Analysis of Lightning Occurence in Zambia

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***Abstract*— This paper presents analysis of human observations on thunder days in five regional centers in Zambia. The regions covered are specifically of interest to aviation industry. The variation pattern of monthly thunder days show that the lightning activity has well-detectable oscillatory pattern over the year. However, the pattern varies from region to region thus, as a single country Zambia experiences lightning almost throughout the year. We strongly recommend the installation of automated lightning detection system in the country to provide more accurate lightning ground flash and cloud flash density mapping. Such information will play a vital role in lightning safety and protection planning.**

Keywords- lightning safety, isokeraunic level, thunderstorm, Zambia

I. INTRODUCTION

Zambia is a landlocked country in Southern part of Africa, which borders Democratic Republic of the Congo from north, Tanzania from north-east, Malawi from east, Mozambique, from south west, Zimbabwe, Botswana and Namibia from south, and Angola from west (Figure-1).

The country is situated in an elevated plateau with height in the order of 1000 m - 1,300 m above mean sea level (msl). Few mountains ranges are spread around the country that peaks over 3000 m above msl. Although most parts of Zambia is flat land, small hills are scattered in many areas that protrudes over the plateau. The country has a land area of about 752,618 km^2. The population is nearly 14 million of which the majority leads rural life.

The capital city, Lusaka, in the south-central part of the country (Figure-1). The major airport in the country, Kenneth Kaunda Airport is located in Lusaka. This airport has a potential of becoming the sub regional aviation hub as Zambia shares its boundaries with eight other countries.

Zambia's rainy season is activated by the southern hemisphere migration of the Meteorological equator. The rainy season spans over the months of September to April. These are the months of thunderstorms and lightning activities as well.

As per the only research paper on lightning accidents in Zambia published so far [1] and many news reports from the country reveals that lightning related human deaths and injuries, loss of livestock and wild animals and damage to electrical utilities and other equipment is extremely high. This is common observation in many countries in the central and southern parts of Africa as per the literature available at present [1-10].

As it has been reported in references [1], lightning in Zambia is a major threat to the livelihood of the public as the major source of income of the rural families, the livestock industry is adversely effected during the lightning seasons. Most domesticated animals are kept in open fields, where they are being affected by lightning. Several cases where multiple deaths of human beings have been reported as the shelters are struck by lightning [1,].

The reference [1] also shows that the losses of power and electrical sector in Zambia is also unbearably high. Due to the lack of proper protection and high exposure of the network to thunderstorm, the damage to transformers, grid stations and LV utilities is ever increasing for the last decade. The biggest losses are encountered at the substation level. The downtime due to lightning caused power outing is not accounted for as such statistics are not available.

Another sector that well concern about thunderstorm activities is the aviation industry. The fact that Zambia lies in the tropics and in the middle of the southern Africa sub region, makes thunderstorms the leading adverse weather threat to Aviation. Personal communications at informal level with the personnel at aviation control division reveals that there are numerous miner mishaps happen at in-flight and control towers due to temporary malfunctioning of avionics and other electronics during thunderstorm events. Although no major accident has happened so far, the industry is aware of the threat and danger of the thunderstorms and lightning.

Despite the unfavorable lightning risk environment that prevails in Zambia, the meteorological statistics related to lightning and thunderstorms is still very scanty in the country. This is one of the prime challenges is curbing the lightning losses both human and property in Zambia as planning of safety/protection schemes cannot be planned properly. Hence, in this study we provide lightning statistics in 5 major cities of Zambia.

In the absence of a proper lightning detection system the only tool available for data collection is human observation. Human observers are prone to missing lightning especially if it occurs at a distance and thunder is not heard. However, with limited resources available to us we have developed a data base on lightning occurrence statistics collected through human observations.

II. METHODOLOGY

Data from five weather stations that characterize the general and localized situations of lightning over Zambia were identified. Observations have been made by field officers of the weather stations who are specifically assigned for the purpose. The locations of the weather stations are Ndola, Kasama, Lusaka, Mwinilunga and Mongu (Figure-1). All of these stations have active airfields except Minilunga, the station that has recorded the most number of thunderstorms during the period of concern..

The annual data sets of stations that has the longest streaks of error free data were chosen. Their monthly averages of thunder was calculated and tabulated to give pattern of variation of lightning activities.

Figure-1: The map of Zambia. The locations of the weather stations are indicated with blue colour circles. *Background map was adopted from www.map.com*

III. RESULTS AND DISCUSSION

In general, all data sets depict a rather periodic pattern of lightning activity that is in synchronous with the variation of the Inter-tropical convergence zone (ITCZ) activity; This variation is depicted below for each region of the data collection stations.

Ndola: Ndola data set shows a systematic cycle of lightning and thunder occurring during the months of October thru May. The higest occurrence of thunderstorms is usually observed in February however, there may be exceptions to such observation. There seems to be a two year period of high lightning and thunder activity followed by another two year period of lower lightning and thunder activity (Figure-2). This may correlate with the quasi biennial oscillation (QBO). The QBO is a stratospheric wind regime that changes direction from easterly to westerly and vice versa every two and half years on average. Studies done by one of the authors (S. Nyambe) in 1995 showed that summer rainfall (thunderstorms) that is mostly due to ITCZ correlate with phases of the QBO (unpublished data).

Kasama: Kasama data had longer streaks of error free data than Ndola. The data set shows that lightning and thunder spans the months of September to May the highest and October to April the lowest (Figure-3). These data shows that lightning and thunder occurs during the times when the ITCZ is active over the area and no thunder activity when the ITCZ is out of the area.

The analysis of a longer data set (1967- 1991) data shows a steady fall followed by a steady rise (Figure-4). The steady rise is then followed by a gentle reduction during the middle of the period and a slow rise till 1991. This structure can be correlated with global cycles of El Nino and Southern Oscillation (ENSO) episodes. Such correlation were also found be a study done in 1995 by one of the authors (S. Nyambe) and also several earlier studies done by Mark Jury of Cape Town University (unpublished data).

Lusaka: The variation of thunderstorms in Lusaka plays an important role in the case of lightning safety and protection in Zambia, as it is the city with highest population density in the country and also the location of the country’s largest and busiest international airport. Lusaka data exhibits thunderstorms occurring mostly between October and April (Figure-5). Similar to the data in many other many other stations in Zambia, thunderstorms are most prevalent in Lusaka during the times the ITCZ is active.

When lager Lusaka data sets are considered; the error free streak shows a low frequency of variability in general and the most active months tending to be near the mid-season months (Figure-6).

Mwinilunga: Mwinilunga data set (Figure-7) shows that thunderstorms start as early as August and generally ends in the month of May. Mwinilunga data exhibits a high occurrence of monthly average values of thunderstorms compared with most other stations in Zambia. This is because as the sun’s apparent position migrate south wards a heat-low forms over Angola/Namibia. This heat low sends a clockwise circulating wind that tilts the axis of the ITCZ from zonal to meridianal. The resulting westerly winds greatly enhance thunderstorms and lightning activities and these activities only tapper of when the heat-low loses strength as the sun migrates north wards out of the southern Africa tropical regions. However, frequency of thunderstorms and lightning remains pronounced until the month of May.

Mongu: Mongu lightning and thunder data shows a low frequency of seasonal variability that is characterized by high monthly variation (Figure-8). Thunderstorms over this area are also due to the presence of the ITCZ. It can be noted that, over Mongu the monthly average range of thunderstorms is high. This can be attributed to anabatic winds from the Zambezi flood plain.

During the 1967- 1995 period, the years of 1971, 1975, 1983, 1987, and 1992 had data that was different from most seasonal data sets. The data sets revealed prolonged lightning activity that reached the month of May as shown in Figures 9, 10 and 11. This can be attributed to high moisture content of the Zambezi flood plain. This moisture supports thunderstorm activities long after the ITCZ has withdrawn from the area.

We emphasize that the most informative opinion on the lightning occurrence pattern is given by the data from a ground-based lightning detection system. Once such ground flash densities are obtained for over 10-20 years the country can be mapped to identify the lightning hotspots. The isokeraunic level can be transformed to the ground flash density by crudely developed empirical formula, however, such equations are region dependent and may carry large errors [11].

Note that the thunderstorm in Zambia data presented in this paper are observed by human-operators. In order to improve the accuracy, at each station several observers have been placed and their average observation has been counted. Such observations have the weaknesses of not being able to distinguish ground flashes from cloud flashes and counting of any number of lightning strikes in a given day as one thunder day. These kind of data neither give information on the direction nor the distance of the phenomenon from the station. The data are also highly subject to the presence and alertness of the observer. This greatly necessitates a country wide use of automated lightning detection devices.

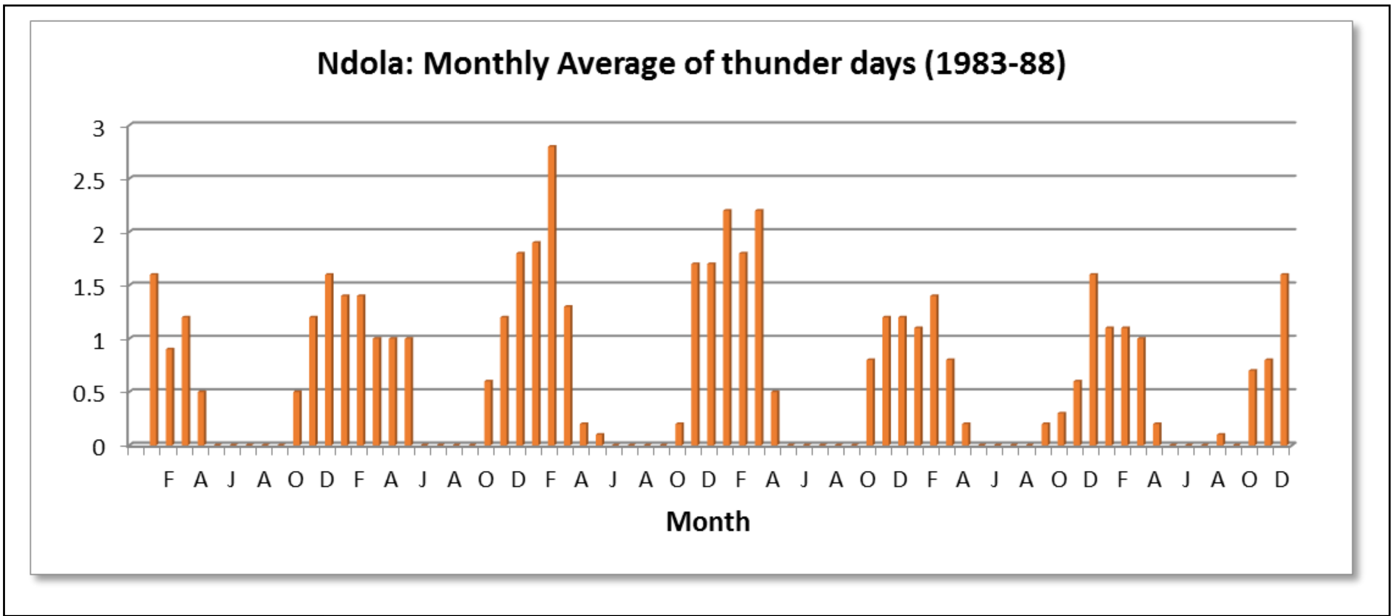


Figure-2: Monthly Average of Thunder days in Ndola, 1983-88

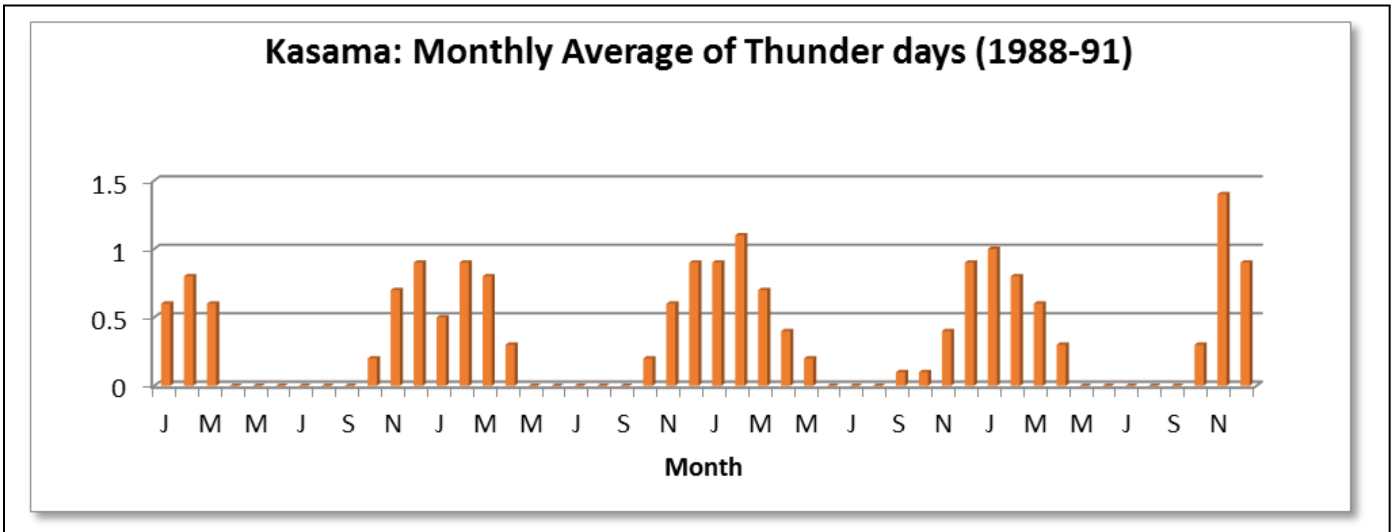
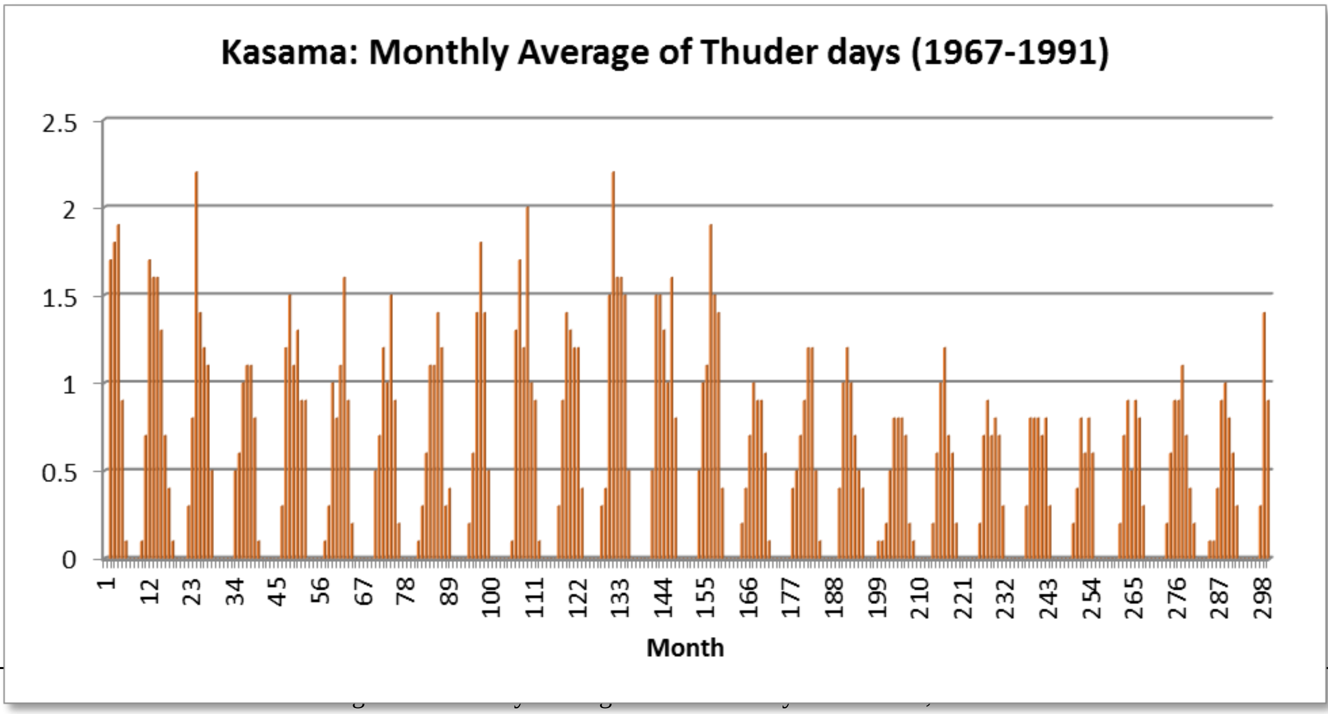


Figure-3: Monthly Average of Thunder days in Kasama, 1988-91



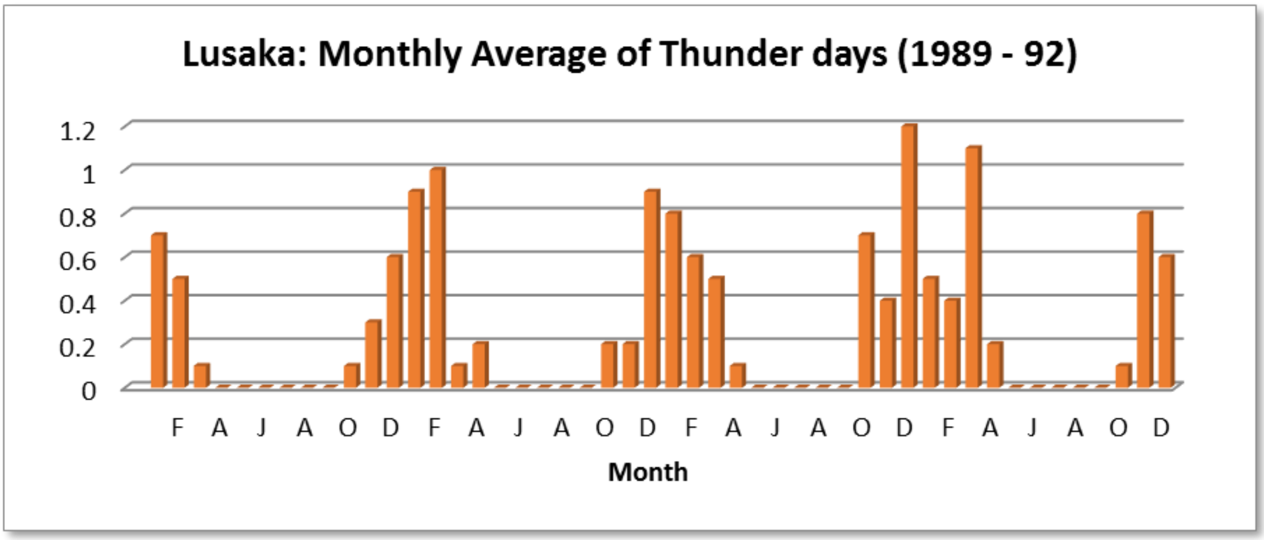


Figure-5: Monthly Average of Thunder days in Lusaka, 1989-92

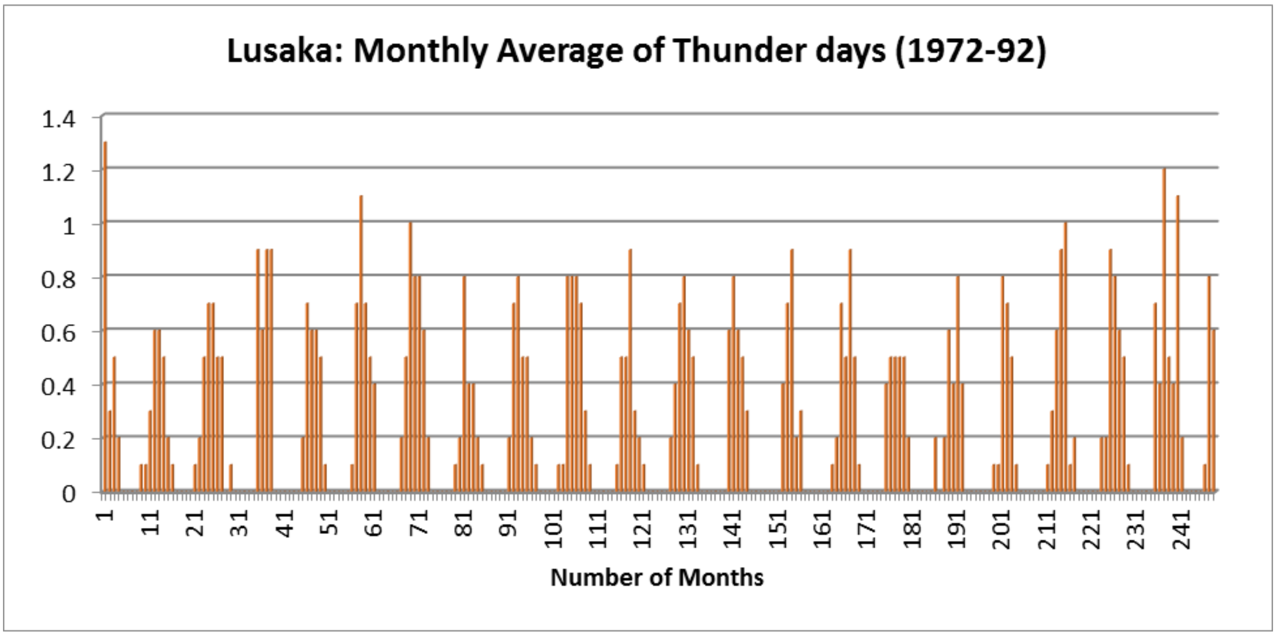


Figure-6: Monthly Average of Thunder days in Lusaka, 1972-92

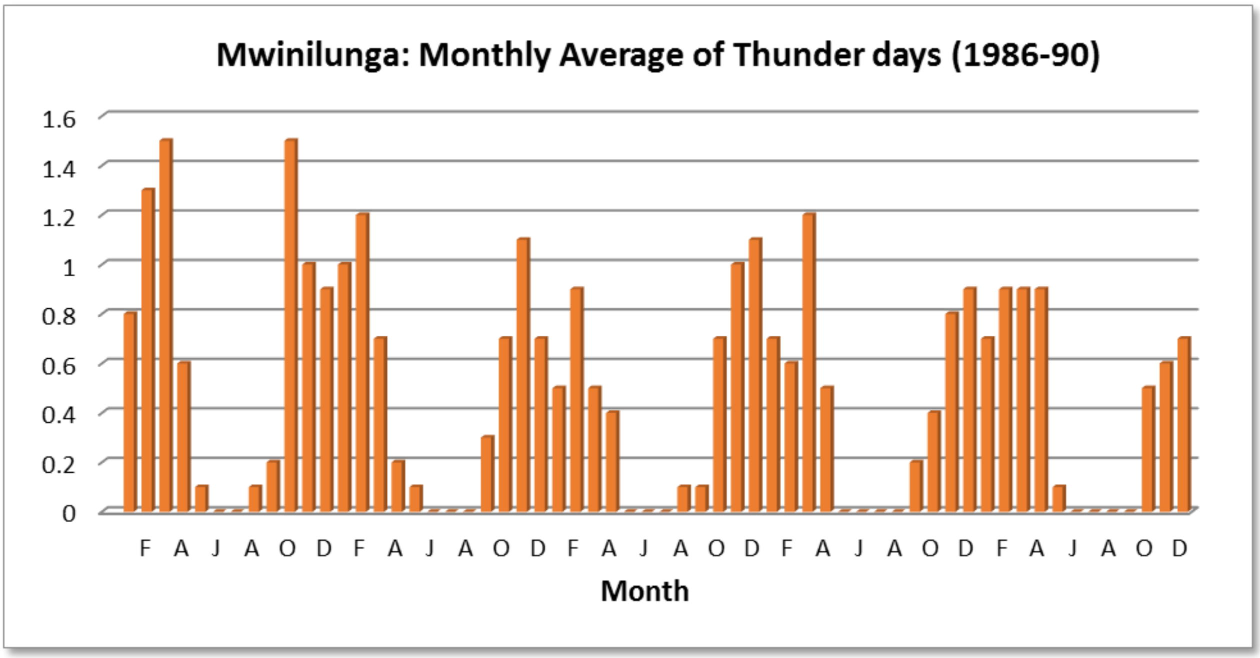


Figure-7: Monthly Average of Thunder days in Mwinlunga, 1986-90

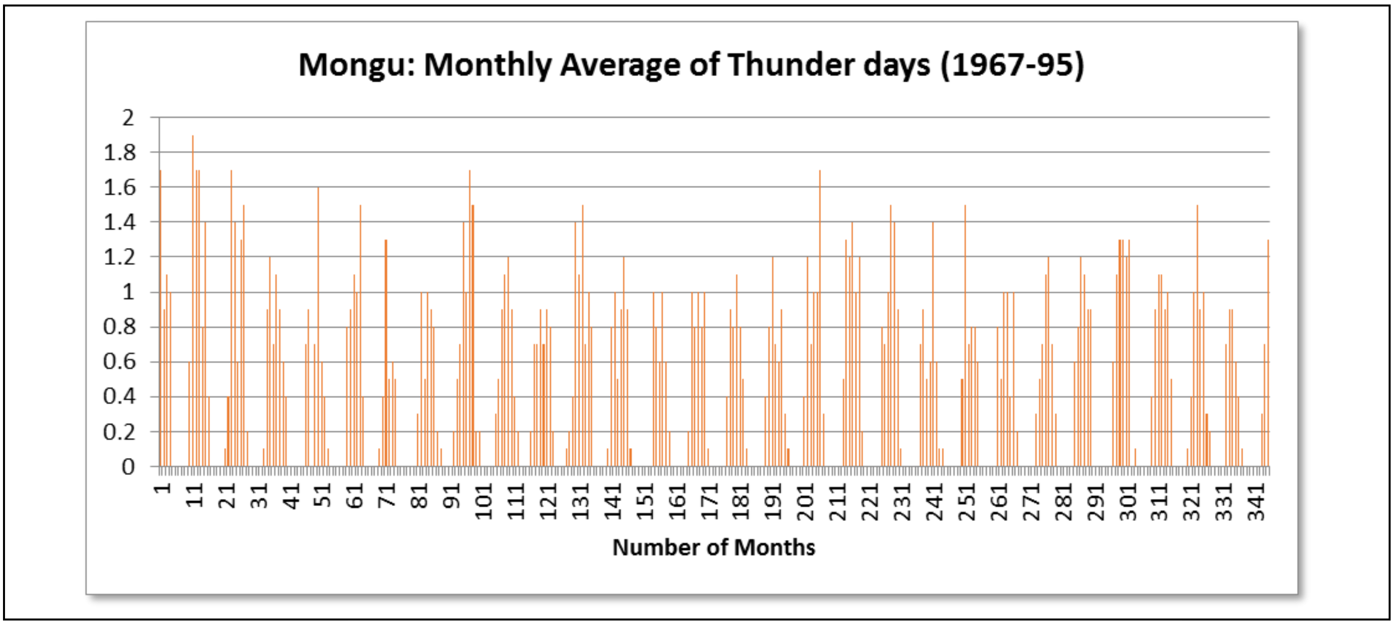


Figure-8: Monthly Average of Thunder days in Mongu, 1967-95

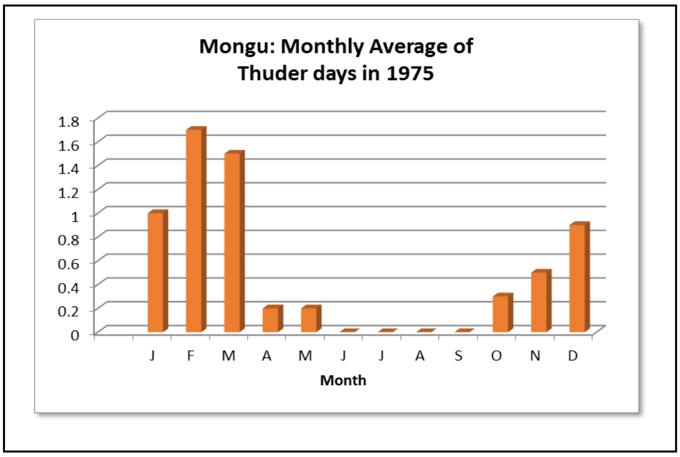


Figure-8: Monthly Average of Thunder days in Mongu, 1975

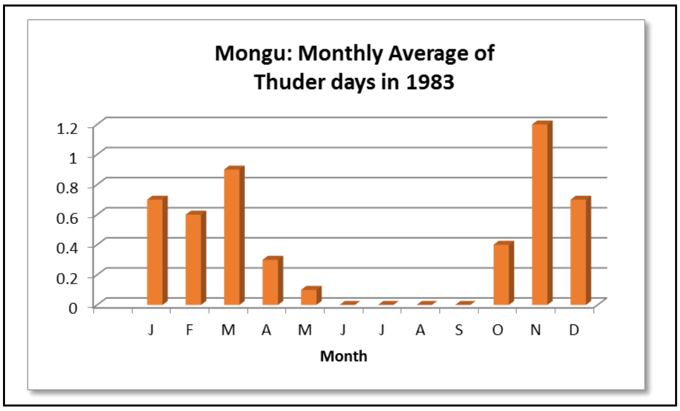


Figure-8: Monthly Average of Thunder days in Mongu, 1983

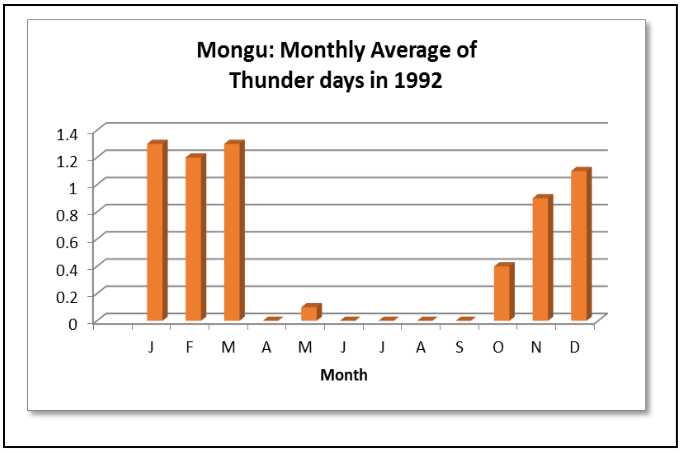


Figure-8: Monthly Average of Thunder days in Mongu, 1992

In reference [12] on Forecasting problems: The meteorological factors, *Smith et al*., says, "*weather forecasting has benefited from diminishing costs of computers through the provisions of microcomputers to the field officers for a variety of purposes. Systems are being used operationally for data acquisition (saving time and forecasters effort and making additional observations quickly available) for message composition and dissemination, and for data analysis*".

We wish that this could be said about meteorology in Africa as well. This work however is a quest towards data uniformity and data quality and fulfilling the quoted Daniel L. Smith's vision. When automated lightning detecting devices are used, errors are relegated to instrument index excluding parallax when observing the thermometers and Barometers and others that are associated with human observers. And at times, errors that could have existed at the station for a long time are exposed.

When we use electronic devices however, we need to define time period or life span for these remote sensors to avoid cases like we have observed from one of the old automated weather station in the country. While this is being done, this software could provide an alternative and standardize data at the station.

The Paradigm has shifted; the observers that are being employed now are familiar with computers. They would rather use computed data than data from tables and slide rules. This work puts the computer as a front line instrument for observation and embraces the paradigm shift.

IV. CONCLUSIONS

In this paper we have presented isokeraunic levels of several major cities in Zambia covering five large areas. The outcomes provide useful information for planning lightning and thunderstorm safety/protection planning in various industries, especially in the aviation sector.

Automated lightning detecting devices are proposed to be used in time-spaced data comparison, a factor that is helpful in monitoring climate change and many other atmospheric phenomena that require accurate data.

We recommend that automated lightning detecting devices be installed and extended to all the meteorological stations and be integrated with the world weather watch program in Zambia and beyond. In Zambia, this could be done by providing training for all meteorological personnel in the ten provinces at provincial level and providing computer IT facilities to every station that would be on the network.

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