

Disclaimer: All examples are preliminary

National Aeronautics and
Space Administration



Enabling Analysis of Air Quality Data from Tropospheric Emissions: Monitoring of POLLution (TEMPO) via Cloud-based Tools

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Outline

- Mission and data
- Questions about access & transformation
- Services to enable analysis
- Where to find out more

The mission



Tropospheric Emissions:
Monitoring of Pollution

Was selected as NASA's first Earth
Venture Instrument in 2012

Principal Investigator is Dr. Kelly
Chance, from Smithsonian Astrophysical
Observatory (SAO)

Goal: to measure Air Quality



TEMPO launched aboard a SpaceX
Falcon 9 vehicle on April 7, 2023



Air quality measurements

UV/Visible spectrometer view of North America

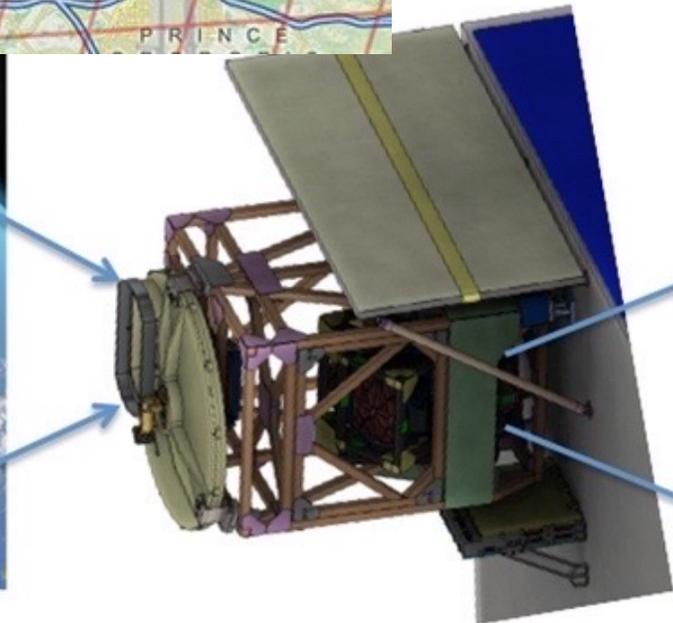
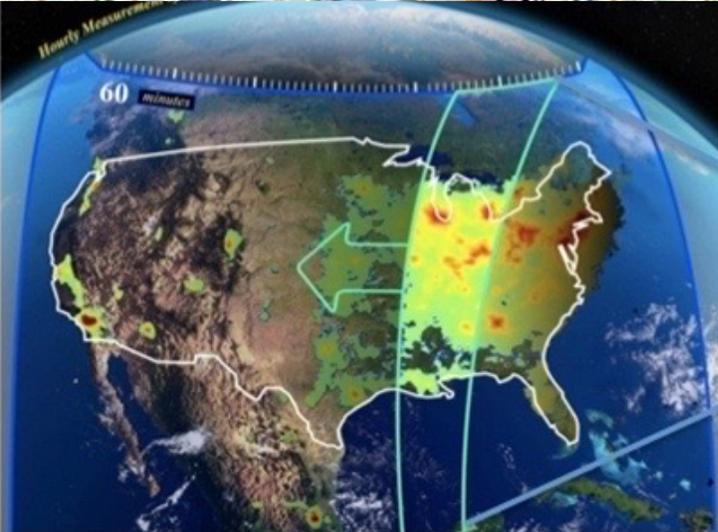
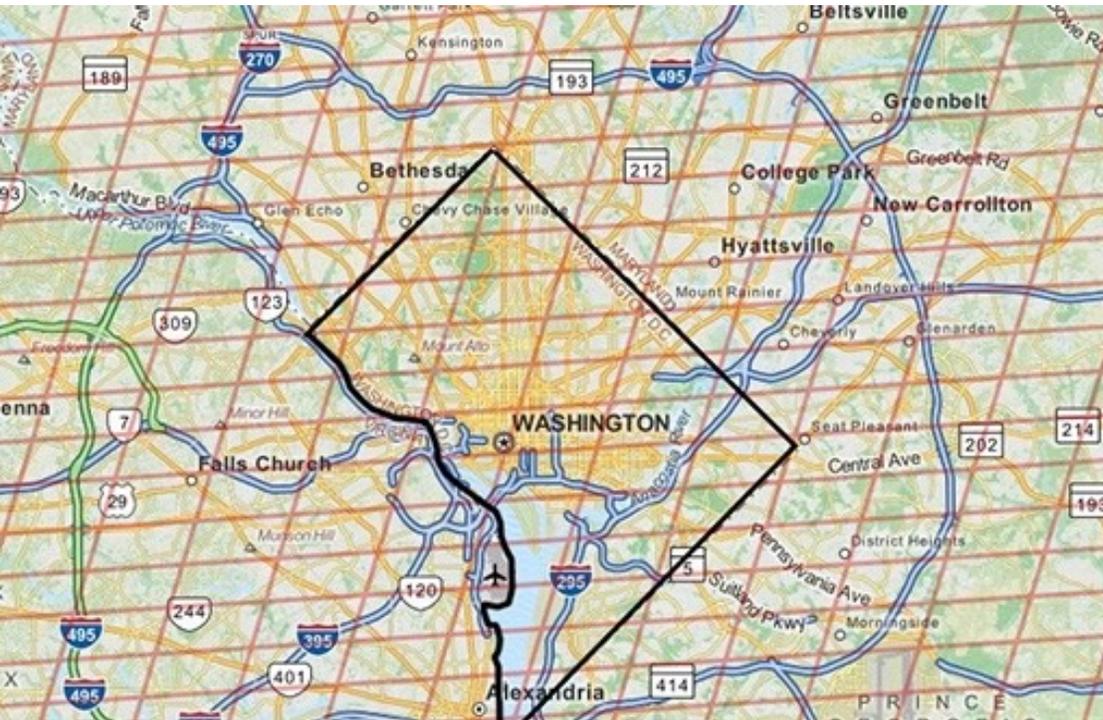
Geostationary orbit at altitude of ~36,000 km (~22,000 mi)

Measures ozone, nitrogen dioxide, formaldehyde, aerosols, and other pollutants

Resolution:

Hourly (~10 mins for special studies)

Approximately 2.4 km N/S × 5.4 km E/W



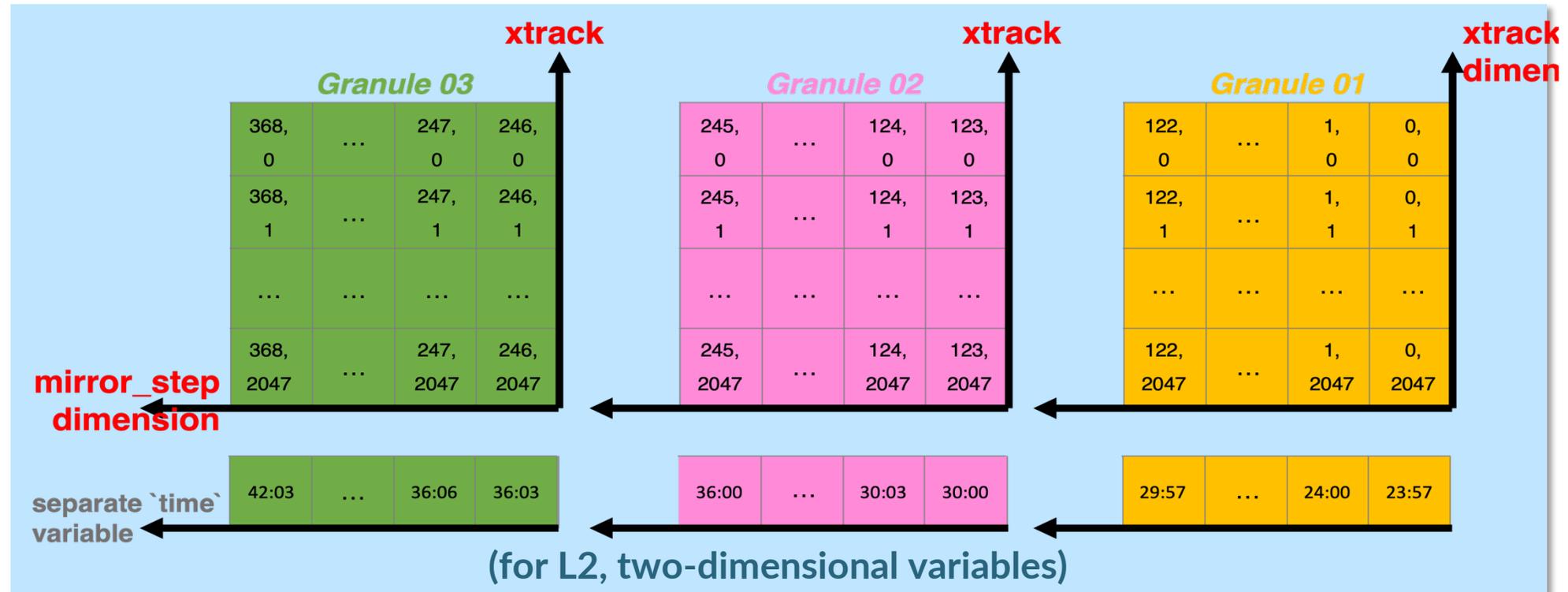
Data Structure



Data Structure

“Beta” data (2 weeks worth) to be available at end of January

- Level-1 (L1), L2, and L3 data collections
- L2 and L3 data files can be roughly 30 – 110 MB for a 6 min. duration
- netCDF-4 format



Example: L2 Ozone Total Column

Similarly, for NO₂ and Formaldehyde, etc.

Name	Long Name	Type
▼ TEMPO_O3TOT_L2_V01_20231017T111336Z_S001G01.nc	TEMPO Level 2 total ozone product	Local File
▼ geolocation	geolocation	—
latitude	latitude	Geo2D
latitude_bounds	latitude bounds	Geo2D
longitude	longitude	Geo2D
longitude_bounds	longitude bounds	Geo2D
relative_azimuth_angle	relative azimuth angle	Geo2D
solar_azimuth_angle	solar azimuth angle	Geo2D
solar_zenith_angle	solar zenith angle	Geo2D
terrain_height	terrain height	Geo2D
time	time	1D
viewing_azimuth_angle	viewing azimuth angle	Geo2D
viewing_zenith_angle	viewing zenith angle	Geo2D
mirror_step	scan mirror position index	1D
▼ product	product	—
column_amount_o3	column amount o3	Geo2D
fc	fc	Geo2D
o3_below_cloud	o3 below cloud	Geo2D
quality_flag	quality flag	Geo2D
radiative_cloud_frac	radiative cloud frac	Geo2D
so2_index	so2 index	Geo2D
uv_aerosol_index	uv aerosol index	Geo2D
▼ qa_statistics	qa_statistics	—
▶ support_data	support_data	—
xtrack	pixel index along slit	1D

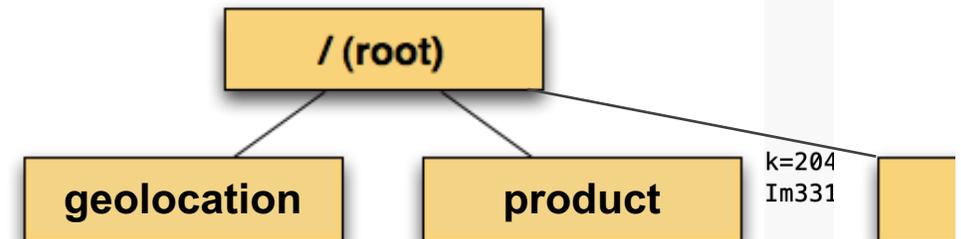
Show: All variables

Group "product"

In file "TEMPO_O3TOT_L2_V01_20231017T111336Z_S001G01.nc"

variables:

```
float column_amount_o3(mirror_step=132, xtrack=2048);
:valid_max = 700.0f; // float
:_FillValue = -1.2676506E30f; // float
```



```
:valid_max = 1.0f; // float
:_FillValue = -1.2676506E30f; // float
:coordinates = "time longitude latitude";

float fc(mirror_step=132, xtrack=2048);
:comment = "effective cloud fraction (mixed LER model)";
:valid_min = 0.0f; // float
:valid_max = 1.0f; // float
:_FillValue = -1.2676506E30f; // float
:coordinates = "time longitude latitude";

float uv_aerosol_index(mirror_step=132, xtrack=2048);
:comment = "UV aerosol index";
:valid_min = -30.0f; // float
```

You may be wondering...

Where online will the data be found?



What about programmatic access?

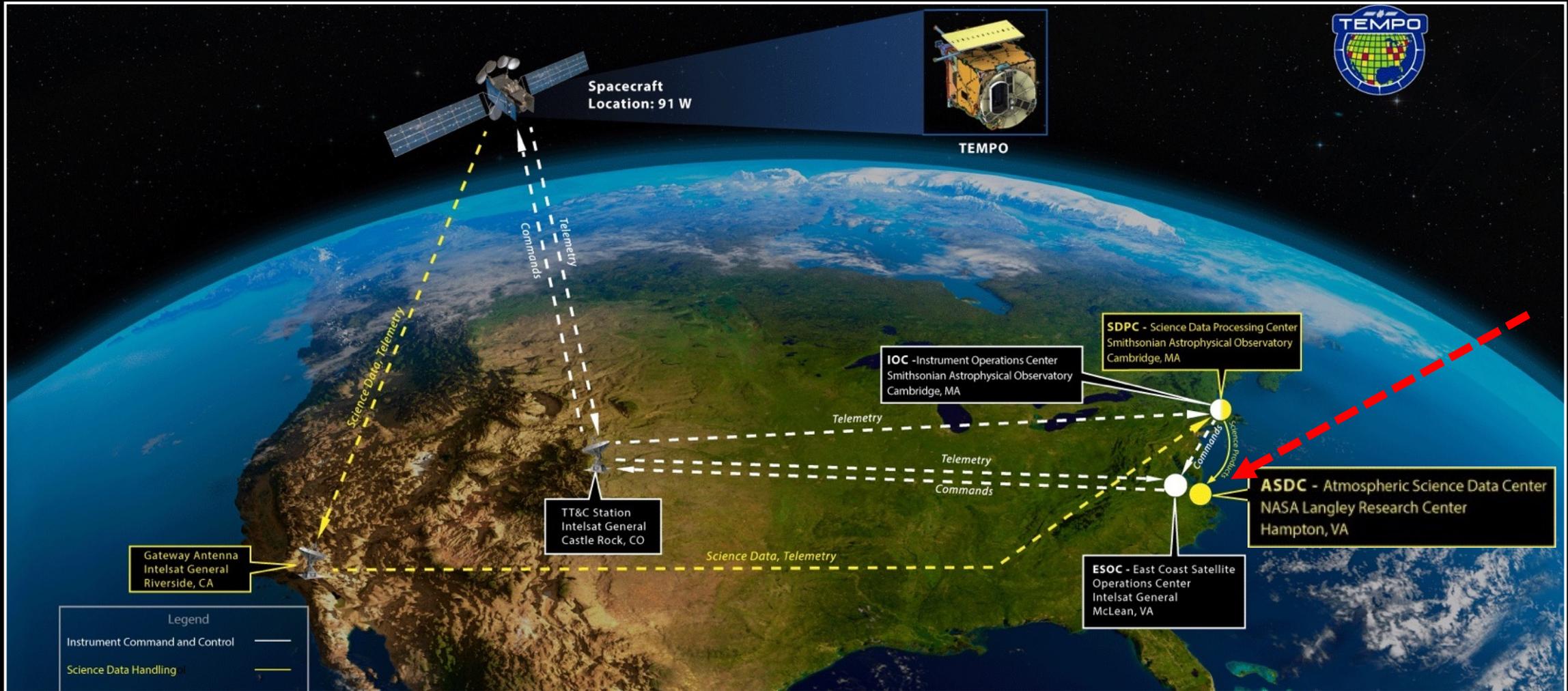


How to extract data for a particularly interesting city / state / region?



How to retrieve data images / rasters?





Atmospheric Science Data Center (ASDC) in Hampton, VA, ingests, archives, and distributes TEMPO data

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 NASA EarthData logo and "Find a DAAC" dropdown are visible. The main search bar contains "EARTHDATA SEARCH" and "Search for collections or topics". The search results are for "TEMPO NO2 tropospheric, stratospheric, and total columns", showing 16 collections and 10,237 granules. A filter sidebar on the left includes "Filter Granules" with options for Granule Search, Temporal (Start/End), and Data Access. The search results are displayed in a grid of granule cards, each showing the granule ID, start/end times, and download options. A map on the right shows the search area over the Caribbean and Central America, with a green bounding box. The bottom of the interface features a timeline for the year 2024, with a blue bar indicating the search period from September to January.



NASA Earthdata Cloud Cookbook



- Welcome
- Our Cookbook
- Cheatsheets & Slides

How do I... >

find data
using Earthdata
Search

using the command
line

using a script

access data >



Find Data: Earthdata Search

The original source for this document is https://nasa-openscapes.github.io/2021-Cloud-Workshop-AGU/tutorials/01_Earthdata_Search.html

This tutorial guides you through how to use [Earthdata Search](#) for NASA Earth observations search and discovery, and how to connect the search output (e.g. download or access links) to a programmatic workflow (locally or from within the cloud).

Step 1. Go to Earthdata Search and Login

Go to Earthdata Search <https://search.earthdata.nasa.gov> and use your Earthdata login credentials to log in. If you do not have an Earthdata account, please see the [Workshop Prerequisites](#) for guidance.

Step 2. Search for dataset of interest

Use the search box in the upper left to type key words. In this example we are interested in the ECCO dataset, [hosted by the PO.DAAC](#). This dataset is available from the NASA Earthdata Cloud archive hosted in AWS cloud.

Click on the **“Available from AWS Cloud”** filter option on the left. Here, 104 matching collections were found with the basic **ECCO** search.

The screenshot shows the Earthdata Search web application. At the top, there's a search bar and navigation options. Below, a sidebar on the left allows filtering collections by categories like 'Available from AWS Cloud'. The main area displays '104 Matching Collections' for the search term 'ECCO'. Two results are visible: 'ECCO Ocean Temperature and Salinity - Monthly Mean 0.5 Degree (Version 4 Release 4)' and 'Northeast Weddell Sea Pre-SWOT Level-4 Hourly MITgcm LLC4320 Native Grid 2km Oceanographic Dataset Version 1.0'. A map on the right shows the search area over the Indian Ocean region.

On this page

- Step 1. Go to Earthdata Search and Login
- Step 2. Search for dataset of interest
- Step 3. Explore the dataset details, including Cloud Access information
- Step 4. Customize the download or data access
- Step 5. Integrate file links into programmatic workflow, locally or in the AWS cloud.

Edit this page

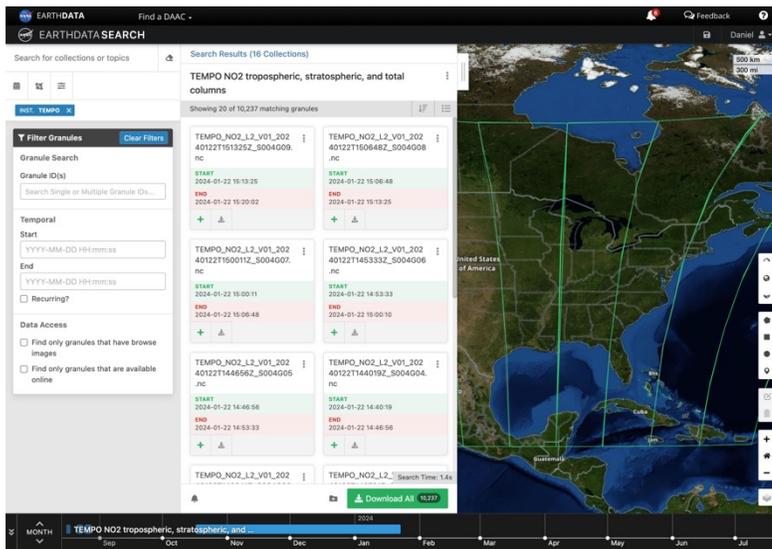
- View source
- Report an issue

NASA Openscapes Earthdata Cloud Cookbook

Learning-oriented to support researchers who use Earthdata as NASA migrates data and workflows to the cloud

How about programmatic access?

(search.earthdata.nasa.gov)

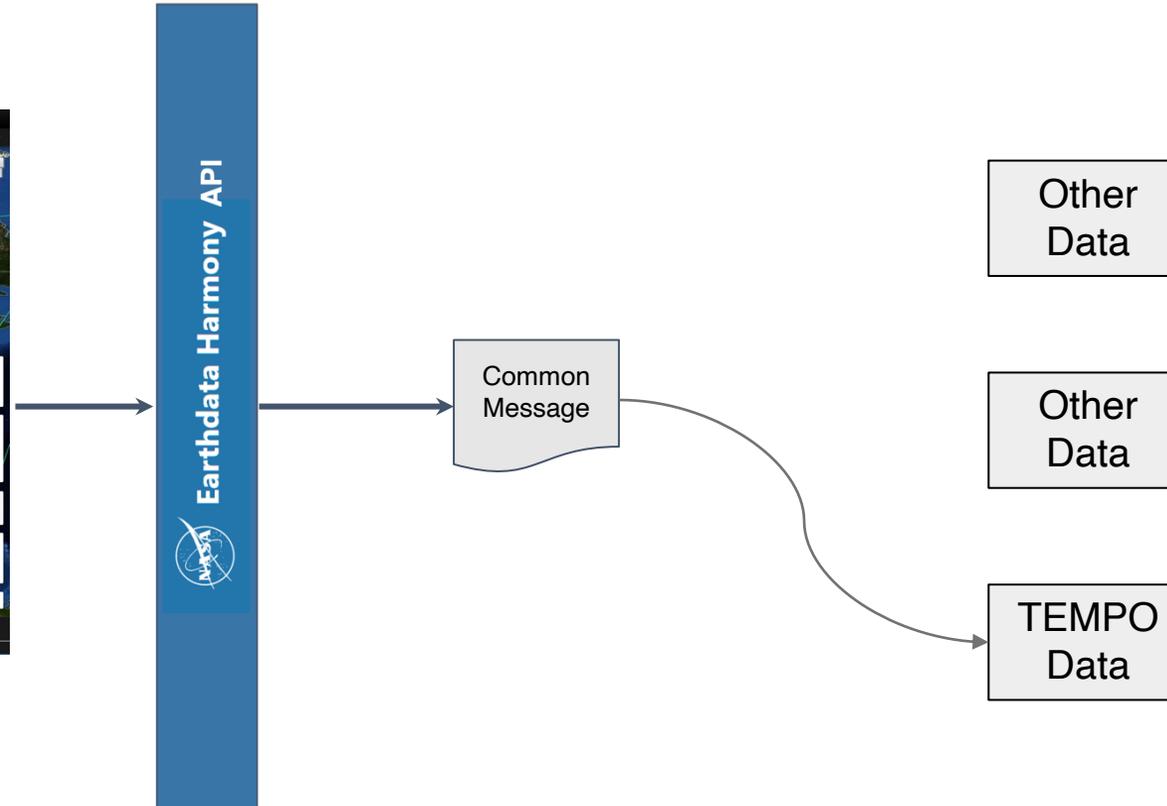
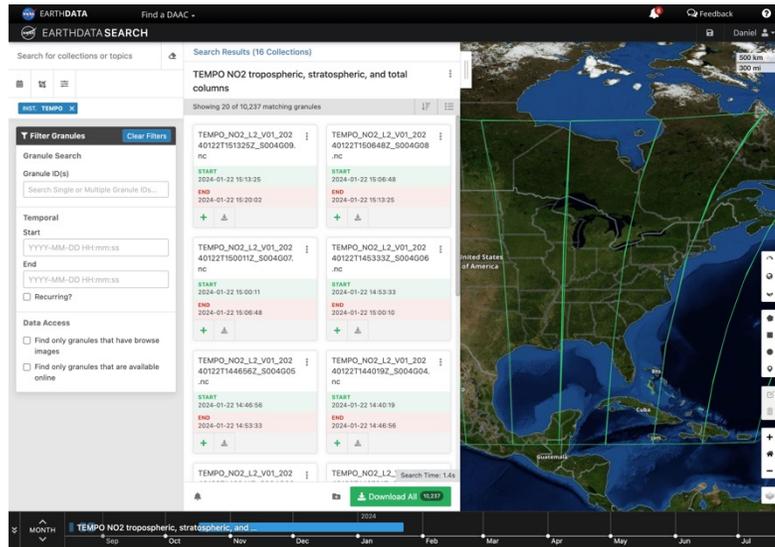


Earthdata Harmony API

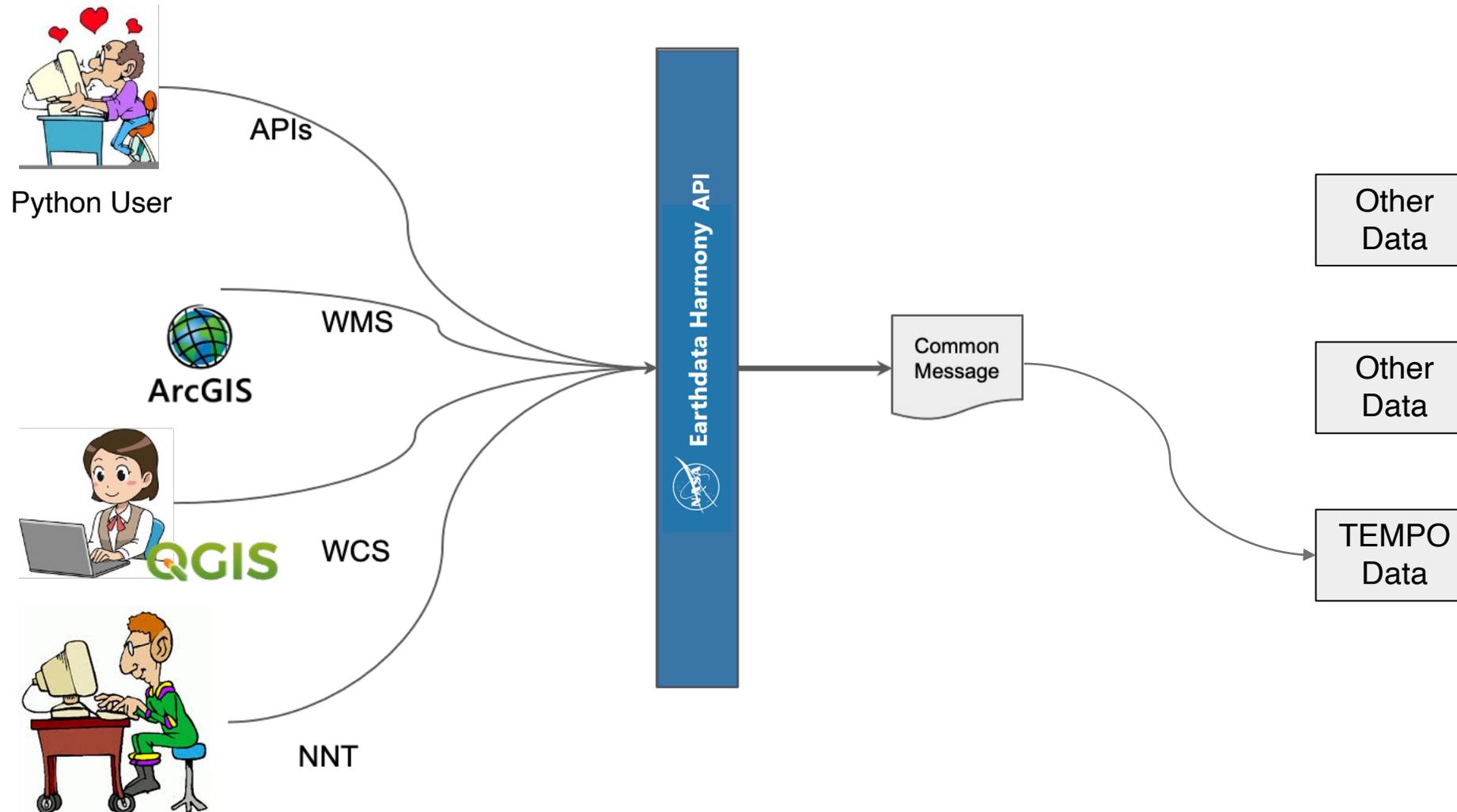
- The *Earthdata* graphical interface is powered by the NASA Common Metadata Repository (CMR), which has its own public API
- In the background, “Harmony” provides Open Geospatial Consortium (OGC)-compatible tools and a customized API to access cloud hosted data
- For many analysis use-cases, *earthaccess* (a Python library) may provide the perfect tool for finding and downloading TEMPO data files

How about programmatic access?

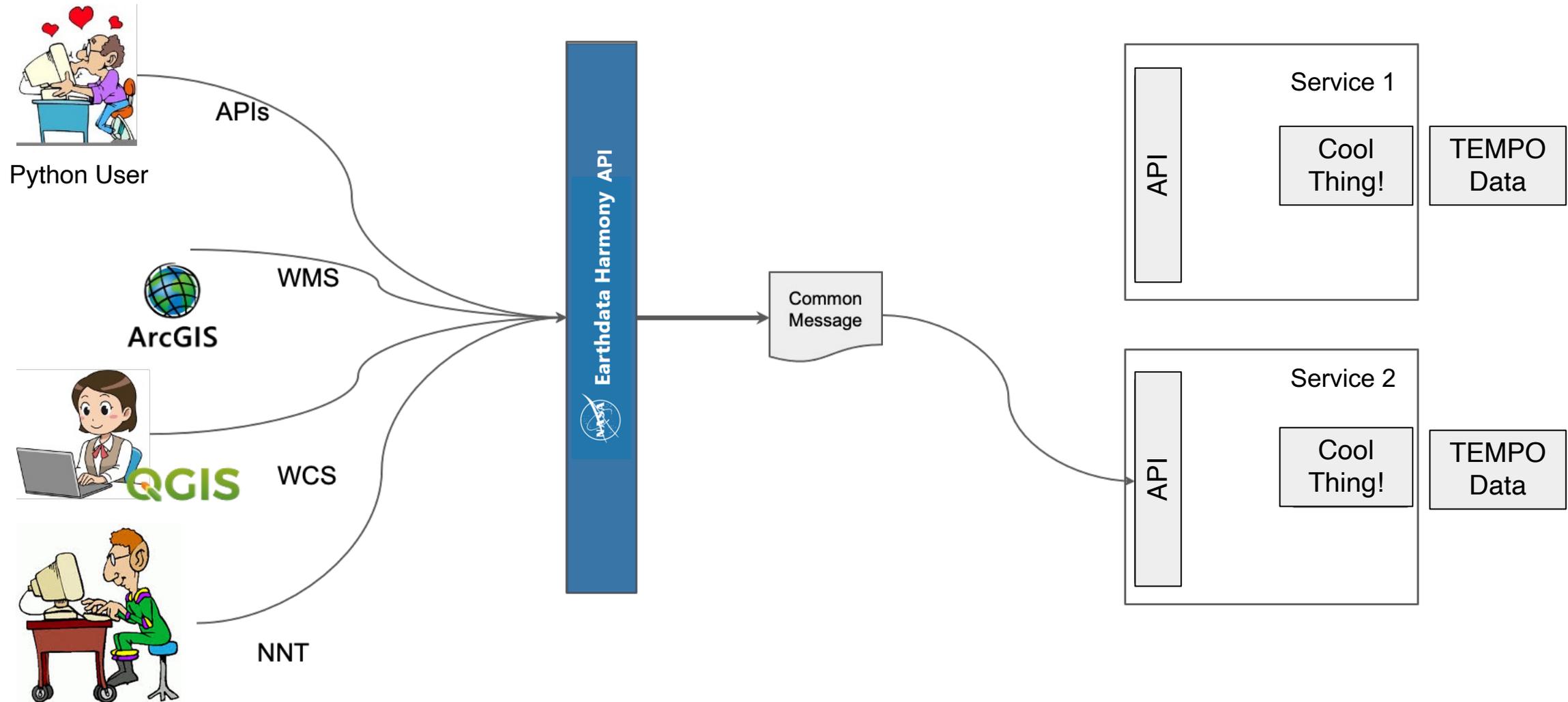
(search.earthdata.nasa.gov)



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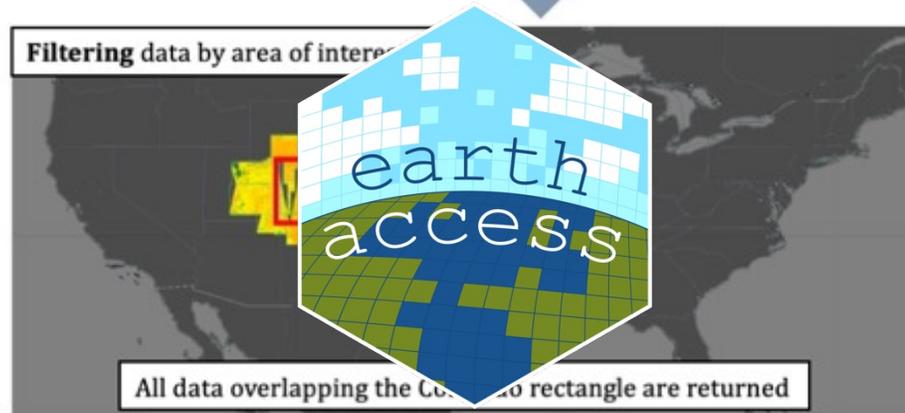
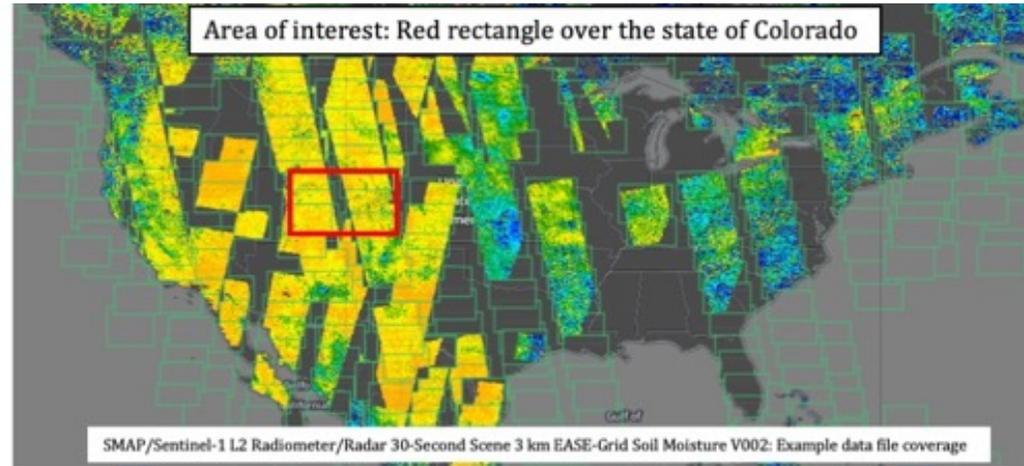
Python library for NASA Earthdata

```
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.

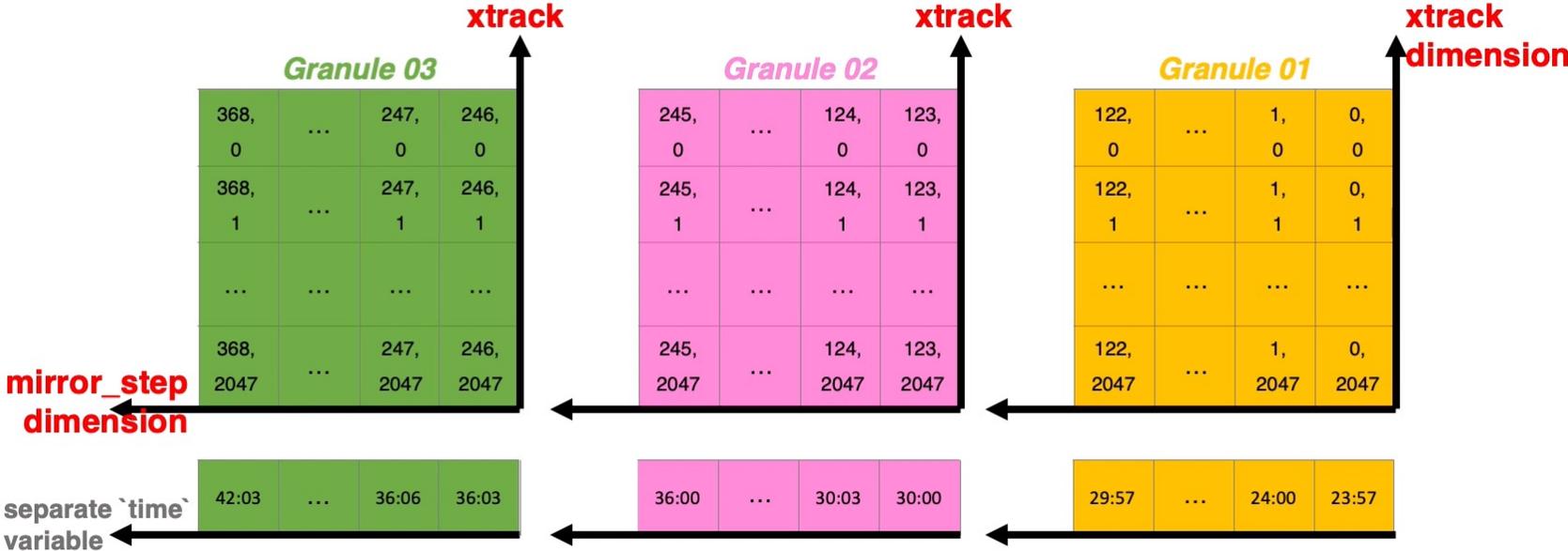
(github.com/nsidc/earthaccess)

How to extract data for the city / state / region that I'm interested in?



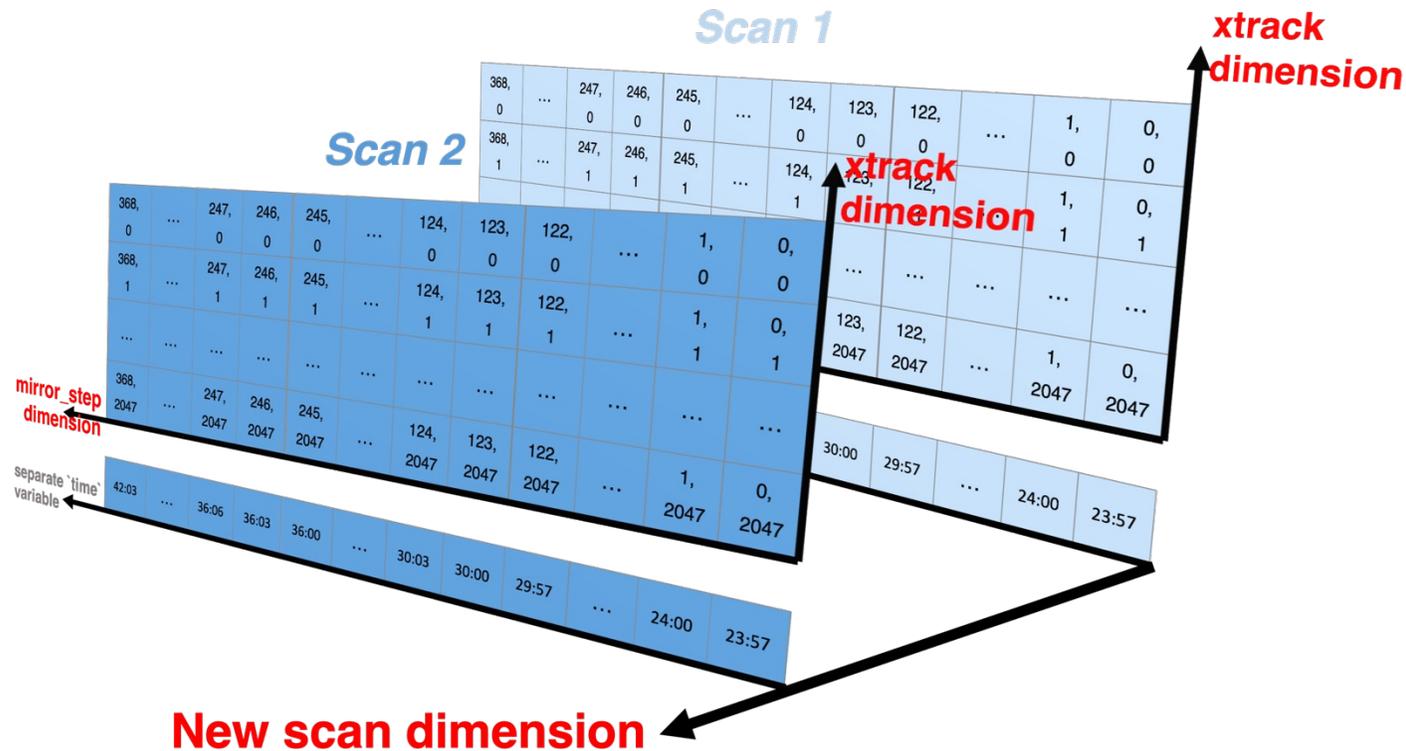
Concatenating the subsetting data

Structure of TEMPO Granules' 2D data

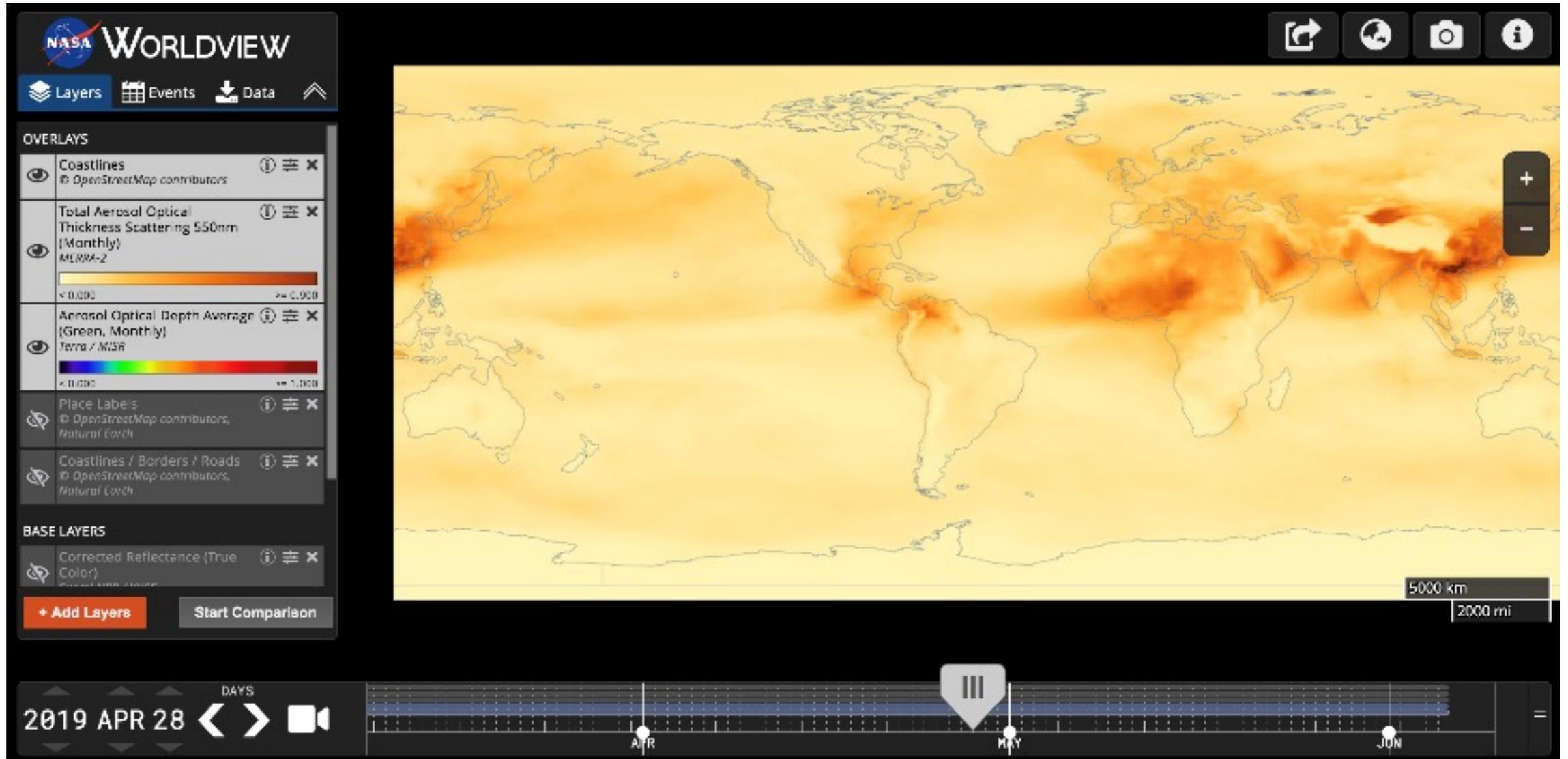


An intuitive structure for further exploration and analysis

Resulting Concatenated Data



How to retrieve images/rasters?

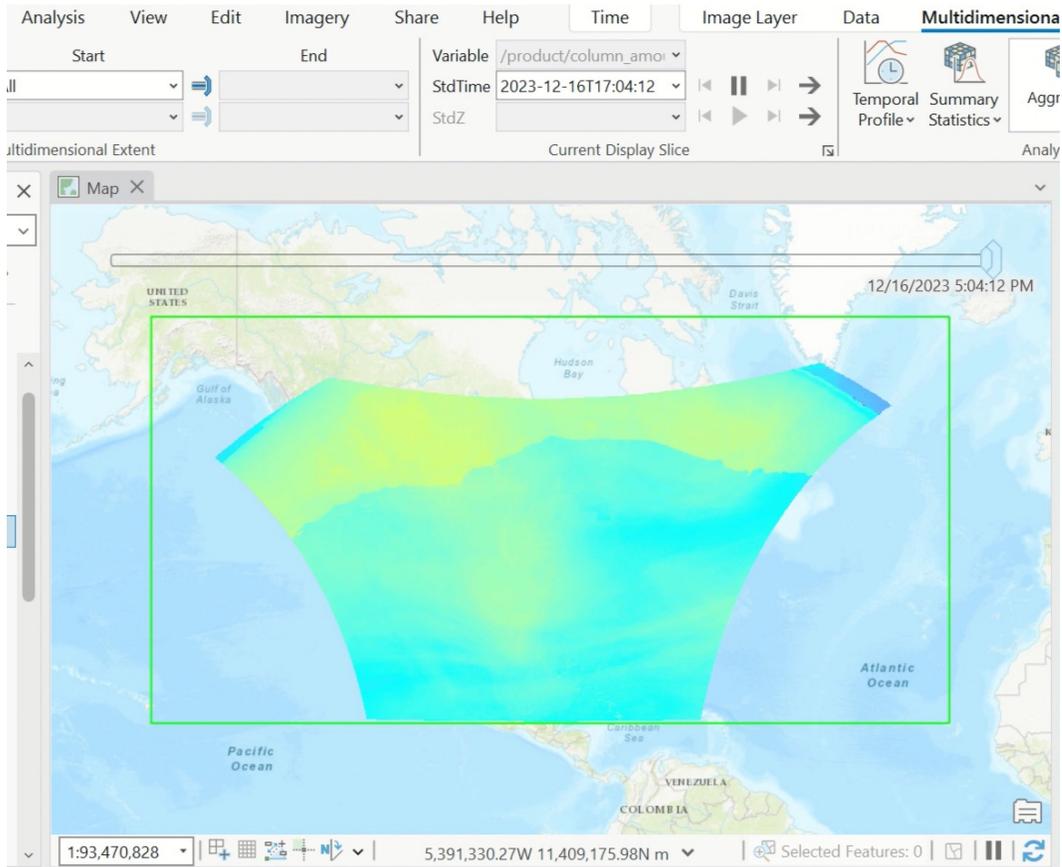


How to retrieve images/rasters?

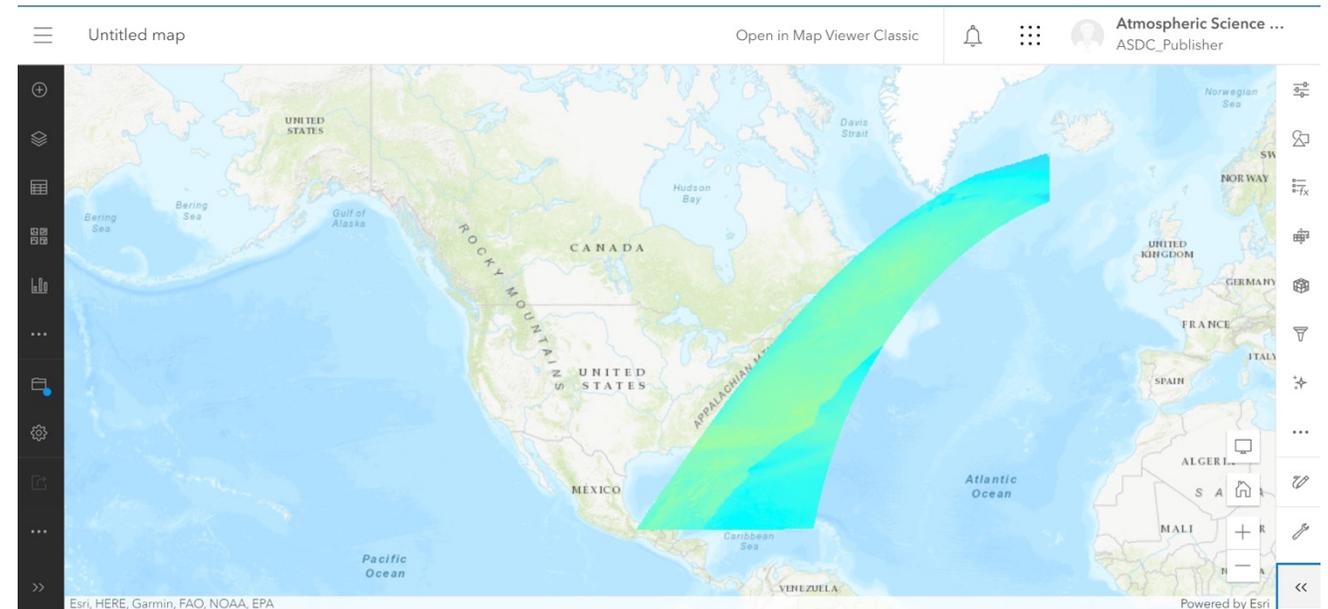
ASDC will release ArcGIS image services available through the NASA Earthdata GIS portal (<https://gis.earthdata.nasa.gov/portal/home/>).

Viewable in both proprietary (e.g., ESRI ArcGIS) and opensource software (QGIS).

ArcPro



Sample image service in a web mapper called from the EGIS portal



Example for L3 Ozone Total

Where to go for more resources?

The screenshot shows the Earthdata Forum homepage. At the top, there is a navigation bar with the NASA logo, 'EARTHDATA Forum', and a 'Find a DAAC' search bar. Below this is a banner with the text: '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.' The main content area features a 'Post a New Question' button highlighted with a red box. Below the button is a search bar with the text 'ATL08' and a search icon. Underneath the search bar are four dropdown menus for 'Discipline', 'DAAC', 'Major Projects', and 'Services/Usage', each with a 'Select' option. Below these are 'Selected Tags' with 'NSIDC' and 'ICESat/ICESat-2' tags. A green 'Submit' button is located below the search bar. At the bottom, there is a 'Forum' section with a table of activity.

	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

Where to go for more resources?

✓ NASA Earthdata Search

- metadata ◦ browse ◦ download
- customize ◦ HTTPS and AWS S3 direct data access



✓ NASA Earthdata WorldView

- visualize ◦ GIBS API



✓ NASA Earthdata Harmony

- subset ◦ concatenate



✓ NASA Earthdata GIS

- ArcGIS Image & Feature Service
- OGC WMS, WFS & WCS



✓ OPeNDAP

- transform ◦ subset ◦ reformat



✓ earthaccess

- search ◦ download ◦ open



User Support and Other Resources

Example scripts

- Python/Jupyter Notebook ◦ R scripts
- contributed tutorials/scripts



Earthdata Forum <https://forum.earthdata.nasa.gov/>

ASDC User Support support-asdc@earthdata.nasa.gov

To keep in mind:

- A “Beta” set of 2-weeks of data will be available at end of January or beginning of February
- TEMPO data (level-2 and level-3) are anticipated to be publicly available in April, 2024