



A Brief Intro to the Data from Tropospheric Emissions: Monitoring of Pollution (TEMPO)

Daniel Kaufman, ASDC

Hazem Mahmoud, ASDC

Caroline Nowlan, Center for Astrophysics

Gonzalo González Abad, Center for Astrophysics

ESIP July 2024
Session: Air Quality

Tropospheric Emissions: Monitoring of Pollution

- Hourly daytime air pollution measurements over North America
- NASA's first Earth Venture Instrument (EVI), selected in 2012
- **Geostationary orbit** means TEMPO can scan the continent continuously
 - High temporal resolution
 - High spatial resolution
- Baseline data products:
 - Ozone
 - Nitrogen dioxide
 - Formaldehyde



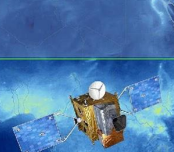
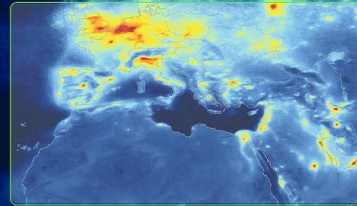
Credit: NASA's Scientific Visualization Studio

Atmospheric Composition Geostationary Constellation

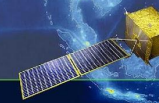
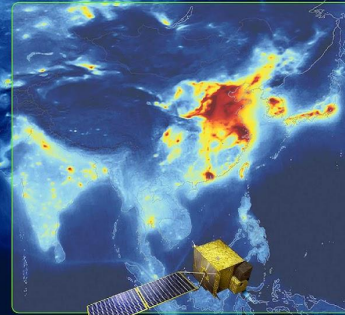
TEMPO (hourly)
Tropospheric Emissions:
Monitoring of Pollution



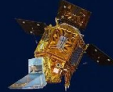
Sentinel-4 (hourly)



GEMS (hourly)
Geostationary Environmental
Monitoring Spectrometer



Sentinel-5P (once per day)



GaoFen-5 (once per day)



TEMPO Operations

Nominal scans

- 2048 North/South pixels
- 1181 East/West steps per hour
- 2 x 4.75 km² at center of field of regard

Optimized scans

- Higher temporal resolution AM and PM scans over coasts (40 minutes)

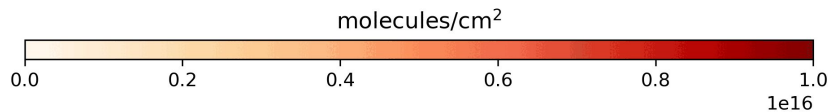
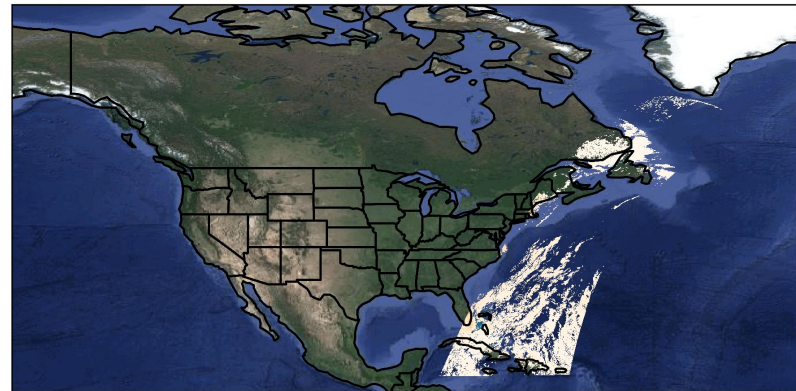
Twilight scans (city lights)

- Performed during darkness, before morning scans

High-time scans

- Frequent scans (5 to 10 minutes) over selected longitudes
- Rare → can be requested but require science team approval

TEMPO tropospheric NO₂ column
01 November 2023
Scan 001 (11:41:47 UTC)



GOME-2

OMI

TROPOMI

TEMPO

Google Earth

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2023 TerraMetrics

20 km



5

TEMPO Level 2 & Level 3 products

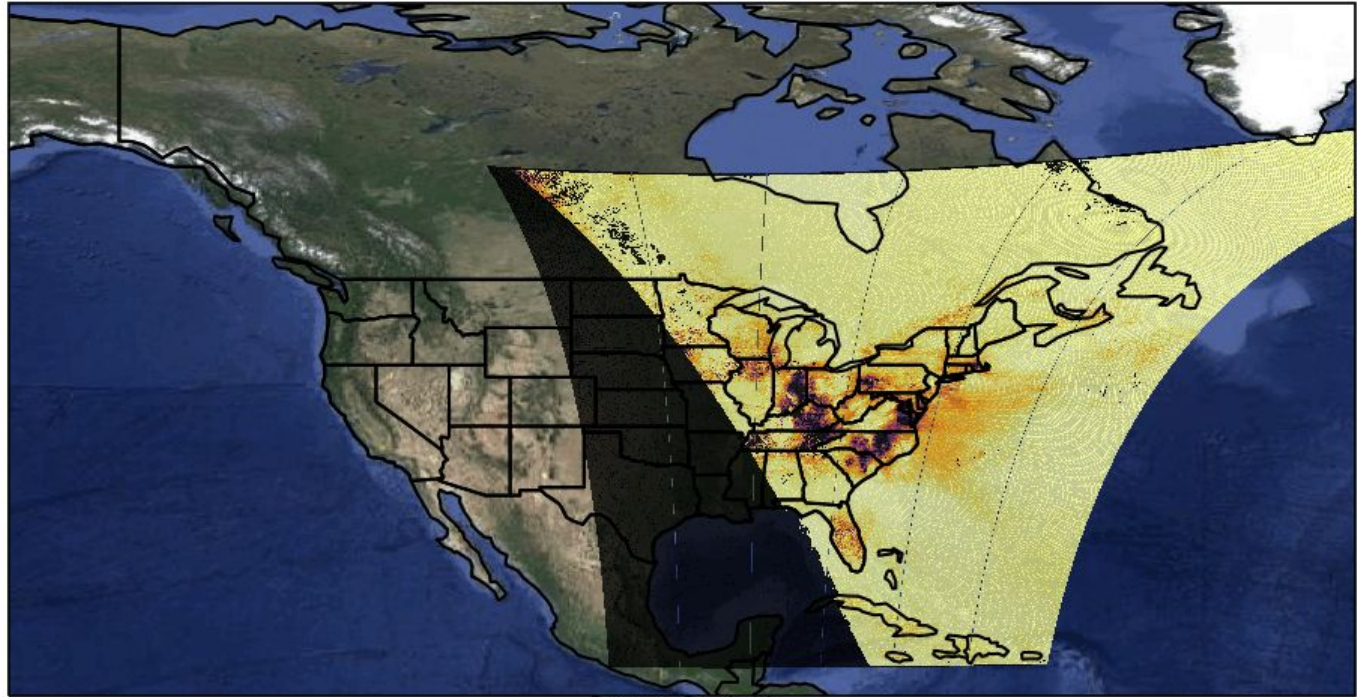
Product	Level(s)	Description	Most relevant variables in level 2 and level 3 file	Maturity level
NO2	2 & 3	Nitrogen dioxide total, tropospheric, and stratospheric columns	vertical_column_troposphere, vertical_column_stratosphere	Beta
HCHO	2 & 3	Total formaldehyde columns	vertical_column	Beta
O3TOT	2 & 3	Total ozone columns	column_amount_o3	Beta
CLDO4	2 & 3	Cloud parameters	cloud_fraction, cloud_pressure	Beta

Level 2: Information provided at TEMPO's native resolution (hourly sampling frequency or less; $\sim 10 \text{ km}^2$); usually one hour East-West scan is broken in 9 to 10 level 2 files.

Level 3: All level 2 data from a TEMPO East-West scan on a regular grid ($0.02^\circ \times 0.02^\circ$)

One day of NO₂ retrievals (unfiltered)

2024-05-09 10:41:07 to 2024-05-09 11:14:16; SCAN S001



Basemap Google (C)

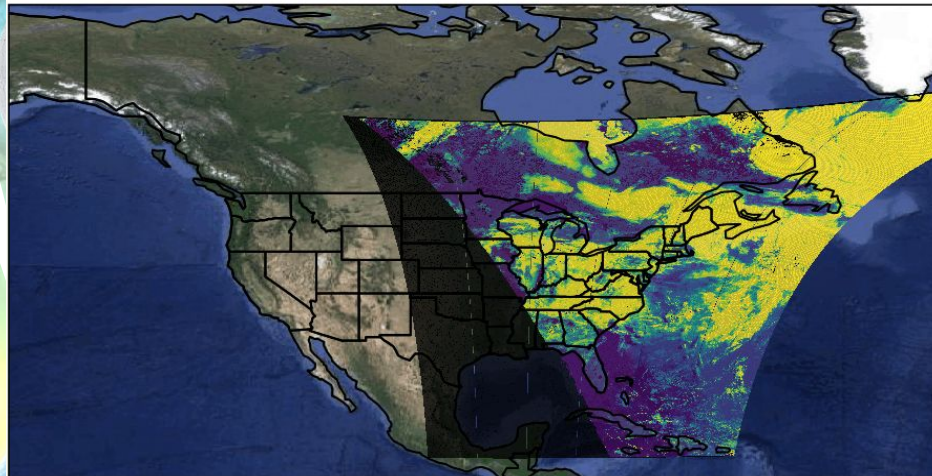
As mentioned previously it is important to filter data using the criteria described in the user guides

One day of HCHO retrievals: filtering data

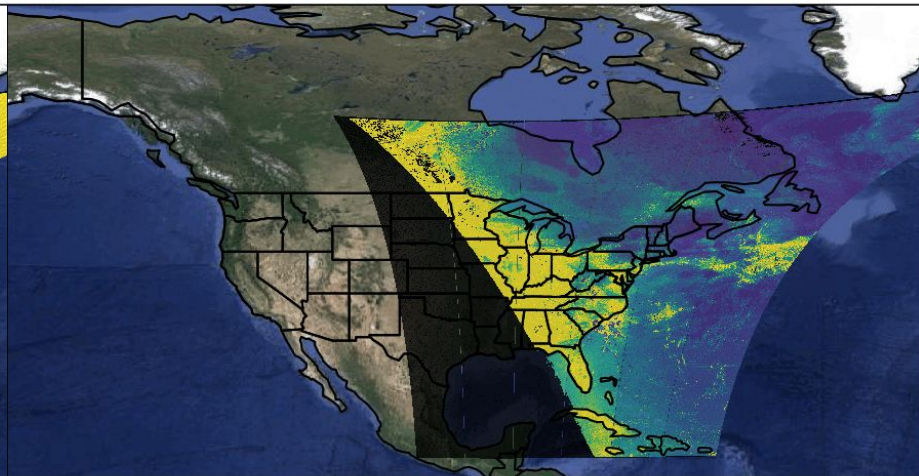
To perform qualitative studies it is essential to perform quality control on the data; multiple variables in the level 2 and level 3 files (main_data_quality_flag, cloud_fraction, vertical_column_uncertainty, snow_ice_fraction...) provide suitable information to filter data depending on the user's application.

2024-05-09 10:41:07 to 2024-05-09 11:14:16; SCAN S001

2024-05-09 10:41:07 to 2024-05-09 11:14:16; SCAN S001

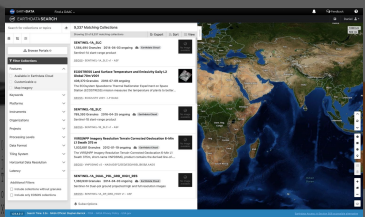
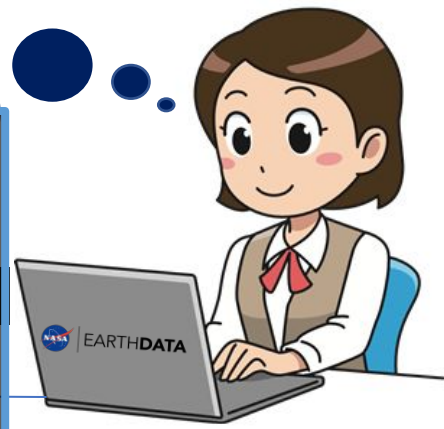


Basemap Google (c)
Cloud fraction

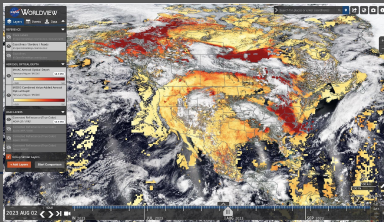


Basemap Google (c)
Vertical column uncertainty

Three places to highlight for data exploring:



Earthdata Search
Amazon EC2



Worldview



earthaccess

WORLDVIEW
+/- 30 Mbps



Earthdata Harmony

-SAMBAH
-HOSS



OPeNDAP



Amazon S3



Database



CUMULUS

EOSDIS Application Services



Networking



Security



Atmospheric Science Data Center



Where online will the data be found?

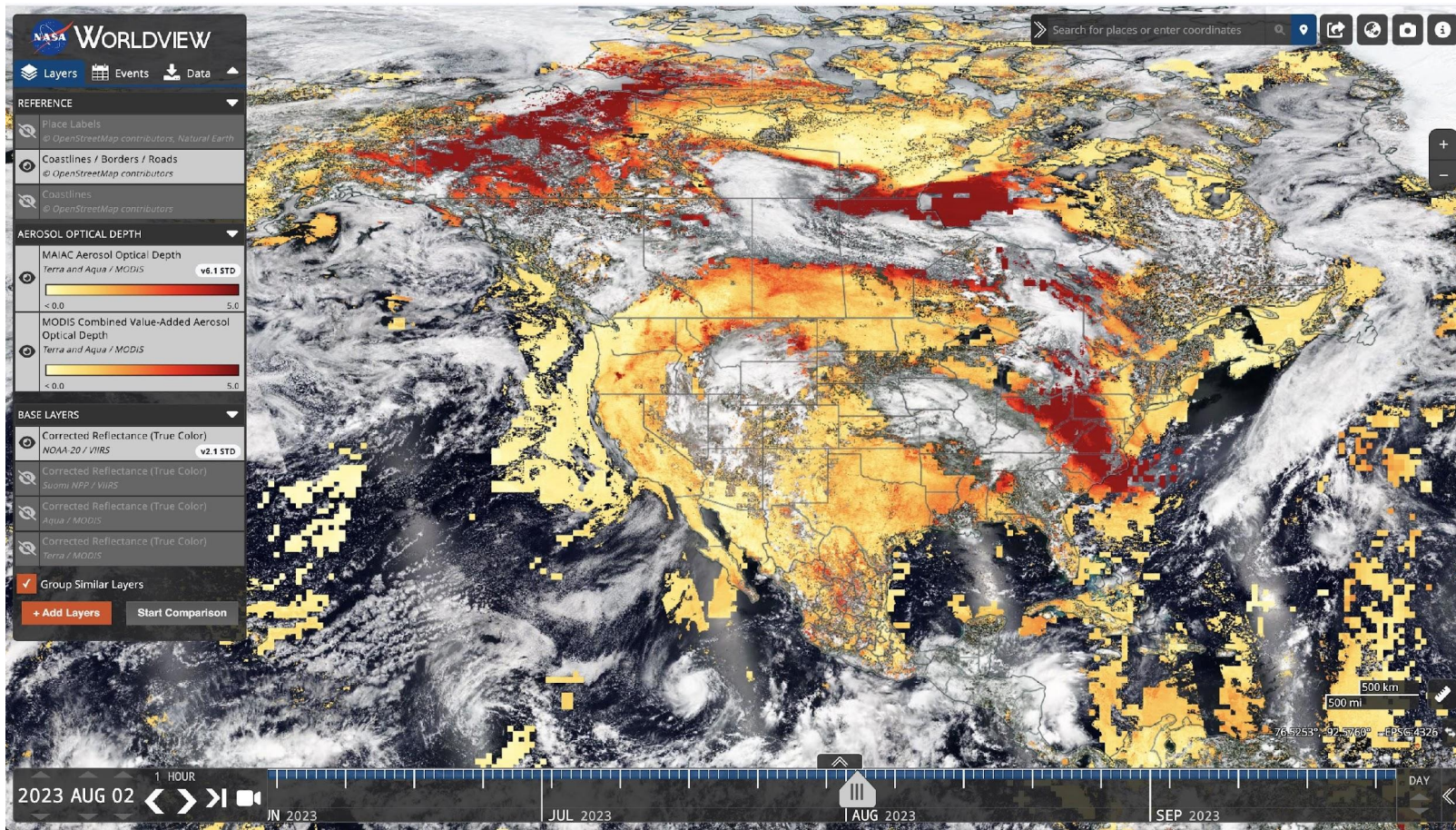
EarthData Search
(search.earthdata.nasa.gov)

Unified search and discovery interface for all of NASA's Earth Science data, with pre-processing and transformation services for select datasets

The screenshot displays the EarthData Search interface. At the top, the header includes the NASA logo, 'EARTHDATA', and a search bar. Below the header, the search results are displayed for the query 'TEMPO NO2 tropospheric, stratospheric, and total columns'. The results show 16 collections, with 20 granules displayed. Each granule entry includes the collection ID, start and end dates, and download options. A filter panel on the left allows for granule search, temporal filtering, and data access options. A map on the right shows the geographic distribution of the data, with a green bounding box indicating the search area over the Caribbean and Central America. The bottom of the interface features a timeline for the year 2024, with a blue bar indicating the search period from January to February.

How to retrieve images/rasters?

(worldview.earthdata.nasa.gov)



How about programmatic access?



Python library for NASA

```
1 import earthaccess
2
3 earthaccess.login(strategy="netrc")
4
5 results = earthaccess.search_data(
6     count=2,
7     short_name="ATL08",
8     bounding_box=(-92.86, 16.26, -91.58, 16.97),
9 )
10
11 earthaccess.download(results, "./research/")
12
```

- Line 3: earthaccess handles authentication with NASA EDL.
- Line 5: earthaccess abstracts NASA's search API (CMR) into a *pythonic* module.
- Line 11: earthaccess can download or open data for both cloud and on-prem hosted datasets.

github.com/nsidc/earthaccess

Where to go for more resources?

The screenshot shows the Earthdata Forum homepage. At the top, there is a navigation bar with the Earthdata Forum logo and a search bar. Below the navigation bar, there is a main header with a welcome message: "Welcome to the Earthdata Forum! Here, the scientific user community and subject matter experts from NASA Distributed Active Archive Centers (DAACs), and other contributors, discuss research needs, data, and data applications." Below the header, there is a navigation menu with "Quick links" and "Help". A "Post a New Question" button is highlighted with a red box. Below the button, there is a search bar with the text "ATL08" and a search icon. Below the search bar, there are four dropdown menus for "Discipline", "DAAC", "Major Projects", and "Services/Usage". Below the dropdown menus, there is a "Selected Tags" section with two tags: "NSIDC" and "ICESat/ICESat-2". Below the tags, there is a "Submit" button. At the bottom of the page, there is a table with the following data:

Forum	Questions	Posts	Last post
Questions/Comments Use this Forum to find information on, or ask a question about, NASA Earth Science data.	3467	13446	(resolved) MOD03 CMR concept ... by earthengine_urs # Sun Apr 23, 2023 12:30 pm America/New_York

Summary

- Hourly daytime air pollution measurements over North America
- Baseline data products:
 - Ozone
 - Nitrogen dioxide
 - Formaldehyde
- TEMPO data can be accessed via Earthdata Search, Worldview, and programmatically



Learn
more!



Credit: NASA's Scientific Visualization Studio