EFFECTS OF SOME METEOROLOGIOCAL PARAMETERS ON THE GEOGRAPHICAL AND SEASONAL DISTRIBUTIONS OF LIGHTNING ACTIVITY IN AUSTRALIA

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1. INTRODUCTION

The Australian Bureau of Meteorology (ABM) has operated a network of CIGRE-500 flash counters, widely distributed across continental Australia, for over 20 years (Kuleshov and Jayaratne, 2004). This has provided one of the longest data records of lightning ground flash density in the world. The data covers a relatively large area and affords a good opportunity to study the effects of various meteorological parameters on the geographical and seasonal distributions of lightning activity in Australia. This paper presents the results of two such correlations between lightning activity and the surface wet bulb temperature and rainfall that we have looked at in detail.

II. LIGHTNING ACTIVITY AND SURFACE WET BULB TEMPERATURE

Ten stations with reliable long-term data were selected from the network. For each of the stations, the monthly total of lightning ground flashes, N, and the monthly mean daily maximum surface wet bulb temperature, Tw,max, were calculated. The results showed that the ground flash intensity was a sensitive function of the surface wet bulb temperature. The dependence was most pronounced near the equator. In Darwin, the station closest to the equator (latitude 12°S), a modest 3-4°C increase in wet bulb temperature increased the lightning activity by over two orders of magnitude (Fig 1). The increase of lightning activity with wet bulb temperature decreased as the station moved away from the equator. In Melbourne (latitude 38°S), the effect was less obvious, but still showed an increase of about half an order of magnitude within a 10°C range of Tw,max.

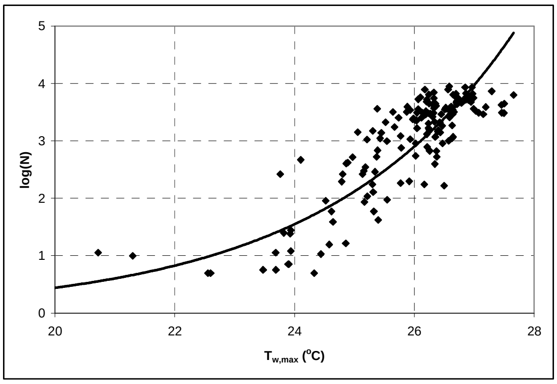

FIG. 1: Monthly total of lightning ground flashes, N, versus the monthly mean daily maximum wet bulb temperature at Darwin (12°S).

Power law approximations of log(N) versus Tw,max for the ten stations were derived according to the relationship proposed by Williams and Renno (1991) :

$$\log(N) = a \ \ T_{w,max} \ \ P$$

The value of P was derived for each station and plotted as a function of the corresponding latitude (Fig 2). It was found that P was a maximum closest to the equator and decreased exponentially with latitude. We have no conclusive reason for this behaviour. However, it is well known that the wet bulb temperature is a sensitive function of convective available potential energy (CAPE) – the driving force for thunderstorm development. Tropical storms generally have more CAPE than temperate storms (Williams and Renno, 1993). Lightning activity has been shown to increase sharply with CAPE (Williams et al. 1992).

We believe that this is the first analysis of lightning activity in terms of wet bulb temperature using data gathered over a sufficiently long period at a number of stations over a wide range of latitudes within the same continent.

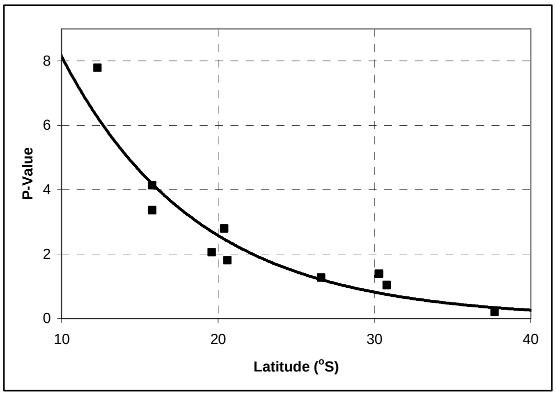

FIG. 2: Value of P derived for the ten selected stations plotted as a function of latitude.

III. LIGHTNING ACTIVITY AND RAINFALL

The rainfall and lightning data analysis was carried out using 23 stations (Fig 3). For each station, the annual rainfall and lightning ground flash density was calculated. The analysis showed a statistically significant linear relationship between annual rainfall and ground flash density. These two parameters were used to estimate rain yields for all the stations as mass of rain per lightning ground flash (units: kg fl^{-1}).

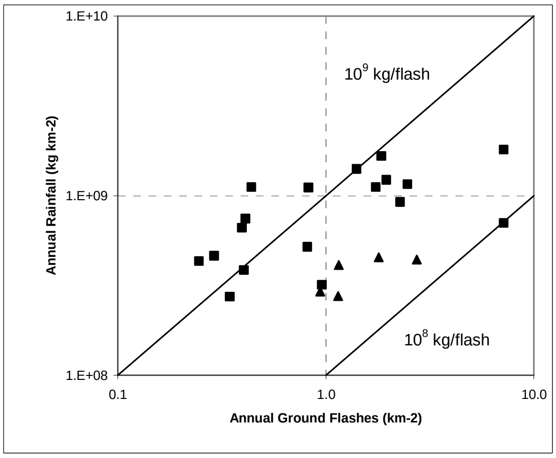

FIG. 3: Rainfall versus ground flash density at 23 stations. The five mid-continental stations are shown as triangles.

Geographical Distribution: It has been shown that the rain yield is strongly controlled by geographical climatic conditions (Peterson and Rutledge, 1998). The present study confirmed this observation for a range of stations within continental Australia for the first time. For example, as seen in Fig 3, six stations showed rain yields greater than 1.0 x 10^9 kg fl^{-1}. All six of these stations were situated on the coast or very near the coast. The five mid-continental stations, shown as triangles, gave rain yields clustered close together with a mean of 2.64 x 10^8 kg fl^{-1}, while all the coastal stations showed a mean value of 9.91 x 10^8 kg fl^{-1} – a difference of a factor of over three. A Students t-test showed that the difference was statistically significant at the confidence level of 95%.

Seasonal Distribution: We separated the annual data into two halves, according to season: April-September (winter-half) and October-March (summer-half). As expected, all 23 stations showed a higher mean rain yield during the winter-half over the summer-half. Mean monthly rain yields were computed for all stations. It was clear that rain yields in the winter months were higher than over the summer months, with the differences being maximum in the tropics and minimum along the southern coast. These observations may be explained in terms of the seasonal variations of CAPE in the atmosphere. There is more surface heating in the summer than over the winter. Surface heating directly increases the magnitude and affects the other characteristics of CAPE in the atmosphere – the driving force for thunderstorm generation.

The 23 stations were classified into the six major seasonal rainfall zones in Australia, as defined by the ABM. These are: winter, winter-dominant, summer, summer dominant, uniform and arid. The results showed that the mean rain yield in the winter and winter-dominant rainfall zones, along the south west and southern coast, was 1.28 x 10^9 kg fl^{-1}, while the value in the summer and summer-dominant rainfall zones, along the north and east coast, was significantly lower at 5.44 x 10^8 kg fl^{-1}. The rain yield in the mid-continental arid zone showed the lowest value of 2.84 x 10^8 kg fl^{-1}. The differences in the mean of the winter and winter-dominant rainfall group and each of the other two groups (summer/summer dominant rainfall and arid) were statistically significant at the 95% confidence level.

IV. ACKNOWLEDGMENTS

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V. REFERENCES

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