

Comparison of relative sunspot numbers measured in Malaysia with international sunspot number calculated by SIDC-SILSO

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Abstract. The accuracy of Langkawi National Observatory (LNO) relative sunspot number (RSN) data has been officially acknowledged when LNO has become one of the contributors to International Sunspot Number (ISN), R_{ISN} since June 2015. However, RSN from LNO (R_{LNO}) can only be obtained if the weather is favourable and the instruments are working well. These disadvantages can be solved if there are other observers across Malaysia that can contribute data of RSN to LNO. This research aims to compare the RSN collected by an amateur observer at National Planetarium, R_{NP} with R_{LNO} and R_{ISN} . 11 days data between the month of November 2014 and January 2015 are analysed to see the differences between R_{NP} to both R_{LNO} and R_{ISN} . Results show that, the value of R_{NP} is lower than R_{LNO} and R_{ISN} . The highest percentage difference is between R_{NP} and R_{ISN} which is due to the different method and instruments used in observing the sunspot. The correlation of relative sunspot number is high between R_{LNO} and R_{ISN} proving the reliability of LNO as contributor to ISN. The observational index is also determined in this study based on the ratio of correction factor of R_{NP} to R_{LNO} .

1. Introduction

Solar activities can affect the earth's magnetic field and affect our ground-based technology especially at high latitude country. Constant monitoring of solar activity including sunspots observation will help researchers to predict the behavior of the sun and provide an early warning to those who will be impacted by the space weather. Sunspot is the dark area that can be seen on the photosphere layer of the sun. The strong magnetic field is the main cause of low temperature of the sunspot area and thus, making the sunspot appears darker [1].

It can be said that sunspot is the subject of interest to many astronomers and solar physicists [2]. Sunspot observation is one of the oldest science existed in this world. Mankind has been observing the sun since the first telescope was built more than 400 years ago [3]. The data of sunspots has been collected ever since and it is the longest-running and still on-going observation [4]. The numbers of sunspots was observed and properly recorded in 1849 by R. Wolf who initiated the International Sunspot Number (ISN) [5]. The formula defined by R. Wolf to calculate the relative sunspot number (RSN) is based on the number of sunspots groups, g and total number of sunspots, f as follows:

$$R = k (10g+f) \quad (1)$$



The variable denoted by k is the correction factor of the observer. Although all observers use the formula that is also known as Wolf formula to calculate RSN, there are still inconsistencies in the data collection due to different instrumentation used, local seeing conditions and also according to the observer skills [6]. Generally, sunspot observation is performed using the projection method. The observers draw or sketch the sunspots image projected from the eyepiece of the telescope. Then, they will manually count the number of sunspots and report it to the World Data Center (WDC).

The WDC for Sunspot Number originally based in Zurich Observatory but it was moved to Royal Observatory of Belgium, Brussels in 1981. This led to the foundation of Solar Influences Data Analysis Center (SIDC). Today, more than 80 observatories contribute daily sunspot numbers to SIDC. From the daily sunspot data, SIDC will calculate R_{ISN} and this relative sunspot number becomes the official index of sunspot number which is known as International Sunspot Number, ISN.

Langkawi National Observatory (LNO) officially became one of the contributors for sunspot numbers observation to WDC at Belgium since June 2015 [7]. Although in Malaysia there are quite many observatories, LNO is the only solar observatory that consistently performed solar observation. However, there are some disadvantages of this as LNO can only collect data if weather permits and if the instruments are working well. Therefore, we need more observers from Malaysia to take part in observing the sun and collecting sunspot numbers data. Amateur observers can support LNO's observation and provide a more complete RSN data from Malaysia.

In this research, we are comparing the data collected by an amateur observer at National Planetarium Observatory (NP) to LNO's data and ISN to see the percentage differences between the three sources. As we encourage amateur observers to support LNO's sunspot data, we introduce a method to calculate the observational index, β or known as correction factor ratio of NP data to LNO data derived from the Wolf formula.

2. Methodology

2.1 Solar Observation at National Planetarium, Kuala Lumpur

The observation was held at National Planetarium Observatory that located at Taman Tasik Perdana, Kuala Lumpur with coordinate $3^{\circ}9' N$, $101^{\circ}41' E$ and 112 meter altitude above sea level. The main instrument that is used to observe the sun and sunspot is telescope Takahashi FS-102 that is mounted on Paramount ME German equatorial mount and covered with a Thousand Oak glass solar filter. The observation of sunspot here was done using digital images using DSLR camera Canon EOS 5D mark III. This camera has CMOS detector that is able to take 6 frames images per second. The setup of the instrumentation used at National Planetarium is shown in Figure 1.



Figure 1. Instrumentation used for sunspot imaging with Camera EOS 5D mark III attached to Telescope Takahashi FS-102 NSV at National Planetarium, Kuala Lumpur.

Sunspot observations at National Planetarium were performed between November 2014 and January 2015 at time range 9.00 am until 12.00 pm. Sometimes the observation is repeated to ensure a

quality image is obtained. In those 3 months duration, there were only 11 days of data have been successfully collected. This is due to the rainy season at the end of the year in Malaysia.

The image of the sun was taken in 10 to 20 shots so that the best image can be selected to be analyzed as shown in Figure 2. The sunspots are manually counted by the observer by referring to the Zurich classification of sunspots and Wolf formula as mentioned before.

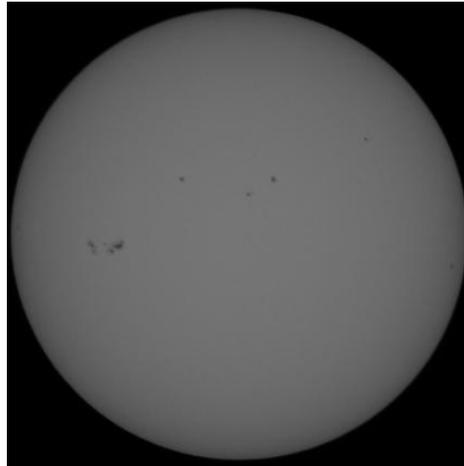


Figure 2. Example of a white light image taken by National Planetarium solar observation system on 16 December 2014.

2.2 Solar Observation at Langkawi National Observatory

Langkawi National Observatory (LNO) is situated at Langkawi Island, north of Peninsular Malaysia with latitude of 6.307°N and longitude of 99.781°E . This observatory has three solar observation systems to observe the sun in three different wavelengths. White light filter is used to observe sunspots, Hydrogen Alpha filter is used to observe chromosphere activity and Calcium K-Line filter is used to observe sunspots and plaques.

In this research, we focus on the images took using the white light filter. LNO used 152mm (6 inch) F/7.9 TMB telescope on a Paramount ME tracking mount and Baader ND5.0 solar filter film is used to achieve white light spectrum which filters 99.999% of sunlight. Besides that, the STL-4020M was chosen among many types of couple charged device (CCD) to take digital images of the sun as it fits the full solar disc when matched with TMB-152 telescope. This type of CCD also equipped with electronic shutter that is needed for very fast exposure. The instrumentation used in LNO is shown in Figure 3.

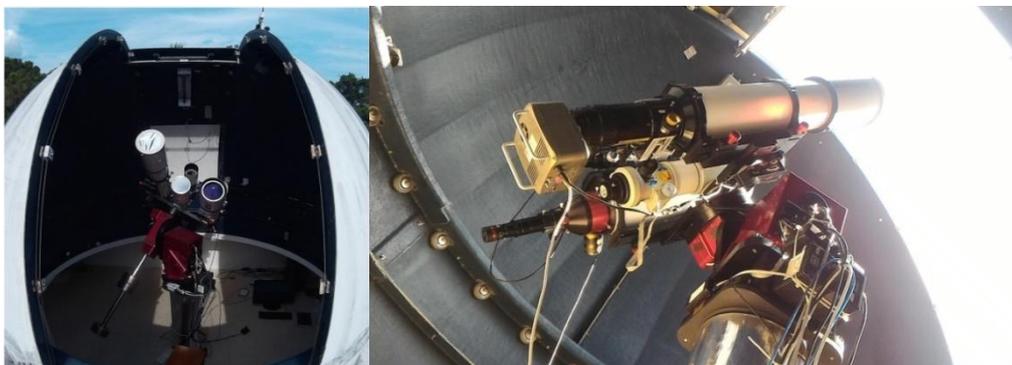
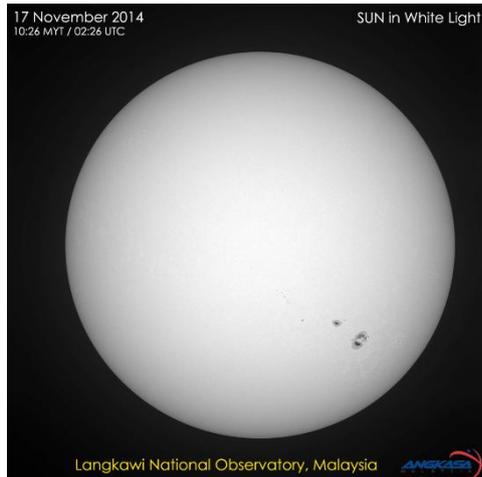


Figure 3. Instrumentation used for sunspot imaging and data collection at LNO: - Telescope TMB 152mm, SBIG STL4020 CCD Camera and Baader Solar Film.

Sunspot observation at LNO is performed daily only if weather permits between 9.30AM to 4.30PM local time [8]. It is preferable to take image of sunspot when the altitude of sun is higher and less affected by the atmosphere so there is less turbulence in the final image. The most crucial procedure in sun observation is making sure that the image is in focus as shown in Figure 4. Once good focus has been achieved, 50 white light full disk images are taken and the best image will be selected for further analysis as shown in Figure 5.



LANGKAWI NATIONAL OBSERVATORY			
YEAR: 2014	MONTH: 11 DATE: 17		
HOURS: 02 (UT)	MINUTES: 26		
WEATHER :	CLOUDY		
SEEING :	3/5		
SCINTILATION :	3/5		
IMAGE :	3/5		
P :	+20.87		
Bo :	+2.64		
Lo :	264.80		
ΔL :	-1.34		
L :	263.46		
JD :	245 6978.5		
$R = k(10G + F) ; k=1 \text{ for LNO}$			
SPOT	G	F	R
NORTH	1	1	11
SOUTH	5	57	107
TOTAL	6	58	118
NOTES : PHOTOGRAPHED			
OBSERVER : NOR RAFIDAH SAIBAKA			
SKETCH ANALYSER : NOR RAFIDAH SAIBAKA			

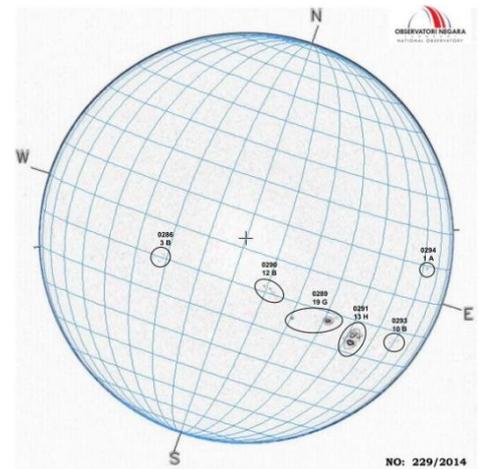


Figure 4. Example of a white light image taken by LNO solar observation system on 17 November 2014.

Figure 5. After analysis, a sketch and detailed sunspot count is produced for reference.

3. Results and Discussions

The RSN data collected from all the three sources are tabulated in Table 1. Unfortunately, there are 5 days missing data from LNO in December and early January due to weather condition. The daily sunspot number observed at National Planetarium, R_{NP} is represented in the red line, the sunspot number observed at LNO, R_{LNO} is green line and the International Sunspot Number, R_{ISN} is blue line in Figure 6. There are total of 11 days of RSN data compared in this study. One can observe that R_{ISN} exceeds both R_{LNO} and R_{NP} in the plot. However, we can perceive similar trends in RSN from all three sources. This indicates that R_{NP} obtained by amateur observer is in good agreement with the one observed by LNO and ISN.

Table 1. Relative sunspot numbers from National Planetarium, Langkawi National Observatory and International Sunspot Number.

Date	R_{NP}	R_{LNO}	R_{ISN}
05/11/2014	67	115	137
09/11/2014	44	76	69
17/11/2014	37	118	99
15/12/2014	122	-	166
16/12/2014	107	-	175
18/12/2014	89	-	154
19/12/2014	64	-	175
02/01/2015	96	-	122
04/01/2015	63	-	88
08/01/2015	87	117	99
15/01/2015	38	85	59

Figure 7 shows the scatter plot of R_{ISN} against R_{LNO} . Linear curve fitting was applied and the correlation coefficient of determination, R^2 are shown in the figure. R^2 represent the correction factor, k as mentioned in equation (1) [9]. The correction factor between R_{ISN} and R_{LNO} is quite high, 0.64 although there are missing data from LNO. This proves the reliability of LNO as one of contributor to ISN data.

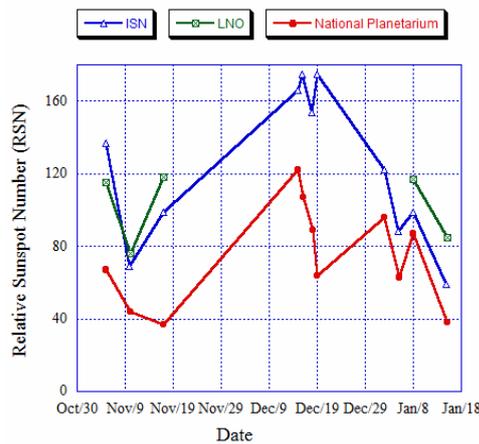


Figure 6. National Planetarium RSN, R_{NP} (red line) compared to Langkawi National Observatory RSN, R_{LNO} (green line) and International Sunspot Number R_{ISN} (blue line).

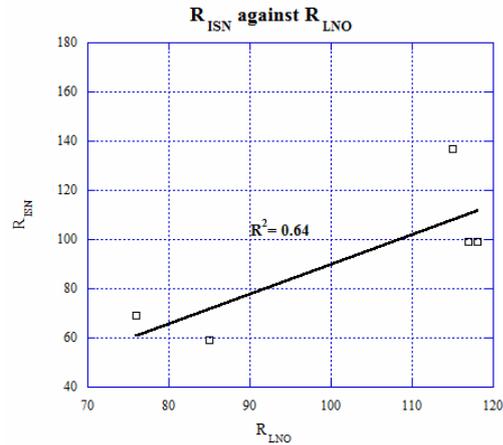


Figure 7. Relationship between the daily sunspot numbers observed at ISN (R_{ISN}) and LNO (R_{LNO}).

We further calculate the percentage differences of each day of the observation. The results obtained are plotted in Figure 8. The highest error between R_{LNO} and R_{ISN} is 27% as shown in Figure 8 (a) that is on Jan 15. The negative value indicates that value of R_{LNO} is higher than value of R_{ISN} . On the other hand, we found that the error between R_{NP} and R_{LNO} is much higher that is 80% as illustrated in Figure 8 (b). This high value could be due to the difference of type instruments used in capturing digital images of the sun as LNO uses CCD which takes better quality image than the DSLR camera used by National Planetarium. Therefore, the R_{LNO} calculated is higher since CCD produces images with higher resolution resulting in clearer images than the DSLR camera used by National Planetarium. Figure 8 (c) shown in the plot that the differences between R_{NP} and R_{ISN} is the highest, which is more than 100% caused by the different methods and instruments used in observing the sun. As mentioned earlier, most of the contributor for ISN used solar projection method to sketch the sunspots while National Planetarium uses digital images from DSLR camera to capture the images of sunspots. From these result, we can conclude that data obtained using solar projection method is more accurate than CCD and DSLR camera and data collection from CCD are more accurate than from DSLR camera.

We continue the analysis by calculating the observational index using equation (1) that is mentioned before. This equation is used to calculate the ratio of correction factor of R_{NP} to R_{LNO} as below:

$$\beta = \frac{k_{NP}}{1} = \frac{(10g_{LNO} + f_{LNO})}{(10g_{NP} + f_{NP})} \quad (2)$$

β is the ratio of correction factor or known as observational index. The best value of ratio is defined as 1 as correction factor of LNO, K_{LNO} as a contributor to ISN is also given as 1. It is shown in Figure 9 that the lowest value of this observational index is on 8th January 2015 which is 1.34 and the highest

ratio is on 17th November 2014 with the value of 3.19. This shows inconsistencies of the observational index of the 5 days data.

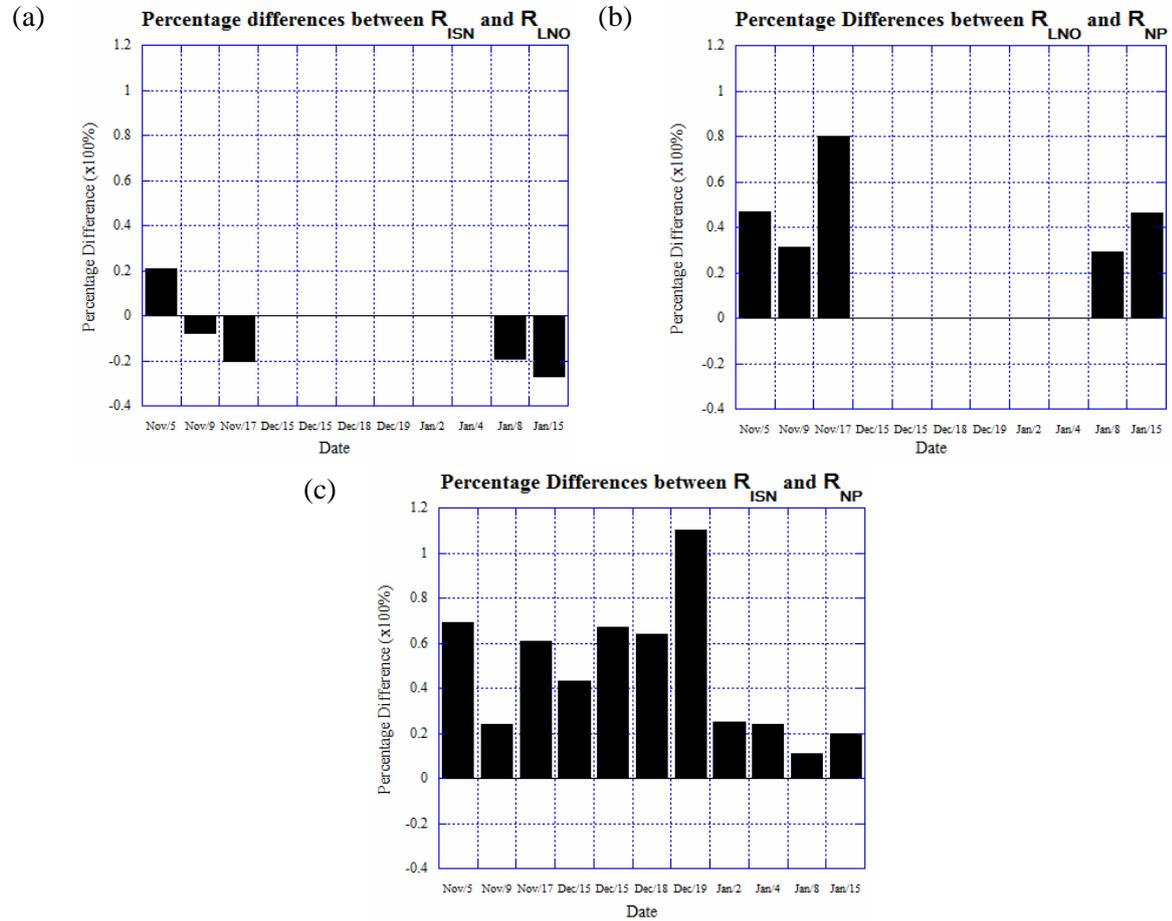


Figure 8. Percentage differences between (a) R_{ISN} and R_{LNO} (b) R_{LNO} and R_{NP} and (c) R_{ISN} and R_{NP} for 11 days.

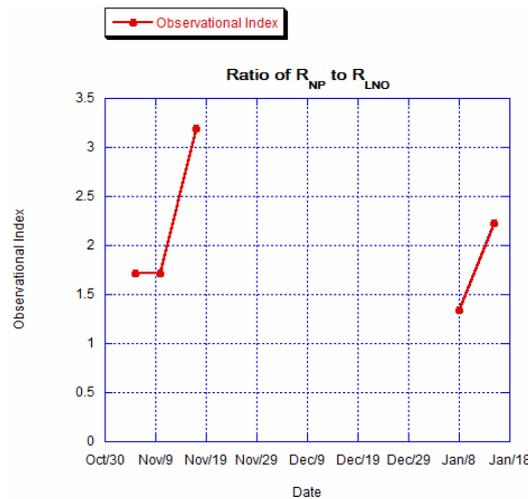


Figure 9. Ratio of correction factor of R_{NP} to R_{LNO} or known as observational index, β .

4. Conclusion

From the result discussed in this paper, LNO has proved its reliability as a dependable solar observatory in Malaysia as its data has high correlation with ISN. However, there is a high percentage difference of R_{NP} with R_{LNO} and R_{ISN} . The observational index, β is determined between R_{NP} and R_{LNO} using the Wolf formula. This index is important as it represents the ratio of correction factor from one source of data to R_{LNO} . We suggest that any studies to support LNO data done by other solar observers in Malaysia to use this method in determining their respective observational index to R_{LNO} .

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