# GeoTASO/GCAS high-resolution aircraft $NO_2$ measurements over NYC/Long Island Sound

**Laura Judd[1,2], Jay Al-saadi[2], Luke Valin[3], Jim Szykman[3], Scott Janz[4], Matt Kowalewski[4,5], Amin Nehrir[2], Tim Berkoff[2], Brad Pierce[6]**

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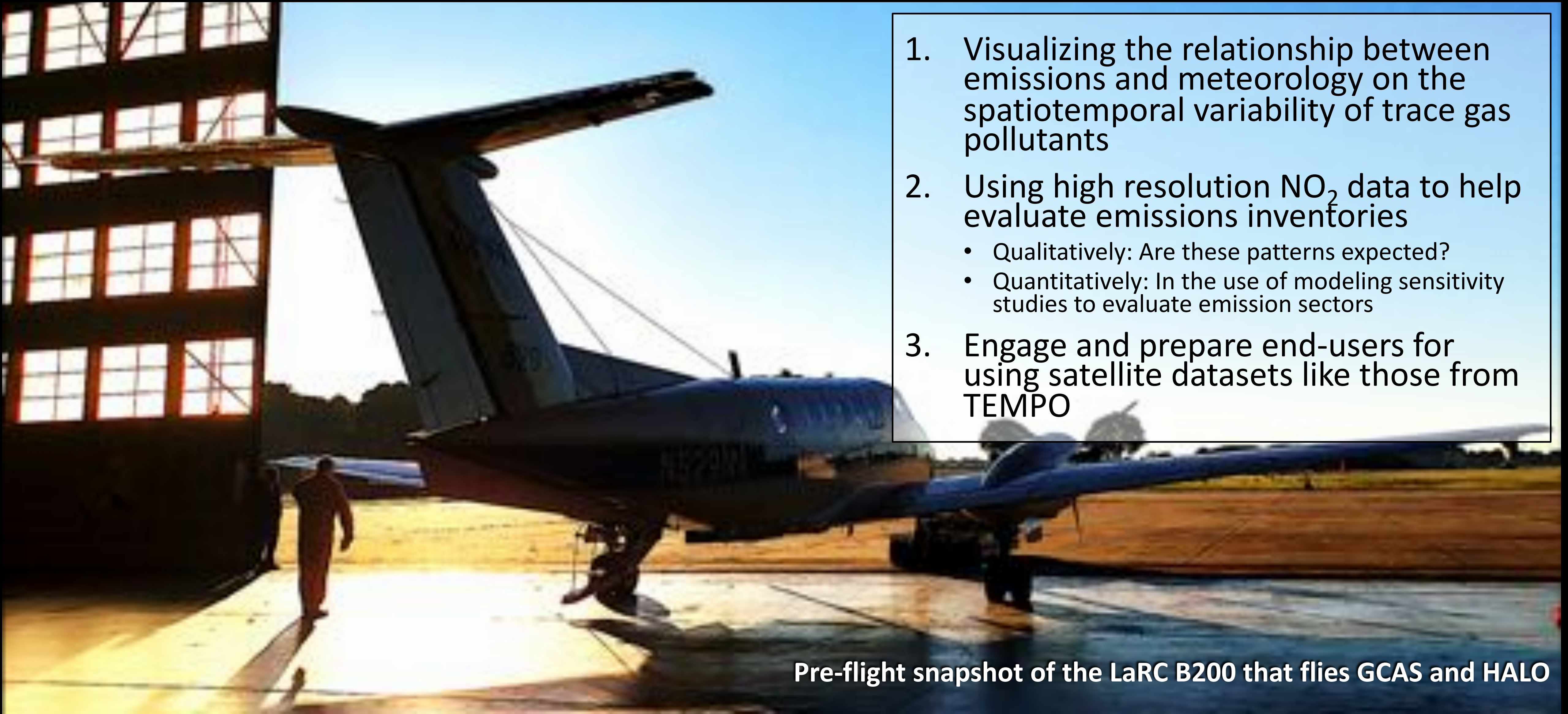
# Potential Applications of GCAS/GeoTASO data for Air Quality and Energy Planning



1. Visualizing the relationship between emissions and meteorology on the spatiotemporal variability of trace gas pollutants
2. Using high resolution $NO_2$ data to help evaluate emissions inventories
   - Qualitatively: Are these patterns expected?
   - Quantitatively: In the use of modeling sensitivity studies to evaluate emission sectors
3. Engage and prepare end-users for using satellite datasets like those from TEMPO

**Pre-flight snapshot of the LaRC B200 that flies GCAS and HALO**

TEMPO

NASA

Smithsonian

Ball

# Airborne Mapping Spectrometers


## GeoTASO

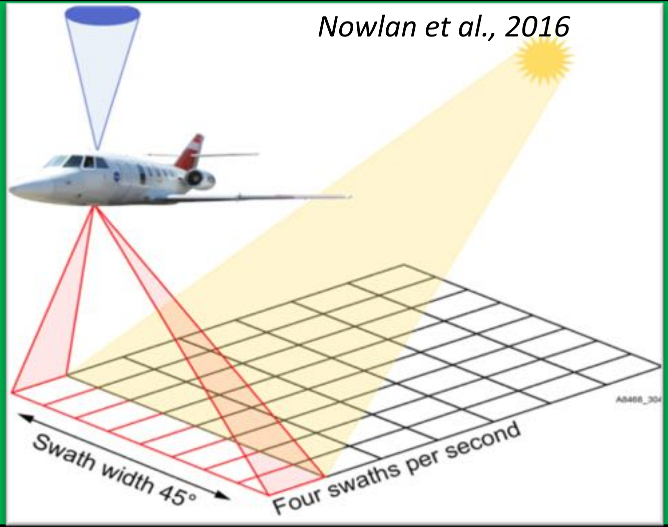
- Geostationary Trace gas and Aerosol Sensor Optimization
- UV-VIS
- Large—300+lbs
- June and October 2018

## GCAS

- GEOCAPE Airborne Spectrometer
- UV-VIS-NIR
- Small— ~100 lbs
- July-October 2018
- Co-located with HALO


**Used to test retrievals for future geostationary observations of air quality**

**Both operate in a push-broom mode measuring high spectral resolution visible spectra for $NO_2$ retrievals at ~250x250 m resolution**

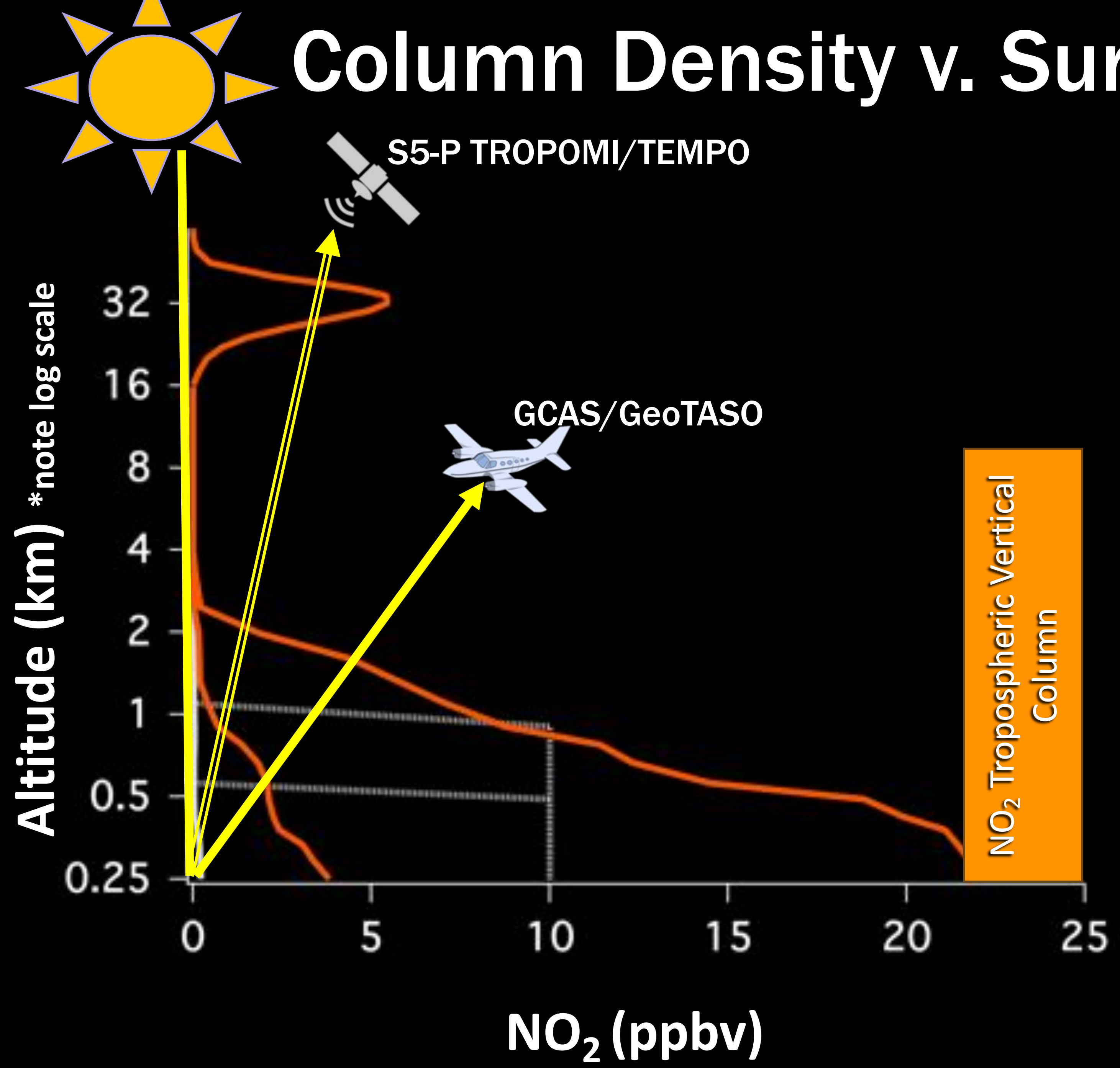



**Preliminary**

Tropospheric $NO_2$ Columns

**GCAS/GeoTASO can also retrieve HCHO: Shown by Scott Janz from NASA GSFC during tomorrow's LISTOS meeting**

# Column Density v. Surface Air Quality




**Surface $NO_2$**: molecular density or mixing ratio directly measured at the surface by an in situ monitor

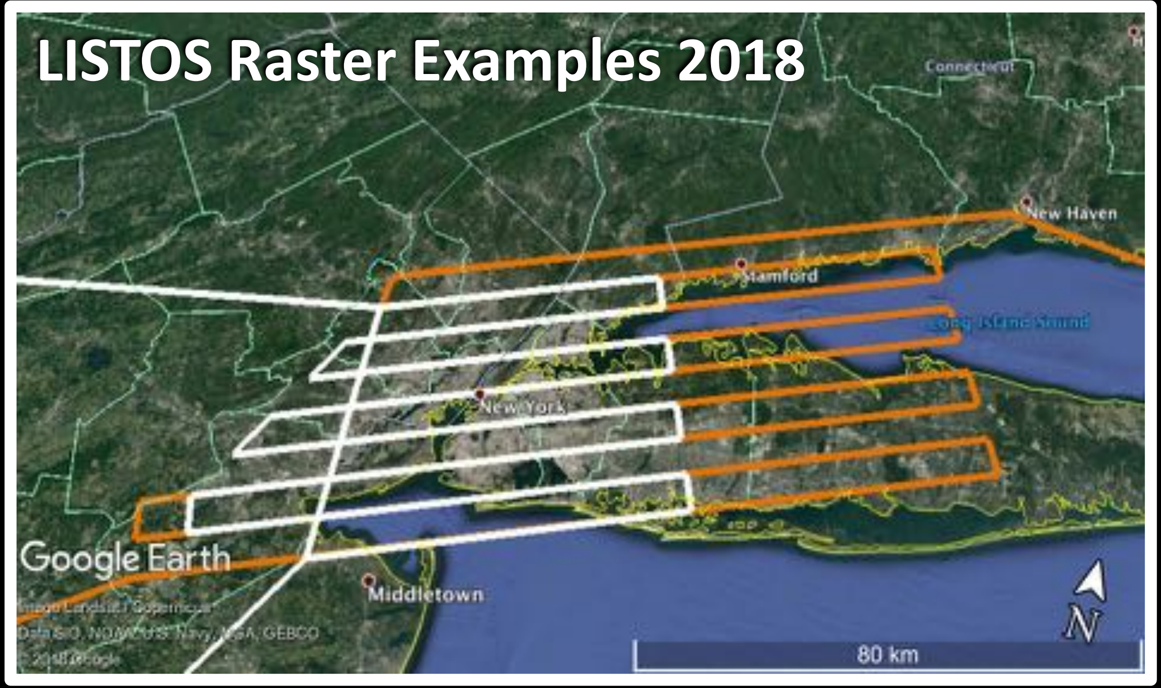
**$NO_2$ Column Density**: Integrated molecular density of $NO_2$ through the vertical

Satellites and GeoTASO/GCAS can only 'remotely sense' $NO_2$ columns by looking at the its absorption signatures in the blue part of the light spectrum (via Differential Optical Absorption Spectroscopy[1]).

*1: Platt, U., & Stutz, J. (2008). Differential optical absorption spectroscopy: principles and applications ; with 55 tables. Berlin: Springer.*

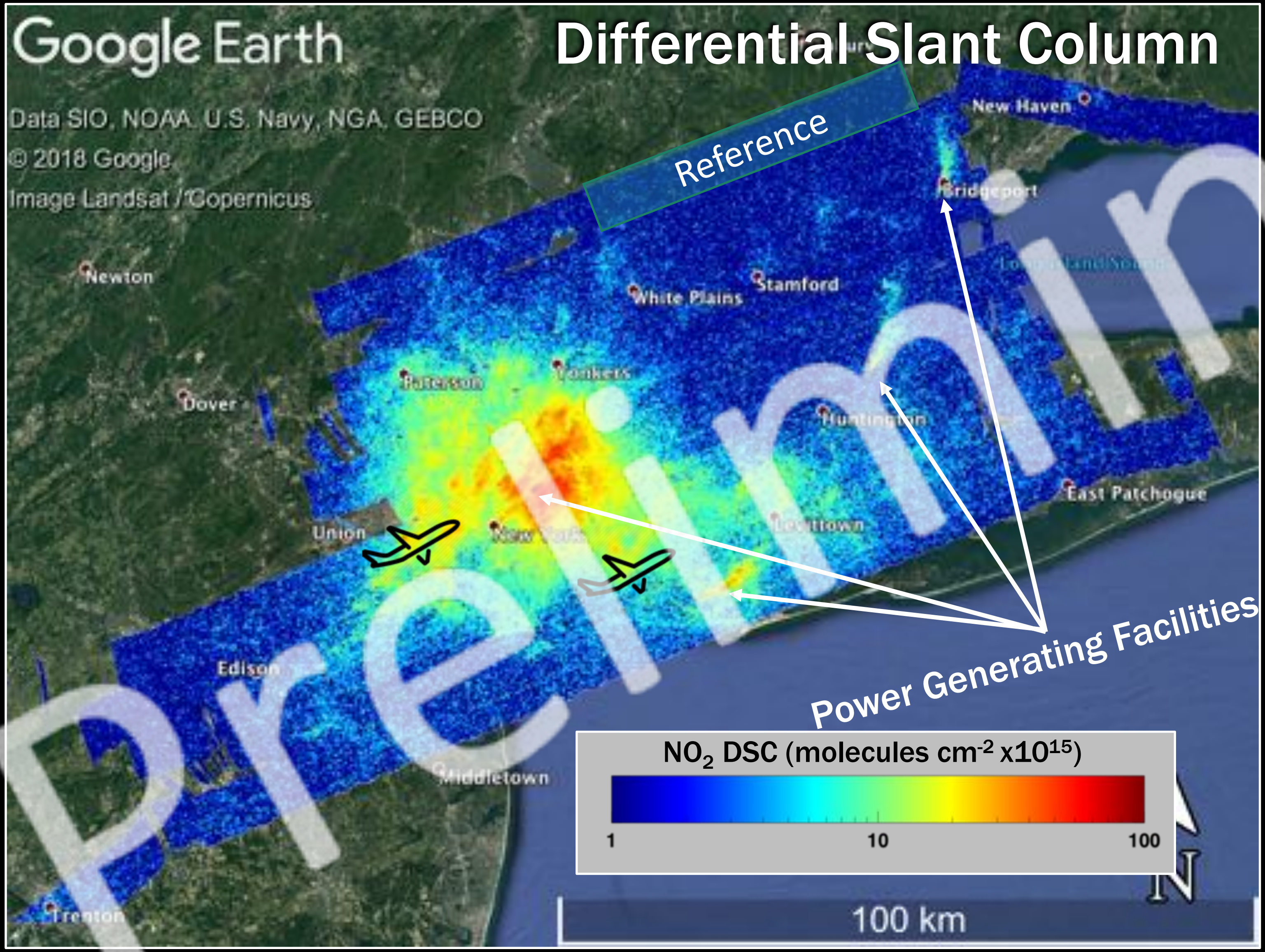
# Sampling Strategy

- Over the area of interest:
  - Build sets of parallel flight lines spaced such that the 45 ° FOV has some overlap
  - Nominal spacing: ~6 km
  - Typical Altitude: 28,000 ft
- Considerations:
  - The area mapped depends on airborne platform (B200 v. HU-25)
  - Air space constraints
  - Emissions inventory information
  - Clouds Forecasts
- Rasters take 2-4 hours to acquire
  - Preparing for geostationary observations




- LMOS: First 'quicklook' differential slant columns with turn-arounds in about 24 hours
- Vertical columns expected in the summer/fall 2019 timeframe

# Example Retrieval: June 30th, 2018 Saturday Afternoon




**Differential Slant Columns (DSCs) represent the $NO_2$ absorption relative to the reference**

- **Shows relative distribution of $NO_2$ quite well**
- **Emission sources are well defined**

**Caution: DSCs are not the final product and some gradients in the data are just related to surface reflectance properties, sun glint, and viewing/solar geometry.**

**DSCs are converted to Vertical Columns through the Air Mass Factor**

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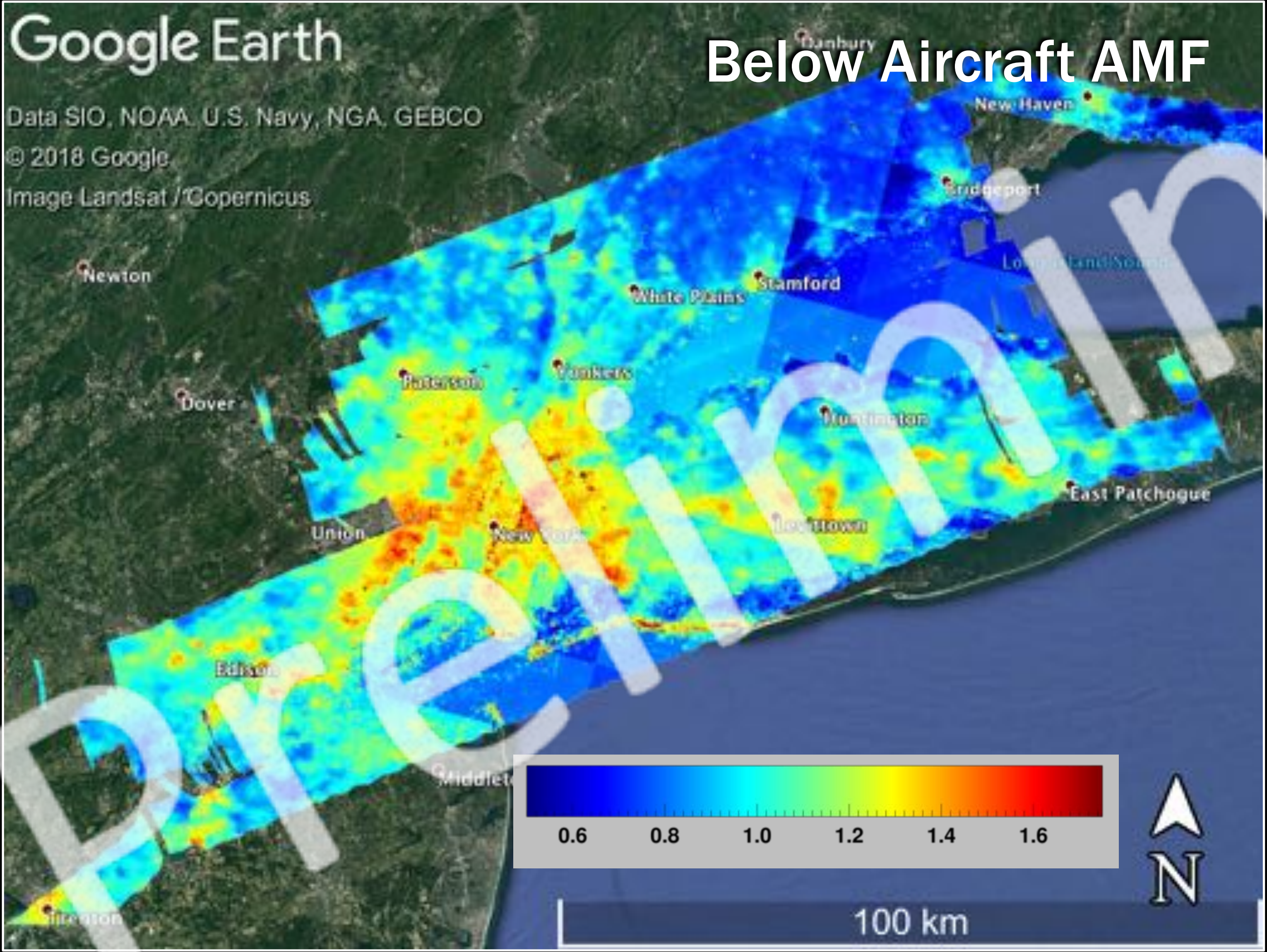



$$Air\ Mass\ Factor\ (AMF) = \frac{Slant\ Column(SC)}{Vertical\ Column\ (VC)}$$

**AMF is described as the mean path length the light traveled through the atmosphere and into our detector relative to the vertical path.**

**Dependent on**

- **Surface reflectivity (500 m MODIS product)**
- **Viewing and solar geometry**
- **$NO_2$ profile shape (12 km NAM CMAQ)**
- **Aerosols (Not included, yet!)**

*Palmer et al.,* *https://doi.org/10.1029/2000JD900772*

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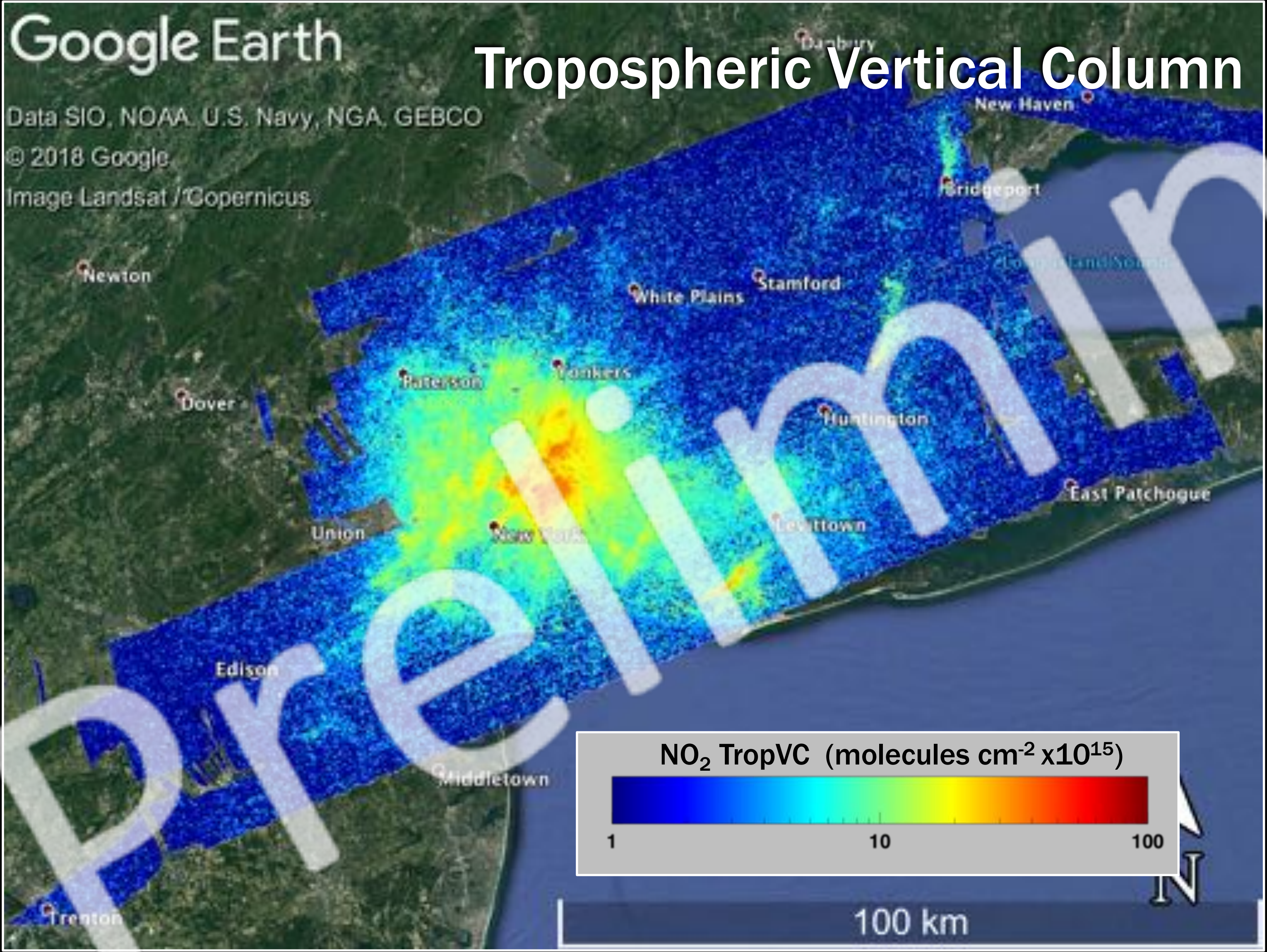



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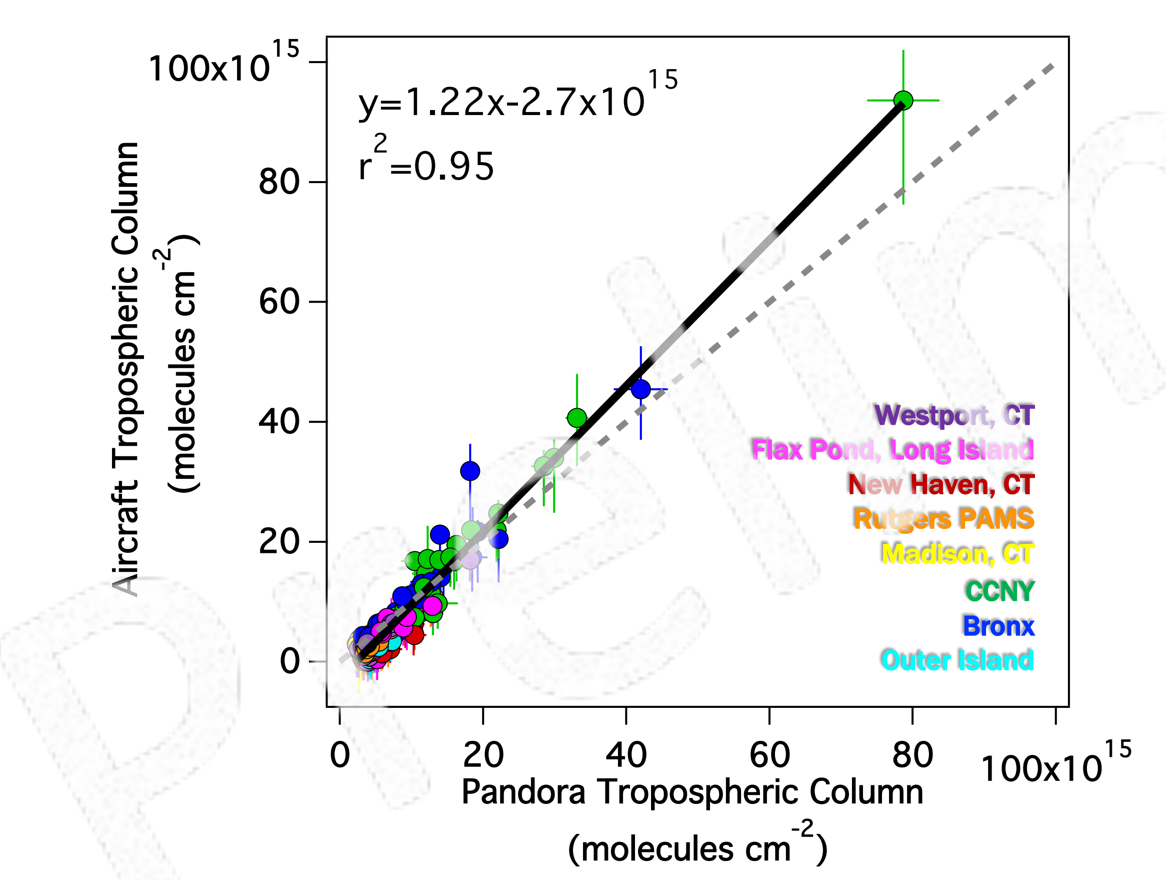
# GeoTASO/GCAS v. Pandora

*Pandora Spectrometers are used as a validation standard for airborne spectrometers and future/present satellite products*




Using methodology from Judd et al., prepared for submission to AMT

## Coincidence Criteria:

- Median GeoTASO/GCAS data within ***750 m*** from the site for each individual overpass (the distance assumption does not significantly alter results at least up to a 1 km radius)
- Closest in time Pandora coincidence (must be within 5 minutes of the overpass)
- Bars indicate the stddev of the data within the spatial/temporal constraints stated above ***[Spatiotemporal variability!]***

**Statistics are mainly driven by Pandora data located inside NYC (CCNY and Bronx: Bayonne and Queens data coming in the future).**

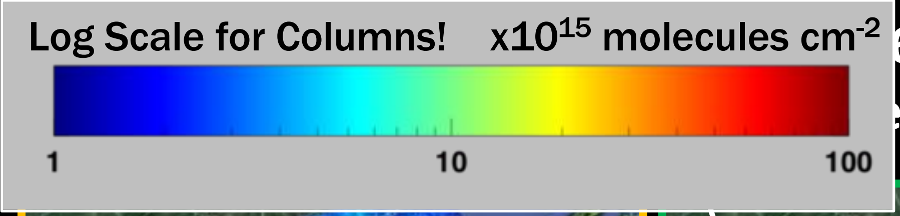
**Very well correlated with a 20% slope bias. Excluding the most polluted point still results in a 20% bias. Cause of this bias is still TBD.**

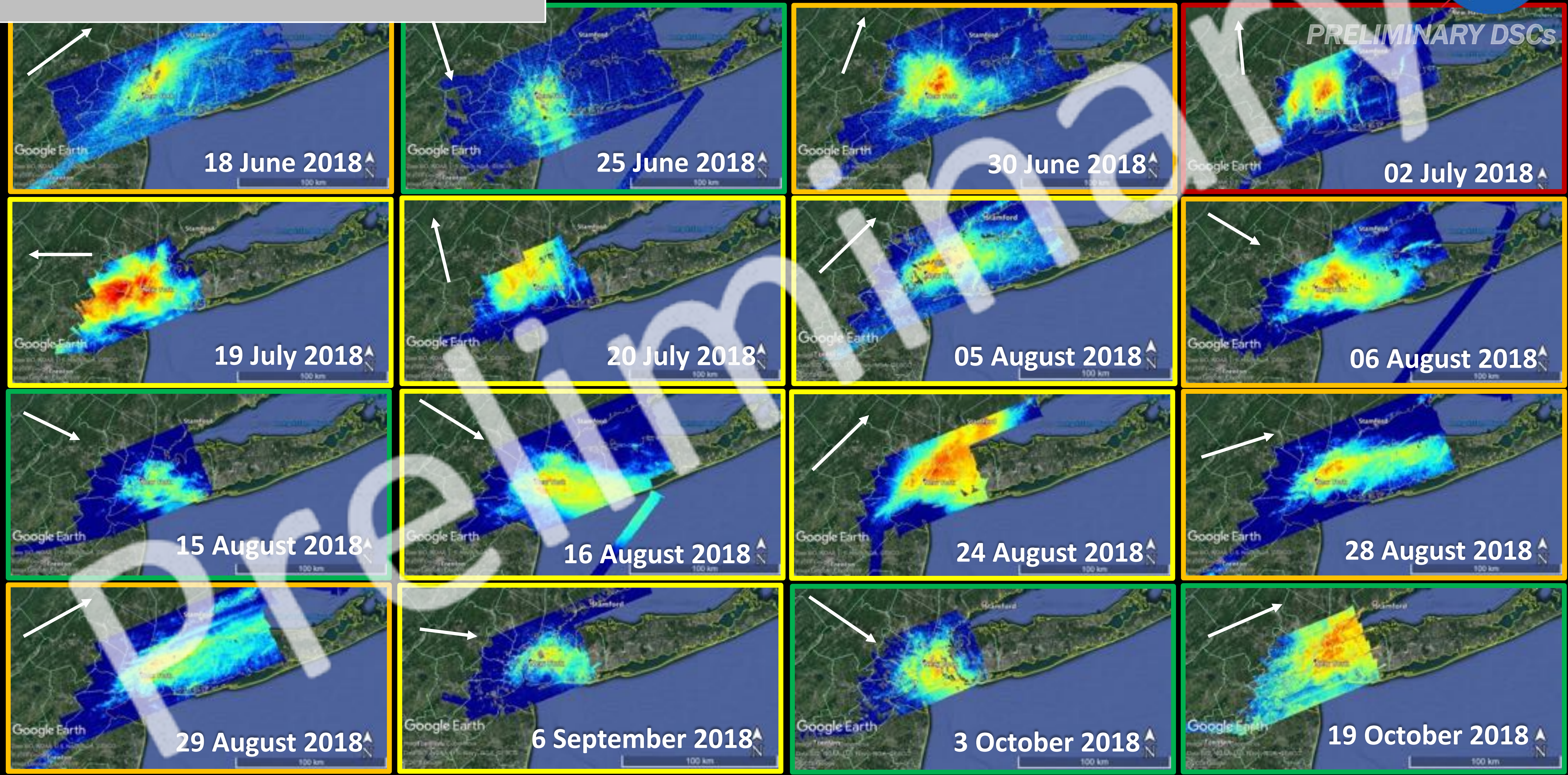
**Negative offset likely caused by uncertainty in the reference spectrum.**

# LISTOS Highlights

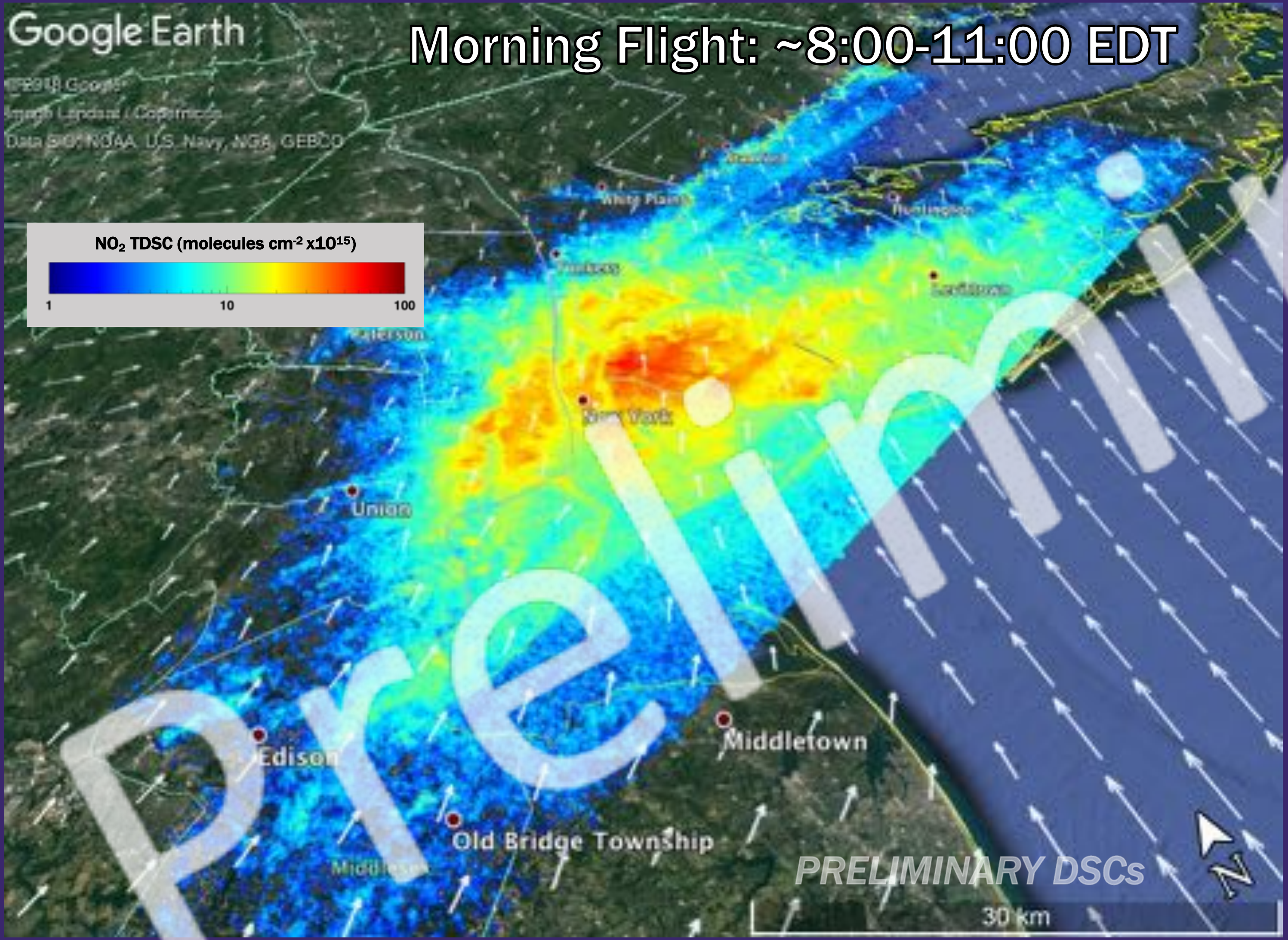
1. Quick overview of flights using an afternoon snapshot
2. Characterization of a classic LIS ozone event
3. Emissions sampling:
   - How do the rasters connect to data seen at ground sites?
   - What types of sources do we see?

6 days with conditions ranging from clean air to unhealthy
e early afternoon rasters of $NO_2$ (satellite overpass time).



# Long Island Sound $O_3$ Event: August 28th, 2018




**Starting in the morning…**
Observations from NASA's airborne LIDAR, HALO, show lower mixed layer heights (MLH) over Long Island Sound than the surrounding land

$NO_2$ amounts, retrieved from NASA's airborne spectrometer, GCAS, are largest over Queens – an area with multiple point sources and likely traffic signatures

Wind vectors from the NAM (09:00 LT) show slow SSW flow over land slowly transporting emissions through the mouth of Long Island Sound

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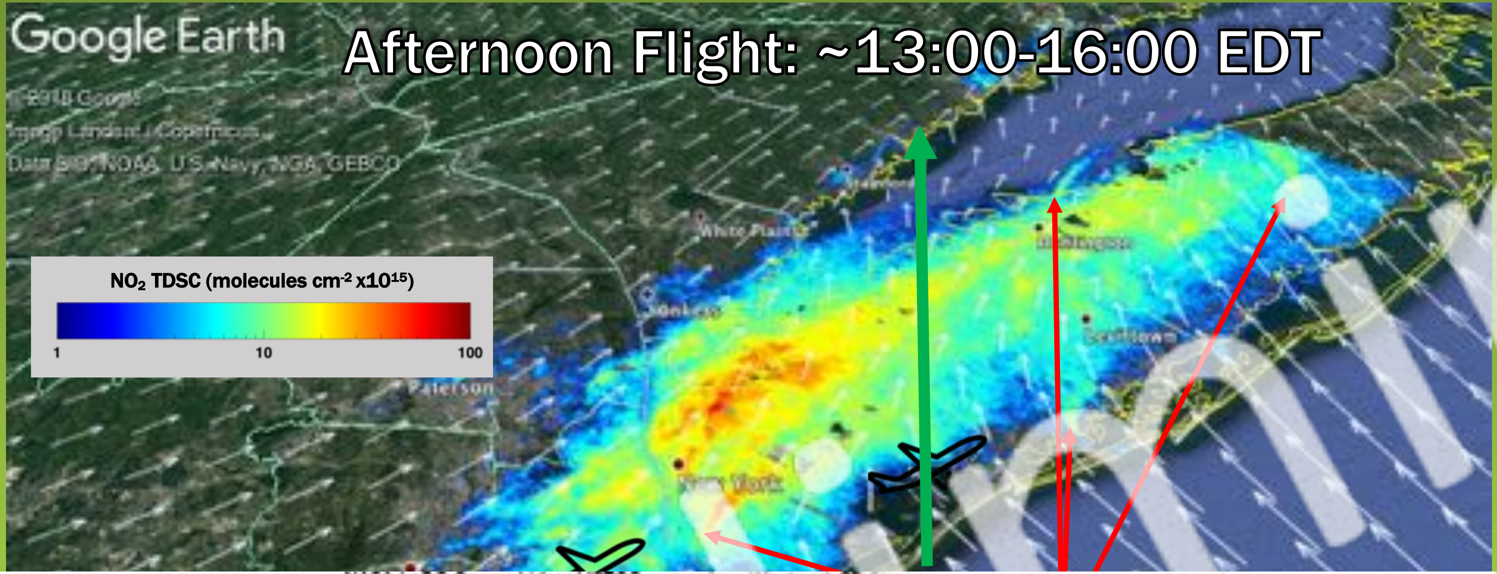
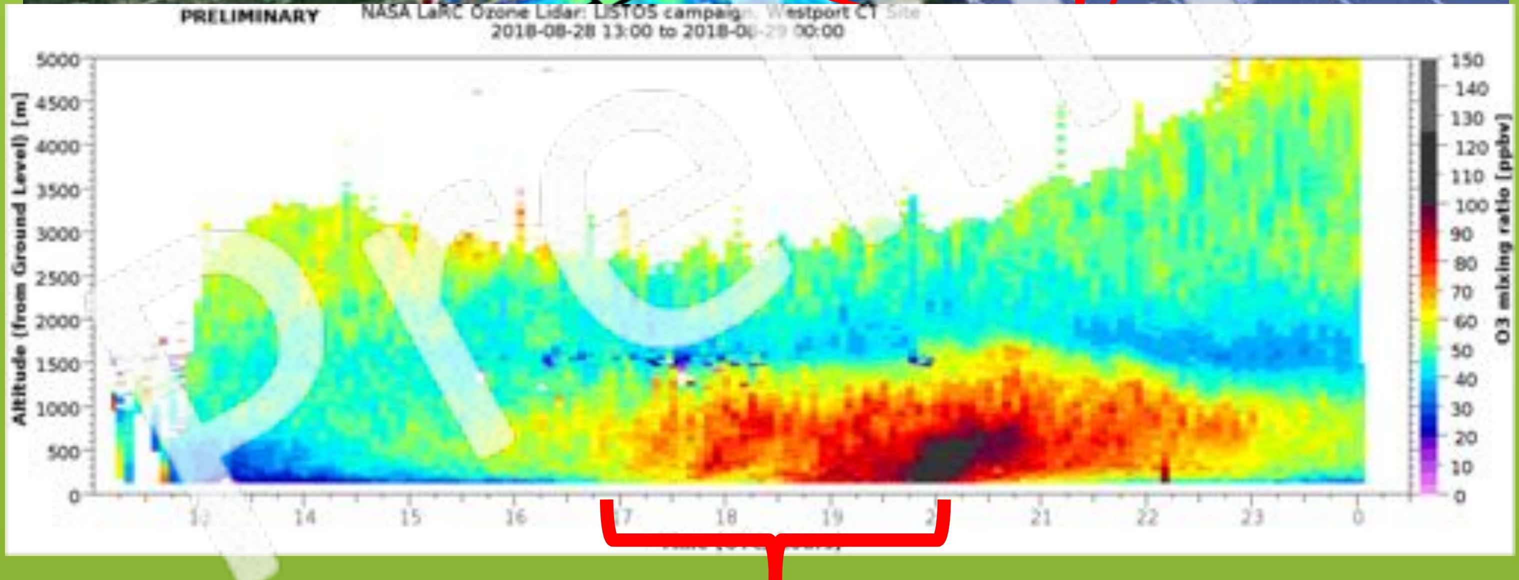


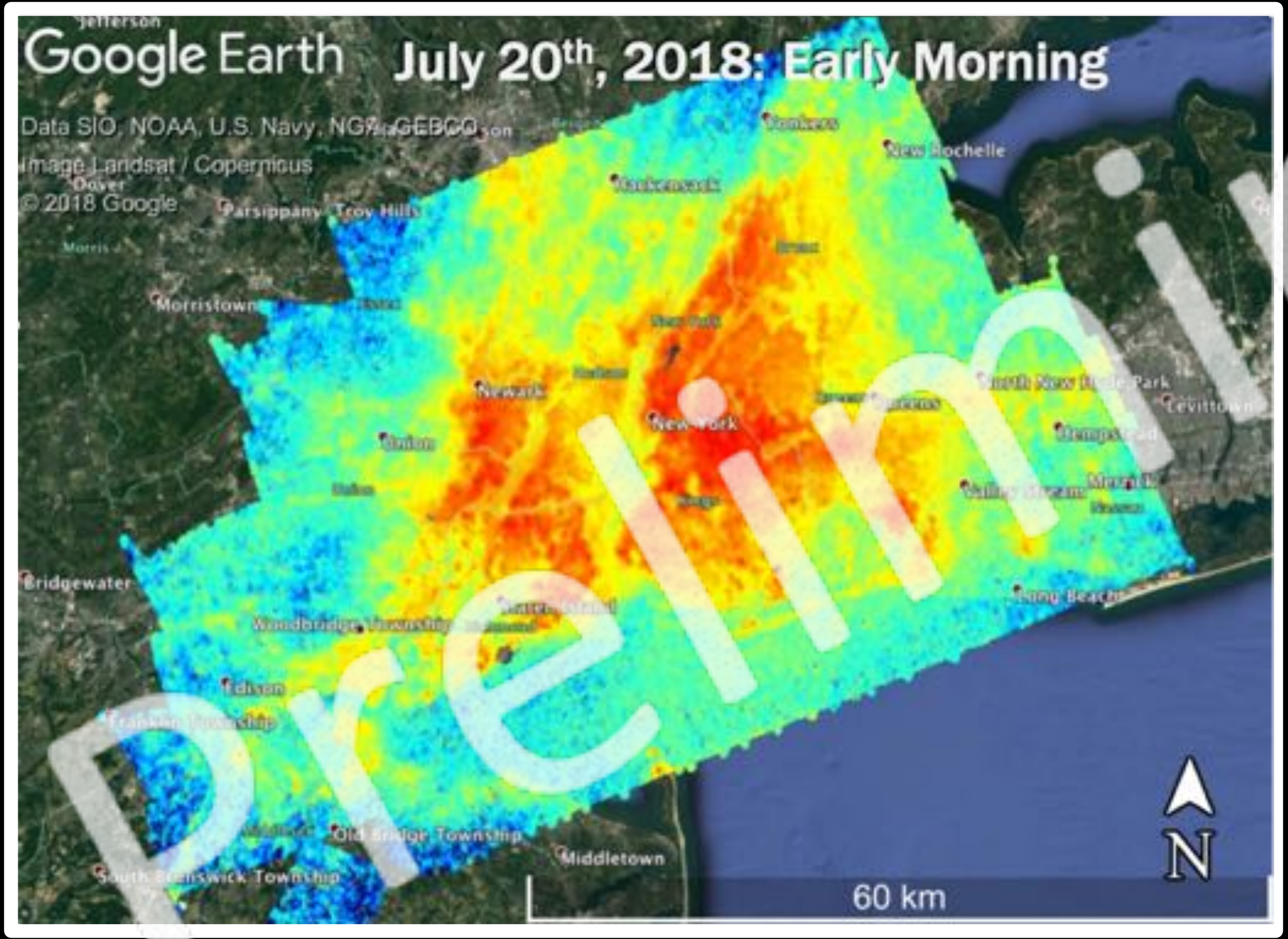

**In the afternoon…**

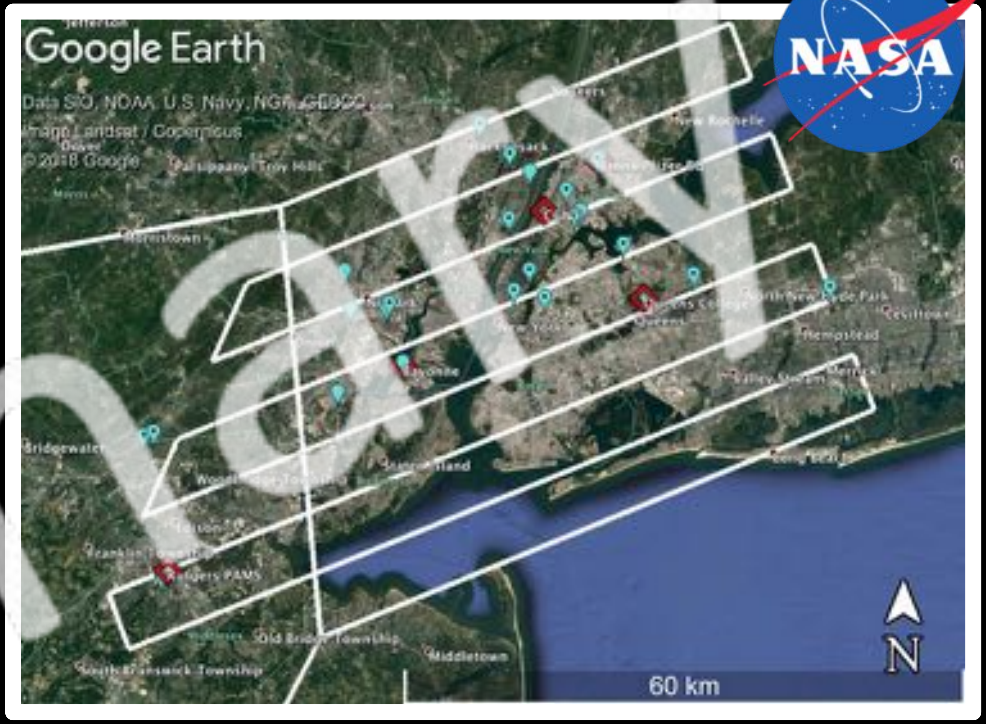
NASA's airborne spectrometer, GCAS, is able to pick up signatures from single point sources [e.g. powerplants, airports, traveling corridors]

3km NAM analysis from 13:00 EDT highlights emissions extending downwind with a convergence zone along the CT Coast

LaRC Ozone Lidar at Westport confirms the production and transport of ozone

# Diurnal Emissions Sampling

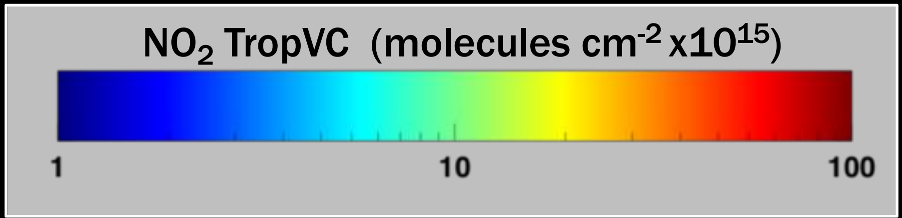



**Goals:**

**(1) capture diurnal variations in emissions sources and transport over the city**

**(2) Gather a dataset for testing time-of-day influences on the retrieval—preparing for geostationary observations**



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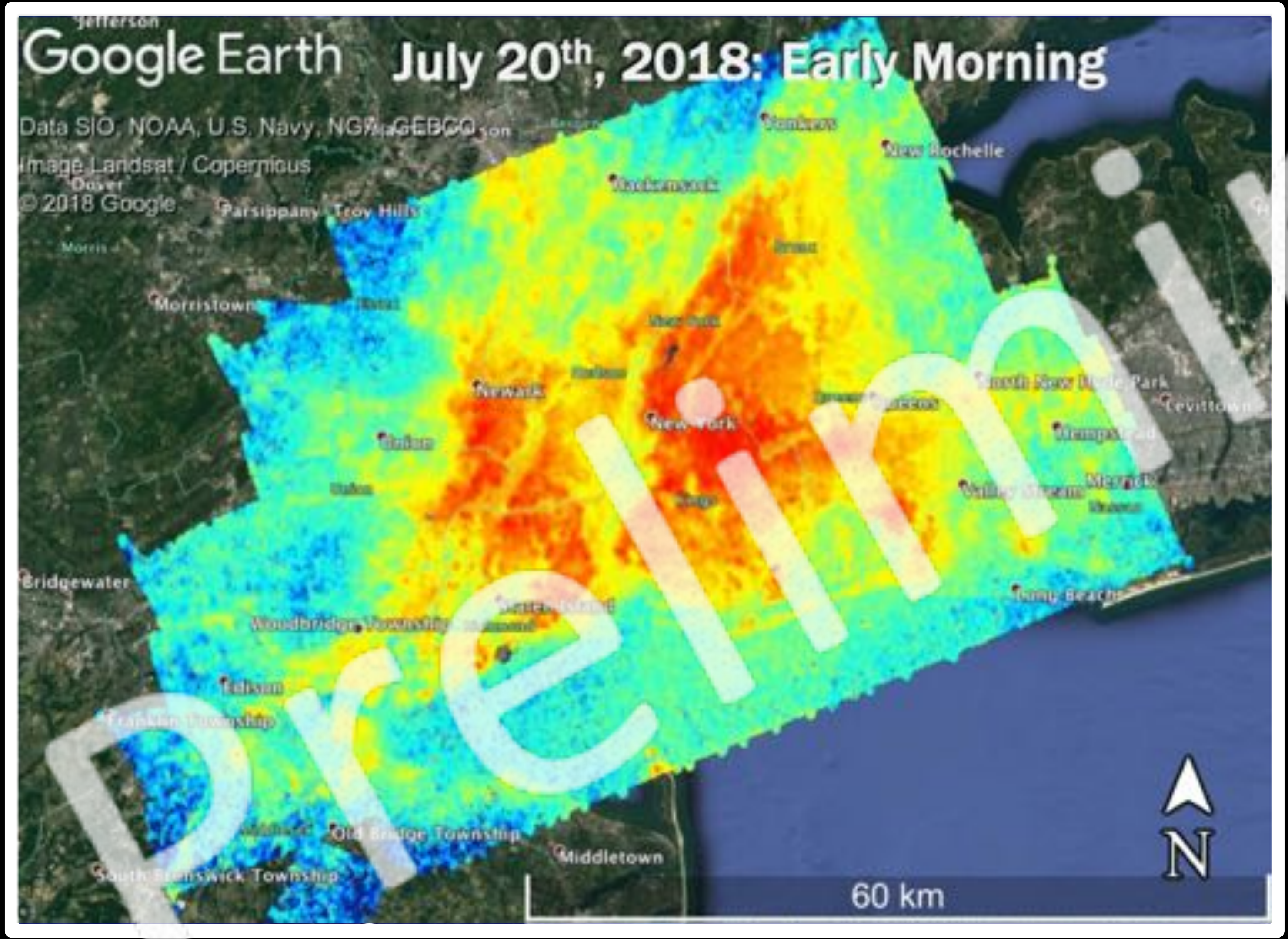


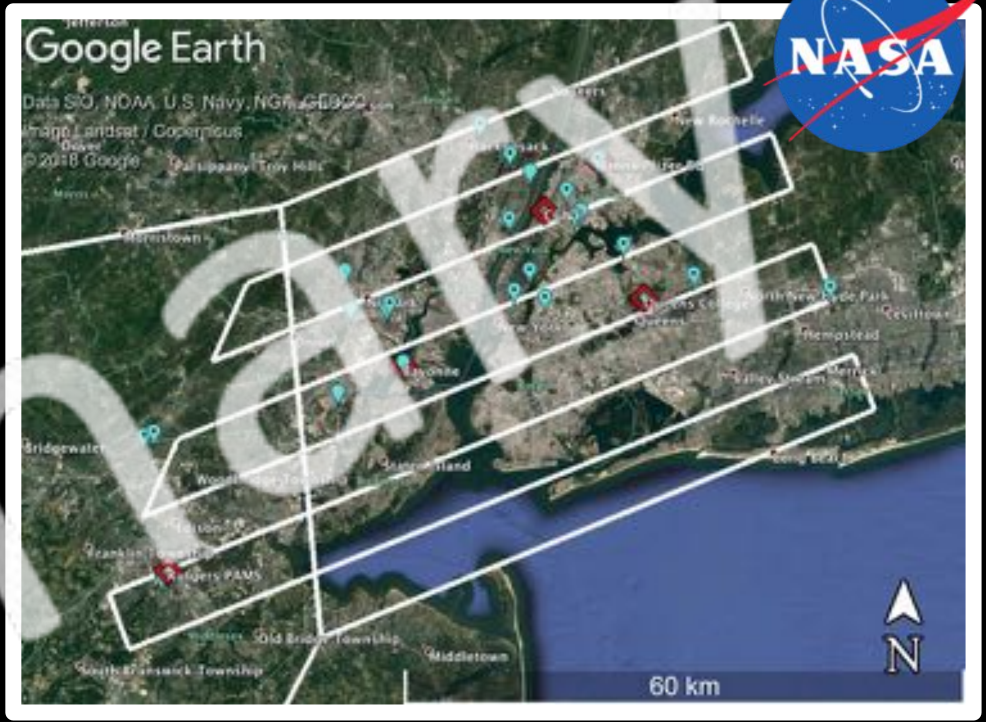


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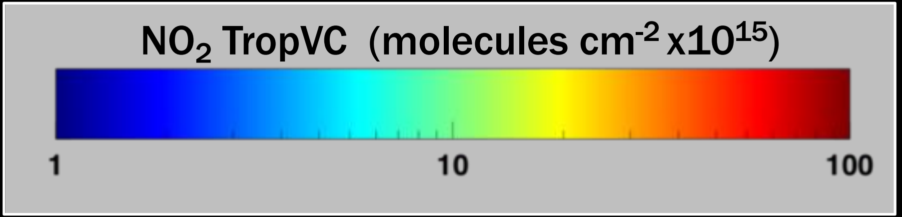
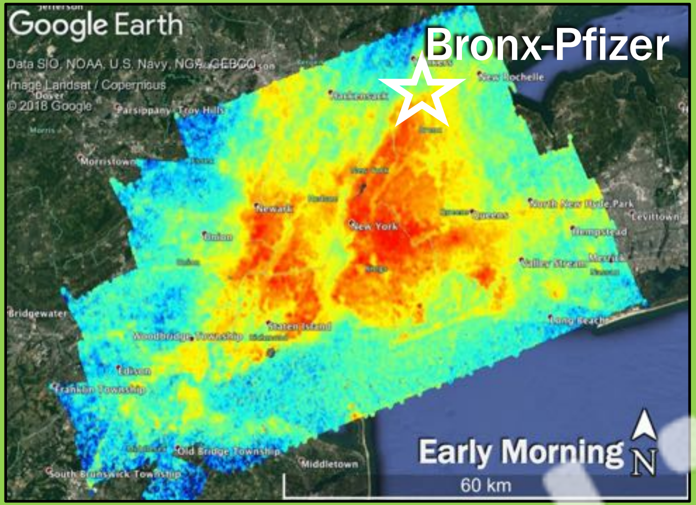
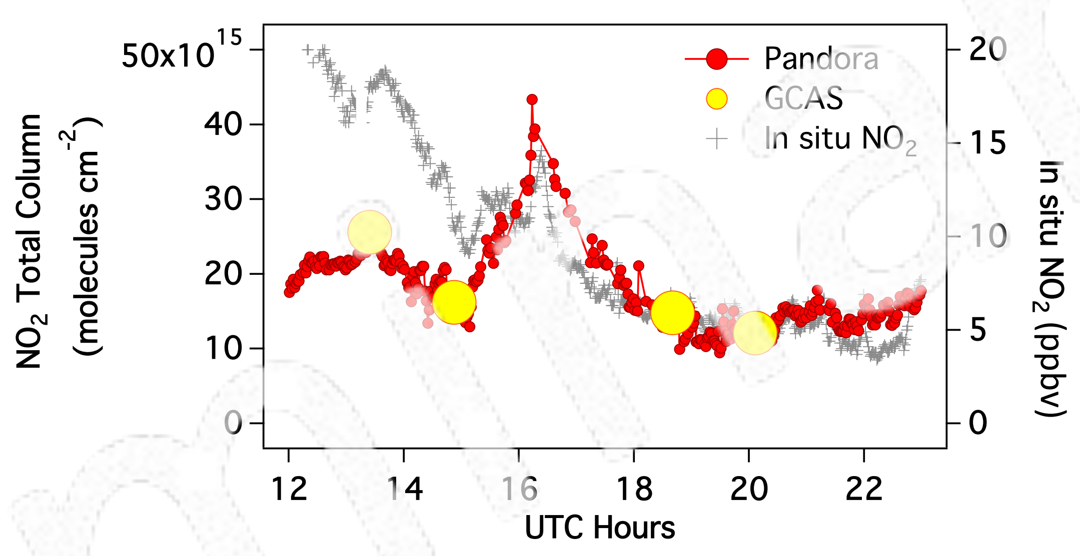


# Connecting a Ground site (Bronx) to the Raster image: Day-to-day Variability

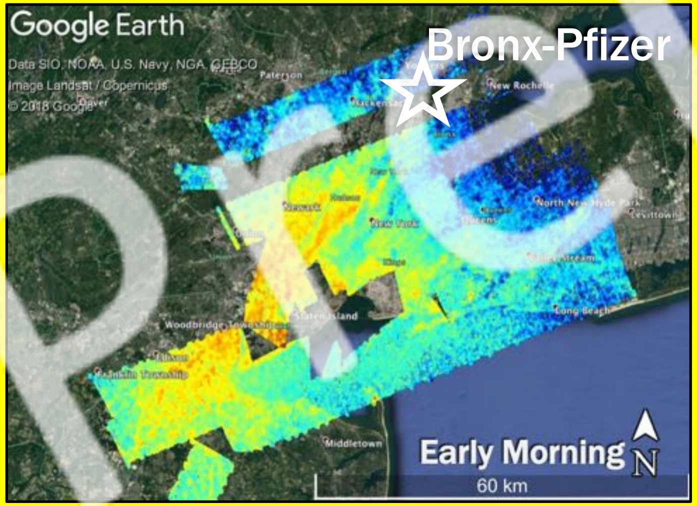
## Friday, July 20th, 2018

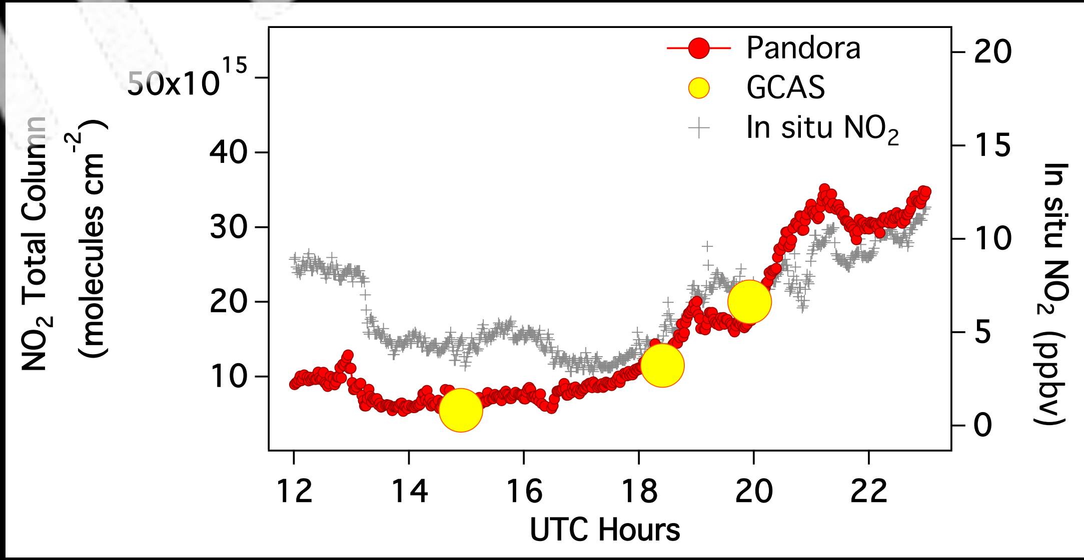



*Preliminary 1 minute ground in situ $NO_2$ data credit to NYSDEC staff*

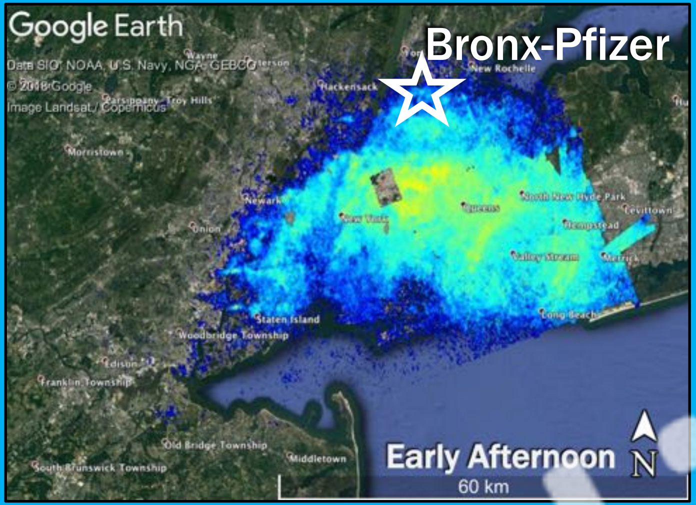
## Thursday, July 19th, 2018

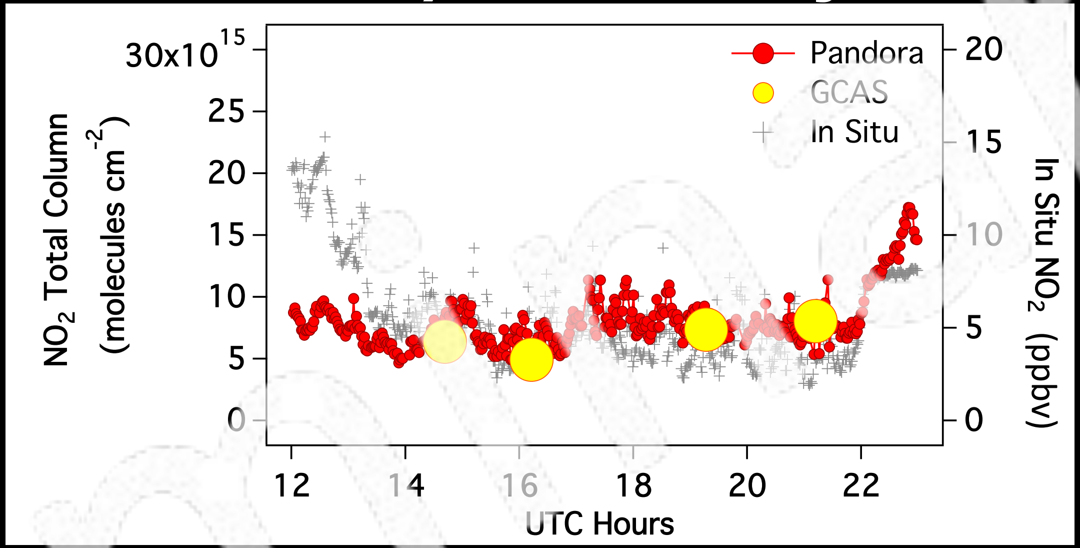


# Connecting a Ground site (Bronx) to the Raster image: Weekend/Weekday Variability

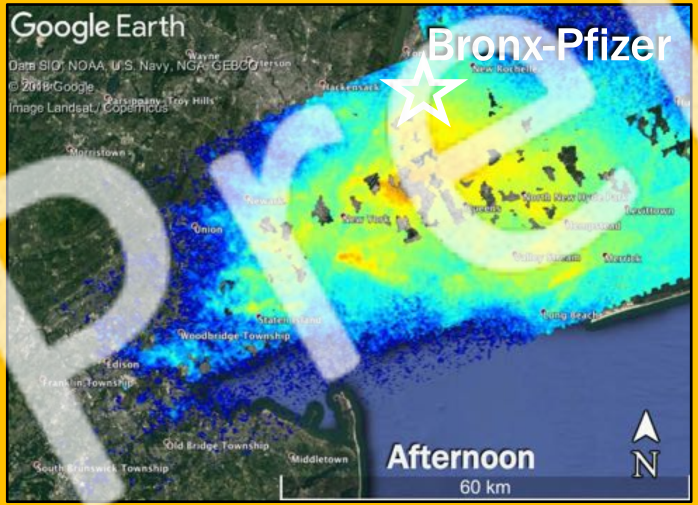
## Sunday, August 5th, 2018

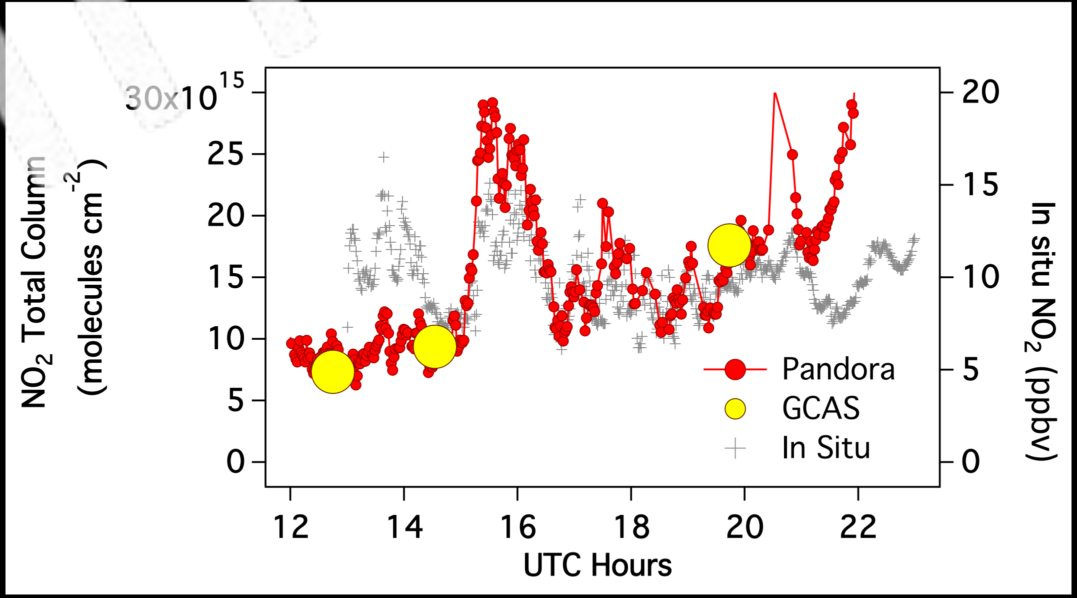



*Preliminary 1 minute ground in situ $NO_2$ data credit to NYSDEC staff*

## Monday, August 6th, 2018

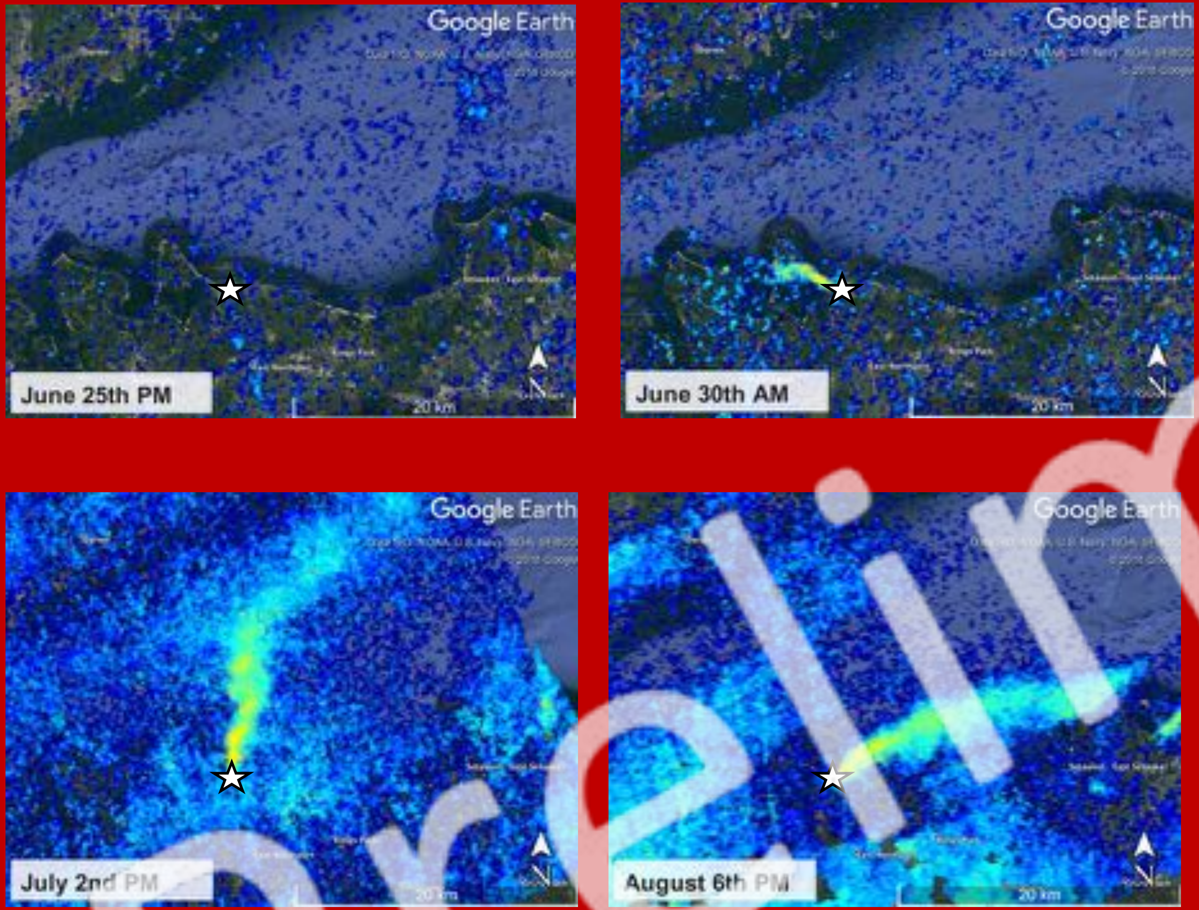


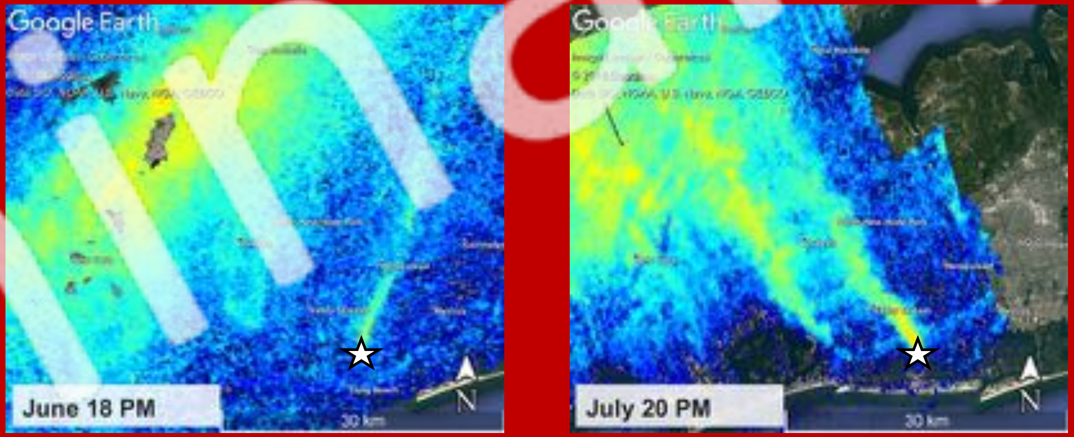
# Common Questions: Can we see...?

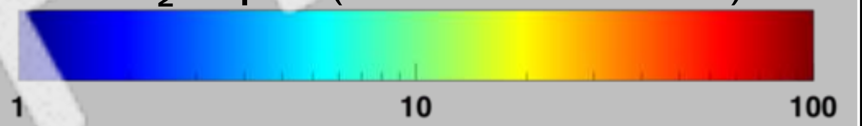
## Non-baseload/Peaking Facilities: Frequently

### Isolated Example: Northport Power Station




### Semi-isolated Example: E.F. Barrett (Bonus: JFK Airport)



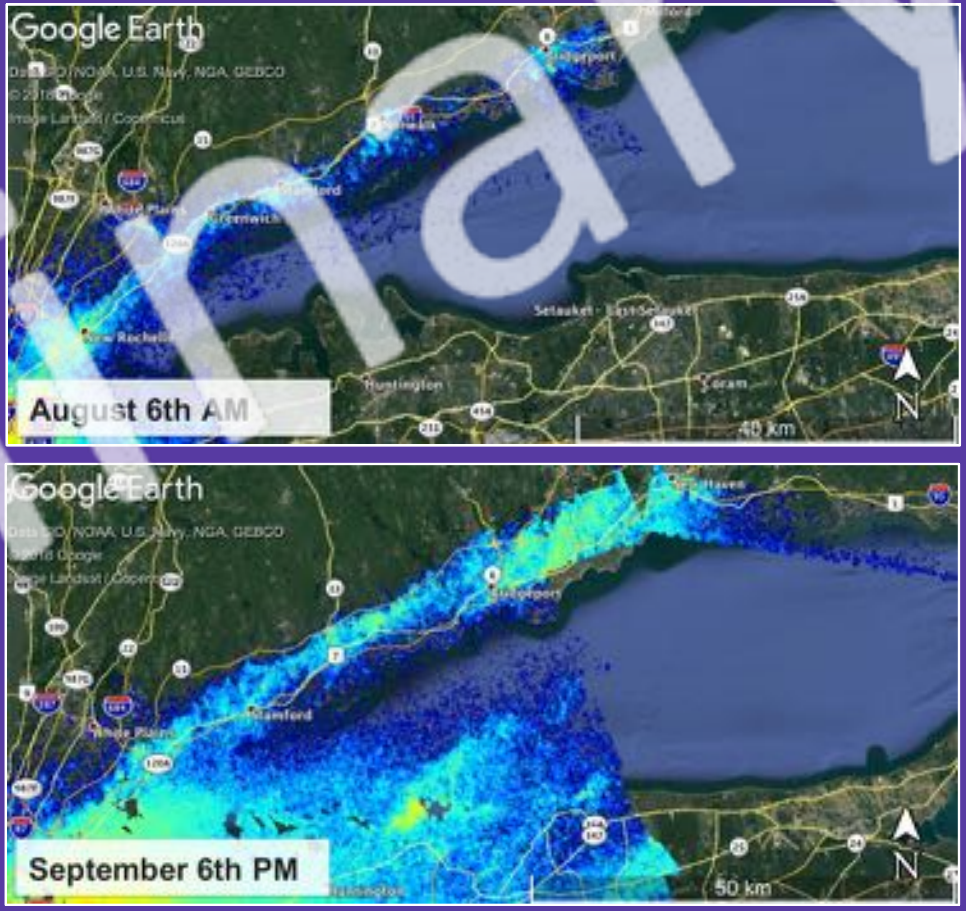

Possible ways to use this data:

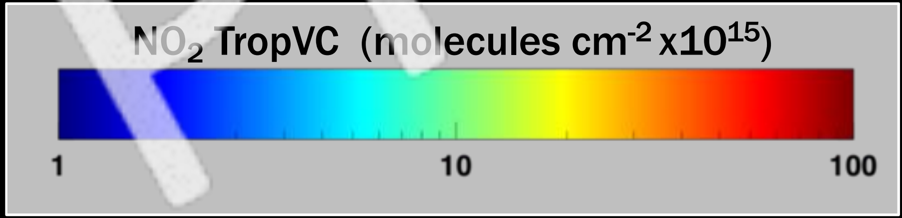
1. Help understand how reported emissions relate to the footprint observed in the column
2. Evaluate a model's ability to simulate the structure and footprint of these emissions
3. We can simulate how these plumes would look at any spatial scale of a satellite/model

# Common Questions: Can we see…?

## Isolated Mobile Sources: occasionally

### I-95 Corridor: Near the most extreme examples

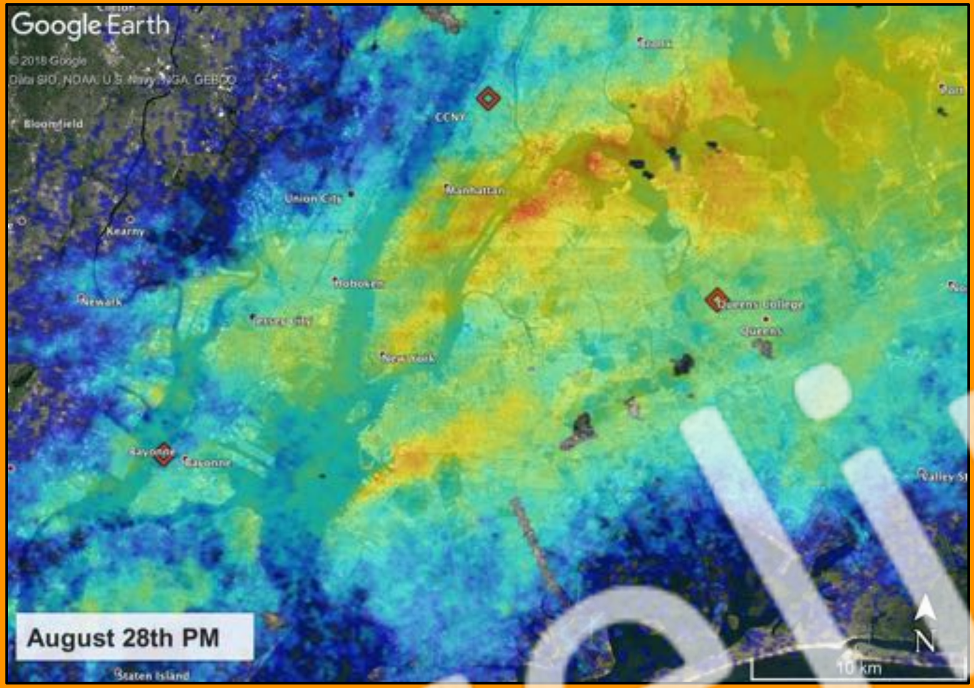




There is the possibility of more road signatures within the urban plume (non-isolated cased), though it may take an experts eye to identify places, but more likely a modeling sensitivity studies evaluating the mobile emissions sector.

# Inside NYC: Are these patterns expected?

## 'Hot' spots within NYC on Classic LIS ozone days

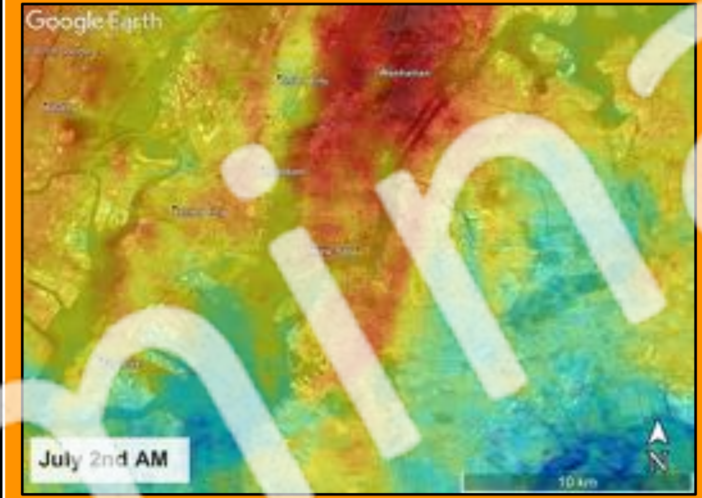


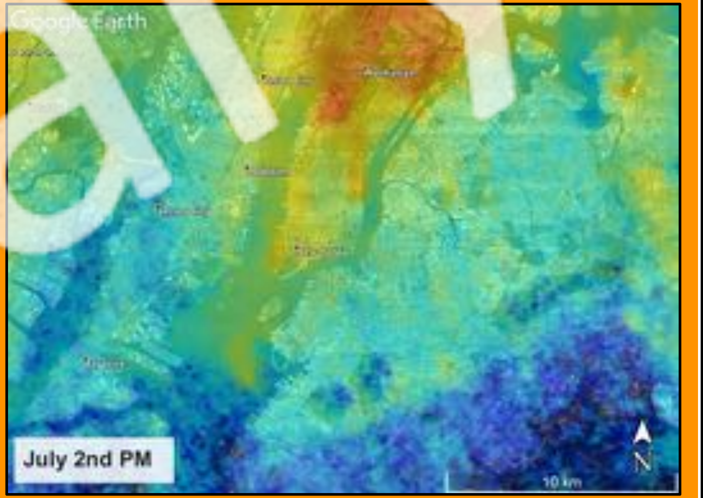

**Questions for the Emissions Experts:**

- Where do you expect enhancements in observations based on emissions inventories?
- What is there that you don't expect?
  (e.g., in Chicago a potential unaccounted source are intermodal facilities)

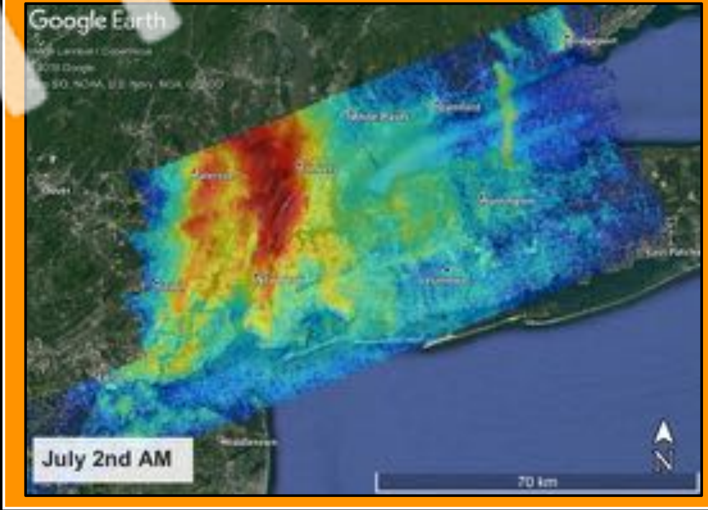
## Non-classic Ozone Day: July 2nd, 2018—day 3 heatwave

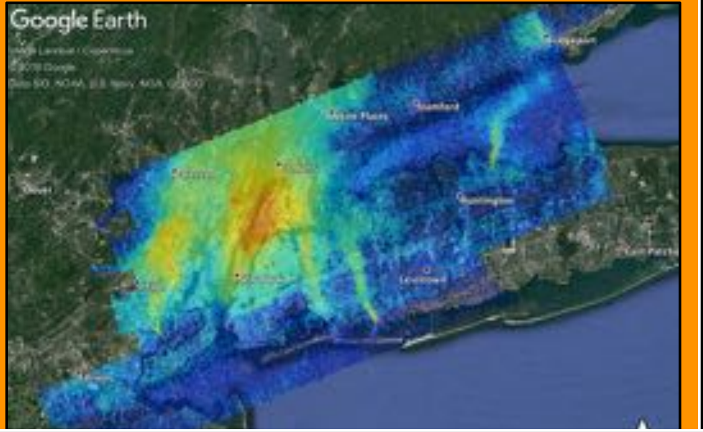
$NO_2$ origins appear to be from the same areas…

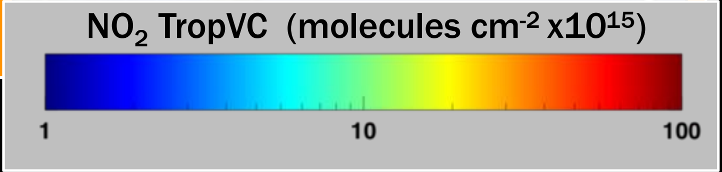



…as well as EGUs

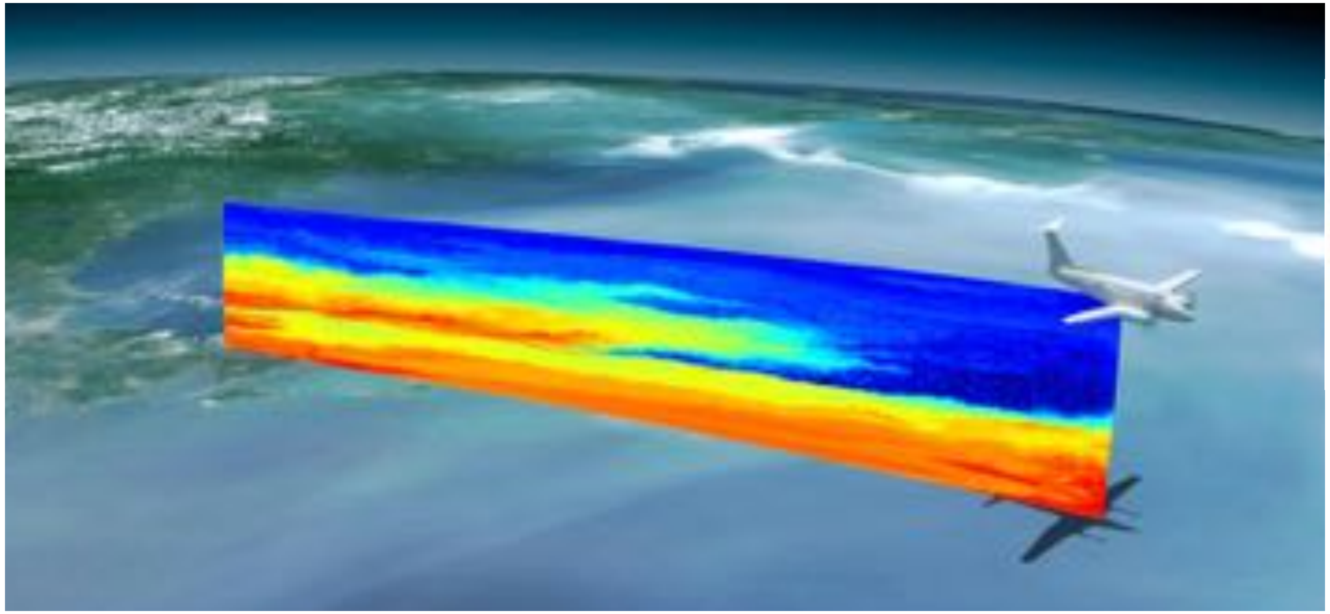


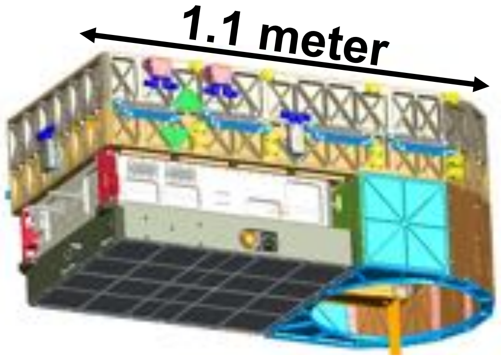



# HALO: NASA LaRC Remote Sensing of Aerosols and Methane

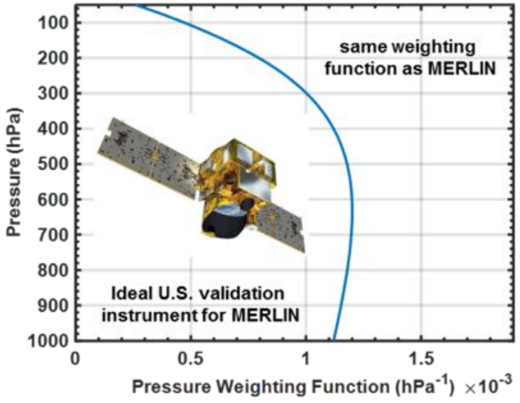
## HALO Aerosol Profiling Capabilities



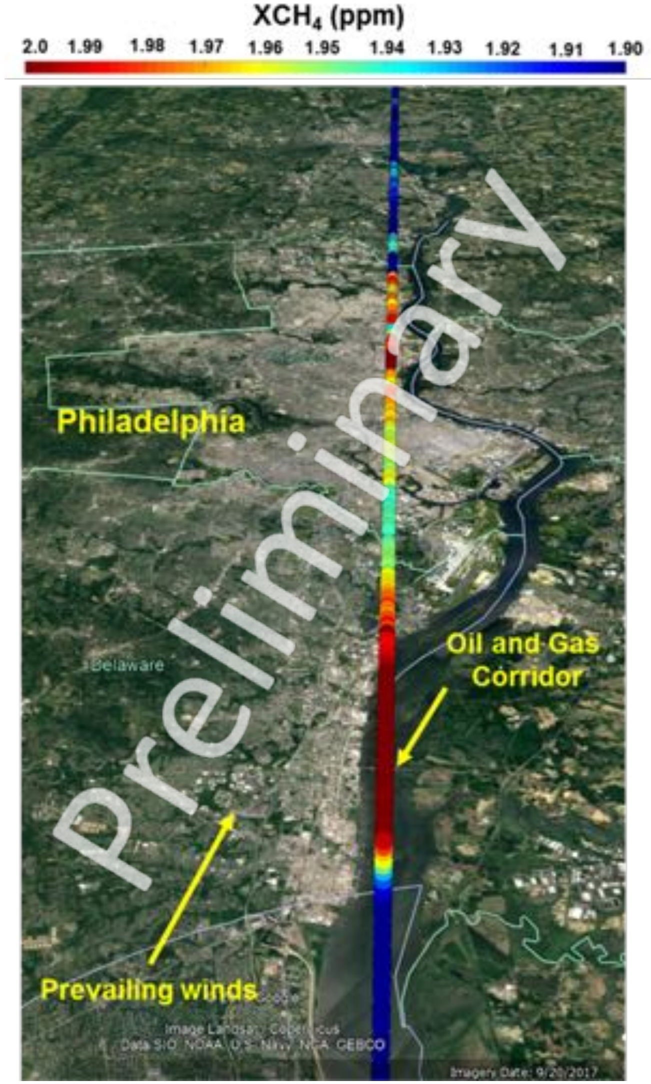
## HALO Instrument




## $CH_4$ Weighting



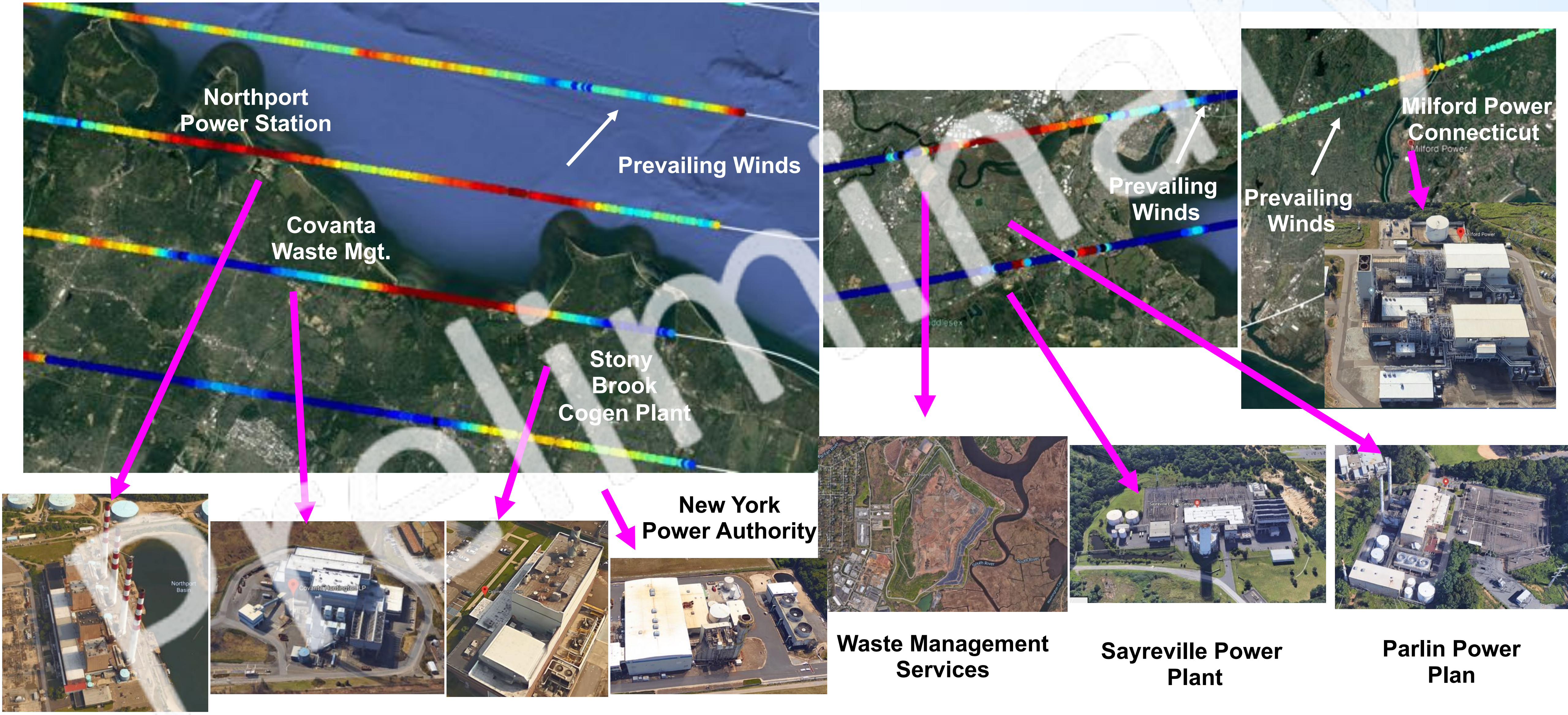

## $CH_4$ Mapping




- HALO NASA remote sensing asset for simultaneous aerosol and methane profiling
- Aerosol profiling for quantification of **boundary layer height** and **PM 2.5** for air quality applications
- **Methane** columns and profiling for source identification
  - < 18 ppb (1%) precision with 100 meter spatial resolution
  - Apportionment of boundary layer $CH_4$ from column for mixing and transport

**Slides created by Amin Nehrir, HALO PI, NASA LaRC**

# Methane Point Source Identification During LISTOS



# Take home points...

We flew 32 flights (> 100 hours) from June-October 2018 over NYC/LIS in support of LISTOS

Preliminary science highlights include:

1) Large day-to-day and hour-to-hour variations in $NO_2$ in the NYC/LIS region
2) Characterization of LIS ozone events from a point of view w.r.t. $NO_2$ emissions and transport
3) Visualizing emission sources like airports, roadways, peaking units, as well as identifying some regions with commonly high pollution levels
4) Co-located with GCAS, HALO measured the vertical distribution of aerosols, mixed layer depths, and methane.

This presentation shared a broad qualitative overview of the dataset we collected, but to start quantifying these these results, we are in need of collaborators! Let us know how you think our measurements can help answer your science questions.

Projected goal for publicly available $NO_2$ data: Fall 2019

Questions: laura.m.judd@nasa.gov


Special thanks:

*NASA GeoTASO/GCAS team*
*NASA HALO Team*
*LISTOS Science Teams (especially those who participated in the daily flight planning telecons)*
*NASA GeoCAPE*
*NASA LaRC RSD Pilots and Crew*
*US EPA*
*Pandora/Pandonia*
*NYSDEC*