J. Ind. Geophys. Union ( September 2017 )
**v.21, no.5, pp: 415-424**

# Distribution of Lightning Casualties over Maharashtra, India

**Omvir Singh*[1], Pankaj Bhardwaj[2] and Jagdeep Singh[2]**
[1]Professor, Department of Geography, Kurukshetra University, Kurukshetra-136119, Haryana, India
[2]Research Scholar, Department of Geography, Kurukshetra University, Kurukshetra-136119, Haryana, India
*Corresponding Author: ovshome@gmail.com

**ABSTRACT**
This study investigates human casualties as a result of lightning strikes in Maharashtra state of India. Records dating from 1979 to 2011 have reported about 2363 casualties resulting from 455 lightning events. On an average 72 casualties per year have been reported with significant increasing trend. About 51 per cent events and 46 per cent casualties have occurred only in six districts of Nagpur, Chandrapur, Yavatmal, Nashik, Amravati and Akola. Remarkably, Vidarbha region has reported about 4 times more lightning events and about 3 times more casualties than second highest Marathwada region. The lightning events and casualties rate per million population per year in the state has been found to be 0.15 and 0.82, respectively. Male casualties are more prominent than females and children, which is probably due to the larger proportion of males performing their work outdoors. The peak lightning events and casualties have been witnessed during the monsoon season, whereas lowest during winters. It is believed that the results of this study will be helpful in developing better disaster management guidelines for lightning safety and preparedness. Apt audio-video presentations would help in better education of vulnerable segments of our society, farmers and daily wage earners present in the rural environment.

**Key words**: Lightning, Thunderstorm, Casualties, Gender variations, Maharashtra.

## INTRODUCTION

Lightning is one of the most significant atmospheric hazards that mankind has encountered since times immemorial. It is associated with development of cumulonimbus clouds and is, therefore, physically related to strong convection. Electric discharges within thunderstorms indicate the intensity of atmospheric convection. Lightning associated with these thunderstorms is highly disastrous in nature and an underestimated threat to infrastructure and people. Globally, lightning leads to thousands of human casualties (including fatalities and injuries) every year. Therefore, many studies pertaining to lightning fatalities (deaths) and injuries have been undertaken in different countries such as Australia (Coates et al., 1993), United States (Curran et al., 2000), United Kingdom (Elsom, 2001), Canada (Mills et al., 2008), Swaziland (Dlamini, 2009), China (Zhang et al., 2011), Brazil (Cardoso et al., 2014), Colombia (Aldana et al., 2015) and India (Singh and Singh, 2015). All these studies have dealt with the phenomenon at macro scale while importance of lightning casualties in micro regions has remained poorly understood. To contribute knowledge towards the micro regions, the present study, therefore, explores the distribution of the lightning casualties over Maharashtra state of peninsular India, an area of known exposed rocky terrain facilitating ground conductance to relatively longer distance and thus making the area relatively more vulnerable to lightning incidences (Murli Das et al., 2007, 2009). Studies on lightning casualties over Maharashtra are scanty, though very recently, Gadge and Shrigiriwar (2013) and Shrigiriwar et al., (2014) have examined the lightning fatalities referring to a very small period of time, a particular district and fatality cases reported at a particular hospital without taking into account a spatial and temporal distribution. To fill this research gap, an attempt has been made in the present study to examine the spatial and temporal distribution of lightning casualties over the state. This study has mainly focused on (1) spatial and temporal distribution of lightning casualties, (2) regional variation in lightning casualties, (3) lightning casualties by gender and (4) top ten lightning strike events.

### Study Area

Maharashtra is third largest state of India (3,07,713 km$^2$) located on the western side of Indian peninsula between the latitudes 15°40´N-22°00´N and longitudes 72°30´E-80°30´E (Figure 1). The state supports a large variety of landscapes, geology, soils, climate, vegetation and natural resources. The climate of the state is tropical monsoon type and most of the annual rainfall occurs during the southwest monsoon season (June-September) with large spatial variations. The state is frequently affected by various natural disasters such as droughts, floods, cyclones, thunderstorms and lightning. Every year hundreds of casualties have been reported due to these natural hazards/disasters.

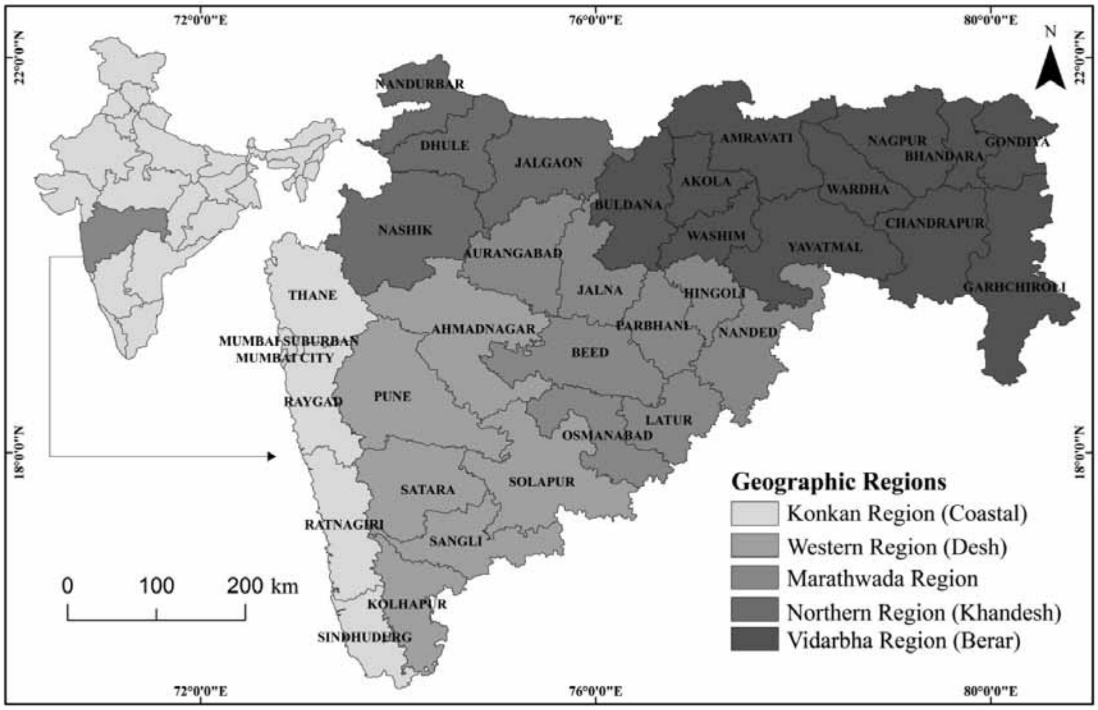


**Figure 1.** Map showing the location of Maharashtra, with different geographic regions.

## DATA AND METHODOLOGY

Casualties in the present study are defined as the sum of fatalities (deaths) and injuries. Data pertaining to casualties for 35 districts of the state has been extracted from 'Disastrous Weather Events' annual reports of India Meteorological Department (IMD), Pune, covering the period from 1979 to 2011. These reports comprise information of each lightning incidence that occurred along with its: (i) year, month and date of the event occurrence; (ii) district of the casualty; (iii) demographic information (e.g. gender); (iv) persons killed/injured and livestock killed/injured; (v) houses damaged and (vi) magnitude of economic loss. Accordingly, this database has been used earlier for comprehensive studies on extreme weather events (De et al., 2005; Singh and Singh, 2015) for Indian region. In addition, district-wise population statistics for Maharashtra state have been collected from Census of India for the decadal census enumeration years 1981, 1991, 2001 and 2011. Subsequently, average annual growth rates of population in percentage have been computed between these adjacent census enumeration years. The average annual growth rates of population so computed has been further applied to estimate the annual population of Maharashtra state as well as individual districts of the state. Lightning events, fatalities, injuries and casualties rates (number of events/fatalities/injuries/casualties per million population per year) have been calculated to make the obtained results comparable with regional, national and global scale. Many researchers have calculated the rate (per million population per year) of a particular disaster globally (Curran et al., 2000; Zhang et al., 2011; Cardoso et al., 2014; Aldana et al., 2015), by using the following formula:

$$R = [(N/P) \times 1000000] / n$$

where,

- ***R*** is the rate to be calculated (per million population per year),
- ***N*** is the number of lightning events, fatalities, injuries or casualties reported,
- ***P*** is the annual total population likely to be affected (i.e. this population is an average of decadal census values for 1981, 1991, 2001 and 2011), and
- ***n*** is the number of years (study period from 1979 to 2011).

These rates were calculated for the 35 districts of the state of Maharashtra and then ranked in descending order. These ranks were then mapped in classes incrementing by steps of 7 ranks (i.e. 1-7; 8-14; 15-21; 22-28 and 29-35). These computed rates have been mapped separately to determine the distribution of high or low number of events, fatalities, injuries and casualties resulting from lightning. Further, to investigate the seasonal variations, a year has been divided into four seasons as per IMD's categorization i.e. winter (January-February), pre-monsoon (March-May), monsoon (June-September) and post-monsoon (October-December). For studying the regional variations of lightning casualties, Maharashtra has been carefully demarcated into five different geographic regions (Figure 1).

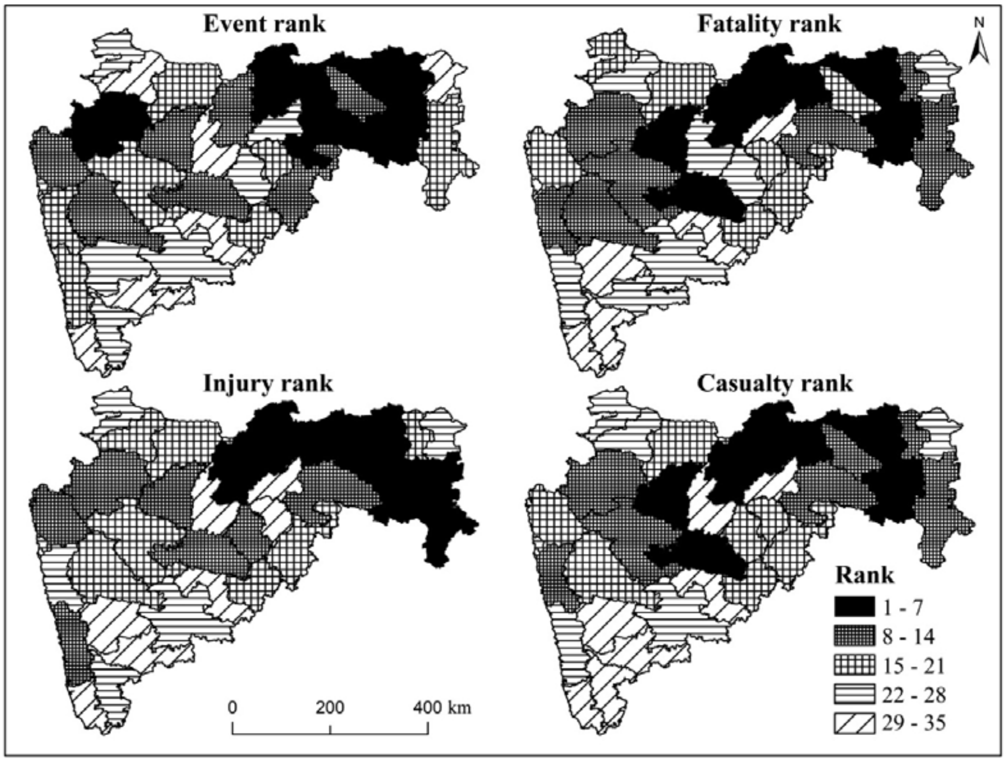


**Figure 2.** Rank of each district in number of lightning events, fatalities, injuries and casualties in Maharashtra from 1979 to 2011.

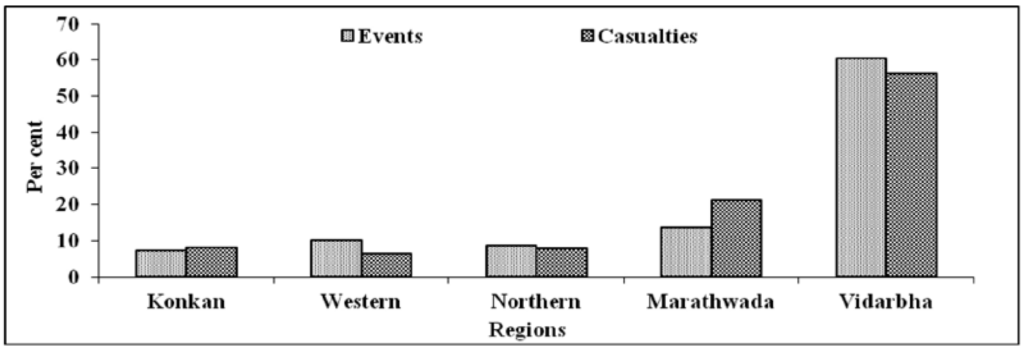


**Figure 3.** Region-wise variation in lightning events and casualties over Maharashtra from 1979 to 2011.

## RESULTS AND DISCUSSION

### Spatial distribution

#### Variations by district

Figure 2 shows the number of lightning events, fatalities, injuries and casualties by steps of 7 rank points from 1979 to 2011. Interestingly, spatial distribution shows that the distribution of casualties is nearly identical to fatalities, since 64 per cent of casualties are fatalities. Most of the lightning events (about 60 per cent) and casualties (about 56 per cent) concentrated over districts of Vidarbha region. Vidarbha region has more than four times higher lightning events than the second highest Marathwada region (about 14 per cent). The maximum events and casualties have been witnessed over Vidarbha region followed by Marathwada, Western, Northern and Konkan regions (Figure 3). Further, only six districts namely Nagpur, Chandrapur, Yavatmal, Nashik, Amravati and Akola are the worst hit, accounting for about 51 per cent of the total lightning events, 44 per cent of the total fatalities, 52 per cent of the total injuries and 46 per cent of total casualties in the state. It has been noticed that all these districts lie in Vidarbha region except Nashik. This dismal situation in this region can be attributed to the local topography (exposed rocky terrain) and climatic conditions. While studying the lightning hazard in Kerala, Murli Das et al., (2007, 2009) observed that about 51 per cent of the lightning accidents have occurred on exposed rocky terrain. Exposed rocky terrains normally have low soil conductivity and facilitate ground conductance

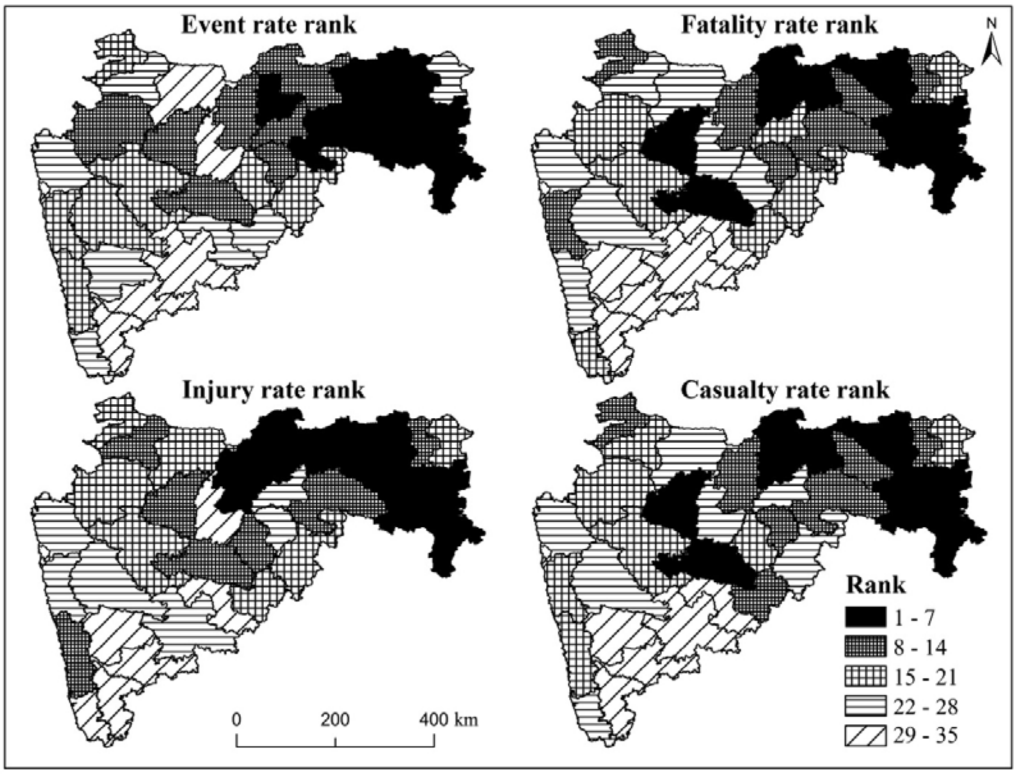


**Figure 4.** Rank of each district in lightning events, fatalities, injuries and casualties per million population in Maharashtra from 1979 to 2011.

to relatively longer distance, and are thus relatively more vulnerable for lightning strikes (Murli Das et al., 2007, 2009). Nagpur is the leading district in terms of number of lightning events, fatalities, injuries and casualties during the study period. Each event has caused approximately 3 casualties in Nagpur district. Also, it has been observed that the districts, which reported more lightning events have more casualties and vice versa.

Furthermore, on an average 0.56 injuries per fatality have been reported over Maharashtra. The geographical distribution of the injury to death ratio has exhibited no coherent pattern. Some districts have slightly more fatalities than injuries such as Ratnagiri, Parbhani, Dhule, Jalgaon, Mumbai and Wardha, while rest of the districts has higher number of injuries than fatalities. For example, Hingoli district has 2 injuries but 38 fatalities and Beed district has only 25 injuries but 118 fatalities. A low ratio may indicate an underreporting of injuries and that deaths are the better statistic for a state (Curran et al., 2000).

**Variations by district weighted by population**

Figure 4 shows the rate of lightning events, fatalities, injuries and casualties per million population by steps of 7 rank points. The rates of event, fatality, injury and casualty per million people per year for Maharashtra have been observed to be 0.15, 0.52, 0.29 and 0.82, respectively for the period 1979 to 2011. It has also been found that lightning casualty rate over Maharashtra state (0.82) is more than three times than the all India value (0.25) (Singh and Singh, 2015). Interestingly, it has been observed that, the maps of rate per million population are almost similar to the maps of absolute number (Figure 2). No significant shift in casualty maxima has been witnessed when population is taken into account. For example, Nagpur, Chandrapur, Akola, Amravati, Aurangabad, Beed and Buldana are top 7 districts in total number of casualties, whereas in terms of casualty rate, Chandrapur, Akola, Garhchiroli, Nagpur, Amravati, Beed and Aurangabad are the top 7 districts.

When population is taken into account for different regions, the annual casualty rates have varied from 0.46 casualties per million population per year (Vidarbha region) to 0.05 casualties per million population per year (Western region). The annual casualty rates can be interpreted as the average probability of a person being struck by lightning and injured/killed in each region and not the probability for different situations, which can change significantly. For instance, if one person is in an open field during a strong thunderstorm, this probability can be one per thousand instead of one per million (Cardoso et al., 2014).

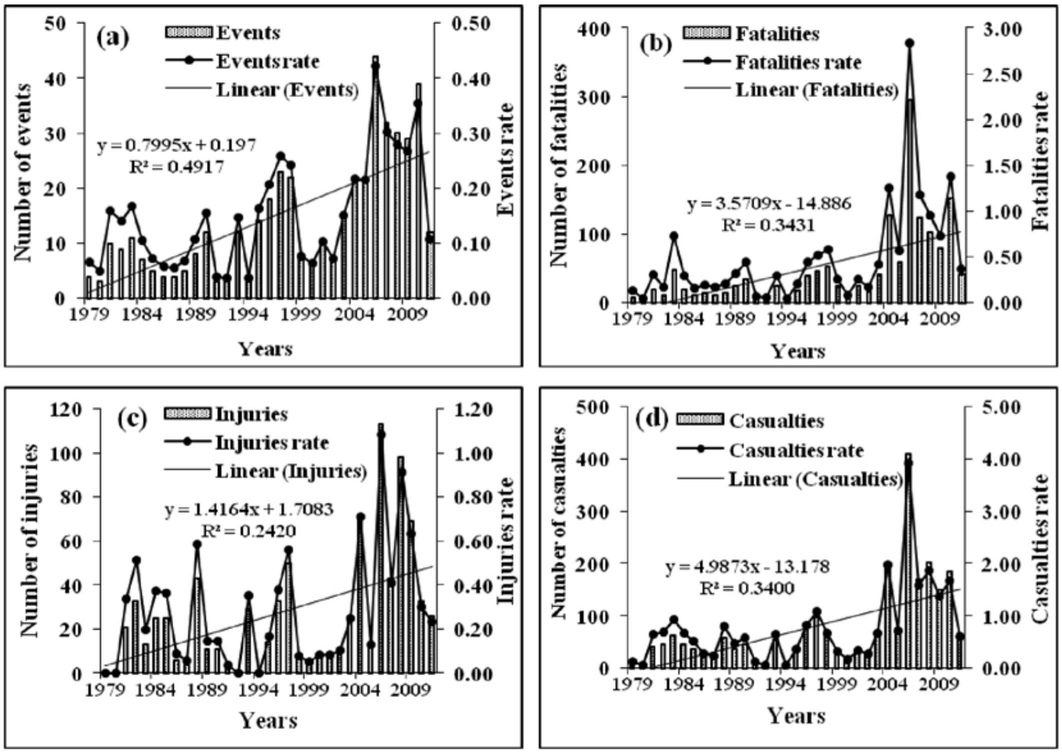


**Figure 5 (a-d).** Annual variation in total number and rate of lightning (a) events, (b) fatalities, (c) injuries and (d) casualties.

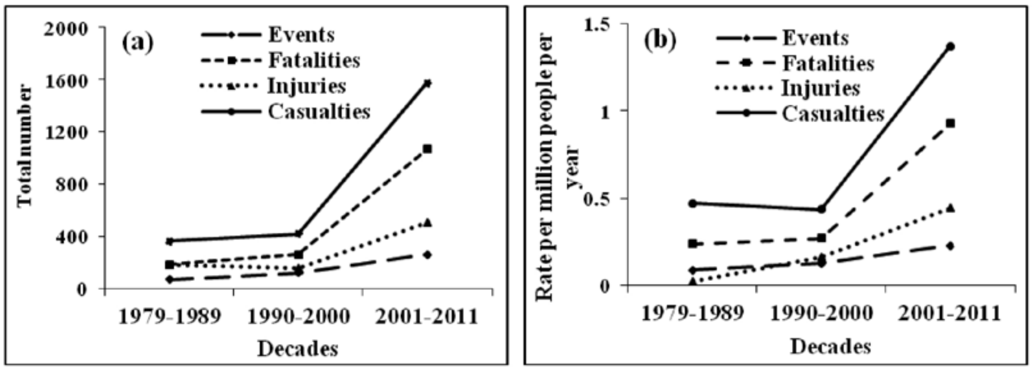


**Figure 6 (a-b).** Decadal distribution of (a) total number and (b) rate per million people per year of lightning events, fatalities, injuries and casualties in Maharashtra during the period 1979-2011.

## Temporal distribution

### Year-to-year variations

Year to year variations in number and rate per million people per year on account of lightning events, fatalities, injuries and casualties recorded over Maharashtra from 1979 to 2011 have been indicated in Figure 5 (a-d). The fit of a linear trend to the annual lightning events, fatalities, injuries and casualties showed upward trend with fluctuation at 1% level of significance. Interestingly, it has been observed that the lightning events, fatalities, injuries and casualties are more or less constant during the first two decades, however, sharply increased during last decade (Figure 6 a-b). About 55, 67, 60, 65 per cent lightning events, fatalities, injuries and casualties have been recorded in last ten years. This increase may be attributed to the improved reporting procedure, especially from remote areas. It could also be attributed to the increased socio-economic vulnerability and development processes. Also, the correlation between lightning activity and atmospheric temperature anomaly is significant, which shows that global warming increases thunderstorm activity, and lightning frequencies in thunderstorms are extremely sensitive to small increase in surface air temperature (Peterson et al., 2005). Further, the annual fluctuations in events and casualties can be attributed to the year to year variability in the climatic patterns resulting from regional and global climatic instabilities and teleconnections (Thapliyal and Kulshreshtha, 1991).

Further, a total of 2363 casualties (1512 fatalities and 851 injuries) have been reported resulting from 455 lightning events leading to 14 events, 46 fatalities, 26 injuries and 72 casualties annually in Maharashtra during the study period. Interestingly, thunderstorm frequency is just 20-60 days in various parts of Maharashtra and it is mostly caused by westward moving monsoon lows/depressions (Tyagi, 2007). In spite of the moderate occurrence of thunderstorm frequency, the maximum fatalities as a result of lightning flashes can be attributed to high vegetation cover, large size of population of the state in comparison to the states having more thunderstorm frequency. The frequent lightning strikes over this region are not only due to its location in tropical area, but also adjoining warm oceanic waters supplying abundant low-level moisture, the movement of the equatorial trough across the region and large topographic variations (Tinmaker et al., 2014).

Further, on an average, 5 casualties per event have been reported in Maharashtra, which has varied from a low of 1 in 1980 to a high of 10 in 2006. During 1988, 5 events have caused 58 casualties, whereas 3 events have caused only 3 casualties during the year 1980. Similarly, 44 events have caused 408 casualties in the year 2006. Therefore, it can be summed up that large number of events in a year does not necessarily lead to large number of casualties. Annual variations in lightning events and casualties over different geographic regions of Maharashtra are shown in Figure 7 (a-e). It has been observed from the figure that only Vidarbha region is experiencing a significant increasing trend in lightning events and casualties, whereas no significant downward or upward trends have been observed over rest of the regions.

**Monthly and seasonal variations**

Figure 8 (a-b) illustrates that lightning events and casualties increase consistently from the month of January and attain first maxima in the months of June. It then decreases till August and then again picks up and attains the second lower maxima in the month of September. After September, both events and casualties have diminished systematically (Figure 8a). Interestingly, June month has recorded highest lightning events (about 26 per cent) and casualties (about 33 per cent). The two maxima in the months of June and September are associated with onset and retreating of monsoon, respectively. The thunderstorms that occurred in the month of June have high value of convective available potential energy giving rise to peak lightning flash count (Manohar et al., 1999).

Further, a seasonal analysis revealed that monsoon is the prime season for lightning events and casualties (both about 66 per cent) followed by pre-monsoon, post-monsoon and winter seasons (Figure 8b). These results coincide with occurrence of thunderstorms. The winds in the lower troposphere become more westerly, and this brings ample moisture over the region from the Arabian Sea and acts as a trigger for the development of thunderstorms (India Meteorological Department, 1931). Therefore, the higher frequency of lightning events and fatalities can be attributed to the higher occurrence of thunderstorm activity during monsoon season. Despite moderate or intense convection during the pre-monsoon season with the heating over Maharashtra, there is lack of enough moisture for the formation of thunderstorms, therefore, lightning strikes are less (Kandalgaonkar et al., 2008). Additionally, the chance of thunderstorms formation decreases due to lack of moisture, cool, dry and stable atmospheric conditions as the season progresses. Therefore, occasional lightning strikes (only 5 lightning incidence during entire study period) have been reported during winter season.

Figure 9 (a-e) illustrates the monthly and seasonal distribution of lightning events and casualties, and casualties almost follow the pattern of lightning events. Like entire state, dual maxima in occurrence of lightning events and casualties have been witnessed over each region. A close examination has revealed that each region has recorded maximum lightning events and casualties during monsoon season (first peak in the month of June). The second lower peak has been noticed in September month over each region except Konkan and Western (in October).

**Gender variations**

Analysis by gender reveals that males account far more fatalities (91 per cent), injuries (86 per cent) and casualties (89 per cent) than female fatalities (5 per cent), injuries (10 per cent) and casualties (7 per cent) by lightning events. Remarkably, males are killed about 13 times more than females due to higher work participation by males in outdoor and labour-intensive activities such as agriculture, herding cattle, ploughing and construction work etc. Besides, where women undertake most of the agricultural work and other outdoor activities, it is possible that they may be the lightning victims rather than men (Elsom, 2001). Apart from this, about 4 per cent casualties have been witnessed among children.

**Top Ten Lightning Strike Events**

Apart from variations in the annual, seasonal and monthly casualties of people hit by lightning during the period 1979-2011 reveal not only temporal variations in lightning activity but also, in some years, a large number of people are affected by a single event. Table 1 highlights the top 10 lightning events in terms of casualties reported over Maharashtra. This is based on the total occurrence of lightning casualties on a particular day at one place. These 10 events (total 455 events) have caused about 14

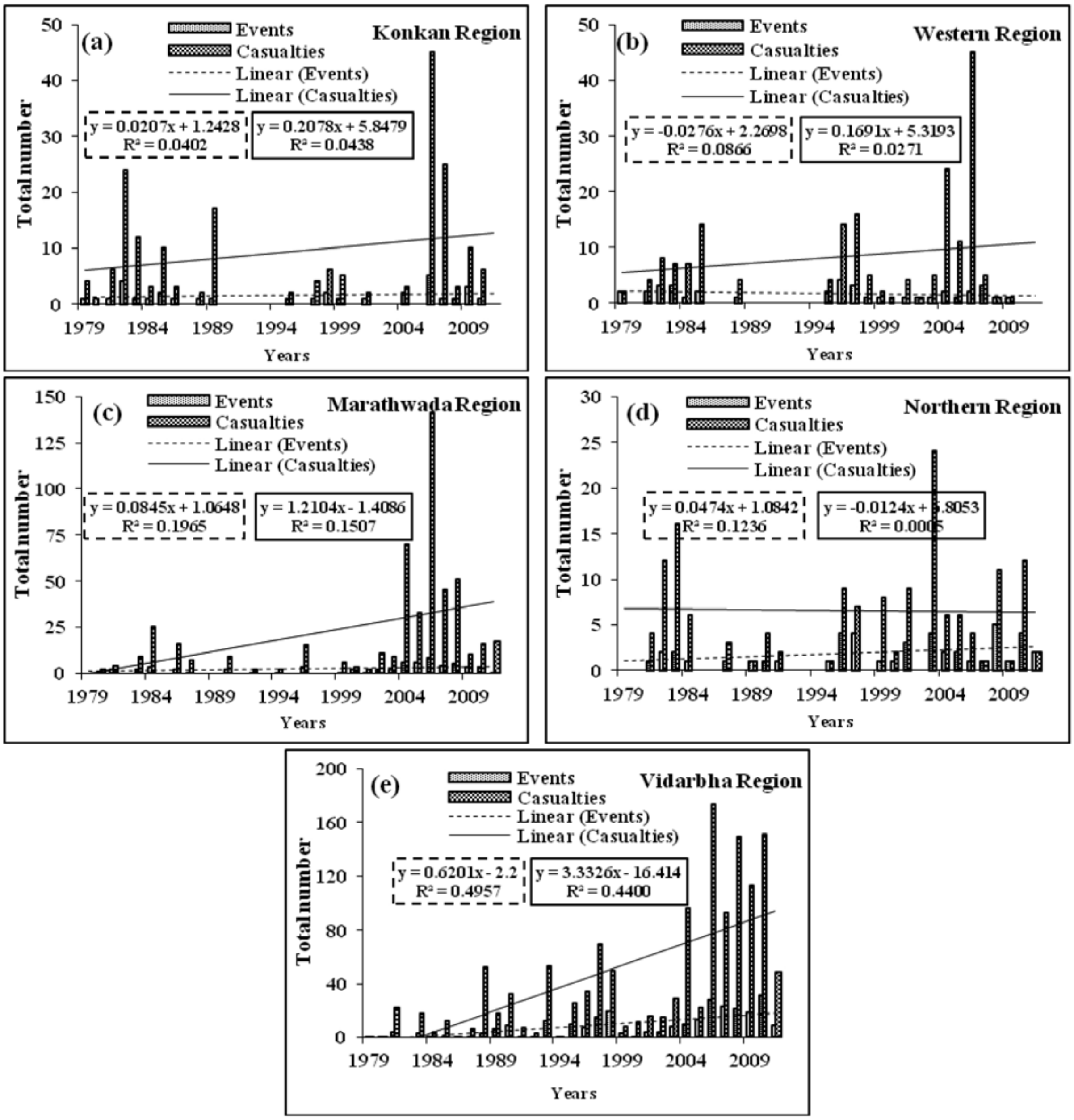


**Figure 7 (a-e).** Annual variation in number of lightning events and casualties by region from 1979-2011.

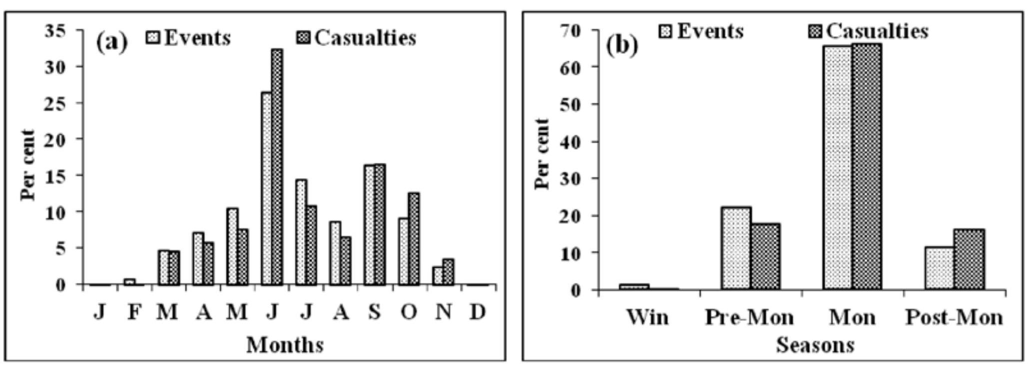


**Figure 8 (a-b).** Variations in (a) monthly and (b) seasonal lightning events and casualties in Maharashtra from 1979 to 2011.

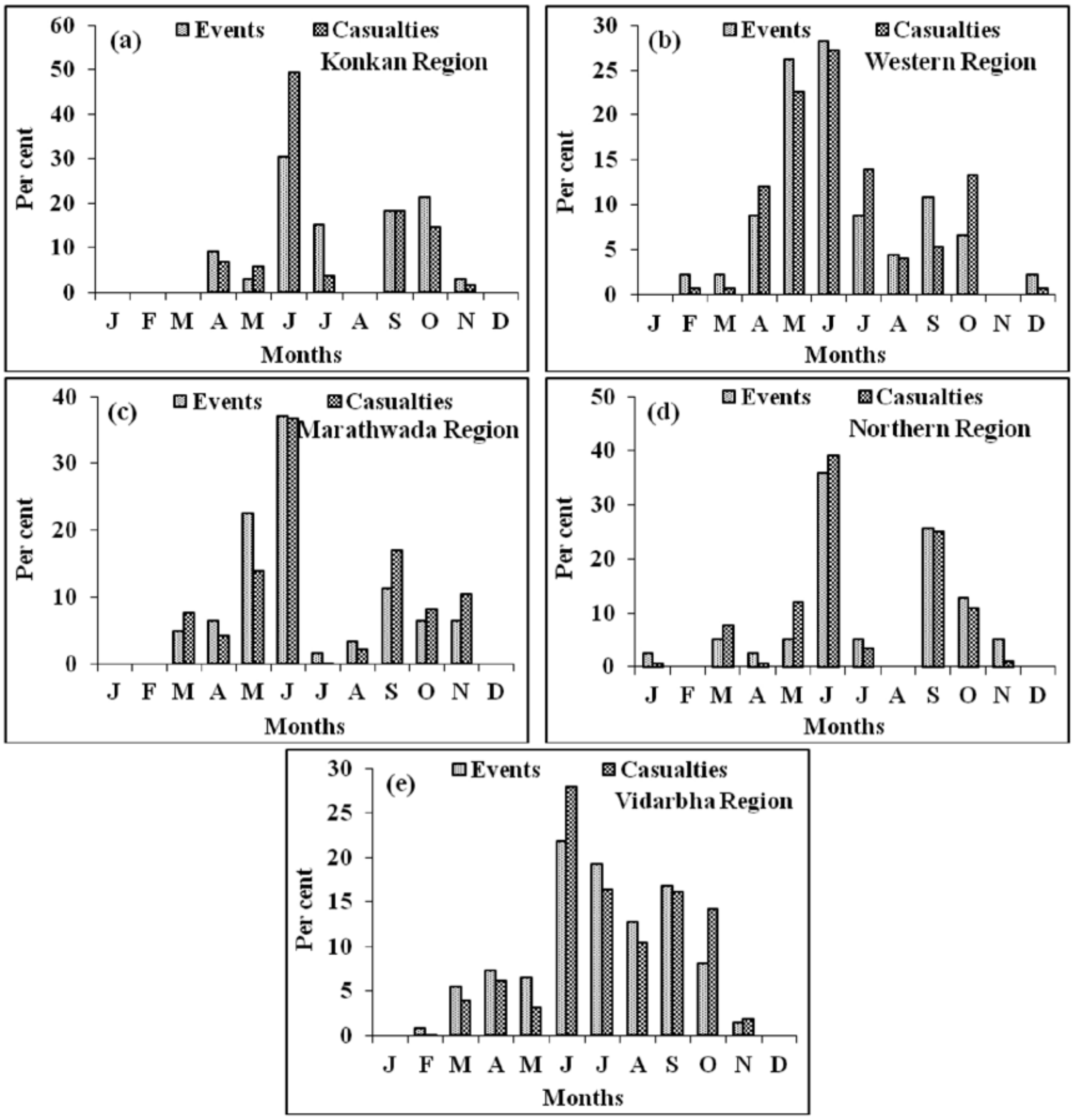


**Figure 9 (a-e).** Monthly variation in the percentage of lightning events and casualties by region from 1979-2011.

**Table 1.** Top 10 lightning casualty incidents reported in Maharashtra during 1979 to 2011

| Date | District | Casualty |
|---|---|---|
| 27-06-2010 | Akola | 49 |
| 18-06-2006 | Aurangabad | 47 |
| 16-06-1988 | Garhchiroli | 34 |
| 13-06-2004 | Chandrapur | 33 |
| 06-04-2008 | Akola | 31 |
| 28-09-2004 | Beed | 31 |
| 19-06-2006 | Nandurbar | 30 |
| 23-08-2009 | Amravati | 25 |
| 30-06-2007 | Raigad | 25 |
| 14-06-2004 | Buldhana | 24 |

per cent of total casualties from 1979 to 2011. The largest lightning casualty incident has been reported on June 27, 2010 in Akola district, which caused 49 casualties. It has been observed that, out of these 10 events, 9 have occurred during the monsoon season alone (Table 1). Out of these 10 lightning events, maximum occurred in Vidarbha region (6 times), followed by Marathwada (2 times), Northern and Konkan regions (1 time each).

## CONCLUSIONS

Analysis of long-term data has shown occurrence of about 2363 casualties resulting from 455 lightning events with an average of 72 casualties annually. A significant upward trend with fluctuation in annual lightning events, fatalities, injuries and casualties has been observed. Nagpur district has led the state in actual number of lightning events, fatalities, injuries and casualties. Lightning events, fatalities, injuries and casualties are more or less constant during the first two decades of the study period, however, sharply increased during the last decade. Dual maxima in lightning events and casualties have been observed: first highest peak in the month of June and the second peak in the month of September. Seasonally, lightning events and casualties have been observed to be highest during monsoon, while lowest during winter season. Regional analysis shows that only Vidarbha region of Maharashtra is experiencing a significant increasing trend in lightning events and casualties, whereas no significant downward or upward trends have been observed over rest of the regions. The annual casualty rates have varied from 0.46 casualties per million population per year (Vidarbha region) to 0.05 casualties per million population per year (Western region). Apart from this, more males than females have been injured or killed by lightning in Maharashtra as a result of higher work participation by males in labour-intensive agricultural practices. Since lightning has become a regular feature it is advisable to educate vulnerable segments of population through audio-video media presentations to gradually lessen the casualties.

## ACKNOWLEDGEMENTS

The authors sincerely thank Prof. B.S. Marh for his critical comments and constructive suggestions which helped in overall improvement of the manuscript. Authors are thankful to Dr. Onkari Prasad for editing the manuscript. They are also thankful to Chief Editor for his support and encouragement and final editing.

## Compliance with Ethical Standards

The authors declare that they have no conflict of interest and adhere to copyright norms.

## REFERENCES

Aldana, N.N., Cooper, M.A., and Holle, R.L., 2015. Lightning fatalities in Columbia from 2000 to 2009, American Meteorological Association, v.7, pp: 1-6.

Cardoso, I., Pinto, O., Pinto, I.R.C.A., and Holle, R., 2014. Lightning casualty demographics in Brazil and their implications for safety rules, Atmospheric Research, v.135-136, pp: 374-379.

Coates, L., Blong, R., and Siciliano, F., 1993. Lightning fatalities in Australia 1824-1991, Natural Hazards, v.8, pp: 217-233.

Curran, E.B., Holle, R.L., and Lopez, R.E., 2000. Lightning casualties and damages in the United States from 1959 to 1994, Journal of Climate, v.13, pp: 3448-3464.

De, U.S., Dube, R.K., and Rao, G.S.P., 2005. Extreme weather events over India in the last 100 years, Journal of Indian Geophysical Union, v.9, pp: 173-187.

Dlamini, W.D., 2009. Lightning fatalities in Swaziland: 2000-2007, Natural Hazards, v.50, pp: 179-191.

Elsom, D.M., 2001. Deaths and injuries caused by lightning in the United Kingdom: analyses of two databases, Atmospheric Research, v.56, pp: 325-334.

Gadge, S.J., and Shrigiriwar, M.B., 2013. Lightning: a 15 year study of fatal cases at SVNGMC Yavatmal, Journal of Forensic Medicine, Science and Law, v.22, pp: 1-5.

India Meteorological Department, 1931. The structure of the sea-breeze at Poona, Scientific Notes, v.3, pp: 131-134.

Kandalgaonkar, S.S., Tinmaker, M.I.R., and Kulkarni, M.K., 2008. Two year observational study of lightning and rainfall activity over Maharashtra, India, International Journal of Meteorology, v.33, pp: 39-48.

Manohar, G.K., Kandalgaonkar, S.S., and Tinmaker, M.I.R., 1999. Thunderstorm activity over India and the Indian southwest monsoon, Journal of Geophysical Research, v.104, pp: 4169-4188.

Mills, B., Unrau, D., Parkinson, C., Jones, B., Yessis, J., Spring, K., and Pentelow, L., 2008. Assessment of lightning related fatality and injury risk in Canada, Natural Hazards, v.47, pp: 157-183.

Murli Das, S., Mohankumar, G., and Sampath, S., 2009. Investigations into mechanisms of involvement of objects and personnel in lightning disaster, Journal of Lightning Research, v.1, pp: 36-51.

Murli Das, S., Sampath, S., and Mohankumar, G., 2007. Lightning hazard in Kerla, Journal of Marine and Atmospheric Research, v.3, pp: 111-117.

Peterson, W.A, Christian, H.J., and Rutledge, S.A., 2005. TRMM observation of the global relationship between ice water content and lightning, Geophysical Research Letters, L14819., v.32.

Shrigiriwar, M.B., Gadhari, R.K., Jadhao, V.T., Tingne, C.V., and Kumar, N.B., 2014. Study of fatalities due to lightning in Nagpur region of Maharashtra, Journal of the Indian Academy of Forensic Medicine, v.36, pp: 259-262.

Singh, O., and Singh, J., 2015. Lightning fatalities over India: 1979-2011, Meteorological Applications, v.22, pp: 770-778.

Thapliyal, V., and Kulshreshtha, S.M., 1991. Climate change and trends over India, Mausam, v.42, pp: 333-338.

Tinmaker, M.I.R., Aslam, M.Y., and Chate, D.M., 2014. Climatology of Lightning Activity over the Indian Seas, Atmosphere-Ocean, doi.org/10.1080/07055900.2014.941323., pp: 1-7.

Tyagi, A., 2007. Thunderstorm climatology over Indian region, Mausam, v.58, pp: 189-212.

Zhang, W., Meng, Q., Ma, M., and Zhang, Y., 2011. Lightning casualties and damages in China from 1997 to 2009, Natural Hazards, v.57, pp: 465-476.

Received on: 26.3.17; Revised on: 16.4.17; Re-revised on: 15.5.17; Accepted on: 18.6.17

## Lightning Quotes

* Genius unrefined resembles a flash of lightning, but wisdom is like the sun.

  - *Franz Grillparzer (1791 –1872) was an Austrian writer who wrote the oration for Ludwig van Beethoven's funeral*.

***

* Human life is as evanescent as the morning dew or a flash of lightning.

  – *Samuel Butler (1835 –1902) an iconoclastic English author*

***

* Thunder is good, thunder is impressive; but it is lightning that does the work.

  - *Mark Twain (1835 –1910) well known American writer, humorist and lecturer.*

***

* They say marriages are made in Heaven. But so is thunder and lightning.

  - *Clint Eastwood (1930--) famous American actor, filmmaker and musician*