CORRELATION ANALYSIS BETWEEN RADAR REFLECTIVITY AND POSITIVE LIGHTNING FLASH RATE

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DEDICATION

To My Beloved Father (Late) and Mother,

My Husband, my kids Joy and Parrish,

My Mighty Supervisor and Co-Supervisor,

and

To those who helped me to complete this project successfully

ACKNOWLEDGEMENT

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ABSTRACT

Lightning is natural phenomena that we will not simply point out its exact origin and when it will strike. Lightning channel is created with extremely high temperature and can occurs multiple of strokes in the same channel. The existence of lightning is known to create damages to properties. This study aims to investigate the correlation analysis between radar CAPPI (Constant Altitude Plan Position Indicator) reflectivity and lightning flash rate in Malaysia. The correlation is made based on the reflectivity index values at 2 to 5 km radius (water droplet intensity in the cloud) with the lightning flash rate. A total number of clouds to ground lightning flashes have been be analyzed in terms of time domain characteristics such as pulse duration, location based on magnetic direction finding (MDF) and the magnitude of the return stroke. The CAPPI radar data of cloud information that carries precipitation in terms of reflectivity index have been plotted using IRIS program. The correlation has been made by observing the pattern of precipitation and lightning occurrence. In conclusion, the result shows that, there are 88 numbers of positive lightning were found from the 5400 data of different type lightning flashes. The result also shows that, when the reflectivity value is high which is between 50dBZ – 55dBZ (the weather is heavy or very heavy rain/small hail) the possibility of the positive cloud to ground happen is high.

ABSTRAK

Petir adalah fenomena semulajadi yang tidak akan menunjukkan tempat asal yang tepat dan ketika ia datang menyerang. Saluran kilat dicipta dengan suhu yang sangat tinggi dan boleh berlaku pelbagai strok dalam saluran yang sama. Kewujudan kilat diketahui boleh menyebabkan bahaya kepada manusia dan kerosakan terhadap harta benda. Kajian ini bertujuan untuk mengkaji hubungan antara radar CAPPI (Penunjuk Kedudukan Pelan Ketinggian Tetap) dengan kadar kilat di Malaysia. Hubungan dibuat berdasarkan nilai indeks reflektif pada radius 2 hingga 5 km (keamatan titisan air di dalam awan) dengan kadar kilat . Sejumlah awan jenis kilat ke tanah akan dianalisa dari segi ciri domain masa seperti tempoh denyut, lokasi berdasarkan arah magnet (MDF) dan magnitud strok pulangan. Data radar CAPPI yang menrupakan pemberi maklumat awan yang membawa hujan dari segi indeks reflektif akan diplot menggunakan program IRIS. Hubungan ini dibuat dengan memerhatikan corak pemendakan dan kejadian kilat. Kesimpulannya, keputusan menunjukkan terdapat 88 kilat jenis positif kilat ke bumi telah diperolehi daripada data yang berjumlah 5400 data kilat yang terdiri daripada berbagai jenis. Keputusan juga menunjukkan nilai pemantulan ada tinggi iaitu diantara 50dBZ – 55dBZ, dimana keadaan cuaca pada ketika ini adalah hujan lebat dan sedikit berais (hujan batu) dan kebarangkalian untuk terjadinya positif kilat ke bumi adalah tinggi.

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LIST OF ABBREVIATIONS

CAPPI	-	Constant altitude plan position indicator
CG	-	Cloud to ground
CID	-	Compact intracloud
IC	-	Intracloud
IEEE	-	Institute of Electrical and Electronics Engineers
IRIS	-	Interactive radar Information System
MDF	-	Magnetic directional finding
NBE	-	Magnetic directional finding
NBP	-	Narrow bipolar pulse
NNBE	-	Narrow negative bipolar event
NNBP	-	Narrow negative bipolar pulse
NPBP	-	Narrow positive bipolar pulse
PBP	-	Preliminary breakdown pulse
RC	-	Resistor capacitor
RS	-	Return stroke
Vs	-	Versus
UTeM	-	Unversiti Teknikal Malaysia Melaka

LIST OF SYMBOLS

+	-	Positive
-	-	Negative
^{o}C	-	Degree Celsius
Q	-	Charge
C	-	Coulomb
Ms	-	Millisecond
A	-	Ampere
kA	-	Kiloampere
km	-	Kilometer
μs	-	Microsecond
%	-	Percent
ms-^{1}	-	Meter per second
^{o}N	-	Degree North
^{o}E	-	Degree East
Hz	-	Hertz
kHz	-	Kilo Hertz
1st	-	First
dBz	-	Decibel relative of reflectivity factor
hPa	-	hectopascal
V	-	Volt
mV	-	milli volt
nF	-	nanofarad

pF - picofarad

CHAPTER 1

INTRODUCTION

1.1 Background of the problem

Lightning flash is one of the world captivating marvels. Despite safeguarded records on naked eyes perception of lightning flashes in old texts, we do not generally comprehend crucial instruments of lightning flashes. Even until today, certain types of lightning flash remain uncertain due to the fundamental mechanisms of lightning flashes.

Lightning flash is an electrical discharge happens in the air that radiates electromagnetic waves (EM) over wide spectra from a several Hertz up to visible wavelength that consists of several processes within 0.5 to 1 second typical record. Recent discovery uncovers that lightning flashes discharge X-rays and gamma rays and furthermore is believed to create positrons which is known as anti-matter particles.

Within a thundercloud, typically the lightning is produced. The thundercloud consists of a tripole charge structure. It has three main charge regions namely main positive charge region, negative main charge region and pocket positive charge region. The positive charge region located at the cloud top, negative main charge region in the middle and lastly the pocket positive charge region located at the cloud base. Figure 1.1 shows the tripole charge structure inside a thundercloud. The movement of the charges (known as current flow) and the polarity determine the types and characteristics of captured lightning flash waveforms.

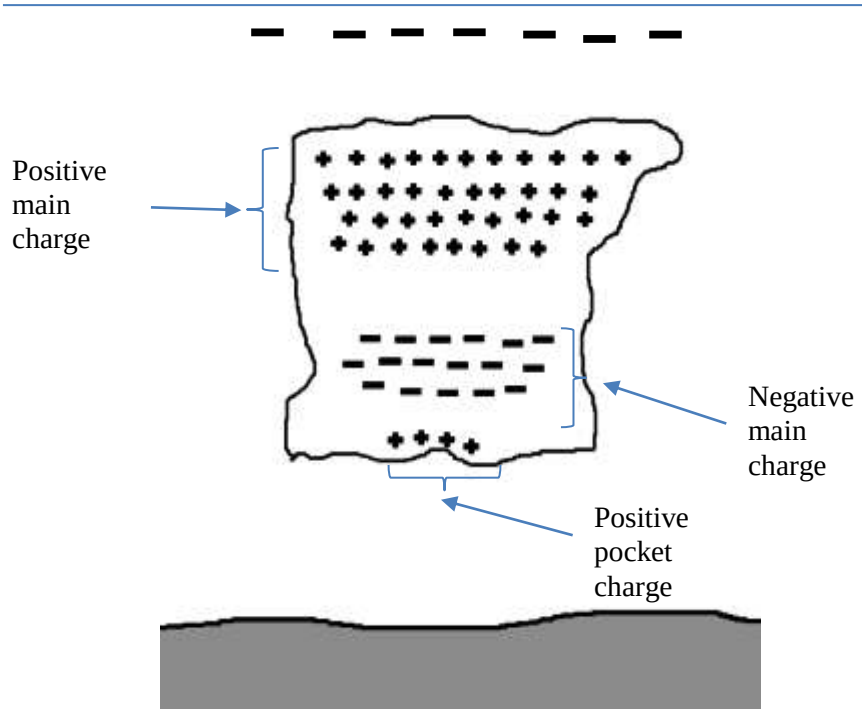

Figure 1.1 Tripole cloud structure and its charge region

Generally, the lightning type is divided into 2 parts that are cloud to ground (CG) flash and cloud flash. The CG consists of positive CG (+CG) flash and negative CG (–CG) flash. The cloud flash has 2 subtypes of flashes that are Inter-cloud or cloud to cloud flash and intracloud (IC) flash. The IC flash has 2 subtypes of flashes that are the normal IC and Narrow bipolar Event (NBE). The NBE is also known as Narrow Bipolar Pulses or NBPs and Compact Intra-cloud Discharges or CID's. The NBE consists of Positive Narrow Bipolar Event (+NBE) and Negative Narrow Bipolar Event (–NBE).

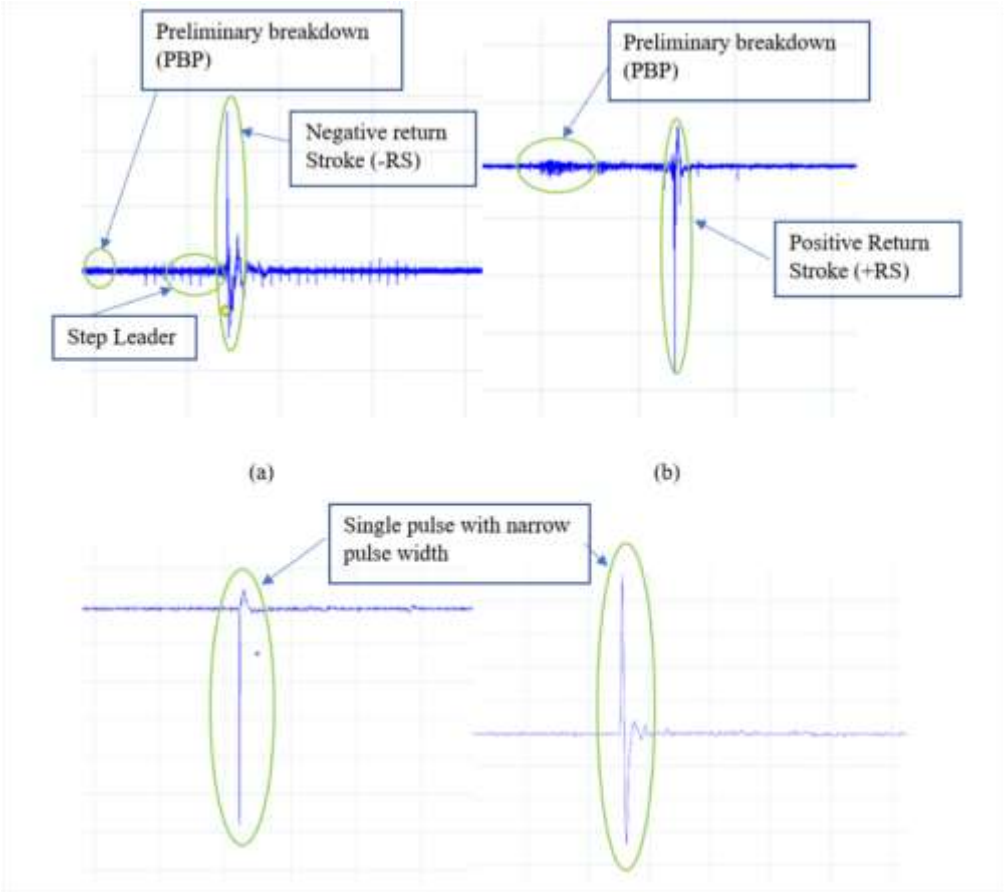

Figure 1.2 Types of flashes (a) Negative Cloud to Ground flash (b) Positive Cloud to Ground flash (c) Positive Narrow Bipolar Event (d) Negative Narrow Bipolar Event. The waveform captured above using atmospheric electricity sign convention.

Remote sensing has been utilized broadly to capture the electric (E) and magnetic (B) fields at different frequency bands. To show the acceleration of the electrical charges, fast-field antenna system (from several tens of Hertz up to several tens of Megahertz) has been used. One second and 13 millisecond decay time constants are used respectively to capture the lightning flashes at that event.

The magnetic field sensor or known as Magnetic Direction Finder (MDF) with high sensitivity and high gain operate at frequencies between 400 Hz and 400 kHz (Zhang et al., 2016) has been used to detect the emission of radiation component emitted from lightning flashes. It has been used widely as localization techniques to determine the lightning strike at certain areas.

After detects the emission of lightning, the captured signal is digitized by using a PC based oscilloscope called the Picoscope (Picoscope 4000 eries and 3000 series have been used in this research work). Detailed explanation about the measurement set up will be explained in chapter 3.

1.2 Statement of the problem

Normally, the positive lightning to ground flashes lowers positive charge from the cloud to ground whereby it happens very rarely. It is only accounted about 10% of the charges are positive CG. Hence, the occurrences of positive CG in Malaysia are very rare compared to the positive Narrow Bipolar Events (+NBE) and negative CG. Many studies have been done on NBE and negative CG. Since positive CG is very rare, the characteristics of it have not fully studied and discovered. When considering the tripole structure, the scarcity of the positive CG flashes can be easily accepted. Nevertheless, inside the cloud, the structure of it is remain unresolved.

The research whether the climate in Malaysia has a significant production of positive CG will be studied and analyzed. The other types of CGs namely negative CG, positive NBE, intracloud charges have been studied and compared with the positive CG to see and investigate the differences in them. Through this research, the evolution of thunderstorm cloud top height which is obtained from the radar data has been analyzed to correlate the cloud top height with the positive occurrences. Besides that, the research on the influence of positive CG to the thunderstorm in Malaysia has been done as well.

1.3 Objectives of the Study

The objectives that should be achieved throughout this project are:

1. To investigate the positive Cloud to Ground (CG) occurrences in Malaysia.
2. To study the correlation analysis between radar CAPPI reflectivity index value and the positive CG lightning flash rate occurred in Southern Region of Malaysia

1.4 Scope of the Study

This study is focused on:

i. Positive cloud to ground pulse duration, location based on magnetic direction finding (MDF) and magnitude of return stroke.
ii. The correlation of between the reflectivity index value and the positive cloud to ground lightning flash rate.

1.5 Thesis Outline

This thesis consists of 5 main chapters. Chapter 1 will be on the background of lightning, problem statements, objectives, scopes, flow of research and last subtopic is the organization of thesis.

Chapter 2 mainly focused about the literature review. In this part is more on the previous studies done by researcher. The chapter starts with detail introduction to several types of lightning flashes and the electromagnetic fields emitted by individual flashes at far distance and close distance. Then, detail explanation on the step-by-step process of lightning happens based on the basic tripole charge. Later, detail explanation of the history of positive cloud to ground.

For the third chapter, it is the research methodology part whereby the experimental setup, how measurements and data are taken are discussed here. Here, the flow chart of research work, introduction of certain software like IRIS software, Picoscope software, CAPPI and RADAR Data are also being deliberated here.

Chapter 4 is about the result and analysis. The results captured using Picoscope and tabulated using bar graph to represent the results. Sample of flash rate, positive CG waveforms, positive CG correlated with Radar and CAPPI Data, reflectivity value versus number of flashes on 13th and 14th September 2016 are written in the thesis.

Chapter 5 is the conclusion and recommendation part whereby the findings of the project with suitable recommendations.

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