Global Hydrology Resource Center

Data User Guide

Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations (RELAMPAGO) Lightning Mapping Array (LMA)

Introduction

The Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations (RELAMPAGO) Lightning Mapping Array (LMA) was an 11-station, ground-based network located in north-central Argentina from November 2018 to April 2019 in support of the RELAMPAGO field campaign. The RELAMPAGO campaign aimed to characterize the atmospheric conditions and terrain effects that facilitate the initiation and growth of intense weather systems in this region of South America. The LMA maps Very High Frequency (VHF) emissions from lightning in three dimensions. These emissions have also been grouped, temporally and spatially, into individual flashes, and the flash characteristics analyzed to produce gridded products. The dataset was produced by NASA Marshall Space Flight Center (MSFC), via an agreement with the National Oceanic and Atmospheric Administration (NOAA), in order to serve as a validation dataset for the Geostationary Lightning Mapper (GLM). These LMA data are available from November 8, 2018 through April 20, 2019 in ASCII, HDF5, and netCDF-4 format.

Notice:
There are data points outside of the RELAMPAGO LMA bounding box within the L1 and L2 data files. Use data in these files beyond the bounding box with caution.

Citation

Lang, Timothy. 2020. Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations (RELAMPAGO) Lightning Mapper Array (LMA) [indicate subset used]. Dataset available online from the

NASA Global Hydrology Resource Center DAAC, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/RELAMPAGO/LMA/DATA101

Keywords:

NASA, GHRC, NSF, NOAA, RELAMPAGO, LMA, VHF, GPS, lightning, Argentina, Córdoba

Campaign

The Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations (RELAMPAGO) field campaign was an international study conducted in the Córdoba Province of Argentina from 2018 to 2019. The campaign studied deep convection in the complex terrain regions of west-central Argentina. The campaign was a collaborative effort between the U.S. National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), Servicio Meteorológico Nacional, Ministry of Education, Culture, Science, and Technology of Argentina, among other organizations. High impact weather systems often impact central Argentina, near the Sierras de Córdoba mountain range. These are deep convective systems that can produce large hail and extreme lighting yet are not fully understood and represented in atmospheric models. The RELAMPAGO campaign aimed to characterize the atmospheric conditions and terrain effects that facilitate the initiation and growth of these intense weather systems in this region of South America. The campaign utilized various airborne and ground-based observations. Instruments included dual-polarization radars, soundings, lightning instruments, lidars, microwave profilers, mobile mesonets, and surface flux measurements. The stated science objectives of the field campaign were to to (1) characterize the pre-convective and convective environments, (2) characterize kinematic and microphysical properties of clouds and precipitation, convective outflows, atmospheric electrification, and hydrometeor size distributions, and (3) observe hydrometeorological interactions with convective systems in a region of repeatable observations. More information about the RELAMPAGO field campaign is available on the RELAMPAGO website.

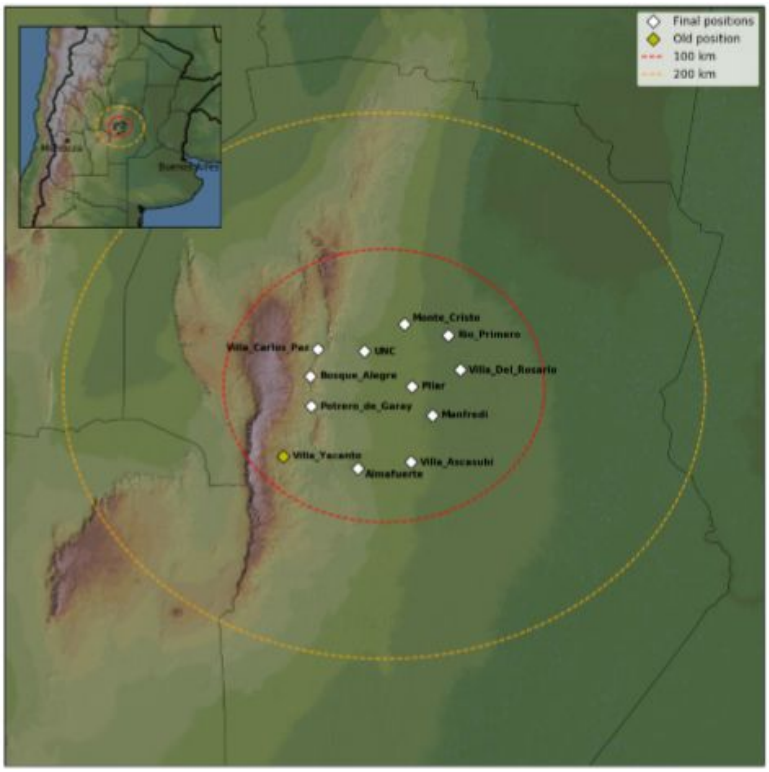

Figure 1: The RELAMPAGO LMA Network, near the Sierras de Córdoba mountains in central Argentina
(Image source: RELAMPAGO LMA Data Presentation)

Instrument Description

The RELAMPAGO Lightning Mapping Array (LMA) was a Very High Frequency (VHF) LMA system installed in the center of Córdoba province, Argentina by NASA Marshall Space Flight Center during the RELAMPAGO field campaign. A LMA is a network of antennas, GPS receivers, and processing systems that detect total lightning; including cloud-to-cloud (CC) and cloud-to-ground (CG) lightning. The system can determine the location and time of the lightning discharge based on the time it takes the VHF signal radiated by the discharge to arrive at the various antenna stations. When a signal is detected, the antenna stations transmit the time at which they received the signal back to the central station. The LMA processing system then calculates the time, latitude, longitude, and altitude of the lightning source using the known distances between each antenna and the difference in the signal time-of-arrival at each of the VHF antennas. There were 11 antenna stations installed for the RELAMPAGO LMA. These LMA antenna stations are typically placed 15 to 20 km apart over a region 60 to 80 km in diameter. Each antenna is equipped with a GPS receiver for time synchronization and wirelessly connected to the central computer station that does the data processing. The antennas are adjusted to only capture events with a signal magnitude above a certain threshold, indicating lightning activity. The LMA detects the various segments of the lightning channel as it develops, revealing the evolution of the lightning structure during discharge. In addition to the campaign's science goals, the

RELAMPAGO LMA also provided validation measurements for the Geostationary Lightning Mapper (GLM) onboard NOAA's GOES satellites. More information about the RELAMPAGO LMA is available in the RELAMPAGO LMA Data Presentation.

Figure 2: A RELAMPAGO LMA VHF antenna station and associated solar panel.
(Image source: RELAMPAGO LMA Data Presentation)

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Data Characteristics

The Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations (RELAMPAGO) Lightning Mapping Array (LMA) dataset files are available at Level 1B (L1), Level 2 (L2), and Level 3 (L3) processing levels. There is one gzipped TAR file per day, each containing 10-minute data files once decompressed. The L1 data are stored in ASCII format, the L2 data in HDF5 format, and the L3 data in netCDF-4 format. More information about the NASA data processing levels is available on the EOSDIS Data Processing Levels webpage. The characteristics of this dataset are listed in Table 1 below.

Table 1: Data Characteristics

Characteristic	Description
Platform	Ground based
Instrument	Lightning Mapping Array (LMA)
Spatial Coverage*	N: -29.856, S: -33.464 , E: -61.959 , W: -66.166 (Córdoba province, Argentina)
Spatial Resolution	Horizontal: approx. 6 - 12 m

	Vertical: approx. 20 - 30 m
Temporal Coverage	November 8, 2018 - April 20, 2019
Temporal Resolution	Daily gzipped TAR files; 10-minute decompressed files
Sampling Frequency	80 - 100 μs
Parameter	Lightning
Version	1
Processing Level	1B, 2, 3

*Note: Some data points are outside of the RELAMPAGO LMA bounding box within the L1 and L2 data files. Use data in these files beyond the bounding box with caution.

File Naming Convention

The Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations (RELAMPAGO) Lightning Mapping Array (LMA) dataset includes files in ASCII, HDF5, and netCDF-4 formats. All files are compressed into gzipped TAR files (*.tar.gz). The dataset files are named using the following convention:

Gzipped L1 Data files: RELAMP_LMA_YYYYMMDD_level1.tar.gz
L1 Data files: RELAMP_LMA_YYYYMMDD_hhmmss_0600.dat

Gzipped L2 Data files: RELAMP_LMA_YYYYMMDD_level2.tar.gz
L2 Data files: goesrplt_REL_YYMMDD_hhmmss_0600.flash.h5

Gzipped L3 Data files: RELAMP_LMA_YYYYMMDD_level3.tar.gz
L3 Data files: goesrplt_REL_YYYYMMDD_hhmmss_600_<variable>.nc

Table 2: File naming convention variables

Variable	Description
YYYY	Four-digit year
YY	Two-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
variable	L3 data variable name: flash_extent flash_extent_3d flash_init flash_init_3d flashsize_std flashsize_std_3d footprint footprint_3d

	source source_3d specific_energy specific_energy_3d total_energy total_energy_3d
.dat	ASCII format
.h5	HDF5 format
.nc	netCDF-4 format
.tar.gz	Gzipped TAR archive

Data Format and Parameters

The Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations (RELAMPAGO) Lightning Mapping Array (LMA) dataset is composed of L1, L2, and L3 LMA data files. There is one gzipped TAR file per day, and each of these files contain 10-minute data files once decompressed. The L1 data consist of VHF source locations in ASCII LMA format. The L2 data consist of identified flashes in HDF5 format. The L3 data consist of gridded flash products in netCDF-4 format. The time format for all files is *hhmmss* and each file time starts (and ends) one second after each 10-minute period (e.g., 000001, 001001, 002001, etc.) due to how the Level 0 data were recorded. Each level of data is described in detail in the sections below.

Level 1B

The L1 files are stored in ASCII format. Each file begins with a header that lists processing and station information such as data start time, number of seconds analyzed, and number of stations. Following the header are the data fields, listed in Table 3 below. More information is available in the L1 Data Documentation.

Table 3: ASCII Data Fields

Field Name	Description	Unit
time	Second of day in UTC	sec
lat	Latitude	degrees
lon	Longitude	degrees
alt	Altitude above the WGS84 ellipsoid	m
Reduced chi^2	Chi-squared goodness-of-fit	-
P	VHF source power	dBW
mask	Hexadecimal mask containing information on number of stations detecting source	-

Level 2

The L2 data files are stored in HDF5 format with two main data groups: “events” and “flashes.” Within each group are the data variables, listed in Table 4 below. More information is available in the L2 Data Documentation.

Table 4: HDF5 Data Fields

Group	Field Name	Description	Data Type	Unit
events	alt	Altitude above the WGS84 ellipsoid	float	m
	charge	Charge identification (always 0)	int	-
	chi2	chisqr value for the VHF source	float	-
	flash_id	Matches each relevant source to its parent flash in the "flashes" table -- see below	int	-
	lat	Latitude	float	degrees
	lon	Longitude	float	degrees
	mask	Hexadecimal mask	str	-
	power	VHF source power	float	
	stations	Number of stations contributing to source's location solution	int	-
	time	Second of day; note that source data from the 2350 UTC file from each day end 1 second into the following day	double	-
flashes	area	Area	float	km^2
	ctr_alt	Altitude of flash centroid above the WGS84 ellipsoid	float	m
	ctr_lat	Decimal latitude of flash centroid	float	degrees
	ctr_lon	Decimal longitude of flash centroid	float	degrees
	duration	Duration of flash	float	seconds
	flash_id	Unique identification number of each flash	int	-
	init_alt	Altitude of flash initiation above the WGS84 ellipsoid	float	m
	init_lat	Decimal latitude of flash initiation	float	degrees
	init_lon	Decimal longitude of flash initiation	float	degrees
	init_pts	Not used; always empty	str	-
	n_points	Number of sources in flash	int	-
	specific_energy	Specific energy	float	J/kg
	start	Second of day for first source in flash; note that flash data from the 2350 UTC file from each day end 1 second into the following day	double	-
	total_energy	Total energy	float	J
	volume	Volume	float	km^3

Level 3

The L3 data are stored in netCDF-4 format and gridded into 1-km resolution grids (all dimensions); binned every minute. There are both 2-dimensional and 3-dimensional data

structures for each variable, with just one variable per file. Each file type is described in Tables 5 - 18 below. More information is available in the L3 Data Documentation.
Note: "crs" is the grid mapping name

Flash Extent (*_flash_extent.nc & *_flash_extent_3d.nc)
Flash extent density (i.e., number of flashes that pass through a given pixel/cube in the given time bin).

Table 5: Data fields for *flash_extent.nc

Field Name	Description	Data Type	Unit
crs	-	int	-
latitude	Latitude	float	degrees_north
longitude	Longitude	float	degrees_east
time	Time	float	Seconds since 2018-11-25 00:00:00
flash_extent	LMA flash extent density	int	Count per grid pixel per 1.0 min

Table 6: Data fields for *flash_extent_3d.nc

Field Name	Description	Data Type	Unit
crs	-	int	-
latitude	Latitude	float	degrees_north
longitude	Longitude	float	degrees_east
altitude	Height above mean sea level	float	km
time	Time	float	Seconds since 2018-11-25 00:00:00
flash_extent	LMA flash extent density	int	Count per grid pixel per 1.0 min

Flash Initiation (*_flash_init.nc & *_flash_init_3d.nc)
Number of flashes that initiated within the given pixel/cube and time bin.

Table 7: Data fields for *flash_init.nc

Field Name	Description	Data Type	Unit
crs	-	int	-
latitude	Latitude	float	degrees_north
longitude	Longitude	float	degrees_east
time	Time	float	Seconds since 2018-11-25 00:00:00
flash_initiation	LMA flash initiation density	int	Count per grid pixel per 1.0 min

Table 8: Data fields for *flash_init_3d.nc

Field Name	Description	Data Type	Unit
crs	-	int	-
latitude	Latitude	float	degrees_north
longitude	Longitude	float	degrees_east
altitude	Height above mean sea level	float	km
time	Time	float	Seconds since 2018-11-25 00:00:00
flash_initiation	LMA flash initiation density	int	Count per grid pixel per 1.0 min

Flash Size Standard Deviation (*_flashsize_std.nc & *_flashsize_std_3d.nc)
Standard deviation of flash sizes within the grid element.

Table 9: Data fields for *flashsize_std.nc

Field Name	Description	Data Type	Unit
crs	-	int	-
latitude	Latitude	float	degrees_north
longitude	Longitude	float	degrees_east
time	Time	float	Seconds since 2018-11-25 00:00:00
flashsize_std	LMA local standard deviation of flash size	float	Count per grid pixel per 1.0 min

Table 10: Data fields for*flashsize_std_3d.nc

Field Name	Description	Data Type	Unit
crs	-	int	-
latitude	Latitude	float	degrees_north
longitude	Longitude	float	degrees_east
altitude	Height above mean sea level	float	km
time	Time	float	Seconds since 2018-11-25 00:00:00
flashsize_std	LMA local standard deviation of flash size	float	Count per grid pixel per 1.0 min

Flash Footprint (*_footprint.nc & *_footprint_3d.nc)
Footprints of flashes that occurred within the pixel/cube and time bin.

Table 11: Data fields for *footprint.nc

Field Name	Description	Data Type	Unit
crs	-	int	-
latitude	Latitude	float	degrees_north

longitude	Longitude	float	degrees_east
time	Time	float	Seconds since 2018-11-25 00:00:00
flash_footprint	LMA local mean flash area	float	km^2 per flash

Table 12: Data fields for *footprint_3d.nc

Field Name	Description	Data Type	Unit
crs	-	int	-
latitude	Latitude	float	degrees_north
longitude	Longitude	float	degrees_east
altitude	Height above mean sea level	float	km
time	Time	float	Seconds since 2018-11-25 00:00:00
flash_footprint	LMA local mean flash area	float	km^2 per flash

Flash Source (*_source.nc & *_source_3d.nc)
Number of sources that occurred in the grid element.

Table 13: Data fields for *source.nc

Field Name	Description	Data Type	Unit
crs	-	int	-
latitude	Latitude	float	degrees_north
longitude	Longitude	float	degrees_east
time	Time	float	Seconds since 2018-11-25 00:00:00
lma_source	LMA source density	int	Count per grid pixel per 1.0 min

Table 14: Data fields for *source_3d.nc

Field Name	Description	Data Type	Unit
crs	-	int	-
latitude	Latitude	float	degrees_north
longitude	Longitude	float	degrees_east
altitude	Height above mean sea level	float	km
time	Time	float	Seconds since 2018-11-25 00:00:00
lma_source	LMA source density	int	Count per grid pixel per 1.0 min

Flash Specific Energy (*_specific_energy.nc & *_specific_energy _3d.nc)
Specific energy of flashes that occurred within the pixel/cube and time bin.

Table 15: Data fields for *specific_energy.nc

Field Name	Description	Data Type	Unit
crs	-	int	-
latitude	Latitude	float	degrees_north
longitude	Longitude	float	degrees_east
time	Time	float	Seconds since 2018-11-25 00:00:00
specific_energy	LMA flash specific energy (approx)	float	J/kg per flash

Table 16: Data fields for *specific_energy_3d.nc

Field Name	Description	Data Type	Unit
crs	-	int	-
latitude	Latitude	float	degrees_north
longitude	Longitude	float	degrees_east
altitude	Height above mean sea level	float	km
time	Time	float	Seconds since 2018-11-25 00:00:00
specific_energy	LMA flash specific energy (approx)	float	J/kg per flash

Flash Total Energy (*_total_energy.nc & *_total_energy _3d.nc)
Total energy (J) of flashes that occurred within the pixel/cube and time bin .

Table 17: Data fields for *total_energy.nc

Field Name	Description	Data Type	Unit
crs	-	int	-
latitude	Latitude	float	degrees_north
longitude	Longitude	float	degrees_east
time	Time	float	Seconds since 2018-11-25 00:00:00
total_energy	LMA flash total energy (approx)	float	J per flash

Table 18: Data fields for *total_energy_3d.nc

Field Name	Description	Data Type	Unit
crs	-	int	-
latitude	Latitude	float	degrees_north
longitude	Longitude	float	degrees_east
altitude	Height above mean sea level	float	km

time	Time	float	Seconds since 2018-11-25 00:00:00
total_energy	LMA flash total energy (approx)	float	J per flash

Algorithm

Individual VHF sources were considered in the analysis based on their goodness-of-fit value. Flashes were identified following the Fuchs et al. (2016) algorithm. The criteria required for a flash were that there could be no more than 0.15 seconds or 3 km between successive sources, there had to be a maximum duration of 3 seconds, and there had to be a minimum of 5 sources in a flash.

Quality Assessment

Goodness-of-fit is a statistical test used to determine how well what is expected (e.g., a model) matches what is observed in the data. In general, the smaller the goodness-of-fit value, the better the fit. For the LMA data, it describes the goodness-of-fit for the VHF source location, time, and the number of stations contributing to the location retrieval. The RELAMPAGO dataset documentation states that individual VHF sources were considered in the analysis if their goodness-of-fit value chi-squared was less than or equal to five ($\chi^2 \leq 5$). More information about the use of chi-squared goodness-of-fit for LMA data is available in Fuchs et al. (2016).

Software

L1 data were created using the lma_analysis software package developed at New Mexico Tech and LMA Technologies. Contacts for this software are listed in the L1 Data Documentation. The L2 and L3 data were created using the lmatools Python package. The Python lmatools package can be used to ingest, analyze, and visualize the data. The XLMA software, available from New Mexico Tech, is another option for reading these data.

Table 19: Software/Tool Information Table

Name	Type	Access	Software	License
lmatools	Data ingest, analysis and visualization	Link	Python 3.6+	Open source

Known Issues or Missing Data

There are data points outside of the RELAMPAGO LMA bounding box within the L1 and L2 data files. Use data in these files beyond the bounding box with caution. The data bounding box coordinates are:
Latitude = -29.856252670288086 N, -33.46372985839844 S
Longitude = -66.16654205322266 W, -61.959259033203125 E

References

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Related Data

All datasets from the RELAMPAGO field campaign are considered related to this dataset. They can be located using the GHRC Hydro2.0 search tool and searching the term 'RELAMPAGO'. LMAs have also been deployed at other sites. The LMA data from other sites can be located by searching 'LMA' in Hydro2.0 and are listed below.

GOES-R PLT Colorado Lightning Mapping Array (LMA)
(http://dx.doi.org/10.5067/GOESRPLT/LMA/DATA101)

GOES-R PLT Washington D.C. Lightning Mapping Array (LMA)
(http://dx.doi.org/10.5067/GOESRPLT/LMA/DATA201)

GOES-R PLT Kennedy Space Center Lightning Mapping Array (LMA)
(http://dx.doi.org/10.5067/GOESRPLT/LMA/DATA301)

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

(http://dx.doi.org/10.5067/GOESRPLT/LMA/DATA401)

GOES-R PLT Oklahoma Lightning Mapping Array (LMA)
(http://dx.doi.org/10.5067/GOESRPLT/LMA/DATA501)

GOES-R PLT Southern Ontario Lightning Mapping Array (LMA)
(http://dx.doi.org/10.5067/GOESRPLT/LMA/DATA601)

GOES-R PLT West Texas Lightning Mapping Array (LMA)
(http://dx.doi.org/10.5067/GOESRPLT/LMA/DATA701)

Contact Information

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

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