TRACER-AQ: An Integrated Approach Linking to TEMPO Science, Applications, and Validation

Presented by: John Sullivan, NASA GSFC & Laura Judd, NASA LaRC

Objective:

To highlight TEMPO-relevant measurements collected during TRACER-AQ and discuss how they can relate to TEMPO product validation, science, and applications. This forum could also be used to highlight other field studies such as the ongoing MOOSE study or validation efforts during 2023 activities in the NYC region post-TEMPO launch.

Possible Discussion topics

- General Information about TRACER-AQ
  (as well as MOOSE 2021 and opportunities in 2023)
- TRACER-AQ links to lessons learned for TEMPO validation, science, and applications
- Observation strategies with multiple observing systems for current/future field campaigns

Sub-sections

1. *TRACER-AQ Overview and Objectives*
2. *Ground-based Measurements*
3. *Aircraft-based Measurements*

Links to TEMPO....

4. *Validation*
5. *Science*
6. *Applications*
7. *Other Activities*

TRACER-AQ Overview and Objectives

Leveraging activities surrounding DOE's TRACER Study

Originally Summer 2021→delayed to October 2021

NASA HQ supporting the development of an air quality component called....TRACER-AQ:

IOP: September 2021

Science Objectives:

1. Ozone Photochemistry and Meteorology
2. Modeling and Satellite Evaluation
3. Intersection of Air Quality and Socioeconomics Factors

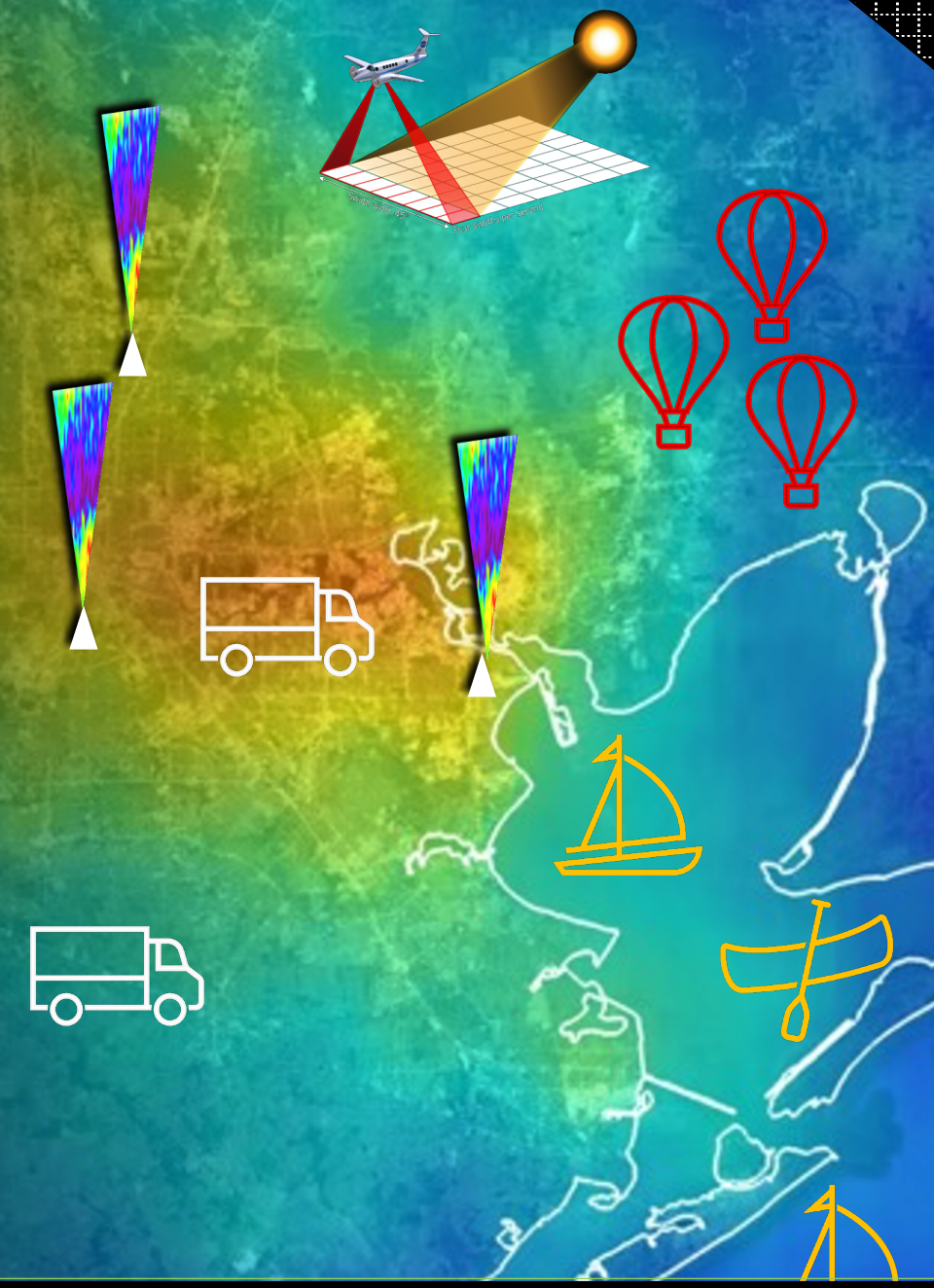
⇢Partners:

⇢DOE Tracking Aerosol Convection interactions ExpeRiment (TRACER)

⇢Texas Commission on Environmental Quality (TCEQ)

⇢NOAA

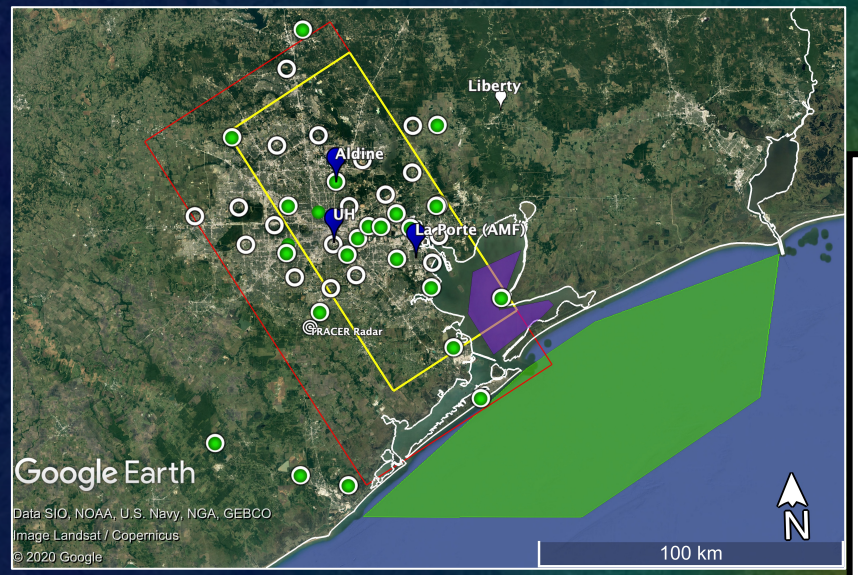
⇢Academic institutions: UH, Baylor, St. Edwards, VTech



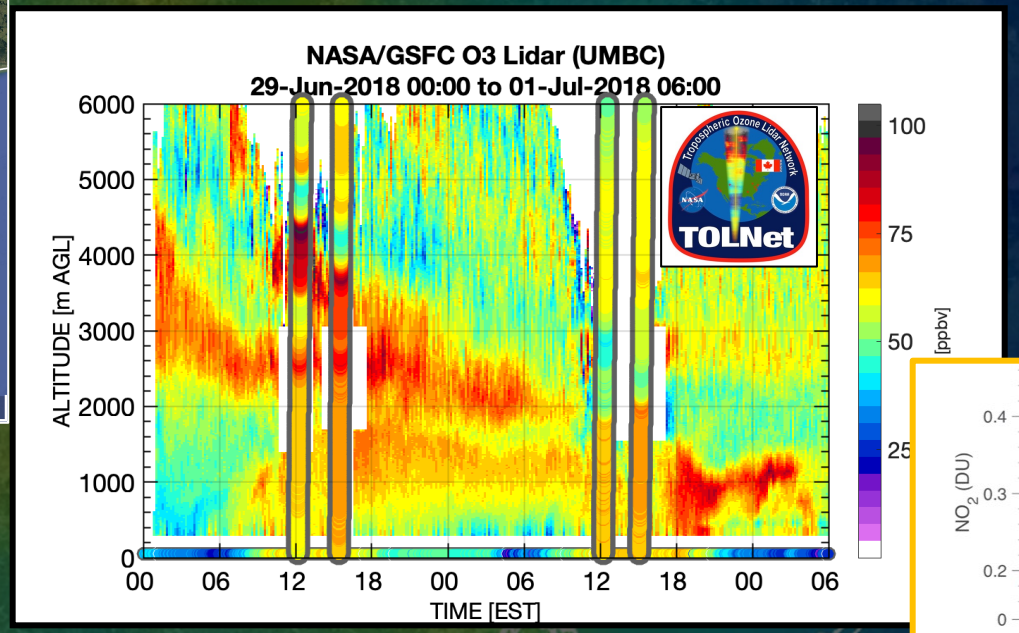
Science Plan Document available at:
https://www-air.larc.nasa.gov/missions/tracer-aq/index.html

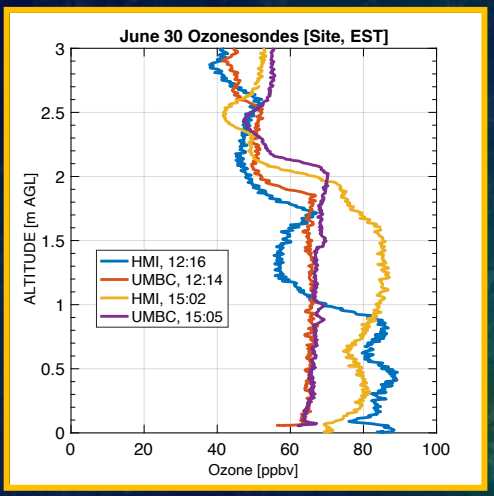
Ground & Aircraft Measurements | Links to TEMPO Validation, Science, and Applications | Other Activities

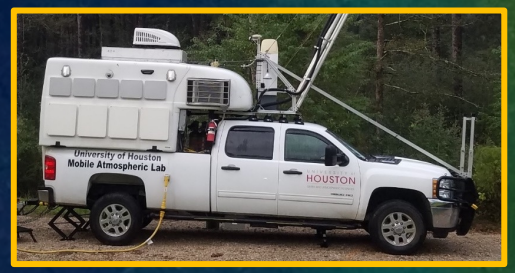
TRACER-AQ Ground Measurements

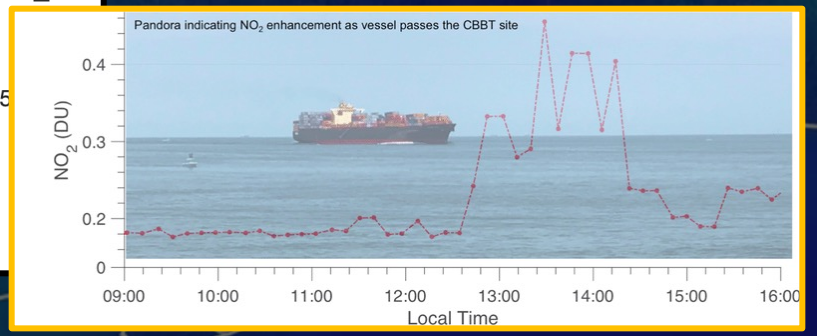


Pandora, TOLNet, Ozonesondes, ground-based and mobiles platform measurements at key super sites









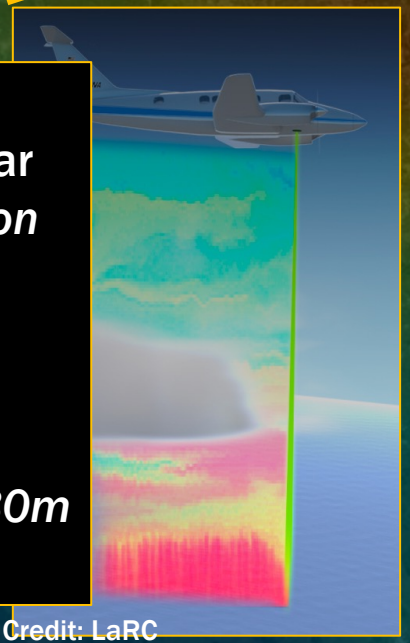
⇢ Deploy key assets to ground sites to better characterize pollution episodes, chemical transport, and coastal gradients, and socio-economic relationships to pollution

- Collaborate and expand relationships with end-users and the backdrop of extensive local regulatory observations
- Connect surface observations to those mapped via aircraft and from satellite platforms in preparation for TEMPO

TRACER-AQ Aircraft Measurements

up to 80 flight hours repeatedly rastering Houston 4x per flight day

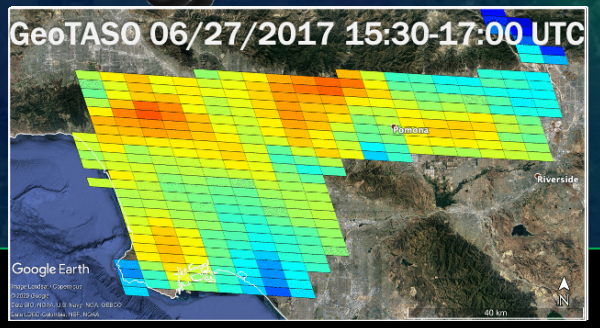
Click here to see tentative flight plans



Credit: LaRC

HSRL 2/DIAL

- Nadir pointing multi-wavelength lidar
- *Aerosol backscatter (10 s), extinction (60s), optical depth, classification*
- *Ozone curtains*
  - *60s running average (13.5 km)*
  - *Vertical resolution 270m or 380m*
- *Mixed layer height*



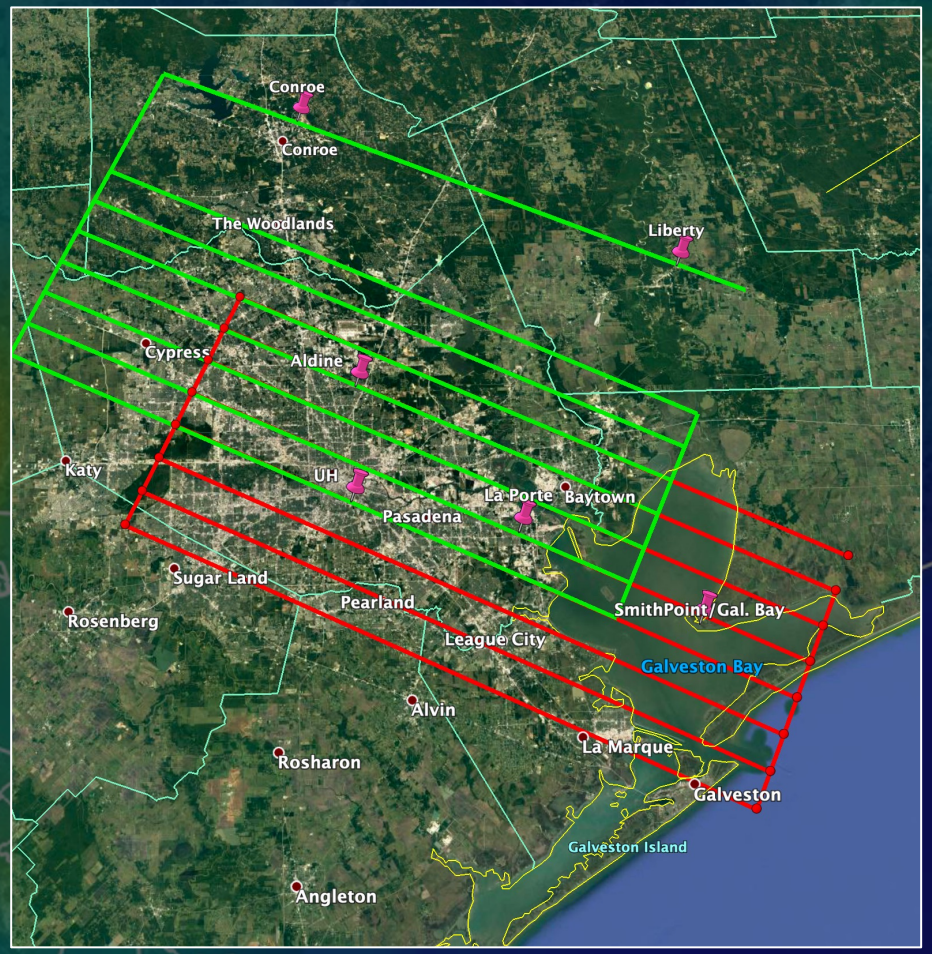
GCAS

- Passive UV-VIS pushbroom spectrometer
- Integration times are typically 4hz (unless lower sun angles)
- Across track FOV is 45°
  - ~7km at FL280 and ~9.7km at FL390
- *NO2 below aircraft columns*
  - *Estimating 500m resolution*
- *HCHO below aircraft columns*
  - *Estimating 1km resolution*

TRACER-AQ Tentative Flight Plans

Goal: repeat gapless maps every 2 hours or less over the area of interest with all rasters including our ground sites

- ⇢ Each raster can be flown 4x in one flight at a flight altitude of 28,000 feet (8.5 hours) with up to 1 hour of time to spare early in the month of September (we lose that sunlight later in Sept.).
- ⇢ Red is the baseline plan and green is if we expect pollution to advect north and/or west over the course of the day.
- ⇢ More area could be mapped at FL390 (5 rasters or 4 larger rasters) at the expense of HSRL ozone vertical profiles having a vertical resolution of 380m (as compared to 270 m).
- ⇢ Other targets could include boats in the GoM, Parrish PP as opportunities are available.



TRACER-AQ Links to TEMPO Validation

Click options below to learn more about individual efforts

Near Surface O_3 from TOLNet and/or HSRL2

Pandora Spectrometers (stationary, boat, mobile)

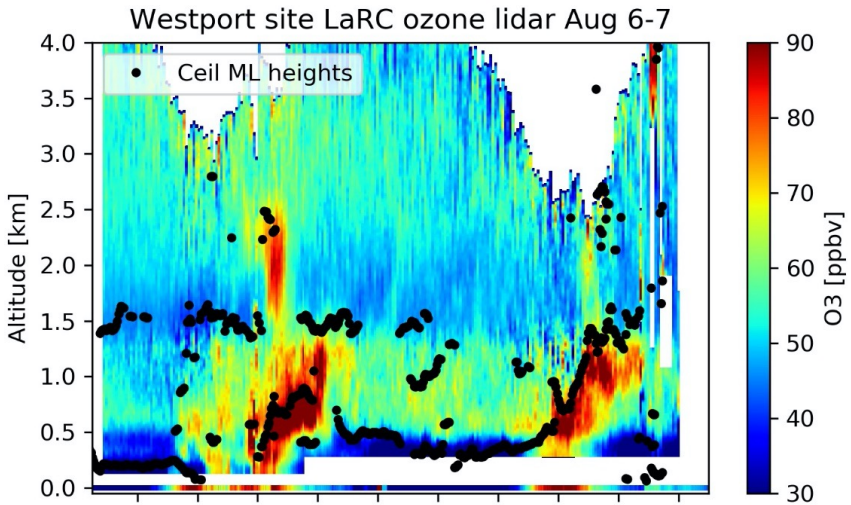
GCAS NO_2 + HCHO Column Mapping

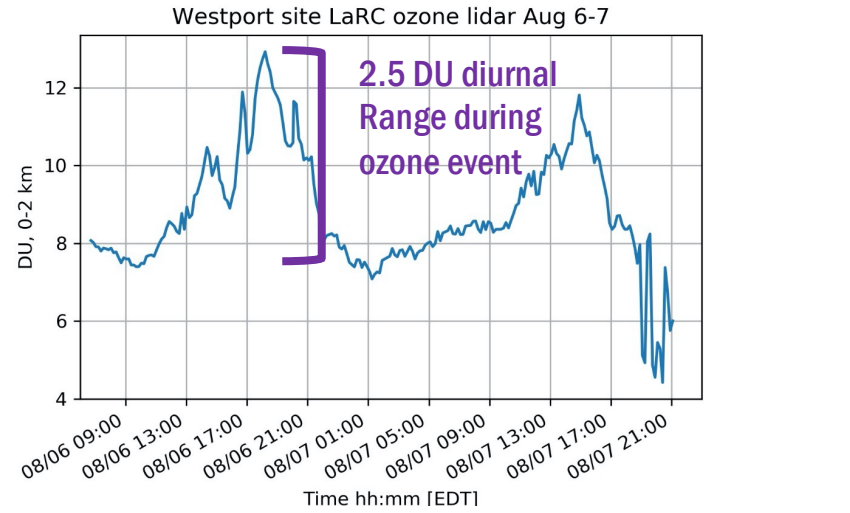
Others

An undemonstrated product from satellites is TEMPO's 0-2km ozone column with an expected precision of 10 ppbv (1.7 DU).

TOLNet can be used to observe the integrated O_3 column within the lowest 2 km as well as show the vertical distribution and how that varies diurnally.

On flight days HSRL-2/DIAL could also show this distribution spatially over Houston with 5 km resolution along-track





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Near Surface O_3 from TOLNet and/or HSRL2

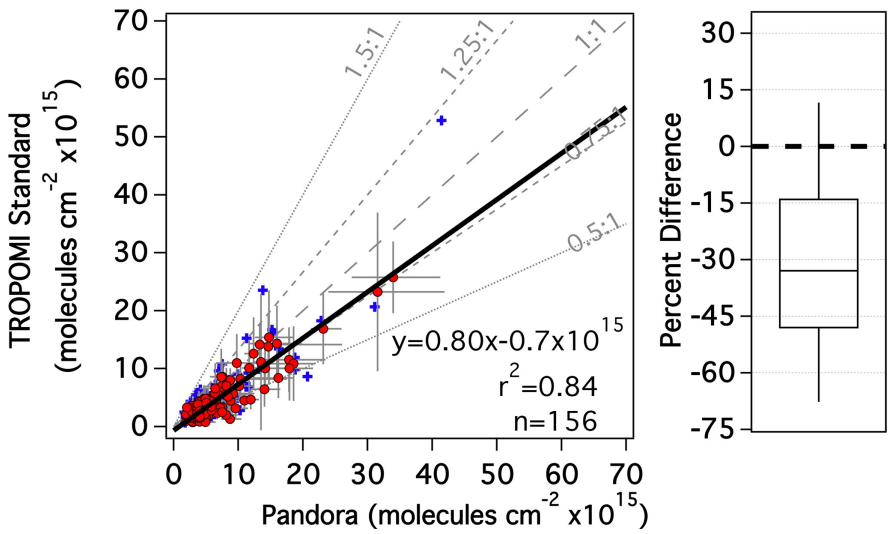
Pandora Spectrometers (stationary, boat, mobile)

GCAS NO_2 + HCHO Column Mapping

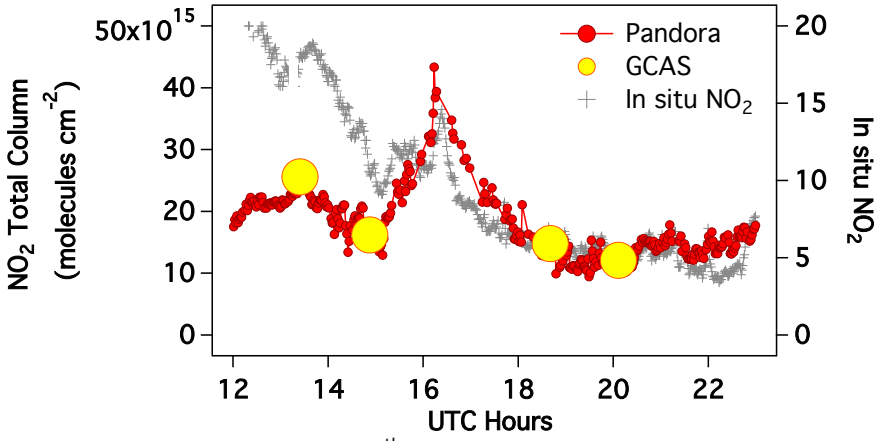
Others

Pandora spectrometers will be installed at 4 ground sites (3 of the sites have a second dedicated for MAX-DOAS courtesy of E. Lind), one boat in Galveston Bay, and potentially another operating on a mobile lab.

These instruments have been used to validate/evaluate OMI and TROPOMI with expected enhanced utility as we transition to geostationary to capture the diurnal evolution of profiles.



TROPOMI Standard Product vs. Pandora network in LISTOS 2018



Bronx Pandora on July 20th, 2018 compared to GCAS and in situ surface

TRACER-AQ Links to TEMPO Validation

Click options below to learn more about individual efforts

Near Surface O_3 from TOLNet and/or HSRL2

Pandora Spectrometers (stationary, boat, mobile)

GCAS NO_2 + HCHO Column Mapping

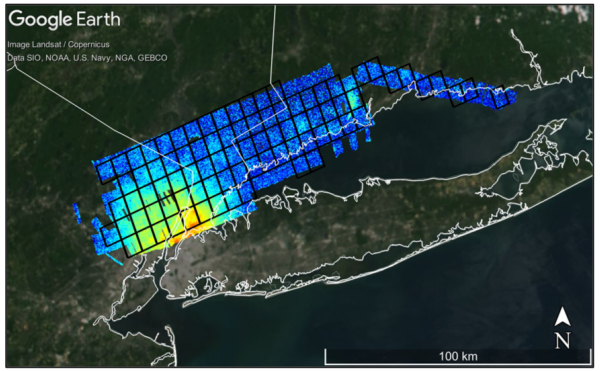
Others

GCAS Trace gas column data will be used to continue validation S5P TROPOMI products with lesson learned to apply to TEMPO data.

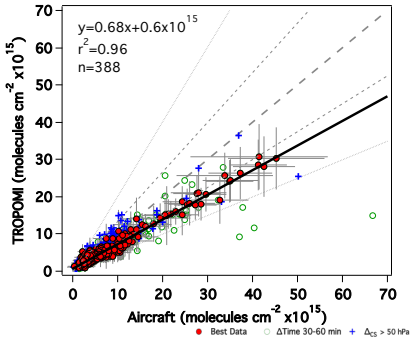
Additionally, similar to LISTOS, this data can be used to simulate what TEMPO will see at all times of day and mimic validation with Pandora.

Similar strategies have been and can be used for HCHO product validation

Previous validation for S5P TROMPOMI



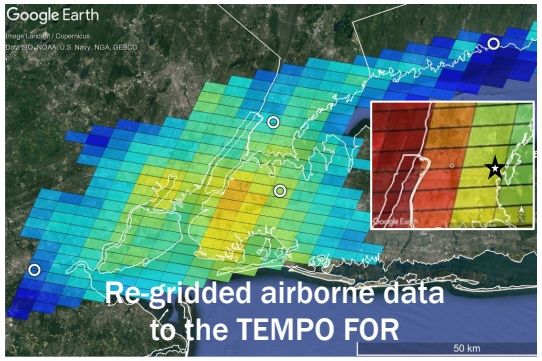
GCAS NO_2 within S5P pixels



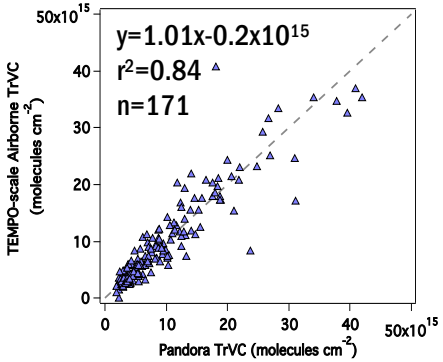
Statistical Comparisons between GCAS and S5P NO_2

Judd et al. (2020): https://doi.org/10.5194/amt-13-6113-2020

Mimicking Pandora Validation for TEMPO



GCAS NO_2 gridded to TEMPO scale



Comparison to Pandora at this scale

TRACER-AQ Links to TEMPO Validation

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Near Surface O_3 from TOLNet and/or HSRL2

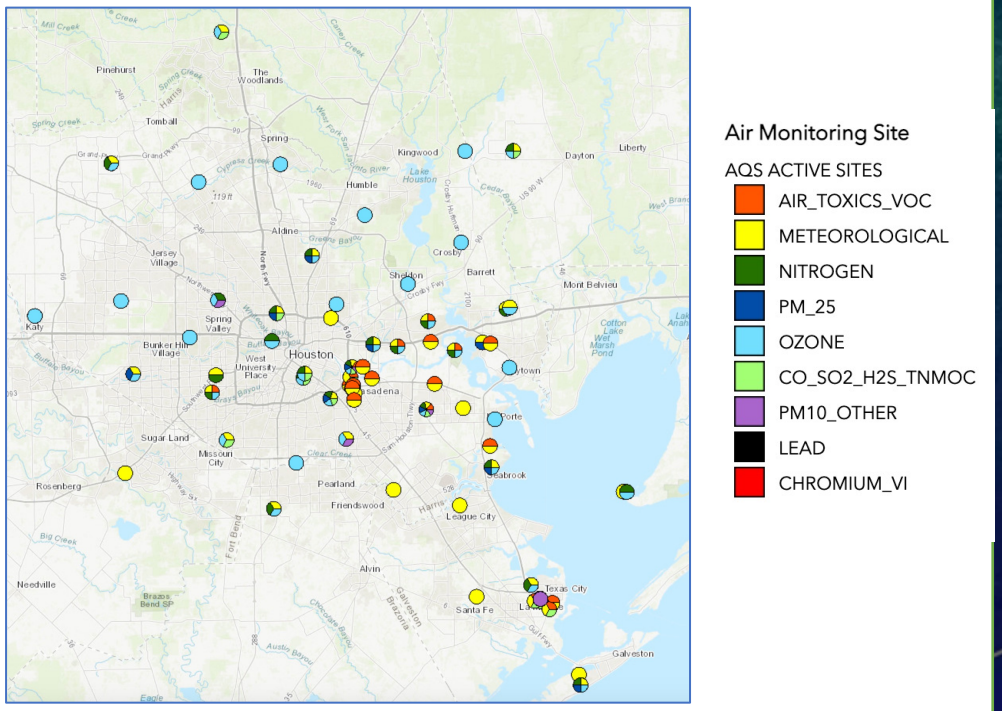
Pandora Spectrometers (stationary, boat, mobile)

GCAS NO_2 + HCHO Column Mapping

Others

Other opportunities include:
Intercomparisons and evaluation of SO_2 from the Langley Mobile Ozone Lidar plus SO_2 sondes from J. Flynn at UH.

Spatial and temporal evolution of aerosols from HSRL2 flights



https://tceq.maps.arcgis.com/apps/webappviewer/index.html?id=ab6f85198bda483a997a6956a8486539

Contextual evaluation of TEMPO products in comparison to the dense AQ network from TCEQ (shown above), City of Houston, and others.

TRACER-AQ Links to TEMPO Science

Click options below to learn more about our science focus areas

Focus Area 1: Ozone Photochemistry and Meteorology

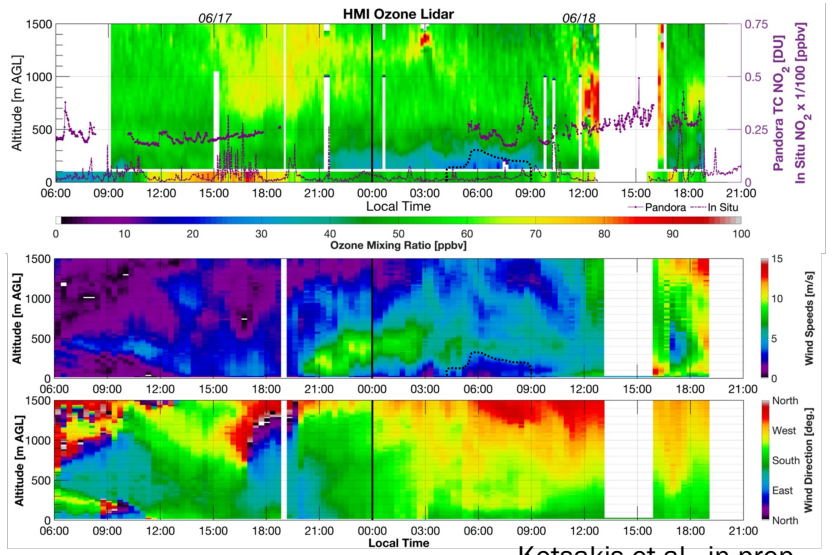
Focus Area 2: Modeling and Satellite Evaluation

Focus Area 3: Intersection of Air Quality and Socioeconomics Factors

During TRACER-AQ, the data collected will characterize the current state of ozone air quality and impact of meteorology in Houston.

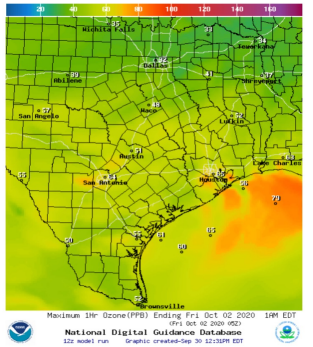
Measurement strategies aim to understand the temporal and spatial variations of emissions and the impact of physical, chemical, and dynamical processes over local spatial scales through all hours of the daytime in September in preparation for TEMPO.

Characterizing mesoscale circulation impacts on horizontal and vertical gradients/transport

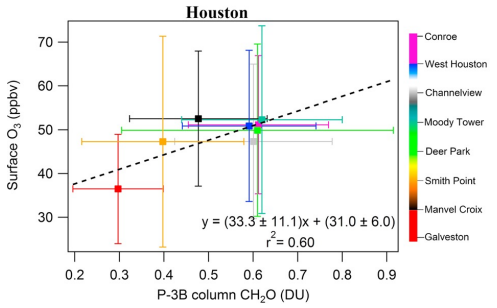


Kotsakis et al., in prep

Role of over water ozone?



O_3 indicator in HCHO



Schroeder et al. 2016: doi: 10.1002/2016JD025419

Please share your science ideas!

TRACER-AQ Links to TEMPO Science

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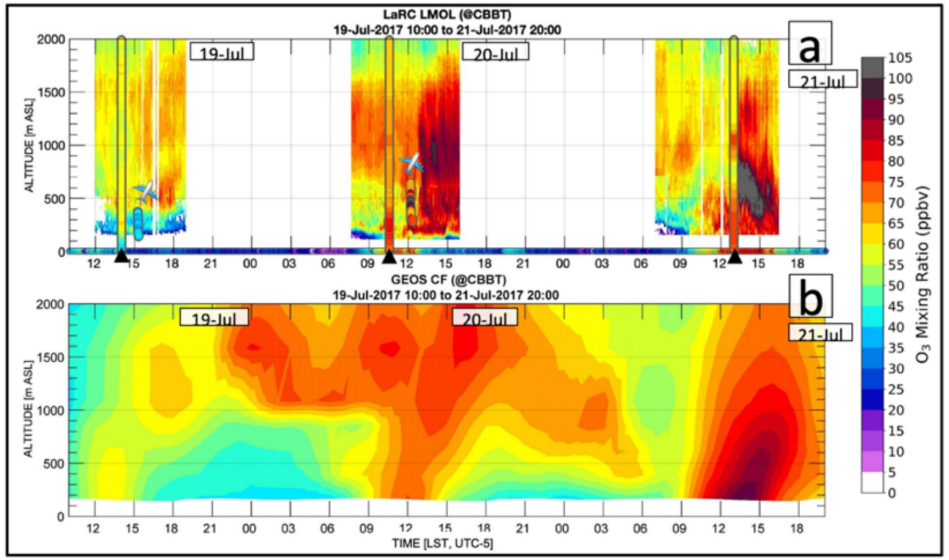
Focus Area 3: Intersection of Air Quality and Socioeconomics Factors

During TRACER-AQ, the data collected can be used to evaluate operational air quality forecasts/models (GEOS-CF, NOAA NAQFC, etc.) to understand the reality of revealed features (e.g., over water ozone) as well as evaluate satellite product retrievals such as those from S5P TROPOMI.

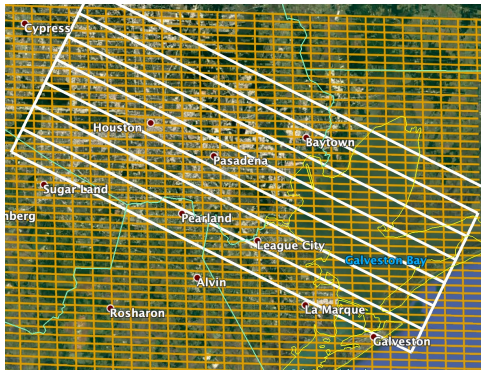
These evaluations will help inform the robustness of GEOS-CF as TEMPO a priori as well as a test for future TEMPO product validation/evaluations.

GEOS-CF evaluation TOLNet, sonde, aircraft observations



Dacic et al., 2020: doi: 10.1016/j.atmosenv.2019.117133

Airborne measurements will encompass hundreds of TEMPO proxy pixels every 2 hours, revealing both TEMPO scale + high resolution information for better understanding the utility of satellite measurements



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Focus Area 2: Modeling and Satellite Evaluation

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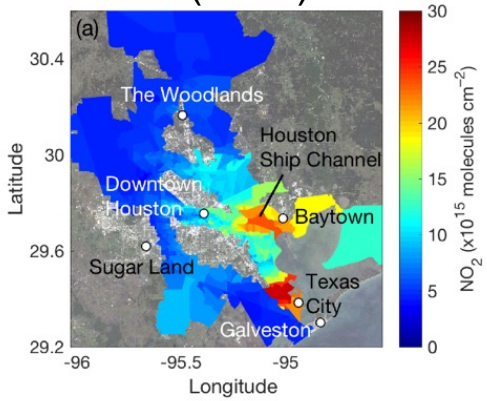
During TRACER-AQ, the airborne, mobile, and dense ground networks will be used to update the work of identifying NO_2 air quality disparities in Houston as documented by Demetillo et al. (2020) as well as expand analysis to HCHO and O_3.

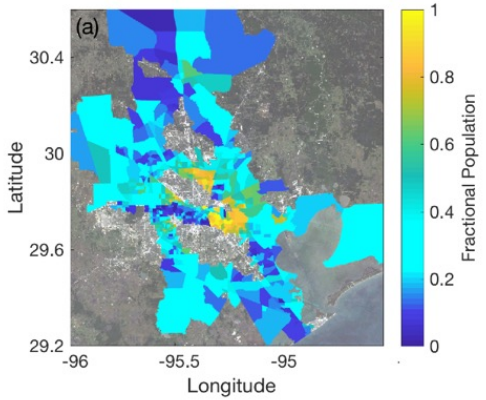
The data collected by the instruments on the airborne platform can be used to create TEMPO proxy datasets for this analysis. This work links to developing methodology for how TEMPO can improve Environmental Justice assessments for societal benefit.

In Houston 2013, Demetillo et al. (2020) found 37 ± 6% higher NO_2 for non-whites and Hispanics living in low-income tracts compared to for whites living in high-income tracts. We found NO_2 disparities of 11–32% by race-ethnicity and 15–28% for poverty status.

Sample GCAS circuit (2013)



Hispanic Population



Demetillo et al., 2020: doi: 10.1021/acs.est.0c01864

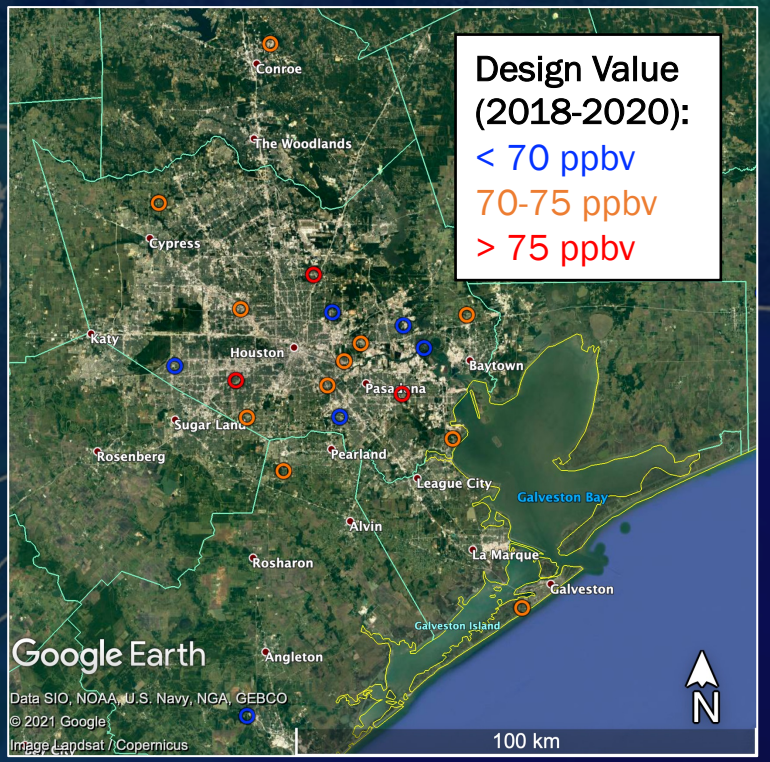
TRACER-AQ Links to TEMPO Applications

Historically, these small NASA campaigns have relied on and thrived on partnerships within the air quality community to best address air quality challenges and attainment strategies for regulations in regions with complex air quality issues. Our objective is to expanding knowledge about NASA Earth observations and tools with a focus on TEMPO adoption and applications.

TRACER-AQ measurements link to TEMPO Early Adopter goals to emulate future TEMPO measurements from the various platforms + TEMPO synthetic data to prepare end-users for use in:

1. Air quality monitoring/forecasting
2. Emissions characterization
3. Environmental health monitoring (Environmental Justice)
4. Attainment strategies to regulatory standards

Specific to TRACER-AQ: Texas Commission on Environmental Quality (TCEQ) is an active partner through their additional support of the NOAA TOLNet system, mobile laboratory measurements, ozonesondes, over-water boating measurements and air quality forecasting support. **One of their primary unanswered question is the role of overwater ozone over the Gulf of Mexico and Galveston Bay and for NASA to explore the application of TEMPO data for this and other needed purposes.**



Think TRACER-AQ observations could help with your application needs? Let us know!

Other Activities to Leverage in 2021 and 2023

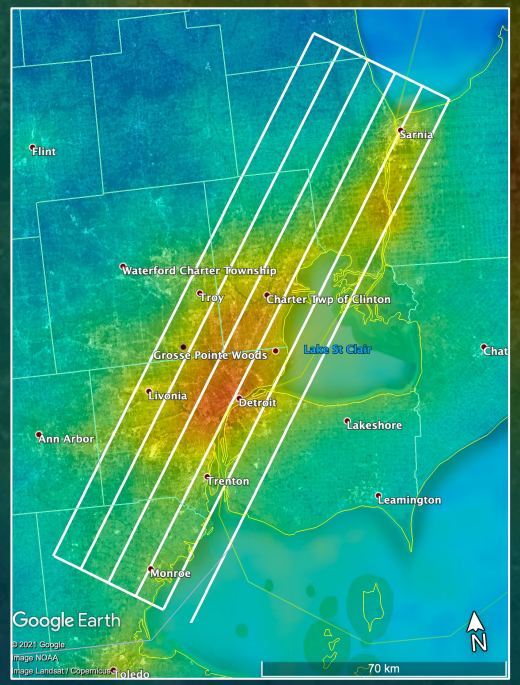
MOOSE: Michigan-Ontario Ozone Source Experiment

Now & Summer 2022

Goal: Community study to investigate attainment strategies for ozone standard attainment in SE Michigan and Ontario

Activities (not all inclusive):

- Characterizing ozone precursor sources (including landfills)
- 3D flows associated with lake breezes, urban heat islands, and their impact on ozone
- Meteorological and chemical modeling to inform control strategies

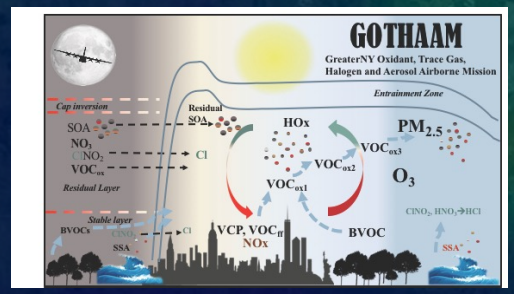


More details here:
https://www-air.larc.nasa.gov/missions/moose/index.html

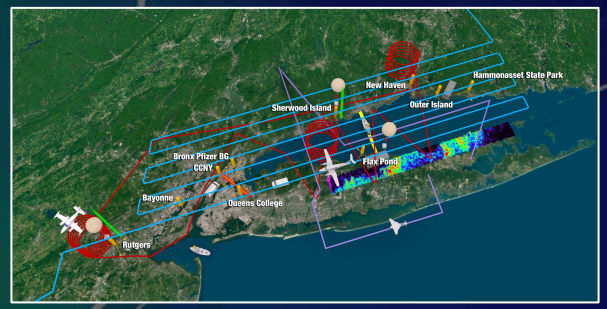
NOAA AEROMMA / NSF GOTHAAM Summer 2023

LISTOS Domain (5 years later)

https://csl.noaa.gov/projects/aeromma/



https://www.somas.stonybrook.edu/2020/09/11/sbu-receives-nsf-grant-to-study-engage-others-on-regional-air-pollution/



Opportunity for the field campaign measurements to contribute to TEMPO validation with a supported payload similar to TRACER-AQ