A Comparison of Space Based Optical Measurements and Ground Based VLF Measurements of Lightning

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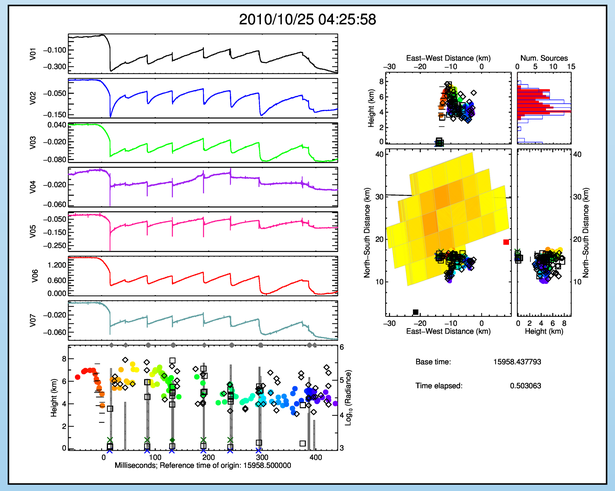
Why are you doing this?

Nominally, space based optical measurements of lightning are thought to provide the best estimate of total lightning. Recently, ground based VLF measurements, made with relatively dense arrays, are also thought to provide total lightning data. To facilitate the comparison of the two techniques, we investigate the relative amount of information provided by each method. To do so, we use LIS and ENTLN (see table, lower right) data from Feb. 2009 through Nov. 2013.

GLM will provide temporally contiguous space based measurements of total lightning. This study aims to assess the relative total lightning information that will be provided by GLM to ground based measurements.

Figure 1. Overview of a flash, as seen by HAMMA, LIS, LMA, NLDN, and ENTLN. The first seven rows on the left show the measured Efield at different sensors. The bottom row on the left contain HAMMA locations (black dashes, diamonds, and squares), LIS groups (gray bars and diamonds), LMA sources (colored circles), NLDN strokes (blue X's) and ENTLN pulses (green X's and diamonds).

The right side contains the spatial evolution of the flash: xy, xz, and zy projections of the data. The yellow to orange squares are LIS events. Other colored squares are the locations of HAMMA sensors. An animation of the data is also available.



How are you doing this?

The base unit of measurement by ENTLN is a pulse, which is roughly the equivalent of a return stroke. Similarly, the base unit of measurement by LIS is a group, also roughly the equivalent of a return stroke. Hence, the natural way to analyze the data is to compare pulses and groups. For this study, we consider a ENTLN pulse and LIS group detects the same physical discharge if they occur with 10 ms and 20 km of each other. The probability that there is a LIS group for a given ENTLN pulse is found. Then, the "reverse" probability is found.

This differs from previous work that compares flashes, a quantity neither method directly detects.

In addition, neither data set is considered the "truth".

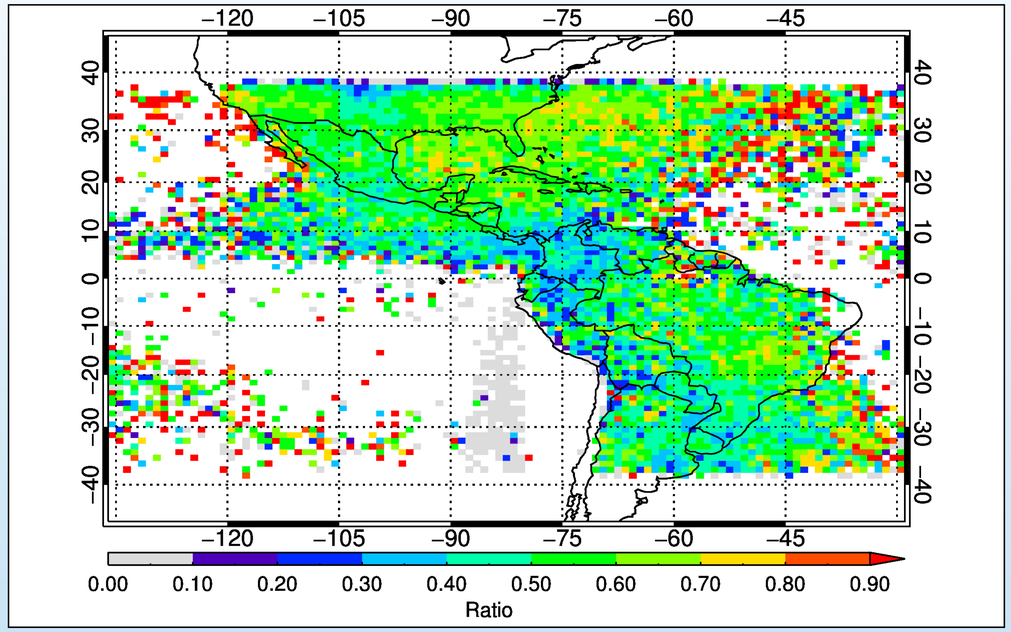


Figure 2. Probability LIS detects an ENTLN pulse. In this field of view, there is a LIS group associated with

55.4%

of ENTLN pulses. Formally, this is the probability LIS detects a discharge, given that ENTLN did.

In North America, there is a LIS group associated with 56.6% of ENTLN pulses.

Globally, there is a LIS groups associated with 54.9% of ENTLN pulses.

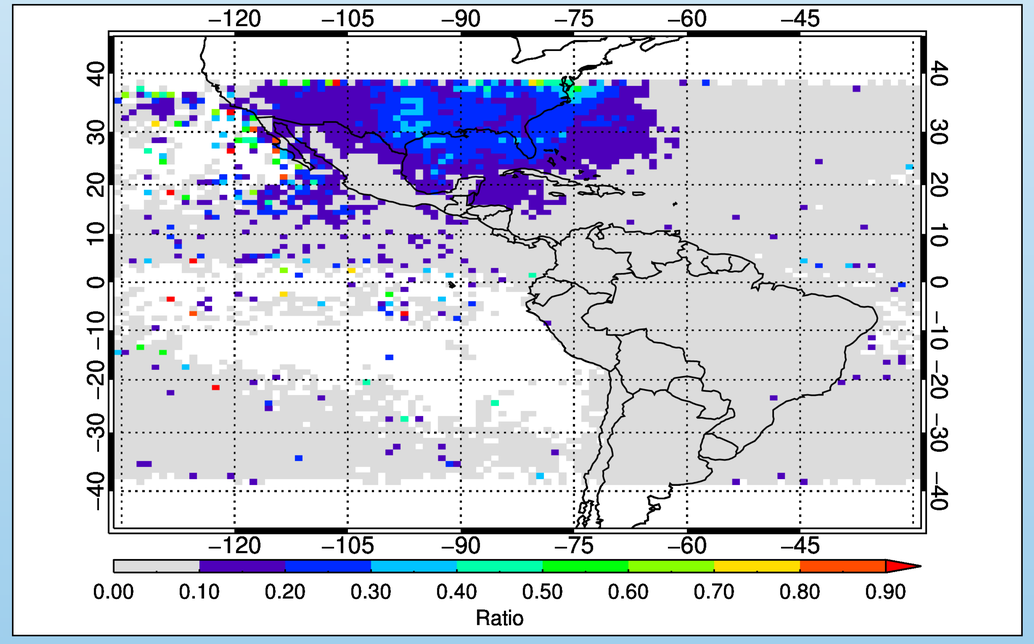
Figure 3. Probability ENTLN detects an LIS group. In this field of view, there is an ENTLN pulse associated with

9.2%

of LIS groups. Formally, this is the probability ENTLN detects a discharge, given that LIS did.

In North America, there is an ENTLN pulse associated with 18.3% of LIS groups.

Globally, there is an ENTLN pulse associated with 3.7% of LIS groups.



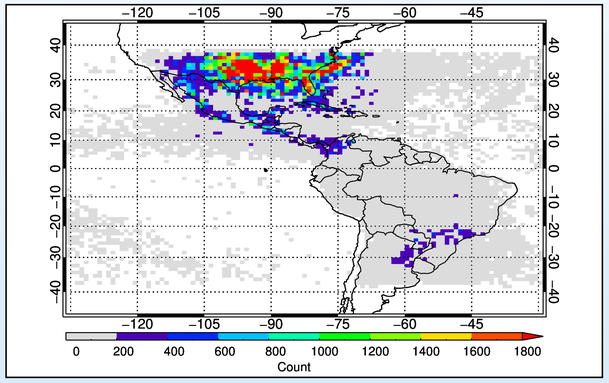
To compare the relative performance of space based optical measurements by LIS and ground based VLF measurements by ENTLN, we use a Bayesian analysis. Even though there is no truth data set, we can assess the relative performance of the two measurement techniques using Bayes' Theorem (right).

$$\frac{P\{\text{ENTLN}\}}{P\{LIS\}} = \frac{P\{\text{ENTLN}|\text{LIS}\}}{P\{\text{LIS}|\text{ENTLN}\}}$$

The probability ENTLN detects any lightning discharge in/around the Americas is 16.5% of the probability LIS detects any lightning discharge.

	Americas, 09-13	Americas, 2013	N. America, 09-13	N. America, 2013	Global, 09-13	Global, 2013
P{LIS I ENTLN}	0.554	0.546	0.566	0.556	0.549	0.541
P{ENTLN I LIS}	0.092	0.137	0.183	0.268	0.037	0.060
P{ENTLN}/P{LIS}	0.165	0.251	0.323	0.483	0.067	0.111

Figure 4. Number of ENTLN pulses in the LIS field of view during 2013.



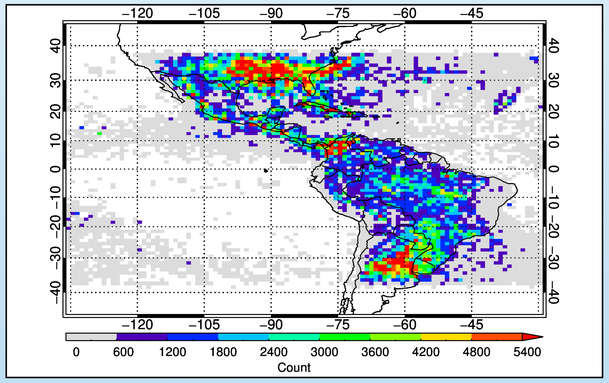


Figure 5. Number of LIS groups in 2013. **Notice the color bar values are different by a factor of three.**

What do I take away from this?

The ability of ground based measurements to provide the same amount of information as space based optical measurements has improved, yet still lags behind space based measurements. Relative performance is still quite poor over large portions of the United States and over the oceans. In addition, the number of discharges detected by each method is quite different.

Space based optical measurements of lightning contain significantly more information than ground based VLF measurements.

GLM is expected to have superior performance to LIS, implying space based measurement of total lightning will continue to outperform ground based measurements.

ENTLN	Earth Networks Total Lightning Network
HAMMA	Huntsville Alabama Marx Meter Array
NLDN	National Lightning Detection Network
LIS	Lightning Imaging Sensor
LMA	Lightning Mapping Array

The Lightning Imaging Sensor (LIS) Science Data were obtained from the NASA EOSDIS Global Hydrology Resource Center (GHRC) DAAC, Huntsville, AL. http://thunder.nsstc.nasa.gov/
Earth Networks Total Lightning Data provided by Stan Heckman and Christopher Sloop.