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Accelerating TEMPO Air Quality Science Through STAQS

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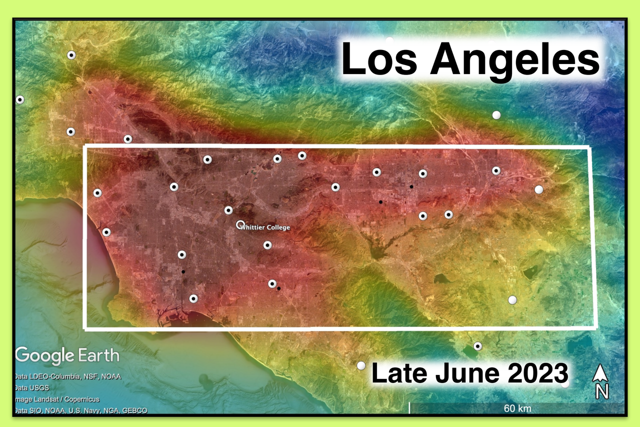
In summer 2023, the Synergistic TEMPO Air Quality Science (STAQS) study seeks to integrate TEMPO observations with traditional and enhanced air quality monitoring to improve the understanding of air quality science for increased societal benefit.

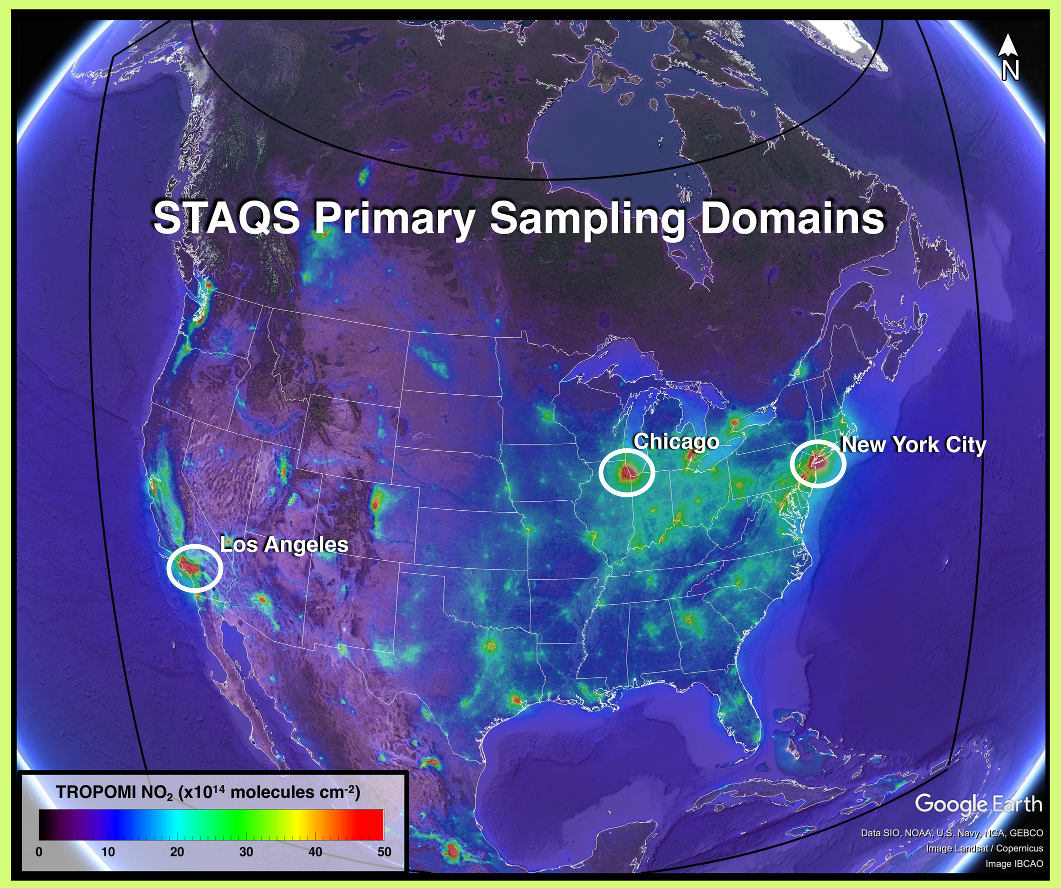
Under TEMPO, STAQS will:

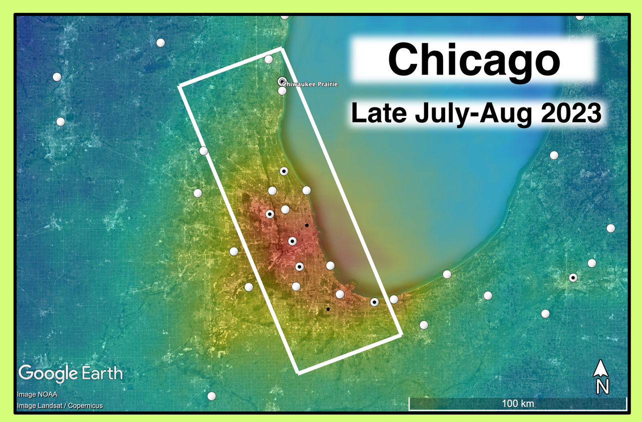
- Build an integrated observing system of ground-, airborne-, and satellite-based platforms and air quality models recognizing the importance of science analysis from multiple perspectives.
- Prioritize repeated systematic airborne sampling in predefined domains during morning, midday, and afternoon over at least 4 days in each primary target areas (LA, NYC, Chicago)
- Collaborate with research teams engaged with multiple activities (AGES+) occurring in summer 2023 with federal and academic partners (NOAA AEROMMA, NSF GOTHAAM, NOAA CUPIDS, and others)

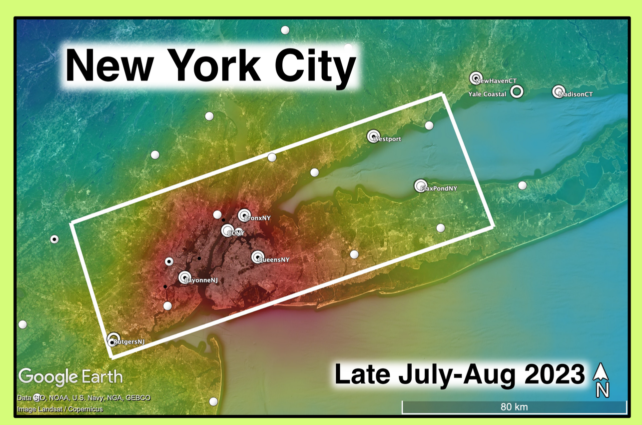
Regions of Interest and Observing System

In three major urban areas, we aim to map NO_2, HCHO, ozone, aerosols, and GHGs multiple times of day over emission sources and ground-sites.









STAQS flights will be coordinated with NOAA AEROMMA DC8 flights in each domain.

Each urban area will be visited at least 4 days.

Table summarizing the observing system deployed for STAQS

Platform	Instrument	Data Products	Sampling Strategy
NASA JSC G-V	GCAS	NO_2 Column (250 x 560 m) HCHO Column (750 x 1680 m)	Systematic sampling of a ~ 50 x 140 km area 3x per day (morning-midday-afternoon)
	HSRL2/DIAL	Ozone profiles, aerosol profiles, mixed layer height	
NASA LaRC G-III	AVIRIS-NG	CH_4 (> 10 kg/hr) and CO_2 (large point sources) emissions	Systematic sampling of a ~ 50 x 140 km area 2x per day (morning-afternoon)
	HALO	CH_4 columns, aerosol profiles, mixed layer height	
Ground-based	TOLNet	Lower tropospheric ozone profiles	Routine sampling with enhanced measurements during flight days within the domain
	Pandora	NO_2 and HCHO columns and profiles	

STAQS Science Objectives

(1) Evaluating TEMPO level 2 products geo-physically, spatially, and temporally

Launching in spring 2023, TEMPO's first observations are expected to occur during STAQS enabling the opportunity to evaluate TEMPO products.

Table of baseline level 2 products from TEMPO

TEMPO Product	Horizontal Resolution center of domain	Product Precision
Total Column O_3	2.0 x 4.75 km^2	3%
Tropospheric Column O_3	8.0 x 4.75 km^2 (4 N/S across-track pixels coadded)	10 ppbv
0-2 km O_3	8.0 x 4.75 km^2 (4 N/S across-track pixels coadded)	10 ppbv
Total Column NO_2	2.0x 4.75 km^2	1.0 × 10^{15} molecules cm^{-2}
Tropospheric NO_2	2.0 x 4.75 km^2	1.0 × 10^{15} molecules cm^{-2}
Tropospheric HCHO	2.0 x 4.75 km^2	1.0 × 10^{16} molecules cm^{-2}

Example studies

Zoogman et al., 2017 *Judd et al., 2020* *Sullivan et al., 2022* *Verhoelst et al., 2021*

Dozens of Pandora spectrometers are already deployed within the TEMPO field of regard measuring NO_2 and HCHO with about a fifth of these within STAQS domains.

GCAS data provides sub-TEMPO-pixel scale measurements to provide a transfer standard between ground-based reference measurements (Pandora) and the satellite products.

TOLNet, HSRL2, and ozonesonde measurements provide a dataset to demonstrate the utility of TEMPO 0-2 km and tropospheric ozone products spatially and temporally.

HSRL2 and HALO can also contribute to evaluating developed TEMPO aerosol products.

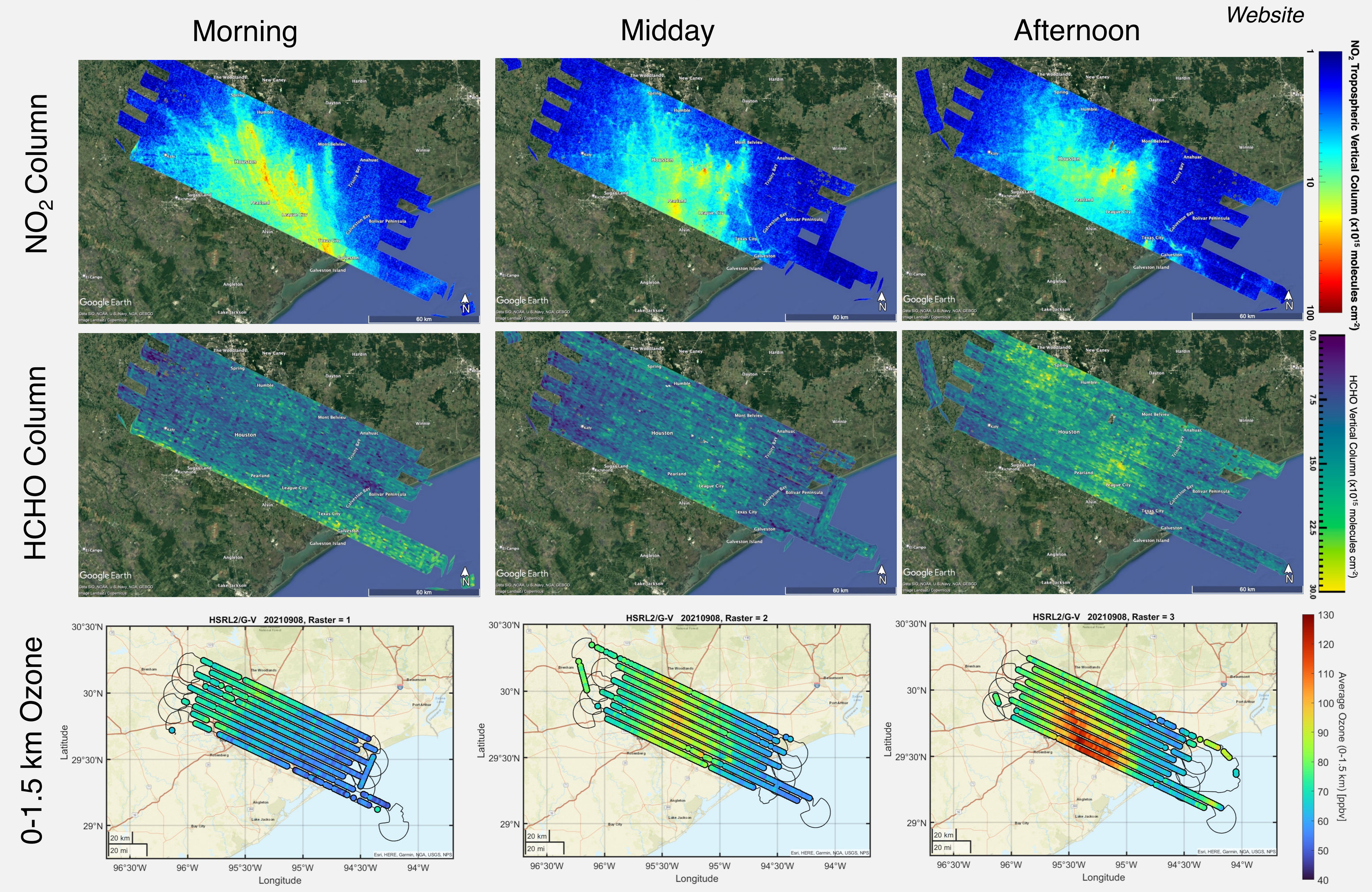
Evaluation analysis will focus on how these products perform at all times of day. (especially morning and late afternoon)

(2) Interpreting the temporal and spatial evolution of air quality events tracked by TEMPO

TEMPO will observe air quality events as they unfold throughout the day. Airborne data reveals finer spatial information to improve interpreting the interconnection of emissions, meteorology, and chemistry.

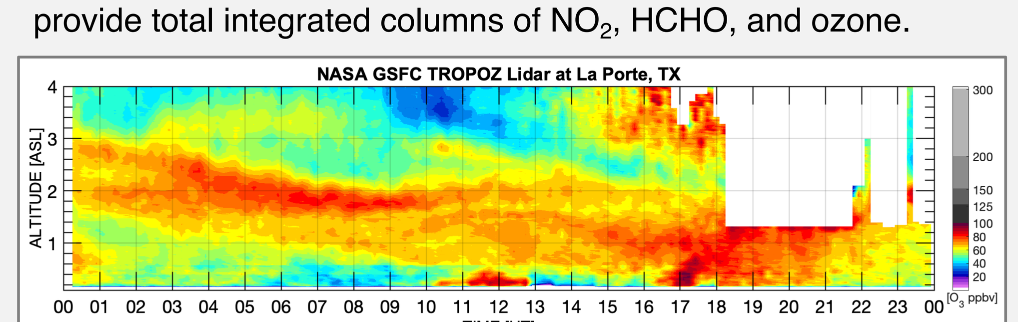
TRACER-AQ Website

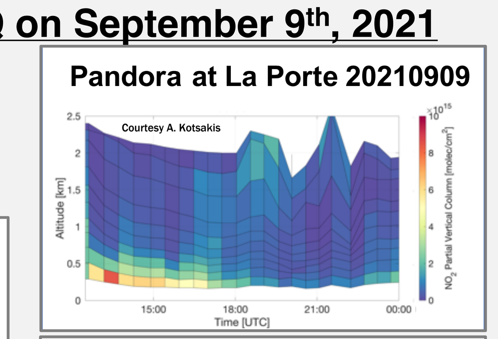
G-V example from TRACER-AQ on September 8th, 2021 in Houston

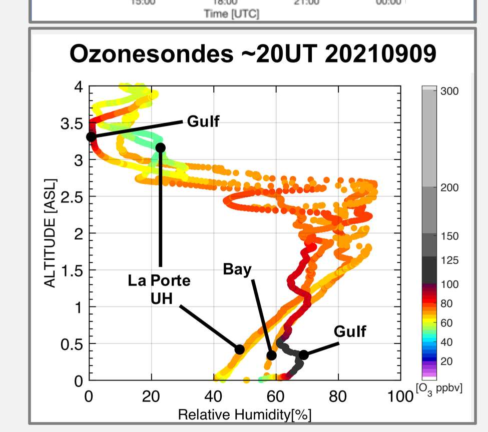


TOLNet and Pandora example from TRACER-AQ on September 9th, 2021

Synchronous enhanced ground-based measurements reveal vertical information about pollution. Pandora and sondes also provide total integrated columns of NO_2, HCHO, and ozone.







STAQS will enable further investigation on how column-based observations relate to surface air quality including the exploration of new proxies (e.g., column HCHO to surface ozone from Travis et al., 2022: https://doi.org/10.1029/2022JD036638).

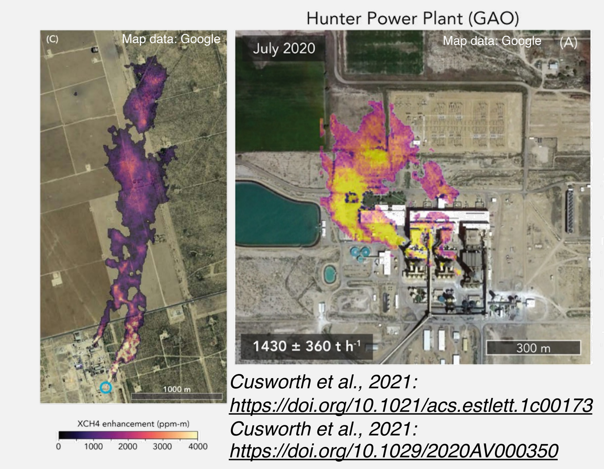
(3) Refining temporal estimates of anthropogenic and GHG emissions

Satellite data has been used to estimate early afternoon city-scale and isolated point-source NOx emissions.

STAQS and TEMPO data can expand that methodology to include multiple times of day and explore the ability to discern sector-based emissions.

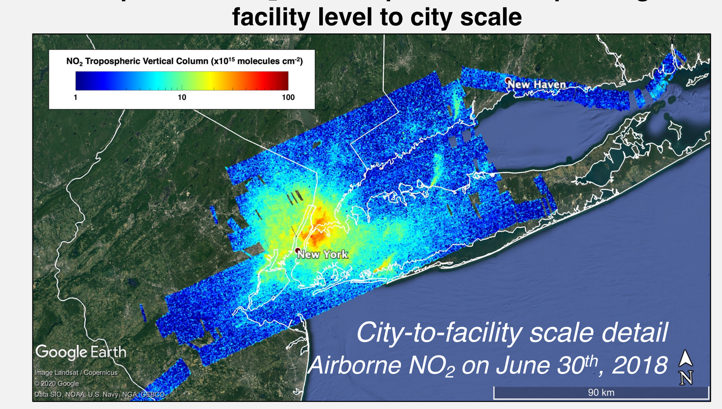
Sampling GHG and NO_2 helps assess if NO_2 satellite-based observations can be used as a tool to track climate mitigation strategies in the coming decades

CH_4 and CO_2 emissions mapping from AVIRIS-NG over point sources



Cusworth et al., 2021: https://doi.org/10.1021/acs.estlett.1c00173
Cusworth et al., 2021: https://doi.org/10.1029/2020AV000350

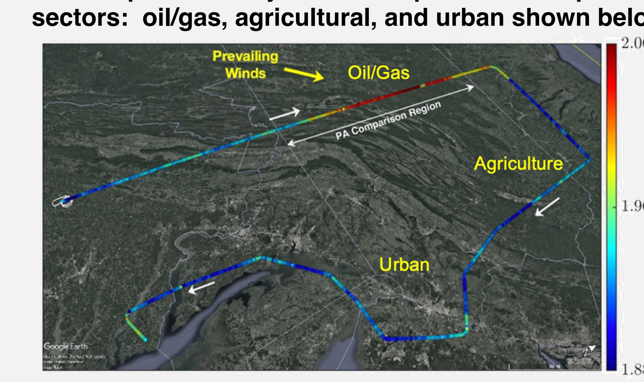
GCAS provides NO_2 data at spatial scales spanning from facility level to city scale



Example studies

Goldberg et al., 2019 *Duren et al., 2019* *Fujinawa et al., 2021*

HALO spatial surveys shows impacts of multiple CH_4 sectors: oil/gas, agricultural, and urban shown below



Barton-Grimley et al., 2022: https://doi.org/10.5194/amt-15-4623-2022

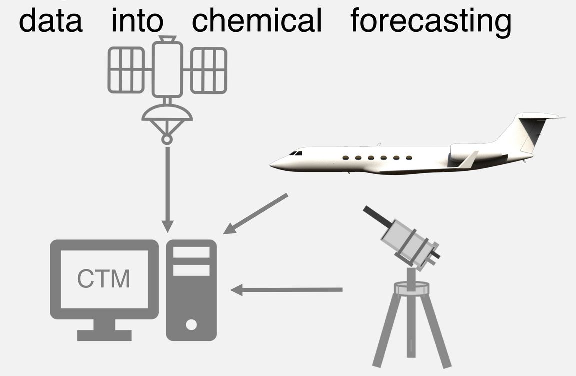
(4) Evaluating Chemical Transport Models

TEMPO, airborne, and ground-based observations from STAQS will evaluate state of the art research and operational chemical transport models with emphasis on whether they accurately capture the diurnal evolution from a surface **and** column-based perspective

Once TEMPO is operating, STAQS airborne and ground-based data can also provide a useful perspective to evaluate the benefits of assimilating geostationary air quality observation data into chemical forecasting efforts.

Example studies

Torres-Vazquez et al., 2022 *Dacic et al., 2020* *Hsu et al., 2022*



(5) Associations between air quality patterns and socio-demographic data

Previous airborne and satellite datasets have revealed that people of color and in low-income communities are burdened with disproportionately higher emissions of NO_2 than high-income and white communities.

Example studies

Dressel et al., 2022 *Kerr et al., 2021* *Demetillo et al., 2020*

STAQS will further analyze these findings by:

- Exploring how these associations vary by time of day
- Connecting results about direct emissions to secondarily formed pollutants like ozone
- Working toward identifying pathways that could improve these disparities

Collaborative Activities

Summer 2023 will bring together researchers and stakeholders from many different field activities occurring including, but not limited to:

- NOAA Atmospheric Emissions and Reactions Observed from Megacities to Marine Areas (**AEROMMA**)
- NOAA Coastal Urban Plume Dynamics Study (**CUPiDS**)
  https://csl.noaa.gov/projects/aeromma/
- Greater New York Oxidant Trace gas Halogen and Aerosol Airborne Mission (**GOTHAAM**)
  https://gothaam.science/
- A broad list of academic researchers
- State air quality agencies and regional consortiums like LADCO and NESCAUM

Learn more about these collaborations with presentations from the AGES+ workshop: https://csl.noaa.gov/events/ages2022/

STAQS Team

- **Laura Judd (Airborne Lead)**
- **John Sullivan (Ground Lead/TOLNet PI)**
- **Scott Janz (GCAS PI)**
- **John Hair (HSRL2 PI)**
- **Taylor Shingler (HSRL2 co-PI)**
- **Amin Nehrir (HALO PI)**
- **Rory Barton-Grimley (HALO co-PI)**
- **Robert Green (AVIRIS-NG PI)**
- **Tom Hanisco (NASA Pandora Project PI)**
- **Luke Valin (EPA Pandora Project Liaison)**
- **Paul Walter (Sonde-lead)**
- **Barry Lefer (Tropospheric Comp. Program Manager)**
- **Melissa Yang Martin (Atmos. Comp. Program Scientist)**
- **Gao Chen (Data Manager)**
- **Michael Shook (Data Manager)**