LIGHTNING DETECTION SYSTEM FOR NOWCASTING APPLICATIONS IN SANTA CATARINA STATE, BRAZIL

Maurici Amantino Monteiro, Lucia Morais Kinceler, Anderson Nascimento Monteiro, Cirio Vieira
Epagri - Agricultural Research and Extension Service Institute for Santa Catarina State
Florianopolis, Brazil

1. INTRODUCTION

The forecast in Brazil was set back in the 50ths, and for decades it was impossible to predict storm and lightning location. The weather information for no more than 24 hours ahead was constructed upon observation data of surface synoptic maps and radiosondes.

The advances in computer technology brought a new scenario with numerical weather prediction models providing more accurate results of weather information for up to 5 days, and information about possibilities for storm formations and lightning occurrences. Although prediction models have shown to be important tools for forecasts, the dynamic changes in atmospheric conditions can not be successfully predicted solely by numerical models. Meteorologists interpret the models in conjunction with weather satellite images, observation and radiosonde data, synoptic maps and the climatology of the area for nowcasting.

Lightning Detection Networks play an important role to add quality to the forecast all around the world. For the tropical and subtropical areas in south of Brazil where respectively heat and atmosphere dynamics are great, meteorologists can now rely on a good tool to generate better weather information products.

2. CLIMATOLOGY

The atmosphere dynamics is greater in the South of Brazil than in other regions of the country (Nimer, 1989), with many meteorological systems each of them with peculiar characteristics in the seasons of the year (Monteiro, 2001 and 2007).

Santa Catarina is one of the Southern Brazilian States in which intense daily weather variation is due to its latitudinal position and topography, but with similar characteristics within the season. Forecast for the state is provided by meteorologists of the Environmental and Hidrometeorological Information Center (Ciram) of the Agricultural Research and Extension Service Institute (Epagri).

During the summer, the tropical convection system brings to the state intense rainfall combined with lightning discharges from 3pm to 10pm (Monteiro, 2001).

The convective process is dependent upon the heat, and intensified by the orography effect. Some regions of the state have more favorable conditions for lightning events such as Rio do Peixe Valley, Mid-West and high areas of the Great Florianopolis near the coast. Nonetheless, they are isolated events rarely indicated by numerical models.

Meteorologists usually predict isolated thunderstorms from afternoon to midnight for areas where the temperature conditions are favorable, without giving the right location where lightning may occur. The weather condition in this season is constantly monitored for changes and latest observational data, satellite images, and radar images sent by neighbor state meteorological team are used for nowcasting. However, a tremendous tool at this moment has been the Lightning Detection System - LDS which was installed in 2005 and is described in section 3. The LDS allows one to monitor active storms that in the summer usually adds hail, strong winds and moderate to heavy rainfall in scattered small areas. When Cold Fronts pass by Santa Catarina in the summer they lead to even stronger convective weather, spreading electric discharges all over the state. In this case, the LDS is fundamental in the monitoring process since neither numerical models nor recent satellite images precisely indicate locations prone to lightning activity.

As autumn approaches in the second half of March, the convective weather systems stop. Lightning is then associated to cold fronts passing in the south of the country. Although the weather is more stable during this season, forecasters need special attention in thunders and lightning events, caused by a frequency of 3 to 4 cold fronts in a month. Cold fronts are formed in a very short time in this season specially when associated to extra tropical cyclone over the ocean.

The winter is mainly influenced by polar air masses which are dry and provide stable weather conditions up to 72 hours. As the dry cold air mass weakens, a cold front usually crosses the state with active storms over the west region due to a Low Pressure system that comes from the Chaco –Paraguay which starts to become more intense during this time of the year.

Spring is the most unstable weather season. Unlikely the summer convective weather systems which bring storms and lightning events from afternoon to midnight, in this season events will show up during early hours, starting in the Chaco area and making a drift toward east/northeast reaching the west region of the state (Figueiredo and Scolar, 1996; Monteiro 2001). The timeframe for lightning activity is short between events and can easily be represented by clusters. The weather is very unstable due to the Mesoscale Convective System (MCS) with profitable amounts of cumulonimbus and nimbostratus, heavy rainfall with strong winds, hail and even tornados. The lightning clusters rise up from several close MCS storm kernels, originated in the very active Chaco Low (Sugahara et al., 1994). Strong intensity MCSs reach the west but as they cross the state they loose intensity, and near the coast lightning events disperse (Monteiro, 2007). Cold fronts also provide significant storm and lightning weather conditions during the spring.

Most of the atmospheric systems that influence the weather bring rainfall and lightning. However, in some cases the interaction of two meteorological systems produces even higher unstable weather conditions, such as cold fronts associated with low pressure at surface, low-level jets, subtropical jet streams, cyclonic vortice and troughs in low, medium and high atmosphere.

This work depicts a case of October 20th, 2007 when a cold front associated with a low pressure at the surface (Figure 1). In early morning and morning hours, scarce clouds were registered in this day, but when the front combined with the low pressure in the south of the state gained strength during the afternoon, severe weather conditions were detected all over the state.

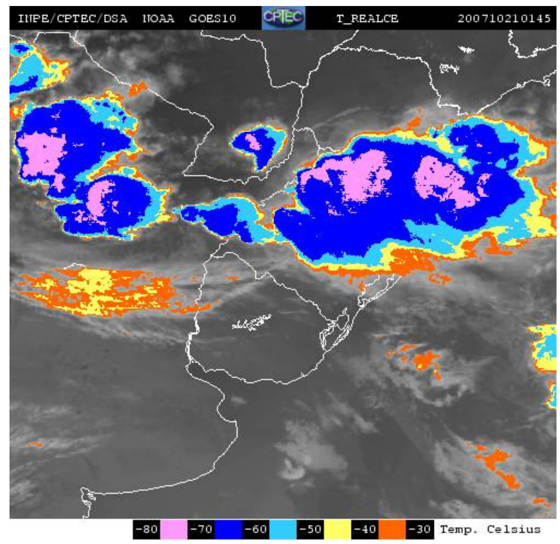

Figure 1. Satellite Image at 11:45 pm of October 20th, 2007

Thunderstorm, hail, and strong winds ranging from 80 to 120 km per hour (50 to 75 mph) in almost all state regions were registered. As stated by Civil Defense and reported in the News, 13 cities had severe damages in this day. Almost three thousand people had to move out from their houses and 50 lost their properties. More than 500 houses were damaged in the West region, and 42 public buildings needed to be repaired. Many agricultural fields were also destroyed, and a hundred percent loss of the corn, soybean and tobacco plantation in the south of the state.

The graph presented in Figure 2 presents the weather conditions from July 2006 to December 2007. High pressure systems in South of Brazil are constant all over the year and trigger cold fronts formation. Other weather systems which are frequent in the state are trough and low pressure, especially in summer and spring. Some anomalies can be observed in the graph: 1) high concentration of lightning events in March 2007, due to semi-stationary front, and 2) number of days under high pressure influence in November of 2007.

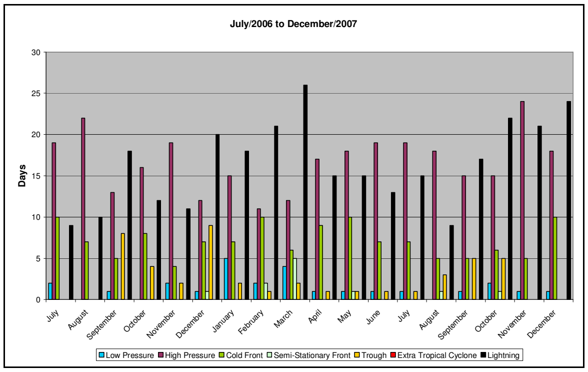

Figure 2. Weather conditions in Santa Catarina, from July/2006 to December/2007

Among the atmospheric systems that influence weather in Santa Catarina, cold fronts are more frequent, reaching the state in a weekly basis and most of the times associated with thunderstorms and lightning. Brief severe storms are regularly seen all over the year in some small areas, but weather conditions during spring and summer seasons are not only more frequent but much more severe and cover wider spatial areas of the state. A good working knowledge of the severe weather climatology from meteorologists is important, and a lightning monitoring system can be extremely helpful in nowcasting.

3. THE REAL TIME MONITORING SYSTEM

The dynamic of a Mesoscale Convective System, such as the one describe in this paper, requires good skilled team of forecasters especially when radar observation data is not available. Early studies demonstrated that lightning characteristics are well correlated with the evolution of thunderstorm intensity (Wilson et al, 2006) and rainfall estimation (Tapia et all, 1998), therefore Lightning Detection Networks (LDN) represent a new asset for nowcasting. Since 2005 when Siddem LDN was installed in Santa Catarina, Epagri´s Meteorologists may rely on a near real time Monitoring System during extreme events.

The Siddem LDN operated by Epagri consists of 11 Impact Sensors, based on Time of Arrival (TOA) and Magnetic Direction Finding (MDF) technologies, and 5 Very High Frequency (VHF) interferometry sensors (Kinceler et all, 2006).

Epagri´s Information Technology team developed a software that access real time lightning data from Siddem LDN to provide a monitoring tool of strong storms evolution, and to depict areas where the storm is more severe such as the one of October 20th, 2007. Lightning maps are very helpful in identifying and tracking the areas more intensely affected by the storms. Figure 3 shows spatial and temporal lightning distribution within a 12 hour interval map, from noon to midnight in this day. It is noticeable that the storm moves from southwest of Rio Grande do Sul toward west of Santa Catarina, and following the little circles with sequential numbers inside them makes storm tracking easier.

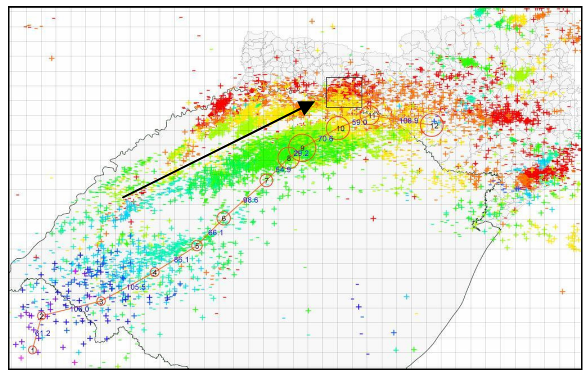

Figure 3. Lightning clusters in October 20th, 2007 from noon to midnight

The map shows one hour clusters of lightning activity in shades of colors with more concentration of events from 11pm to midnight where the arrow points to. It is possible to visually track the storm. But the approximate speed of the storm, that is moving toward the target area, can be calculated by measuring the seeds displacements distance, using the distance function of the system.

For the analysis of October 20th, forecasters may zoom in for a closer look of the cluster with more lightning concentration. They can also break down one or more clusters of lightning events into small clusters of 15 or 5 minutes intervals to analyze the storm within a short period of time.

Frequency graphs add extra information for the analysis. Figure 4 is such a frequency graph representation for the area in the box of Figure 3, for a 48 hour period. By looking Figure 4 there is no doubt that lightning events started in this area at 11pm and finished at 1 am of October 21st.

The forecasters consider the severity of a storm not only by the frequency and distribution of lightning events detected by the LDN but by the intensity as well. The system has the appropriate option to help visual observations of lightning intensity as can be seen in Figure 5, also for the area in the box of Figure 3.

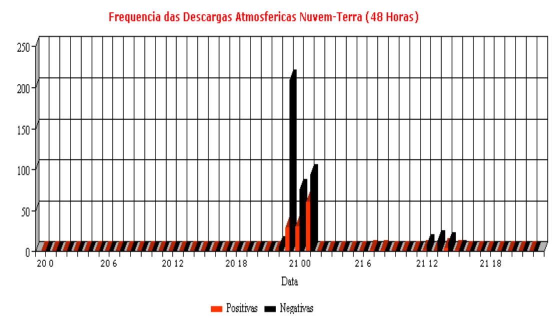

Figure 4. Lightning Frequency on October 20, 2007 in the west region

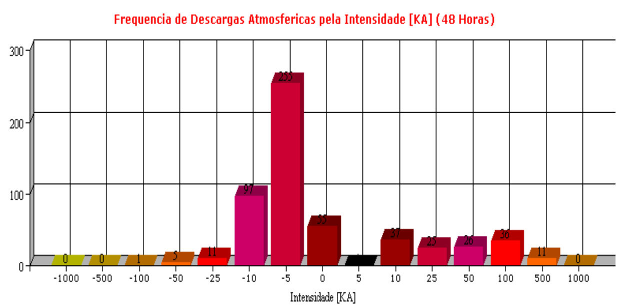

Figure 5. Lightning Intensity in a 48 hour period in the west region

Although a high concentration of negative discharges can be noticed in Figure 5, the intensity in this case is low. On the other hand, positive discharges have better distribution in much higher intensities.

This information augments the certainty in a prediction process, because high lightning intensity storms are usually associated with strong winds and heavy rainfall. These storms cause severe and threatening conditions, considerable damages, and flood in large areas like the one registered on October 20th, 2007.

4. CONCLUSIONS:

Lightning Detection System (LDS) overcomes the limitations of weather prediction when observational data, satellite images and numerical models where the only tools available. The Siddem LDS showed substantial benefits for forecasting especially under convective systems and unstable conditions caused by cold fronts in Santa Catarina.

Appropriate advisories and warnings to the public, civil defense and electric power companies are now possible in nowcasting applications within a short timeframe.

More accurate spatial and temporal distribution data of a LDS provides a helpful tool for severe weather and heavy rainfall distribution predictions.

Further studies will be carried out to better understand the power of this technology for forecasting, and for future data integration in an automatic procedure for rainfall estimation and for thunderstorms advisory.

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