

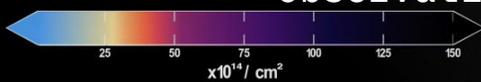


Air Quality (AQ) Monitoring from Space by NASA using TEMPO

The TEMPO instrument, a cutting-edge venture by NASA, stands at the forefront of Earth observation technology for hourly AQ Observations.

02 Aug 2023 11:11 EDT

Nitrogen Dioxide Tropospheric Column Density



In an era marked by escalating environmental concerns, understanding the Earth's atmosphere and its complex interactions is paramount. The Tropospheric Emission Monitoring of Pollution (TEMPO) instrument is a cutting-edge venture by NASA that stands at the forefront of Earth observation technology and exemplifies NASA's commitment to unraveling the intricacies of the air we breathe. TEMPO was launched with the primary objective of monitoring air quality. This story map explores the innovative technology behind the TEMPO instrument, its mission objectives, tools and services provided by the Atmospheric Science Data Center (ASDC) for data access and the potential impact of TEMPO data findings on our health and Earth's environmental future.

Introduction

In a monumental leap for scientific research and environmental understanding, TEMPO instrument embarked on a journey into space aboard SpaceX's Falcon 9 rocket. This mission, a collaborative endeavor between NASA, the Smithsonian Astrophysical Observatory, Ball Aerospace, Harvard University, and SpaceX, marks an unconventional initiative at the intersection of space technology and environmental science. The TEMPO satellite's launch signifies a collective effort to deepen our comprehension of air quality dynamics, which incorporates advanced instrumentation and insights as part of the largest civilian Earth Observation fleet.

This revolutionary venture not only underscores the synergy between renowned academic institutions and space agencies but also highlights the fusion of state-of-the-art technology and scientific expertise. The TEMPO instrument, equipped with cutting-edge sensors developed in collaboration with the Smithsonian Astrophysical Observatory and Harvard University, embodies the culmination of years of meticulous research and engineering. As it embarks on its mission, TEMPO promises to revolutionize our understanding of air pollution, offering unparalleled insights into atmospheric composition and pollutant distribution every daylight hour.

The TEMPO instrument is a grating spectrometer, sensitive to visible (VIS) and ultraviolet (UV) wavelengths of light with a spectral range of 290-740 nm and 0.6nm spectral resolution. The

TEMPO instrument is attached to the Earth-facing side of a commercial telecommunications satellite (Intelsat40e) in geostationary orbit over 99° west longitude. This allows TEMPO to maintain a continuous view of North America so that the instrument's light-collecting mirror can make a complete East to West scan of the "Field of Regard" each and every hour of the day. By measuring sunlight reflected and scattered from the Earth's surface and atmosphere back to the instrument's detectors, TEMPO's ultraviolet and visible light sensors will provide measurements of ozone, nitrogen dioxide, and other elements involved in the chemical dynamics of our atmosphere.

TEMPO data are designed for studies of North America's air quality and atmospheric composition. The data are archived and distributed by the Atmospheric Science Data Center (ASDC), Science Directorate, NASA Langley Research Center (LaRC) located in Hampton, Virginia. The Science Directorate's Climate Science Branch, Atmospheric Composition Branch, and Chemistry and Dynamics Branch work with the ASDC to study changes in the Earth and its atmosphere. Data products derived from TEMPO observations translate those findings into meaningful knowledge that will inspire action by scientists, researchers, epidemiologists, educators, decision-makers, and the public.

The ASDC supports over 100 projects and provides access to more than 3,000 archived collections with a global user community from more than 150 countries. ASDC datasets were created from

satellite measurements, field experiments, and modeled data products. ASDC projects focus on the Earth science disciplines of Radiation Budget, Clouds, Aerosols, and Tropospheric Composition.

TEMPO Launch

SpaceX launched a commercial Maxar Technologies manufactured communications satellite Intelsat 40e (IS-40e) into orbit with the TEMPO instrument aboard early Friday morning (April 7, 2023). The Falcon 9 rocket lifted off from Florida's Cape Canaveral Space Force Station at 12:30 a.m. EDT (0430 GMT). TEMPO will make observations from a geostationary vantage point, about 22,000 miles above Earth's equator.

IS-40e separated from the vehicle at 1:02 a.m. EDT and Intelsat confirmed its signal acquisition at 1:14 a.m. EDT.

Fact Sheet: [Intelsat 40e](#)



SpaceX launches Intelsat 40e satellite with NASA TEMPO instrument at 12:30 a.m. EDT (0430 GMT)

Technological Marvel: The TEMPO Instrument

The TEMPO instrument is equipped with a spectrometer capable of measuring trace gases in the Earth's atmosphere with unprecedented precision. By focusing on key pollutants such as nitrogen dioxide, sulfur dioxide, ozone, and formaldehyde, TEMPO aims to create detailed, high-resolution maps of air quality across North America. These observations are instrumental in tracking the sources and movements of pollutants, enabling policymakers to make informed decisions for environmental conservation.

The instrument beamed back its [first images](#) on August 2nd, 2023, showing the interstate I-95 corridor in the U.S. Northeast (New York, Philadelphia and Washington, DC areas), a slice of the South (central and eastern Texas stretching to New Orleans) and a section of the

Southwest (Los Angeles to Las Vegas). As expected, the maps reveal heavy nitrogen dioxide density over cities and their suburban sprawl.



Reference: <https://svs.gsfc.nasa.gov/5142>

Nitrogen Dioxide Tropospheric Column De...

Reference <https://svs.gsfc.nasa.gov/5142>



https://svs.gsfc.nasa.gov/vis/a0000000/a005100/a005142/tempo_no2_2160p60.mp4

TEMPO Mission Objectives

The primary mission objectives of TEMPO revolve around understanding the dynamics of air quality, pollution sources, and their impact on climate change. By providing near real-time data and comprehensive atmospheric composition

measurements, TEMPO assists scientists in studying pollution patterns, evaluating the efficacy of environmental policies, and predicting future trends in air quality.

The TEMPO satellite mission by NASA represents a beacon of hope in the fight against climate change. By leveraging cutting-edge technology and diverse collaboration, TEMPO provides invaluable insights into our planet's atmospheric composition in high temporal resolution. As we delve deeper into the intricacies of air quality and pollution patterns, the data gleaned from TEMPO will not only inform policy decisions but also inspire a global commitment to preserving the Earth's delicate ecological balance. In essence, TEMPO is not just a satellite mission; it is a symbol of humanity's dedication to safeguarding the future of our planet and the health of humankind.

ASDC Data Access

TEMPO data represents a valuable resource for environmental researchers, educators and policymakers as it offers free and publicly accessible information crucial for monitoring air quality over North America. Researchers and enthusiasts alike can benefit from the wealth of data provided by TEMPO, enabling them to gain insights into atmospheric pollution trends and make informed decisions. Moreover, the availability of several services tailored for TEMPO data, including user-friendly interfaces for data access, visualization tools, and subsetting capabilities, greatly enhances its

usability. The ASDC dedicated a multi disciplinary team of physical scientists, geographers, computer engineers and cloud computing architects to leverage a comprehensive suite of tools and usability services for TEMPO data. These services not only facilitate seamless access to the data but also empower users to manipulate and interpret it effectively, fostering a deeper understanding of air quality dynamics. Such accessibility and the array of services offered make TEMPO data a vital asset in the pursuit of environmental research and policy-making efforts.

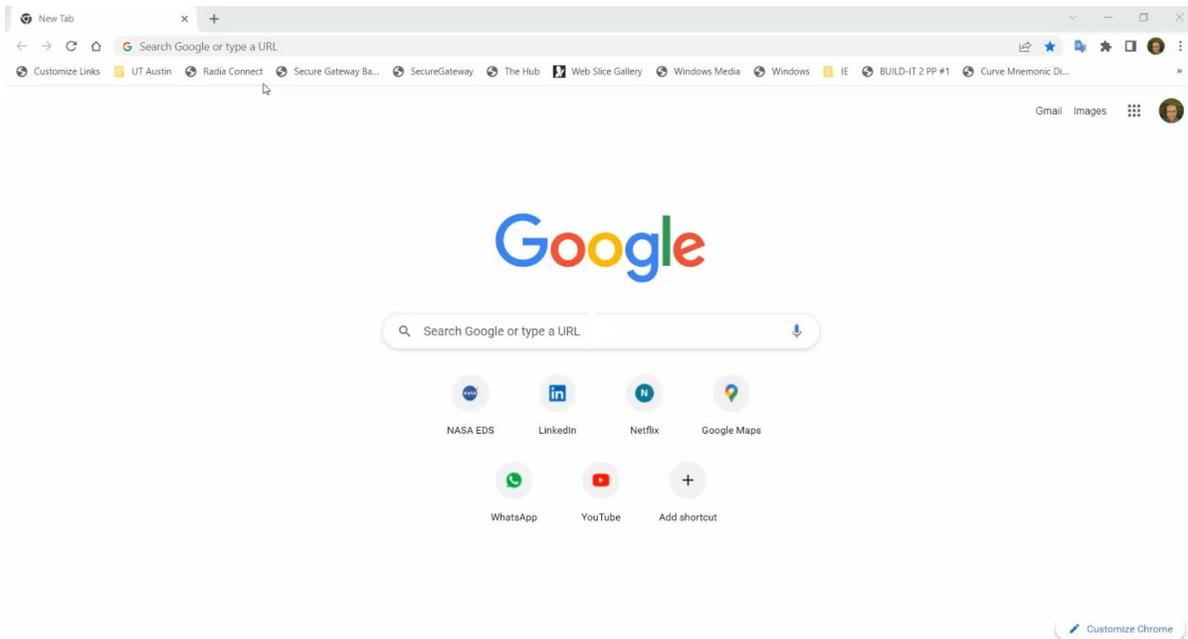
The videos below demonstrates how you can search, access, and download the TEMPO archived data at the ASDC website. Go to

<https://asdc.larc.nasa.gov/> and click on "DATA" in the upper right menu, where you can access data via Earthdata Search. Please note that all the data demonstrated in this article are simulated proxy data in the User Acceptance Testing (UAT) environment because the live TEMPO data are currently undergoing calibration and validation.

Earth Data Search for data download and thumbnails Visualization

You can access TEMPO data through NASA Earthdata Search <https://search.earthdata.nasa.gov/search>. Browse through the search results to find datasets related to the TEMPO mission. NASA Earthdata Search provides detailed information about each dataset, including its description, temporal coverage, and data format. TEMPO data

will be available for download from Earthdata Search in addition to thumbnail visualization, subsetting, and concatenation .

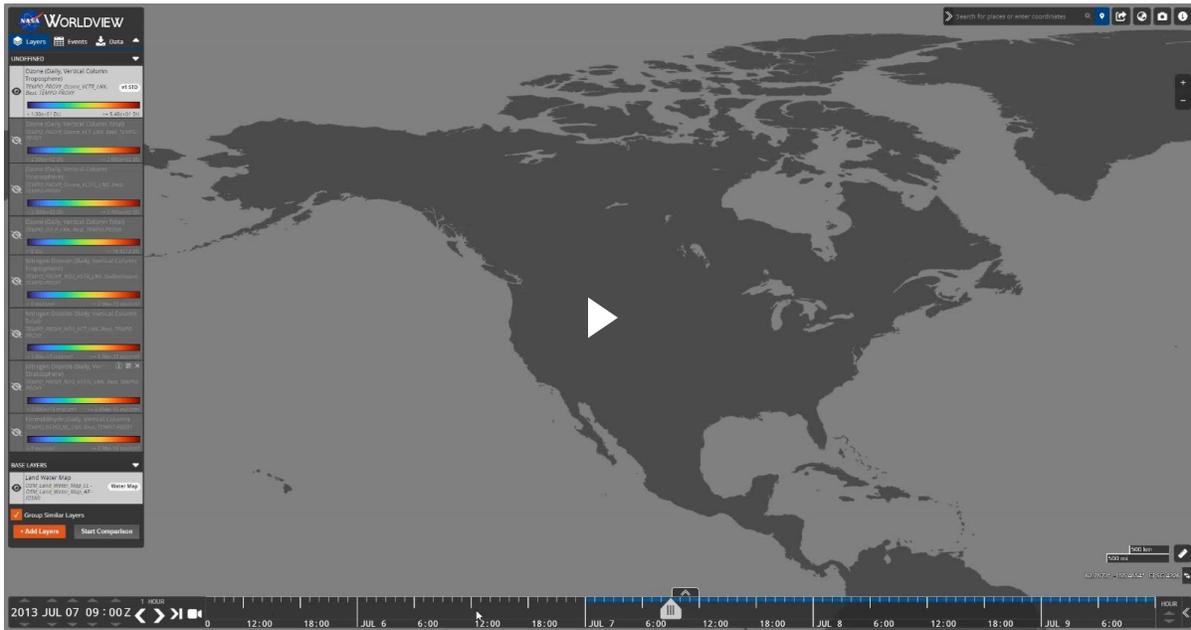


Nitrogen Dioxide Thumbnails Proxy Data from TEMPO Using NASA Earthdata Search

NASA Worldview in the Amazon Web Service (AWS) Cloud User Acceptance Testing (UAT) Environment

[GITC UAT \(nasa.gov\)](https://www.nasa.gov)

Another way to explore TEMPO data is to use the Worldview interface to select a date range, location, and specific data layers you are interested in. NASA Worldview allows you to visualize and download various Earth science data layers, including those related to air quality, climate, and environmental factors. Once you have selected the desired data layers and timeframe, you can download the data for your research and analysis.

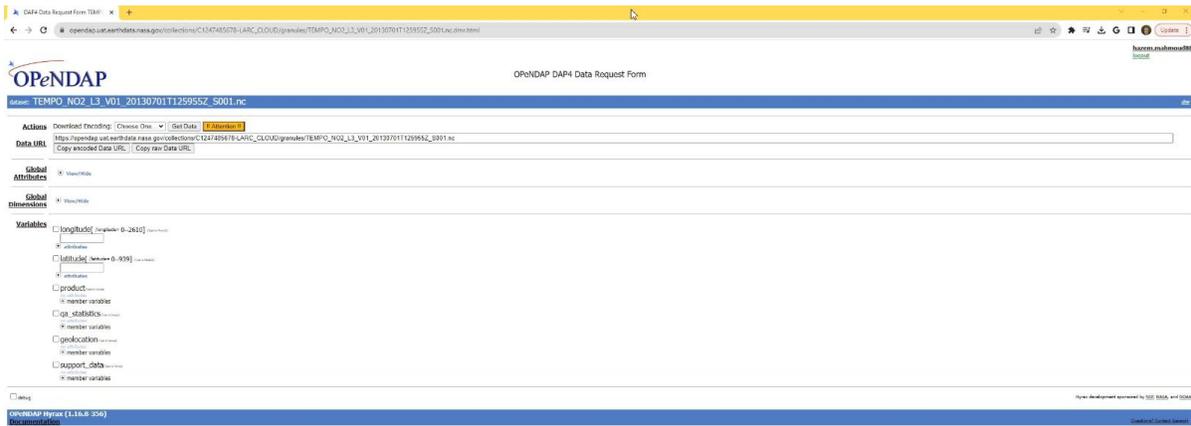


Total Ozone Proxy Data from TEMPO using NASA Worldview

Open-source Project for a Network Data Access Protocol (OPeNDAP) in the Amazon Web Service (AWS) Cloud

https://opendap.uat.earthdata.nasa.gov/collections/C1247485678-LARC_CLOUD/granules/TEMPO_N02_L3_V01_20130701T125955Z_S001.nc.dmr.html

OPeNDAP is a protocol and software toolset designed to simplify and standardize the process of accessing scientific data remotely over the internet. To access TEMPO data via OPeNDAP, you'll need to know the specific URL or server endpoint where the TEMPO datasets are hosted. OPeNDAP URLs typically end with ".dap" or ".dds".

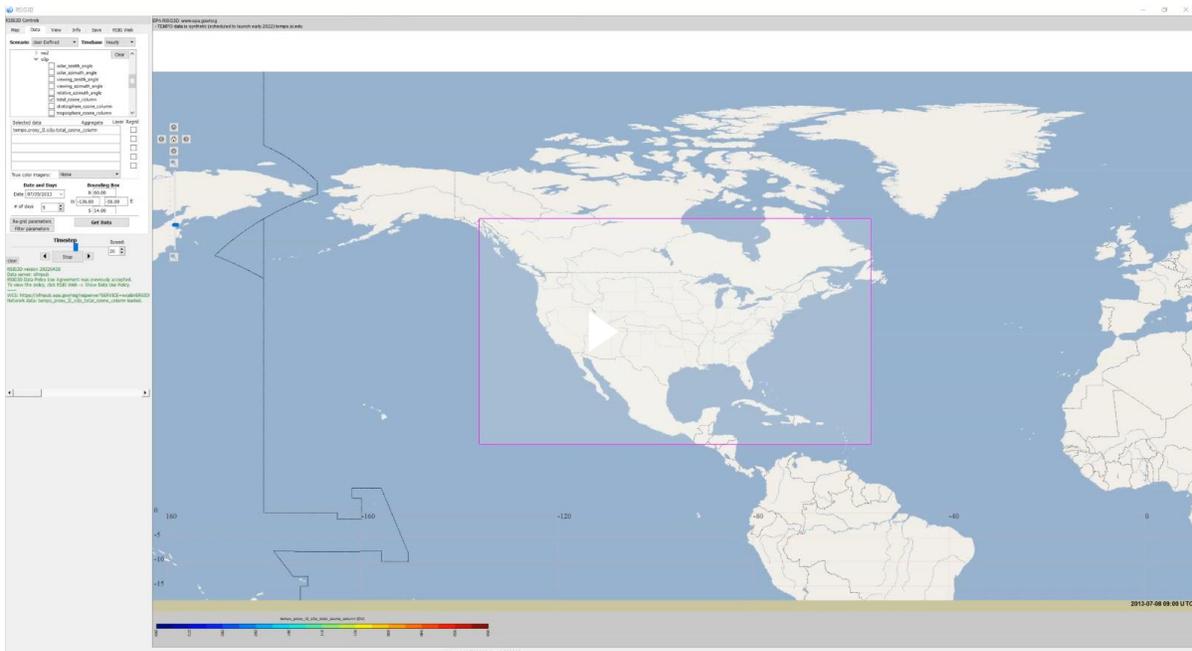


Nitrogen Dioxide Proxy Data from TEMPO using OPeNDAP

The Remote Sensing Information Gateway (RSIG)

<https://www.epa.gov/hesc/remotesensing-information-gateway>

TEMPO data will also be available on the U.S. Environmental Protection Agency's (EPA) Remote Sensing Information Gateway (RSIG). This platform allows for quick and easy access to subsets of multi-terabyte environmental datasets, including other satellites, modeled, and *in-situ* sensor data. The old process of downloading and parsing data (taking days, weeks, or months) is reduced to minutes with RSIG. It is developed by the U.S. Environmental Protection Agency (EPA). Hosting TEMPO data via RSIG will help scientists and researcher integrate air quality data from space-based platforms and ground stations, and numerical models.

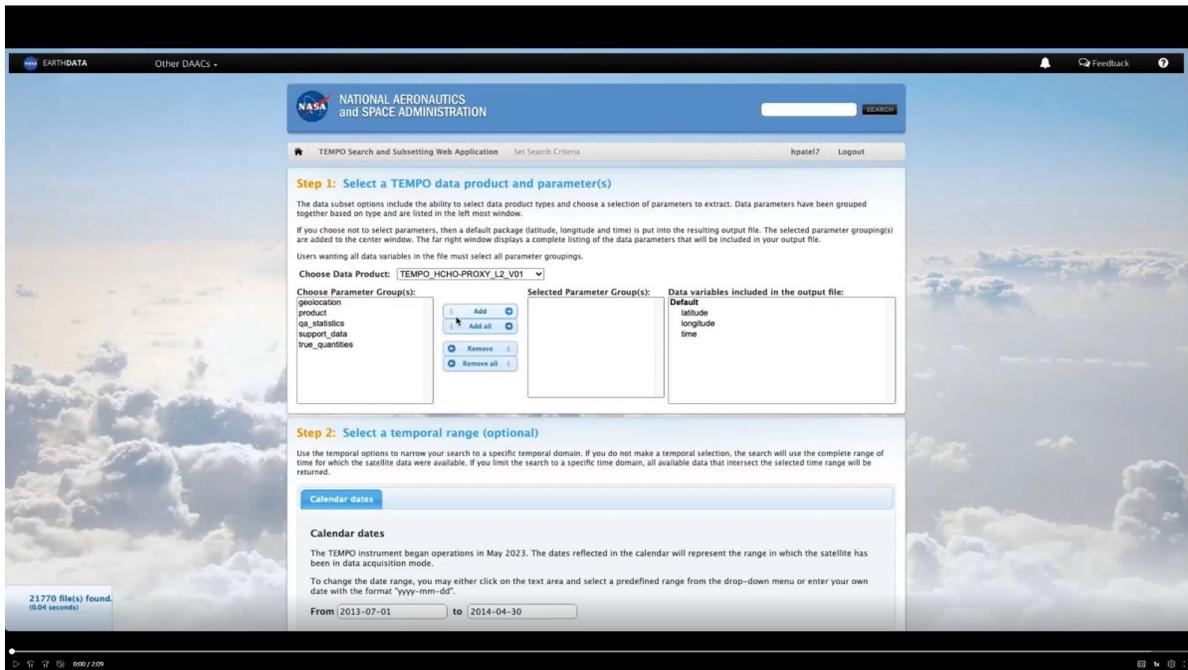


Total Ozone Proxy Data from TEMPO Using RSIG

ASDC Subsetter Graphic User Interface (GUI) for TEMPO

<https://subset.larc.nasa.gov/tempo/>

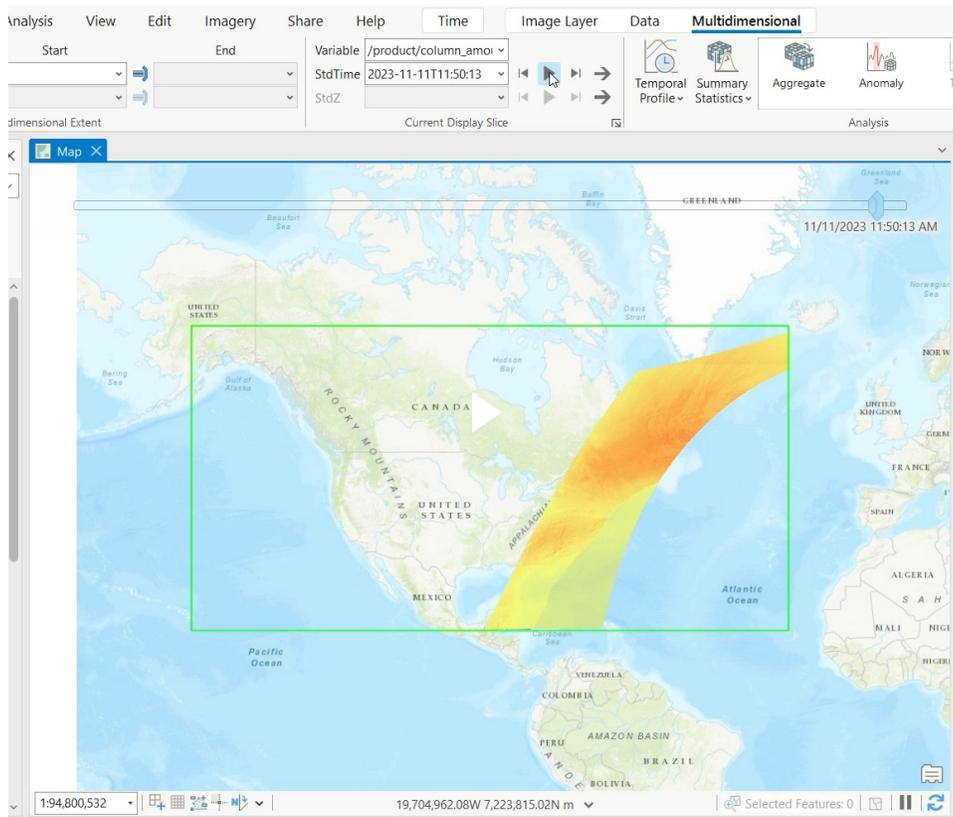
The ASDC Subsetter Graphic User Interface (GUI) for TEMPO is a software tool designed to facilitate the process of subsetting data specifically tailored for the Tropospheric Emissions: Monitoring of Pollution (TEMPO) project. This user-friendly interface allows users to interact with and customize data subsets, providing a streamlined and efficient means to extract the specific information they need from the larger dataset associated with TEMPO. The GUI enhances user experience by offering a visual and intuitive platform for manipulating and refining data according to individual requirements.



Formaldehyde HCHO Proxy Data from TEMPO Using ASDC GUI Subsetter

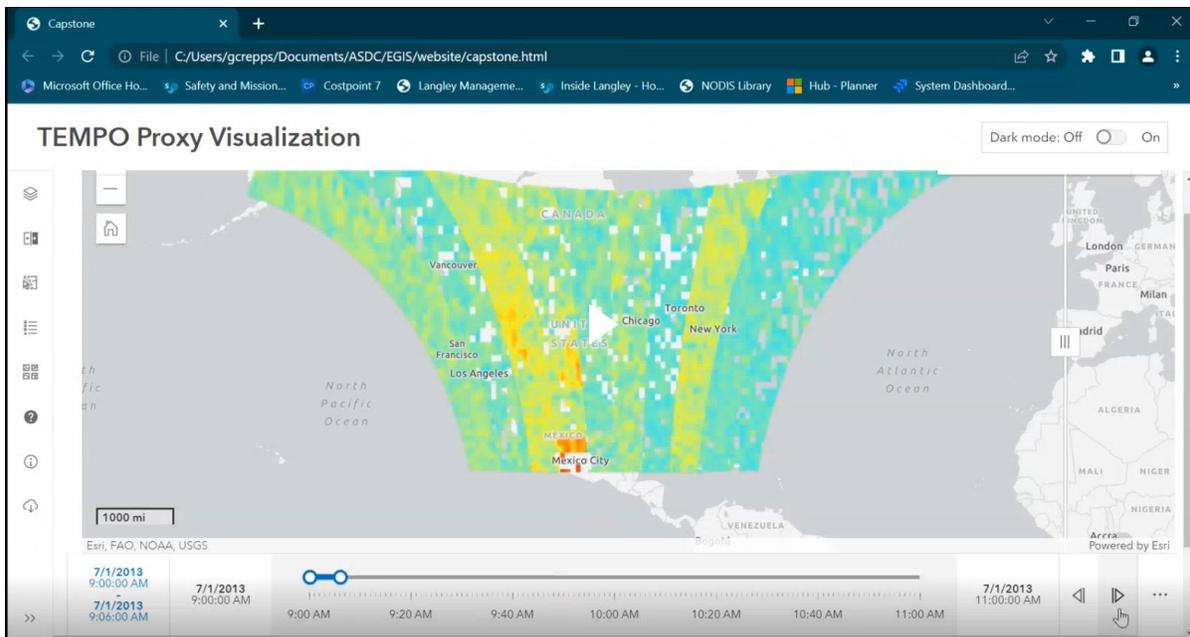
Earthdata GIS (EGIS) for TEMPO

TEMPO data will be hosted on NASA's Earthdata Geographic Information System (EGIS). EGIS is a resource for distributing cloud-native, GIS-ready NASA Earth observation data, services, and resources. This includes ArcGIS and Open Geospatial Consortium (OGC)-compliant raster and feature geospatial services and raster analytic functions.



Level 3 Total Ozone TEMPO Data Hosted On ASDC EGIS Cloud
Using ArcGIS Pro

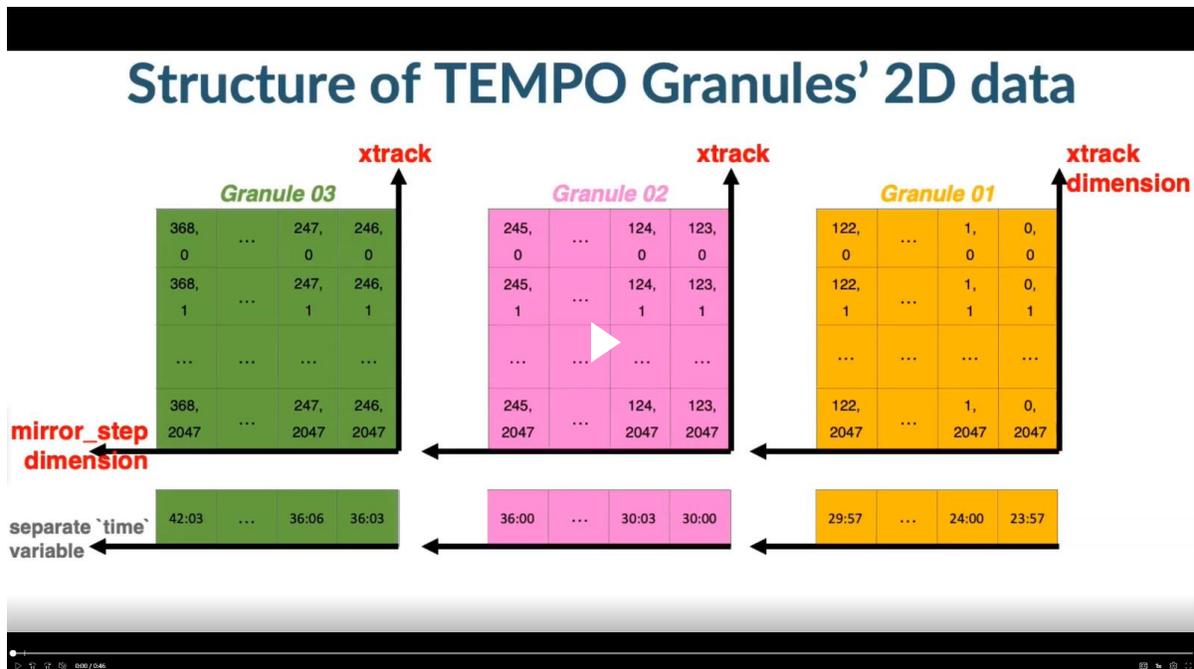
Another example of TEMPO data on EGIS local instance:



TEMPO Proxy Data Using ASDC EGIS

Earthdata Concatenation for TEMPO

This tool (called “stitchee” behind the scenes of Earthdata Search) concatenates multiple hierarchical data – e.g., Network Common Data Form (netCDF) and Hierarchical Data Format (HDF) – files into a single file by stitching together the data arrays along a specified dimension. To perform the concatenation operation, the hierarchical structure of the data variables is flattened prior to concatenation and then any group hierarchy is reconstructed post-concatenation. Configuration options allow the saving of temporary directories to facilitate testing in a local computing environment. The core functionality is configured such that it is containerized and operates in configuration with NASA Harmony orchestrator service.

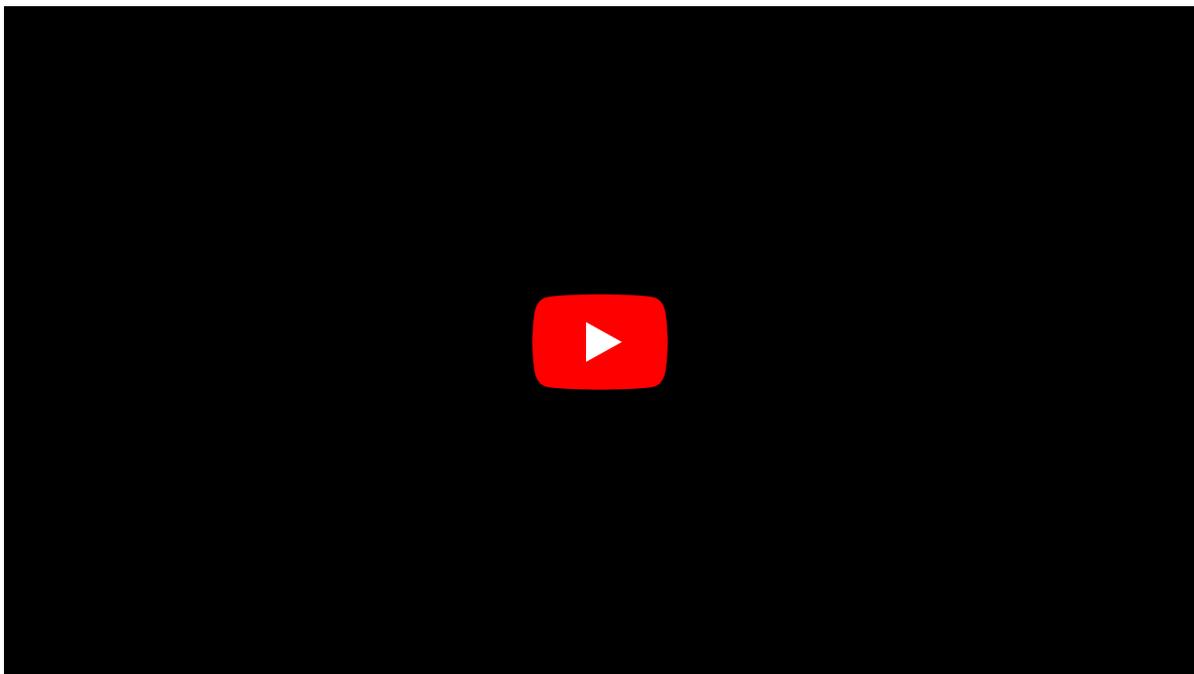


TEMPO Data Concatenation using Harmony

Earthdata Forum

The main objectives of the Forum are to improve

user services and to support knowledge sharing and management throughout the NASA Earth science community. The Forum assumes both a proactive and reactive approach to NASA products' scientific queries. The Forum proactively posts announcements and news regarding products, new data releases, and more. In addition, the Forum allows the scientific community to ask questions about NASA's products, tools, and services. All users of the Forum can navigate the site and view posts and announcements; however, to post a question to the Forum, a user must be registered with an Earthdata Login account.



NASA's Earthdata Forum provides a central, online location where data users can interact with discipline-specific subject matter experts from the Earth Observing System Data and Information System (EOSDIS) Distributed Active Archive Centers (DAACs); discuss data applications and research needs, and get answers to specific questions about accessing, viewing, and manipulating NASA Earth observation data.

Acknowledgements:

- NASA (The National Aeronautics and Space

Administration)

- LaRC (Langley Research Center)
- GSFC (Goddard Space Flight Center)
- ASDC (Atmospheric Science Data Center)
- ADNET (ADNET Systems Inc.)
- AMA (Analytical Mechanics Associates)

