STAQS Data Product User Guide

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Introduction:

NASA's Synergistic TEMPO Air Quality Science (STAQS) mission aimed to combine Earth observation data from Tropospheric Emissions: Monitoring of Pollution (TEMPO) with traditional air quality monitoring methods. By integrating these approaches, STAQS carefully studied air quality science within the TEMPO viewing area and validated TEMPO data products. STAQS was a multifaceted campaign that included airborne data captured from multiple platforms (including planes, drones, and balloons) and ground site data captured through different types of sensors. STAQS was conducted over the major cities of Chicago, New York, Los Angeles, and Toronto with additional field sites in other locations.

The data from STAQS contained on EARTHDATA Search is in the following formats: NetCDF, HDF5, CDF, and ICARTT. These formats are widely used for scientific data and compatible with various analysis software, such as Python, MATLAB, or GIS tools.

The purpose of this user guide is to contextualize the STAQS mission and give helpful insight into the use and formatting of STAQS data.

Citation:

Cite ASDC Data

DOI Citation Formatter

Campaign Level DOI:

STAQS: 10.5067/SUBORBITAL/STAQS/DATA001

Campaign Overview:

Objectives

The overarching goal of the STAQS campaign was to support the science and validation of data of the TEMPO observations. This was done in a few ways. First, STAQS set out to improve the current understanding of air quality science in the TEMPO viewing area. Next, STAQS took data to directly evaluate TEMPO data Level 2 products. Data from STAQS also served to interpret air quality events tracked by TEMPO and improve estimates of different types of emissions.

Platforms

STAQS collected data in Summer 2023 on different Platforms: manned aircraft, ground sensors, and unmanned aircraft (drones and balloon sondes). The manned aircraft were the major portion of the campaign. Johnson Space Center's Gulfstream-V (G-V) aircraft featured the GeoCAPE Airborne Simulator (GCAS) and combined High Spectral Resolution Lidar-2 (HSRL-2) and Ozone Differential Absorption Lidar (DIAL). This payload provided repeated high-resolution mapping of nitrogen dioxide (NO_2) and formaldehyde (HCHO) from GCAS and ozone (O_3) and aerosols from HSRL-2/DIAL. This mapping occurred up to 3 times per day over targeted cities in the morning, at midday, and in the afternoon.

Meanwhile, NASA Langley Research Center's (LaRC's) Gulfstream-III (G-III) measured city-scale emissions 2 time per day over the targeted cities with the High-Altitude Lidar Observatory (HALO) and Airborne Visible InfraRed Imaging Spectrometer – Next Generation (AVIRIS-NG). HALO measured partial column-averaged methane (CH_4) concentration and aerosol profiles while AVIRIS-NG measured CH_4 and CO_2 column density. Additionally, the G-III also carried the GCAS instrument for the final 4 flight days.

The G-III and G-V aircraft took data over the cities of Los Angeles, Chicago, New York, and Toronto between June and August of 2023. There were 17 flight days and a total of 270 flight hours. See the table below for more specific flight information. Bolded Flights occurred after TEMPO started taking data.

Table 1. Flight dates and locations for manned STAQS flights

Date (2023)	Location	G-III Flight	G-V Flight
June 26	Central Valley, VA	Yes	Yes
June 27	Los Angeles, CA	Yes	Yes
June 28	Los Angeles, CA	Yes	Yes
July 26	New York City, NY	Yes	Yes
July 28	New York City, NY	Yes	Yes
August 1	Chicago, IL	Yes	Yes
August 2	**Chicago, IL**	**Yes**	**Yes**
August 4	**Toronto, Canada**	**Yes**	**Yes**
August 5	**New York City, NY**	**Yes**	**Yes**
August 8	**Chicago, IL**	**Yes**	**Yes**
August 9	**New York City, NY**	**Yes**	**Yes**
August 12	**Chicago, IL**	**Yes**	**Yes**
August 15	**Chicago, IL**	**Yes**	**Yes**
August 22	**Los Angeles, CA**	**Yes***	**-**
August 23	**Los Angeles, CA**	**Yes***	**-**
August 25	**Los Angeles, CA**	**Yes***	**-**
August 26	**Los Angeles, CA**	**Yes***	**-**

*Indicates a G-III flight that included the GCAS instrument

STAQS also incorporated ground-based tropospheric ozone profiles from the NASA Tropospheric Ozone Lidar Network (TOLNet); NO_2, HCHO, and O_3 measurements from Pandora spectrometers; and leveraged existing networks operated by the EPA and state air quality agencies.

STAQS was part of a larger collaborative effort, AGES+. AGES+ included all NASA and National Ocean and Atmospheric Administration (NOAA) aircraft-based field activities from summer 2023 and their associated ground data collection efforts. Some additional platforms collected

data in support of STAQS as part of the larger AGES+ collaboration. These included data from the University of Alabama in Huntsville's (UAH) SeaRey aircraft; the University of Wisconsin-Madison's HALO Doppler Lidar; drone data from UAH and the University of Wisconsin-Eau Claire (UWEC); ground-based data taken by UWEC; data from the Inexpensive Network Sensor Technology for Exploring Pollution (INSTEP) network; and a series of Balloon Sondes from UAH, NASA Goddard, and St. Edward's University.

Data Products:

The STAQS campaign plays a significant role in advancing TEMPO's ability to monitor air quality. By leveraging diverse airborne, ground-based, and remotely sensed data, STAQS provides valuable insights for improving emissions estimates, interpreting pollution events, and validating TEMPO data products. This collaboration enriches NASA's air quality research capabilities with long-term benefits for public health and environmental policymaking.

EARTHDATA Search

A majority of data products from the STAQS campaign are archived on EARTHDATA. Table 2 below shows these products with their accompanying table number where more information is detailed about each product. In order to access this data, you can either use the query function on EARTHDATA Search or scroll to the respective table and click on the EARTHDATA button. To download the datasets of your choosing, you will need an EARTHDATA account.

Table 2. Data Products Available on EARTHDATA Search

Data Product	Table Number
G-V GCAS	Table 3
G-V HSRL	Table 4
G-III GCAS	Table 5
G-III HALO	Table 6
HALO Lidar Doppler Chiwaukee	Table 7
Drone Data from UAH and UWEC	Table 8
Kenosha/Lighthouse Ground Data	Table 9
INSTEP	Table 10
SeaRay	Table 11
Balloon Sondes	Table 12
AVIRIS-NG	Table 13

These datasets feature a combination of the following file formats:

- Hierarchical Data Format 5 (HDF5)
- Network Common Data Form (NetCDF)
- Common Data Form (CDF)
- ICARTT (International Consortium for Atmospheric Research on Transport and Transformation)

To view these datasets, you will need the appropriate viewer. HDF5, NetCDF, CDF can all be viewed in NASA's Panoply or other HDF Viewers such as HDFView. ICARTT data is a common text-based data format that allows for uniform standardization of data; thus it can be opened with any text reader. Once you download a data file, a "README" file may be available that gives you details on how to open, read, and use it.

Table: 3

Collection: STAQS_AircraftRemoteSensing_JSC-GV_GCAS_Data_1 EARTHDATA

DOI: 10.5067/ASDC/SUBORBITAL/STAQS/DATA001/GV/AircraftRemoteSensing/GCAS_1

Platform: NASA Gulfstream V

Dates: June 26 – August 15, 2023

Data ID	Key Variables	File Format	Instrument	Sampling Frequency	Principal Investigator	Institution
staqs-GCAS-HCHO	HCHO Column Density	NetCDF	GeoCAPE Airborne Simulator (GCAS)	Up to 12 Hz	Scott Janz	NASA Goddard
staqs-GCAS-NO2	NO_2 Column Density	NetCDF	GeoCAPE Airborne Simulator (GCAS)	Up to 12 Hz	Scott Janz	NASA Goddard

Table: 4

Collection: STAQS_AircraftRemoteSensing_JSC-GV_HSRL2_Data_1 EARTHDATA

DOI: 10.5067/ASDC/SUBORBITAL/STAQS/DATA001/GV/AircraftRemoteSensing/HSRL2_1

Platform: NASA Gulfstream V

Dates: June 24 – August 15, 2023

Data ID	Key Variables	File Format	Instrument	Sampling Frequency	Principal Investigator	Institution
staqs-HSRL2	532 nm backscatter, 1064 nm backscatter, 532 nm aerosol optical depth, cloud top height	HDF5	High Spectral Resolution Lidar-2	0.1 Hz	Jonathan Hair and Taylor Shingler	NASA Langley
staqs-HSRL2-NearSurface	532 nm backscatter, 1064 nm backscatter, 532 nm aerosol optical depth	HDF5	High Spectral Resolution Lidar-2	0.1 Hz	Jonathan Hair and Taylor Shingler	NASA Langley

staqs-HSRL2-images	Images of Lidar profile plots of each Lidar variable for each day of flight	Zipped Folder of PNGs for Each Day	High Spectral Resolution Lidar-2	0.1 Hz	Jonathan Hair and Taylor Shingler	NASA Langley

Table: 5
Collection: STAQS_AircraftRemoteSensing_NASA-G3_GCAS_Data_1 EARTHDATA
DOI: 10.5067/ASDC/SUBORBITAL/STAQS/DATA001/G3/AircraftRemoteSensing/GCAS_1
Platform: NASA Gulfstream III
Dates: August 22 – August 26, 2023

Data ID	Key Variables	File Format	Instrument	Sampling Frequency	Principal Investigator	Institution
staqs-GCAS-HCHO	HCHO Column Density	NetCDF	GeoCAPE Airborne Simulator (GCAS)	Up to 12 Hz	Scott Janz	NASA Goddard
staqs-GCAS-NO2	NO_2 Column Density	NetCDF	GeoCAPE Airborne Simulator (GCAS)	Up to 12 Hz	Scott Janz	NASA Goddard

Table: 6
Collection: STAQS_AircraftRemoteSensing_NASA-G3_HALO_Data_1 EARTHDATA
DOI: 10.5067/ASDC/SUBORBITAL/STAQS/DATA001/G3/AircraftRemoteSensing/HALO_1
Platform: NASA Gulfstream III
Dates: June 26 – August 15, 2023

Data ID	Key Variables	File Format	Instrument	Sampling Frequency	Principal Investigator	Institution
staqs-HALO	532 nm backscatter, 1064 nm backscatter, 532 nm aerosol optical depth, cloud top height	HDF5	High-Altitude Lidar Observatory	Up to 2 Hz	Amin Nehrir	NASA Langley

staqs-HALO-XCH4	Partial column averaged CH_4 dry air mole fraction	HDF5	High-Altitude Lidar Observatory	Up to 2 Hz	Amin Nehrir	NASA Langley
staqs-HALO-images	Images of Lidar profile plots of each Lidar variable	Zipped Folder of PNGs for Each Day	High-Altitude Lidar Observatory	Up to 2 Hz	Amin Nehrir	NASA Langley

Table: 7
Collection: STAQS_Chiwaukee-Prairie_Data_1
DOI: 10.5067/ASDC/SUBORBITAL/STAQS/DATA001/Chiwaukee-Prairie_1
Platform: Chiwaukee Prairie Field Site
Dates: May 10 – September 11, 2023

Data ID	Key Variables	File Format	Instrument	Sampling Frequency	Principal Investigator	Institution
staqs-halo-vad	Horizontal Wind Vector	Common Data Format	Halo Doppler Lidar	0.0033 Hz	Tim Wagner	University of Wisconsin - Madison
staqs-halo-stare	Backscatter, Vertical Velocity	Common Data Format	Halo Doppler Lidar	0.05 Hz	Tim Wagner	University of Wisconsin - Madison

Table: 8
Collection: STAQS_Drone_Data_1
DOI: 10.5067/ASDC/SUBORBITAL/STAQS/DATA001/Drone_1
Platform: Uncrewed Aircraft Systems (UAS)
Dates: August 1 – August 17, 2023

Data ID	Key Variables	File Format	Instrument	Sampling Frequency	Principal Investigator	Institution
staqs-O3-PM25-MET	O_3, $PM_{2.5}$, VOC (experimental)	ICARTT	2B Model 205; Plantower PMS5003; BME680	1 Hz	Mike Newchurch	University of Alabama-Huntsville
staqs-UWEC-UAS-Wind	Wind Direction, Wind Speed	ICARTT	Winds were derived from flight controller data through AirData.com	0.2 Hz	Patti Cleary	University of Wisconsin-Eau Claire
staqs-UWEC-UAS	O_3, Meteorological Parameters	ICARTT	2B Tech Personal Ozone Monitor; Two separate iMET-XQ2 from Intermet Systems; DJI flight controller records	0.1 Hz	Patti Cleary	University of Wisconsin-Eau Claire

Table: 9
Collection: STAQS_Ground_Data_1
DOI: 10.5067/ASDC/SUBORBITAL/STAQS/DATA001/Ground_1
Platform: Ground-based instrumentation, Kenosha, Wisconsin
Dates: July 1 – August 31, 2023

Data ID	Key Variables	File Format	Instrument	Sampling Frequency	Principal Investigator	Institution
staqs-Ground-Kenosha-DOAS	SO_2, NO_2, O_3, HCHO	ICARTT	Differential Optical Absorption Spectrometer (DOAS); light emitted at Kenosha Municipal Building; receiver and analyzer	0.0033 Hz	Patti Cleary	University of Wisconsin-Eau Claire

			at Kenosha Water Treatment Facility			
staqs-Ground-Kenosha-KNSW3	Meteorological Parameters	ICARTT	NOAA Meteorological Station at Kenosha Harbor Lighthouse Station KNSW3	0.0017 Hz	Patti Cleary	University of Wisconsin-Eau Claire

Table: 10
Collection: STAQS_INSTEP_Data_1
DOI: 10.5067/ASDC/SUBORBITAL/STAQS/DATA001/INSTEP_1
Platform: Inexpensive Network Sensor Technology Exploring Pollution
Dates: June 7, 2023

Data ID	Key Variables	File Format	Instrument	Sampling Frequency	Principal Investigator	Institution
staqs-Whittier-CH4-CH2O-O3-CO2	CH_4, HCHO, O_3, CO_2	ICARTT	INSTEP Sensor located at Whittier College	0.017 Hz	Kristen Okorn	NASA Ames
staqs-TMF-CH4-CH2O-O3-CO2	CH_4, HCHO, O_3, CO_2	ICARTT	INSTEP Sensor located at NASA JPL's Table Mountain Facility	0.017 Hz	Kristen Okorn	NASA Ames
staqs-Redlands-CH4-CH2O-O3-CO2	CH_4, HCHO, O_3, CO_2	ICARTT	INSTEP Sensor located in Redlands, CA	0.017 Hz	Kristen Okorn	NASA Ames
staqs-Caltech-CH4-CH2O-O3-CO2	CH_4, HCHO, O_3, CO_2	ICARTT	INSTEP Sensor located at the California Institute of Technology	0.017 Hz	Kristen Okorn	NASA Ames
staqs-AFRC-CH4-CH2O-O3-CO2	CH_4, HCHO, O_3, CO_2	ICARTT	INSTEP Sensor located at NASA Armstrong Flight Research Center	0.017 Hz	Kristen Okorn	NASA Ames

Table: 11
Collection: STAQS_SeaRey_Data_1
DOI: 10.5067/ASDC/SUBORBITAL/STAQS/DATA001/SeaRey_1
Platform: Progressive Aerodyne SeaRey
Dates: July 18 – August 18, 2023

Data ID	Key Variables	File Format	Instrument	Sampling Frequency	Principal Investigator	Institution
STAQS-O3-NO2-PM25-MET_SEAREY	Meteorological Parameters, O_3, NO_2, $PM_{2.5}$	ICARTT	2B Model 205, NOAA CSL mACES, Plantower PMS5003, BME688	1 Hz	Mike Newchurch	University of Alabama in Huntsville

Table: 12
Collection: STAQS_Sondes_Data_1
DOI: 10.5067/ASDC/SUBORBITAL/STAQS/DATA001/Sondes_1
Platform: Windsonde Balloons and Ozonesondes
Dates: May 26 – October 20, 2023

Data ID	Key Variables	File Format	Instrument	Sampling Frequency	Principal Investigator	Institution
staqs-ChiwaukeePrairie_SONDE…_windsonde	Meteorological Parameters	ICARTT	Windsonde Balloons	Varies	Todd McKinney	University of Alabama in Huntsville
staqs-ChiwaukeePrairie_SONDE…_ozonesonde	O_3, Meteorological Parameters	ICARTT	radiosonde = iMet Radiosonde, ozonesonde = 2Z41162 En-Sci ozonesonde, 1% KI with 1/10th buffer solutions with NOAA Average (Johnson et al. 2002) pump corrections	Varies	Todd McKinney	University of Alabama in Huntsville
staqs-FlaxPond	O_3, Meteorological Parameters	ICARTT	Ozonesondes - Electrochemical Concentration Cell (En-Sci), iMet-4 RSB Radiosondes	Varies	John Sullivan	NASA Goddard
staqs-Austin	O_3, Meteorological Parameters	ICARTT	Ozonesondes - Electrochemical Concentration	Varies	Paul Walter	St. Edward's University

			Cell (En-Sci), iMet-4 RSB Radiosondes			
staqs-ElPaso	O_3, Meteorological Parameters	ICARTT	Ozonesondes - Electrochemical Concentration Cell (En-Sci), iMet-4 RSB Radiosondes	Varies	Paul Walter	St. Edward's University
staqs-Houston	O_3, Meteorological Parameters	ICARTT	Ozonesondes - Electrochemical Concentration Cell (En-Sci), iMet-4 RSB Radiosondes	Varies	Paul Walter	St. Edward's University
staqs-HoustonGBay	O_3, Meteorological Parameters	ICARTT	Ozonesondes - Electrochemical Concentration Cell (En-Sci), iMet-4 RSB Radiosondes	Varies	Paul Walter	St. Edward's University
staqs-HoustonGulf	O_3, Meteorological Parameters	ICARTT	Ozonesondes - Electrochemical Concentration Cell (En-Sci), iMet-4 RSB Radiosondes	Varies	Paul Walter	St. Edward's University
staqs-SanAntonio	O_3, Meteorological Parameters	ICARTT	Ozonesondes - Electrochemical Concentration Cell (En-Sci), iMet-4 RSB Radiosondes	Varies	Paul Walter	St. Edward's University
staqs-Westport	O_3, Meteorological Parameters	ICARTT	Ozonesondes - Electrochemical Concentration Cell (En-Sci), iMet-4 RSB Radiosondes	Varies	Paul Walter	St. Edward's University
staqs-YaleCoastal	O_3, Meteorological Parameters	ICARTT	Ozonesondes - Electrochemical Concentration Cell (En-Sci), iMet-4 RSB Radiosondes	Varies	Paul Walter	St. Edward's University

AVIRIS-NG

Unlike previous the data from the previous tables which are hosted by the ASDC, AVIRIS-NG data is hosted by Oak Ridge National Laboratories Distributed Active Archive Center (ORNL DAAC). For more information on AVIRIS-NG, find the AVIRIS-NG user guide on this page.

Table: 13
Collection: **STAQS AVIRIS-NG-derived Methane and Carbon Dioxide Plumes, 2023** EARTHDATA
DOI: 10.3334/ORNLDAAC/2406
Platform: Gulfstream III
Dates: July 18 – August 18, 2023

Data ID	Key Variables	File Format	Instrument	Sampling Frequency	Principal Investigator	Institution
AVIRIS-NG_CH4_CO2_Plumes	CH_4, CO_2	TIF	AVIRIS-NG	1 Hz	Robert Green, Daniel Jensen, Holly Bender, Andrew Thorpe	NASA JPL

Datasets Outside of EARTHDATA Search

TOLNet

TOLNet is a network of permanent and mobile ground-based lidar instruments that focus on identifying ozone. For the STAQS mission, one TOLNet sensor took readings in Chicago, four sensors took data in New York City, and three took data in Los Angeles. Table 12 shows which TOLNet sensors took part in the STAQS campaign. Note that some lidars are permanent while others are mobile. For instance, the RO3QET lidar was moved from Huntsville, AL to Kenosha, WI to take data near the Chicago flights.

Table 14. TOLNet Lidars that took part in the STAQS mission

Lidar Name	Location for STAQS	Dates	Links to ASDC Collections
CCNY Lidar	**New York, NY**	June 29, 2023 – August 31, 2023	CCNY TOLNet Collection at the ASDC
NASA GSFC TROPOZ Lidar	**Oldfield, NY**	July 12, 2023 – August 16, 2023	TROPOZ TOLNet Collection at the ASDC
NASA JPL SMOL Lidars	**Table Mountain, CA; JPL/Pasadena, CA; San Bernardino/Cal State, CA**	JPL TMF: August 22, 2023 – August 27, 2023 JPL SMOL-1 (Pasadena): June 25, 2023 – September 7, 2023* JPL SMOL-1 (San Bernardino): June 23, 2023 – September 1, 2023*	JPL TOLNet Collection at the ASDC
NASA LaRC LMOL Lidar	**Sherwood Island, CT**	July 17, 2023 – August 26, 2023	LMOL TOLNet Collection at the ASDC
NOAA CSL TOPAZ Lidar	**Yale Coastal Field Site, Guildford, CT**	July 4, 2023 – August 14, 2023	TOPAZ TOLNet Collection at the ASDC
UAH RO3QET Lidar	**Kenosha, WI**	July 18, 2023 – August 16, 2023	RO3QET TOLNet Collection at the ASDC

*Indicates data is not available for each date in date range

While TOLNet data are not included with broader STAQS collections on EARTHDATA Search, they are still archived by the ASDC. There are two locations you can find TOLNet data. First is the download section of the TOLNet website: https://tolnet.larc.nasa.gov/download. Here you can query data by date, location, sensor, and parameter. Using the graph icon at the top corner of each file, you can preview the data contained in the file. TOLNet files are in HDF format, so they will require an HDF viewer in order to view them. The other location is on the ASDC

website: https://asdc.larc.nasa.gov/project/TOLNet . To download from either the TOLNet website or the ASDC website, you will need to have an EARTHDATA login.

PANDORA

Pandora Spectrometers are a part of the Pandonia Global Network, which sets consistent low-cost sensors across the globe to validate pollution-monitoring satellites in low Earth orbit. What sets these sensors apart is that they are able to measure total column profiles of HCHO, NO_2, and O_3 of the whole atmosphere from the ground. For the STAQS mission, multiple spectrometers collected data at each location. Specifically, two were used in Chicago, six were used in Toronto, nine were used in New York City, and two were used in Los Angeles.

Data for Pandora is hosted at https://data.hetzner.pandonia-global-network.org/. On this site, you will choose the city for data you wish to download. In each city folder there will be a set of folders to each processing level of data. The folders labelled "L2_geoms/" contain HDF5files (*.H5 file extension) for each trace gas which can be visualized, and these specific data is governed by the Generic Earth Observation Metadata Standard (GEOMS) format. The other folders contain .txt files with readings on separate columns. Note that each .txt file contains a key for each column's parameter in the file itself. The .txt files may contain all measured gases or just one of them. For more information about GEOMS, visit its website here: https://evdc.esa.int/documentation/geoms/. For more information about the Pandora project as a whole visit its website here: https://pandora.gsfc.nasa.gov/.

Resources:

STAQS Landing Page

TEMPO Landing Page

STAQS Micro Article

ICARTT File Format

TEMPO/STAQS StoryMap

Acronyms:

Short Name	Long Name
AVIRIS-NG	Airborne Visible InfraRed Imaging Spectrometer – Next Generation
CDF	Common Data Format
CH_4	Methane
DIAL	Ozone Differential Absorption Lidar
GCAS	GeoCAPE Airborne Simulator
G-III	NASA Langley's Gulfstream-III Aircraft
G-V	NASA Langley's Gulfstream-V Aircraft
HALO	High-Altitude Lidar Observatory
HCHO	Formaldehyde
HDF5	Hierarchical Data Format 5
HSRL-2	High Spectral Resolution Lidar-2
ICARTT	International Consortium for Atmospheric Research on Transport and Transformation
NO_2	Nitrogen Dioxide
O_3	Ozone
$PM_{2.5}$	Particulate Matter with a dimeter of less than 2.5 micrometers
SO_2	Sulfur Dioxide
STAQS	Synergistic TEMPO Air Quality Science
TEMPO	Tropospheric Emissions: Monitoring of Pollution
UAH	University of Alabama in Huntsville
UWEC	University of Wisconsin – Eau Claire
VOC	Volatile Organic Compound