National Aeronautics and Space Administration

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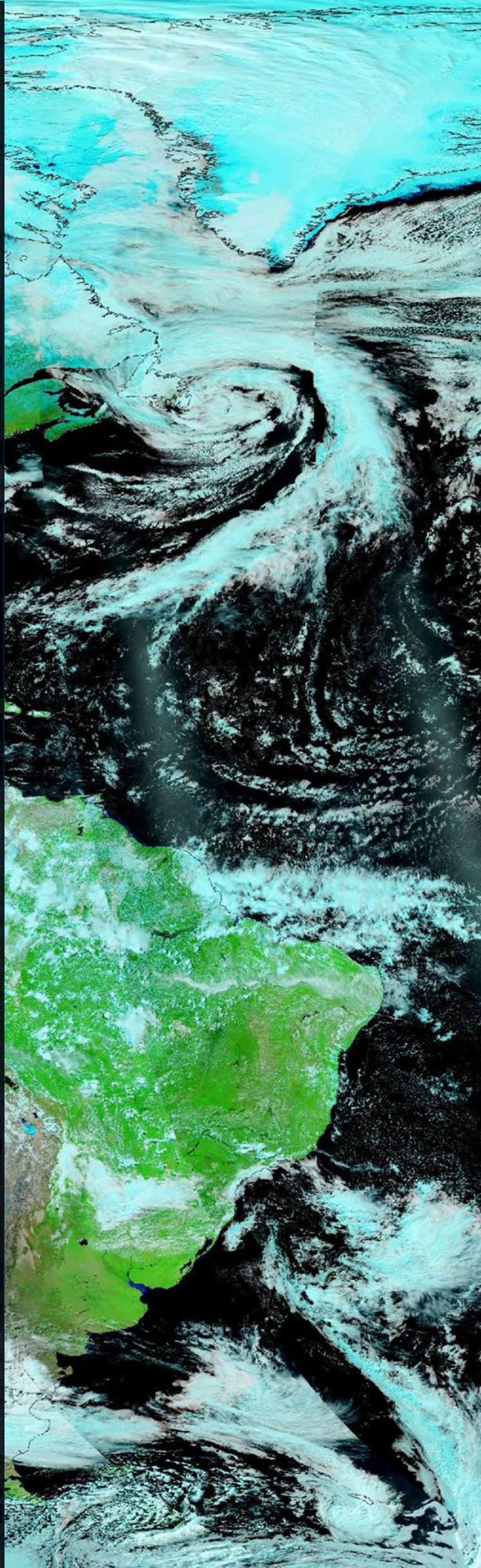
TEMPO Auxiliary Data, Version 1.0

User Guide

July 20, 2026



How to Cite These Data

As a condition of using these data, it is recommended that you include a citation using the following format:

Author. Date. Data set title, Version #. [Indicate subset used]. Hampton, Virginia USA. NASA Atmospheric Science Data Center Distributed Active Archive Center. https://doi.org/10.5067/doc/tempo/Auxiliary_Data_UserGuide/V1.0*. [Date Accessed].*

For Questions About These Data

Contact support-asdc@earthdata.nasa.gov

For Current Information, Visit https://www.earthdata.nasa.gov/data/catalog/larc-cloud-tempo-auxiliary-v01

TEMPO Auxiliary Data User Guide

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User Guide Revision Record

Table 1. User Guide Revision Record

Document Version Number	Date of Change	Summary of Document Updates
1.0	*July 20, 2026*	*Initial Release*

1.0 Data Description

Summary

The Tropospheric Emissions: Monitoring of Pollution (TEMPO) Auxiliary data collection contains the static reference data used by the TEMPO science data processing software. The collection includes reference solar spectra, reference molecular absorption spectra, terrestrial surface reflectance, land cover data, digital elevation maps, atmospheric chemical transport model trace gas climatologies, look-up tables calculated from radiative transfer models, instrument calibration parameters and other reference data required for the processing of the standard and near-real time TEMPO data products.

1.1 Collection Overview

TEMPO (Zoogman et al., 2017) is a geostationary satellite mission designed to measure air quality over North America during daylight hours at high spatial resolution (2×4.75 km^2 at the center of field of regard) and with a temporal resolution of one hour or less. Launched on 7 April 2023, TEMPO obtained first light on 2 August 2023 and began nominal operations after passing its post-launch acceptance review in October 2023.

The TEMPO data products are generated by the Science Data Processing Center (SDPC) at the Smithsonian Astrophysical Observatory (SAO). All products, once generated at SAO, are pushed to NASA's Earth Observing System Data and Information System (EOSDIS) Cumulus cloud for public distribution by the NASA Atmospheric Science Data Center (ASDC). These include Level 1B (L1B) files (calibrated solar irradiance and geolocated radiance spectra), Level 2 (L2) files (cloud and trace gas products at the native ground pixel footprint for the East-West granules which make up part of a TEMPO scan) and Level 3 (L3) files (cloud and trace gas products on a regular grid created from all Level 2 granules constituting an entire East-West scan).

The TEMPO Auxiliary data collection contains the static reference data used by the TEMPO science data processing software. The reference data are organized into directories associated with individual data products, or specific topics such as atmospheric climatologies or instrument calibration parameters. For distribution, the collection has been organized into a set of 65 zip files, plus 290 netCDF4 data files. Note that although all the reference data used in the SDPC can be found in the collection, the collection also contains files that are not used in SDPC, such as heritage files from algorithm development.

1.2 Collection Identification

The collection name is “TEMPO science data processing reference data V01.” The collection short name is TEMPO_Auxiliary_V01. The “V01” here refers to the release version number which will change with each release of the auxiliary data files. This is not necessarily the same as the version assigned to a corresponding TEMPO Level 1, 2 and 3 data collection. For instance, TEMPO_Auxiliary_V01 is the auxiliary file collection used to produce V04 standard and V02 near-real time products.

1.3 Collection Introduction

The TEMPO science data processing reference data is a collection of time-independent reference data that are used in the TEMPO Science Data Processing Center (SDPC) pipeline to create the TEMPO standard and near-real time data products. The collection contains reference solar spectra, reference molecular absorption spectra, terrestrial surface reflectance tables, land cover data, digital elevation maps, tables for top-of-atmosphere normalized radiance, tables of scattering weights, tables of hourly mean atmospheric structure and composition for each month of the year, as well as TEMPO instrument calibration parameters. The resolution and coverage vary with the type of data, as shown in the Data Description section.

1.4 Objective/Purpose

These reference data are needed to run the open source code used in the TEMPO SDPC pipeline. The open source code is located in the Smithsonian Institution's GitHub: https://github.com/Smithsonian/tempo_sdpc. The auxiliary data V01 collection is current as of SDPC code release v4.8.4 (May 2026).

Note that the GitHub repository also contains codes that are not currently used by the SDPC. Users are strongly encouraged to contact the TEMPO team for guidance before attempting to use either the TEMPO pipeline code or the auxiliary data.

1.5 File Format and Parameters

These files are provided in netCDF4/HDF5, geotiff or ASCII formats. Most of the files have been compressed into zip files based on subdirectories used in the reference data directory tree of the SDPC pipeline software.

Some directories contain heritage files that were used in development but may not be part of the current processing pipeline. These files are not described in this user guide. For proper use of the data, users are encouraged to contact a TEMPO team member listed in Section 5.0.

1.6 File Contents

The contents of the self-describable netCDF and HDF5 files can be viewed using standard software, such as Panoply, ncdump, etc. Molecular absorption reference cross sections are in ASCII format and typically include a header at the beginning of each file describing the content. Many other types of reference data are also included in the collection.

1.7 Directory Structure

The default TEMPO software configuration assumes that this data collection is installed in a directory named 'refdata'. While the zip files unpack into a 'refdata' directory tree by default, the netcdf4 files should be manually stored in a specific 'refdata' subdirectory.

The reference data have the following sub-categories:

refdata/*

- refdata/climatology
- refdata/cloud (Not used)
- refdata/cloud_o4
- refdata/elevation
- refdata/gler
- refdata/instrument
- refdata/land_cover
- refdata/o3_profile
- refdata/o3_total
- refdata/polarization
- refdata/trace_gas
- refdata/zoneinfo

To install the collection, first choose a directory, $ROOT, that will host the 'refdata' directory, then move to that directory and unpack the 65 zip files. Note that each zip file unpacks into a subdirectory of the 'refdata' directory:

```
$ cd $ROOT

$ unzip refdata_20260414_cloud_o4.zip

$ unzip refdata_20260414_elevation.zip

$ unzip refdata_20260414_gler_340nm_land_v5.zip

$ unzip refdata_20260414_gler_340nm_ocean_v2.zip
```

```
$ unzip refdata_20260414_gler_340nm_snow_v4.zip
...
$ unzip refdata_20260414_trace_gas.zip
$ unzip refdata_20260414_zoneinfo.zip
```

The 290 netcdf4 files should be organized as follows: First, create these directories:

```
$ mkdir -p $ROOT/refdata/climatology/monthly_by_hour
```

The 288 monthly climatology files have filenames names of the form:

```
GEOS-CF_NRT.monthMM_HHz_reorder.nc4
```

where MM is the month 01, 02, ...,12, and HH is the hour, 00, 01,...,23. These files should be stored in this subdirectory:

```
$ROOT/refdata/climatology/monthly_by_hour
```

The netcdf4 files omcldrr_pressure.nc, and GEOS-Chem_72_layer_vertical_grid.nc should be stored in the subdirectory $ROOT/refdata/climatology.

1.8 Naming Convention

The zip files containing the auxiliary data have naming convention:

refdata_<YYYYMMDD>_<refdata_subdirectory>.zip

where <YYYYMMDD> is the date of the file's creation and <refdata_subdirectory> is the subdirectory listed in Section 1.7. The exceptions are the files used to zip the GLER surface reflectance climatologies. These have file format:

refdata_<YYYYMMDD>_gler_<wavelength>nm_<surface_type>_v<version_number>.zip

For example, "refdata_20260414_gler_340nm_land_v5.zip" is the zip file created on April 14, 2026 which contains version 5 (v5) of the GLER surface reflectance climatologies at 340 nm over land. The surface type can be "land" (snow-free land), "snow" or "ocean".

The naming conventions of individual file types contained within the zip files are described in a later section.

2.0 Data Acquisition and Processing

2.1 Background

Reference data are acquired from a variety of external sources, or in some cases generated internally by the TEMPO team. For example, atmospheric monthly climatological data are generated by NASA's Global Modeling and Assimilation Office (GMAO) using the Goddard Earth Observing System Composition Forecast (GEOS-CF), with file dimensions modified by the TEMPO SDPC for ingest into the TEMPO pipeline. Radiative transfer look-up tables for trace gas retrievals were created by the TEMPO team using the VLIDORT radiative transfer model (Spurr et al., 2006). Surface reflectance tables were derived from look-up tables by collaborators at NASA GSFC (Fasnacht et al., 2019; Qin et al., 2019) used in combination with MODIS climatologies constructed by the TEMPO team (over land) (Hou et al., 2026), or look-up tables of surface reflectance using Cox-Munk approximation (over water). Radiative transfer look-up tables for CLDO4 were provided by Eun-Su Yang at NASA GSFC. Molecular absorption cross sections are from a variety of laboratory sources which have been published in the literature. Many other file types exist, and users should consult the TEMPO algorithm theoretical basis documents (ATBDs) for radiances and irradiances (Chong et al., 2026), clouds (Wang et al., 2025) and trace gases (González Abad et al., 2025; Nowlan et al., 2025; Park et al., 2026a; Park et al. 2026b) for details on their sources.

2.2 Processing

The reference data are used in processing the Level 1 radiances and irradiances and Level 2 and 3 cloud and trace gas products. For details on how the reference data are used in the operational pipeline, please refer to the TEMPO ATBDs and algorithm description documents

(Chong et al., 2026; González Abad et al., 2025; Nowlan et al., 2025; Park et al., 2026a; Park et al., 2026b; Wang et al., 2025).

3.0 Data Description

The auxiliary reference data consists of a variety of file types. The following tables describe the main files used in the pipeline and their spatial and temporal coverage and resolution, if applicable.

Table 2. File description for GLER files. These files are provided as individual .zip files due to their size. However, in the pipeline they are stored in directories with syntax: refdata/gler/<wavelength>nm.

File Name	***Description***	***Spatial Coverage and Resolution***	***Temporal Coverage and Resolution***
<wavelength>/modis_<surface_type>_v<version_number>_d<doy>.nc	MODIS-derived surface GLER climatology	[15° W, 167° W] [14° N, 73° N] 0.05° x 0.05° (land/snow) 1° x 1° (ocean)	Multi-year 15-day climatology, every 30 minutes
`<wavelength>` = Wavelength in nm (e.g., `340`). `<surface_type>` = Surface type (e.g., `land, snow, ocean`). `<version_number>` = Version of GLER dataset (e.g., `5`). `<doy>` = Day of year (e.g., `045`).			

Table 3. File description for refdata/climatology

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
GEOS-Chem_72_layer_vertical_grid.nc	Defines the 72-level hybrid sigma-pressure vertical coordinates used in GEOS-CF	N/A	N/A
GEOS-CF_NRT.month <mm>_<hh>z_reorder.nc4	GEOS-CF atmospheric model climatology for month <mm> and UTC hour <hh>	Global 0.25° x 0.25°	Multi-year monthly climatology, every hour
omcldrr_pressure.nc	Cloud pressure climatology from historical OMI observations	Global 1° x 1°	Multi-year monthly climatology
<mm> = Month number (e.g., September=09). <hh> = UTC hour of day (e.g., 23).			

Table 4. File description for refdata/cloud_o4

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
LUT_4400_RAD.h5	440nm TOA RAD/IRR for cloud radiance fraction	N/A	N/A
LUT_4660_RAD.h5	466nm TOA RAD/IRR for effective cloud fraction	N/A	N/A
LUT_4770_CLEAR.h5	477nm clear sky RAD/IRR and scattering weight	N/A	N/A

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
LUT_4770_CLOUD_MLER.h5	477nm scattering weight for overcast cloud	N/A	N/A
LUT_4770_CLOUD_LER_6D.h5	477nm scattering weight for scene albedo and scene pressure	N/A	N/A
LUT Nodes: SZA (degree): 0, 5, 10, 15, 20, 25, 30, 34, 42, 46, 50, 54, 57, 60, 63, 66, 69, 72, 75, 78, 80, 82, 84, 85, 86, 87, 88, 88.5, 89 VZA (degree): 0, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 44, 48, 52, 56, 60, 64, 58, 72, 75, 78, 81, 84, 87, 89 RAA (degree): 0 to 180 every 5 degrees Albedo: 0.00, 0.01, 0.02, 0.04, 0.06, 0.08, 0.10, 0.12, 0.14, 0.16, 0.18, 0.20., 0.30, 0.40., 0.50, 0.60, 0.70, 0.80, 0.90, 1.00 Pressure (hPa): 1100, 1050, 1013, 899, 795, 701, 617, 541, 472, 411, 357, 308, 265, 227, 194, 166, 142, 121, 104, 89,76, 65, 55			

Table 5. File description for refdata/elevation

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
mea/[Lat][Lon]_20101117_gmted_mea300.tif	GMTED2010 digital elevation tiles containing the spatial mean (mea) terrain elevation data	Regional tiles spanning [0° W, 180° W] and [10° N, 70° N] 30 arc-seconds (~1 km)	N/A N/A
std/[Lat][Lon]_20101117_gmted_std300.tif	GMTED2010 digital elevation tiles containing the standard deviation (std) of the terrain elevation data	Regional tiles spanning [0° W, 180° W] and [10° N, 70° N]	N/A N/A

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
		30 arc-seconds (~1 km)	
mea/30n090w_20101117_gmted_mea300_v2.tif	Elevation tile corrected for unphysical elevation values over Great Lakes	Regional tile spanning [120° W, 90° W] and [30° N, 50° N] 30 arc-seconds (~1 km)	N/A N/A
The [Lat][Lon] prefix defines the latitude and longitude at the southwestern corner of each 20° x 30° geographic tile grid cell.			

Table 6. File description for refdata/instrument

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
TEMPO_Dmat_Ainv4intrachannel_SLCorrection.h5	Stray-light correction matrices	N/A	N/A
TEMPO_Slit_Function_<note>_V<version>.nc	Prelaunch slit function	N/A	N/A
TEMPO_senscal_batc_deliverable_<date>_v<version>.nc	Calibration key data derived using BATC's analyses (now BAE Systems, Inc.)	N/A	N/A
TEMPO_senscal_larc_update_V2_<date>_v<version>.nc	Calibration key data derived by combining	N/A	N/A

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
	BATC's and NASA LaRC's analyses		
ccdtiming<date>.nc	Example combinations of co-adds and integration time	N/A	N/A
tempo_tpinfo_r<revision>.csv	Descriptions of telemetry points	N/A	N/A
tempo_trend_example.nc	Correction parameters for instrument degradation	N/A	N/A
wavcal_refspec_TEMPO_ILS<modifier>.nc	Reference spectra used for UV spectral calibration, including absorption cross-sections of trace gases and solar irradiance	N/A	N/A
wavcal_refspec_TEMPO_ILS_Band2<modifier>.nc	Reference spectra used for visible spectral calibration, including absorption cross-sections of trace gases and solar irradiance	N/A	N/A
wavecal_adjust_<date>.nc	Table required in case of further adjustment is needed for the fitted wavelength shifts	N/A	N/A

<note> = Note for the slit function data (e.g., 0.6nmGaussian).
<version> = Data version.
<date> = Creation date.
<revision> = Revision status.
<modifier> = File state (e.g., _reformat_V2).
**Some data files are obsolete and should not be used. For the ones currently used in the SDPC, please refer to Appendix B.*

Table 7. File description for refdata/land_cover

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
modis/modis_v<X>_mosaic.Land_Cover_Type_1.tif	MODIS-derived static land cover mosaic containing 17 primary surface classification types	[50° W, 180° W] [10° N, 70° N]* 30 arc-seconds (~1 km)	Multi-year climatology N/A
modis/modis_v<X>_mosaic.Land_Cover_Type_QC.Num_QC_Words_01.tif	Quality Control (QC) mask and confidence metric indicators, used for land/water flag	[50° W, 180° W] [10° N, 70° N]* 30 arc-seconds (~1 km)	Multi-year climatology N/A
Mosaics are constructed from original MODIS tiles which have file names such as MCD12Q1.A2013001.h07v0<X>.051.2014308185055.Land_Cover_Type_1.tif, where <X> denotes a latitude band (for example "v05"). *Combining all rasters, each one identified by latitude band <X>.			

Table 8. File description for refdata/o3_profile

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
/data/refdb/OMSAO_NKPNO_SolarSpec_ReCal.dat	Recalibrated high-resolution solar irradiance based on Chance and Spurr, Kurucz, and ATLAS-3 spectra	N/A; spectral input, 240.01−800.00 nm at 0.01 nm sampling	N/A; static reference spectrum
/data/refdb/OMSAO_<gas>_<temp>_<source>.dat	Laboratory absorption cross-section reference spectra for specific trace gases and temperatures	N/A; spectral absorption cross-section input	N/A; static reference spectrum

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
/data/refdb/ozcrs_sol_for_alb.dat	Cross-section table used for initial cloud fraction/albedo calculation at 347 nm	N/A; spectral absorption cross-section input centered at 347 nm with 1.132 nm triangular FWHM	N/A; static reference spectrum
/data/refdb/o3abs_bw_uvvis_vacfinal.dat	Ozone absorption cross-section database	N/A; spectral absorption cross-section input	N/A; static reference spectrum
/data/ATMOS/NO2/<mon>_strat_NO2.dat	Monthly stratospheric NO2 climatological profile for stratospheric	Zonal; 10º latitude bands from -85º to 85º; SZA-dependent; 25 vertical levels	Monthly climatology
/data/ATMOS/NO2/gcno2_06<mm>.dat	GEOS-Chem NO2 climatological profile for lower atmosphere	Global; 144 × 91 longitude-latitude grid; 2.5º longitude × ~2º latitude; 19 vertical layers	Monthly climatology
/data/ATMOS/BRO/<mon>_atm_BrO.dat	Monthly atmospheric BrO climatological profile	Zonal; 10º latitude bands from -85º to 85º; SZA-dependent; 25 vertical levels	Monthly climatology
/data/ATMOS/geoschem_hcho/<mon>_hcho_avg.dat	Monthly GEOS-Chem HCHO climatological profile	Global; 144 × 91 longitude-latitude grid; 2.5º longitude × ~2º latitude; 19 vertical layers	Monthly climatology
/data/ATMOS/mipasprof/MIPAS_IG2_O3clima.dat	MIPAS IG2 ozone climatology used for the upper-atmosphere	Zonal; 6 latitude bands at 75ºS, 45ºS, 10ºS, 45ºN,	Seasonal climatology;

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
	ozone a priori above ~60 km	and 75ºN; 121 pressure-altitude levels from 0 to 120 km at 1 km spacing	January, April, July, and October
/data/ATMOS/tbclima/TB14<location>-5.vs	Extratropical and Tropical tropopause-based ozone climatology and a priori error construction	Zonal; 18 latitude bands; 80 altitude layers from approximately -20 to 60 km relative to the tropopause-based grid	Monthly climatology
/data/ATMOS/MLclima/ML_<unit>_table.dat	McPeters/Labow merged sonde/MLS ozone climatology	Zonal; 18 latitude bands; 66 vertical layers on the Z* pressure-altitude grid	Monthly climatology
/data/SoftCal/TEMPO_2024m07_xtrack_v4p4_V03_all_fnl_tb_soft.dat	Soft-calibration correction table for Xtrack- and wavelength-dependent radiance bias correction	N/A; TEMPO Xtrack- and wavelength-dependent	N/A; static reference spectrum
leapsec.dat	Standard leap second reference file for UTC/TAI time conversions	N/A	N/A

<gas> = Target trace gas molecule (e.g., NO2, BrO, HCHO).
<temp> = Temperature in Kelvin (e.g., 220K, 228K, 300K).
<source> = Laboratory group or publication source (e.g., IASB, Wilmouth, Cantrell).
<mon> = Three-letter month abbreviation (e.g., jan, feb, …, dec)
<mm> = Two-digit month number (e.g., 01, 02, …, 12)
<location> = Extratropical and Tropical (e.g., L, H)
<unit> = Unit (e.g., du, ppmv)

o3abs_bw_uvvis_vacfinal.dat:
Wavelength range (nm): 260.00–660.00

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
Sampling interval (nm): 0.01 Number of wavelength points: 40,001 Cross-section scaling factor: 1.0E-20 Ozone cross-section representation: 3-term polynomial coefficients ozcrs_sol_for_alb.dat: Wavelength range (nm): 300.007–399.993 Sampling interval (nm): 0.01 Number of wavelength points: 9,997 O3 cross sections: Brion/Daumont/Malicet-based quadratic coefficients Other cross sections: NO2, SO2, BrO, HCHO, O4, and OClO Columns: wavelength, O3 c0, O3 c1, O3 c2, NO2, SO2, BrO, HCHO, O4, OClO, solar reference <mon>_strat_NO2.dat and <mon>_atm_BrO.dat: Latitude nodes (degree): -85, -75, -65, -55, -45, -35, -25, -15, -5, 5, 15, 25, 35, 45, 55, 65, 75, 85 Solar zenith angle nodes: 34 values for most latitude bands; 22 values at 85°N Vertical levels: 25 altitude levels Altitude range (km): approximately 9.57–56.40 gcno2_06<mm>.dat: Longitude grid: 144 grid cells from -180.0° to 177.5° at 2.5° spacing Latitude grid: 91 grid cells: -89.5°, -88.0° to 88.0° at 2.0° spacing, and 89.5° Vertical layers: 19 Unit: ppbv <mon>_hcho_avg.dat: Longitude grid: 144 grid cells from -180.0° to 177.5° at 2.5° spacing Latitude grid: 91 grid cells: -89.5°, -88.0° to 88.0° at 2.0° spacing, and 89.5° Vertical layers: 19 Unit: ppbv Z* = 16 × log(1013 / P), where P is pressure in hPa ML_du_table.dat: Latitude bands: 18 zonal bands from 80–90°S to 80–90°N Month nodes: January–December Vertical coordinate: Z* pressure-altitude layers Vertical layers: 65 one-km Z* layers from 0–1 to 64–65 Unit: DU per Z* layer ML_ppmv_stats.dat: Latitude bands: 18 zonal bands from 80–90°S to 80–90°N Month nodes: January–December Vertical coordinate: Z* pressure-altitude levels Vertical levels: 66 Z* levels from 0 to 65 Unit: ppmv			

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
MIPAS_IG2_O3clima.dat: Season nodes: January, April, July, October Latitude nodes (degree): -75, -45, -10, 10, 45, 75 Vertical coordinate: pressure-altitude Z* Vertical levels: 121 levels from 120 km to 0 km at 1 km spacing Ozone unit: DU per 1-km Z* layer TEMPO_2024m07_xtrack_v4p4_V03_all_fnl_tb_soft.dat: Channels: UV1 and UV2 (UV2 is not used for current V04) Cross-track pixels: 512 Wavelength grid per channel: 286 points Wavelength range (nm): 293.0–350.0 Sampling interval (nm): 0.2 Data structure: wavelength-dependent correction factors for each TEMPO xtrack pixel			

Table 9. File description for refdata/o3_total

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
/data/CLIM/<species>_CLIM.txt	Monthly latitude-dependent climatological LUT for the target species	Zonal; 10º latitude bands from -85º to 85º (No longitude dependence)	Monthly climatology; 12 monthly fields
/data/V8ANC/terrainPressure0303.he4	Gridded terrain pressure field	Global; 1080 × 540 geographic grid; ~1/3º × ~1/3º	Static auxiliary field; N/A
/data/V8ANC/cloud_pressure.he4	Gridded monthly cloud pressure climatology	Global; 360 × 180 geographic grid; 1º × 1º	Monthly climatology; 12 monthly fields
/data/V8ANC/v8snowice.he4	Gridded monthly snow/ice climatology	Global; 360 × 180 geographic grid; 1º × 1º	Monthly climatology; 12 monthly fields

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
/data/LUT/NVAL_TEMPO_RRS_CoefO3_Brion_20250617.nc	TOMRAD/LRRS radiative transfer LUT including Raman scattering terms for ring-effect correction	N/A; spectral/radiative-transfer LUT	Static auxiliary LUT
/data/LUT/DNDX_TEMPO_CoefO3_Brion_20250617.nc	TOMRAD radiative transfer LUT for standard and ozone-layer-perturbed profiles	N/A; spectral/radiative-transfer LUT	Static auxiliary LUT
leapsec.dat	Standard leap second reference file for UTC/TAI time conversions	N/A	N/A

<species> = Target species (e.g., Ozone, Temperature)
<species>_CLIM.txt LUT Nodes:
Month: 1-12
Latitude (degree): -85, -75, -65, -55, -45, -35, -25, -15, -5, 5, 15, 25, 35, 45, 55, 65, 75, 85
Total ozone node (DU): 125, 175, 225, 275, 325, 375, 425, 475, 525, 575
Vertical structure: 10 log-pressure layers from 1013.25 hPa to ~0.989 hPa, plus an upper layer extending above ~0.989 hPa
Approximate finite-layer midpoints (km): 2.8, 7.7, 12.5, 17.0, 21.3, 25.8, 30.4, 35.2, 40.2, 45.5
Fill value: 999.0 or 999.00

NVAL_TEMPO_RRS_CoefO3_Brion_20250617.nc LUT Nodes:
Wavelength (nm): 308.70, 310.80, 311.85, 312.61, 313.20, 314.40, 317.62, 322.42, 331.34, 345.40, 360.15, 372.80
Surface pressure (atm): 1.0, 0.7, 0.4, 0.25
Solar zenith angle (degree): 0, 30, 45, 60, 70, 77, 81, 84, 86, 88
Viewing zenith angle (degree): 0, 15, 30, 45, 60, 70, 77, 81, 84, 86, 88
Standard ozone profiles: 21
Ozone absorption coefficients: Brion cross sections, TEMPO slit-convolved

DNDX_TEMPO_CoefO3_Brion_20250617.nc LUT Nodes:
Wavelength (nm): 308.70, 310.80, 311.85, 312.61, 313.20, 314.40, 317.62, 322.42, 331.34, 345.40, 360.15, 372.80
Surface pressure (atm): 1.0, 0.7, 0.4, 0.25
Solar zenith angle (degree): 0, 30, 45, 60, 70, 77, 81, 84, 86, 88
Viewing zenith angle (degree): 0, 15, 30, 45, 60, 70, 77, 81, 84, 86, 88
Standard ozone profiles: 21
Perturbation nodes: 12; standard profile plus +10% perturbations for layers 1–11

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
Ring effect: not included Ozone absorption coefficients: Brion cross sections, TEMPO slit-convolved			

Table 10. File description for refdata/polarization

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
Polarization_LUT_qu_SIqu_clima<version>_reordered.nc	Look-up table for Stokes parameters (I, Q, and U)	N/A	N/A
TEMPO_lps_table_V2_reordered.nc	Linear polarization sensitivity and angle of maximum transmission interpolated onto TEMPO CCD dimensions	N/A	N/A
lps_table.nc	Original data for linear polarization sensitivity and angle of maximum transmission	N/A	N/A
<version> = Data version. **Some data files are obsolete and should not be used. For the ones currently used in the SDPC, please refer to Appendix B.*			

Table 11. File description for refdata/trace_gas

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
AMFs_lookup_<gas>_<wavelength>.he5	AMF look-up tables for trace gas retrievals	N/A	N/A
OMSAO_<gas>_<temp>_<source>.dat*	Laboratory absorption cross-section reference spectra for specific trace gases and temperatures	N/A	N/A
OMSAO_CU2020_SolarSpec.dat	TSIS-1 solar reference spectrum	N/A	N/A
OMSAO_MolecularRing_CU2020.dat	Raman scattering spectrum derived from TSIS-1 reference spectrum	N/A	N/A
OMSAO_VibrationalRaman_Spectrum.dat	Vibrational Raman spectrum	N/A	N/A
OMSAO_Zero_Spec.dat	Zero reference spectrum baseline file	N/A	N/A
leapsec.dat	Standard leap second reference file for UTC/TAI time conversions	N/A	N/A

`<gas>` = Target trace gas molecule (e.g., `O3`, `NO2`, `HCHO`).
`<temp>` = Temperature in Kelvin (e.g., `293K`).
`<source>` = Laboratory group or publication source (e.g., `SerdyuchenkoGorshelev`, `IASB`).
`<wavelength>` = Wavelength of radiative transfer calculation (e.g., `340nm`).
**Some cross sections are obsolete and should not be used. For the ones currently used in the SDPC, please refer to Appendix A.*

Table 12. File description for refdata/zoneinfo

File Name	Description	Spatial Coverage and Resolution	Temporal Coverage and Resolution
leap-seconds.list	Standardized text file to keep track of leap seconds generated by NIST	N/A	N/A

4.0 Quality, Errors, and Limitations

4.1 Data Quality Summary

Limitations and validation of the TEMPO data products may be found in their respective user guides, Algorithm Theoretical Basis Documents, and validation reports.

5.0 Investigators

5.1 Title of Investigation

TROPOSPHERIC EMISSIONS: MONITORING OF POLLUTION (TEMPO) PROJECT

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6.0 Software and Tools

The TEMPO science data processing software which uses this auxiliary data set is available from https://github.com/Smithsonian/tempo_sdpc.

7.0 Related Data Sets and Websites

The TEMPO science data processing software is available from https://github.com/Smithsonian/tempo_sdpc.

The main TEMPO mission page is at https://tempo.si.edu.

The NASA TEMPO project page with current documentation, operations logs and links to datasets is at https://www.earthdata.nasa.gov/data/instruments/tempo.

8.0 Acknowledgments

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10.0 Acronyms

Acronym	*Acronym Meaning*
AMF	Air mass factor
ASDC	Atmospheric Science Data Center
ATBD	Algorithm Theoretical Basis Document
EOSDIS	Earth Observing System Data and Information System
DU	Dobson Unit
GEOS-CF	Goddard Earth Observing System Composition Forecasting
GLER	Geometry dependent Lambertian Equivalent Reflectance
GMAO	Global Modeling and Assimilation Office
GMTED	Global Multi-resolution Terrain Elevation Data
GSFC	Goddard Space Flight Center
L1	Level 1
L2	Level 2
L3	Level 3
LUT	Look-up table
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
NRT	Near real-time
OMI	Ozone Monitoring Instrument
SAO	Smithsonian Astrophysical Observatory
SDPC	Science Data Processing Center

SZA	Solar zenith angle
TAI	International Atomic Time
TEMPO	Tropospheric Emissions: Monitoring of Pollution
TOA	Top of Atmosphere
UTC	Coordinated Universal Time
VLIDORT	Vector Linearized Discrete Ordinate Radiative Transfer
VZA	Viewing Zenith Angle

Appendix

Appendix A. Trace Gas Cross Sections used in SDPC

(1) CLDO4

OMSAO_CU2020_SolarSpec.dat

OMSAO_MolecularRing_CU2020.dat

OMSAO_O3_223K_SerdyuchenkoGorshelev.dat

OMSAO_O3_293K_SerdyuchenkoGorshelev.dat

OMSAO_NO2_220K_IASB.dat

OMSAO_O4_223K_Finkenzeller.dat

OMSAO_H2O_HITRAN2020_283K_0.90atm_RJH_HIT20update.dat

OMSAO_LQH2O_Mason_Pure.dat

OMSAO_VibrationalRaman_Spectrum.dat

OMSAO_Zero_Spec.dat

(2) NO2

OMSAO_CU2020_SolarSpec.dat

OMSAO_MolecularRing_CU2020.dat

OMSAO_O3_223K_SerdyuchenkoGorshelev.dat

OMSAO_NO2_220K_IASB.dat

OMSAO_O4_293K_Finkenzeller.dat

OMSAO_H2O_HITRAN2020_283K_0.90atm_RJH_HIT20update.dat

OMSAO_LQH2O_MasonFry_Pure.dat

OMSAO_VibrationalRaman_Spectrum.dat

OMSAO_Zero_Spec.dat

(3) HCHO

OMSAO_CU2020_SolarSpec.dat

OMSAO_MolecularRing_CU2020.dat

OMSAO_O3_223K_SerdyuchenkoGorshelev.dat

OMSAO_O3_243K_SerdyuchenkoGorshelev.dat

OMSAO_NO2_220K_IASB.dat

OMSAO_O4_293K_Finkenzeller.dat

OMSAO_BrO_228K_Wilmouth.dat

OMSAO_HCHO_300K_Cantrell_MMcorrected.dat

OMSAO_VibrationalRaman_Spectrum.dat

OMSAO_Zero_Spec.dat

Appendix B. Instrument and polarization data files used in SDPC

(1) Instrument

TEMPO_senscal_batc_deliverable_10312025_v8.0.nc

tempo_trend_example.nc

wavcal_refspec_TEMPO_ILS_reformat_V3.nc

wavcal_refspec_TEMPO_ILS_Band2_reformat_V3.nc

(2) Polarization

Polarization_LUT_qu_SIqu_clima_v2_reordered.nc

TEMPO_lps_table_V2_reordered.nc

ASDC

TEMPO Auxiliary Data, Version 1.0

User Guide

Version: 1.0

Date: July 20, 2026

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