Global Hydrology Resource Center

Data User Guide

Lightning Imaging Sensor (LIS) on TRMM Datasets

Introduction

The TRMM Lightning Imaging Sensor (LIS) dataset was collected by the LIS instrument on the Tropical Rainfall Measuring Mission (TRMM) satellite used to detect the distribution and variability of total lightning occurring in the Earth's tropical and subtropical regions. This data can be used for severe storm detection and analysis, as well as for lightning-atmosphere interaction studies. The LIS instrument makes measurements during both day and night with high detection efficiency. These data are available in both HDF-4 and netCDF-4 formats, with corresponding browse images in GIF format.

Notice:
The Lightning Imaging Sensor (LIS) Science Data consists of lightning and lightning density measurements by LIS on the TRMM satellite. The TRMM satellite stopped collecting data on April 8, 2015 and crashed in the Indian Ocean on June 15, 2015. Note that this dataset does not contain uniform algorithm processing over the length of operation. There are plans to reprocess the entire dataset in the future.

Citations:

There are two citations provided below, one for each data file type - Science or Background data products. Please select the appropriate citation for the data you are using:

Lightning Imaging Sensor (LIS) on TRMM Science Data Citation

Blakeslee, Richard J. 1998. Lightning Imaging Sensor (LIS) on TRMM Science Data [indicate subset used]. Dataset available online from the NASA EOSDIS Global Hydrology Resource Center Distributed Active Archive Center, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/LIS/LIS/DATA201

Lightning Imaging Sensor (LIS) on TRMM Backgrounds Citation

Blakeslee, Richard J. 1998. Lightning Imaging Sensor (LIS) on TRMM Backgrounds [indicate subset used]. Dataset available online from the NASA EOSDIS Global Hydrology Resource

Center Distributed Active Archive Center, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/LIS/LIS/DATA101

Keywords:
NASA, GHRC, TRMM, Lightning Imaging Sensor, LIS, lightning, lightning density

Mission/Instrument Description

The LIS instrument was placed on the Tropical Rainfall Measuring Mission (TRMM) satellite on November 28, 1997. The TRMM orbit allowed the LIS instrument to travel in a nearly circular orbit inclined at 35 degrees with an altitude of about 350 km. A later orbital boost increased the altitude of TRMM and extended the lifetime of the satellite and instruments. The TRMM satellite instruments were used to study mesoscale phenomena, such as storm convection, dynamics, and microphysics. These phenomena are related to global rates and transport of latent heat, which are all influenced by global scale processes. The TRMM satellite stopped collecting data on April 8, 2015 and crashed in the Indian Ocean on June 15, 2015.

Two LIS instruments were originally designed by the Lightning Team at the Global Hydrology and Climate Center and manufactured at the NASA Marshall Space Flight Center (MSFC) in Huntsville, Alabama. One was installed on to the TRMM satellite, and the other LIS instrument was installed on the International Space Station (ISS) in February 2017 and remains in operation. The LIS has significantly contributed to several TRMM mission objectives by providing a global lightning and thunderstorm climatology.

The LIS contains a staring imager which is optimized to locate and detect lightning with a storm-scale resolution of 3 km at nadir (directly below the instrument) increasing to 6 km at limb (at edge of measurement region), over a large region of about 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 about 90 seconds, which is adequate timing to estimate the lightning flash rate of many storms. The pushbroom, matrix array consisting of 128 x 128 detectors allows for each Earth location to be observed continuously every 2 milliseconds for about 90 seconds. The TRMM LIS instrument records the time of occurrence, radiant energy, and location of each lightning event.

LIS uses a wide FOV expanded optics lens with a narrow-band filter centered at 777 nm in conjunction with a high speed charge-coupled device detection array. A Real-Time Event Processor (RTEP) is used to determine when a lightning flash occurred even within bright, sunlit clouds. Weak lightning signals that occur during the day are hard to detect due to background illumination. The RTEP removes the background signal, thus enabling the system to detect these weak lightning signals with about a 90% detection efficiency. More information about the LIS instrument is available in the Earth Observations: Lightning Imaging Sensor (LIS) Micro Article, the TRMM LIS PMM webpage, Christian et al., 1992, and Christian et al., 1999.

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Data Characteristics

The Lightning Imaging Sensor (LIS) on TRMM datasets contain measured lightning flashes from January 1, 1998 through April 8, 2015. These data files are available in both HDF-4 and netCDF-4 formats with associated browse imagery in GIF format, as well as summary yearly, seasonal, and monthly browse imagery in PNG format. There are two datasets associated with the LIS on TRMM:

- Lightning Imaging Sensor (LIS) on TRMM Science Data
- Lightning Imaging Sensor (LIS) on TRMM Backgrounds

The science data are at a Level 2 processing level, while the background data are at a Level 1B processing level. More information about the NASA data processing levels are available on the NASA Data Processing Levels website. Table 1 shows the characteristics of the data files.

The TRMM LIS data files contain orbital data, as well as a browse image showing the data plotted on a map. The background data are for use with the science data to aid in removing erroneous flashes. One form of intercomparison of the LIS geolocation and lightning events involves using the LIS background data to determine the surrounding storm structure of the lightning events. Because the radiant properties from land and water differ, where the LIS instrument points can be verified by coastline discrimination in the background data. Users, therefore, need both the science data and the background data to interpret the lightning events. In addition, the LIS background cloud-field data are matched to appropriate visible and near-infrared satellite data.

Table 1: Data Characteristics

Characteristic	Description
Platform	Tropical Rainfall Measuring Mission (TRMM)
Instrument	Lightning Imaging Sensor (LIS)
Projection	Centroid
Spatial Coverage	N: 38.0, S: -38.0, E: 180.0, W: -180.0 (Tropics)
Spatial Resolution	3-6 km
Temporal Coverage	January 1, 1998 - April 8, 2015
Temporal Resolution	1 file per orbit
Sampling Frequency	Every 2 milliseconds over ~90 seconds
Parameter	Lightning, lightning density
Versions	4.1, 4.2, and 4.3*
Processing Level	1B (background files) and 2 (science data)

*See Algorithm section for a description of differences between versions 4.1, 4.2, and 4.3

File Naming Convention

The Lightning Imaging Sensor (LIS) on TRMM Datasets have the file naming convention shown below. These data files are available in both HDF-4 and netCDF-4 formats with associated browse imagery in GIF format, as well as summary browse images of yearly, seasonal, and monthly plots in PNG format. These data have the following naming convention as shown below and in Table 2.

Data files: TRMM_LIS_[SC|BG].04.x_YYYY.JJJ.#####.[*|nc]
Browse files: TRMM_LIS_BR.04.x_YYYY.JJJ.gif
YYYY[_xxx].png

Table 2: File naming convention variables

Variable	Description
[SC|BG]	SC = science data BG = background data
YYYY	Four-digit year
JJJ	Three-digit Julian day of year
#####	Orbit number
[*|nc]	* = HDF-4 files do not have a file extension at the end of the file name nc = netCDF-4 file format
.gif	Graphics Interchange Format files (browse images)
xxx	Month or season name, no additional notation for year summary image
.png	Portable Network Graphics files
4.x	algorithm version: 4.1, 4.2 or 4.3 (described in algorithm section below)

Data Format and Parameters

These TRMM LIS datasets were obtained from measurements made by the LIS instrument onboard the TRMM satellite. The datasets contain science and background data from January 1, 1998 through April 8, 2015. The science dataset contains single orbit files of lightning count and lightning flash density measurements, while the background data, also organized as 1 file per orbit, can be used to check and verify geolocation calculations and monitor the stability of the LIS instrument. Lightning flash density is considered to be the number of lightning flashes per kilometer squared while the events were in the LIS instruments field-of-view.

The Lightning Imaging Sensor (LIS) on TRMM Science Data are stored in HDF-4 and netCDF-4 format files. Tables 3-12 describe each parameter in each TRMM LIS data file. More information about these parameters can be found in Christian et al., 2000.

The Lightning Imaging Sensor (LIS) on TRMM Backgrounds dataset consists of background data. These background data were created approximately one to two seconds apart and provide the scene on which lightning can be plotted. When using the IDL code to read the files, an entire orbit of background data can be displayed in a simple animation to allow a

quick way to see if interesting cloud systems, such as hurricanes or frontal systems, are within the FOV. Data within the background files align with the same parameters in the science files are not described in further detail in this guide so we don't repeat the same information tables.

Browse images for these LIS data are available in GIF format. Daily browse images were created showing the ascending and descending orbits, location of lightning, and statistical data. **Please note that the 'day' in the browse imagery and the 'day' in the science data are defined differently.** The browse imagery day begins at 00Z and ends 24 hours later, i.e. from midnight to midnight, while the science data day starts during the first orbit of the GMT day and ends during the last orbit of the GMT day.

The science dataset contains orbit data and a browse image showing the data plotted on a map. The browse images can be located using the link on the dataset landing page. Also, the browse images can be viewed at the Quality Controlled Browse Imagery webpage.

Table 3: **Orbit Summary Attribute Parameter Field Descriptions**. The orbit summary consists of summarized orbit attributes.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
configuration_code	orbit_summary_configuration_code	Code indicating which code configuration scenario was used when processing the data	short	-
end_longitude	orbit_summary_end_longitude	Longitude boundary defining end of this orbit	float	Degrees East
GPS_start	orbit_summary_GPS_start	Orbit start time for the Global Positioning System	double	s
id_number	orbit_summary_id_number	The number of this orbit, where the orbit count starts with LIS installation on ISS	int	-
inspection_code	orbit_summary_inspection_code	Code indicating which problem scenarios were checked by the QA inspector	short	-
one_second_address	Orbit_summary_one_second_address	Address of the first element in the one second data	int	-
one_second_count	orbit_summary_one_second_count	Number of one second records	int	-
point_data_address	orbit_summary_point_data_address	Point data child record number	short	-
point_data_count	orbit_summary_point_data_count	Number of point data records	short	-
start_longitude	orbit_summary_start_longitude	Longitude boundary defining start of this orbit	float	Degrees East
summary_image_address	orbit_summary_summary_image_address	Summary GIF image record number	short	-
summary_image_count	orbit_summary_summary_image_count	Number of summary GIF images	short	-
TAI93_end	orbit_summary_TAI93_end	TAI93 end time	double	Seconds since 1993-

				01-01 00:00:00.000
TAI93_start	orbit_summary_TAI93_start	TAI93 start time	double	Seconds since 1993-01-01 00:00:00.000
UTC_start	orbit_summary_UTC_start	UTC start time	char	-

Table 4: **One Second Field Descriptions**. The one second fields show the one-second sets. These measurements provide information regarding the status of the LIS instrument in a series of one-second intervals.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
alert_summary	one_second_alert_summary	Bit masked summary of alert flags. Bit1 is the Least Significant Bit (LSB) bit1=1: instrument_fatal_flag bit2=1: instrument_warning_flag bit3=1: platform_fatal_flag bit4=1: platform_warning_flag bit5=1: external_fatal_flag bit6=1: external_warning_flag bit7=1: processing_fatal_flag bit8=1: processing_warning_flag	byte	-
attitude_quality_flag	one_second_attitude_quality_flag	one second granule attitude quality flag	int	-
boresight_threshold	one_second_boresight_threshold	one second granule threshold estimate	byte	-
ephemeris_quality_flag	one_second_ephemeris_quality_flag	one second granule ephemeris quality flag	int	-
event_count	one_second_event_count	One second granule event count	short	-
external_alert	one_second_external_alert	Bit masked status of external factors. Bit1 is the Least Significant Bit (LSB) bit1=1:Warning_Satellite_within_SAA_Model1 bit2=1:Warning_satellite_within_SAA_Model2 bit3=1:Warning_direct_solar_reflection_possible_within_FOV bit4=1:Indifferent_TRMM_Microwave_imager_ on bit5=1:Indifferent_Precipitation_Radar_on bit6=1:Indifferent_Visible_Infrared_Scanner_on bit7=1:Indifferent_Clouds_and_Earth_Radiant_Energy_System_sens	byte	-

		or_on bit8: (reserved)		
instrument_alert	one_second_instrument_alert	bit masked status of instrument. Bit1 is the Least Significant Bit (LSB) bit1=1:Fatal_instrument_off bit2=1:Indifferent_instrument_command_executed bit3=1:Fatal/Warning_FIFO_buffer_overflow bit4=1:Warning_threshold_set_very_high bit5=1:Fatal_instrument_warning_up bit6=1:Warning_improper_operating bit7=1:Fatal_Packet_gap bit8=1:Warning_data_handling_problem	byte	-
noise_index	one_second_noise_index	One second granule noise index	byte	%
platform_alert	one_second_platform_alert	Bit masked status of platform. Bit1 is the Least Significant Bit (LSB) bit1=1:Warning_no_attitude_or_ephemeris_quality_flags_available bit2=1:Fatal_ephemeris_not_available bit3=1:Warning_ephemeris_possibly_inaccurate bit4=1:Fatal_attitude_not_available bit5=1:Warning_attitude_possibly_inaccurate bit6=1:Fatal_clock_not_available bit7=1:Warning_clock_possible_inaccurate bit8: (reserved)	byte	-
position_vector	one_second_position_vector	One second granule platform coordinates	float	m
processing_alert	one_second_processing_alert	Bit masked status of processing algorithms. Bit1 is the Least Significant Bit (LSB) bit1=1:Warning_QA_inspector_warning_flag bit2=1:Fatal_QA_inspector_fatal_flag bit3=1:Fatal_data_too_garbled_for_software_to _read bit4=1:Fatal_data_set_too_large_to_process bit5=1:Fatal/Warning_unforseen_software_error_caused_improper_	byte	-

		reporting_of_data bit6=1:Warning_grouping_algorithm_buffer_limitation_Problem bit7=1:Warning_viewtime_algorithm_failure_to_ accurately_determine_FOV bit8: (reserved)		
solar_vector	one_second_solar_vector	Unit vector from center of earth to sun in ECR coordinates	float	-
TAI93_time	one_second_TAI93_time	Whole second value starting before and continuing beyond one orbit	double	Seconds since 1993- 01-01 00:00:00.00 0
thresholds	one_second_thresholds	Values of the instrument threshold settings for each 256 count background interval	byte	-
transform_matrix	one_second_transform_matrix	Components of transform from pixel plane boresight coordinates to ECR coordinates of boresight and pixel plane	float	-
velocity_vector	one_second_velocity_vector	One second granule platform velocity	float	m/s

Table 5: **Point Summary Parameter Field Descriptions**. These measurements allow a user to quickly get to point datasets, such as addresses (the data file addresses of parameters) and counts (the total number of point data in the data file).

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
area_address	point_summary_area_address	Area record number	int	-
area_count	point_summary_area_count	Number of areas	int	-
bg_address	point_summary_bg_address	Background image summary record number	int	-
bg_count	point_summary_bg_count	Number of backgrounds	int	-
event_address	point_summary_event_address	Event record number	int	-
event_count	point_summary_event_count	Number of events	int	-
flash_address	point_summary_flash_address	Flash record number	int	-
flash_count	point_summary_flash_count	Number of flashes	int	-
group_address	point_summary_group_address	Group record number	int	-
group_count	point_summary_group_count	Number of groups	int	-
parent_address	point_summary_parent_address	Parent record number	int	-
vt_address	point_summary_vt_address	View time granule record number	int	-
vt_count	point_summary_vt_count	Number of view time granules	int	-

Table 6: **View time Parameter Field Descriptions**. The View time Parameter fields show view time parameters that are required in order to determine flashing rates on the Earth.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
alert_flag	viewtime_alert_flag	Reflects status of instrument, platform, external factors and processing algorithms. Bit1 is the Least Significant Bit (LSB).	byte	-

		bit1=1: instrument_fatal_flag bit2=1: instrument_warning_flag bit3=1: platform_fatal_flag bit4=1: platform_warning_flag bit5=1: external_fatal_flag bit6=1: external_warning_flag bit7=1: processing_fatal_flag bit8=1: processing_warning_flag		
approx_threshold	viewtime_approx_threshold	Threshold of instrument corresponding with grid cell position, proxied from solar zenith angle at a time halfway between start and end time	byte	-
effective_obs	viewtime_effective_obs	Time of observation of the grid cell, adjusted by the percentage of area in the grid cell within the FOV	float	s
-	viewtime_lat	Latitude of the center of the grid cell of dimensions 0.5 deg x 0.5 deg	float	Degrees North
location	viewtime_location	Latitude/Longitude of the center of the grid cell of dimensions 0.5 deg x 0.5 deg	float	degrees
-	viewtime_lon	Longitude of the center of the grid cell of dimensions 0.5 deg x 0.5 deg	float	Degrees East
TAI93_end	viewtime_TAI93_end	TAI93 whole second when location last within FOV	int	Seconds since 1993-01-01 00:00:00.000
TAI93_start	viewtime_TAI93_start	TAI93 whole second when location was first within FOV	int	Seconds since 1993-01-01 00:00:00.000

Table 7: **Bg_Summary Parameter Field Descriptions.** The Bg_Summary parameter fields show parameters that describe details of the background data, although they are stored separately due to the large file sizes.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
address	bg_summary_address	Background image number within orbit	int	-
boresight	bg_summary_boresight	Latitude/Longitude location of center pixel (63, 64)	float	degrees
corners	bg_summary_corners	Latitude/Longitude location of corner pixels	float	degrees
-	bg_summary_lat	Background image boresight latitude	float	Degrees North
-	bg_summary_lon	Background image boresight longitude	float	Degrees East
TAI93_time	bg_summary_TAI93_time	TAI93 time of the background image	double	Seconds since 1993-01-01 00:00:00.000

Table 8: **Area Parameter Field Descriptions**. The area parameter field descriptions show data associated with each area identified during the orbit. An area is defined as a contiguous region on the surface of the Earth that has produced lightning during a single orbit of the LIS instrument.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
address	lightning_area_address	Area record number	int	-
alert_flag	lightning_area_alert_flag	Bit masked status of instrument, platform, external factors and processing algorithms. Bit1 is the Least Significant Bit (LSB) bit1=1: instrument_fatal_flag bit2=1: instrument_warning_flag bit3=1: platform_fatal_flag bit4=1: platform_warning_flag bit5=1: external_fatal_flag bit6=1: external_warning_flag bit7=1: processing_fatal_flag bit8=1: processing_warning_flag	byte	-
approx_threshold	lightning_area_approx_threshold	Estimated value of 8-bit threshold for the area determined from background level or solar zenith angle	byte	-
child_address	lightning_area_child_address	Area child record number of 1st flash in a sequential list	int	-
child_count	lightning_area_child_count	Area child record number of flashes	int	-
cluster_index	lightning_area_cluster_index	Pixel density metric; higher numbers indicate area is less likely to be noise	byte	%
delta_time	lightning_area_delta_time	Time between first and last event that compose the area	float	s
density_index	lightning_area_density_index	Spatial density metric; higher if area geolocated in a region of high lightning activity	byte	-
footprint	lightning_area_footprint	Area footprint extent	float	km^2
grandchild_count	lightning_area_grandchild_count	Number of groups in area	int	-
greatgrandchild_count	lightning_area_greatgrandchild_count	Number of events in area	int	-
grouping_sequence	lightning_area_grouping_sequence	Time sequence of area used when grouping algorithm is applied	int	-
grouping_status	lightning_area_grouping_status	End status of the area	byte	-
-	lightning_area_lat	Latitude radiance-weighted centroid	float	Degrees North
location	lightning_area_location	Latitude/Longitude radiance-weighted centroid	float	Degrees
-	lightning_area_lon	Longitude radiance-weighted centroid	float	Degrees East
net_radiance	lightning_area_net_radiance	Sum of event radiances composing this area	float	$uJ/sr/m^2/um$
noise_index	lightning_area_noise_index	Signal-to-signal plus noise ratio	byte	%
oblong_index	lightning_area_oblong_index	Eccentricity of the area	float	-

observe_time	lightning_area_observe_time	Duration of observation of the region where the area occurred	short	s
parent_address	lightning_area_parent_address	Area parent record number	int	-
TAI93_time	lightning_area_TAI93_time	TAI93 times of 1st event in area	double	Seconds since 1993-01-01 00:00:00.000

Table 9: **Event Parameter Field Descriptions**. The Event Parameter fields show data that are associated with events recorded during the TRMM orbit. An event is defined as a single pixel exceeding the background threshold.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
address	lightning_event_address	Event record number	int	-
alert_flag	lightning_event_alert_flag	Bit masked status of instrument, platform, external factors and processing algorithms. Bit1 is the Least Significant Bit (LSB) bit1=1: instrument_fatal_flag bit2=1: instrument_warning_flag bit3=1: platform_fatal_flag bit4=1: platform_warning_flag bit5=1: external_fatal_flag bit6=1: external_warning_flag bit7=1: processing_fatal_flag bit8=1: processing_warning_flag	byte	-
amplitude	lightning_event_amplitude	Uncalibrated optical amplitude reported by instrument (a 7-bit digital count)	byte	-
approx_threshold	lightning_event_approx_threshold	Estimated value of 8-bit threshold for the area determined from background level or solar zenith angle	byte	-
bg_radiance	lightning_event_bg_radiance	Background radiance associated with pixel at time of event	short	uJ/sr/m^2/um
bg_value	lightning_event_bg_value	Level of background illumination (16-bit) at time of event	short	-
bg_value_flag	lightning_event_bg_value_flag	Background (bg) radiance has been 0: estimated from sza 1: interpolated from bgs	byte	-
cluster_index	lightning_event_cluster_index	Pixel density metric; higher numbers indicate area is less likely to be noise	byte	%
delta_time	-	Time between first and last event that compose the area	float	s
density_index	lightning_event_density_index	Spatial density metric; higher if area geolocated in a region of high lightning activity	byte	-
footprint	lightning_event_footprint	Area footprint extent	float	km^2
glint_index	lightning_event_glint_index	Angle between line of sight vector and direct solar reflection vector	byte	degrees
grouping_sequence	lightning_event_grouping_sequence	Time sequence of area used when grouping algorithm is applied	int	-

grouping_status	-	End status of the area	byte	-
-	lightning_event_lat	Latitude radiance-weighted centroid	float	Degrees North
location	lightning_event_location	Latitude/Longitude radiance-weighted centroid	float	degrees
-	lightning_event_lon	Longitude radiance-weighted centroid	float	Degrees East
noise_index	lightning_event_noise_index	Signal-to-signal plus noise ratio	byte	%
observe_time	lightning_event_observe_time	Duration of observation of the region where the area occurred	short	s
parent_address	lightning_event_parent_address	Area parent record number	int	-
radiance	lightning_event_radiance	Event calibrated radiance	float	uJ/sr/m^2/um
sza_index	lightning_event_sza_index	Event solar zenith angle	byte	degrees
TAI93_time	lightning_event_TAI93_time	TAI93 times of 1st event in area	double	Seconds since 1993-01-01 00:00:00.000
x_pixel	lightning_event_x_pixel	Event CCD pixel column	byte	-
y_pixel	lightning_event_y_pixel	Event CCD pixel row	byte	-

Table 10: **Flash Parameter Field Descriptions.** The flash parameter fields show data associated with each area or flash identified during the orbit. A flash is defined as one to multiple pulses that occur in the same storm cell within a specific time and distance corresponding to several related groups in a limited area.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
address	lightning_flash_address	Flash record number	int	-
alert_flag	lightning_flash_alert_flag	Bit masked status of instrument, platform, external factors and processing algorithms. Bit1 is the Least Significant Bit (LSB) bit1=1: instrument_fatal_flag bit2=1: instrument_warning_flag bit3=1: platform_fatal_flag bit4=1: platform_warning_flag bit5=1: external_fatal_flag bit6=1: external_warning_flag bit7=1: processing_fatal_flag bit8=1: processing_warning_flag	byte	-
approx_threshold	lightning_flash_approx_threshold	Estimated value of 8-bit threshold for the flash determined from background level or solar zenith angle	byte	-
child_address	lightning_flash_child_address	Address of 1st group in a sequential list	int	-
child_count	lightning_flash_child_count	Flash child record count	int	-
cluster_index	lightning_flash_cluster_index	Pixel density metric; higher numbers indicate flash is less likely to be noise	byte	%
delta_time	lightning_flash_delta_time	Time between first and last group that compose the flash	float	s
density_index	lightning_flash_density_index	Spatial density metric; higher if flash geolocated in a region of high lightning activity	byte	-
footprint	lightning_flash_footprint	Flash footprint size	float	km^2

glint_index	lightning_flash_glint_index	Flash solar glint cosine angle	byte	degrees
grandchild_count	lightning_flash_grandchild_count	Flash grandchild record count	int	-
grouping_sequence	lightning_flash_grouping_sequence	Time sequence of flash used when grouping algorithm is applied	int	-
grouping_status	lightning_flash_grouping_status	Flash grouping status	byte	-
-	lightning_flash_lat	Latitude radiance-weighted centroid	float	Degrees North
location	lightning_flash_ocation	Latitude/Longitude radiance-weighted centroid	float	degrees
-	lightning_flash_lon	Longitude radiance-weighted centroid	float	Degrees East
noise_index	lightning_flash_noise_index	Signal-to-signal plus noise ratio	byte	%
oblong_index	lightning_flash_oblong_index	Eccentricity of the flash	float	-
observe_time	lightning_flash_observe_time	Duration of observation of the region where the flash occurred	short	s
parent_address	lightning_flash_parent_address	Flash parent record number	int	-
radiance	lightning_flash_radiance	Flash calibrated radiance	float	uJ/sr/m^2/um
TAI93_time	lightning_flash_TAI93_time	TAI93 times of 1st event in flash	double	Seconds since 1993-01-01 00:00:00.000

Table 11: **Group Parameter Field Descriptions**. The Group Parameter fields show data associated with each group identified during the orbit. A group is defined as one or more simultaneous events that register in adjacent pixels in the focal plane array, which may consist of only one or many events.

HDF Field Name	netCDF Field Name	Description	Data Type	Unit
address	lightning_group_address	Group record number	int	-
alert_flag	lightning_group_alert_flag	Bit masked status of instrument, platform, external factors and processing algorithms. Bit1 is the Least Significant Bit (LSB) bit1=1: instrument_fatal_flag bit2=1: instrument_warning_flag bit3=1: platform_fatal_flag bit4=1: platform_warning_flag bit5=1: external_fatal_flag bit6=1: external_warning_flag bit7=1: processing_fatal_flag bit8=1: processing_warning_flag	byte	-
approx_threshold	lightning_group_approx_threshold	Estimated value of 8-bit threshold for the group determined from background level or solar zenith angle	byte	-
child_address	lightning_group_child_ad	Group child record number	int	-

	dress			
child_count	lightning_group_child_count	Group child record count	int	-
cluster_index	lightning_group_cluster_index	Pixel density metric; higher numbers indicate group is less likely to be noise	byte	%
density_index	lightning_group_density_index	Spatial density metric; higher if - group geolocated in a region of high lightning activity	byte	-
footprint	lightning_group_footprint	Group footprint size	float	km^2
glint_index	lightning_group_glint_index	Group solar glint cosine angle	byte	degrees
grouping_sequence	lightning_group_grouping_sequence	Time sequence of group used when grouping algorithm is applied	int	-
grouping_status	lightning_group_grouping_status	Group grouping status	byte	-
-	lightning_group_lat	Latitude radiance-weighted centroid	float	Degrees North
location	lightning_group_location	Latitude/Longitude radiance-weighted centroid	float	degrees
-	lightning_group_lon	Longitude radiance-weighted centroid	float	Degrees East
noise_index	lightning_group_noise_index	Signal-to-signal plus noise ratio	byte	%
oblong_index	lightning_group_oblong_index	Eccentricity of the group	float	-
observe_time	lightning_group_observe_time	Length of observation of the region where the group occurred (view time approximation at group centroid)	short	s
parent_address	lightning_group_parent_address	Group parent record number	int	-
radiance	lightning_group_radiance	Group calibrated radiance	float	$uJ/sr/m^2/um$
TAI93_time	lightning_group_TAI93_time	TAI93 time of all events in group	double	Seconds since 1993-01-01 00:00:00.000

Table 12: **Raster Images Parameter Field Descriptions.** These parameters consist of an image plot of the orbit and the associated color table.

HDF Field Name	netCDF Field Name	Description	Unit
raster_image	raster_image	Raster image plot of the orbit in each file. It is included for quick examination and manual identification of specific orbits of interest.	-
raster_image_color_table	raster_image_color_table	color table for raster image plot of the orbit in each file	-

Algorithm

The LIS software produces lightning data and corresponding background data from instrument measurements. The software decodes, filters, clusters, and then outputs the

data in HDF-4 and netCDF-4 files. Table 13 shows the steps needed to create the data products. More detailed information about LIS software is available in Christian et al., 2000.

Table 13: Software Tasks

Step	Task
1	TRMM to native lightning/background format converting
2	Pixel based filtering
3	TRMM to native ephemeris format converting
4	Ephemeris filtering
5	Geo-Locating
6	Determining TRMM view time
7	Flash clustering
8	Flash based filtering
9	Area clustering
10	Area based filtering
11	HDF-4 and netCDF-4 file creation

These TRMM LIS data consist of versions 4.1, 4.2, and 4.3.
Version 4.1 corrected the following issues:

1. Orbit number scheme made to match that of the other TRMM satellite data. In the past, LIS used a different method to determine the orbit number that was inconsistent with that used by TRMM. Over time, orbit numbers did not match.
2. Subsecond timing corrected in all orbits to make it easier to compare the LIS results with ground-based lightning measurements.
3. Several orbits that could not be processed by V4.0 vode now successfully processed using V4.1 code.
4. The V4.1 code made to use the actual ephemeris data. The V4.0 code sometimes used 'predicted' ephemeris files for processing.
5. Due to the subsecond timing difference and new processing, the LIS lightning numbers changed slightly. Overall, the number of flashes in the V4.1 files vary less than 1% from those produced in the V4.0 code.

Version 4.2 corrected the following issues:

1. Fixed a problem with the clustering of events near the International Dateline (±180 degrees Longitude)
2. Fixed issue with LIS event ephemeris tagged as missing Near 00 UTC which resulted in lost events and clustering/location issues

Version 4.3 corrected the following issues:

1. Moved from SGI hardware and IRIX operating system to LINUX. The port to a new hardware architecture and operating system included a change from the original DREP geolocation software provided with the Science Data Processing Toolkit to a geolocation algorithm developed by the LIS science team, as well as an upgrade to the latest version of the Toolkit.
2. Improvements were made in the handling of platform warning flags resulting in more lightning events, groups, flashes, and areas, as well as background images

being recovered because periods formally labeled as 'fatal' changed to labeled as 'warning'.

There are plans in the future to reprocess the entire TRMM LIS dataset using the most recent algorithm version in use for the ISS LIS data processing.

Quality Assessment

The calibration of LIS data was split into two different categories: an absolute radiometric calibration of the LIS sensor performed pre-launch stage, and an in-orbit calibration of the LIS sensor once operating on the TRMM satellite. The in-orbit calibration was extremely important for the interpretation and utilization of the LIS data. LIS data were also validated by verifying the true amplitude, location, and time of detected lightning events. Verification of background image alignment, image brightness, and remote adjustment of threshold settings was performed to minimize false alarms and maximize lightning detection.

Geolocation of lightning events and background images involve many facets of the LIS program testing processes. The orientation of the Charged Coupled Device (CCD) with respect to the LIS alignment cube was determined from an Euler angle analyses of precise yaw and pitch maneuvers of the LIS sensor head assembly during radiometric calibration of LIS. The orientation of the LIS alignment cube to the spacecraft-based attitude reference frame was then determined. The alignment correction is simply a constant angular measure applied to space atitude. Given real-time updates of the spacecraft ephemeris and attitude data, accurate LIS geolocation is determined. Lightning detection efficiency ranges from 69% near noon to 88% at night.

One form of intercomparison of the LIS geolocation and lightning events involves using the LIS background data. Because the radiant properties from land and water differ, where the LIS instrument points can be verified by coastline discrimination in the background data. In addition, the LIS background cloud-field data are matched to appropriate visible and near-infrared satellite images for storm location.

For quality assurance, all events, flashes, areas, and groups have been assigned data quality tags, indicating whether the data were associated with high noise rates, solar glint, or randomly spaced events, or if the data were positioned relative to events with high lightning probabilities. In addition, the LIS data files were manually inspected for irregularities in the dataset. The data files that failed specific quality assurance were flagged. The high-level quality flags assigned to each LIS data file included instrument, platform, external, and processing/algorithm alert flags. These data were assigned a 'class' including 'Good files', 'Good files containing zero events', 'Files unreadable with the IDL code', 'Files with known anomalies', and 'Missing files'. Files that were flagged as 'Files unreadable with the IDL code', 'Files with known anomalies', and 'Missing files' have not been distributed. These file dates can be found on the TRMM LIS anomalies page.

The TRMM LIS instrument existed in a noisy space environment. It also responded to a number of optical signals, not all of which are necessarily lightning related. A significant amount of software filtering is required to produce the science data, which maximizes both the detection efficiency and the confidence level so that each datum is a lightning signal and not noise. Each lightning event in a file is tagged with four low-level quality indicators. Also, each data file is assigned four high-level flags designed to notify potential users of possible irregularities in the data. An automated process is used to tag each optical event with a set of four numbers that indicate the relative likelihood that the event was produced by lightning, as opposed to solar glint, energetic particles in the Van Allen radiation belt, or electronic noise. Table 14 lists and describes the low-level tags. In addition, the LIS data files were manually inspected for irregularities. The data files that failed specific quality assurance tests were flagged. The high-level quality flags assigned to the LIS data files are described in Table 15. TRMM LIS orbit files are defined as 1 of five classes as described in Table 16. More information about the quality assessment of these LIS data are available in Christian et al., 2000.

Table 14: Low-level quality tags

Tag	Name	Description
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

Table 15: High-level quality tags

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

Table 16: Classes of TRMM LIS orbit files

Class	Description
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 wanting. Unless these flags are contiguous, the data are considered to be good data. The vast majority of the LIS files are in this category.
2	Good files containing 0 events: These are a subset of the good data files, except no lightning events were observed. This subset is listed separately because even though the data files contain no lightning events, there is a dummy data set of length 1 inserted into these files to prevent problems in reading the files. All fields in the dummy point data are set to 0. The view time data are good and are necessary when computing climatological lightning rates. These files are not listed separately anywhere. It is up to the user to determine how to work with them. There are only about 10 of these data files per year.
3	Files unreadable with the IDL code: These files contain good orbit data, but the LIS instrument

	wasn't working because it was turned off. The one-second data can be read in, but the lightning data has a length of 0 that causes some software to crash. It should be noted that there is no lightning information in these files since the instrument was turned off. These anomalies can be found on the TRMM LIS Processing Anomalies page.
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. These files are documented on the TRMM LIS Processing Anomalies page. It should be noted that not all the files anomalies may be listed. It is up to the user to check the one-second data to verify that the data are good. In particular, the LIS buffer overflows may not be listed due to the short duration of the data outage.
5	Missing files: Some data files are simply not produced. The causes of these missing data files vary, but are mainly due to LIS instrument outages due to sun acquisition maneuvers, Leonid meteor stream, etc.

Software

These LIS data are available in both HDF-4 and netCDF-4 formats. Panoply can be used to easily view the netCDF-4 files and HDFView can be used to easily view the HDF-4 files. Also, the ISS LIS Lightning Flash Location Quickview using Python and GIS Data Recipe can be used to plot these data. The LIS/OTD software package, developed by the LIS team, can be used to directly read the HDF data files. IDL code is also available to plot these data. Specific system and platform requirements are spelled out in Chapter 3 of the LIS/OTD software manual. The browse images can also be viewed on the TRMM LIS Quality-Controlled Browse Calendar provided by GHRC.

Known Issues or Missing Data

Some of the TRMM LIS data files consist of no lightning events in the files due to the instrument not observing lightning while overhead. Also, a list of anomalies data can be found on the TRMM LIS Processing Anomalies page.

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Related Data

Two LIS instruments were originally built. One was installed on the TRMM satellite platform and operated from 1998 through 2015. The other LIS instrument was installed on to the International Space Station (ISS) in 2017. This ISS LIS dataset has the same data format and is processed in a consistent manner to the TRMM LIS data. Higher level lightning data products are available from the NASA GHRC DAAC that include TRMM LIS data. Any products containing LIS data can be found using the HyDRO 2.0 search tool.

Non-Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Provisional Science Data (http://dx.doi.org/10.5067/LIS/ISSLIS/DATA204)

Non-Quality Controlled Lightning Imaging Sensor (LIS) on International Space Station (ISS) Provisional Backgrounds (http://dx.doi.org/10.5067/LIS/ISSLIS/DATA104)

NRT Lightning Imaging Sensor (LIS) on International Space Station (ISS) Provisional Science Data (http://dx.doi.org/10.5067/LIS/ISSLIS/DATA205)

NRT Lightning Imaging Sensor (LIS) on International Space Station (ISS) Provisional Backgrounds (http://dx.doi.org/10.5067/LIS/ISSLIS/DATA105)

LIS 0.1 Degree Very High Resolution Gridded Lightning Climatology Data Collection (http://dx.doi.org/10.5067/LIS/LIS/DATA306)

LIS/OTD Gridded Lightning Climatology Data Collection (http://dx.doi.org/%2010.5067/LIS/LIS-OTD/DATA311)

Contact Information

To order these data or for further information, please contact:

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