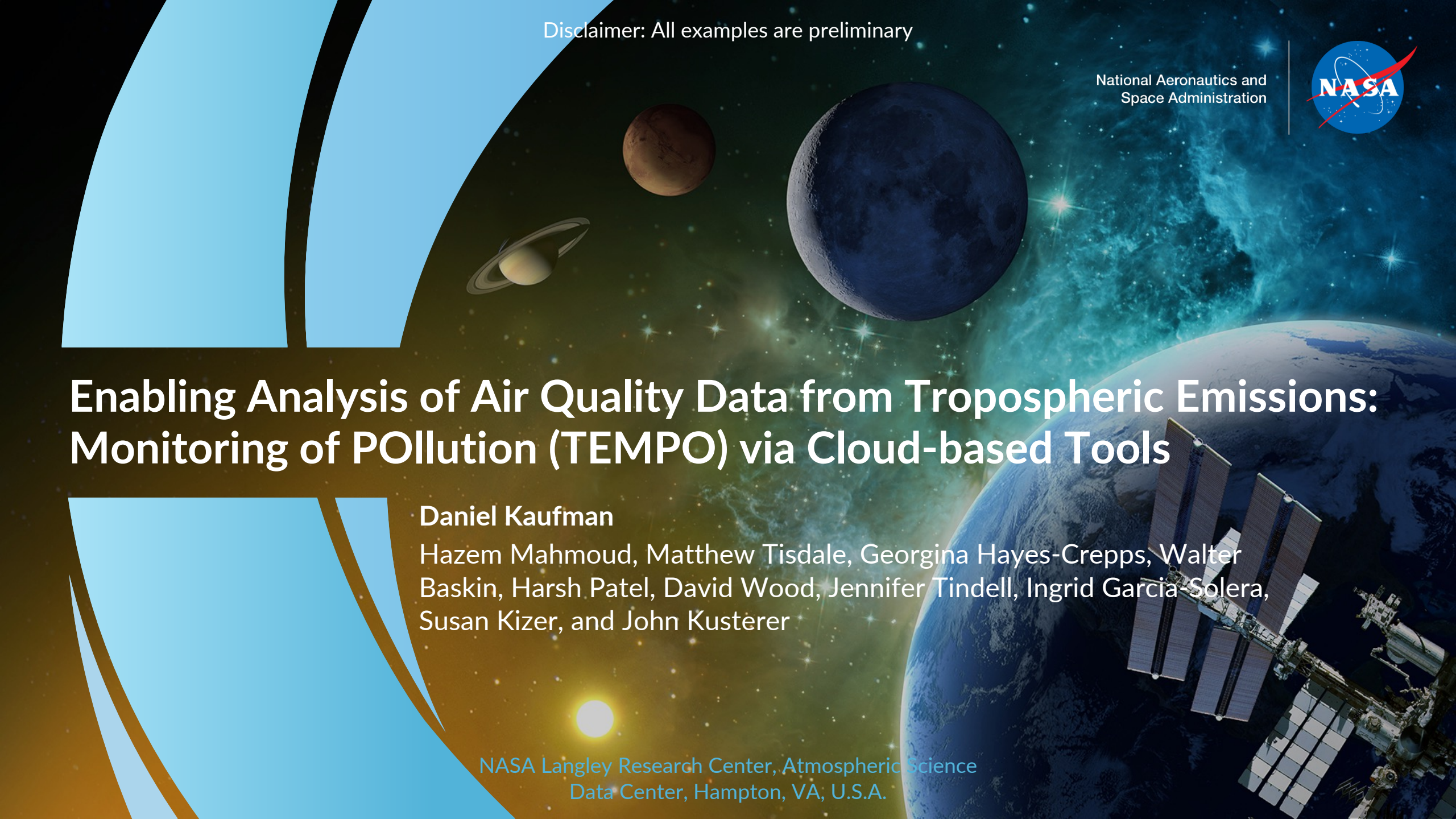
Disclaimer: All examples are preliminary

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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NASA Langley Research Center, Atmospheric Science Data Center, Hampton, VA, U.S.A.

Outline

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

The mission

Tropospheric Emissions: Monitoring of Pollution

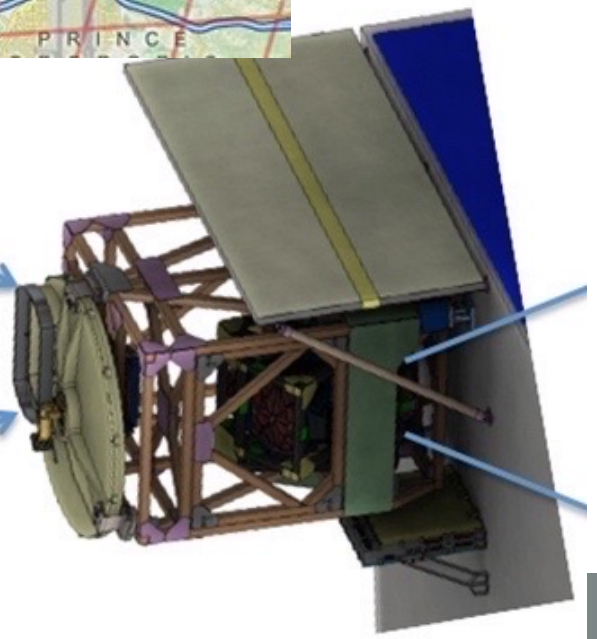
Was selected as NASA's first Earth Venture Instrument in 2012

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

Goal: to measure Air Quality

http://tempo.si.edu/gallery.html


TEMPO launched aboard a SpaceX
Falcon 9 vehicle on April 7, 2023
https://pweb.cfa.harvard.edu/news/liftoff-tempo-instrument-soars-space



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

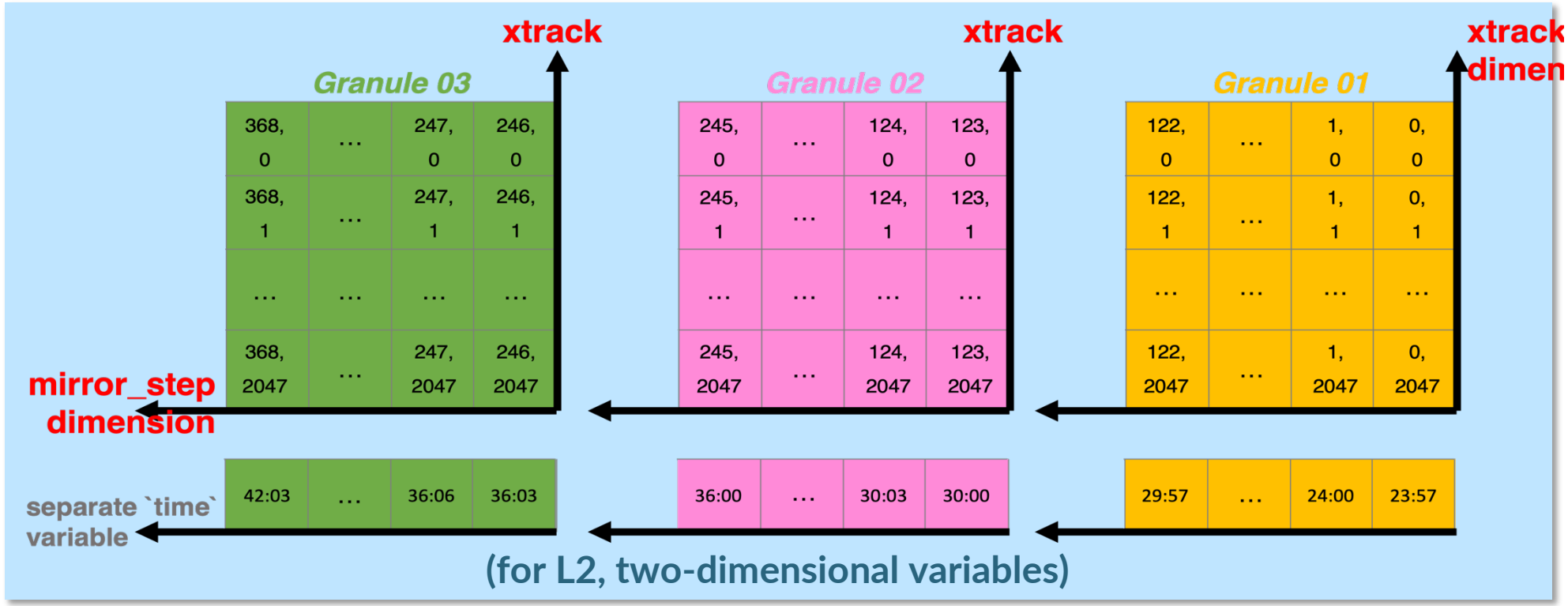
http://tempo.si.edu/instrument.html

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 NO_2 and Formaldehyde, etc.

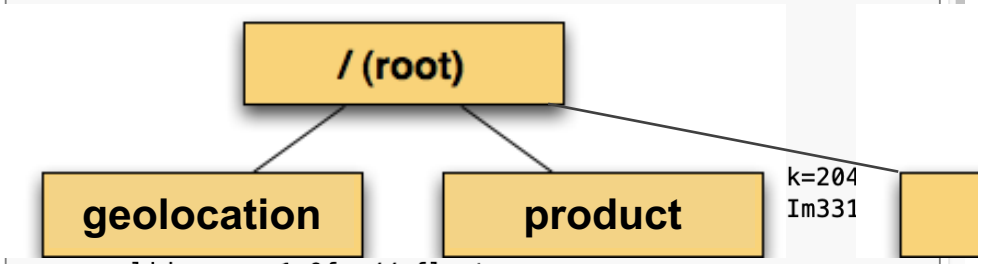
Name	Long Name	Type
TEMPO_O3TOT_L2_V01_20231017T111336Z_S001G01.nc	TEMPO Level 2 total ozone product	Local File
geolocation	geolocation	—
latitude	latitude	Geo2D
latitude_bounds	latitude bounds	Geo2D
longitude	longitude	Geo2D
longitude_bounds	longitude bounds	Geo2D
relative_azimuth_angle	relative azimuth 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…

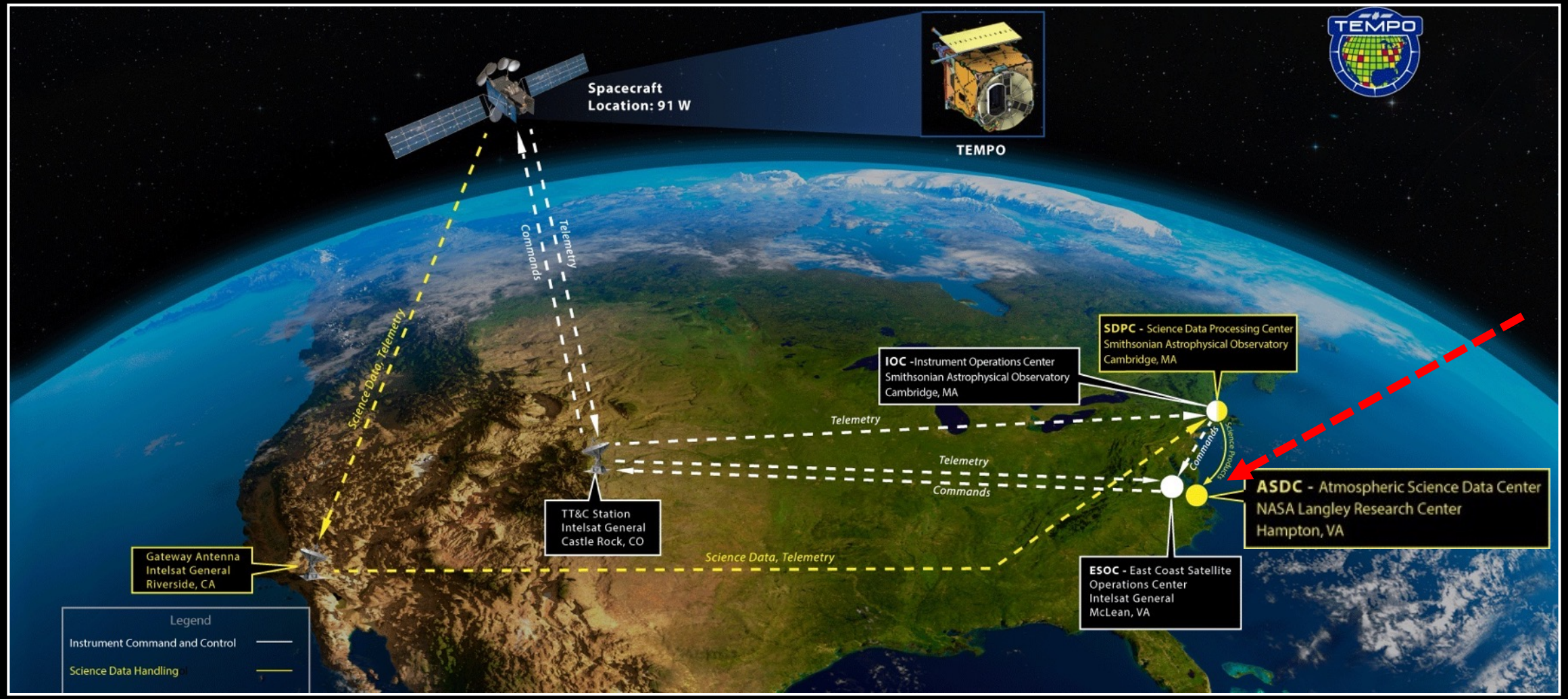
Where online will the data be found?

What about programmatic access?

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

How to retrieve data images / rasters?

http://tempo.si.edu/gallery.html

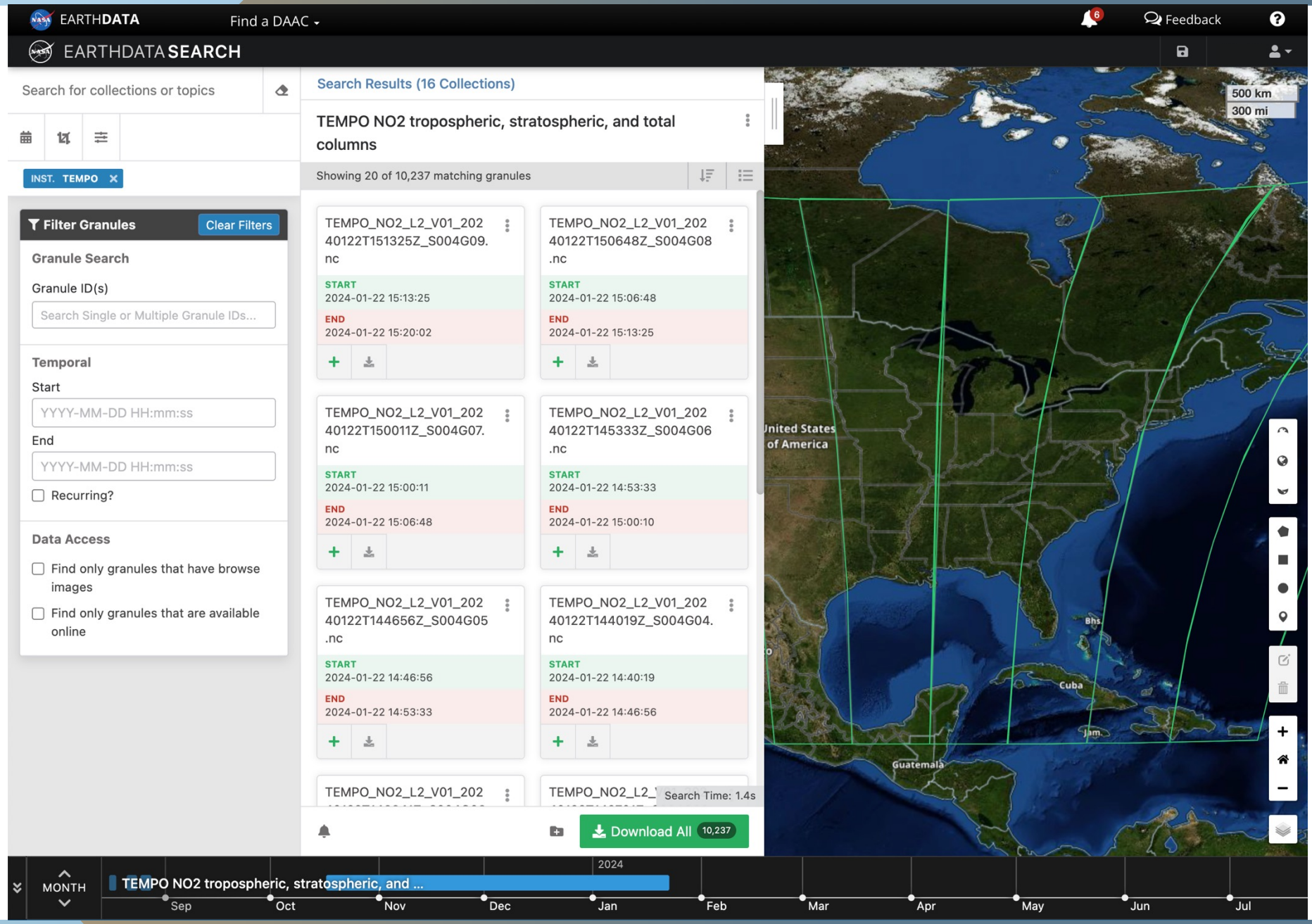


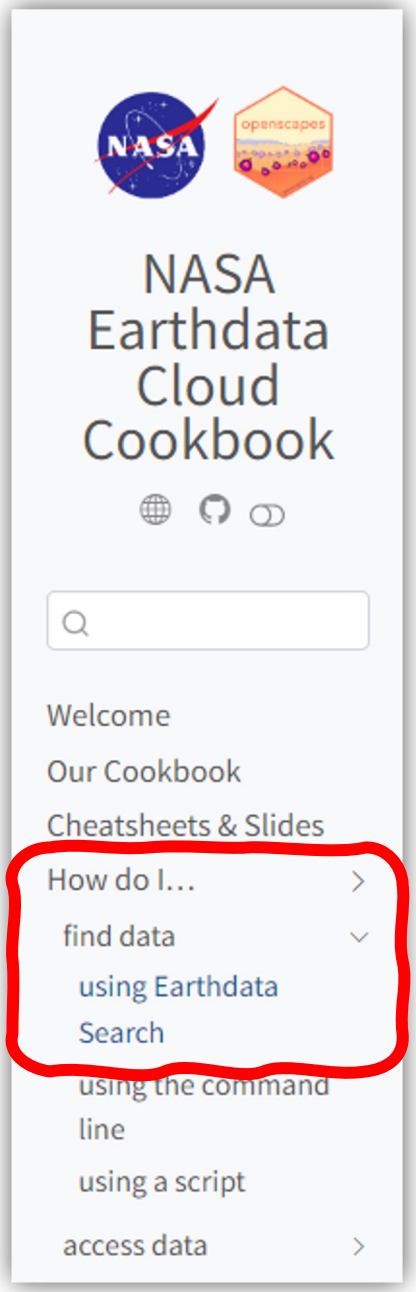
Atmospheric Science Data Center (ASDC) in Hampton, VA, ingests, archives, and distributes TEMPO data

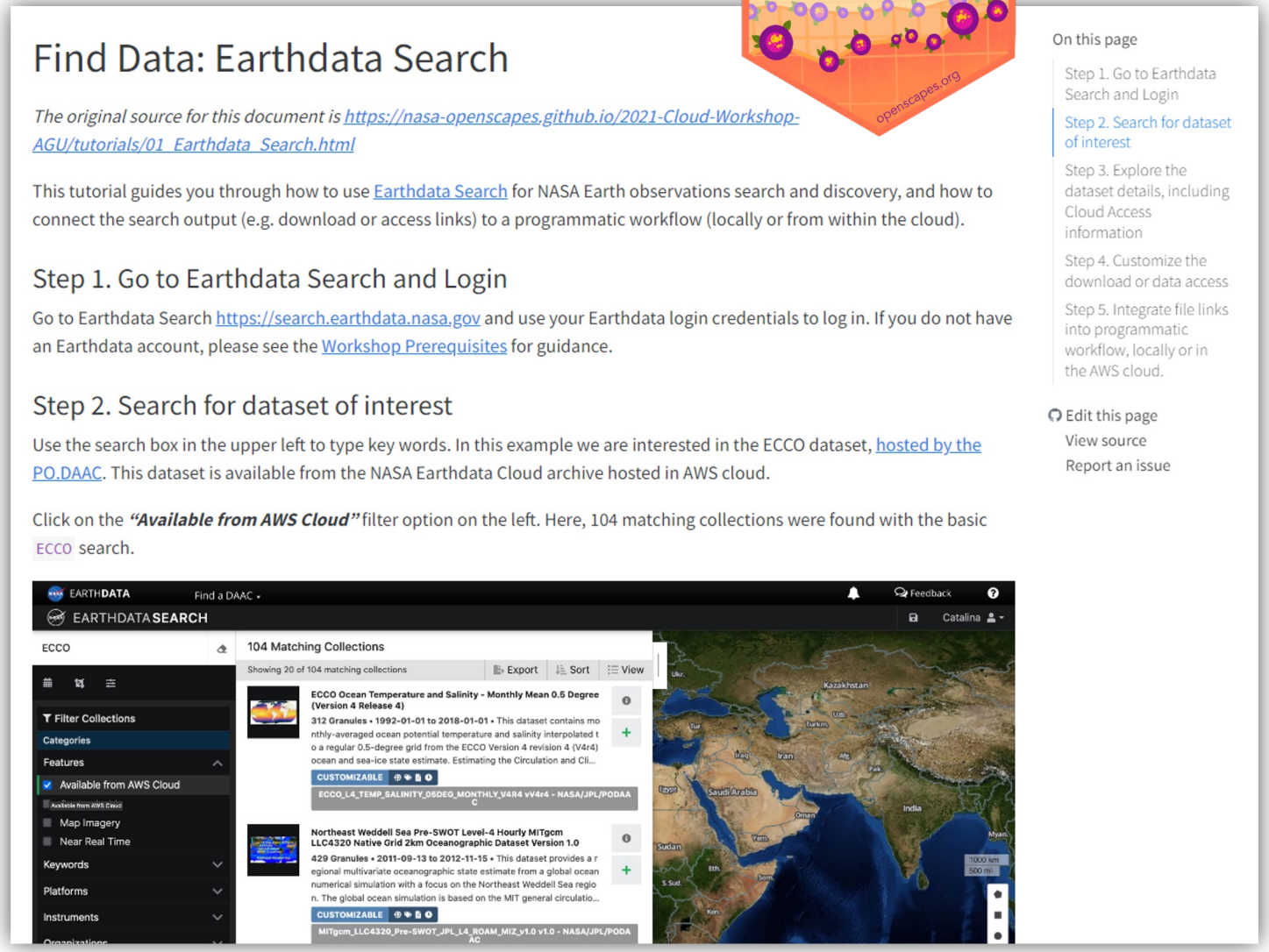
Where online will the data be found?

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





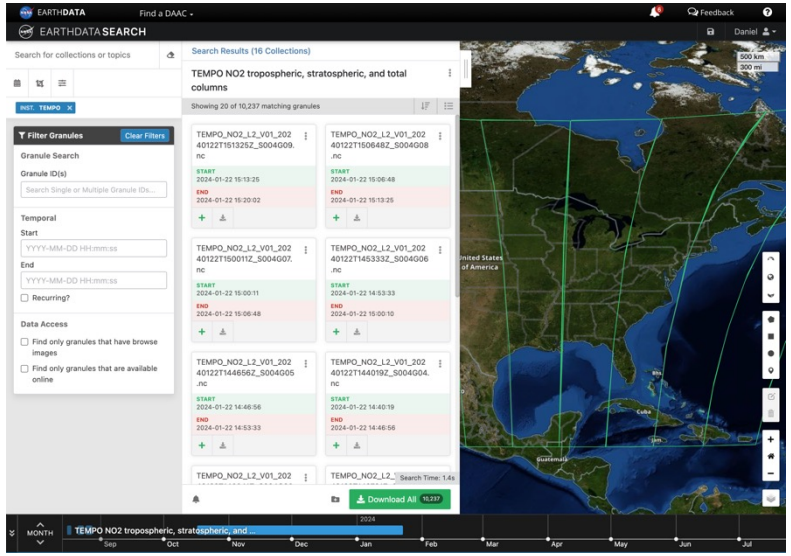


NASA Openscapes Earthdata Cloud Cookbook

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

How about programmatic access?

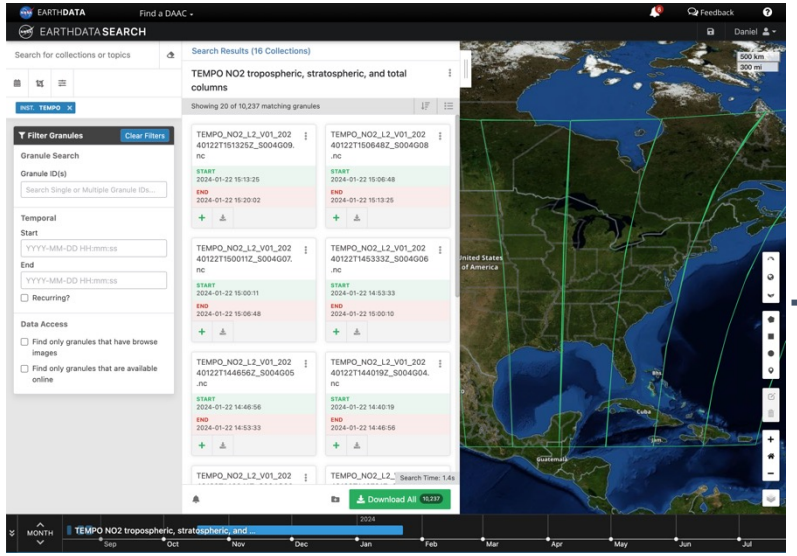
(search.earthdata.nasa.gov)

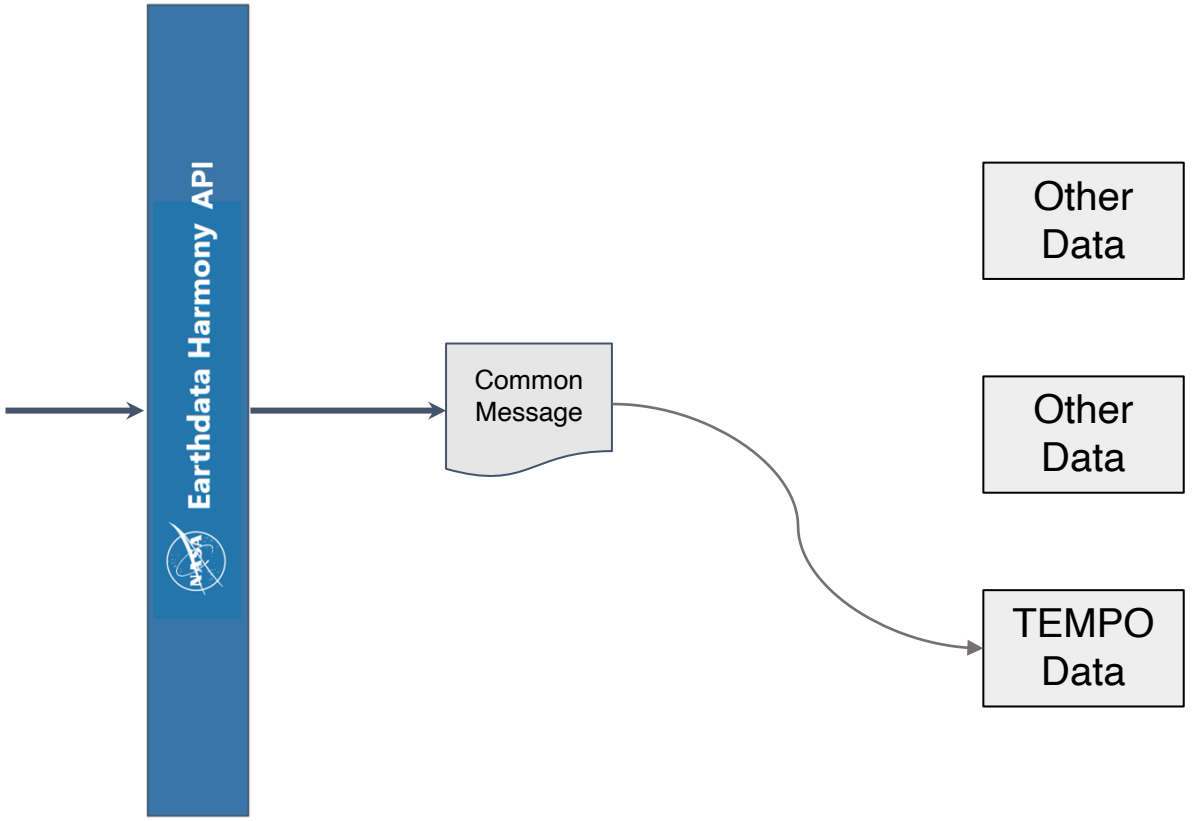


- The *Earthdata* graphical interface is powered by the NASA Common Metadata Repository (CMR), which has its own public API
- In the background, “Harmony” provides Open Geospatial Consortium (OGC)-compatible tools and a customized API to access cloud hosted data
- For many analysis use-cases, *earthaccess*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

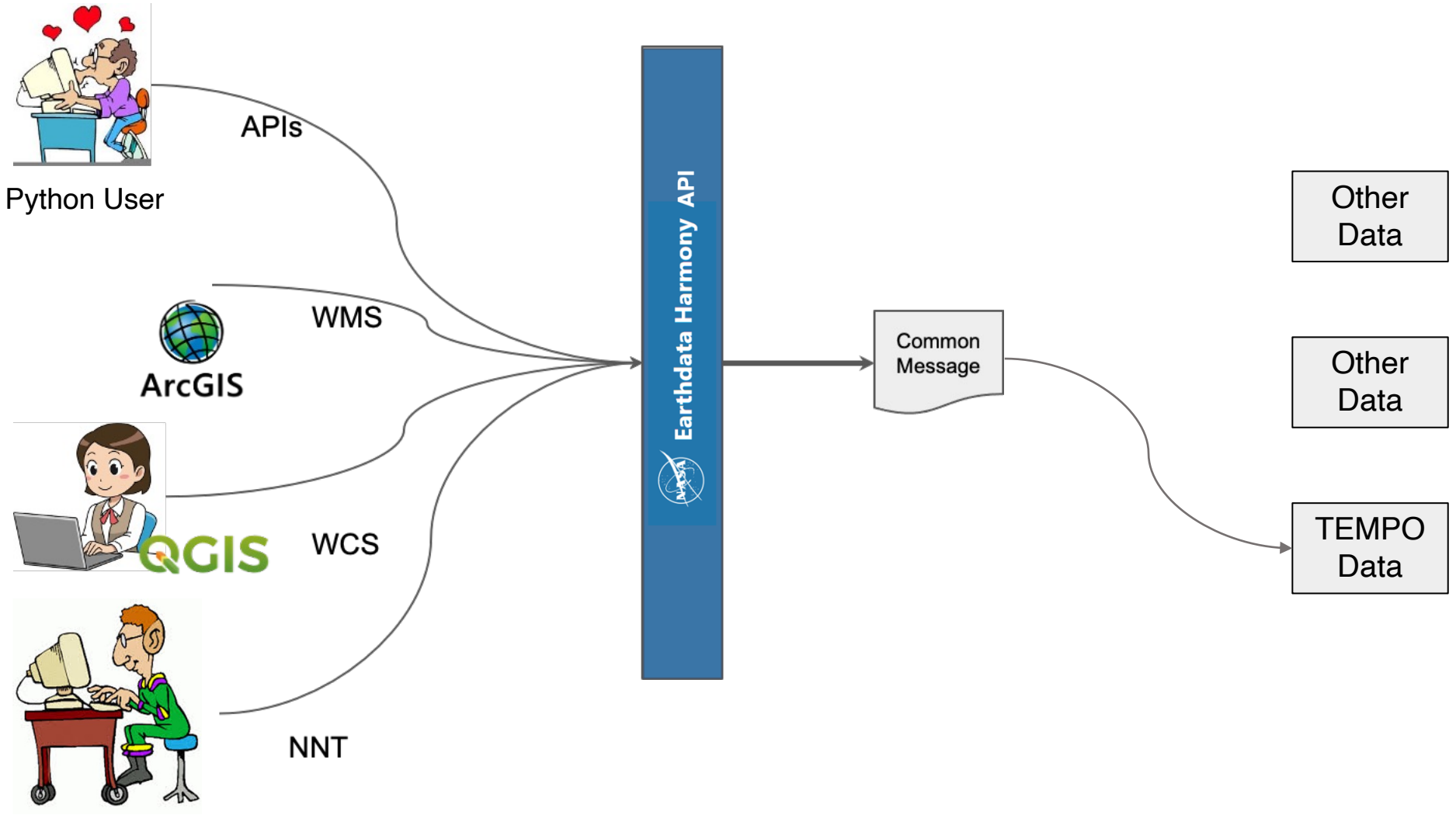
How about programmatic access?

(search.earthdata.nasa.gov)

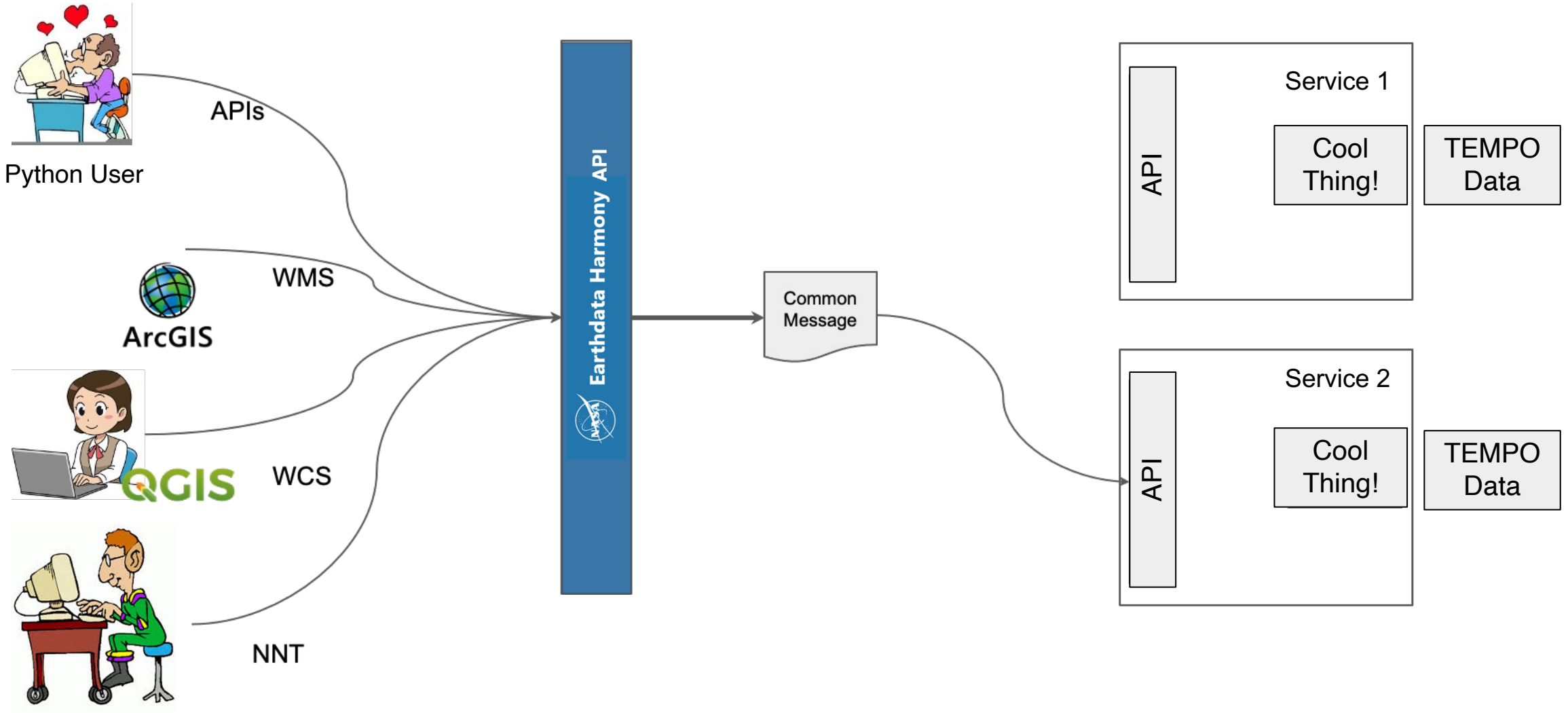




How about programmatic access?



How about programmatic access?



How about programmatic access?

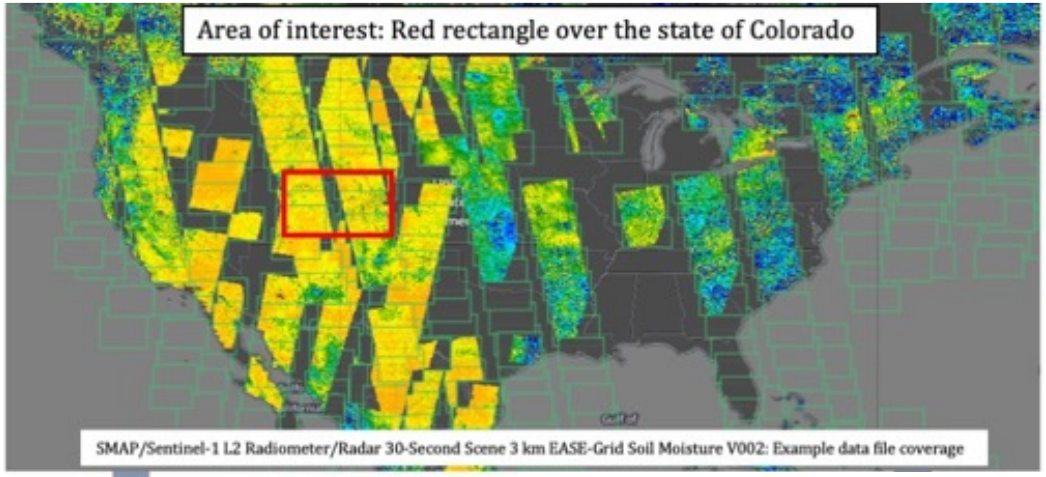
Python library for NASA Earthdata

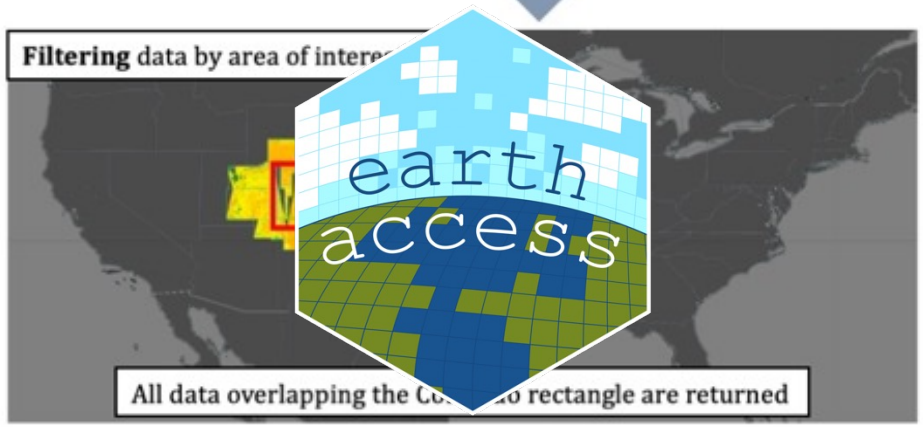
```
1 import earthaccess
2
3 earthaccess.login(strategy="netrc")
4
5 results = earthaccess.search_data(
6     count=2,
7     short_name="ATL08",
8     bounding_box=(-92.86, 16.26, -91.58, 16.97),
9 )
10
11 earthaccess.download(results, "./research/")
12
```

- 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?

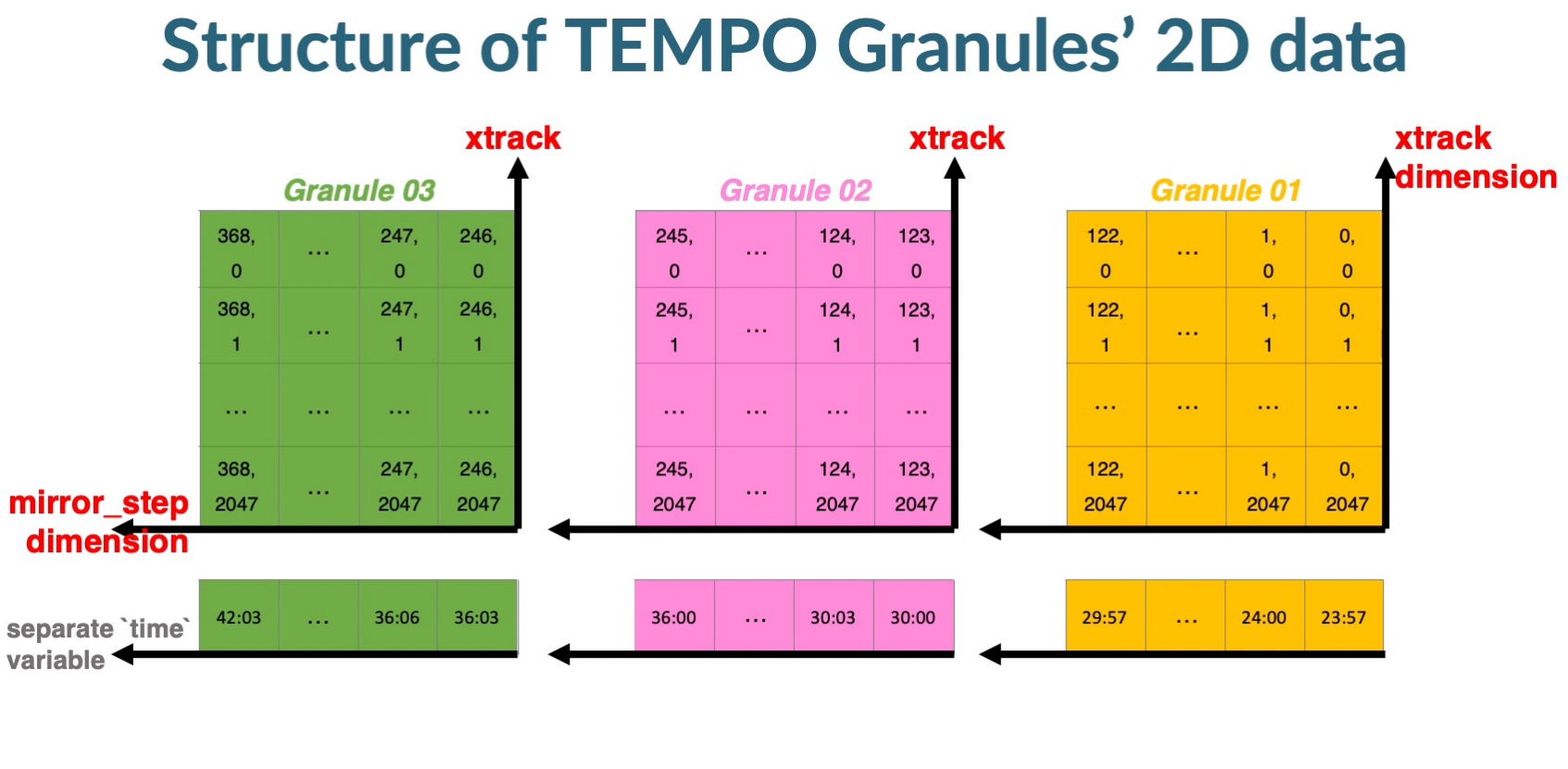




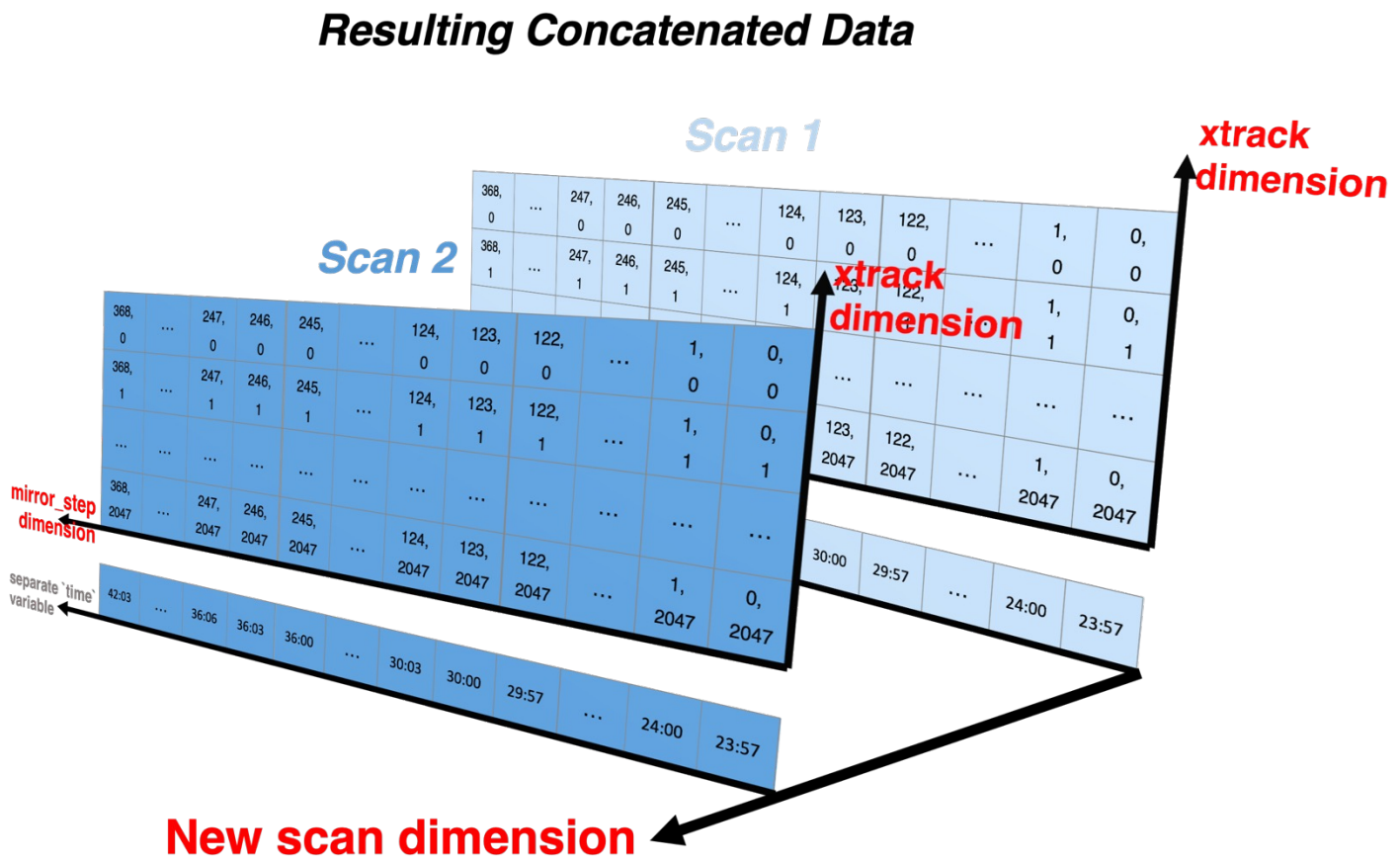
EARTHDATA Search

Earthdata Harmony API

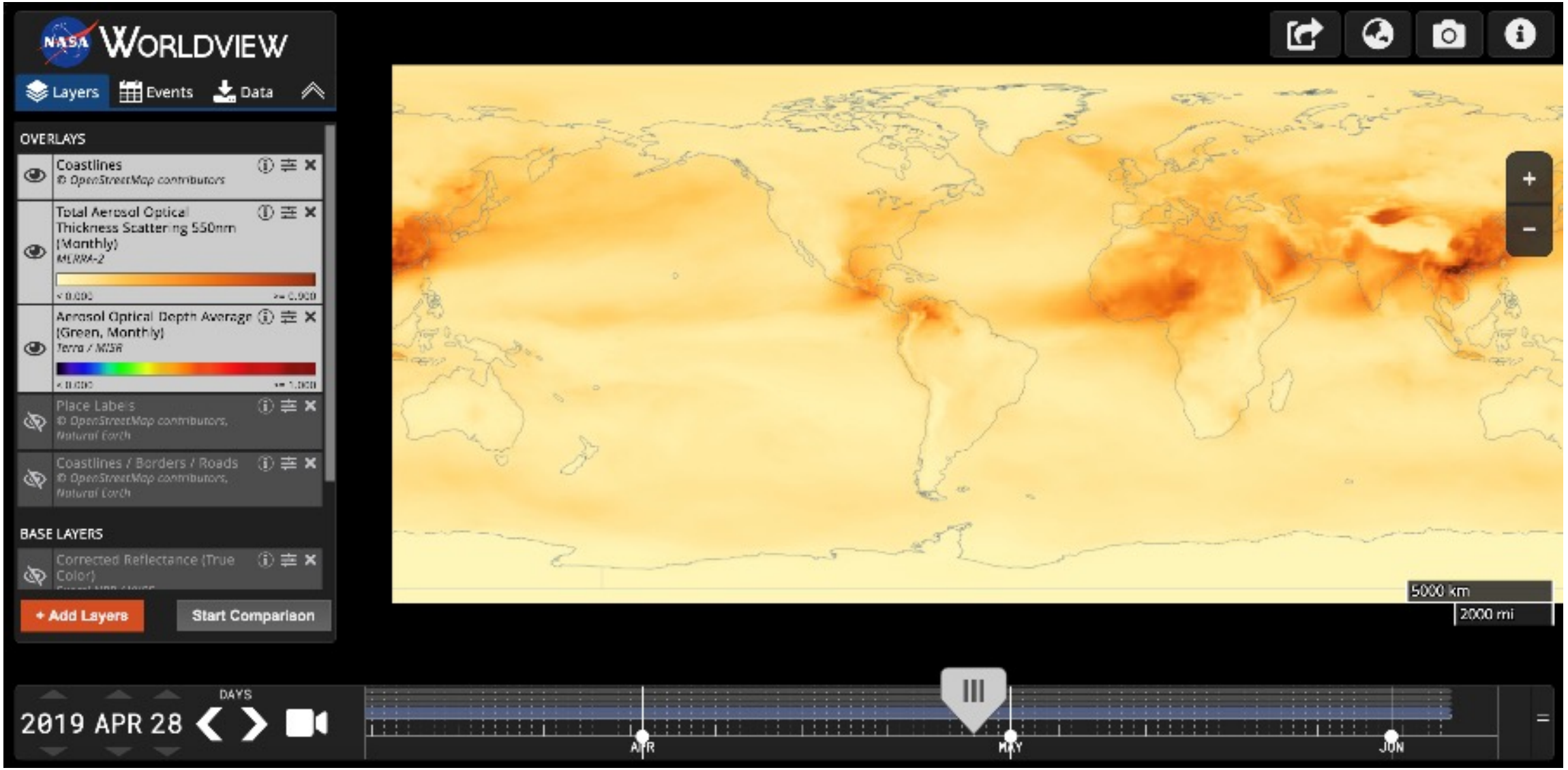
Concatenating the subsetted data



An intuitive structure for further exploration and analysis



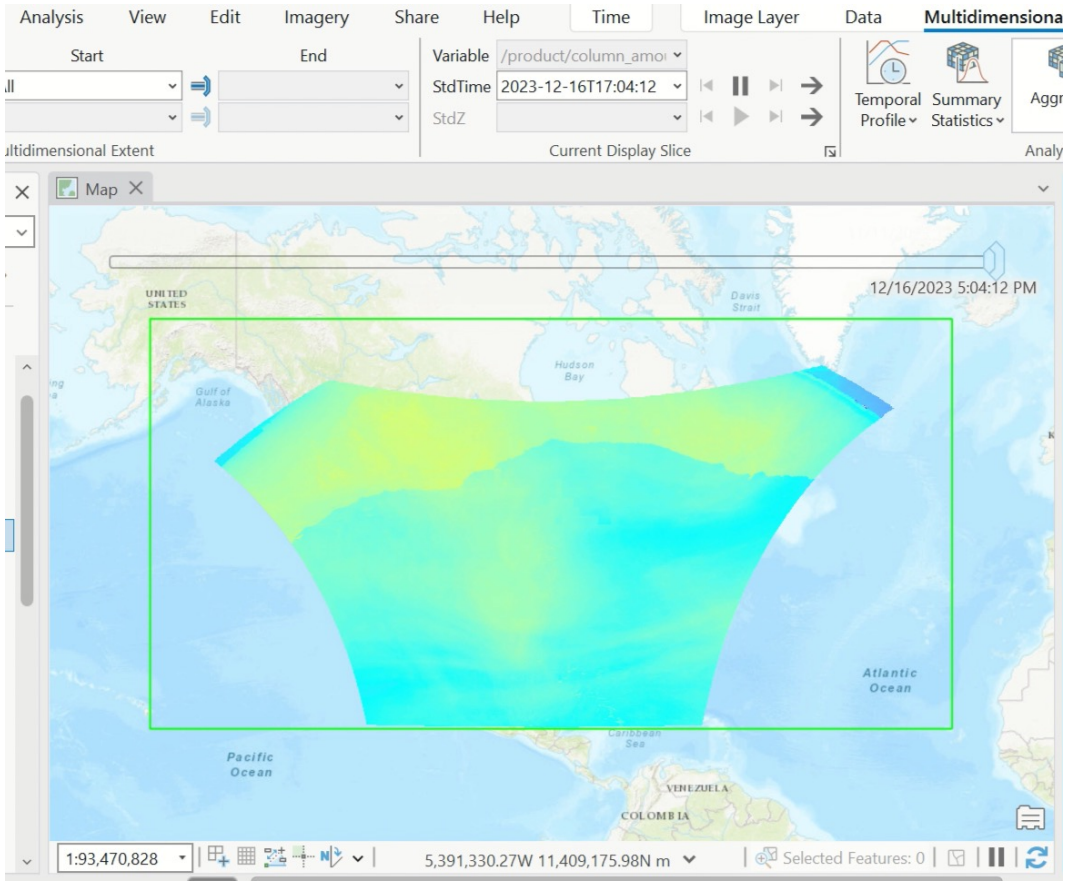
How to retrieve images/rasters?



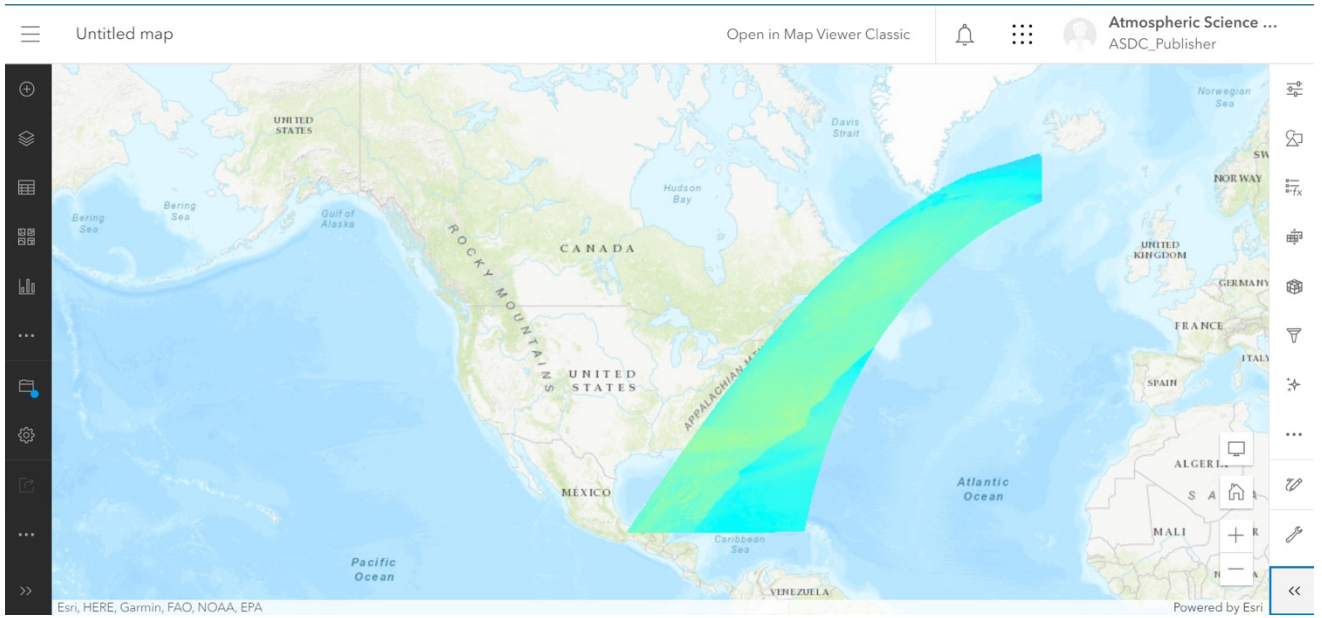
How to retrieve images/rasters?

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

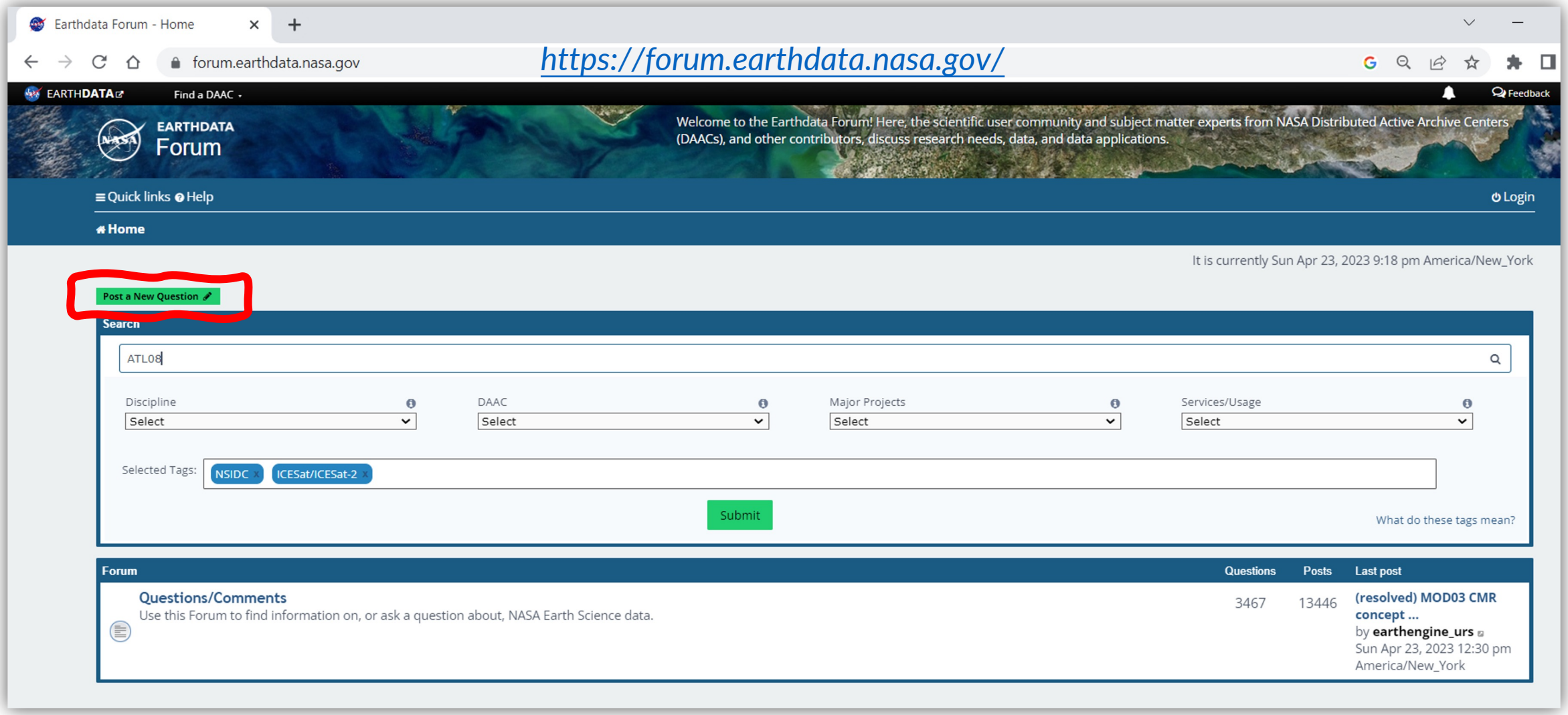


Sample image service in a web mapper called from the EGIS portal



Example for L3 Ozone Total

Where to go for more resources?



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