THE SÃO PAULO LIGHTNING MAPPING ARRAY (SPLMA): PROSPECTS FOR GOES-R GLM AND CHUVA

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RESUMO: Este trabalho apresenta as características e as perspectivas de um "*Lightning Mapping Array*" a ser implantado na cidade de São Paulo (SPLMA). Esta rede LMA irá fornecer à campanha CHUVA raios totais, mapeamento do canal de raios e informações detalhadas sobre os locais responsáveis pelas regiões de cargas das nuvens de tempestade investigadas durante um de seus períodos de observação intensiva. A disponibilidade em tempo real das observações do LMA também irá contribuir para a concientização da situação meteorológica e apoio à execução da missão do CHUVA. Para o programa do GOES-R irá formar uma base de dados "proxy" única e valiosa para ambos os sensores GLM e ABI em apoio à vários questões de pesquisa em curso.

ABSTRACT: This paper presents the characteristics and prospects of a Lightning Mapping Array to be deployed in São Paulo (SPLMA). This LMA network will provide the CHUVA campaign with total lightning, lightning channel mapping and detailed information on the locations of cloud charge regions for the thunderstorms investigated during one of its Intensive Observation Periods (IOP). The real-time availability of LMA observations will also contribute to and support improved weather situational awareness and mission execution. For the GOES-R program it will form the basis of generating unique and valuable proxy data sets for both the GLM and ABI sensors in support of several on-going research investigations.

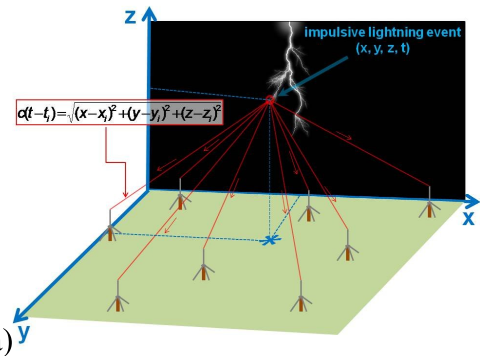
Palavras-chave: raios, relâmpagos, sistemas de localização de raios, CHUVA, GLM.

1 – INTRODUCTION

Lightning flashes have been the object of interest and research for decades. Thunderstorm lightning activity is tightly controlled by the updraft intensity and ice precipitation formation in the clouds, which makes it closely related to storm dynamics and microphysics. Therefore, cloud electrification conveys useful information about the rate, amount and distribution of convective precipitation (Goodman and Buechler, 1990; Petersen 1998; Cecil et al., 2005; Liu et al., 2008), as well as severe weather (Williams et al., 1999, Schultz et al., 2009, Gatlin and Goodman, 2010) with potential threats to life, wild fires and damages to structures and facilities. All these implications make the location of lightning occurrence of high interest to several sectors of society. In this matter, lightning location systems (LLS) have been in operation over many decades.

LLS are based on the detection of the electromagnetic radiation emitted by lightning, which can be done mainly using radio and optical frequencies. Radio emissions from lightning occur in the form of short pulses by accelerated charges during the fast changing current steps, while the optical emissions occur from ionized and dissociated gases by thermal radiation of the lightning channel (Christian and Goodman, 1987). High energetic processes of lightning (e.g., return strokes) can be detected on the range of low (LF) to very low (VLF) radio frequencies (Cummins and Murphy 2009). Other processes (e.g., less energetic breakdown processes) are only detected by very high frequencies (VHF). Most of the LLS operational worldwide are networks of LF and VLF sensors, which makes possible the location of lightning (mainly cloud-to-ground, CG) occurrence in space and time only in two-dimensional coordinates (i.e., latitude and longitude).

The New Mexico Institute of Mining and Technology developed a detection system called the Lightning Mapping Array (LMA) (Rison et al. 1999), based on the Lightning Detecting and Ranging (LDAR) system developed to be used at the NASA Kennedy Space Center (Maier et al. 1995). The LMA system locates the peak source of impulsive VHF radio signals from lightning in an unused television channel by measuring the time-of-arrival of the magnetic peak signals at different receiving stations in successive 80 μs intervals. Hundreds of sources per flash can be detected in space and time, allowing a three-dimensional (3-D) lightning map to be constructed with nominally <50 m error within 150 km (Goodman et al. 2005). Figure 1a illustrates the time-of-arrival approach used in the LMA system. Global Positioning System (GPS) receivers at each station provide both accurate signal timing and station location knowledge required to apply this approach. Figure 1b is a picture of a portable LMA station hardware.



(a)

(b)

Figure 1 – (a) Illustration of the time-of-arrival technique used by the LMA system. The times (t_i) when a signal is detected at N≥4 stations are used to solve for the 3D source location ($\underline{x}$, y, z, t) of the impulsive breakdown processes associated with a discharge. (b) Portable LMA station electronic box and antenna.

In the United States there are research and operational VHF lightning mapping systems (LMAs in New Mexico, Oklahoma (OKLMA), Alabama (NALMA) and Washington D.C. (DCLMA), and LDARs in Houston, Texas and Kennedy Space Center, Florida). These networks provide 3-D total lightning (i.e. cloud-to-ground and intracloud) data for local weather service offices and national prediction centers, where it is used in the severe weather forecast and warning decision-making process. Total lightning information gives us a complete picture of the thunderstorm electrification and lightning activity, which is not possible using conventional LF and VLF networks where mostly only CG lightning is detected, although VHF networks not providing precise information of CG lightning ground contacts should be complemented by LF and VLF networks.

LMA data is being used as proxy data for the upcoming Geostationary Lightning Mapper (GLM) optical sensor onboard the GOES-R satellite. GOES-R is scheduled to be launched in late 2015 and will also carry the Advanced Baseline Imager (ABI). ABI is a visible and infrared imager that offers significant improvements over the current generation of

GOES imager in spectral-band coverage, spatial resolution, and sampling frequency. The GLM was built on the heritage of the NASA Optical Transient Detector (OTD) and the Lightning Imaging Sensor (LIS), consistent of a wide field-of-view telescope focused on a high speed charge coupled device (CCD), combined with a narrow band interference filter centered on 777.4 nm (Christian et al, 2000; Christian et al., 2003). The signal is read out from the focal plane into a real-time event processor for event detection, which are sent to the satellite ground station for geolocation processing in space and time, resulting in a "flash" (multiple CCD events grouped into time and space).

The GOES-R Algorithm Working Group (AWG) is developing and validating operational algorithms that will use products from GOES-R instruments so that these algorithms will be ready for use on "day 1" following GOES-R launch. During this pre-launch phase, these activities rely on the generation and use of proxy and simulated instrument data sets to develop, validate and test products and data processing. LMA total lightning from the United States networks are being used to generate the necessary GLM proxy data. In addition, the ABI proxy data can be derived from SEVERI (Spinning Enhanced Visible and Infrared Imager) onboard of the Meteosat Second Generation (MSG) satellite, which does not cover the United States. Therefore, a unique opportunity to acquire collocated ABI and GLM proxy data, as well as intensive atmospheric measurements to validate and calibrate GOES-R candidate algorithms, will be the CHUVA ("***C***loud processes of t***H***e main precipitation systems in Brazil: A contrib***U***tion to cloud resol***V***ing modeling and to the GPM (Glob***A***l Precipitation Measurement)") field campaign. CHUVA project covers climate and physical processes studies using conventional and special observations (polarimetric radar, radiometer, LIDAR, etc) to create a database describing the cloud processes of the main precipitating system in Brazil. It intends to create and exploit this database to improve remote sensing precipitation estimation, rainfall ground validation and microphysical parameterizations of the tri-dimensional characteristics of the precipitating clouds.

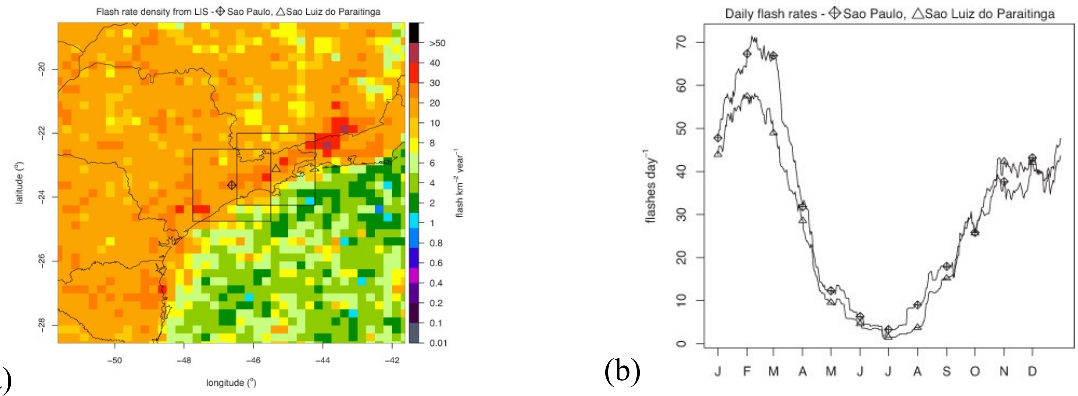
Thereby, the deployment of a LMA network to Brazil will occur during one of CHUVA's Intensive Observation Periods (IOP). This effort will acquire unique total lightning proxy data from the LMA to the GLM collocated to SEVRI proxy data for ABI. The next session describes the proposed network.

2 – THE SAO PAULO LIGHTNING MAPPING ARRAY (SPLMA)

The first CHUVA IOP was conducted in Alcantara, Ceara state, in March and April of 2010. The objective of this first IOP was to study warm clouds, tropical squall lines and easterly waves. The second IOP will be conducted in São Luiz do Paraitinga, São Paulo state, Brazil, from December 2010 to January 2011, in order to learn more about the South Atlantic Convergence Zone (SACZ), local convection and enhancement of orographic precipitation. São Luiz do Paraitinga is near one of the biggest cities in the world, São Paulo (about 150 km). São Paulo has a unique infrastructure in the Latin America which makes the perfect place to deploy a LMA network. Moreover, as a mega urban center, the city constantly suffers with flash floodings and severe weather, where the potential nowcasting algorithms based on LMA measurements could be developed and tested with a very high value to the society.

The total lightning activity over the city of São Paulo and São Luiz do Paraitinga are shown in Figure 2. Moderate (10-30 fl km^{-2} yr^{-1}) to high (>30 fl km^{-2} yr^{-1}) lightning activity is observed along São Paulo state coast (Figure 2a). São Paulo's east coast is composed of two sets of high elevated terrain (> 1500 m) with a valley (Paraiba Valley) in between, where São Luiz do Paraitinga is located. The annual cycle of lightning over these regions (Figure 2b) show a minimum (<5 fl day^{-1}) from June to August (austral winter) and a gradually increase from September (~15 fl day^{-1}) to November (~42 fl day^{-1}). A steep increase during the summer is observed: ~40 fl day^{-1} in December jumps to a peak in February of 57 fl day^{-1} for

São Luiz do Paraitinga and 71 fl day^{-1} for São Paulo. The reason for a higher peak in the city of São Paulo is believed to be related to the enhancement of deep convection by the urban heat island, which will also be studied during the SPLMA deployment.



(a) (b)

Figure 2 – (a) Lightning flash rate density (fl km^{-2} yr^{-1}) for Southeast Brazil. (b) Daily flash rate (flashes per day) around São Paulo and São Luiz do Paraitinga (i.e, flash rate over black squares (2 ¼º) around these cities on item (a)). Lightning data is from LIS climatology from 1 January 1998 to 31 December 2008 in ¼º of resolution.

The SPLMA deployment is intended to be completed by the end of October 2010, so that the onset of summer and the high lightning activity period can be monitored as shown in Figure 2. The length of the deployment will be from six months to one year. The SPLMA will consist of an 8-10 station network deployed in the vicinity of São Paulo. An 8-10 (or more) station LMA provides redundancy and increases overall robustness and signal detection, since not all receiving stations detect all the lightning signals. Spacing between stations is typically on the order of 15-30 km, with the network "diameter" being on the order of 80 km. Details on the NALMA and DCLMA, which show station spacing can be found at http://branch.nsstc.nasa.gov/PUBLIC/DCLMA/.

Figure 3 shows the preliminary layout for SPLMA, where the blue balloons are the suggested locations for 9 stations around the city of São Paulo. The red balloons are additional stations under consideration around the city of São José dos Campos, closer to CHUVA IOP site (São Luiz do Paraitinga – yellow "push pin"). The São José dos Campos LMA network is centered at INPE, where an instrumentation tower with high speed cameras and other instruments can add valuable information for GLM and CHUVA purposes. Since a LMA provides good 3D coverage out to 150 km, this coverage will overlap nicely with the areal coverage by the São Luiz do Paraitinga dual polarization radar (especially toward the west) that will be working at the area during this CHUVA IOP. LMA provides 2D detections

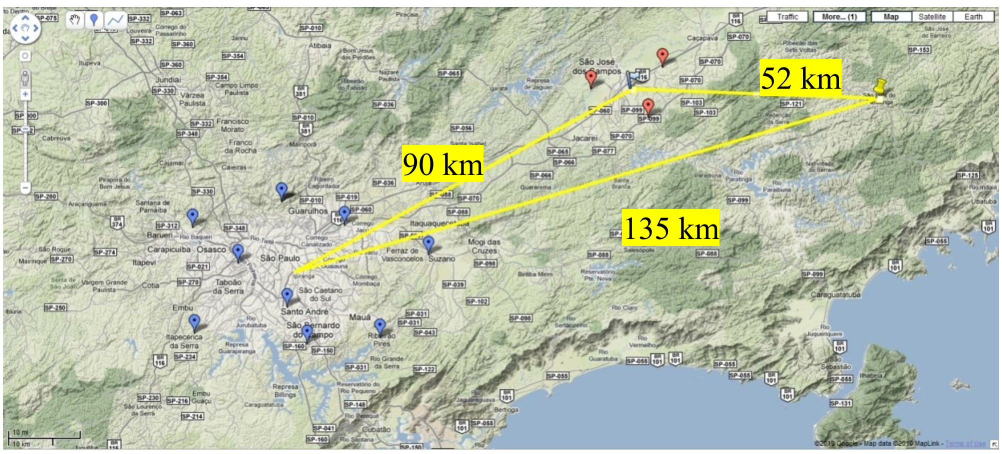


Figure 3 - Blue balloons show preliminary configuration for the SPLMA network for CHUVA. The red balloons show a second network configuration, centered at INPE (Sao Jose dos Campos). Yellow "push pin" is the São Luiz do Paraitinga CHUVA IOP site. Yellow lines show distance between the networks and CHUVA IOP.

out to 250+ km (and often detects lightning even farther away). LMA data will be processed and make available online through a SPLMA web site. The "modus operandi" for SPLMA will be very similar to that used by the DCLMA, in which all the stations are connected to the internet for real time collections, processing and display of decimated data, and post real time processing of the full data sets.

3 – CONCLUSIONS

The contribution of SPLMA will be to provide the CHUVA campaign with total lightning, lightning channel mapping and detailed information on the locations of cloud charge regions for the thunderstorms investigated during the São Luiz do Paraitinga IOP. Much of the lightning information will not be available without the LMA. The real-time availability of LMA observations will also contribute to and support improved weather situational awareness and mission execution. For GOES-R program it is a target-of-opportunity to acquire unique proxy data for GLM and ABI. The measurements obtained from SPLMA deployment will provide for the first time total lightning measurements in conjunction with SEVIRI observations. The data acquired through the combination of CHUVA IOP and the SPLMA will form the basis of generating unique and valuable proxy data sets for both GLM and ABI sensors in support of several on-going research investigations.

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