Global Hydrology Resource Center

Data User Guide

GOES-R PLT Lightning Mapping Array (LMA)

Introduction

The GOES-R PLT Lightning Mapping Array (LMA) datasets consist of total lightning data measured from multiple LMA systems, including Colorado (COLMA), Washington DC (DCLMA), NASA's Kennedy Space Center (KSCLMA), North Alabama (NALMA), Oklahoma (OKLMA), Southern Ontario (SOLMA), and West Texas (WTXLMA), during the GOES-R Post Launch Test (PLT) airborne science field campaign. The GOES-R PLT airborne science field campaign took place in support of the post-launch product validation of the Advanced Baseline Imager (ABI) and the Geostationary Lightning Mapper (GLM). The LMA measures the arrival time of radiation from a lightning discharge at multiple stations and locates the sources of radiation to produce a three-dimensional map of total lightning activity. These data files are available in compressed ASCII files and are available from March 1, 2017 through June 1, 2017.

Citations

There are seven citations, each for one of the Lightning Mapping Array systems, including Colorado, Washington DC, NASA's Kennedy Space Center, North Alabama, Oklahoma, Southern Ontario, and West Texas, respectively. Please select the appropriate citation for the data you are using:

GOES-R PLT Colorado Lightning Mapping Array (LMA)

Rutledge, Steven. 2019. GOES-R PLT Colorado Lightning Mapping Array (LMA) [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/GOESRPLT/LMA/DATA101

GOES-R PLT Washington D.C. Lightning Mapping Array (LMA)

Blakeslee, Richard. 2019. GOES-R PLT Washington D.C. Lightning Mapping Array (LMA) [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/GOESRPLT/LMA/DATA201

GOES-R PLT Kennedy Space Center Lightning Mapping Array (LMA)

Wilson, Jennifer G. and Robert G. Brown. 2019. GOES-R PLT Kennedy Space Center Lightning Mapping Array (LMA) [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/GOESRPLT/LMA/DATA301

GOES-R PLT North Alabama Lightning Mapping Array (LMA)

Blakeslee, Richard. 2019. GOES-R PLT North Alabama Lightning Mapping Array (LMA) [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/GOESRPLT/LMA/DATA401

GOES-R PLT Oklahoma Lightning Mapping Array (LMA)

MacGorman, Don and Alex Fierro. 2019. GOES-R PLT Oklahoma Lightning Mapping Array (LMA) [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/GOESRPLT/LMA/DATA501

GOES-R PLT Southern Ontario Lightning Mapping Array (LMA)

Sills, David. 2019. GOES-R PLT Southern Ontario Lightning Mapping Array (LMA) [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/GOESRPLT/LMA/DATA601

GOES-R PLT West Texas Lightning Mapping Array (LMA)

Bruning, Eric. 2019. GOES-R PLT West Texas Lightning Mapping Array (LMA) [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/GOESRPLT/LMA/DATA701

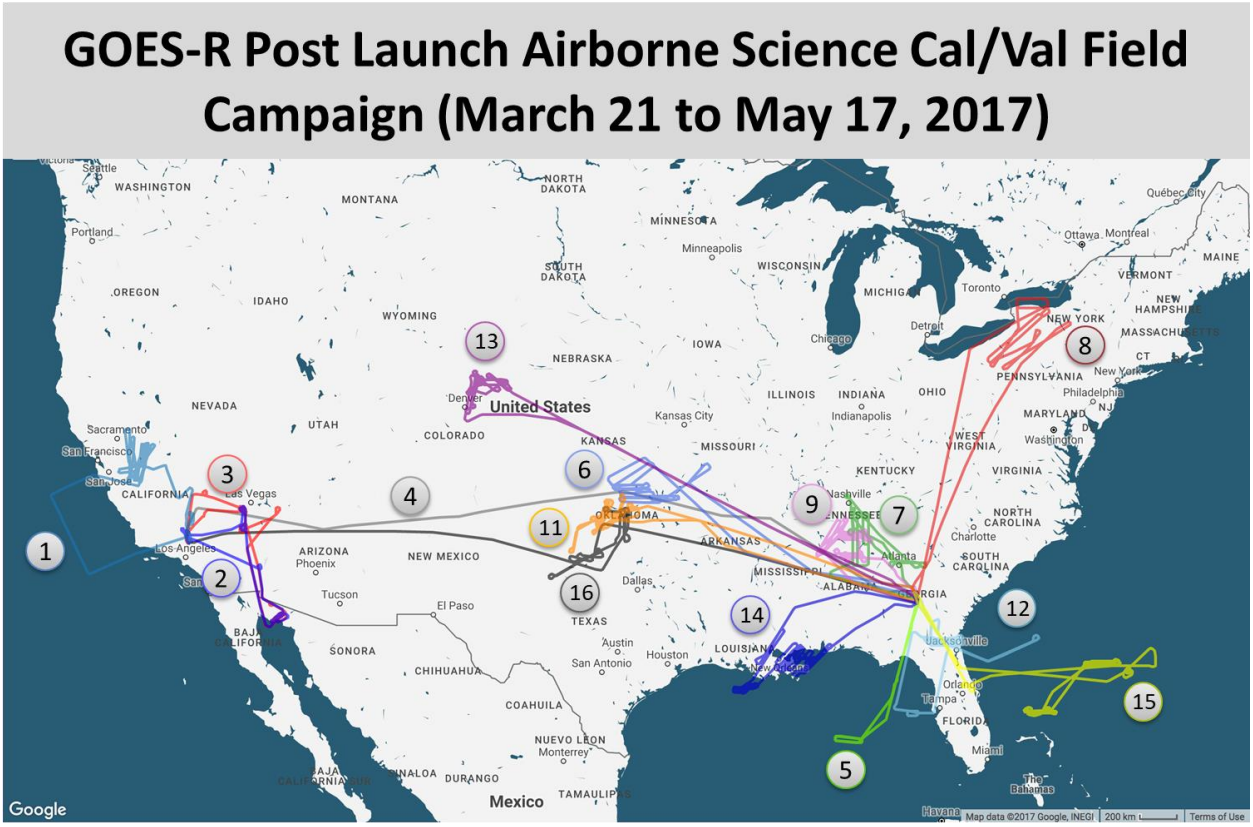
Keywords:

NASA, GHRC, Colorado, Washington D.C., KSC, North Alabama, Oklahoma, Southern Ontario, West Texas, GOES-R, PLT, GLM, lightning, LMA, COLMA, DCLMA, KSCLMA, NALMA, OKLMA, SOLMA, WTXLMA

Campaign

The Geostationary Operational Environmental Satellite-R (GOES-R) series is a four-satellite program including GOES-R, GOES-S, GOES-T, and GOES-U. The GOES-R Series Program is a collaborative development and acquisition effort between the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) to develop, launch and operate the satellites. The first satellite in the GOES-R series, GOES-R, launched on November 19, 2016 and became GOES-16 when it reached geostationary orbit. GOES-16 replaced GOES-13 as NOAA's operational GOES East satellite at 75.2 degrees west longitude on December 18, 2017. GOES-16 observes North and South America, as well as the Atlantic Ocean all the way to the west coast of Africa. GOES-16 provides high spatial and temporal resolution imagery of the Earth using its Advanced Baseline Imager (ABI). GOES-16's Geostationary Lightning Mapper (GLM) is the first operational lightning mapper flown in geostationary orbit. GOES-16 also includes four other scientific instruments for monitoring space weather and the Sun.

The GOES-R PLT airborne science field campaign took place between March 21 and May 17, 2017 in support of the post-launch validation of NOAA's new generation of geostationary Earth observing instruments: ABI and GLM (Figure 1). The validation effort included targeted data collections from a NASA ER-2 high-altitude aircraft integrated with nine payloads (both passive and active instruments) coordinated with ground based and low earth-orbit referenced data from several operational and research satellite missions. Sixteen ER-2 aircraft validation missions, totaling 105.1 mission flight hours, were conducted over ideal Earth validation targets, such as deserts and oceans, thunderstorms, active wildfires, and an expansive set of cloud and moisture phenomenology. Dedicated ABI 30-second mesoscale (MESO) imagery collections were conducted concurrent with the ER-2 high-altitude aircraft based sensors during each GLM mission. The GOES-R PLT field campaign provided critical reference data and new insights into the performance NOAA's new generation of geostationary Earth observing instrument products. More information about the GOES-R PLT field campaign is available at https://www.goes-r.gov/mission/fieldCampaignBegins.html and https://www.goes-r.gov/multimedia/events/goes16FieldCampaign.html.



*Flight #10 - April 27, 2017 - Huntsville, AL not shown due to aircraft navigation not reporting

Figure 1: GOES-R PLT airborne science field campaign
(Image Source: Frank Padula)

Instrument Description

The Lightning Mapping Array (LMA) is a three-dimensional total lightning location system. The system measures the arrival time of impulsive Very High Frequency (VHF) radiation from lightning discharges at multiple stations, and uses the arrival times to locate the sources of the radiation to produce a three-dimensional map of total lightning activity. LMAs generally consist of 6 to 20 antennas with baselines, or the distances between individual sensors, of kilometers. Each antenna has a computer that records the time and power of the strongest pulse in 10 microsecond bins. After a lightning flash, the times of radio frequency pulses measured by each antenna can be analyzed with a time of arrival (TOA) technique (Proctor, 1971), and the lightning flash can be mapped out in three spatial dimensions and time (Rison et al., 1999).

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Data Characteristics

The GOES-R PLT Lightning Mapping Array (LMA) datasets consist of total lightning estimates measured from multiple LMA systems, including Colorado, Washington DC, NASA's Kennedy Space Center, North Alabama, Oklahoma, Southern Ontario, and West Texas, during the GOES-R PLT airborne science field campaign. Data files are in ASCII format at a Level 1B processing level. More information about the NASA data processing levels are available on the EOSDIS Data Processing Levels webpage. Table 1 shows the characteristics of this dataset.

Table 1: Data Characteristics

Characteristic	Description
Platform	Ground station network
Instrument	Lightning Mapping Array (LMA)
Spatial Coverage	COLMA: N: 40.456, S: 40.436, E: -104.627, W: -104.647

	DCLMA: N: 38.899, S: 38.879, E: -77.159, W: -77.179 KSCLMA: N: 28.596, S: 28.576, E: -80.641, W: -80.661 NALMA: N: 34.735, S: 34.715, E: -86.635, W: -86.655 OKLMA: N: 35.289 , S: 35.269, E: -97.908, W: -97.928 SOLMA: N: 43.676, S: 43.656, E: -79.596, W: -79.616 WTXLMA: N: 33.617, S: 33.597, E: -101.813, W: -101.833
Spatial Resolution	Point
Temporal Coverage	March 1, 2017 to June 1, 2017 COLMA: March 1, 2017 to May 31, 2017* DCLMA: April 6, 2017 to June 1, 2017* KSCLMA: March 1, 2017 to June 1, 2017 NALMA: March 1, 2017 to June 1, 2017 OKLMA: March 1, 2017 to June 1, 2017 SOLMA: April 1, 2017 to June 1, 2017 WTXLMA: March 1, 2017 to June 1, 2017
Temporal Resolution	COLMA, KSCLMA, OKLMA, SOLMA, WTXLMA: every 10 minutes a file DCLMA, NALMA: every 1 hour a file
Sampling Frequency	10 microseconds
Parameter	Lightning
Version	1
Processing Level	1B

*Have missing data files shown in the 'Missing Data' section below

File Naming Convention

The GOES-R PLT Lightning Mapping Array (LMA) data files are available in compressed ASCII files and are available at a Level 1B processing level. These data and browse files have the following file naming convention:

Data files: goesr_plt_<network>_YYYYMMDD_<hhmmss|hh>_[0600|3600].[dat|qua|aux].gz

Table 2: File naming convention variables

Variable	Description
network	LMA network: COLMA, DCLMA, KSCLMA, NALMA, OKLMA, SOLMA, WTXLMA
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
hh	Two-digit hour in UTC
mm	Two-digit minute in UTC
ss	Two-digit second in UTC
dat|qua|aux	qua - quality

	aux - auxiliary dat - analyzed data
0600|3600	Number of seconds analyzed
.gz	Compressed file

Data Format and Parameters

The GOES-R PLT Lightning Mapping Array (LMA) datasets contain three types of data files (*.dat, *.qua, *.aux) in compressed ASCII format. All seven datasets have *.dat files. Each *.dat file contains a multiple-line file header describing product-specific attributes (summarized in Table 3). A '***data***' line marks the end of the file header. Following the header are 7 columns of data fields (Table 4). Each row of data represents one lightning source event (i.e., an individual piece of a larger lightning flash). In addition to *.dat files, both the NALMA and WTXLMA datasets provide *.qua files, and the WTXLMA dataset includes *.aux files. The *.qua file header section ends with a line of '*** data ***'. Each data records contains a single line data header (formatted as 'yy/mm/dd, hh:mm:ss, second-of-day, sources') and 8 rows of data fields (Table 4). The *.aux file contains auxiliary data corresponds to one of the lightning source events recorded in the *.dat file. Each set of auxiliary data includes 12 times, 12 raw powers, 12 above thresholds and 10 covariance elements (upper triangle, 0=[0][0], 1=[0][1] … 9=[3][3]), where 12 is the total number of stations of WTXLMA.

Table 3: Product-specific attributes in LMA data file header.

	COLMA	DCLMA	KSCLMA	NALMA	OKLMA	SOLMA	WTXLMA
number of seconds analyzed	600	3600	600	3600	600	600	600
Coordinate center (lat, lon, alt)	40.446, -104.637, 1000.00	38.889, -77.169, 30.00	28.586, -80.651, -2000	34.725, -86.645, 0.00	35.279, -97.918, 417.90	43.666, -79.606, -200.00	33.607, -101.823, 984.00
number of stations	21	10	13	20	18	15	12
number of active stations	8	5	9	13	17	12	10
Minimum number of stations per solution	6	5	6	6	6	6	5
maximum reduced chi-squared	5	5	5	2	5	5	5
maximum number of chi-squared iterations	20	20	20	20	20	20	20

Table 4: Data fields in LMA *.dat files.

Column	Data field	Unit
1	Time	Second of day in UTC

2	Latitude	Degree North
3	Longitude	Degree East
4	Altitude	Meter
5	Reduced Chi-squared	-
6	VHF source power radiated by lightning	dBW
7	mask	-

Table 4: Data fields in LMA *.qua files.

row	Data field	Unit
1	Station id	-
2	Triggers	-
3	Solutions	-
4	Contribution	%
5	Average P/P_med	-
6	Satellites	-
7	Threshold	-
8	Data loss flag	-

Algorithm

The use of time of arrival (TOA) technique for locating a lightning flash was pioneered by D. E. Proctor in South Africa (Proctor, 1971, 1981; Proctor et al., 1988).

The time of arrival (t_i) of the VHF signal at station i is

$$t_i = t + \frac{\sqrt{(x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2}}{c} \quad (1)$$

Where t is the time the radiation is emitted from source location (x, y, z), (x_i, y_i, z_i) is the location of station i, and c is the speed of light. With the time of arrival of the radiation from a breakdown event measured at six or more stations, the four unknowns x, y, z and t can be found with the least-squares fit to Equation (1).

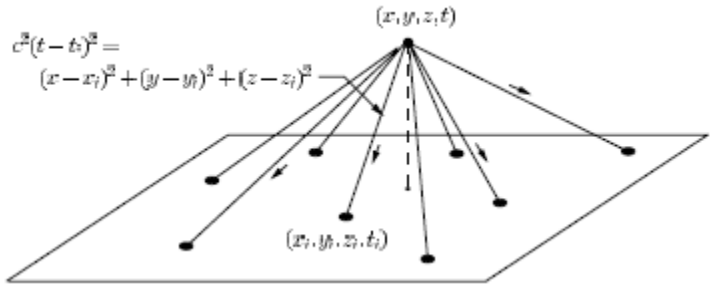

Figure 2: Basic TOA technique. Measurements of the arrival times t_i at N>=4 locations are used to determine the location and time of the source event (x, y, z, t).

(Image source: Thomas et al., 2004)

Quality Assessment

The accuracy of the lightning source locations depends on the uncertainty of the arrival time measurements and on the number and positions of the stations used to obtain each solution. The arrival times are measured independently at each station using an accurate time base provided by a GPS receiver. Sources over the LMA network are located with an uncertainty of 6-12 m root-mean-square (rms) in the horizontal and 20–30 m rms in the vertical. This corresponds well with the uncertainties of the arrival time measurements, determined from the distribution of chi-square values to be 40–50 ns rms. Outside the network the location uncertainties increase with distance. The range (r) and altitude errors increase as the range squared, r^2, while the azimuthal error increases linearly with the range (Thomas et al., 2004).

Software

No software is required to view these ASCII data files.

Known Issues or Missing Data

COLMA does not have data files for March 3, 16, 18 and 27, 2017; DCLMA does not have data files for April 8, 9 and 10, 2017.

References

Proctor, D. E. (1971). A Hyperbolic System for Obtaining VHF Radio Pictures of Lightning. J. Geophys. Res., 76, 1478-1489. doi: https://doi.org/10.1029/JC076i006p01478

Proctor, E. E. (1981). VHF radio pictures of cloud flashes. J. Geophys. Res., 86, 4041-4071. doi: https://doi.org/10.1029/JC086iC05p04041

Proctor, D. E., R. Uytenbogaardt, and B. M. Meredith (1988). VHF radio pictures of lightning flashes to ground. J. Geophys. Res., 93, 12,683-12,727. Doi: https://doi.org/10.1029/JD093iD10p12683

Rison, W., R. J. Thomas, P. R. Krehbiel, T. Hamlin, and J. Harlin (1999). A GPS-based Three-Dimensional Lightning Mapping System: Initial Observations in Central New Mexico. Geophys. Res. Lett., 26, 3573–3576. doi: https://doi.org/10.1029/1999GL010856

Thomas, R. J., P. R. Krehbiel, W. Rison, S. J. Hunyady, W. P. Winn, T. Hamlin, and J. Harlin (2004). Accuracy of the Lightning Mapping Array. J. Geophys. Res., 109, D14207. doi: https://doi.org/10.1029/2004JD004549

Related Data

All datasets from GOES-R PLT field campaign can be considered related to this dataset. Other GOES-R PLT campaign data can be located using the GHRC HyDRO 2.0 search tool, by entering the term 'GOES-R PLT'.

Contact Information

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

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