

# Magnetic Data Acquisition System (MAGDAS) Malaysia: Installation and Performance Analysis of Local Data Logger with Kyushu University Data Logger at USM Transkrian, Pulau Pinang

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**Abstract**— Magnetic Data Acquisition System (MAGDAS) is a magnetometer that originated from the International Centre for Space and Weather Science and Education at Kyushu University, Japan, to study space weather. The latest real-time Magnetic Data Acquisition System/Circum-pan Pacific Magnetometer Network (MAGDAS/CPMN) was installed at the West Coast Universiti Sains Malaysia Engineering Campus, Pulau Pinang, Malaysia. This is the seventh Magnetometer installed under MAGDAS network by Kyushu University in Malaysia (geographic latitude and longitude: 5.117N, 100.00E and geomagnetic latitude and longitude: 4.32S, 173.07E). The magnetic field component represents earth's geomagnetic field by MAGDAS. There is three main magnetic field component which describes the magnetic field which is Horizontal Intensity (H-component), Declination (D-component) and Vertical Component (Z-component). The strength of the earth's magnetic field can be monitored through the magnetometer installed at the targeted location and the value of the magnetic field can be compared with the World Magnetic Map (WMM) or any local magnetometer station in the region the installed magnetometer. This paper studies/narrates the deployment and performance analysis of the newly installed MAGDAS using Local and Kyushu Data Logger at the University Sains Malaysia. The deployment of the magnetometer is referenced with the magnetometer data logger from the Kyushu Universities. The magnetometer. The Kyushu University data logger deployment is becoming a benchmark for localizing the data logger developed locally.

**Keywords**— IoT; MAGDAS; YU-8T; world magnetic map; horizontal intensity; declination; vertical component.

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## I. INTRODUCTION

Real-time Magnetic Data Acquisition System (MAGDAS)/Circum-pan Pacific Magnetometer Network (CPMN) was originated from International Centre for Space Weather, Science, and Education (ICSWSE) located in Kyushu University, Japan [1]–[3]. The Earth Magnetic Field strength is different depending on the region of the magnetometer being installed. There are various installations of the MAGDAS station throughout the world [4]. Most MAGDAS stations used MAGDAS II and MAGDAS 9 magnetometer as shown in Figure 1. The magnetic field variation having a close relationship with the solar flare from the sun. Rearrangement of the magnetic field is associated with

the penumbral transformation on solar flare[5]. It is important to have many stations along the magnetic equator to investigate the longitudinal variations of the equatorial electrojet [3], [6]. The MAGDAS station installation mostly used MAGDAS II and MAGDAS 9 where the most magnetometer was densely installed at 210° magnetic meridians, and the other MAGDAS station was located in the magnetic equator region as shown in Figure 1 [7]. MAGDAS I appear in light green color only having seven stations worldwide, and the black triangle symbol is FM-CW radar which is not MAGDAS station. MAGDAS II and MAGDAS 9 appear in red color, having over 66 stations globally. Malaysia includes the country that used MAGDAS II and MAGDAS 9. The reason for the MAGDAS station was being installed at the West Coast Universiti Sains Malaysia (USM)



and (2) [7]. WMM provides a detailed strength of the magnetic field throughout the whole world. Magnetic Field Strength direction of H, D, and Z-components can be described in the presence of North Component (X-component), East Component (Y-component), and Vertical Component (Z-component)[8][11].

$$X = H \cos (D) \quad (1)$$

$$Y = H \sin (D) \quad (2)$$

The magnetic field components of X, Y, and Z-component vertically oppose each other 90°. Where H-component is between X-component and Y-component. The value of D-component is the angle between X-component and H-component. The value of D-component depends on the direction of H-component. The value of D-component in units of degree (°) are convertible to the unit of nanoTesla (nT) by formula obtained from (3).

$$D(nT) = H \tan (D^\circ) \quad (3)$$

The value of magnetic field intensity can be expressed in nanoTesla(nT) [7]. The inclination or dip angle, I can be obtained by the following formula expressed in (4).

$$\frac{Z}{H} = \tan(I) \quad (4)$$

The value of the H-component is the magnetic field in the direction of the north-south direction. Earth dipole field naturally attracting the north pole of the magnetic field toward the northern arctic region. The range of the Magnetic Field Strength in Malaysia can be monitor through the WMM. Table I shows the range of the magnetic field strength in Malaysia.

TABLE I  
THE RANGE OF MAGNETIC FIELD STRENGTH IN MALAYSIA

Magnetic Field Strength	H	D	Z
Range	40000nT and above	~0nT	-15000nT to 0nT

The H parameters of the magnetic field having a different value in nanotesla(nT) depending on the location where the magnetic field is measured. Normally the magnetic field strength in Malaysia is between 40000nT to 43000nT. Declination (D) is the magnetic field angle between geographic north (X-component) and magnetic north (H-component). D value in Malaysia is near 0 nT which is on the top of the green line as shown in Figure 3. Vertical Component (Z). The magnetic field strength of Z parameters is between 0nT to -10000nT. There are seventh installed MAGDAS stations in Malaysia which involve collaboration from Kyushu University, Fukuoka, Japan (ICSWSE), Universiti Teknologi MARA (UiTM), Malaysian Space Agency (MYSA), Universiti Sains Malaysia (USM), and Universiti Kebangsaan Malaysia (UKM)[1].

The first MAGDAS station was installed in the Langkawi National Observatory (LNO) on 4<sup>th</sup> September 2006 located in Kedah Malaysia[9]. The MAGDAS is located at LNO due to the location near the magnetic equator and encountering lower disturbance from human daily routine [1], [9]. Figure 4 shows the location for MAGDAS stations in Malaysia

Langkawi (LKW), Sabah (SBH), Perak (PER), Banting (BTG), Johor (JOH), Terengganu (TRE), and Pulau Pinang (PIN). The variance value of the magnetic field strength will fluctuate if there is a solar event occur. The magnetic field's absolute value can be monitored by referring to the World monitor Magnetic Field Strength at the installed region, which is known as variance value. The variance value will vary depending on the strength of the surrounding magnetic field. Magnetic Map (WMM)[7].

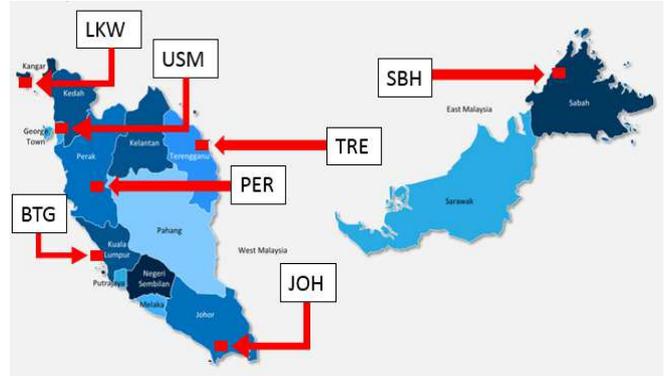


Fig. 4 The Location of the MAGDAS installation in Malaysia

The absolute value of the magnetic field strength can be identified by locating the geographic/geomagnetic coordinate on the WMM web server. The latest installation takes place at the USM Transkrian, Pulau Pinang. The MAGDAS stations in Malaysia are located using geographic and geomagnetic coordinates where the absolute value of the magnetic field strength can be monitored through WMM. Table II shows the coordinate (geographic and geomagnetic) for MAGDAS stations in Malaysia

TABLE II  
COORDINATES OF MAGDAS STATION IN MALAYSIA

STA	GG. LAT	GG. LON	GM. LAT	GM. LON	SITES
LKW	6.3°	99.78°	3.30°	172.44°	LNO
SBH	6.02°	116.07°	3.56°	188.66°	UMS
PER	3.72°	101.53°	5.92°	174.14°	UPSI
BTG	2.78°	101.51°	6.86°	174.10°	MYSA
JOH	1.53°	103.88°	8.04°	176.69°	UiTM PG
TRE	5.23°	103.04°	4.21°	175.91°	UniSZA
PIN	5.117°	100.0°	4.32°	173.07°	USM

### B. Data Logger Development and Parallel Installation Method of MAGDAS at the Ground Station

The magnetometer used for the project is MAGDAS II YU-8T SN60 model where the magnetometer is installed and provides the variance magnetic field value at the location where the magnetometer where installed. The author creates a data logger based on the internet of things (IoT) to collect the data from the pre-amplifier and transmit to the cloud server for real-time data monitoring. IoT is a system that involves sensor application, computation, and digital software which is globally accessible by the existing internet connection for real-time data share and transfer [12], [13]. To verify the workability of the developed data logger, the performance of the data logger was compared with the data logger from Kyushu University, Japan. Figure 5 shows the

developed data logger used with YU-8T magnetometer. The YU-8T MAGDAS II is a Japanese three axial ring core magnetic sensor[1]. The sensitivity of the magnetometer is approximately 0.1 nanoTesla (nT) [7]. The YU-8T connects

with the amplifier, SN60 by using a cable. The surrounding magnetic field, H-component, D-component, and Z-component are converted to a digital value and operate at 24 bits system and 10Hz resolution and sampling frequency [7].

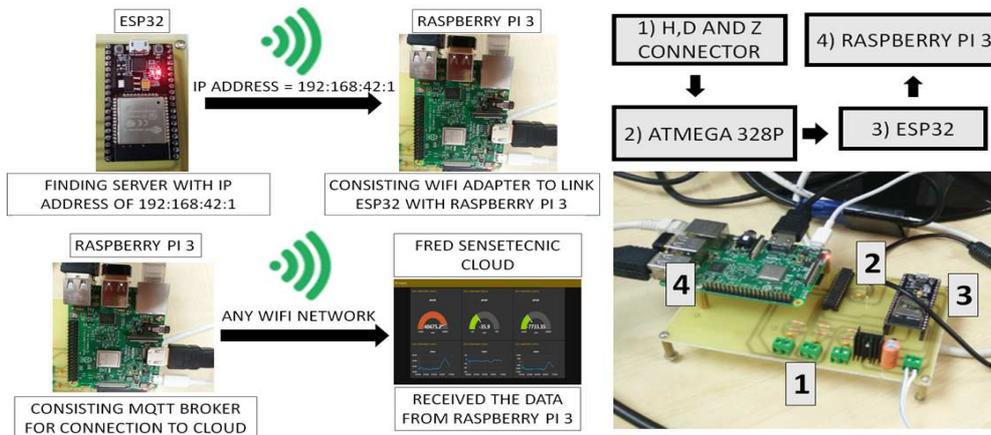


Fig. 5 The developed data logger used for MAGDAS installation.

The hardware developed for the data logger consists of 2 sets of Wi-Fi connections, where the first one is to link raspberry pi 3 and finally link to ESP32 microcontroller for data transfer and the second Wi-Fi link to a local Wi-Fi network for data transmission to cloud server. The purpose of linking the data to the cloud server is to allow 24 hours of data monitoring. The data is also saved in the raspberry pi 3 to further analyze if an event occurs at the installed location. The

idea of the installation is to create a parallel data acquisition system between the developed data logger with the data logger from Kyushu University. The YU-8T SN60 (Magdas II) Pre-Amplifier data will be delivered directly to the local data logger and DCR-5SD data logger, and Armadillo 9 Linux Computer. Figure 6 shows the flow diagram of the parallel data logger installation for MAGDAS at USM Pulau Pinang.

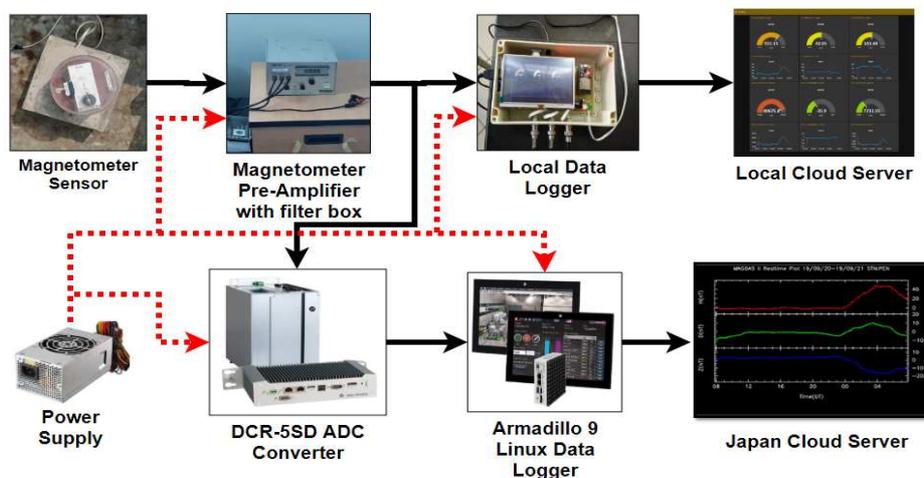


Fig. 6 The flow diagram of parallel data logger installation for MAGDAS at USM Pulau Pinang

### C. Installation of MAGDAS at the ground field of USM Transkrian

The deployment of the magnetometer with the data logger taking place at the USM Transkrian where the hardware deployment is the first MAGDAS installation at the USM Transkrian.

1) *Data Logger Deployment at the ground field:* The hardware deployment was compared with the data logger from Kyushu University, Japan to verify the workability and the consistency of the data logger deployed in the field. Figure 7 shows the installation picture of the local and Kyushu

University data logger in the ground field. YU-8T SN60 needs to be connected to the filter box to generate lower input voltage from the pre-amplifier. The connection of the local data logger and DCR-5SD data logger to the filter box is through the BNC connector. BNC connector used for the connection consists of a parallel splitter that will be connected to two sets of the data logger. DCR-5SD data logger needs to be connected to the 3MO power unit to power on the data logger and link to the Armadillo 9 Linux Computer to send the data to the cloud system. ESP32 powered local data loggers to collect H, D, and Z data from Pre-amplifier.

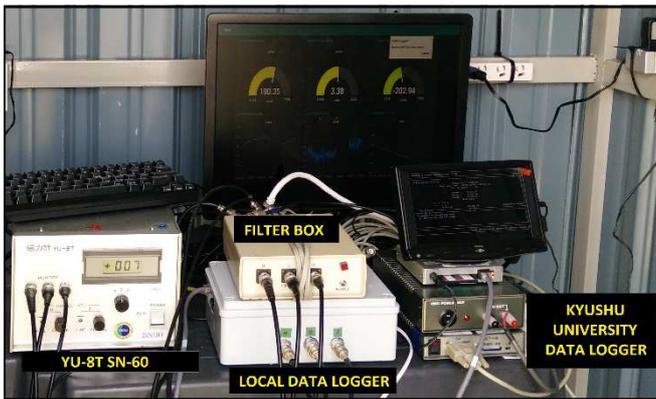


Fig. 7 The Installation of MAGDAS II YU-8T Magnetometer.

After gathering the H, D, and Z data, ESP32 will be sent the data to the raspberry pi 3 through a WIFI connection and Message Que Telematics Transport (MQTT) broker. Once the data received by the raspberry pi 3 is saved in an excel file and displayed using the Node-Red dashboard. Node-Red will link the data to Fred Senelec cloud server for a real-time monitoring system. Based on the installed data logger from local and Kyushu University, the summary of the hardware setup is concluded in Table III.

TABLE III  
THE DATA LOGGER USED FOR MAGNETIC FIELD STRENGTH MEASUREMENT AT THE USM TRANSKRIAN

Data Logger	Kyushu University	Local Newly Design
Power Supply	3M0 Power Supply	12 Volts Audio Jack
ADC Conversion	DCR-5SD ADC	ESP32 ADC
Linux Operating System	Armadillo 9 Linux Data Logger	Raspberry pi 3 Linux Operating System

2) *Sensor Deployment at the ground field:* YU-8T SN60 sensor is connected directly to the YU-8T SN60 Pre-amplifier. The sensor is installed 1 Meter underground to prevent disturbance from any electrical devices, which will disturb the

workability of the YU-8T sensor[1]. Figure 8 shows the YU-8T Sensor used for the MAGDAS installation.



Fig. 8 The Installation of YU-8T Magnetometer Sensor

The ideal distance between the YU-8T sensor and Pre-Amplifier is about 5 meters from each other [7]. Therefore, the cable which links the sensor and pre-amplifier need to be buried as well. The hardware installation is planned for a long time and needs to be properly planned.

#### D. Comparison Of MAGDAS data with Solar Event Data

The purpose of the MAGDAS system is to understand the behavior of Sun-Earth coupling, electromagnetic and plasma environments by studying the globally three-dimensional current system, plasma mass density, and the penetration process of the polar electric fields into the equatorial ionosphere [7], [14], [15]. Sun produces different solar winds speed depending on the region of the sun. The speed of the solar wind can be divided into two types which are low-speed and high-speed. For low-speed solar winds move less than  $400\text{ km s}^{-1}$  and for high-speed solar, wind moves at  $400$  to  $800\text{ km s}^{-1}$  [1], [2], [16]. Usually, high-latitude region magnetic field activity varies effectively with the high-speed solar wind streams. Figure 9 shows the solar event and a large coronal hole coming from the sun. The geomagnetic activities at the high latitude region are very active at high-speed solar activities impact [17]. High-speed solar wind produces a geomagnetic storm, while Low-speed solar wind produces calm space weather[18]. Therefore, when there is a high-speed solar wind, there will be a solar event at that time [1].

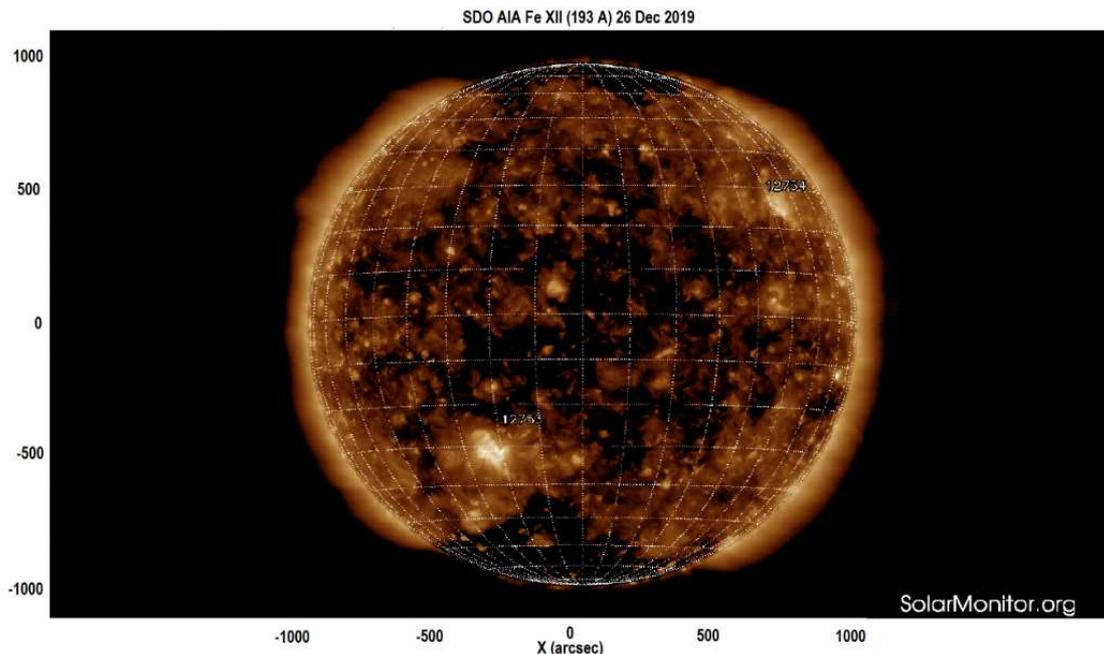


Fig. 9 Solar event from the sun [19]

### III. RESULT AND DISCUSSION

The data collected were plotted in real-time and the discussion between the selected MAGDAS station was conducted. The MAGDAS station selected for data comparison with the USM MAGDAS station is Banting (BTG). The MAGDAS station from Langkawi (LKW) and Perak (PER) is under troubleshooting and the only possible selection is Banting (BTG) MAGDAS station. The reason for the MAGDAS station selection is the location which is the 3<sup>rd</sup> nearest MAGDAS station from USM MAGDAS station. To test the accuracy of the data logger, the comparison of the data selected for 7 days from 23<sup>rd</sup> to 29<sup>th</sup> December 2019. The amount of the data selected is sufficient enough considering

the MAGDAS data is almost similar in day and nighttime. The only fluctuation that existed on the data is between 25<sup>th</sup> to 27<sup>th</sup> December 2019, which is existed on all the data loggers. Due to these abnormalities, the data from the data logger was compared to the data from the solar event to verify any solar activities during that period.

#### A. The Data of Magnetic Field Parameters Collected from 23<sup>rd</sup> December 2019 to 29<sup>th</sup> December 2019

The data from Local and Kyushu University data logger installed in USM MAGDAS station was compared with the data from Banting (BTG). Figure 10 shows the data were taken for H, D, and Z components from 23<sup>rd</sup> to 29<sup>th</sup> December 2019.

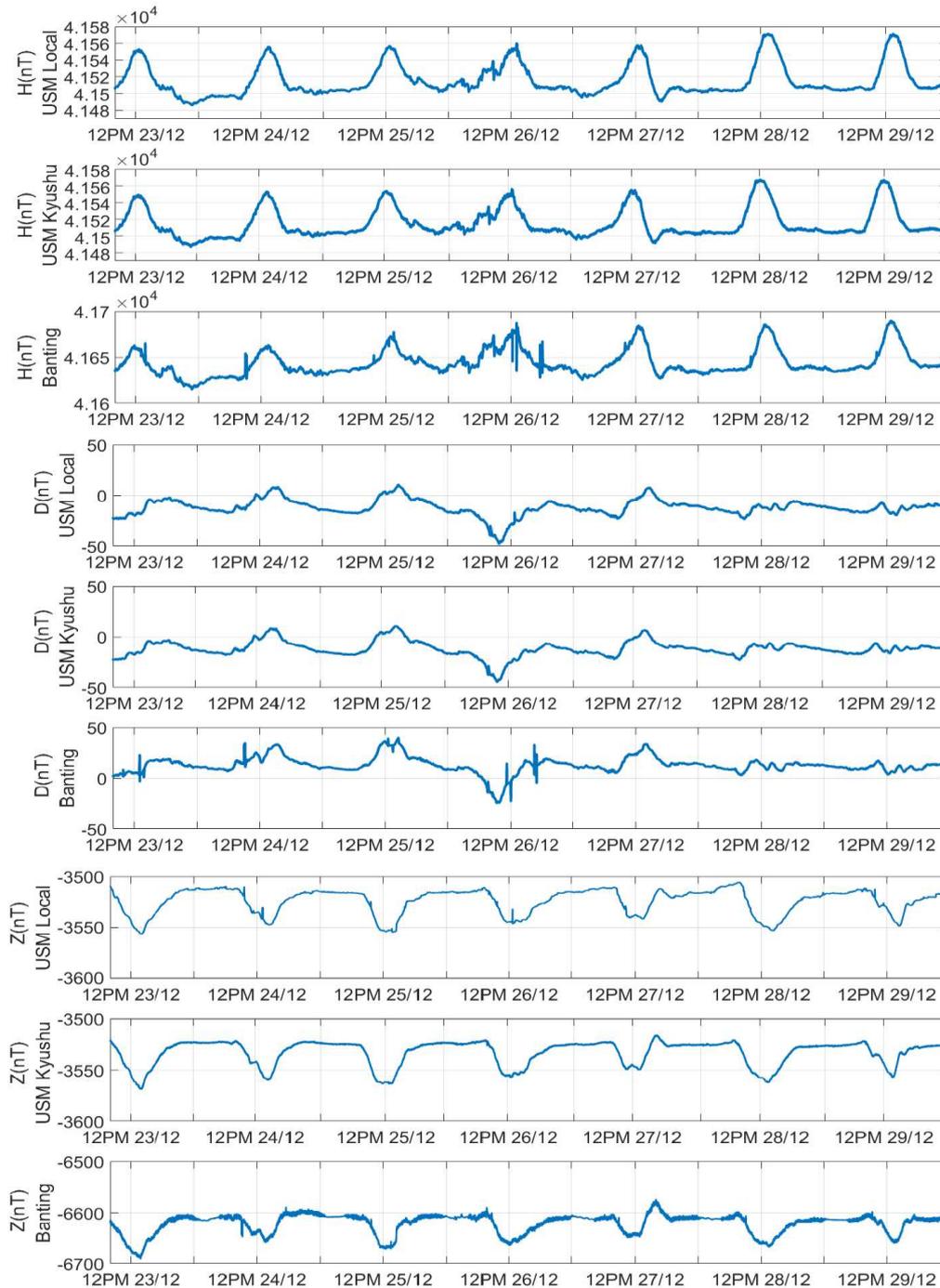


Fig. 10 The H, D and Z(nT) component magnetic field comparison between Local, Kyushu and banting data logger

Based on the data collected from Local, Kyushu, and Banting (BTG) data loggers. The pattern of the graph is almost identical to each other. Only spikes existed on the graph that might be affected by human activities or due to the solar event from the sun. Based on the  $H(nT)$  data from all data loggers that were collected. The pattern of  $H(nT)$  from 12 PM 25/12 to 12 PM 27/12 is generating the same kind of spike due to the solar event. To identify this event, the data from solar wind were collected and plotted in Figures 12. Based on the  $H(nT)$  data collected, the local data logger is in the range of 41486nT to 41571.8 nT, Kyushu data logger is between 41484nT to 41 569.2nT, Banting (BTG) data logger is between 41615nT to 41689.7nT. While  $D(nT)$  from the local data logger ranges from -47.79nT to 11.36nT, Kyushu data logger is between -44.67 to 10.95nT and Banting (BTG) from -24.85nT to 41.36nT. The value of  $Z(nT)$  from local data logger is from -3569.33nT to -3515.8nT, Kyushu data logger

from -3569.15nT to -3515.61nT and Banting (BTG) is from -6694.53nT to -6573.21nT.

*B. The Artificial Noise of  $H(nT)$ ,  $D(nT)$  and  $Z(nT)$  from Local, Kyushu and Banting(BTG) data logger*

The Artificial Noise helps to identify the sensitivity of the data collected from the MAGDAS station and the rate of change of the data due to human activities and Solar events [7], [8]. Figure 11 shows the artificial noise value from  $H(nT)$ ,  $D(nT)$  and  $Z(nT)$  from local, Kyushu, and Banting (BTG) data logger. The value of the artificial noise from all the data logger is very small. Kyushu data logger produces the most stable data throughout time, followed by a Local data logger installed at the USM and Banting (BTG) data logger. The value of the artificial noise might vary depending on the amount of disturbance from human activities [7]. The amount of population existed at the MAGDAS station will cause the artificial noise to fluctuate.

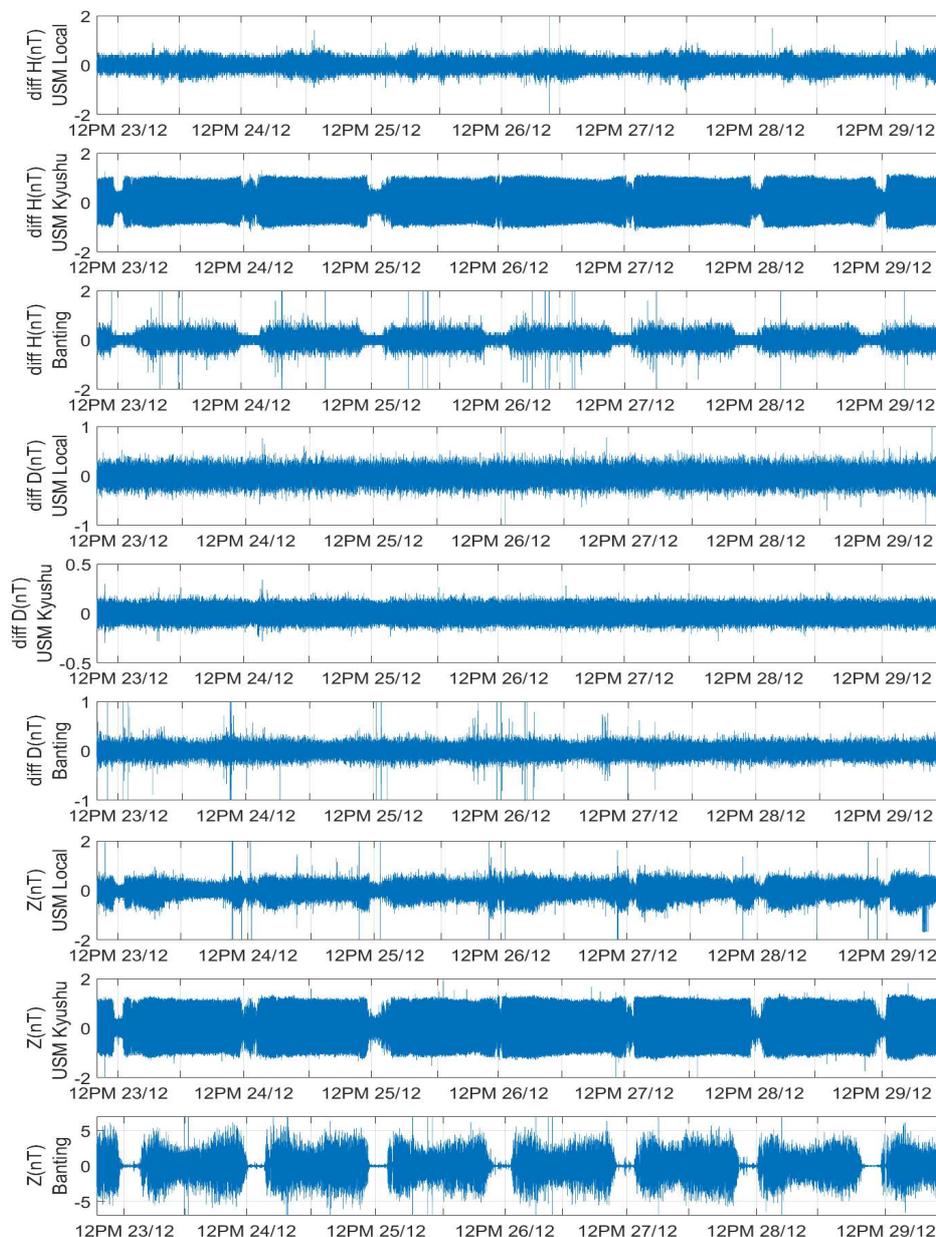


Fig. 11 The artificial noise from H, D and Z(nT) of Local, Kyushu and banting data logger

### C. Comparison of MAGDAS Data from Local and Kyushu USM data logger with Solar event

Solar event occurs continuously throughout time where any unusual pattern from the MAGDAS station can be monitor by comparing the data with solar events. This is due to the earth's magnetic field's response to the solar wind impact. Figures 12 show the comparison from solar event data with H(nT) from Local and Kyushu data logger. During the measurement, from 23<sup>rd</sup> to 29<sup>th</sup> December 2019. The recorded interplanetary magnetic field (Bz) value is between -10 to 10nT, which is normal during the quiet period of solar perturbation. The small fluctuation occurs on 26<sup>th</sup> and 29<sup>th</sup> December 2019. However, the value recorded is between -10nT to 10nT. The Solar flow speed recorded is between 300Km/s to 400Km/s. Solar wind can be higher than 800Km/s during the disturbed

period of the solar event [1]. The density of the solar flow shows that during the 26<sup>th</sup> and 29<sup>th</sup> of December 2019, the state of the solar event is unstable. This shows that some solar activities that occur at the sun might involve small coronal holes or sunspots during the measurement of magnetic data at MAGDAS USM. Based on data collected from the symmetrical index of H, (SYM/H) from Figure 12, the graph is having a small fluctuation during 26<sup>th</sup> December 2019 similar to the data collected from Bz and solar flow pressure. The fluctuation on 29<sup>th</sup> December 2019 occurs only on Bz while solar flow speed, solar flow density, and SYM/H remain at a calm state. Bz will fluctuate close to zero during the calm space weather and fluctuate more than -10nT to 10nT during solar storm [20]. The value of H(nT) from local and Kyushu data logger fluctuated on 26<sup>th</sup> December 2019 and remained calm on 29<sup>th</sup> December 2019.

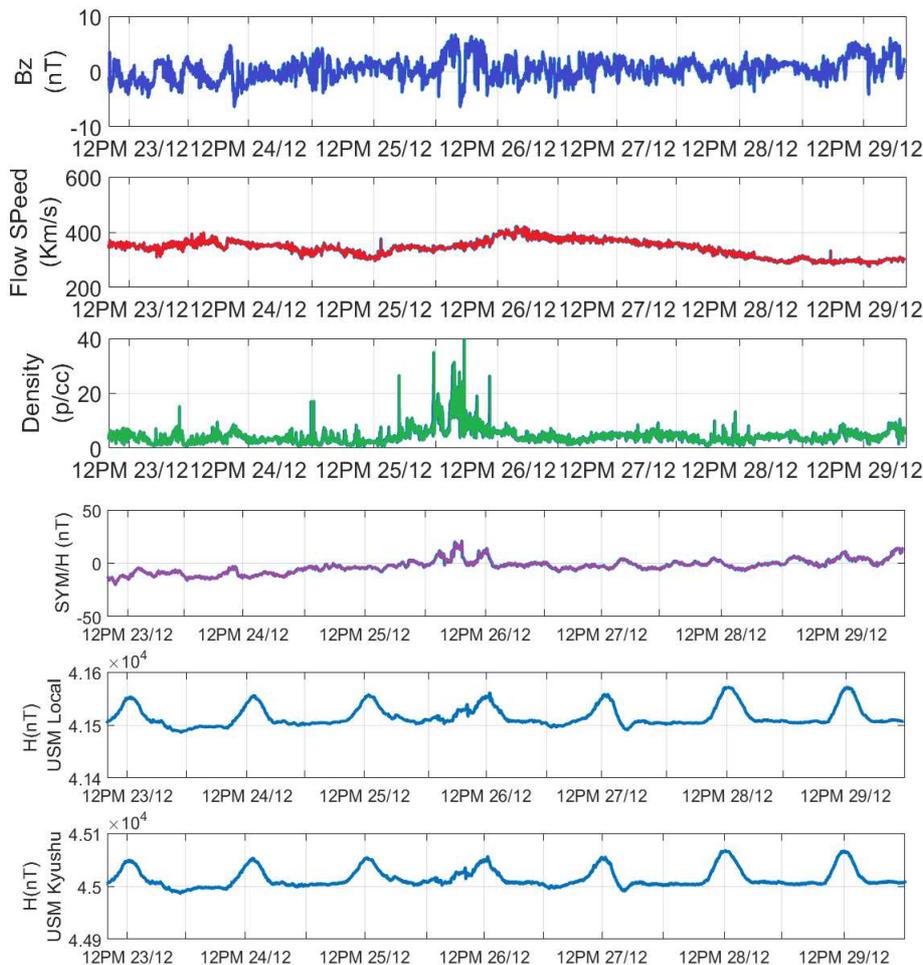


Fig. 12 The value of interplanetary Magnetic field, Bz, Flow Speed, Density of solar wind, SYM/H (nT), Local H(nT), and Kyushu H(nT) from the data logger.

### D. The Novelty of the Research

The development of the data logger was conducted to test the workability and reliability of the developed data logger with the data logger originated from Kyushu University. This will help to localize the data gathering process and one step forward toward building the magnetic field data gathering method, which originated in Malaysia. The deployment of the data logger is important to identify the fluctuation of the magnetic field caused by solar events in Malaysia, which is in

the equatorial region [9]. The magnetic field fluctuation caused by solar activities in Malaysia might cause the generation of Geomagnetic Induced Current (GIC), which is harmful to electrical appliances, etc. [9], [21]. Based on the GIC current measurement at the low latitude region, the GIC value ranges between 1A to 30A. The value of the GIC magnitude existed in spike, and the study on GIC depends on the statistical investigation on the analyzed sample [22], [23]. The GIC identification is important due to the risk that it carries and harmful effect to the power grid system; GIC

occurrence on transformer might disrupt, cause overheating, burn of the winding, reduce the reliability, reduce lifespan, and might cause sudden blackout due to the over the generation of undesired GIC [22]–[25].

### E. Result Benchmarking

To ensure the local data logger is working and reliable. The magnetic data was collected properly, and the result

obtained from the YU-8T Magnetometer was compared with the Kyushu University data logger, Banting (BTG) data logger, and Worldwide Magnetic Declination Forecast (WMM). The validation for this guideline is only every five years. The current model used is from 1<sup>st</sup> January 2015 until 31<sup>st</sup> December 2020 [11]. Based on the data gathered from the MAGDAS station, Table IV summarizes the data collected from the data logger.

TABLE IV  
GEOMAGNETIC RANGE BASED ON LOCAL, KYUSHU UNIVERSITY AND BANTING DATA LOGGER

Parameter	Data Logger			
	Local	Kyushu	Banting MAGDAS station	WMM
H component	41,486 nT to 41,571.8 nT	41,484 nT to 41,569.2 nT	41615 nT to 41689.7 nT	40,000 nT and above
D component	-47.79 nT to 11.36 nT	-44.67 nT to 10.95 nT	-24.85 nT to 41.36 nT	~0 nT
Z component	-3569.3 nT to -3515.8 nT	-3569.15 nT to -3515.61 nT	-6694.53 nT to -6573.21 nT	-15,000 nT – 20,000 nT

Based on the Mercator projection, H-component in Malaysia is approximately 40,000nT, and the measured H-component is around 40,000nT to 43,000nT. For the D-component, the measured value needs to be close to 0nT because Malaysia is located near the equator. The measured result from the YU-8T magnetometer was between -47.79nT to 11.36nT and the value is approaching 0nT in the afternoon. Z-component measured from the local data logger in between -3569.3 nT to -3515.8 nT. All the measurement from Local, Kyushu University and Banting data logger was in the range of WMM specification.

### IV. CONCLUSIONS

The development of the data logger was successfully deployed at the USM Transkrian MAGDAS station. The workability of the data logger has been successfully tested and verified. It can be concluded that the data from the local data logger is in the range of WMM and the range of Kyushu University data logger. The magnetometer helps to identify any abnormalities regarding the magnetic field variations at the installed MAGDAS station. Future work related to magnetic field variation is to identify the value of geomagnetic induced current (GIC) at the installed MAGDAS station. The magnetic field of the earth is closely related to the formation of GIC. The existence of GIC harms the surface and underground technological devices. Therefore, observing the magnetic field variation and GIC reading in Malaysia is important to identify the level of harmful effects on technological appliances.

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