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WWLLN Data User Manual

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Abstract

The World Wide Lightning Location Network (WWLLN) provides continuous global lightning monitoring and detection. This document is a user guide for Los Alamos National Laboratory (LANL) ISR-2 users of the WWLLN data. At LANL we collect and archive these data on a daily basis. This document describes the WWLLN data, how they are collected and archived, and how to use the data at LANL.

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Contents

1 World Wide Lightning Location Network

The World Wide Lightning Location Network (WWLLN) is a global network of more than 60 very-low-frequency (VLF; 3-30kHz) receivers. WWLLN locates and time-tags lightning from anywhere around the world. The network is hosted by the University of Washington and the sensors are deployed and maintained by various research institutes and universities. LANL ISR-2 hosts one of the sensors on top of the SM-40 building. The main WWLLN website can be found at `www.wwlln.net`.

The detection efficiency (DE) of WWLLN has increased as the network has grown. Most published estimates of WWLLN DE are around 10% globally [1][2], although some regions have greater DE due to better station coverage. Recent work has been done to characterize the relative detection efficiency dependent on location and universal time [3] and to estimate the radiated energy from each lightning stroke [4]. WWLLN has been found to detect nearly every lightning-producing storm [5], which is useful if you need to determine if a given region is electrically active at a given time or not.

2 Data Access

2.1 Yellow Network Usage

If you want to access and analyze WWLLN files on the Yellow Network, you should be a member of the ISR-3 scheme group `wwln`. Note that there is only one "L" in the group name. If you are not yet a member of the group, email Aaron Morrison to be added to the group. The WWLLN directory on the Yellow Network is then found in the `wwln` projects directory on the ISR-3 scheme. All the data and codes described in this manual are stored in this `wwln` projects directory.

2.2 Red Network Usage

The path to access WWLLN data and codes on the Red Network is found in the `emp` project directory under the folder `wwlln/hdf5/`. New WWLLN data is currently uploaded to the Red Network at the beginning of each month. If you need a particular day of data sooner than that on the red, please contact Erin Lay to move it up to the Red Network. Alternatively, you could just move it yourself if you have Yellow access to the `wwln` group.

3 WWLLN Daily Files

3.1 Archive Procedure

There is a cron procedure that is run daily to pull the daily ascii WWLLN file from the University of Washington server and process it to an HDF5 file for storage on the ISR

scheme. The ascii file is titled `Ayyyymmdd.loc`, where `yyyymmdd` is the year, month, day string of the data. Each line of a `*.loc` file refers to one WWLLN-detected lightning event in the following format:

`yyyy/mm/dd, hr:mi:second, latitude, longitude, timing error (`μ`s), # of stations detecting the event`.

For example, the first few lines of `A20150201.loc` are as follows:

2015/02/01,00:00:00.219715,-15.3046, -50.6718, 18.9, 5

2015/02/01,00:00:00.608029, 3.6370, 83.9473, 15.7, 9

2015/02/01,00:00:01.412014,-39.1283, -64.4658, 23.4, 12

2015/02/01,00:00:01.499557, 34.8194, -59.4852, 19.9, 7

The daily cron process for WWLLN data does the following:

1. Copies the daily ascii file with WWLLN locations from the University of Washington server to the `ascii/` folder in the `wwln` project directory.
2. Checks for completeness of the file.
3. Converts the ascii file to HDF5 format, and saves to the `yyyy/` folder in the `wwln` project directory, where `yyyy` is the year for the data file. The HDF5 file name is `Ayyyymmdd.loc.h5`.
4. Zips the ascii file, and moves it to `/n/archive/projects/forte/archive/wwll/yyyy/mm/`.

The saved HDF5 files are of the format described in [6], typical of the HDF5 files used in on-orbit data processing. The UNIX epoch seconds (i.e. seconds past midnight on 1-Jan-1970) and microseconds are saved as the "time" group, while all the other characteristics (latitude, longitude, residual, number of stations) are saved in the "data" group.

A retired cron process converted the WWLLN ascii files to binary. These binaries were named `Lyyyymmdd.bin.gz` files. All old binary files have been converted to HDF5 at this time. However, if a user still has an old binary file, the current WWLLN IDL programs presented in Section 3.2 will work on either binary or HDF5 files.

3.2 Basic Usage

There are several IDL routines that have been written to easily read and plot WWLLN data in IDL code. These routines can be found in `code/pro/` folder in the `wwln` projects directory on the ISR scheme.

To read in the WWLLN data to IDL use `read_wwlln.pro` with the following syntax:

```
IDL> data=read_wwlln(yyyymmdd)
```

where `yyyymmdd` is a string representing year, month, day.

To plot the WWLLN data that was read into the variable `data` from the call to `read_wwlln.pro`, use `map_wwlln.pro` with the following syntax:

```
IDL> map_wwlln, data, yyyymmdd
```

This will produce a map of all WWLLN-detected lightning for the entire Earth for the day of interest. Universal time of day is represented by the color of the points. Alternatively, you can select for a smaller spatial range and/or time range by using the following syntax:

```
IDL> map_wwlln, data, yyyymmdd, range=range, tminmax=tminmax
```

where `range` is an array of the format: [minimum latitude, minimum longitude, maximum latitude, maximum longitude]. `tminmax` is an array of the format: [minimum time in UT hours, maximum time in UT hours].

There are other IDL procedures and functions called by `read_wwlln.pro` and `map_wwlln.pro` included in the same `code/pro/` folder, so if you copy the IDL *.pro files to your own directory, make sure to copy all the files in that directory.

If you use a language other than IDL, there are no specific WWLLN codes written. However, the HDF5 format of the data should provide ease of use for any language. The HDF5 organization is consistent with the new on-orbit data HDF5 files written by Kyle Wiens [6].

3.3 Caveats on Usage

WWLLN is a research network, and has been developed over a number of years. With that development, agreement on what constitutes "good" data has evolved. Of these changes, it is important to note the one on 2005/07/27, in which WWLLN decided that events must be detected by a minimum of 5 stations to be listed as an event. Prior to that, detections with 4 stations were included, but they could lead to significant geolocation errors (arcs) based on observing geometry. If one uses data prior to this time, it is suggested to only use events if they were detected by 5 or more stations, even though events with 4 stations detecting are included in the dataset.

4 Real Time Data

The daily WWLLN files described in Section 3.1 are produced at 2400 UTC and downloaded to the LANL server via the cron job at 18:00 local time, or 0100 UTC on the following day. If data from a given time period is required before the end of the UT day, a 10-minute WWLLN file containing the time of interest can be downloaded. Each 10-minute file starts at the beginning of a 10-minute period (0, 10, 20, 30, 40, 50 minutes) and contains the next 10 minutes of data. At the end of the day, it is these files that are concatenated to create the daily file that is pulled to the LANL servers. So the real time 10-minute files are only required if you need the data before 0100 UTC the following day.

4.1 Retrieval of Real Time Files

To retrieve and process a 10-minute WWLLN file:

1. Determine the 10-minute time window of interest: `yyyymmdd` = 4-digit year, 2-digit month, 2-digit day (same as for daily file); `hr` = 2-digit hour; `mi` = 2-digit minute for the beginning of the 10-minute period of interest (this number can only be 00, 10, 20, 30, 40, 50).
2. Retrieve the file from the WWLLN server and convert it to an HDF5 file by calling `code/scripts/wwllget_10min.sh yyyymmdd hr mi` from the `wwln` projects directory. Example:

   `>code/scripts/get_wwlln_10min.sh 20160228 00 50`

   for an event in the 50-59 minute range of the first hour of 2016/02/28.

The ascii file will be downloaded to `10min_files/ascii/` in the `wwln` projects directory, and the HDF5 file will be processed and put in `10min_files/hdf5/`. Note that you will get a message with the `hour:minute` of the last time in the file, and you may get a warning that the "`ascii file is likely incomplete`". This warning can be ignored since the conversion program is checking for times at the end of the day for completeness (i.e. 23:59), and your 10-minute file likely does not contain the end of the day times.

4.2 Real Time Data Usage

To read in the 10-minute WWLLN data to IDL use `read_wwlln.pro` with the following syntax: `data=read_wwlln(yyyymmdd,filename=filename)`, where filename is the full file name, including path, to the 10-minute HDF5 file. This output structure can be plotted using the `map_wwlln.pro` procedure as described in Section 3.2. For non-IDL coding, you must write your own reader program for the HDF5 format as found in [6].

5 Lightning Energy

A new capability that WWLLN has added in recent years is a calculation of the radiated energy per lightning stroke in the 6-18 kHz frequency band. This is a characterization of lightning stroke strength, akin to the peak current estimate that is calculated by the National Lightning Detection Network (NLDN). However, the peak current estimate is based on the rise time of the lightning waveform while the radiated energy is based on the integration of the waveform over time. Because the WWLLN VLF signals become extremely dispersed during their propagation over thousands of kms, the initial part of the signal no longer contains useful information about the rise time. Therefore, WWLLN uses the radiated energy measurement to indicate stroke strength instead of peak current. A description of how the energy per stroke is calculated can be found in [4]. The files that contain energy estimates are available after 0800 UTC on the day following the day of interest.

5.1 Energy File Retrieval

The energy files are labeled `AEyyyymmdd.loc` for ascii files or `AEyyyymmdd.mat` for matlab binary files. To download an ascii file and convert to HDF5 from the `wwln` projects directory:

`code/scripts/get_wwlln_energy.sh yyyymmdd`

To download a matlab .mat file: `code/scripts/get_wwlln_energy_mat.sh yyyymmdd`

These codes will place the retrieved files in the folder called `ae_files/`. The file `AEreadme.txt` is also found in that directory, and describes these files in more detail.

5.2 Energy File Usage

To read in the WWLLN energy HDF5 file to IDL use `read_wwlln_energy.pro` with the following syntax: `data=read_wwlln_energy(filename)`, where filename is the full file name, including path, to the HDF5 energy file. This output structure can be plotted using the `map_wwlln.pro` procedure as described in Section 3.2. For non-IDL coding, you must write your own reader program for the HDF5 format as found in [6]. For MATLAB coding, you can simply download and use the `AEyyyymmdd.mat` file.

6 Detection Efficiency

It is important to understand the detection efficiency (DE) of any lightning detection network. No network has a DE of 100% or completely uniform coverage. Since the WWLLN is a global network that operates in the VLF with stations often several thousand km from lightning regions, the detection efficiency is lower than a regional network (such as the NLDN that operates in the LF/VLF with receiver spacing of tens to hundreds of km). Furthermore, it is not possible to make the spacing of the WWLLN receivers as regular as a regional land-based network due to infrastructure requirements and the large areas of Earth covered by oceans. Finally, the far distances that the VLF propagation signal must travel to the receivers allows the ionospheric conditions (day/night) to play a large role in DE. For that reason, relative DE maps have been created for WWLLN for given time of day and day of year.

6.1 Detection Efficiency File Retreival

These can be downloaded by using the following scripts:

To download an ascii file from the `wwln` projects directory:

`> code/scripts/get_wwlln_de_dat.sh yyyymmdd`

To download a matlab .mat file:

`> code/scripts/get_wwlln_de_mat.sh yyyymmdd`

These codes will put the file in the directory `de_files/`. There is a `deREADME.txt` file in that same directory explaining the contents of the files. Note: you may have to unzip a `DEyyyymmdd.dat.gz`

6.2 Detection Efficiency Map Usage

To read in a WWLLN DE map to IDL use `read_de.pro` with the following syntax: `data=read_de(filename)`, where filename is the full file name, including path, to the `DEyyyymmdd.dat` file. Note: the file must be unzipped before running the IDL code. For MATLAB coding, you can simply download and use the `DEyyyymmdd.mat` file.

7 Earth Networks Collaboration

WWLLN has been collaborating with Earth Networks Global Lightning Network (ENGLN), which has a higher density of receiver stations in some regions of the world, leading to a higher DE in those areas. If there is a particular event of interest that requires a network with higher DE, you can contact Bob Holzworth at the University of Washington (`bobholz at u dot washington dot edu`; 206-685-7410) to ask him to search through the ENGLN data or send you a day or region of the data.

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