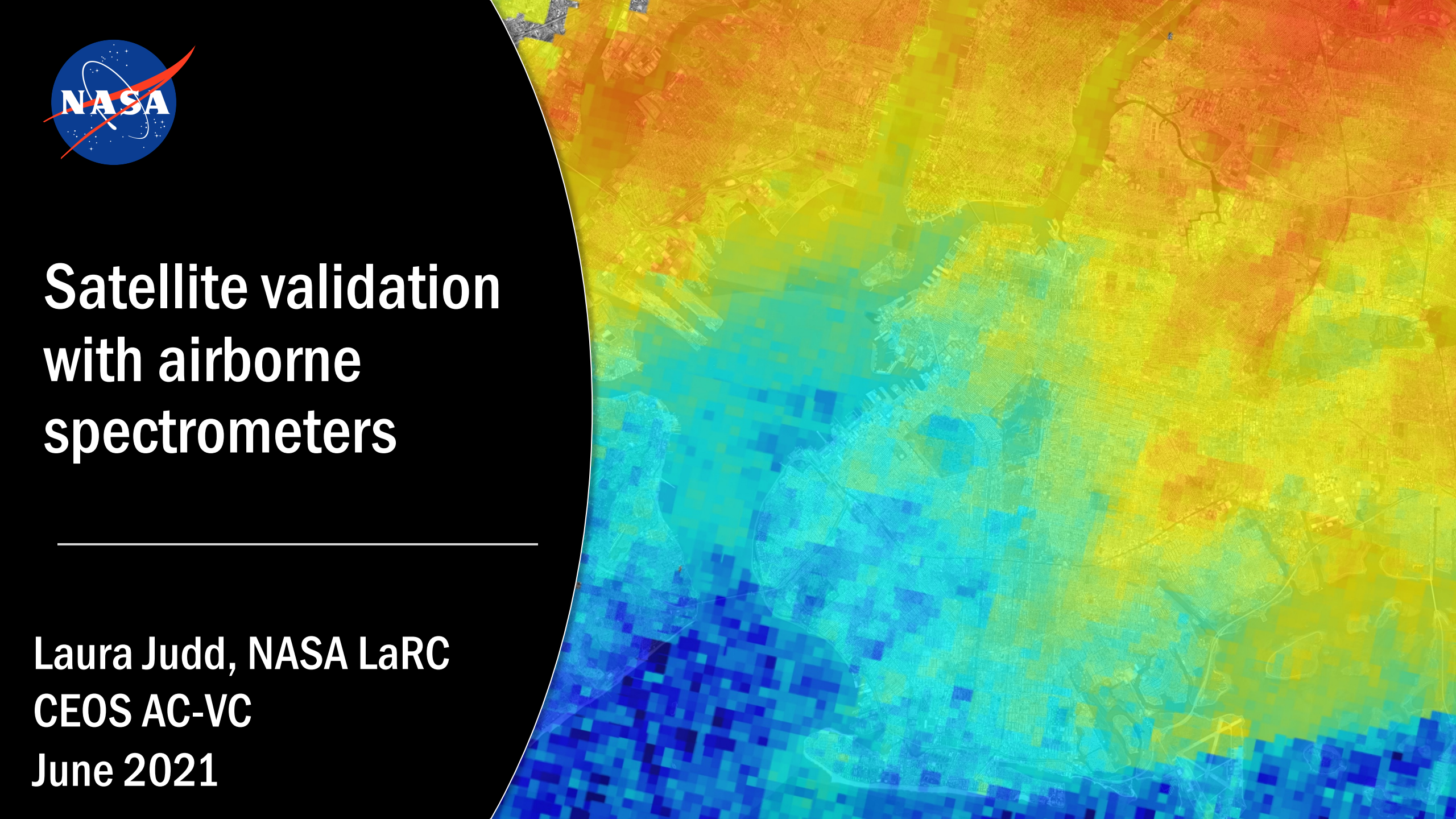


Satellite validation with airborne spectrometers

Laura Judd, NASA LaRC

CEOS AC-VC

June 2021

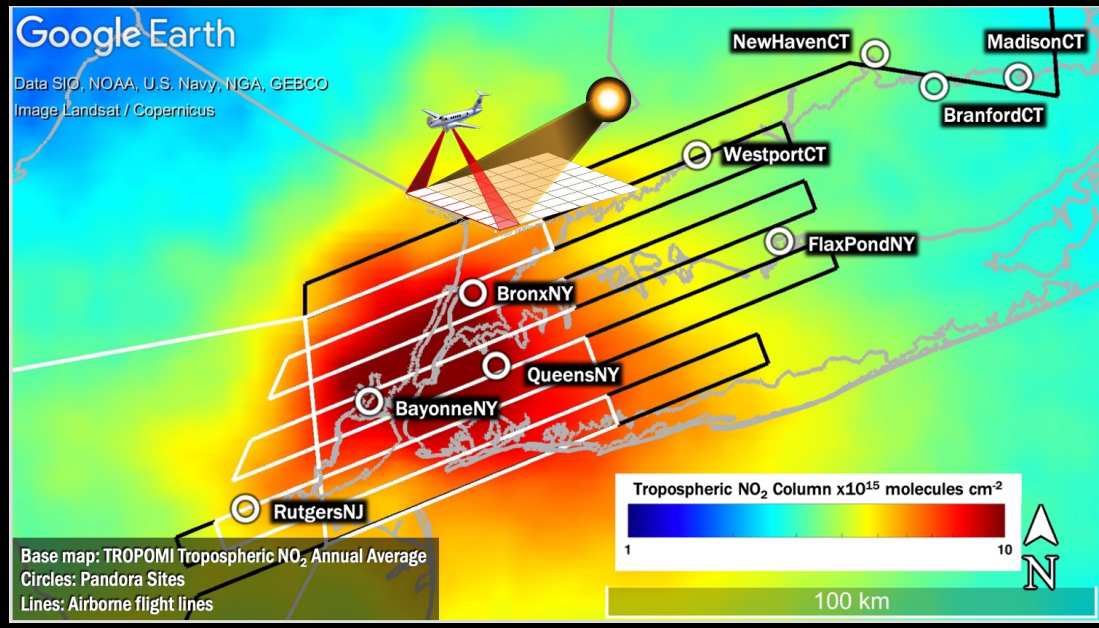
NASA GCAS/GeoTASO Airborne Spectrometer

Instrument PI:
Scott Janz, GSFC

- Primarily been used for preparatory measurements for geostationary air quality observations as well as emissions mapping
  - Heritage campaigns: DISCOVER-AQ, KORUS-AQ, GOES-R, LMOS, LISTOS, OWLETS, FIREX-AQ
- Observes from the bottom of an airplane with a field of view of ~7 km at a nominal altitude of 28,000 feet executing gapless mapping over areas of interest
- Measures spectra in the UV-VIS-(NIR) at high spectral and spatial resolution from which trace gas columns can be remotely retrieved (NO_2 and HCHO) (nominally 250 m x 250 m)

Retrieval Details: Only done for cloud free scenes – Fitting window is 425-460 nm

12 km NAM-CMAQ a priori- Troposphere (testing 0.25 deg. GEOS-CF)	TROPOMI daily bias corrected PRATMO Climatology- Stratosphere
Reflectivity: Land: MODIS BRDF Kernels (MCD43A1) Water: 3% Lambertian + Cox-Monk kernel	Reference Collected over Pandora



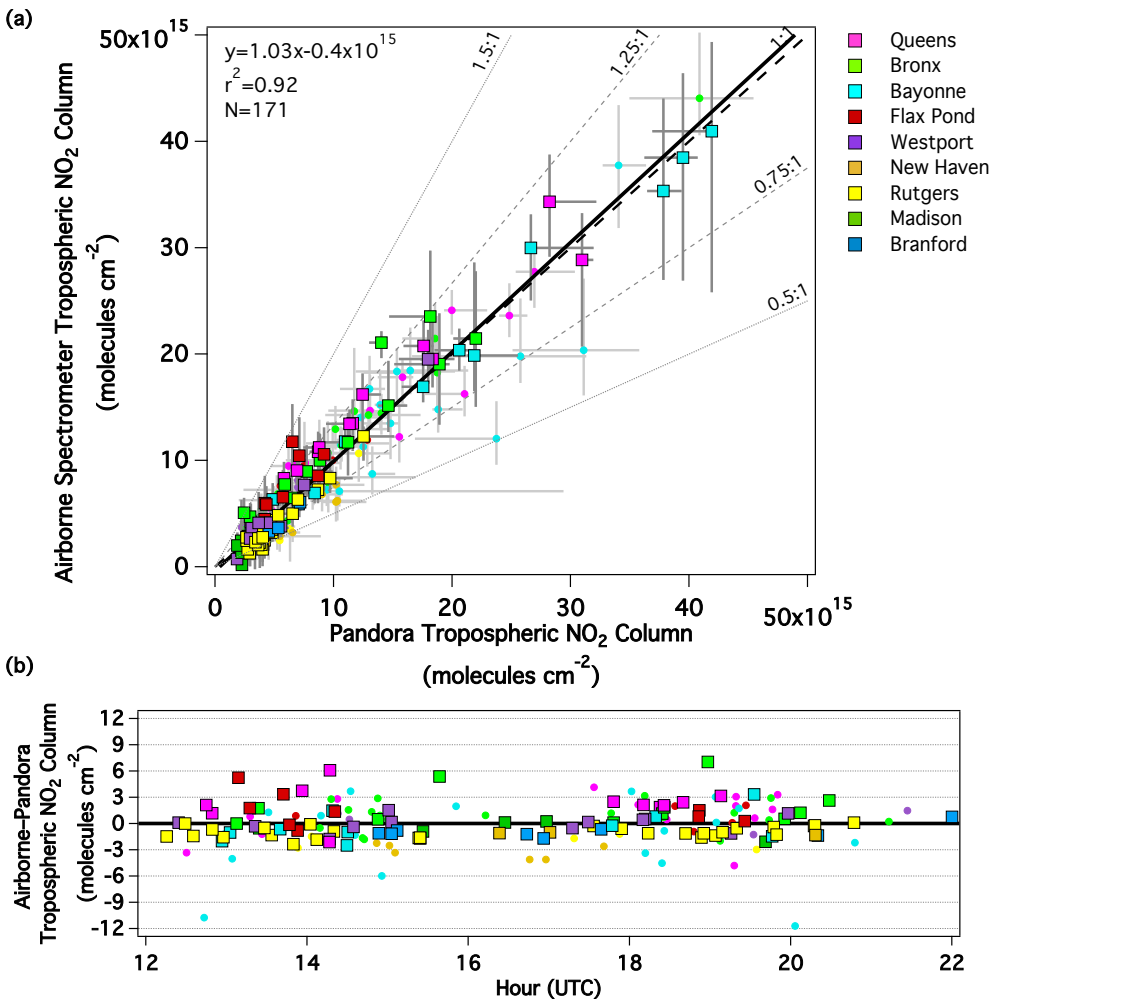
Sampling strategy for the airborne spectrometers operating in a push-broom configuration (adapted from Nowlan et al., 2016)

Some References:

Kowalewski & Janz, 2014: doi:10.1117/12.2062058
Leitch et al., 2014: doi: 10.1117/12.2063763
Nowlan et al., 2016: doi:10.5194/amt-9-2647-2016
Nowlan et al., 2018: doi:10.5194/amt-2018-156
Judd et al., 2019: doi: 10.5194/amt-12-6091-2019

All data available in the LISTOS and other field study archives

Airborne Spectrometer vs. Network of Pandoras



Coincidence Criteria

- Median airborne NO_2 Tropospheric Vertical Column (TrVC) within 750 m radius of Pandora location
- Temporally nearest Pandora observations (± max/min observation within 5 minutes of overpass)
- Pandora total VC is converted to TrVC by subtracting airborne-retrieval derived stratospheric column

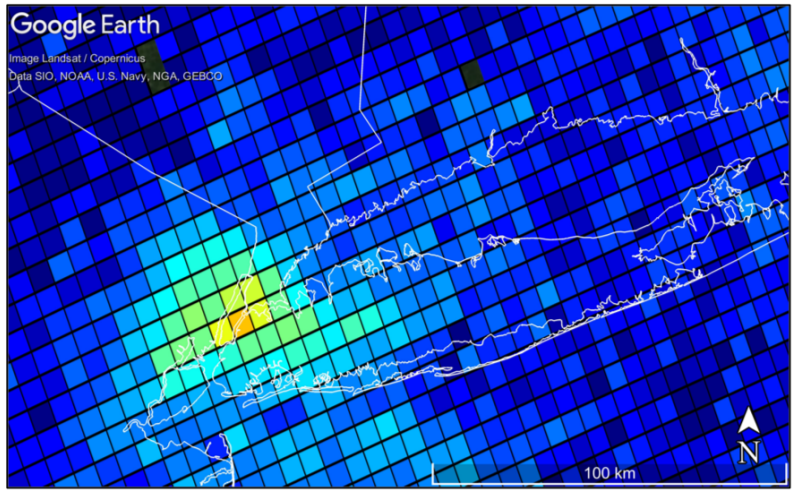
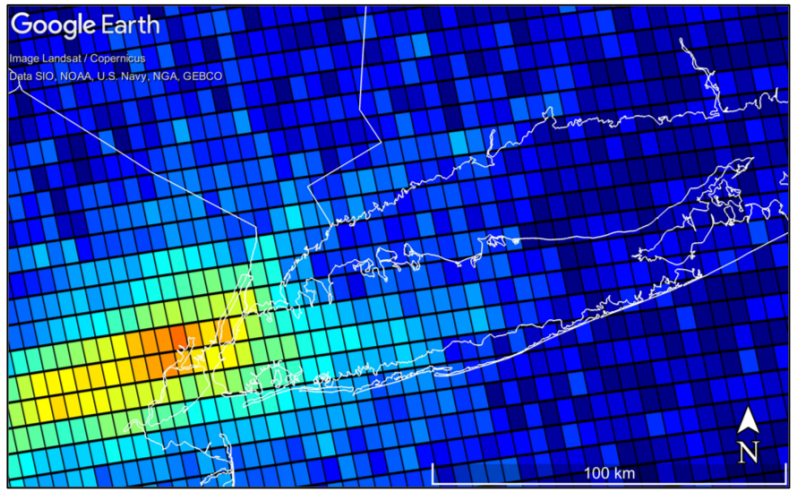
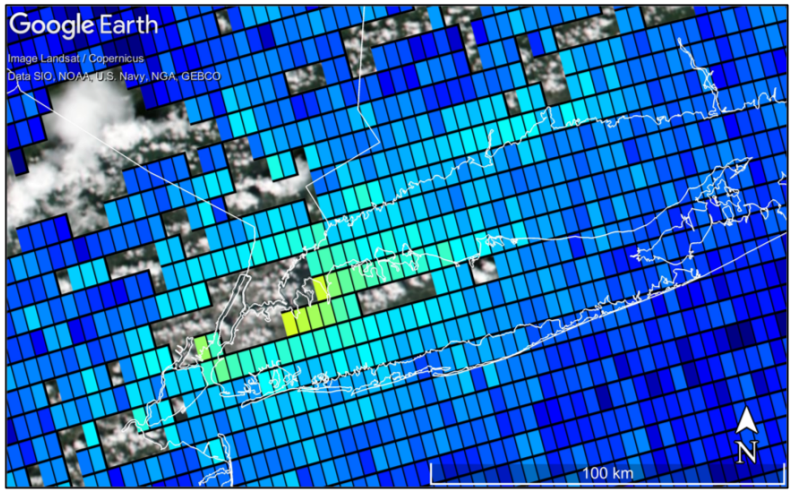
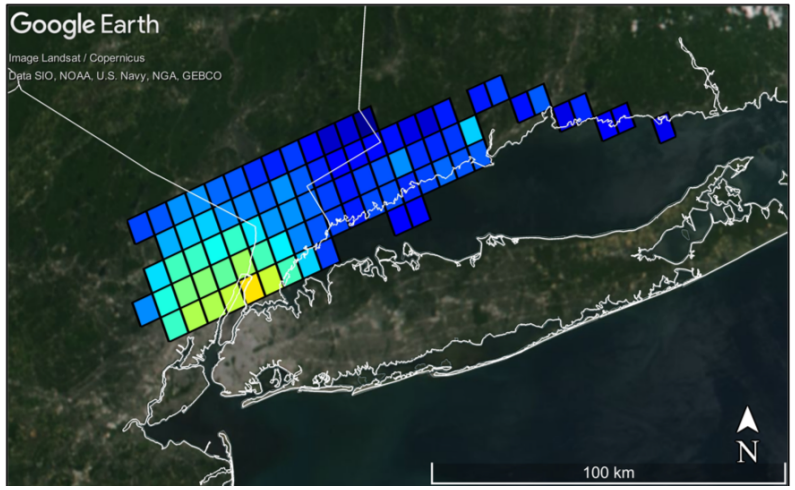
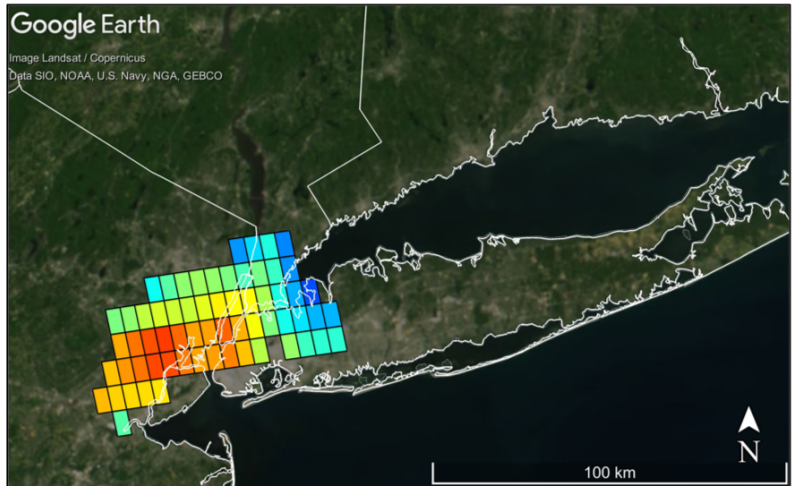
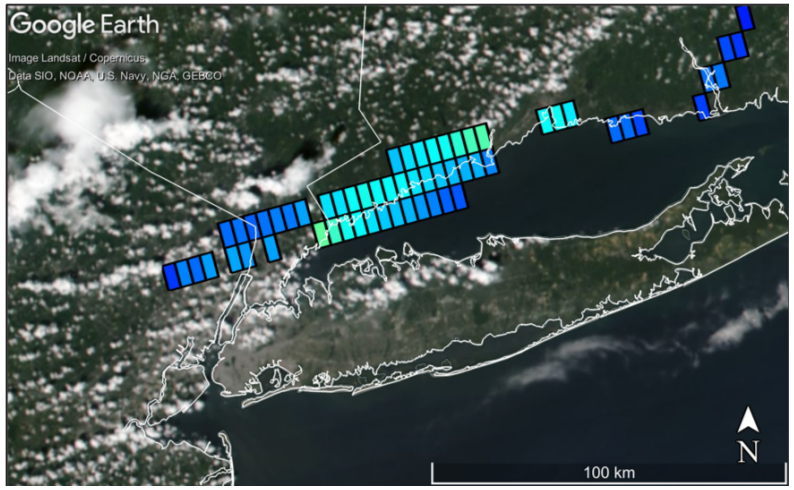
(see paper supplement for sensitivity analysis to this criteria)

Note: Squares in figures are coincidences where Pandora NO_2 columns are not varying more than 30% in a ± 15-minute window

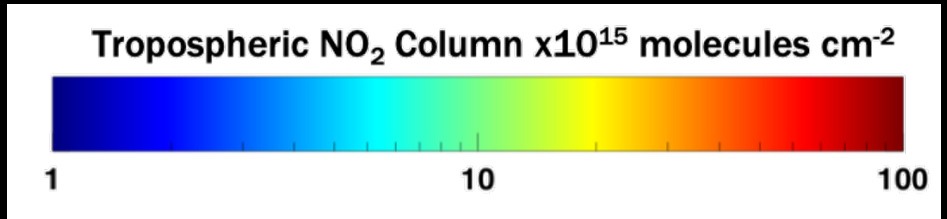
- There were 171 coincidences over 26 flights/13 days from June-Sept. 2018.
- Airborne and Pandora TrVCs are highly correlated with a slope near 1:1 and no obvious time of day impacts.
- Median percent difference of -1.2% with 95% of temporally stable points (squares) within ± 25 % or 0.1 DU

(a) Scatter plot showing the temporally closest Pandora TrVC to the aircraft overpass (± min/max observation within a ± 5-minute window from the aircraft overpass) vs. the median airborne TrVC (±10th-90th percentile) within a 750 m radius of the Pandora site. The thick solid black line represents the RMA linear regression. Each point is colored by Pandora location where the outlined squares are points where Pandora TrVCs do not vary more than 30% within a ± 15-minute window from the aircraft overpass, whereas the circles indicate times where Pandora TrVCs do vary more than 30%. (b) The difference between airborne and Pandora tropospheric NO_2 columns vs. time of day in hours (UTC) colored similarly to (a).

TROPOMI CRF < 50% and airborne data within a ± 30-minute from overpass and area mapped > 75%

	30 June 2018	19 July 2018	06 September 2018
TROPOMI Tropospheric NO_2			
TROPOMI Scale Airborne Pixels			

Airborne v. TROPOMI



Slant-to-slant:

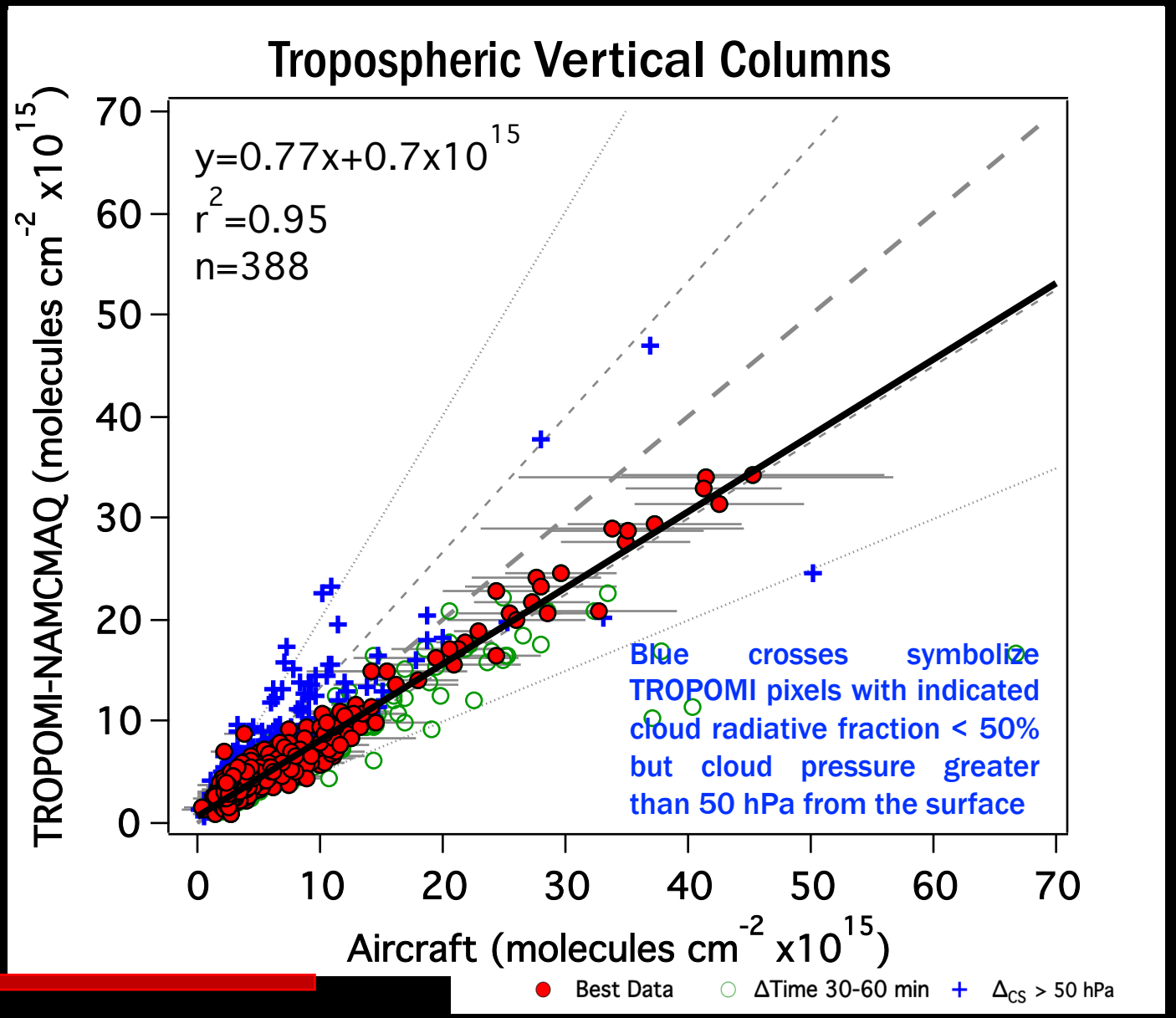
- Very high correlation indicating that satellite and aircraft are sampling largely similar slant columns (at least near the surface where most of the pollution is located)
- Correlation drops when the temporal window is opened from ± 30 to ± 60 minutes (r^2=0.91)

Vertical-to-vertical:

- Slope improves (expected) it though appears that TROPOMI is biased low in comparison to the airborne TrVC data
  (Median percent bias of -19%).
- Bias partially attributed to the a priori profile resolution in the TROPOMI retrieval (1º x 1º)

Vertical-to-vertical with NAMCMAQ 12 km analysis"

- Percent bias improves to -7%
- *Remainder of the bias: ?albedo impacts?*
- Outliers related to cloud pressure height seem to become important when higher resolution data is used (all stats are in manuscript)

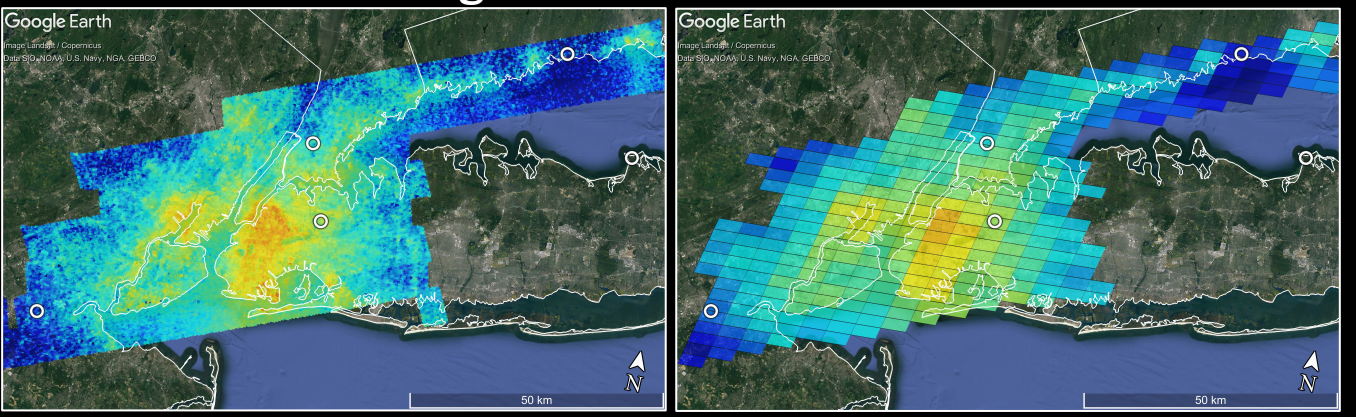


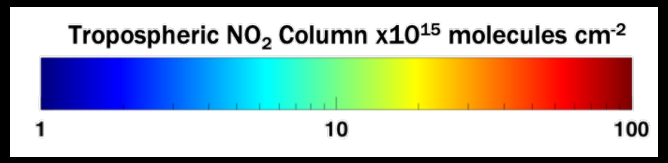
Airborne v. TROPOMI

Unless noted: Stats are applied to red points
Ignore blue points for now.

How could Pandora comparisons to TEMPO look?

24 August 2018: 4 raster animation

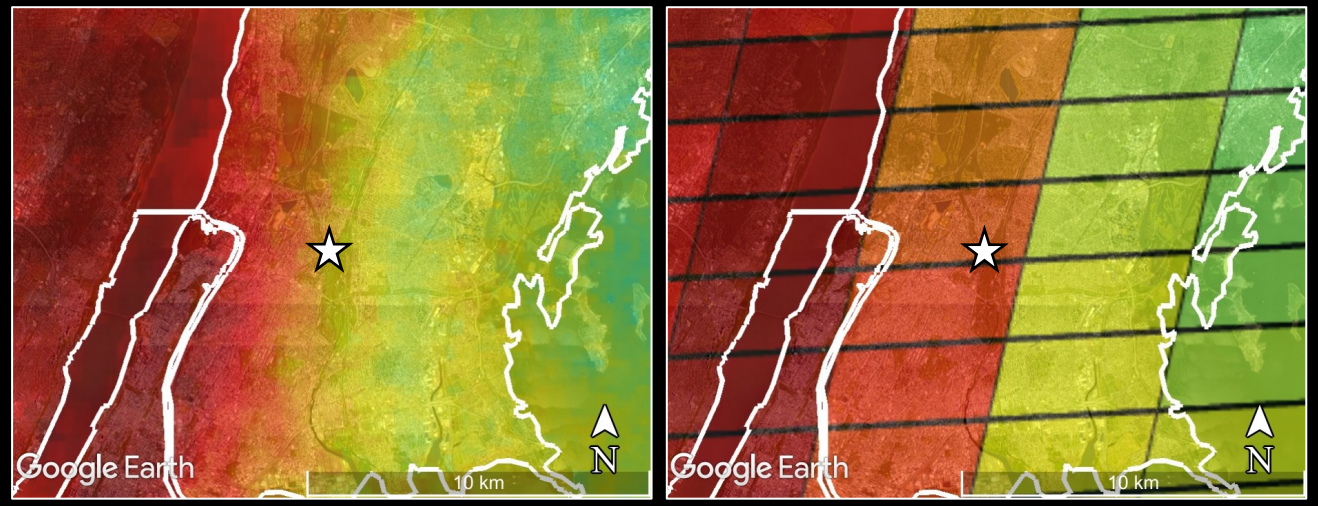


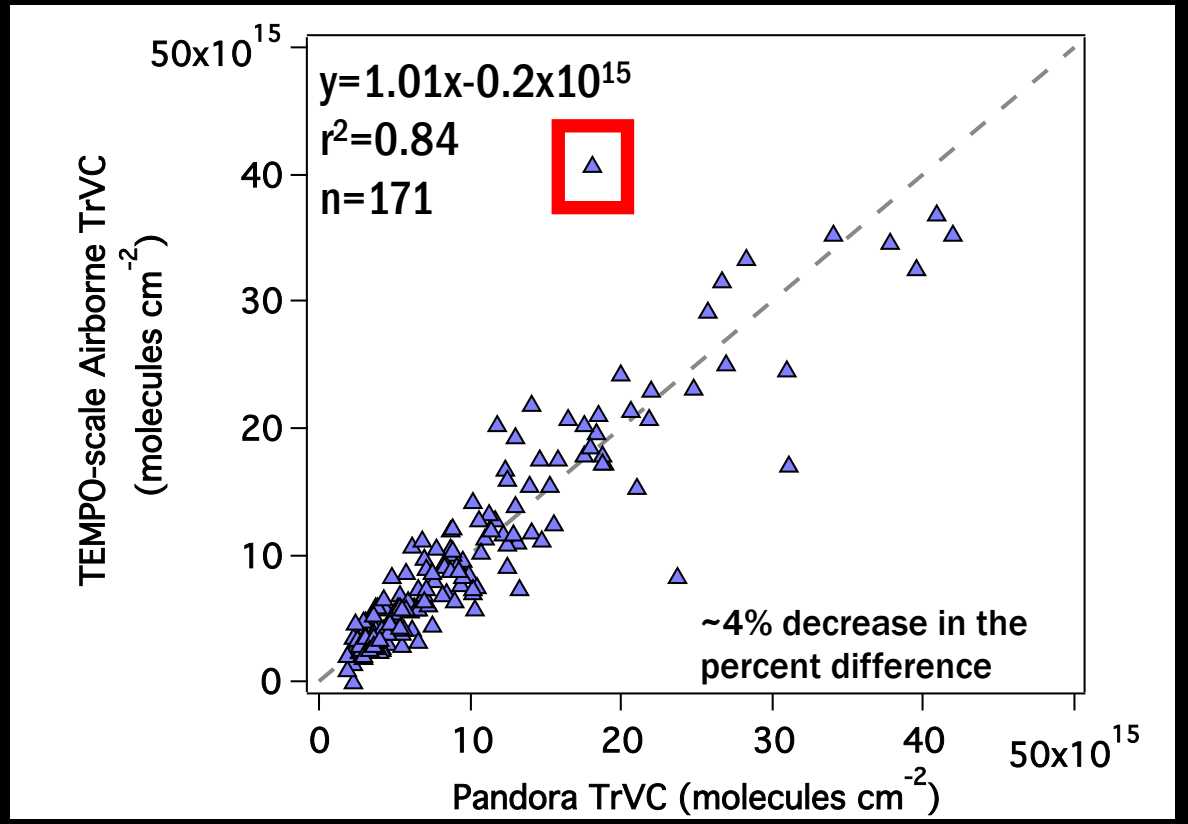


Re-gridded airborne data to the TEMPO FOR

TEMPO FOR data courtesy of Xiong Liu, SAO

Bronx Pandora: July 2nd AM



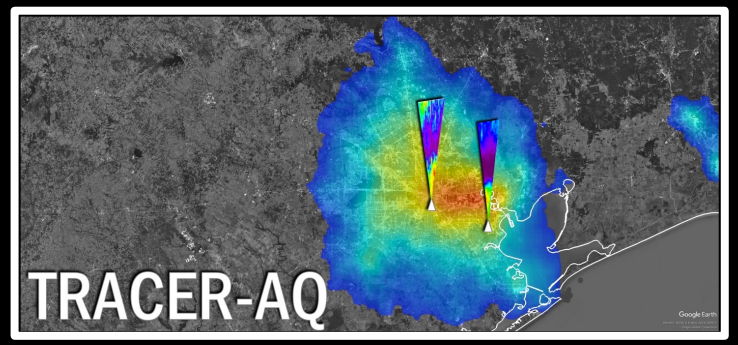


Two Challenges

1. Spatial heterogeneity: Less of an issue than before but still can lead to mis-matches in areas with strong gradients
2. Temporal heterogeneity: the high temporal resolution of Pandora and the hourly measurements from TEMPO could help in identifying large changes over the hour time-frame

Looking ahead toward future/current field work

TRACER-AQ is a parallel field study to the DOE-led TRACER (researching cloud/aerosol microphysics) which will focus on air quality measurements in Houston, TX. Includes partners from TCEQ, academic institutions, and other federal agencies.



Co-led by John Sullivan, GSFC and Laura Judd, LaRC

NASA Assets involved Sept. 2021:

NASA JSC GV: GCAS + HSRL2-DIAL

Ground: 3 TOLNet lidars + multiple Pandoras + MPL

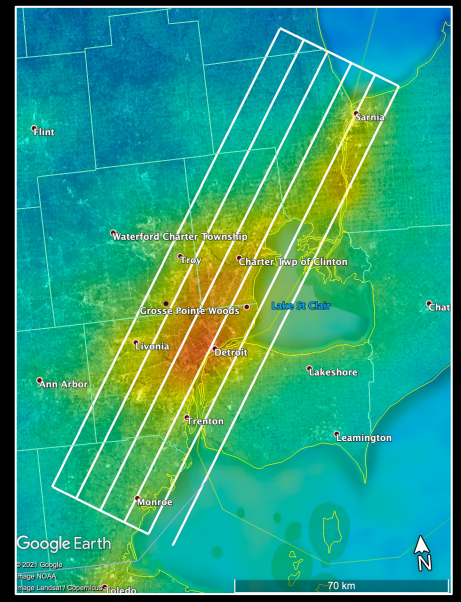
GMAO GEOS-CF Model for forecasting and analysis

MOOSE

GCAS will also be mapping over the Michigan/Ontario over nominally 6 flight days.

First flight was on Saturday!

First potential opportunity to fly on a Gulfstream jet
(LaRC G-III).

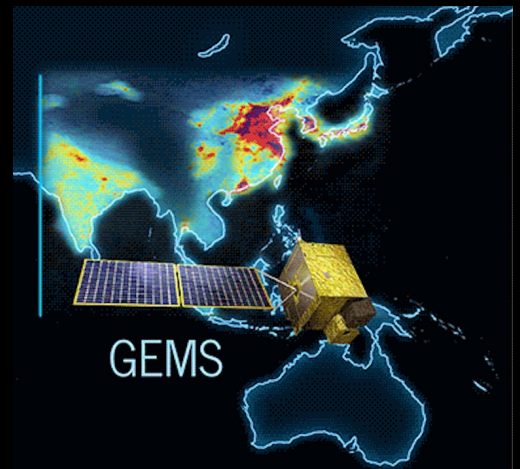


Images show the average TROPOMI NO_2 + our flight plan
April 2018-March 2019 (source: Eskes/KNMI)

GEMS Validation Team – dawn of the geostationary era!

NASA plans to loan GCAS to NIER to support validation data collection flights

Initially planned for November 2020—aiming instead for fall 2021





Thanks for listening!

Laura.m.judd@nasa.gov

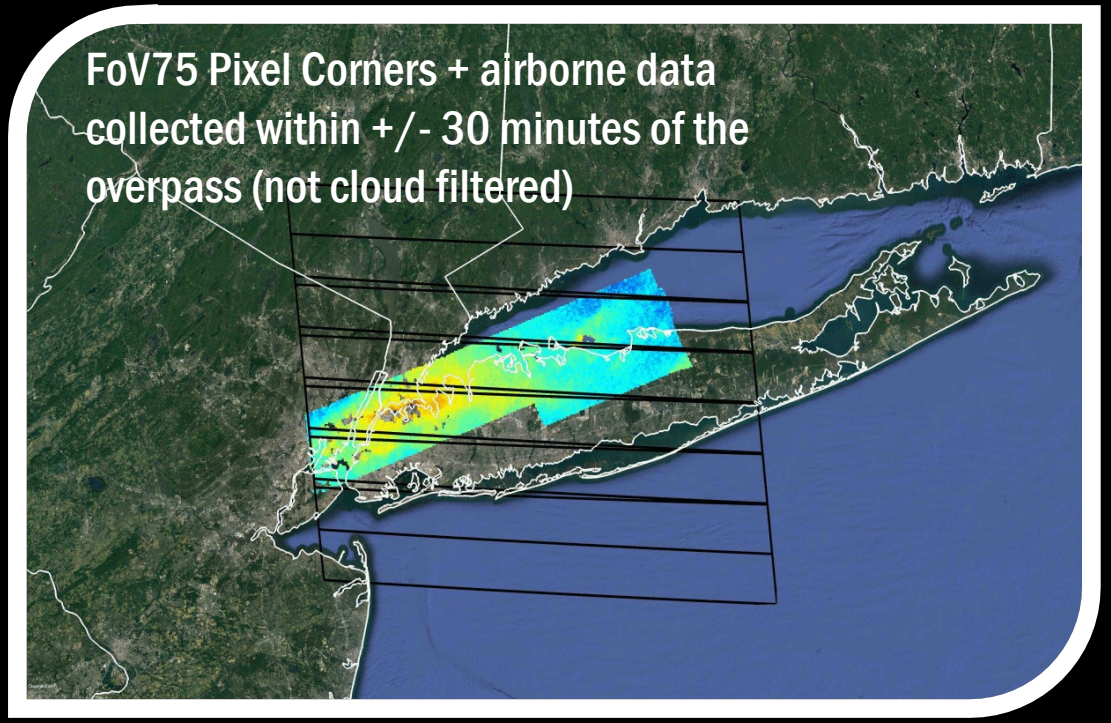
Backup Slides

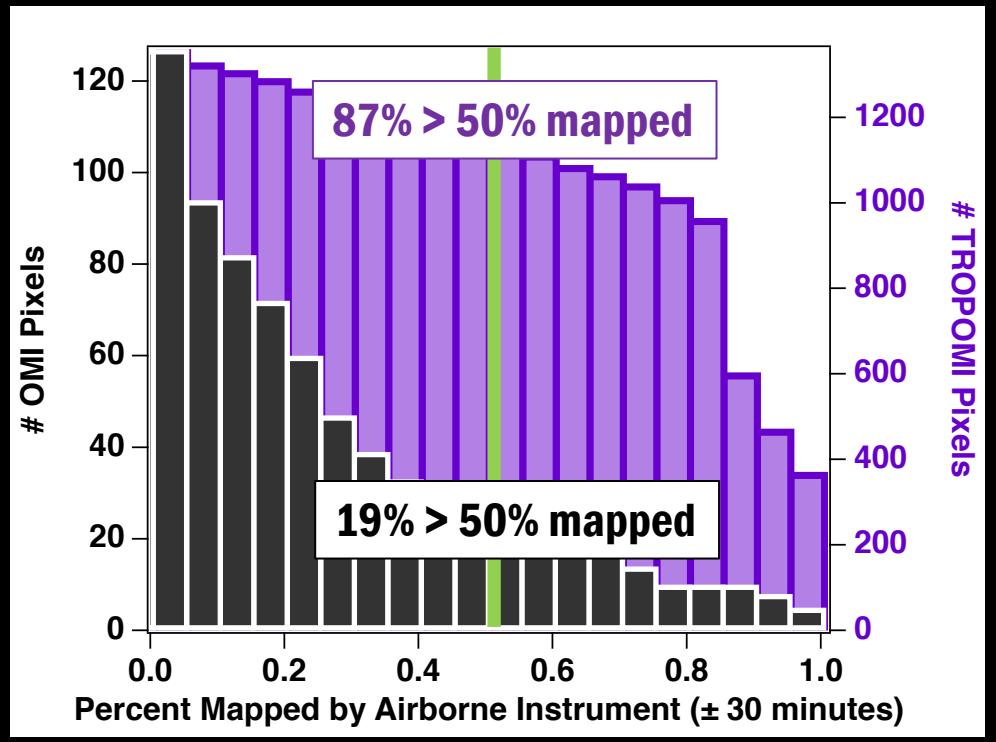
Airborne v. OMI V4 L2 NO_2

Preliminary Results!

More of a challenge due to the much larger pixel size of OMI.

However, LISTOS was the largest single raster dataset from airborne spectrometers to date (as far as I know…)



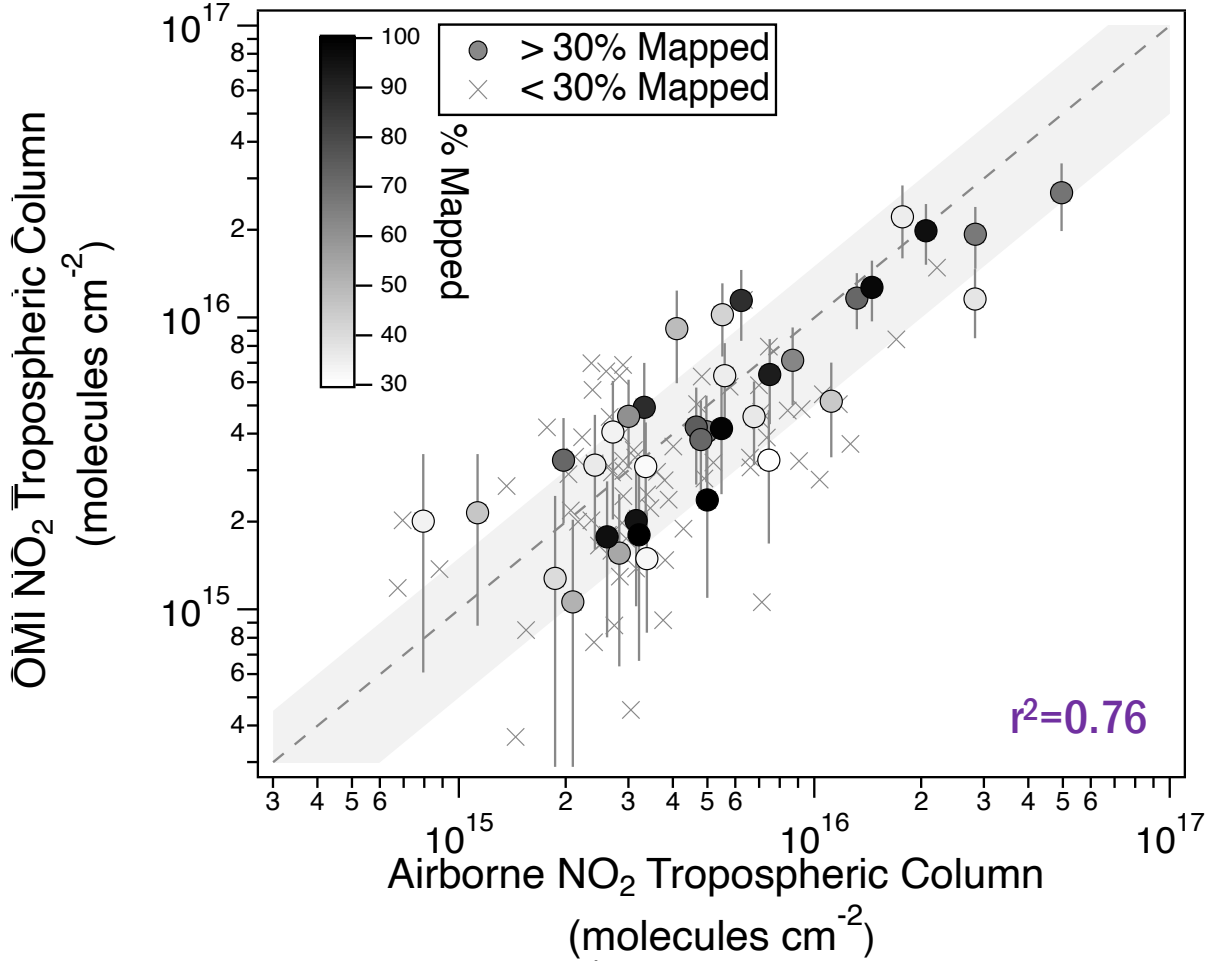


OMI:
- 14 overpasses
- 9 days
- 128 pixels

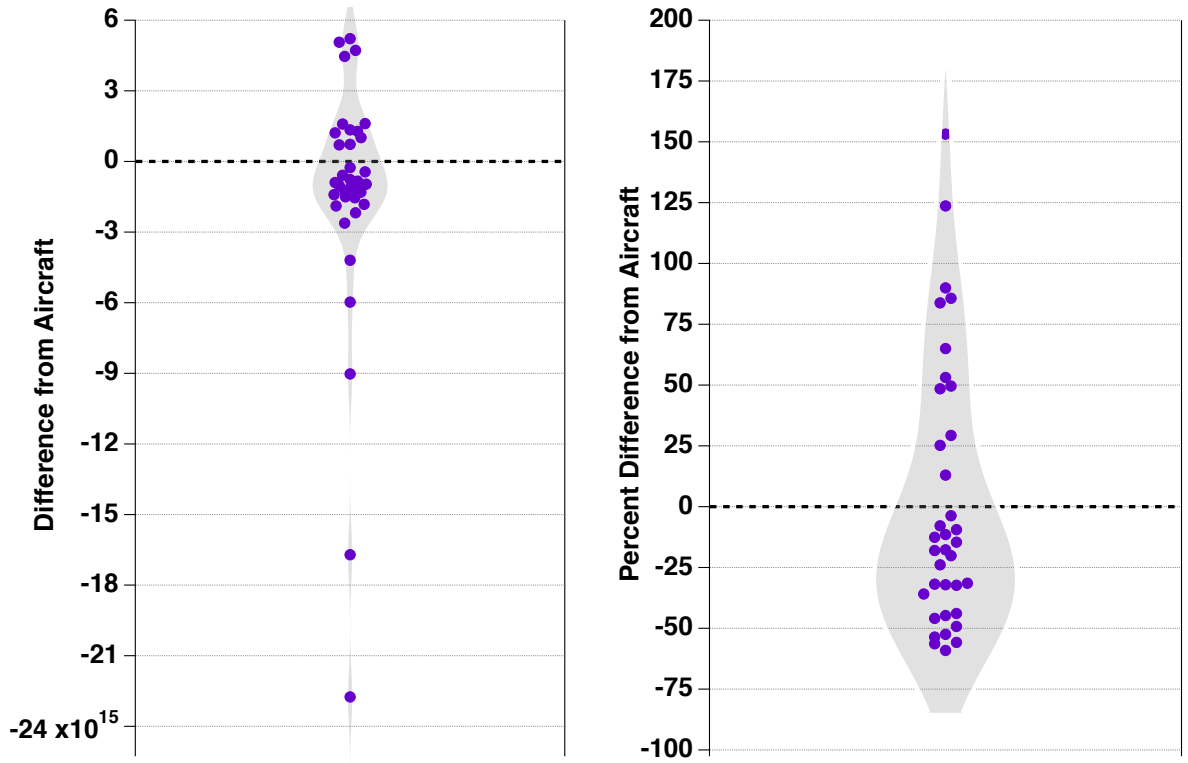
TROPOMI:
- 15 overpasses
- 12 days
- 1361 pixels

Airborne v. OMI V4 NO_2

Preliminary Results!



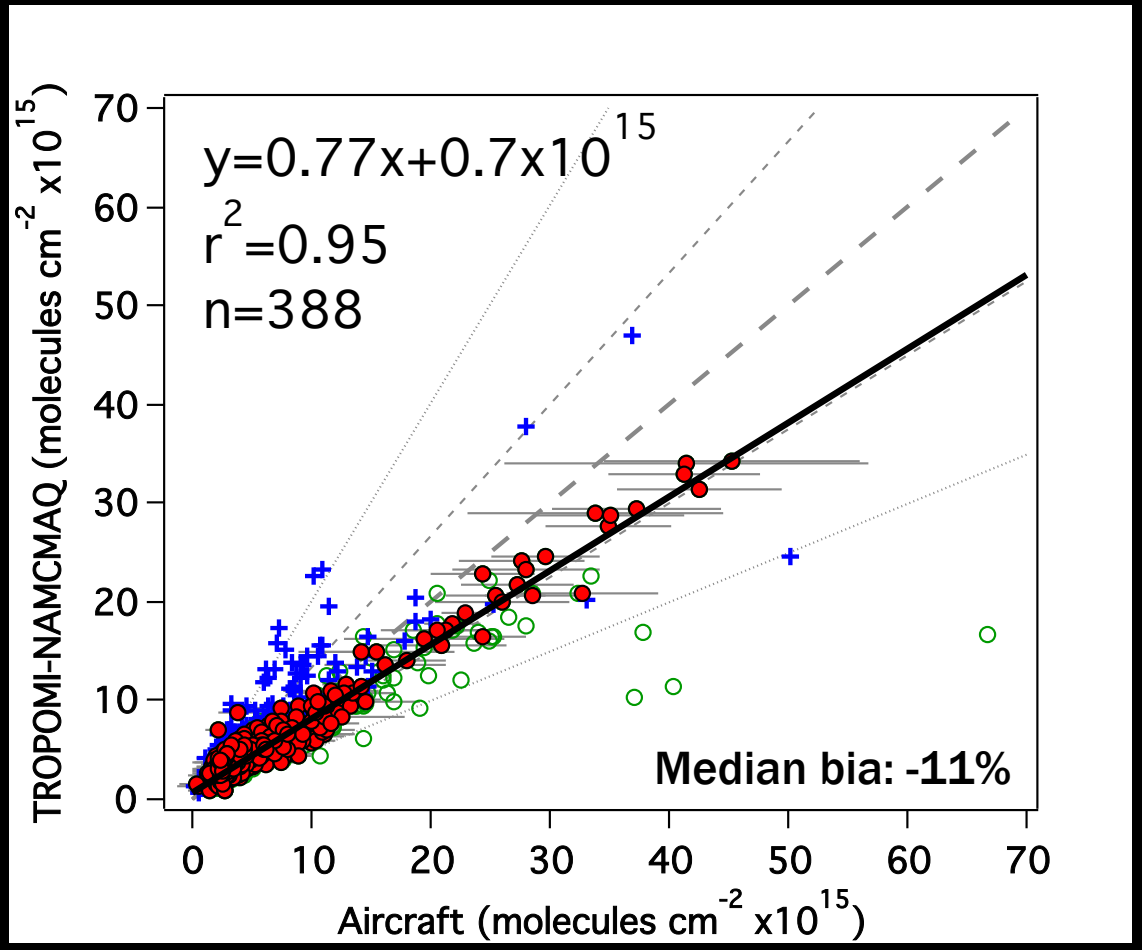
For points at least 30% mapped with CRF < 50%



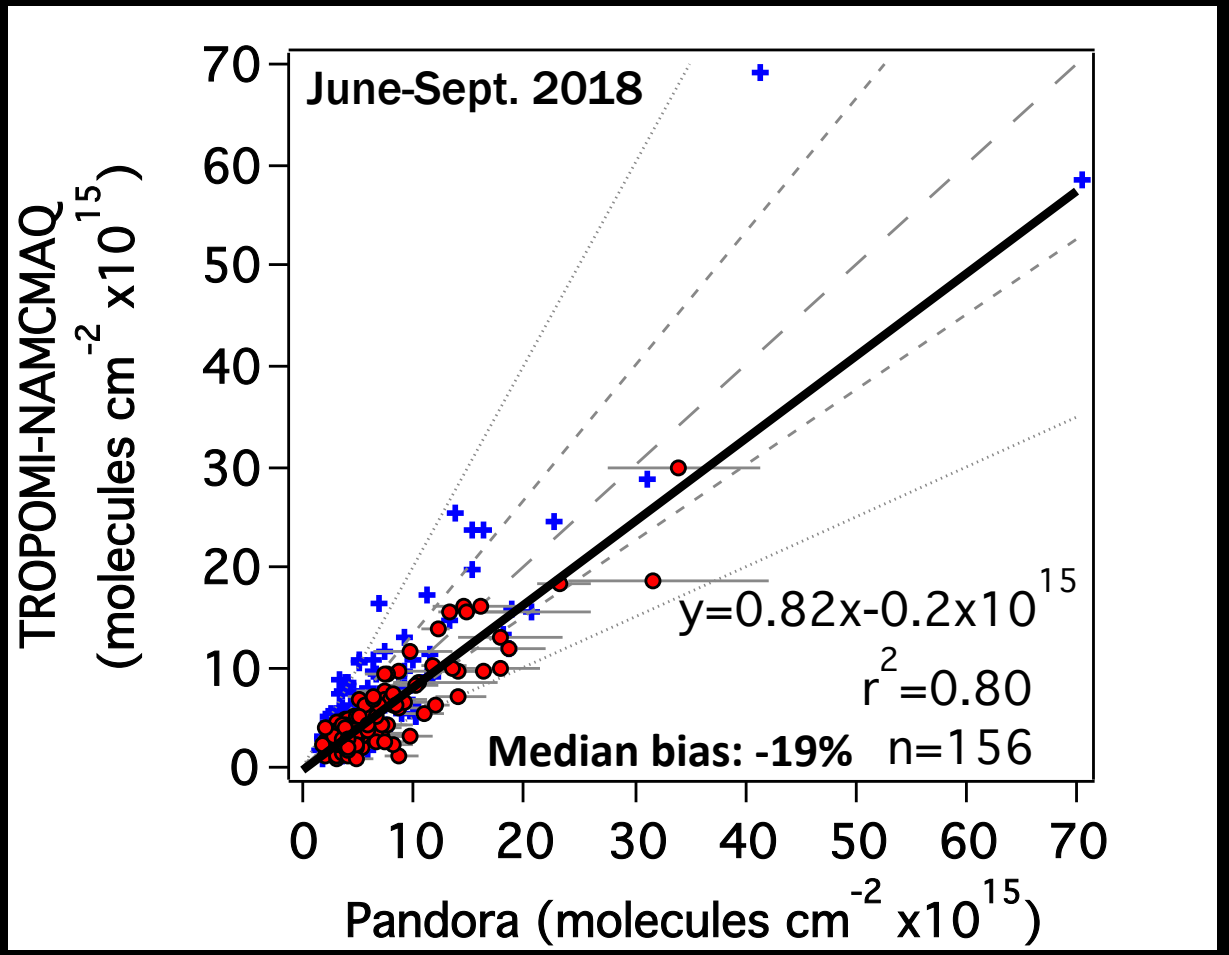
Not shown: I did recalculate the OMI tropospheric AMF using the 12 km NAM-CMAQ a priori.
This improved comparisons above 20×10^{15} molecules cm^{-2} but led to a high bias in lower polluted points.
Largely, may be artifact of lack of pixel sampling toward urban environments.

Airborne v. Pandora v. TROPOMI

Results between Pandora and airborne spectrometer comparison to TROPOMI are similar.



Airborne spectrometers are only deployed for short periods of time, but their observations are more spatially representative of the satellite measurements with the added capability of retrieving at subpixel resolutions.



Pandora spectrometer have the benefit of being systematically placed and collect data over a long time period though may be more impacted by spatial heterogeneity in areas subject to variability.

How will an analysis like this look for TEMPO?