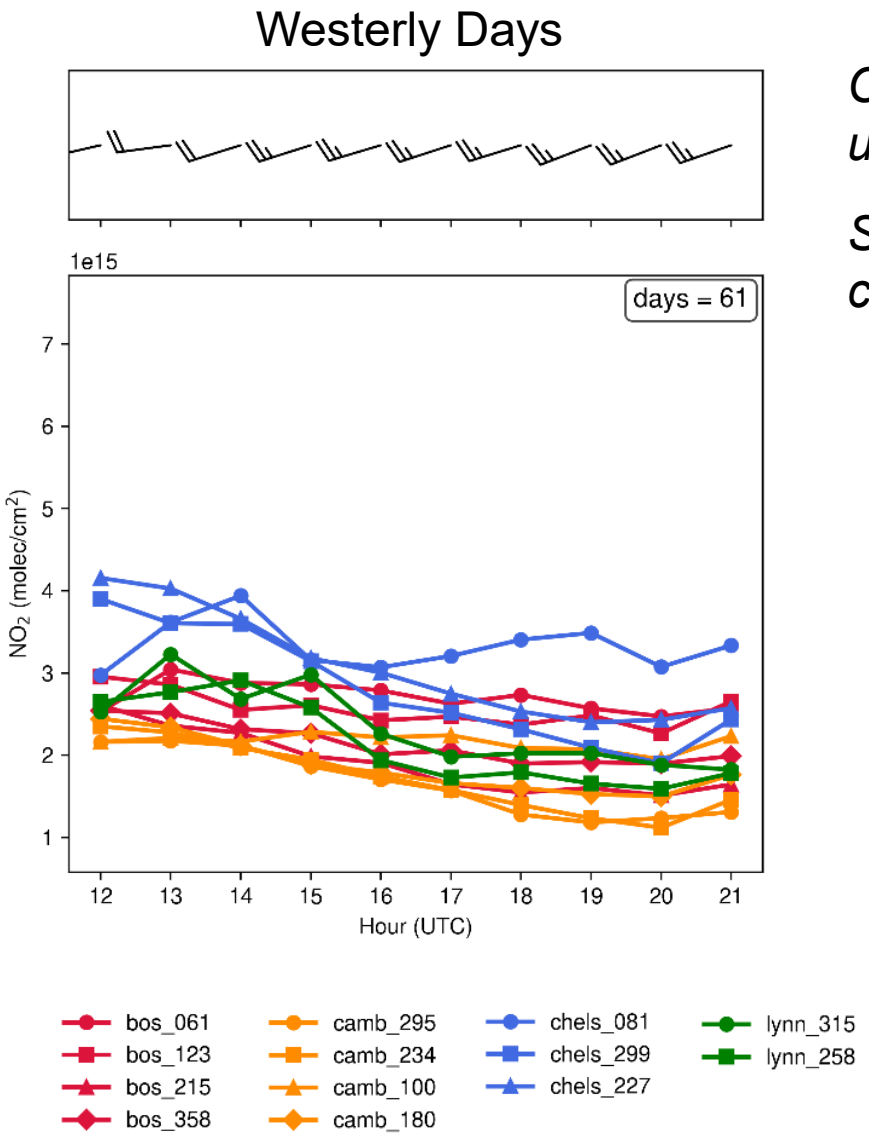
Retrieves:

- *Tropospheric Column (~3 km)*
- *Vertical Profile*
- *Near-Surface Concentration Estimate*

Each multi-axis scan takes ~8 minutes

Direct sun measurements for remainder of 15-minute blocks

Multi-Azimuth Mapping Experiment in Boston

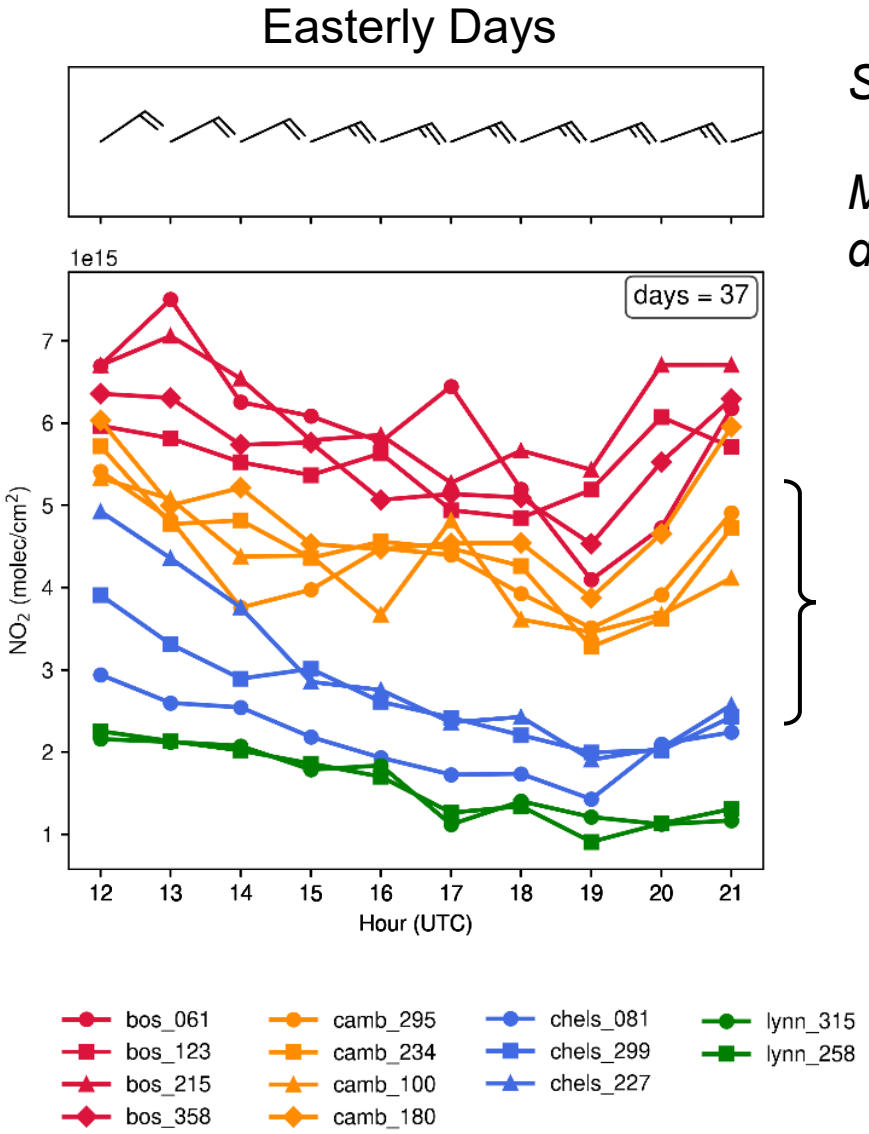


Confirms previous indirect evidence that NO_2 columns are homogeneous under synoptic westerly conditions.

Simplest case to use in model and satellite comparisons to avoid confounding factors that might also drive complex vertical NO_2 fields.

Mooers et al. (in prep)

Multi-Azimuth Mapping Experiment in Boston

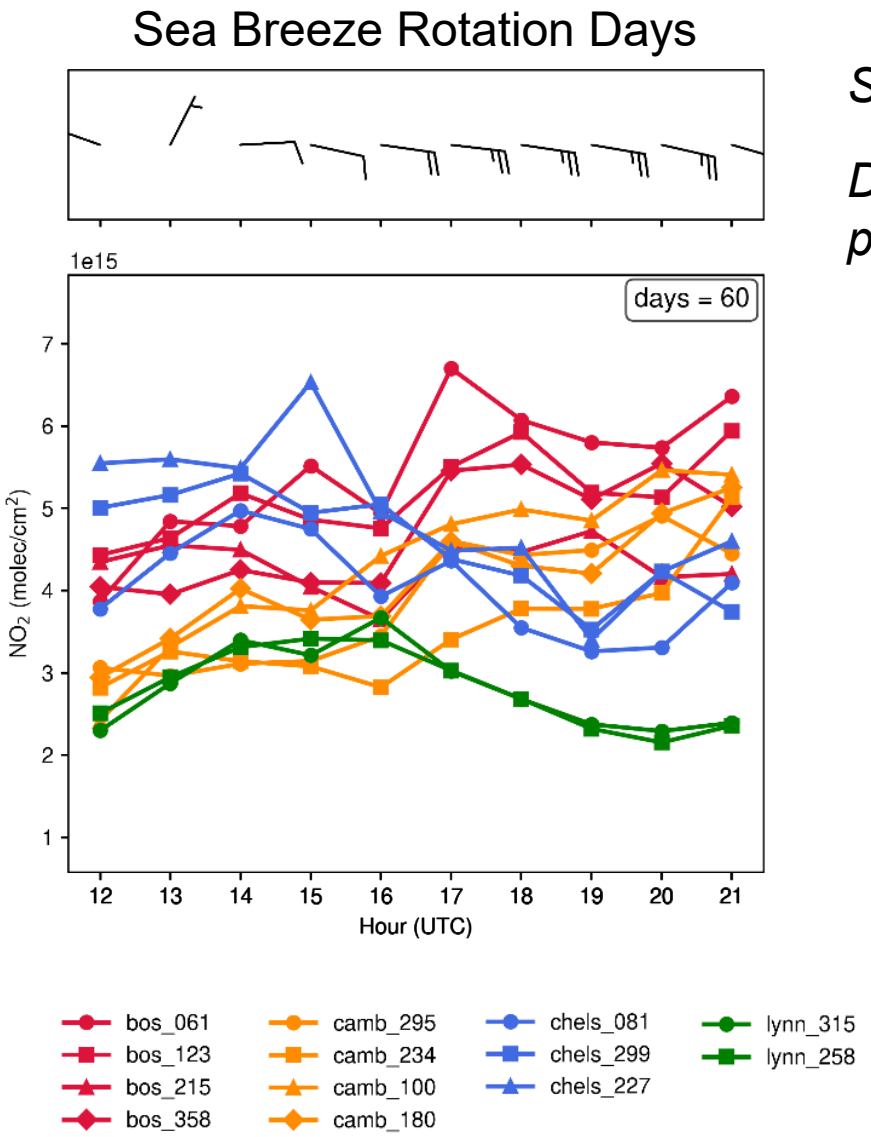


Steep upwind-downwind horizontal gradients on easterly days.

Measurements from a single location pointing in different directions can vary by 50-60%.

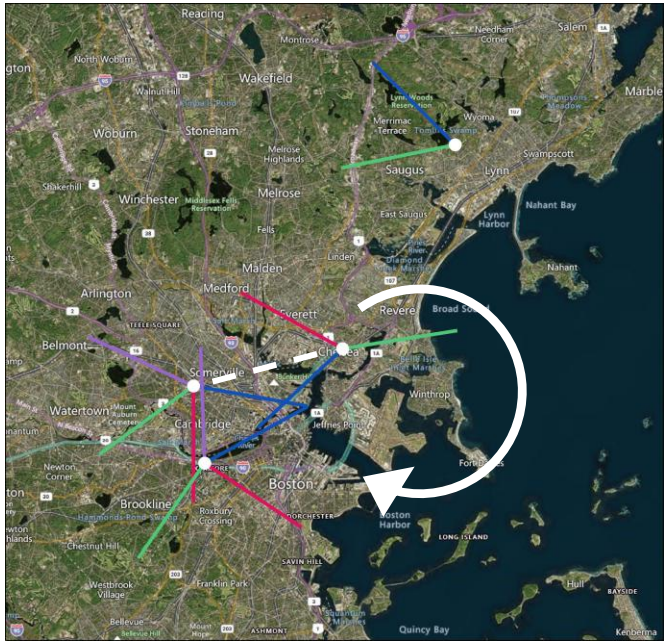
Mooers et al. (in prep)

Multi-Azimuth Mapping Experiment in Boston



Sea breeze days are a fascinating mess...

Diurnal shape depends strongly on site, and sometimes on pointing angle.



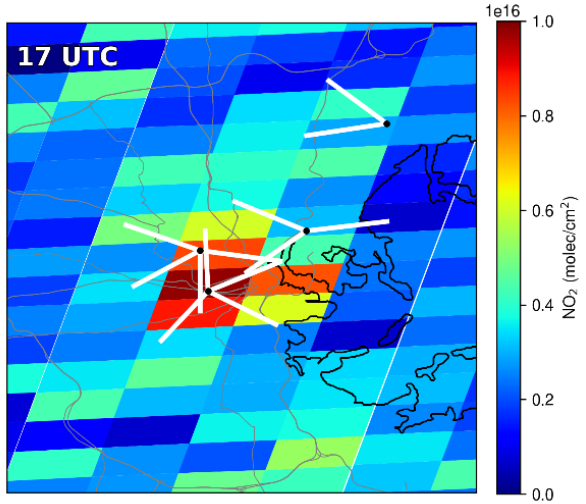
Chelsea and Harvard have opposite diurnal profiles, and they are ~7 km apart from each other

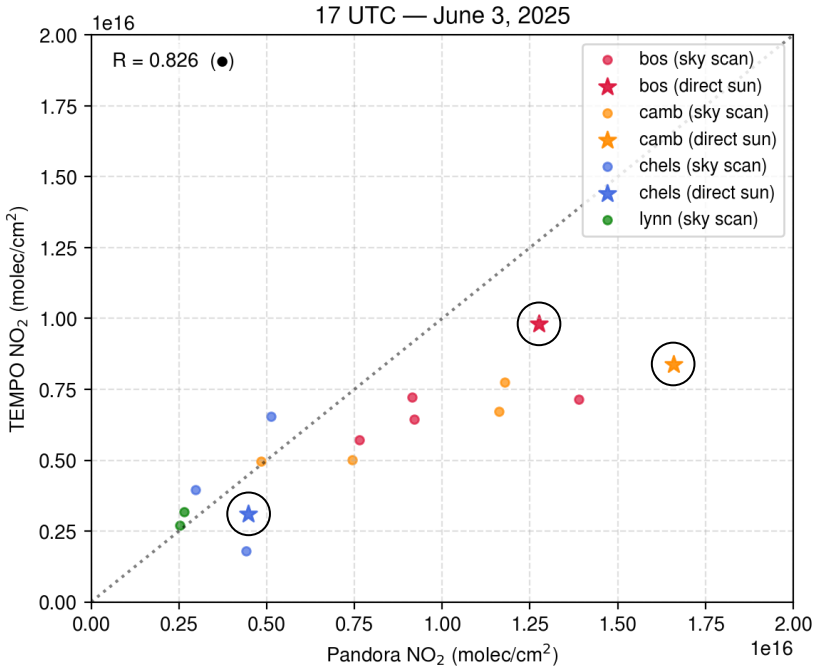
Note: TEMPO Pixel over Boston is 3 x 6 km!

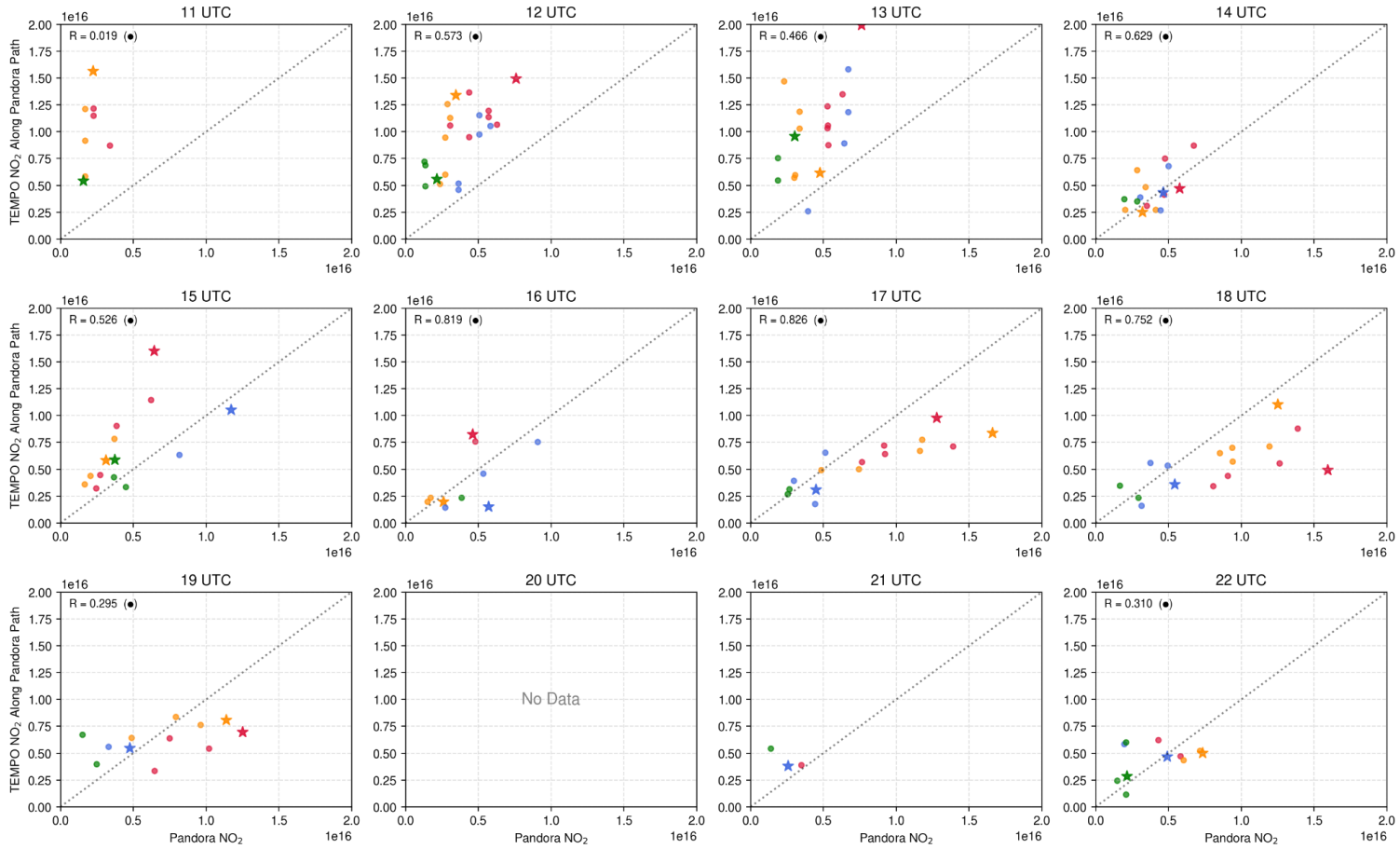
Mooers et al. (in prep)

Using Multi-Azimuth Mapping to Examine TEMPO Performance

June 3, 2025



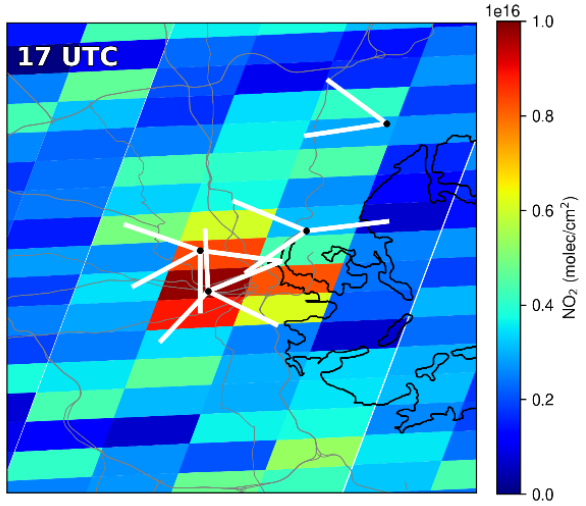


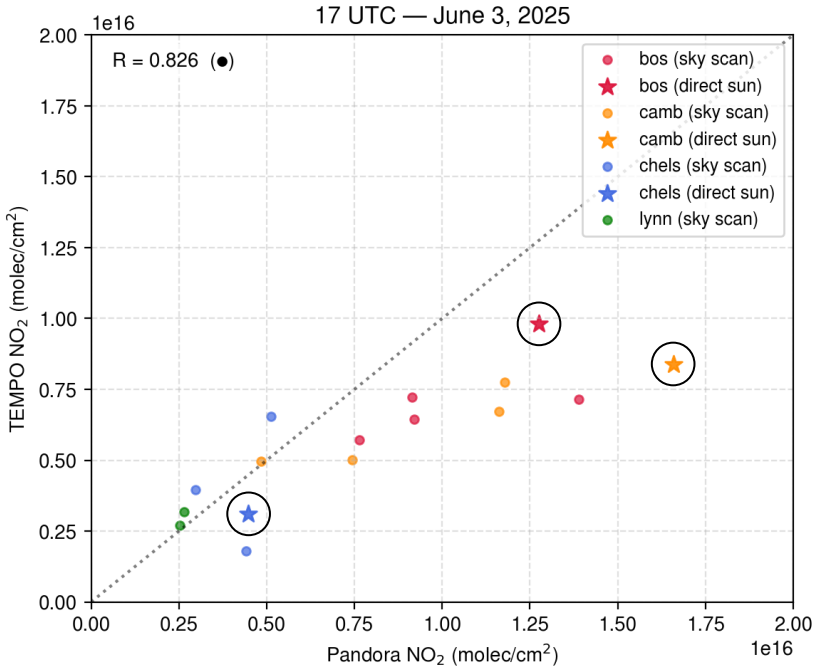


TEMPO "hallucinates" spatial gradients in the morning that are not observed by the Pandora network

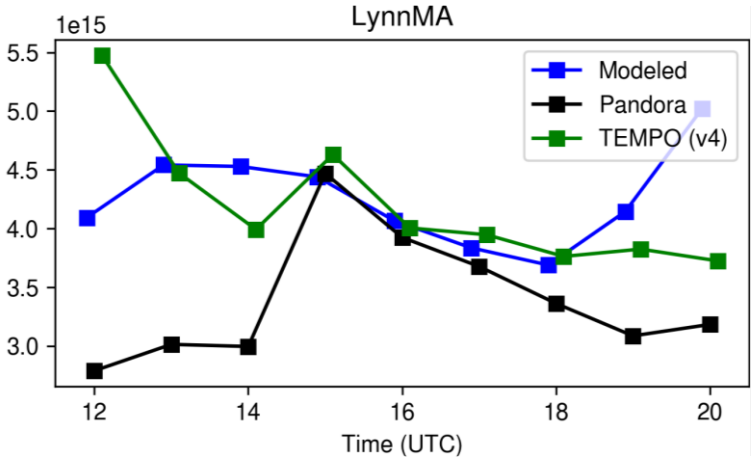
Using Multi-Azimuth Mapping to Examine TEMPO Performance

June 3, 2025





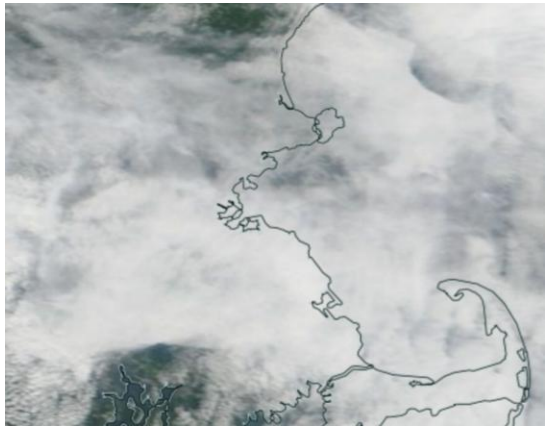
October 2025
All coincidently sampled for:
TEMPO Quality Flag = 0
Effective Cloud Fraction < 0.1



and problem does not seem to be resolved with v4…

More on this another time!

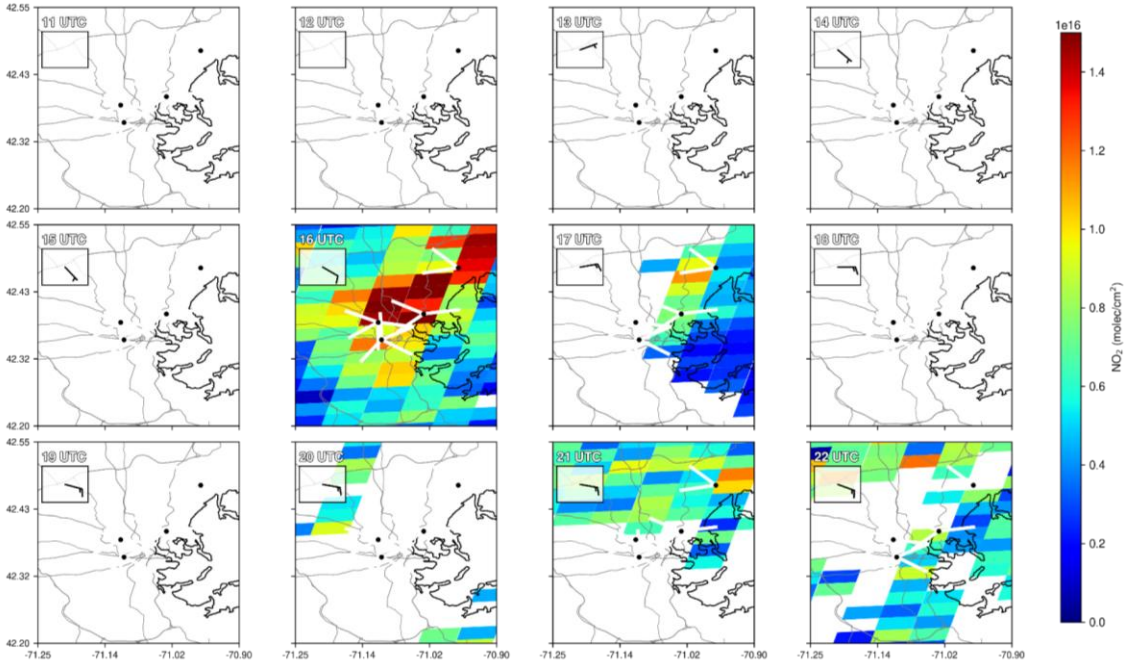
Unique Opportunities During Cloudy Conditions



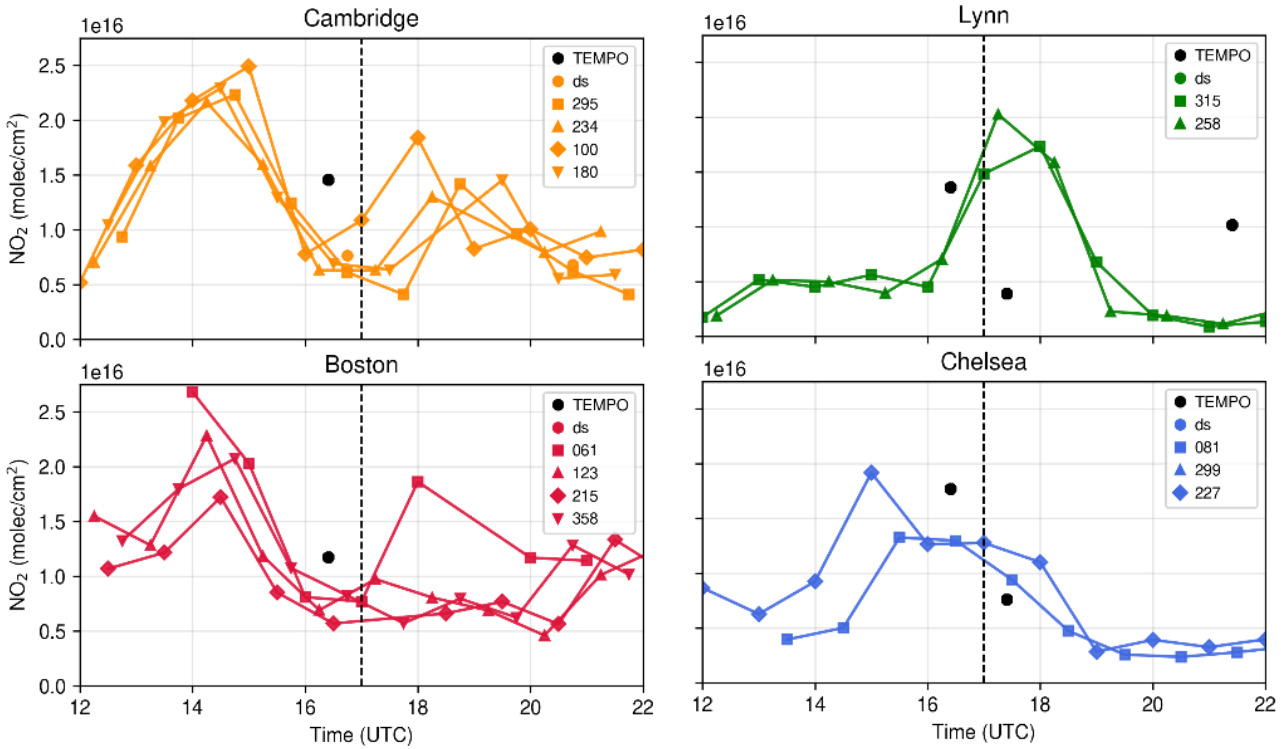
10:30 LT

13:30 LT

July 11, 2025



If sky conditions are steady over the course of a retrieval (minutes), multi-axis scan can retrieve column density regardless of cloud cover.

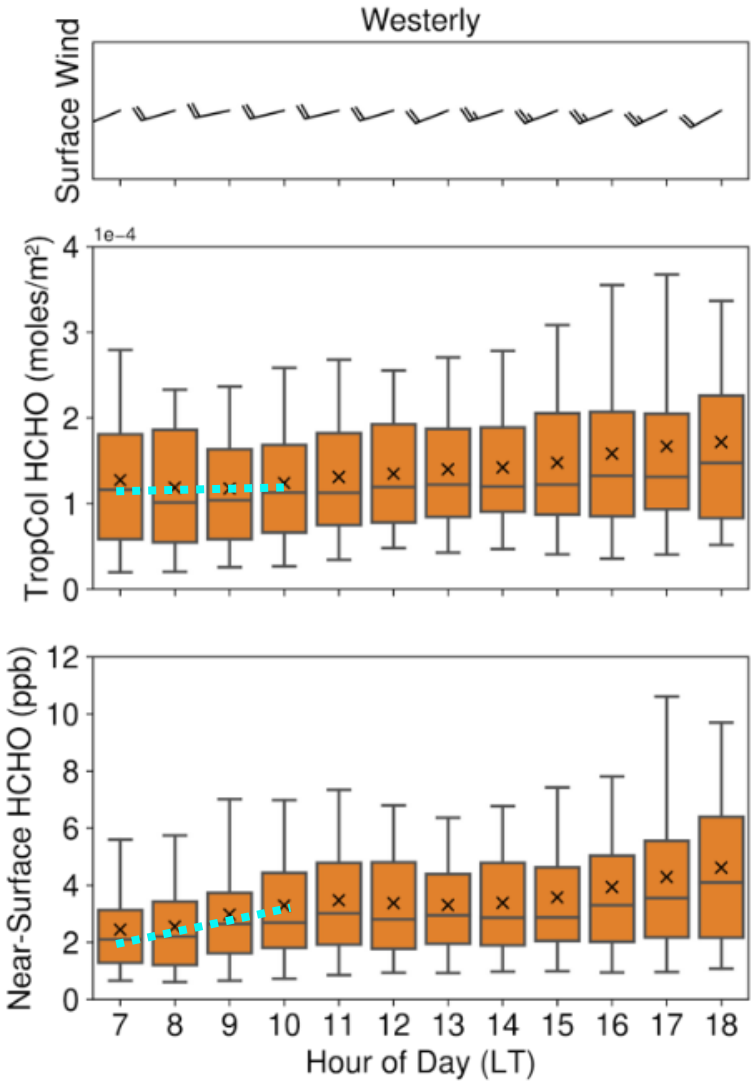


Opportunity to “map” below-cloud columns missed by satellites

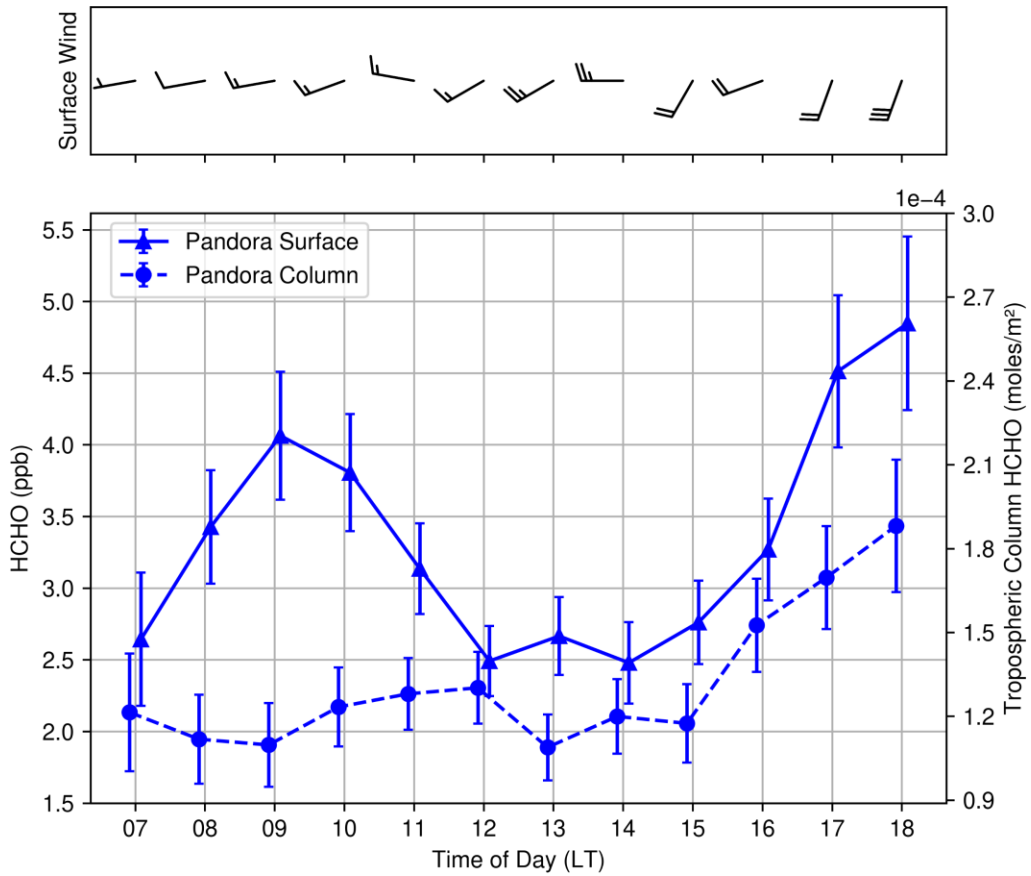
Powerful constraint on potential “cloud selection bias” from space

Model validation during traditionally “unobserved” satellite conditions

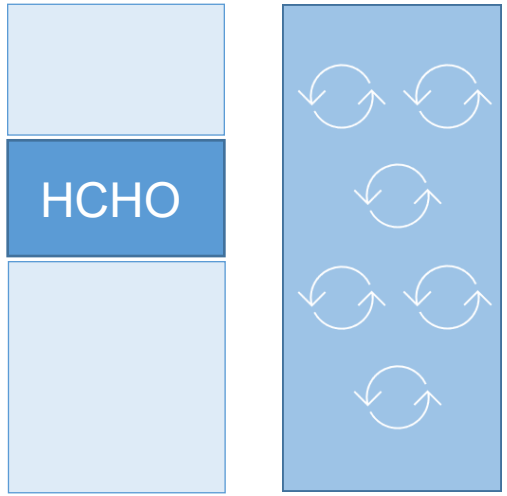
Understanding Local Diurnal Variability in HCHO



Observations from individual days often imply a localized HCHO enhancement aloft



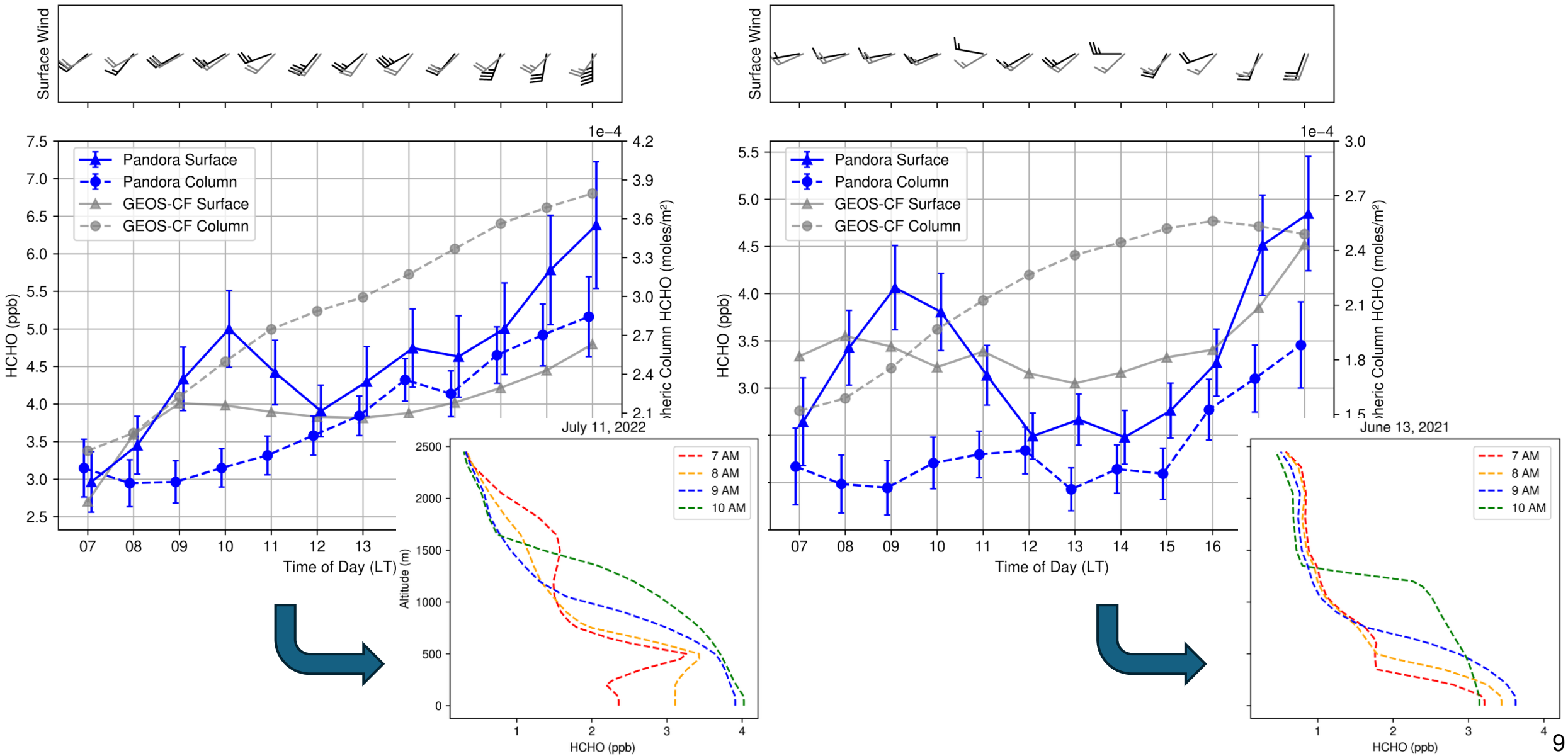
June 13, 2021



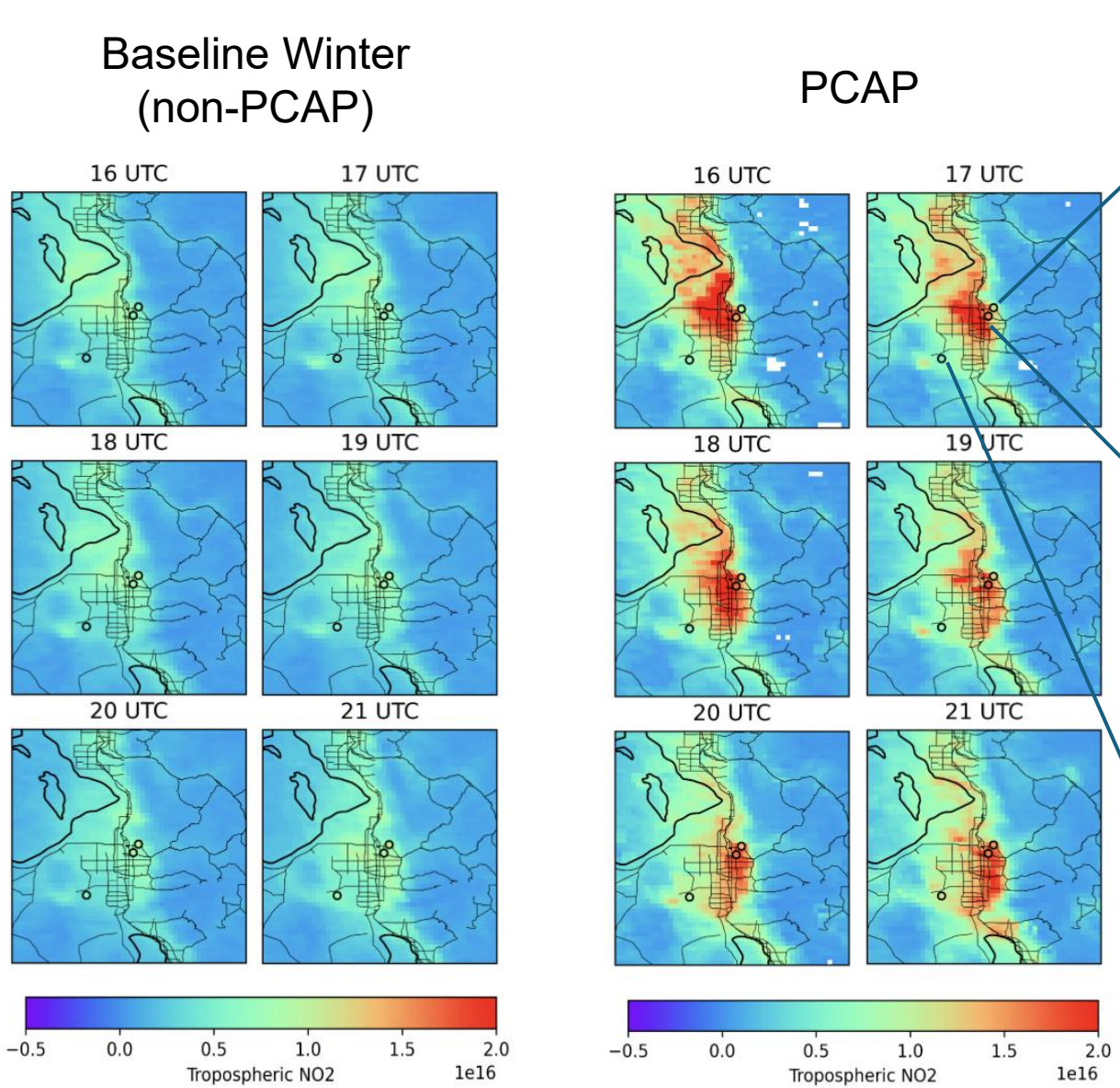
Expect this to be missed by TEMPO… (and potentially propagate errors in the retrieval)

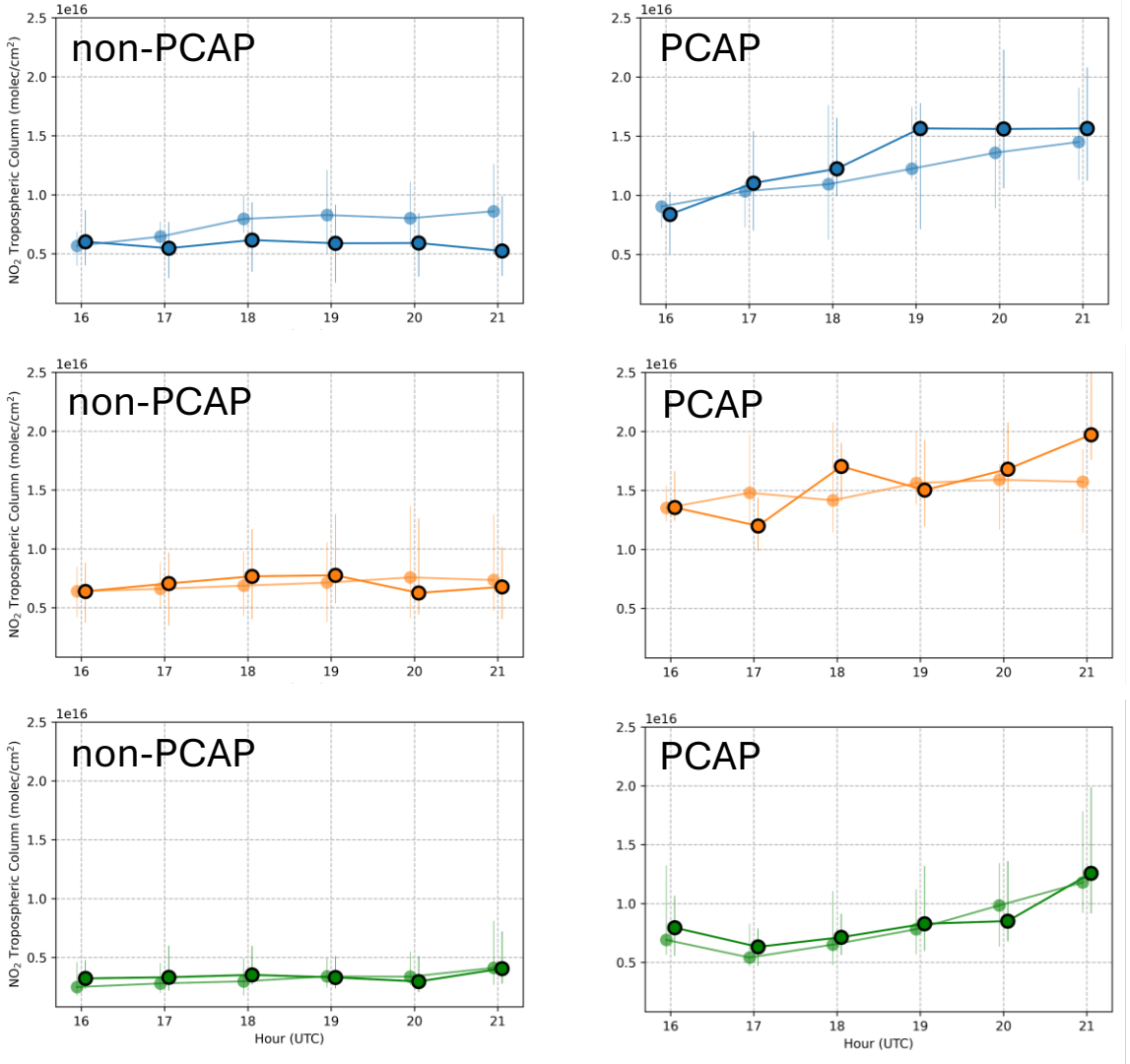
Naughton et al. (in prep)

Testing the Representation of these Dynamics in a Model (GEOS-CF)



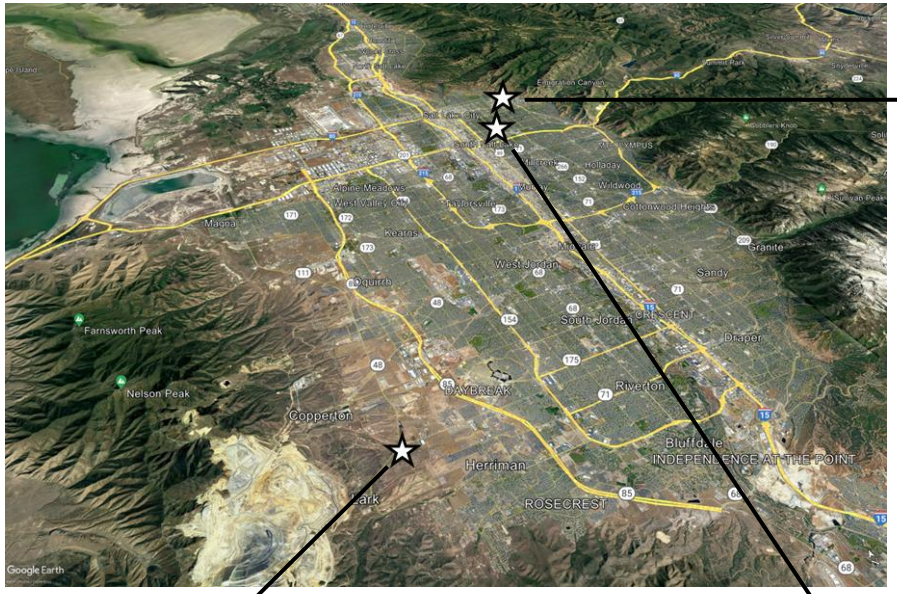
Cold Air Pooling Events in Salt Lake City

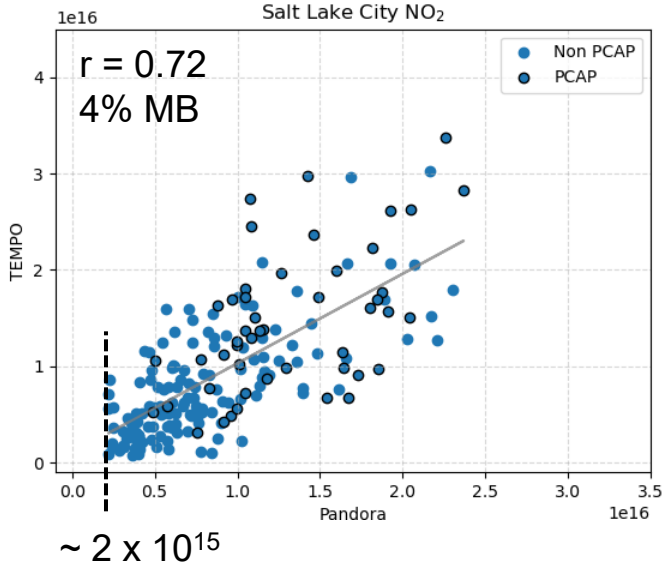


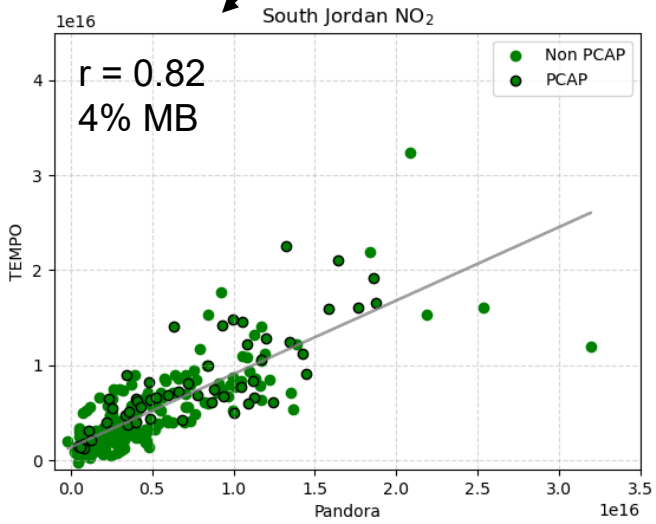


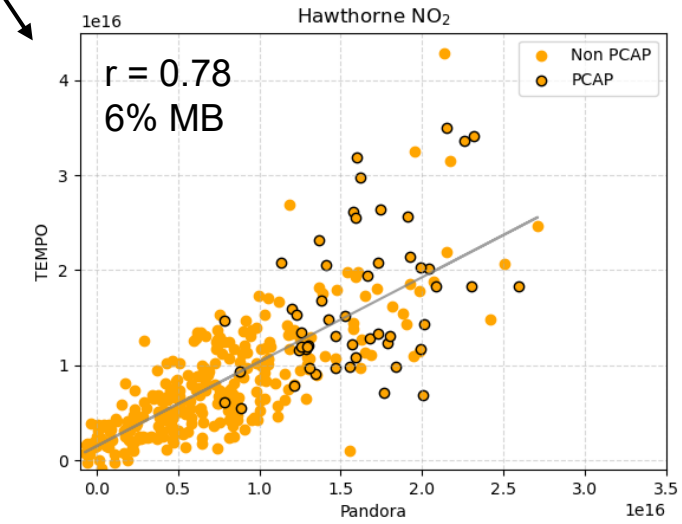
Barlett et al. (submitted)

Wintertime Evaluation of TEMPO Against Pandora NO_2









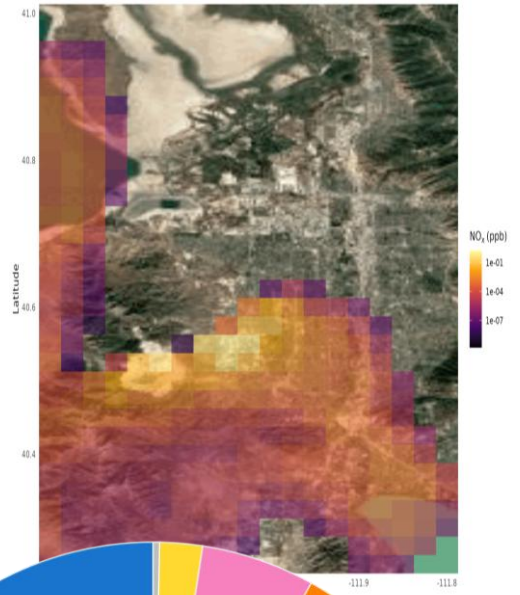
Offset in field reference spectrum?

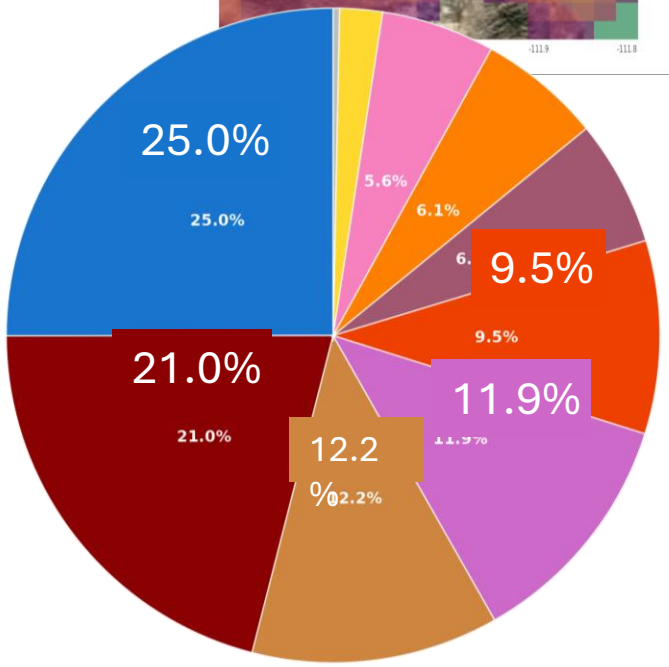
Two-way TEMPO-Pandora evaluation…

Barlett et al. (submitted)

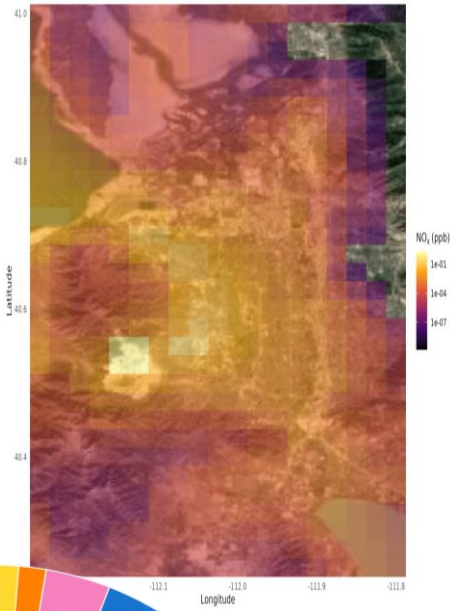
Constraining Salt Lake City NOx Emissions with Pandora- and TEMPO-STILT

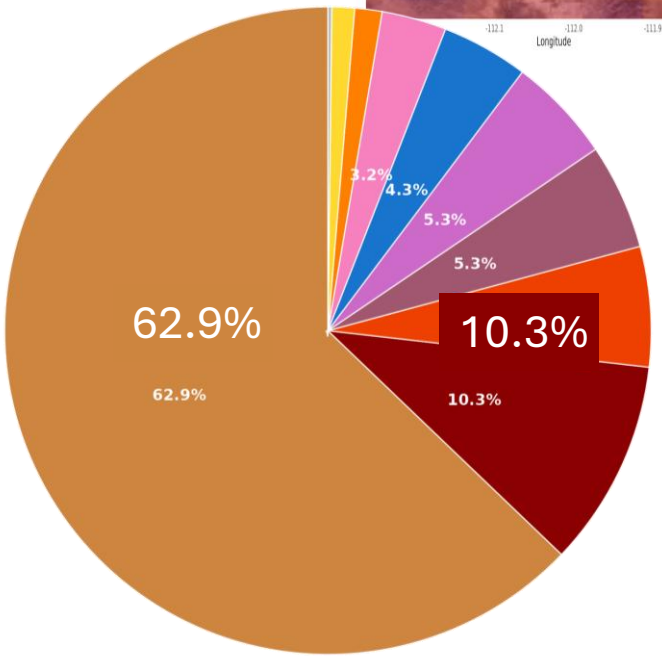
Friday July 1, 2022

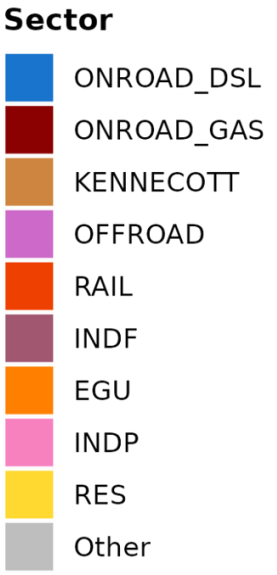




Sunday July 10, 2022

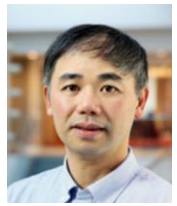


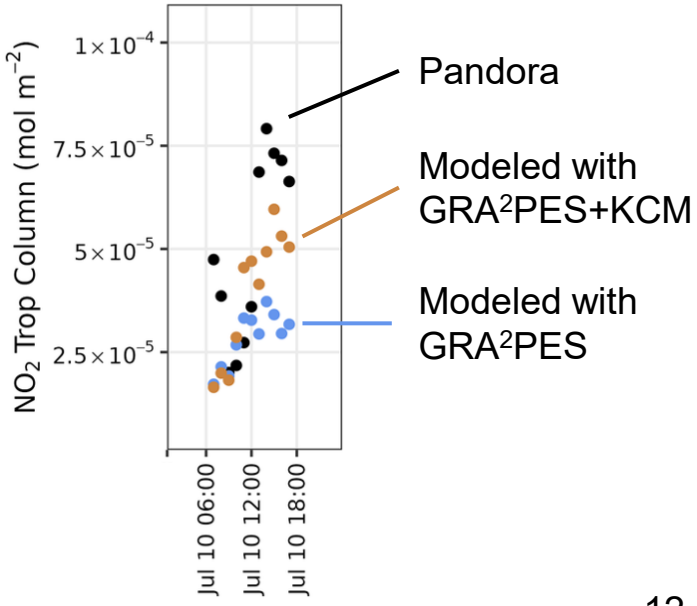




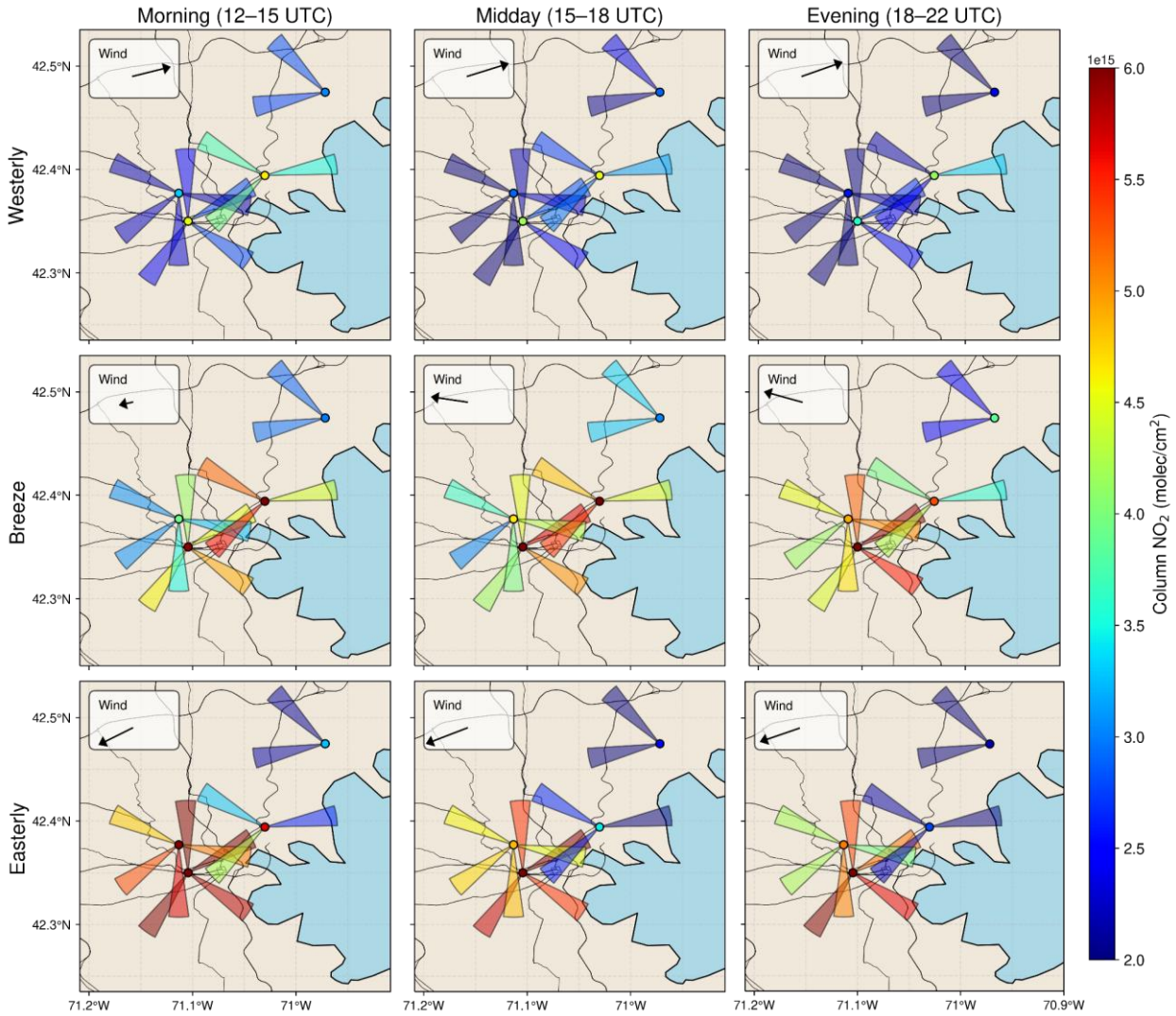
Haley Humble

John Lin





Thanks!


Morning (12–15 UTC)
Midday (15–18 UTC)
Evening (18–22 UTC)
Westerly
Breeze
Easterly
Wind
42.5°N
42.4°N
42.3°N
71.2°W
71.1°W
71°W
70.9°W
1e15
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
Column NO2 (molec/cm2)