Data User Guide

North Alabama Lightning Mapping Array (NALMA) Dataset Collection

Introduction

The North Alabama Lightning Mapping Array (NALMA) dataset collection includes three different NALMA datasets: North Alabama Lightning Mapping Array (NALMA), Near Real-Time (NRT) North Alabama Lightning Mapping Array (NALMA), and North Alabama Lightning Mapping Array (NALMA) Raw Data. These data are used to validate the Lightning Imaging Sensor (LIS) on the International Space Station (ISS), the Geostationary Lightning Mapper (GLM) instrument, and other current and future lightning measurements. These data are also used in convective storm process studies, including but not limited to validation of convection-resolving models that predict lightning. These NALMA dataset files are available from December 17, 2018 and are ongoing in ASCII format.

Citation

Lang, Timothy, Richard Blakeslee, Matthew Wingo, William Rison, Daniel Rodeheffer, and Paul Krehbiel. 2020. North Alabama Lightning Mapping Array (NALMA) [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/NALMA/DATA101

Lang, Timothy, Richard Blakeslee, Matthew Wingo, William Rison, Daniel Rodeheffer, and Paul Krehbiel. 2020. NRT North Alabama Lightning Mapping 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/NALMA/DATA201

Lang, Timothy, Richard Blakeslee, Matthew Wingo, William Rison, Daniel Rodeheffer, and Paul Krehbiel. 2020. North Alabama Lightning Mapping Array (LMA) Raw Data [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/NALMA/DATA301

Keywords:

GHRC, NALMA, LMA, North Alabama, lightning

Instrument Description

A Lightning Mapping Array (LMA) is a three-dimensional total lightning location system. Total lightning includes both lightning that occurs within the clouds and lightning that reaches the ground. The system determines the location and time of lightning discharge based on the time it takes the very high frequency (VHF) signal radiated by the discharge to arrive at the various antenna stations. LMAs generally consist of 6 to 20 antennas placed 15 to 20km apart over a region 60 to 80 km in diameter. The antennas can detect hundreds of sources per lightning flash over a domain extending around 200 km from the central point of the antenna network. Each antenna is adjusted to only capture events with a signal magnitude above a certain threshold, indicating lightning activity. 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). The North Alabama Lightning Mapping Array (NALMA) came into operation in 2001 and is located over the greater North Alabama region. The NALMA antenna locations are listed in Table 1 below.

Table 1: NALMA Site Locations

Site name	Latitude	Longitude
firetower	34.809	-87.036
boeing	34.643	-86.771
annex	34.725	-86.645
keel	34.666	-86.359
mtsano	34.746	-86.513
ardmore	34.984	-86.839
aamu	34.900	-86.558
green	34.612	-86.520
hospital	34.523	-86.968
courtland	34.658	-87.343
pulaski	35.153	-87.061
fayetteville	35.068	-86.562

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Data Characteristics

The North Alabama Lightning Mapping Array (NALMA) datasets consists of total lightning data collected by NALMA antenna stations over the Southeast United States. Data files are available 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. The characteristics of these datasets are listed in Table 2 below.

Table 2: Data Characteristics

Characteristic	Description
Platform	Ground stations
Instrument	North Alabama Lightning Mapping Array (NALMA)
Spatial Coverage	N: 36.725 , S: 32.725, E: -84.645, W: -88.645 (Southeast U.S.)
Spatial Resolution	point
Temporal Coverage	December 17, 2018 - ongoing*
Temporal Resolution	Every 1 hour
Sampling Frequency	10 microseconds
Parameter	lightning
Version	1
Processing Level	1B

*Start date varies per station

File Naming Convention

The North Alabama Lightning Mapping Array (NALMA) dataset files are stored in compressed ASCII format. These data files have the following file naming convention:

Compressed NALMA/NRT NALMA files: NALMA_YYMMDD_hhmmss_<####>.dat.gz
Compressed NALMA Raw Data files: L<X>_NALMA_<station>_YYMMDD_hhmmss.dat.gz

Decompressed NALMA/NRT NALMA files: NALMA_YYMMDD_hhmmss_<####>.dat
Decompressed NALMA Raw Data files: L<X>_NALMA_<station>_YYMMDD_hhmmss.dat

Table 3: File naming convention variables

Variable	Description
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
station	NALMA antenna site: firetower, boeing, annex, keel, mtsano, ardmore, aamu, green, hospital, courtland, pulaski, or fayetteville
####	Number of seconds analyzed
X	NALMA station ID: A, B, C, D, E, F, G, H, J, K, or M
.dat	Analyzed ASCII data file
.gz	GNU zip archive file

Data Format and Parameters

The North Alabama Lightning Mapping Array (NALMA) dataset collection consists of 3 datasets: NALMA, NRT NALMA, and NALMA Raw Data. Each dataset consists of compressed ASCII data files (*.dat) and are described in further detail below.

NALMA Raw Data Dataset

The NALMA Raw Data dataset consists of the raw NALMA data and the files are separated by antenna site.

NALMA and NRT NALMA Datasets

The NALMA and NALMA NRT datasets contain the processed LMA data. The NALMA NRT data are decimated in order to function in near real-time, while the NALMA dataset is the full dataset without decimation. Each file begins with a header that lists the data start time, number of seconds analyzed, location, coordinate center, number of stations, active stations, station information, station data, and other variables. The general header information is listed first and an example of this section is shown in Figure 1.

```
Lightning Mapping Array analyzed data
Analysis program: /lma/bin/lma_analysis -d 20200827 -t 051000 -s 600 -g /lma/etc/nalma.gps -o /data/lma/nalma/fullrate/2020/08/27
Analysis program version: 10.14.9R
File created: Thu Aug 27 13:01:45 2020
Data start time: 08/27/20 05:10:00
Number of seconds analyzed: 600
Location: NALMA
Coordinate center (lat,lon,alt): 34.7246100 -86.6453300 0.00
Coordinate frame: cartesian
Maximum diameter of LMA (km): 70.985
Maximum light-time across LMA (ns): 236828
Number of stations: 11
Number of active stations: 7
Active stations: B C D G J K M
Minimum number of stations per solution: 6
Maximum reduced chi-squared: 5.00
Maximum number of chi-squared iterations: 20
```

Figure 1: General Header Information Section from a NALMA file

Next, the header station information and station data are listed for each available NALMA station. An example of the station information section is shown in Figure 2 along with field descriptions in Table 4. An example of the station data section is shown in Figure 3 along with field descriptions in Table 5.

```
Station information: id, name, lat(d), lon(d), alt(m), delay(ns), board_rev, rec_ch
Sta_info: A  firetower          34.8092586  -87.0357225   207.62  720 3  3
Sta_info: B  boeing             34.6433808  -86.7714025   174.40  822 3  3
Sta_info: C  annex              34.7253536  -86.6449781   198.30  815 3  3
Sta_info: D  keel               34.6656331  -86.3586129   486.50  999 3  3
Sta_info: E  mtsano             34.7455622  -86.5126506   507.40  962 3  3
Sta_info: F  ardmore            34.9836496  -86.8393545   288.10  945 3  3
Sta_info: G  aamu               34.8996936  -86.5578487   218.60  945 3  3
Sta_info: H  green              34.6121906  -86.5196873   465.20  954 3  3
Sta_info: J  hospital           34.5231382  -86.9681644   213.70  918 3  3
Sta_info: K  annex              34.7253536  -86.6449781   198.30  815 2  5
Sta_info: M  fayetteville       35.0684567  -86.5624089   276.69   22 3  3
```

Figure 2: Header Station Information

Table 4: Station Information Fields

Field Name	Description	Unit
id	Station ID	-
name	Station name	-
lat	Latitude	degrees
lon	Longitude	degrees
alt	Altitude	m
delay	Delay	ns
board_rev	Board revision	-
rec_ch	Receiving channel number	-

```
Station data: id, name, win(us), dec_win(us), data_ver, rms_error(ns), sources, %, <P/P_m>, active
Sta_data: A  firetower            0     0   70        0   0.0  0.00  NA
Sta_data: B  boeing              80    10   70       11 100.0  0.02   A
Sta_data: C  annex               80    10   70       11 100.0  1.18   A
Sta_data: D  keel                80    10   70       11 100.0  6.07   A
Sta_data: E  mtsano               0     0   70        0   0.0  0.00  NA
Sta_data: F  ardmore              0     0   70        0   0.0  0.00  NA
Sta_data: G  aamu                80    10   70       11 100.0  0.08   A
Sta_data: H  green                0     0   70        0   0.0  0.00  NA
Sta_data: J  hospital            80    10   70       11 100.0  0.98   A
Sta_data: K  annex               80    10   70        0   0.0  0.00   A
Sta_data: M  fayetteville        80    10   70       11 100.0  1.61   A
Metric file version: 4
Station mask order: MKJHGFEDCBA
```

Figure 3: Header Station Data

Table 5: Station Data Fields

Field Name	Description	Unit
id	Station ID	-
name	Station name	-
win	Window length	µs
dec_win	Decimated window length	µs
data_ver	Data version	-
rms_error	RMS Error	ns
sources	Number of sources	-
%	Percent contribution	%
<P/P_m>	Average P/P_med	dBW
active	Active station flag (A: active, NA: not active)	-

The last section is the data section. The data field names, data format, and number of events are listed first. The '***data***' line marks the end of the file header and the start of the actual NALMA data. An example of this section is shown in Figure 4. The NALMA data field descriptions are listed in Table 6.

```
Data: time (UT sec of day), lat, lon, alt(m), reduced chi^2, P(dBW), mask
Data format: 15.9f 12.8f 13.8f 9.2f 6.2f 5.1f 5x
Number of events: 11
*** data ***
19002.810494692  36.54657579  -90.77496131  47628.16   2.43  23.2 0x54e
19002.979690607  36.15454310  -89.96110914  26640.00   0.32  17.5 0x54e
19003.229390853  36.20584141  -90.00221595  21048.46   1.27  17.6 0x54e
19021.593008915  35.86533915  -89.80318599  18969.00   1.46  17.9 0x54e
```

Figure 4: NALMA data section

Table 6: Data Fields

Field Name	Description	Unit
time	Time in UTC (sec of day)	-
lat	Latitude	Degree North
lon	Longitude	Degree East

alt	Altitude	m
reduced chi^2	Reduced Chi-squared	-
P	VHF source power radiated by lightning	dBW
mask	Hexadecimal Mask value to identify which stations observed an individual event	-

Note: The "Number of events" header field states the number of events contained in the file. If this field is listed as "0", there will be no data listed in the file after the '*** data ***' marker.

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) shown above.

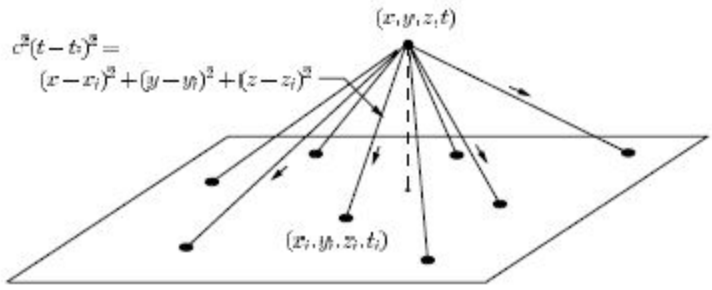

Figure 5: Basic TOA technique. Measurements of the arrival times t_i at N>=4 locations are used to determine the location and time of the source event (x, y, z, t).
(Image source: Thomas et al., 2004)

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

The NALMA and NRT NALMA **.dat* files can be viewed in any text editor, such as Notepad however, the NALMA Raw Data **.dat* files contain raw data and are not viewable in a standard text editor.

Known Issues or Missing Data

If there were no lightning events recorded for a particular day, the NALMA data file will only include header information.

References

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Related Data

All datasets using LMAs are considered related to this dataset. Other LMA data can be found using the GHRC HyDRO 2.0 search tool by entering the term 'LMA'. Below is a list of datasets that used the NALMA instrument.

GOES-R PLT North Alabama Lightning Mapping Array (LMA) (http://dx.doi.org/10.5067/GOESRPLT/LMA/DATA401)

Contact Information

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

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Web: https://ghrc.nsstc.nasa.gov/

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