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GeoRayos a new aplication for severe weather warning

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***Abstract*—This work presents a lightning jump algorithm (LJA): "GeoRayos" to detect severe weather; it is based on the algorithm presented by Schultz et al. (2011) [1]. The lightning data used in this study came from the World Wide Lightning Location Network which is a real-time, world-wide and ground network. In this study, the lightning activity occurred during spring and summer of 2013 on the region [20–50]S of latitude and [50–70]W of longitude was examined. The LJA was validated by using information of severe weather occurrence in the report *"Estudio de los Tornados en la Rep. Argentina"* this unpublished report (M. L. Altinger de Schwarzkopf, personal communication) provides severe phenomena occurred since 1930 to the present, also we used information from the National Weather Service in Argentina, local argentinean media, and radar data. The spatial and time distributions of lightning jumps were analyzed by using different spatial and temporal scales.**

Keywords— lightning, nowcasting, warning, WWLLN

I.INTRODUCTION

The lightning activity in a thunderstorm is related to the kinetic energy of the thunderstorm updraft. Strong updrafts provide a suitable environment favoringthe mixed-phase cloud and precipitation processes, which associated to the electric charge transfer mechanism can lead to the formation of cloud-scale charge centers. Many studies over the past several decades have attempted to correlate trends in lightning to severe weather occurrence; because the total flash rate rapidly increases several minutes prior to the onset of severe weather.

Many studies using information from multiple satellite platform observations (e.g., TRMM, GOES, MODIS, etc) have shown that some of the most intense thunderstorms on Earth occur over northern and central Argentina (Zipser et al 2006, [2], Cecil and Blackenship 2012 [3], among other). These studies suggest that southeastern South America is a prolific severe weather producer, as supported by a relatively high frequency of severe weather events reported by the media. It is well know that over Argentina occur several severe weather events that are related to thunderstorms (Rassmusen et al 2011 [4], Matsudo and Salio 2010 [5], Zipser et al 2006 [2], Silva Dias 2011 [6], Nascimento et al 2014 [7], Altinger 1982 [8], among others). However, there is a lack of knowledge about the frequency and spatial distribution of these events Altinger [8] made an important contribution to the severe weather climatology in Argentina by identifying 646 strong wind events between 1930 and 1987. 12% of those events were tornadoes, and at least 6% had an intensity of F3 or more in the region between 25°S and 40°S. Peak frequencies of severe weather were found in the center and north of the country.

Recently, Schwarzkopf and Rosso presented the results of the project "Estudio de los tornados en la Argentina" (Study of the tornadoes over Argentina Republic) which incorporate the results from field research since 1971 until present day. The study reported the intensity distribution of tornadoes and the coverage area, with hand orientation of the damages. Nevertheless, National Weather Service in Argentina is working to improve their warning systems that allow the government to warn emergency manager and population in case of severe weather events.

In this sense, the aim of this study was to develop and evaluate GeoRayos as a tool to anticipate the development of severe weather. GeoRayos algorithm is based on previous study from Schultz, 2011 [1]), but this algorithm is defined over Central USA. The implementation of this algorithm over the particular deep and wide storms in central-north Argentina is a great challenge for severe weather detection.

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II. DATA AND METODOLOGY

The lightning data used by GeoRayos came from the World Wide Lightning Location Network (WWLLN, see http://wwlln.net) which is a ground-based network with global observations beginning in 2004. The WWLLN record is now long enough to support studies of seasonal, diurnal, and synoptic lightning variability over most of the globe (Hutchins et al.,2012 [9], Virts et al., 2013[10]). The WWLLN network consists of more than 60 stations, each of one receives and process the very low frequency (VLF) radio waves generated by lightning. This network uses the time of group arrival technique to detect spheric waveforms for lightning location within ~5 km and < 10 µs (Dowden Richard L, Brundell James B, and Rodger Craig, 2002 [11], 2008 [12]).

The GeoRayos algorithm cluster the lightning detected by WWLLN that lies within a given spatial domain and a given lapse time. The clustering is done by the Density-Based Spatial Clustering of Applications with Noise (DBSCAN) algorithm (Ester et al., 1996 [13]).The DBSCAN was chosen due to its ability to detect arbitrarily shaped clusters and it does not require a prior knowledge of the number of clusters that has to be considered. One advantage of using a cluster algorithm is that it allows more flexibility in the determination of storm regions, in contrast with a grid approach.

DBSCAN use two main parameters to cluster data, the Epsilon and the MinPts parameters. The first parameter is the maximum distance at which two points could be considered as neighbors and thus, possible members of the same cluster. The MinPts is the minimum number of points required for a set to be considered as a cluster. A set with less than MinPts points is considered as Noise.

Based on the study of WWLLN data,Hutchins et al. (2014) [9] found valuesfor the clustering parameters of 12km and 2 for Epsilon and MinPts, respectively. These values are adopted in GeoRayos.

Each cluster that was determined by DBSCAN is considered as a Storm-Cluster (SC) with an area equal to the minimum convex polygon that overlay all the lightning associated to the cluster. For instance, Figure 1a show the lightning data from 2013-03-02 at 03:10:00(UTC) without clustering and Figure 1b is the same data after the clustering algorithm.

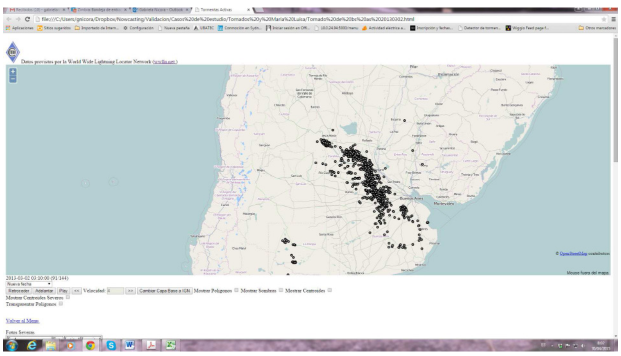

Figure 1a - lightning without clustering

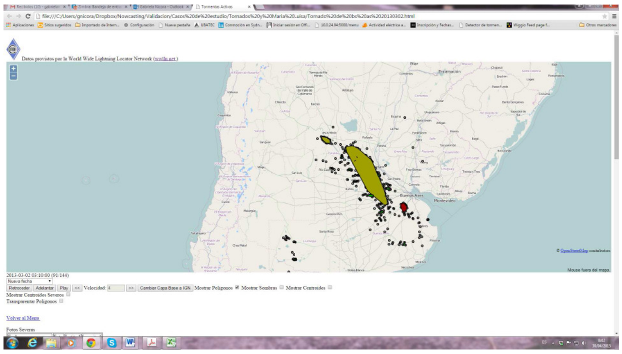

Figure 1b - is the same data that 1a after the clustering algorithm

After the identification of the SC, GeoRayos classified them as Sparse and Dense according to the number of lightning associated to it.

The classification in Sparse or Dense is based in the amount of lightning data associated to the SC in the last two minutes (Storm Threshold). If the amount of lightning is less than the Storm Threshold, the SC is considered as Sparse, otherwise, is classified as Dense.

The Dense SC are the candidates to develop severe weathers and will be classified as Severe Storms according to the time variation of the amount of lightning inside it. If the lightning number increase over time and the increasing rate over the last 2 minutes is larger than twice the increasing rate in the previous 10 minutes. In this case, a Lightning Jump (LJ) is identified and the SC is classified as Severe. Otherwise, the Dense SC classification remains.

Therefore, GeoRayos provide a collection of SC with the classification of Sparse (green), Dense (yellow) and Severe (red) every 10 minutes.

Severe weather database (M. L. Altinger de Schwarzkopf, personal communication) was used to adjust the classification given by GeoRayos,. The severe weather data from summer and spring of south hemisphere (January, February, March, October, November and December) of 2013 that had occurred within the spatial area between [20–50]S of latitude and [50–70]W of longitude were taken into account. The severe weather data reported are classified in different categories, according to the most relevant feature of the severe data. But, for the GeoRayos adjust, only four categories were used: Hail, Severe Thunderstorm, Intense precipitation and Tornadoes.

RESULTS AND CASE OF STUDY

A. Results

From the severe weather data, 140 severe events were used in GeoRayos adjustment from austral warm season 2013. According to the classification, 29 were hail, 81 severe thunderstorm, 21 intense precipitation and 9 tornadoes.

We used the criteria presented by Schultz et al. [1].about temporal duration of a severe weather warning: once a JL in a

Dense SC has been detected, a severe warning is placed on the thunderstorm for 45 min. The verification of this warning occurs if severe weather is observed within the warning time period.

Table I shows the percentage of events that were detected by Georayos using two different Storm Threshold for the Severe storm classification, 5 (JL 5) and 10 (JL 10) lightning every two minutes.

	JL 5	*JL 10*
TOTALES (140)	62%	28%
Hail (29)	55%	17%
Severe thunderstorm (81)	67%	30%
Intense precipitation (21)	52%	33%
Tornadoes (9)	78%	44%

According to the results found and the severe weather data available, five lightning every two minutes seems to be a good Storm Threshold for the area under study.

B. *A case of sudy*

On March first of 2013 a severe storm developed over the central region of Argentina and moved across Buenos Aires (Figure 2). The National Weather Service (Servicio Meteorológico Nacional, SMN) of Argentina reported the events as an incipient and unstable tornado with F1intensity in Fujita scale. At 2:24 (local hour) of March 2, the tornado presented maximum wind gust in the range between 120 and 130 km h^{-1} over Villa Lugano (marcaren el mapa).

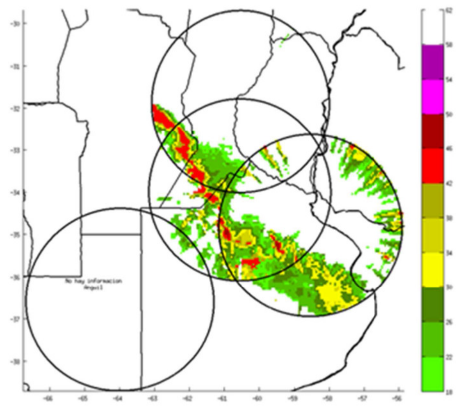

Figure 2. Composite image radar of a storm starting at 23:20 hs LT on 01-03-2013.

Figure 3 and 4 show the Severe SC detected by GeoRayos at 1:50 local time (4:50 UTC) and at 2:30 local time (5:30 UTC), respectively. Therefore, GeoRayos provided a warning alert 34 minutes before the maximum severity of the event.

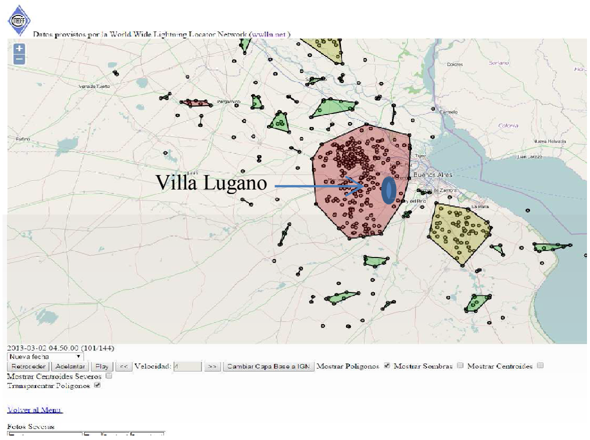

Figure 3. Red area shows the Severe SC detected by GeoRayos at 1:50 local time (4:50 UTC).

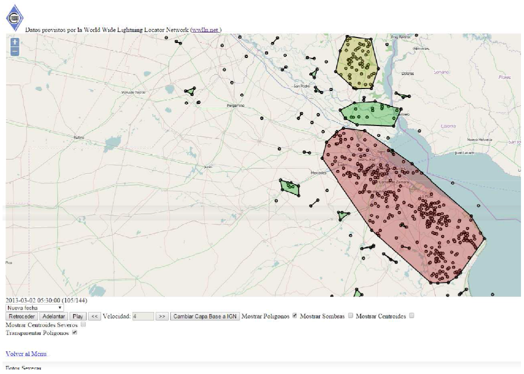

Figure 4. Red area shows the Severe SC detected by GeoRayos at 2:30 local time (5:30 UTC).

CONCLUSIONS

This study shows that GeoRayos could be used as warning systems of severe weathers events.

The best Storm Threshold found for central Argentina is five lightning every two minutes, threshold that allows GeoRayos to identify more than 60% of the reported severe weathers over central Argentina.

The study case had shown that warning could be send well in advance, which allows the alert of the severe event to the population.

The current study suggests that the WWLLN lightning data are suitable to anticipate the development of severe weather.

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