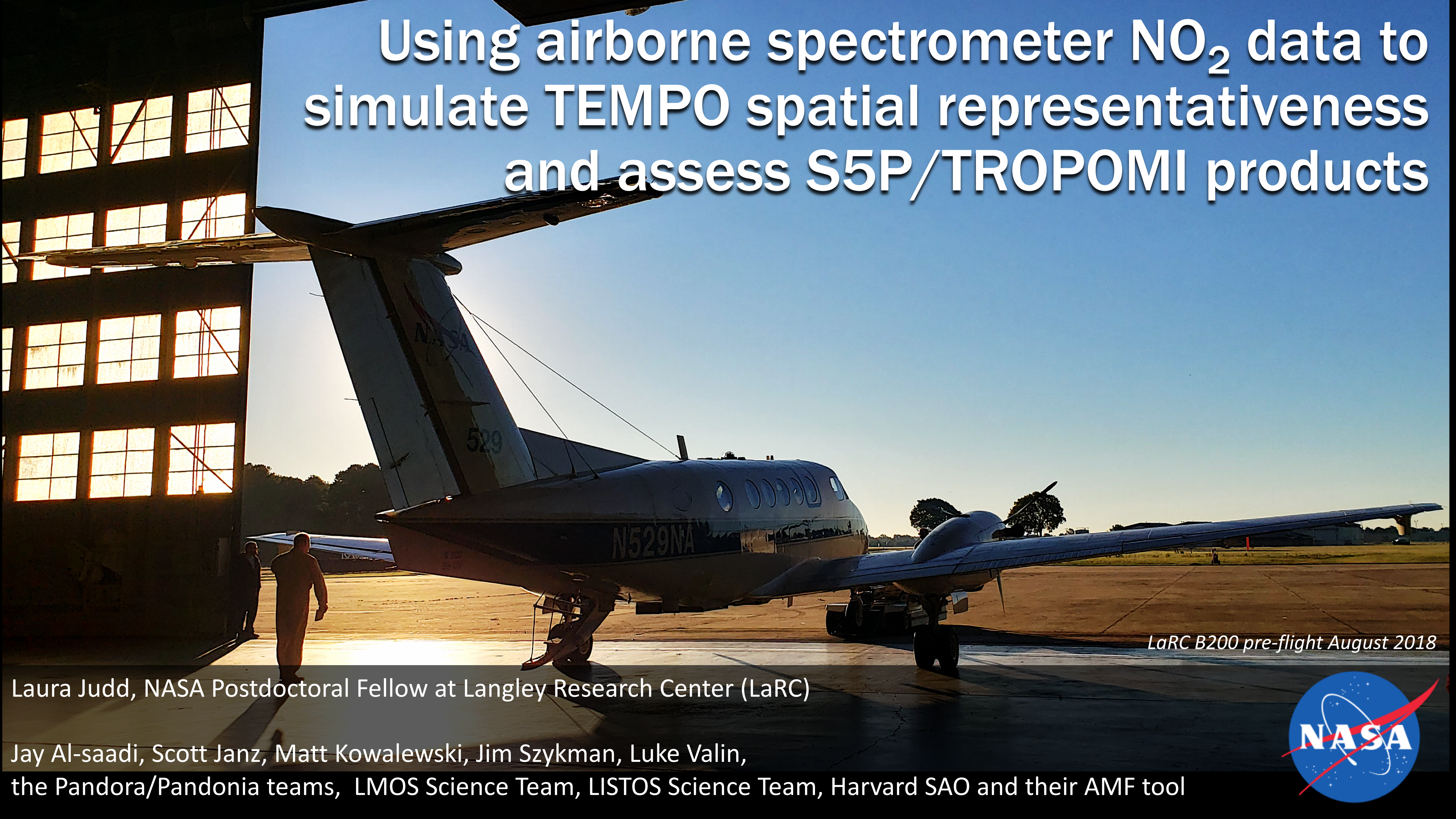
Using airborne spectrometer NO_2 data to simulate TEMPO spatial representativeness and assess S5P/TROPOMI products



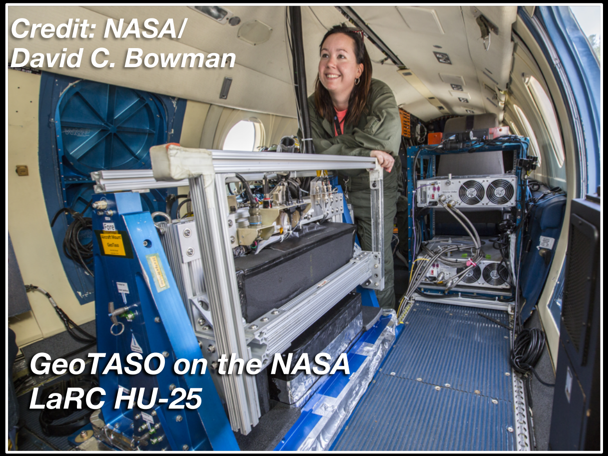
LaRC B200 pre-flight August 2018

Laura Judd, NASA Postdoctoral Fellow at Langley Research Center (LaRC)

Jay Al-saadi, Scott Janz, Matt Kowalewski, Jim Szykman, Luke Valin,
the Pandora/Pandonia teams, LMOS Science Team, LISTOS Science Team, Harvard SAO and their AMF tool

Airborne Mapping Spectrometers: LaRC/GSFC Partnership

Scott Janz, NASA GSFC Instrument PI; LaRC Aircraft and Science

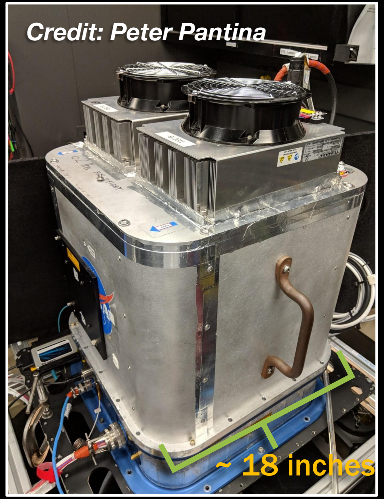


GeoTASO

- Geostationary Trace gas and Aerosol Sensor Optimization
- Flown during all Studies
- UV-VIS
- Large—300+lbs

GCAS

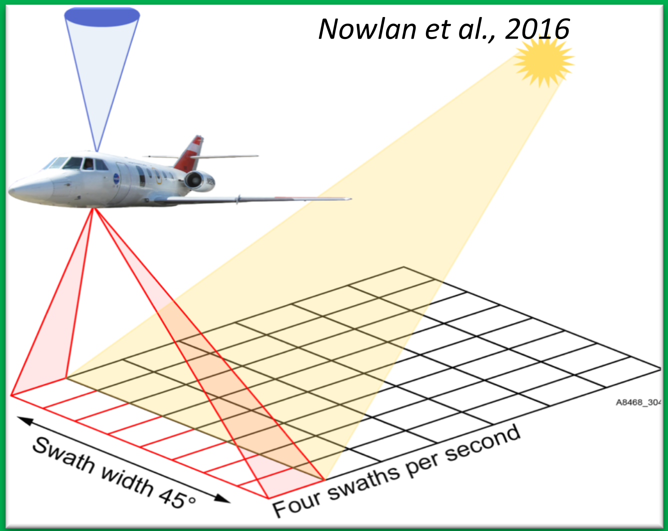
- GEOCAPE Airborne Spectrometer
- Flown during LISTOS
- UV-VIS-NIR
- Small— ~100 lbs
- Co-located with HALO



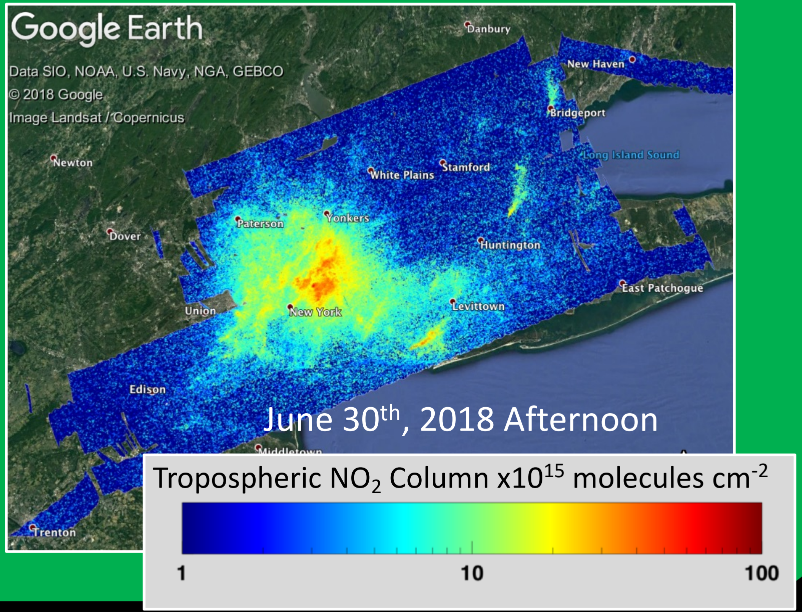
Used to improve and validate retrievals for future geostationary observations of air quality (e.g. TEMPO)

Both operate in a push-broom mode recording high spectral resolution visible spectra for NO_2 retrievals at ~250 x 250 m resolution

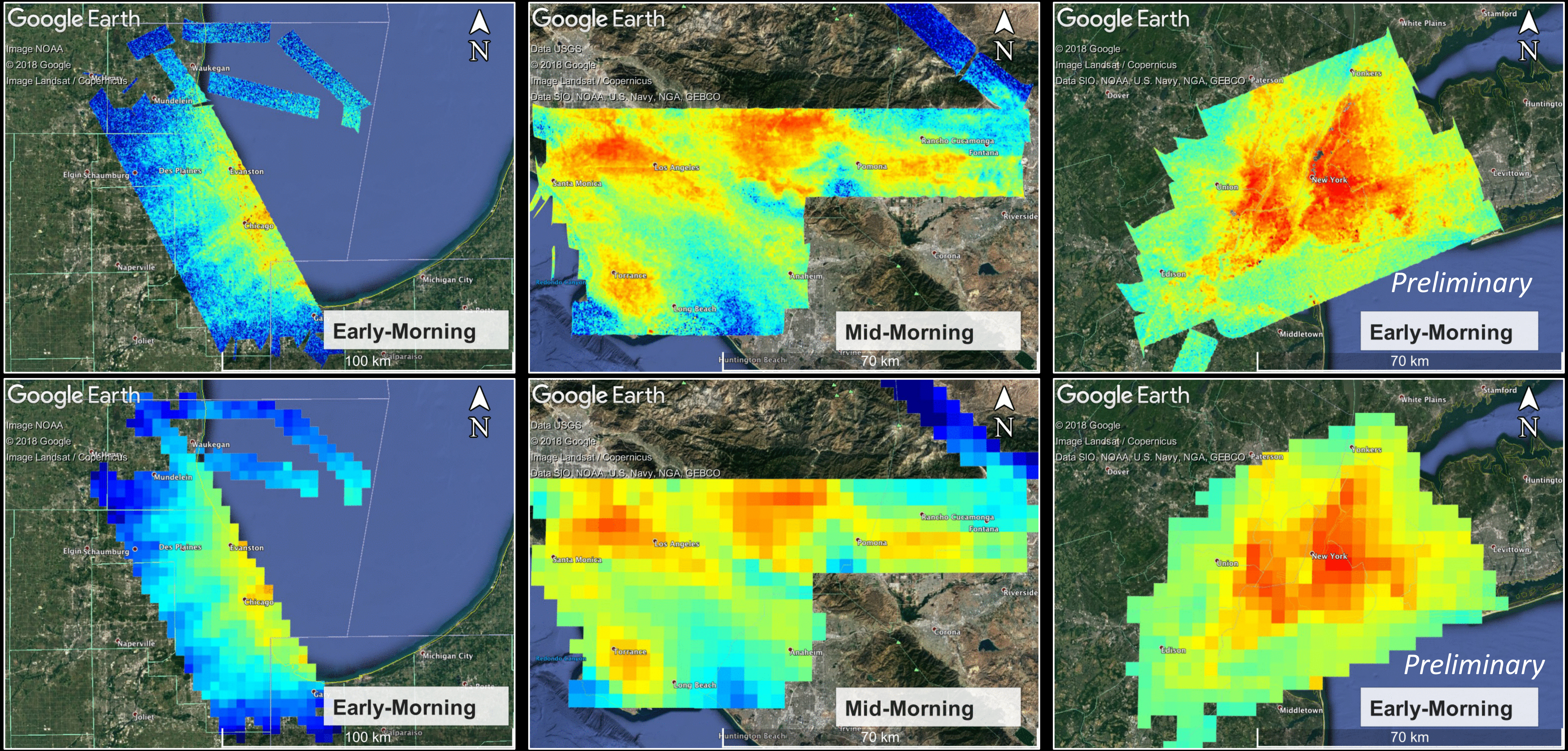
Also capable of retrieving HCHO

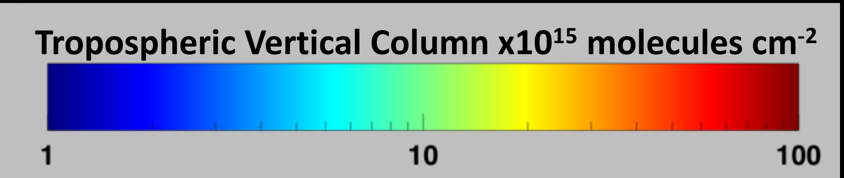


Gapless mapping strategy: 1.5-4 hours



May 22nd, 2017 | June 27th, 2017 | July 20th, 2018

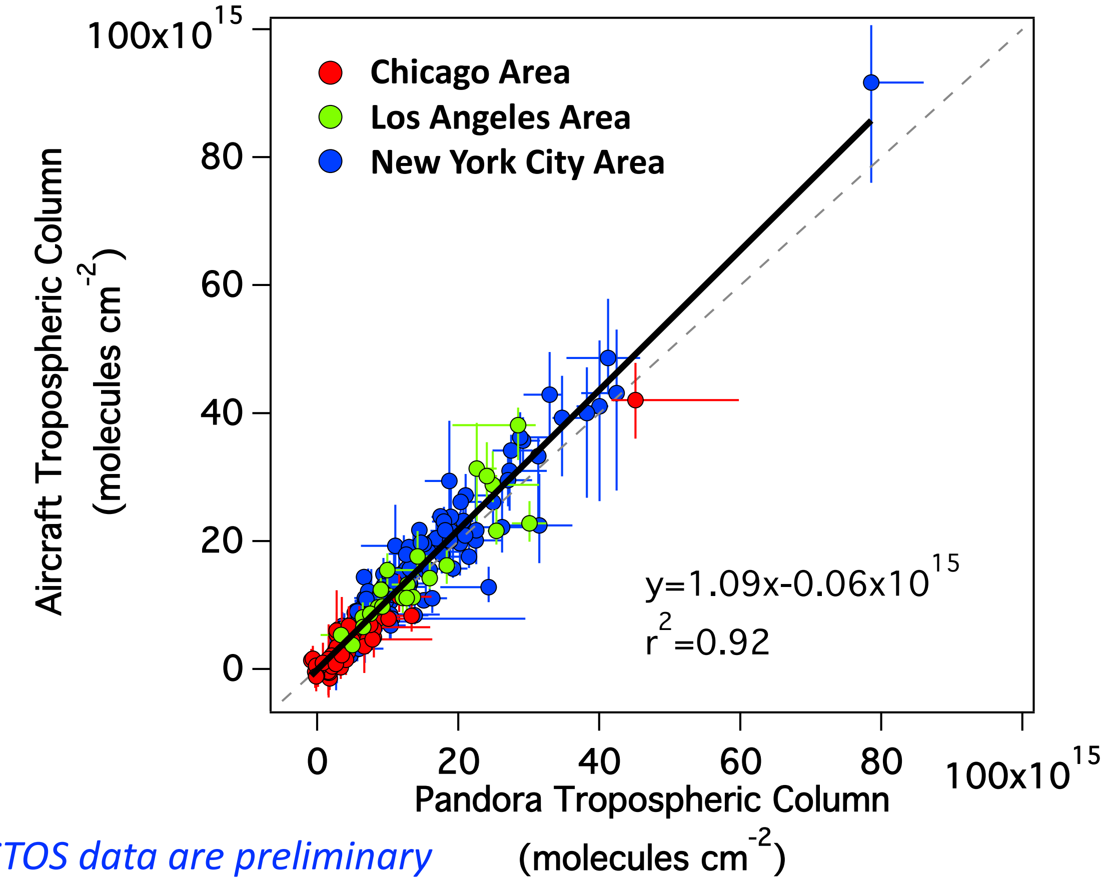




Zoogman et al. (2017) reports TEMPO resolution as 2.1 km x 4.4 km (9.24km^2)

Would TEMPO provide the same information as the airborne spectrometers?

Pandora Comparisons: finest spatial resolution



LISTOS data are preliminary

Removing outlier decreases slope to 1.07 and r^2 to 0.91

Coincidence Criteria:

- Median GeoTASO/GCAS data within ***750 m*** from the site for each individual overpass
- Closest in time Pandora coincidence (must be within 5 minutes of the overpass)
- Bars indicate max/min Pandora column and the 10th and 90th percentile for GCAS/GeoTASO

[Spatiotemporal variability!]

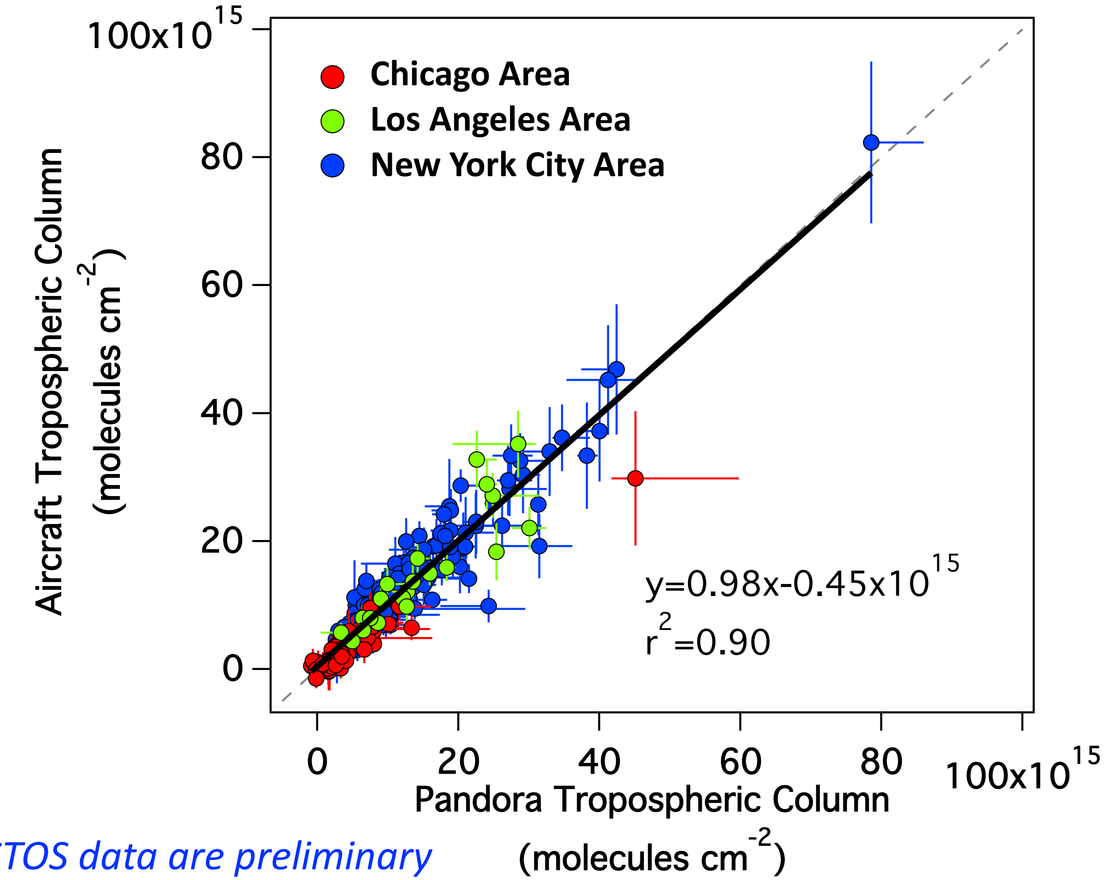
Methodology discussed in Judd et al., AMTD 2019

2017 and 2018 flights resulted in 279 coincidences with Pandora Spectrometers.

Data are highly correlated (even excluding outlier). Slight high bias is more apparent in LISTOS data which are still preliminary.

Scatter in LMOS and LA Basin data have been shown to be related to coincidence criteria and the spatial heterogeneity of NO_2 (Judd et al., AMTD 2019).

Pandora Comparisons: TEMPO's Areal Resolution



LISTOS data are preliminary

Coincidence Criteria:

- GeoTASO/GCAS data at 3km resolution in which Pandora resides during that raster
- Closest in time Pandora coincidence (must be within 5 minutes of the overpass)
- Bars indicate max/min Pandora column and the stddev of GCAS/GeoTASO inside the 3x3 km pixel

[Spatiotemporal variability!]

Methodology discussed in Judd et al. (2019)

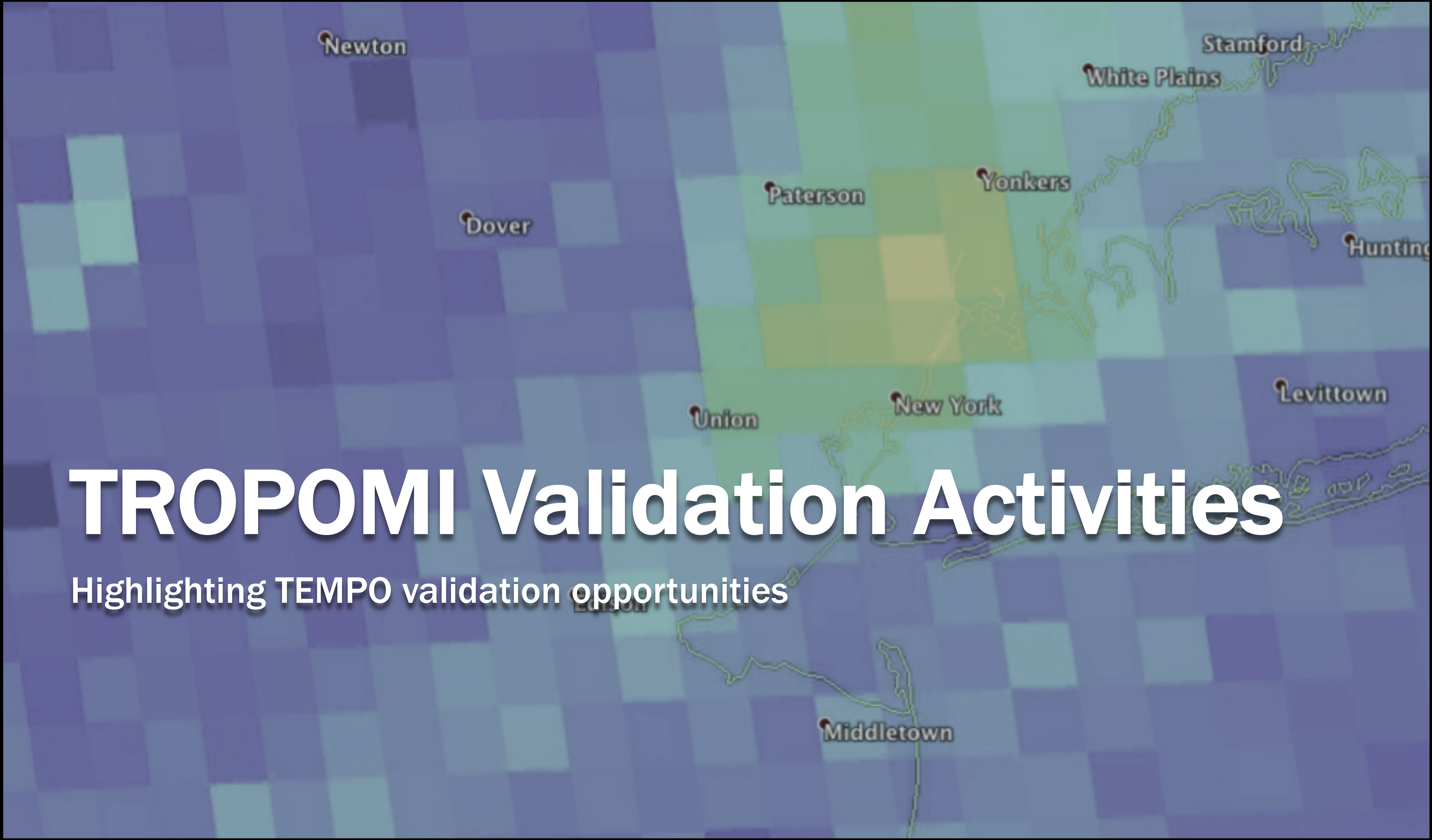
There is an approximately 10% decrease in slope at TEMPO's areal resolution in comparison to Pandora. Average percent decrease is 5%.

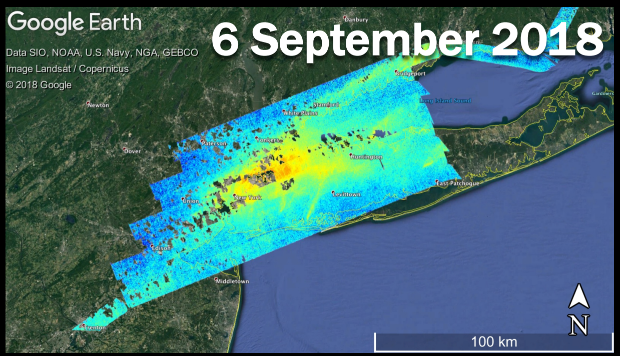
Measurements are nearly as correlated as the finest spatial resolution comparisons.

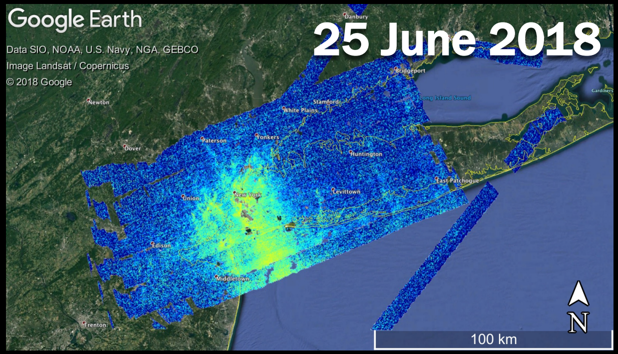
Removing outlier decreases slope to 0.96 and r^2 to 0.88

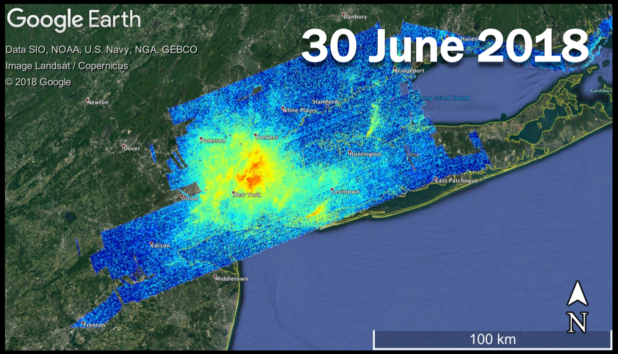
TROPOMI Validation Activities

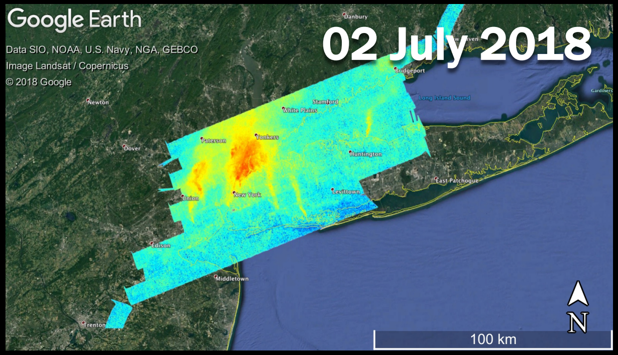
Highlighting TEMPO validation opportunities

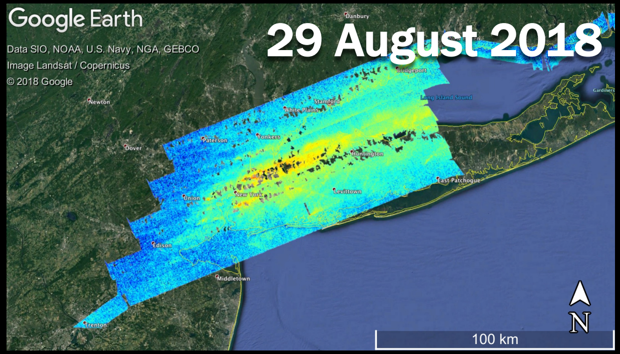




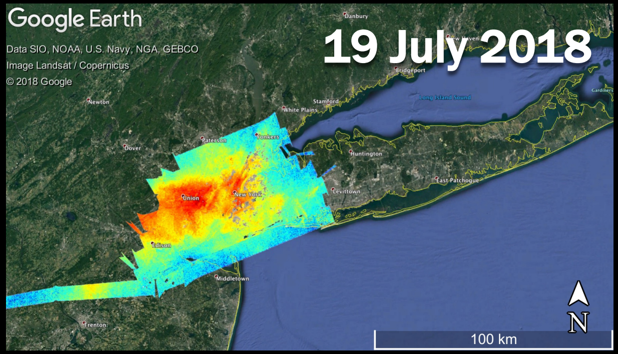


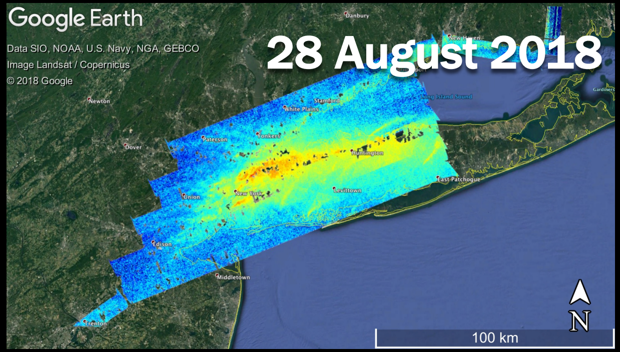




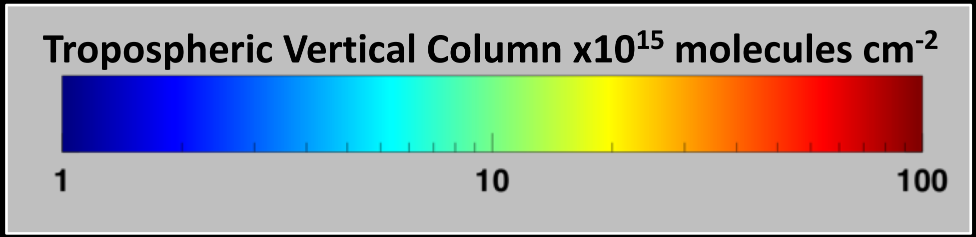


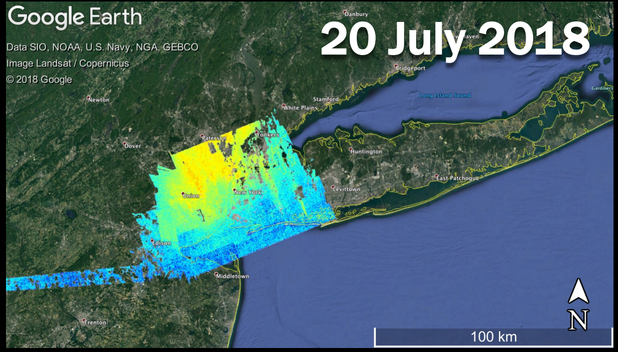
From June-September 2018, our aircraft measurements coincided with TROPOMI during 15 orbits over 12 days with highly variable meteorological and air quality patterns.

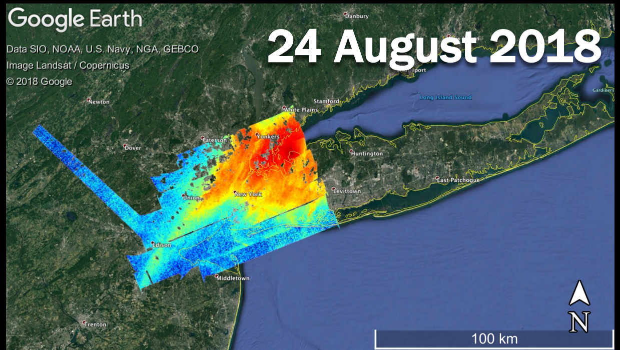


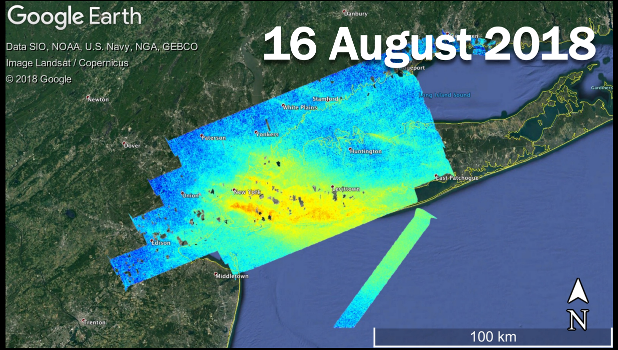


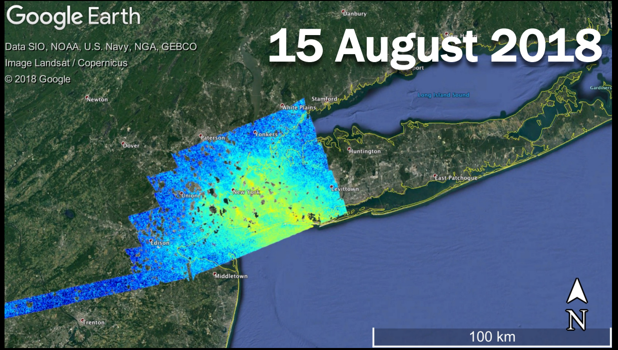
Aircraft data filtered for bright detector pixels suggesting cloud cover
All data are preliminary

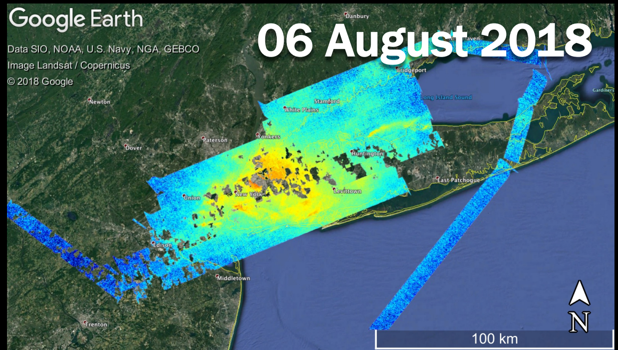


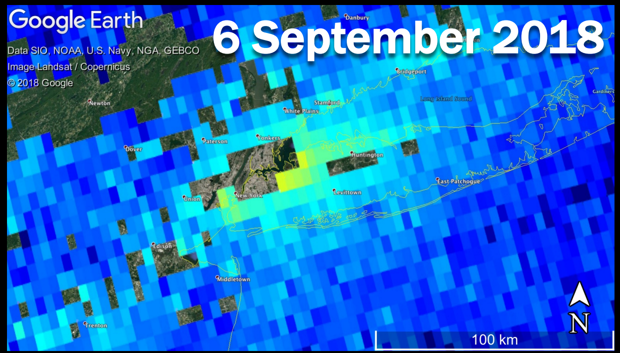


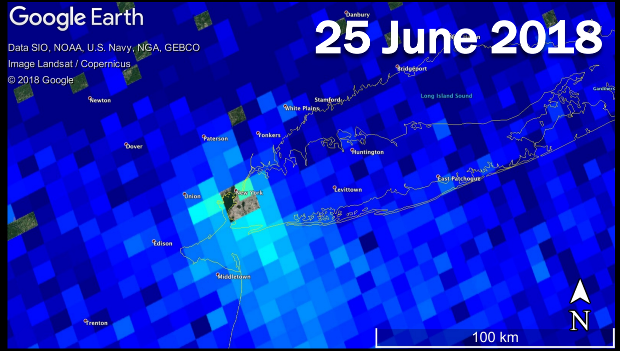


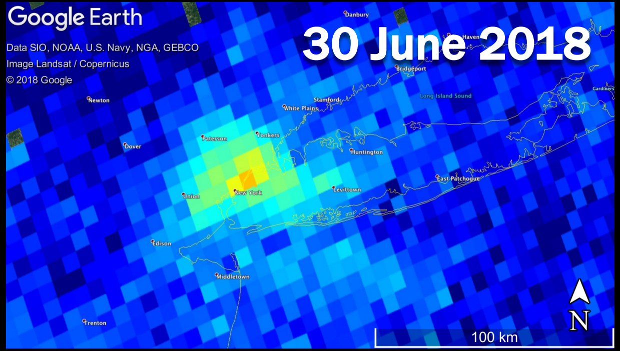


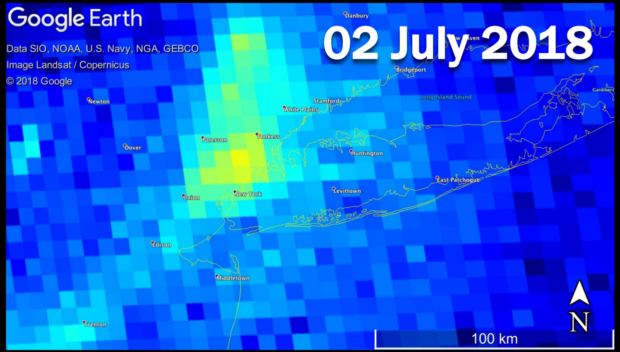


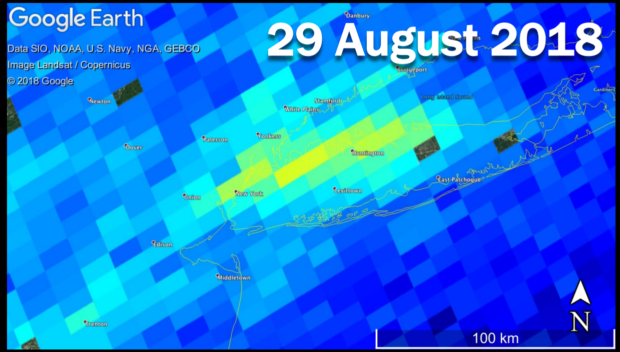




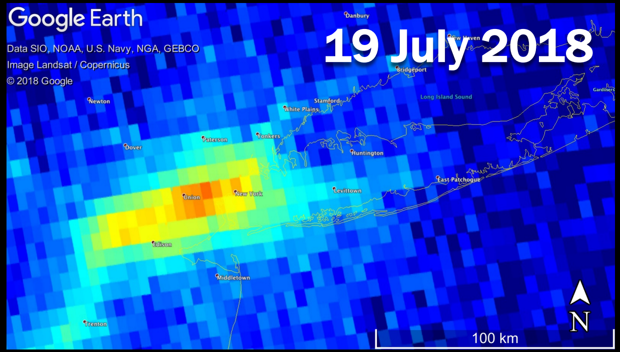


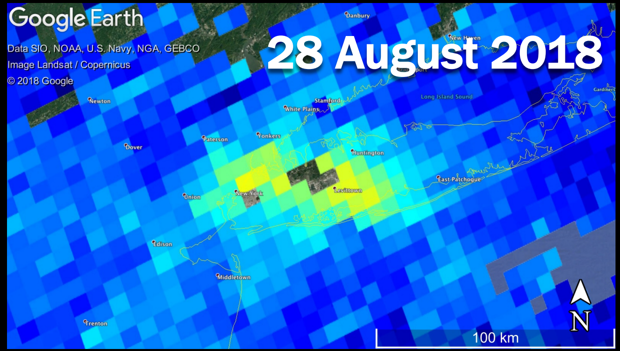




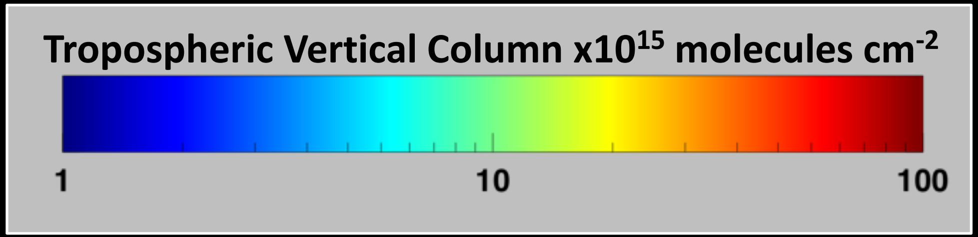


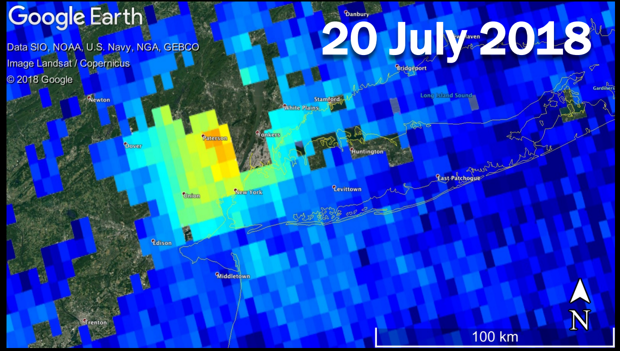
From June-September 2018, our aircraft measurements coincided with TROPOMI during 15 orbits over 12 days with highly variable meteorological and air quality patterns.

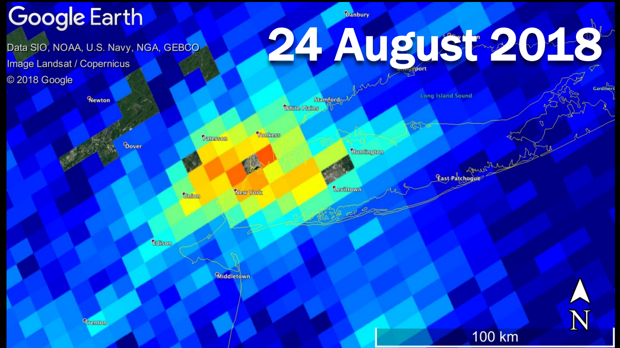


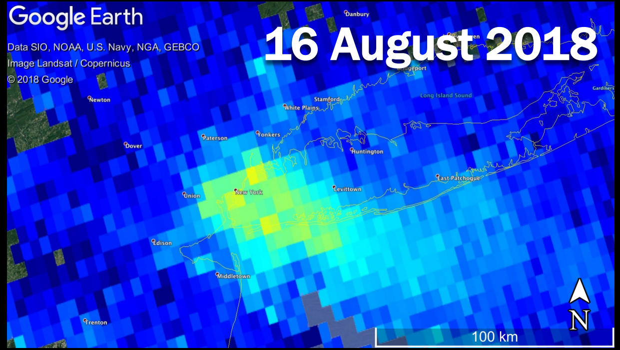


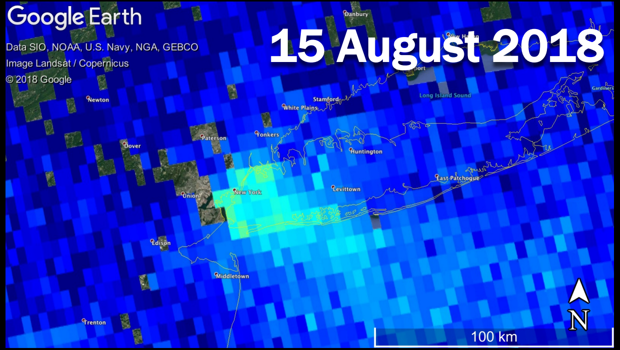
Mapped data from the RPRO Product tropospheric NO2 v1.2.2 and has cloud radiance fraction less than 50%

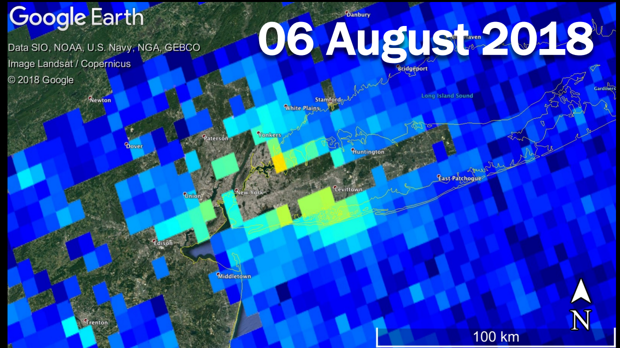












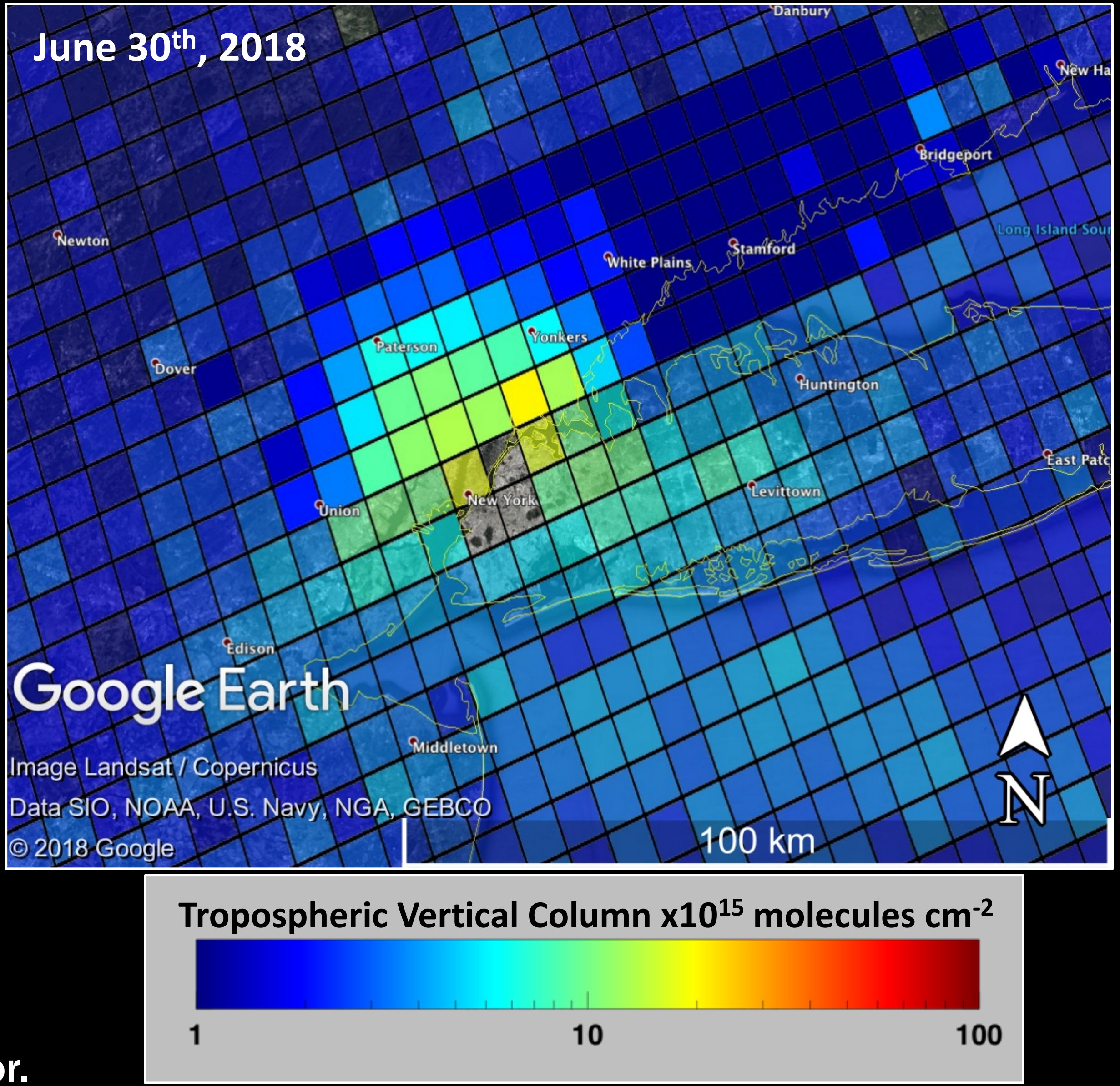
Aircraft V. S5P TROPOMI RPRO v1.2.2 NO_2

Methodology

- TROPOMI NO_2 RPRO v1.2.2 with qa > 0.75
- Extracted all aircraft points that were inside a TROPOMI pixel within ± 30 minutes of the overpass
- Area weighted average aircraft data to scale to the spatial scale of the TROPOMI pixel

Results: 638,065 Aircraft pixels inside 1385 TROPOMI pixels

- All Data
  - 861 pixels > 50% mapped
  - 649 pixels > 75% mapped
  - 404 pixels – 100% mapped
- Cloud radiative fraction in the NO_2 window less than 0.25
  - 539 pixels > 50% mapped
  - 417 pixels > 75% mapped
  - 268 pixels –100% mapped

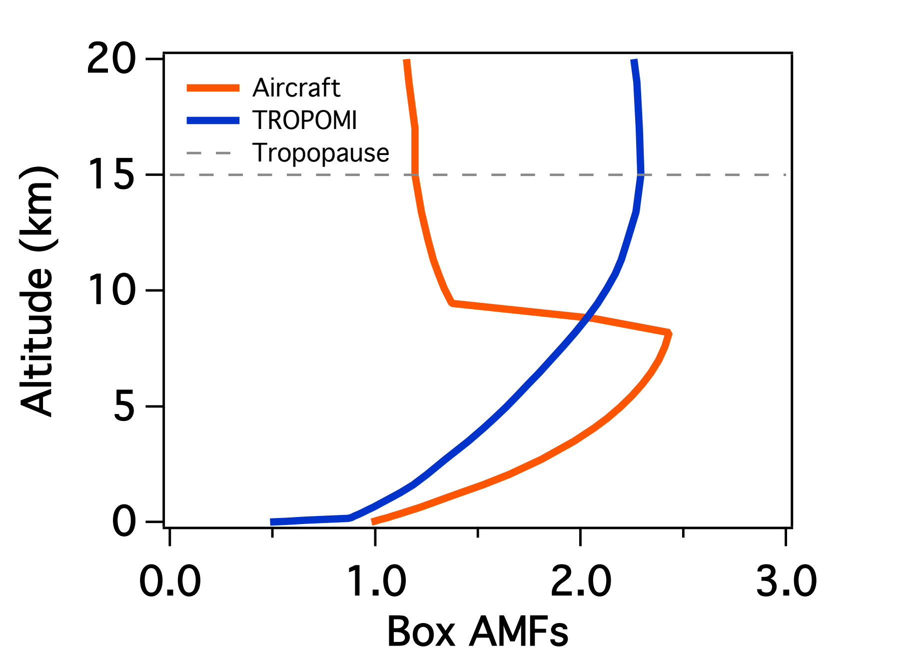


Aircraft data: clouds are filtered by count rates on the detector.

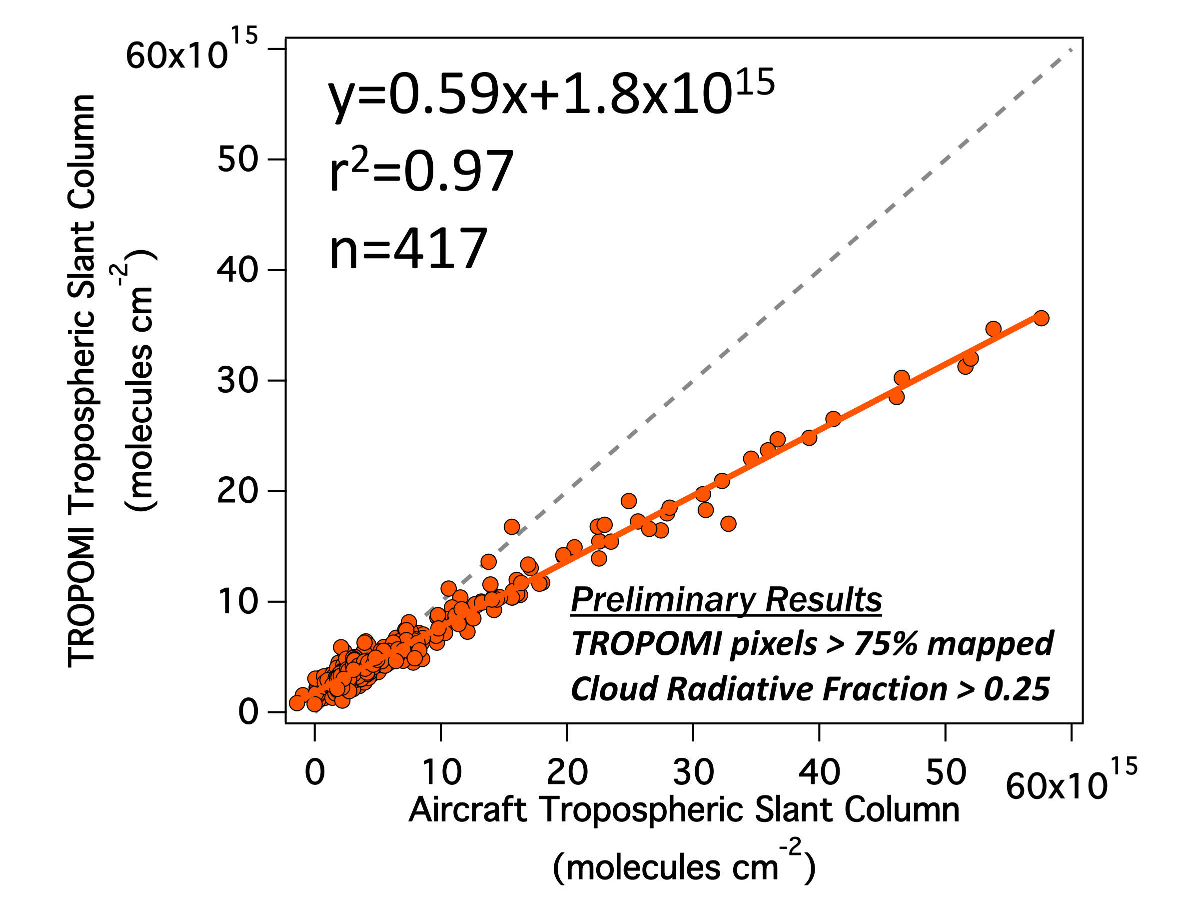
Aircraft V. S5P TROPOMI RPRO v1.2.2 NO_2

Slant-to-slant columns are highly correlated with aircraft columns being greater than TROPOMI columns

- Partially expected due to different vertical sensitivities through the troposphere



Slant-to-slant tropospheric column

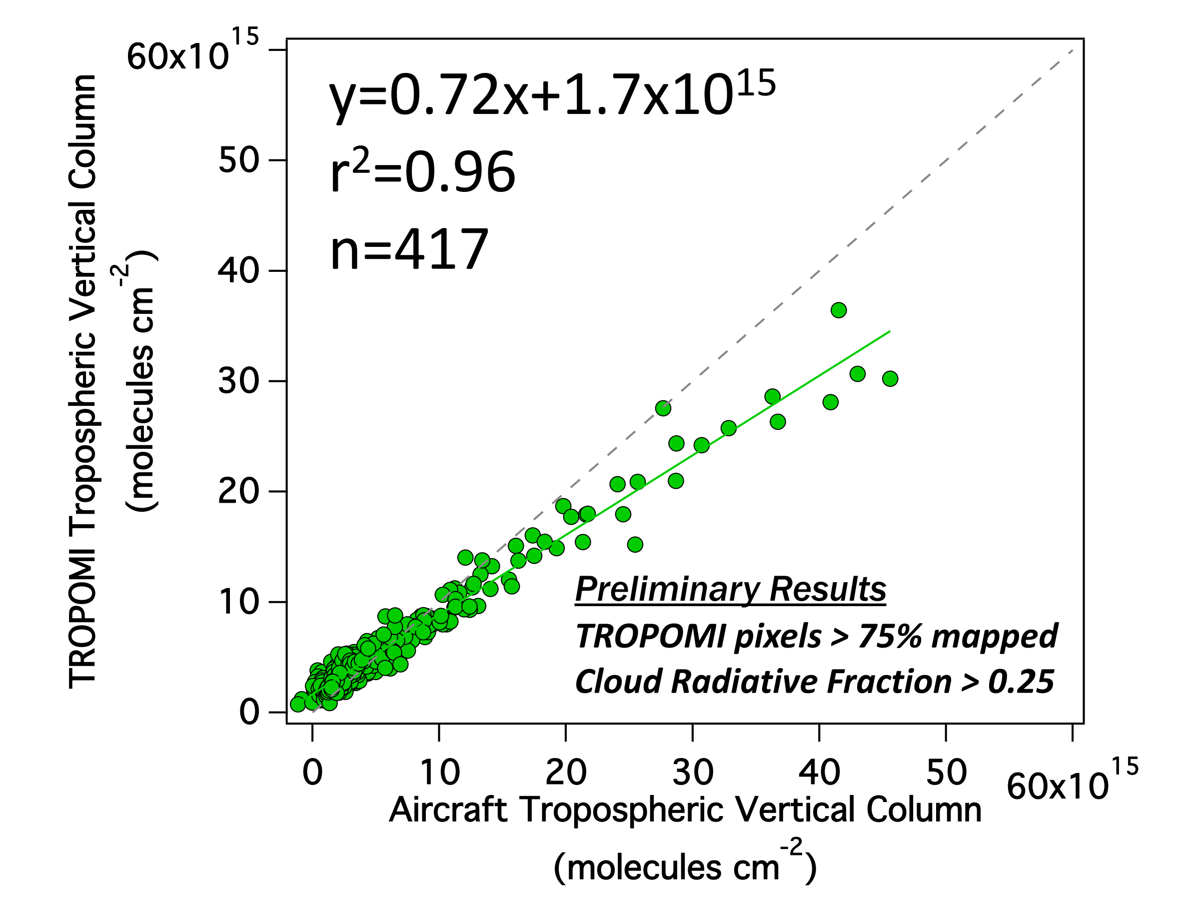


Aircraft V. S5P TROPOMI RPRO v1.2.2 NO_2

TROPOMI standard vertical columns compared to our aircraft vertical column comparisons (with the 12-km NAM CMAQ A priori) result in an increase in slope.

- **TROPOMI appears to be ~30% biased low in the polluted regions NYC region.**
- **Likely cause, the 1 deg x 1 deg TM5-MP is missing the urban profile shape**

Vertical-to-vertical tropospheric column with the standard TROPOMI output



Aircraft V. S5P TROPOMI RPRO v1.2.2 NO_2

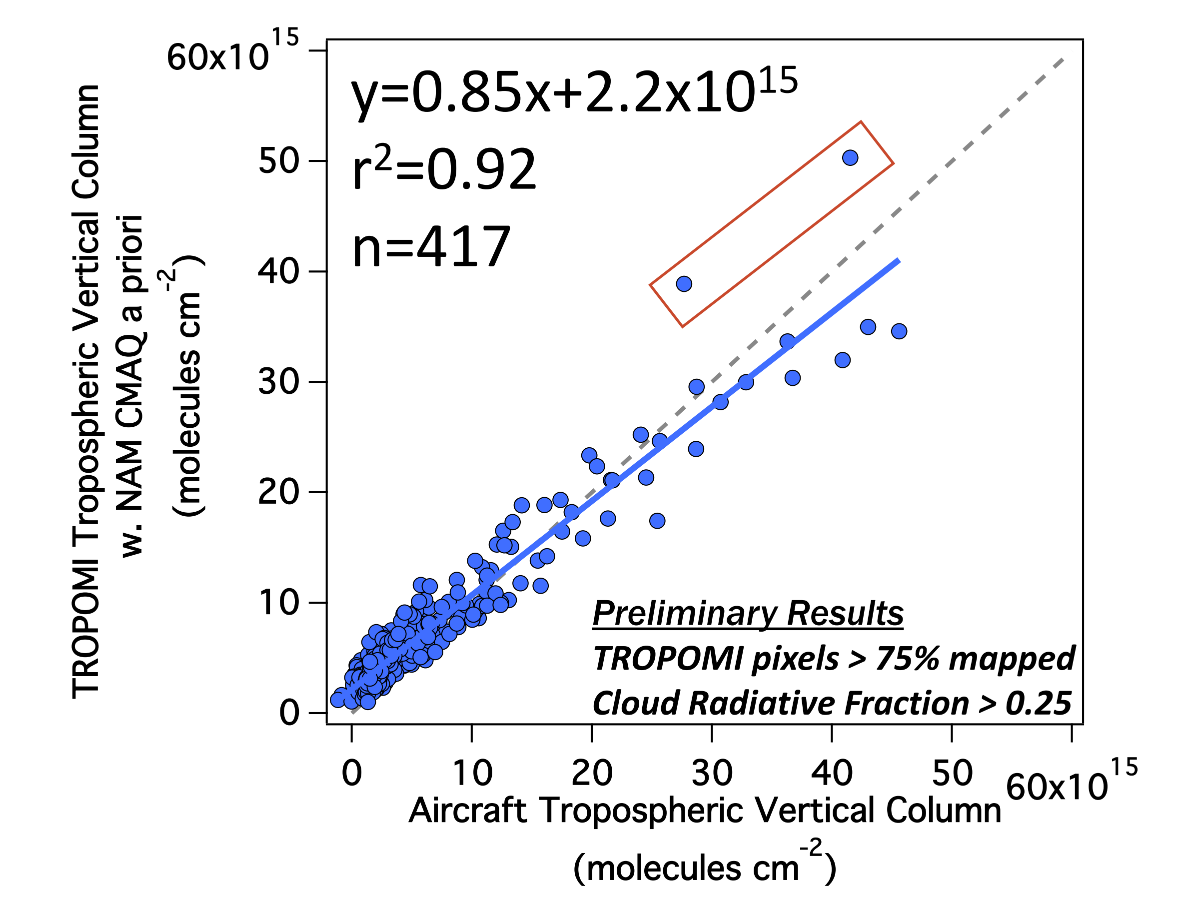
When the aircraft a priori (12-km NAM CMAQ output) is replaced in the TROPOMI product, the slope improves further.

- May still be slightly low biased when really polluted; Slight loss in correlation.

Added noise due to introduced variability in the modeled shape factor?

The TROPOMI team is advocating for partners to create their own regional products using higher resolution a priori model inputs.

Vertical-to-vertical tropospheric column with 12km NAM CMAQ a priori applied



Slant-to-slant: $y=0.59x+1.8x10^{15}$; $r^2=0.97$

Vertical-to-Original Vertical: $y=0.72x+1.7x10^{15}$; $r^2=0.96$