JABATAN PENYELIDIKAN & INOVASI
NO BORANG : UMP/JPI/REPORT
KUATKUASA: 01/06/2020

RESEARCH PROJECT REPORT FORM

Final	/	Progress		Progress Period : ___July 2020______________	√ Please tick

PROJECT DETAILS *(Keterangan Projek)*

A	**Grant No**	RDU170375
	Faculty/CoE	FTKEE
	Project Title	CHARACTERISTIC OF ELECTRICAL SIGNAL OF TRANSIENT LUMINOUS EVENTS (TLES)IN PEKAN PAHANG
	Project Leader	AMIR IZZANI BIN MOHAMED (01557)
	Project Member	CHAN HWEE GEEM (MEE14005)

PROJECT ACHIEVEMENT *(Pencapaian Projek)*

B

ACHIEVEMENT PERCENTAGE				
Project progress according to milestones achieved up to this period	**0 - 25%**	**26 - 50%**	**51 - 75%**	**76 - 100%**
Percentage (please state %)				100

EXPENDITURE *(Perbelanjaan)*

C

Budget Approved *Peruntukan diluluskan*	**Amount Spent** *Jumlah Perbelanjaan*	**Balance** *Baki*	**% of Amount Spent** *Peratusan Belanja*
RM 28,400.00	**RM 24,961.75**	**RM 3438.25**	**87.9%**

RESEARCH OUTPUT *(Output Penyelidikan)*

D

NO OF PUBLICATION

KPI FOR NO OF PUBLICATION

	ISI	Scopus	Index Proceedings	Others
KPI	**1**	**1**	**0**	**0**
Achievement	**1**	**1**	**0**	**0**

The contribution of funder (UMP, MOHE, MOSTI, Industry etc.) as the fund provider must be acknowledged at all times in all forms of publications. Please state the grant number (RDU/UIC) and grant name.

	ISI	**Scopus**
Number of articles/ manuscripts/books *(Please attach the **full paper** of Publication)*	1. C. H. Geem and **A. I. Mohamed**, Investigation on the occurrence of positive cloud to ground (+CG) lightning in UMP Pekan, *Journal of Atmospheric and Solar-Terrestrial Physics* 179 (2018) 206-213 2.	1. C. H. Geem, M. S. Jadin and **A. I. Mohamed**, Observation of Transient Luminous Events (TLEs) in Pekan, *ARPN Journal of Engineering and Applied Sciences*, Vol 10 No. 22 Dec 2015 2.

	International	National
Conference Proceeding *(Please attach the* ***full paper*** *of Publication)*	1. C. H. Geem, M. M. Saari, **A. I. Mohamed** and M. H. Sulaiman, Determination of Image Conversion Ratio for Transient Luminous Events (TLEs) Observation System, *IEEE ICSGRC* 2017	1. 2.

HUMAN CAPITAL DEVELOPMENT

KPI FOR HUMAN CAPITAL DEVELOPMENT

	PhD Student	Master Student
KPI	**0**	**1**
Achievement	**0**	**1**

Human Capital Development	**Number**				**Others** (please specify)
	On-going		**Graduated**		
Citizen	Malaysian	Non Malaysian	Malaysian	Non Malaysian	
PhD Student	0	0	0	0	
Masters Student	0	0	1	0	
Undergraduate Student					
Total			1		

Name of Student: **ID Matric No:** **Faculty:** **Thesis title:** **Graduation Year:** **Name of Student:** **ID Matric No:** **Faculty:** **Thesis title:** **Graduation Year:** *** enter for more space*	**Name of Student:** CHAN HWEE GEEM **ID Matric No: MEL14005** **Faculty: FTKEE** **Thesis title: INVESTIGATION ON THE OCCURRENCE OF POSITIVE CLOUD TO GROUND (+CG) LIGHTNING IN UMP PEKAN** **Graduation Year : 2019**

INTELECTUAL PROPERTIES

KPI FOR INTELECTUAL PROPERTIES

Patent, Copyright, Trademark,Industrial Design: ____0_______

Patent, Copyright, Trademark, Industrial Design ect	0

OTHERS

KPI FOR OTHERS

Prototype, Technology,Collaborations etc: __0__________

Prototype, Technology, Collaborations etc	**1 Collabration with University of Electro-communication (UEC Tokyo, Jpn).** **2 Collabration with UTeM, UTM, UNIMAP and University of Science and Technology of China (USTC)**

ASSET *(Aset)*

E

Bil	**Peralatan** *(Equipment)*	**Model**	**No Daftar Aset** *(Asset Tagging No)*	**Amount** (RM)	**Lokasi** *(Location)*

0	Digital lowlight camera	Watec902h Ultimate	FTK1000-PB101(R)-1907-0002-00001	3,350.00	FTKEE E11-C30

PRODUCT DESCRIPTION FOR UMP R&D DIRECTORY (SHORT & BRIEF) *Only for Final Report*

F	No product

PRODUCT PICTURE FOR UMP R&D DIRECTORY *Only for Final Report*

G	No product

SUMMARY OF RESEARCH FINDINGS *(Ringkasan Penemuan Projek Penyelidikan)*

H	This Reserach is going to find the direction of +CG lightning and its relationship with monsoon season in Malaysia by using data obtained from Malaysia Meteorological Department (MMD) for 2015. Analysis from this study found that a high numbers of lightning occur during dry season compares to rainy season. This is contradicted with general perception in Malaysia where lightning only occurs during rainy day. It is also understood that +CG lightning makes up approximately 20% of total lightning and the rest is −CG lightning events. The occurrence of +CG lightning during day and night will be discussed. From this, the direction where most +CG lightning occurs will be determined and used as a guide in order to observe TLEs afterward. The first TLEs in Malaysia was successfully observed in 31 march 2019.

PROBLEMS / CONSTRAINTS IF ANY *(Masalah/ Kekangan sekiranya ada)*

I	

Date :
Tarikh 14 July 2020

Project Leader's Signature:
Tandatangan Ketua Projek

COMMENTS, IF ANY/ ENDORSEMENT BY FACULTY *(Komen, sekiranya ada / Pengesahan oleh Fakulti)*

J

Recommend / Not Recommend / KIV / Need Ammendment

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Name:
Nama:

Signature:
Tandatangan:

Date:
Tarikh:

**** Dean/TDR/Director/Deputy Director**

COMMENTS, IF ANY/ ENDORSEMENT BY RMC PNI (*Komen, sekiranya ada / Pengesahan oleh RMC PNI)*	
K	**Recommend / Not Recommend / KIV / Need Ammendment** …………………………………………………………………………………………………… …………………………………………………………………………………………………… …………………………………………………………………………………………………… **Name:** *Nama:* **Signature:** *Tandatangan:* **Date:** *Tarikh:*

CHARACTERISTIC OF ELECTRICAL SIGNAL OF TRANSIENT LUMINOUS EVENTS (TLES)IN PEKAN PAHANG

AMIR IZZANI BIN MOHAMED
MOHD RAZALI BIN DAUD
NURUL HAZLINA BINTI NOORDIN
MOHD MAWARDI BIN SAARI
WAN ISMAIL BIN IBRAHIM

RDU170375

UNIVERSITI MALAYSIA PAHANG

ACKNOWLEDGMENTS

My first importance appreciation goes directly to Allah S.W.T for the great wellbeing, the prosperity that was essential and for the brilliant open door given to finish this project, " *Characteristic of Electrical Signal Of Transient Luminous Events (TLEs) In Pekan Pahang*".

I take this opportunity to thank my family particularly my parents for trusting and supporting me profoundly all through composition this proposition and my life when all is said in done. The spirit that they give keeps me to move forward and fighting so as to finish this project. They never give up on me and dependably realizes how to influence me to emerge again when I fall.

To wrap things up, thank you to the majority of the faculty members for their assistance and support. I likewise thank my fellow friends for unceasing encouragement, support, and attention. The work illustrated in this proposal would not have been conceivable without the commitments of numerous individuals.

ABSTRACT

Lightning is a phenomenon occurring over the atmospheric area. Transient luminous events (TLE) is a kind of lightning incident that exceeds the speed of lightning in a lightning strike event. It is very difficult to spot the occurrence and it happens in a very short period of time. Thus, a high-frame-rate photo frame is required. This project examines the probability of occurrence of transient luminous events and positive cloud to ground (+CG) above Kuala Lumpur by using a monochrome camera. Transient luminous events are divided into several types such as Elves, Sprites, Halo (Halos), Blue Jets, and Gigantic Jets. This incident was detected using a monochrome camera facing the direction of Kuala Lumpur from Pekan with an altitude of 20 km altitude so that the incident could be recorded clearly and its features could be analyzed and categories with video and frames recorded. The recorded videos have been extracted into photos frame by frame. Thousands of photos extracted were examined one by one to get the result as transient luminous events and +CG phenomenon only happened in a few milliseconds. The study reveals that it is possible to have Transient luminous events above the atmospheric area in Malaysia. Jets and Halos have been captured by using high frame rate monochrome camera.

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LIST OF SYMBOLS

º	Degree
α	Alpha
β	Beta
%	Percentage

LIST OF ABBREVIATIONS

TLEs	Transient Luminous Events
CG	Cloud to ground
+CG	Positive cloud to ground
-CG	Negative cloud to ground
-GC	Negative ground to cloud
+GC	Positive ground to cloud
CC	Cloud to cloud
DVR	Digital Video Recorder
ELF	Extremely low frequency
FOV	Field of view
Fps	Frame per second
IR	Infrared
kA	Kiloampere
km	Kilometer
m	meter
mm	millimeter
ms	millisecond
NASA	National Aeronautics and Space Administration
n.d	No date
PAL	Phase alternation by line
PC	Personal computer

s	Second
UK	United Kingdom
UMP	Universiti Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.1 Introduction

The observation of Transient Luminous Events (TLE) has been implemented for the last 30 years ago. It started in 1989 and there is still not much finding on these TLE as it can be considered as new in studies related to the field of lightning. This observation on Transient Luminous Events explores the activities of Transient Luminous Events and positive cloud to ground lightning above Kuala Lumpur. In this chapter, the background of the study, research motivation, objectives, the significance of the study, project scope, the definition of terms, and intro to the project flow related to the study are discussed.

1.2 Project Background

The occurrence of thunder and lightning has mesmerized humankind for a long period of time. The frightening risk of being exposed to lightning was first analyzed scientifically by Benjamin Franklin during the time 1750s and 1760s. He investigated charged thunderclouds with kites, 'drawing lightning from the heavens'; he also invented the lightning conductor to be connected to important buildings to stop these from being struck by lightning(Krider 2006).

Explanation of lightning. A small part of the charge of ~−100 C In most lightning discharges near the bottom of a thundercloud is transferred to the Earth's surface; this constitutes the bright and powerful return stroke(Rakov and Uman 2003). In equivalent to a negative cloud-to-ground (−CG) discharge, a high current (commonly 30 kA) flows for ~10−4 s. The positive charge is transferred to ground (+CG discharges) In a minority of discharges which rarely happened; the peak current is again typically ~30 kA in the short duration return stroke, but there is also lasting up to ~10−2 s a continuing current (~1 kA). Intra-cloud discharges are three times more frequent than −CG discharges, which are ten times more likely than +CG discharges; the global average number of lightning discharges is 44 s−1(Christian 2003).

Initially, researcher Franz, Nemzek, and Winckler(Franz, Nemzek, and Winckler 1990) planned to conduct a study on observation of lightning activities. However, they recorded an extraordinary lightning activity which takes place on the upper side of the atmosphere. Serge Soula found that the incident of TLEs, especially Sprites is triggered by the ability of +CG lightning(Soula et al. 2009). At the upper atmosphere or in the D region (60 km to 100 km) of the ionosphere there is transient luminous events gleam of light occurrence. TLEs appear when feedback in excited gas molecules causes an electrical breakdown. The gas molecules will radiate light in this excited state for a few milliseconds and then return back to their normal state. Chapter 2 is a continuation of this mechanism of TLEs.

At the lower region of the ionosphere area which is located at the altitude of 80 km from earth's surface, there is some occurrence of TLEs and some of them are located at an altitude of 100 km above the ground(Passas et al. 2014). The types of TLEs have included Elves, Sprites, Blue Jets, Halos and Gigantic Jets, There are some types of TLEs that can be observed in figure 1.1. At a specific altitude in the upper atmosphere, each of them happens independently. However, the focus of this research is on triggering sprites by +CG lightning.

The main objective of this project is to explore +CG lightning besides confirming the occurrence of various TLEs inside a height limit of 80 km is exist above Kuala Lumpur and can be proved. A monochrome camera has been set up to record the events. This is to watch the shape and time of the event.

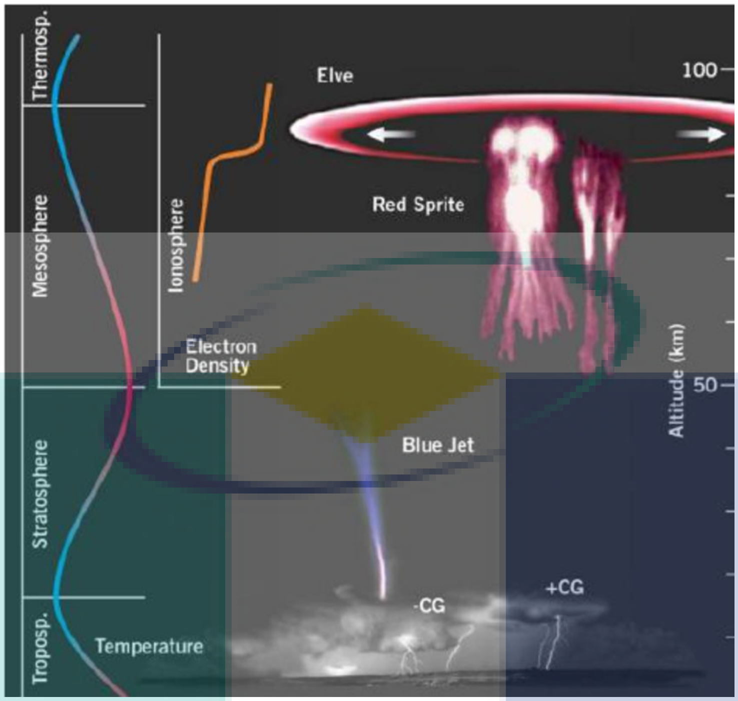


Figure 1.1: Different TLEs occur below ionosphere

1.3 Problem Statement

Lightning indicates to a natural phenomenon that appears often during thunderstorms(Martin A. Uman 1972). This phenomenon characterized as an event of electrical discharge at the rate where the discharge process will distribute a large amount of voltage and current(Odam and GOA Consultancy, Barmouth n.d.). TLEs are also known as a part of a lightning event that happened in the upper atmosphere where the electrical discharge is visible as colorful lightning strikes with a series of form. TLEs are also well-known as a part of a lightning event that takes place in the upper atmosphere where the electrical discharge is noticeable as multi-colored lightning strikes with a series of form.

Furthermore, lightning is classified under visible light and its wavelength length from 400 nm to 700 nm which can simply be noticed by the human eye. However, the wavelength for TLEs is in the range of 600 nm to 900 nm(Ashcraft 2011). This, wavelength of TLEs falls under the Infrared (IR) range with a wavelength from 750 nm to 1 mm, hence, it is hardly visible to the human eye. Consequently, a low light condition monochrome camera is needed to observe TLEs as it is suited to focus the flashes of the light precisely.

The analysis and observation on TLEs have progressed often in other countries since 1989, where a scientist Hugo have recorded the first-ever Sprites, United States, as reported by Stanford VLF Group. Differences of colors and stroke patterns of TLEs have been classified from the studies. In research studies, Sprites and Elves were generally known. Yet, the occurrence patterns of Sprites and Elves are justified by lesser specific characteristics. Research results from the past decades are just purely event capturing and data analysis that needs approval on the changeable attributes of the findings obtained from the capture site.

furthermore, the result by Dan Robinson(Robinson 1995), Lyons et al. (Lyons et al. 2003), Serge Soula et al. (Soula et al. 2009), and V. P. Pasko, Yair, and Kuo(Victor P. Pasko, Yair, and Kuo 2012b) highlight that +CG lightning characteristics produced by sprites within a stratiform cloud region. According to Rocha, Diniz, Carvalho, and Filho(Pinto et al. 2002), Pettegrew, Market, Holle, and Demetriades(Biagi et al. 2007), and Arnone et al. (Arnone et al. 2008), northern countries such as Italy, US, UK, and Japan and southern countries such as Brazil is countries that have most occurrence of +CG lightning which take place during the winter season. The winter month for southern countries begins from June until August while for northern countries begins from December to February. Yet, there is no four-season climate exist in Malaysia. Malaysia only experiences monsoon seasons such as the Southwest Monsoon season and Northeast Monsoon season rather than other Europe country. Thus, the existence of +CG lightning and Transient Luminous Events during these monsoon seasons make a compelling topic to be exposed.

Malaysia is positioned at top five in having the most rainstorms which are number three on the planet according to National Lightning Safety Institute (NLSI)((NLSI) n.d.). TLEs are caused by lightning. There is a high probability for the existence of TLEs in Malaysia referring to the NLSI report. Therefore, these investigations try to observe + CG lightning and the possibility of TLEs event in Malaysia. Nevertheless, the approach of TLEs requires an ample view to guarantee that the recording procedure should be achieved successfully.

1.4 Objectives

The main objectives of this project are:

- To prove the occurrences of TLEs (Jet and Halo) above Kuala Lumpur, Malaysia directed from UMP Pekan.
- To observe TLEs above Kuala Lumpur from UMP Pekan

1.5 Project Scope

The scope of the project is focused on the:

- The project was limited to the direction facing Kuala Lumpur.
- The events were traced at an altitude of 20 km above the earth’s surface.
- The only image was included for examination.

CHAPTER 2

LITERATURE REVIEW

2.1 Lightning Generation

Regular lightning appearance is commonly detectable to the human eye as the thunder strike from clouds to the earth surface. This quick flash event happens within a second or two after a thundering sound is heard. In scientific terms, lightning generations a form of electrostatic discharge. There are three stages of lightning generation as stated by Martin A. Uman(Martin A. Uman 2008). Separation of positive and negative charges within a cloud is the first stage of lightning generation. The ice crystals inside the cloud will collide against one another caused by a strong static charge builds which depending on the strong updrafts in the cloud. Positively charged crystals then rise to the top causing the top of the cloud to develop a positive static charge. The decreased production of ice crystals causes a cumulonimbus cloud to fail in creating a sufficient amount of static electricity for lightning production.

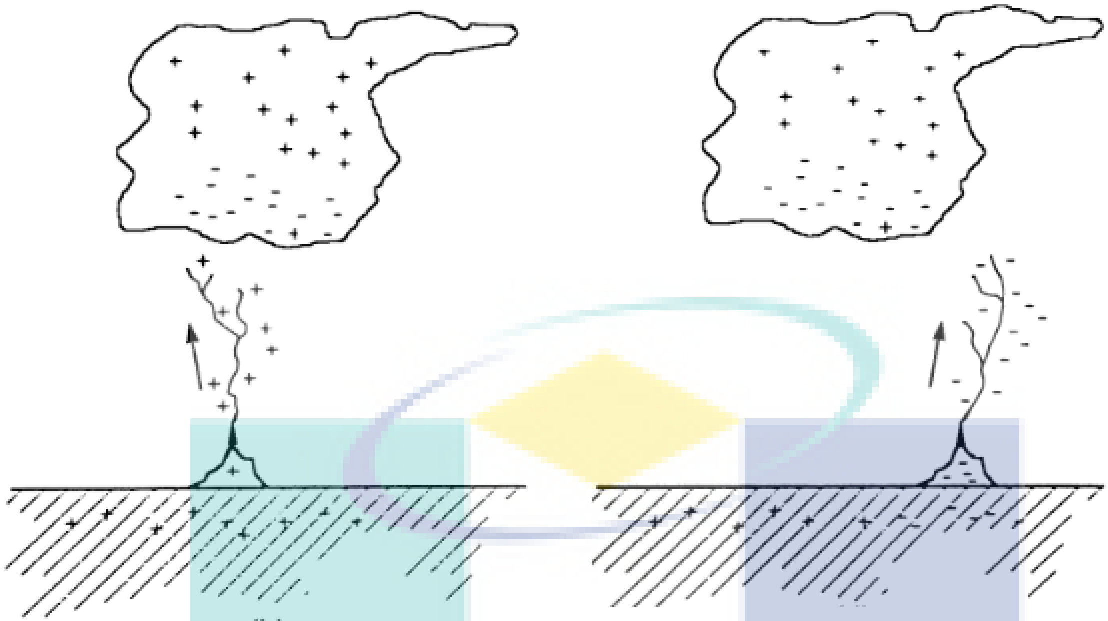
The formation of positive charge on the ground below the clouds is the second stage of lightning formation. The earth's ground is typically negatively charged. When the thunderstorm passes over the ground, the negative charge at the bottom layers of the cumulonimbus cloud attracts the positive charges from the ground to gather along the surface for a few miles over the storm. The charges then focus on vertical objects such as trees and other tall buildings. This is why people are warned to stay away from pole objects to avoid being struck by lightning during the lightning storm.

The third stage takes place when the negative charges and positive charges are even up and assemble together, generate an electrical discharge as a result of which thunderbolt appears within the clouds or between the clouds and ground. Lastly, the lightning appears. Thomas Ashcraft(Ashcraft 2011) stated that TLEs form after some of the lightning bolts is formed. Natural lightning is visible with colors and happens within seconds. The lightning strikes may result in very high currents that will be lead to fatal.

2.2 Types of Lightning

National Aeronautics and Space Administration (NASA)((NASA) n.d.) reported that normally there are 3 types of lightning events, namely cloud to ground (CG) lightning, inter-cloud lightning or cloud to air lightning, and intra-cloud (IC) lightning. Referring to this, Uman(M.A. Uman 1994) informed that CG lightning can be classified into four categories which are positive cloud to ground (+CG) lightning, negative cloud to ground (-CG) lightning, positive ground to cloud (+GC) lightning, and negative ground to cloud (-GC) lightning. An upward-moving leader from the ground will cause +GC lightning and -GC lightning occurrences as shown in figure 2.1. Yet, both of these are not taken into consideration in this study due to their rarity and as they normally occur at mountain peaks and tall built structures such as transmission towers.

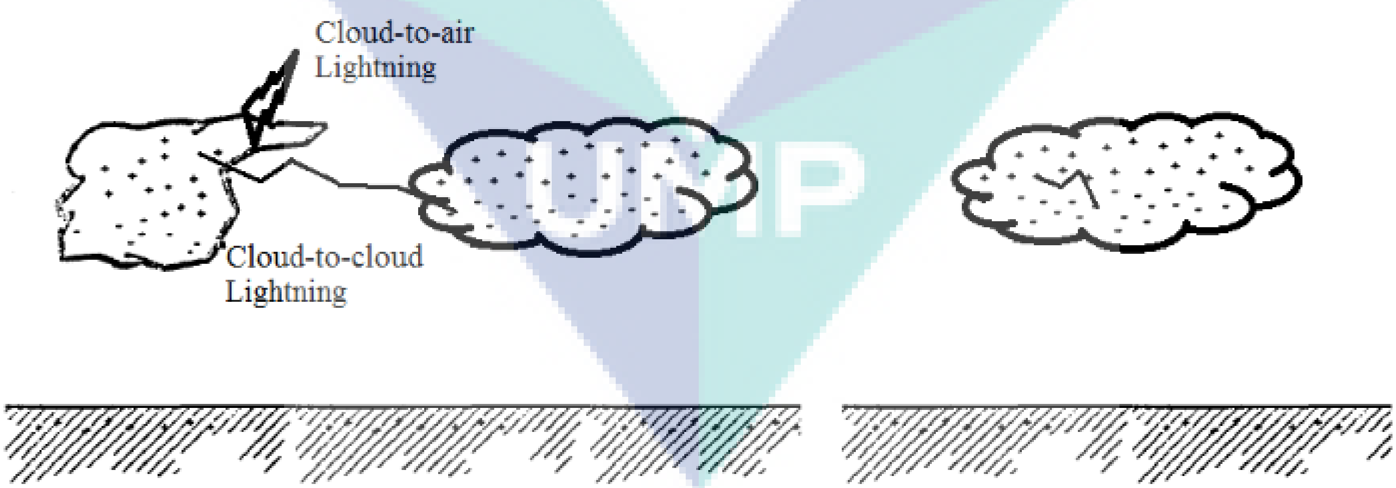
In a review on intra-cloud lightning and inter-cloud lightning by Uman, they were classified as cloud-to-cloud (CC) lightning and they appear due to the electrical breakdown that takes place inside the cloud without reaching the ground. The electrical breakdown generates a weakened return stroke within the clouds. Inter-cloud lightning occurs between charges that are centered in two distinct clouds or sometimes in between the air. still, intra-cloud lightning occurs between positively charged and negatively charged centers in the same cloud. Figure 2.2 shows the variation of inter-cloud lightning and intra-cloud lightning.



(a) (b)

Figure 2.1: (a) Upward-moving positively charged leaders; (b) Upward-moving negatively charged leaders

Source: (Martin A. Uman 2008)



(a) (b)

Figure 1.2: (a) Inter-cloud lightning; (b) Intra-cloud lightning.

Source: (Martin A. Uman 2008)

2.2.1 Negative Cloud to Ground (-CG) Lightning

Lightning appears due to the connection of positive charges and negative charges between cloud and ground. A light to be emitted for a few milliseconds when an immediate connection of positive and negative charges happened and it is called lightning. Moreover, -CG lightning appear due to the electrical breakdown that takes place within the lower part of the thundercloud and the ground. Martin A. Uman(Martin A. Uman 2008) declare that the negative charge at the lower part of the thunderclouds experiences an electrical breakdown and form a downward-moving negative leader transmit to the ground. Then, the electric field around the ground produces a small breakdown and upward-moving discharge to contact the downward-moving negative leader. When the upward-moving discharge and the downward-moving negative leader meet, a -CG lightning appear. According to Uman (M.A. Uman 1994), 10% of CG lightning is initiated by the downward-moving positive leader while 90% of CG lightning is proposed by downward-moving negative leader around the globe. Figure 2.3 display the downward-moving negatively charged leaders.

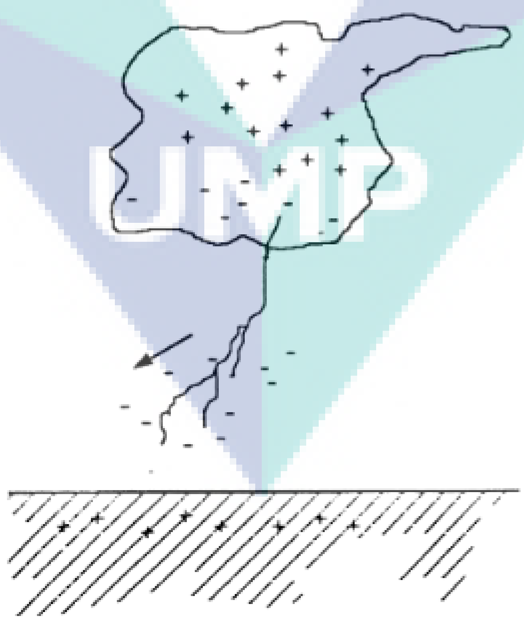


Figure 2.2: Downward-moving negatively charged leaders

Source: (Martin A. Uman 2008)

2.2.2 Positive Cloud to Ground (+CG) Lightning

An analysis from Uman(M.A. Uman 1994) described that a positively charged +CG lightning appears at the upper part of a thundercloud. It begins with the electrical breakdown at the upper part of thunderclouds and is started by a positively charged downward-moving step leader. Only one return stroke reveal during the +CG lightning event, where –CG lightning does not occur simultaneously. Furthermore, NASA((NASA) n.d.) expressed that +CG lightning appears when the last stage of the thunderstorm. The thunderstorm ends after several +CG lightning occurrences. At the same time, most of the +CG lightning occurs in winter months as claimed by Arnone et. al(Arnone et al. 2008). The percentage of +CG lightning is less than –CG as conclude by Dan Robinson(Robinson 1995) and he found that the appearance of Sprites events is usually connected to the strong +CG lightning. Figure 2.4 demonstrates the downward-moving positively charged leaders. From that, it was decided that the focus of the research is to be placed on +CG lightning as it influences the occurrence of TLEs

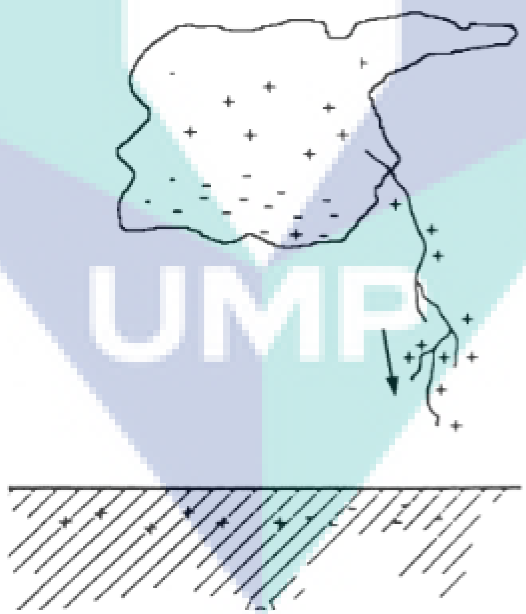


Figure 2.4: Downward-moving positively charged leaders.

Source: (Martin A. Uman 2008)

2.3 TLEs

Some TLEs appear at lower altitudes of about 80 km from earth's surface while some of them at roughly 100 km above the ground as stated by María Passas et al. (Passas et al. 2014). The different types of electrical discharge phenomena in the upper atmosphere makes it electrically induced form that exists in the upper atmosphere, which absence several characteristics of tropospheric lightning. They belong to Extremely Low Frequency (ELF) group, as to declare by Bailey(Bailey 2010). TLEs types involve Sprites, Halos, Elves, Gigantic Jets, and Blue Jets. An investigation on the appearance rate of TLEs on land, coastal area, and the ocean was performed by Chen et al. (Chen et al. 2008). The outcome showed that Elves dominate the highest number of TLE events and they are exposed frequently above the sea surface compared to above the land surface. Sprites and Halos have almost similar numbers of occurrence, yet they appear more in various places like land surface and above the coastal surface respectively. Sprites and Halos have almost the same number of occurrence probably because Sprites always emerge together with Halo. Lastly, Gigantic Jets has the minimum numbers of events and events often take place above the sea surface. Figure 2.5 shows the global occurrence of most TLEs. Different luminous transient produced at different heights is shown in Figure 1.1.

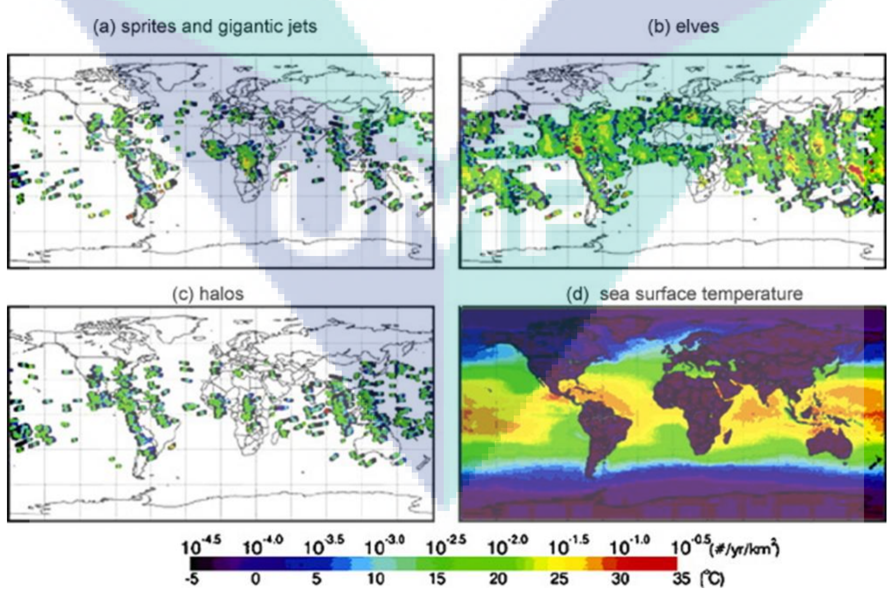


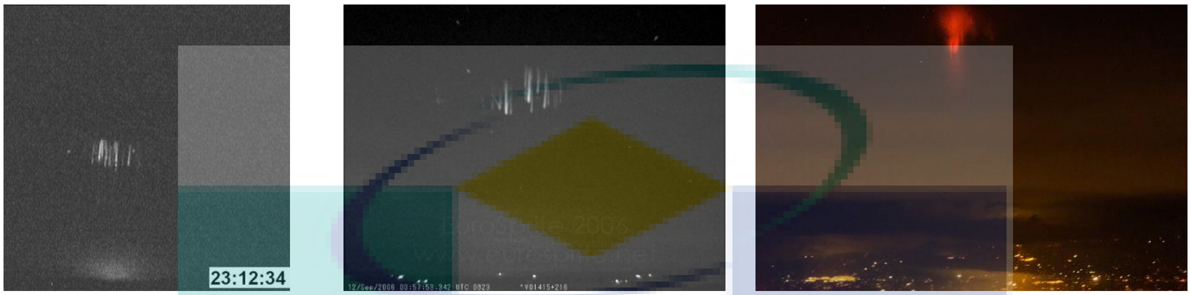
Figure 2.5: Global occurrence of most TLEs: (a) Sprite and Gigantic Jets, (b) Elves, (c) Halos.

Source: (Chen et al. 2008)

2.3.1 Sprites

Initially, Sprites was found by Franz et al. (Franz, Nemzek, and Winckler 1990) in 1989. Then, other researchers studied it and found other types of Sprites such as Carrot Sprites, Column Sprites, Jellyfish Sprites, and firework, as declared by V. P. Pasko, Yair and Kuo(Victor P. Pasko, Yair, and Kuo 2012b). Referring to Sentman et.al(Sentman et al. 2004), Sprite event occurs as a large luminous discharge and takes place at altitude ranges of approximately 40km to 90km. Large peak current can be discovered when the event appears. The duration of Sprites occurrence is approximately 5s to 30s, as stated by M. Hayakawa, Y. Hobara, and T.Suzuki(Hayakawa, Hobara, and Suzuki 2012). The excitation of nitrogen gas in the atmosphere causing Sprites are red in color (Mende et al. 1995)(Stanford University News Service 1995). Haldoupis et al. (Haldoupis et al. 2010) discover that second Sprites occurs after the past event shown up, so, it can last over certain frames setting after the first streamer is generate at about 70 km above the earth's surface. The shape of Sprites can be horizontally displaced from the parent lightning or sometimes align towards it. Sprites generate a +CG lightning flashes inside the stratiform region of the storm, as reported by Serge Soula et al. (Soula et al. 2009), Lyons et. al(Lyons et al. 2003), and V.P. Pasko et al. (Victor P. Pasko, Yair, and Kuo 2012b).

The Carrot Sprites have the mix of a bright "head" with a red gleam color as their "hair"(Hayakawa, Hobara, and Suzuki 2012). They are capable to lengthen to as high as 95 km in altitude and their bluish tendrils consistently reached 20 km from the top clouds with a width of roughly 25km to 50km(Sentman et al. 2004)(V. P. Pasko, Inan, and Bell 1996). The Column Sprite was uncovered by E. M. Wescott, Sentman, M. J. Heavner, and D. L. Hampton(Wescott, Sentman, Heavner, Hampton, Lyons, et al. 1998) in the year 1998 and it shows that they present in a form of group. The Column Sprite strike without the hair-like and tendrils formation. Sprites are vertically aligned cylindrical-shaped with a height of approximately 10km and the diameter is below 1km. Yaniv et al. (Yaniv et al. 2014) recognized that the Column Sprite potentially occurs due to the production of weak +CG flashes. so, the current study pursues to observe Sprites, namely those that are identical to the first TLEs established in 1989 as they are generated by +CG lightning. Figure 2.6 sum up the variation of Sprites.



(a) (b) (c)

Figure 2.6: Carrot Sprites (a), Column Sprites (b), Jellyfish Sprites (c).

Source: Carrot Sprites(O. A. van der Velde et al. 2006), Column Sprites(O. van der Velde 2006), Jellyfish Sprites(Tanya Lewis 2014)

2.3.2 Halos

Halos are defined as the soften glow with a side area of 40km to 70km and are sometimes produced together with Sprites. They are usually based at the tops of Sprites(Christopher P Barrington-Leigh and Inan 2001). They were initiated to accompany the development of more developed Sprites. María Passas et al. (Passas et al. 2014) declared that Sprites and Halos occur 25km across an average horizontal distance source from the initial lightning strike. Figure 2.7 display the images of the Halos formed with Sprites.

Figure 2.7: Sprites and Halos

Source: (Victor P. Pasko, Yair, and Kuo 2012a)

2.3.3 Elves

Fukunishi et al. (Fukunishi et al. 1996) is the first researcher who defined Elves. The speed of Elves occurrence is faster than 1ms while the speed of Elves' downward motion to the ground is 1/10 to 1/3 of the speed of light ($3\ x\ 10^{8}\ ms^{-1}$). They appear at an altitude height of 75 km to 105 km after a large peak current of Cloud to Ground lightning discharge is identified. The immediate horizontal extension of Elves is defined by the structure of luminous rings with a diameter of up to 400 km or bigger. Elves expand in a radially outward direction afterwards by following the lower edge of the ionosphere which is situated at an altitude of around 80 km to 90 km above the earth(Newsome and Inan 2010). Elves are fora m of lights red in colour that caused by a +CG lightning or a –CG lightning with a huge peak current. This is relate to the significant percentage of –CG stroke discovered by Barrington-Leigh and Inan(C. P. Barrington-Leigh and Inan 1999). Elves have an occurrence possibility high above energetic CG lightning of either positive or negative polarity(Sprites, Jets and Elves n.d.). Elves' thickness measurement reach 10 km to 20 km and their can reach until approximately 95 km in height, as expressed by M. Hayakawa et al.(Hayakawa, Hobara, and Suzuki 2012).

The rapid occurrence duration of Elves made it almost impossible to see them with the naked eye and it is even difficult to capture them by using a video camera with 25 frames per second (fps). Nevertheless, a greater quality video camera with 100 fps or above is more convenient to capture Elves event. It is a natural wonder that is able to predict and prevent earlier by the human eye because Elves are the kind of TLEs that usually occur around the globe. Large storms can develop hundreds of Elves in several hours. Elves captured by Van der Velde(O. A. van der Velde 2008) as displayed in Figure 2.8 below.

Figure 2.8: Elves

Source**:** (O. A. van der Velde 2008)

2.3.4 Gigantic Jets

The exploration of gigantic jets by researcher Su et al. (Su et al. 2003) and Pasko et al. (Victor P. Pasko and George 2002) from Taiwan and Puerto Rico respectively have enlarged the group of recorded types of middle atmospheric TLEs. Even though red sprites and elves are typical over a large thunderstorm network(Lyons et al. 2003) and also thunderstorm at oceanic winter(Takahashi et al. 2003), space-based and ground-based observation of the jet-like phenomenon are both categorized as TLEs family and have been relatively irregular.

Some of the accessible observations have proved the stratospheric jets to be bluish in color(Wescott et al. 1996), however, palm tree events happened to be observed as red in color (Heavner et al. 2000). The gigantic jets stated by Pasko et al.(Victor P. Pasko et al. 2002) and Su et al.(Su et al. 2003) extended to upper altitudes than blue jets, 70 to 90 km as an alternative of 40 km, and did not reveal a modest cone figure but revealed one or more parallel rising channels, branching out into altitudes where sprites usually take place, at 50 to 90 km

Gigantic Jets seem to be less often if a comparison between Sprites and Elves are made. It can scatter through an altitude of as great as 80km with upward directed lightning striking out above the cloud tops and it is big in size(Victor P. Pasko 2010). S. Soula et al. (Soula et al. 2011)verified the glare of Gigantic Jets that seemed to be blue in color. Nevertheless, additional new color of Gigantic Jets was witnessed by Y. Yair et al. (Yair et al. 2013) which involved of reddish-orange diffused arc and bluish in color at the lower side. Gigantic Jets are primarily initiated by discharges of intracloud at the lower ionosphere with the thundercloud and without a CG flash spotted at the same time(Victor P. Pasko et al. 2002)(Su et al. 2003). Thus, no charge transmit to the Earth was detected during the occurrences of the Gigantic Jets.

On the opposing, Jing and Gui Li(Yang and Feng 2014) state that Gigantic Jets was ruled by -CG lightning when its discharge. This indicates that TLEs types specifically Gigantic Jets are hard to be found (Victor P. Pasko et al. 2002) (Su et al. 2003) (Yang and Feng 2014). Four constructions are required for a massive Gigantic Jets production. The initial Gigantic Jets construction is leading jet. Its period ranges from 33 ms until 167 ms and it transmits at a higher elevation. Throughout the following stage, a tailing jet occurs with reducing brightness in dissimilar parts such as at the transition region and lower channels. At the third structure which are the lower channels, it generates blue light at an elevation of roughly around 20 km to 40 km. The blue light then disperses with time as it drops in altitude. Last but not least, the transition state situated about 40 km to 65 km, involved of bright red luminous beads that slowly going up and retracing the first leading jet channels(S. Soula et al., 2012). Figure 2.9 shows the images of one of the Gigantic Jets physical appearances.

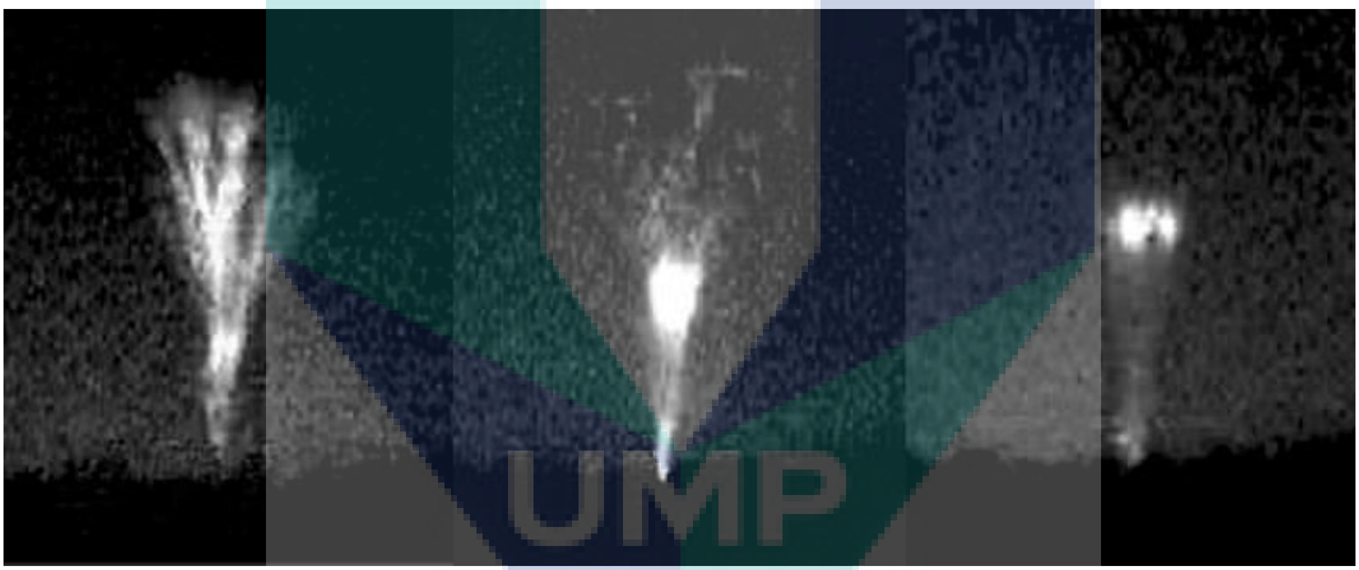


Figure 2.9: A sequence of still pictures from a caught video series of a gigantic jet observed nearby Duke University.

Source: (Thompson 2009)

2.3.5 Blue Jets

A smaller sized version of Gigantic Jets is called blue jets. Jet are types of TLEs which its strike direction is upward from the top of the cloud. Therefore, they prolong only a small number of kilometers from the top of thunderclouds up above the clear air (Wescott et al. 1996). E. M. Wescott et al. (Wescott, Sentman, Heavner, Hampton, and Vaughan 1998) also stressed that Blue Jets can extend to an elevation of up to 40 km from earth's surface which is half the distance of Gigantic Jets. When there is an electrical breakdown separating the upper storm charge and the screening charge that is attracted through the uppermost of thunderclouds then it will happen.

The occurrence takes place for approximately 5 s to 10 s or lesser, with the results of an unexpected imbalance charge in the storm due to the CG or discharge of intracloud, as point out by Krehbiel et al. (Krehbiel et al. 2008). The period of Blue Jets consume more time compared to Sprites and their brightness is also brighter compared to Sprites, as stated by M. Hayakawa et al. (Hayakawa, Hobara, and Suzuki 2012). Besides, the speed of upward direct Blue Jets reached 100 kms^{-1}(Wescott et al. 1995). Blue Jets have a blue pointed shape with an angular cone at about 15º, as revealed by E.M. Wescott, D.D. et. al (Wescott et al. 2004).

The primary stage of blue jets is called blue starter. At an altitude of 17 km to 18 km, it extends upward from the top of the cloud as stated by E M Wescott et al. (Wescott et al. 1996). The process of discharge for both Blue Jets and Gigantic Jets leads to propagation at the storm top and n there are no polarity is found during the occurrence (Wescott et al. 1995). Figure 2.10 displays the shape of a Blue Jet witnessed in Kanto, Japan in the year 2011.

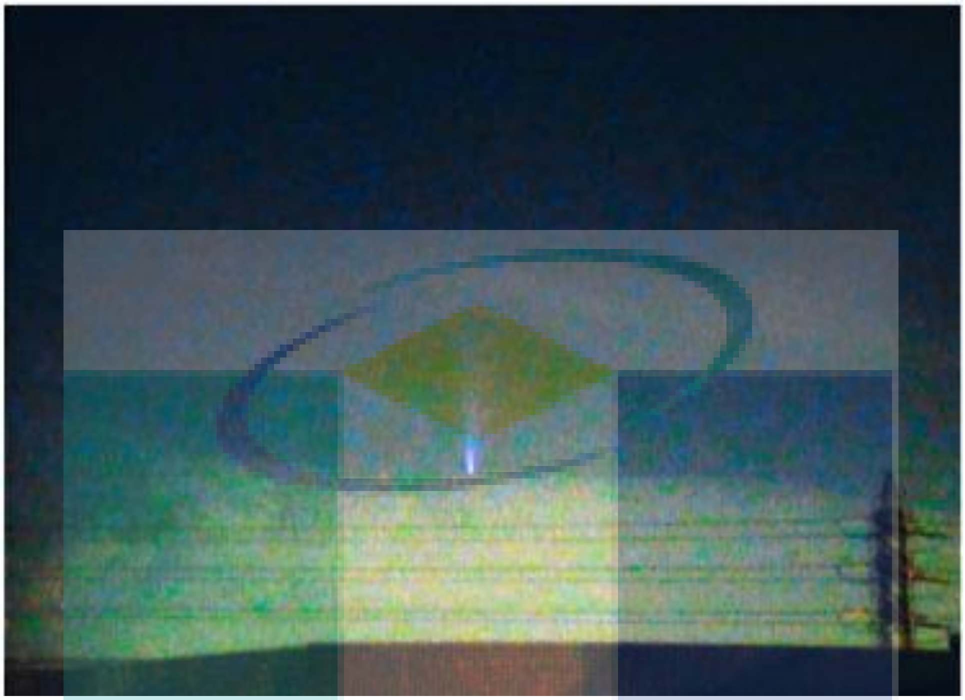


Figure 2.10: Blue Jets

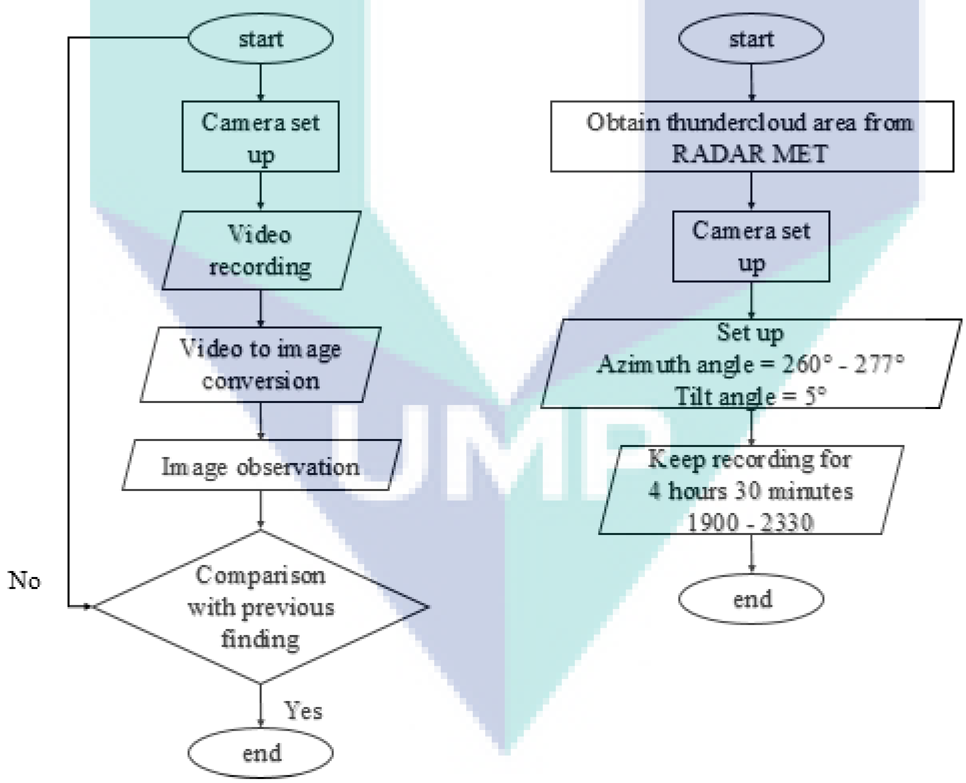
Source: (Suzuki et al. 2012)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter mainly focuses on the observation methodology and discuss the methodology by producing an instruction and a few steps to execute the study by using some techniques, methods, and instruments. This chapter is divided into several parts which are flowchart of the project, flowchart of camera setup and the project approach will be discussed. There is something need to take into consideration such as the camera choice, method to convert the analog input into digital input, the method to install the camera into the desired direction and method to observe the TLEs and +CG events so that this project can be conducted.



(a) (b)

Figure 3.1: project flowchart (a), camera setup flowchart (b)

3.2 Image capture

Watec Ultimate 902H2 is a camera that has been choosing as a video capturing device which has high sensitivity to the bright environment. BK6 Faculty of Electrical and Electronics Engineering UMP Pekan Campus have been choosing as a camera set up location as its position is suitable for the observation as it facing to the desired location which is facing Kuala Lumpur. the monochrome camera that has been used was frequently used earlier by the researcher for capturing natural phenomena such as full moon events and meteor. The video was recorded by using the highly sensitive camera only during night time as it is very sensitive to light. There are two types of field of view that were used in this project which are the wide and low-angle viewpoint. While the video recording process conducted, Digital Video Recorder (DVR) have been used to display and save the recorded video into the laptop automatically for every 30 minutes. Moreover, the DVR act as a bridge to convert the recorded analog video into a form of the digital format and the result will be review in a separate folder. Then, video to JPG converter is used to extract every frame of the video to be inspected later when image observation process is conducted. A block diagram of images captured and the camera setup panel is shown in Figure 3.2.1 and 3.2.2 respectively.

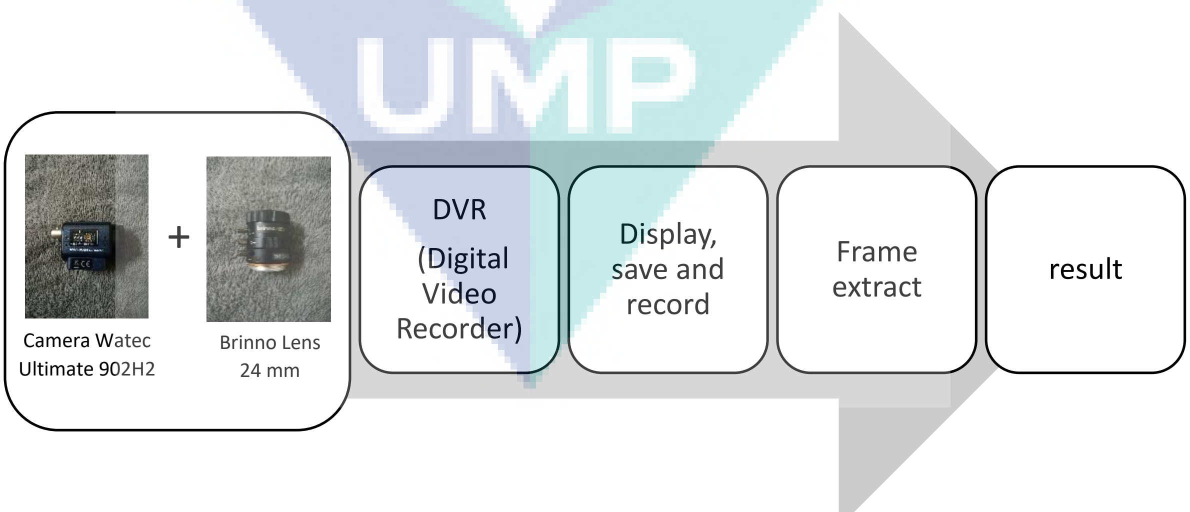


Figure 3.2.1: block diagram of images captured

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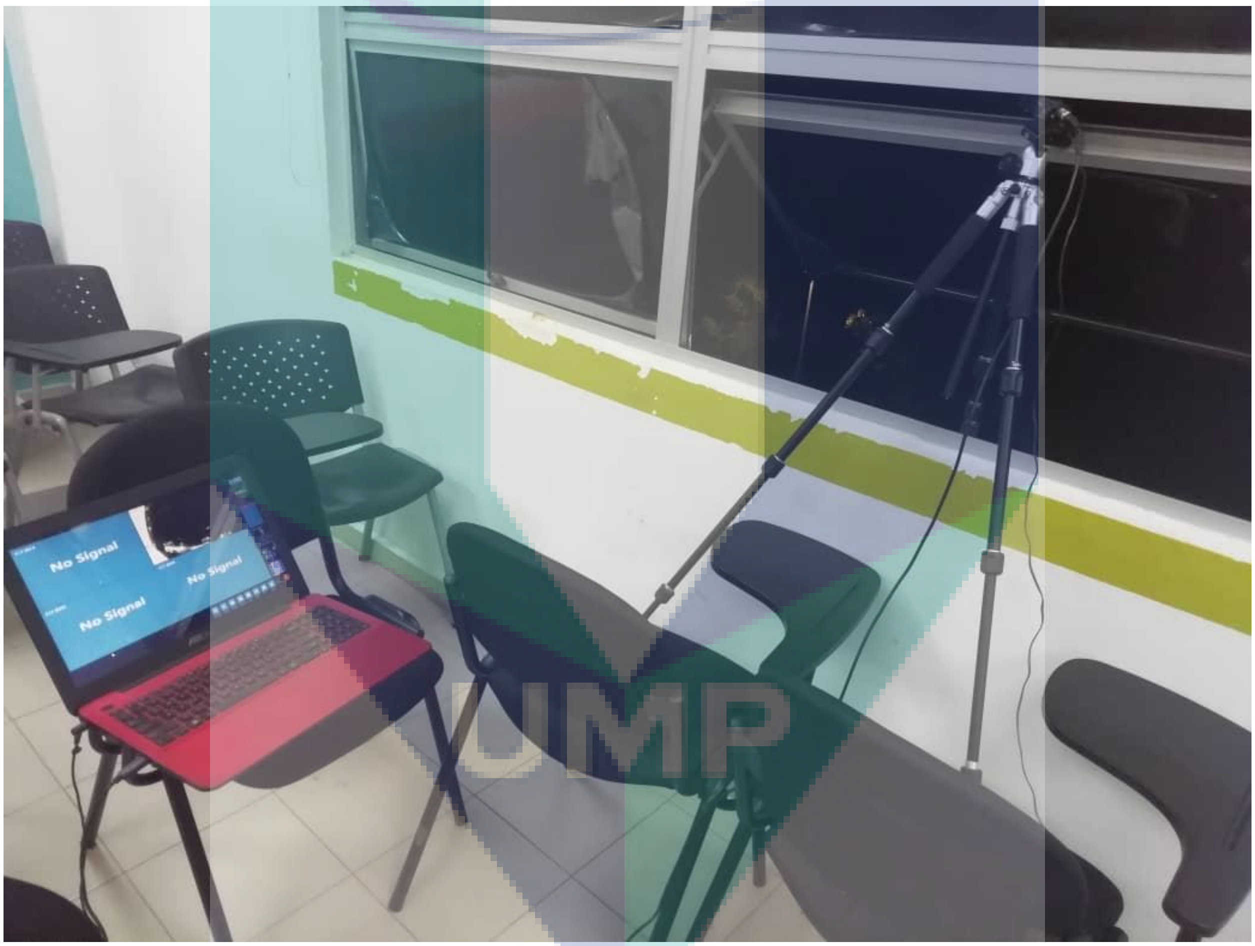


Figure 3.2.2: Camera setup panel

3.3 Lens

Brinno lens which has 24 mm to 70 mm focal length with f1.4 lens aperture was attached with Watec Ultimate 902H2 camera. Brinno lens is a lens which capable to be adjusted or controlled to focus on a more specific field of view. A better view can be achieved by using this type of lens as it is more reliable. The user manual of the Brinno lens is located at the appendix.

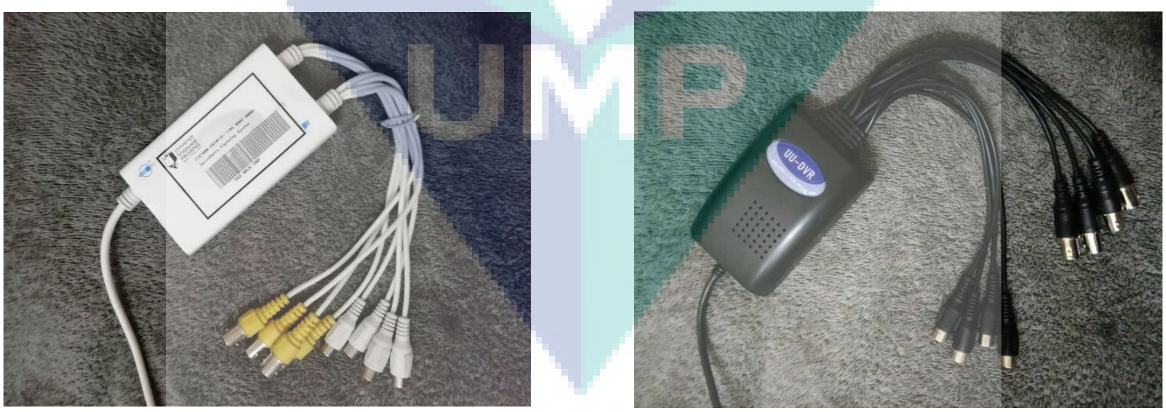
There are three types of setting that can control which are the zoom, aperture, and its focus. In order to adjust the camera view, firstly, the zoom screw was adjusted to set the view into a smaller or bigger size. And then, the aperture screw was adjusted to overcome too much light entering the lens to get a better image intensity as shown on the DVR display. Lastly, the focus screw was turned to adjust the focus of the object. After all of the setting have been adjusted, the screws were tightened. Figure 3.15 exposed Brinno Lens that used in the observation

Figure 3.3: Brinno lens

3.4 Digital Video Recorder (DVR)

A digital video recorder with high frame per second is used to capture the detail sequences of the event and the nature of TLEs. It is stated that a high frame rate which is related to high resolutions are able to ensure a high definition frames captured the occurrence of TLEs. Hence, a good digital video recorder that comes with a high frame rate is chosen as the connector between the personal computer and the camera. Apart from having a feature that is able to expose the occurrence of TLEs in details, it also able to controls the frames per seconds (fps) from each of the video recorder or image captured by the camera. Since the recorded video is in analog mode, it needs to be converted first into a digital mode so that it can be transferred into PC disk drive easily. However, the mode conversion will cause declining in the resolutions of the images.

Therefore, two types of DVRs with different function is used in order to conduct this research. Initially, Jovision (JVS C300Q DVR) was used during this research, but later on, was replaced by the UU-DVR since Jovision (JVS C300Q DVR) has a low resolution and also the low frame rate. Moreover, it is quite difficult to use Jovision (JVS C300Q DVR) since it was protected by the related authority and also required software named "Jfilter" to review the related recorded video by using VLC player. Both of the DVRs stated above are shown in Figure 3.4 and both of its features also compared in the table below.



(a) (b)

Figure 3.4: JVS C300Q DVR(a), UU-DVR(b)

Based on Table 3.1 above, it shows that UU-DVR has 25 fps which is quite higher compared to Jovision (JVS C300Q DVR) that has only 12.5 fps. Jovision (JVS C300Q DVR) records its video in .sv4 file video format which requires a special application to be installed before it can be reviewed since it is a unique format while UU-DVR has .avi file video format. Even though both file format is small in size, UU-DVR has a better resolution at 1920 x 1080 compared to Jovision (JVS C300Q DVR) which is only at 704 x 576. Both of the DVR has the same video system format, Phase Alternation by Line (PAL) which is commonly used in countries such as Malaysia, United Kingdom (UK) and Australia(Diffen 2013)

Based on all the comparison above, it is found that UU-DVR is the best device that can be used as the connector between PC and camera since it has a high frame rate of 25 fps and also uses a smaller file type which is .avi video file format. Apart from having a high resolution which is at 1920 x 1080, it is also suitable to be used in Malaysia since it has a video system format, Phase Alternation by Line (PAL).

Descriptions	**Jovision (JVS C300Q DVR)**	**UU-DVR**
Format	PAL	PAL
Frame rate (fps)	12.5	25
File Type	.sv4	.avi
Resolution	704 x 576	1920 x 1080

Table 3.1: Comparison between JVS C300Q DVR and UU-DVR

3.5 Control panel

In Malaysia Phase Alternation Line (PAL) have been applied by several types of recording systems. 25 fps is the maximum PAL that can be found. On the other hand, fps is something that can be adjusted to the recording control panel. It is important to set the recording setup and make sure the date and time of the laptop are synchronized with wifi before starting any recording. First of all, the recording control panel (figure 3.5) must be open in order to connect the DVR with a laptop. Then, in the setting window (figure 3.6), location to save the video and the time taken of the video for every file is changed.in this project, every file was set up to have 30 minutes video. Next, the video setting tab (figure 3.7) was selected to adjust the fps and the fps is selected to be maximum which is 25 fps. And another setting on the video setting tab is set to be the default.

Figure 3.5: Control panel

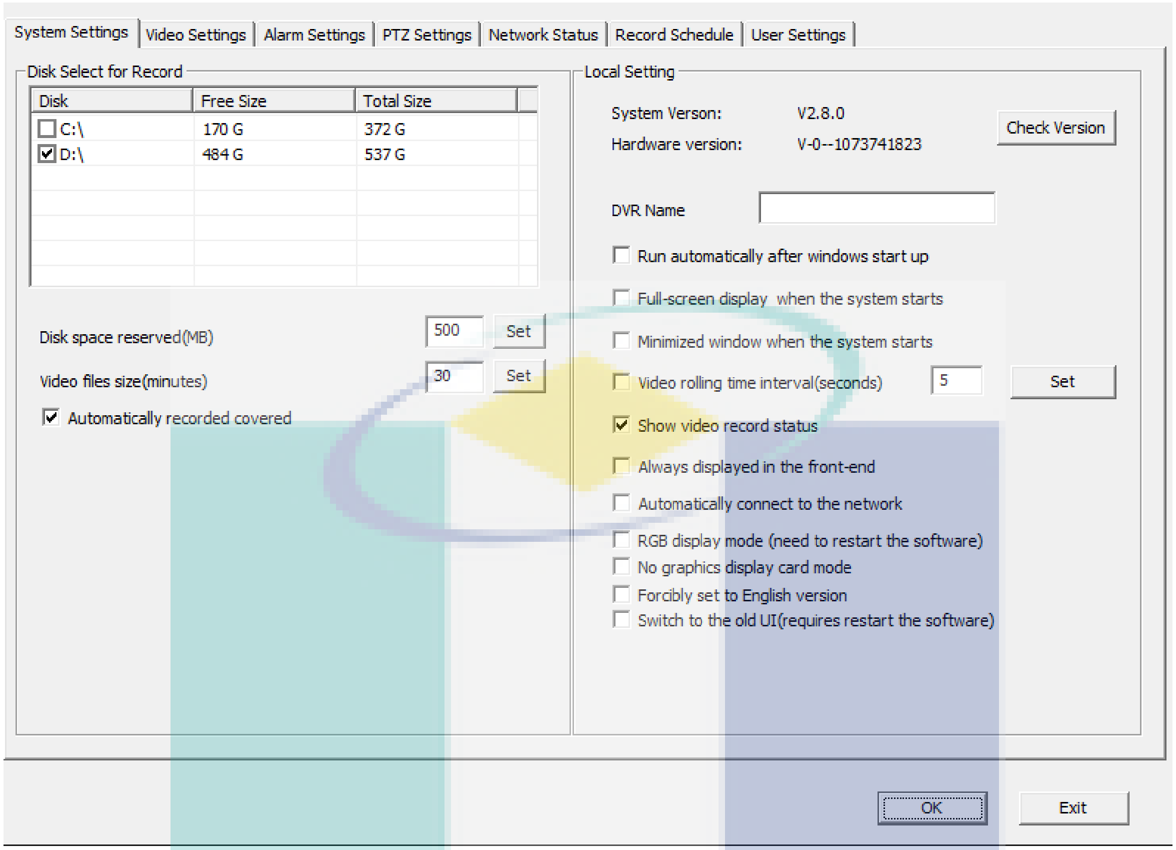


Figure 3.6: Setting window

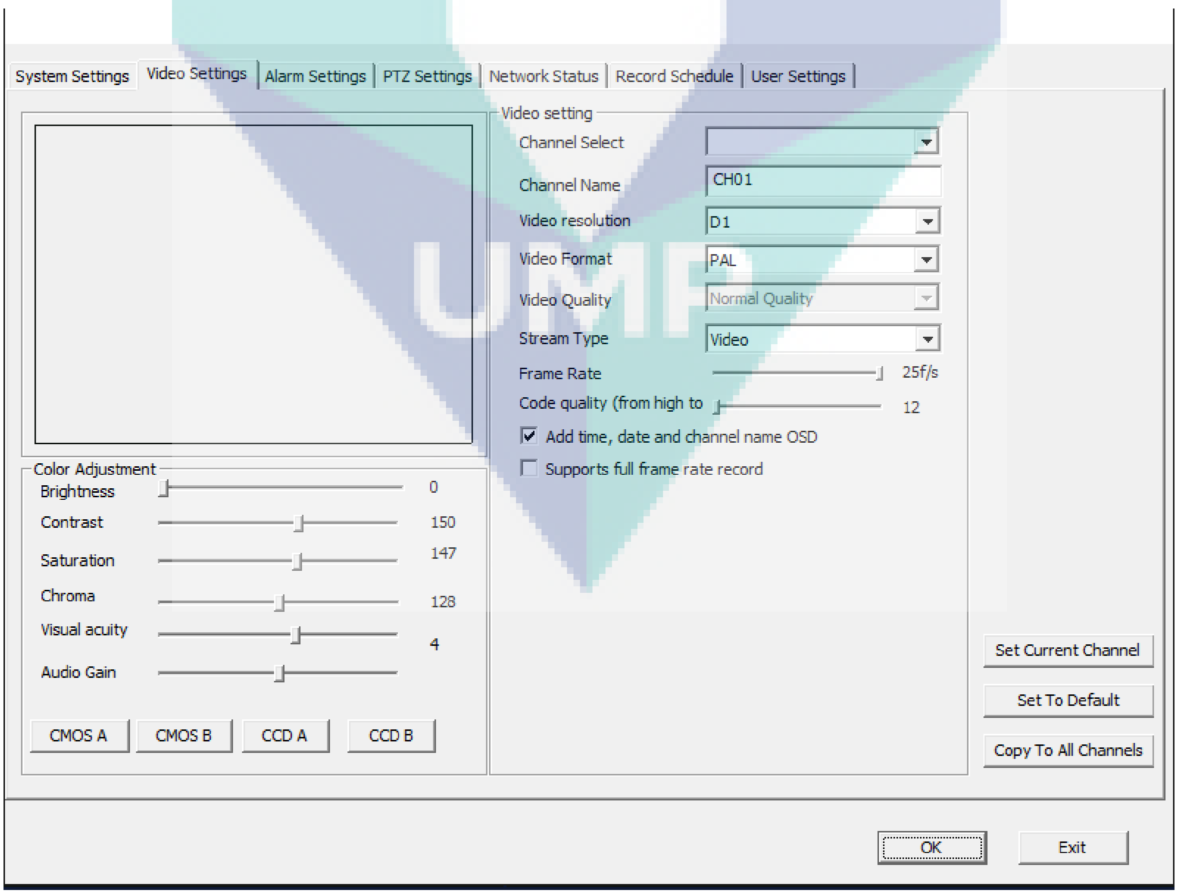


Figure 3.7: Video setting tab

3.6 Video extraction

After the video recording process has been done, the video must be extracted so that the observation of TLEs and +CG can be more detail. When the video is extracted the video will be converted into an image format. Thousands of image will be produced from the 30 minutes video. Furthermore, the video has been extracted by using Video to JPG Converter (figure 3.8). From the extraction software, the first step to extract the video is to select video files from the add files tab (figure 3.9). Multiple files can be selected to be extracted. Then, the video extraction setting has been set to be every frame so that a more detailed image can be obtained from the video extraction. After multiple files have been chosen to be extracted the save file location have been chosen (figure 3.10) and the videos are ready to be extracted.

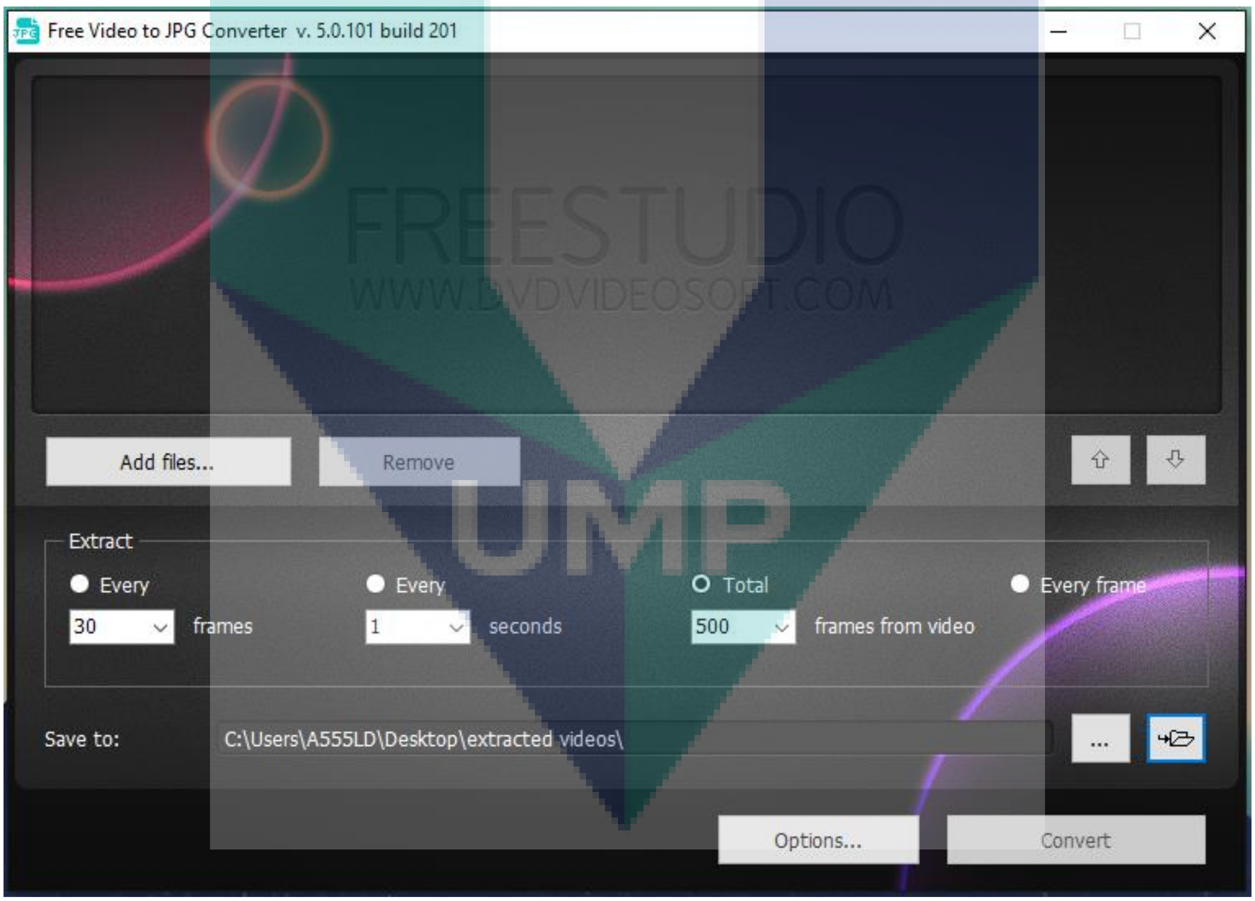


Figure 3.8: Video to JPG Converter

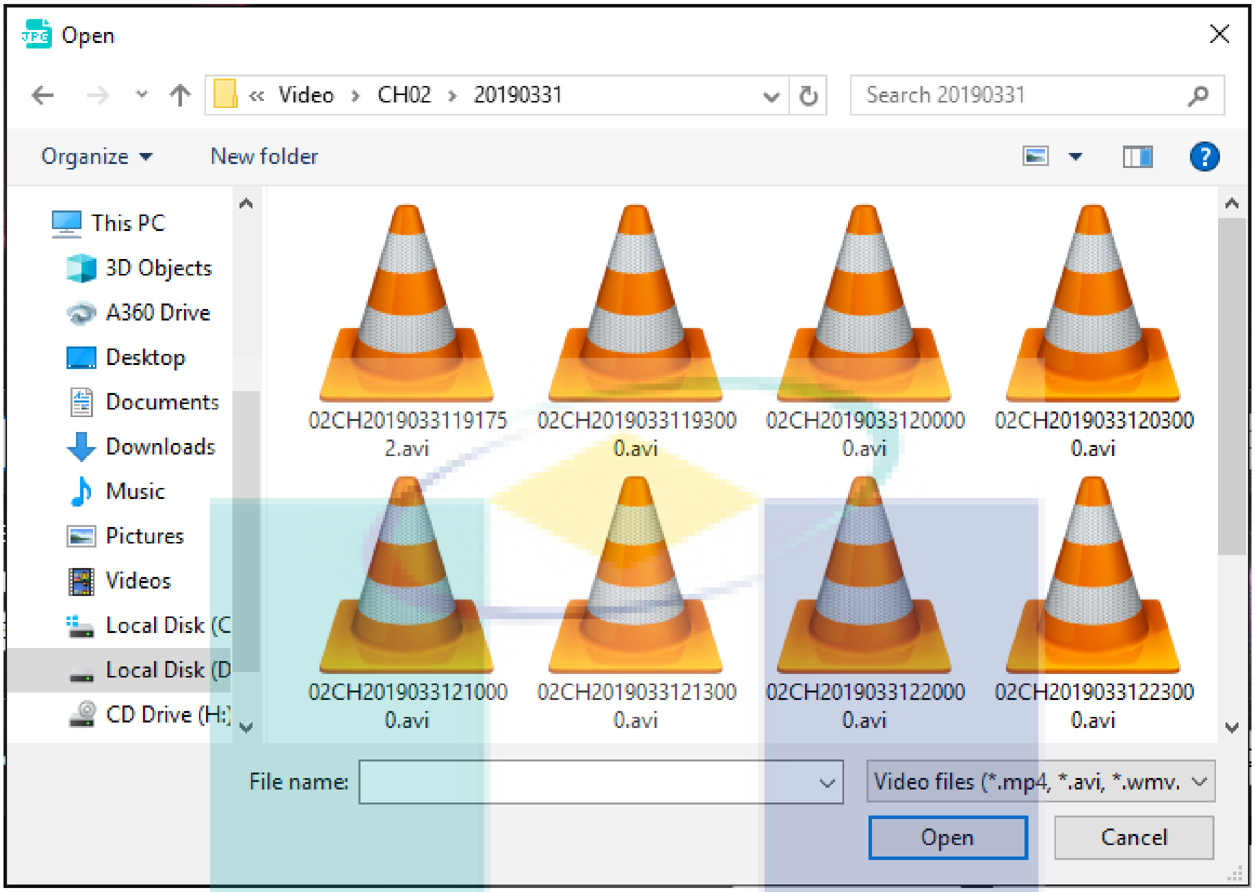


Figure 3.9: select video files from the add files tab

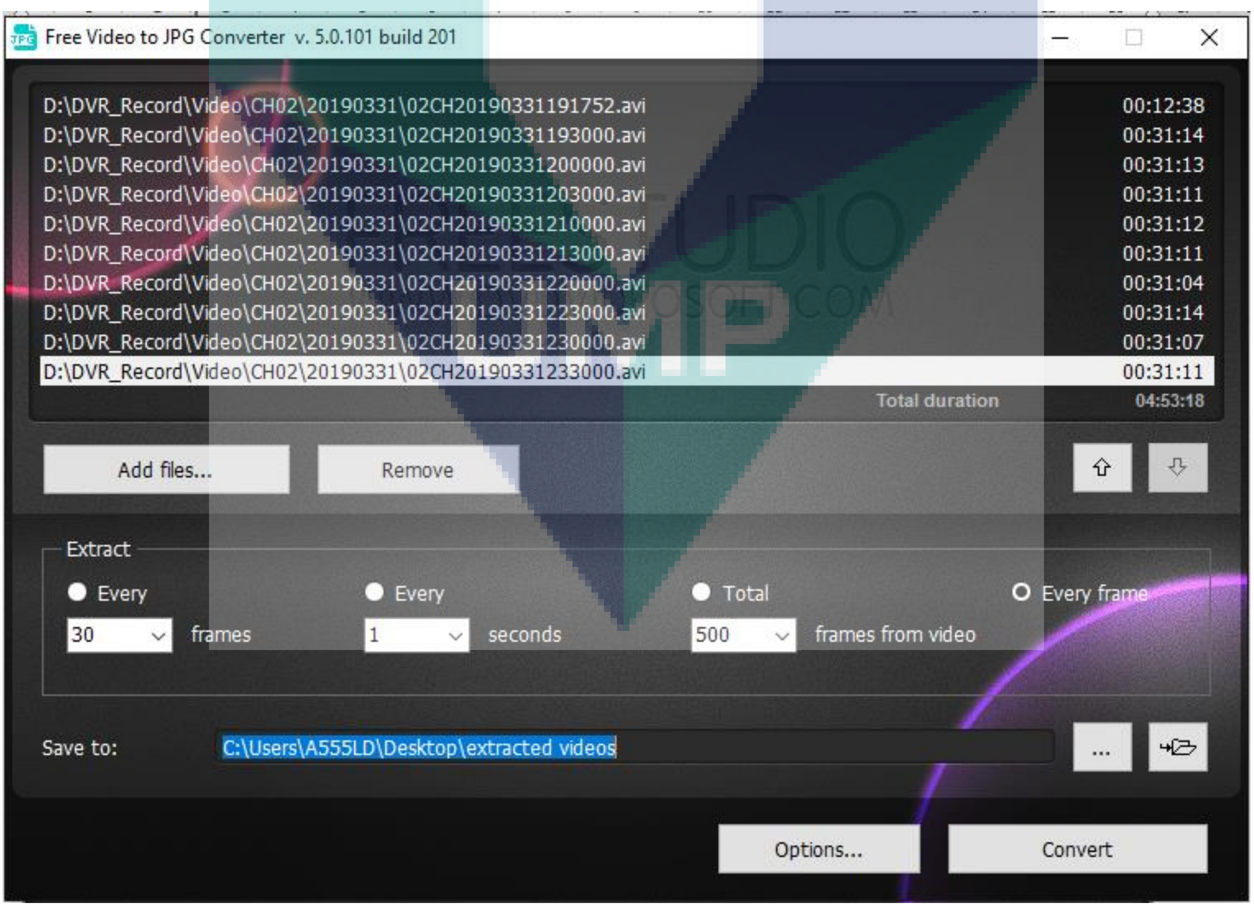
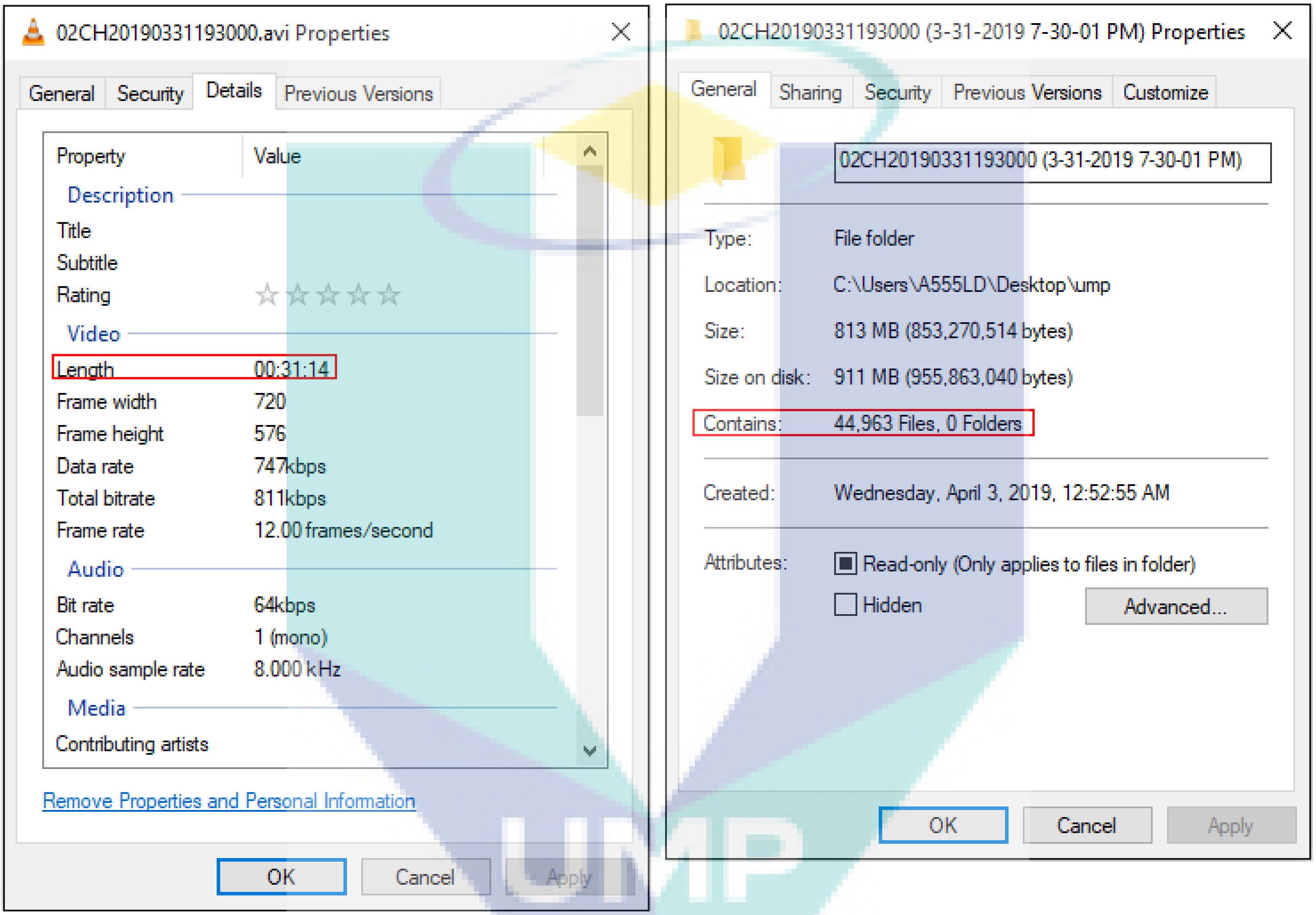


Figure 3.10: After multiple file have been chosen to be extracted the save file location have been chose

3.7 Frame rate

To obtain the period of each frame a calculation has been made by using equation 3.1. Figure 3.11 shows the duration of the original videos and the number of the extracted file.



(a) (b)

Figure 3.11: Video length (a), number of extracted images (b)

$$fps = \frac{videos\ length}{no. of\ image\ files} \tag{3.1}$$

$$= \frac{(31\ x\ 60) + 14}{44963}$$

$$= 0.04168\ \approx 40\ ms\ per\ frame$$

3.8 Field of view (FOV) calculation

The FOV was calculated by using equation 3.2

$$FOV, \beta = 2\tan^{-1}\frac{d}{2f} \quad (3.2)$$

$$d = \text{Dimension}$$

$$f = \text{Focal length}$$

Brinno lens is a lens which has an adjustable focal length from the range 24 mm to 70 mm. by using these type of lens the FOV can be adjusted according to the desired angle. The dimension of the image can be obtained by looking at the extracted image properties (figure 3.12). FOV of Brinno lens are showed in table 3.2.

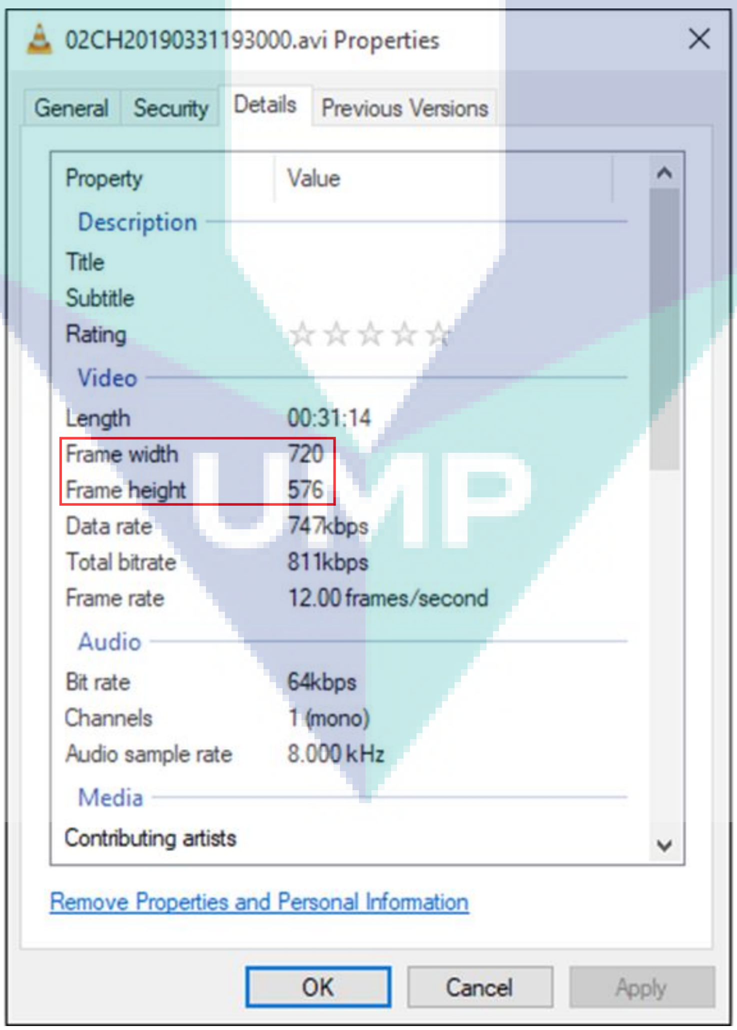


Figure 3.12: dimension of image

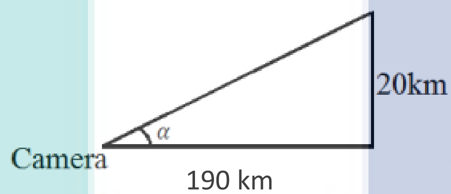
Lens	FOV
Brinno (24 mm)	17°
Brinno (70 mm)	5.9°

Table 3.2: Field of view

3.9 Camera setting calculation

In view of trigonometry theorem, the tangent function was applied to calculate the camera angle during executing the observation. Equation 3.3 explains the tangent function. The lowest and highest height 20 km and 70 km respectively were chosen for this condition where the separation was set according to the displacement between Pekan and Kuala Lumpur which is 190 km.

$$\tan\alpha = \frac{opposite}{adjacent} \tag{3.3}$$



The calculated result of the camera setting in degree is presented in Table 3.3.

Height condition (km)	Degree
20	6
70	20

Table 3.3: The calculated result of the camera setting in degree

The angle was set up by using smartphone compass apps as shown in figure 3.13 where the smartphone is aligned with the camera base and tilt it to get the desired angle.

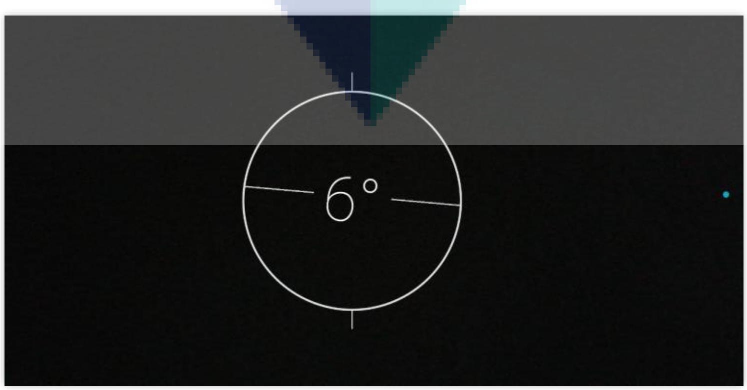


Figure 3.13: Android compass apps

3.10 Direction

The project scope is set the direction to be to Kuala Lumpur. Rain alarm apps are used to get a specific direction and to identify the occurrence of rain above Kuala Lumpur in real time. The apps will show the current location and what direction the device currently facing. Kuala Lumpur in real time. So that the occurrence of +CG and TLEs can be predicted. Figure 3.14 shows the Rain Alarm apps

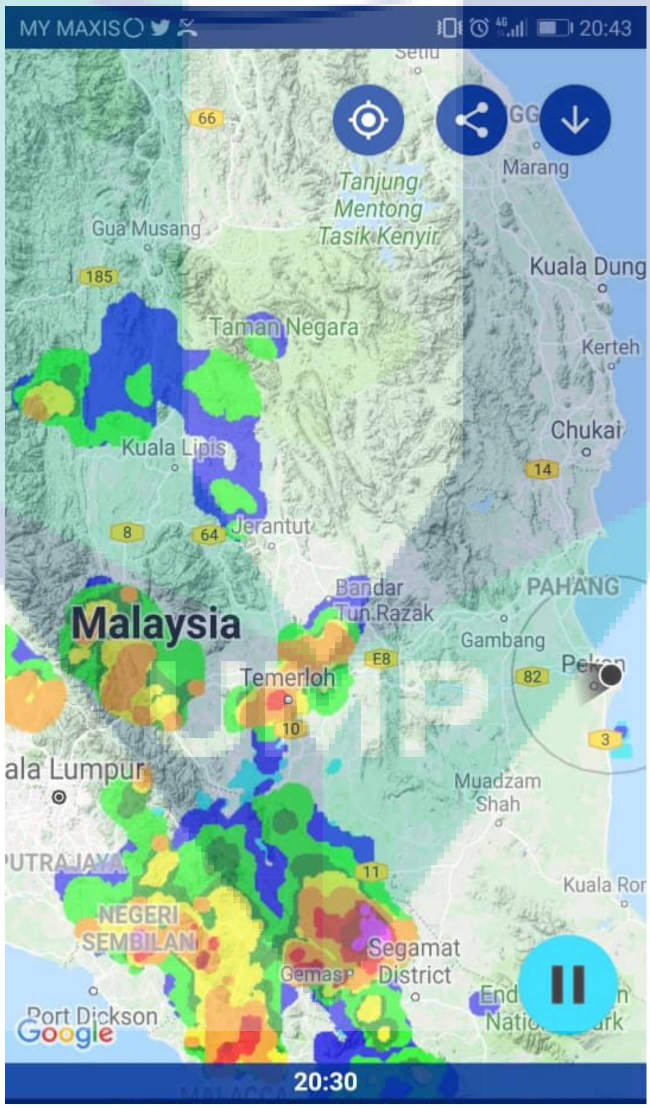


Figure 3.14: Rain Alarm apps

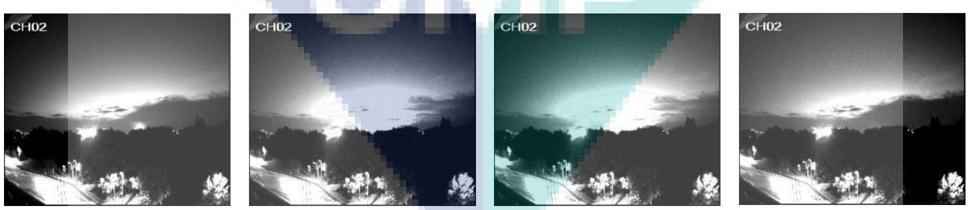
CHAPTER 4
RESULT AND DISCUSSION

4.1 Introduction

In this chapter, the occurrence of TLEs will be explained. The comparison of Jet and Halos obtain from this project and TLEs from the previous finding has been made. Side by side comparison is made from the comparison. Furthermore, the exact altitude of the observed TLEs (Jets) also calculated.

4.2 Occurrence of Halos and Jets

In this project, two TLEs occurrence have been discovered potentially to be blue Jets and Halos. As stated by Wescott et. al (Wescott et al. 1996), blue Jets occur at an altitude of 17 km to 18 km it extends upward from the top of the cloud which is identical to this projects finding. From the recorded video, an upward discharge Jets have been captured at 1930 at night but the color of the events cannot be confirmed as this project used a monochrome camera which has black and white output. Just a few minutes before the occurrence of Jets, another events of TLEs which potentially to be Halos are exposed by the same monochrome camera on the same night but different in time. This halo is just a single Halos which not came with Sprites. Halos usually accompanied by sprites as stated by (Christopher P Barrington-Leigh and Inan 2001). The occurrence of both captured TLEs events speed is believed to be around 40 ms and below as it only takes 2 frames from the extracted videos. Figure 4.1 display the occurrence of Halos and Jets.



(a)

(b)

Figure 4.1: Halos (a), Jets (b)

4.3 Comparison with previous findings

Comparison of the founding of this project which is Jets and Halos have been made by comparing the image obtained by using Watec monochrome camera paired with a Brinno lens with previous founding by another researcher. The result is the image from other researcher is similar to image obtain by this project but this project cannot identify the color of the events as the output of Watec monochrome camera black and white. Figure 4.2.1 shows the side by side comparison of halos and figure 4.2.2 shows the side by side comparison of Jets

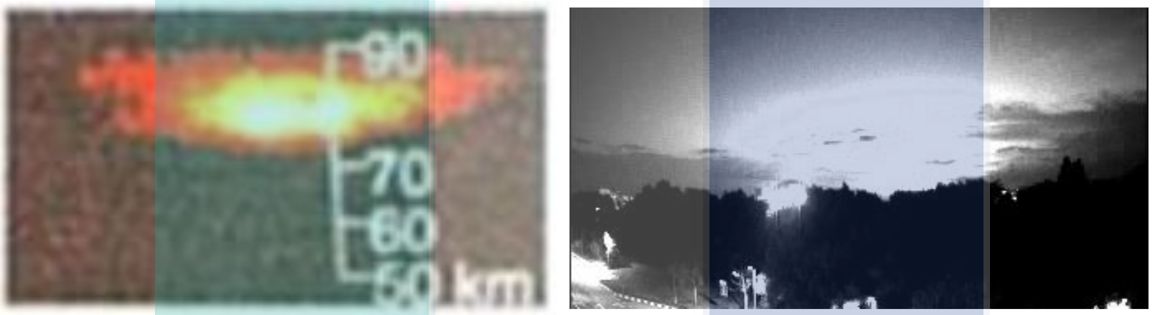


Figure 3.2.1: Side by side comparison of halos

Source: (Christopher P Barrington-Leigh and Inan 2001)

Figure 4.2.2: side by side comparison of Jests

Source: (Wescott et al. 1995)

4.4 Position of TLEs

Earth shape must be considered to calculate the altitude of TLEs. As the earth is round, h1 on figure 4.3 must be calculated to get the actual altitude. r_{earth} refers to the radius of the earth which is 6371 km from the center of the earth to the outer surface of the earth. While d_0 indicates the distance between UMP Pekan Campus to Kuala Lumpur which is 190 km. To get α_3 equation 4.1 is applied.

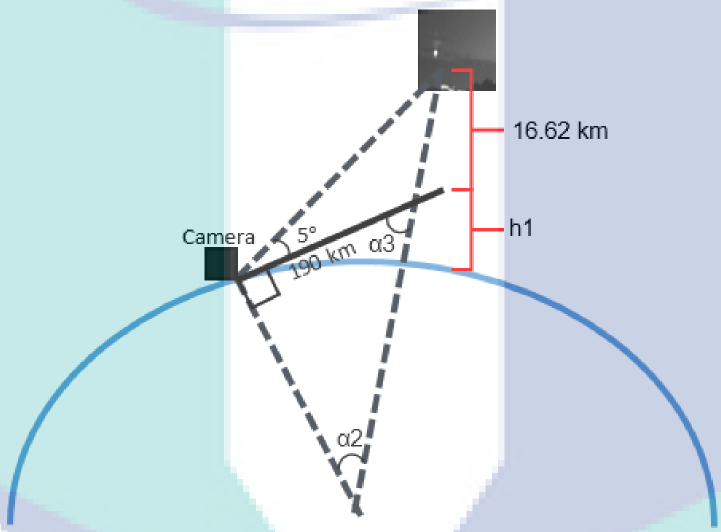


Figure 4.3: TLEs position

$$tan\ \alpha_3 = \frac{r_{earth}}{d_0} \tag{4.1}$$

$$tan\ \alpha_3 = \frac{6371\ km}{190\ km}$$

$$\alpha_3 = tan^{-1}\ 33.53$$

$$= 88.29°$$

To find α_2, equation 4.2 is applied. The total angle for a triangle is equal to 180º hence

$$\alpha_2 = 180 - 90 - \alpha_3 \tag{4.2}$$

$$\alpha_2 = 180 - 90 - 88.29$$

$$\alpha_2 = 1.71^\circ$$

Lastly, the horizon distance, h1 can be achieved by using equation 4.3.

$$cos\alpha_2 = \frac{r_{earth}}{h1 + r_{earth}} \tag{4.3}$$

$$cos1.71^\circ = \frac{6371 \text{ km}}{h1 + 6371\ km}$$

$$h1 = 2.838 \text{ km}$$

The exact altitude of TLEs from the bottom of Kuala Lumpur can be achieved by total up h1 and 16.62 as shown in equation 4.4.

$$Altitude = 16.62km + h1 \tag{4.4}$$

$$Altitude = 16.62\ km + 2.838\ km$$

$$Altitude = 19.458\ km$$

The altitude of TLEs captured by Watec monochrome camera meet the expectation as the occurrence is comparable to figure 1.1

Chapter 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter mainly focuses on the conclusion of the results obtained from this project and recommendation to enhance the observation in the future.

5.2 Conclusion

In conclusion, this project is considered as successful as the image of TLEs is manage to be captured. The first Jet and Halos in Malaysia have been recorded throughout this project. As stated by the National Lightning Safety Institute ((NLSI) n.d.) Malaysia is one of the most countries that has the highest distribution of lightning. Throughout this project, it is possible and has been proved by using Watec monochrome camera that the occurrence of TLE exists in Malaysia.

Furthermore, the occurrence height of the TLEs namely Jets above the sea level calculated from this project which is 19.458 is approximately the same as stated by Wescott (Wescott et al. 1996). While making the calculation the earth surface is taken into consideration as the earth is shape is round. So that the new altitude from as seen by the camera has to be calculated.

Side by side comparison also has been done to strengthen the result obtained from the observation. From the comparison, it can be concluded that Jet and Halos obtain from this project and Jet and Halos obtain by previous research is identical. But the color of these events cannot be confirmed as the camera used output is only in black and white. The charge produced by the TLEs obtain from this project also cannot be identified as this project not supported by an antenna to get the real-time signal.

5.3 Recommendation

Even though this project objective has been achieving but there are a lot of things need to be improved in order to get better observation result. As these observations are using a monochrome camera which has a black and white output, the color of the events cannot be observed. The observation result will be more reliable if the color of the TLEs can be observed. However, bigger space is required to store the video file and it can be counter by using multiple hard disks with a bigger size.

Moreover, the result of this project is not very convincing as this project not include with the TLEs signal output. The signal can be achieved in the future by installing an antenna system. In addition, to execute the observation, the camera has to be reinstalled every time the project is conducted. So, an observation station can be built to conduct the observation for 24 hours of observation. Therefore probability to capture the TLEs occurrence is higher.

Furthermore, to run the observation 24/7 consume a lot of power. So solar energy can be used as an alternative power supply. As Kuala Lumpur has a lot of dust particle, it makes the tendency of thundercloud occurrence become higher. So the observation is only focused on the direction above Kuala Lumpur only. But the lightning occurrence is unpredictable. Therefore, lightning detector system can be installed to support the observation.

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APPENDIX

Watec

WAT- 902H 2 / 3 ULTIMATE

SPECIFICATIONS

Model	WAT-902H2 ULTIMATE (EIA)	WAT-902H2 ULTIMATE (CCIR)
Pick-up element	1/2" interline transfer CCD image sensor	
Number of total pixels	811(H) × 508(V)	795(H) × 596(V)
Number of effective pixels	768(H) × 494(V)	752(H) × 582(V)
Unit cell size	8.4um(H) × 9.8um(V)	8.6um(H) × 8.3um(V)
Shutter speeds	EI1: 1/60 sec. - 1/100000 sec. EI2: 1/100 sec. - 1/100000 sec. FL: 1/100 sec. OFF: 1/60 sec.	EI1: 1/50 sec. - 1/100000 sec. EI2: 1/120 sec. - 1/100000 sec. FL: 1/120 sec. FL: 1/50 sec.
	1/250, 1/500, 1/1000, 1/2000, 1/5000, 1/10000, 1/100000 sec.	
Minimum illumination	0.0001 lx. F1.4	

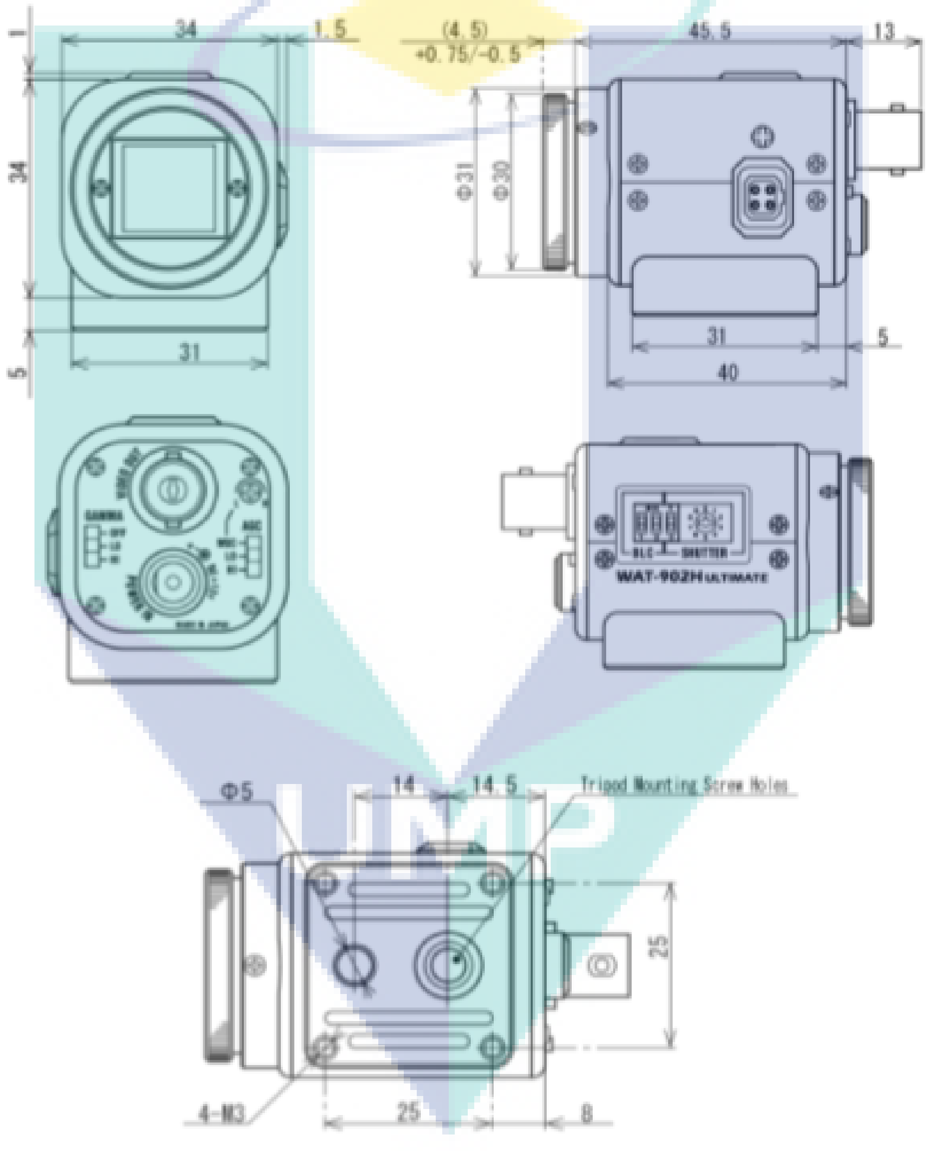
Model	WAT-902H3 ULTIMATE (EIA)	WAT-902H3 ULTIMATE (CCIR)
Pick-up element	1/3" interline transfer CCD image sensor	
Number of total pixels	811(H) × 508(V)	795(H) × 596(V)
Number of effective pixels	768(H) × 494(V)	752(H) × 582(V)
Unit cell size	6.35um(H) × 7.40um(V)	6.50um(H) × 6.25um(V)
Shutter speeds	EI1: 1/60 sec. - 1/100000 sec. EI2: 1/100 sec. - 1/100000 sec. FL: 1/100 sec. OFF: 1/60 sec.	EI: 1/50 sec. - 1/100,000 sec. EI2: 1/120 sec. - 1/100000 sec. FL: 1/120 sec. FL: 1/50 sec.
	1/250, 1/500, 1/1000, 1/2000, 1/5000, 1/10000, 1/100000 sec.	
Minimum illumination	0.0002 lx. F1.4	

	Common specifications
Synchronizing system	Internal sync.
Video output	1Vp-p, 75ohms, unbalanced
Resolution (H)	570TVL (Center)
SN ratio	More than 50dB (AGC OFF)
AGC	①HI: 5-60dB ②LO: 5-32dB ③MGC(5-60dB)
Back light compensation	①OFF(Default) ②Center ③Lower ④Center + lower
Gamma correction	①HI (γ≒0.35) ②LO (γ≒0.45) ③OFF (γ≒1)
Power supply	DC12V ± 10%
Power consumption	1.32W (110mA)
Operating temperature	-10°C - +40°C
Storage temperature	-30°C - +70°C
Dimensions(W×H×L)	35.5 × 40 × 63 (mm)
Weight	approx. 98g

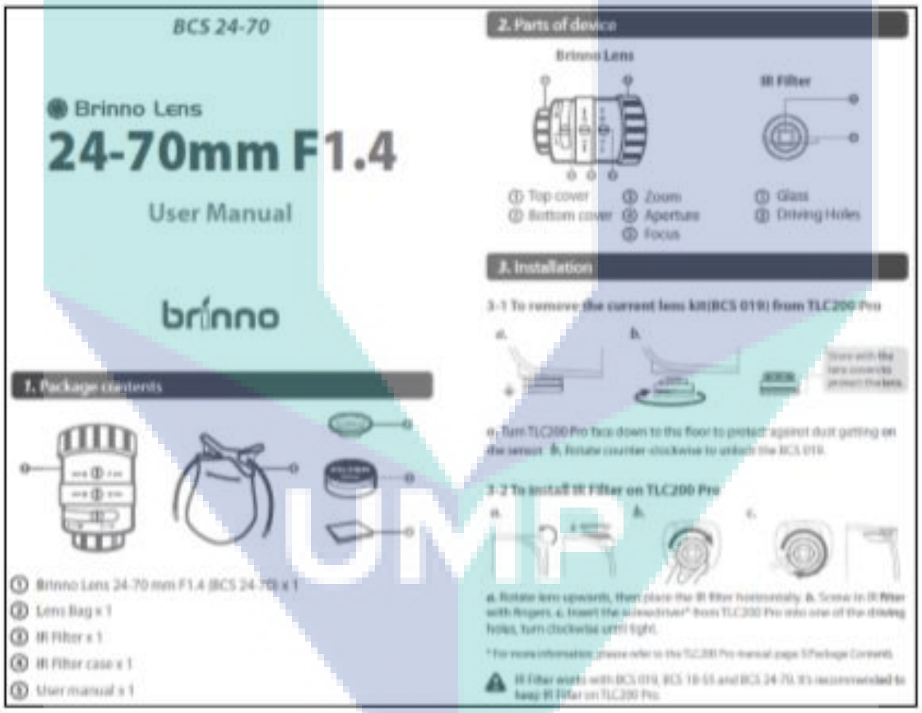
Design and specifications are subject to change without notice.

Watec Co., Ltd. 1/2 P060215E-1

DIMENSIONS (mm)



Technical Specification Data Sheet



BCS 24-70

Brinno Lens

24-70mm F1.4

User Manual

brinno

1. Package contents

1. Brinno Lens 24-70 mm F1.4 (BCS 24-70) x 1
2. Lens Bag x 1
3. IR Filter x 1
4. IR Filter case x 1
5. User manual x 1

2. Parts of device

Brinno Lens

IR Filter

1. Top cover
2. Bottom cover
3. Zoom
4. Aperture
5. Focus

1. Glass
2. Driving Holes

3. Installation

3-1 To remove the current lens kit(BCS 019) from TLC200 Pro

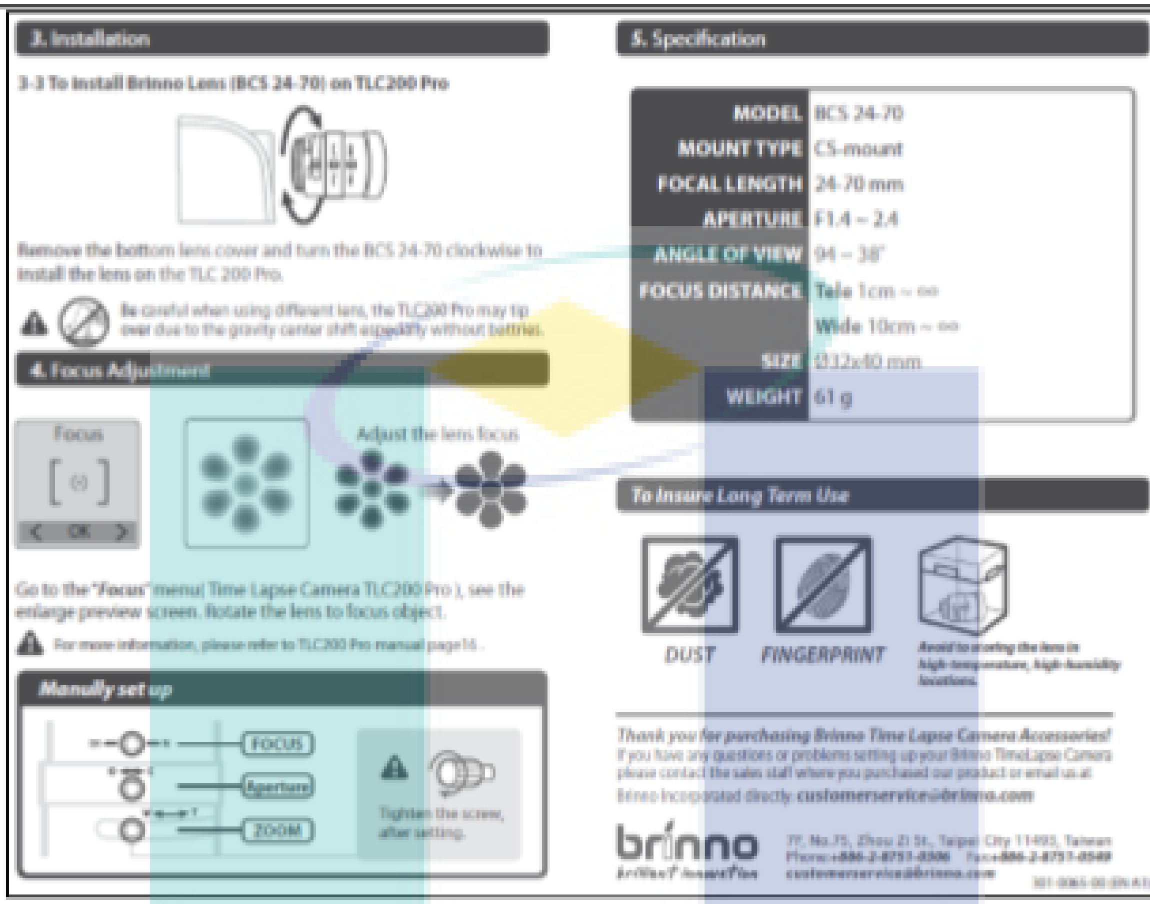
a. Turn TLC200 Pro face down to the floor to protect against dust getting on the sensor. b. Rotate counter clockwise to unlock the BCS 019.

3-2 To install IR Filter on TLC200 Pro

a. Rotate lens upwards, then place the IR filter horizontally. b. Screw in IR filter with fingers. c. Insert the screwdriver* from TLC200 Pro into one of the driving holes, turn clockwise until tight.

* For more information, please refer to the TLC200 Pro manual page 5(Package Content).

IR Filter works with BCS 019, BCS 18-55 and BCS 24-70. It's recommended to keep IR Filter on TLC200 Pro.



Source: https://www.bhphotovideo.com/c/product/1021210-REG/brinno_bcs_24_70_cs_24_70mm_f_1_4_lens.html

Determination of Image Conversion Ratio for Transient Luminous Events (TLEs) Observation System

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***Abstract*— Transient Luminous Events (TLEs) is a type of lightning events occurs at the upper atmosphere or in the D region of the ionosphere during a thunderstorm. The occurring of TLEs is fast and difficult observed by human eyes. Therefore, a camera sensitive to low light condition is needed for observation of this phenomena. In this paper, the camera is coupled with 50 mm f1.4 lens and Digital Video Recorder (DVR). A conversion of analog-to-digital between personal computer (PC) and the camera was applied to transfer the file by using DVR. This paper covers calculation of the conversion ratio between image dimension in PC monitor to a real dimension for horizontal and vertical axis. In the end of the paper, it is found that the calculated horizontal size is twice as smaller than the actual size and vertical size is 1.92 times smaller than actual size.**

Keywords—Video recorder; conversion ratio; TLEs; Lightning

I. Introduction

Transient Luminous Events (TLEs) is one type of the natural phenomena found on the earth. It is grouped as lightning family [1]. A high sensitivity and low light condition camera is required to capture TLEs due to it is fast and hardly seen by human eyes [2]. The camera Watec 902H2 Ultimate was chosen as it is frequently used to observe meteor and other natural phenomena in low light condition [3].

There are several types of colour encoding system such as Phase Alternation by Line (PAL), National Television System Committee (NTSC), and Sequential Colour with Memory (SECAM). The PAL recording system commonly used in countries such as Malaysia, United Kingdom (UK), and Australia as stated in [4]. CCIR is a black and white television (TV) standard. It is the ancestor of Phase Alternation by Line (PAL) system where PAL system offers automated colour correction and 25 frame rate [5]. PAL system was chosen for this project as it is the standard used in Malaysia.

A monitoring system is required to monitor the camera condition and to capture the image. In addition, the monitoring control panel can invoke from the functioning of digital video recorder (DVR). DVR act as an analog-to-digital convertor between personal computer (PC) and the camera [6]. It also can control the frames per seconds (fps) for the video recorded. Furthermore, the video recorded are in analogue type. The resolution might loss during conversion from analog to digital file. According to the [7], the real object size can be calculated by using Field of View (FOV). They have the advantage to use actual coordinate between 2 points on earth, in this case, 2 wind turbines as their reference. However, in this paper it is difficult to use earth object as point of reference due to poor visibility and lack of suitable landmark. Therefore, real object size calculation was carried out by using image conversion ratio. A calculation details on conversion ratio and the setup of the control panel will be discussed through this project.

II. Experimental Setup

An experimental set up as following to validate the conversion ratio of DVR from analogue to digital image is shown in Fig. 1. Table 1 shows the setup condition for this test. A Nikon 50 mm f 1.4 lens is adapted to Watec camera through C-mount to F-mount converter. The object is set from 200 cm to 1000 cm distance from the camera with the camera and object at the same height.

TABLE I. Initial condition for image calculation.

Description	**Condition**
Camera lens, d_1	50 mm
Distance between camera and the object, d_2	200 cm, 300 cm, 400 cm, 500 cm, 600 cm, 700 cm, 800 cm, 900 cm, and 1000 cm
Height	0 cm
Camera angle	0^o
Object actual size	17.4 cm (H) × 14.4 cm (V)

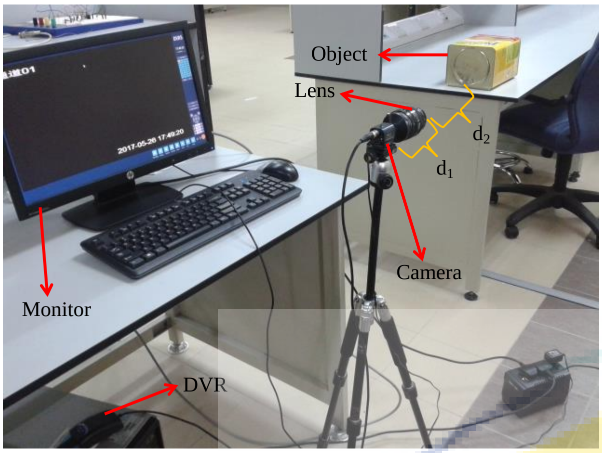

Fig. 1. Actual experimental setup panel.

An illustration of real object on PC monitor and camera sensor; illustration of the camera setup, and front view of object is shown in Fig. 2, where

a_x = horizontal full frame in pixel;

a_y = vertical full frame in pixel;

$b_{x, monitor}$ = horizontal object size on screen in pixel;

$b_{y, monitor}$ = vertical object size on screen in pixel;

$b_{x, object}$ = horizontal real object size;

$b_{y, object}$ = vertical real object size;

$b_{x, sensor}$ = horizontal object size on camera sensor;

$b_{y, sensor}$ = vertical object size on camera sensor;

c_x = horizontal camera sensor size;

c_y = vertical camera sensor size;

d_1 = distance between camera sensor to lens;

d_2 = distance between lens to object.

Fig. 3 shown the actual object size displayed on the monitor screen. The full frame pixel of the image is 720 pixels horizontal (H) and 576 pixels vertical (V) while the object occupied 246 pixels (H) and 224 pixels (V) from the full frame image. It is able to calculate the actual object size by multiply the actual object size on camera and field ratio where field ratio described as the ratio to convert image dimension in PC monitor to a real dimension. Finally, Fig. 4 illustrates the actual camera sensor size.

Equation (1) until (6) is used to calculate the actual object size for horizontal (H) and vertical (V).

A. Ratio between image in monitor and sensor.

Equation (1) and (2) showed the ratio between image in monitor and camera sensor size in one pixel. It is to find out the value of camera sensor size per pixel.

For horizontal:

$$p_x = \frac{c_x}{a_x} \quad (1)$$

where,

p_x = ratio between image in monitor and sensor for horizontal.

For vertical:

$$p_y = \frac{c_y}{a_y} \quad (2)$$

where,

p_y = ratio between image in monitor and sensor for vertical.

B. Object size on camera sensor.

Equation (3) and (4) showed the product of ratio between image in monitor and sensor, p and horizontal object size on screen in pixel, $b_{n, monitor}$. It is to find out the actual object size displayed on camera sensor, $b_{n, sensor}$.

For horizontal:

$$b_{x,sensor} = p_x \times b_{x,monitor} \quad (3)$$

For vertical:

$$b_{y,sensor} = p_y \times b_{y,monitor} \quad (4)$$

C. Real object size.

By referring to Fig. 1 (c), 50 mm focal length, d_1, with d_2 is 200 cm actual FOV, hence, the ratio of distance between camera sensor to lens, d_1 and lens to object, d_2, is 4 cm mm^{-1}. The ratio of d_1 and d_2 is changeable by replacing different actual FOV, d_2 as shown in Table I.

The real object size on camera sensor is required to multiply the ratio of distance between camera sensor to lens to find out the actual object size.

For horizontal:

$$b_{x,object} = b_{x,sensor} \times \frac{d_2}{d_1} \quad (5)$$

For vertical:

$$b_{y,object} = b_{y,sensor} \times \frac{d_2}{d_1} \quad (6)$$

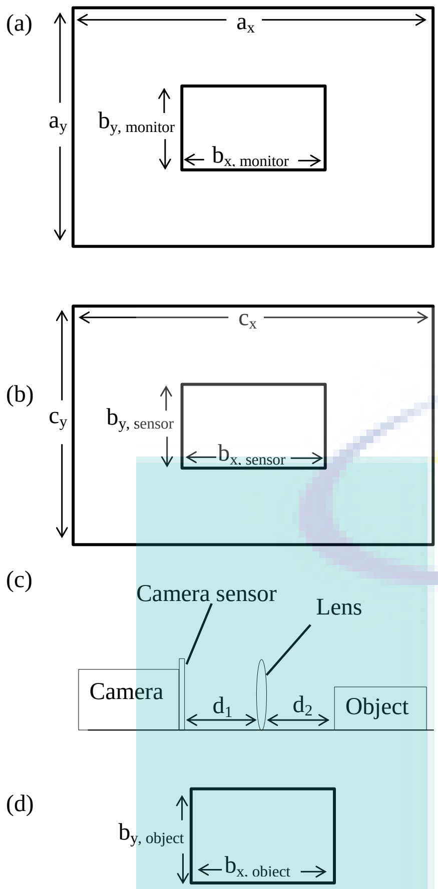

Fig. 2. (a) Illustrated real object on PC monitor; (b) Illustrated real object on camera sensor; (c) Illustration of the camera setup; and (d) front view of object.

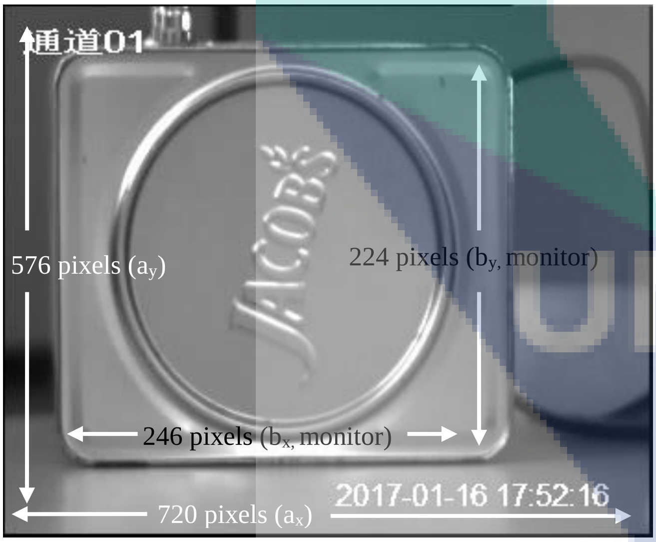

Fig. 3. Actual object size displayed on the monitor screen with distance d_2 from camera.

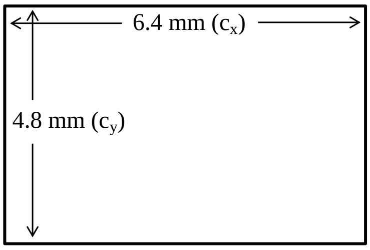

Fig. 4. Camera sensor size.

III. Result

The calculated actual size was tabulated in Table II. The average value for horizontal size (H) is 8.70 cm and average value for vertical size (V) is 7.50 cm. However, real size of the object is 17.40 cm (H) and 14.40 cm (V). The result also tabulated into graph as shown in Fig. 4 and Fig. 5.

Fig. 5 explained the comparison result between actual size and calculated size for horizontal values in line chart. The calculated result shows constant value through the distance. By using this calculation method, it is understood that the size became 2 times smaller compared to actual size for horizontal axis after passing through the DVR system.

Fig. 6 clarified that the comparison results between actual size and calculated size for vertical in line chart. The calculated results also show constant value through the distance. By using this calculation method, it is understood that the size became 1.92 times smaller compared to actual size for vertical axis after passing through the DVR system.

TABLE II. Calculated Horizontal and Vertical Size in cm.

d_2 (cm)	Horizontal size (cm), $b_{x, object}$	Vertical size (cm), $b_{y, object}$
200	8.7	7.5
300	8.7	7.5
400	8.6	7.5
500	8.8	7.4
600	8.6	7.5
700	8.7	7.5
800	8.7	7.6
900	8.5	7.5
1000	8.7	7.3

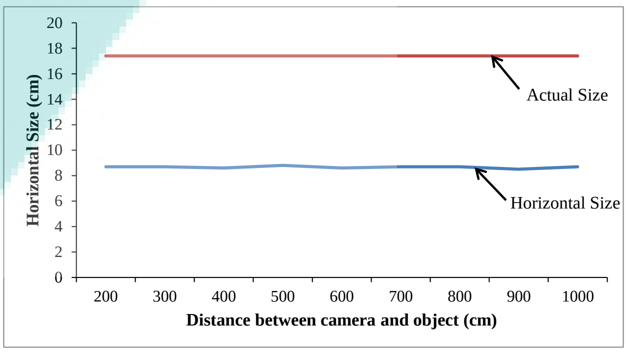

Fig. 5. Comparison actual size and calculated horizontal size.

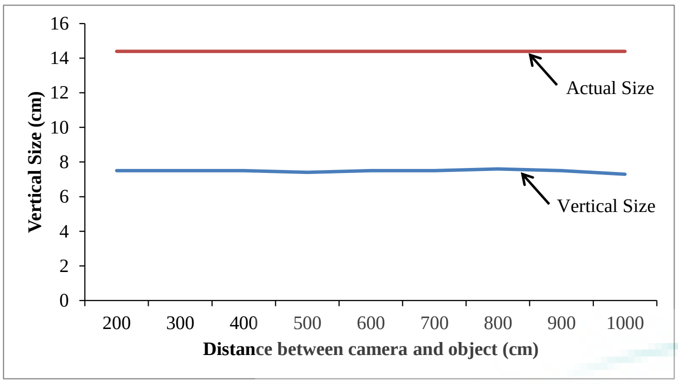

Fig. 6. Comparison actual size and calculated vertical size.

IV. Conclusion

The average value for horizontal size (H) is 8.70 cm and average value for vertical size (V) is 7.50 cm through the distance measured. However, the actual size of the object is 17.40 cm (H) and 14.40 cm (V). Therefore, in order to determine the actual size of an object observed through this system, one should multiply 2 for horizontal component and multiply by 1.92 for vertical component.

Acknowledgment

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OBSERVATION OF TRANSIENT LUMINOUS EVENTS (TLEs) IN PEKAN

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ABSTRACT

Transient Luminous Events (TLEs) are classified as a type of lightning events that occurs above a thunderstorm. It is a very fast event that is hardly seen by the naked eyes and happened in a very short period of time. So, a high frame rate capturing device is required in order to capture the scenes of TLEs. This paper reveals a study to verify the occurrences possibility of TLEs in Malaysia by selecting a simple and suitable device to detect and capture the event. There are various types of TLEs such as Elves, Sprites, Halos, Blue Jets, and Gigantic Jets that differs in height within atmosphere. Experimental studies are made to observe Elves and Sprites in Malaysia partially in Pekan, Pahang. The event is being traced using amplified antenna with noise filter and a data acquisition (DAQ) module used to interface between antennas and personal computer (PC) aided with online data logging device to perform a live characteristic recording through PC software. Verification of the obtained TLEs data will be carried out by comparing them with data recorded by Department of Meteorology Malaysia.

Keywords: lightning, transient luminous events, sprites, elves, data acquisition.

INTRODUCTION

Lightning is one of the phenomena that occur above the atmosphere area. It occurs during a thunderstorm and generally have three types of lightning when electrical breakdown among the cloud such as cloud to cloud (CC) lightning, cloud to ground (CG) lightning, and intra-cloud (IC) lightning. Lightning not only occurs on the lower atmosphere but also in the upper atmosphere which is 40 km until 100 km above the earth's surface area, which is called transient luminous events (TLEs). TLEs are described as short lived electrical breakdown phenomena and the flashes of light occur at lower ionosphere (D region). It occurs when gas molecules are excited and results in electrical breakdown. During the process, light is emitted for a few milliseconds when the ionised gas returns to their normal state. The process called return stroke [1].

Some of the TLEs occur at lower places which are located 80 km away from earth's surface while some of them located approximately 100 km away from the ground. The types of TLEs included Sprites, Elves, Gigantic Jets, Blue Jets, and Halos. Differences between TLEs produced with a different height as shown in Figure-1. The Figure explains that transient flashes produced in different altitudes were classified so that for every distance of altitude, the characteristics of the flashes can be identified. A Sprite, which is one kind of TLEs, was first documented by Franz and his partners in the year 1989. The Sprite was captured by using a low light level television camera. The event was recorded on the night of 22 and 23 September 1989 during a hurricane Hugo storm at the eastern coast of United States [2]. Since then, other types of TLEs were found and discussed by scientists around the world.

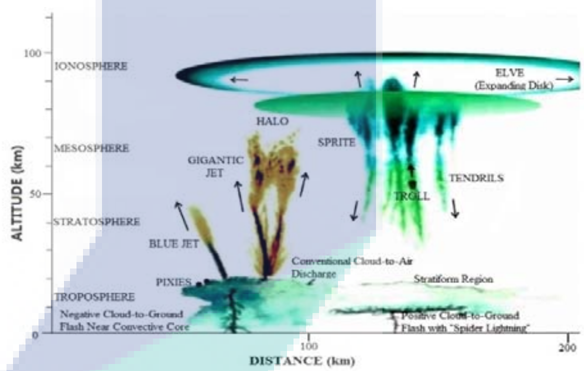

Figure-1. Different TLEs occur below ionosphere [3].

The research aimed to identify the possibility of occurrences for different transient luminous with a height limit 80 km. The events will be traced using a Lightning Detector System (LD-250). Daily and monthly lightning for six months (October 2014 until March 2015) was observed and recorded. Furthermore, the location of the frequent lightning event was traced as well and concluded at the end of the paper. Lastly, the direction of camera capture process will decide to capture TLEs.

The productions of TLEs reveal their own characteristics such as process, colour, shape, duration, frequency, and feature. The characteristics are shown in Table-1.

METHODOLOGY

The research was divided into two sections which were signal detection and image observation. These two methods were used to categories the types of TLEs by figuring out their unique signal, size, and shape. The function flow diagram of the research project is shown in the Figure-2.

Table-1. Characteristics of TLEs [4] [5] [6] [7] [8].

TLE	Process	Shape	Frequency / Period	Feature
Sprites	• Occurs after many normal CG flash lightning take place in a time. Result in high peak current produced at the same time. • Positive cloud to ground (CG) lightning flashes within the stratiform region of the storm.	• Horizontally displaced from the parent lightning.	• 0.2min-1	• Carrot Sprites: Can be associated with Halos and produced a large peak current. • Will occur again at the same location once the same event take place before. • Color: Red (due to excitation of gas nitrogen in atmosphere)
Elv es	• Produced either by positive or negative CG flashes when a large peak current occurs in the event.	• Luminous rings with diameter up to 300 km.	• Shorter than 1ms • Flash speed: faster than speed of light	• Observed unique polarity during producing flash in a storm given. • Expand radially outward follow the lower edge of the ionosphere. (80km to 90km) • Color: Bright red.
Gigantic Jets (G.J)	• Produced by intra-cloud discharge without detection of CG flashes. • Leading jets (33ms to 167ms) propagated at higher altitude while tailing jets decreasing luminosity at different parts of the jet (lower channels and transition region). • Low channels produce decreasing blue luminosity at about 20km to 40km altitude. • Transition region produces bright red luminosity around 40km to 65km retracing leading jet channels.	• Large in size.		• Discharge without any charges transfer to earth • Spread altitude as high as 80km with upward-directed lightning shooting out of the cloud tops. • Normal intra-cloud discharge. Appear in between dominant level charge and screening-depleted upper level charge. • Color: Blue.
Blue Jets (B.J)	• Occurs when an electrical breakdown in between upper storm charge and screening charge was getting attracted across top of thunderclouds. • Production of sudden charge imbalanced in storm due to CG or intra-cloud discharge.	• Small size of GJ called blue starter	• 5s to 10s or less	• Upward directed lightning producing. • Extends in a few kilometers only from the top of thunderclouds up to a clear air above. • Spread altitude up to 40km (half of GJ). • Discharge process for BJ and GJ preceding propagation on top of storm. • Color: Blue
Halos	• Produced with Sprites. • Decreasing glow with side area of 40km to 70km.			• Inspected to escort the happening of more structured Sprites. • Sprites and Halos happened 25km across an average horizontal distance source from the first lightning strike. • Color: Red glow

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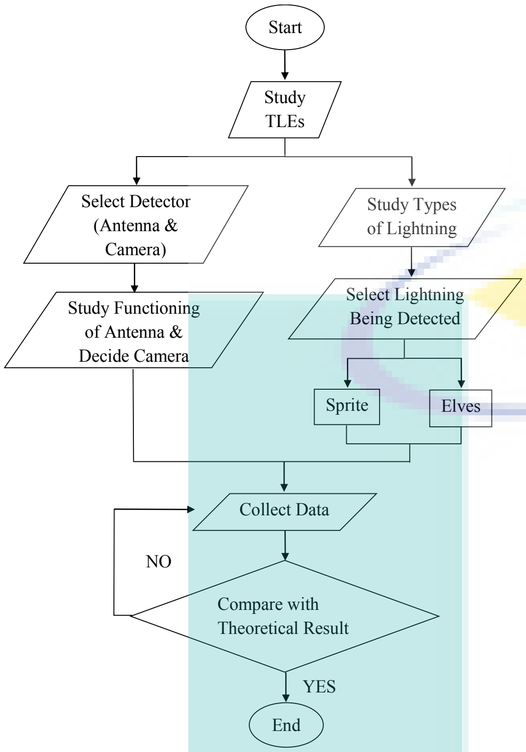

Figure-2. Function flow diagram of the project.

There is a large radio frequency produced at the atmosphere when TLEs occurs. The amplified antenna connected with noise filter is to detect the signal. The signal received was processed through a Data Acquisition (DAQ) module NI USB 6212 which transfer the signal to the desktop for researcher to tabulate data collected by the system.

There is limited information for the TLEs if research is only done by collecting lightning signal. Therefore, the image will also be captured simultaneously by using video camera along the data collection process. The researcher can make a conclusion by data collected from both systems.

Image of TLEs

A high sensitivity camera model Watec Ultimate 902H2 coupled with Nikon 50mm f1.4 lens, was used to capture TLEs image. The camera was set up at the ground floor of Block 1 in Faculty of Electrical and Electronic Engineering (FKEE), Universiti Malaysia Pahang along with an antenna. The camera is a monochrome camera used by other researcher to capture natural phenomena such as a meteor. It was operated in standby mode during the recording process. High frame rate (frame per second – fps) relative high resolution ensures high definition frames are captured during happening of TLEs. This feature is to ensure detail sequences of the event and exposes the nature of TLEs. However at this time, the available digital video recorder (DVR) frame rate is limited to 29fps. A block diagram of camera setup is shown in Figure-3.

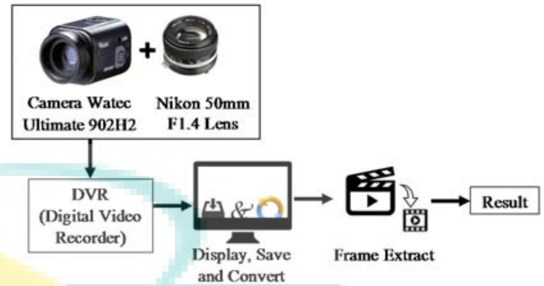

Figure-3. Block diagram of camera setup.

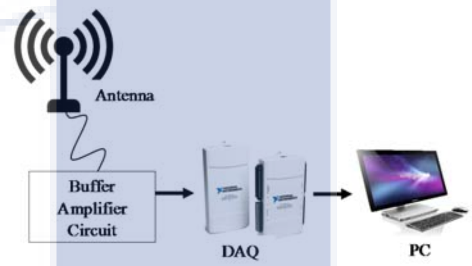

Figure-4. Block diagram of antenna setup.

Signal of TLEs

There are many types of signals propagates around the atmosphere such as radio signal, television signal, satellite signal, microwave, and normal lightning signal. When TLEs occurred, a large amount of radio frequency signal will be released. The TLEs signal will appear along that portion of frequency containing other frequencies. The frequencies range and characteristics of each signal type must be identified. Otherwise, it is a compilation of many signal including noises that makes analyse process complicated. Captured signal will be analysed using DAQ module to verify the characteristic of TLEs. The frequency of TLEs is in the extremely low frequency (ELF) range. Therefore, an antenna with high gain and low frequency response is an ideal antenna to detect signal released by TLEs. L-600S antenna from LF Engineering [9] with a frequency response from 300 Hz to 30 kHz is a suitable candidate. Currently, the system is under consideration and will not be discussed further. A possible setup is shown in Figure-4.

RESULTS

In this section, preliminary works are limited to lightning location detection, occurrence data, and image capture. These preliminary works are to verify the lightning occurrence possibility and the suitable season for TLEs observation. Lightning Detector System (LD-250) was installed at the top roof of block 1 in FKEE, UMP. Analysis on a number of flashes and strokes captured during six months was carried out. UMP was set as the midpoint and data taken within 100 miles (160.9344 km) radius away from UMP. The data were recorded and tabulated in Table-2. Figure-5 shows the changes numbers flashes and strokes from October 2014 until March 2015.

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Table-2. Number of flashes and strokes from October 2014 until March 2015.

	Flashes	Strokes
Oct	17,785	18,992
Nov	11,408	11,945
Dec	12,069	12,892
Jan	597	627
Feb	6,283	6,415
Mac	13,127	13,979
Total	**61,269**	**64,850**

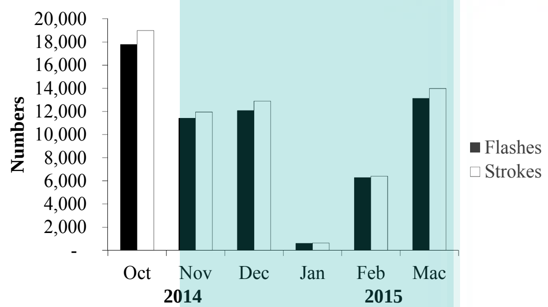

Figure-5. Changes number of flashes and strokes from October 2014 until March 2015.

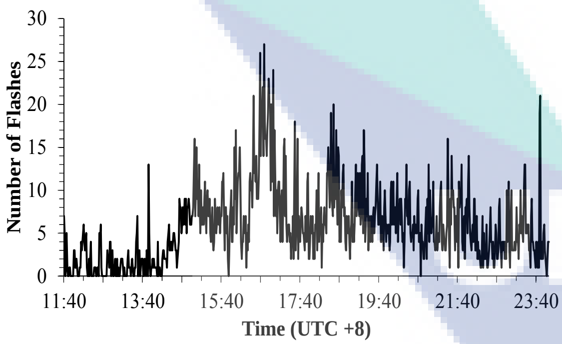

Figure-6. Number of flashes on 17th October 2014.

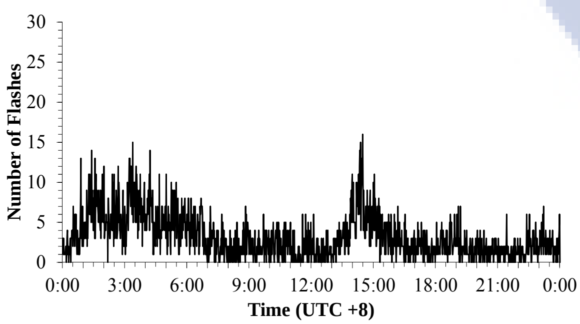

Figure-7. Number of flashes on 21st October 2014.

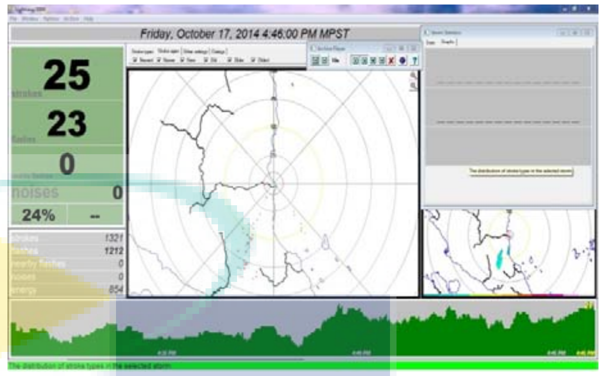

Figure-8. Lightning location.

Data of 5 days out of 31 days in October 2014 is taken out with the highest number of flashes and strokes for the past six months. It shows that a large numbers of flashes and strokes happened at the end of the year. This phenomenon continues to appear even during the dry season (starting February 2015) where the rainfall is much less. Hence, it is believed that Malaysia also has high TLEs occurrence potential by considering that some TLEs such as Sprite, which occurs after negative CG lightning strikes [10]. January 2015 shows the lowest numbers of flashes and strokes due to only 2 days out of 31 days had been recorded by Lightning Detector System (LD-250).

Analysis was done for the days experienced the highest flashes per day. Results of flashes per day for 17th October 2014 and 21st October 2014 are shown in Figure-6 and Figure-7 respectively. On 17th October 2014, the total numbers of flashes is 3937. It is found that the highest numbers of flashes is 27 in one minute. The highest flashes events take place on 16:45 pm UTC +8 and energy ratio was 99% showing a strong strike. Form the Figure-7, the total numbers of flashes on 21st October 2014 is 4669 which is the highest numbers compared to other days for overall data observation. It is also found that the highest numbers of flashes is 16 in one minute on 14:29 pm UTC +8. The energy ratio reached over 100% and nearly 400% once flashes take place.

From the lightning location data, it is understood that most of the lightning take place at above land's surface more than above sea's surface. Figure-8 shows the direction of lightning during the peak time. The midpoint is UMP Pekan Campus and Lightning Detector System traced around 100 miles radius from UMP. Lightning occurs frequently in Malaysia, especially during the monsoon season. On 17th October 2014, most lightning happened at a location between South and Southwest from UMP Pekan. Based on the location recorded, it is possible to point the camera towards the direction to capture TLEs for this research.

A Carrot Sprite like event was detected on 2nd July 2015 at the time of 21:19 pm UTC +8. Only the head of the Sprite was visible. The full view of the Sprite was unseen may be due to the cloud and the camera location on the ground. The evolution of a Carrot Sprite up to time t = 103.5ms discharge above a thundercloud is filmed with 25 frames per second as shown in Figure-9. Before the Carrot Sprite was captured, there are 41 lightning observed on camera recording. At the beginning of the recording, a lightning return stroke starts to transport electrical charge to earth and the electric field produced above the cloud. The electric field produced had forms a Carrot Sprite event. The Sprite observed was a clot and small in shape due to the panel set up location near to the event take place.

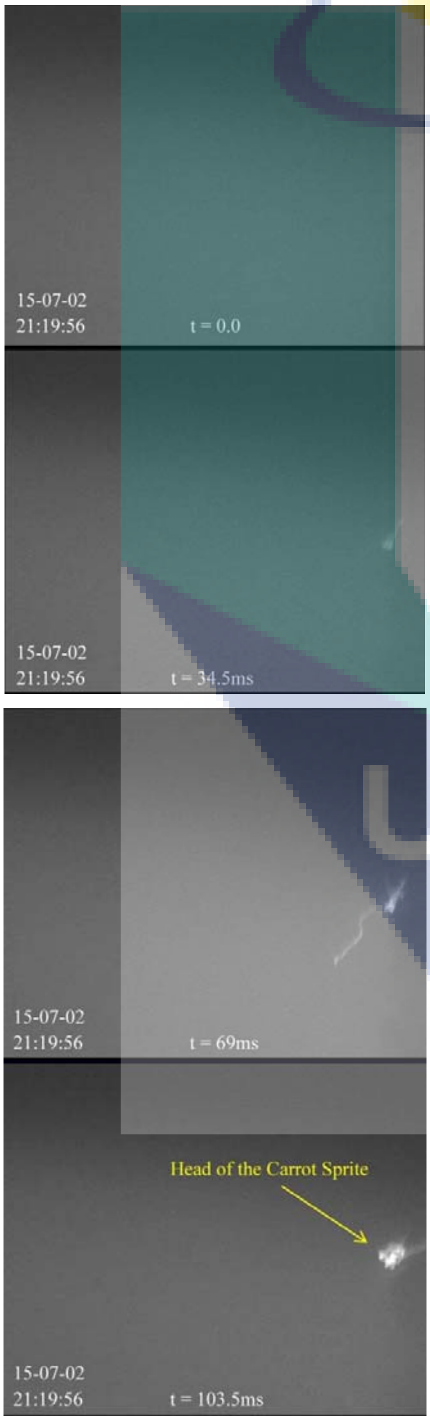

Figure-9. TLE was detected on 2nd July 2015 at 21:19 pm UTC +8.

At time t = 34.5ms, the Carrot Sprite starts to discharge and shooting down from the ionosphere. Then, the discharge was downward directed from the parent lightning flash at the time t = 69ms. Finally, the Carrot Sprite disappears at time t = 103.5ms. The whole discharging process is taking approximately 138ms. The Carrot Sprite appeared after many CG lightning and it is a CG lightning discharged based on the observation.

By comparing the data that found from the camera image captured and Department of Meteorology Malaysia, the result was matched and Sprite event taken place in between Sungai Tulang and Sungai Belat, Gambang, Pahang, Malaysia. It was located 45.7 km away from UMP Pekan. There was a large quantity of negative CG lightning occur before the only one positive CG lightning strike taken place on 9:19:50 pm UTC +8 at latitude and longitude 3.78˚N, 103.098˚E (3˚46'48.0"N 103˚05'52.8" E) respectively.

CONCLUSIONS

Preliminary results were taken to verify the feasibility of the research. Lightning happened frequently in Malaysia during a monsoon season as shown in Table-2 and Figure-5. It keeps occur although during a lesser rain after monsoon season (February 2015 and March 2015). This may be due to Malaysia is located near the Equator. According to all data result shown in the paper, the best time to do TLEs research is during the end of the year and the camera should point towards the location between South and Southwest. The first Sprite event was found in Malaysia at latitude 3.78˚N and longitude 103.098˚E. These results conclude that the occurrences of TLEs in Malaysia are possible.

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Investigation on the occurrence of positive cloud to ground (+CG) lightning in UMP Pekan

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ABSTRACT

This paper is going to find the direction of +CG lightning and its relationship with monsoon season in Malaysia by using data obtained from Malaysia Meteorological Department (MMD) for 2015. Analysis from this study found that a high numbers of lightning occur during dry season compares to rainy season. This is contradicted with general perception in Malaysia where lightning only occurs during rainy day. It is also understood that +CG lightning makes up approximately 20% of total lightning and the rest is −CG lightning events. The occurrence of +CG lightning during day and night will be discussed. From this, the direction where most +CG lightning occurs will be determined and used as a guide in order to observe TLEs afterward.

1. Introduction

Lightning refers to a natural phenomenon that happens frequently during thunderstorms (Williams, 1987; Uman, 1972). This phenomenon was described as an event of electrical discharge at the rate where the discharge process will deliver a large quantity of current and voltage (GAM Odam, n. d.) (Yair, 2008) stated that, a large quantity of radio frequency made up of electromagnetic field (E-field) and magnetic field (H-field) are emitted during lightning. TLEs are also known as a part of a lightning event that happened in the upper atmosphere where the electrical discharge is visible with various form. The observation on TLEs has progressed since 1989 (Franz et al., 1990). Various studies classify TLEs by the differences of colours and stroke patterns. Sprites and Elves are commonly known TLEs in research studies. Yet, there are lesser specific characteristics that justify the occurrence patterns of Sprites and Elves.

Refs. National Lightning Safety Institute (NLSI) (1988); Ab-Kadir (2016) reported that Malaysia is ranked the third in having the most thunderstorms in the world. This fact suggested that there is a high possibility of TLEs to occur in this country. Sprites are often displaced from the parent positive clouds to ground (+CG) lightning. The displacement can be up to several tens of kilometres (Dan Robinson, 1995; Lyons et al., 2003; Soula et al., 2009; Pasko et al., 2012). In addition (Dan Robinson, 1995), concluded that the percentage of +CG lightning is less than −CG and found that the occurrence of Sprites events are usually triggered by a very strong +CG lightning.

A review from Uman (1994) reported that +CG lightning occurs at the upper part of a thundercloud which is positively charged. It starts with the electrical breakdown at the upper part of thunderclouds and is initiated by a positively charged downward-moving step leader. In addition, (National Aeronautics and Space Administration (NASA), n. d.) reported that +CG lightning occurs during the last stage of the thunderstorm.

According to Rocha et al. (1999), Pettegrew et al. (2003), and Arnone et al. (2008), +CG lightning also takes place during the winter season in northern countries such as Italy, US, UK, and Japan and southern countries such as Brazil. The winter month for northern countries starts from December to February while for southern countries from June until August. However, the four-season climate does not exist in Malaysia. Instead, Malaysia only experiences monsoon seasons such as the Southwest Monsoon season, Northeast Monsoon season, and inter monsoon season (Tangang et al., 2012). Inter monsoon season represents the transition period in between monsoon seasons. Hence, the occurrences of +CG lightning during these monsoon seasons make an interesting topic to be discovered.

This paper will elaborate about the occurrence of both +CG and −CG according to data obtained from Malaysia Meteorological Department. It is one part of verification process for another study, where video observation of upwards lightning was carried out. The location and polarity of lightning were analysed based on data obtained from Malaysia Meteorological Department (MMD) and the authors do not involve on how MMD acquired the data. The sole purpose of this paper is to determine the timing and direction on where to point the camera in order to observe lightning/TLEs.

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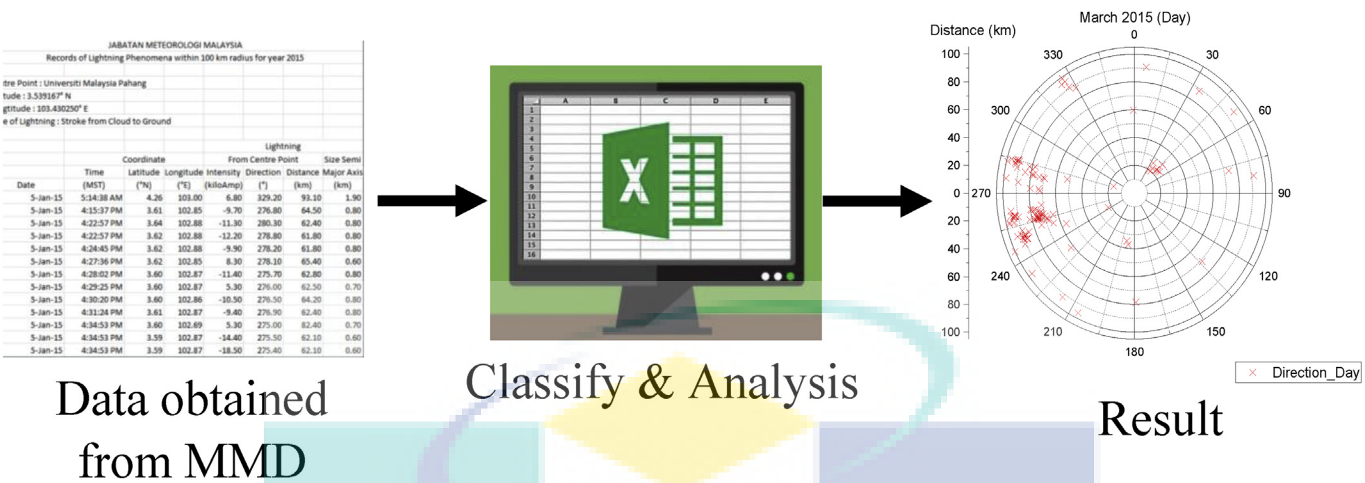

Fig. 1. Data processing flow.

2. Data processing

Fig. 1 clarifies the function flow for the process of data collection. The data from Malaysian Meteorology Department (MMD) within an area of 100 km radius coordinated at the centre point of Universiti Malaysia Pahang's (UMP) Pekan campus. Fig. 2 presents the coverage area of within 100 km radius. The MMD use *Surveillance et Alerte Foudre par Interférometrie Radioélectrique* (SAFIR 3000) with 8 sensors installed around Peninsular Malaysia. The system is able to detect and record the lightning events such as IC, CG activities and the peak current (in kA) with using VHF interferometry technique (Suparta et al., 2011). The maximum distance between the SAFIR sensor and between the stations is about 160 km–220 km that can cover the range of detection is between 270 km and 280 km. However, the efficiency will be reduced to

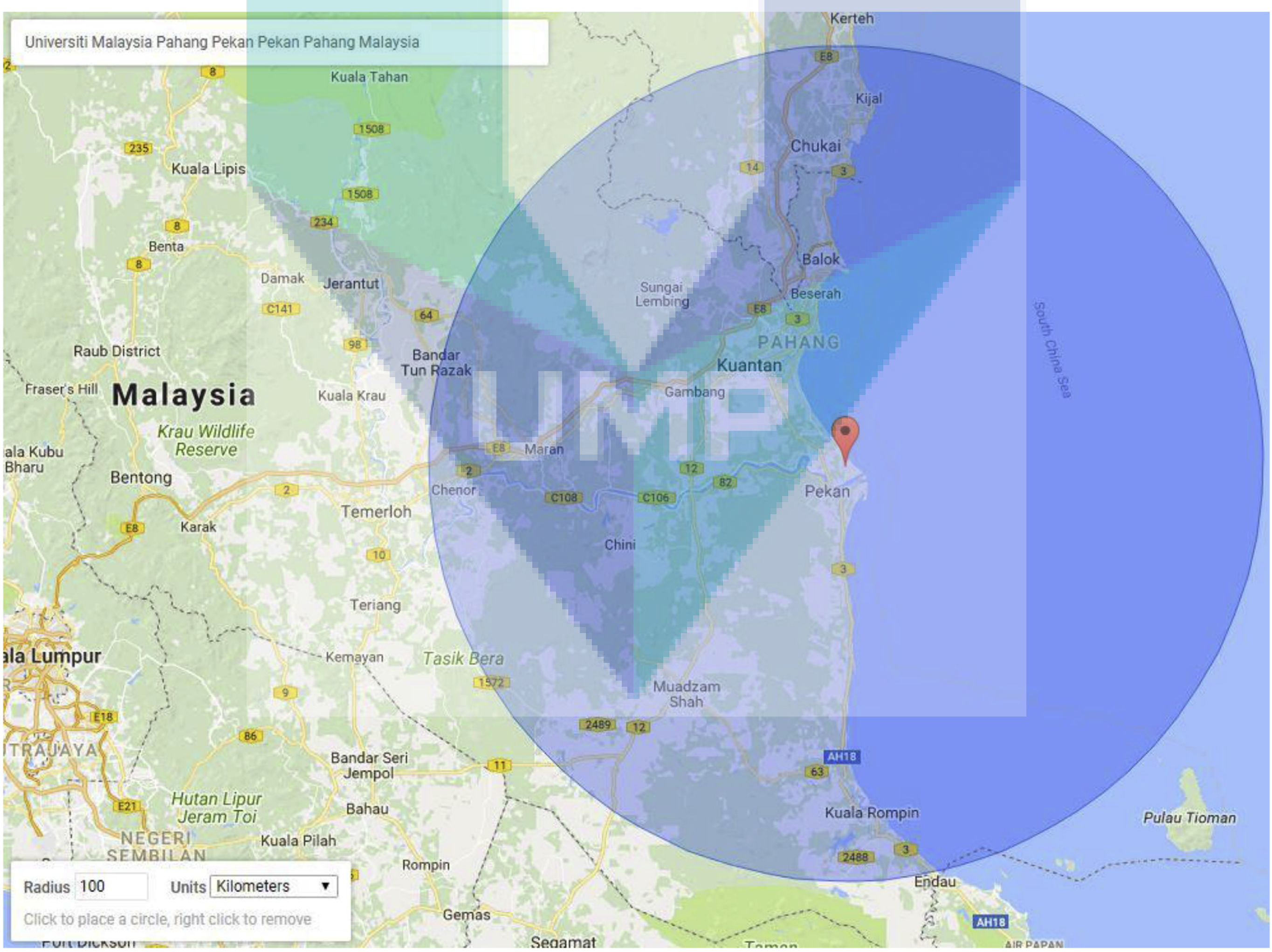

Fig. 2. Covered area within 100 km radius from Universiti Malaysia Pahang Pekan Campus.

90% if the distance is more than 150 km (Suparta et al., 2011). This system works by using two electrical discharge sensor, each operating at a very high frequency (VHF) and low frequency (LF). The first sensor detects the electrical discharge (pulse) at VHF radio band (114 MHz) using interferometric principles and direction finding to determine the discharges' position. The second detector was operated in LF range (300 Hz - 3 MHz) to detect the stroke of lightning discharge (Mohamed, 2011). The data are from 1 January 2015 until 31 December 2015. Then, +CG lightning will be extracted and plotted into lightning map to find out the location of +CG parent lightning. All data are recorded in Malaysia time UTC +8.

A group of data for rainfall events in mm^3 density occurring within Pekan area was obtained from Pahang Department of Irrigation and Drainage (PAID). This data was used to find the relationship between the lightning events and rainfall quantity of the area. The analyses will show the relationship between polarity of lightning and season.

Lightning data are separated into two sections, namely "the monthly day and night occurrences of +CG lightning" and "the annual occurrences of +CG lightning". Duration for daytime and night were set to be within 7:00 a.m. to 6:59 p.m. and 7:00 p.m. to 6:59 a.m. respectively. In addition, the lightning direction was divided into eight regions: East, South, West, North, South-east, South-west, North-west, and North-east directions where 0° or 360° represented North and 180° represented South. The PolarXrYTheta type, one of the system plotting templates was chosen and used to plot as lightning map due to it clearly defined the direction from 0° until 360°.

3. Result

3.1. 2015 lightning data analysis

The following data were analysed according to the percentages of the occurrence of +CG lightning compared to −CG lightning for the lightning events in the year 2015. It mainly focused on +CG due to its relationship to TLEs.

3.2. Occurrence of +CG lightning and −CG lightning

Lightning data for the year 2015 was analysed based on occurrences of +CG lightning and −CG lightning events by including the number of events that had taken place and the percentages within the radius of 100 km from UMP Pekan campus. The highest peak current of +CG lightning achieved was 100.50 kA while the lowest peak current achieved was 1.90 kA. On the contrary, the highest −CG peak current recorded was up to 140 kA and the lowest peak current was 1.80 kA. Table 1 shows the percentage and number of lightning events for the year 2015. Based on the data, the total lightning events recorded within 100 km radius from the midpoint at UMP Pekan was 201,296 events. −CG lightning constituted 157,200 events or 78.09% while +CG lightning recorded 44,096 events or 21.91%. The result clearly showed that +CG lightning has lower possibility to occur than −CG lightning.

3.3. Monthly +CG lightning events and relationship between rainfalls

Fig. 3 displays the number of +CG lightning for each month. It was found that +CG lightning events occurred most frequently in May with 9065 events, followed by July and August with 8531 and 8266 events respectively. The least number of +CG lightning event was found in February with only 15 events. The result indicated that +CG lightning occurred most frequently during the mid-year period, from May to September. According to Arnone et al. (2008), +CG lightning occurs more often during winter months whereas the four seasons climate does not exist in Malaysia due to its equatorial location. Instead, Malaysia experiences rainy season at the end of the year and dry season at the beginning of the year. Malaysia experiences three types of Monsoon seasons: the Southwest monsoon season, Northeast monsoon season, and inter monsoon season. The Southwest monsoon season spans from May until September while the Northeast monsoon starts from November and ends in March. Moreover, inter monsoon season is the transition period between monsoon seasons and its period are during April and October. The Northeast monsoon season brings more rainfall than the Southwest monsoon season. This indicates that rainy season does not affect the frequency of lightning since it was found to be occurring frequently during mid-year which is a dry season. The occurrence of lightning event is triggered by the electrostatic charged as previously claimed by Uman (2008).

Table 1
Percentage of +CG lightning and −CG lightning for the year 2015.

Descriptions	Total Lightning Event	Percentage (%)
Lightning in year 2015	201,296	100.00
Occurrence of −CG lightning	157,200	78.09
Occurrence of +CG lightning	44,096	21.91

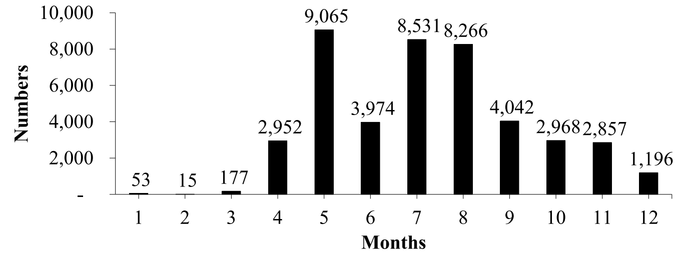

Fig. 3. Number of +CG lightning for each month in 2015.

A combined line and bar chart in Fig. 4 shows the comparison of rainfall quantity and numbers of lightning occurrence around Pekan area. It shows that the lightning events were inversely proportional to the rainfall quantity. Huge quantities of rainfall were detected towards the end of the year, starting from October 2015 to December 2015 which was during the Northeast Monsoon season. However, the total number of lightning events showed a decrease during the same period. May 2015 had the highest lightning events with less rainfall.

3.4. Monthly percentage of +CG lightning events on day and night

Table 2 indicates the percentage of occurrences of +CG lightning during daytime and night for each month. The total percentage for the year during day was 10.01% while at night was 11.90%. Although +CG lightning events occurred most intense in May as shown in Fig. 3, it was found that during night, the +CG lightning events occurred the most in the months of July and August which are 2.86% and 2.72% respectively

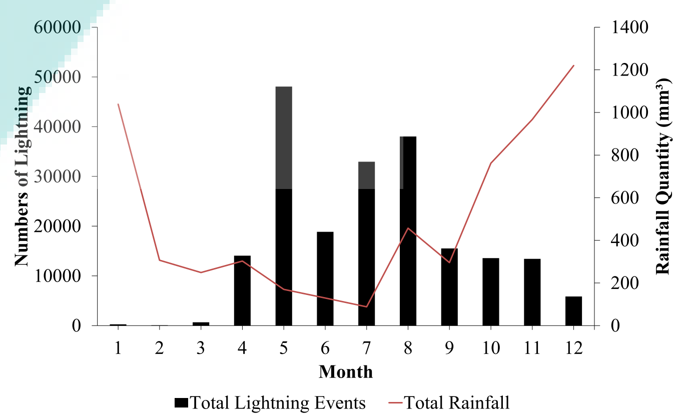

Fig. 4. Comparison of total lightning events and rainfall quantity in Pekan in Year (2015).

Table 2
Percentage of +CG lightning for day time and night-time in Pekan for 2015.

Month	Day (%)	Night (%)
1	0.02	0.01
2	0.00	0.01
3	0.06	0.03
4	1.11	0.36
5	2.68	1.83
6	1.11	0.86
7	1.52	**2.72**
8	1.24	**2.86**
9	0.76	1.25
10	0.58	0.89
11	0.63	0.79
12	0.30	0.30
Total	**10.01**	**11.90**

The bold numbers indicate the highest percentages and the second highest percentages of +CG lightning for year 2015.

as shown in Table 2. The least +CG lightning events at night was recorded in January and February which are 0.01%. This shows that July and August has the highest possibility for TLEs observation even though not all +CG will trigger TLEs such as sprites.

3.5. Day and night +CG lightning map for 2015

Day and night +CG lightning maps were formed to detect the exact location of events of parent lightning for +CG lightning. It was divided into different groups based on the month – from January to December.

According to the lightning map showed in Fig. 5, Fig. 6, and Fig. 7, February experienced the least +CG lightning events. There were only 15 events as pointed out in Fig. 3, whereas Fig. 5 (b) clearly shows that the site experienced 15 +CG lightning events. It occurred between the directions of North (0°) and North-west (315°) during daytime and South-west (225°) and North-west (315°) during night-time. Then, followed by January where found that a large quantity of the +CG lightning events occurred during daytime more than night-time. +CG lightning happened between the directions of South (180°) and South-west (225°) during daytime. However, they occurred between the directions of Southeast (135°) and South (180°) in the night-time as shown in Fig. 5 (a). March is the third lesser +CG lightning events and found that +CG lightning events occurred frequently during the daytime. Most of the +CG lightning events occurred between the directions of South-west (225°) and North-west (315°) during the daytime and between North-west (315°) and North-east (45°) during the night-time. Details of the lightning locations are presented in Fig. 5 (c). According to Fig. 7 (d), more lightning events occurred in December as compared to January, February, and March. Both day and night conditions were almost the same. The events occurred repeatedly in the directions of South (180°) to South-west (225°) and North (0°) to North-east (45°) during the daytime. However, +CG lightning events occurred repeatedly in different directions during the night-time, between North-west (315°) and North-east (45°) and South-east (135°) and South (180°). The +CG lightning events decreased dramatically in December. Again, this might be due to Northeast Monsoon season with the increase in the rainfall conditions. In fact, December showed a low possibility to observe TLEs.

April has more lightning events compared to November. This is due to the Southwest monsoon season that was bound to take over the dry season in the coming months which is called inter monsoon season. Most of the events took place near the western area during the daytime, yet, it happened between the directions of North-west (315°) and East (90°) during night-time. The +CG lightning events mostly occurred during the daytime compared to the night-time. Fig. 5 (d) points out the location of +CG lightning events during the daytime and the night-time. Moreover, November experienced approximately same quantity of +CG lightning events with October. The frequency of occurrence was fairly distributed for both the day and night times which as in November. However, they appeared in different locations. During the daytime, lightning events normally happened between South-west (225°) and North-west (315°) while it occurred between North-west (315°) and North-east (45°) at night. November is the month that experiences the Northeast Monsoon season and the quantity of rainfall only increases, as stated by Mohamed (2011). Thus, November showed a lesser possibility of occurrences of +CG lightning events compared to previous months. Fig. 7 (c) showed +CG lightning events in November 2015.

+CG lightning events in May has the largest and increased dramatically in year 2015. It occupied the West during daytime and it covered areas between South-west (225°) and West (270°) during night-time. Fig. 6 (a) showed +CG lightning events occurred repeatedly during daytime. In summary, this may be caused by the approach of the Southwest monsoon season on the specific month whereby the rainfall during the daytime increased.

July has the second larger +CG lightning events in year 2015 as presented in Fig. 6 (c). It occurred frequently between South (180°) and West (270°) during the daytime and between North-west (315°) and North-east (45°) during the night-time. It was also found that July recorded the most +CG lightning events during the night-time. To conclude, July showed the potential for TLEs to be captured and the camera was set to be pointing to the directions between North-west (315°) and North-east (45°). It is different with northern and southern country which has the absolute observing TLEs during winter season.

The third larger +CG lightning events are followed by August. August occurred more +CG lightning events during night-time compared to daytime as observed from Fig. 6 (d). The lightning occurred repeatedly from directions West during daytime yet it repeatedly occurred from directions North-west (315°) to East (90°) during night-time. On the other hand, August experienced lesser lightning events on day while increased quantity of lightning events on night compared to July. In short, due to TLEs only can observe during night-time, hence, directions from North-west (315°) to East (90°) are suitable used to observe TLEs in August.

Lightning map for October is illustrated in Fig. 7 (b). The figure shows that the quantity of +CG lightning events decreased significantly compared to September. In October, it is an inter monsoon season. +CG lightning events occurred between North-west (315°) and North (0°) during the daytime and between North-west (315°) to East (90°) during the night-time. Both +CG lightning conditions were not consistent and it may be due to the commencement of the Northeast monsoon season in October. Therefore, +CG lightning events in both the day and night times were mostly the same quantity. In summary, October can be considered as a suitable month to observe TLEs, yet the success of the observation decreased. In September, it experienced +CG lightning events as shown in Fig. 7 (a). It was found that +CG lightning events mostly covered the directions from West during the daytime. Similarly, it mostly occurred in the directions of North during the night-time. In comparison with previous months, especially July and August, September had lesser +CG lightning events in both the day and night times. This might be due to the end of the Southwest monsoon season in September. In brief, September was still found as a suitable month to observe TLEs due to the quantity of lightning events at night compared to the daytime.

Lastly, in June the occurrences of +CG lightning events in June decreased compared to September, but, has a larger amount of events compared to October. Fig. 6 (b) pointed out the lightning events condition during June. +CG lightning events in June was observed to have regularly occurred between South-west (225°) and North-west (315°) during the daytime. Nevertheless, it occurred in two directions: between South (180°) and South-west (225°), and between North (0°) and North-east (45°) during the night-time.

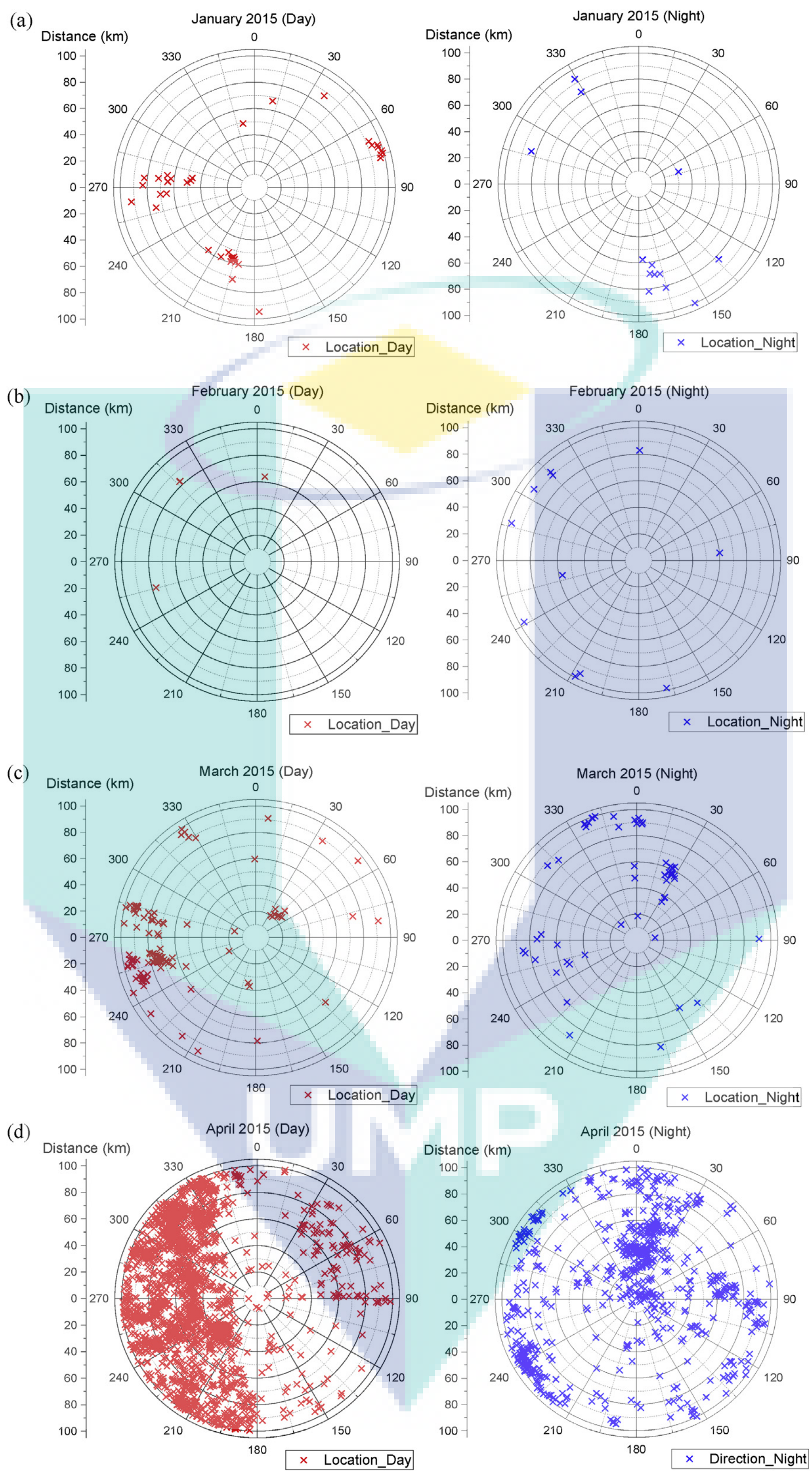

Fig. 5. Day and night +CG lightning map for: (a) January, (b) February, (c) March, (d) April.

3.6. Day and night yearly +CG lightning map for 2015

The daytime +CG lightning map for 2015 indicated that the lightning events happened around the western area of UMP Pekan campus frequently, as shown in Fig. 8 (a). It was also found that +CG lightning events occurred above the land's surface area more often than above the sea's surface. +CG lightning events occur when both the charged steps leader and the upward-moving discharge are connected as previously noted by Uman (1994). This could possibly be the main reason why most of the +CG lightning events happened above the land's surface due to land's surface is charged negatively (Rakov and Uman, 2003). +CG lightning events during the daytime in 2015 also

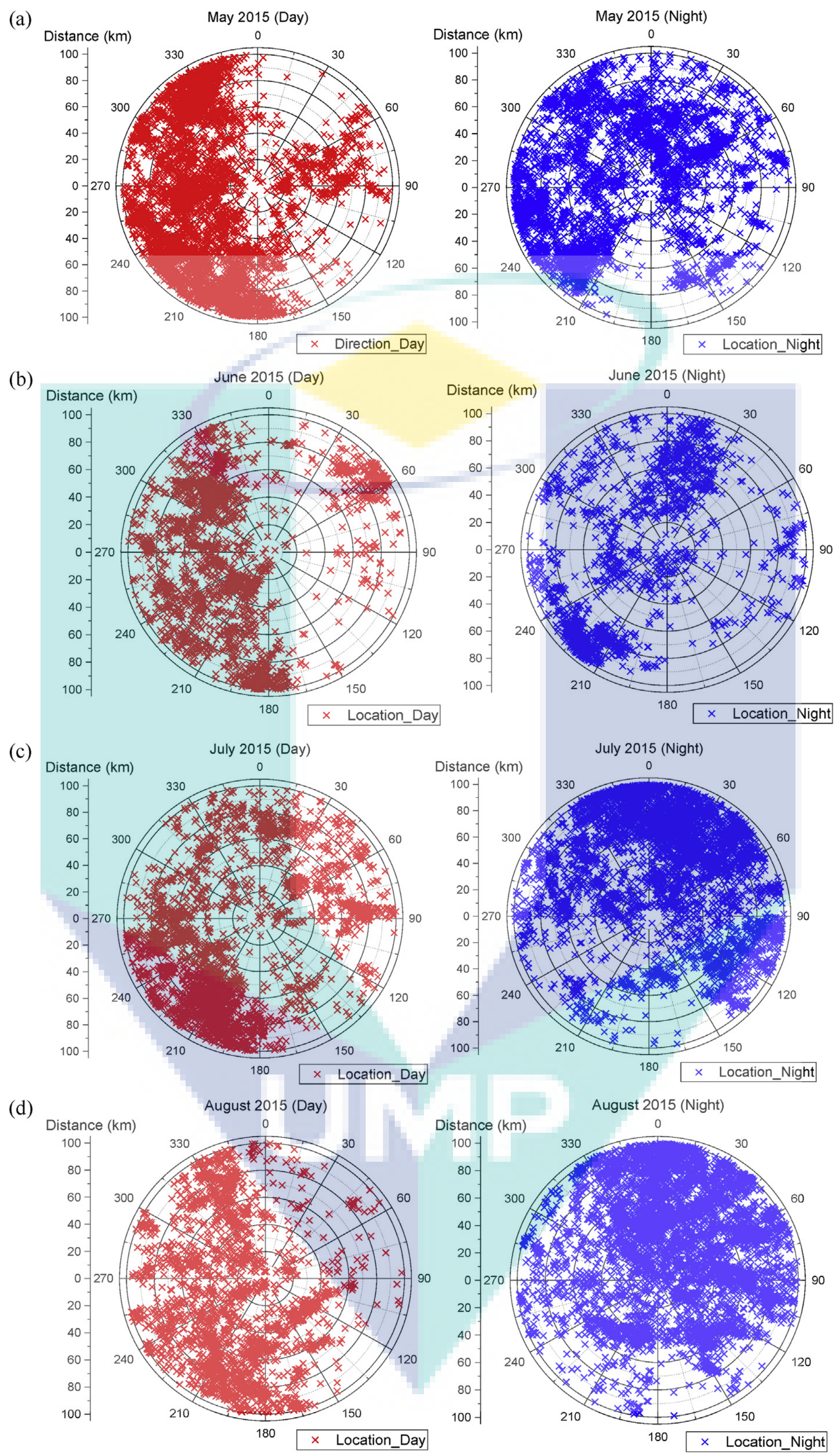

Fig. 6. Day and night +CG lightning map for: (a) May, (b) June, (c) July, and (d) August.

occurred near the seaside and above the sea's surface. Both conditions may have activated the occurrences of Blue Jets, and Elves as reported by Chen et al. (2008). Unfortunately, daytime TLEs events are more difficult to observe (Thomas Ashcraft, 2011).

+CG lightning events were also detected in the night-time, as illustrated in Fig. 8 (b) for the year 2015. The majority of +CG lightning events occurred around the North (0°) area from UMP Pekan campus. During the night-time, the quantity of +CG lightning were fairly detected on land surface, coastal surface, and ocean surface. The conditions increased the possibility of observing TLEs including Sprites, Elves, Blue Jets, and Halos.

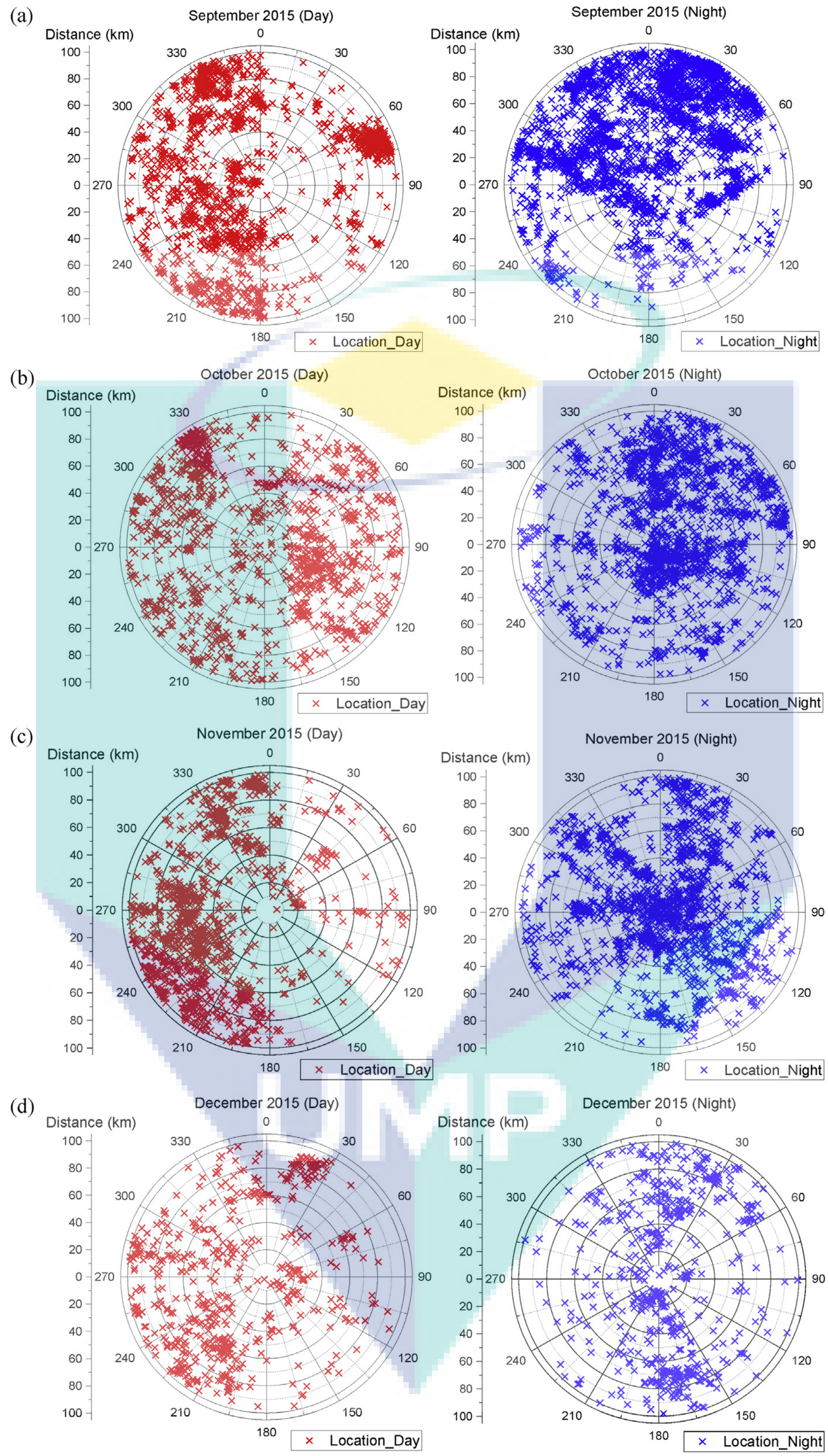

Fig. 7. Day and night +CG lightning map for: (a) September, (b) October, (c) November, and (d) December.

4. Conclusion

Based on the data, the occurrence of +CG lightning showed a minor percentage which is 21.91% compared to the occurrence of −CG lightning which was reported at 78.09% from the overall lightning events in the country. The analysis indicated that +CG lightning occurred more frequently at night from July until November during the period of the study. To conclude, July and August showed the potential for TLEs to be captured. The camera should be pointed to the directions between North-west (315°) and North-east (45°) in July and from North-west (315°) to East (90°) in August.

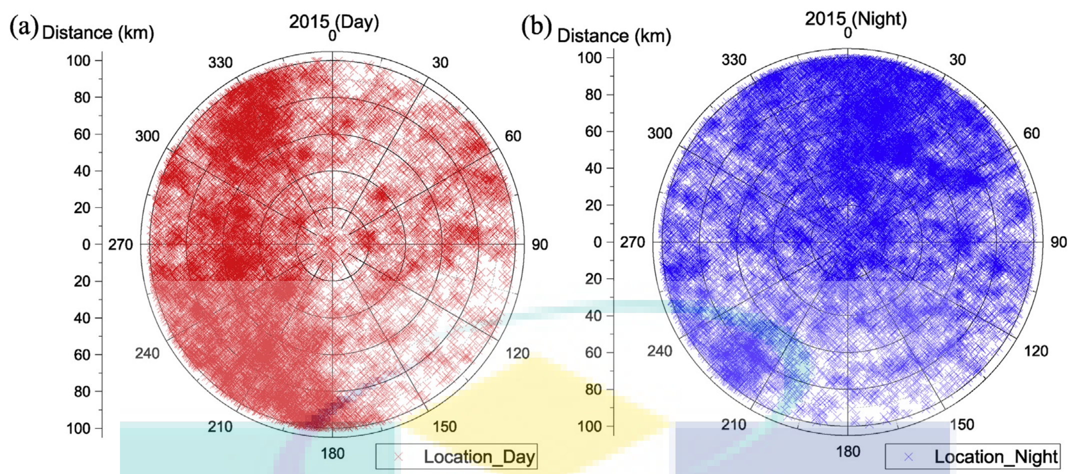

Fig. 8. (A) Daytime +CG lightning map for 2015, (b) Night-time +CG lightning map for 2015.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jastp.2018.07.016.

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