**Lightning detection**

**LIS instrument\_TRMM V2 & QC\_ISS\_V2 products**

* **About Mission – TRMM and ISS**

TRMM is a joint NASA/JAXA (formerly NASDA) mission within NASA's ESE (Earth Science Enterprise) program with a low-inclination (equatorial) orbit. TRMM is the first mission dedicated to observing and understanding tropical and subtropical rainfall, one of the most important, but least understood parameters in global change.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. (Kramer)

After more than 17 years on orbit, the LIS instrument, flown on the TRMM has demonstrated successfully space-based lightning observations as an effective remote sensing tool for Earth science research and applications. In April 2013, a space-qualified LIS built as the flight spare for TRMM, was selected for flight as a science mission on the International Space Station. The ISS-LIS will be flown as a hosted payload on the DoD STP-H5’s investigations mission, which is scheduled for launch in 2017 aboard a SpaceX launch vehicle for a 2-4 year or longer mission. (Kramer, ISS:LIS)

* **About Instrument - LIS:** (H. Christian, 2000)

The LIS 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.

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.

The LIS 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.

A real-time event processor (RTEP) removes 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.)

* **Measurement science:** (H. Christian, 2000)

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)*

* **About TRMM\_LIS** (Kramer)

*Platform: TRMM (Tropical Rainfall Measuring mission): Earth observation 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 (Bugbee, 2020)

*Orbital period:* 91.3 mins (before August 2001) and 92.4 mins (after August 2001). 42 days 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

* **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 (Bugbee, 2020)

*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. *(to be checked)* (Robinson, n.d.)

*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:* 1file per orbit (2mins for NRT)

*Native Format:* HDF4 and netCDF-4

*Data lag*: 2 days

* **Quality Control of the LIS Data** (H. Christian, 2000)(Bugbee, Data User Guide - Lightning Imaging Sensor (LIS) on TRMM, 2020)(Bugbee, Data User Guide - International Space Station (ISS) Lightning Imaging Sensor (LIS) datasets, 2020)

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. (H. Christian, 2000)
* **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. (H. Christian, 2000)

* **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.)* (H. Christian, 2000)

*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.eoportal.org/satellite-missions/iss-lis

<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]