Analysis of the Mexican lightning activity monitored by NASA satellites

Isaias Ramirez-Vazquez*, Ramiro Hernandez-Corona, Gerardo Montoya T., Carlos Romualdo-Torres

Instituto de Investigaciones Electricas, Reforma 113, Col. Palmitas Cuernavaca, Morelos, Mexico

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Abstract

Lightning is the main cause of transmission line outages in Mexico. For this reason, it is necessary to investigate the areas where lightning occurs more frequently in order to improve or establish necessary countermeasures.

Since 1998, the Mexican Institute for Electrical Research has been gathering the database recorded by the operational line scan (OLS), optical transient detector (OTD) and lightning imaging sensor (LIS) systems from USA-NASA. These systems have been installed in satellites to detect and count lightning occurring all around the world.

This information has been analyzed by the IIE to perform seasonal maps of atmospheric discharge frequency along the Mexican Republic. The obtained maps have shown a good agreement with the statistic of transmission line outages caused by lightning. Namely, the zones determined with the highest discharges frequency are those where the highest number of line outages have been reported by the Mexican electrical utility Comision Federal de Electricidad (CFE).

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1. Introduction

The USA-NASA and the Japan-NADSA performed jointly a project to study the changes of climate around the planet. A part of the project consists in detecting the electric activity by means of operational line scan (OLS), optical transient detector (OTD) and lightning imaging sensor (LIS) systems. These systems are installed in satellites to detect the atmospheric discharges all over the world [1–4].

The sensors detect optically all the atmospheric activity taking place: between clouds and from cloud to earth. This was proven by NASA, simultaneously measuring the same events on Earth [5]. However, these sensors cannot distinguish if the discharge is from cloud to cloud or from cloud to earth, due to the optic pulses generated, because both discharge types are quite similar [6,7].

The NASA and the Marshall Special Center started to detect the atmospheric discharges since June 1973 using the OLS sensor. The detection of atmospheric discharges with this sensor finished in November 1995. Subsequently, the OTD sensor was set in orbit and worked from April 1995 to January 1998. The LIS sensor started working on November 1997, at present it is still in operation.

In this case, the IIE is only analyzing the data recorded in the database corresponding to Mexico. It is important to clarify that the data recorded by the sensors is not monitored 24 h a day in the same area, because the satellite travels 24 h a day in the same area, because the satellite travels around the world, passing at the same point every 100 min. Therefore, the data is only partials.

2. Development

The data is obtained as follows: the satellite sends the data to earth as a format which is called level 0. Subsequently, it is processed in the LIS/SCF software as a “production code”. Then, the data is organized and filtered, computing...
Fig. 1. Lightning flash activity recorded by the OLS sensor.

Fig. 2. Lightning flash activity recorded by the OTD sensor (time period: 1 July 1995–30 September 1995).
Fig. 3. Lightning flash activity recorded by the OTD sensor (time period: 1 July 1996–30 September 1996).

Fig. 4. Lightning flash activity recorded by the OTD sensor (time period: 1 July 1997–15 September 1997).
only certain parameters. The production code produces HDF data files, which are distributed to the international scientific community. The NASA data is analyzed using the LIS/OTD and SCF software installed in a Silicon Graphics system model 02, which allows quick analysis of large data block. After analyzing the data, the maps are obtained [8,9] as shown in Figs. 1–5.

3. Discussion of results

3.1. Maps obtained from OLS sensor

The algorithm of this sensor counts only the number of atmospheric discharges occurring during the night. The sensor has low detection efficiency, compared with the OTD and LIS sensors. Due to the few results obtained with this sensor, only a map is presented (Fig. 1).

The data obtained, from 1973, 1985, 1987, 1990 and 1991, by the sensor showed small atmospheric discharge activity, it only recorded discharges classified into a frequency scale of one event: either cloud to cloud or cloud to earth discharge. Meanwhile, there were also scattered discharges recorded for 1986, 1994 and 1995, into the frequency scale of two events.

From the years mentioned above, the largest number of atmospheric discharges recorded in 1995 was 3887. Therefore, the data obtained by the OLS sensor is too small in order to make representative maps of the atmospheric electrical discharges frequency in Mexico. However, from these data, it was seen that the atmospheric discharges take place mainly in a certain zone which is from the western part to the southern-southeastern part of Mexico (Fig. 1). The same pattern is also observed in the data recorded by the OTD and LIS sensors.

3.2. Maps obtained from OTD sensor

This sensor has a better efficiency, and consequently, the number of atmospheric discharges recorded was larger than those recorded by the OLS sensor, (it was between 40% and 65% in excess). This better efficiency allowed obtaining a more accurate plotting of monthly and seasonal maps.

During 1995, both sensors (OLS and OTD) were working properly. The difference between the data recorded by each sensor showed that the OLS sensor had low detection efficiency. The OLS sensor recorded 7824 electrical discharges in the 1 June 1973 to 31 November 1995 period, while the OTD sensor recorded 144,074 electrical discharges in only 3 months (1 July 1995 to 30 September 1995) (Figs. 1 and 2).
Fig. 2 shows the discharges map for 1995 season. As it can be analyzed, the major activity occurred during the summer, with 144,074 electrical discharges recorded. This performance is also observed in the maps obtained during 1996 and 1997, as illustrated in Figs. 3 and 4.

3.3. Maps obtained from LIS sensor

The LIS sensor was improved with respect to the OLS and OTD sensors. Consequently, the amount of data recorded was larger. Fig. 5 shows a seasonal map for data recorded during 1998. According to this figure, the major discharge frequency also takes place during the summer and the pattern is also similar to that corresponding to the maps obtained by the OLS and OTD sensors. Fig. 6 shows the discharges map for 1999 to January 2003 season.

4. Correlation between atmospheric discharges and transmission line outputs

Tables 1 and 2 show statistics of the transmission line outages per 100 km, occurring in Mexico from 1995 to 2003, caused by lightning [10, 11].

Table 1
Summary of transmission line outages per 100 km in Mexico from 1995 to 2003 due to lightning

<table>
<thead>
<tr>
<th>Area</th>
<th>400 kV</th>
<th>230 kV</th>
<th>161 kV</th>
<th>150 kV</th>
<th>138 kV</th>
<th>115 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western</td>
<td>6.897</td>
<td>5.574</td>
<td>39.43</td>
<td>–</td>
<td>–</td>
<td>68.19</td>
</tr>
<tr>
<td>Southeastern</td>
<td>8.427</td>
<td>10.775</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>36.194</td>
</tr>
<tr>
<td>Peninsular</td>
<td>–</td>
<td>8.518</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>33.424</td>
</tr>
<tr>
<td>Central</td>
<td>7.69</td>
<td>8.337</td>
<td>5.16</td>
<td>–</td>
<td>–</td>
<td>22.64</td>
</tr>
<tr>
<td>Eastern</td>
<td>4.704</td>
<td>6.145</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.982</td>
</tr>
<tr>
<td>Northwestern</td>
<td>3.54</td>
<td>3.47</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>2.348</td>
</tr>
<tr>
<td>Northeastern</td>
<td>2.552</td>
<td>2.355</td>
<td>0.951</td>
<td>5.37</td>
<td>–</td>
<td>6.201</td>
</tr>
<tr>
<td>Baja California</td>
<td>3.54</td>
<td>1.855</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>3.199</td>
</tr>
<tr>
<td>Total</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>304.832</td>
</tr>
</tbody>
</table>

Total (%)

100
Table 2

Number of transmission line outages per 100 km per year in Mexico from 1995 to 2003 due to lightning

<table>
<thead>
<tr>
<th>Area</th>
<th>Voltage (400 kV)</th>
<th>Voltage (230 kV)</th>
<th>Voltage (161 kV)</th>
<th>Voltage (150 kV)</th>
<th>Voltage (138 kV)</th>
<th>Voltage (115 kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>7.69</td>
<td>8.337</td>
<td>5.16</td>
<td>10.775</td>
<td>6.145</td>
<td>68.19</td>
</tr>
<tr>
<td>Southeastern</td>
<td>8.427</td>
<td>10.775</td>
<td>22.84</td>
<td>36.194</td>
<td>6.291</td>
<td>36.194</td>
</tr>
<tr>
<td>Western</td>
<td>6.897</td>
<td>8.337</td>
<td>22.84</td>
<td>22.044</td>
<td>3.61</td>
<td>36.194</td>
</tr>
<tr>
<td>Northern</td>
<td>3.540</td>
<td>6.145</td>
<td>22.84</td>
<td>22.044</td>
<td>3.61</td>
<td>22.044</td>
</tr>
<tr>
<td>Northeastern</td>
<td>2.527</td>
<td>5.16</td>
<td>22.84</td>
<td>5.16</td>
<td>3.48</td>
<td>22.044</td>
</tr>
<tr>
<td>Baja California</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>37.747</td>
<td>47.229</td>
<td>174.315</td>
<td>141.944</td>
<td>99.14</td>
<td>181.315</td>
</tr>
</tbody>
</table>

By correlating the values of Tables 1 and 2 with the discharge frequency values as indicated in different maps (Figs. 2–6), it can be observed that there is a direct relationship between both data: namely, the zones of the Mexican Republic having the highest outages per 100 km per year are located where the highest discharge frequencies were obtained from different sensors.

For example, according to Table 1, the zones with larger outages caused by lightning are: the western, southeastern, peninsular and central zones. As shown in the maps, particularly for the summer season, these zones present a high lightning activity. However, it is necessary to carry out a detailed analysis for each transmission line by considering its real coordinates, since the maps were obtained using latitudes and longitudes.

From Table 1, it can also be observed that the atmospheric discharges cause more outages at 115 kV transmission lines than at 230 kV and 400 kV transmission lines, as it was expected.

5. Conclusions

The data of atmospheric discharges frequency obtained from the sensors installed in different satellites was reviewed. The first (OLS) generation, which only detects events occurred during the night, shows low detection efficiency. The second (OTD) and third (LIS) sensor generation have a higher resolution to detect atmospheric discharges, and consequently, more data can be recorded and analyzed to develop accurate maps showing the zones with higher atmospheric discharges frequency in the Mexican Republic for each season of the year.

The review of the data monitored from 1995 to January, 2003 shows that the atmospheric discharges occur more often over the western mountains and southern-southeastern zones of the Mexican Republic and that the season where the highest frequency of discharges takes place is during the summer.

From the maps obtained and transmission line outage statistics, it is observed that the zones where the highest frequency of atmospheric discharges was obtained are those where the statistics show the larger number of outages caused by lightning over the Mexican transmission lines.

The maps developed for the years 1995 to January, 2003 show that there is a pattern of zones with high frequency of atmospheric discharges. However, this pattern considers both cloud to cloud and cloud to ground discharges. Therefore, it is necessary to determine the percentage corresponding to cloud to ground discharges, in order to carry out a direct correlation ship to transmission line outages caused by atmospheric discharges.

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