**INFORMATION ABOUT SATELLITE INSTRUMENT AND DATASET DERIVED FROM ALGORTIHM FOR GEOD@C PROJECT**

**Lightning Imaging Sensor (LIS) instrument**

* **About LIS:**

This instrument records the time of occurrence of a lightning flash, measures the radiant energy, and determines the location of flashes within its field-of-view.

A real-time event processor (RTEP) will remove the background signal, thus enabling the system to detect weak lightning and achieve a 90% detection efficiency (ranges from 69% near noon to 88% at night.)

The algorithm accumulates the individual LIS events into groups, flashes, and areas. Flash events from adjacent pixels occurring at a certain time are grouped together, Flashes within 330ms time interval are grouped together and finally if flashes occur within 5kms of area they are grouped.

The LIS sensor contains a staring imager which is optimized to locate and detect lightning with storm-scale resolution of 3 km at NADIR, 6km at limb in case for LIS on TRMM (4-8kms spatial resolution in case of LIS on ISS) over a large region (FOV 550-550 km) of the Earth's surface. The field of view (FOV) is sufficient to observe a point on the Earth or a cloud for 90 seconds, adequate to estimate the flashing rate of many storms. It can estimate lightning frequency for storms with flash rates as low as 1-2 discharges per minute. Sampling frequency of every 2ms over 90 seconds.

* **Measurement science:**

The optical pulse sensors are designed to detect the prominent emission optical spectra produced by oxygen emission triplet in the lightning spectrum from cloud-topline to image at 777.4 nm (OI line) onto a 128 x 128 high-speed CCD array detector

1. *Measurement threshold:* 4.7 mJ m-2 sr -1

*(Based on peak radiant energy density produced from 90% of lightning studied in extensive measurements from an instrumented NASA U-2)*

1. *Maximal:* 181 mJ m-2 sr -1

*(as reported by Goodman et al. (1988), any event more energetic than the optical energy associated with the maximum 0x7f reading will be tagged 0x7f, i.e., saturation will occur.)*

1. *Telemetry link data transfer rate:* 6kb/s

*(If the on-board buffers are not sufficiently large to handle some high pulse data rate incidents, the buffers will overflow. This will result in unrecoverable loss of data. Data correction in such overflow condition is automated)*

* **The TRMM LIS operated successfully for over 17 years, from launch in 1997 until April 2015. The spare LIS was placed in Feb 2017 on the**[**International Space Station (ISS)**](https://www.nasa.gov/mission_pages/station/main/index.html)**for a two - four-year mission The TRMM satellite orbit gradually declined in the last year of operation from 2014 - 2015. In 2015, TRMM was removed from orbit. Field-of-view and measurement spatial resolution varied slightly for each of the two orbital altitudes**

1. **About TRMM\_LIS**

*Platform: TRMM (Tropical Rainfall Measuring mission): Earth obervation satellite*

*Instrument: Lightning Imaging Sensor*

*Launch date: 28 November 1997*

*Designed by scientists at the*[*University of Alabama in Huntsville*](http://www.uah.edu/)

*Manufactured at the*[*Marshall Space Flight Center*](http://www.nasa.gov/centers/marshall/home/).

Spatial coverage: N: 38.0, S: -38.0, E: 180.0, W: -180.0

Orbital period: 91.3 mins (before August 2001) and 92.4 mins (after August 2001). 42 day repeat cycle for same given location at different time.

Data access source: EARTHDATA

Filename: Lightning Imaging Sensor (LIS) on TRMM Science Data V4

Data temporal extent – January 01,1998 to April 08,2015

Temporal resolution: 1file per orbit

Native Format: HDF4 and netCDF-4

1. **About ISS\_LIS**

*Platform:* International Space Station (ISS)

*Instrument:* Lightning Imaging Sensor (LIS)

*Launch date: February 2017*

Designed by scientists at the [University of Alabama in Huntsville](http://www.uah.edu/)

Manufactured at the [Marshall Space Flight Center](http://www.nasa.gov/centers/marshall/home/)

Spatial coverage: 55.0, S: -55.0, E: 180.0, W: -180.0

Orbital period: 90-93 minutes, there are approximately 16 orbits per day. *(NOTE: The exact number of orbits per day is generally 15.5 to 15.9 orbits/day).* There is an approximate repeat of orbit tracks over the same area on the ground every 3 days depending on the ISS altitude.

Data access source: EARTH DATA

Filename: Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Science Data V2

Data temporal extent – March 01,2017 – **ongoing**

Temporal resolution: 2mins for NRT

Native Format: HDF4 and netCDF-4

* **Quality Control of the LIS Data**

LIS responds to several optical signals, not all of which are necessarily lightning-related. A significant amount of software filtering maximizes both detection efficiency and confidence level so that each datum is a lightning signal and not noise.

Each LIS lightning event in a LIS file is tagged with four low-level quality indicators, as follows:

1. Non-noise Probability (the probability that the event is not caused by random noise or energetic particles).
2. Solar Glint Factor (a number that indicates the likelihood that the event was caused by direct reflected solar radiation).
3. Event Rate Ratio (a number that represents the ratio of "accepted" events to the raw detected events during a one-second period at the time of the event).
4. Probability Density (a number that indicates whether the event is geolocated in the vicinity of other events that are likely to be lightning).

The LIS data file is manually inspected for irregularities in the data set. The data files that fail specific quality assurance are flagged. The high-level quality flags assigned to each LIS HDF data file (included as part of the HDF file) are as follows:

1. Instrument Alert Flag
2. Platform Alert Flag
3. External Alert Flag
4. Processing and Algorithm Alert Flag

* **Orbit file Varieties**

The orbit files from LIS can come in 5 varieties, or classes:

Class 1- Good files - these files contain good data - be forewarned that occasionally the instrument/platform fatal flags may be intermittently set in some of these orbits. In these orbits, about 50 of the one second data flags are set to fatal or warning. Unless these flags are contiguous, the data is considered good. The vast majority of the LIS files are in this category.

Class 2- Good files containing 0 events - These are a subset of the good files, except that no events were observed. There are only about 10 of these files a year.

Class 3- Files unreadable with the idl code

Class 4- Files with known anomalies - These files have been observed to have some sort of anomaly, such that lightning data are available for only part of the orbit. The one second data flags are set correctly in these files. (*NOTE: However, that not all the files anomalies may be listed on the web site. It is up to the user to check the one second data to verify that the data are good. In particular, LIS buffer overflows may not be listed due to the short duration of the data outage.In addition, files that occur immediately before and after files of type Class 3 will probably be in this category and will not be listed on the anomalies page.)*

Class 5- Missing files

*NOTE: Because they contain no useful science data, files of type Class 3 and Class 5 will not be distributed.*

* The **pre-launch calibration** primarily addresses LIS radiometric calibration, and the **post-launch calibration** is carried out once the LIS is launched and becomes operational the performance of the LIS will be characterized and key performance parameters are calibrated. The coincident databases that are assembled from regional ground-based lightning networks, long range sferics networks, interferometry, VHF time-of-arrival, optical and electric field sensors and LIS prototype Optical Transient Detector (OTD), the high altitude ER-2 aircraft for the calibration/validation efforts.
* **Validation** is the process of verifying and tuning the performance of both the data processing

algorithms described in this document and the LIS hardware. This process will include- remotely adjusting threshold settings to maximize detection and minimize false alarm rate,

verifying the true amplitude, time of occurrence, and location of lightning events detected, and verifying background image brightness and alignment.**Pre-launch validation:** Use data from OTD and process using LIS algorithm, check with other ground truth observations.

**Post-launch validation:** Use data from OTD as well as LIS sensor and process both using LIS algorithm check with other ground truth observations.

**The LIS data for a single orbit is stored in two HDF files: one containing the major science**

**data and the other the background images.** *(This is done so users who are not interested in the background images do not have to download the large background files to get to the lightning data.)*

*For more information:*

* Lightening research by GHRC: [Lightning Research - Micro Articles - Data Recipes | GHRC Lightning (nasa.gov)](https://ghrc.nsstc.nasa.gov/lightning/lightning-research.html)
* Lightning measurement science using LIS instrument? Refer following paper:

Christian and S. J. Goodman, 1987. Optical observations of lightning from a high-altitude airplane

Goodman, H. J. Christian, and W. D. Rust, 1988a. Optical pulse characteristics of intracloud and

cloud-to-ground lightning observed from above clouds.

Goodman, D. E. Buechler, P. D. Wright, and W. D. Rust, 1988b. Lightning and precipitation history of a microburst producing storm

Goodman, and P. J. Meyer, 1988c. Convective tendency images derived from a combination

of lightning and satellite data]

* [LIS Algorithm Theoretical Basis Document](http://lightning.nsstc.nasa.gov/bookshelf/pubs/atbd-lis-2000.pdf)
* Information related to TRMM satellite and mission:

<https://www.eoportal.org/satellite-missions/trmm#lis-lightning-imaging-sensor>

* Information related to ISS satellite and mission:

<https://www.nasa.gov/mission_pages/station/main/index.html>

* Differences in LIS placed on TRMM and ISS:

<https://ghrc.nsstc.nasa.gov/home/micro-articles/earth-observations-lightning-imaging-sensor>

* LIS on TRMM information by GHRA: <https://ghrc.nsstc.nasa.gov/uso/ds_docs/lis/lis_dataset.html>
* Data user guide of LIS on TRMM: <https://ghrc.nsstc.nasa.gov/pub/lis/trmm/doc/lislip_dataset.pdf>
* Data user guide of LIS on ISS, September 2021 Version 2 updates: <https://ghrc.nsstc.nasa.gov/pub/lis/iss/doc/isslis_dataset.pdf>
* Orbit files with known anomalies (Class 4 error) for TRMM-LIS are listed in: <https://ghrc.nsstc.nasa.gov/lightning/data/data_lis_trmm_anomalies.html>
* Orbit files with known anomalies (Class 4 error) for ISS-LIS are listed in: https://ghrc.nsstc.nasa.gov/lightning/data/ISSLIS-Anomalies.pdf]

**TROPOspheric Monitoring Instrument (TROPOMI) instrument for NO2 detection**

* **About TROPOMI**

TROPOMI is the most advanced multispectral imaging spectrometer to date – was developed jointly by ESA and the Netherlands Space Office. It observes sunlight that is scattered back to space by Earth’s surface and atmosphere, detecting the unique fingerprints of gases in the UV and visible (270–500 nm), near-infrared (675–775 nm) and shortwave infrared (2305–2385 nm) spectral bands of the spectrum, thus a wide range of pollutants such as nitrogen dioxide, ozone, formaldehyde, sulphur dioxide, methane and carbon monoxide can be imaged more accurately and to improve our understanding of chemical and physical atmospheric processes.

The Copernicus Sentinel-5 Precursor (Sentinel-5P or S5P) satellite mission is one of the European Space Agency's (ESA) new mission family - Sentinels, and it is a joint initiative between the Kingdom of the Netherlands and the ESA. The sole payload on Sentinel-5P is the TROPOspheric Monitoring Instrument (TROPOMI), which is a nadir-viewing 108-degree Field-of-View push-broom grating hyperspectral spectrometer, covering the wavelength of ultraviolet-visible (UV-VIS, 270nm to 495nm), near infrared (NIR, 675nm to 775nm), and shortwave infrared (SWIR, 2305nm-2385nm). Sentinel-5P is the first of the Atmospheric Composition Sentinels and is expected to provide measurements of ozone, NO2, SO2, CH4, CO, formaldehyde, aerosols and cloud at high spatial, temporal and spectral resolutions.

1. **Copernicus Sentinel 5 Precursor Tropospheric Monitoring Instrument (S5P/TROPOMI) nitrogen dioxide (NO2) Level 2 data product – version 02.03.01 (11/17/2021)**

For variables nitrogendioxide\_tropospheric\_column, nitrogendioxide\_total\_column, nitrogendioxide\_summed\_total\_column:

* • qa\_value > 0.75

This is the recommended pixel filter. It removes cloud-covered scenes (cloud radiance fraction > 0.5), partially snow/ice covered scenes, errors, and problematic retrievals.

* • qa\_value > 0.50

Compared to the stricter filter, this adds the good quality retrievals over clouds and over scenes covered by snow/ice. Errors and problematic retrievals are still filtered out. In particular, this filter may be useful for assimilation and model comparison studies.

For variable nitrogendioxide\_stratospheric\_column:

* • qa\_value > 0.50

Known Data Quality Issues

Currently, the following data quality issues are known, not covered by the quality flags, and should be kept in mind when using the NO2 product.

**Bands 4 and 6 spatial misalignment**

The band 4 (450 pixels per scanline) footprints, used for the NO2 DOAS retrieval, are not fully aligned with the band 6 footprints, used for cloud and scene pressure retrievals. In the worst case, the misalignment can be in the order of half a ground pixel. The misalignment requires interpolation of the cloud and scene pressure, which may introduce additional uncertainty in those parameters. These parameters are used in the NO2 air-mass factor calculations. Note that the cloud fraction is determined in the NO2 fitting window, avoiding the uncertainty by misalignment for this parameter.

**Surface albedo climatology**

The current surface albedo climatology has a spatial resolution of 0.5°x0.5°, which is coarse compared to the much higher spatial resolution of S5p TROPOMI of 3.5 x 7 km. As a consequence, the albedo grid affects the NO2 column products quality especially at coastal areas.

**Conservative filtering**

The pixel flagging, reflected in the qa\_value, is defined in a conservative way. When the FRESCO cloud retrieval reports an error, in combination with the misalignment issue, one consequence is the loss of the first row (west side of the orbit), even though good NO2 slant column retrievals are possible. Another example is the removal of observations when the albedo database shows suspiciously high values.

**Data in snow\_ice\_flag variable for pixels with SZA > 88°**

The snow\_ice\_flag value for ground pixels with SZA > 88° is incorrectly set to 255, the NISE flag for “ocean”, rather than the FillValue 254 (the NISE flag for an error). Since ground pixels with SZA > 88° are not processed, these pixels do not have NO2 column data, hence the NO2 data quality is not affected. The issue will be solved in the next processor update.

**Variables in the NO2 DOAS fit with an across-track low-order “wave” (since version 02.02.00)**

Some variables in the NO2 DOAS fit have an across-track low-order "wave", causing unexpected values mainly in the western part of the swath. The variables concerned are the slant columns of ozone, liquid water and O2-O2 in the NO2 fit. The NO2 slant columns are *not* significantly affected. This indicates the effect is caused by something that varies smoothly with wavelength and thus may be related to the L1b degradation correction, i.e.: to the fact that the irradiance is corrected for degradation (since the usage of L1b version 02.00.00, beginning of July 2021, see Table 2) while the radiance is not. The issue may change once the radiance degradation correction is also in place.

*Unable to access S5-P data hub -* [*https://scihub.copernicus.eu/*](https://scihub.copernicus.eu/)

*API hub not found for S5-P on Copernicus*

**DATA availability in Earth data-**

**Sentinel-5P TROPOMI Tropospheric NO2 1-Orbit L2 7km x 3.5km V1 (S5P\_L2\_\_NO2\_\_\_) at GES DIS – 30/04/2018 to 06/08/2019**

**Sentinel-5P TROPOMI Tropospheric NO2 1-Orbit L2 5.5km x 3.5km V1 (S5P\_L2\_\_NO2\_\_\_\_HiR) at GES DISC – 06/08/2019 to 01/07/2021**

Starting from August 6th in 2019, Sentinel-5P TROPOMI along-track high spatial resolution (~5.5km at nadir) has been implemented. For data after August 6th of 2019, please check S5P\_L2\_\_CO\_\_\_\_ data collection.

**Sentinel-5P TROPOMI Tropospheric NO2 1-Orbit L2 5.5km x 3.5km V2 (S5P\_L2\_\_NO2\_\_\_\_HiR) at GES DISC – 01/07/2021 to 11/08/2022**

For more information:

**Sentinial 5P TROPOMI user guide -** https://sentinel.esa.int/web/sentinel/user-guides/sentinel-5p-tropomi

**Products and Algorithms -** <https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-5p/products-algorithms>

**MODIS\_C6\_fire product**

FP confidence

Fire-pixel confidence classes associated with the confidence level C computed for each

fire pixel.

Range Confidence Class

0% ≤ C < 30% low

30% ≤ C < 80% nominal

80% ≤ C ≤ 100% high

The algorithm examines each pixel of the MODIS swath, and ultimately assigns to

each one of the following classes: *missing data*, *cloud*, *water*, *non-fire*, *fire*, or *unknown*. Processing continues on the remaining clear land pixels.

Additional specialized tests are used to eliminate false detections caused by sun

glint, desert boundaries, errors in the water mask, and small forest clearings. Candidate fire pixels

that are not rejected in the course of applying these tests are assigned a class of *fire*. Pixels for which

the background characterization could not be performed, i.e. those having an insufficient number of

valid pixels, are assigned a class of *unknown*

At most latitudes a single MODIS instrument simply does not sample the Earth’s surface

adequately in time periods shorter than about 8 days to “average out” most of the sampling bias.

The fire may be too small or too cool to be detected in the 1 km2 MODIS footprint.

Cloud cover, heavy smoke, or tree canopy may completely obscure a fire.

The Level 2 swath and Level 3 tiled fire products available before November

2000

The CMG fire products are not totally useless despite the early calibration problems. In addition,

these products are less often used for time series analysis.

Because a MODIS product at daily temporal resolution will be plagued by extremely large sampling

bias errors. At most latitudes a single MODIS instrument simply does not sample the Earth’s surface

adequately in time periods shorter than about 8 days to “average out” most of the sampling bias.

**What to use??**

**Climate Modeling Grid Fire Products (MOD14CMQ, MYD14CMQ, etc.)**

The CMG fire products are gridded statistical summaries of fire pixel information intended for use

in regional and global modeling. Generated at 0.25◦ spatial resolution for time

periods of one calendar month (MOD14CMQ and MYD14CMQ) and

eight days (MOD14C8Q and MYD14C8Q).

**Global Monthly Fire Location Product (MCD14ML)**

For some applications it is necessary to have the geographic coordinates of individual fire pixels.

New for Collection 5 is the global monthly fire location product (MCD14ML), which contains this

information for all Terra and Aqua MODIS fire pixels in a single monthly ASCII file.

**Near Real-Time MODIS Imagery and Fire Products**

The Land Atmosphere Near Real-time Capability for EOS (LANCE)

* **DATA in CSV format yearly, country-wise**

**MODIS**

Each MODIS active fire/thermal hotspot location represents the center of a 1km pixel that is flagged by the algorithm as containing one or more fires within the pixel.

[**VIIRS S-NPP**](javascript:viewYears('viirs-snpp');)

Each VIIRS active fire/thermal hotspot location represents the center of a 375m pixel. The VIIRS data complement the MODIS fire detections, but the improved spatial resolution of the 375 m data provides a greater response of fires over relatively small areas and has improved nighttime performance.

**MODIS Collection 6.1: Temporal Coverage: 11 November 2000 - present  
  
VIIRS S-NPP 375m: Temporal Coverage: 20 January 2012 – present  
  
VIIRS NOAA-20 375m: Temporal Coverage: 1 January 2020 – present**

**NRT data available with 2-3 months time lag , fire DATA from FIRM in file formats shapefiles (.shp), comma-separated text files (.csv) or JSON files (.json)**

**Black earth marble**

Mandatory\_Quality\_Flag

|  |  |  |
| --- | --- | --- |
| Value | Retrieval Quality | Algorithm Instance |
| 00 | High-Quality | Main Algorithm (Persistent Nighttime Lights) |
| 01 | Good-Quality | Back up Algorithm (Temporal Gap-Filling) |
| 02 | Poor-Quality | Back up Algorithm (Outlier Removal) |
| 255 | No Retrieval | Fill Value |

Recent NASA Black Marble product validation efforts have therefore focused on developing guidelines for accuracy assessment of NTL products through a number of international initiatives

Earth DATA:

A screenshot of a computer

Description automatically generated

**Data availability:**

**VIIRS/NPP Daily Gridded Day Night Band 500m Linear Lat Lon Grid Night (VNP46A1) – 19-01-2012 – 26-7-2022**

The first of two VIIRS DNB-based datasets is a daily, top-of-atmosphere, at-sensor nighttime radiance product called VIIRS/NPP Daily Gridded Day Night Band 15 arc-second Linear Lat Lon Grid Night. Known by its short-name, VNP46A1, this product contains 26 Science Data Sets (SDS) that include sensor radiance, zenith and azimuth angles (at-sensor, solar, and lunar), cloud-mask flags, time, shortwave IR radiance, brightness temperatures, VIIRS quality flags, moon phase angle, and moon illumination fraction. It also provides Quality Flag (QF) information specific to the cloud-mask, VIIRS moderate-resolution bands M10, M11, M12, M13, M15, M16, and DNB.

**VIIRS/NPP Gap-Filled Lunar BRDF-Adjusted Nighttime Lights Daily L3 Global 500m Linear Lat Lon Grid (VNP46A2) - 19-01-2012 – 26-7-2022**

The second of the two VIIRS DNB-based datasets is a daily moonlight- and atmosphere-corrected Nighttime Lights (NTL) product called VIIRS/NPP Gap-Filled Lunar BRDF-Adjusted Nighttime Lights Daily L3 Global 500m Linear Lat Lon Grid. Known by its short-name, VNP46A2, this product contains seven Science Data Sets (SDS) that include DNB BRDF-Corrected NTL, Gap-Filled DNB BRDF-Corrected NTL, DNB Lunar Irradiance, Latest High-Quality Retrieval, Mandatory Quality Flag, Cloud Mask Quality Flag, and Snow Flag. VNP46A2 products are provided in standard Hierarchical Data Format–Earth Observing System (HDF-EOS5) format.

Timeline

Description automatically generated