Sun Casted Shadow Measurement by Using Gnomon Apparatus

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ABSTRACT

The sun casted shadow was studied by using a simple Gnomon apparatus. The length of shadow projected from a small stick was measured at the location of Jatukam Wittayacom elementary school, Nakhon Ratchasima, Thailand (GPS location 14° 41' 37.66" N, 102° 4' 22.69" E). The observation times were 7.30 a.m., 10.30 a.m., 12.15 p.m., 2.30 p.m. and 4.30 p.m. From this study, the sun trajectory can be modeled. A long shadow length was observed in the morning. They were the longest and the shortest in the evening and at noon, respectively. When compare the shadow measured at the same time of the day in different week, the length increased. This correlated well with the decreasing of the measured azimuth angle of the sun which is known as winter solstice phenomenon.

Keywords: Sun shadow, Gnomon

INTRODUCTION

We observed the shadows of ourselves and of the tree with variety of length and direction on different time. Because of this, we would like to study more with the casted shadow of the object from the sun by using a simple Gnomon apparatus.

A Gnomon / ˈnəʊmɒn, ˈnō-mən, nōˈmon / is the raised part of a sundial that casts the shadow. Moreover, Gnomon is an early astronomical instrument consisting of a vertical shaft, column, or the like, for determining the altitude of the sun or the latitude of a position by measuring the length of its shadow cast at noon [1].

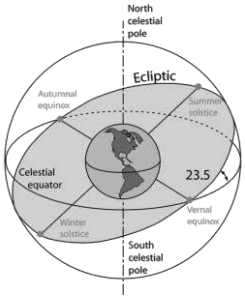

Figure 1. The celestial sphere. (http://hyperphysics.phy-astr.gsu.edu/hbase/eclip.html)

The objective of this observation is to study the shadow length and direction casted from the sun for different time of the day and understand the sun trajectory during observation period.

As illustrated in Fig.1, if the sun's path is observed from the Earth's reference frame, it appears to move around the Earth in a path which is tilted with respect to the spin axis at 23.5°. This path is called the ecliptic. The points where the ecliptic crosses the equatorial plane of the celestial sphere are called equinoxes (around 21-22 March and 22-23 September). On those dates there are 12 hours each of daylight and dark. The most northern excursion of the sun is called the summer solstice (around 20-21 June) and will have the longest amount of daylight. The winter solstice (around 21-22 December) opposite it is the shortest period of daylight [2], [3].

METHODOLOGY

A nine centimeter length shadow stick called Gnomon was used as an object for shadow casting from the sun. The Gnomon stick was placed normal to the ground by installing on a rigid support placing at the same location for all measurement. The study took place for 7 weeks starting from 1 October 2015 to 12 November 2015 at Jatukam Wittayacom elementary school, Nakhon Ratchasima, Thailand (GPS location 14° 41' 37.66" N, 102° 4' 22.69" E). The observation times were 7.30 a.m., 10.30 a.m., 12.15 p.m., 2.30 p.m. and 4.30 p.m. On 22 November 2015, the shadows were observed every hour. In this observation, we focused on the shadow length and its direction which corresponds to the azimuth angle. The altitude angle had also been measured from the tip of the Gnomon stick and the tip of its shadow casted on the ground.

RESULTS

The shadow observation was done every day. As shown in Fig. 2, the data from every Thursday starting from 1 Oct 2015 were selected for illustration proposes. From the observation results, the longest shadow length was observed in the morning at 7.30 a.m. It was decreasing and became the shortest at noon. The length increased again from noon to the evening. The trend of increasing shadow length was also observed when we compare the results obtained from the same day in each week.

As show in Fig. 3, the average altitude angle was increasing from morning, became the highest at noon and decreasing from noon to the evening. When compare the results from 7 weeks, the angle was the highest in the first week and the lowest in the seventh. The relation between Fig. 2 and Fig. 3 is that the decreasing in altitude angle corresponds to the increasing of the shadow length. In the other words, the highest angle of first week provided the shortest shadow. The reason is that the measured altitude angles from the tip of shadow and Gnomon stick can be interpreted as the altitude angles of the sun with respect to the ground. The lower the sun altitude angle, the longer the casted shadow. On the other hands as the sun moved near the zenith at noon, the Gnomon shadow would be short.

The variation in azimuth angle, the shadow length and the virtual sun position observed on 22 Nov 2015 which is a month before winter solstice are showed in Fig. 4.

The shadows length and azimuth angle were plotted as the solid color lines while the sun trajectory can be obtained by projecting these lines into the opposite direction (dash lines). It can be seen that all the shadows laid toward the north direction implying the sun position was in south direction. This is because our observation period is closed to the winter solstice of 21-22 December where the sun moved toward the most south direction as shown in Fig. 1. It should be noted that more change of the azimuth angle were observed during noon time where the sun are almost normal to the ground as compared to the morning or the evening.

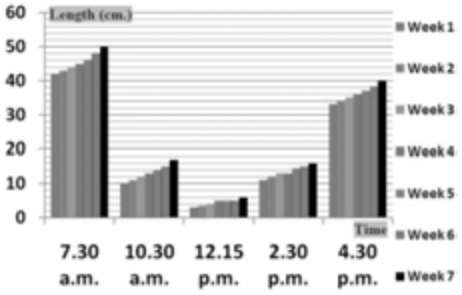

Figure 2. Comparison of shadow lengths at different time from every Thursday in 7 weeks during 1 Oct – 12 Nov 2015.

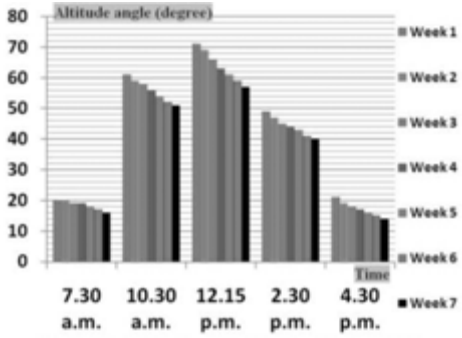

Figure 3. Comparison of altitude angles measured from the tip of shadow and Gnomon stick at different time from every Thursday in 7 weeks during 1 Oct – 12 Nov 2015.

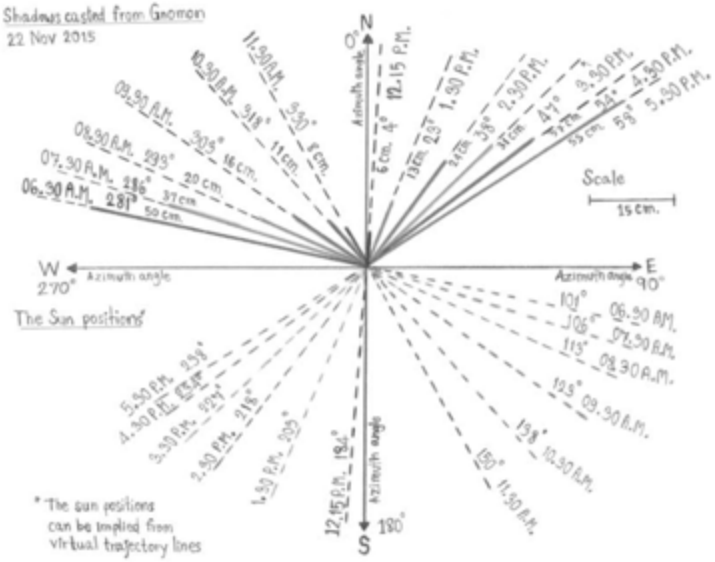

Figure 4. The shadow length with its azimuth angle and its virtual projected line of the sun position at different time on 22 Nov 2015.

CONCLUSIONS

Shadow length and direction contain information about the sun position and trajectory. As the day changes toward December, the daily shadow length increases. This agrees well with the decreasing of the azimuth angle measured from the tip of the Gnomon stick. This results correlate with the winter solstice period where the sun moved toward the south direction giving the decreasing sun's azimuth angle and casted shadow toward the north direction.

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