TITLE: GLD360

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1.0 DATA SET OVERVIEW:

Introduction

GLD360 is a global lightning dataset provided by Vaisala, Inc. The data are generated by a network of sensors operating in the Very Low Frequency (VLF; 3—30 kHz) band that measure the magnetic field of radio impulses generated by individual lightning return strokes and strong cloud pulses (these radio impulses are called radio atmospherics, or, colloquially, sferics). The network uses both time of arrival and magnetic direction finding to estimate the time and location of each event. The peak VLF field value, measured in picoteslas, is used together with an empirical propagation model to estimate peak current for ground strokes.

Time period covered by the data

Start: 2011-Sep-1 00:00:00 UT
End: 2012-Mar-31 23:59:59 UT

Area covered by data

Latitude: [-20,20] degrees North
Longitude: [40,120] degrees East

Data source

Vaisala, Inc.

Web reference

http://www.vaisala.com/en/products/thunderstormandlightningdetectionsystems/Pages/GLD360.aspx

2.0 INSTRUMENT DESCRIPTION:

The sensors in the underlying long-range network use orthogonally oriented air-core magnetic loop antennas to measure the horizontal magnetic field vector between ~300 Hz and ~48 kHz. Broadband data sampled at 100 kSamples/second are processed to partially remove local power line noise and various anthropogenic narrowband noise sources in the VLF band. Individual impulsive waveforms generated by received radio atmospherics from lightning discharges are analyzed using a locally stored waveform bank in order to identify a low time variance feature in the waveform for use by the central analyzer.

The sensor technology used at each sensor is detailed in Cohen et al, 2010.

3.0 DATA COLLECTION AND PROCESSING:

The central analyzer compares sensor records to generate the location, time, and peak current and polarity estimate for individual strokes. Each reported event corresponds to one return stroke, which may be one of many return strokes in a cloud-to-ground (CG) flash. The stroke order—the index of the stroke within a flash—is not reported.

Some events reported correspond to the latitude and longitude projection of a cloud pulse, which is a sufficiently large discharge in the cloud to generate a pulse in the VLF range. GLD360 assigns an effective peak current to these events based on the received signal amplitude at the sensors, even though the concept and validation of peak current values is only valid for CG strokes. GLD360 does not report the event type (CG stroke versus cloud pulse).

The primary performance metric values of interest for lightning detection networks are location accuracy, detection efficiency (DE), and peak current and polarity accuracy. Each of these factors depends on the available sensor locations with respect to the storm location, the propagation conditions (including the state of the ionosphere) along the path between the storm and each sensor, and the local noise environment at each sensor. GLD360 was designed to have ~70% CG flash DE around the globe, a median location accuracy of 2—5 km, a magnitude peak current estimation error of 20%, and a polarity determination that is over 90% accurate. However, the performance in any given location will fluctuate with time in accordance with the above sensor availability and propagation factors. At this time, there is not a separate database of modeled or empirical performance correction factors to help calibrate statistical measurements of the data.

The methodology behind the network is detailed in Said et al, 2010. Each sensor stores a local empirical waveform bank, which catalogs the expected sferic waveform shape, indexed by distance and ionospheric profile. The most reliably repetitive features (either the rising portion of the ground wave or the zero-crossing of the first or second ionospheric reflection) is used to establish the arrival time of the sferic at the receiver. Finally, the arrival angle is determined by comparing the signal strengths on the two orthogonally oriented magnetic loop antennas. This information is sent back to a central processor, which then aggregates arrival time data to make a determination of the event's time and location using an optimization routine that minimizes the squared error of all time and azimuth measurements. An event must be simultaneously detected by at least three sensors to be geo-located, though most are detected by more. The network also measures the polarity of each stroke using results from the cross correlation with the waveform bank.

The effective peak current is estimated using propagation curves that refer the amplitude measured at the receiver back to the source location. An empirical conversion factor, which was derived using data from the National Lightning Detection Network (NLDN) [Cummins and Murphy, 2009] as a reference, is then used to convert this range-normalized signal strength to an effective peak current, reported in kAmperes.

Estimated performance metrics for GLD360 are available in the literature (eg Poelman et al, 2012, Pohjola and Makelab, 2012), and typically involve using a local precision network or ground truth instrument (such as a tower) as a reference. Performance estimates over the U.S. using data from the NLDN as a reference are listed here. The data for these performance metrics are taken from July 21, 2011 – July 21, 2012, from the latitude/longitude bound [25,55] deg N and [-125,-70] deg E, respectively. These performance metrics are only validated in that region, and while they will be reflective of the performance in other regions of the globe, they do not guarantee the same performance will be found elsewhere in the network. In particular, regions in more remote areas, such as deep in oceanic regions, will have longer average sensor baselines and hence decreased location accuracy and detection efficiency.

Averaged over all flashes for the one year period beginning July 21, 2011, and using the latitude and longitude bounds given above, GLD360's relative ground flash DE was 57%. For NLDN flashes with a peak current magnitude (determined by the first stroke in the flash) over 15 kA, the relative DE was 67%.

Averaged across all peak current values, the two networks measured the same polarity for 96% of matched events. The overall geometric (arithmetic) peak current magnitude error is 6 (21)%.   From these results, we estimate a worst-case magnitude mean error of 38%, and a geometric mean error of 19%. The relative peak current performance metrics degrade for weak reference events, particularly below ~7kA. The decreased performance for these weak events may be due to a lower signal to noise ratio and likely due to some mixing with misclassified cloud pulses or miscorrelated stepped leaders.

Over the same latitude/longitude and time window used above, the median (90th percentile) location accuracy is ~2.5 (17.5) km. The majority of events are located within a typical storm cell size, and thus the extent of the thunderstorm activity is well captured by the network.

4.0 DATA FORMAT:

The data are provided in flat ASCII files. Each line corresponds to a single GLD360-detected event, which may be either a single return stroke or a large cloud pulse. For each event, the following parameters are reported:

- Date and time, in UT, specified with millisecond resolution
- Location, given by the latitude and longitude in degrees
- Peak current magnitude and polarity, given in kAmperes.

The detected events are not grouped into flash data.

Each line has the following format:

```
YYYY-MM-DD HH:mm:SS.SSS LAT LON IP
```

`YYYY`	: Year
`MM`	: Month (1-12)
`DD`	: Day (1-31)
`HH`	: Hour (0-23)
`mm`	: Minute (0-59)
`SS.SSS`	: Seconds
`LAT`	: Latitude in degrees North
`LON`	: Longitude in degrees East
`IP`	: Peak current magnitude in kAmperes and polarity

Example line:

```
2012-01-15 01:02:03.456  12.3456   50.1234   -12.3
```

5.0 REFERENCES:

Cohen, M.; Inan, U. & Paschal, E.
Sensitive Broadband ELF/VLF Radio Reception with the AWESOME Instrument
Transactions on Geoscience and Remote Sensing Letters, IEEE, **2010**

Cummins, K. L. & Murphy, M. J.
An Overview of Lightning Location Systems: History, Techniques, and Data Uses, With and In-Depth Look at the U.S. NLDN
IEEE Transactions on Electromagnetic Compatibility, **2009**, *51*

Poelman, D.; Schulz, W. & Vergeiner, C.
Performance characteristics of distinct lightning detection networks covering Belgium
Journal of Atmospheric and Oceanic Technology, **2012**, *In press*

Pohjola, H. & Mäkeläb, A.
The comparison of GLD360 and EUCLID lightning location systems in Europe
Atmospheric Research, **2012**, *In Press, Corrected Proof*

Said, R. K.; Inan, U. S. & Cummins, K. L.
Long-range lightning geolocation using a VLF radio atmospheric waveform bank
Journal of Geophysical Research (Atmospheres), **2010**, *115*, 23108